| 15EE208 | ELECTRON DEVICES AND CIRCUITS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

| | | | |
|---|---|---|---|
| *Co-requisite:* | NIL | | |
| *Prerequisite:* | 15EC101 | | |
| *Data Book / Codes/Standards* | NIL | | |
| *Course Category* | P | PROFESSIONAL CORE | ELECTRONICS |
| *Course designed by* | Department of Electrical and Electronics Engineering | | |
| *Approval* | 32nd Academic Council Meeting, 2016 | | |

| PURPOSE | To familiarize the students with the design,analyze and application of electronic devices. |
|---|---|

| INSTRUCTIONAL OBJECTIVES | | STUDENT OUTCOMES | | | | | | |
|---|---|---|---|---|---|---|---|---|
| At the end of the course,the student will be able to | | | | | | | | |
| 1 | Familiarize with the electronic device. | a | | | | | | |
| 2 | Understand the concepts of frequency response of amplifiers and different types of feedback | a | c | e | | | | |
| 3 | Gain knowledge about the design and analysis of multi-vibrators,oscillators and waveshaping circuits | a | | | | | | |

| Session | Description of Topic | Contact hours | C-D-I-O | IOs | Reference |
|---|---|---|---|---|---|
| | **UNIT I: SEMICONDUCTOR DEVICES AND ITS APPLICATIONS** | 8 | | | |
| 1. | Construction andCharacteristics of DIAC, TRIAC, GTO,HEMT | 2 | C | 1 | 1,7 |
| 2. | LED, LCD characteristics, Tunnel diode, Schottky diode. | 2 | C | 1 | 3,4 |
| 3. | MOS as a charge transferring device-CCD,BBD | 1 | C | 1 | 2 |
| 4. | Analysis and Performance of L,C,LC,CLC filters ,series and shunt regulators | 2 | C | 5 | 3 |
| 5. | Switched mode power supply | 1 | C | 5 | 3 |
| | **UNIT II - SMALL SIGNAL ANALYSIS** | 10 | | | |
| 6. | Operating point of a BJT - Biasing circuits for BJT-Bias stability-Thermal runaway - Use of a heat sink | 2 | C | 2 | 3 |
| 7. | JFET – Biasing a JFET and MOSFET | 2 | C | 2 | 3 |
| 8. | CE,CB,CC amplifier,Hybrid model- Evaluation of H- parameters - Cascade – Darlington connection | 2 | C | 2 | 3 |
| 9. | Small signal equivalent circuits-Miller's theorem-boot-strapping | 2 | C | 2 | 4 |
| 10. | Small signal model – CS and CD amplifiers-problems | 2 | C | 2 | 3 |
| | **UNIT III - LARGE SIGNAL AMPLIFIERS** | 9 | | | |
| 11. | Classification of large signal amplifiers, Distortion in amplifiers | 1 | C | 2 | 6 |
| 12. | Frequency response of different coupling schemes | 2 | C | 2 | 3,7 |
| 13. | Determining efficiency of Class A amplifiers, Class B amplifier, push-pull amplifier | 2 | C | 2 | 3 |
| 14. | Class C-Single , Double-stagger tuned amplifiers-neutralization methods, Class D amplifier – Class S amplifier - | 2 | C | 2 | 3 |
| 15. | MOSFET power amplifier -Differential amplifiers: DC and AC analysis-CMRR, | 2 | C | 2 | 3,5 |
| | **UNIT IV - FEED BACK AMPLIFIERS AND OSCILLATORS** | 10 | | | |
| 16. | Feedback amplifiers – Barkhausen criterion- Stability –Distortion | 2 | C | 2 | 2,7 |
| 17. | Current - Voltage, series / shunt feedback amplifiers | 3 | C | 2 | 3,7 |
| 18. | Design and analysis of RC phase-shift oscillator. | 1 | C,D | 3 | 3,4 |

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| | | | | | |
|---|---|---|---|---|---|
| 19. | Design and analysis - Wien-bridge oscillator ,Hartely oscillator, | 2 | C,D | 3 | 3,4 |
| 20. | Design and analysis of Colpitt's oscillator and Crystal oscillators. | 1 | C | 3 | 3 |
| 21. | Working - Franklin, Armstrong and Twin T oscillators. | 1 | C | 3 | 3,4 |
| | **UNIT V – WAVE SHAPING CIRCUITS** | 8 | | | |
| 22. | RC wave shaping circuits- Clampers and Clippers | 1 | C | 3 | 3 |
| 23. | RC,RL-Integrator and Differentiator circuits-Storage, Delay and Calculation of Transistor Switching Times | 1 | C | 3 | 5 |
| 24. | Speed-up Capacitor -Voltage Multiplier | 1 | C | 3 | 5 |
| 25. | Multivibrators – Astable, Monostable | 2 | C | 3 | 3 |
| 26. | Bistable - Analysis of performance parameters of multivibrators | 1 | C | 3 | 3 |
| 27. | Schmitt trigger -UJT relaxation oscillators-Blocking Oscillators | 1 | C | 3 | 3 |
| 28. | Time base circuits – Voltage-Time base circuit, Current-Time base circuit | 1 | C | 3 | 3 |
| | Total contact hours | 45 | | | |

| LEARNING RESOURCES | |
|---|---|
| **Sl. No.** | **TEXT BOOKS** |
| 1. | Jacob. Millman, Christos C.Halkias, "Electronic Devices and Circuits", Tata McGraw Hill Publishing Limited, New Delhi, 2010. |
| 2. | Floyd, "Electronic Devices", Pearson Education Ltd", New Delhi, 2012 |
| | **REFERENCE BOOKS/OTHER READING MATERIAL** |
| 3. | Sedha.R.S, "A Text Book of Applied Electronics", Sultan Chand Publishers, 2008.. |
| 4. | TheodreF.Bogart,JeffreyS.Beasley&GuilermoRico,Electronic Devices & Circuits, Pearson education ltd", New Delhi,2013 |
| 5. | Malvino, "Electronic Principles", Tata McGraw Hill, 6th edition,2006. |
| 6. | Boylestad&Nashelsky, "Electronic Devices & Circuit Theory", Prentice Hall Of India (P) Ltd., Eighth edition, 2003. |
| 7. | Gupta.J.B, "Electron Devices and Circuits"- S.K.Kataria& Sons, 2012 |

| **Course nature** | | | | | | **Theory** | |
|---|---|---|---|---|---|---|---|
| **Assessment Method (Weightage 100%)** | | | | | | | |
| **In-semester** | **Assessment tool** | Cycle test I | Cycle test II | Cycle Test III | Surprise Test | Quiz | **Total** |
| | **Weightage** | 10% | 15% | 15% | 5% | 5% | 50% |
| | | | | | | **End semester examination Weightage :** | 50% |

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## UNIT - 2 - SMALL SIGNAL ANALYSIS

1) CE, CB, CC amplifier → Refer Notes

2) Hybrid model (H-Parameters) → Refer Notes

3) Cascaded, darlington Connection → Refer Notes.

4) Miller's theorem, Boot strapping → Refer Notes.

5) Biasing circuits, Bias stability, operating point → Refer N

6) Thermal runaway - heat sink → Refer notes.

7) JFET BIASING → R.S. Sedha Pg. No - 878-87

8) CS - CD amplifier → 892, 900 R.S. Sedha.

problems → 879 - 884 / 902 - 903
R.S. Sedha.

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## UNIT - 1 → Semiconductor devices & Applications

Refer notes Completely.

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6) Franklin, Armstrong oscillator → Refer notes.

7) Twin-T oscillator → [S. Salaivaharan - Pg. No: 607]

8) Barkhausen criterion → Refer notes

9) Current-Voltage, series-shunt feedback amplifier } → Refer notes

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UNIT-3 → LARGE SIGNAL AMPLIFIER

(A)
1) Class-A amplifier
2) Class-B amplifier
3) push pull amplifier
} → Refer notes

(B)
4) Class-C amplifier → S. Salaivaharan - Pg. No: 484
5) Class-D amplifier → S. Salaivaharan - Pg. No: 486
6) Class-S amplifier → S. Salaivaharan - Pg. No: 487

7) Tuned amplifier → R.S. Sedha Pg. No 839-843

8) MOSFET Power amplifier → S. Salaivaharan. Pg. No: 488

9) Differential amplifier DC analysis → Refer Notes
AC analysis → Refer Notes.

10) CMRR → Refer Notes.

11) Classification of Power amplifier → Refer Notes

12) Distortion in amplifier → Refer Notes.

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# ELECTRONIC DEVICES AND CIRCUITS

## UNIT-5 WAVE SHAPING CIRCUITS

1) Multivibrators (Astable, Monostable, Bistable) → Refer Notes
2) Clippers → Refer notes
3) Clampers → [Pg. No - 661, S. Salaivahanan]
4) Integrator and Differentiator circuits → Refer Notes
5) RC wave shaping circuits → Refer Notes.
6) Schimitt trigger → [S. Salaivahanan - Pg. No. 682-685]
7) UJT relaxation oscillators → Refer notes
8) Blocking oscillators → [S. Salaivahanan, Pg. No: 703]
9) Voltage and current time based circuit → [S. Salaivahanan, Pg. No. 7
10) Storage, Delay and Calculation of Transistor switching times, speed up capacitor } → Refer notes
11) Voltage Multiplier → Refer notes.

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## UNIT-4 FEEDBACK AMPLIFIER AND OSCILLATORS

1) RC phase-shift oscillator
2) Hartley oscillator } → Refer Notes
3) Wein Bridge oscillator → S. Salaivahanan 603-605
4) Colpitts oscillator → Refer notes
5) Crystal oscillator → Refer notes

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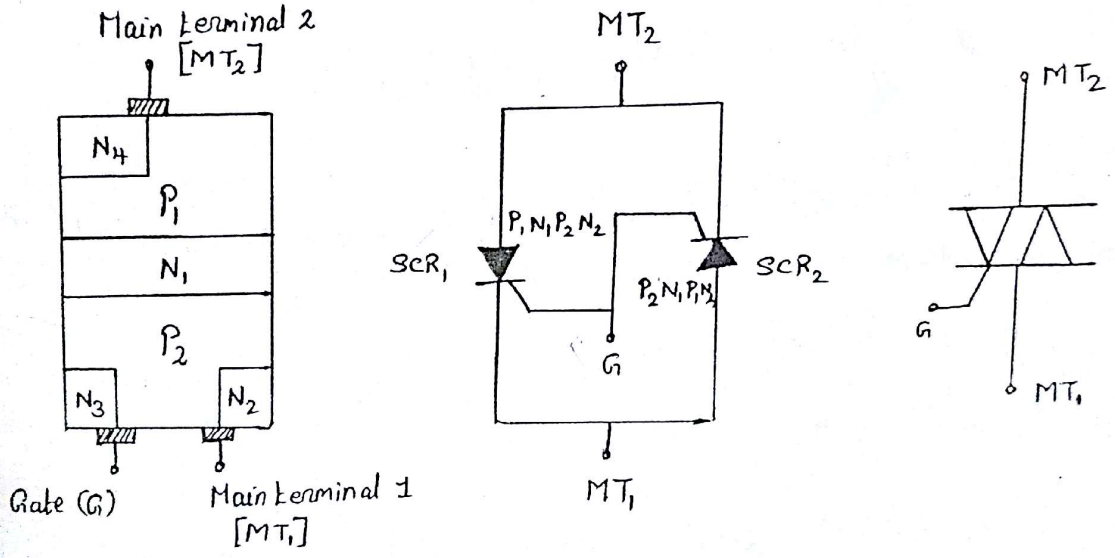
UNIT-1

# TRIAC

* TRIAC is nothing but Triode AC switch.
* It is four layer, three terminal device which conducts in both the direction, so it is called bidirectional device.
* This device is used to control AC power.

