Unit 5
Basic Electronic Devices & Thyristors

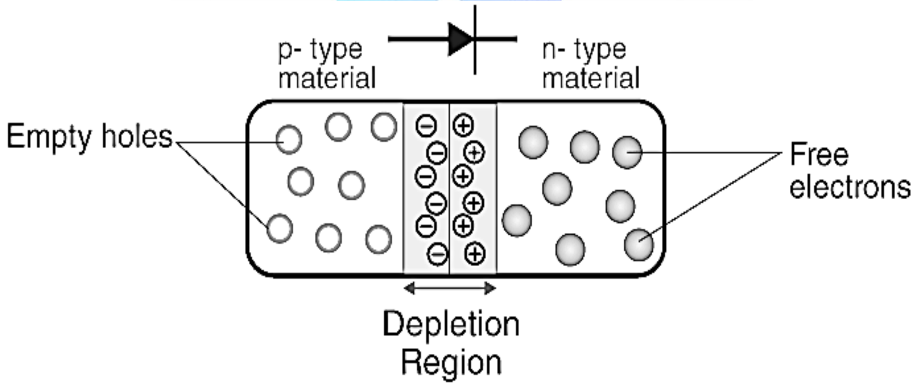
BASIC ELECTRONIC DEVICES

PN JUNCTION DIODE

A PN junction diode is a two-terminal semiconductor device formed by joining P-type and N-type materials. It allows current to flow in only one direction, acting as a rectifier.

Construction

- *P-type region:* Doped with trivalent elements (e.g., Boron), has holes as majority carriers.
- *N-type region:* Doped with pentavalent elements (e.g., Phosphorus), has electrons as majority carriers.
- The junction is the boundary where both regions meet.
- Formed by diffusion or alloying techniques.
- Metallic contacts are provided for external connections.



Formation of Depletion Region

- At the junction, electrons from N combine with holes from P → forms depletion layer (no free carriers).
- Fixed ions create an electric field → barrier potential develops (about 0.3V for Ge, 0.7V for Si).
- No current flows in equilibrium without bias.

Biasing

Forward Bias:

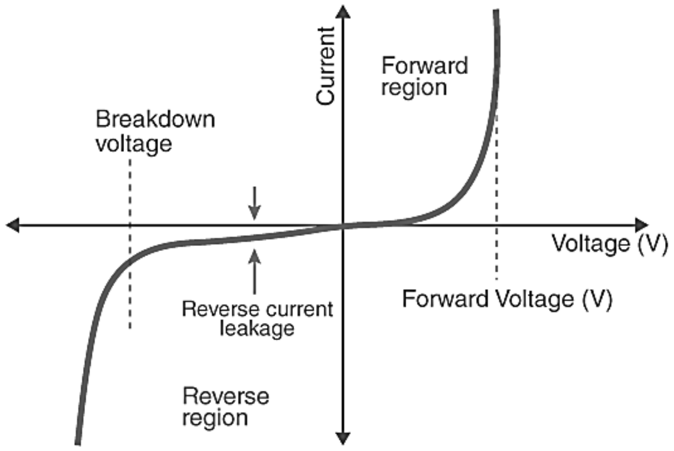
- P connected to +ve terminal, N to –ve.
- Barrier potential reduces.
- Electrons & holes cross junction → current flows.

Reverse Bias:

- P to –ve, N to +ve.
- Barrier potential increases.
- Only small leakage current flows (due to minority carriers).
- If voltage exceeds breakdown, diode may be damaged (unless Zener diode)

VI Characteristics of PN Diode

Bias	Region	Behaviour
Forward	Above 0.7V	Current increases exponentially
Reverse	Small reverse bias	Leakage current
Reverse	High reverse bias	Breakdown (Zener or Avalanche)



Equation of Diode Current

$$I = I_0\left(e^{\frac{qV}{kT}} - 1\right)$$

Where:

- I_0: Reverse saturation current
- q: Charge of electron
- V: Applied voltage
- k: Boltzmann's constant
- T: Absolute temperature

