EW

@ENGINEERINGWALLAH

104010: BASIC ELECTRONICS ENGINEERING (BXE)

Prof. Sayali Madhikar

Mobile No:7588117341

BXE Rules and Regulation

- Assignment completion & checking in every practical
- Manual completion & Checking after practical
- Lecture Attendance
- Practical Attendance
- Follow Lecture Time
- Preliminary Exam
- Discipline

Cabin Location : C1 Building (E & TC Dept.) 1St Floor BXE Lab

BXE Lab Location : C1 - 07 (E & TC Dept.)

Credit Structure for Semester-I

TABLE -1 First Engineering _Structure for Semester-I															
Course Code	Course Name	Teaching Scheme (Hours/Week)			Examination Scheme and Marks						Credits				
		Theory	Practical	Tutorial	ISE	ESE	TW	PR	OR	Total	TH	PR	TUT	Total
107001	Engineering Mathematics-I	03	--	01	30	70	25	--	--	125	03	--	01	04
107002/ 107009	Engineering Physics / Engineering Chemistry	04	02	--	30	70	--	25	--	125	04	01	--	05
102003	Systems in Mechanical Engineering	03	02	--	30	70	--	25	--	125	03	01	--	04
103004 / 104010	Basic Electrical Engineering / Basic Electronics Engineering	03	02	--	30	70	--	25	--	125	03	01	--	04
110005/ 101011	Programming and Problem Solving / Engineering Mechanics	03	02	--	30	70	--	25	--	125	03	01	--	04
111006	Workshop@	--	02	--	--	--	--	25	--	25	--	01	--	01
	Total	16	10	01	150	350	25	125	--	650	16	05	01	22
101007	Audit Course 1&	02	Environmental Studies-I											
Induction Program : 2 weeks at the beginning of semester-I and 1 week at the beginning of semester-II														

Credit Structure for Semester-II

TABLE -2 First Engineering_ Structure for Semester-II

Course Code	Course Name	Teaching Scheme (Hours/Week)			Examination Scheme and Marks						Credits			
		Theory	Practical	Tutorial	ISE	ESE	TW	PR	OR	Total	TH	PR	TUT	Total
107008	Engineering Mathematics-II	04	--	01	30	70	25	--	--	125	04	--	01	05
107002/ 107009	Engineering Physics/ Engineering Chemistry	04	02	--	30	70	--	25	--	125	04	01	--	05
103004 / 104010	Basic Electrical Engineering / Basic Electronics Engineering	03	02	--	30	70	--	25	--	125	03	01	--	04
110005/ 101011	Programming and Problem Solving / Engineering Mechanics	03	02	--	30	70	--	25	--	125	03	01	--	04
102012	Engineering Graphics [Ω]	01	02	01	--	50	25		--	75	01	01		02
110013	Project Based Learning[§]	--	04	--	--	--	25	50	--	75	--	02	--	02
	Total	15	12	02	120	330	75	125	--	650	15	05	02	22
101014	Audit Course 2[&]	02	Environmental Studies-II											
107015		--	Physical Education-Exercise and Field Activities											

Teaching Scheme:

- **TH : 03 Hrs./week**
- **PR : 02 Hrs./week**

Examination Scheme

- **In - Semester : 30 Marks (on Unit 1 & 2)**
- **End - Semester : 50 Marks (All 4 Units)**
- **PR : 25 Marks**

Credits 04

Syllabus

Unit I Introduction to Electronics [8L]

- Evolution of Electronics, Impact of Electronics in industry and in society.
- Introduction to active and passive components, P-type Semiconductor, N-type Semiconductor. Current in semiconductors(Diffusion and Drift Current)
- P-N Junction Diode: P-N Junction diode construction and its working in forward and reverse bias condition, V-I characteristics of P-N junction Diode, Diode as a switch, Half Wave Rectifier, Full wave and Bridge Rectifier.
- Special purpose diodes: Zener diode, Light Emitting Diode (LED) and photo diode along with V- I characteristics and their applications.

Syllabus

Unit II Transistor and OPAMP [7L]

- **Bipolar Junction Transistor : Construction, type, Operation, V-I Characteristics, region of operation, BJT as switch and CE amplifier**
- **Metal Oxide Semiconductor Field Effect Transistors (MOSFET): Construction, Types, Operation, V-I characteristics, Regions of operation, MOSFET as switch & amplifier.**
- **Operational amplifier: Functional block diagram of operational amplifier, ideal operational amplifier, Op-amp as Inverting and Non inverting amplifier**

Syllabus

Unit III Number System and Logic Gates [7L]

- Number System:- Binary, BCD, Octal, Decimal, Hexadecimal their conversion and arithmetic, De-Morgan's theorem.
- Basic Gates:- AND, OR, NOT, Universal Gate- XOR, XNOR, Half adder, Full adder Flip Flop's SR, JK, T and D
- Introduction to Microprocessor and Microcontroller (Only block diagram and explanation)

Sinhgad Institutes

Syllabus

Unit IV Electronic Instrumentation [6L]

- **Electronic Instruments: Principles and block diagram of digital multimeter, Function Generator,**
- **Digital Storage Oscilloscope (DSO) Power scope, AC/DC power supply,**
- **Auto transformer, Analog ammeter and voltmeter.**

Syllabus

Unit V Sensors [7L]

- Classification of a sensors, Active /Passive Sensors, Analog/Digital Sensors,
- Motion Sensors (LVDT, Accelerometer), Temperature Sensors (Thermocouple, Thermistor, RTD), Semiconductor Sensors(Gas Sensors), Optical Sensors (LDR), Mechanical Sensors (Strain Guage, Load Cell,
- Pressure sensors), Biosensors. (Working Principle and one application).

Syllabus

Unit VI **Communication Systems** **[7L]**

- **Basic Communication System: Block Diagram, Modes of Transmission, Communication Media: Wired and Wireless, Electromagnetic Spectrum, Allotment of frequency band for different applications,**
- **Block Diagram of AM and FM Transmitter and receiver,**
- **Mobile Communication System: Cellular concept, Simple block diagram of GSM system.**

Text Books

1. <u>***"Electronics Devices" by Thomas. L. Floyd, 9th Edition, Pearson (Unit I, II)***</u>
2. "Modern Digital Electronics" by R.P. Jain, 4th Edition, Tata McGraw Hill (Unit III)
3. "Electronic Instrumentation" by H.S. Kalsi, 3rd Edition, Tata McGraw Hill (Unit IV)
4. "Sensors and Transducers" by D. Patrnabis, 2nd Edition, PHI (Unit V)
5. "Electronic Communication Systems" by Kennedy & Davis, 4th Edition, Tata McGraw Hill (Unit VI)
6. "Mobile Wireless communication" by M. Schwartz, Cambridge University Press (Unit VI)

Reference Books

1.“Digital Fundamentals” by Thomas. L. Floyd, 11th Edition, Pearson

2.“Mobile Communication” by J. Schiller, 2nd Edition, Pearson

3.“Sensors Handbook”, by S. Soloman, 2nd Edition.

Sinhgad Institutes

List of Experiments

Experiment No.	Title/Name of Experiment
1	**To Study Electronics Components.**
2	**To Study Electronics Measuring Instruments.**
3	**To Study V-I characteristics of P-N Junction Diode & Zener Diode.**
4	**To Study Rectifier circuits.**
5	To Study Frequency response of MOSFET (Simulation).
6	Linear applications of Op-amp.
7	To Study Digital Circuits.
8	Study of transducers. (Any 3)
9	Build and test any circuit using BJT/MOSFET/Op-Amp/Logic Gates using any one sensor.
10	Case Study of any one electronics appliance with block diagram, specification etc.

Guidelines for Student's Lab Journal

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- The laboratory assignments/experiments are to be submitted by student in the form of journal.

- Journal consists of Certificate, table of contents, and handwritten write-up for each experiment.

- Each experiment should consist of :

✓ Title.
✓ Objectives.
✓ Problem Statement, Outcomes
✓ Hardware / Software (If any) requirements.
✓ Concept.
✓ Experimental procedure / Setup.
✓ Observation table
✓ Conclusion.

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Guidelines for Lab /PR Assessment

- ***Continuous assessment of laboratory work is done based on overall performance.***

- **Each lab assignment/ experiment assessment will assign grade / marks based on parameters with appropriate weightage.**

- **Suggested parameters for overall assessment as well as each lab assignment / experiment assessment include:**

✓ ***Timely completion.***

✓ ***Performance.***

✓ ***Punctuality and neatness.***

Unit 1

Introduction to Electronics

Syllabus

Unit I Introduction to Electronics [8L]

- Evolution of Electronics, Impact of Electronics in industry and in society.
- Introduction to active and passive components, P-type Semiconductor, N-type Semiconductor. Current in semiconductors(Diffusion and Drift Current)
- P-N Junction Diode: P-N Junction diode construction and its working in forward and reverse bias condition, V-I characteristics of P-N junction Diode, Diode as a switch, Half Wave Rectifier, Full wave and Bridge Rectifier.
- Special purpose diodes: Zener diode, Light Emitting Diode (LED) and photo diode along with V- I characteristics and their applications.

Evolution of Electronics

Sr. No.	Year	Invention/Discovery
1	1720	Stephen Gray discovered Insulator and Conductor
2	1745	Ewald Georg Von Kleist and Pieter Van Musschenbroek invented first capacitor
3	1826	Georg Ohm introduced Ohm’s law
4	1831	Reverend Nicholas Callan of Ireland invented the Inductor coil. Faraday’s law by Joseph Henry (1832) and Michael Faraday (1831)
5	1836	Nicholas Callan Invented Transformer
6	1876	Alexander Graham Bell invented Telephone
7	1888	Heinrich Hertz proved that electromagnetic waves (EM) travel over some distance
8	1897	Karl Ferdinand Braun invented Cathode Ray Oscilloscope (CRO)
9	1901	Guglielmo Marconi made first transatlantic Radio Broadcast
10	1904	John Ambrose Fleming invented Diode
11	1906	Lee de Forest invented Triode
12	1912	Edwin Howard Armstrong developed Electronic Oscillator

13	1920	Otis Frank Boykin invented Resistor in Dallas, Texas
14	1928	First Experimental Television Broadcast in the US
15	1929	First public TV broadcast in Germany
16	1941	Konrad Zuse developed the first programmable computer
17	1943	Paul Eisler invented the Printed Circuit Board (PCB)
18	1944	John Logie Baird developed the first Color Picture Tube
19	1947	First Transistor at Bell laboratories by William Shockley, John Bardeen and Walter Brattain
20	1958	Jack Kilby invented the Integrated Circuit (IC)
21	1960	Theodore Harold Maiman invented the Laser (Light amplification by stimulated emission of radiation)
22	1962	Hofstein and Heiman invented MOSFET transistors
23	1962	Nick Holonyak Jr. invented the LED
24	1970	INTEL introduced the first Microprocessor
25	1973	John F. Mitchell and Dr. martin Cooper of Motorola invented the first Mobile Phone
26	2007	Apple introduced iPhone

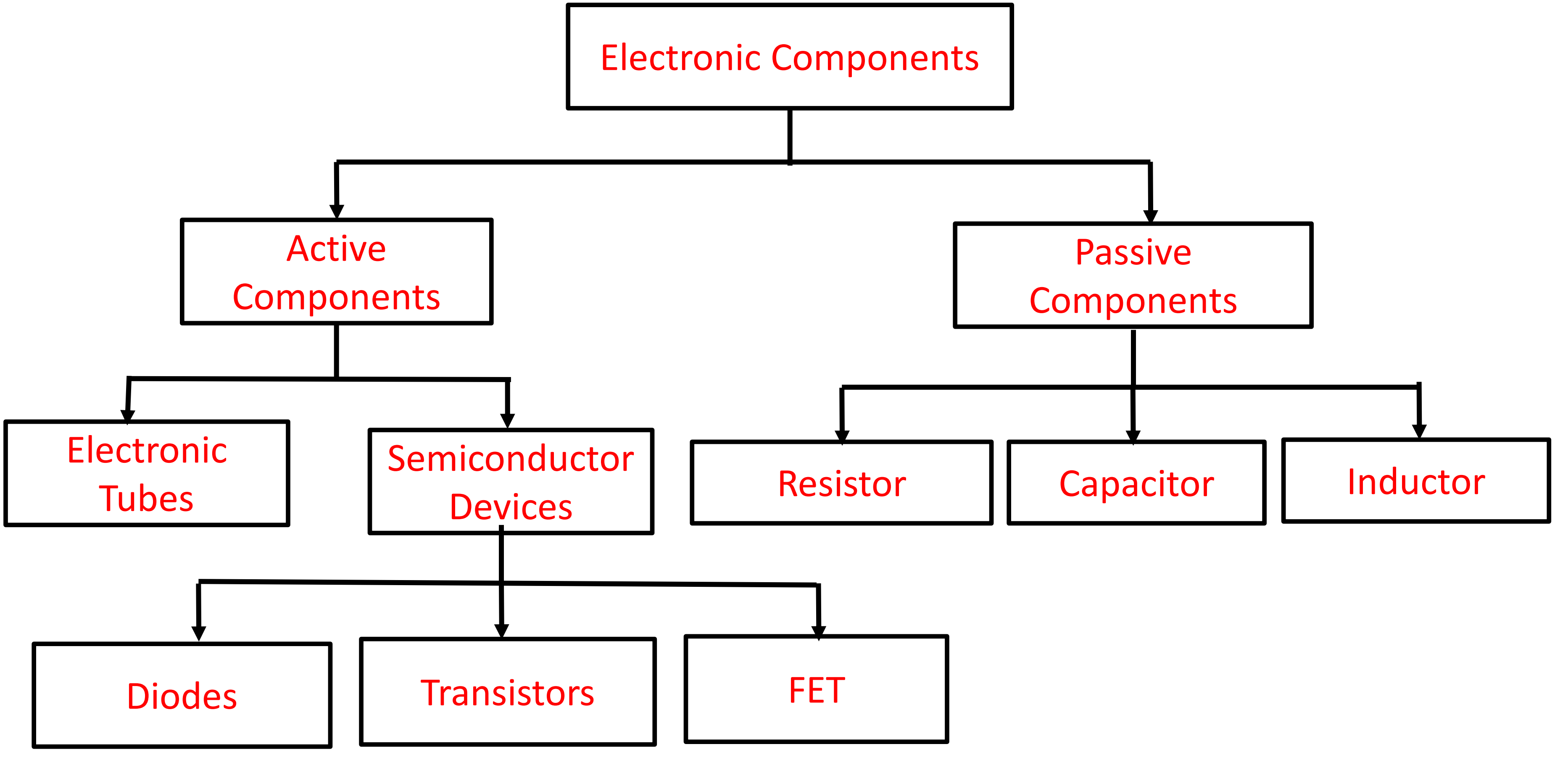
IMPACT OF ELECTRONICS IN INDUSTRY AND SOCIETY

- Industrial Applications
- Defence Applications
- Medical Sciences
- Instrumentation
- Communication and Entertainment
- Communication on Social Media

Electronics Components

- Circuits : Combination of Active & Passive Components connected in required fashion to get meaningful result.

Types of Electronics components



Comparison

Parameter	Passive Components	Active Components
Amplification	The electronic components which by themselves are not capable of amplifying or processing an electrical signal are called passive components	The electronic components which by themselves are capable of amplifying or processing an electrical signal are called active components
Gain	It does not introduce any gain	It may introduce gain
Direction	It has bidirectional function	It has generally unidirectional functions
Source of energy	These components do not act as an energy source	These components do act as an energy source
Function	Energy acceptor	Energy Donor

Parameter	Passive Components	Active Components
Generation of energy	These components consume energy	These components produce energy
Operation	Consume energy in the form of voltage or current	Produce energy in the form of voltage or current
Current Control	Cannot control the flow of current	Can control the flow of current
Examples	Resistors, Inductors and capacitors	Transistors, diodes and Power devices

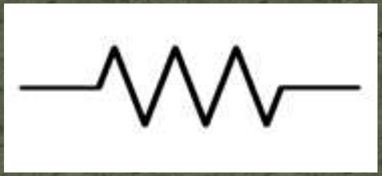
Passive Components

- RESISTOR CAPACITOR INDUCTOR

Resistor

Def : A discrete components which oppose the flow of current
A resistor is a passive component that limits the electrical current flowing in a circuit.

Unit is Ohms (Ω).



TYPES OF RESISTOR

RESISTOR

- **FIXED RESISTOR**
- **VARIABLE RESISTOR**

FIXED RESISTOR

- CARBON COMPOSITE RESISTOR
- FILM RESISTOR
- WIRE WOUND RESISTOR
- RESISTANCE WIRE

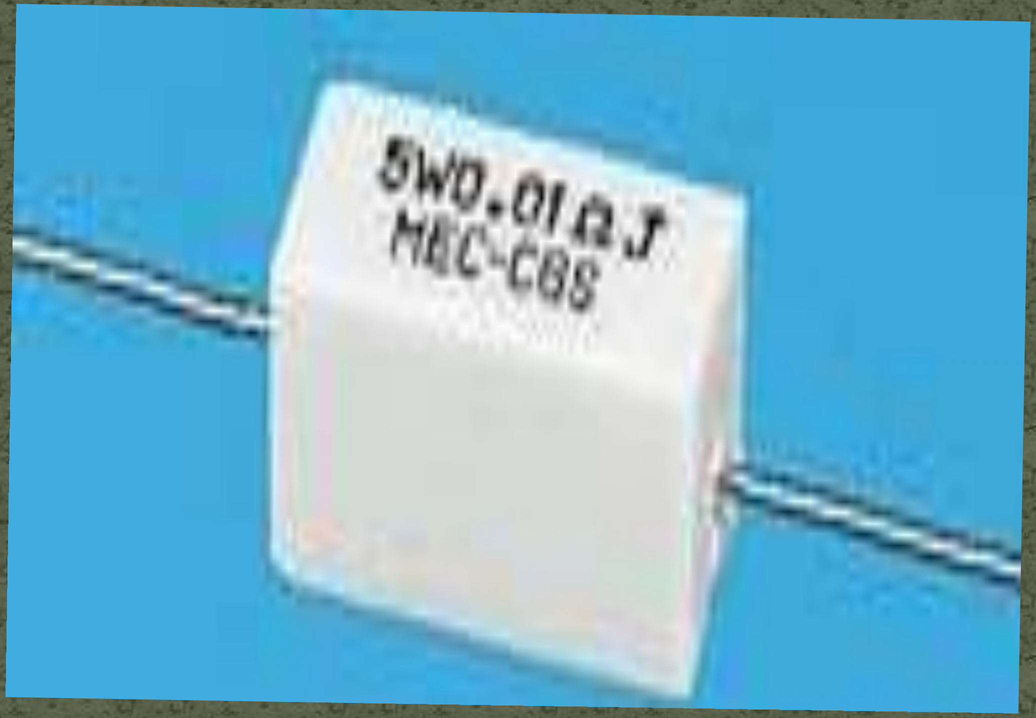
VARIABLE RESISTOR

- RHEOSTAT
- POTENTIOMETER
- THERMISTOR
- PHOTORESISTOR

Fixed Types

- Def : With irrespective any parameter changing the value resistor remains constant or fixed.

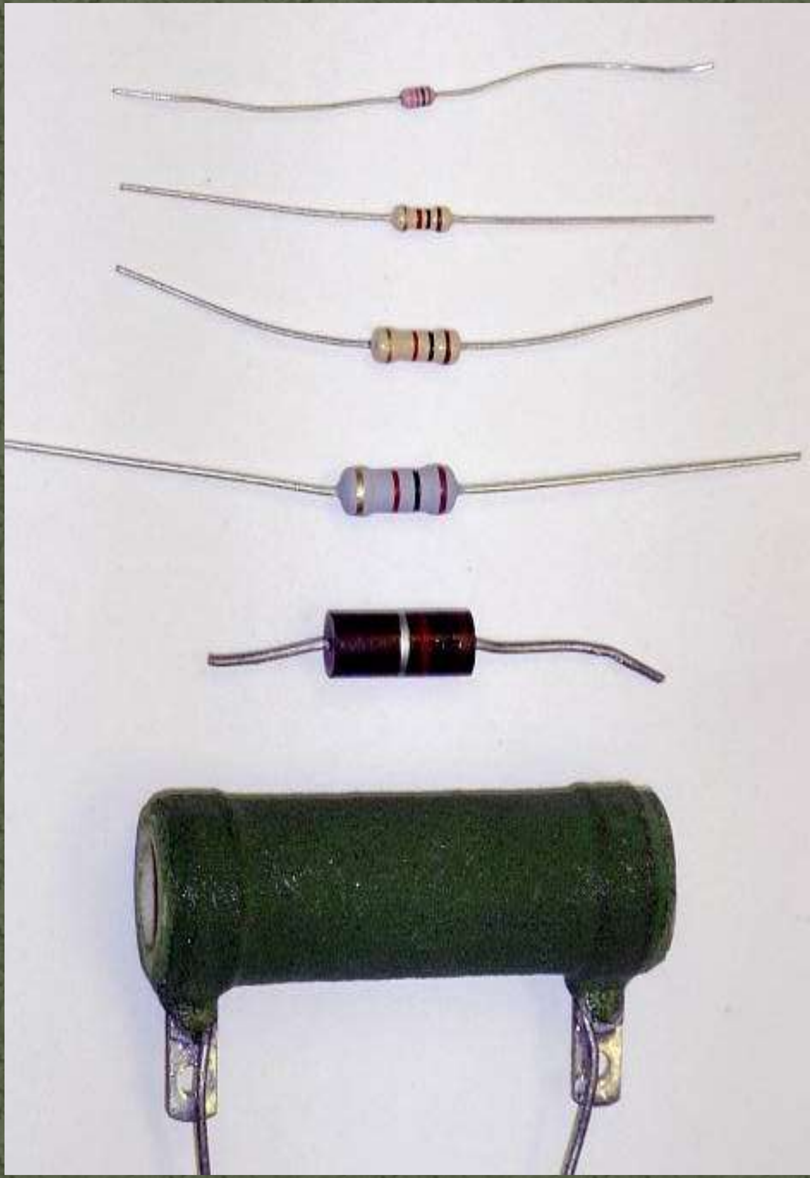
- Colour code Resistor Fusable Resistor



Fixed types

WIRE WOUND RESISTOR

Resistor Network



CARBON COMPOSITE RESISTOR

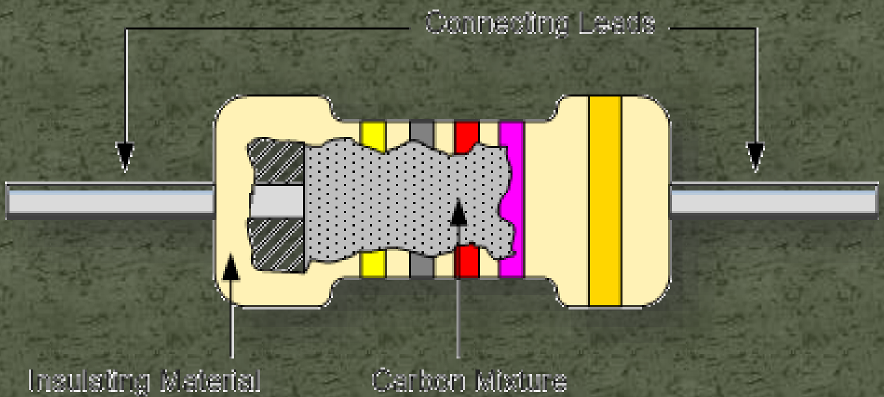
- LOW INDUCTANCE

- RAW MATERIAL USED IS CARBON BLACK, RESIN BINDER AND REFRACTORY FILLINGS

- IDEAL FOR LOW POWER APPLICATIONS

- VERY CHEAP TO MAKE

- HAVE VERY LARGE TOLERANCES

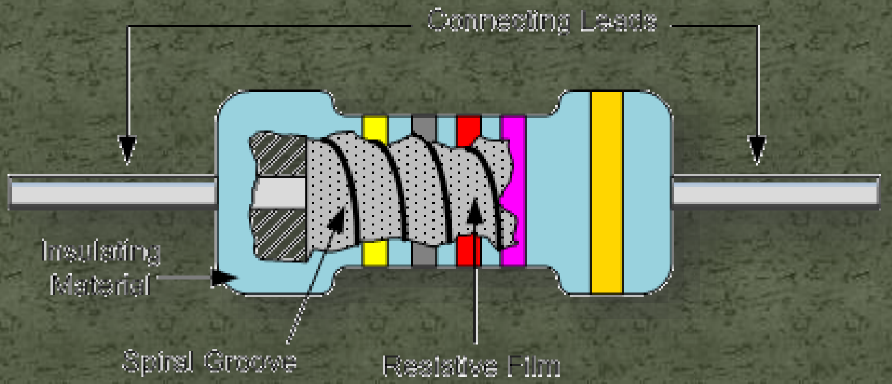


FILM RESISTOR

- THE RESISTIVE VALUE OF THE RESISTOR IS CONTROLLED BY INCREASING THE DESIRED THICKNESS OF THE DEPOSITED FILM.

- RESISTANE UPTO 10MΩ CAN BE OBTAINED.

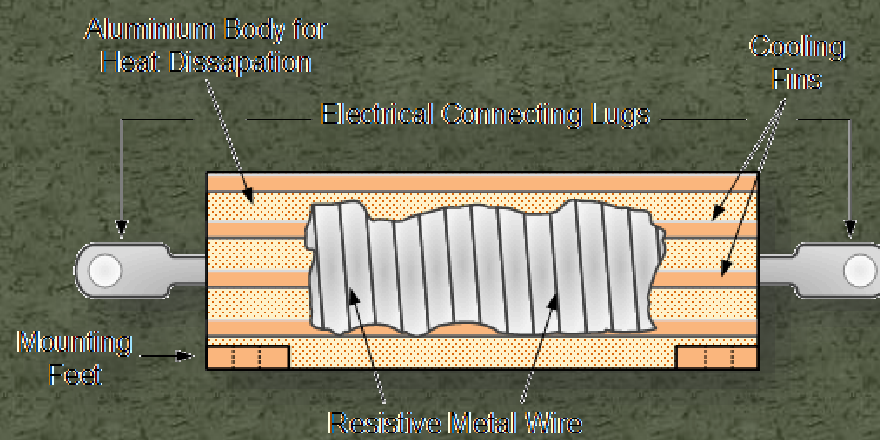
- HAVE TOLERANCE 1% OR LESS



WIRE WOUND RESISTOR

➢MADE BY WINDING A THIN METAL ALLOY WIRE ONTO AN INSULATING CERAMIC FORMER IN THE FORM OF A SPIRAL HELIX

➢ AVAILABLE IN VERY LOW OHMIC AND HIGH PRECISION VALUES
(FROM 0.01 TO 100KΩ)



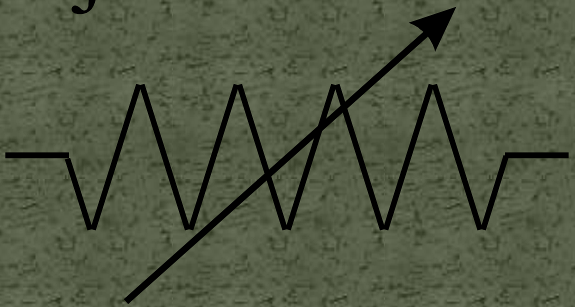
Application of Fixed Types

- Feed Back Circuits
- Tuner Circuits
- Voltage Divider Circuits
- Phase Shift Circuits
- Tank Circuits
- Filter Circuits

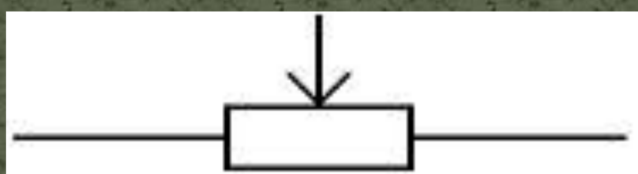
Variable Resistor & its types

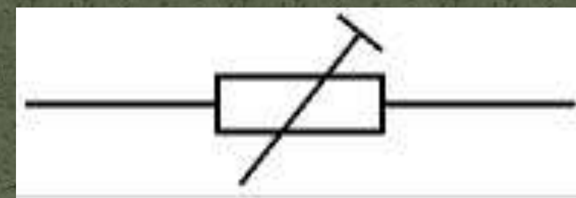
Def: If the value of the resistor can be varied within the given limit, then it is known as variable resistor

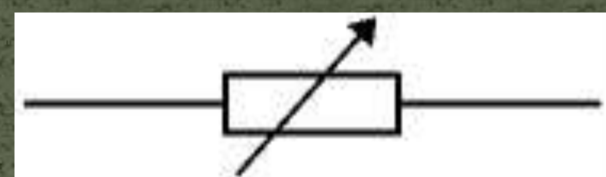
adjustable resistor



Variable Resistor



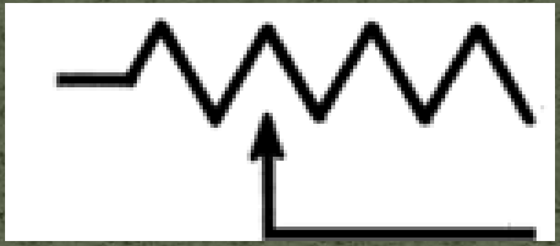




- Variable resistors consist of a resistance track with connections at both ends and a wiper which moves along the track as you turn the spindle

RHEOSTAT

- RHEOSTAT IS A ADJUSTABLE RESISTOR USED IN APPLICATIONS THAT REQUIRE ADJUSTMENT OF CURRENT OR VARYING OF RESISTANCE IN AN ELECTRIC CIRCUIT

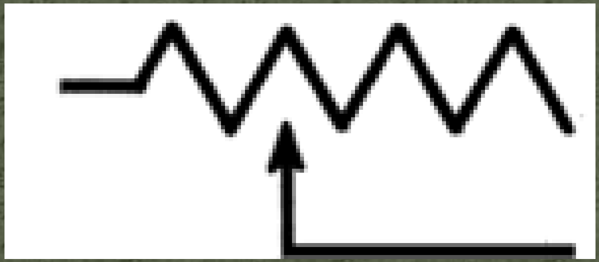


- A SPECIAL TYPE OF RHEOSTAT IS THE POTENTIOMETER

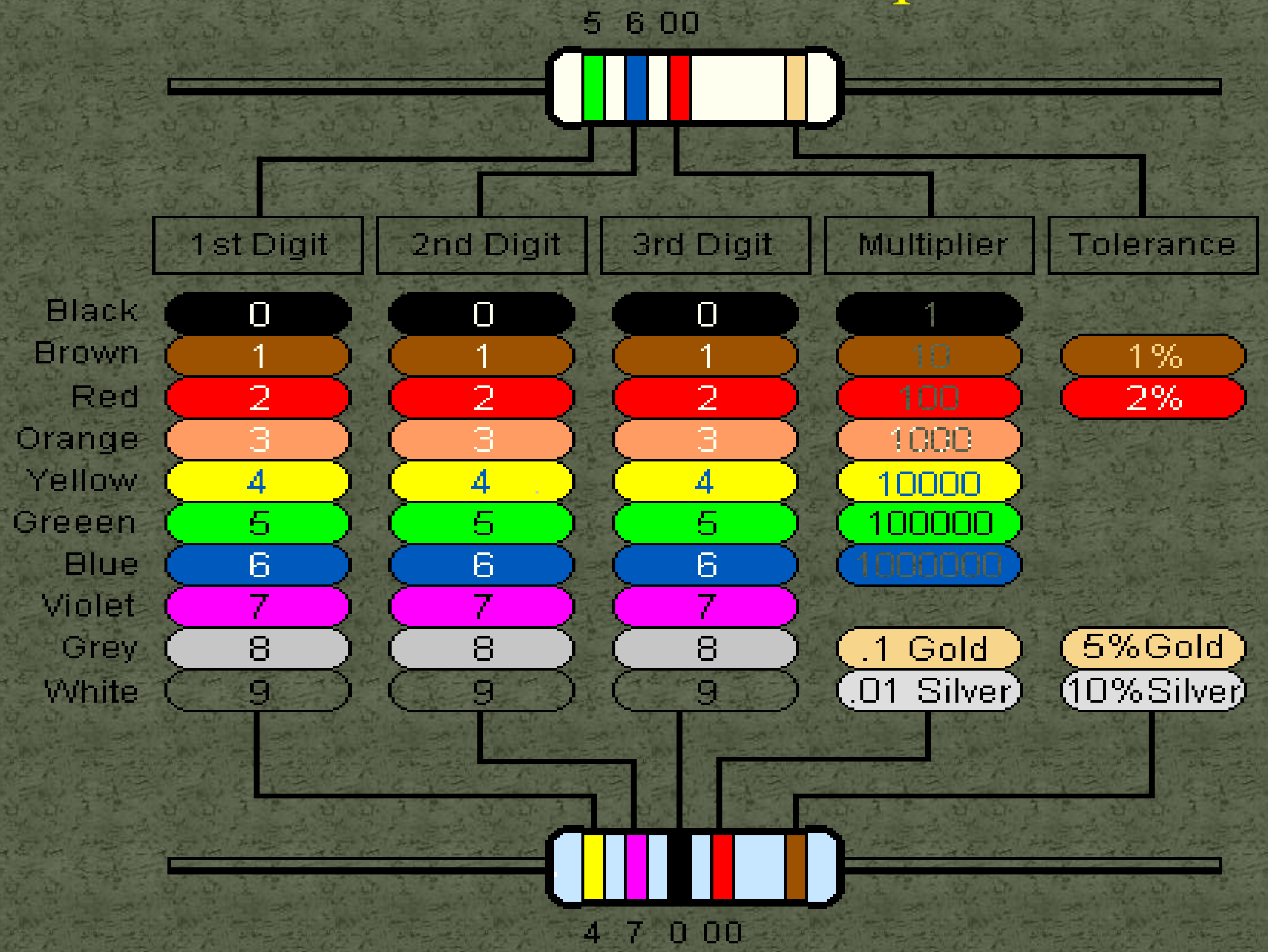
POTENTIOMETER

- A POTENTIOMETER IS, A POT, IN ELECTRONICS TECHNOLOGY IS A THREE-TERMINAL RESISTOR WITH A SLIDING CONTACT THAT FORMS AN ADJUSTABLE VOLTAGE DIVIDER.

- POTENTIOMETERS ARE COMMONLY USED TO CONTROL ELECTRICAL DEVICES SUCH AS VOLUME CONTROLS, JOYSTICKS ETC.



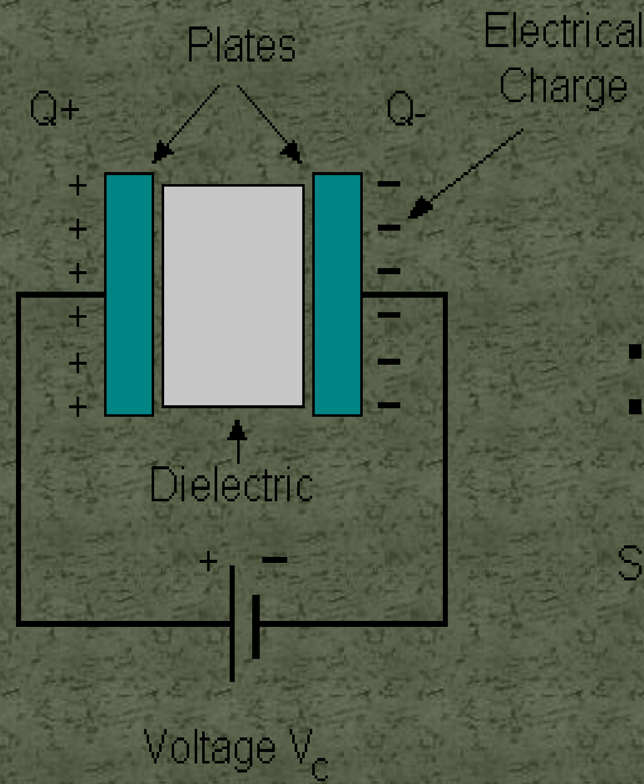
Resistor colour Code Technique



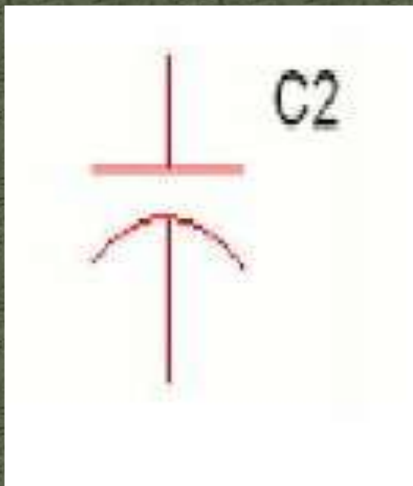
Introduction to Capacitor

Capacitor

- Def : Its two terminal device, consisting of two parallel plate separated by dielectric material which has capacity to store energy in the form charges.
- Measured in terms of : Farads
- Also indicated by volts



- Schematic Symbol :



Description of Capacitor

- It Block DC , Pass AC.
- Di-electric used are Glass, Paper, Plastic, Mica, Ceramic, Electrolyte, etc.,
- Storage capacity of the capacitor depends on area of the plate, distance between them & type of dielectric used.

$$\boxed{C = \epsilon \frac{A}{d}}$$

- Voltage rating indicate the maximum voltage which can be applicable. (VDC)
- $\mu = 10^{-6}$ F, $n = 10^{-9}$ F, $p = 10^{-12}$F

Capacitor Family Tree

- CAPACITORS
  - ELECTROSTATIC
    - CERAMIC
    - FILM
  - ELECTROLYTIC
    - ALUMINUM
    - TANTALUM

- Non polarized
- AC or DC operation
- Lower Capacitance

- Polarized
- DC operation
- Higher Capacitance

Types of capacitors

- Polarized

  which have specified positive and negative terminals.

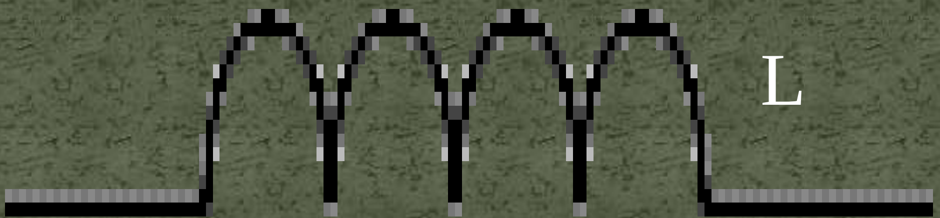
- Non-polarized

  no defined polarity for terminals.

Introduction to Inductors

Inductors

DEF: is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it.



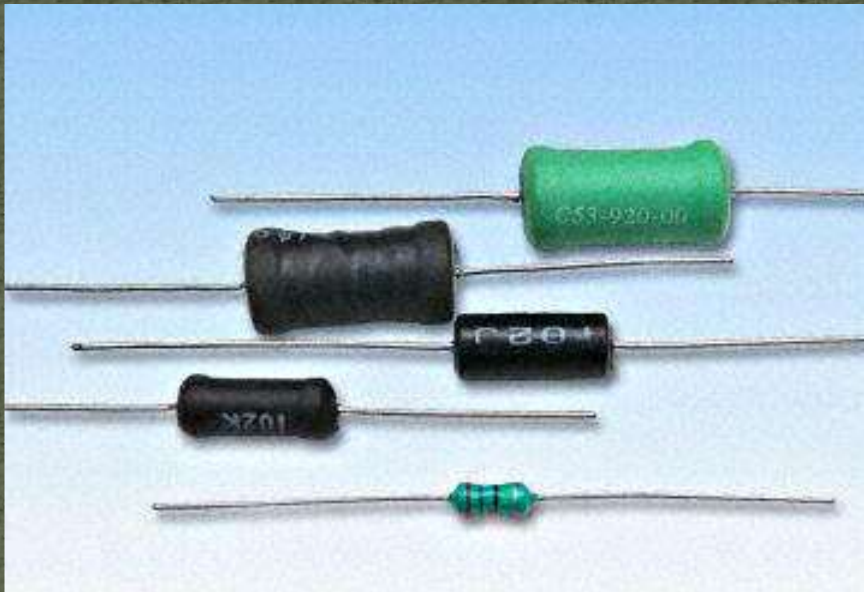
L

Schematic Symbol

- *Measured in HENRY Practically available value will be in terms Micro Henry & Milli Henry.*

- Like capacitors, inductors temporarily store energy.

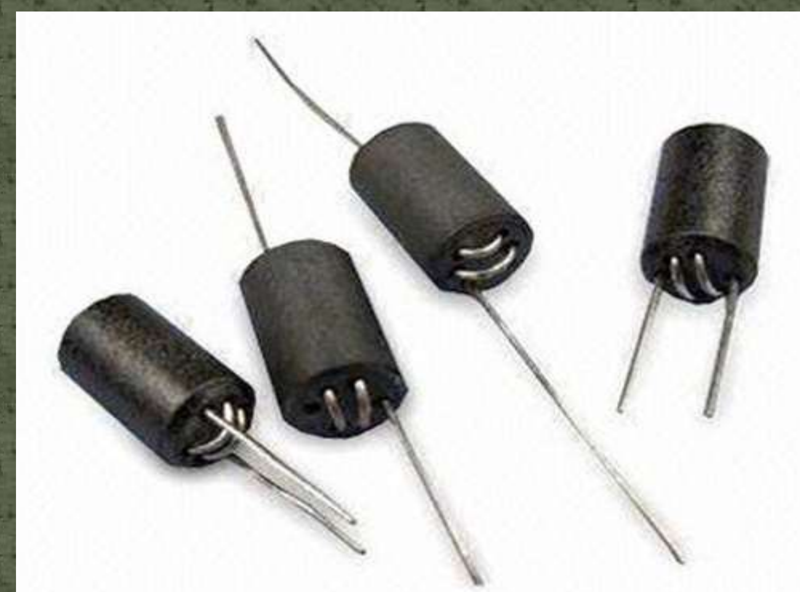
- Types of Inductance : Self Inductance & Mutual Inductance



Radial Lead Inductor

Axial Power Inductor

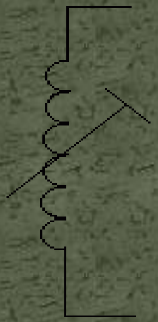
SMD Power Inductor



Beads Inductor

Variable Inductors

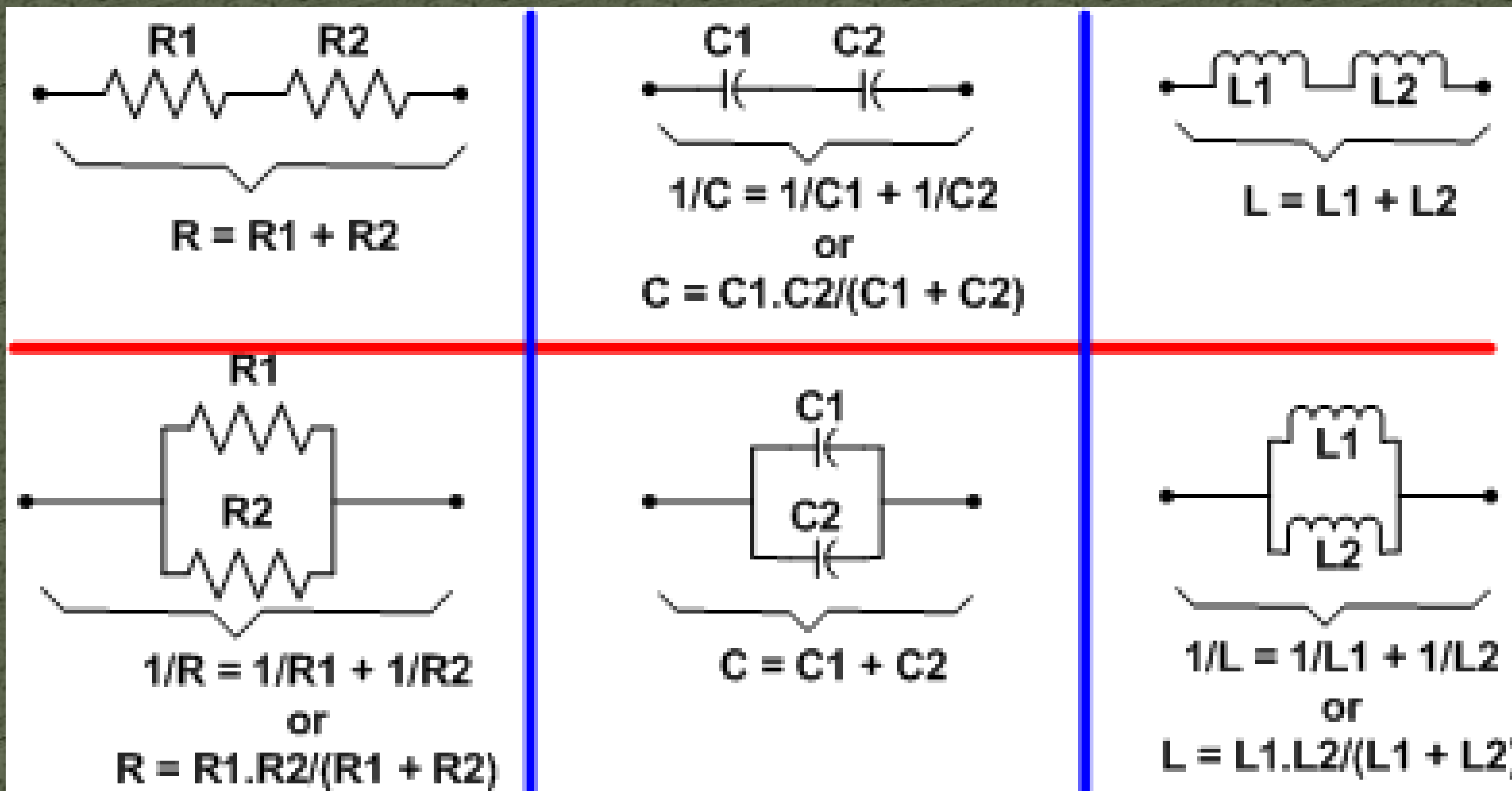
- DEF : if the value of the inductor can be varied within the specified limit, then its Variable Inductor.



Adjustable Air-Wound Inductor

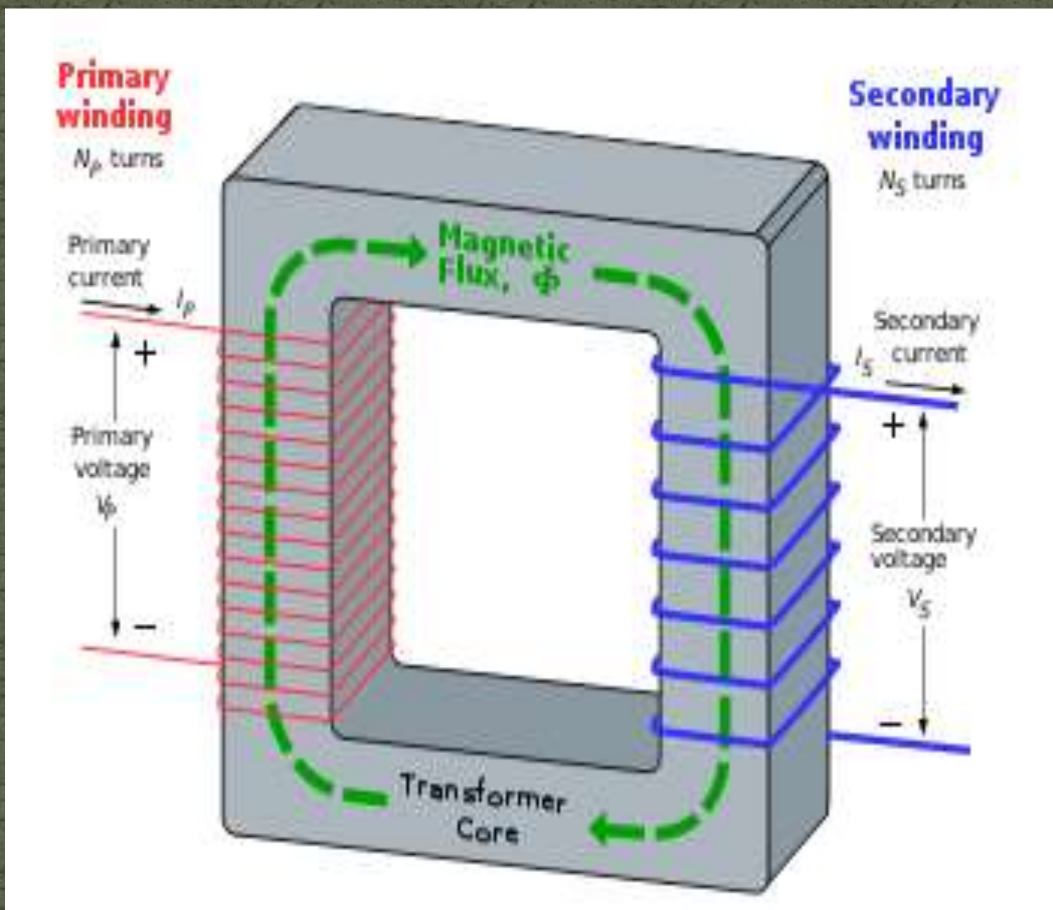
Variable Inductor

Series and Parallel Combinations

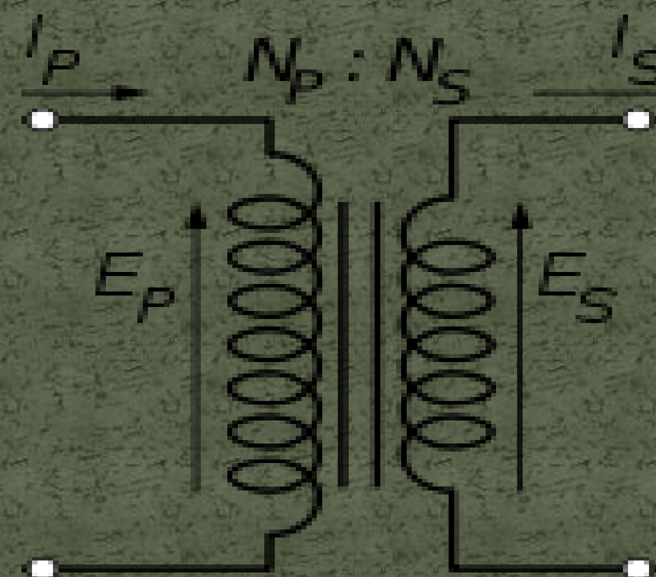


Transformer

- Def: it static devices works on the principle of mutual inductance, which transfer the signal from primary winding to secondary winding



Schematic Symbol



$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Description & Types

- Works on the principle of Mutual Inductance.
- Basic Type: Step -Down & Step – Up.
- Def : If the secondary windings in greater than primary winding, then is know as Step – Up.
- Area of application: R&D Lab, Transmission station.
- Def : If the secondary winding is lesser than Primary winding, then it is know as Step-Down.
- Area of Application: House Hold Appliance, Labs , Adapter, Mobile Chargers.

Types of Transformer

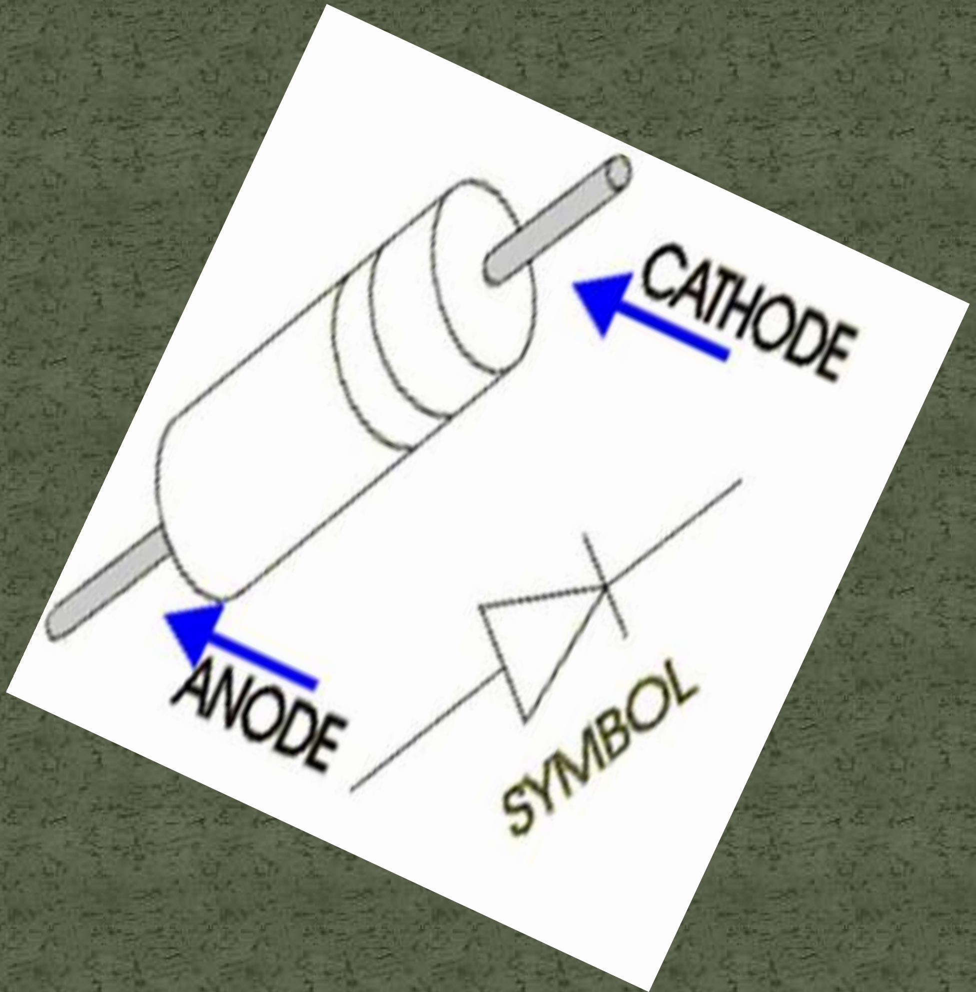
- Isolation Transformer
- Pulse Transformer
- Auto Transformer or Variac
- Current & Voltage transformer
- Leakage Transformer
- Intermediate Frequency Transformers.

Introduction
to
Active Components

- Def: If a components have inner capacity to change energy format from one form to another, then it is known as Active Components
- Its actions can be controlled & it require external source to work
- All Semi- Conductor Devices like Diode , Transistors, IC

Diodes

- It's a two terminal & layer devices formed using P-type & N-types SC, which can conduct in only direction. Its consists of terminal like anode & cathode.