## CONSTRUCTION




BASIC STRUCTURE — ELECTRICAL EQUIVALENT CIRCUIT — SCHEMATIC SYMBOL

* The three terminals are $MT_1$, $MT_2$ and Gate.
* $MT_1$ is connected to $P_2$ and $N_2$
* Gate (G) is connected to $P_2$ and $N_3$
* $MT_2$ is connected to $P_1$ and $N_4$
* The construction looks like two SCR's connected in antiparallel.

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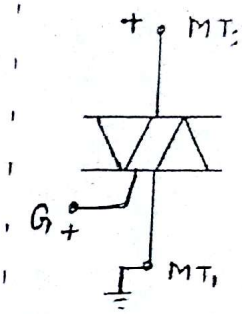
## WORKING

TRIAC operation can be explained in 4 modes.

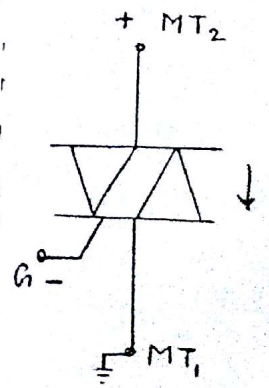
**MODE 1:** $MT_2$ is positive and Gate current is positive

* In this mode Main terminal 2 is given positive with respect to main terminal 1 and gate (G) is given positive current.
* Gate current flows through $P_2N_2$ junctions and forward biases the $P_2N_1$ junction
* Current flows through $P_1N_1P_2N_2$




**MODE 2:** $MT_2$ is positive and Gate current is Negative

* In this mode main terminal 2 is is given positive supply with respect to Main terminal 1 and gate (G) is given Negative current
* Gate current flows through $P_2N_3$ junction and forward biases the $P_2N_1$ junction
* Current flows through $P_1N_1P_2N_2$
* This mode is less sensitive compared to Mode 1

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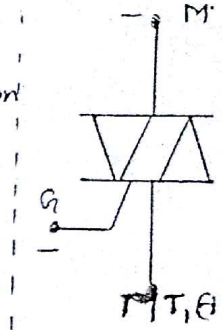
## MODE 3 : $MT_2$ is negative and gate current is negat

* In this mode Main terminal 2 is given negative supply with respect to main terminal 1 and gate is given negative current.

* Gate current flows $P_2N_3$ junction and forward biases the $P_1N_1$ junction, ~~which~~ due to injection of more electrons.

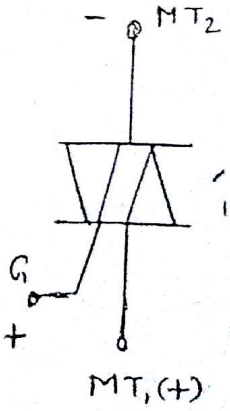



* Current flows through $P_2N_1P_1N_4$

* Since this mode has remote gate, the device is more sensitive at this mode.

## MODE 4 : $MT_2$ is negative and gate current is positive

* In this mode main terminal 2 is given negative supply with respect to main terminal 1 and gate is given positive current




* Gate current flows through $P_2N_2$ junction and forward biases the $P_1N_1$ junction.

* Current flows through $P_2N_1P_1N_4$

* In this mode the device is less sensitive.

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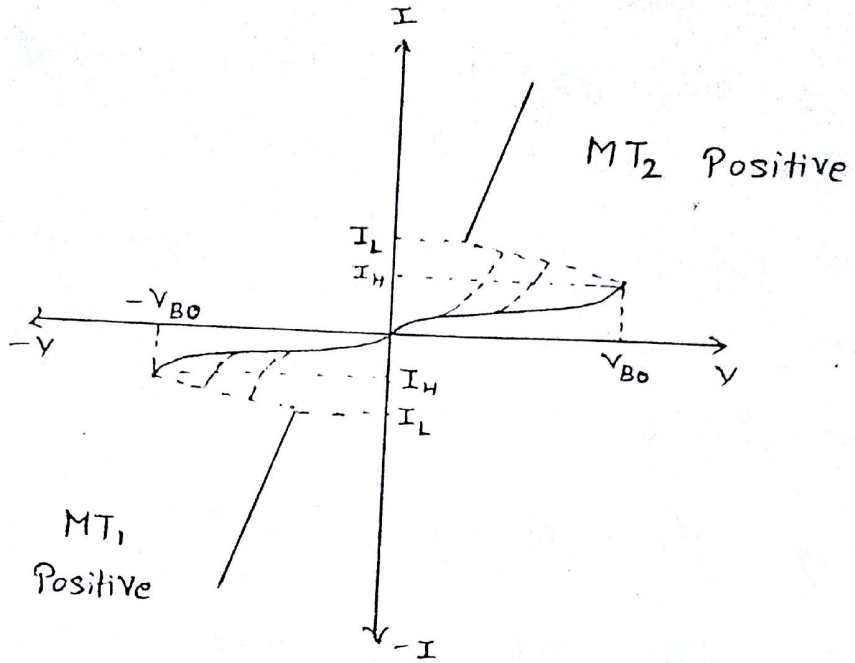
# V.I CHARACTERISTICS




* V.I characteristic of TRIAC is symmetrical both at Quadrant 1 and 3.
* As the applied voltage exceeds the breakover voltage, TRIA starts conducts on either side.
* As the gate current increases, the breakover voltage lower
* LATCHING CURRENT : It is the minimum value of current which it must attain during turn-ON process to maintain conduction when gate signal is removed.
* HOLDING CURREN : It is minimum value of current to be maintained, below which thyristor turns OFF.

## APPLICATIONS :

* Light dimming control
* Static switch for AC power application
* Heater control

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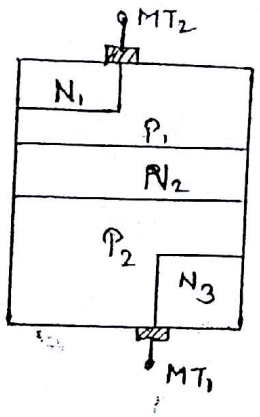
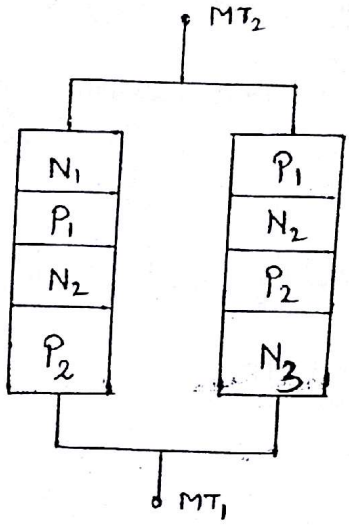
## DIAC

* DIAC is nothing but Diode AC Switch
* It is four layer two terminal device. Since the is no gate terminal, it is called as uncontrolled bidirectional device.

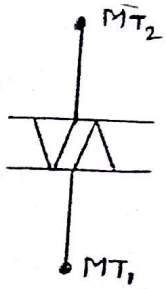
### CONSTRUCTION




BASIC STRUCTURE




EQUIVALENT CIRCUIT




SYMBOL

* Here the terminals are Maintermnal 1 and Main termin
* $MT_2$ is Connected between $N_1$ & $P_1$
* $MT_1$ is Connected between $N_3$ & $P_2$
* No terminal attached to the middle layer
* The three regions are identical in size
* The doping level at the two end P-layer is the Same same so that the device gives symmetrical switching Characteristics for either polarity of the applied voltage.

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## WORKING

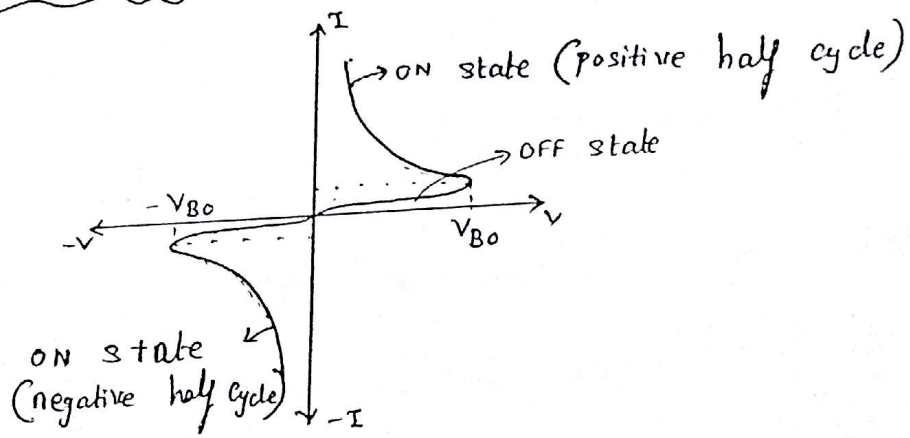
* When the terminal $MT_2$ is positive with respect to $MT_1$ the conduction takes place through $P_1 - N_2 - P_2 - N_3$

* When the terminal $MT_1$ is positive with respect to $MT_2$ the conduction takes place through $P_2 - N_2 - P_1 - N_1$

* When voltage is applied in either polarity, a small amount of leakage current flows.

* Once it reaches the breakover voltage, the current increases rapidly with reduction in voltage.

## V-I CHARACTERISTICS




* The V-I characteristic graph is symmetrical at Quadrant I.
* The characteristic shows negative resistance characteristic i.e. Voltage decreases with increase in current.
* It has high voltage drop.

## APPLICATION

* Triggering circuit for DIAC
* Heat control circuit.