Applications of Diode

- Rectification (AC to DC)
- Clipping, clamping circuits
- Voltage regulation (Zener diode)
- Signal demodulation
- Logic gates (AND, OR)

RECTIFIERS

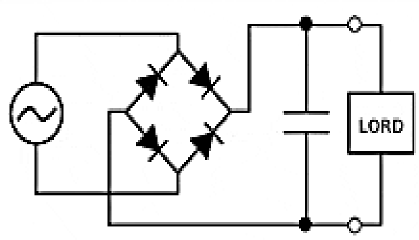
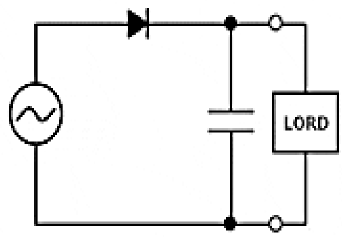
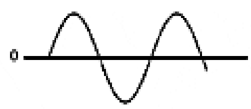
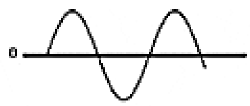
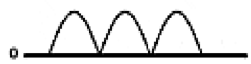
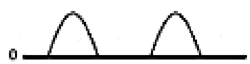
A rectifier is a circuit that converts alternating current (AC) into direct current (DC) using diodes. Diodes conduct only in one direction and block the other, enabling AC-to-DC conversion.

Types of Rectifiers

1. *Half-Wave Rectifier (HWR):*
   - Uses one diode.
   - Passes only one half (positive or negative) of the AC signal.
   - Simple and inexpensive but inefficient.
   - Circuit: AC source → Diode → Load resistor.
   - Output:
     - Pulsating DC during positive half-cycle.
     - No output during negative half.
   - Waveform:
     - Positive pulses with gaps in between.

2. *Full-Wave Rectifier (FWR):*
    (a) Center-Tap Full Wave Rectifier:
    - Requires a center-tapped transformer and 2 diodes.
    - One diode conducts in positive half, the other in negative half.
    - Circuit: Center-tap transformer with two diodes connected to load.
    - Output:
        - Full-wave rectified output (positive pulse for both half-cycles).

    (b) Bridge Rectifier:
    - Uses 4 diodes in a bridge configuration.
    - Does not require center-tap transformer.
    - Conducts in both half-cycles.
    - Circuit: Four diodes arranged in bridge across AC input and load.
    - Output:
        - More efficient and continuous pulsating DC.

	Full-Wave Rectification	Half-Wave Rectification
Circuit Configuration		
Input Voltage Waveform		
Voltage Waveform After Rectification		
Voltage Waveform After Rectification Smoothing		

Applications of Rectifiers
- DC power supplies
- Battery chargers
- Radio signals demodulation
- SMPS (Switched Mode Power Supplies)

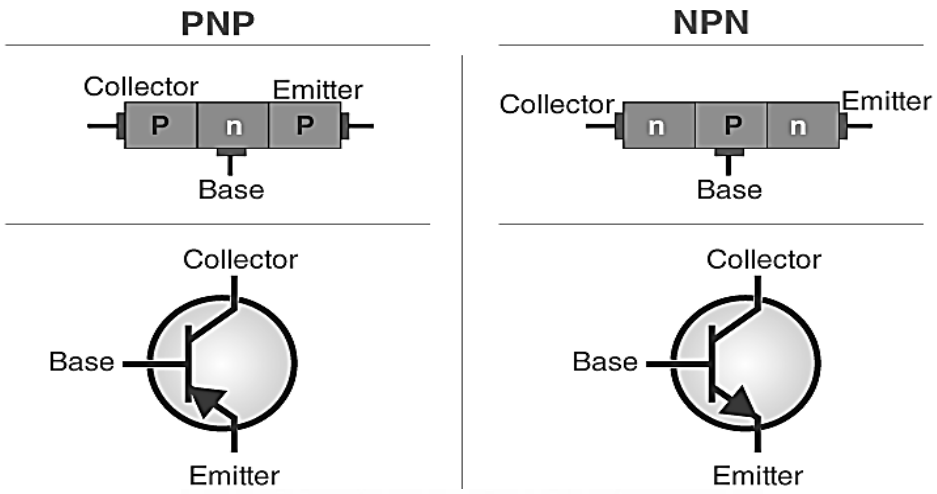
BIPOLAR JUNCTION TRANSISTOR (BJT)