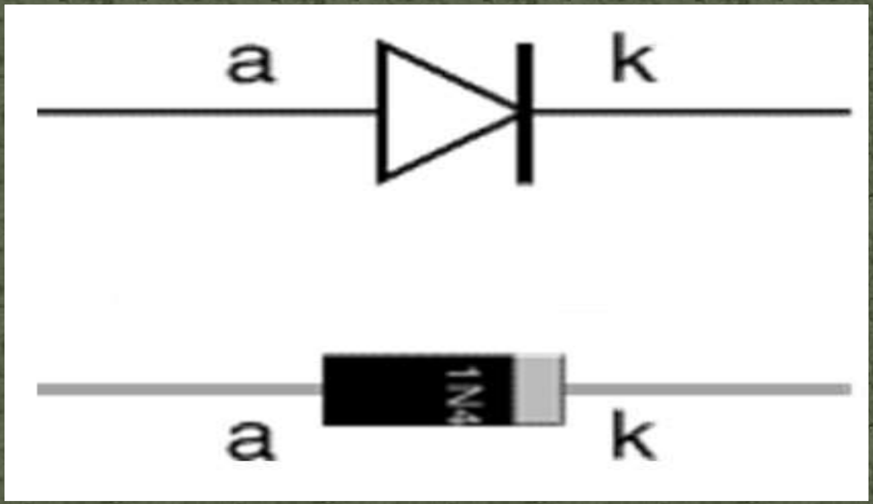
Other Diode :

- PN Junction Diode
- Switching / Signal Diode
- Zener Diode
- Photo Diode
- LED
- Schottky Diode
- Studs

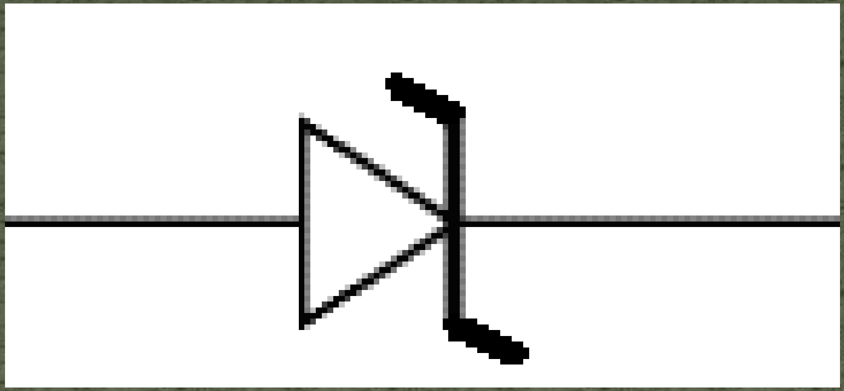
Types of diode

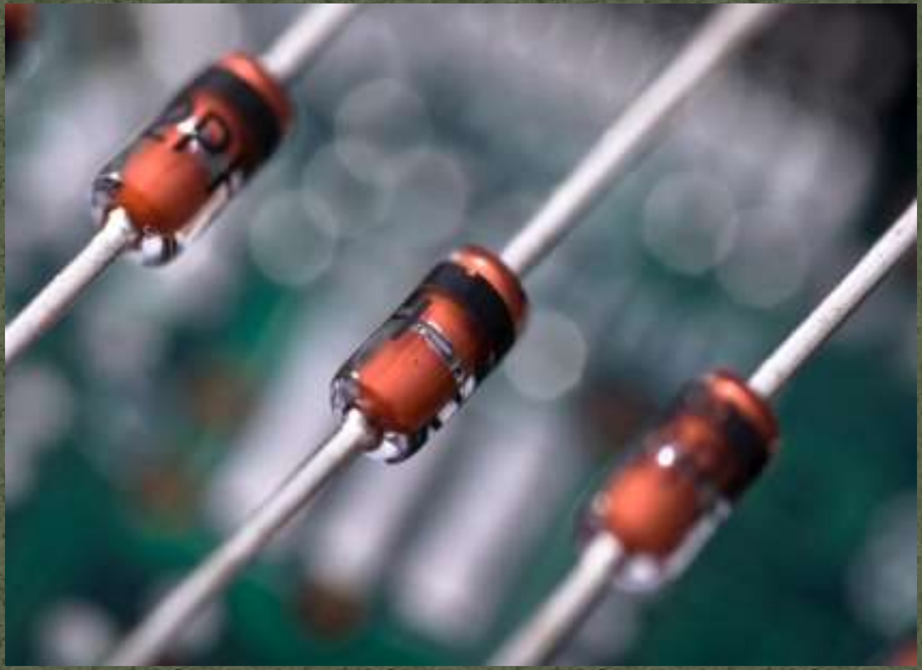
- PN Junction

  or
- Rectifier Diode



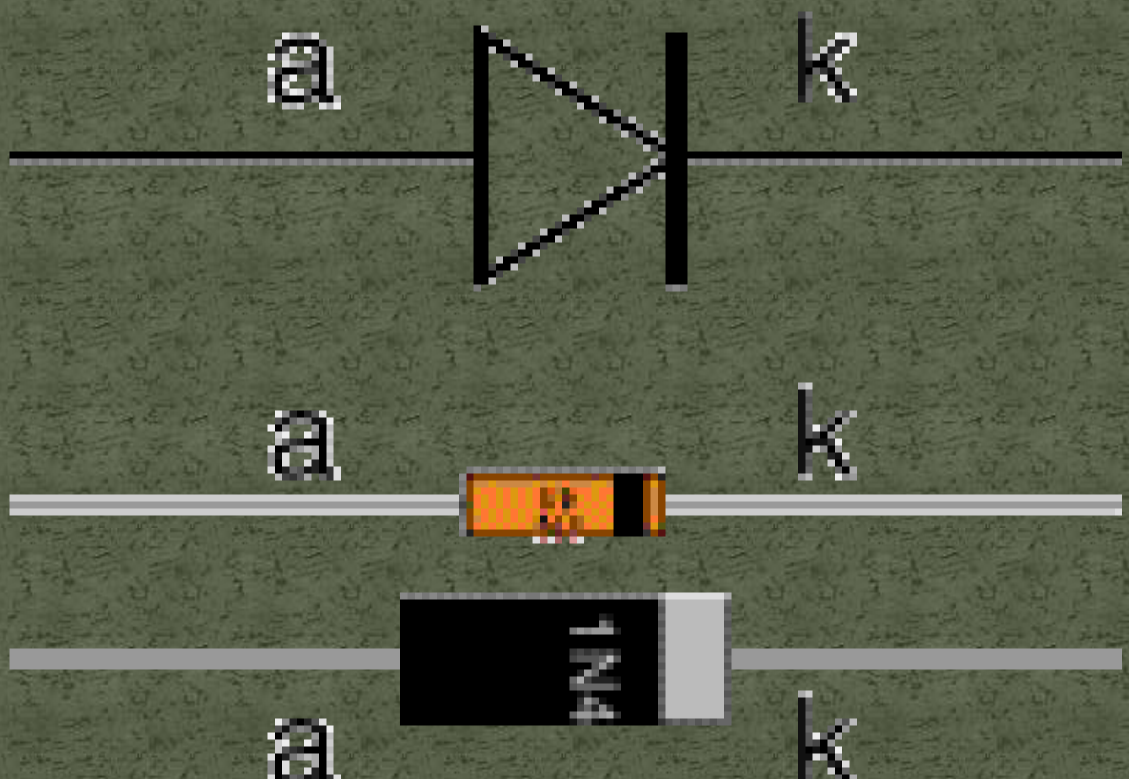
- Zener Diode :



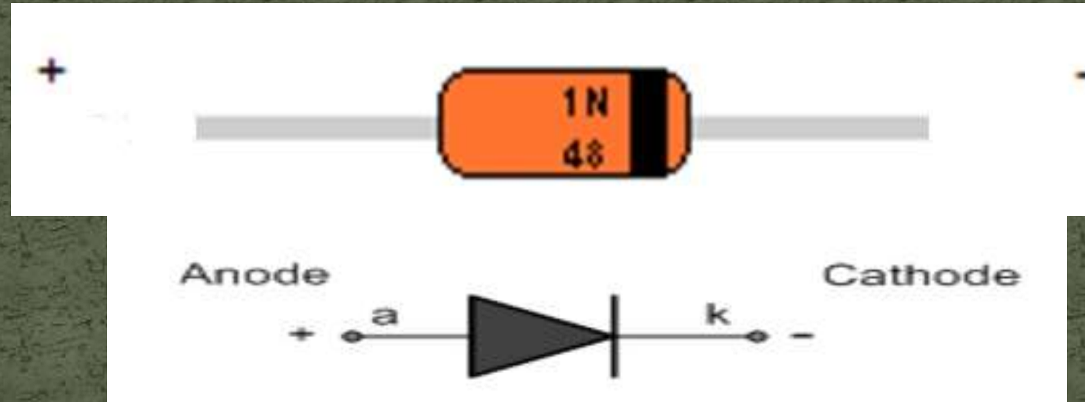


DIODES

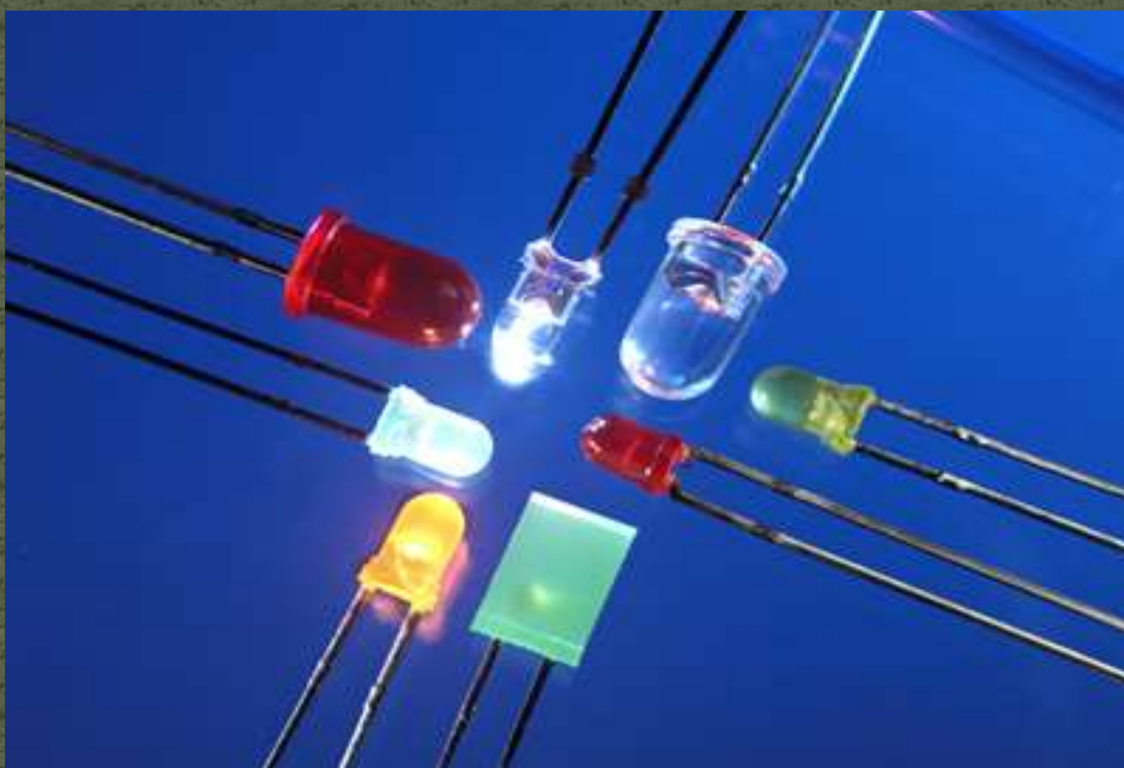
- A two-terminal electronic component that conducts electric current in only one direction.

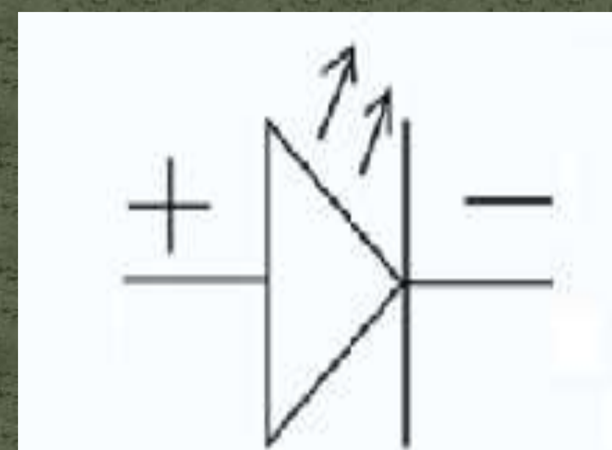


- Signal Diode :

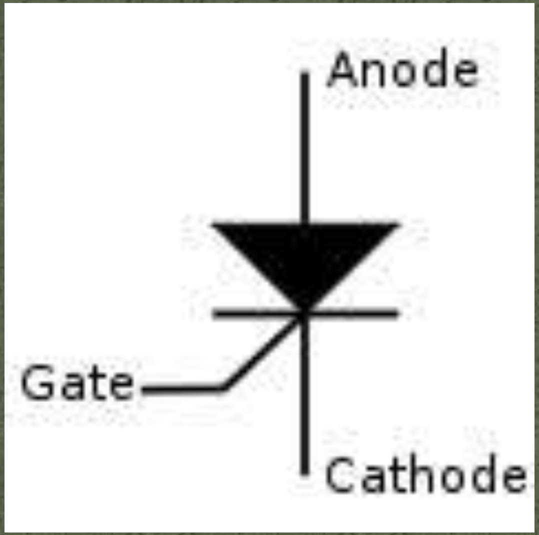


- LED :





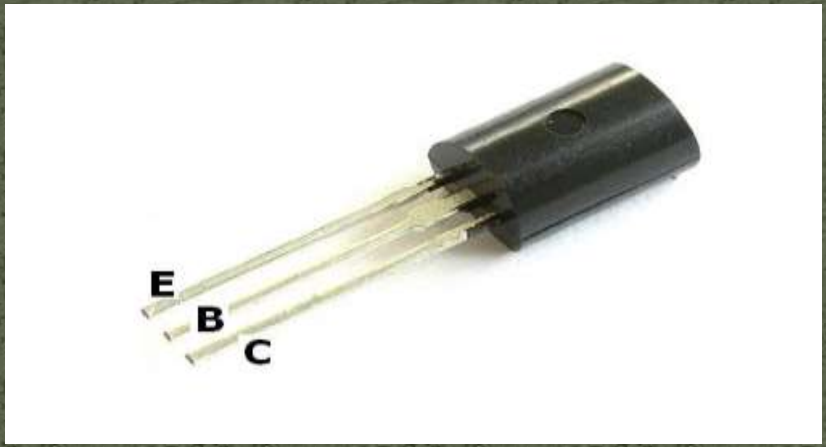
Thyristor

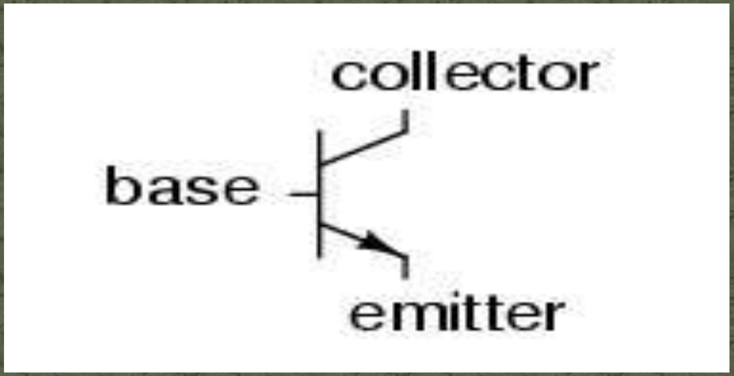


- The thyristor act as bistable switches, conducting when their gate receives a current pulse, and continue to conduct for as long as they are forward biased (that is, as long as the voltage across the device has not reversed).

Transistor

- A transistor is a semiconductor device commonly used to amplify or switch electronic signals.
- Device with three terminals where one terminal can be use to control the flow of current through the other two terminals.

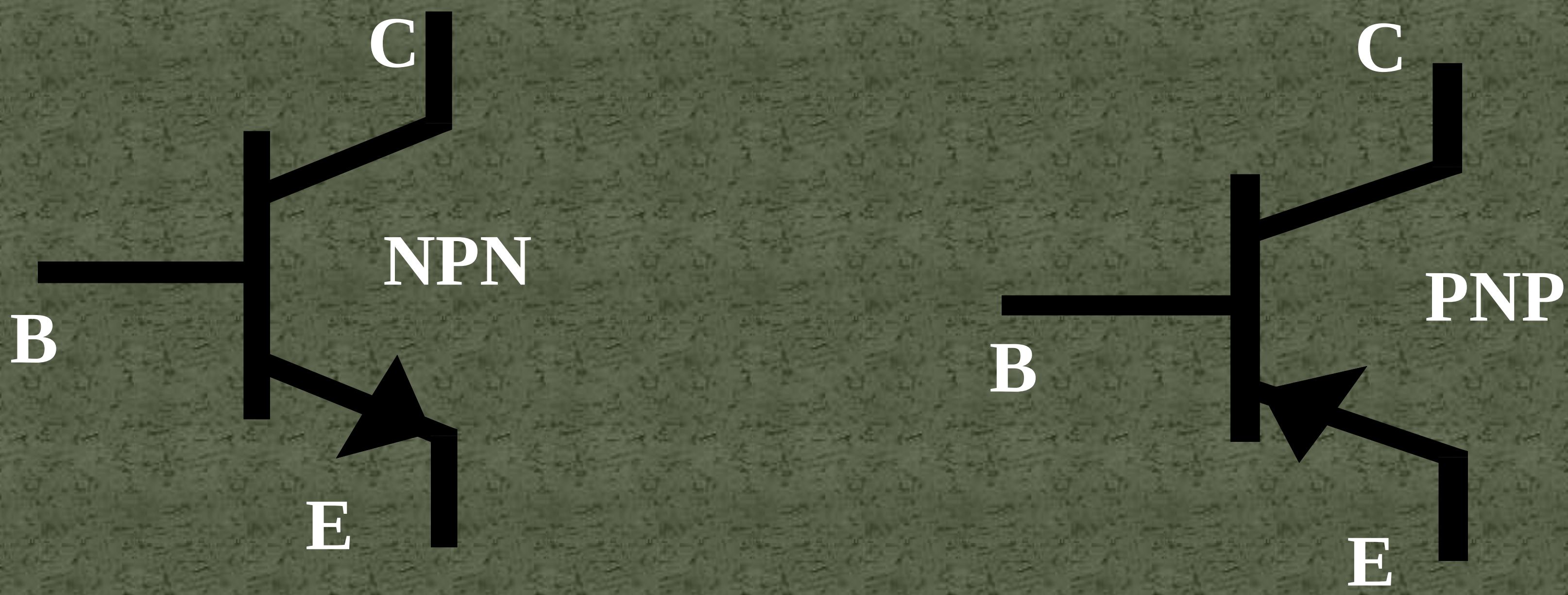




- Transistors are commonly used as electronic switches, for both high power applications including switched-mode power supplies and low power applications such as logic gates.

Transistor

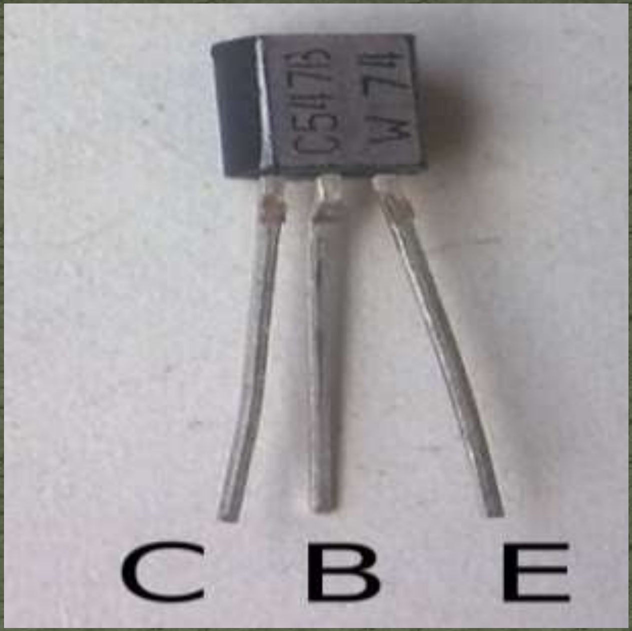
- DEF: It's a three terminal & two junctions devices which transfer signal from low resistance to high resistance region.
- Emitter, Base, Collector

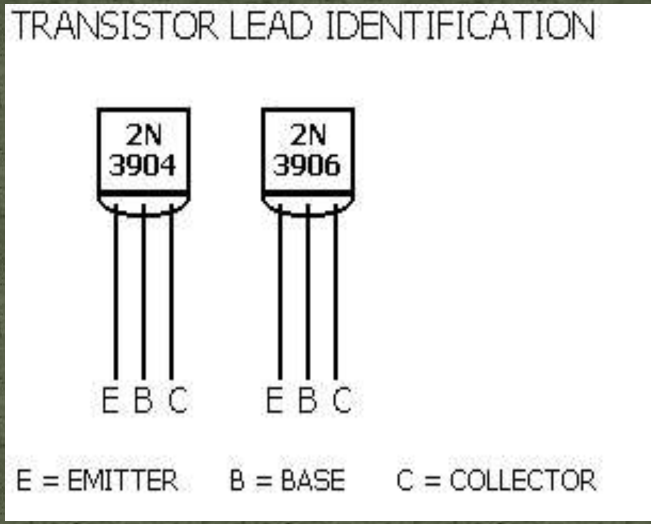


Schematic Symbol

Types of transistor

- Transistor are Classified into three main groups :
- Low Power

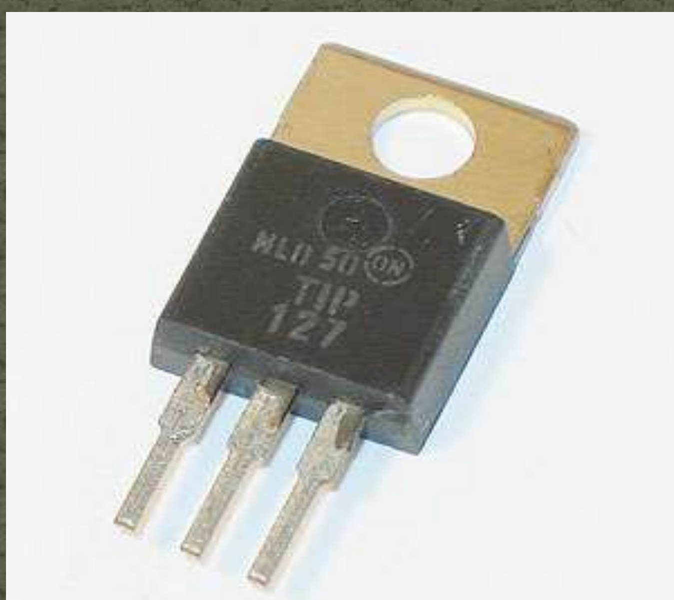




- Medium Power :

- High Power :

B C E

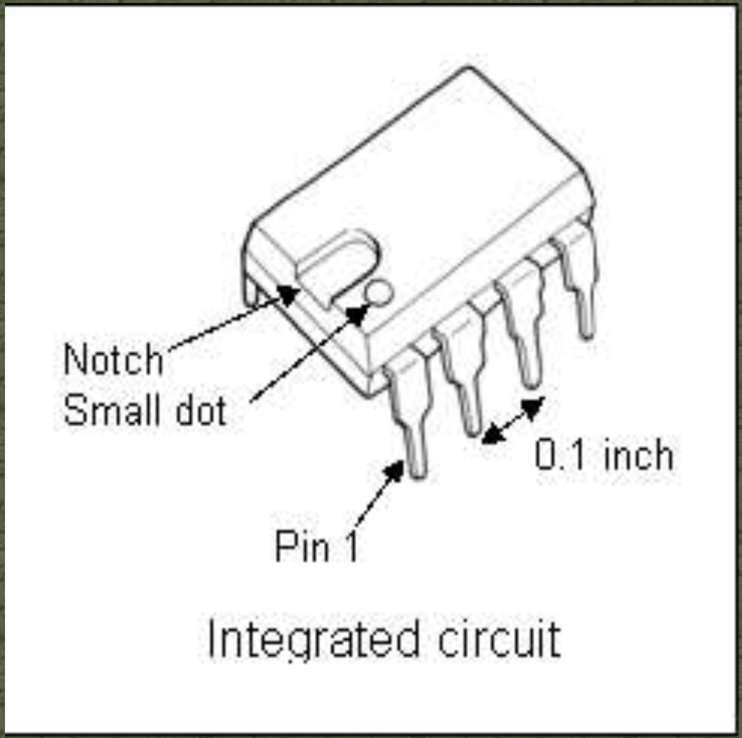


Applications

- Amplifier
- Oscillator
- Switching Ckt
- Comparator
- Series Regulator Ckt
- Sensors & Photo Transistor

Integrated Chips (IC)

- Def : An integrated circuit (IC) is a miniature ,low cost electronic circuit consisting of active and passive components fabricated together on a single crystal of silicon.



Schematic Symbol

Types

- Metal Packages :

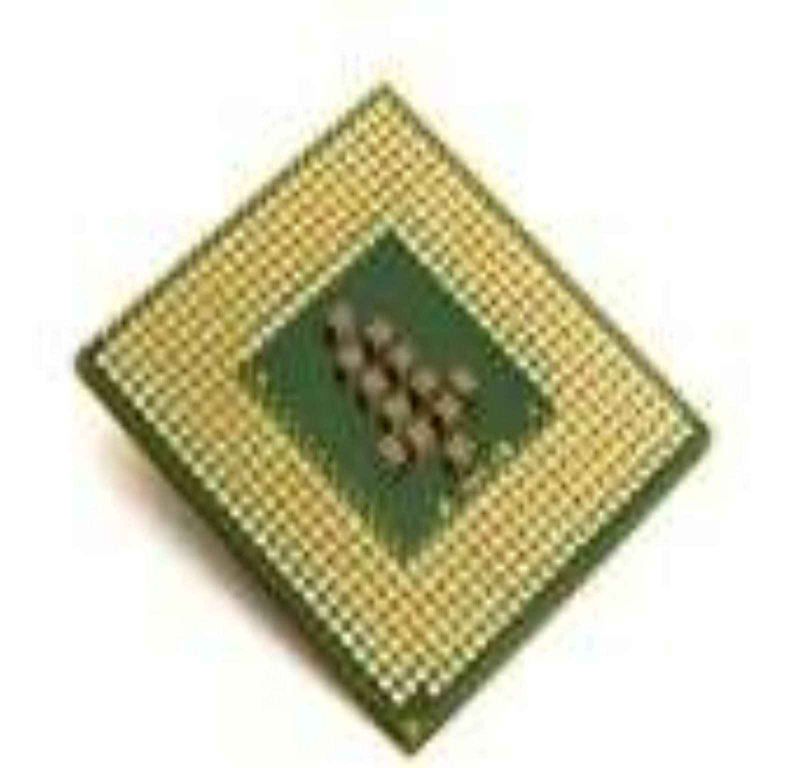
SIP PACKAGE

Types

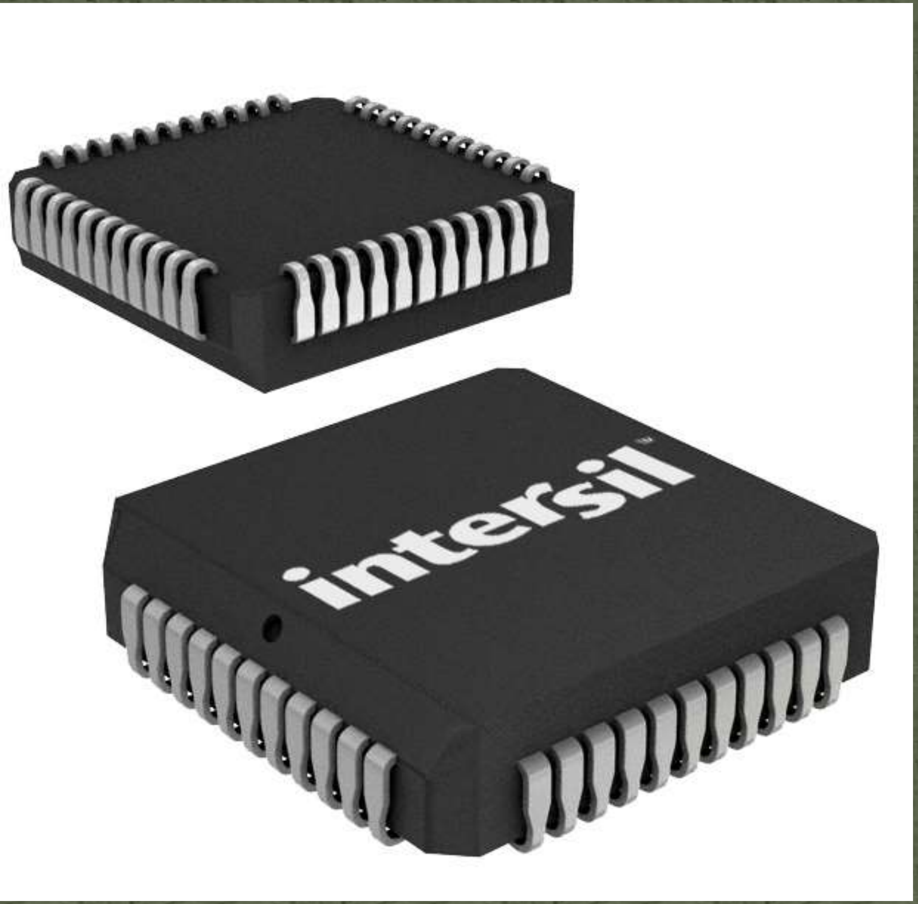
Dip Package

Flat Quad Package

Types

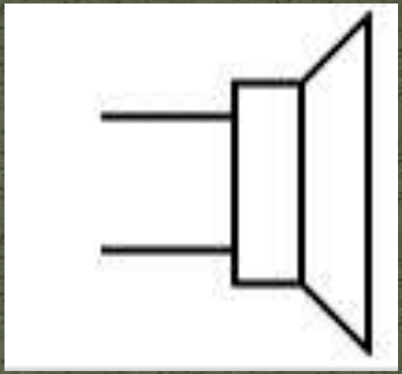


Micro processors



PLCC

Speaker

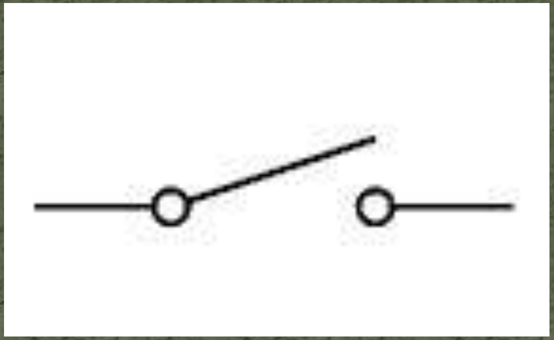


- A **speaker** is an electro acoustic transducer that converts an electrical signal into sound.
- The speaker moves in accordance with the variations of an electrical signal and causes sound waves to propagate through a medium such as air or water.

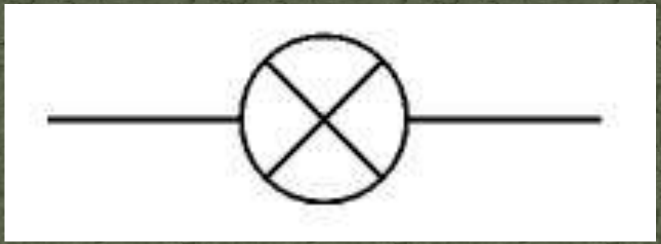
Buzzer

- Buzzers make a loud noise when connected to a battery.
- They are often used as warning devices.

Switches

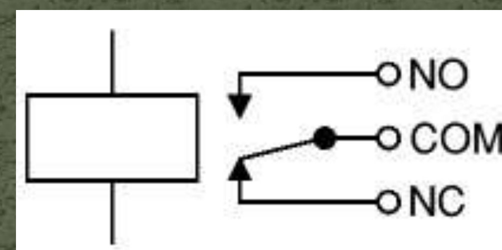


Filament Bulb

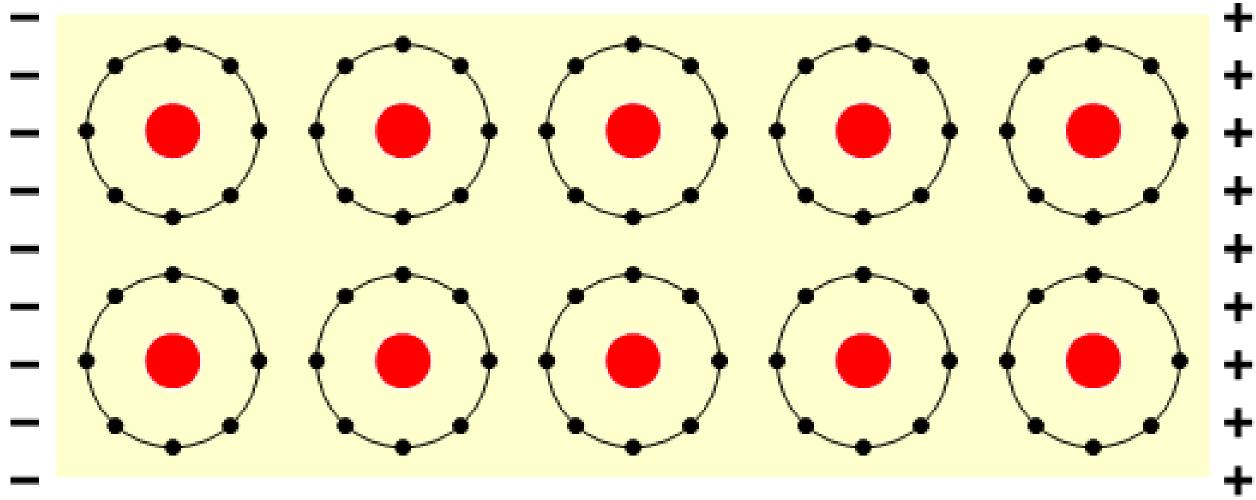


- Filament Bulb emit light when an electric current passes through them.
- They have a thin wire filament which becomes very hot and glows brightly when a current passes through it.
- The filament is made from a metal with a high melting point such as tungsten and it is usually wound into a small coil.

Relays



Relays enable a low voltage circuit to switch on a high voltage or high current circuit.



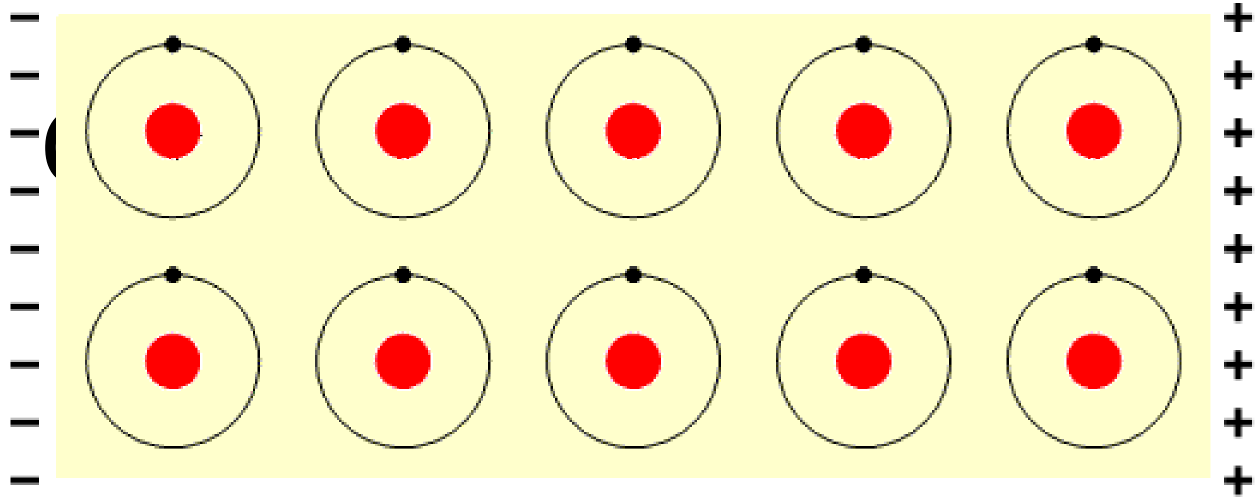
Insulators have tightly bound electrons in their outer shell

These electrons require a very large amount of energy to free them for conduction

Let's apply a potential difference across the insulator above…

The force on each electron is not enough to free it from its orbit and the insulator does not conduct

Insulators are said to have a high resistivity / resistance



Conductors have loosely bound electrons in their outer shell

These electrons require a small amount of energy to free them for conduction

Let’s apply a potential difference across the conductor above…

The force on each electron is enough to free it from its orbit and it can jump from atom to atom the conductor conducts

Conductors are said to have a low resistivity / resistance

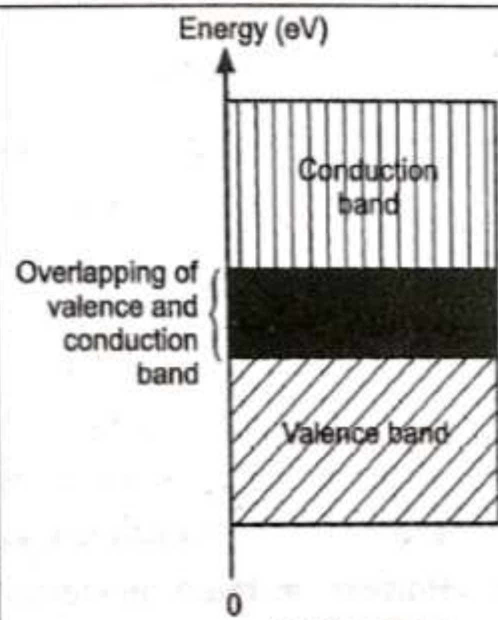
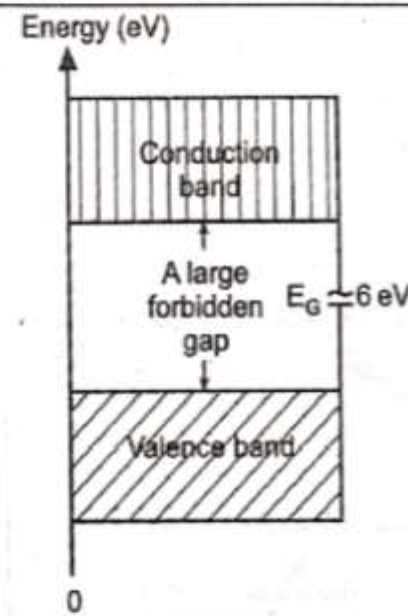
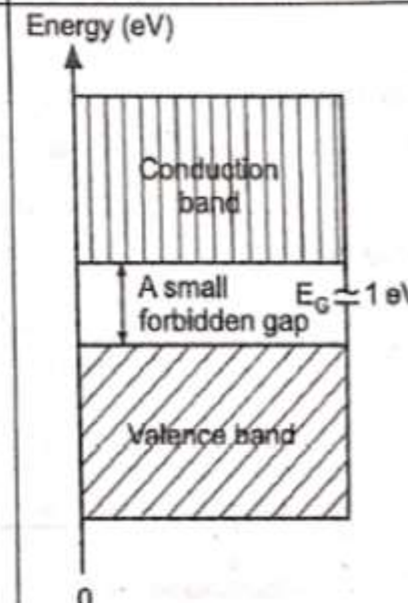
Semiconductors

Semiconductors have a resistivity/resistance between that of conductors and insulators

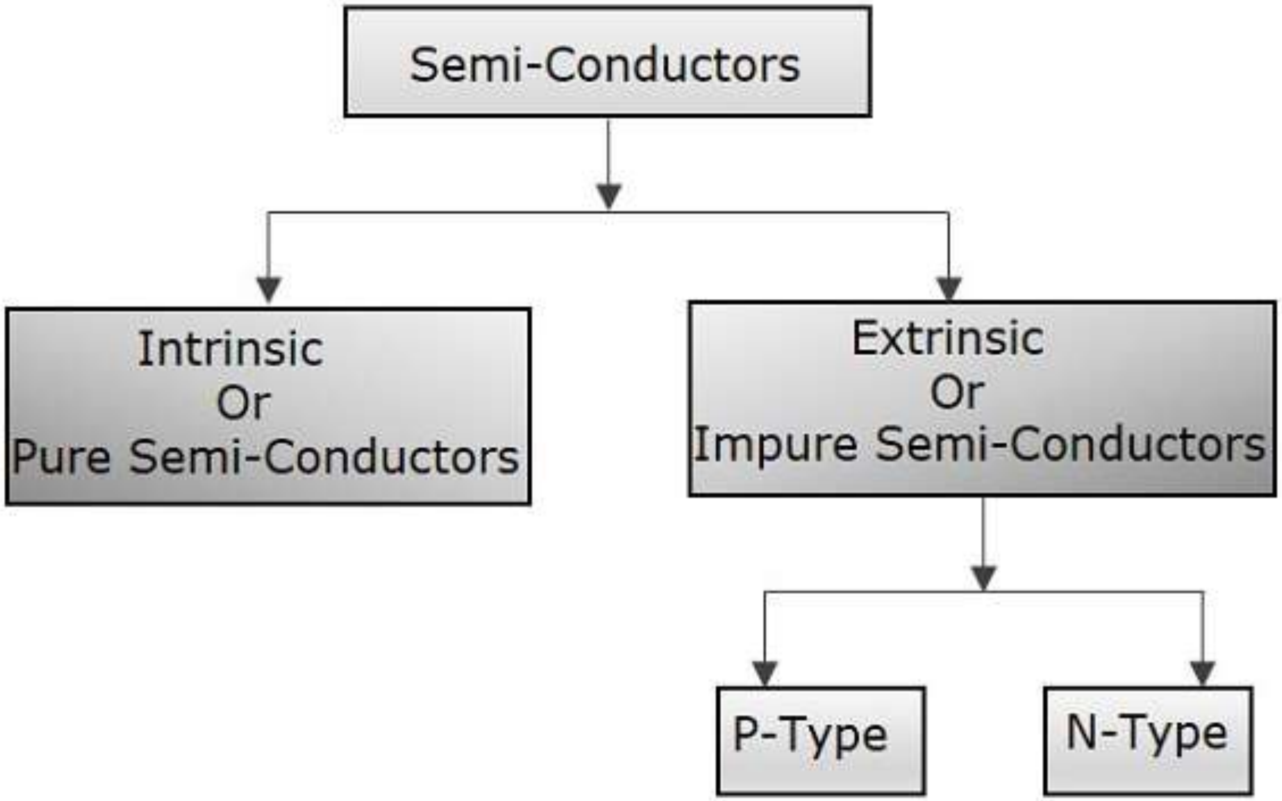
Their electrons are not free to move but a little energy will free them for conduction

The two most common semiconductors are silicon and germanium

Comparison

Parameters	Conductor	Insulator	Semiconductor
Material	Copper, Iron, Gold, Silver, etc.	Wood, Rubber, Plastic, mica, etc.	Silicon, Germanium, etc.
Current	Flowing	Not flowing	Flowing (if biased)
External Bias	Not required	Not applicable	Required
Resistivity	Low (10-16Ω-m) Copper	High(1012Ω-m) Mica	Medium(50*103Ω-m) Silicon
Forbidden Energy Gap	 **(a) Conductor** Overlapped	 **(b) Insulator** Large gap 6eV 1eV=1.6*10^{-9} Joules	 **(c) Semiconductor** Small gap For Ge: 0.75eV For Si: 1.16eV

Semiconductors Classification



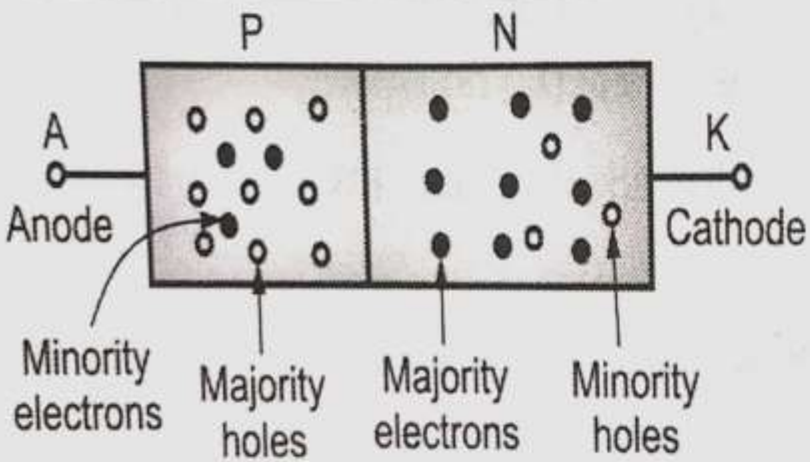
Comparison of Intrinsic and Extrinsic Semiconductors

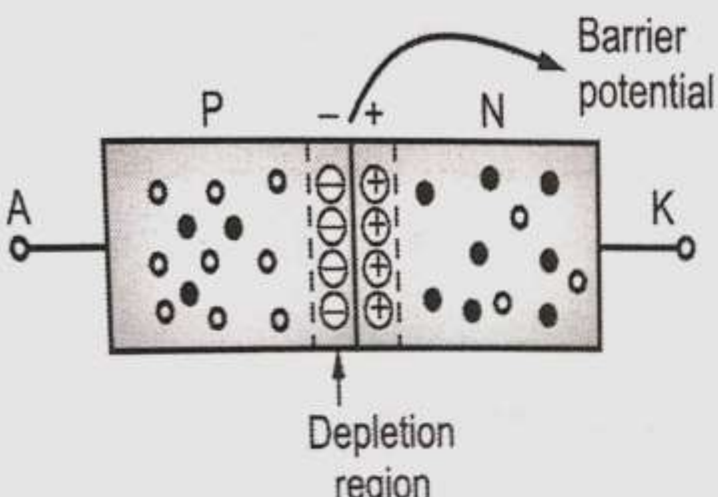
Parameter	Intrinsic	Extrinsic
Form	Pure	Impure
Concentration	Number of Holes = Number of Electrons	Number of Holes ≠ Number of Electrons
Electrical conductivity	Low	High
Electrical conductivity	Depends upon temperature	Depends upon temperature As well as impurity added
Example	Crystalline form of pure Silicon and Germanium	Impurity like As, Sb, P, In, Bi, Al etc. are dopped with Germanium and Silicon atom.

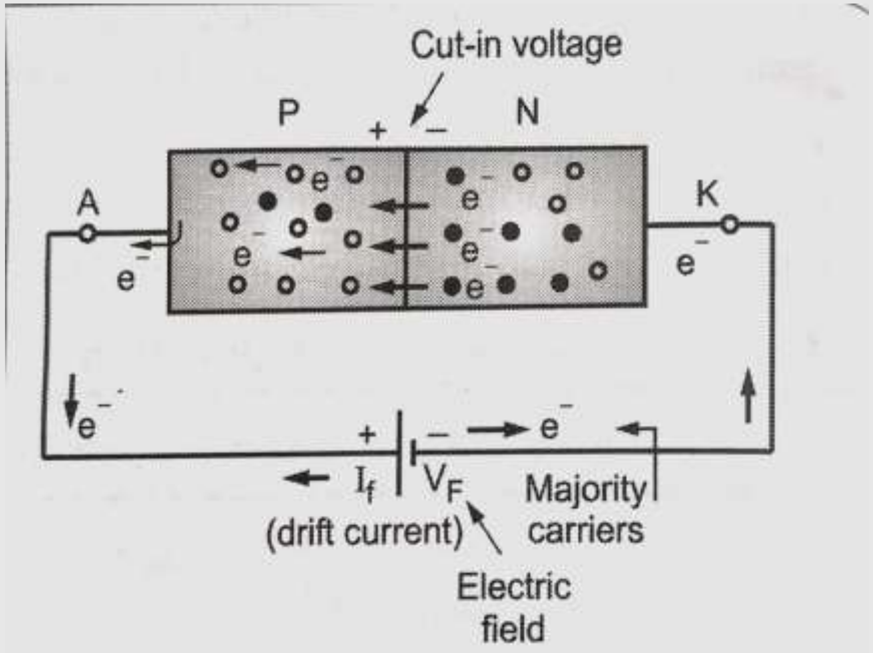
Comparison of P type and N Type Semiconductors

Parameter	P Type	N Type
Group of Doping Element	III group element is added as doping element.	V group element is added as doping element.
Nature of Doping Element	Impurity added creates vacancy of electrons (holes) called as Acceptor Atom	Impurity added provides extra electrons and is known as Donor Atom.
Type of impurity added	Trivalent impurity like Al, Ga, In etc. are added.	Pentavalent impurity like P, As, Sb, Bi etc. are added.
Majority Carriers	Holes are majority carriers	Electrons are majority carriers
Minority Carriers	Electrons are minority carriers	Holes are minority carriers
Type	Acceptor Impurity	Donor Impurity

Diffusion Current	Drift Current

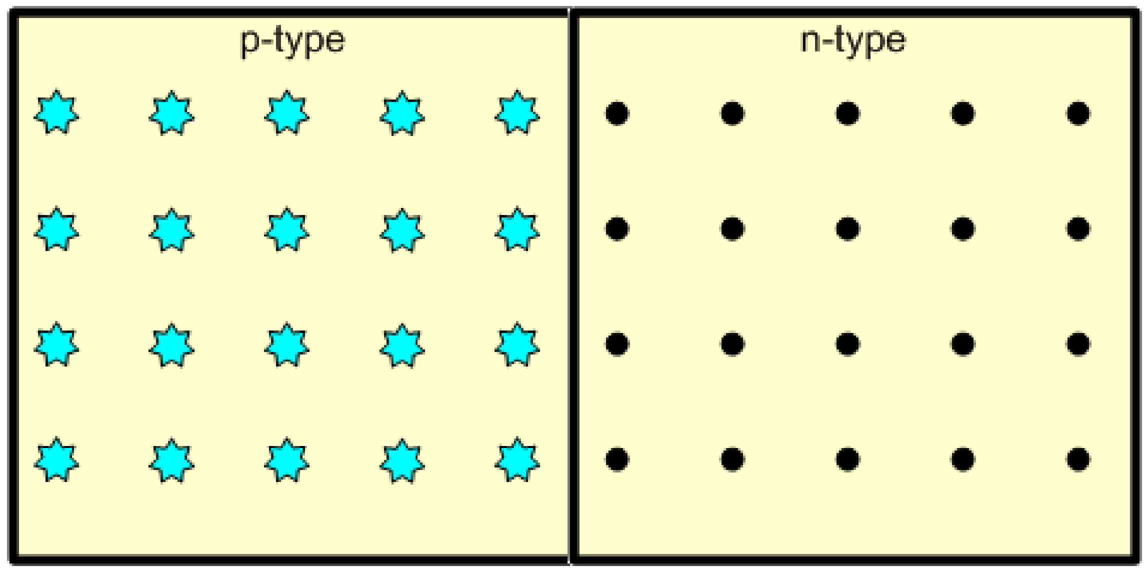






The p-n Junction

Suppose we join a piece of p-type silicon to a piece of n-type silicon



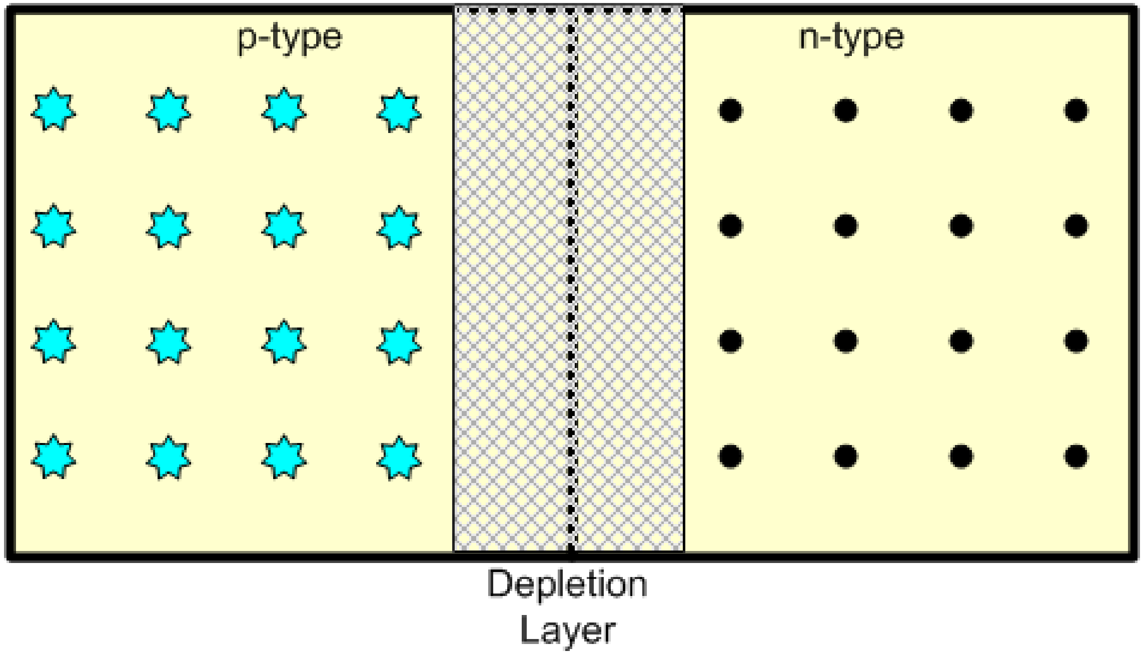
We get what is called a p-n junction

Remember – both pieces are electrically neutral

The p-n Junction

When initially joined electrons from the n-type migrate into the p-type – less electron density there

When an electron fills a hole – both the electron and hole disappear as the gap in the bond is filled

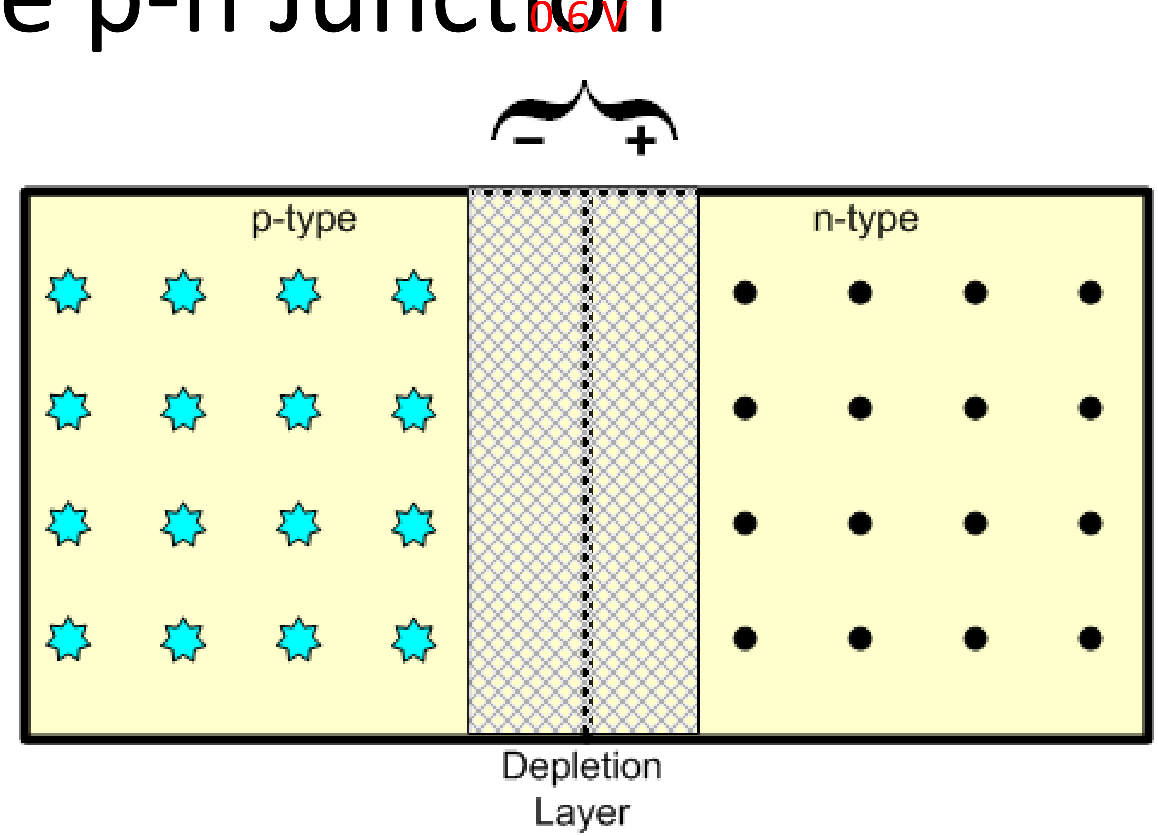


This leaves a region with no free charge carriers – the depletion layer – this layer acts as an insulator

The p-n Junction

As the p-type has gained electrons – it is left with an overall negative charge…

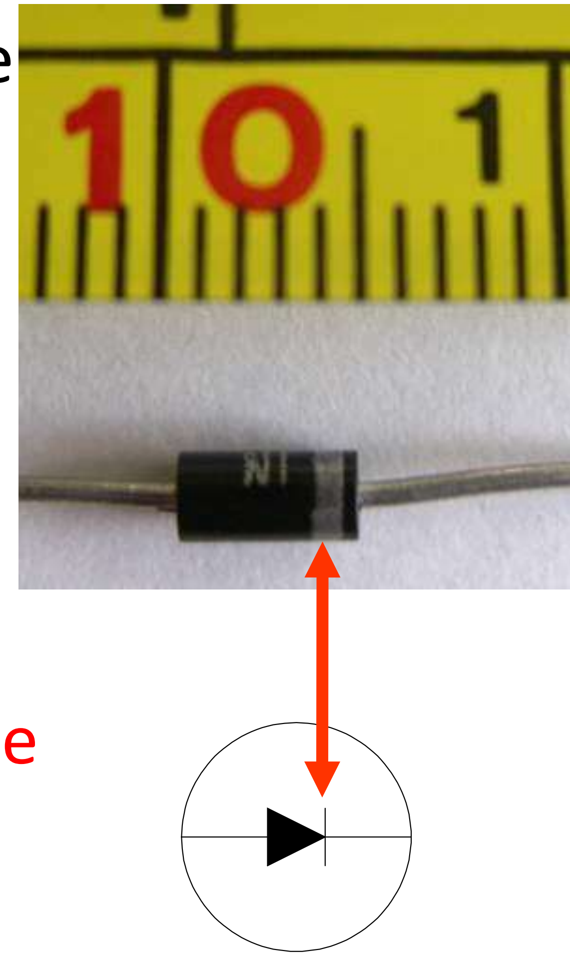
As the n-type has lost electrons – it is left with an overall positive charge…



Therefore there is a voltage across the junction – the junction voltage – for silicon this is approximately 0.6 V

The Semiconductor Diode

- The silver line drawn on one side of the diode represents the line in its symbol
- This side should be connected to the negative terminal for the diode to be forward biased
- Diodes are used to change alternating current to direct current
- Diodes are also used to prevent damage in a circuit by connecting a battery or power supply the wrong way around