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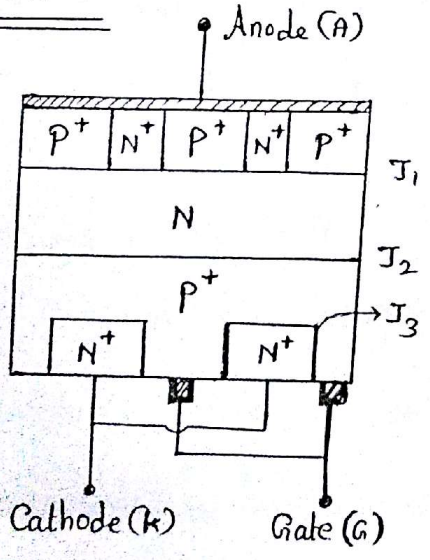
# GTO [GATE TURN-OFF THYRISTOR]

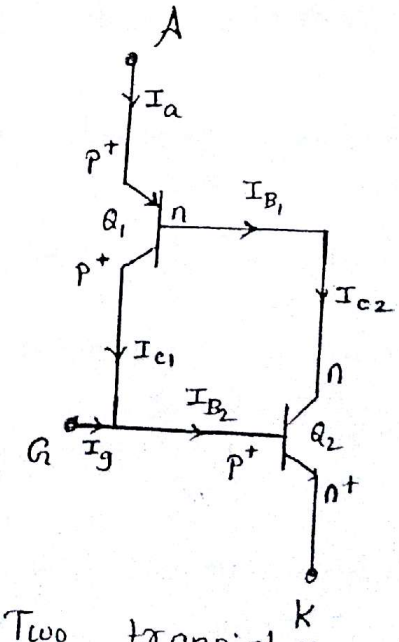
## INTRODUCTION

* In a conventional thyristors, once it turns ON it starts conducting even if the gate supply is remove
* To turn OFF special kind of commutation circuit is required.
* This difficulty is overcome by a special kind of thyristor called GTO.
* GTO turns on → Applying positive gate pulse
* GTO turns OFF → Applying Negative gate pulse

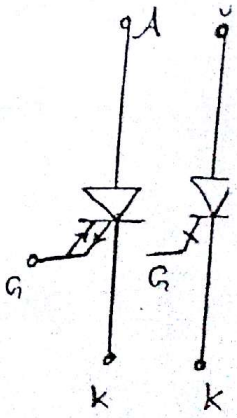
## CONSTRUCTION




Basic structure




Two transistor Analogy




SYMBOL

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* It is four layer, three terminal device
* In the anode side, highly doped $N^+$ material is pla alternatively which forms the anode short structure wh helps in fast turn OFF of the circuit.
* Gate terminal is placed very close to the cathode terminal which forms the inter digitized pattern whic helps in rapid conduction of silicon.
* GTO can be considered as a two transistor mode in addition to gate turn OFF mechanism.

## WORKING

### GATE TURN - ON

* When positive gate pulse is given, junction $J_2$ becomes forward biased.
* Since $J_1$ & $J_3$ are already forward biased due to anode ~~and~~ to cathode voltage, the conduction happen through $p^+ - N - p^+ - N^+$.
* Due to interdigitized structure, more conduction area is provided, so that GTO turns ON at faster rate.

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## GATE TURN OFF [GIVING NEGATIVE PULSE]

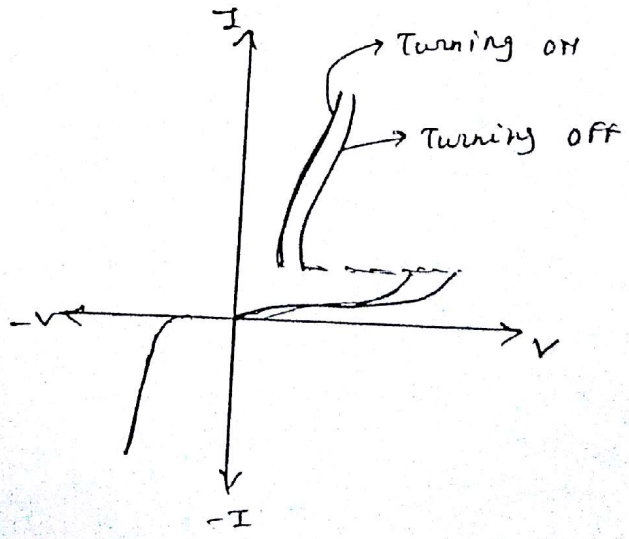
* Gate is given with negative pulse to turn OFF the device.

* When negative gate current is given excess of hole in the P-region are absorbed by the gate terminal, leaving the junction $J_2$ as a narrow filament under each cathode finger.

* Therefore the anode current path breaks down.

* current through $G_{ro}$ slowly decreases due to residu charges in the remote region of crystal.

## V-I CHARACTERISTICS




* Here reverse blocking voltage is less due to anode short structure.

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## ADVANTAGES

* Faster turn-off device
* Large current capability
* Elimination of commutating device

## DISADVANTAGES

* Latching and holding current values are high.
* ON-state voltage drop is high
* Gate current is more.

## APPLICATION

* High performance drive system like rolling mills,
* robotics and machine tools.
* Traction purpose
* Adjustable frequency inverter drive.

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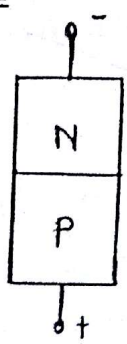
# TUNNEL DIODE

* The tunnel diode is a high conductivity, heavily dope two terminal P-N junction.

* The impurity concentration is about 1 part in $10^3$, a to this the depletion layer width is reduced considera

* Even a little amount of voltage is sufficient for the electrons to punching through the depletion layer instead of climing the potential barrier, and this phenom is called Tunneling.

## CONSTRUCTION:




BASIC STRUCTURE

SYMBOL

* Tunnel diodes made from germanium, gallium arsenide (or) gallium antimonide.

* Tunnel diode should be handled with great care, because they are low power device and can be easily damaged by heat and static electricity.

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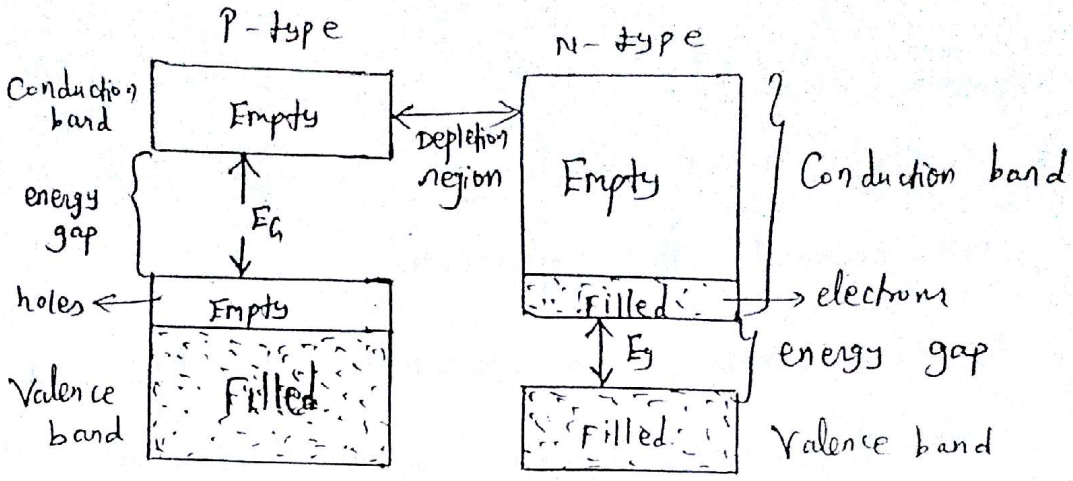
## WORKING




Energy band diagram of tunnel diode

* Due to the addition of more impurities to the P-type material, more numbers of holes will be generated which forms an empty layer in valence band of P-type material.

* Similarly, in N-type material more electrons will be generated which forms a filled layer in conduction band of N-type material.

* When small voltage is given across tunnel diode, potential barrier slightly reduces and electrons from N-type material starts tunneling through the depletion layer to the P-type material.

* The tunneling of electrons are due to the mechanism, called quantum mechanism of electrons. If this has to happen, it must satisfy two condition

  * The extra electron layer and extra hole layer must be at same height
  * Sufficient amount of electric field must be provided for tunneling

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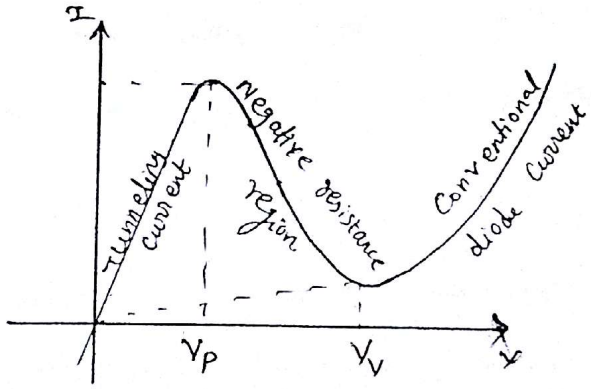
* If supply voltage increases, more and more tunnel happens till the peak voltage.
* Once peak voltage reaches, the potential barrier further decreases and height of empty and filled layer changes and tunneling of electrons starts reducing.
* It reduces till valley voltage.
* After valley voltage, the tunnel diode behaves like a normal diode.

V - I CHARACTERISTICS:




$V_P \rightarrow$ peak volt
$V_V \rightarrow$ Valley Vol

* Till $V_P$ - voltage, current increases → Tunneling current
* $V_P - V_V$ → Negative resistance region (∵ current ↓ with ↑ Volt
* $V > V_V$ → Conventional diode current.

ADVANTAGES

* High speed, low power device

DISADVANTAGE

* Less voltage range

APPLICATIONS

* ultra high speed switch, Amplifier, Microwave oscillator.

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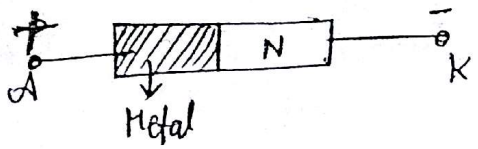
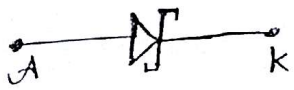
# SCHOTTKY DIODE

* Schottky diode is formed by joining N-type material with metal such as gold, silver or platinum.
* It is also called as hot carrier diode.
* Schottky diodes are specially used in high frequency applications where normal P-N junction diode fails to work

## CONSTRUCTION:




Basic structure




Symbol

* In schottky diode, anode is connected to the metal and cathode is connected to the N-type material.