A Bipolar Junction Transistor (BJT) is a three-layer, three-terminal semiconductor device that amplifies or switches electrical signals using both electron and hole charge carriers.
- *"Bipolar":* Involves both majority and minority carriers.
- Three terminals:
    - *Emitter (E):* Heavily doped, emits majority carriers.
    - *Base (B):* Very thin and lightly doped, controls the transistor action.
    - *Collector (C):* Moderately doped, collects carriers.

Types of BJT

1. *NPN Transistor:* Current flows from collector to emitter when base is positive.
2. *PNP Transistor:* Current flows from emitter to collector when base is negative.

Feature	NPN	PNP
Majority carriers	Electrons	Holes
Arrow Direction	Outward	Inward

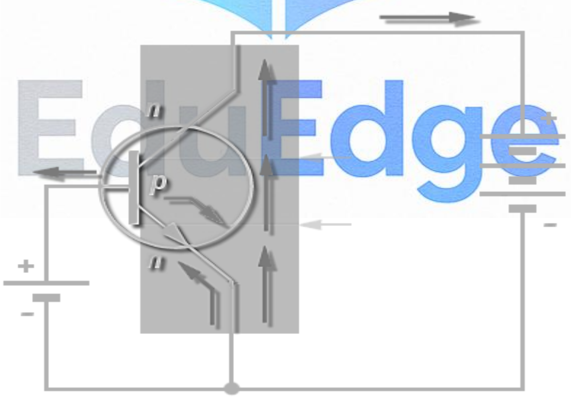


TRANSISTOR CURRENT COMPONENTS

Basic Current Relations

$$I_E = I_B + I_C$$

- *Emitter Current (I_E):* Total current injected into the base and collector.
- *Base Current (I_B):* Small current (~5%) used to control larger current.
- *Collector Current (I_C):* Major part (~95%) of emitter current.



In Active Region

- Emitter-base junction: *forward-biased*
- Collector-base junction: *reverse-biased*

Majority carriers move from emitter to base. Most carriers cross into the collector. Only a few recombine in base → base current is small.

Current Gain Parameters

1. *Alpha (α)* – Common Base current gain:

$$\alpha = \frac{I_C}{I_E}(0.9 < \alpha < 0.99$$

2. *Beta (β)* – Common Emitter current gain:

$$\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}(20 < \beta < 500)$$

CHARACTERISTICS OF CE, CB, AND CC CONFIGURATIONS

BJTs can be configured in 3 ways, depending on which terminal is common to both input and output.

(a) Common Base (CB) Configuration

- Base is common to input and output.
- Input: Emitter → Base
- Output: Collector → Base

Input Characteristics:

- Plot of I_E vs V_{EB} (with V_{CB} constant)
- Forward-biased

Output Characteristics:

- Plot of I_C vs V_{CB} (with I_E constant)
- Reverse-biased

Key Points:

- Voltage gain: High
- Current gain: Low ($\alpha \approx 0.95$)
- Input resistance: Low (30–300 Ω)
- Output resistance: High

(b) Common Emitter (CE) Configuration

- Emitter is common
- Most widely used configuration in amplifiers
- Input: Base → Emitter
- Output: Collector → Emitter

Input Characteristics:

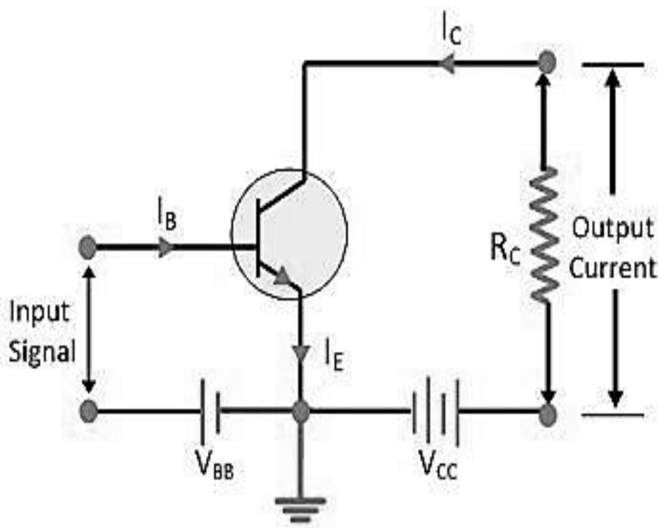
- I_B vs V_{BE} (V_{CE} constant)