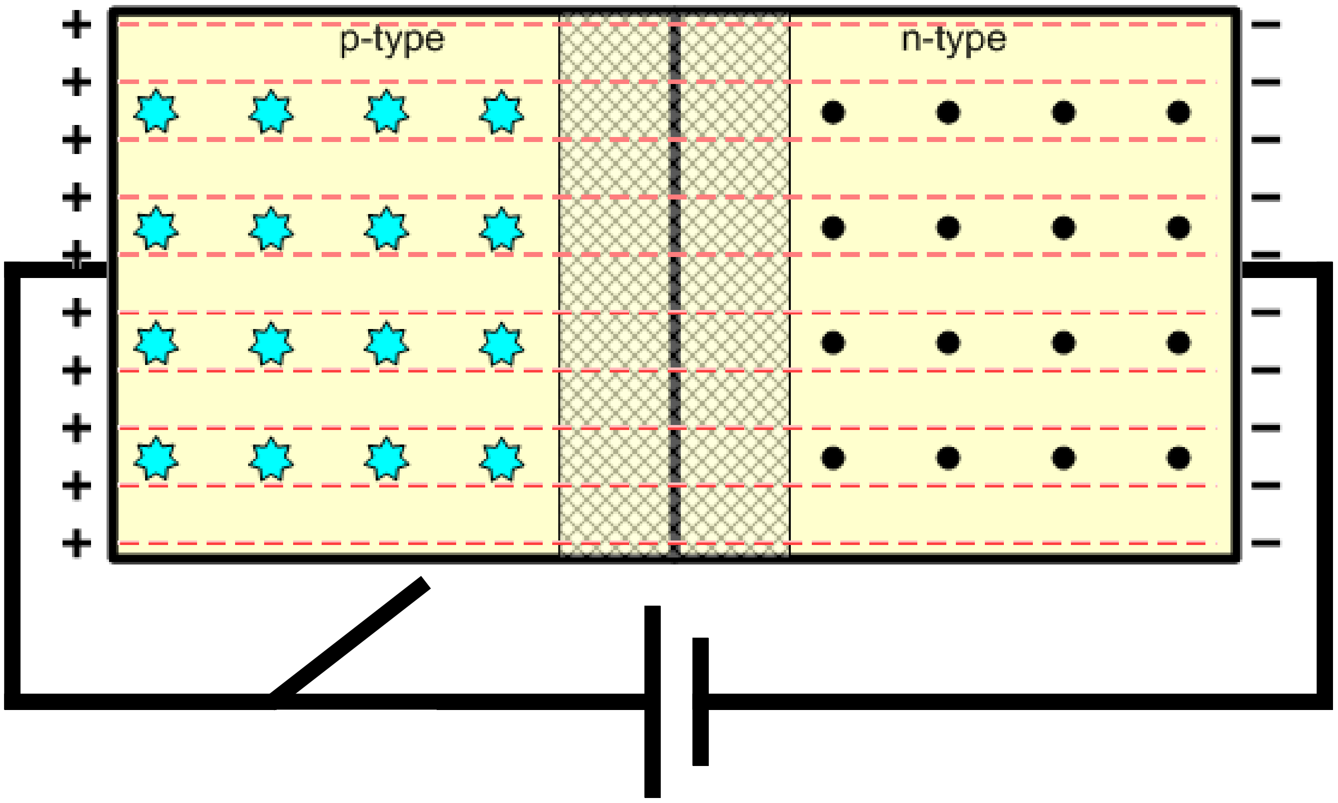
The Forward Biased P-N Junction

Take a **p-n junction**

Apply a voltage across it with the

p-type postitive

n-type negative



Close the switch

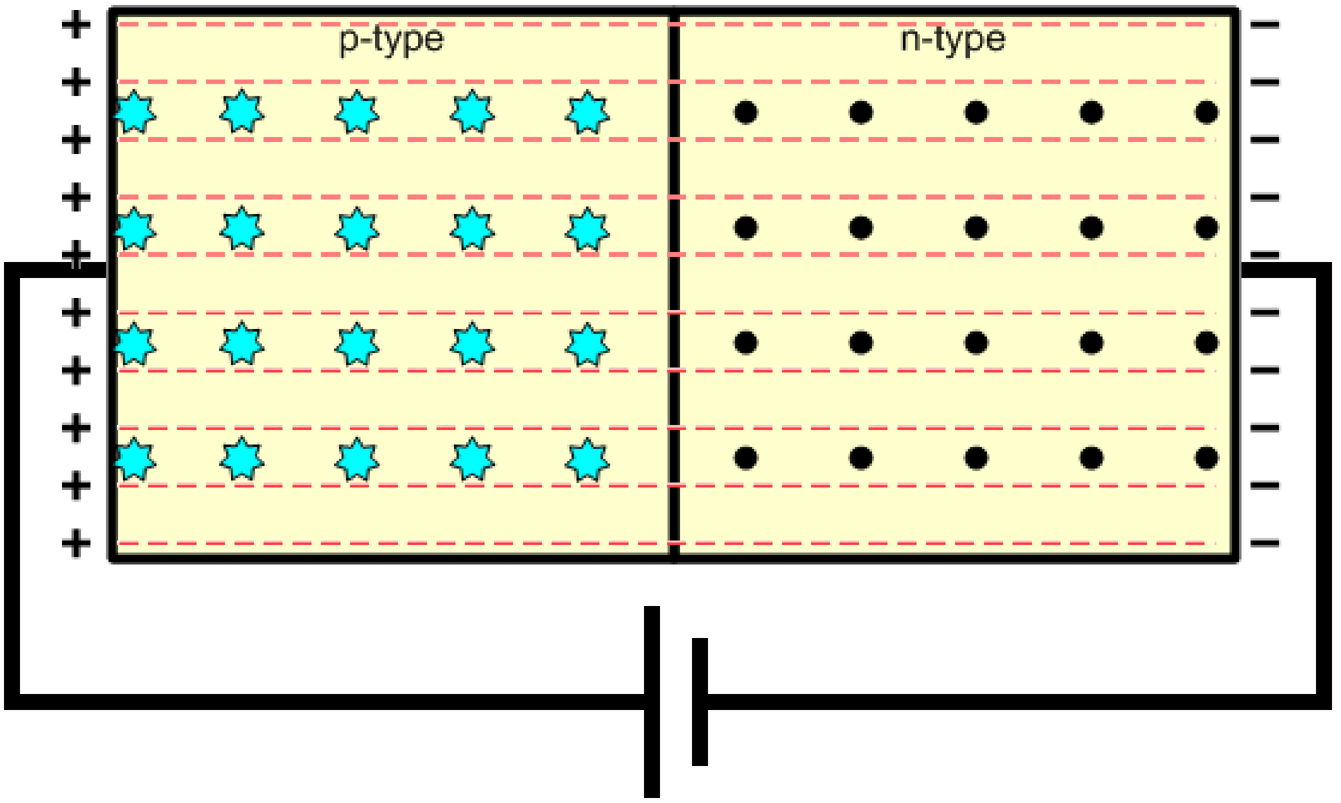
The voltage sets up an **electric field** throughout the junction

The junction is said to be **forward – biased**

The Forward Biased P-N Junction

Negative electrons in the n-type feel a repulsive force which pushes them into the depletion layer

Positive holes in the p-type also experience a repulsive force which pushes them into the depletion layer



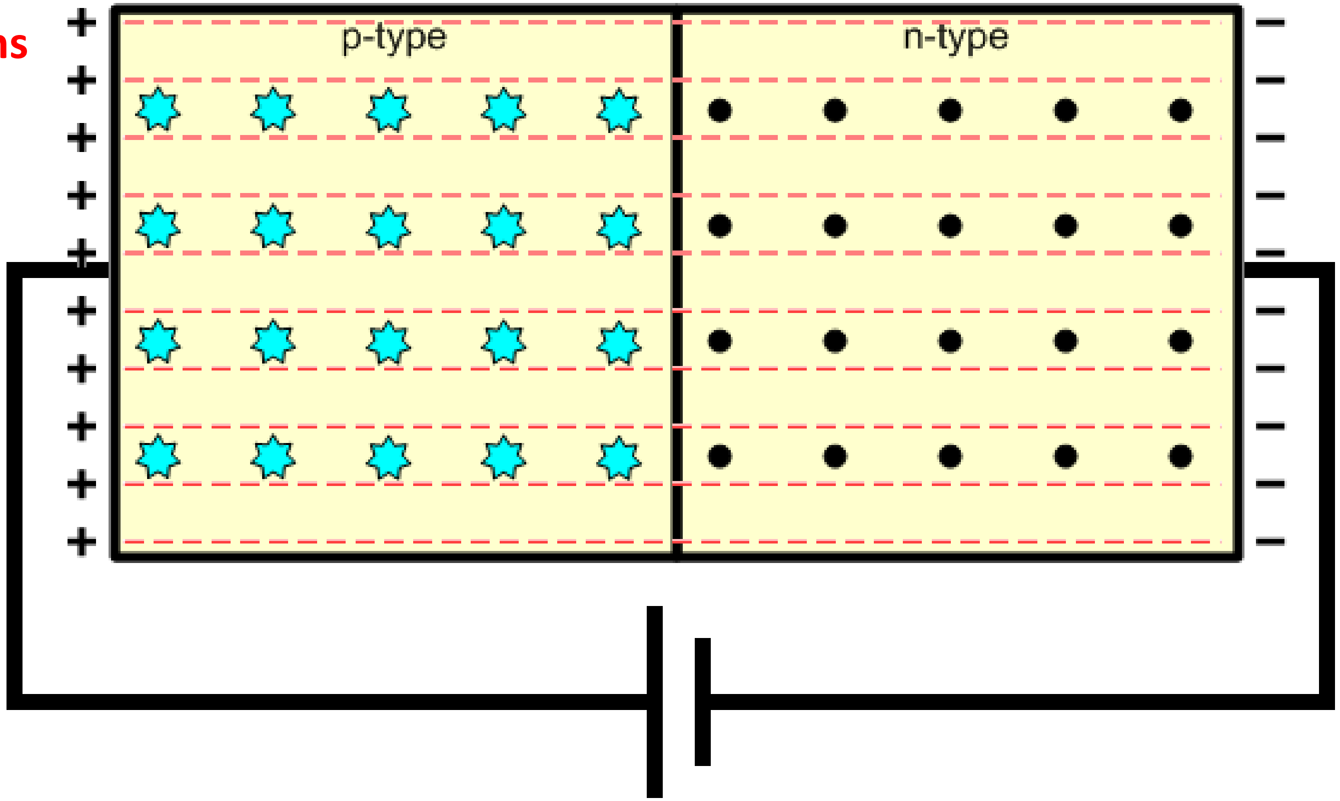
Therefore, the depletion layer is eliminated and a current flows through the p-n junction

The Forward Biased P-N Junction

At the junction **electrons fill holes**

Both **disappear** as they are no longer free for conduction

They are **replenished** by the external cell and **current flows**



This continues as long as the external voltage is **greater than** the junction voltage i.e. **0.6 V**

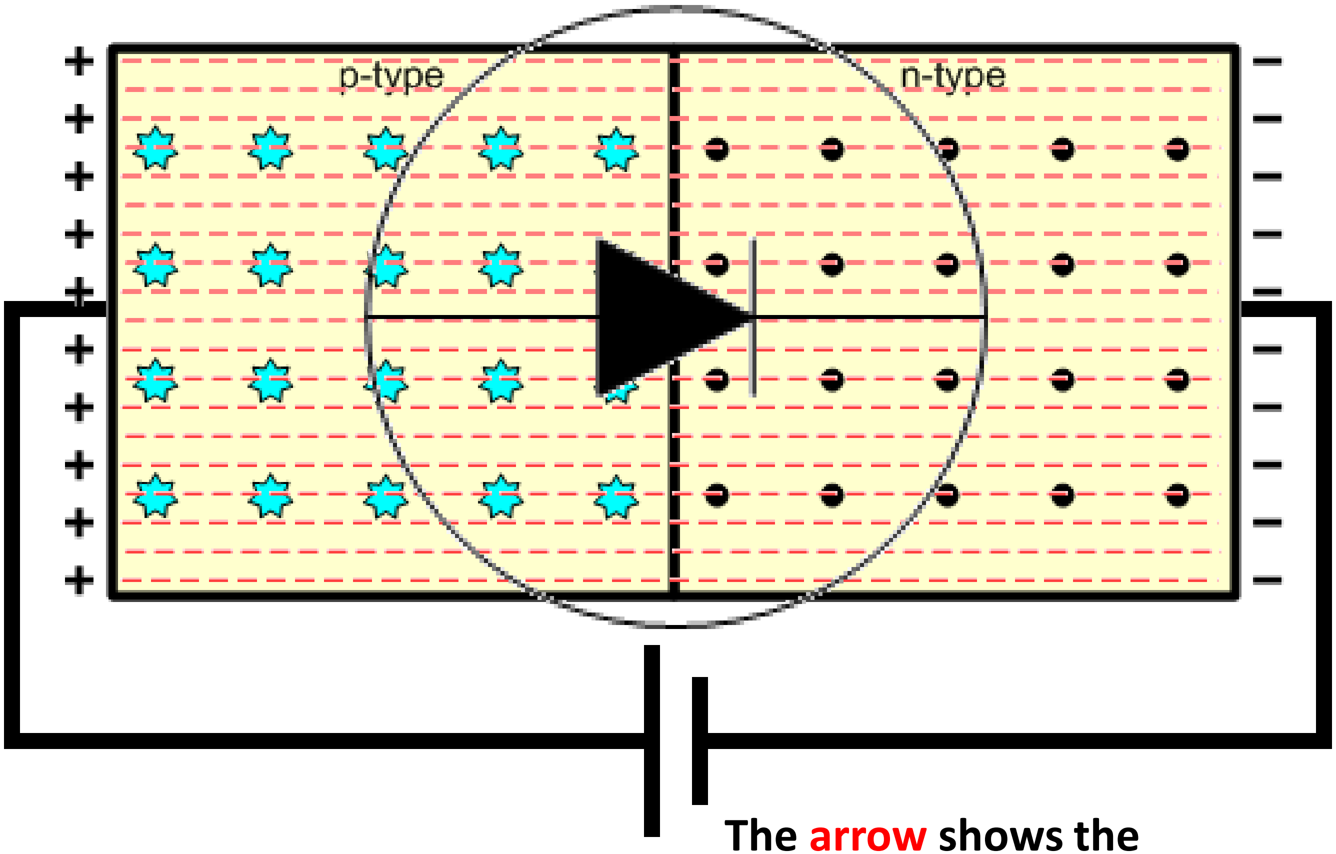
The Forward Biased P-N Junction

If we apply a **higher** voltage…

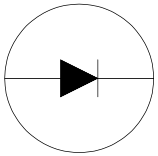
The electrons feel a greater force and move **faster**

The current will be **greater** and will look like

this….

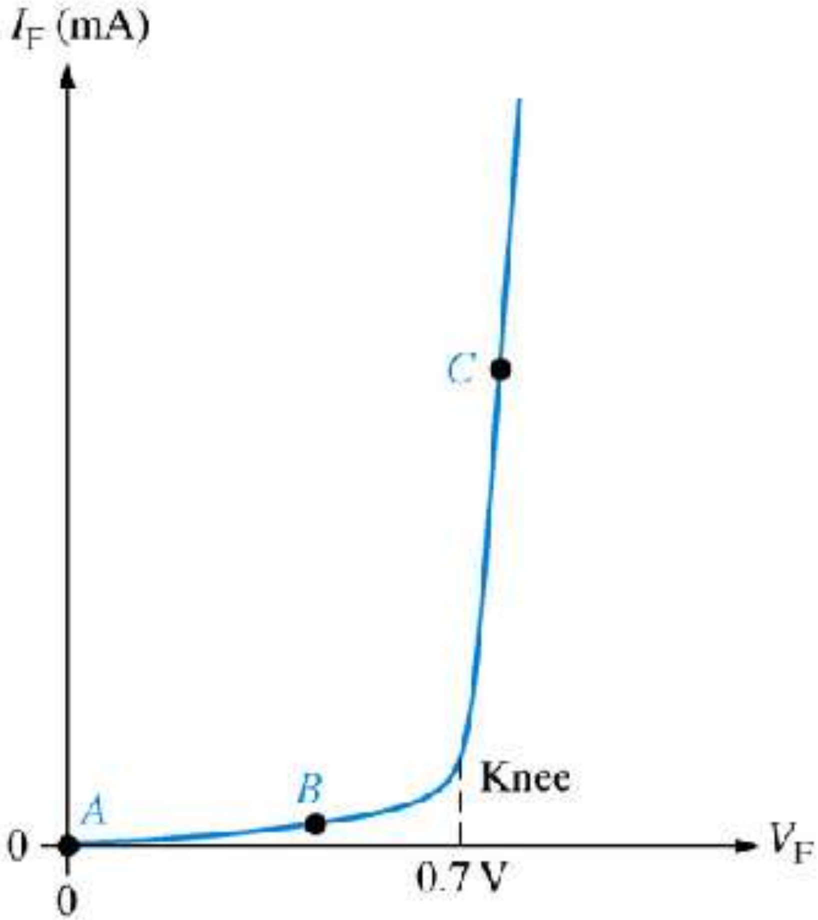


The **p-n junction** is called a **DIODE** and is represented by the symbol…



The **arrow** shows the **direction** in which it **conducts current**

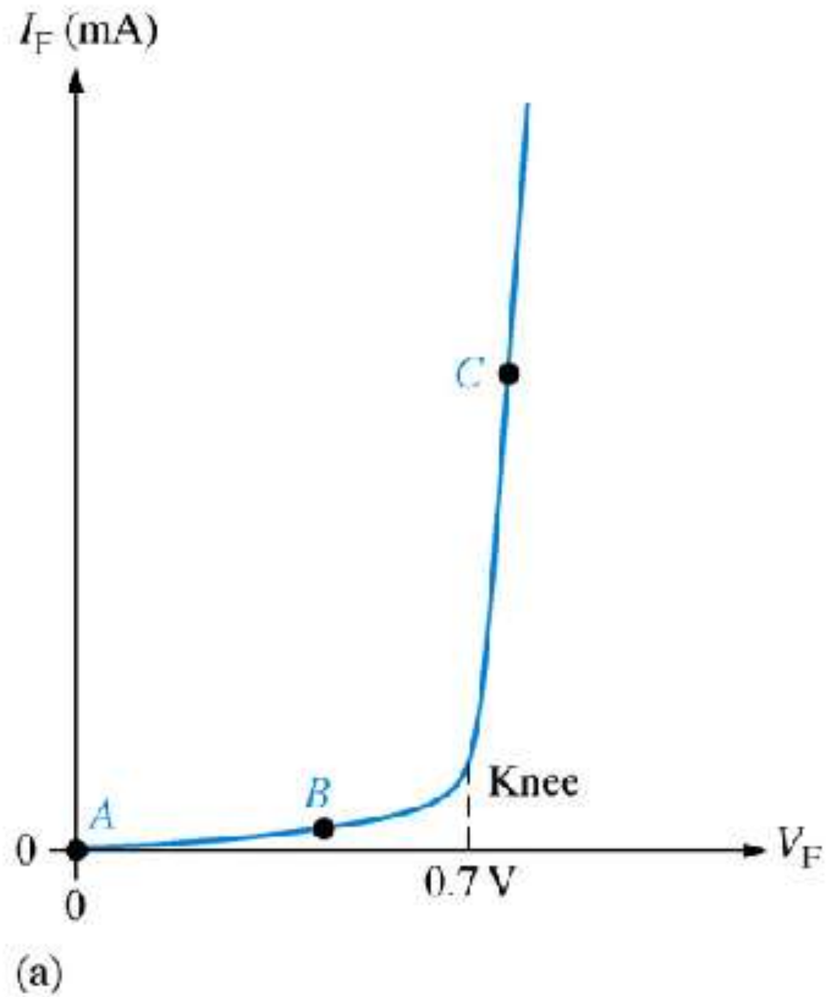
V-I Characteristics for Forward bias



(a)

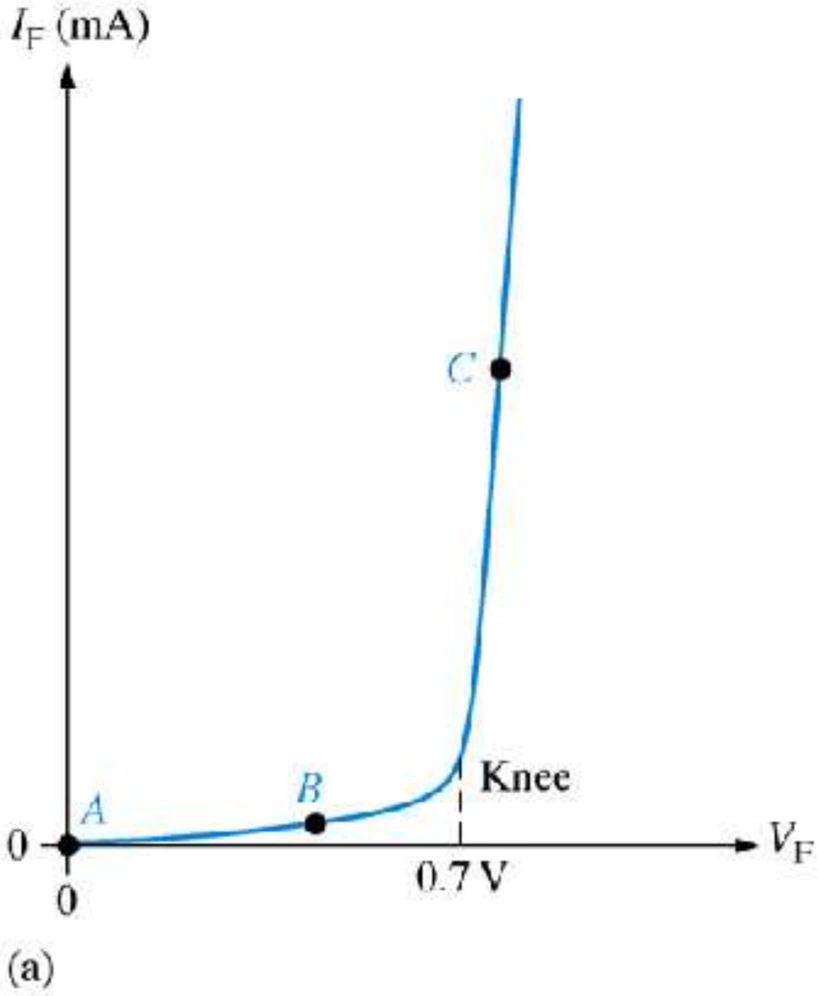
The forward characteristics is divided into two portions, AB and BC as shown in figure.

V-I Characteristics for Forward bias



- **Region A to B**
- **In the region A and B of the forward characteristics shown in figure the forward voltage is small and less than the cut in voltage (knee voltage).**
- **Therefore the forward current flowing through the diode is small.**
- **With further increase in the forward voltage , it reaches the level of the cut in voltage and the width of depletion region goes decreasing**

V-I Characteristics for Forward bias



- **Region B to C**
- **As soon as the forward voltage equals the cut in voltage, current through the diode increases suddenly.**
- **The nature of current is exponential. The large forward current in the region B-C of the forward characteristics is limited by connecting a resistor "R" in series with the diode.**

V-I Characteristics for Forward bias

- Dynamic resistance

$$r_d = \Delta V_F/\Delta I_F.$$

- Static resistance

$$r_d = Vdc/I_{dc}.$$

The Reverse Biased P-N Junction

Take a p-n junction

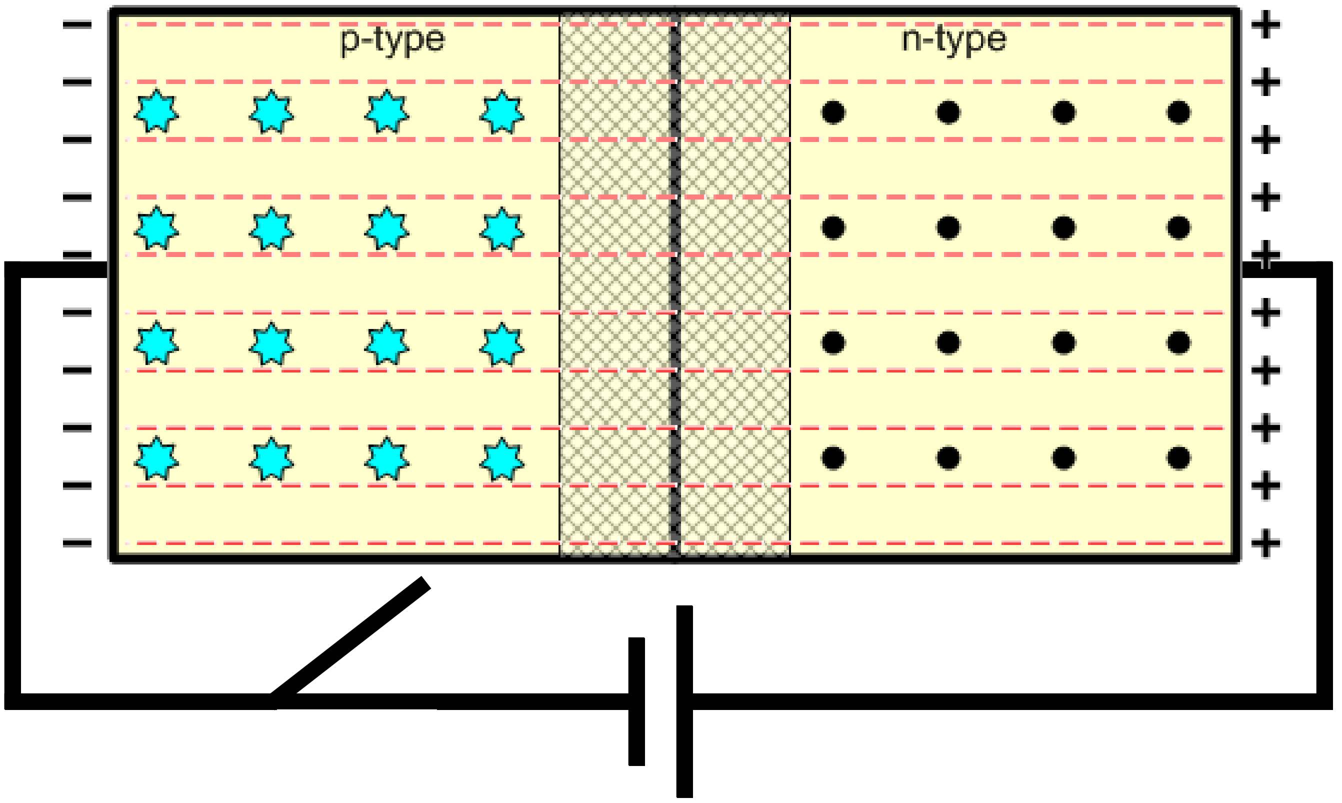
Apply a voltage across it with the

p-type negative

n-type positive

Close the switch

The voltage sets up an electric field throughout the junction

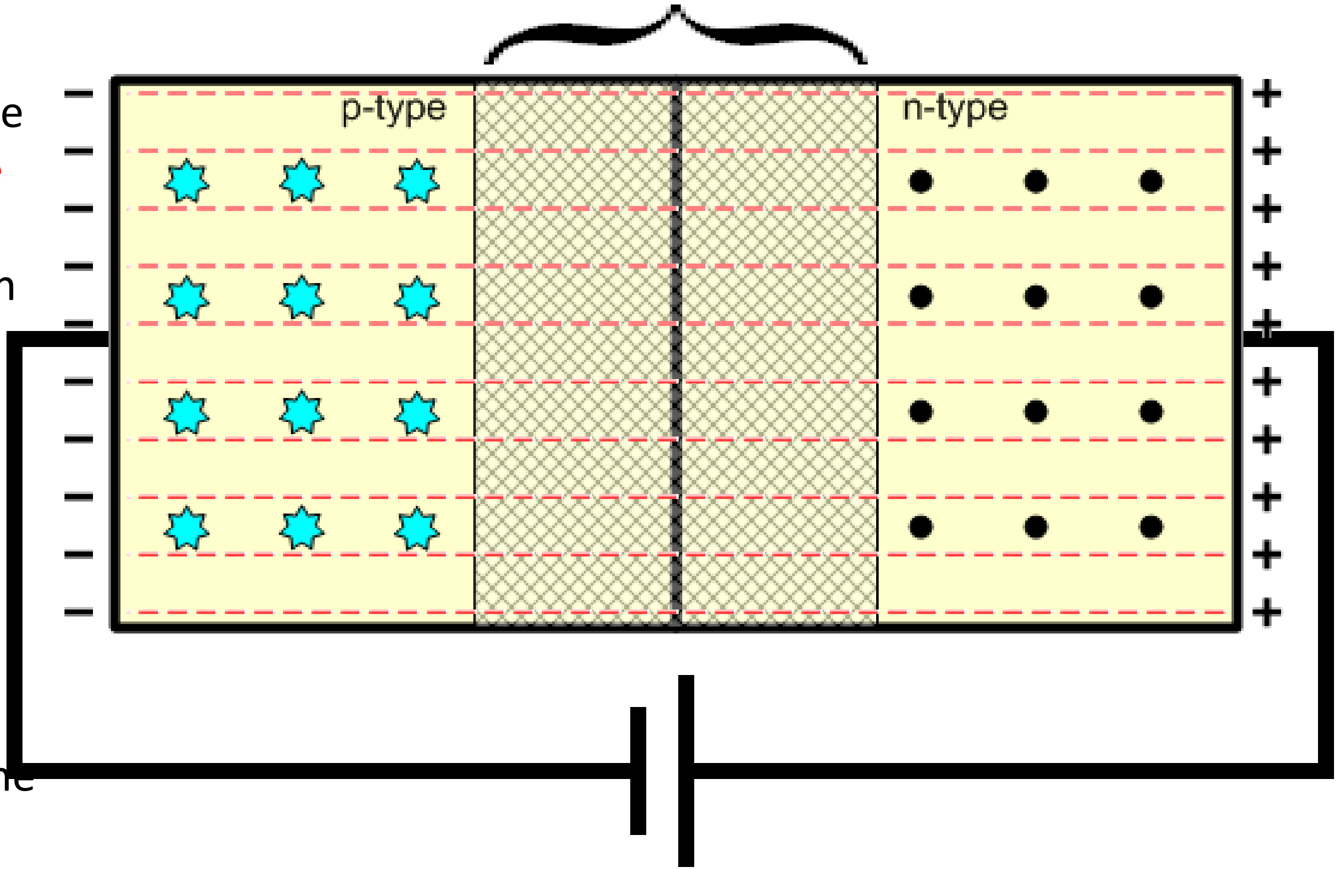


The junction is said to be reverse – biased

The Reverse Biased P-N Junction

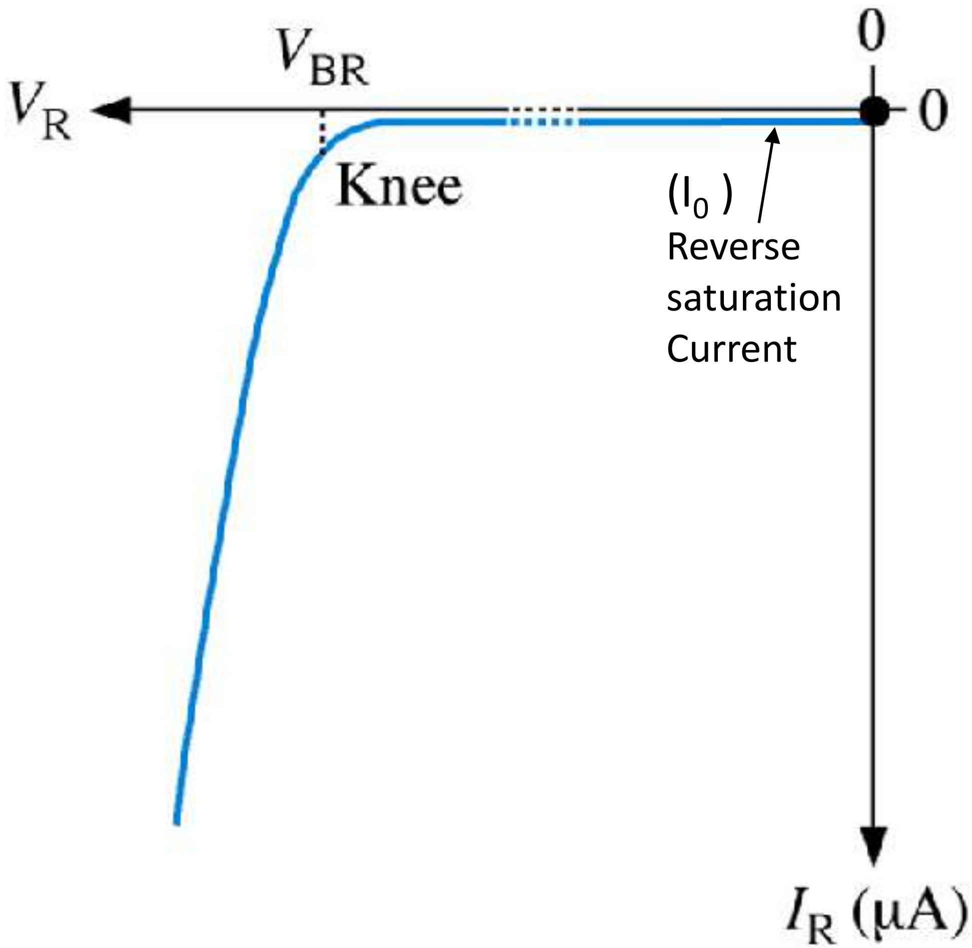
Negative electrons in the n-type feel an attractive force which pulls them away from the depletion layer

Positive holes in the p-type also experience an attractive force which pulls them away from the depletion layer



Thus, the depletion layer (INSULATOR) is widened and no current flows through the p-n junction

V-I Characteristics for Reverse bias

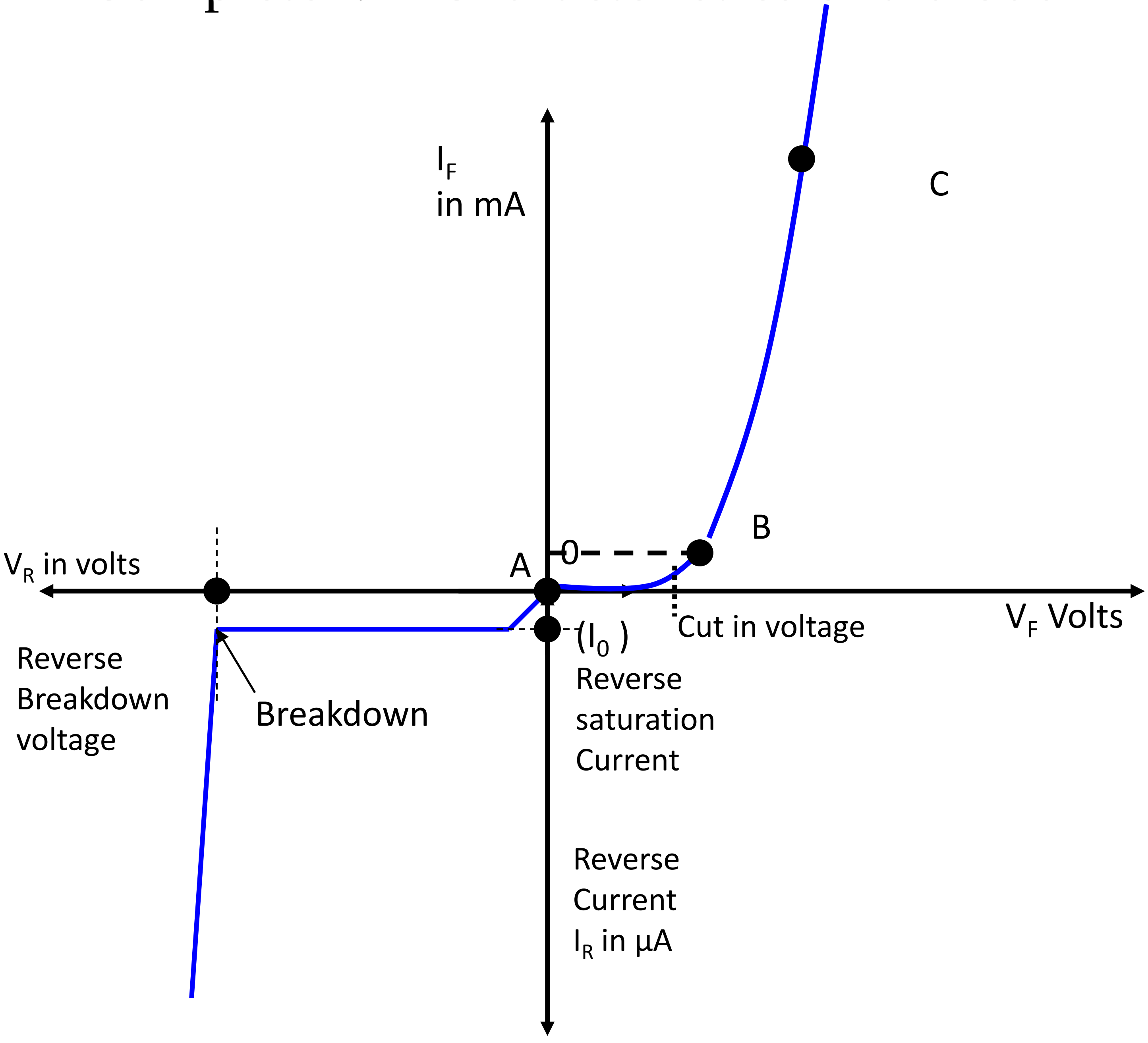


- Reverse characteristics is a graph of reverse voltage (V_R) versus reverse current (I_R) as shown in figure
- Current flowing through the diode in the reverse biased state is the reverse saturation current which flows due to the minority carriers.
- Therefore it is treated as a negative current. Hence the reverse characteristics appears in the third quadrant as shown in figure.

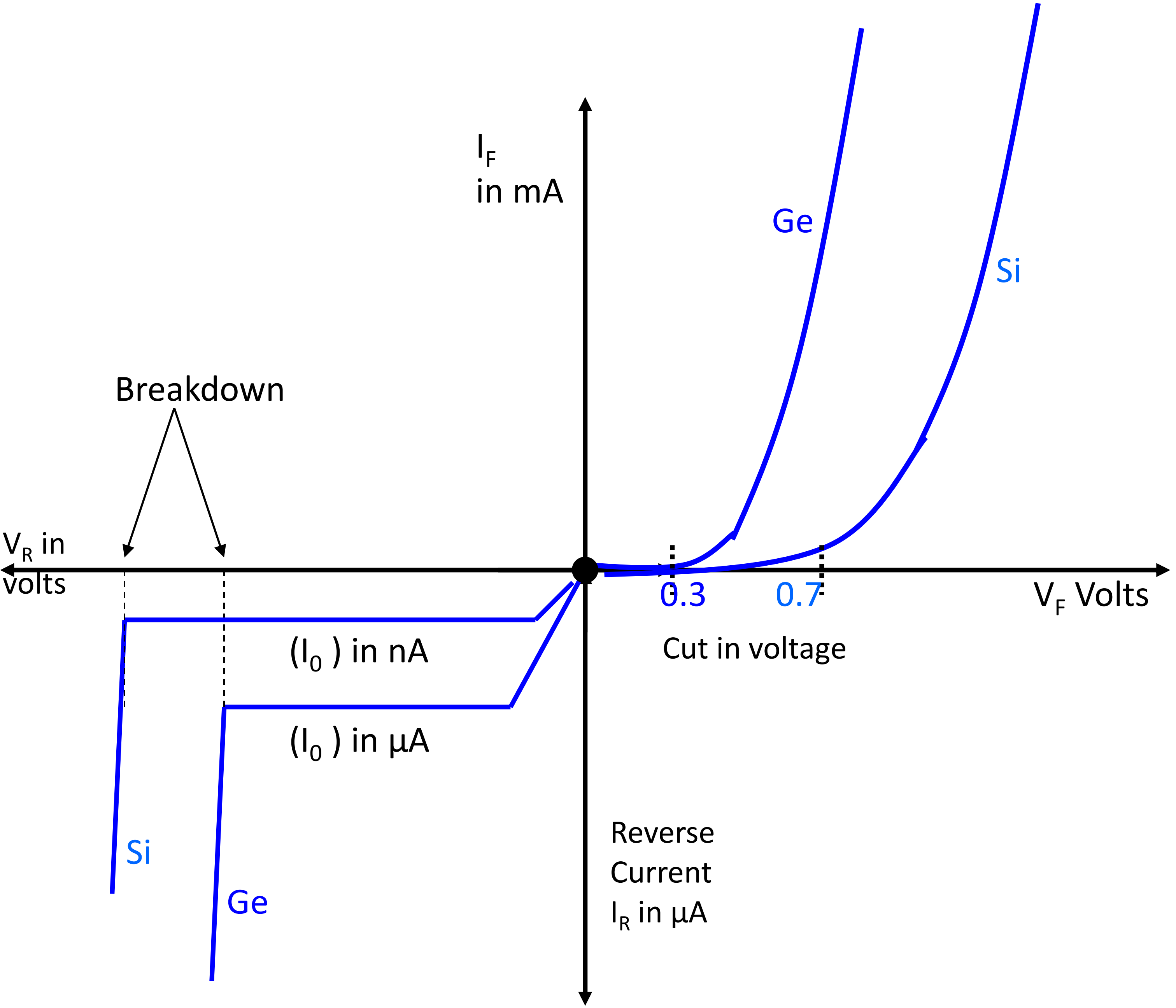
Important points about the reverse current

- It flows from cathode to anode.
- It flows due to minority carriers.
- Its value is much smaller that of the forward current.
- It is independent of the reverse voltage but dependent on the temperature.
- The reverse current is small which indicates that the resistance offers by a reverse biased diode is very large. It is denoted by R_F and its value is few hundred KΩ.

Complete V-I Characteristics of a diode



Complete V-I Characteristics of Si and Ge diode



Mathematical expression for the diode current

1. The diode current I_D has an exponential shape. It is expressed as:

$$I_D = I_O\,[\,e^{V/\eta V_t} - 1]$$

Where Io = reverse saturation current

Vt = T/11,600 and it is called volt equivalent of temperature

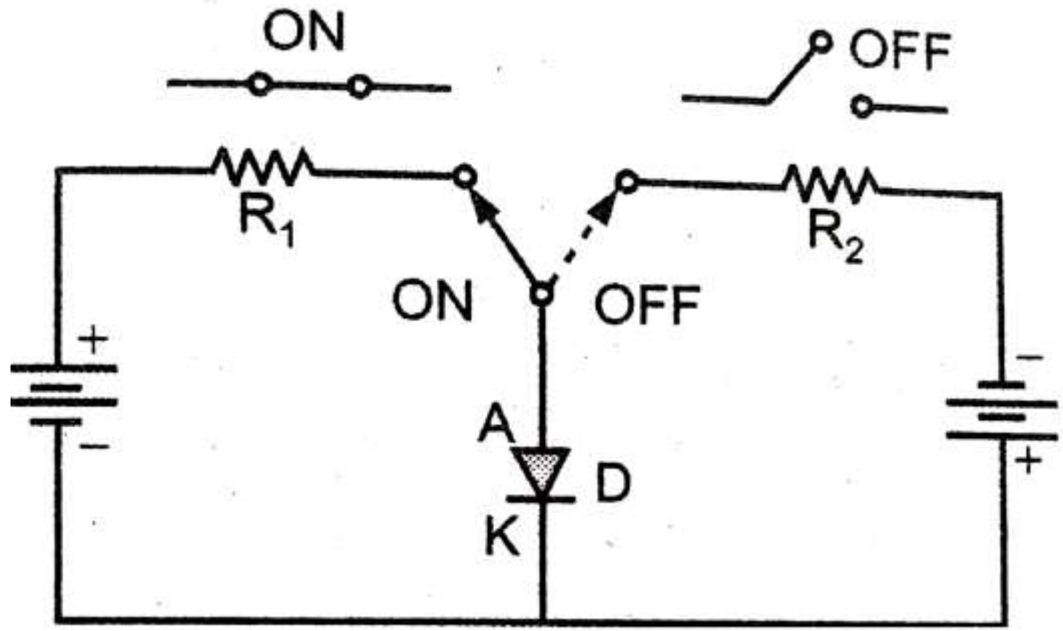
η = 1 for germanium

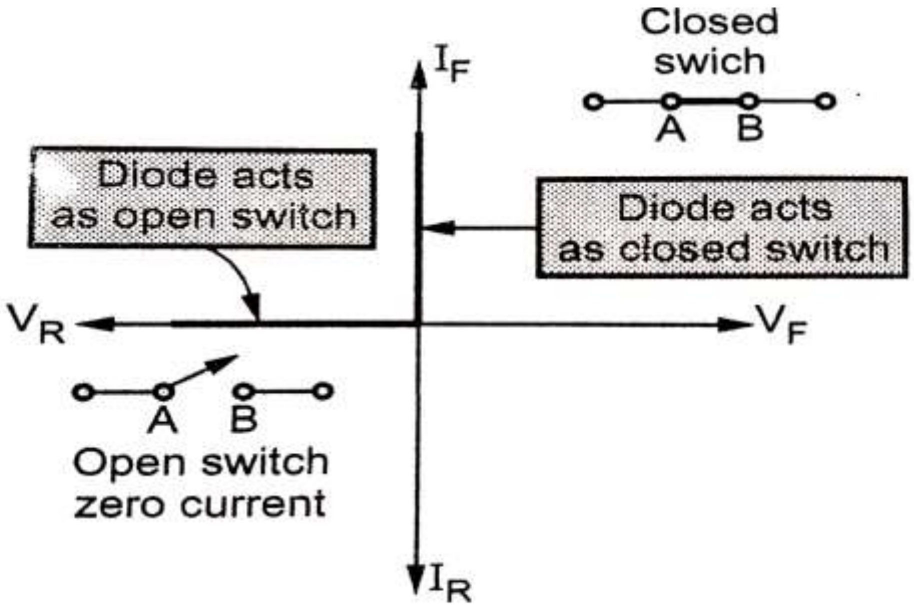
= 2 for silicon

T = temperature in ^{O}K

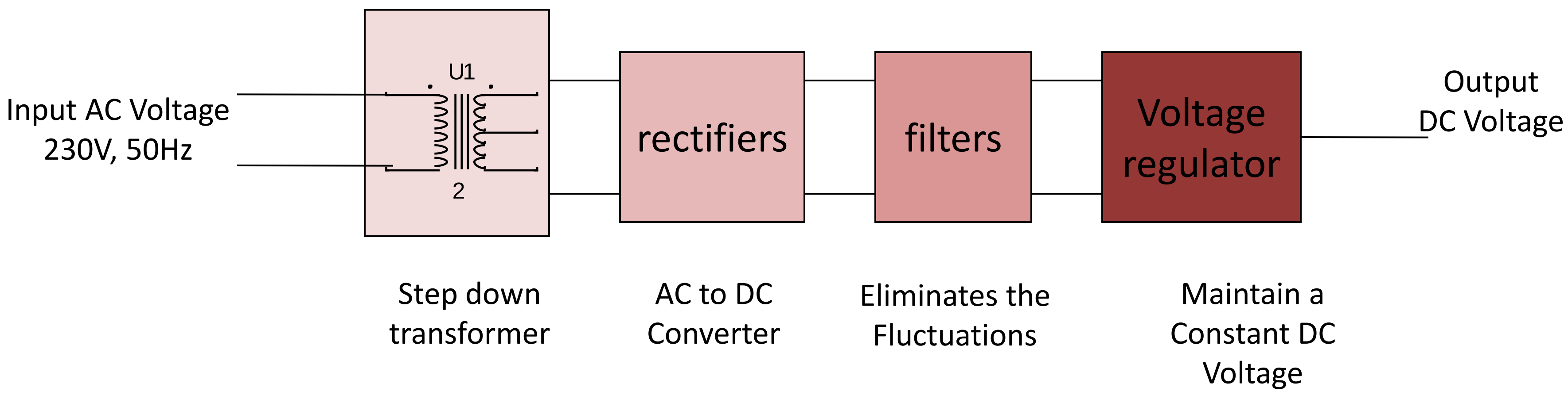
V = Voltage across the diode

Diode as a Switch

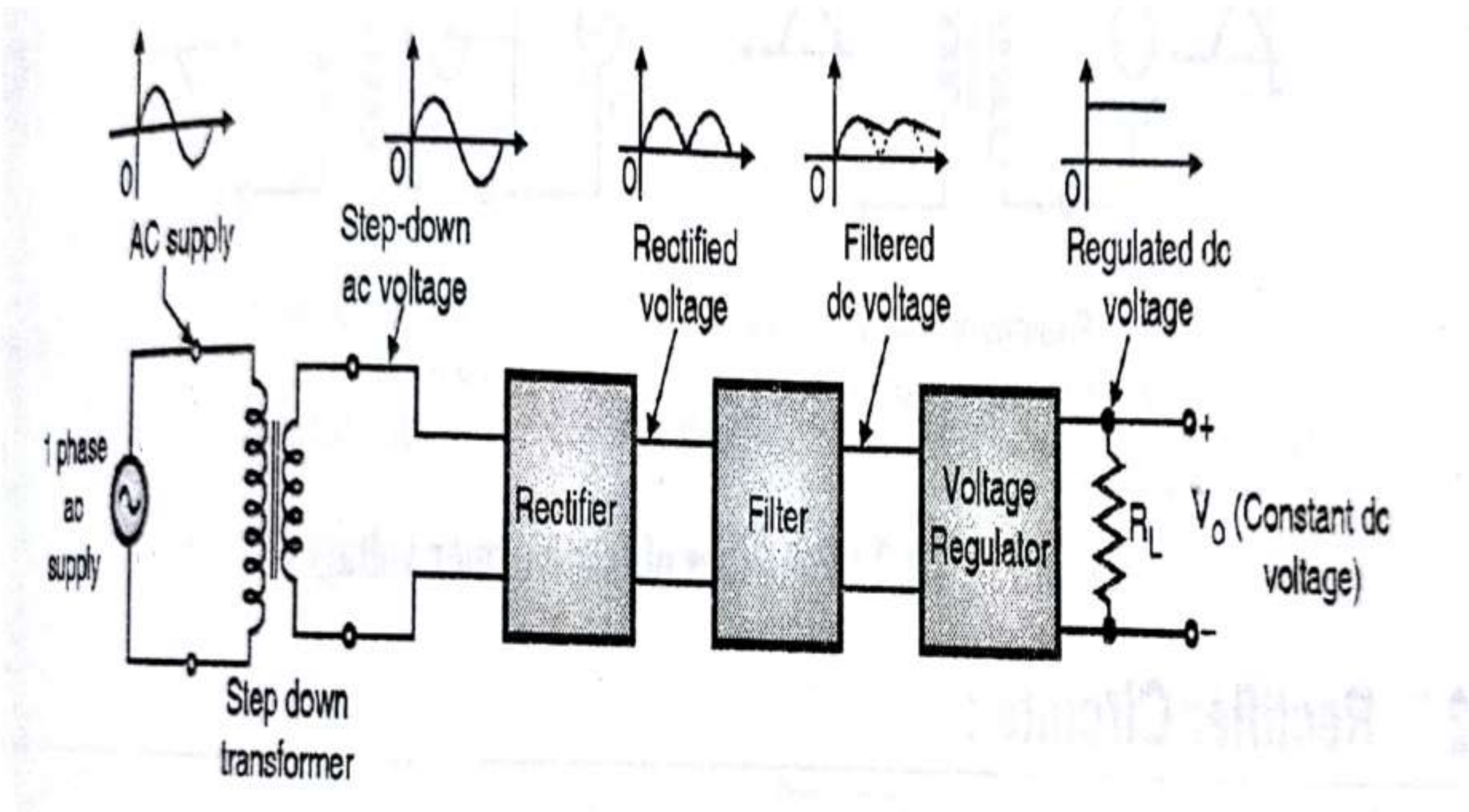


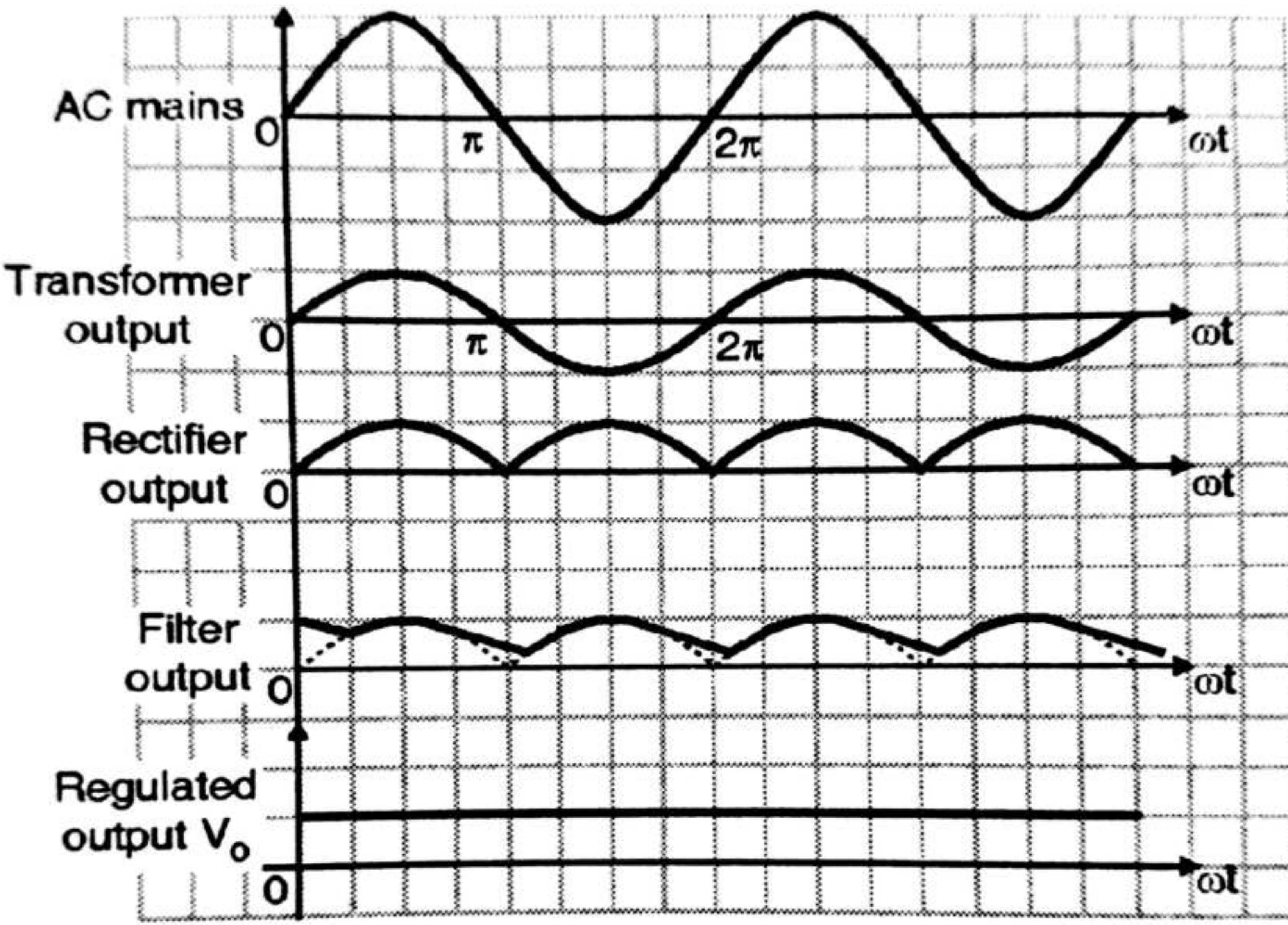


Block diagram of a regulated dc power supply are:



Block diagram of a regulated dc power supply are




AC mains
0
π
2π
ωt
Transformer output
0
π
2π
ωt
Rectifier output
0
ωt
Filter output
0
ωt
Regulated output V_o
0
ωt

Rectifier with transformer coupled input

- These days, most of the electronic circuits use a transformer to coupled a.c. input voltage from source to the rectifier circuit .
- The transformer coupling provides the following advantages:

1. It allows the source voltage to be stepped up or stepped down.
2. The a.c. power source is electrically isolated from the rectifier circuit. It reduces the chances of getting a shock.

- A primary and secondary voltages of an ideal transformer are related by the expression,

$$V2/V1 = N2/N1$$

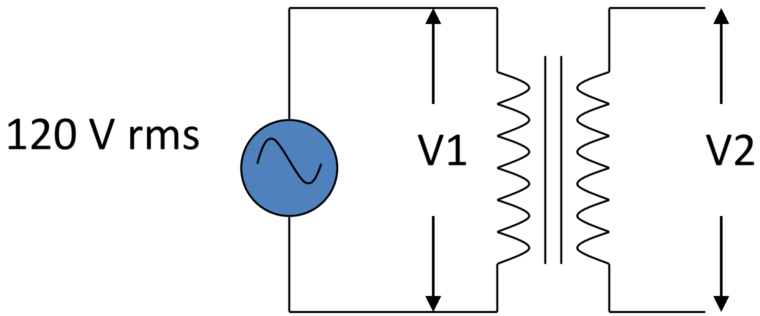
Where V1= the rms value of primary voltage

V2= the rms value of secondary voltage

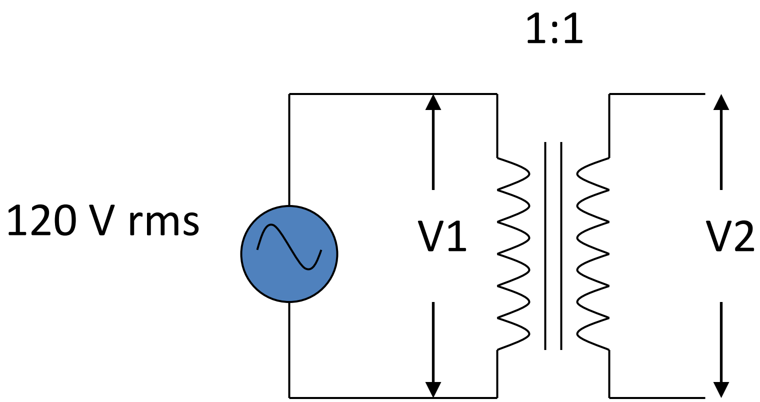
N1= number of turns in the primary windings and

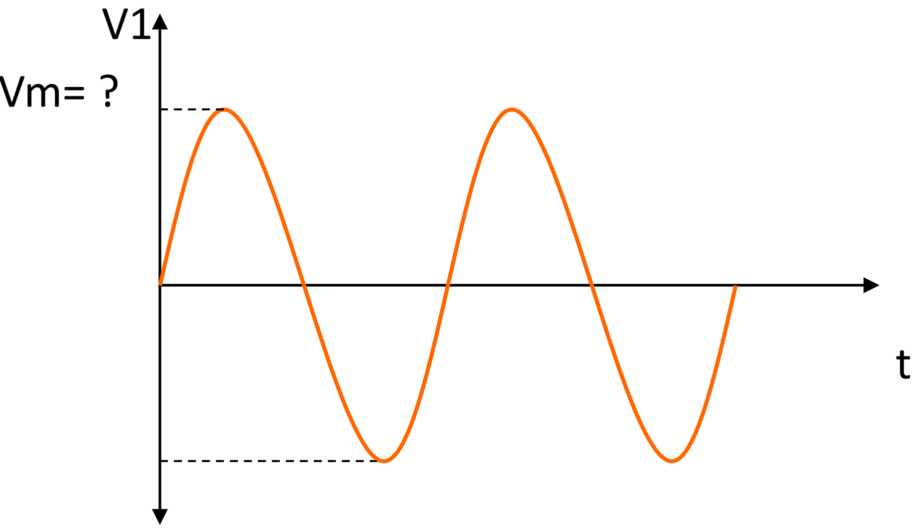
N2= number of turns in the secondary windings.