## WORKING

* When Schottky diode is unbiassed, the electrons in the N-type material are at lower energy level where as electrons in the metal are at higher energy level which ~~come~~ creates a barrier called Schottky barrier.
* When it is biassed, the schottky barrier breaks down and electrons are plunged into the metal with large energy.
* Since there is no minority charge carriers, this diode can be brought to OFF condition at faster rate.

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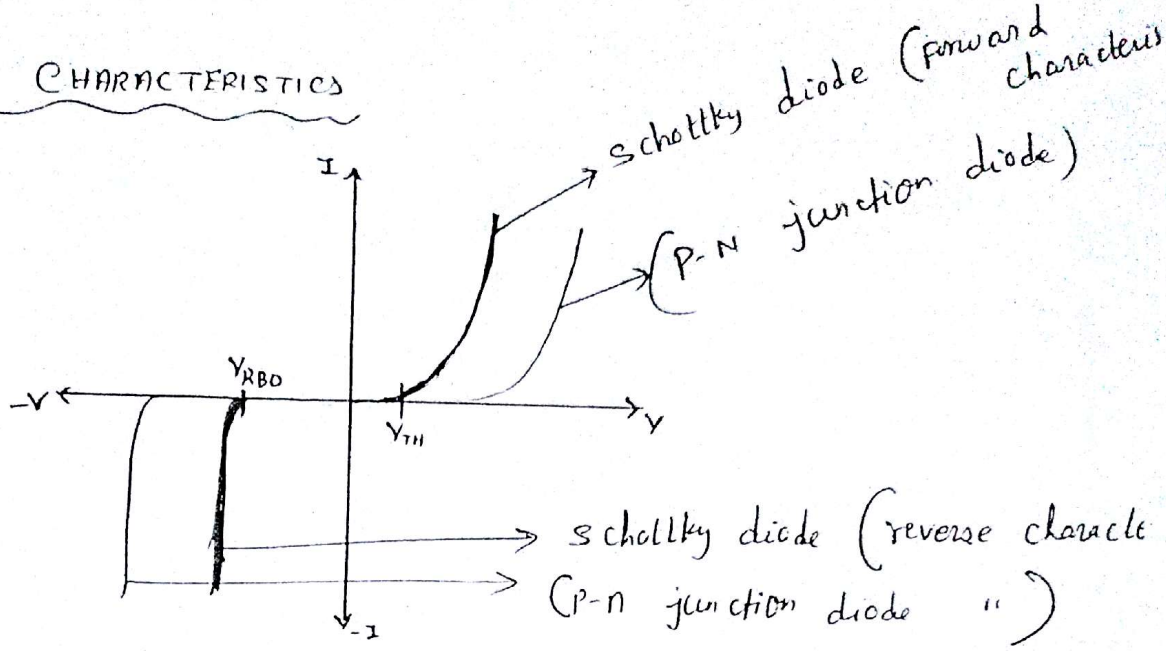
## V-I CHARACTERISTICS




* Compare to P-N junction diode, schottky diode conducts very faster.
* Its Reverse breakdown voltage is less compare to P-N junction diode

## ADVANTAGES

* It is an high frequency device.
* Forward resistance drop is less.

## DISADVANTAGES

* Its reverse leakage current is high.

## APPLICATIONS

* It is used in digital computers where fast process is required.
* Used in rectification of signals over the frequency of exceeding 300MHz.
* Clipping and Clamping circuits

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## LIGHT EMITTING DIODE [LED]

* Light emitting diode [LED] is a well known opto electronic device which emits light when forward biased by a phenomenon called electroluminescence.

* In a normal P-N junction diode, during recombination of electron-hole pair, the energy is given out as heat, whereas in LED, the energy is given out in the form of light.

* Mostly used semiconductors for LED are,
    * Gallium arsenide phosphide [GaAsP]
    * Gallium arsenide [GaAs]
    * Gallium phosphide [GaP]

* The above mentioned semiconductors has the photons of light energy which is sufficient to create a visible light source.

## CONSTRUCTION

* N-type semiconductor layer is grown on a substrate and a P-type is deposited on it by diffusion.

* Since carrier recombination takes place in the P-layer, is kept uppermost.

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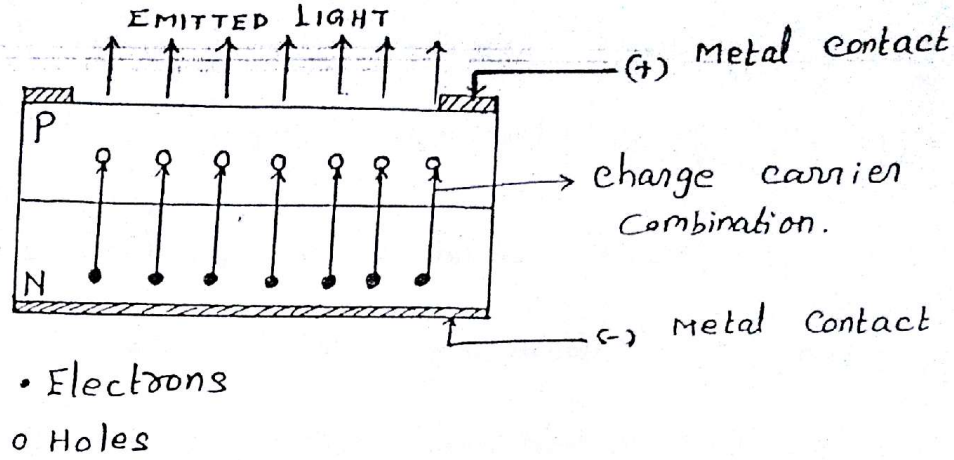
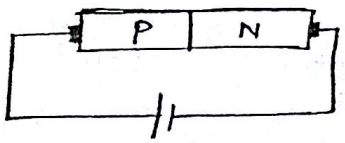
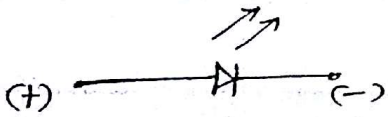
* Metal anode connections are made at the outer edges more central the P-layer so as to allow surface area for the light to escape.




## RECOMBINATION AND EMISSION OF LIGHT




LED under forward biasing




SYMBOL

**WORKING:**

* When the LED is forward biased, the electron and hol move towards the junction and recombination takes place. As result of recombination, the electrons lying in the Conductio band of N-region falls into the holes lying in the valence band of a P-region.

* The difference in energy leads to the emission of light

* Brighness of the light depends upon forward bias current.

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## CHARACTERISTICS

* LED radiate different colour such as red, green, yellow, orange and white.
* Some LED radiate infrared (invisible) light also.
* The wavelength of emitted light depends on the energy gap of the material.

Gallium arsenide (GaAs) → infrared radiation.
Gallium phosphide (GaP) → red (or) green
Gallium arsenide phosphide (GaAsP) → red (or) yellow.

* LED emit no light when reversed.
* LED operates at voltage levels from 1.5 to 3.3 V
* Power requirement is typically from 10 to 150 mW.

## APPLICATIONS

* burglar alarm systems
* Picture phones
* multimeters
* Calculators
* Digital meters
* Digital watches.

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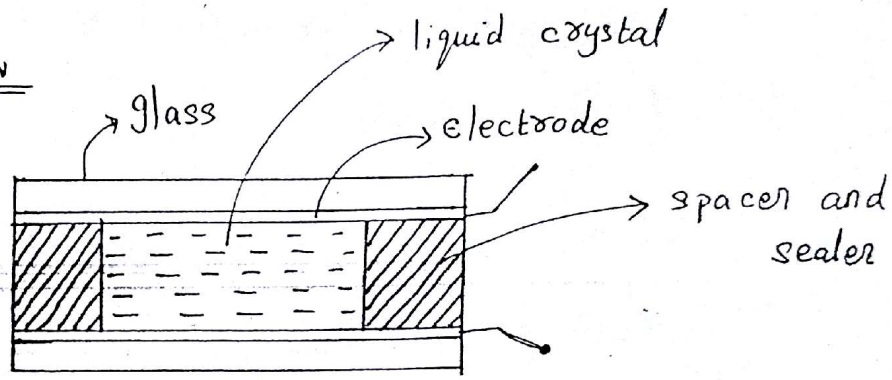
# LIQUID CRYSTAL DISPLAY (LCD)

Liquid crystals have been called the "fourth state of matter" because they have certain crystal properties normally found in solids, yet flow like liquids.

## BASIC CONSTRUCTION




BASIC CONSTRUCTION OF LCD

* A thin layer of liquid crystal, 10-20 μm thick, is sandwiched between two glass sheets
* To enable application of an electric field across the crystal a transparent conducting material is deposited on the inside surface of each glass sheet.
* Material used for electrode includes Tin-oxide ($SnO_2$) and Indium oxide ($In_2O_3$)
* The electrodes are etched in patterns or in individually accessible segments that can be selectively energized to develop a desired display.

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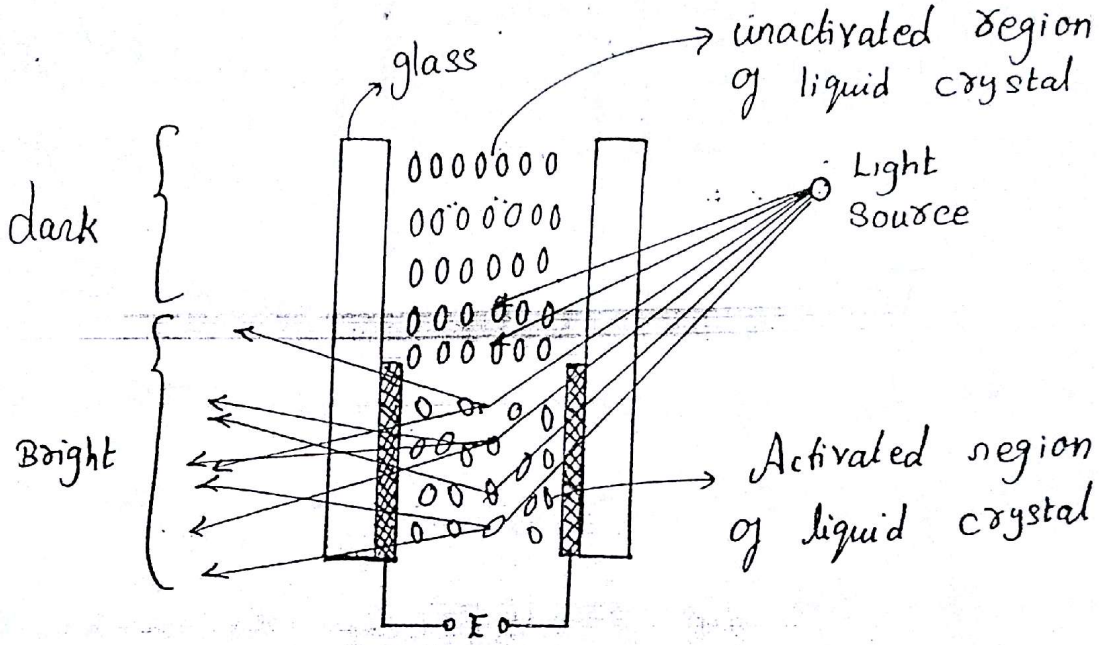
* There are two types of LCD displays
  * Dynamic scattering display
  * Field - effect display

## DYNAMIC SCATTERING DISPLAY




DYNAMIC - SCATTERING LCD IN TRANSMISSIVE MODE OPERATION

* In the activated region of liquid crystal, when light source falls on the scattered liquid crystals, it scatters the light in all direction and that particular area looks bright.
* Unactivated region looks dark, because it absorbs the light
* The molecules of energized area of the display become turbulent and scatters light in all directions.