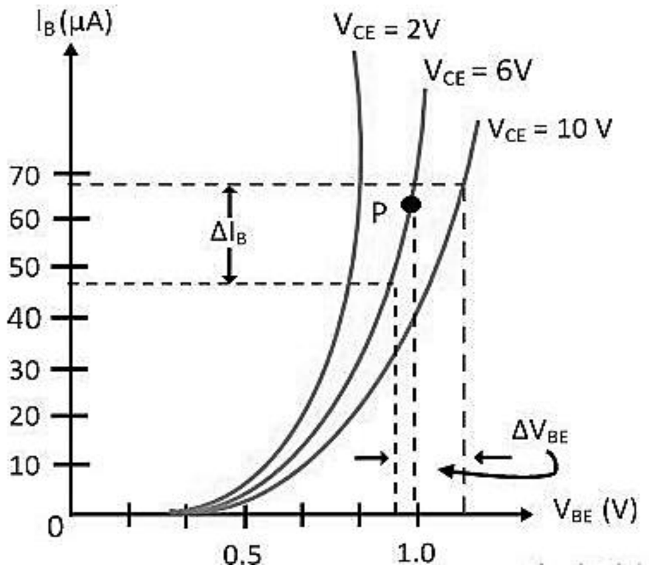
Output Characteristics:

- I_C vs V_{CE} (I_B constant)

Key Points:

- Voltage gain: High
- Current gain: Very High (β)
- Power gain: High
- Phase shift: 180° between input & output
- Used in audio & RF amplifiers





(c) Common Collector (CC) Configuration (Emitter Follower)

- Collector is common
- Used as buffer
- Input: Base → Collector
- Output: Emitter → Collector

Characteristics:

- Voltage gain: ≈ 1 (Unity)
- Current gain: High (β+1)
- Power gain: Medium
- Input resistance: High
- Output resistance: Low

Comparative Table

Parameter	CB	CE	CC
Voltage Gain	High	High	≈1
Current Gain	<1	High (β)	High (β+1)
Power Gain	Medium	Very High	Medium
Input Resistance	Low	Medium	High
Output Resistance	High	High	Low
Phase Shift	0°	180°	0°
Application	High-freq amps	General amps	Impedance matching

APPLICATION OF BJT AS AMPLIFIER

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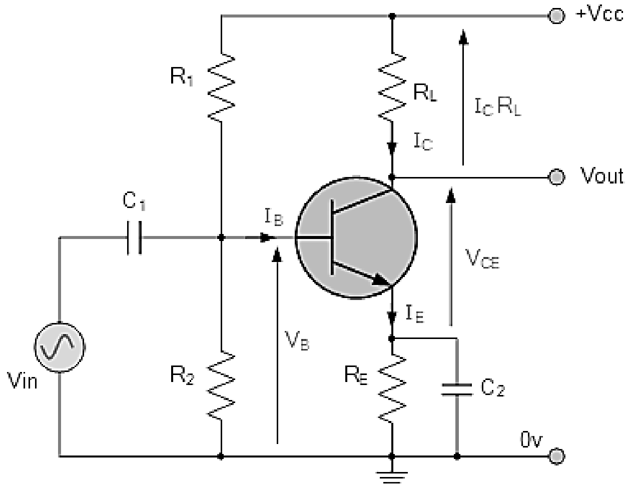
An amplifier is a device that boosts the strength of a weak signal (voltage, current, or power) using an external power supply.