Unloaded transformer



Unloaded transformer





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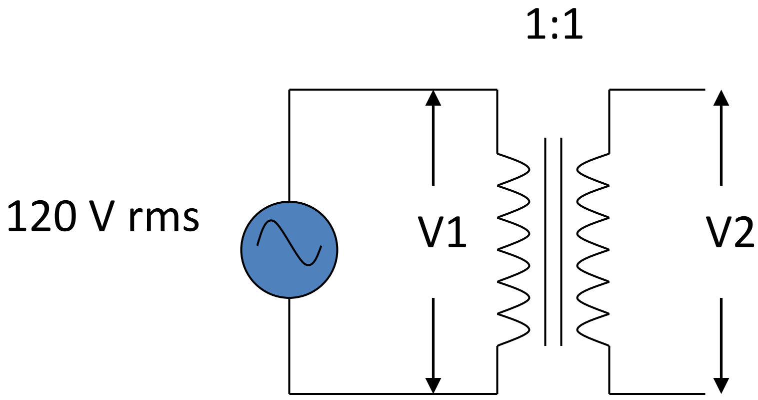

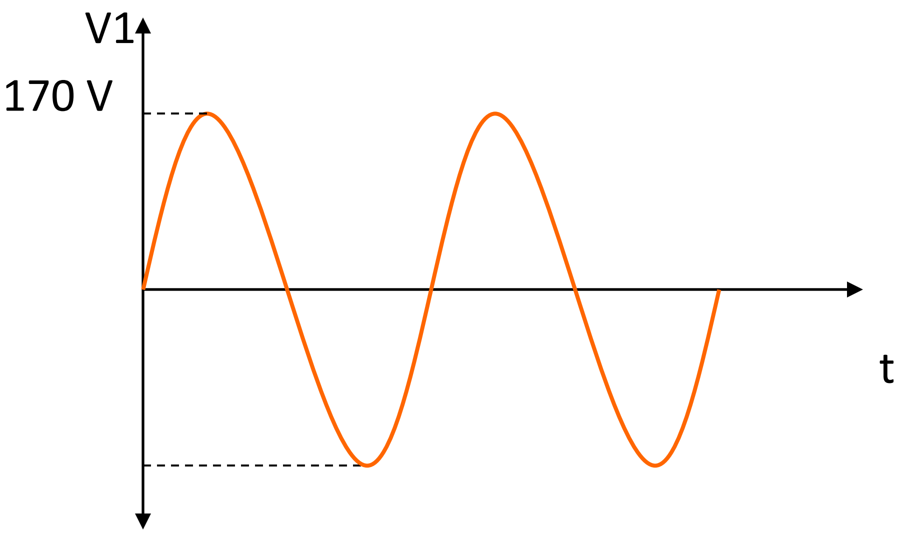

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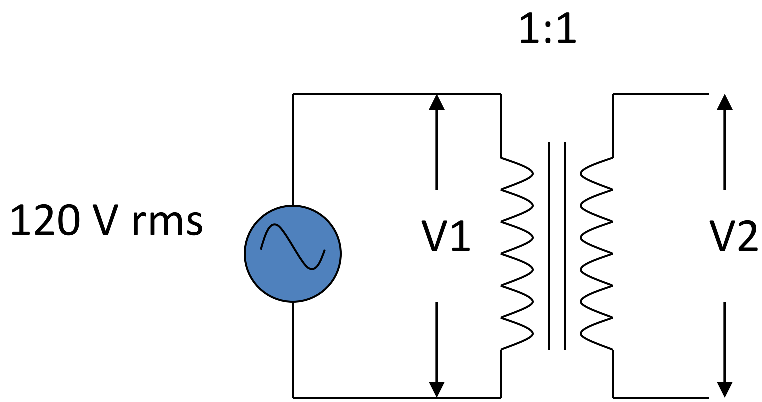

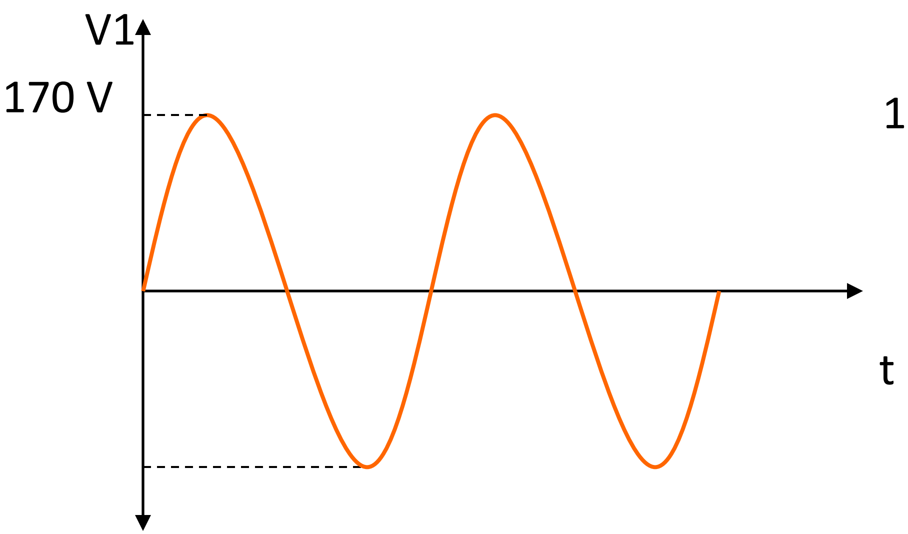

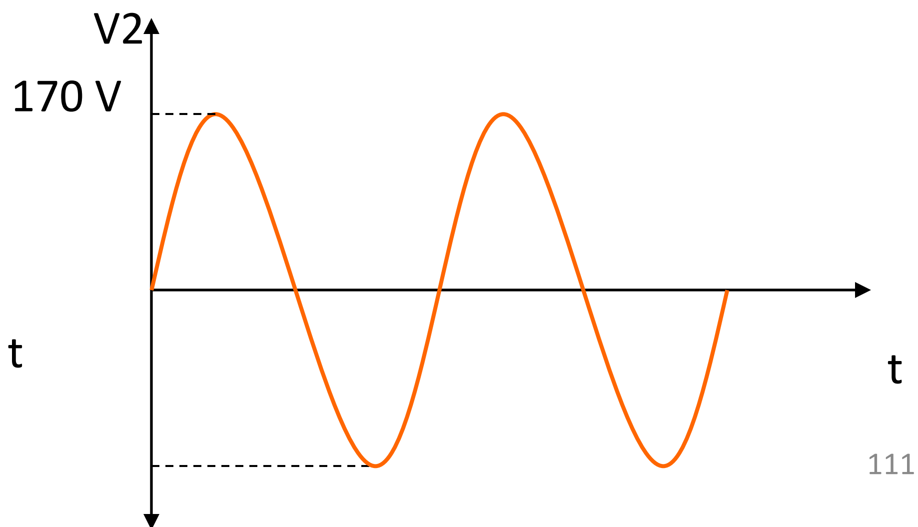

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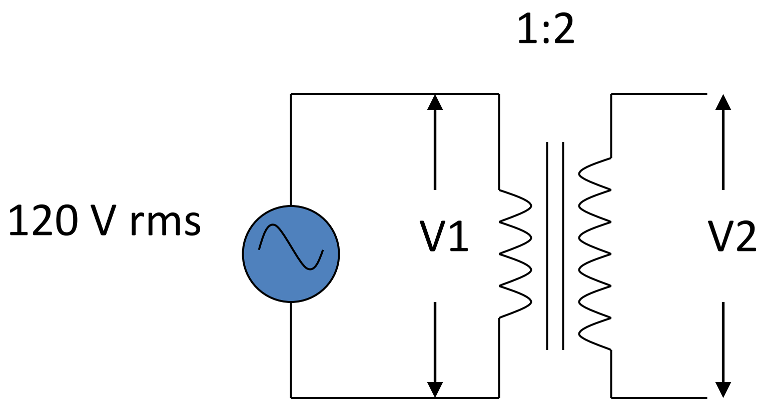

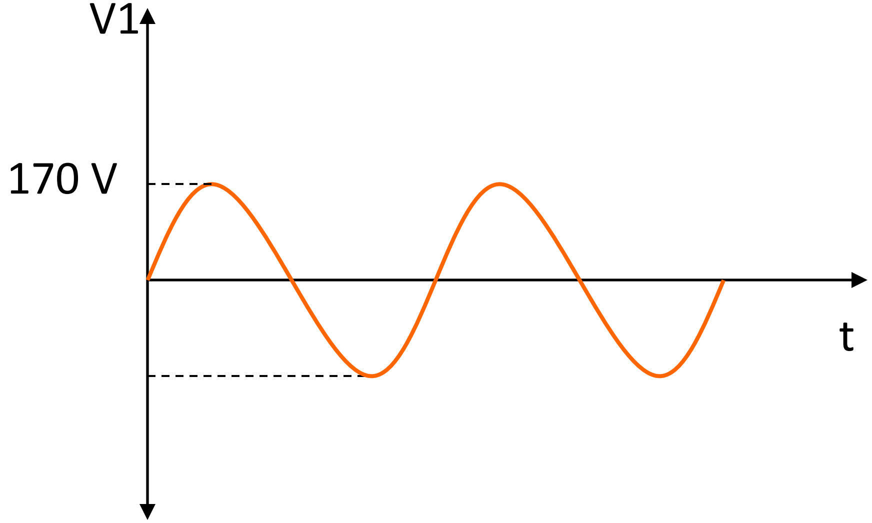

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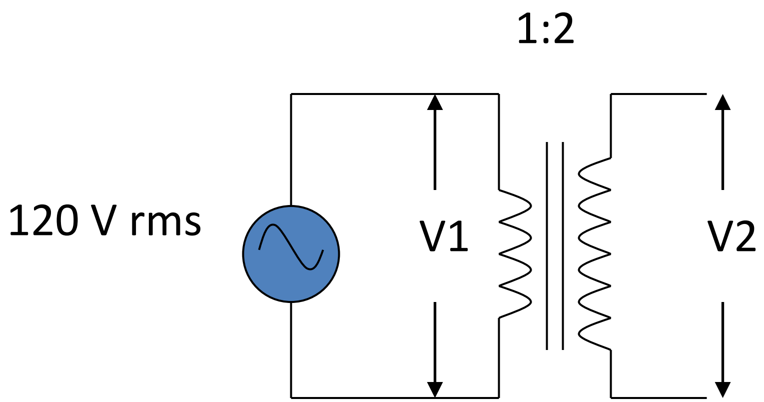

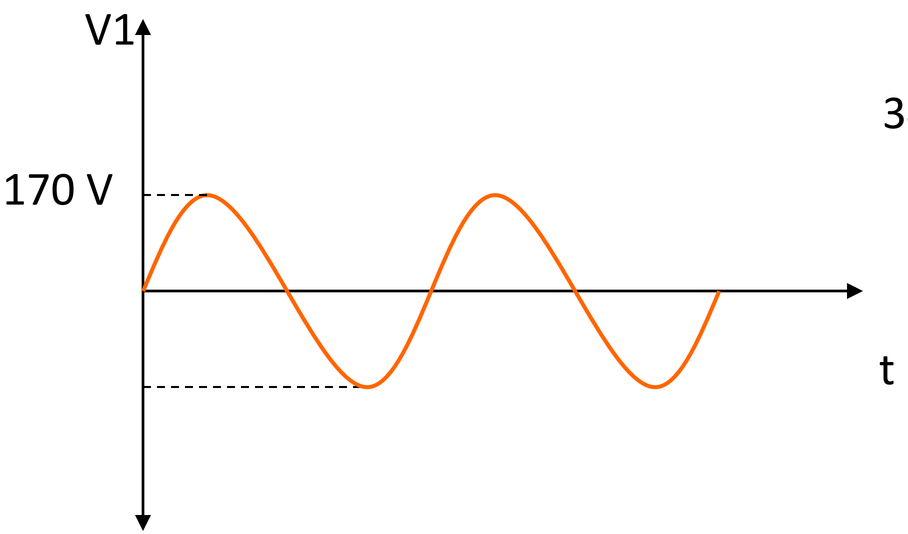

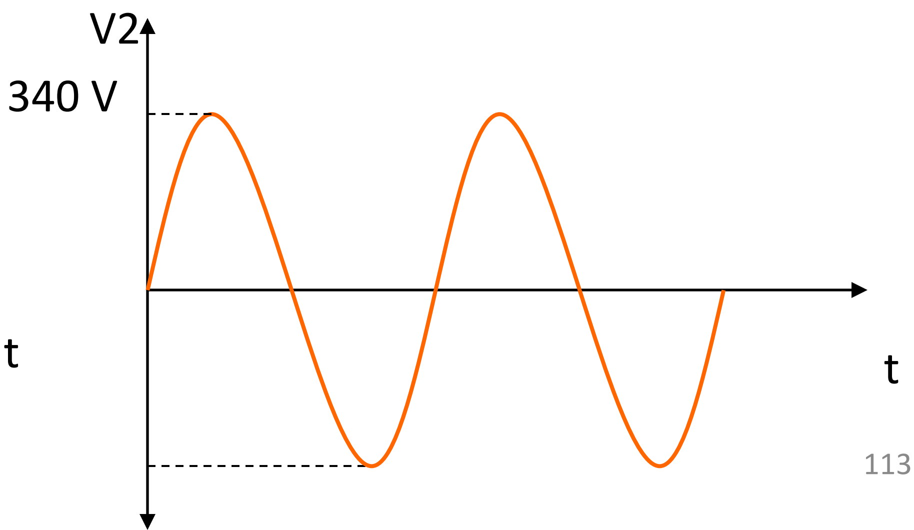

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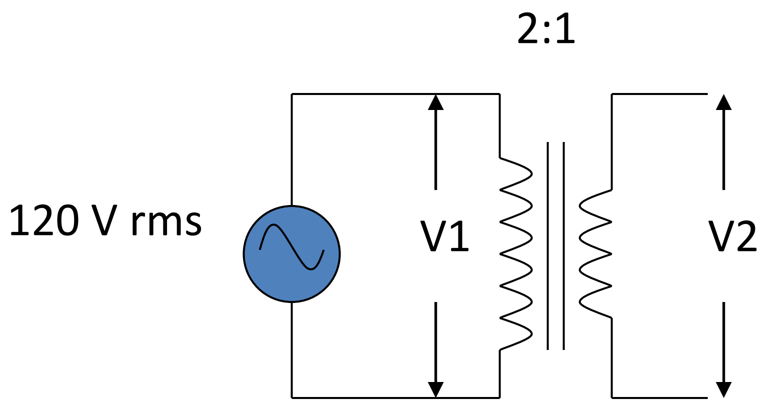

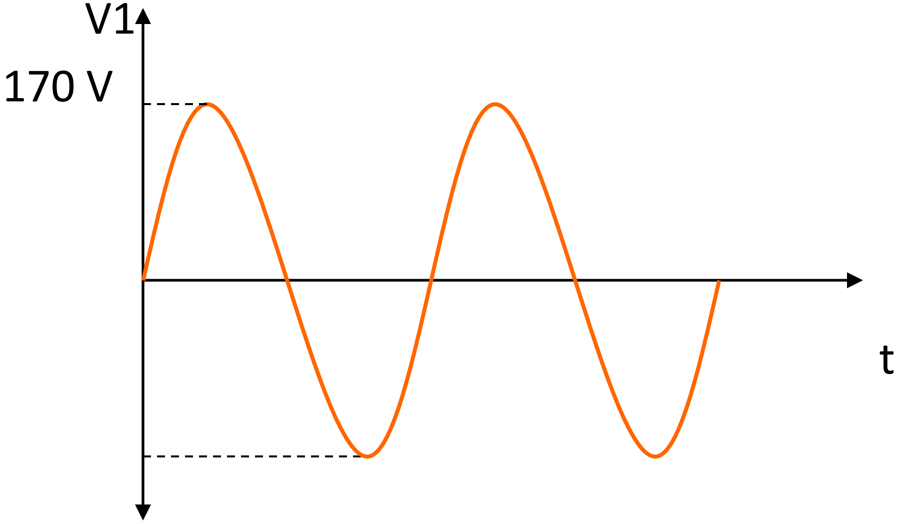

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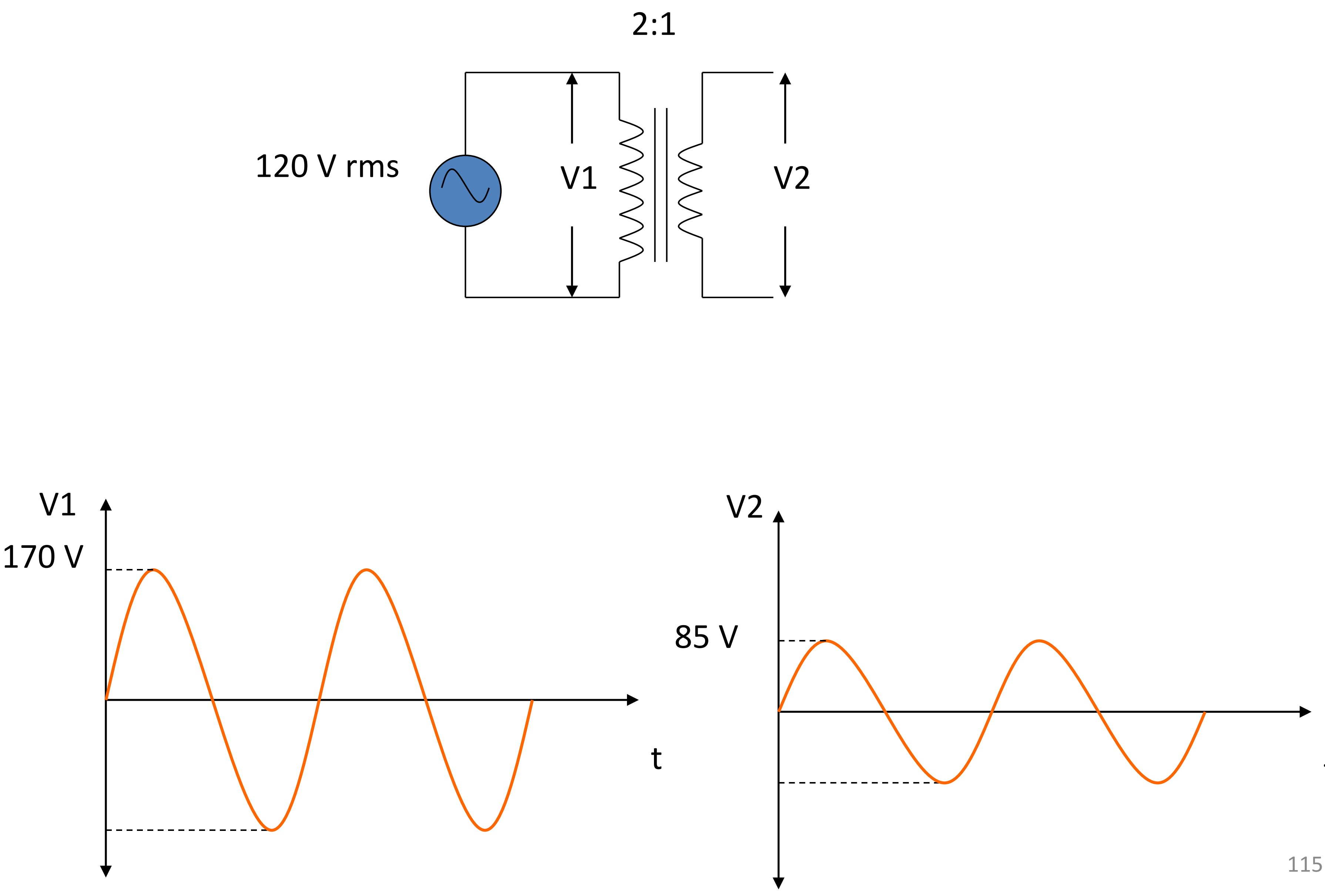
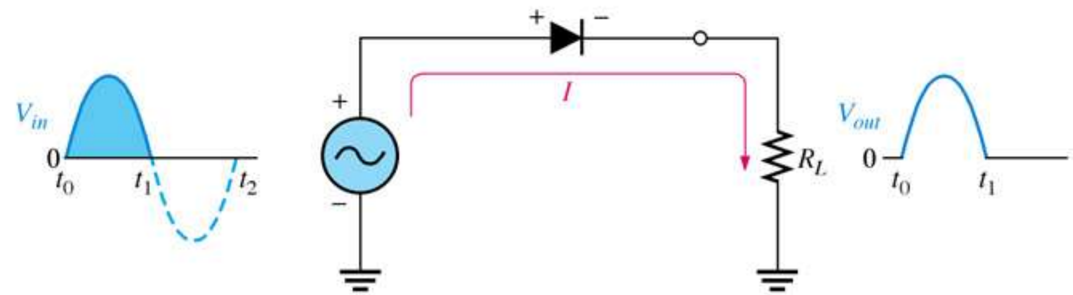
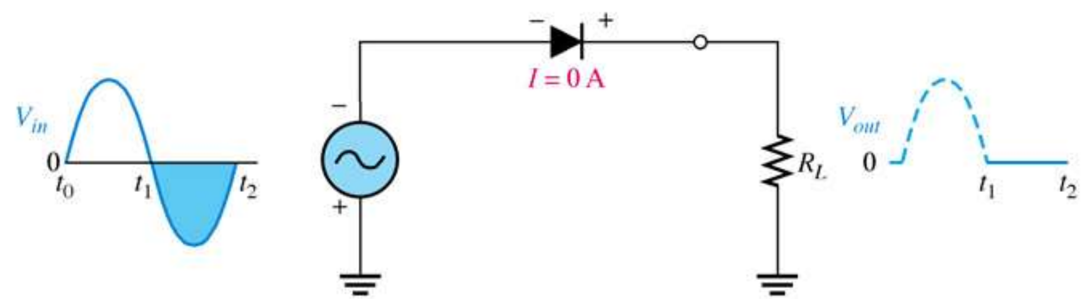


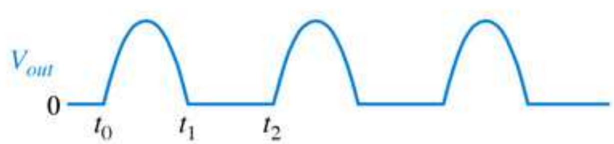
Half wave rectifier



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



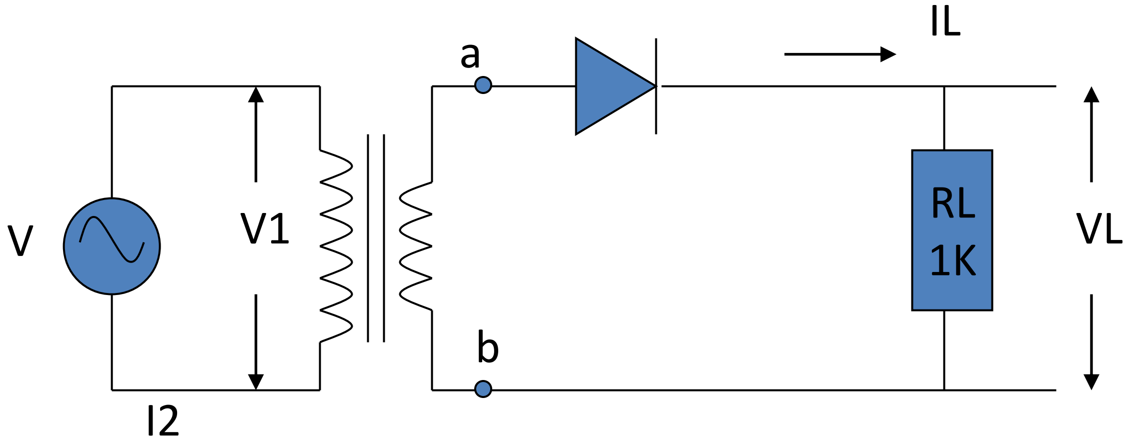
(b) During the negative alternation of the input voltage, the current is 0, so the output voltage is also 0.

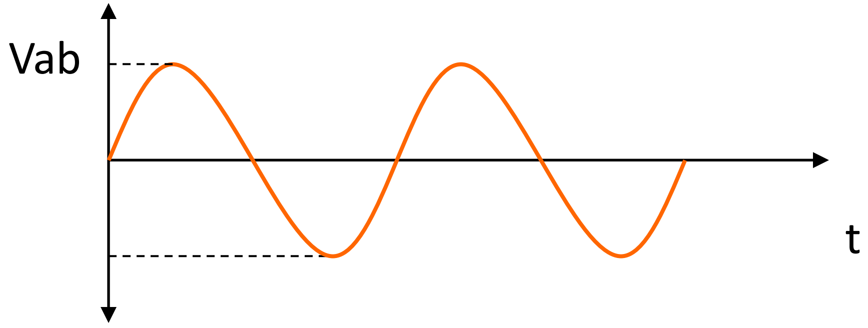


(c) 60 Hz half-wave output voltage for three input cycles

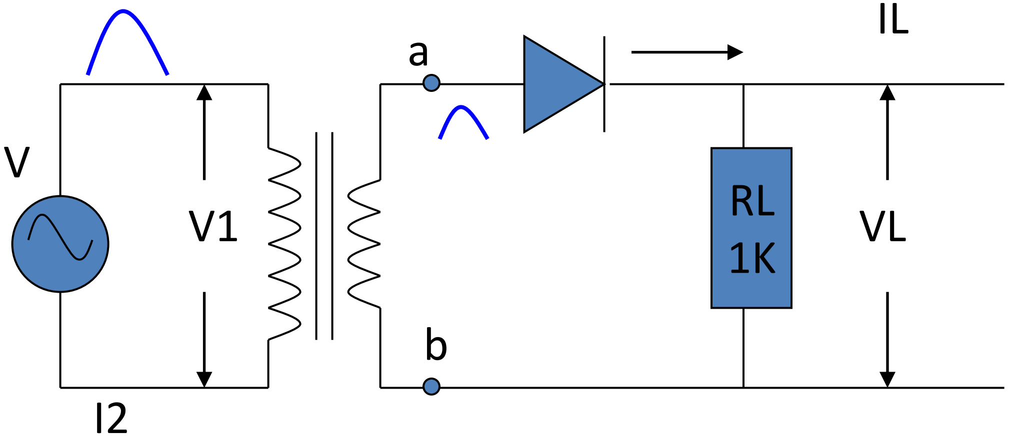
FIGURE 2-2 Half-wave rectifier operation. The diode is considered to be ideal.