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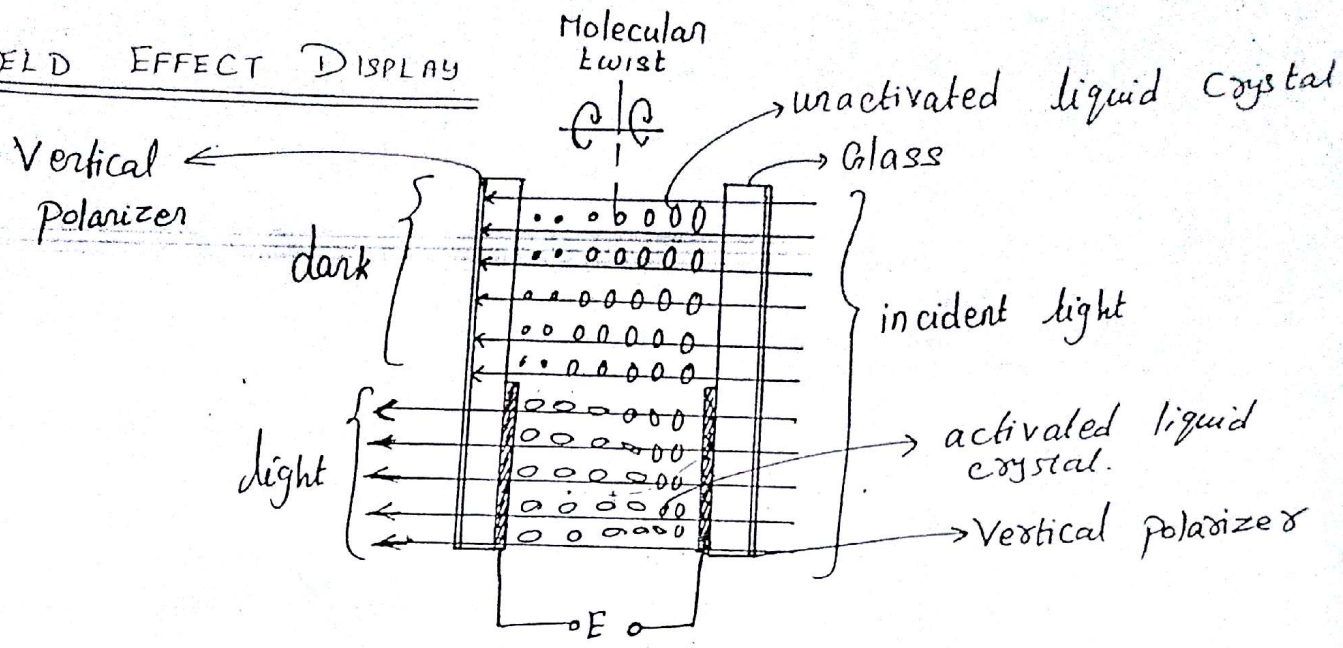
# FIELD EFFECT DISPLAY




## TWISTED - NEMATIC FIELD - EFFECT LCD

* In this type of LCD, the liquid crystals undergo 90° rotation from one side of the cell to the other.
* Consequently light undergoes 90° change in polarization when it passes through the crystals.
* Here, in the both sides, vertical polarizer is placed whi will allow only vertically polarized light.
* when light falls on the unactivated region, the light undergoes 90° twist and it transfers into horizontally polarize light and it strikes the vertical polarizer and this portion looks dark.
* when light falls on the activated liquid crystal, it doesn't undergoes any twist and it again strikes the vertical polar and passes through it, and this portion looks bright.

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## CHARACTERISTICS OF LCD

* LCD are very slow devices and have a turn-on th of few milliseconds.

* Less power consumption

* The electric field needed to activate LCD's is typically of the order of 1000 V/mm

* operating voltage range is 3-20 V.

## APPLICATIONS

* Computer and TV monitor

* Portable DVD player

* Digital display in electronic devices

—x—

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# OPTO COUPLERS

* An optocoupler is basically an interface between two circuits which operates at two different voltage lev

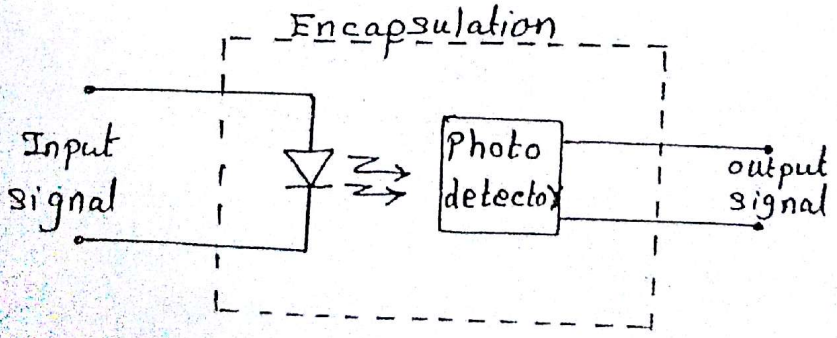
* With an optocoupler, the only contact between th input and the output is beam of light.

* The insulation resistance between two circuits will be around thousands of megaohms.

* Isolation like this is useful in high voltage applicat where the potential of two circuits may differ by sever thousands volts.

## CONSTRUCTION

* Optocoupler is a solid-state component in which the light emitter, the light path and the light dete are all enclosed with in the component.




Schematic representation of an optocoupler

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## CHARGE TRANSFER DEVICE [CTD]

* Charge transfer device is widely used in

  i) Shift registers
  ii) Imaging systems
  iii) Dynamic memories
  iv) High speed filtering

* There are two methods of constructing CTD

  a) Charge - Coupled device (CCD)
  b) Bucket Brigade device (BBD)

## CHARGE COUPLED DEVICE [CCD]

* A CCD can store and transfer analog signals, either electrons or holes which may be introduced electrically or optically

* The structure consists of a series of metal gate electrodes separated from P or N type silicon substrate by a thin silicon dioxide layer.

* On top of the silicon dioxide is an array of metallised electrodes which are connected to signal voltages $V_1$, $V_2$ and $V_3$

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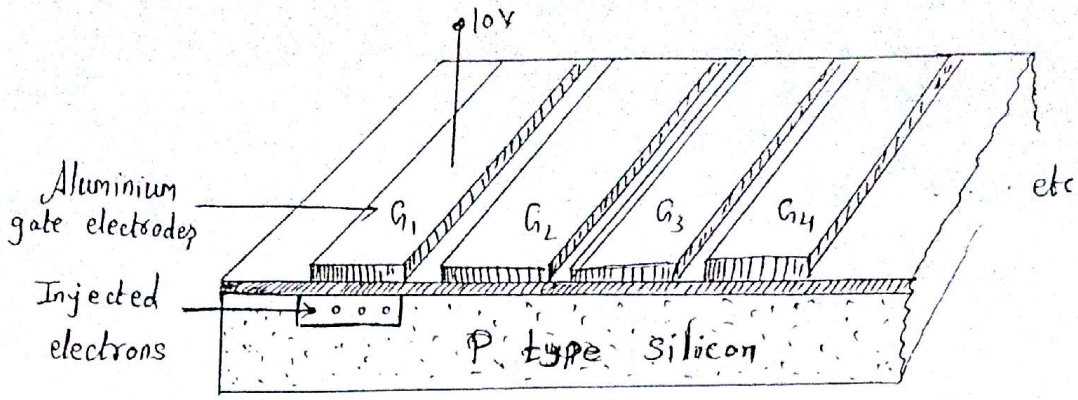
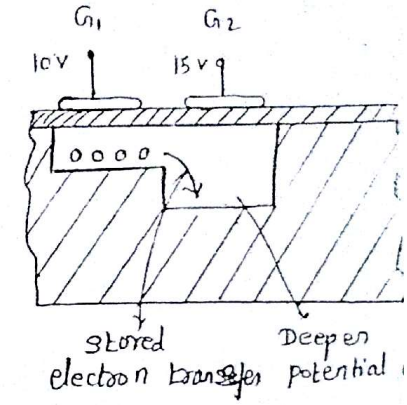
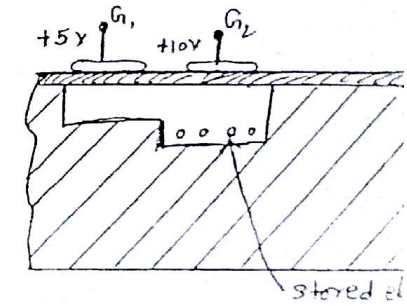


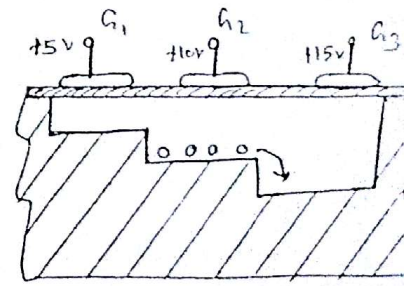

Basic Structure of CCD

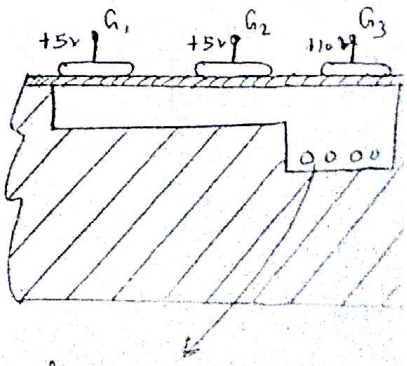
## WORKING

* Initially $G_1$ is given with 10 V DC supply, a depletion layer created in the P type substrate below $G_1$.
* In the depletion layer, the electrons are injected which act as a signal.
* Next, $G_2$ is given with 15V supply, a deeper potential well is created so that charge gets transferred below $G_2$
* Once charge gets transferred to $G_2$, $G_1$ Voltage is reduced to +5V and $G_2$ to 10 V
* Next $G_3$ is excited with 15 V and deeper potential well is created in P type substrate and charge gets transferred into that potential well which is below $G_3$ and Voltage to $G_1$ and $G_2$ is reduced to 5V and to $G_3$ is reduced to 10V




electrons temporarily stored before moving to

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* For effective operation following conditions must be satisfied.