Transistor as Amplifier (CE mode)

1. Input is fed between Base-Emitter
2. Output is taken from Collector-Emitter
3. Biasing keeps the transistor in the active region
4. A small input voltage (base current) causes a large collector current, leading to amplified output voltage



Key Concepts

- Power comes from V_CC (DC supply), not from the signal
- Output signal is 180° out of phase with input (CE)
- Proper biasing ensures linearity and avoids distortion

Applications of Transistor Amplifiers

- Audio amplifiers
- RF amplifiers (radio)
- Oscillator circuits
- Communication systems
- Signal processing
- Sensor signal conditioning

THYRISTORS

Thyristors are four-layer, three-terminal semiconductor devices used for switching and controlling high-power applications. They operate mainly in ON or OFF states (unlike transistors which work in the active region for amplification).

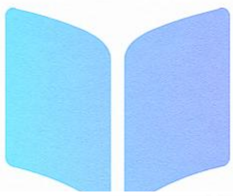
Types of Thyristors

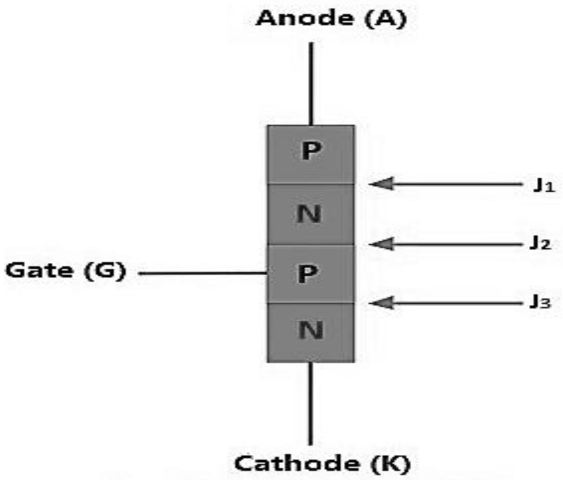
1. SCR (Silicon Controlled Rectifier)
2. TRIAC (Triode for Alternating Current)
3. UJT (Unijunction Transistor) – not a true thyristor but used for triggering thyristors

SCR – SILICON CONTROLLED RECTIFIER

Structure

- 4 layers (PNPN)
- *3 terminals:*
    - Anode (A)
    - Cathode (K)
    - Gate (G)





Working Principle

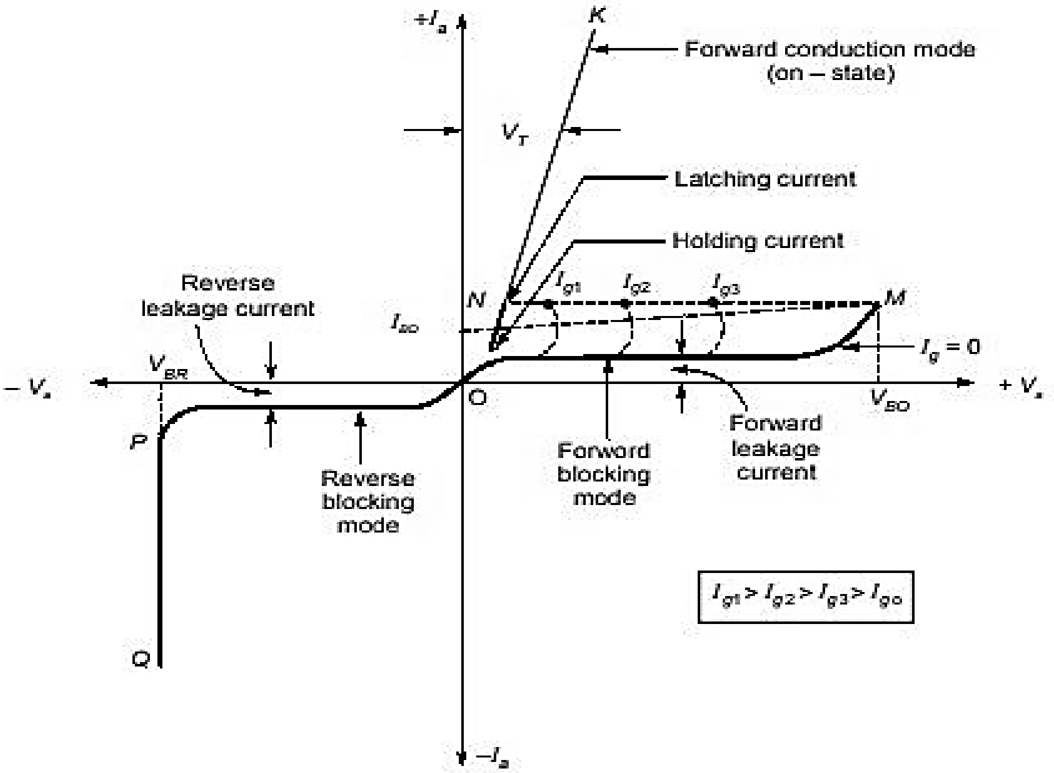
- SCR is a unidirectional device.
- Works like a diode but with controlled turn-on via the gate.
- Once turned ON, it remains ON even after the gate signal is removed (latching property).