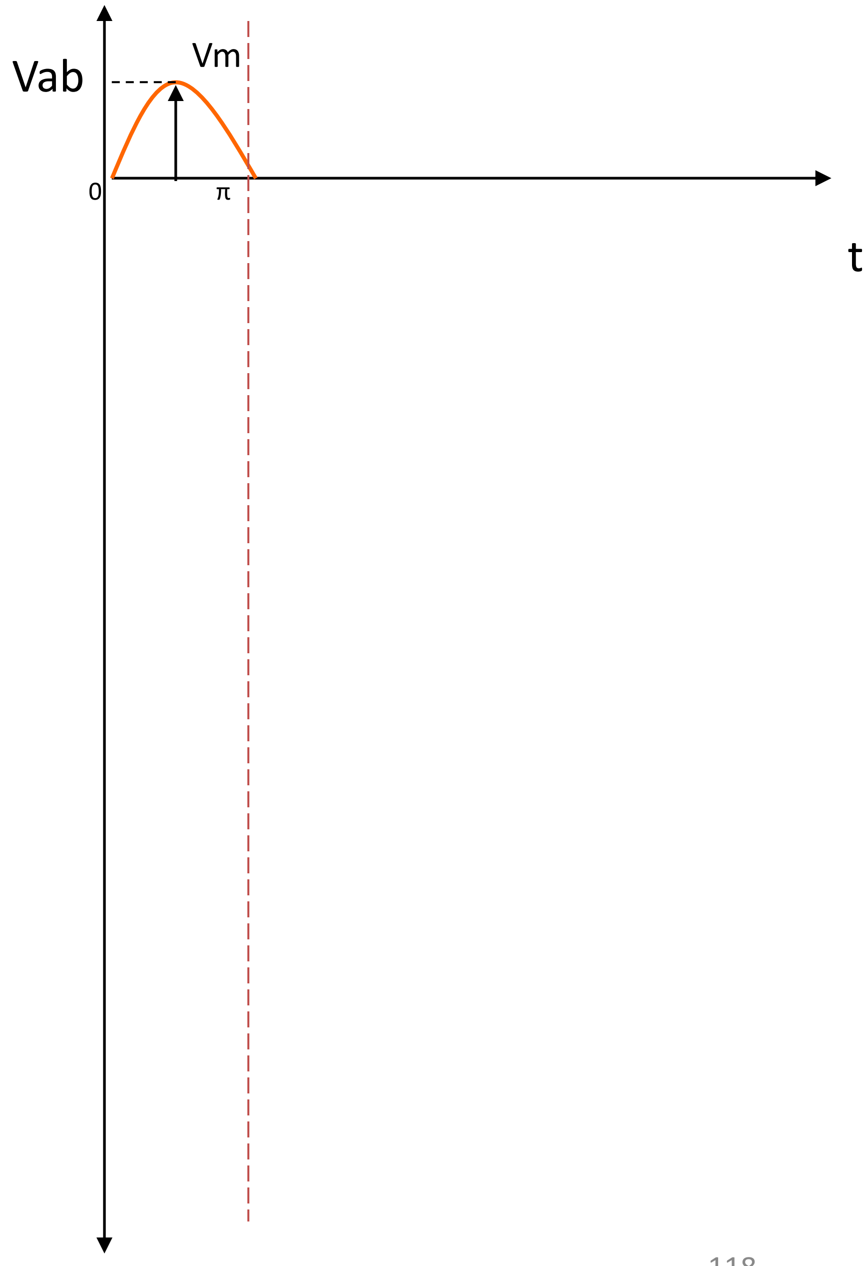
Half wave rectifier



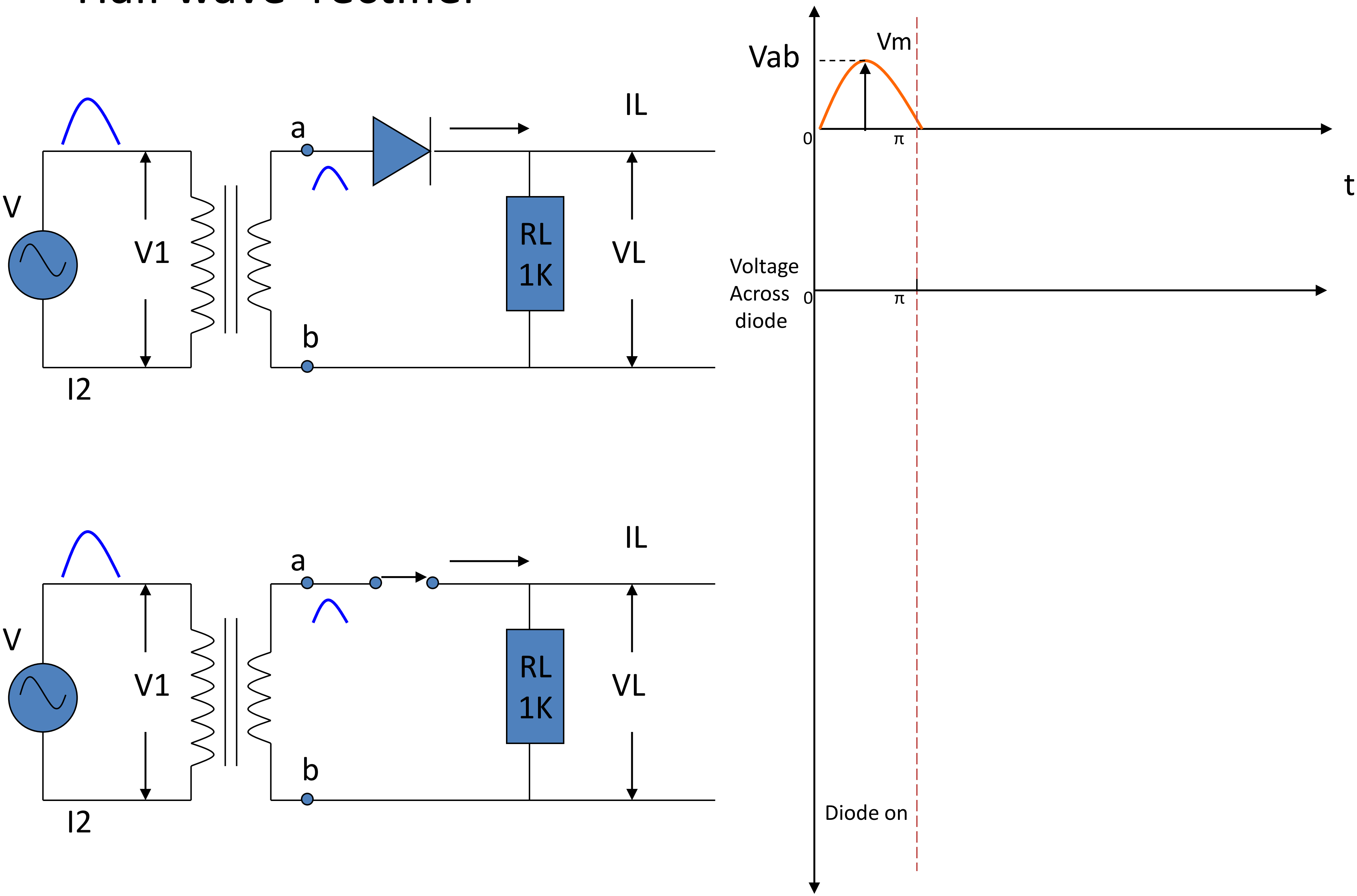


Half wave rectifier

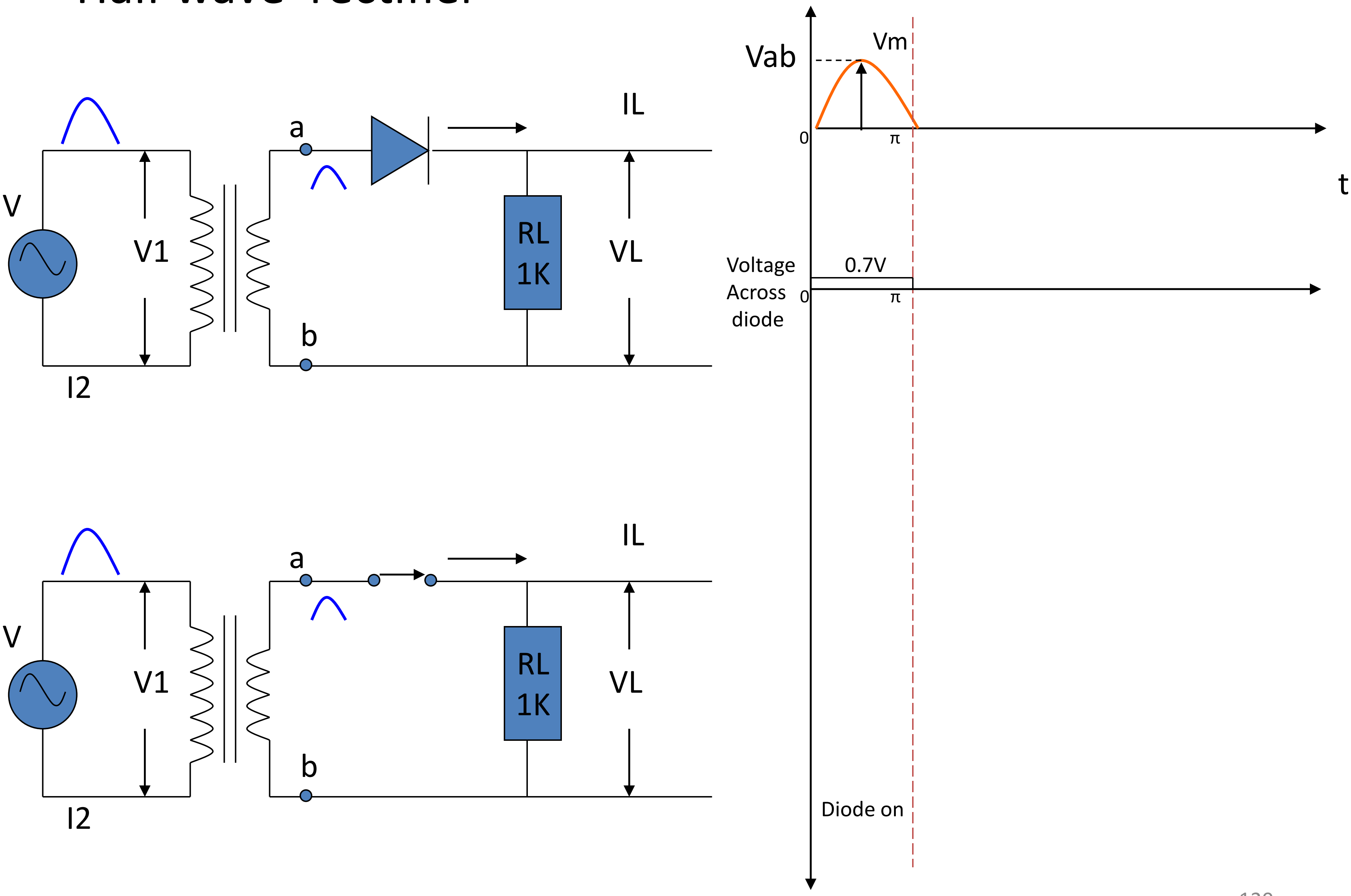




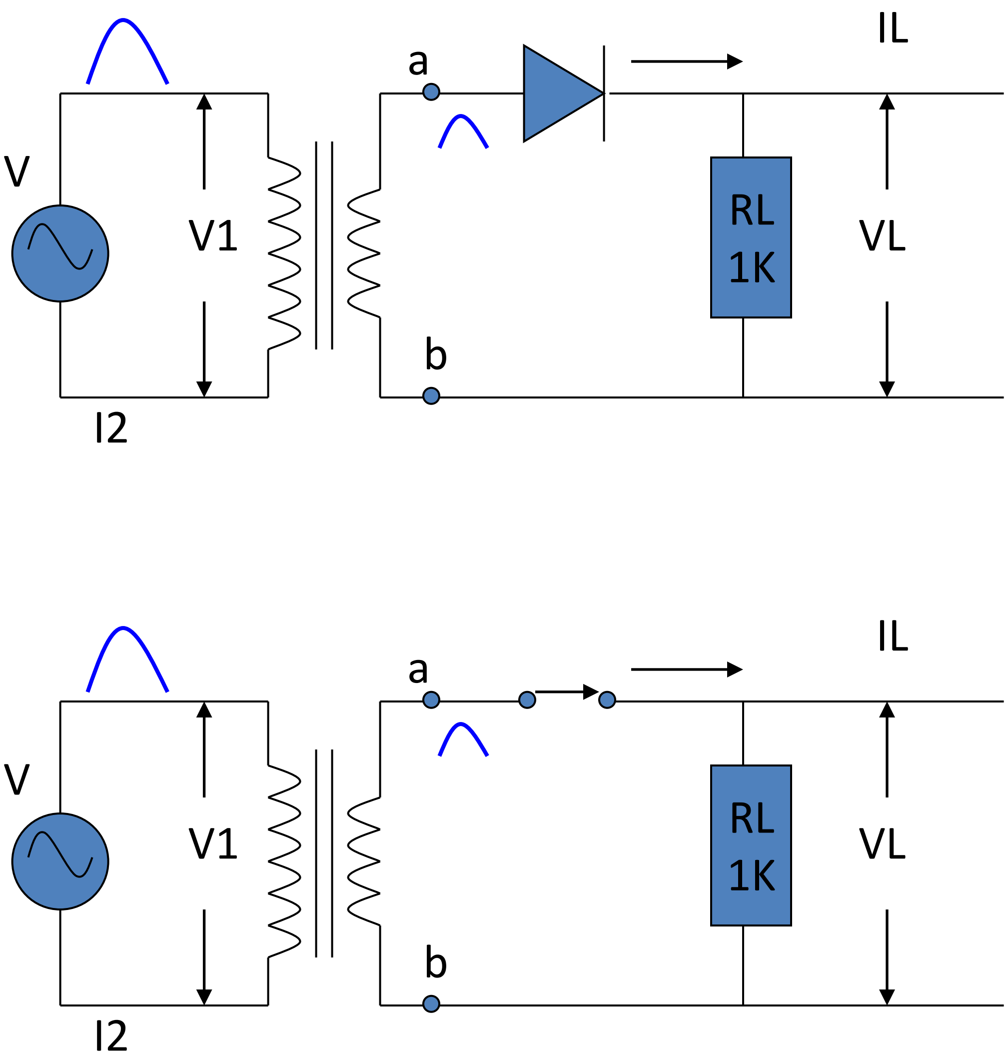
Half wave rectifier

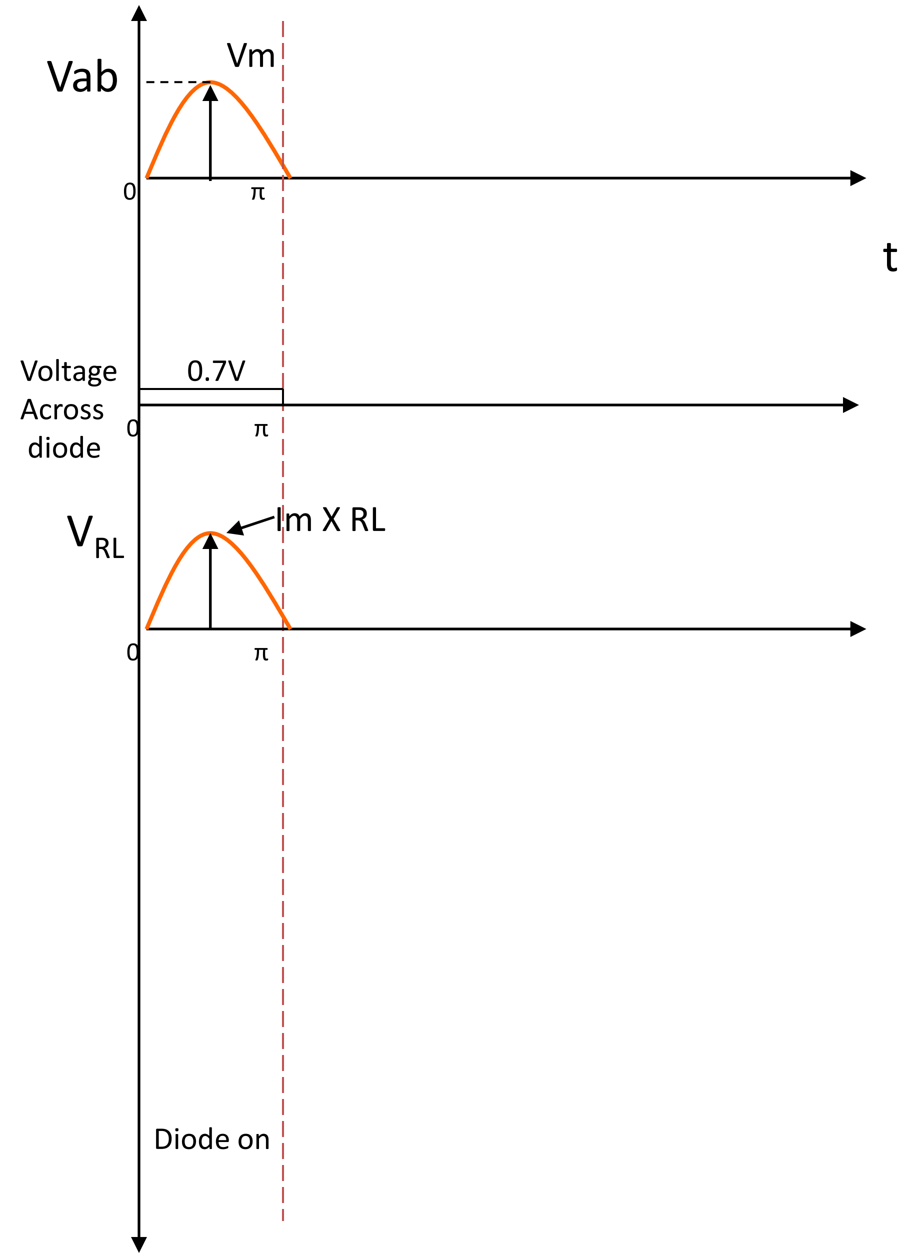


Half wave rectifier

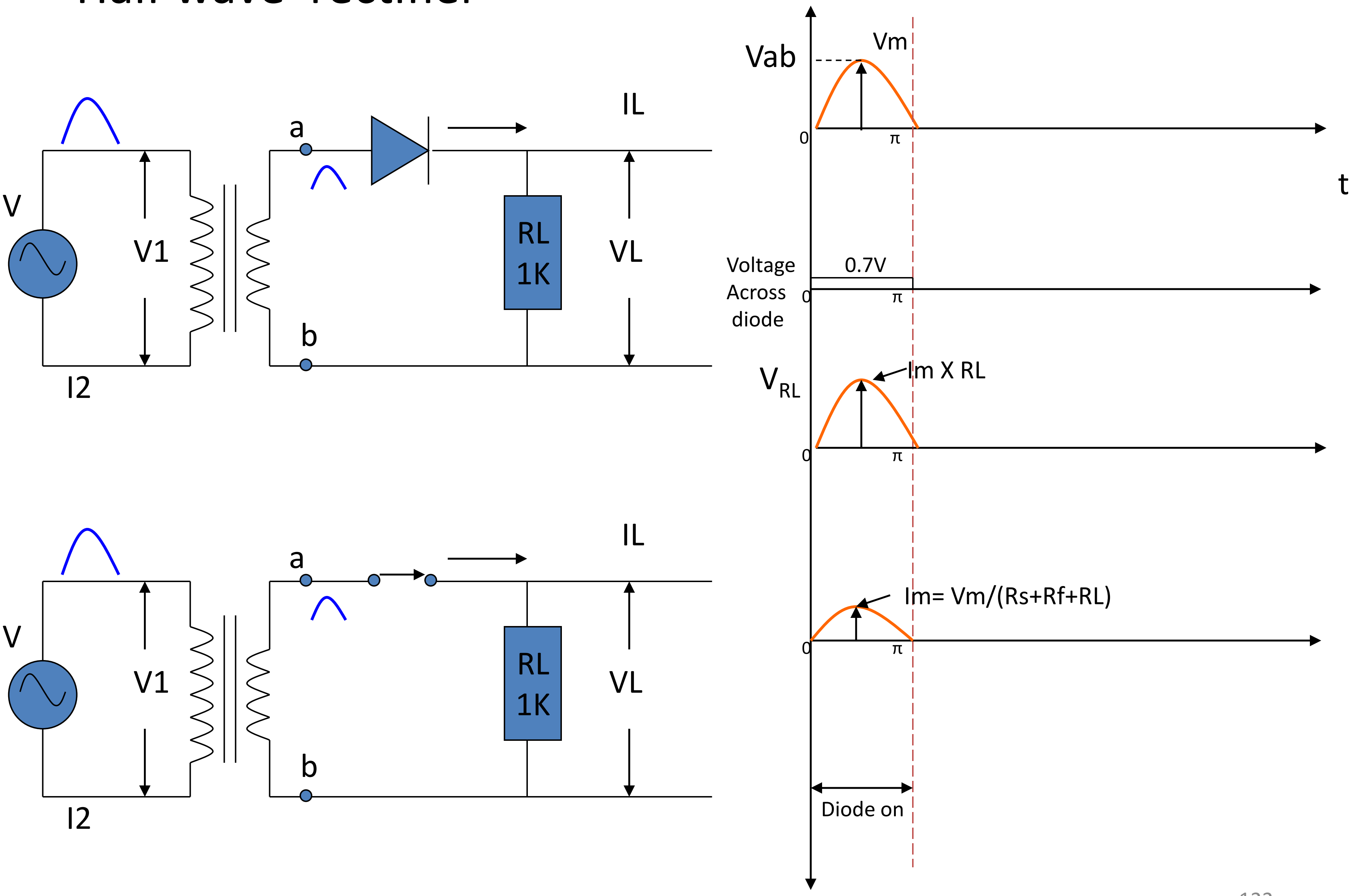


Half wave rectifier

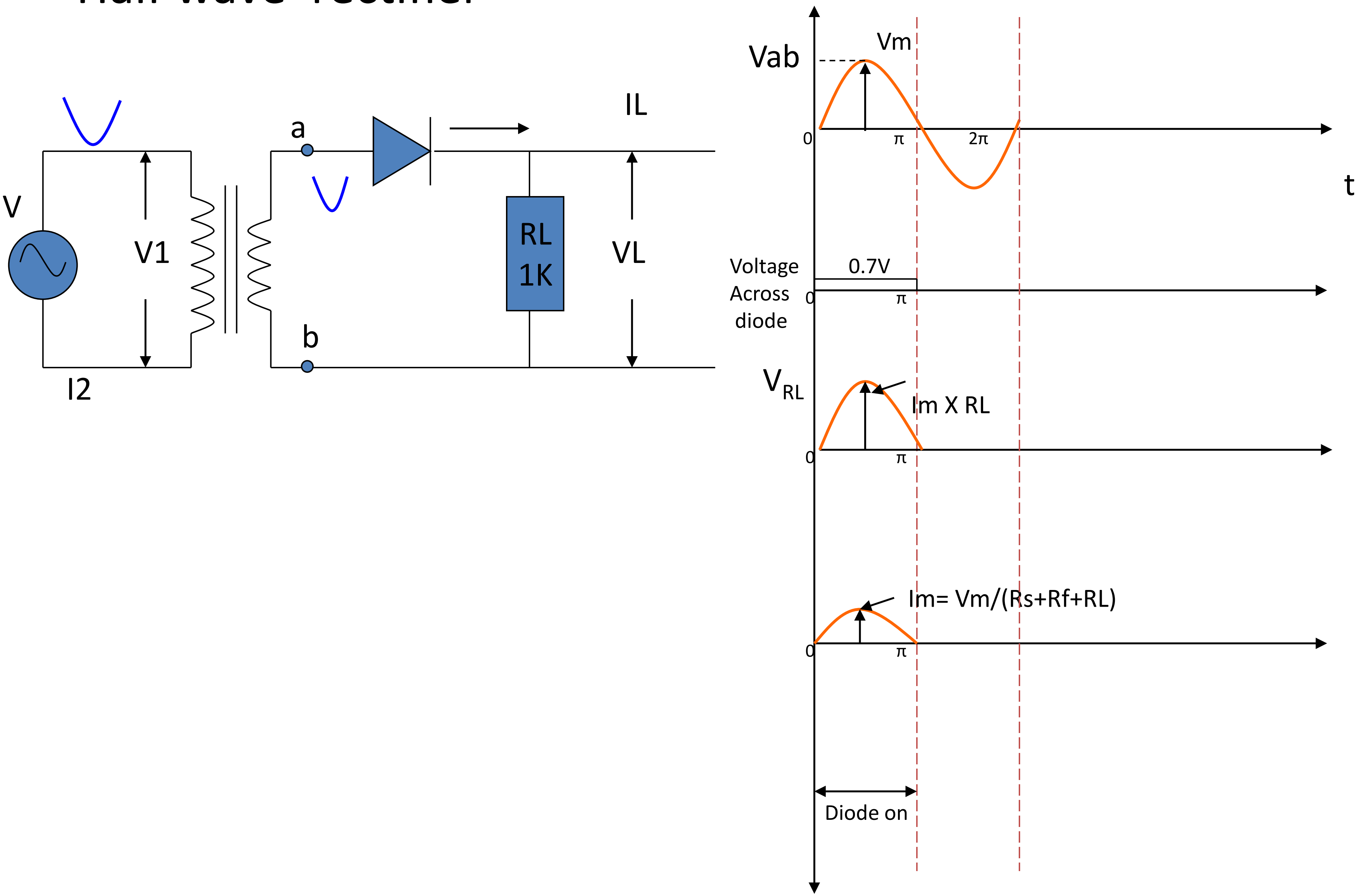




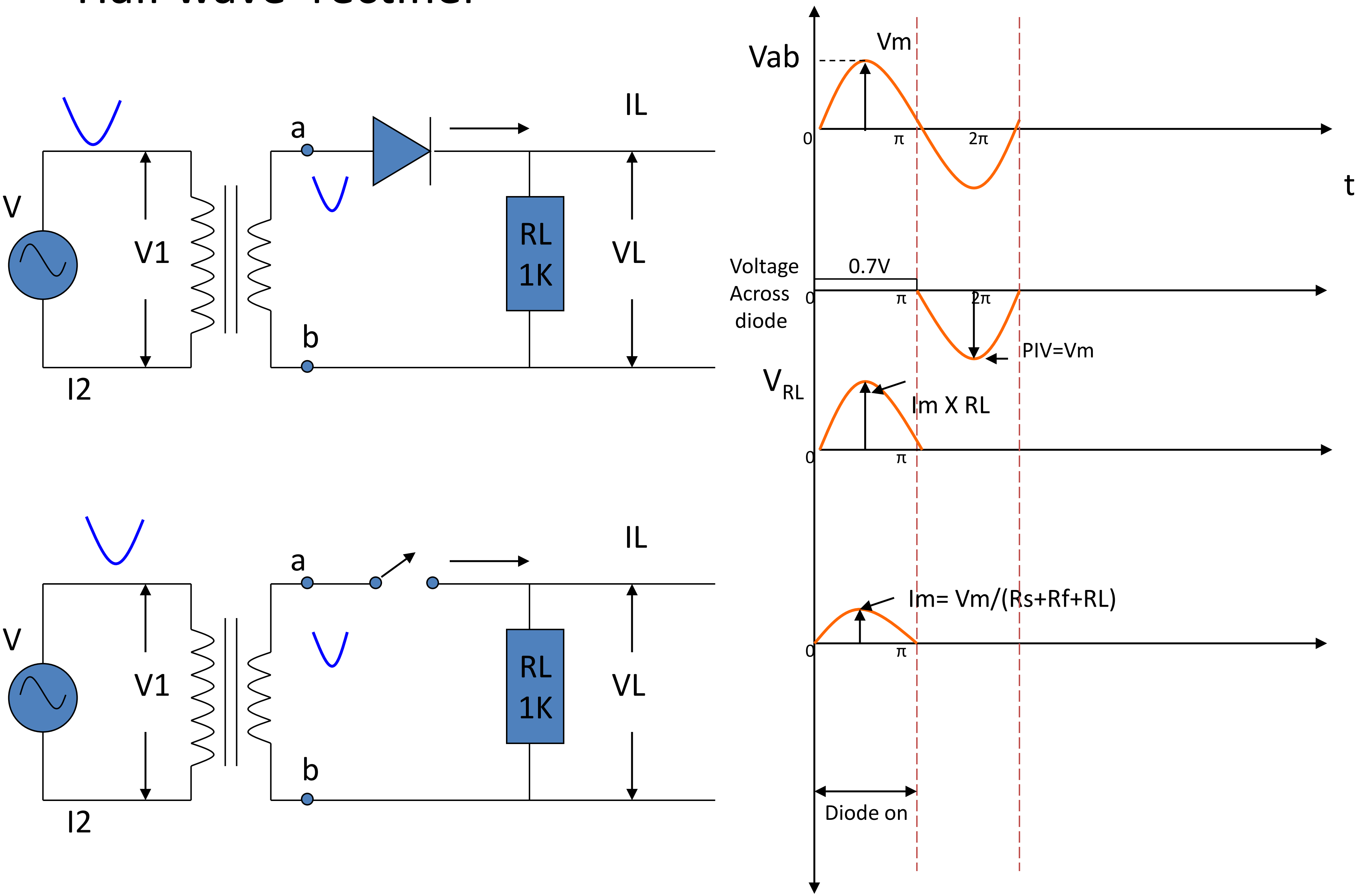
Half wave rectifier



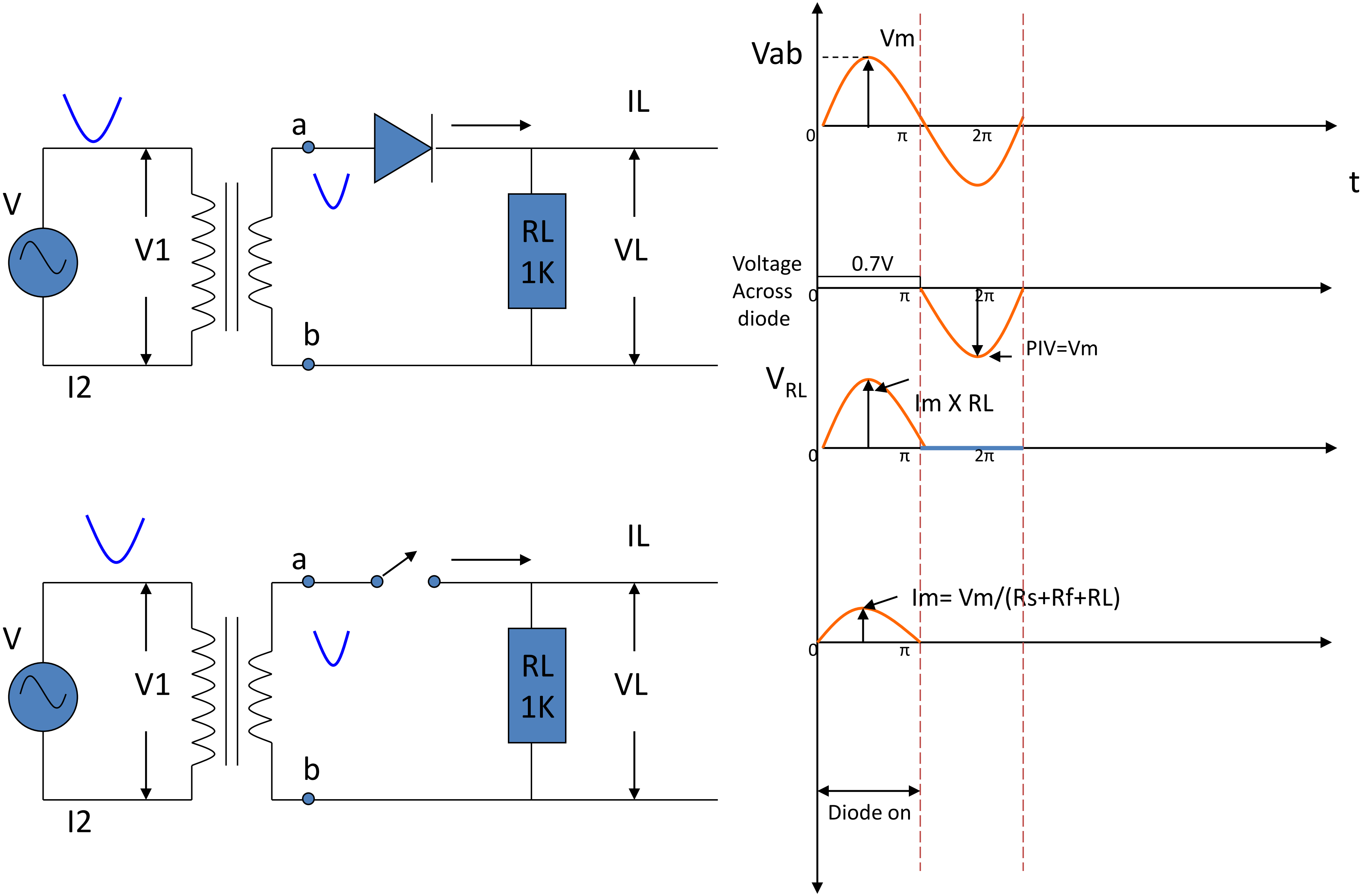
Half wave rectifier



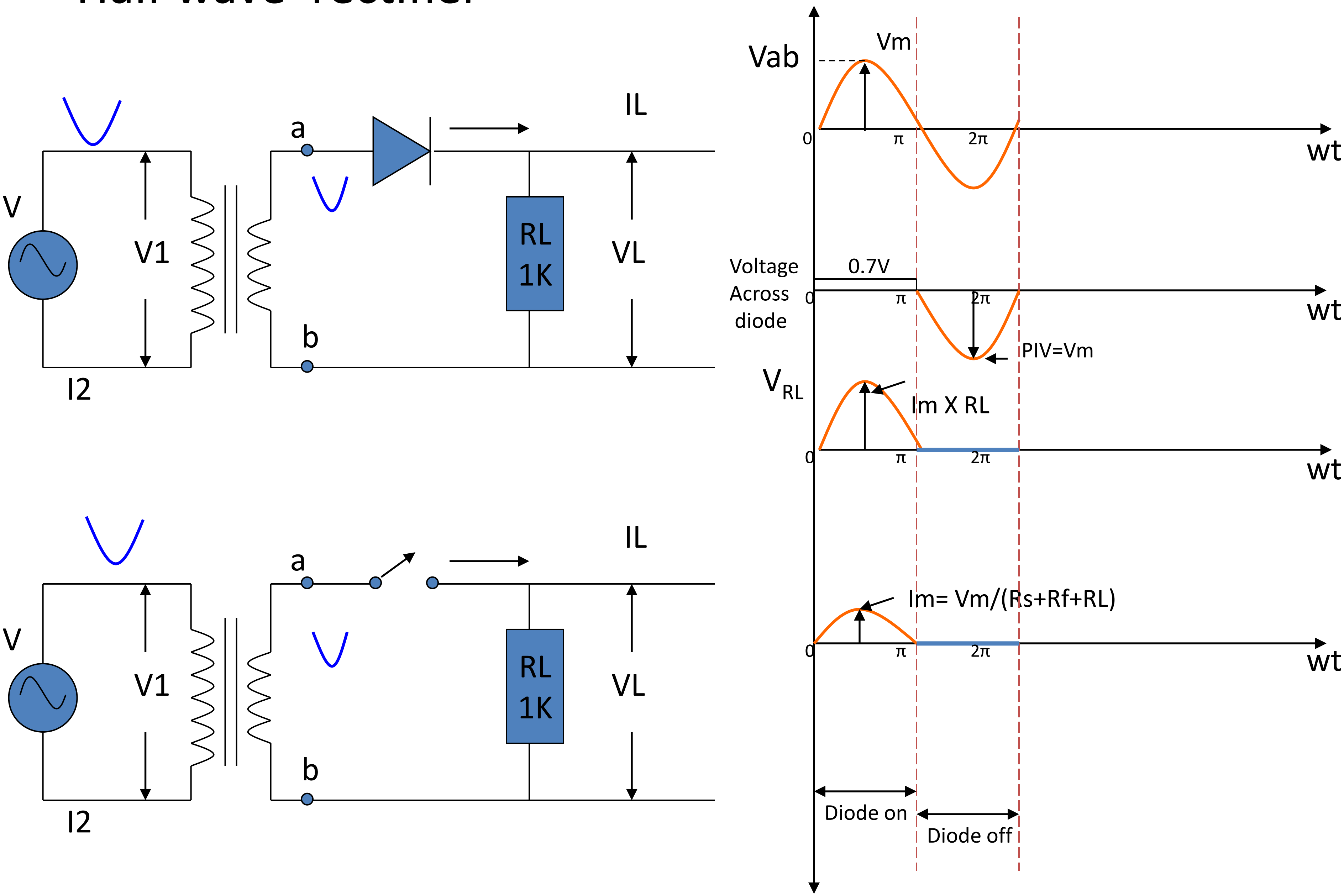
Half wave rectifier



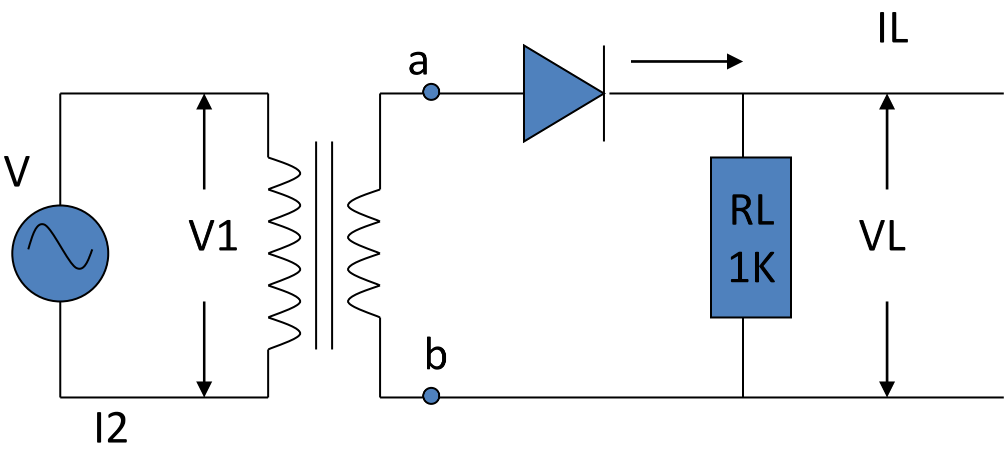
Half wave rectifier

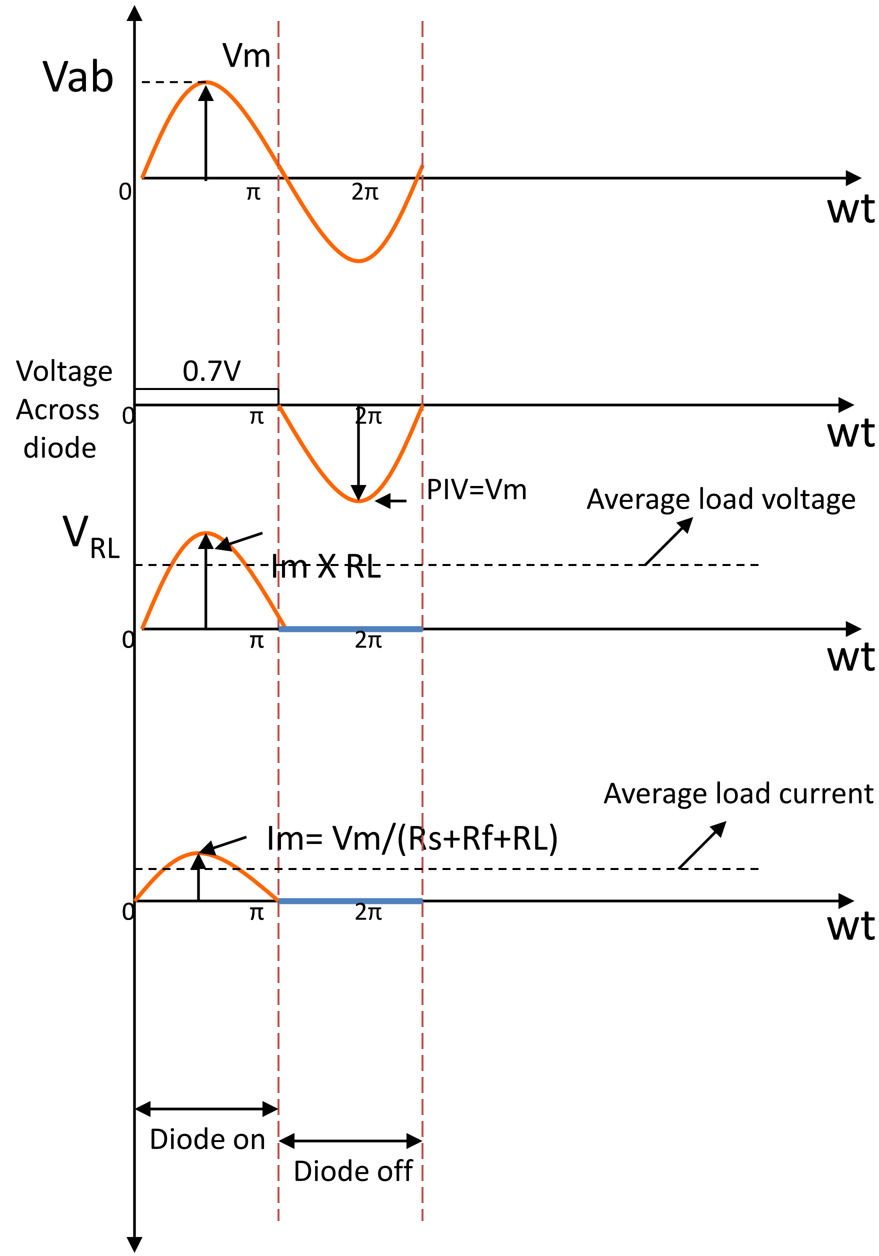


Half wave rectifier



Half wave rectifier





Analysis of rectifier

- The important parameters :

- $V_{rms} = V_m/\sqrt{2}$

- $I_{rms} = I_m/\sqrt{2}$

Analysis of rectifier

- The important performance parameters of a rectifier are as follows :

- Average load current (I_{LDC})
- Average load voltage (V_{LDC})
- RMS load current (I_{Lrms})
- RMS load Voltage (V_{Lrms})
- Ripple factor
- Voltage regulation
- TUF and
- PIV
- Ripple Frequency

Average values of output voltage and load current in a Half wave rectifier

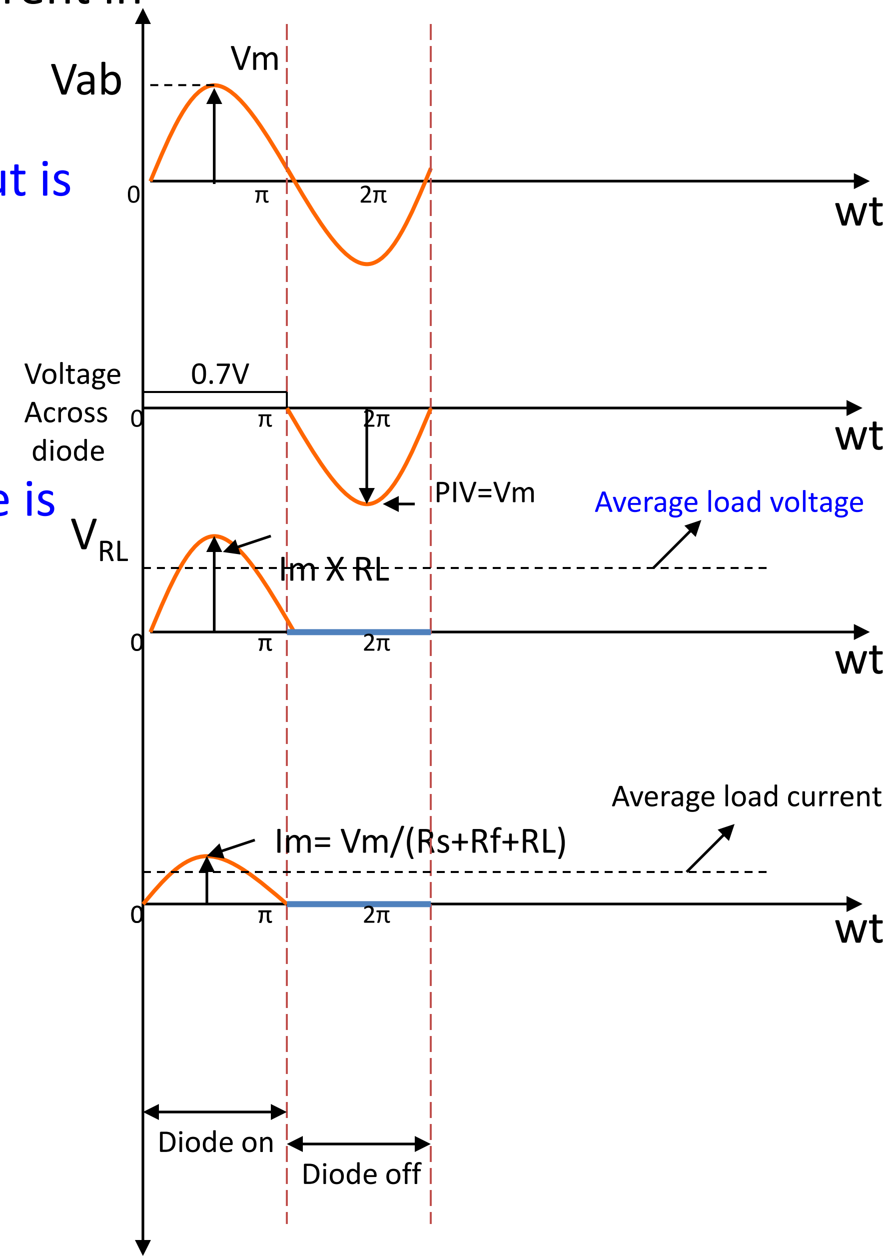
instantaneous value of the sinusoidal a.c. input is given by the relation

v = Vm sin wt

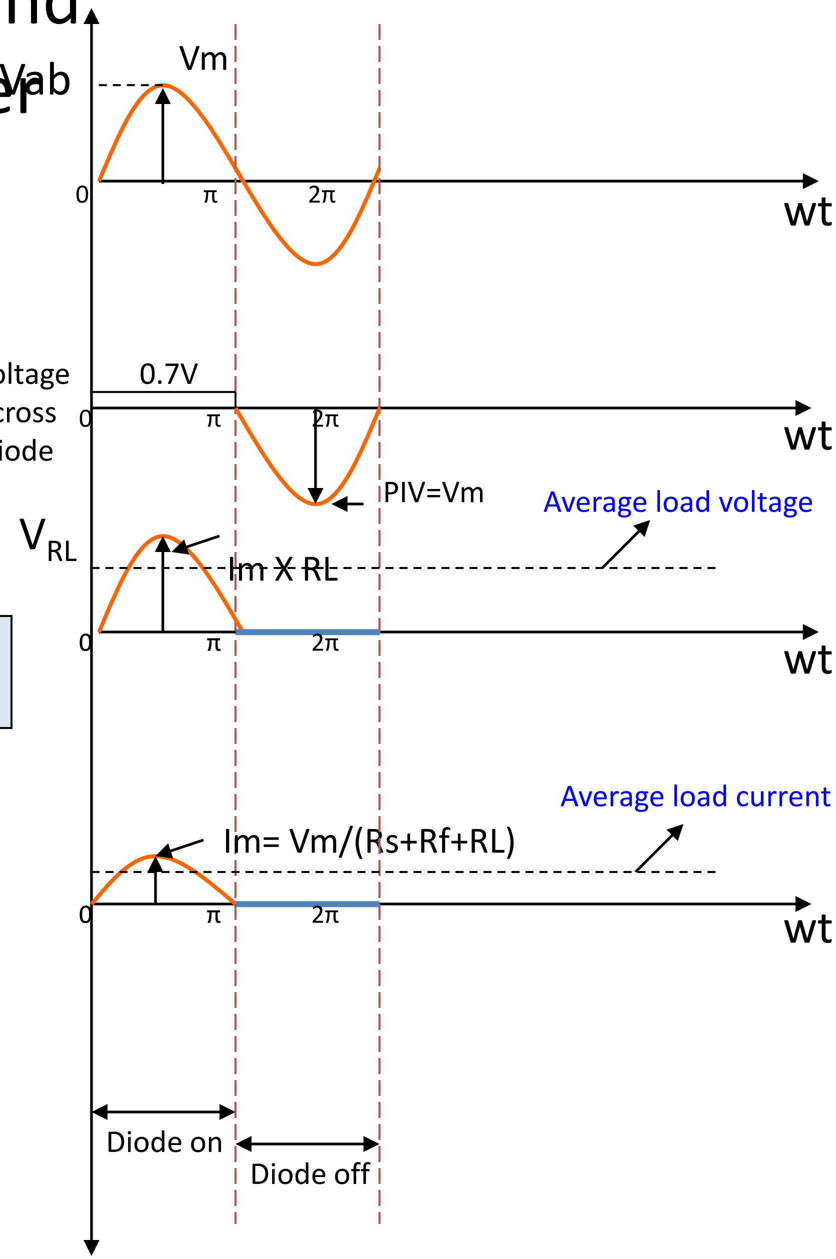
the average or d.c. value of the output voltage is given by the relation

V_{Ldc}= area under the curve over the full cycle

$$V_{LDC} = 0.318\ Vm$$



Average values of output voltage and load current in a Half wave rectifier



$I_{LDC} = V_{LDC}/R_L$

$I_{LDC} = V_m/\pi R_L$

$I_{LDC} = I_m R_L/\pi R_L$

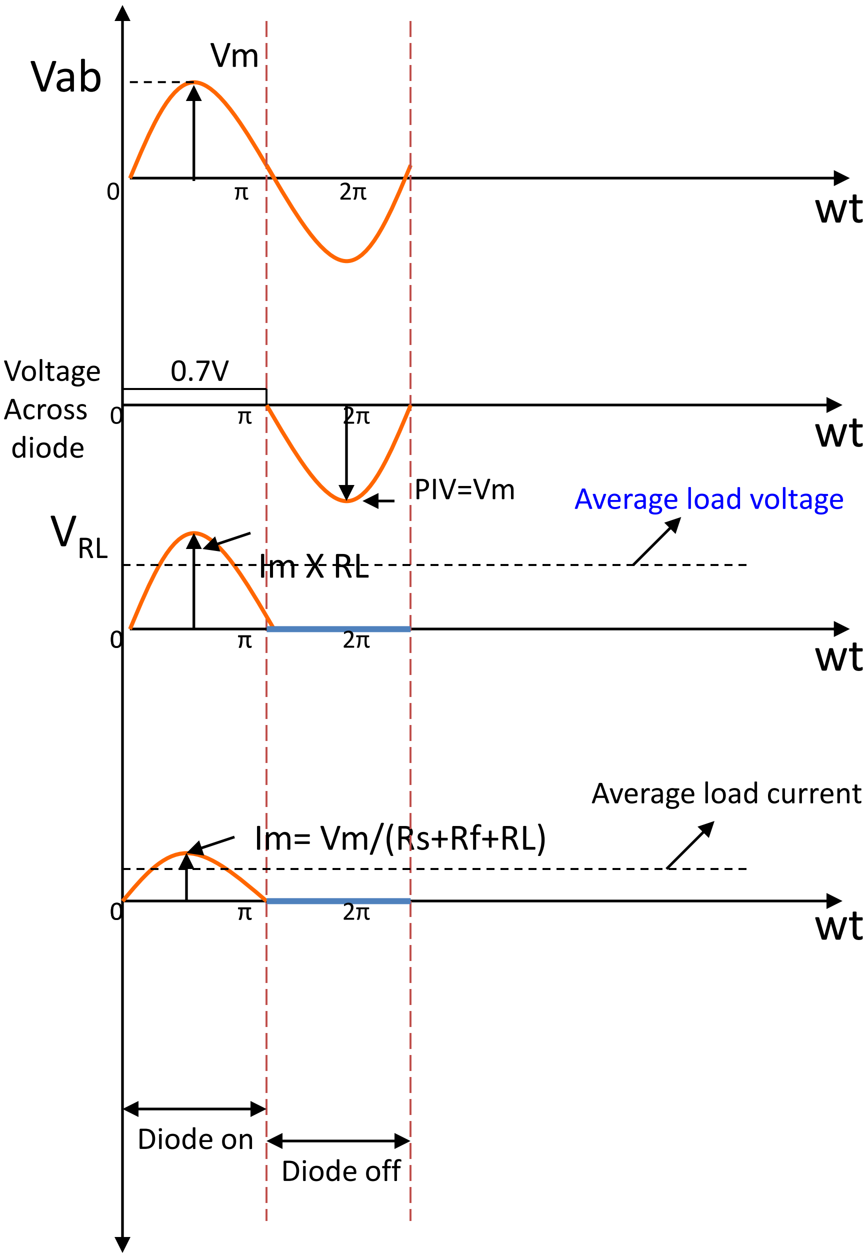
$I_{LDC} = I_m/\pi$

$\boxed{V_{LDC} = 0.318\ Vm}$

$\boxed{I_{LDC} = 0.318\ Im}$

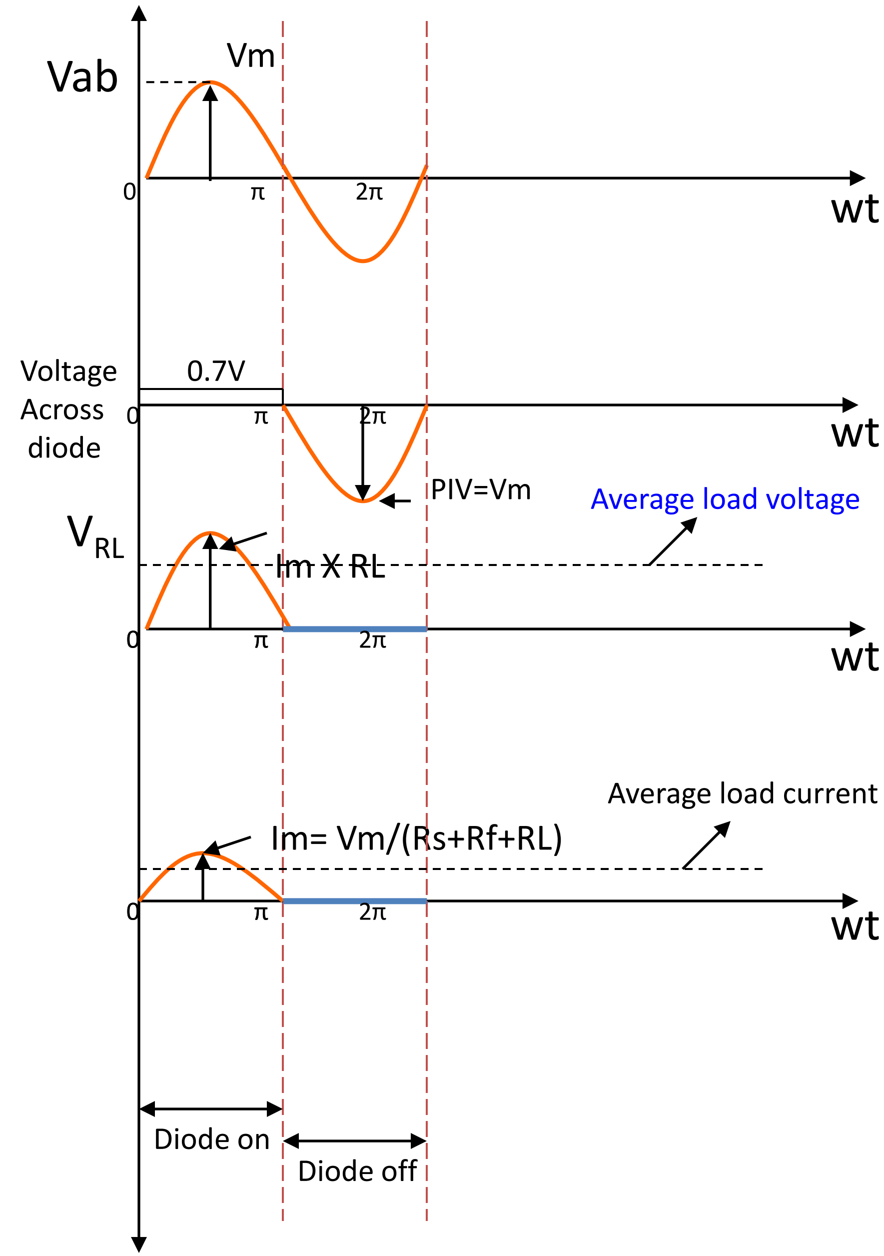
RMS or AC load current

$I_{LRMS} = Im/2$



RMS or AC load voltage

$$V_{LRMS} = Vm/2$$



Ripple factor

$$\text{ripple factor} = \frac{\text{RMS value of the AC component of output}}{\text{DC or average value of the output}}$$

$$\boxed{r = 1.21 \text{ or } 121\,\%}$$

Equation indicates that the ripple content in the output voltage is 1.21 times the dc component.

This is very high value of ripple factor which indicates that the output of HWR is no way close to the pure DC voltage

Voltage regulation

- Ideally the average rectifier output voltage should remain constant. But practically it varies with the changes in the load current
- Voltage regulation is defined as:

- Voltage regulation = $\dfrac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$

Ideally the load regulation should be 0 % and practically it should be as low as possible.

DC output power

- **The DC output power delivered to the load is given by:**
- $P_{LDC} = I^2_{LDC} \quad X \;\; RL$

AC input power

- The AC input power delivered to the load is given by:
- $P_{LAC} = I^2_{LRMS} \quad X\,(Rs + Rf + RL)$

Rectifier efficiency

- Rectifier efficiency is defined as,
- $$\eta = \frac{\text{DC output power}}{\text{AC input power}}$$
- Rectifier efficiency of a rectifier indicates the percentage of ac input power, actually converted into the average load power. Hence it should be as high as possible.

Transformer utilization factor (TUF)

- It may be defined as the ratio of DC power delivered to the load and the AC ratings of the transformer secondary.

- $$\text{TUF} = \frac{\text{DC power delivered to the load}}{\text{AC rating of the transformer secondary}}$$

$$= \frac{P_{DC}}{P_{AC}\text{ (rated)}}$$

For HWR the TUF = 0.287

Parameter	Value HWR
Average DC load current (I_{LDC})	$I_M/п$
Average DC load Voltage (V_{LDC})	$V_M/п$
RMS value of load current (I_{LRMS})	$I_M/2$
RMS value of load voltage (V_{LRMS})	$V_M/2$
DC output power (P_{DC})	$(I^2_m$ / $п^2$) X R_L
AC input power (P_{AC})	$(I^2_m$ / 4) X ($R_L + R_F + R_S$)
Maximum rectification efficiency (η_{max})	0.4 or 40 %
Ripple factor (RF)	1.21or 121% very high
Ripple frequency	50 Hz
Peak inverse voltage (PIV)	Vm
Average transformer utilization factor (TUF)	0.287or 28.7%

Example 1

- An a.c. supply of 200 v is applied to a half wave rectifier circuit through a transformer of turns ratio 10:1, find
- d.c. output voltage
- PIV of a diode, assume that diode is an ideal one.

Example 1

- An a.c. supply of 230 v is applied to a half wave rectifier circuit through a transformer of turns ratio 10:1, find

1. d.c. output voltage
2. PIV of a diode, assume that diode is an ideal one.

Ans:

- d.c. output voltage

we know that the secondary voltage,

$V2= V1 * (N2/N1) = 23V$

The maximum value of secondary voltage

$Vm= \sqrt{2} * V2 = 32.5 V$

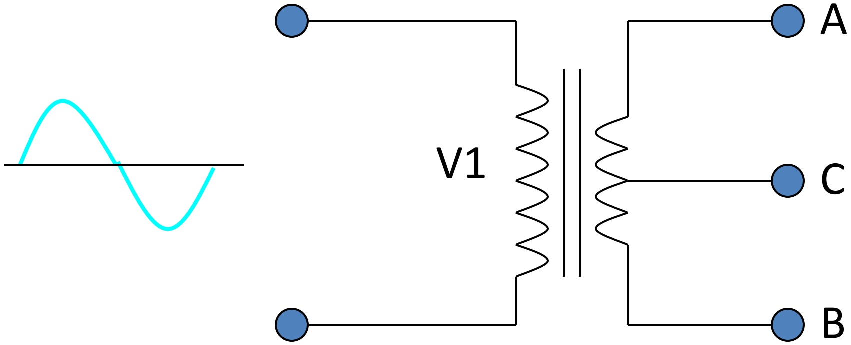
d.c. output voltage $Vdc = 0.318 Vm = 10.3 V$

- PIV of a diode

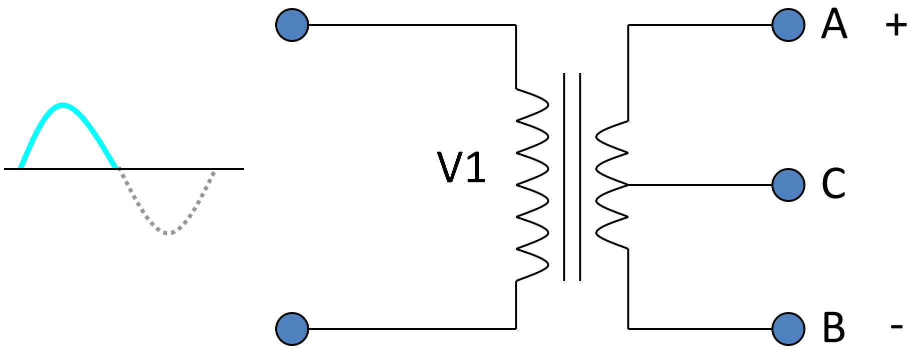
We also know the peak inverse voltage

$PIV = Vm = 32.5V$

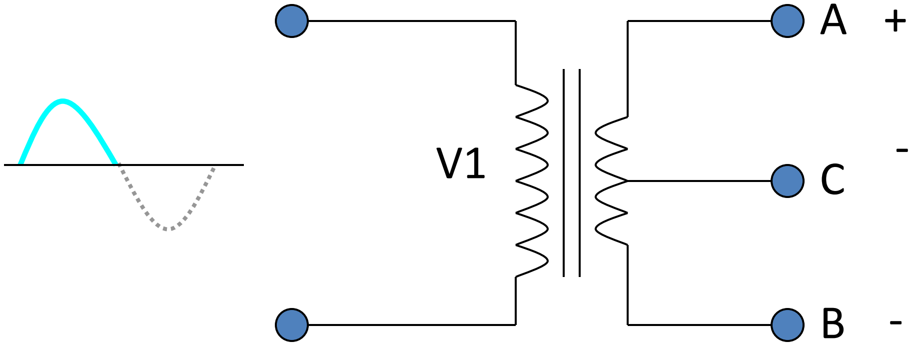
Centre tapped transformer



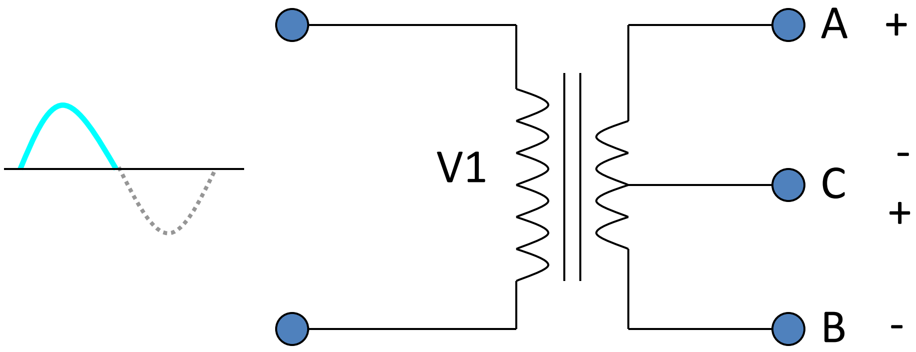
Centre tapped transformer



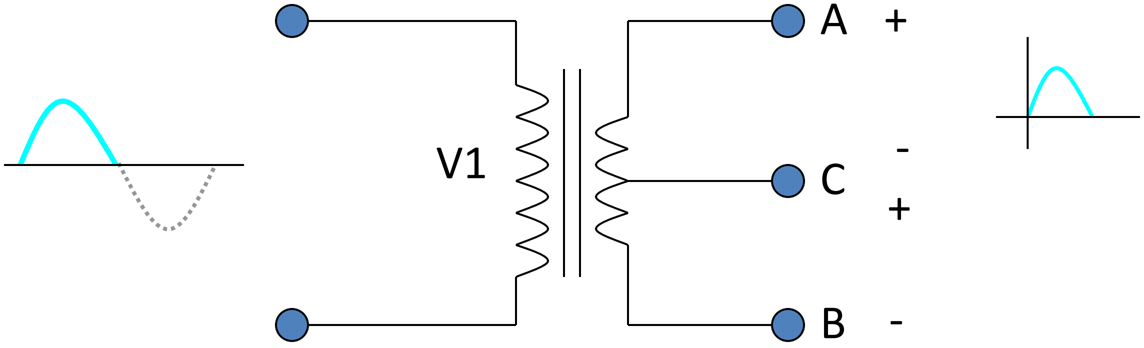
Centre tapped transformer



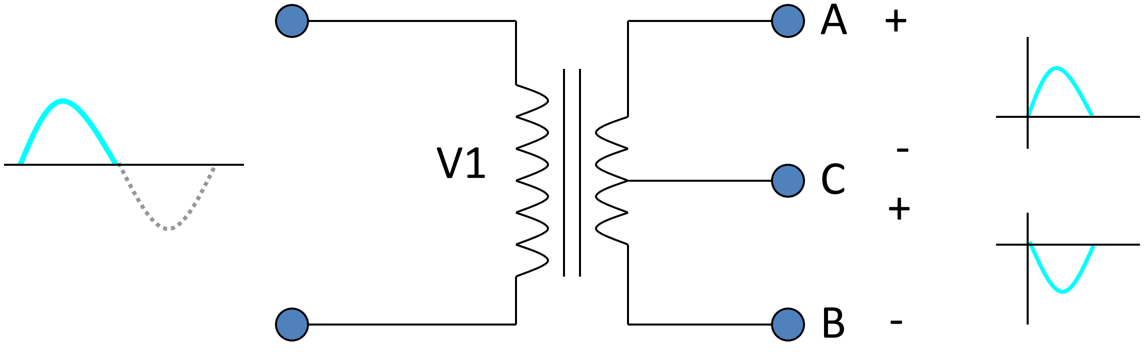
Centre tapped transformer



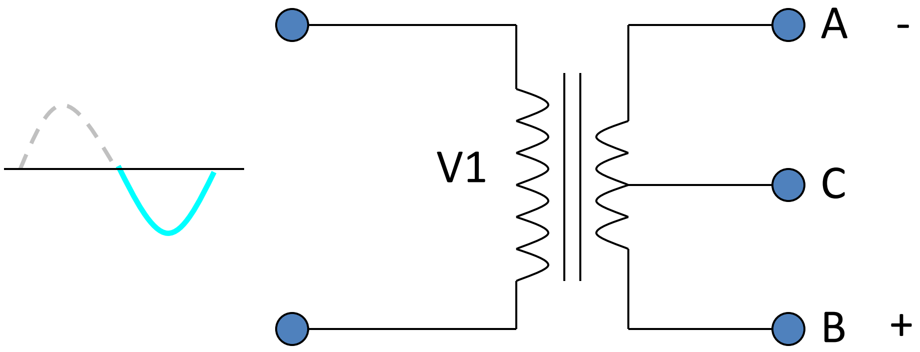
Centre tapped transformer



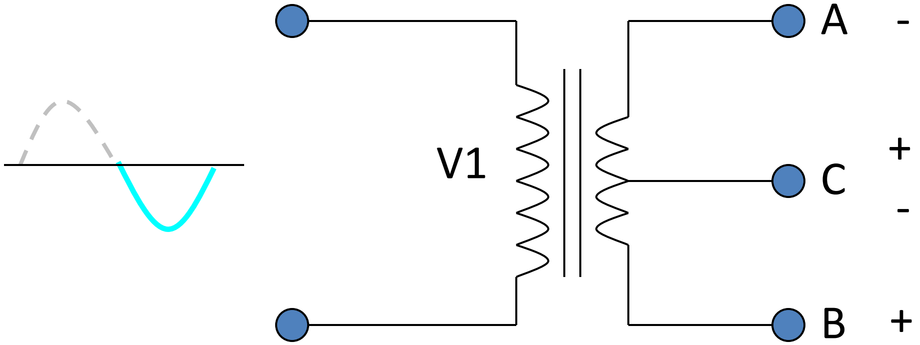
Centre tapped transformer



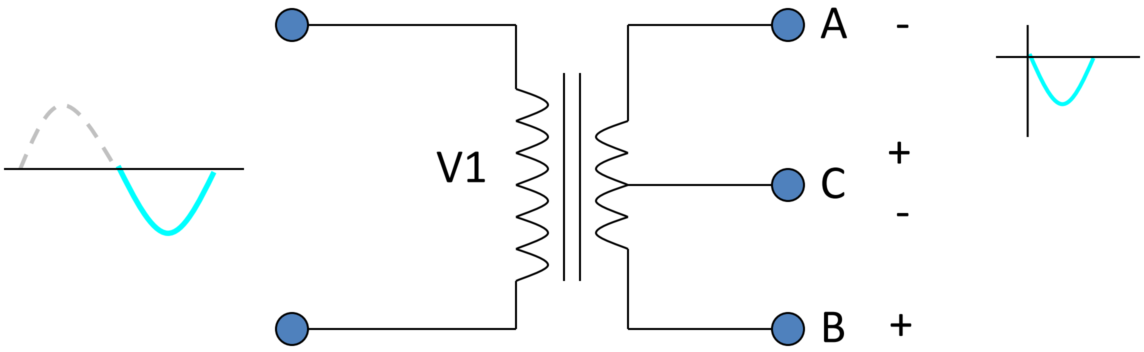
Centre tapped transformer



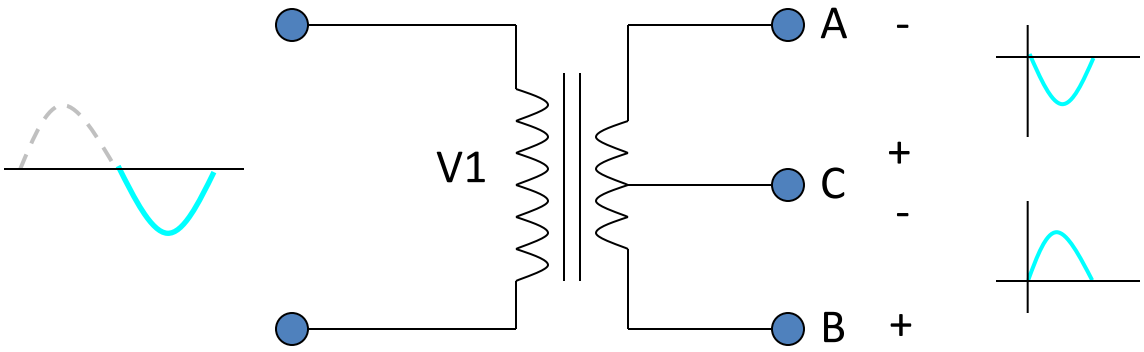
Centre tapped transformer



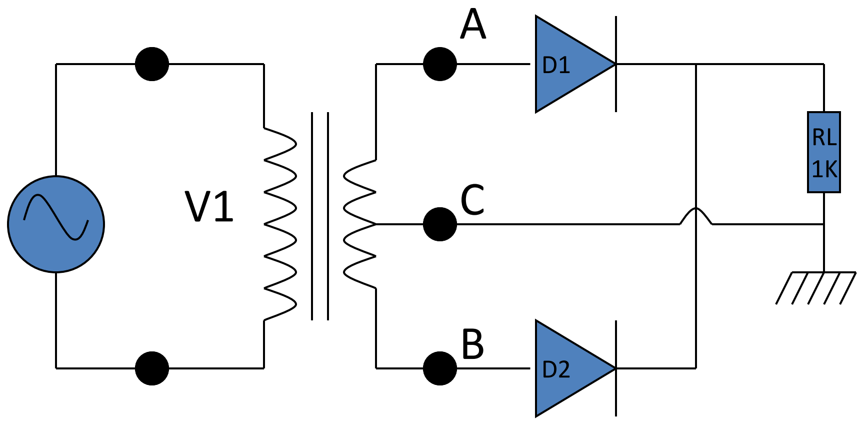
Centre tapped transformer



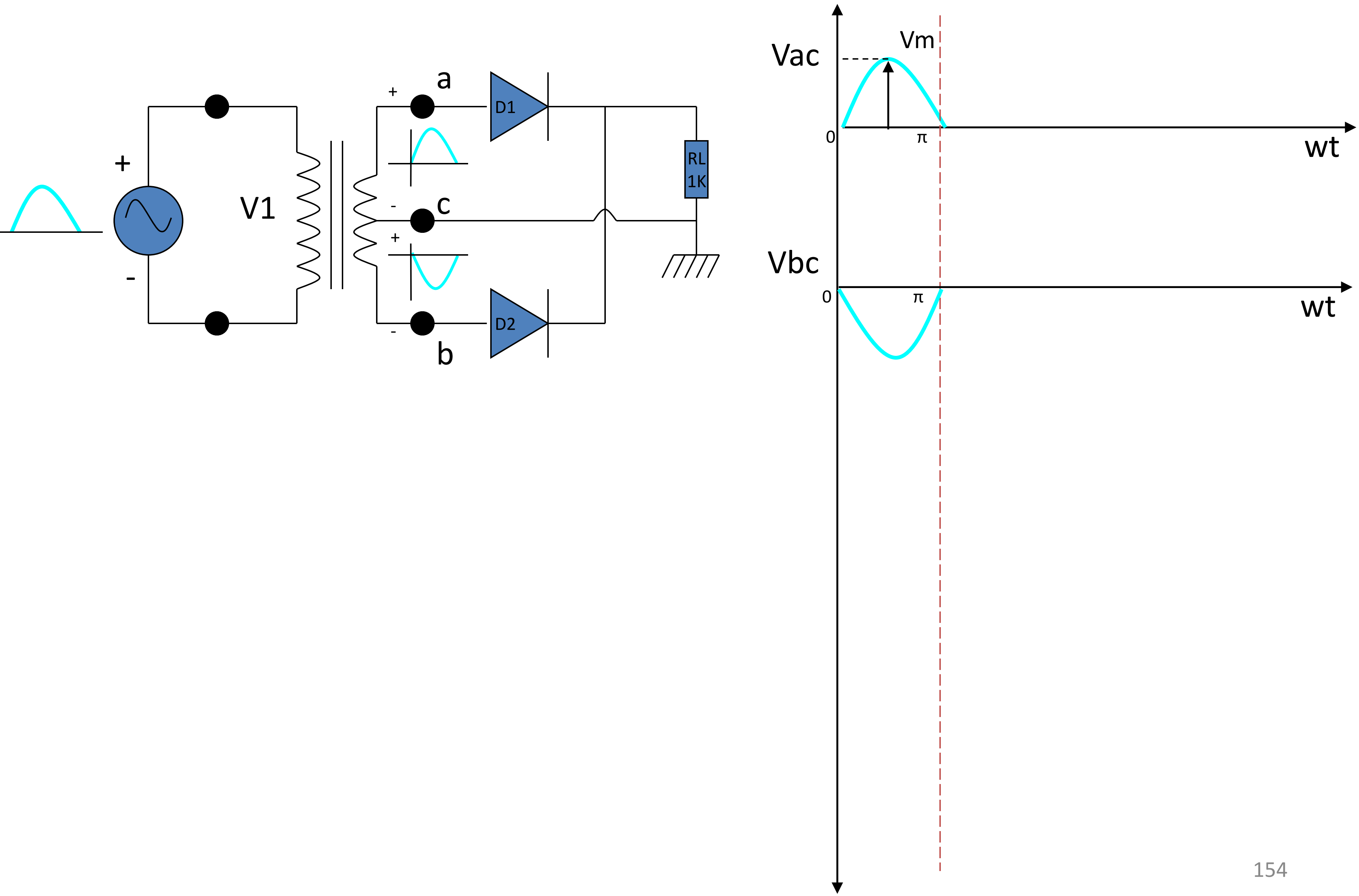
Centre tapped transformer



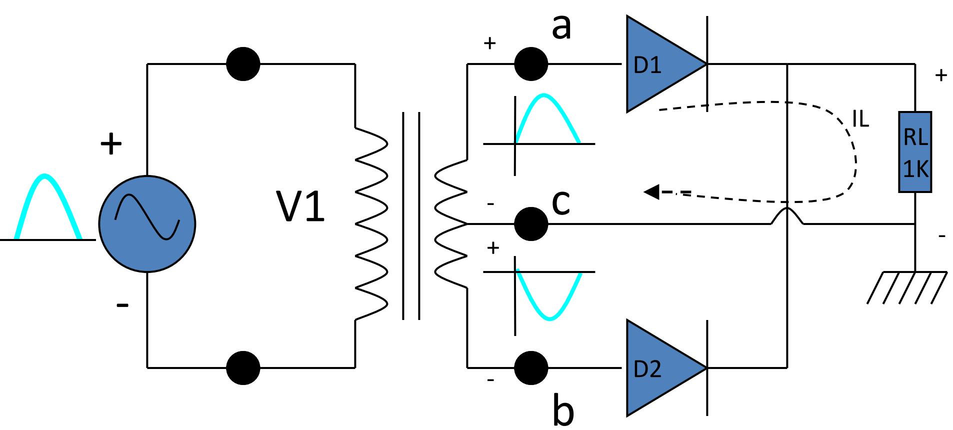
Full wave rectifier with Centre tapped transformer

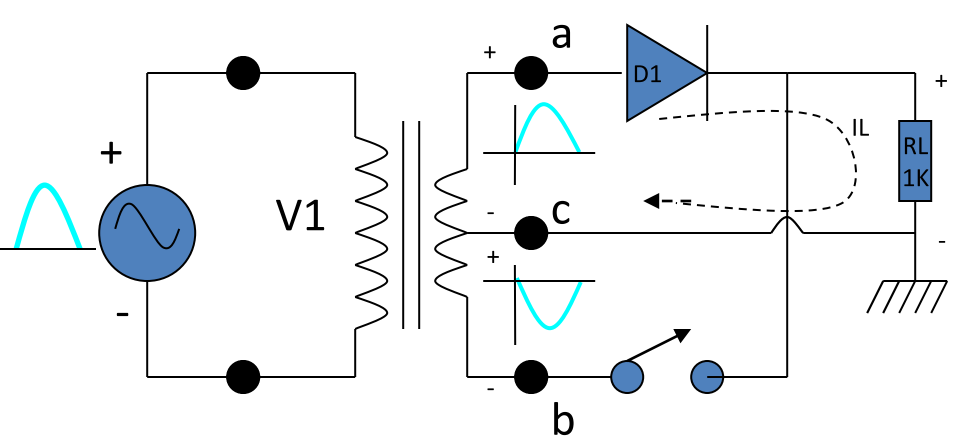


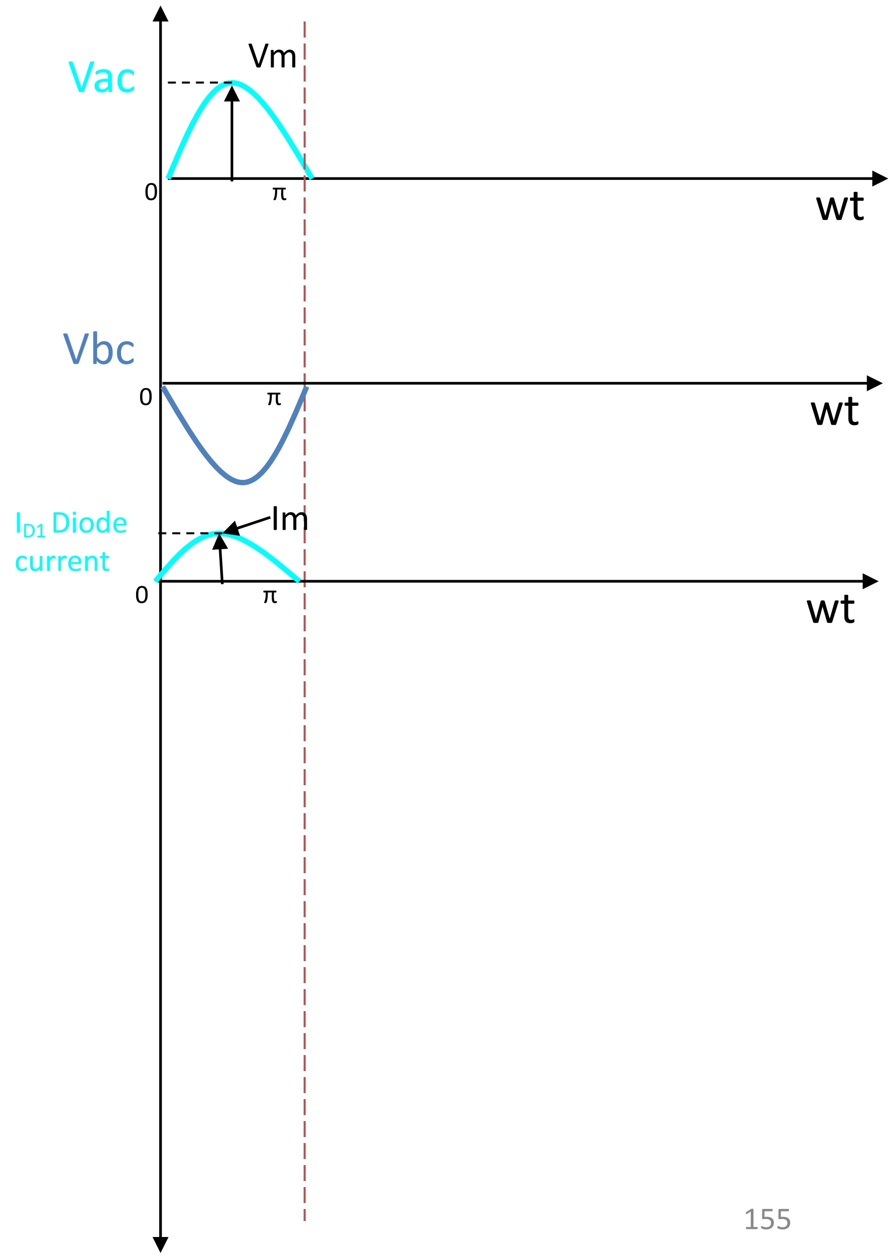
Full wave rectifier with Centre tapped transformer



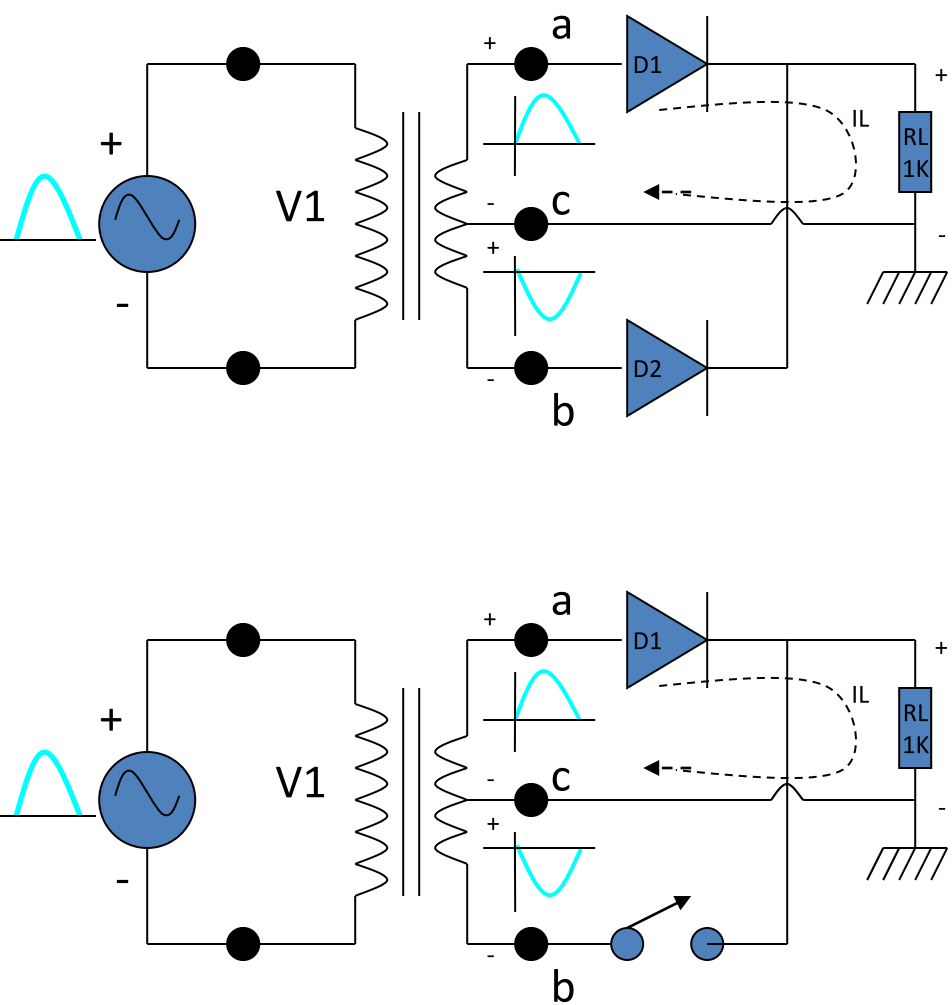
Full wave rectifier with Centre tapped transformer