(i) Series of clock pulse is given to the gate electrodes [15V - 10V - 5V - 15V]

(ii) Depletion layer must be overlap each other

(iii) The charge has to be transferred fast, otherwise an inversion layer is created which absorbs the charges and the information get lost. It must be transferred at the rate less than 1 ms.

## APPLICATIONS

* It can be used as as memories by storing charge.
* In solid-state imaging.
* CCD is used as a shift registers in digital computers.
* It is used in photo sensor arrays.

## ADVANTAGES

* CCD consumes less power and operates at high frequencies.

voltage is below $G_3$ and voltage to $G_1$ and $G_2$ is reduced to 5V and electrons temporarily

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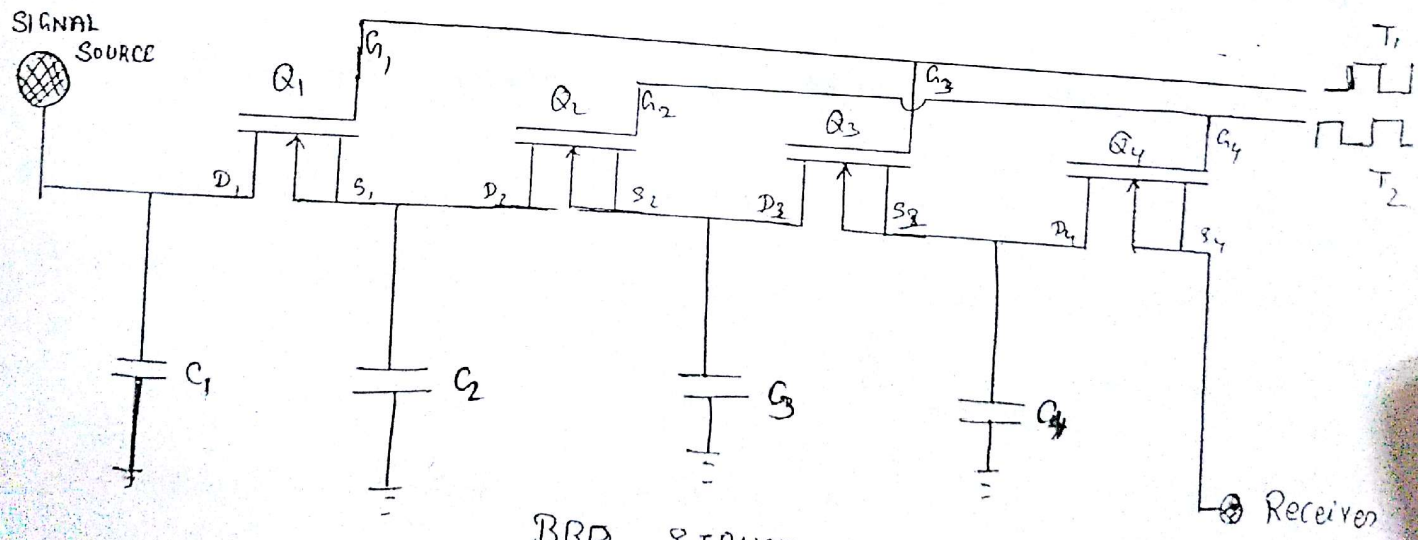
# BBD - BUCKET BRIGADE DEVICE

* Bucket Brigade Devices are formed by connecting a series of capacitors with switches.
* Generally the switches will be FET.
* BBD operates on the basis of charge transfer to the adjacent wells.

## CONSTRUCTION

* The BBD structure consists of a series of MOS transistor in which the drain of the first transistor acts as the source of the adjacent transistor and so on.




BBD STRUCTURE

* The signal from the source is initially stored in the capacitor $C_1$.
* The pulse from $T_1$ turns ON the switch $Q_1$ so charge gets transferred to $C_2$

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* Next pulse from $T_2$ turns ON switch $Q_2$ so the charge transfers to the $Q_2$

* This action repeats and the signal gets received at signal receiver.

CHARACTERISTICS

* BBD normally operates at lower maximum frequency than CCD because the transfer speed is limited.

* BBD have large cell area, fabrication process is relatively simple.

* BBDs are used in area such as audio delay lines to implement reverberation.

* BBD can transfer signal at a rate of 1 MHz.

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# Analysis And Performance Of Filters

## Introduction

* The output of the rectifier contains d.c. Component as well as a.c Component.
* Filter are used to minimize the undesirable a.c (i.e, ripple) leaving only the d.c. Component to appear at the output.

## Types

i) Inductor filter (L)
ii) Capacitor filter (C)
iii) LC (or) L-Section filter
iv) CLC (or) π-type filter

## Inductor Filter

* In this type of filter, the inductor has to be Connected in series with load resistance '$R_L$'.
* Inductor blocks AC Component (since inductor opposes Change in current) and allow only DC Component
* Inductor filter works more effectively when the the load current is high.

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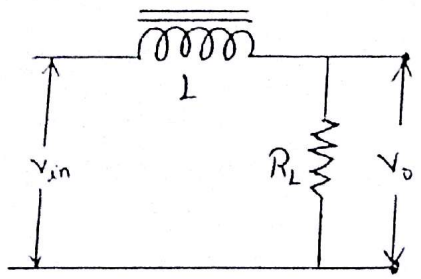
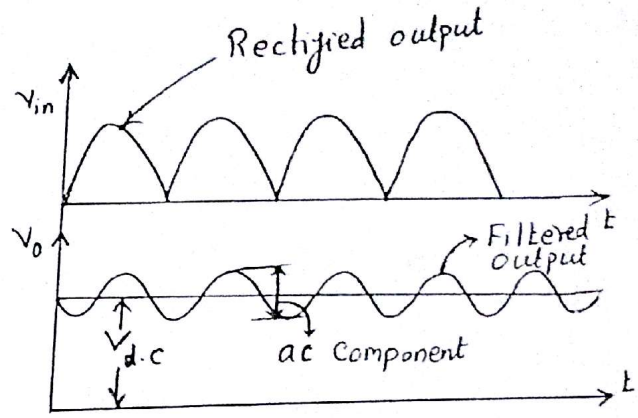
* In actual practice, the output voltage contains a small a.c component as well.

## DIAGRAM & O/P WAVEFORM




FILTER




I/P & O/P Waveform

## RIPPLE FACTOR ($\gamma$)

$$\gamma = \frac{\text{RMS Value of a.c Component}}{\text{DC Value of Component}} = \frac{I_{ac(rms)}}{I_{dc}}$$

* The output voltage $V_o$ can be written in the form of fourier series as,

$$V_o = \underbrace{\frac{2V_m}{\pi}}_{\text{dc Component}} - \underbrace{\frac{4V_m}{\pi}\left[\frac{1}{3}\cos 2\omega t + \frac{1}{15}\cos 4\omega t + \frac{1}{35}\cos 6\omega t + \cdots\right]}_{\text{ac Component}}$$

* In the above eqn higher term contributes lesser o/p

$$\therefore V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t.$$

$$\left[\because V_{rms} = \frac{V_m}{\sqrt{2}}\right.$$

$$I_{dc} = \frac{2V_m}{\pi R_L} \quad \Bigg| \quad \frac{4V_m}{\sqrt{2}\,3\pi\, Z} = \frac{4V_m}{\sqrt{2}\,3\pi\sqrt{R_L^2 + (2\omega L)^2}} = I_{ac(}$$

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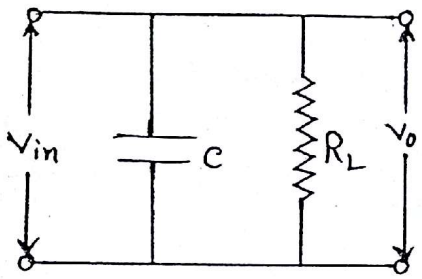
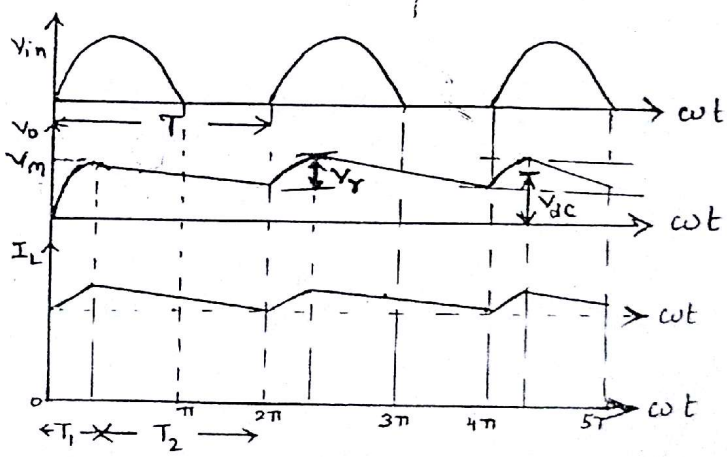
## SHUNT CAPACITOR FILTER :

* In this type of filter, a capacitor(C) is connected in parallel with load resistance ($R_L$).
* The property of the capacitor is that it allows a.c component and blocks d.c component.
* The capacitor filter short the a.c ripple to the ground and leave the d.c component to appears at the output.

## CIRCUIT DIAGRAM AND WAVEFORM OF HALFWAVE RECTIFER :




From wave form, $\boxed{V_{dc} = V_m - \frac{V_r}{2}}$

## RIPPLE FACTOR

$$\gamma = \frac{V_{ac(rms)}}{V_{dc}}$$

$$Q_{discharge} = I_{dc}\, T_2 \qquad \left[\because I = \frac{Q}{T},\ \frac{\text{charge}}{\text{Time}}\right]$$

$$Q_{charge} = V_r\, C \qquad \left[\because C = \frac{Q}{V}\right]$$

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$$\gamma = \frac{\dfrac{4V_m}{\sqrt{2}\,3\pi\sqrt{R_L^2 + 4\omega^2L^2}}}{\dfrac{2V_m}{\pi R_L}}$$

$$\cancel{\gamma = 2V_m}$$

$$\gamma = \frac{2}{3\sqrt{2}} \frac{R_L}{\sqrt{R_L^2 + 4\omega^2L^2}}$$

$$\gamma = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{1 + \dfrac{4\omega^2L^2}{R_L^2}}}$$

$$\gamma = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{\dfrac{4\omega^2L^2}{R_L^2}}} \qquad \left\{ \because \frac{4\omega^2L^2}{R_L^2} >> 1 \right.$$

$$\gamma = \frac{\sqrt{2}}{3} \frac{R_L}{2\omega L}$$

$$\boxed{\gamma = \frac{R_L}{3\sqrt{2}\,\omega L}}$$

Conclusion

* Ripple factor reduces with decrease in Load resistance.
* For high load current ripple factor is minimum for 'L' filter.