Modes of Operation

Mode	Anode-Cathode Bias	Gate	Result
Reverse Blocking	Reverse	Any	OFF
Forward Blocking	Forward	0	OFF
Forward Conduction	Forward	Positive Pulse	ON

V-I Characteristics

- Three regions:
  - Reverse Blocking
  - Forward Blocking
  - Forward Conduction (ON state)
- Has a latching and holding current



Applications

- AC/DC motor control
- Power control in heaters, lamps
- Battery chargers
- Controlled rectifiers

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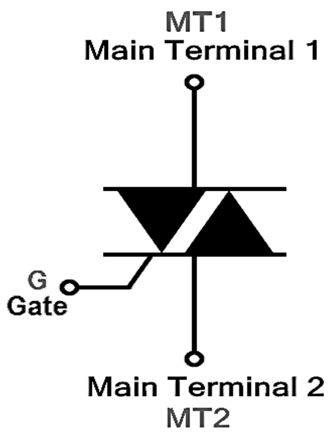
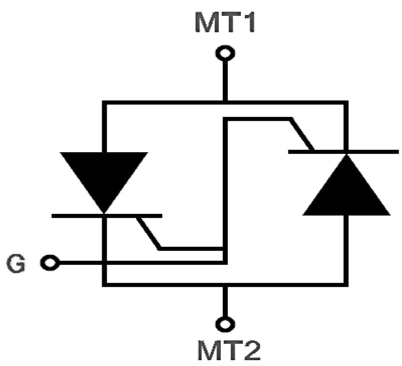
TRIAC (TRIODE FOR ALTERNATING CURRENT)

Structure

- 5-layer, 3-terminal bidirectional thyristor
- Can conduct in both directions
- Equivalent to 2 SCRs connected in anti-parallel