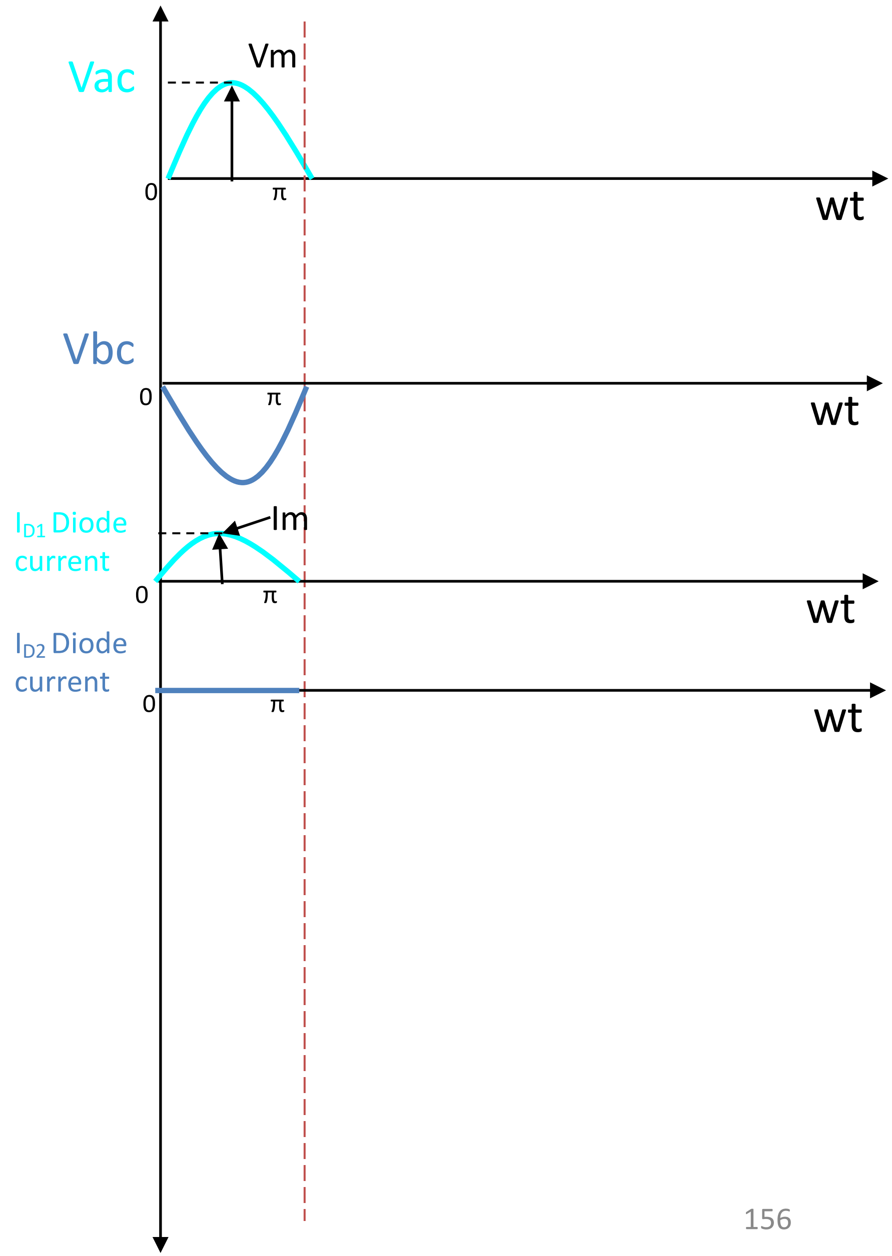




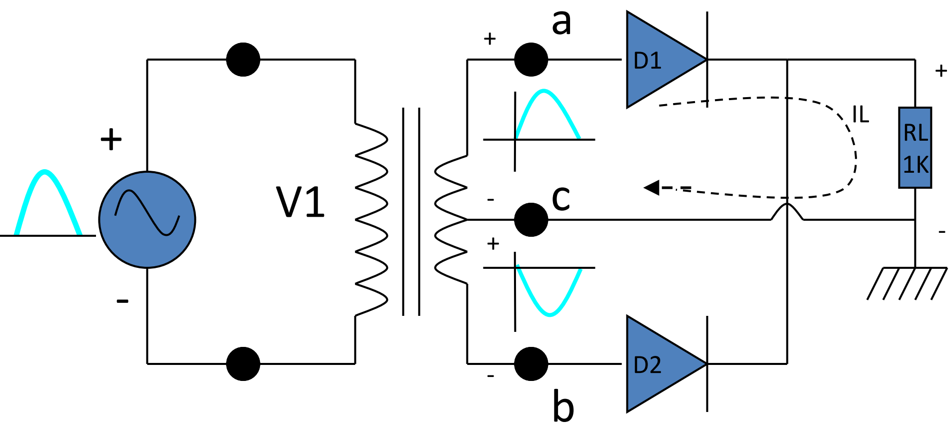


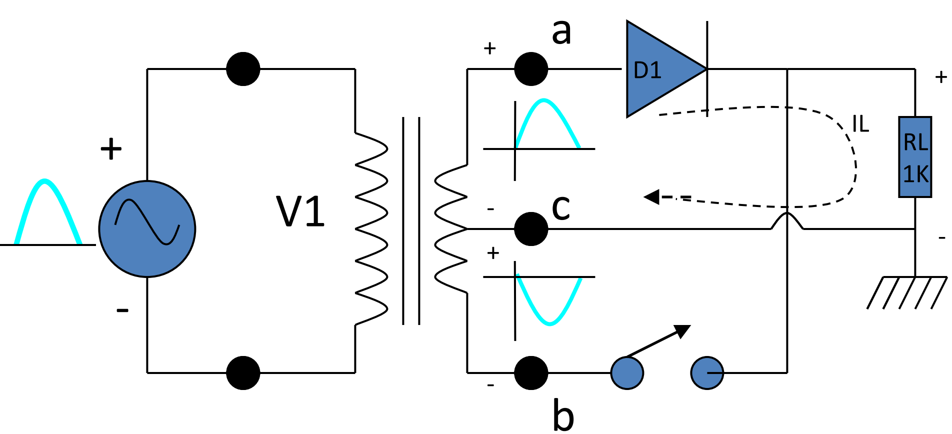
Full wave rectifier with Centre tapped transformer

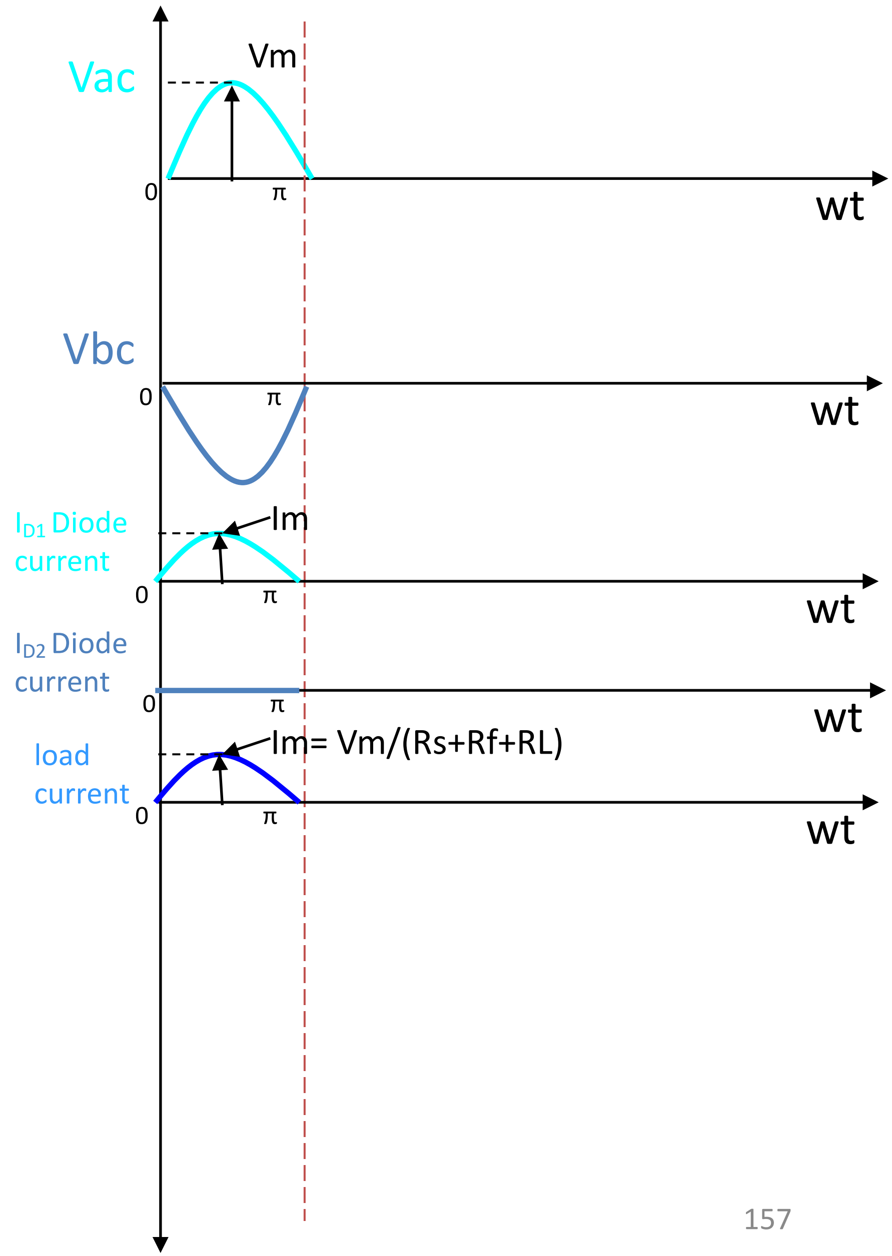




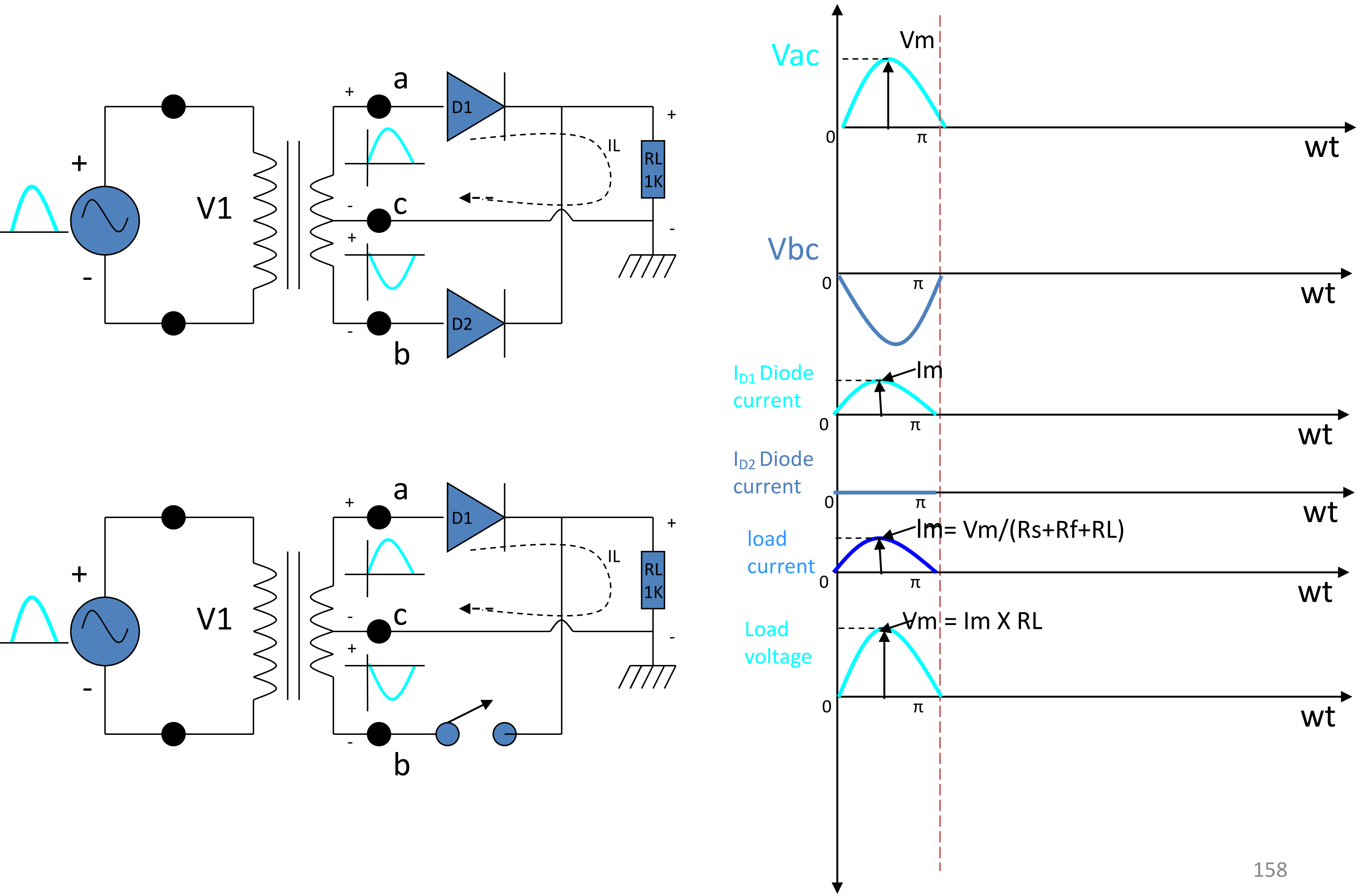
Full wave rectifier with Centre tapped transformer



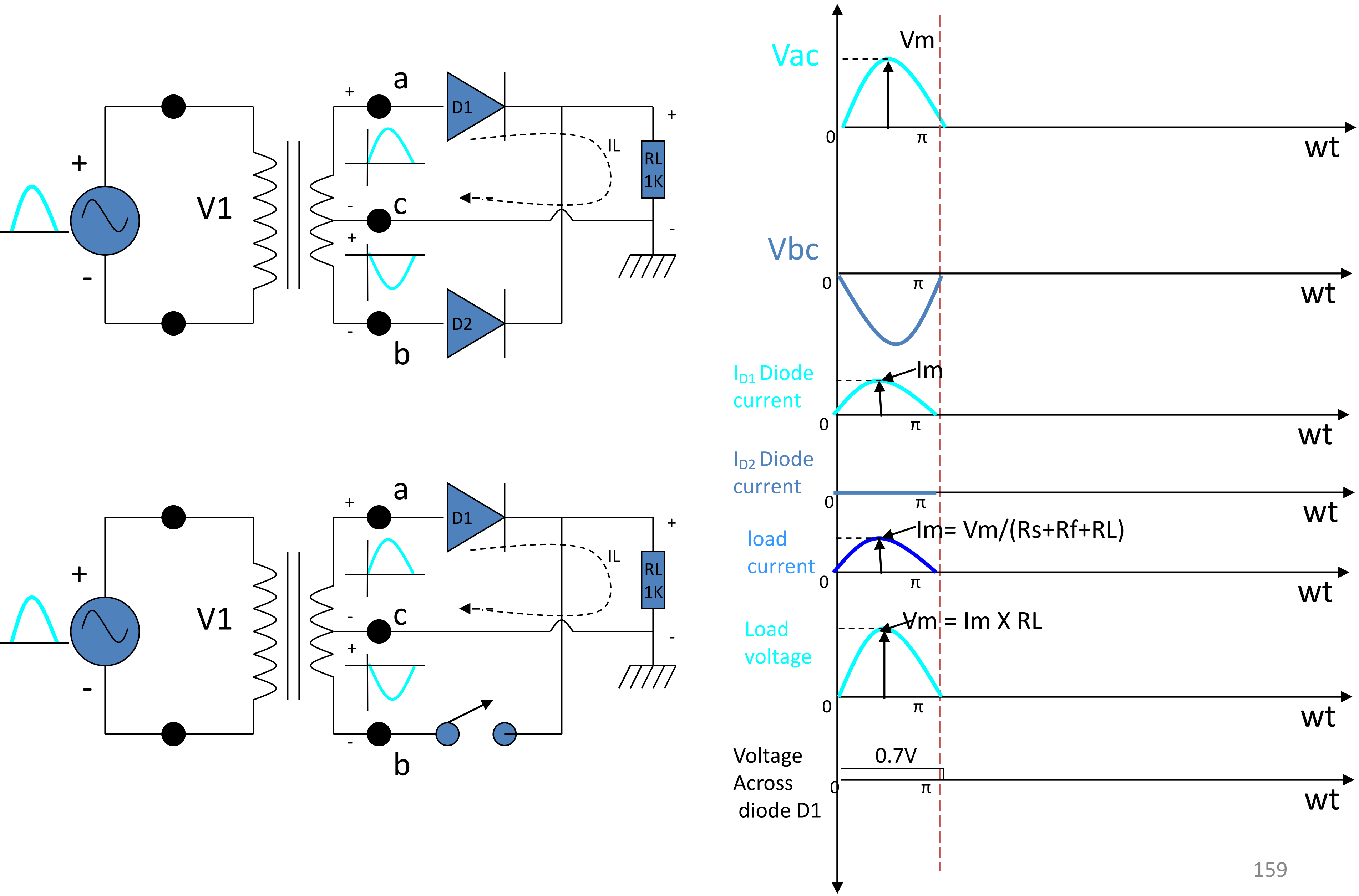




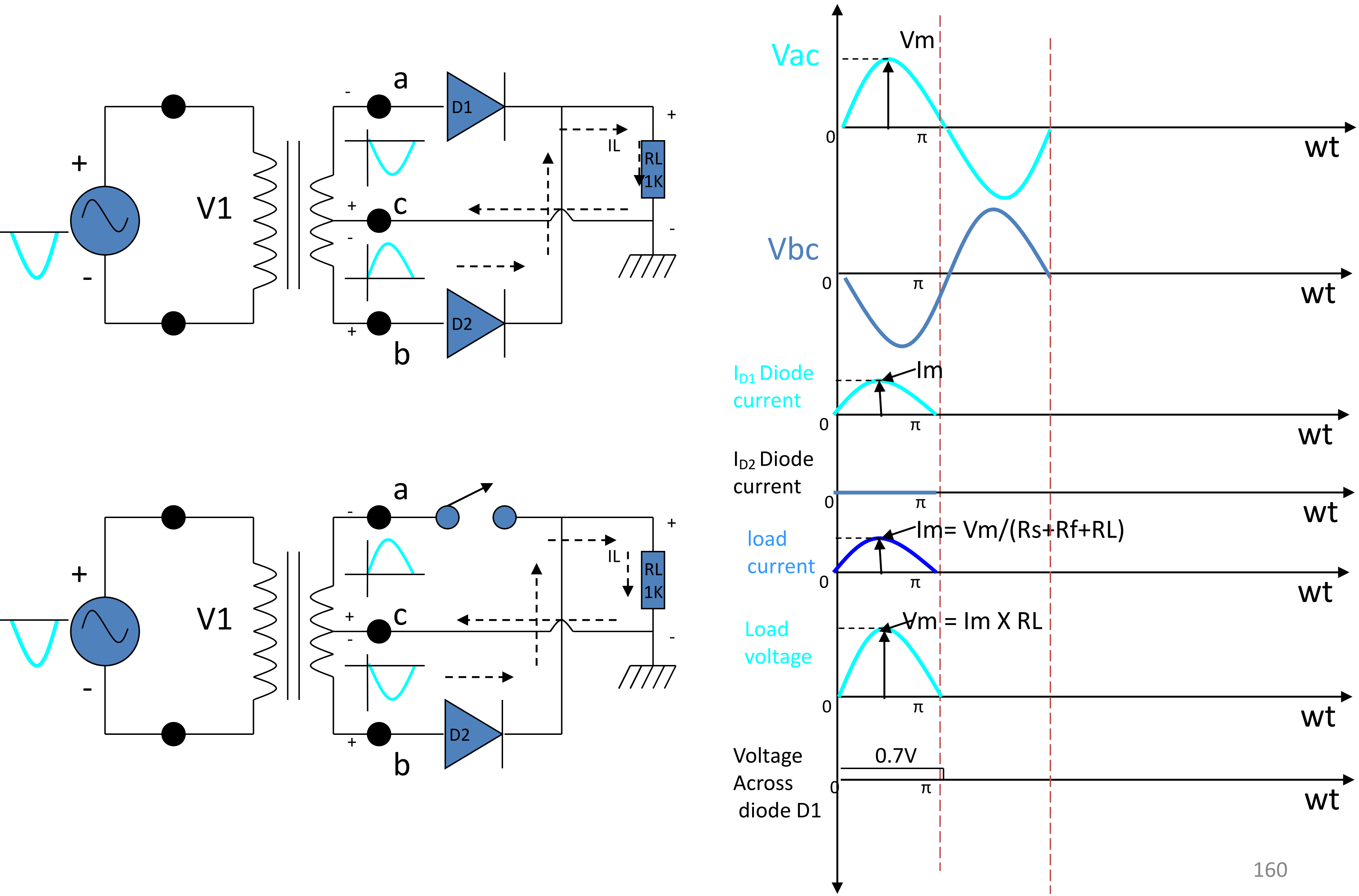
Full wave rectifier with Centre tapped transformer



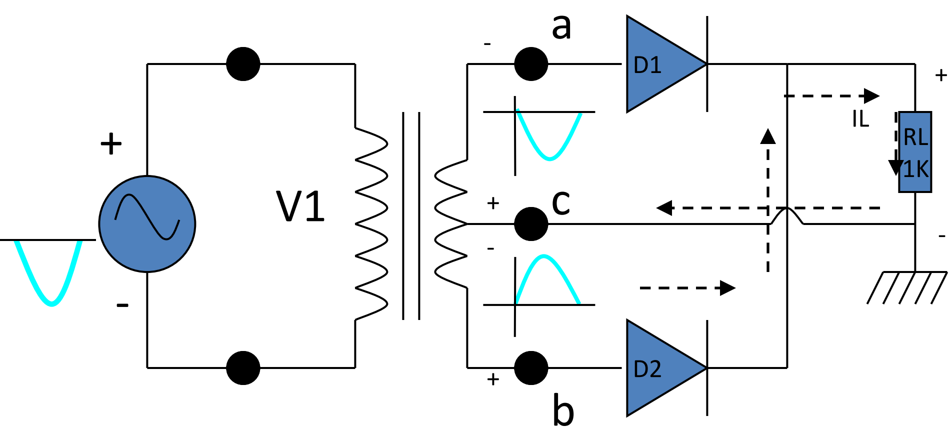
Full wave rectifier with Centre tapped transformer

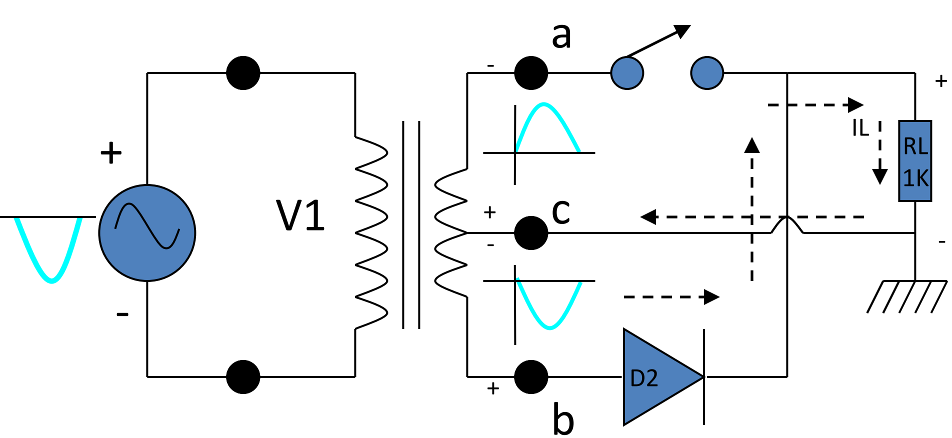


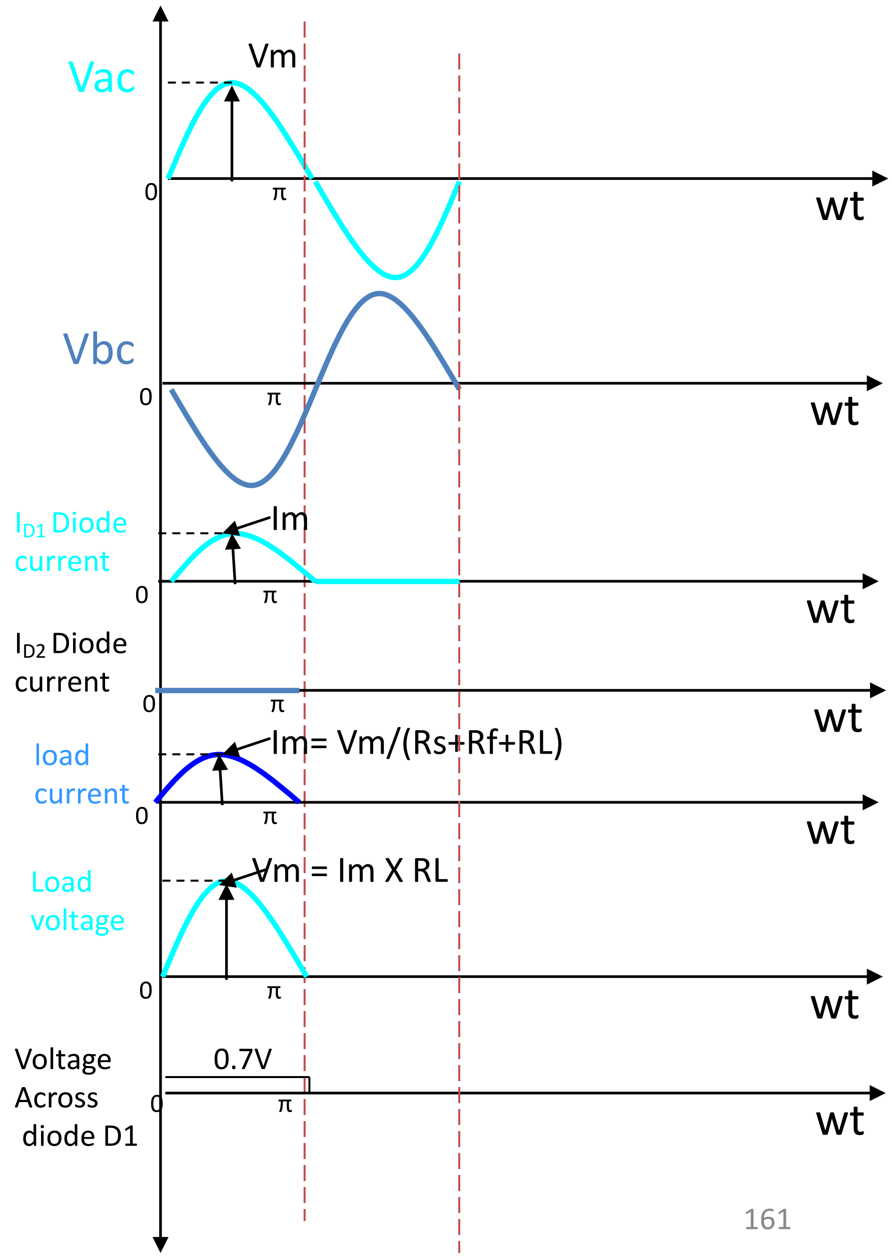
Full wave rectifier with Centre tapped transformer



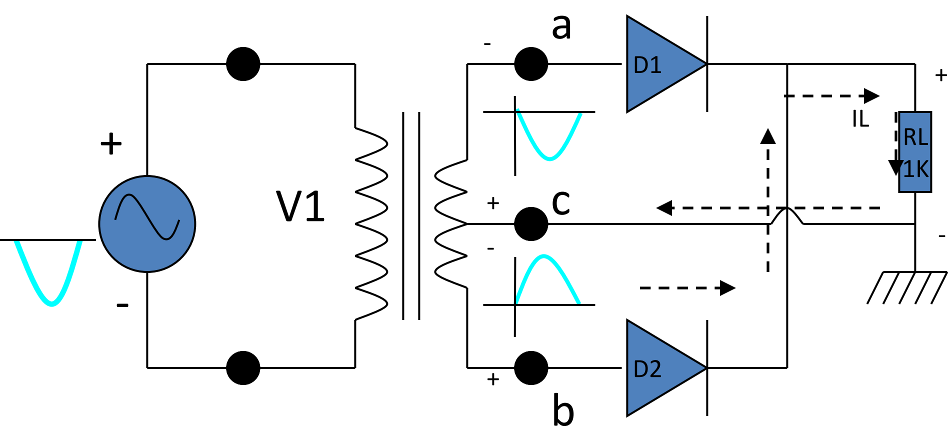
Full wave rectifier with Centre tapped transformer

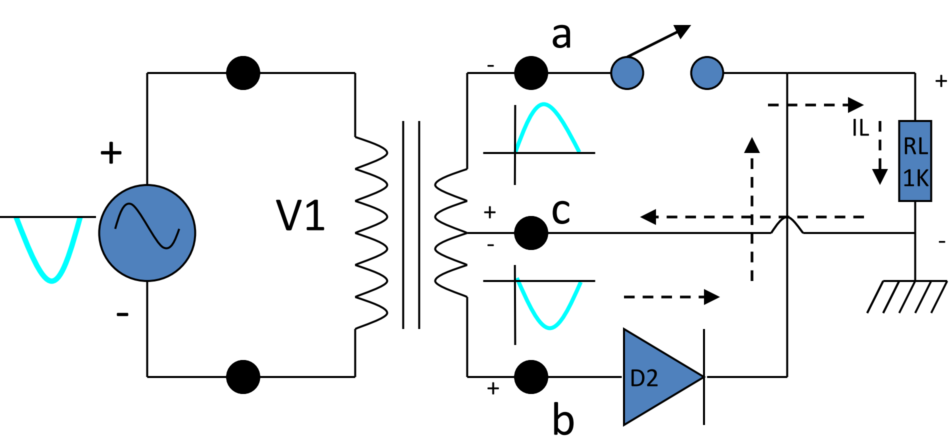


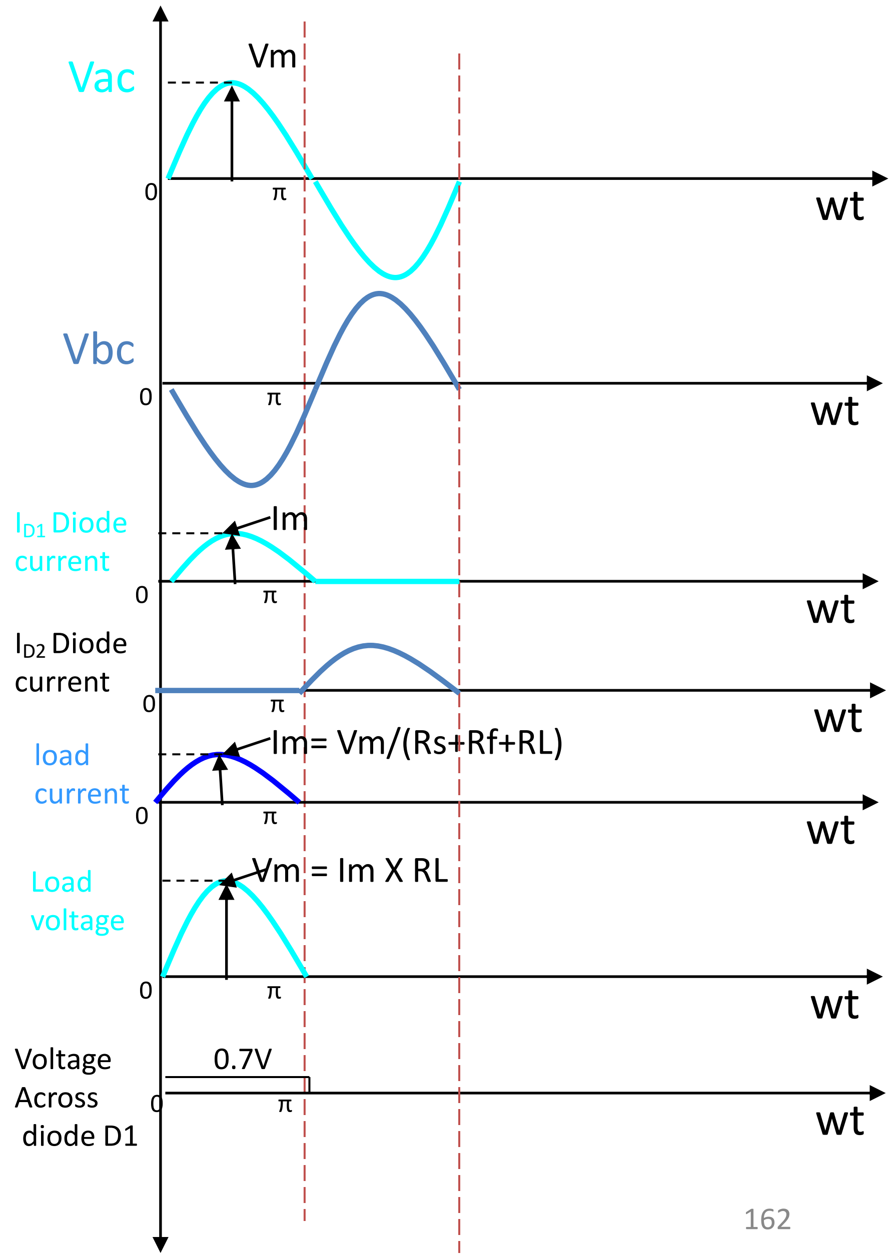




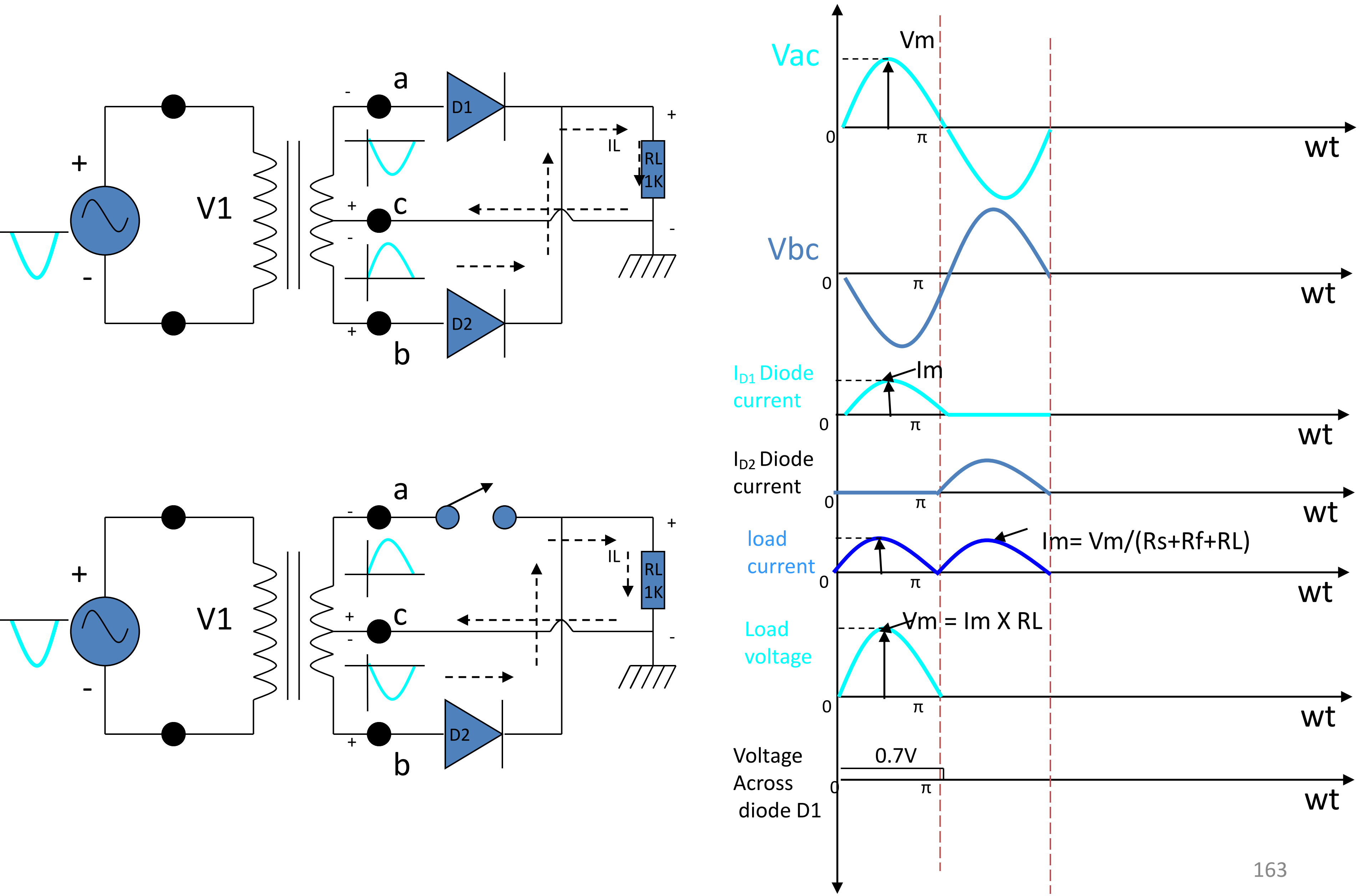
Full wave rectifier with Centre tapped transformer



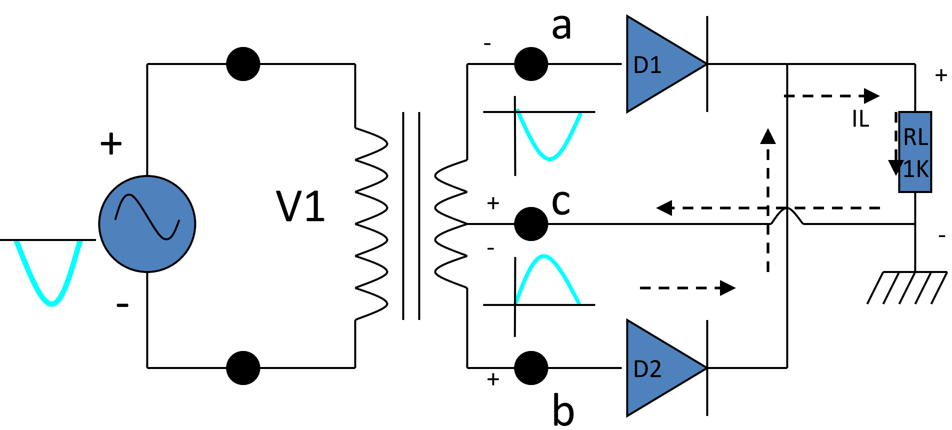


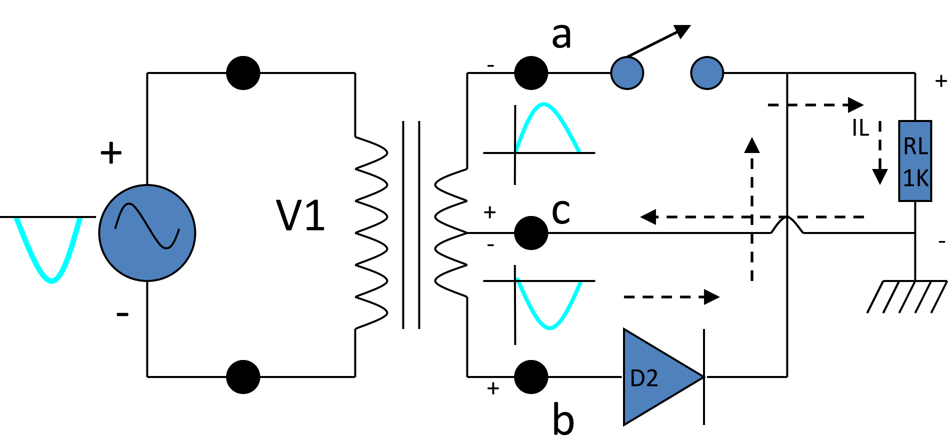


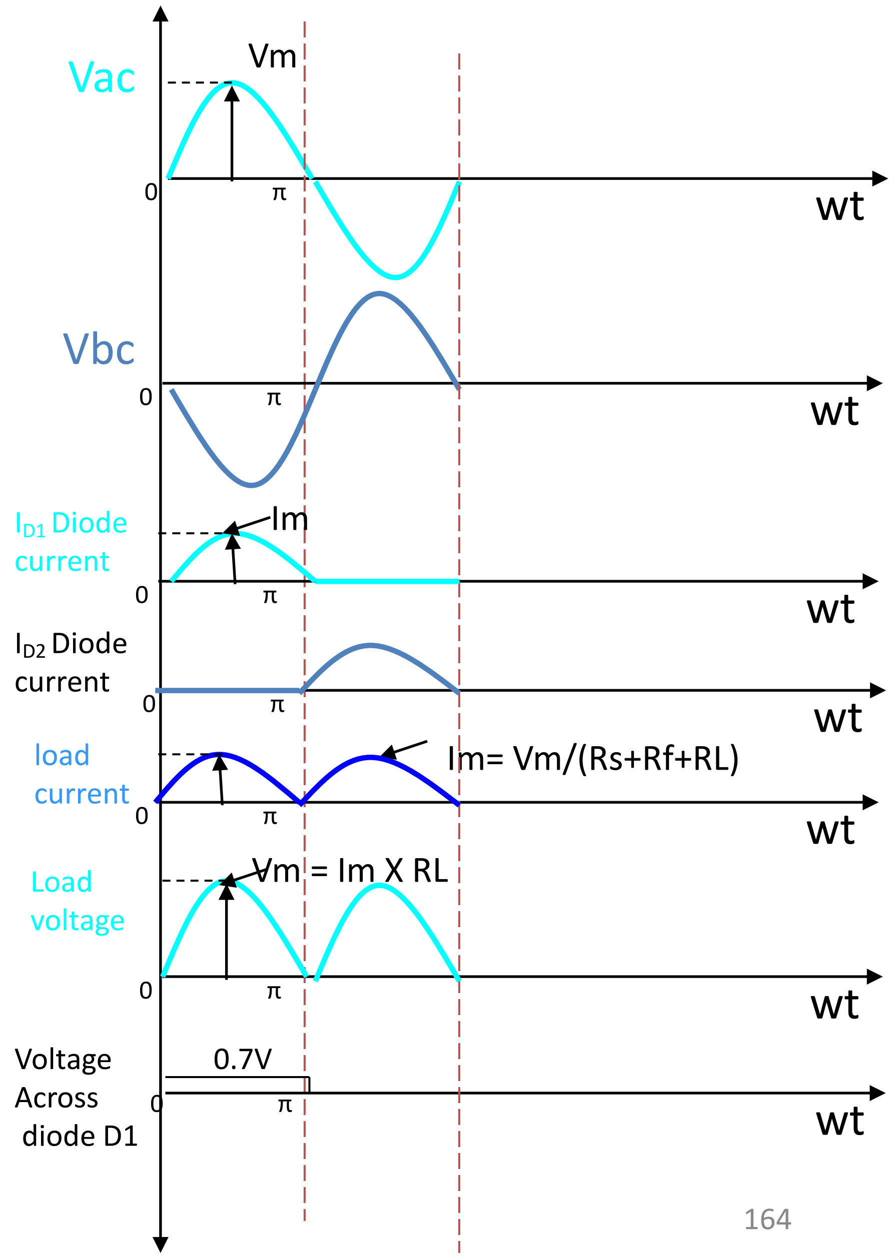
Full wave rectifier with Centre tapped transformer



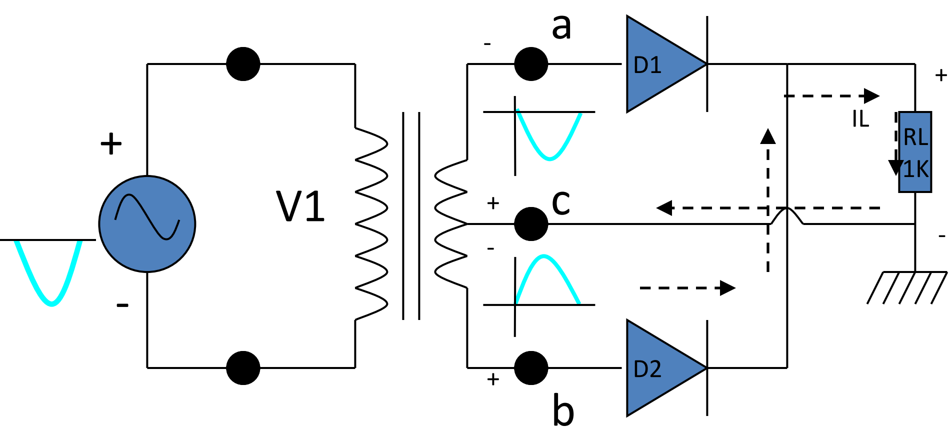
Full wave rectifier with Centre tapped transformer

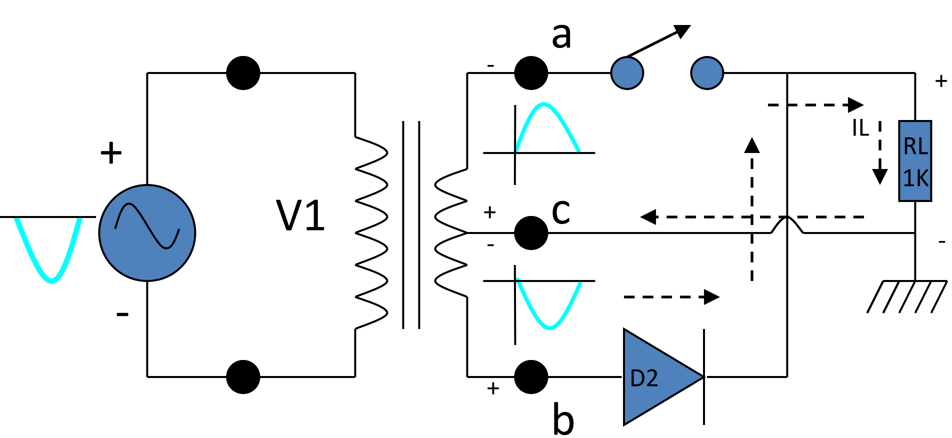


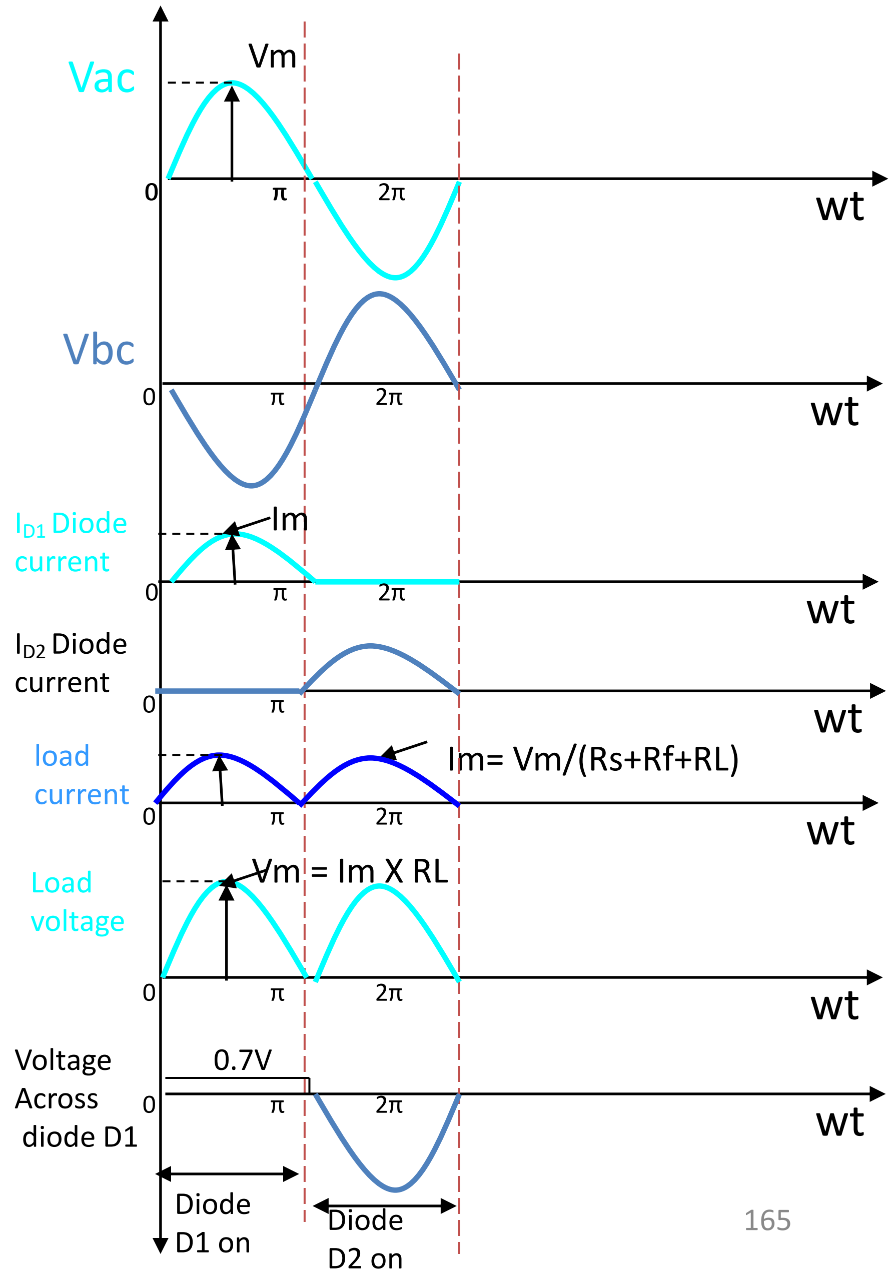




Full wave rectifier with Centre tapped transformer







Performance parameter of a full wave rectifier

Parameter	Value
Average DC load current (I_{LDC})	$2I_M/π$
Average DC load Voltage (V_{LDC})	$2V_M/π$
RMS value of load current (I_{LRMS})	$I_M/\sqrt{2}$
RMS value of load voltage (V_{LRMS})	$V_M/\sqrt{2}$
DC output power (P_{DC})	$(4I^2_m / π^2)$ X R_L
AC input power (P_{AC})	$(I^2_m / 2)$ X $(R_L + R_F + R_S)$
Maximum rectification efficiency (η_{max})	0.812 or 81.2 %
Ripple factor (RF)	0.48 or 48%
Ripple frequency	100 Hz
Peak inverse voltage (PIV)	2 Vm
Average transformer utilization factor (TUF)	0.693 or 69.3%

Advantage of full wave rectifier

- **The dc load voltage and current are more than half wave.**
- **Better rectification efficiency**
- **Low ripple factor as compared to HWR**
- **Better TUF**

Disadvantage of full wave rectifier

- **Since PIV of the diodes is 2Vm size of the diodes is larger and they are more costly.**

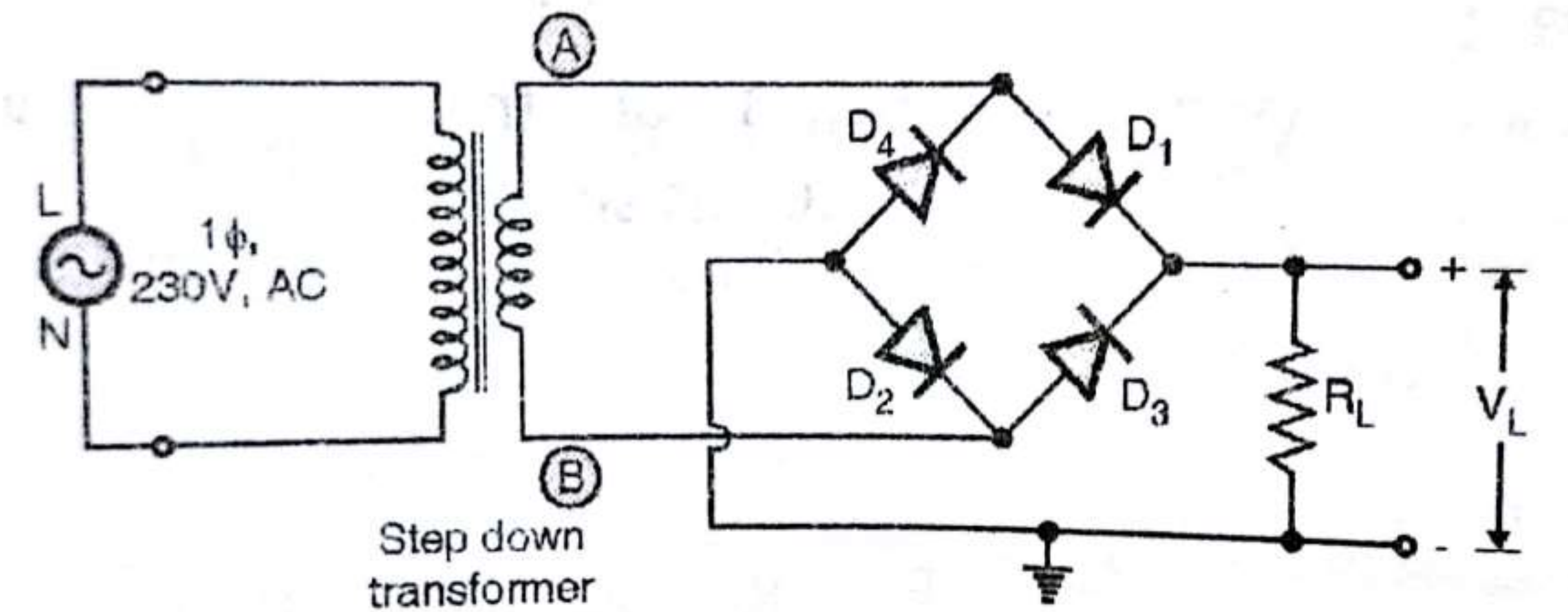
- **Cost of center tapped transformer is high.**

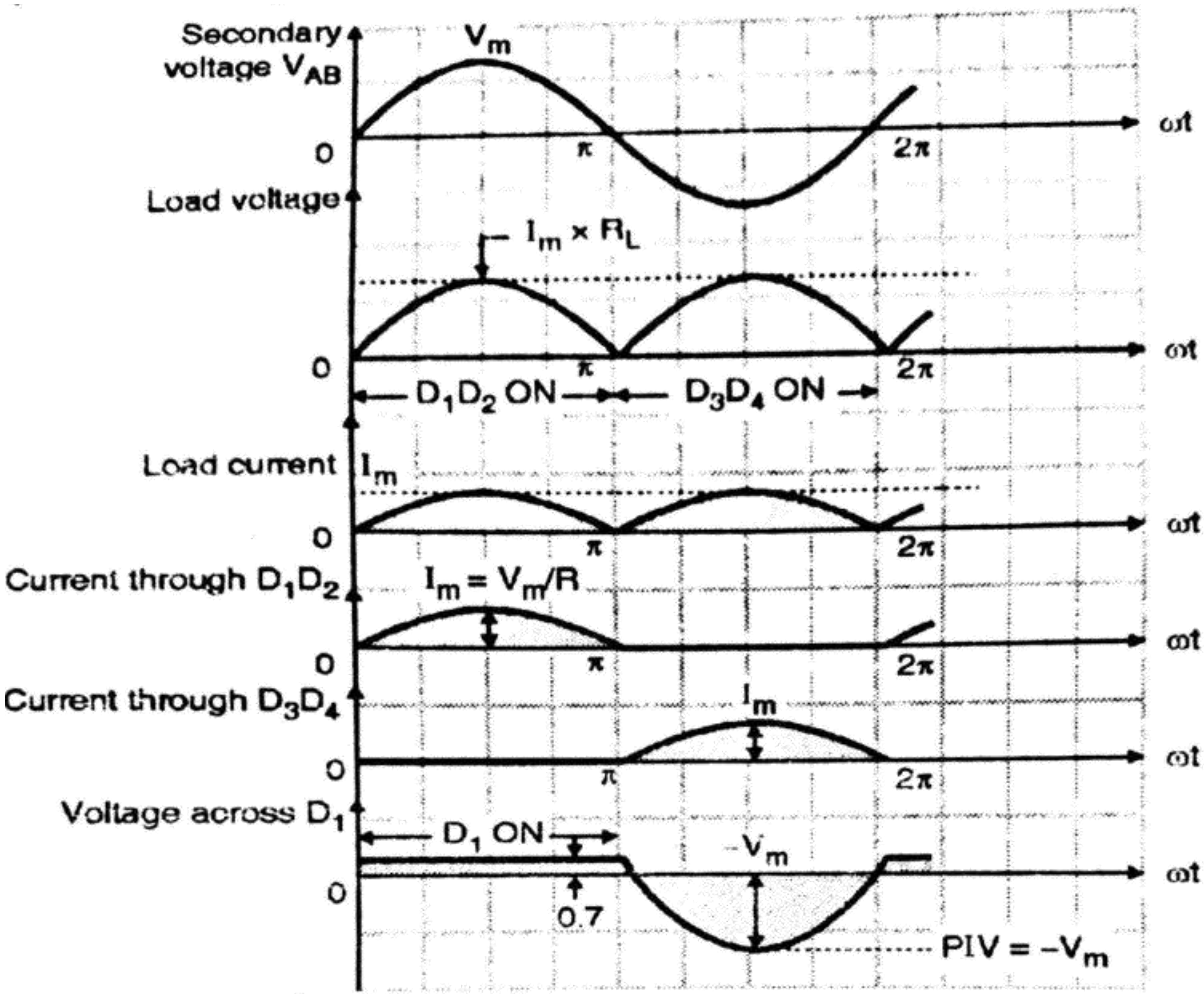
Comparison of a full wave rectifier and half wave rectifier

Parameter	Value HWR	FWR
Average DC load current (I_{LDC})	I_M/π	$2I_M/\pi$
Average DC load Voltage (V_{LDC})	V_M/π	$2V_M/\pi$
RMS value of load current (I_{LRMS})	$I_M/2$	$I_M/\sqrt{2}$
RMS value of load voltage (V_{LRMS})	$V_M/2$	$V_M/\sqrt{2}$
DC output power (P_{DC})	$(I^2_m / \pi^2) \times R_L$	$(4I^2_m / \pi^2) \times R_L$
AC input power (P_{AC})	$(I^2_m / 4) \times (R_L + R_F + R_S)$	$(I^2_m / 2) \times (R_L + R_F + R_S)$
Maximum rectification efficiency (η_{max})	0.4 or 40 %	0.812 or 81.2 %
Ripple factor (RF)	1.21or 121% very high	0.48 or 48%
Ripple frequency	50 Hz	100 Hz
Peak inverse voltage (PIV)	Vm	2 Vm
Average transformer utilization factor (TUF)	0.287or 28.7%	0.693 or 69.3%

Bridge Rectifier

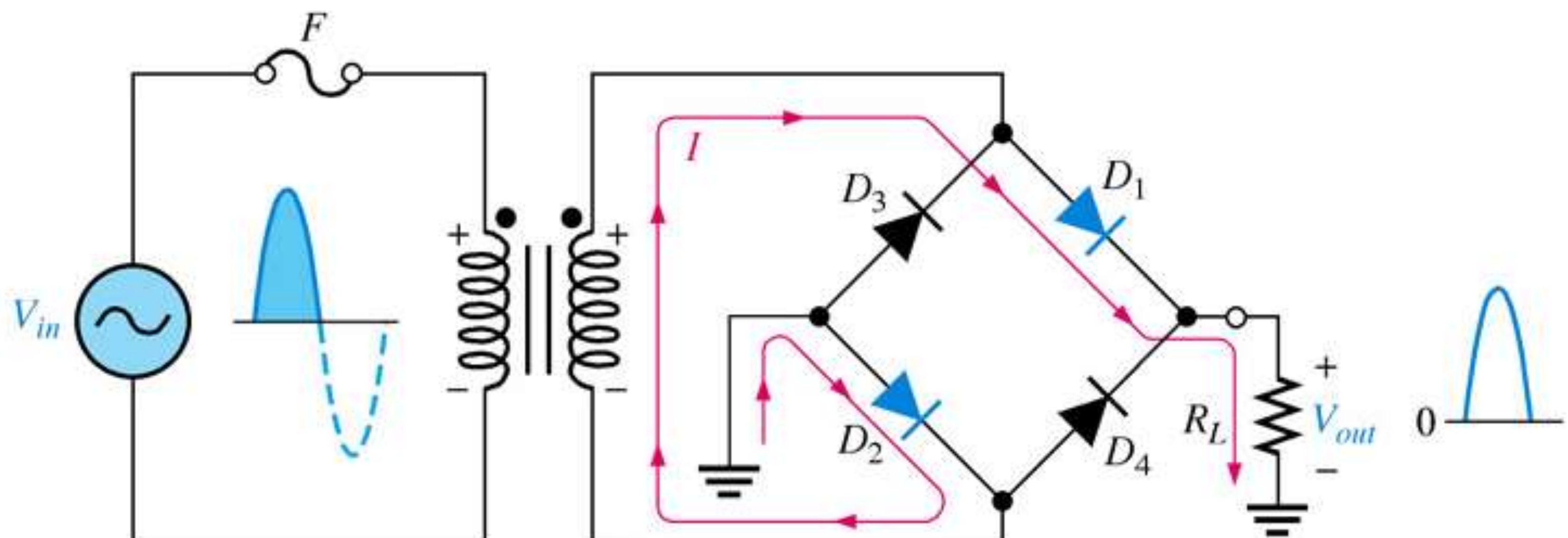
- Disadvantages of the full wave rectifier such as high PIV and compulsory use of center tapped transformer are overcome in the bridge rectifier.
- The circuit configuration of a bridge rectifier, it consist of four diodes connected to form a bridge





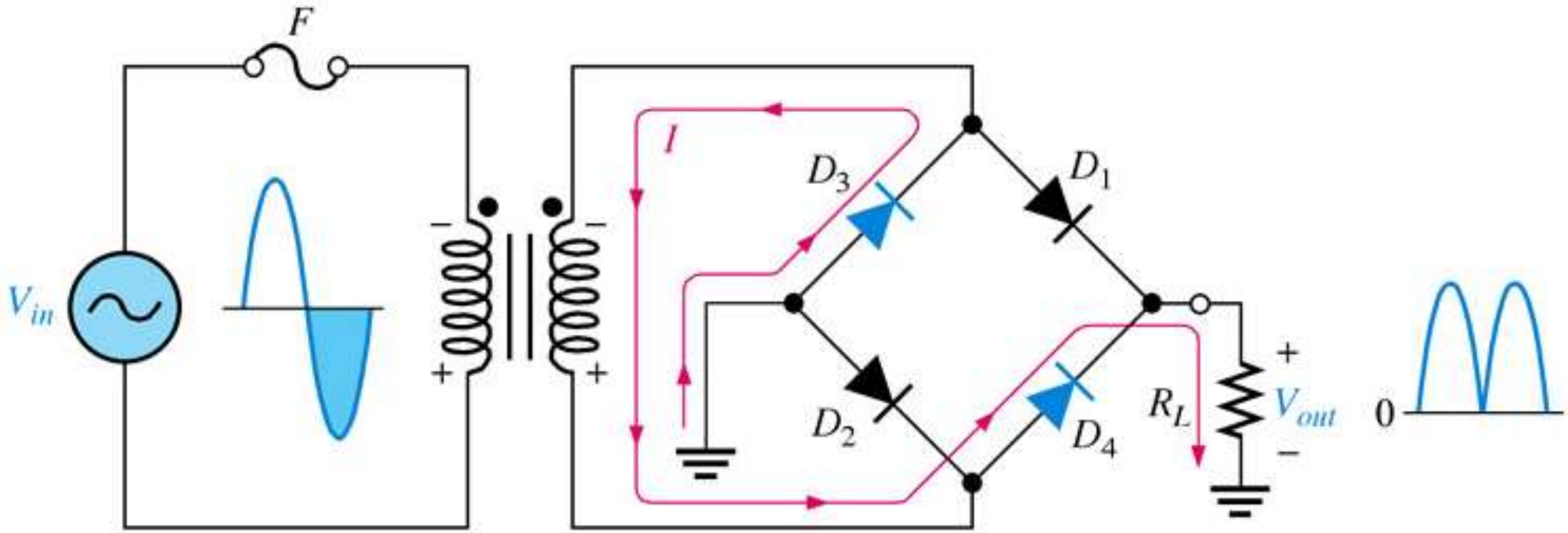
Secondary voltage V_{AB}
V_m
0
π
2π
ωt
Load voltage
$I_m \times R_L$
0
π
2π
ωt
D_1D_2 ON
D_3D_4 ON
Load current
I_m
0
π
2π
ωt
Current through D_1D_2
$I_m = V_m/R$
0
π
2π
ωt
Current through D_3D_4
I_m
0
π
2π
ωt
Voltage across D_1
D_1 ON
$-V_m$
0
0.7
ωt
PIV = $-V_m$

Operation of a Bridge Rectifier.