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$$\therefore \quad V_{ac\,(rms)} = \frac{\sqrt{2}\, I_{dc}\, X_{c1}\, X_{c2}}{X_L}$$

$$\gamma = \frac{V_{ac\,(rms)}}{V_{dc}} = \frac{\sqrt{2}\, \cancel{V_{dc}}\, X_{c1}\, X_{c2}}{R_L\, X_L\, \cancel{V_{dc}}}$$

$$\boxed{\gamma = \frac{\sqrt{2}\, X_{c1}\, X_{c2}}{R_L\, X_L}} \quad \left\{ \begin{array}{l} X_{c1} = \dfrac{1}{2\omega C_1} \; ; \; X_{c2} = \dfrac{1}{2\omega C_2} \\ X_L = 2\omega L \end{array} \right.$$

## CONCLUSION

* The filter provided a fairly smooth output and is characterized by a highly peaked diode currents and poor regulation

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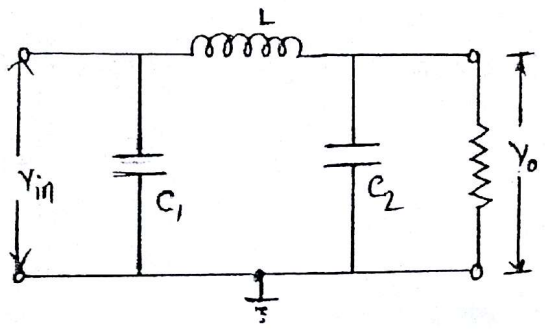
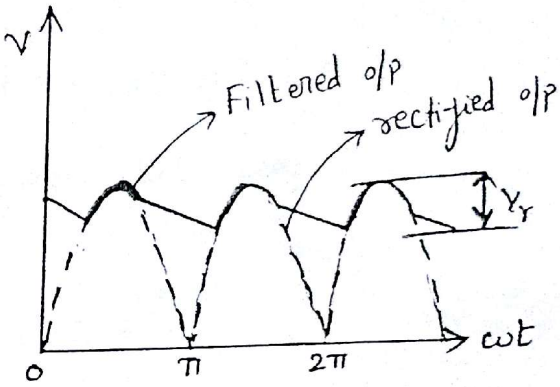
# CLC FILTER (π - FILTER)

* Here major part of filtering is accomplished by the input capacitor $C_1$. Most of the remaining ripple is removed by the L-section filter consisting of choke and capacitor $C_2$.

* Input capacitor $C_1$ offers very low reactance.




## RIPPLE FACTOR

Consider the fourier series of the triangular wave form.

$$v = V_{dc} - \frac{V_r}{\pi}\left(\sin 2\omega t + \frac{\sin 2\omega t}{2} + \frac{\sin 6\omega t}{3} + \cdots\right)$$

Eliminating high order terms.

$$v = V_{dc} - \frac{V_r}{\pi}\sin 2\omega t$$

Wkt,

$$V_r = \frac{I_{dc}}{2fC_1} \; ; \quad V_{rms} = \frac{V_r}{\pi\sqrt{2}} = \frac{I_{dc}}{2\pi f C_1\sqrt{2}} = \frac{\sqrt{2}\, I_{dc}}{4\pi f C_1}$$

$$V_{rms} = \sqrt{2}\, I_{dc}\, X_{C1} \quad \left\{ \because X_{C1} = \frac{1}{2\omega C_1} = \frac{1}{4\pi f C_1} \right.$$

Now $V_{rms}$ is applied to L-section filter, so the ripple voltage can be multiplied by $\frac{X_{C2}}{X_L}$

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The RMS Current that flows through the inductor 'L' is given by,

$$I_{rms} = \frac{4V_m}{3\pi\sqrt{2}\,X_L} = \frac{2 \times \overbrace{2V_m}^{V_{dc}}}{3\,\pi\,\sqrt{2}\,X_L}$$

$$\therefore \left\{ I_{rms} = \frac{\sqrt{2}}{3} \cdot \frac{V_{dc}}{X_L} \right\}$$

The ripple voltage across the capacitor will appe across the load.

$$\therefore V_{ac(rms)} = I_{rms} \cdot X_c$$

$$V_{ac(rms)} = \frac{\sqrt{2}}{3} V_{dc} \frac{X_c}{X_L}$$

Now,

$$\gamma = \frac{V_{ac(rms)}}{V_{dc}} = \frac{\frac{\sqrt{2}}{3} \cancel{V_{dc}} \frac{X_c}{X_L}}{\cancel{V_{dc}}}$$

$$\gamma = \frac{\sqrt{2}}{3} \frac{X_c}{X_L} \quad ; \quad X_c = \frac{1}{2\omega C} \quad ; \quad X_L = 2\omega L$$

$$\gamma = \frac{\sqrt{2}}{3} \frac{1}{(2\omega L)(2\omega C)} = \frac{\sqrt{2}}{3 \times 4\omega^2 LC}$$

$$\boxed{\gamma = \frac{1}{6\sqrt{2}\,\omega^2 LC}}$$

CONCLUSION

* Here ripple factor is independent of load resistance 'R'.

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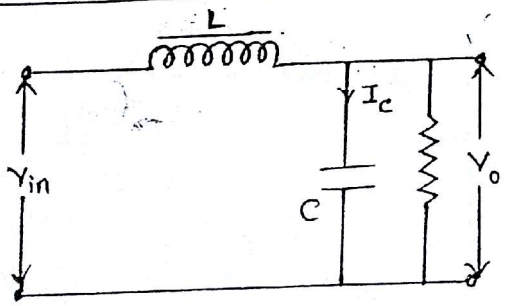
# LC FILTER [L-SECTION FILTER]

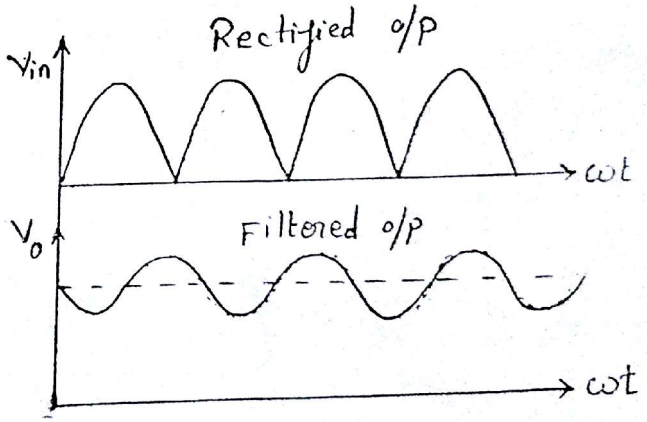
* In L-Section filter, inductor (L) is connected in ser with the load and capacitor (C) is connected in para with load.

* The inductive reactance ($X_L$) must be chosen higher com to capacitive reactance ($X_C$) and '$R_L$'

* The ac component is greatly blocked by $X_L$ and remaining fluctuation that remains in the current even after passing through the inductor are largely bypassed around the load by the shunt capacitor (since $X_L < R_L$)

## CIRCUIT DIAGRAM AND WAVEFORM




## RIPPLE FACTOR

From fourier series, the output voltage can be expressed as

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t$$

Here

$$V_{dc} = \frac{2V_m}{\pi}$$

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during steady state,

$$Q_{discharge} = Q_{charge}$$

$$\therefore \quad I_{dc} T_2 = V_r C$$

$$\frac{I_{dc}}{f} = V_r C \qquad \left\{ \begin{array}{l} \because \text{ Assume } T_2 \gg T_1 \\ T_1 + T_2 = T \; ; \; T_2 = T = 1/f \end{array} \right.$$

$$\boxed{V_r = \frac{I_{dc}}{fC}}$$

Since output voltage resembles triangular waveform, and the rms value of triangular wave form is given by

$$V_{ac(rms)} = \frac{V_r}{2\sqrt{3}} \qquad \Big| \qquad V_{ac(rms)} = \frac{I_{dc}}{2\sqrt{3}\, fC}$$

Also,

$$V_{dc} = I_{dc} R_L$$

$$\therefore \quad \gamma = \frac{\dfrac{\cancel{I_{dc}}}{2\sqrt{3}\, fC}}{\cancel{I_{dc}} R_L} = \frac{1}{2\sqrt{3}\, fCR_L}$$

$$\boxed{\gamma = \frac{1}{2\sqrt{3}\, fCR_L}}$$

For Full wave rectifier

$$\boxed{\gamma = \frac{1}{4\sqrt{3}\, fCR_L}} \qquad \left\{ \begin{array}{l} \text{Assume } T_2 \gg T_1 \\ \because \; T_1 + T_2 = T/2 \\ T_2 = T/2 = \frac{1}{2f} \end{array} \right\}$$

<u>CONCLUSION</u>

* The ripple may be decreased by increasing C or $R_L$.

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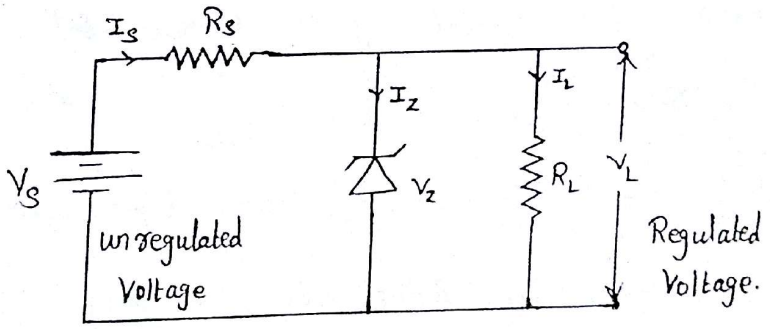
## VOLTAGE REGULATOR

A voltage regulator is a device which maintains const. dc output voltage regardless of changes in either its input voltage or its load current.

## TYPES OF VOLTAGE REGULATORS

1. Zener diode shunt regulator
2. Transistor shunt regulator
3. Transistor series regulator.

## ZENER DIODE SHUNT REGULATOR




* Here zener diode is connected in reverse bias with parallel to the supply voltage.