Terminals

1. MT1 (Main Terminal 1)
2. MT2 (Main Terminal 2)
3. Gate (G)

Working Principle

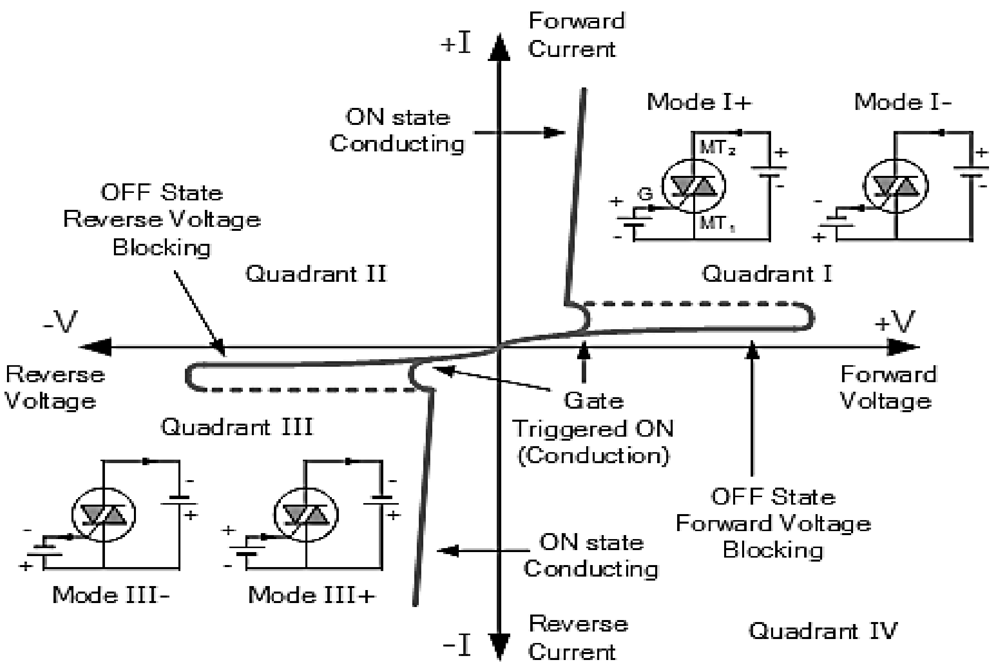
- Conducts in both halves of AC cycle
- Triggered by applying a gate pulse
- Once triggered, it continues conduction till the current drops below holding current

Triggering Modes

Quadrant	MT2	Gate	Description
I	+ve	+ve	Most sensitive
II	+ve	-ve	Moderate sensitivity
III	-ve	-ve	Moderate
IV	-ve	+ve	Least sensitive

V-I Characteristics

- Symmetrical for both positive and negative voltages
- Turns ON when gate is triggered or breakover voltage is exceeded



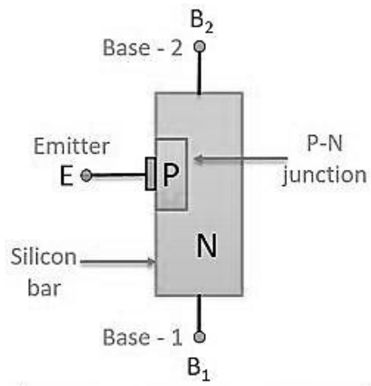
Applications

- Fan and lamp dimmers
- Speed control of universal motors
- AC switching
- Temperature control

UJT – UNIJUNCTION TRANSISTOR

Structure

- Not a thyristor but a triggering device
- Has one PN junction and three terminals:
  - Emitter (E)
  - Base 1 (B1)
  - Base 2 (B2)

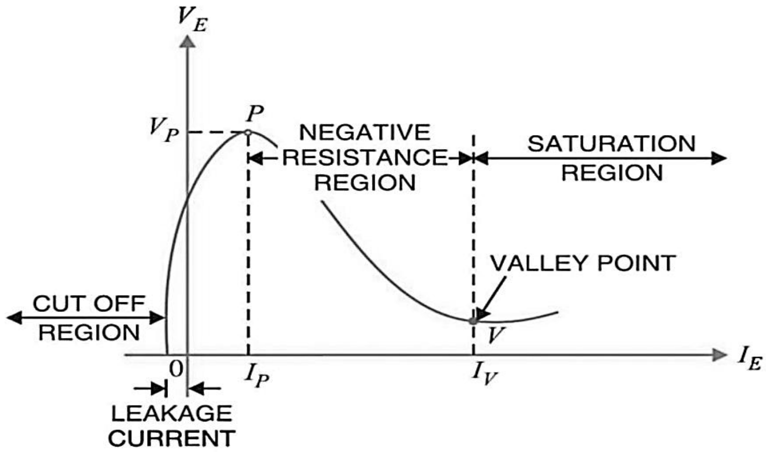


Working

- When the emitter voltage exceeds the intrinsic standoff ratio, it starts conducting
- Exhibits negative resistance region in V-I characteristics
- Ideal for pulse generation, timing circuits, and triggering SCR

V-I Characteristics

- Initially, emitter current is very small
- After peak voltage, emitter current increases rapidly and voltage drops (negative resistance)



Applications

EduEdge

- Relaxation oscillator
- Triggering SCRs and TRIACs
- Sawtooth wave generation