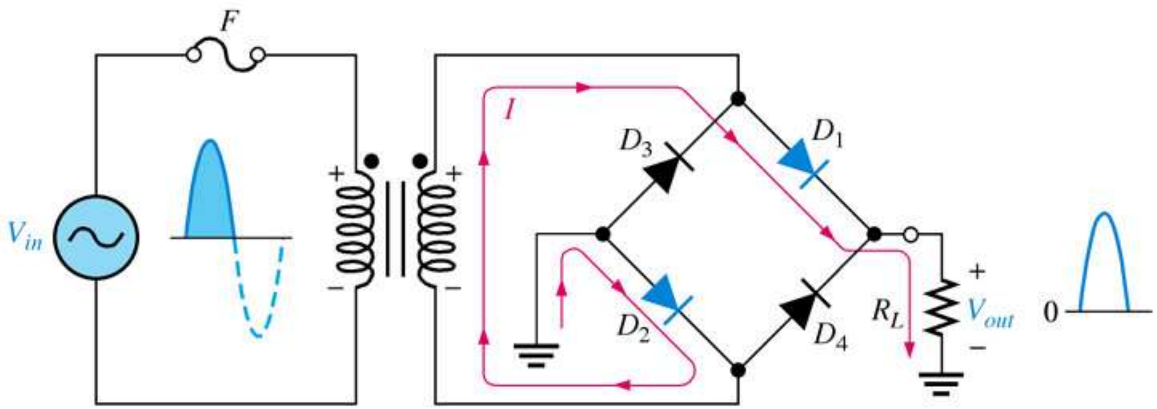
(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

Operation of a Bridge Rectifier.

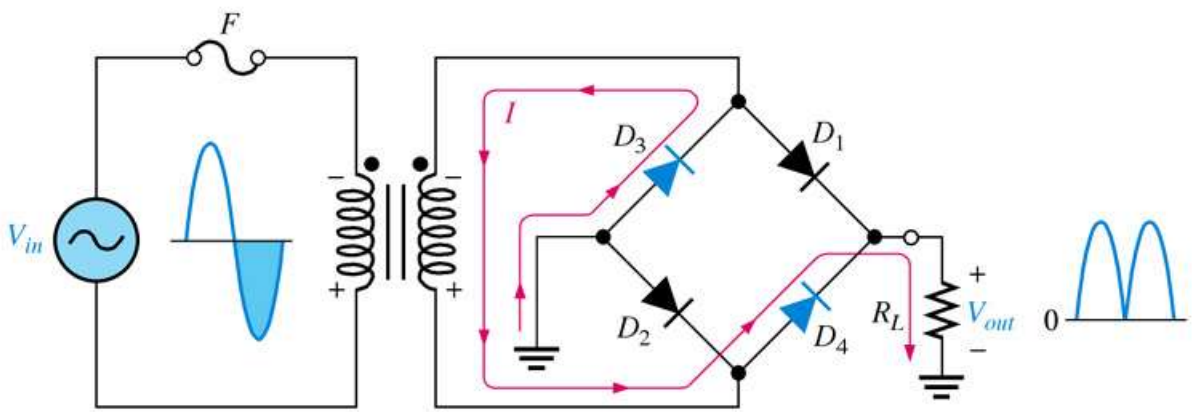


(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

Operation of a Bridge Rectifier.



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



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

Comparison of a full wave rectifier and half wave rectifier

Parameter	Value HWR	FWR and Bridge Rectifier
Average DC load current (I_{LDC})	I_M/π	$2I_M/\pi$
Average DC load Voltage (V_{LDC})	V_M/π	$2V_M/\pi$
RMS value of load current (I_{LRMS})	$I_M/2$	$I_M/\sqrt{2}$
RMS value of load voltage (V_{LRMS})	$V_M/2$	$V_M/\sqrt{2}$
DC output power (P_{DC})	$(I^2_m / \pi^2) \times R_L$	$(4I^2_m / \pi^2) \times R_L$
AC input power (P_{AC})	$(I^2_m / 4) \times (R_L + R_F + R_S)$	$(I^2_m / 2) \times (R_L + R_F + R_S)$
Maximum rectification efficiency (η_{max})	0.4 or 40 %	0.812 or 81.2 %
Ripple factor (RF)	1.21or 121% very high	0.48 or 48%
Ripple frequency	50 Hz	100 Hz
Peak inverse voltage (PIV)	Vm	2 Vm for
Average transformer utilization factor (TUF)	0.287or 28.7%	0.693 or 69.3%

Comparison of a full wave rectifier and half wave rectifier

Parameter	Value HWR	FWR and Bridge Rectifier
Average DC load current (I_{LDC})	I_M/π	$2I_M/\pi$
Average DC load Voltage (V_{LDC})	V_M/π	$2V_M/\pi$
RMS value of load current (I_{LRMS})	$I_M/2$	$I_M/\sqrt{2}$
RMS value of load voltage (V_{LRMS})	$V_M/2$	$V_M/\sqrt{2}$
DC output power (P_{DC})	(I^2_m / π^2) X R_L	$(4I^2_m / \pi^2)$ X R_L
AC input power (P_{AC})	$(I^2_m / 4)$ X $(R_L + R_F + R_S)$	$(I^2_m / 2)$ X $(R_L + R_F + R_S)$
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Ripple frequency	50 Hz	100 Hz
Peak inverse voltage (PIV)	Vm	2 Vm for Bridge Vm
Average transformer utilization factor (TUF)	0.287or 28.7%	0.693 or 69.3%

Comparison of a full wave rectifier and half wave rectifier

Parameter	Value HWR	FWR and Bridge Rectifier
Average DC load current (I_{LDC})	I_M/π	$2I_M/\pi$
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DC output power (P_{DC})	$(I^2_m / \pi^2) \times R_L$	$(4I^2_m / \pi^2) \times R_L$
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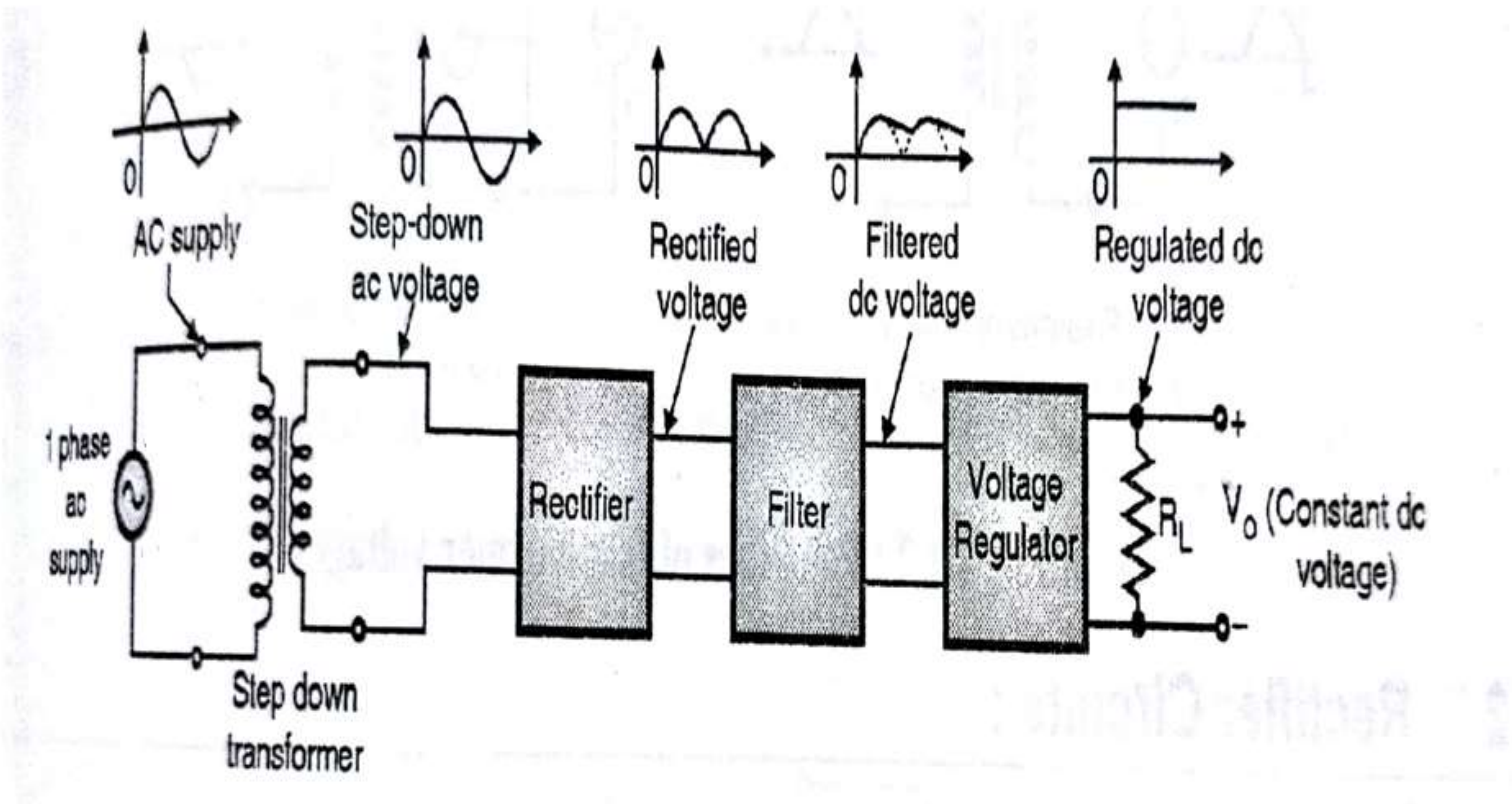
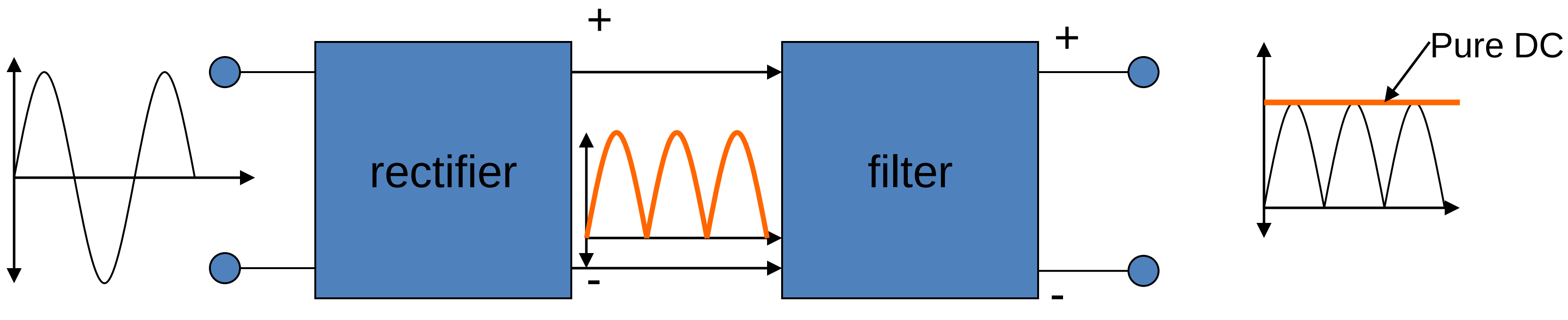
Ripple frequency	50 Hz	100 Hz
Peak inverse voltage (PIV)	Vm	2 Vm for Bridge Vm
Average transformer utilization factor (TUF)	0.287or 28.7%	0.693 or 69.3% For Bridge 81.2%

Block diagram of a regulated dc power supply are



Filter

- Output of a rectifier contains d.c. component as well as a.c. component.
- The presence of a.c. components is most undesirable and therefore must be removed from the rectifier output. It is achieved by a circuit called filter.
- Filter are the electronic circuits used along with rectifiers in order to get a pure ripple free d.c. voltage



Types of Filter

- Thus the filter is an electronic circuit composed of capacitor, inductor or combination of both and connected between the rectifier and the load so as to convert pulsating a.c. into pure d.c.

- Inductor filter or chock input filter
- Capacitor
- Inductor-capacitor or LC filter
- Pie (π) type filter

Zener Diode

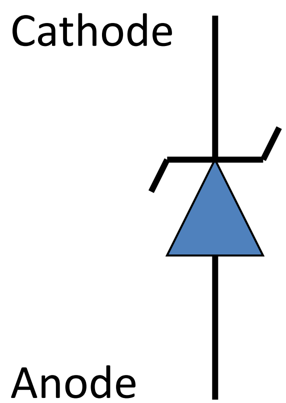
- **“Zener diode” is a special type p-n junction semiconductor diode. Is construction is similar to that of conventional p-n junction diode.**

- **However in constructing the zener diodes, the reverse breakdown voltage is adjusted precisely between 3V to 200V.**

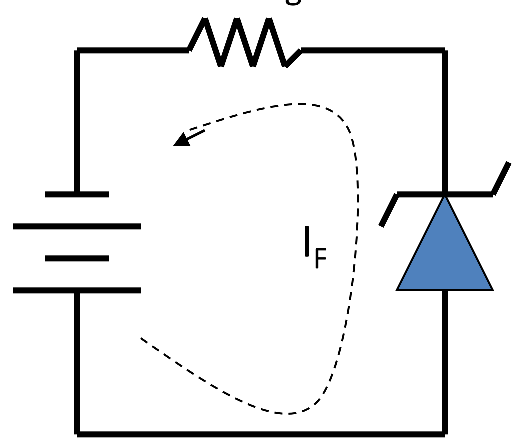
- **The doping level of the impurity added to manufacture the zener diodes is controlled in order to adjust the precise value of breakdown voltage.**

Circuit symbol and biasing of a Zener Diode

- **The circuit symbol of a zener diode is as shown in figure.**
- **The arrowhead in the symbol points towards the conventional direction of current through the diode, when it is forward bias.**



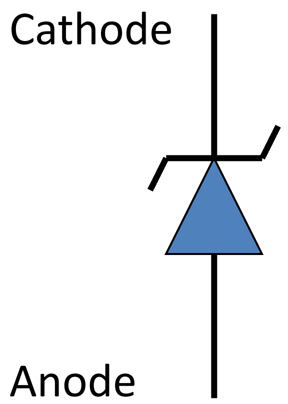
Circuit symbol



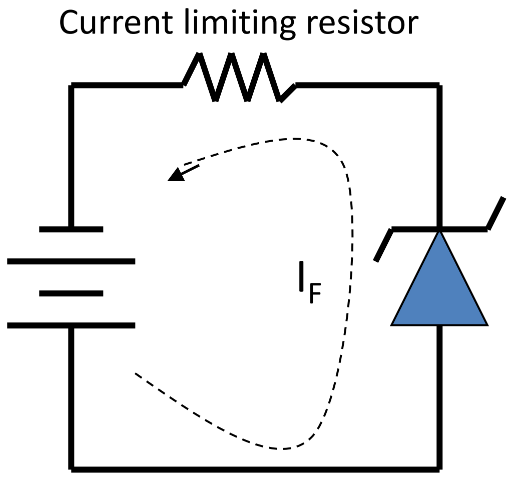
Forward biasing

Forward biasing of a Zener Diode

- When the anode of the zener diode is connected to the positive terminal of the DC source and the cathode is connected at the negative terminal, the zener diode is said to be forward bias.
- The forwards bias zener diode is behaves identical to a forward biased diode



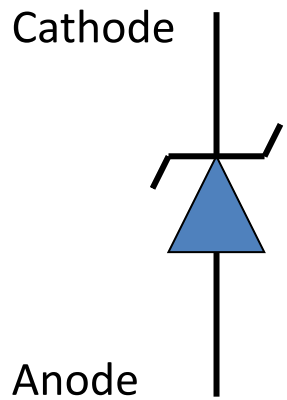
Circuit symbol



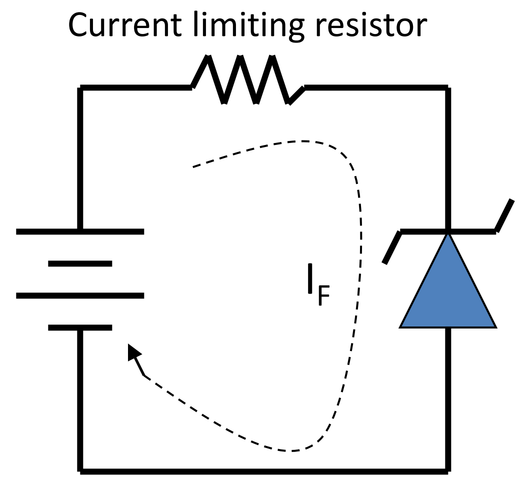
Forward biasing

Reverse biasing biasing of a Zener Diode

- When a cathode is connected to the positive terminal and the anode is connected to the negative terminal of the DC source, the zener diode is said to be reverse bias.



Circuit symbol



Reverse biasing

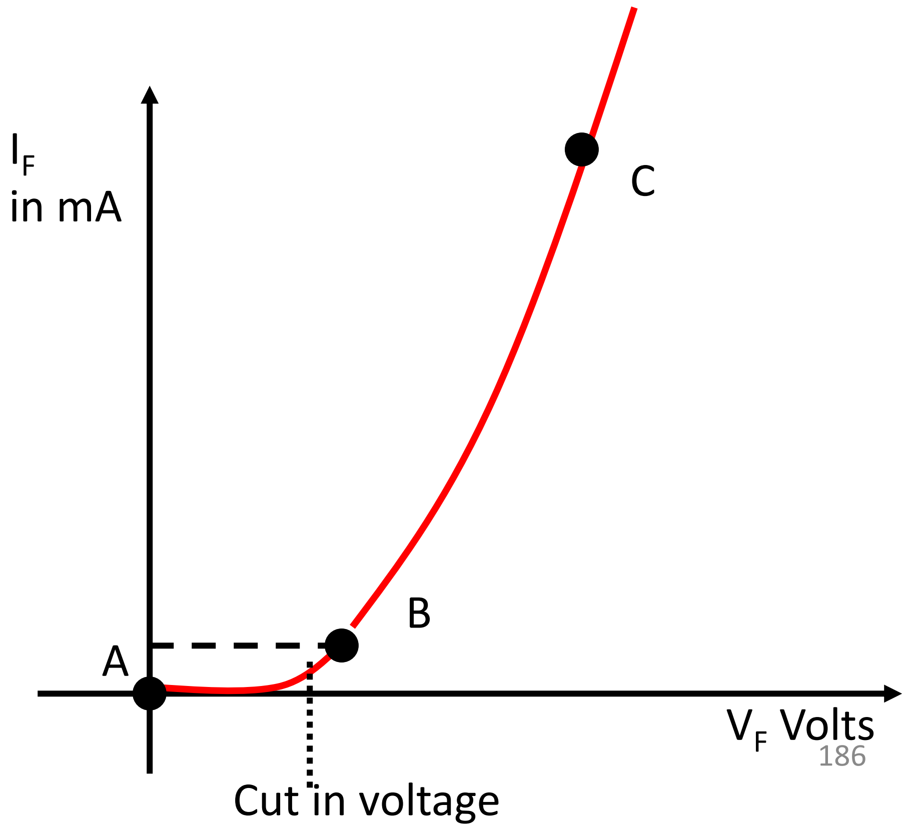
V-I characteristics of a Zener Diode

- The V-I characteristics of a zener diode can be divided into two parts.

- Forward characteristics
- Reverse characteristics.

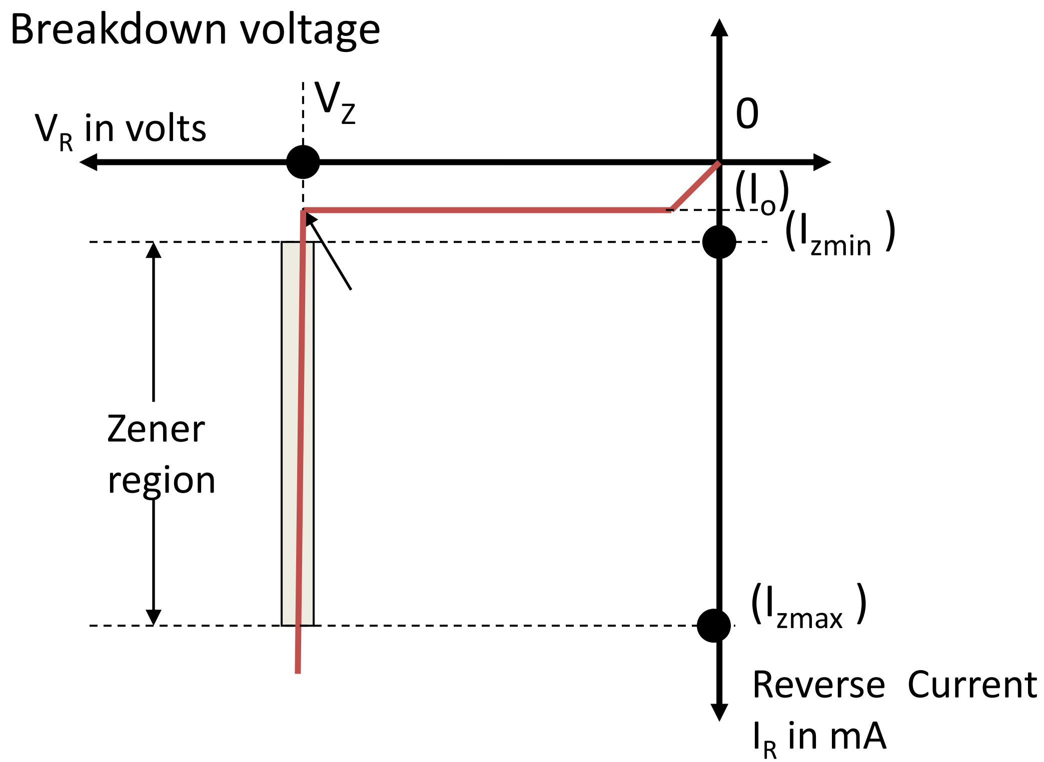
forward characteristics of a Zener Diode

- The Forward characteristics of a zener diode is shown in figure.



Reverse characteristics of a Zener Diode

- The reverse characteristics of a zener diode is shown in figure.



Complete V-I characteristics of a Zener Diode

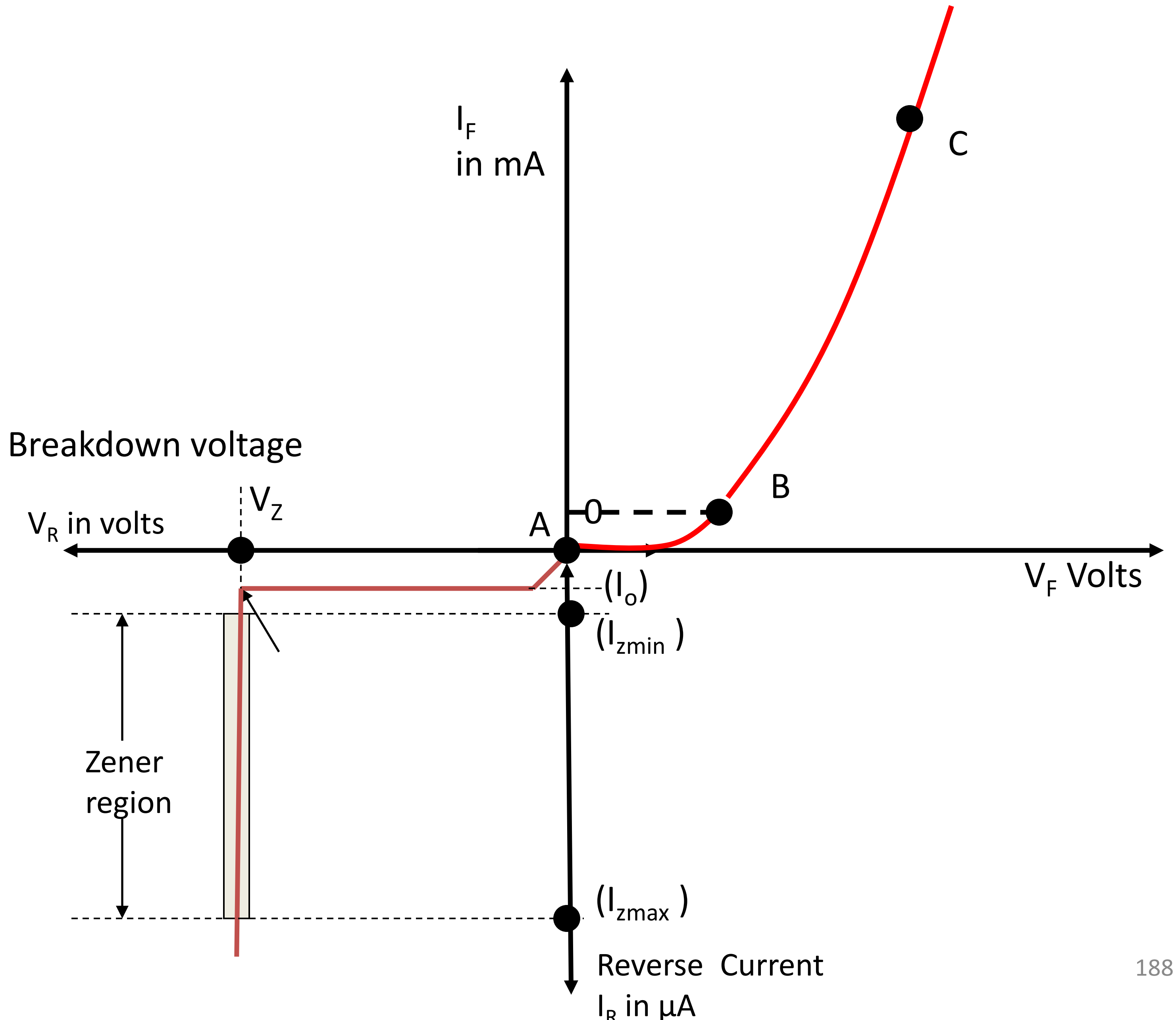
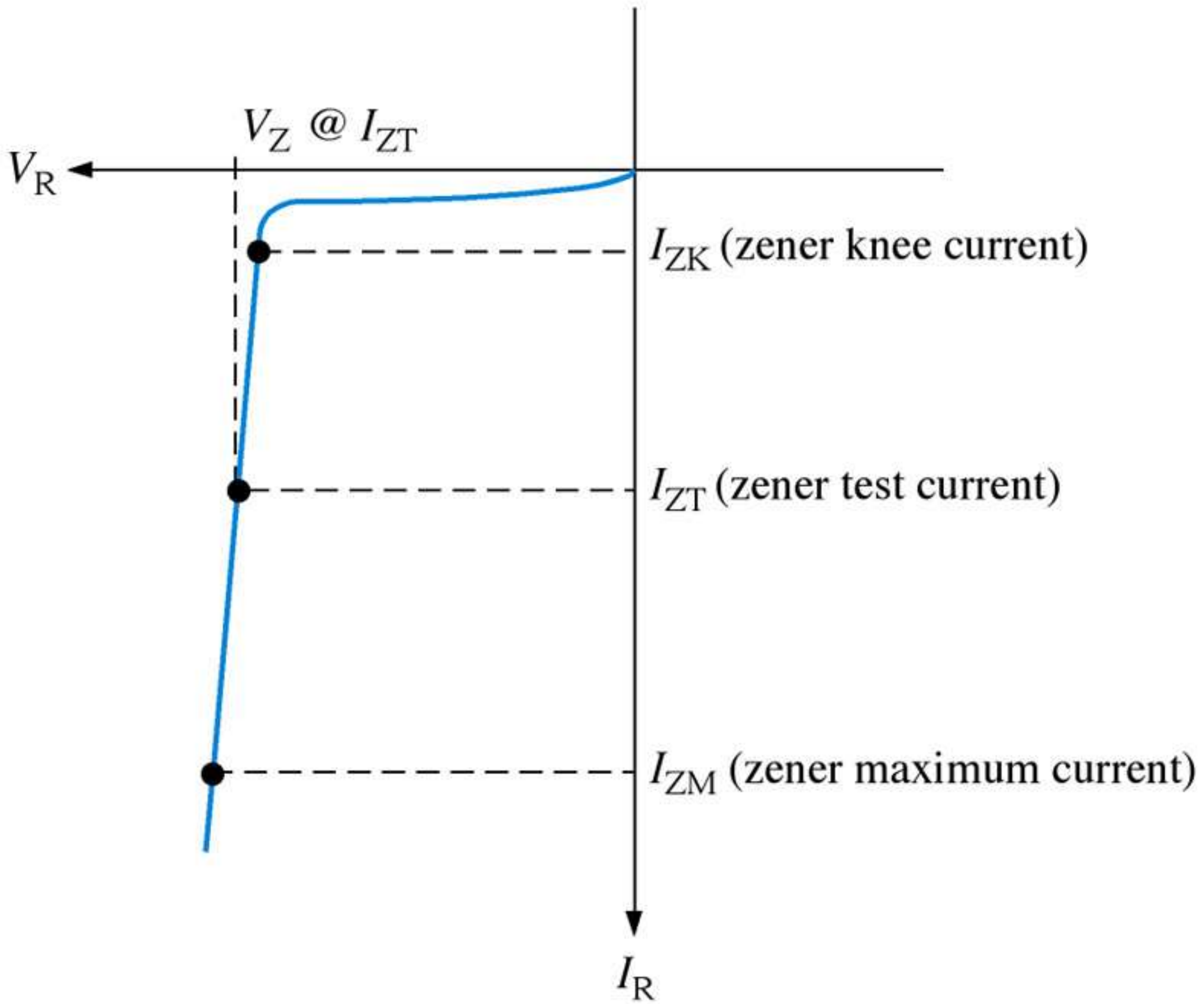


FIGURE 3-3 Reverse characteristic of a zener diode. V_Z is usually specified at the zener test current, I_{ZT}, and is designated V_{ZT}.



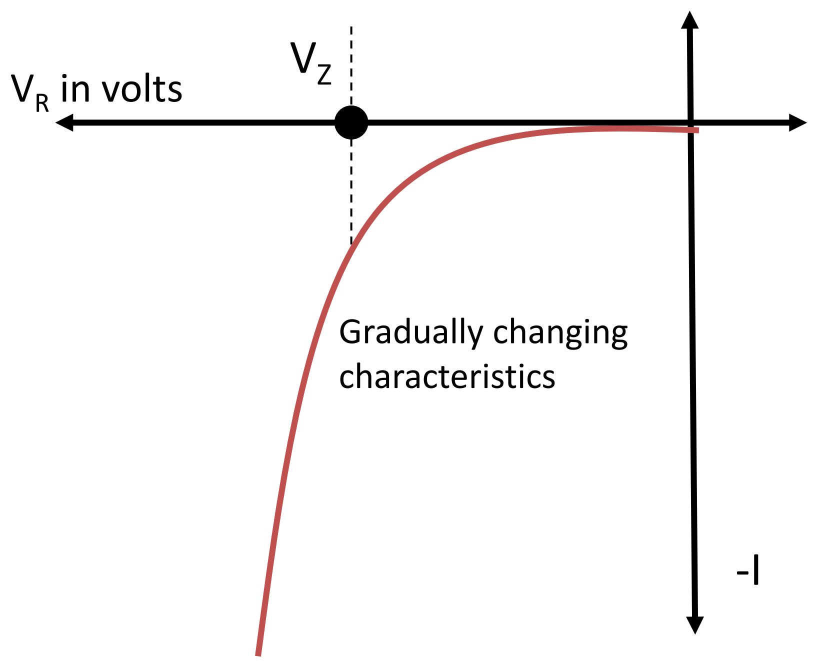
Breakdown mechanism in the zener diode

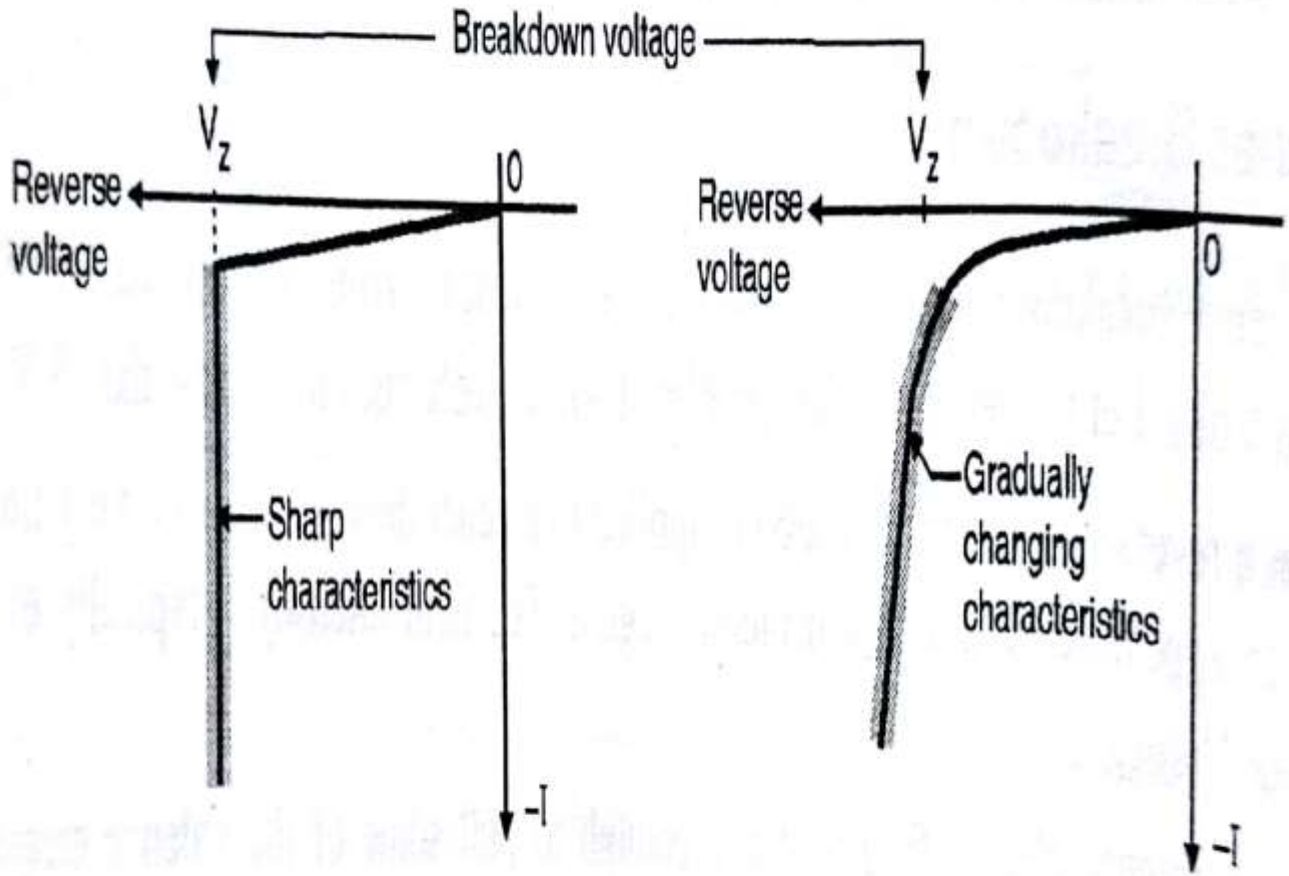
- **Zener breakdown :**
- **The zener breakdown is observed in the zener diodes having V_Z less than 5V or between 5 to 8 Volts.**

- **Avalanche breakdown :**
- **The avalanche breakdown is observed in the zener diodes having V_Z higher than 8 V.**

Breakdown mechanism in the zener diode

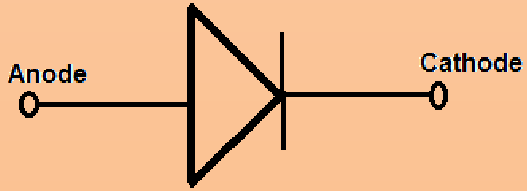
- Avalanche breakdown :
- The avalanche breakdown is observed in the zener diodes having V_Z higher than 8 V.





(a) **Zener breakdown** (b) **Avalanche breakdown**

Parameter	Avalanche Breakdown	Zener Breakdown
Definition	The Avalanche breakdown is phenomena of increasing the free electrons or electric current in semiconductor & insulating material by applying the higher voltage	The process in which the electrons are moving across the barrier from the valance band of p type material to the conduction band of lightly filled n material is known as Zener breakdown
Depletion Region	Thick	Thin
Junction	Destroy	Not Destroy
Electric Field	Weak	Strong
Produces	Pair of Electron & hole	Electrons
Doping	Low	Heavy
Reverse Potential	High	Low
Temperature Coefficient	Positive	Negative
Ionization	Because of Collision	Because of Electric field
Breakdown Voltage	Directly proportional to temperature	Inversely Proportional to temperature
After Breakdown	Voltage Vary	Voltage remain same

Parameter	Avalanche Breakdown	Zener Breakdown
Symbol		
Reuse	Avalanche breakdown damages the diode & it can not be reused again	Zener breakdown is to temporary & diode can be reused again.
Property	This type of breakdown take place in medium or lightly doped PN Junction diode or ordinary diode	It takes place in heavily doped zener diode designed to operate in breakdown region
Temperature Coefficient	Positive	Negative

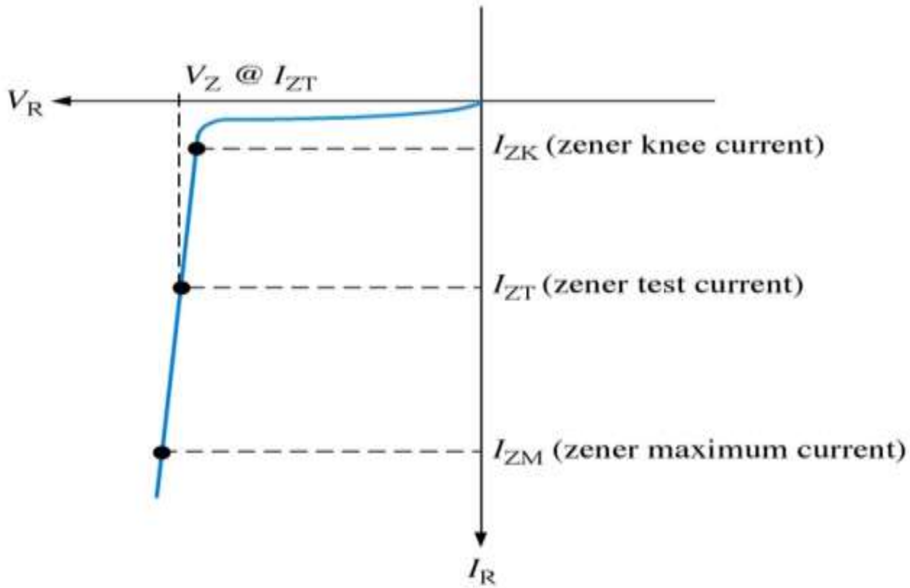
Specification of zener diode

Important ratings of the zener diode are :

- Zener Voltage
- Power dissipation
- Zener test current
- Zener impedance
- Reverse leakage current
- Maximum zener current

Specification of zener diode

- **Zener Voltage :**
- The manufacturer specify the value of breakdown voltage known as Zener voltage, Vz, at some of test current, I_{ZT}.
- This is on the linear portion of the reverse characteristics.
- Values of Vz are available at various values from 2.4 to 200 V with accuracy between 5 and 20%, depending upon cost.



Specification of zener diode

Important ratings of the zener diode are :

2. **Power dissipation (P_z):**

- Power dissipation in the diode is the product of Vz and reverse current, Iz, with maximum power ranging from 150 mW to 50 W.

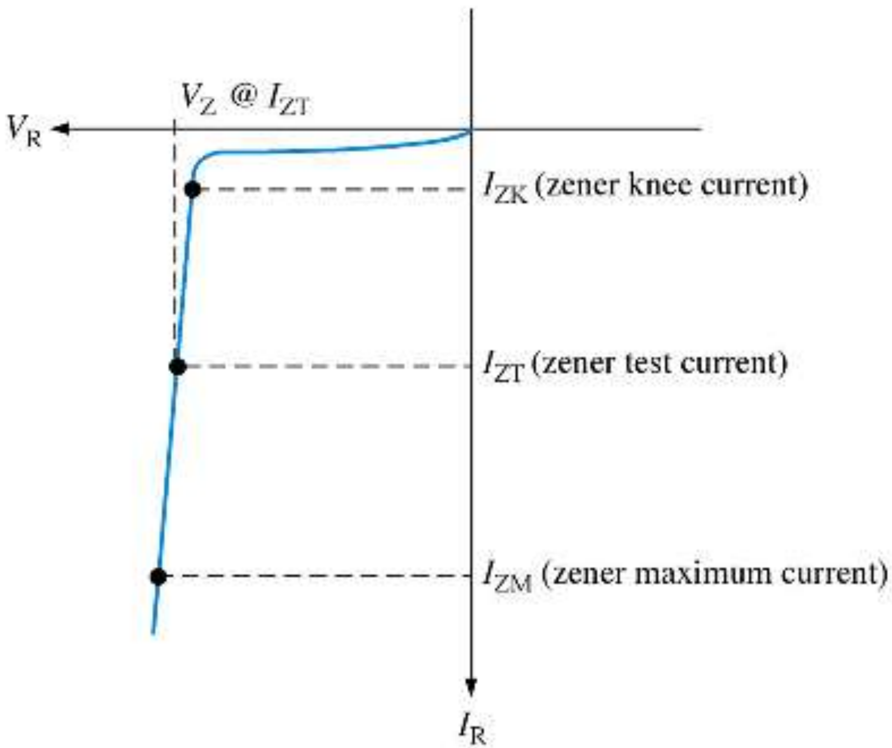
$$P_z = V_z \times I_z$$

Specification of zener diode

Important ratings of the zener diode are :

3. <u>Zener Test Current :</u>

- The value of zener current I_{ZT} in mA at which the nominal voltage is specified.

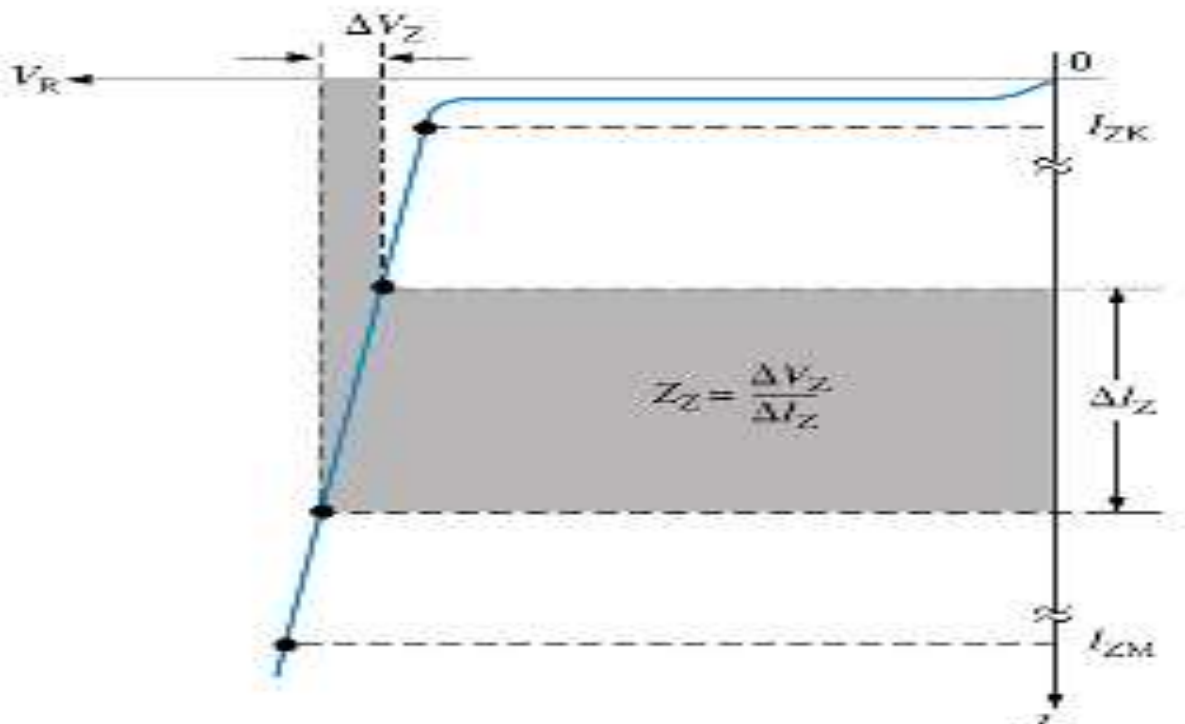


Specification of zener diode

Important ratings of the zener diode are :

4. **Zener impedance :**

- Z_{ZT} is The value of **dynamic impedance in ohms** measured at the test current

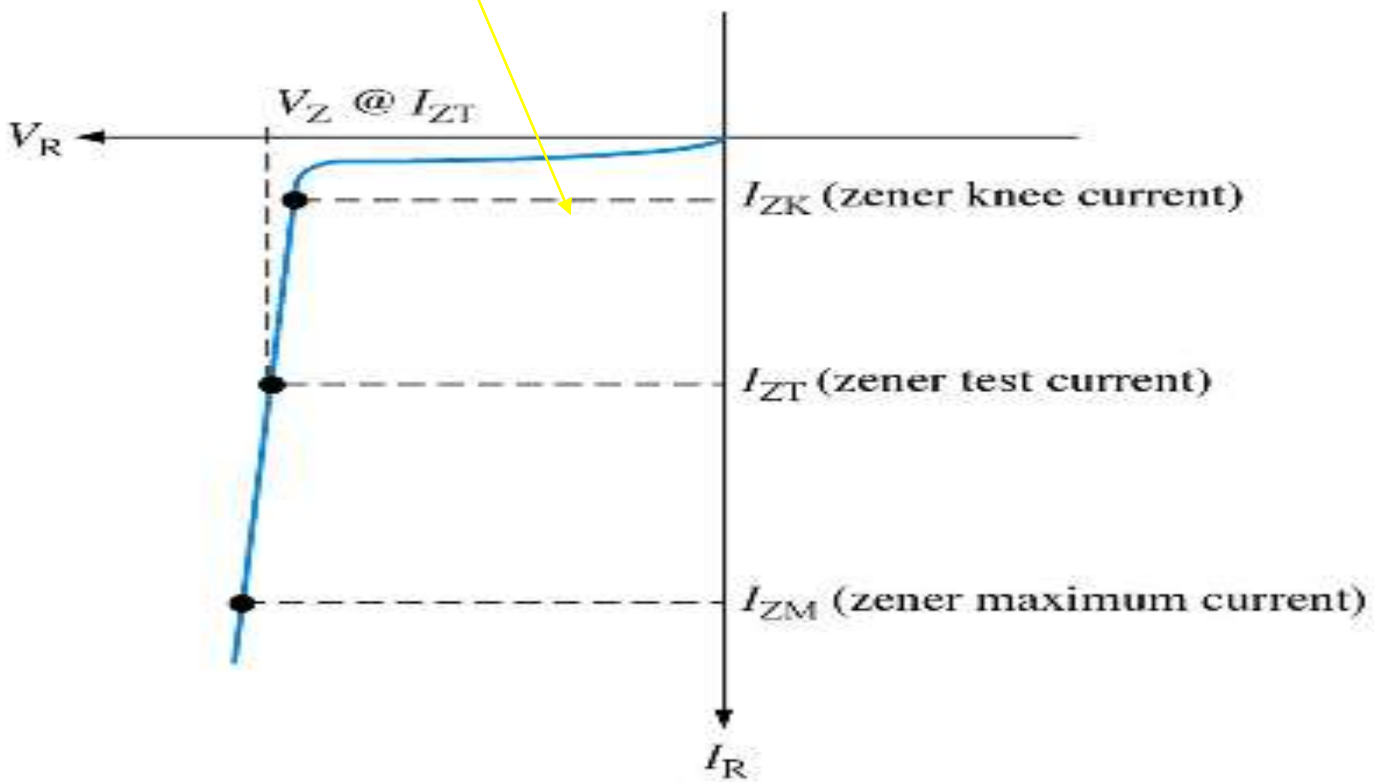


(c) Characteristic curve

Specification of zener diode

5. **Reverse leakage current :**

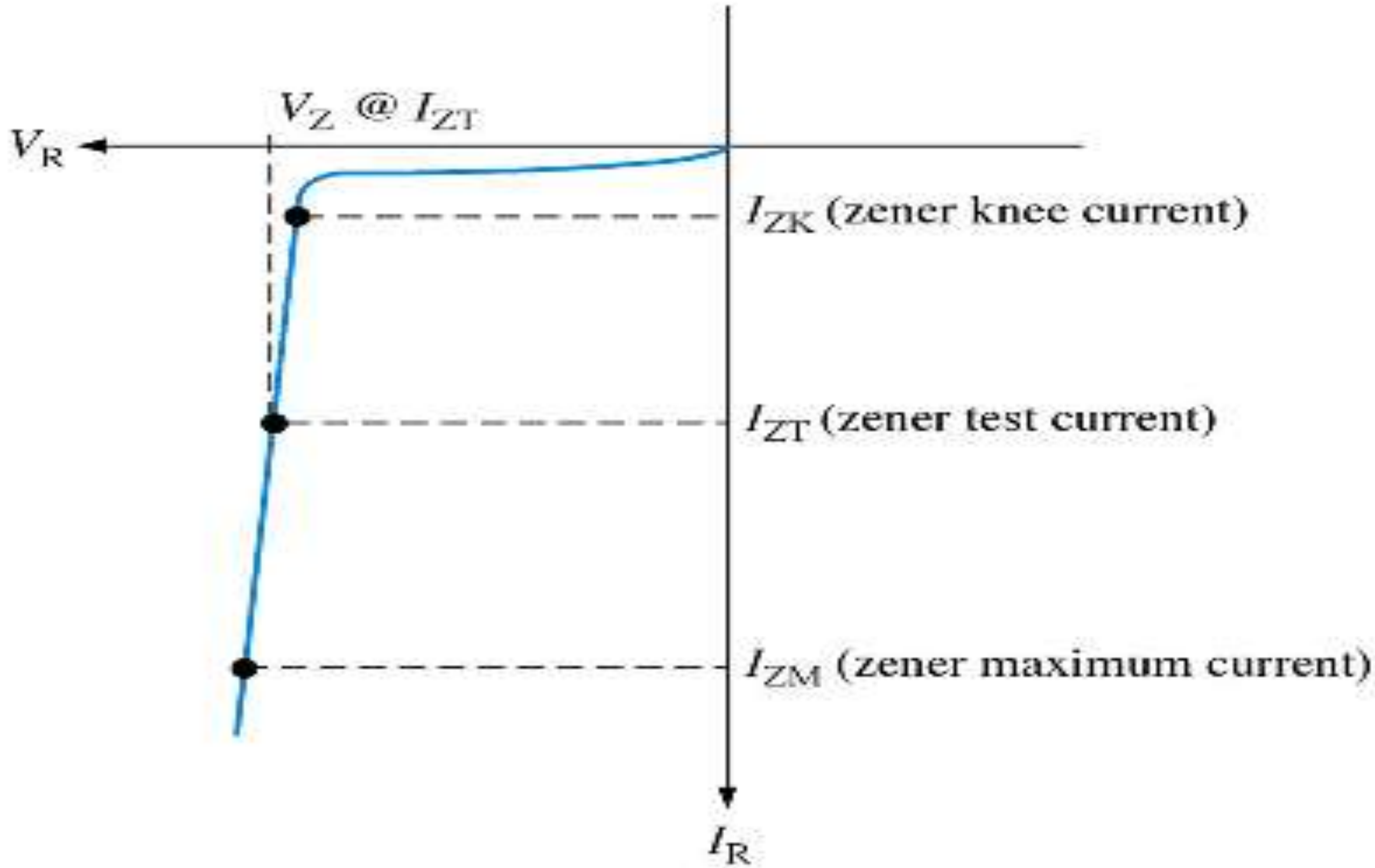
- The leakage current is the current through the reverse biased zener diode for value of reverse voltage less than the value at the knee of the characteristics curve.
- Note that the values are extremely small .



Specification of zener diode

6. **Maximum zener current :**

- The maximum reverse current that can flow through a zener diode without damaging it due to excessive heating.



Advantages

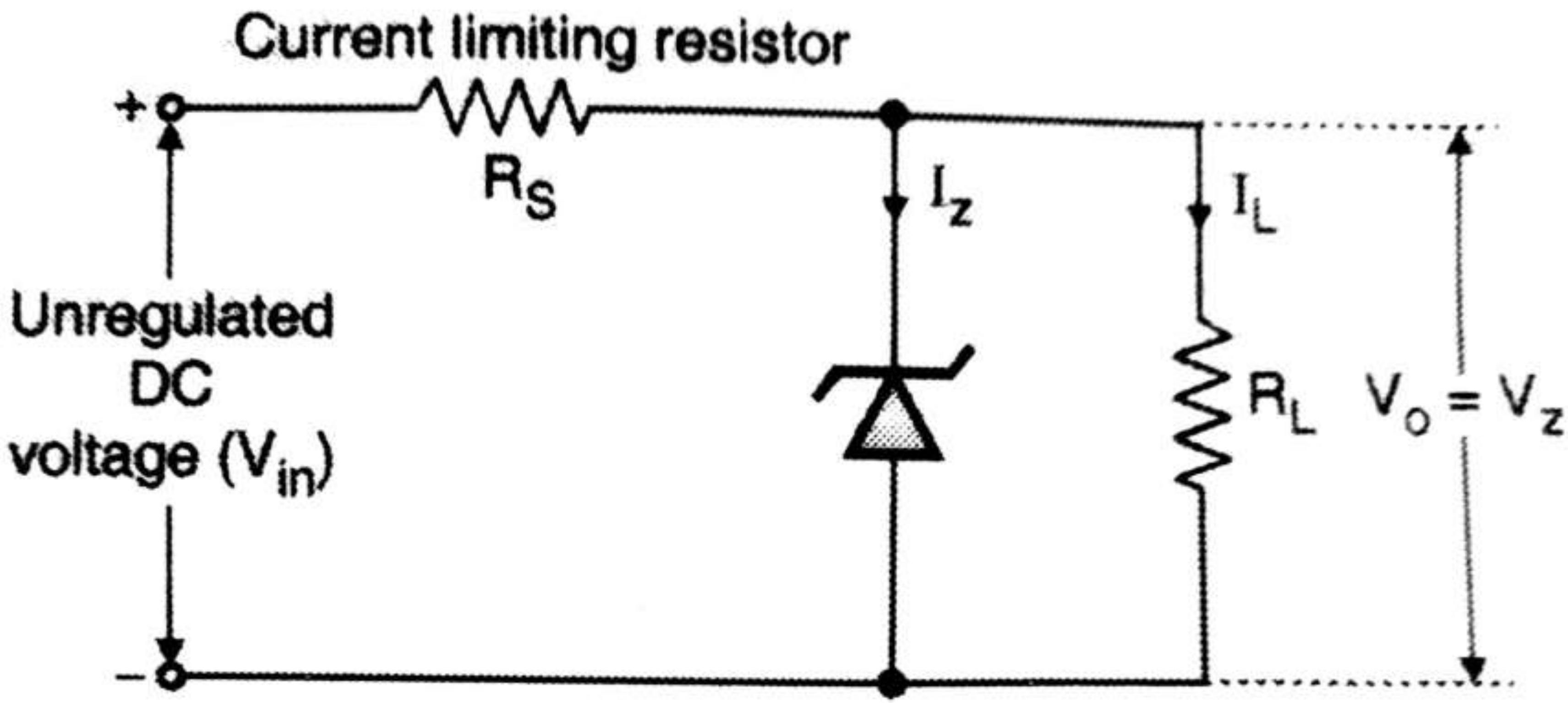
- It has ability to control its current hence can be used to regulate & stabilize voltage in a circuit
- Small Size
- Low cost

Disadvantages

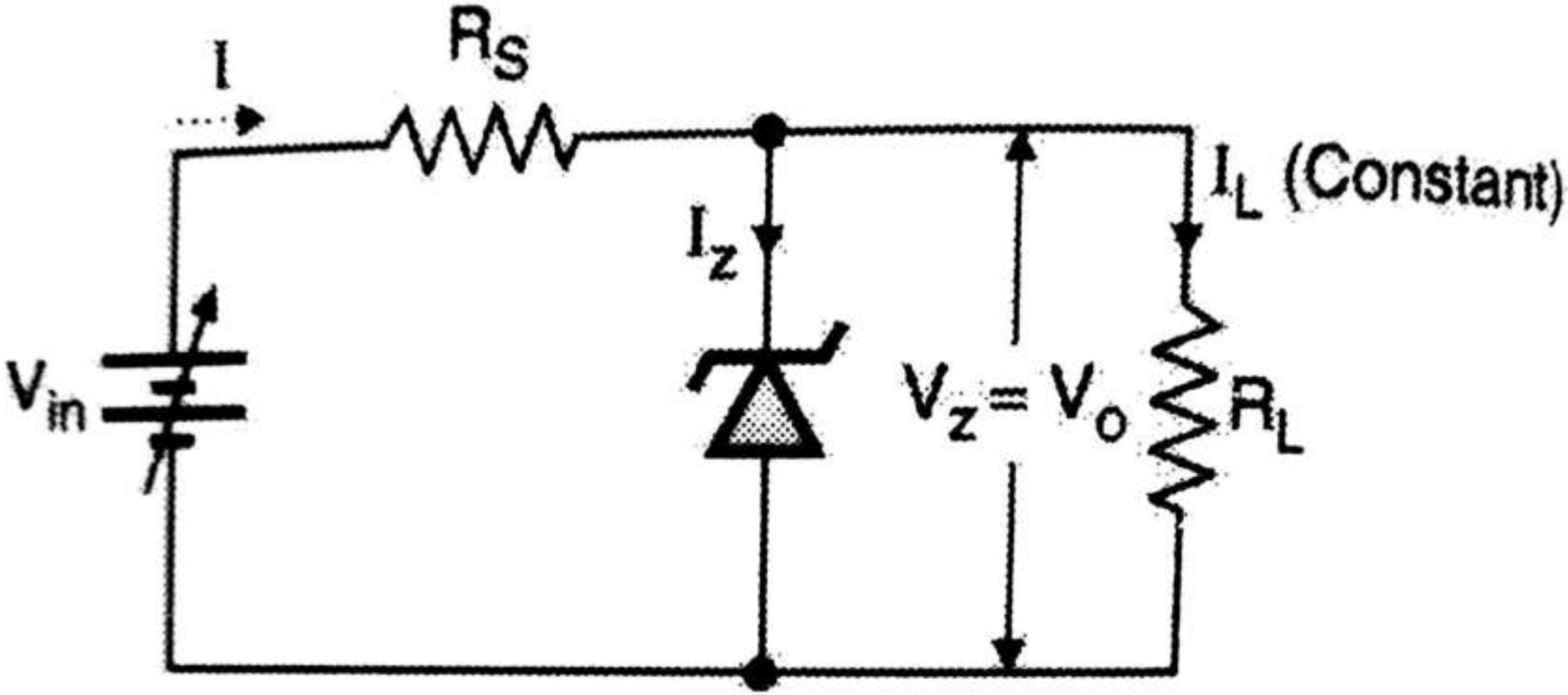
- Heavy Current grater than Izmax Can damage the diode
- Breakdown voltage decreases with temperature, hence early breakdown can take place

Application of a zener diode

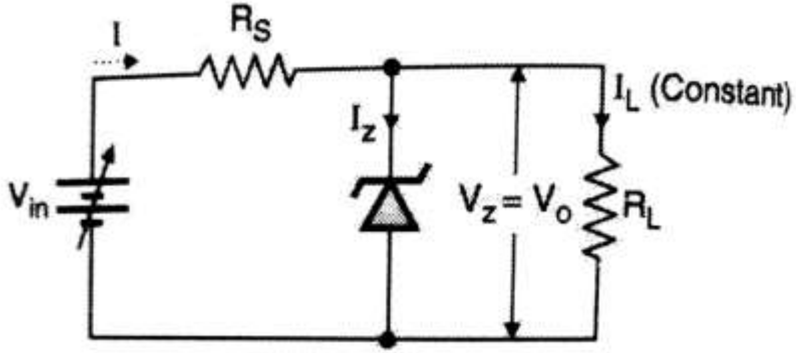
1. **Voltage regulator.**
2. **Meter Protection**
3. **Battery Charger**
4. **Wave Shaping**
5. **Transistor Biasing**
6. **As a regulated power supply**
7. **In a clipping circuits**
8. **Clamping circuits.**
9. **In the protection circuits for MOSFET**



Zener Diode as a Voltage Regulator



Regulating action with a varying input voltage (Constant I_L)

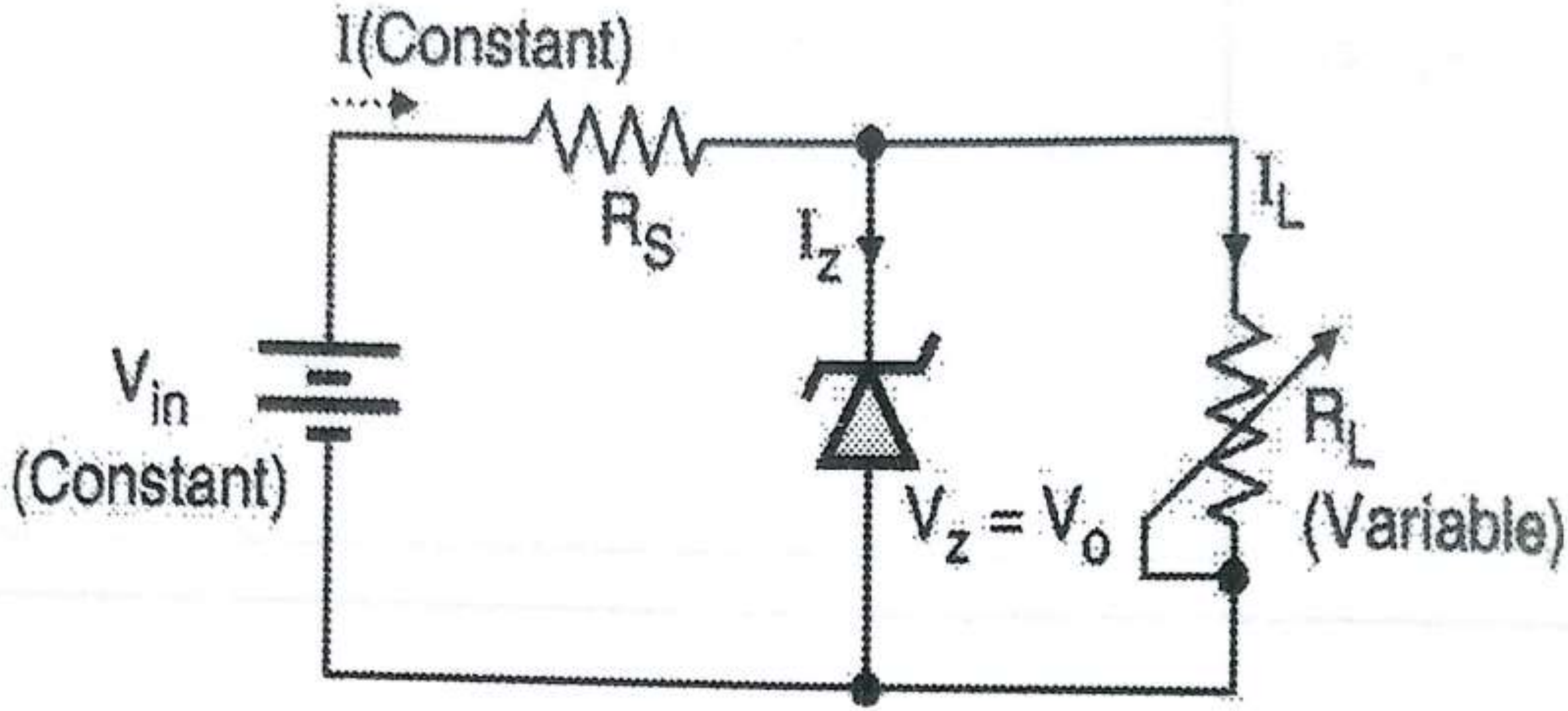


$$I_Z = \frac{V_{in} - V_z}{R_s}$$

$$I = I_Z + I_L$$

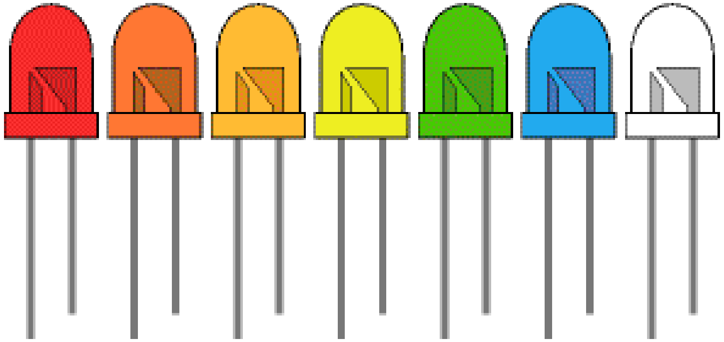
If Vin Increase	If Vin Deceases
Then I Increases	Then I decrease
But I_L is Constant as $I_L = V_Z/R_L$	But I_L is Constant
Hence Iz increase as $I_Z = I - I_L$	Hence Iz Decreases
If Iz < Izmax then Zener diode operates in the Zener Region & output voltage remains constant	If Iz >Izmin then Zener diode operates in the Zener Region & output voltage remains constant

Regulating action with a varying Load (Vin Constant)



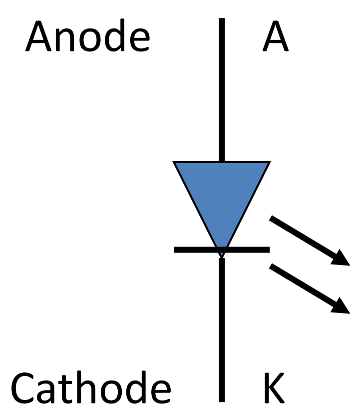
Light Emitting Diodes (LED)

- **A PN junction diode, which emits light when forward biased, is known as light emitting diode.**
- **The emitted light may be visible or invisible**
- **The amount of light output is directly proportional to the forward current.**
- **Thus higher the forward current, higher is the light output**

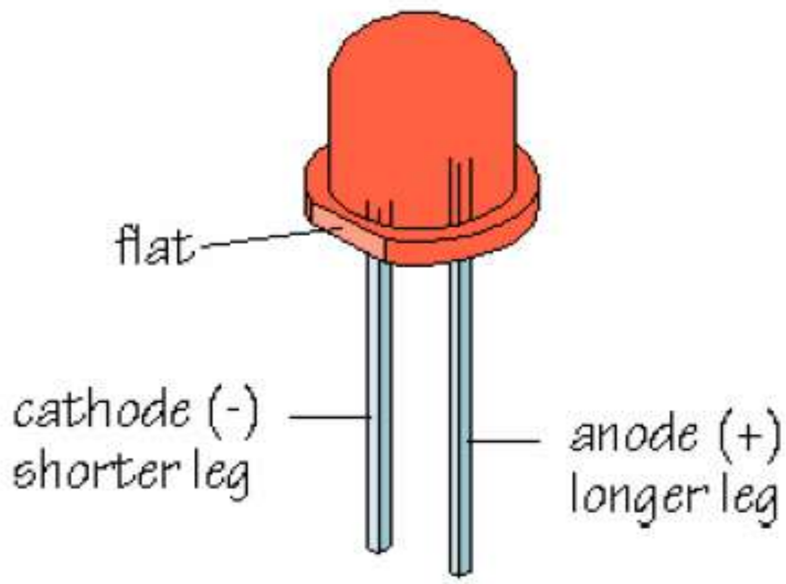


Light Emitting Diodes (LED)

- **The schematic symbol of a light emitting diode is shown in figure.**
- **The arrows pointing away from the diode symbol represent the light, which is being transmitted away from the junction.**

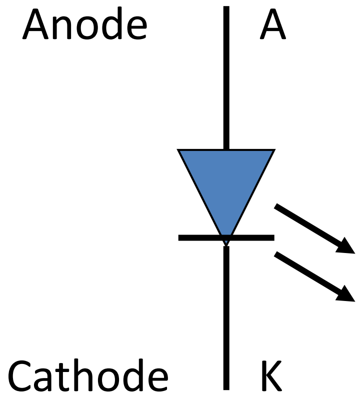


Circuit symbol

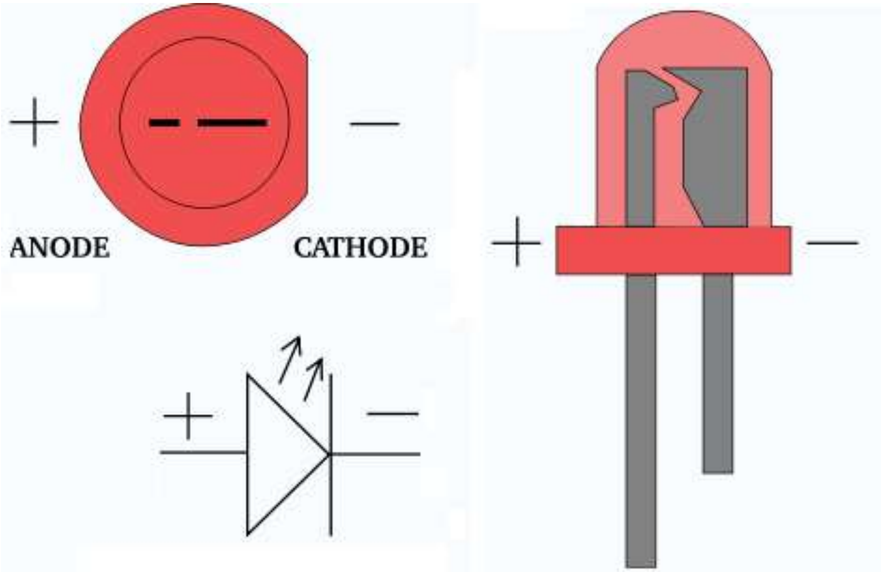


Light Emitting Diodes (LED)

Electrical polarity



Circuit symbol



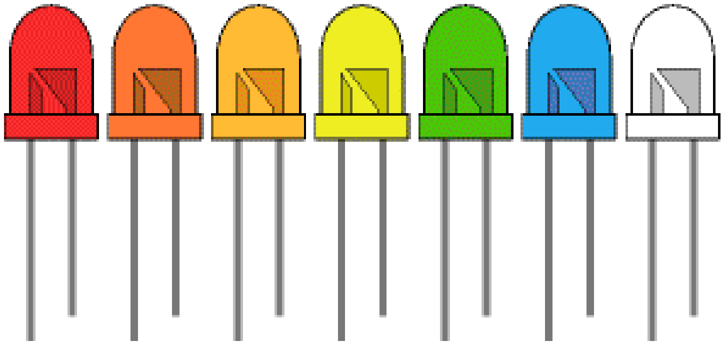
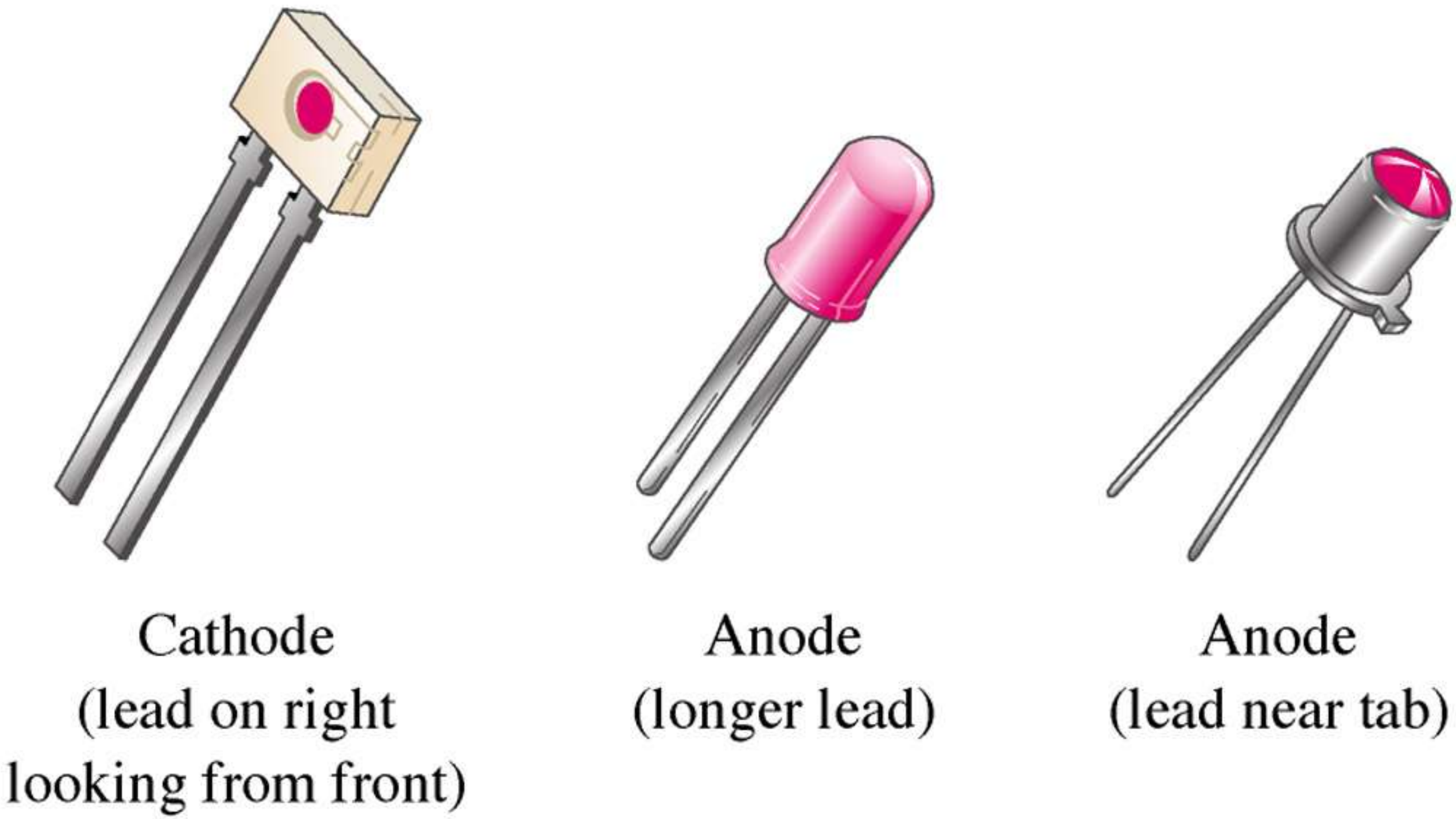
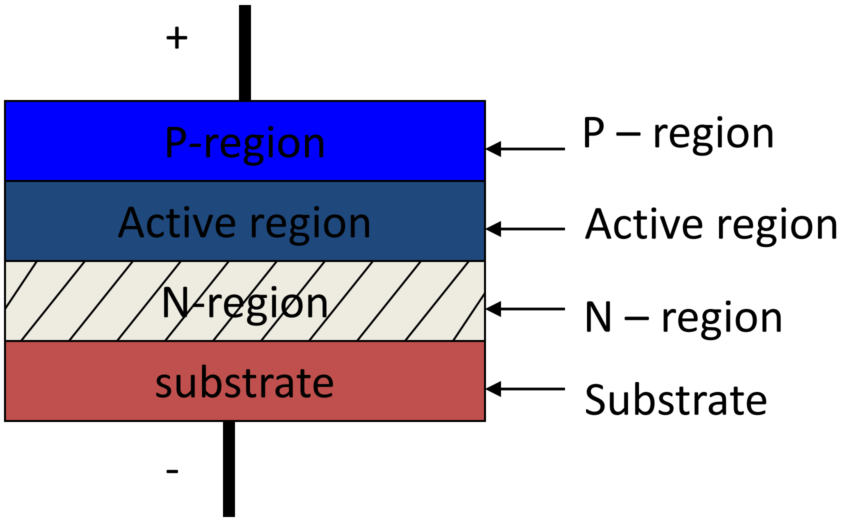


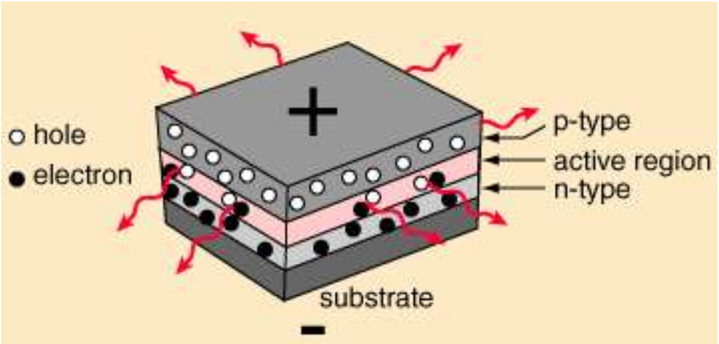
FIGURE 3-30 Typical LEDs.



Construction of LED

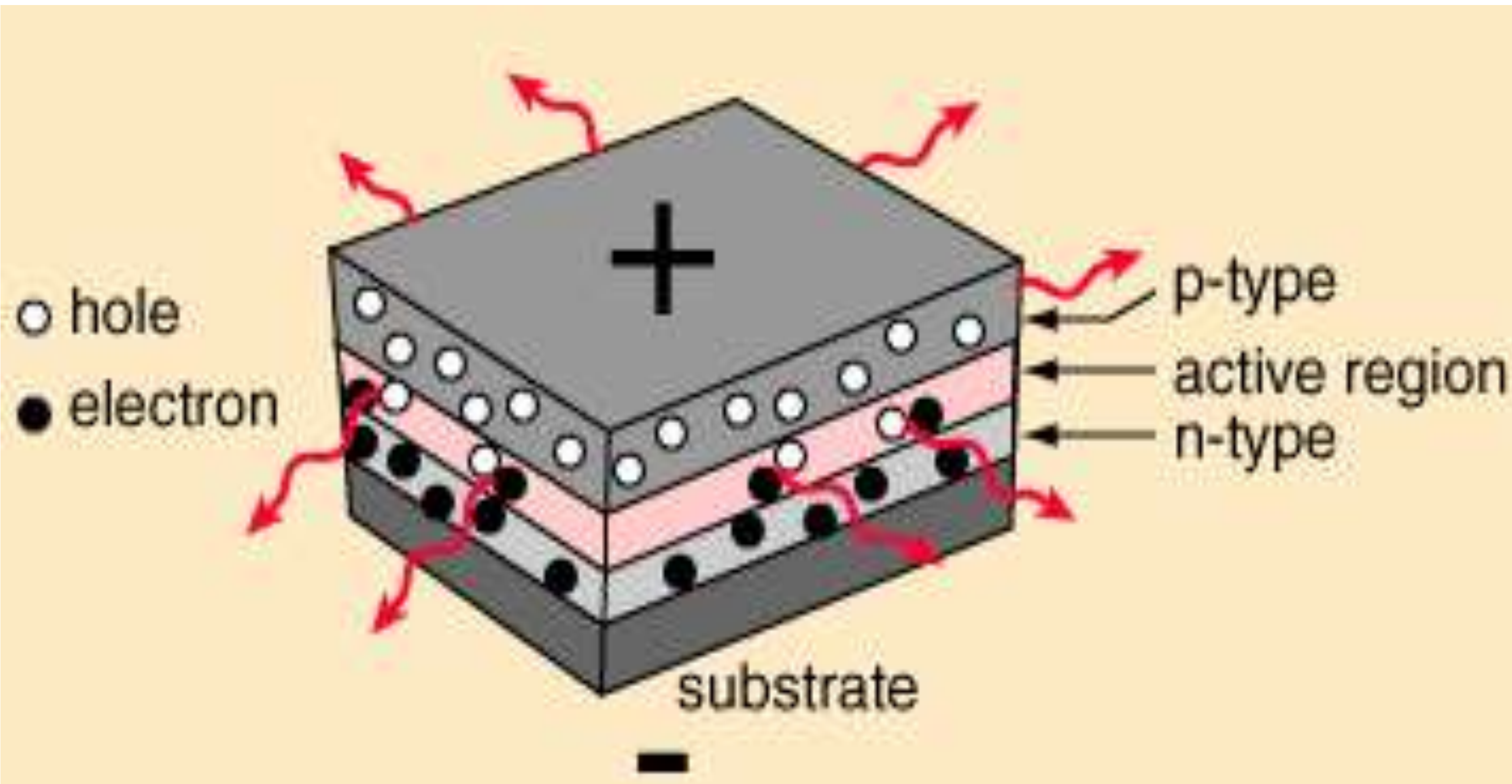
1. The construction of LED is same as that of a p-n junction semiconductor diode.
2. One of the popular methods of construction of LED is to deposite three semiconductor layers on the substrate as shown in figure.
3. The active region is exist between the p and n regions. The light emerges from the active side in all the directions when electron hole pairs recombine.





Construction of LED

1. In this particular structure, the LED emit light all the way around the layered structure. Thus the basic layered structure is placed in a tiny reflective cup so that the light from the active layer will be reflected towards desired exit direction.



Materials and colours

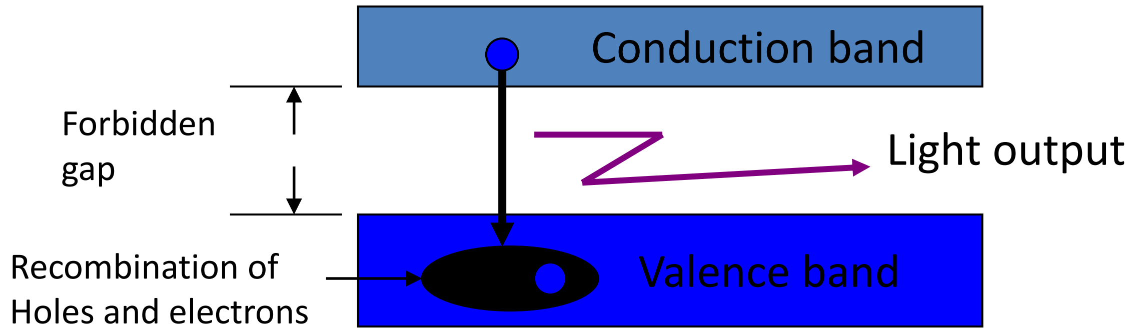
1. The LEDs use mixtures of Gallium (Ga), Arsenic (As) and Phosphorous (P).
2. The colour of emitted light is decided by its wavelength which depends on forbidden energy gap.
3. This gap is different for different mixtures. Hence different mixtures give the different colours.

No.	Mixture used	Symbol	Colour
1	Gallium Arsenide	GaAs	Infrared, invisible
2	Gallium Phosphide	GaP	Red or Green
3	Gallium arsenide Phosphide	GaAsP	Red or Yellow

- Silicon and germanium are not used for LEDs because their forbidden gap do not allows the light emission in visible spectrum.

Principle of LED operation

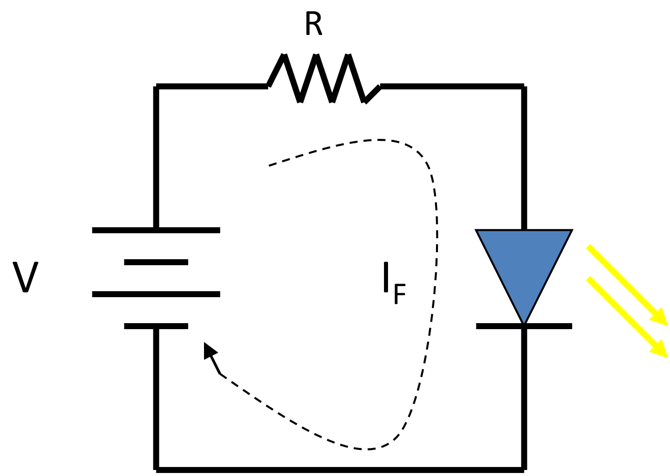
1. When the LED is forward biased, the electrons in the n-region will cross the junction and recombine with the holes in the p-type materials.
2. These free electrons resides in the conduction band and hence at a higher energy level than the holes in the valence band.
3. When recombination takes place, these electrons return back to the valence band which is at lower energy level than the conduction band.
4. While returning back, the recombining electrons gives away the excess energy in the form of light. This process is called as **Electroluminescence.**



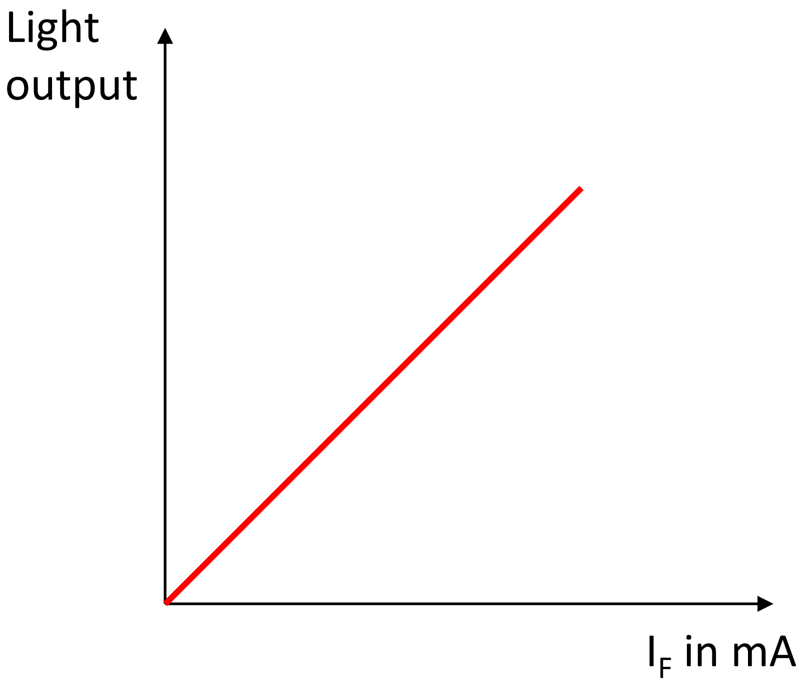
LED biasing

- **The voltage drop across a conducting LED is in the range of 1.2 V to 3.2 V, depending on the material used.**
- **This voltage is much higher than that across a conventional diode. The current range of the LEDs available in the market is 10 to 80 mA.**
- **LEDs have extremely low reverse breakdown voltage of the order of 3 to 10 V. So they should not be subjected to high reverse voltage.**

LED biasing



Forward biasing



Advantages of LEDs

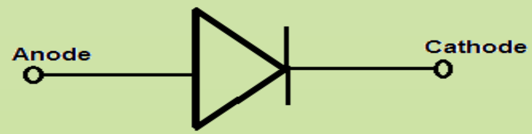
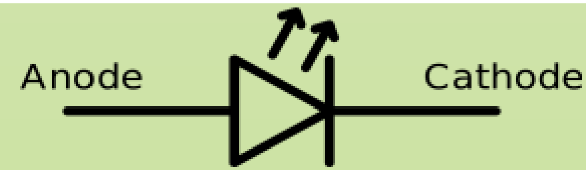
- **LEDs are of small size and light weight. Therefore it is possible to pack a large number of LED in a small space while manufacturing a display.**
- **They are available in a different spectral colors.**
- **They have larger life as compared to the lamps.**
- **The light emitted by a LED is proportional to the amount of current flowing through it. Hence we can control the current flowing through the LEDs to vary their brightness as per the requirements of the application.**
- **They are suitable at high operating speeds as they takes less than 1 μs to turn on or off.**
- **LEDs can be easily interfaced with the other electronic circuits**

Disadvantages of LEDs

1. **Output power is affected by changes in temperature.**
2. **Over current can damage it easily.**
3. **They need larger power for their operation**

Applications of LEDs

1. **In the opto-couplers.**
2. **In the infrared remote controls.**
3. **As indicators in various electronic circuits.**
4. **In seven segment and alphanumeric display.**

Parameter	PN Junction or Ordinary Diode	LED
Symbol		
Material Used	Silicon or Germanium	Gallium Arsenide , Gallium Phosphide , Gallium arsenide Phosphide
Light Emitting Capacity	No	Yes
Cut in Voltage	0.7V – Si 0.3 V- Ge	Range 1.2 V to 2V
Reverse Breakdown Voltage	High. It is above 6V to hundred of Volt	Very low from 3V to 10V
Voltage Drop	about 0.7 V.	about 2 V
Application	Switch , Rectifier , Clipper, Clamper	Seven Segment Display, opto-couplers Disco Decorative lighting
Power Requirement	Less	More

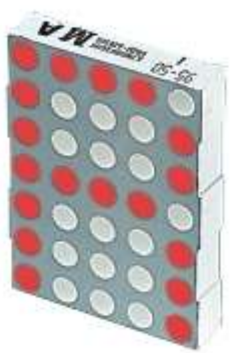
LEDs configurations

LED displays are packages of many LEDs arranged in a pattern, the most familiar pattern being the 7-segment displays for showing numbers (digits 0-9). The pictures below illustrate some of the popular designs:

Bargraph

7-segment

Starburst

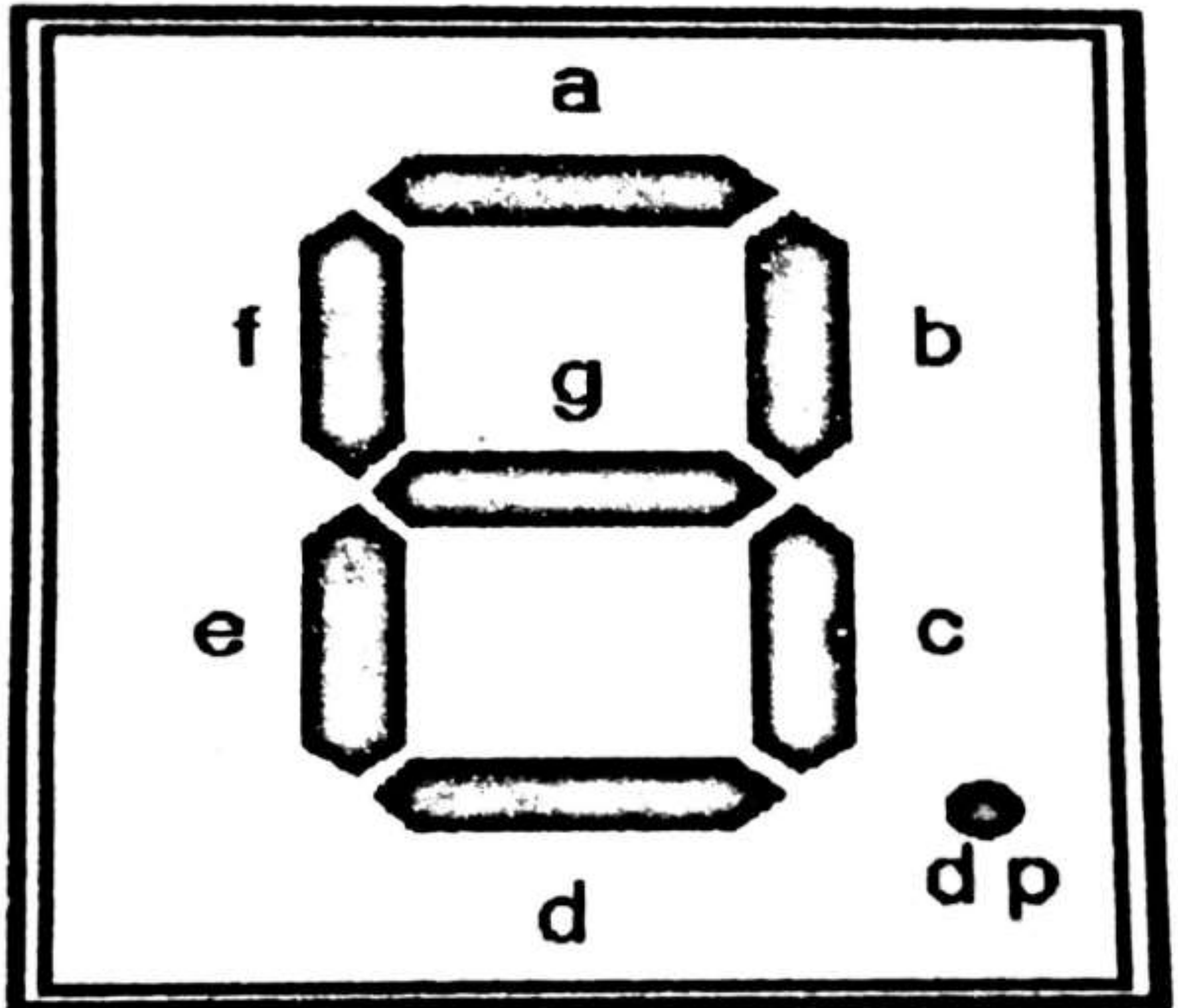


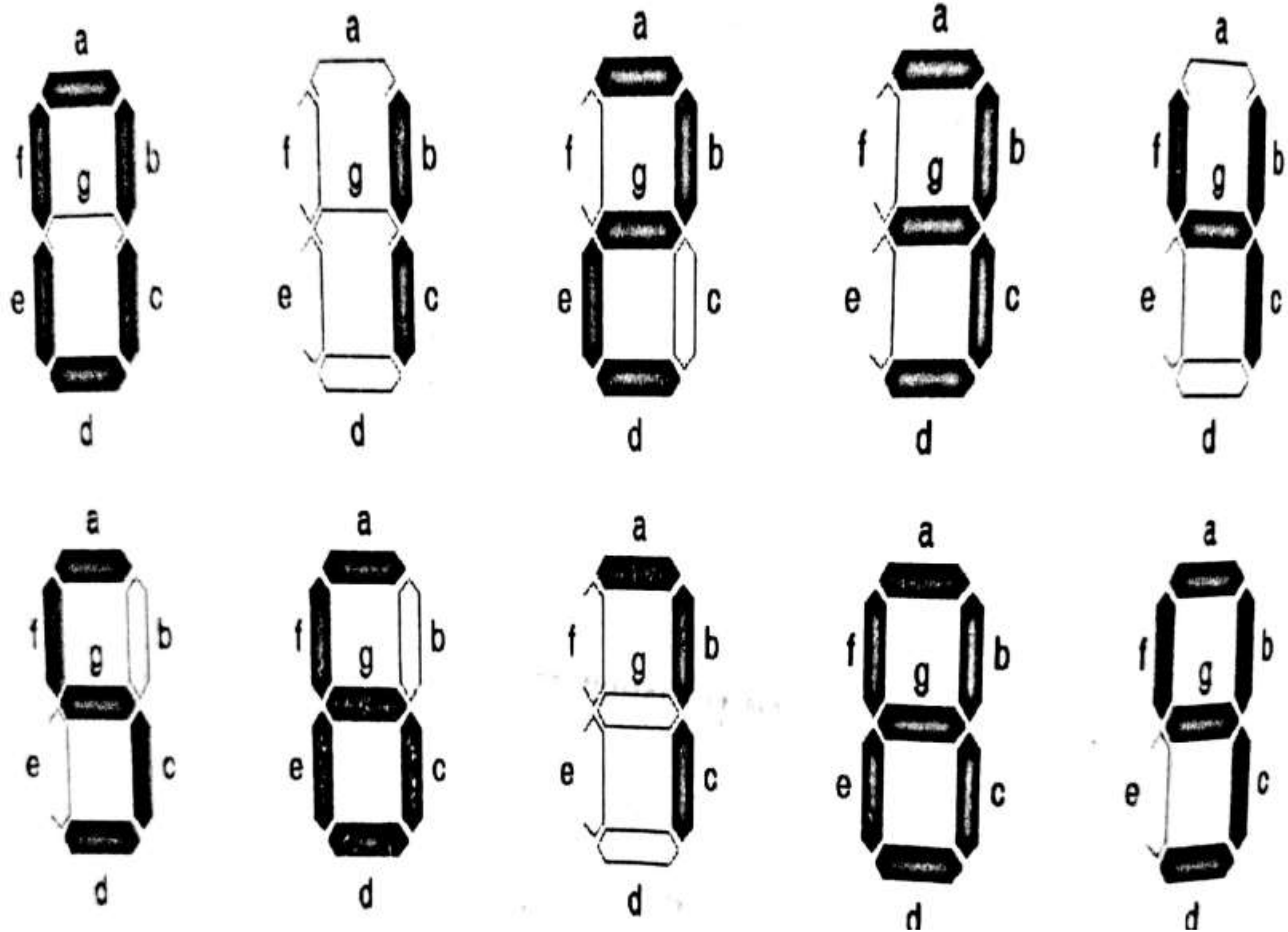
Dot matrix

Single Digit Seven-Segment LED Display

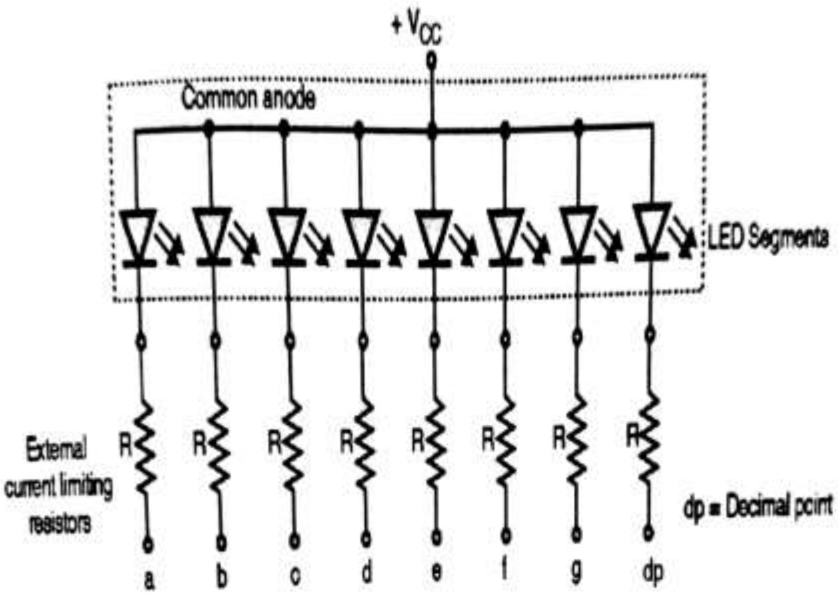
Features

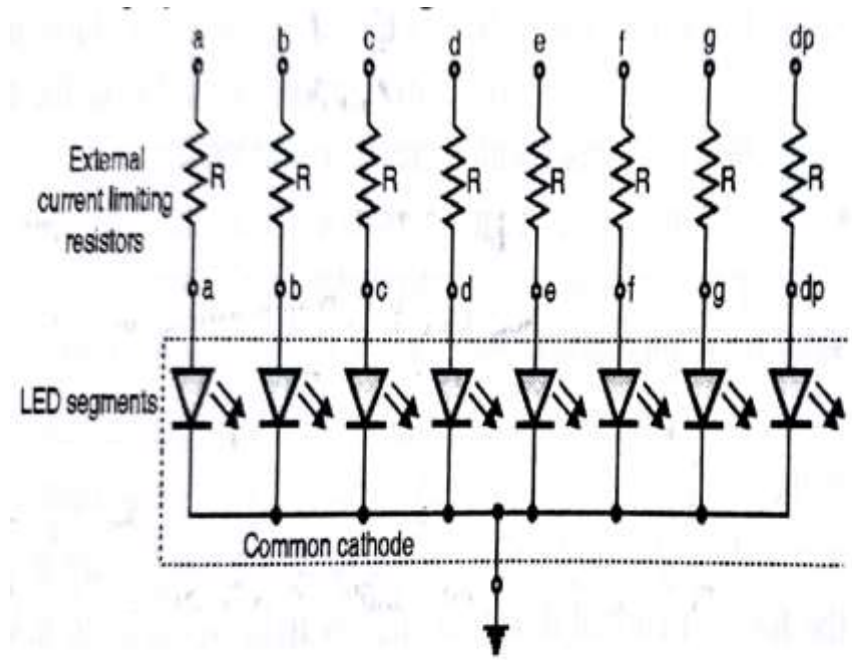
- Low Current Consumption
- High Brightness
- Easy to Use
- PCB Mounting


a
f
b
g
e
c
d
dp


a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d
a f g b e c d

Segments							Display
a	b	c	d	e	f	g	
ON	ON	ON	ON	ON	ON	–	0
–	ON	ON	–	–	–	–	1
ON	ON	–	ON	ON	–	ON	2
ON	ON	ON	ON	–	–	ON	3
–	ON	ON	–	–	ON	ON	4
ON	–	ON	ON	–	ON	ON	5
ON	–	ON	ON	ON	ON	ON	6
ON	ON	ON	–	–	–	–	7
ON	ON	ON	ON	ON	ON	ON	8
ON	ON	ON	ON	–	ON	ON	9

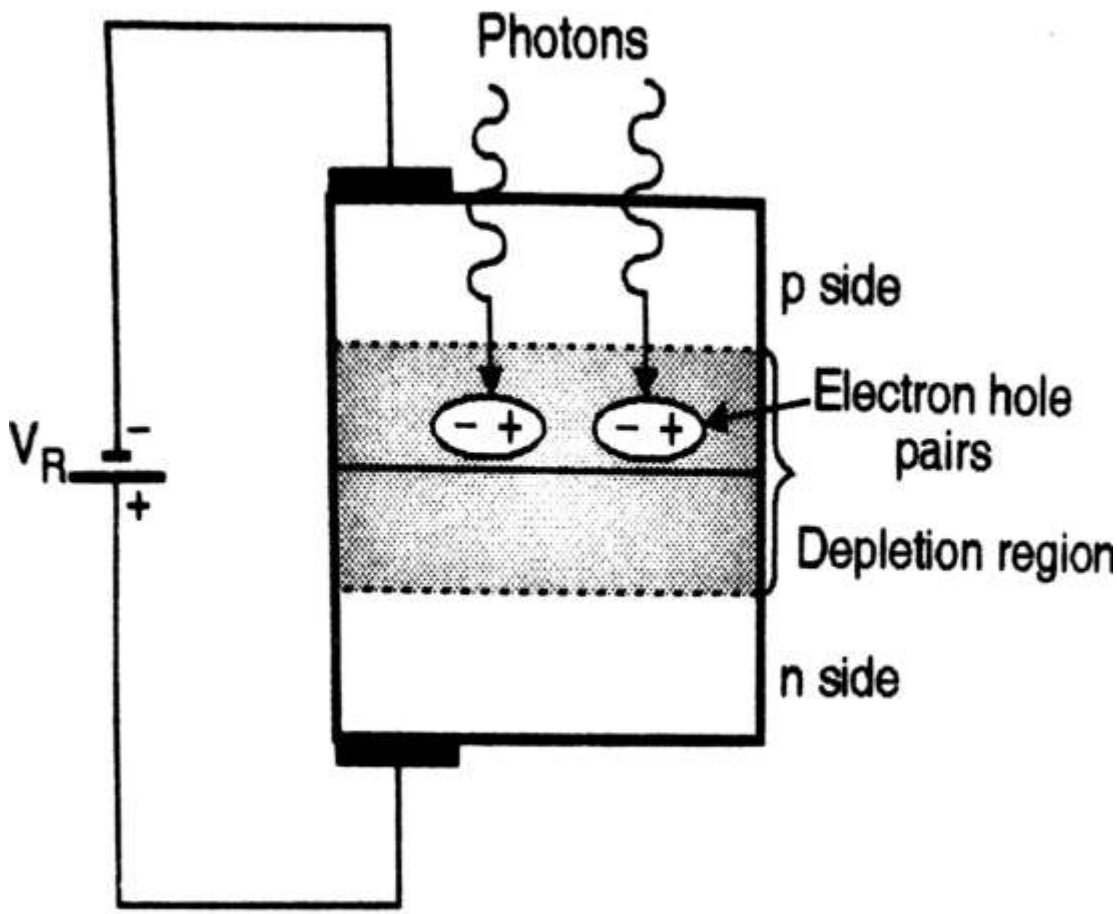

+ VCC
Common anode
LED Segments
External
current limiting
resistors
R
dp = Decimal point
a
b
c
d
e
f
g
dp

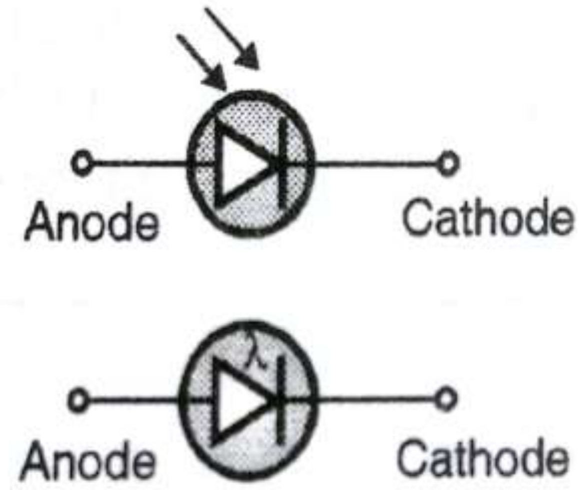

a
b
c
d
e
f
g
dp
External
current limiting
resistors
R
LED segments
Common cathode

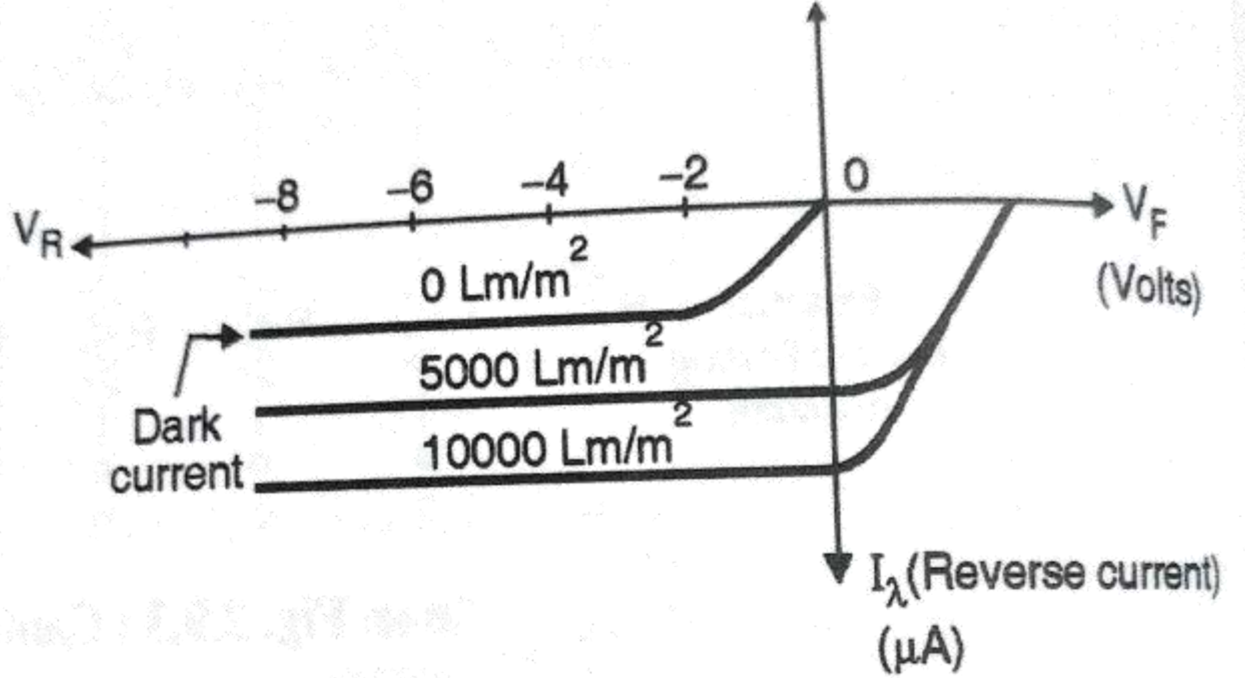
Photodiode

A photodiode is a type of **photodetector** capable of converting light into either current or voltage, depending upon the mode of operation. The common, traditional solar cell used to generate electric solar power is a large area photodiode.

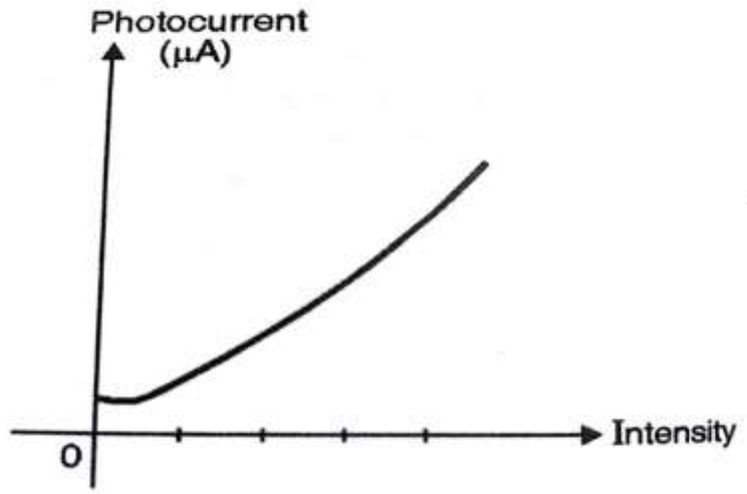
Symbol & Construction







V – I Characteristics of a photodiode



Variation of Photocurrent with intensity of light

Photocurrent (I_λ)

- The Reverse Current I_λ (Photocurrent) depend only on the intensity of light incident on the junction.
- It is almost depend independent of the reverse voltage.
- It is proportional to the Light intensity

Dark Current

- It is the current flowing through a photodiode in the absence of light.
- Dark current flows due to the **thermally generated minority carriers**
- **Hence increases with increase in temperature**

Advantage of Photodiode

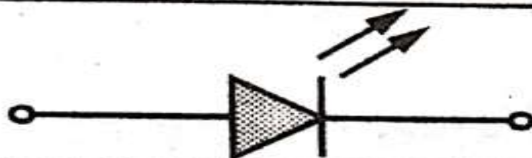
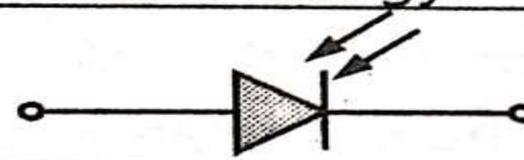
- High sensitivity
- High Speed of operation

Disadvantage of Photodiode

- Dark Current Increase with Temperature
- Amplification is Required, as the output current is of small magnitude
- External Bias Voltage is Essential for Operation

Applications of Photodiode

- Photodiodes are used in consumer electronic devices such as compact disc players, smoke detectors, and the receivers for infrared remote control devices used to control equipment from televisions to air conditioners.
- In Fiber Optic Receiver
- Object Counting System
- In the Cameras For sensing the light Intensity
- Burglar Alarms
- Light Intensity meter

Parameter	LED	Photodiode
Definition	LED is a device that converts electric energy into light energy.	Photodiode is a device that converts light energy into electric energy.
Symbol		
Operating principle	Electro-luminance	Photoconduction
Function	It emits light.	It detects light.
Type of biasing	Forward biased	Reverse biased
Fabricated with	GaAs, GaAsP, GaP etc.	Si, InGaAs etc.
Leakage current	Not exist	Exist, and known as dark current.
Application	Indicators in seven segment displays, use as light source.	Rectifiers, voltage multipliers, clamping etc.

UNIT – 1 FINISHED