* When zener diode operates under zener break down voltage, it acts as a voltage regulator.

* For effective operation, supply voltage '$V_S$' must be greater than Zener breakdown voltage, $V_Z$.

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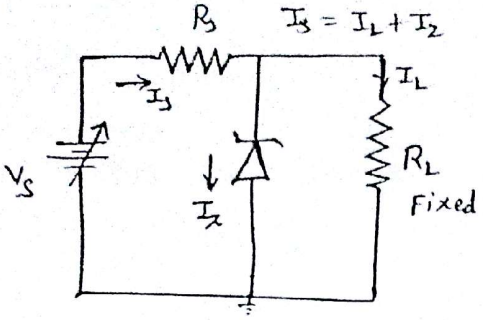
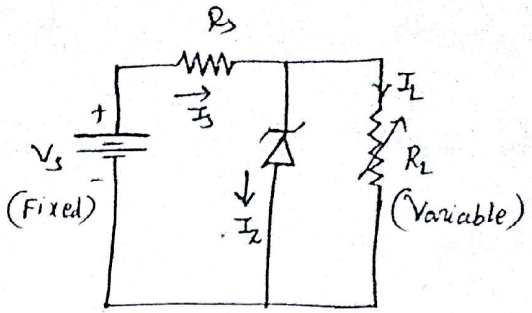
## WORKING




(a) Varying input Voltage




(b) Varying load resistance.

### Regulation with Varying input Voltage:

* When input voltage increases, input current ($I_S$) also increase
* This increase in current increases the current through Zener diode ($I_Z$) and keeps $I_L$ and $V_L$ Constant.
* This increase in current gets compensated across ~~Source~~ series resistance '$R_S$'.
* When input voltage decreases, the drop across '$R_S$' decreases, so that $I_Z$ decreases keeping $V_L$ & $I_L$ Constant

### Regulation with Varying load resistance, $R_L$: $\{I_S = I_L + I_Z\}$

* When load resistance '$R_L$' is ~~varied~~ decreased keeping '$V_S$' Constant, $I_L$ increases so that $I_Z$ decreases which maintain the the series resistance drop and $V_S$ Constant which inturn maintains '$V_L$' Constant
* When load resistance '$R_L$' is increased, $I_L$ decreases so that $I_Z$ increases, maintaining series resistance drop and $V_S$ Constant, Maintaining $V_L$ Constant.

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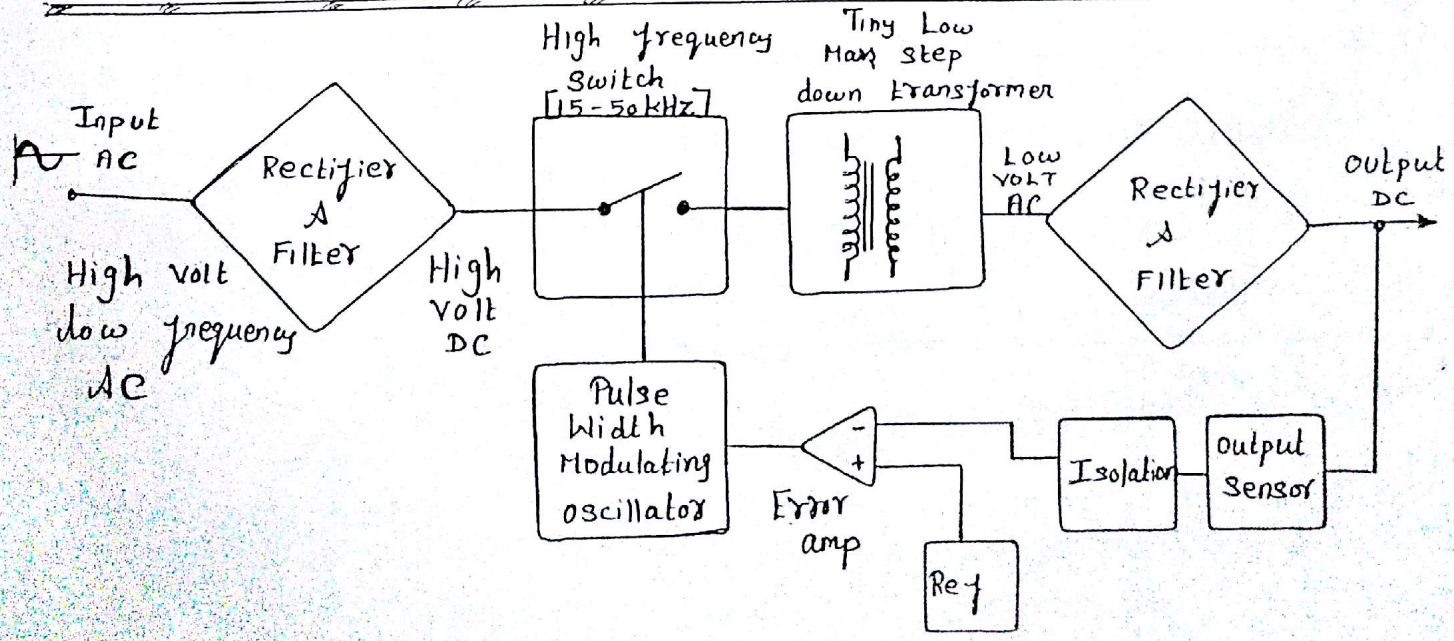
# SWITCHED MODE POWER SUPPLY [SMPS]

* The main feature of SMPS is that elimination of Massive transformer.
* It is smaller, lighter package and reduced manufactu cost.
* Switching regulator acts as a continuously variable po Converter and hence its efficiency is high compared with linear regulators.
* In a switching power supply, the device that provi regulation is always operated in a switched mode.
* The input DC is chopped at high frequency of 15 to 50 kHz

## BLOCK DIAGRAM OF SWITCHING POWER SUPPLY




BLOCK DIAGRAM OF SMPS

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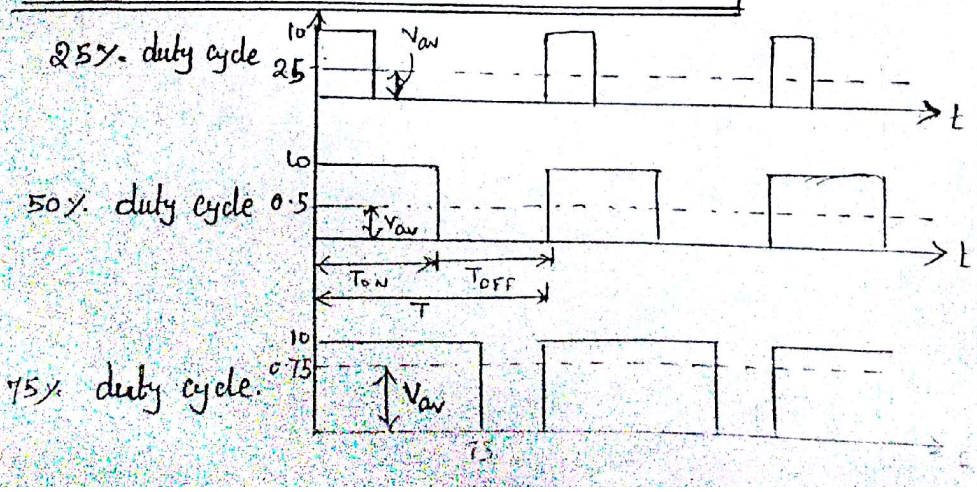
## EXPLANATION

* The high voltage AC with 50 Hz frequency is recti, and filtered which gives high voltage DC as the
* This high voltage DC is chopped at high frequen (50 to 15 kHz) using high frequency switches like MOSFET, SCR, BJT, etc.
* The chopped DC voltage is again given to high frequency tiny transformer (step down) which gives low voltage AC as the o/p
* This o/p is again given to rectifier and filter unit which gives the required DC output.
* If o/p voltage varies, it is sensed by sensor unit and it is given to error amplifier where refere voltage is given to non-inverting terminal.
* The o/p of the ~~triggering~~ error amplifier is given to PWM oscillating circuit which feeds the triggering pulse to the high frequency switches.

## PWM [PULSE WIDTH MODULATION]




* If ON time is more average volt is more
* If ON time is less average voltag is less.

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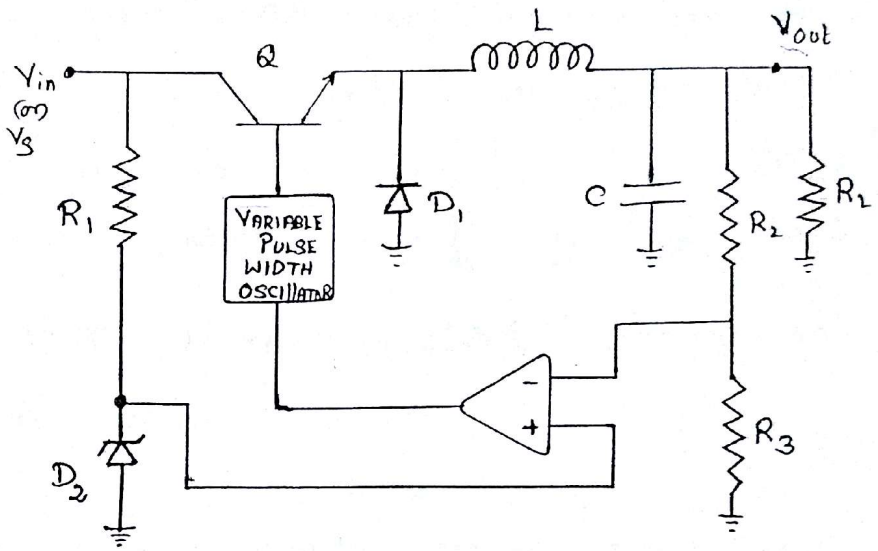
## TYPES OF SMPS

Basically switching regulator can be of two types

i) Step-down switching regulator [Buck Regulator]

ii) Step-up switching regulator [Boost Regulator]

## STEP DOWN SWITCHING REGULATOR




* Step down switching regulator (or) buck regulator is used to regulate the output voltage, below supply voltage.

### CASE i "Transistor is ON"

* Here transistor is operated under saturation region.

* A series of pulse is given to the transistor base to switch ON and OFF the transistor.

* During ON time, the current flows through the ~~diode~~ inductor and charges the capacitor to the value of output voltage.

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* During this time, the diode $D_1$ is reverse bias and magnetic field expands across the inductor.

CASE ii : "Transistor is OFF"

* During OFF condition, Q is cut-off and acts like an open switch.
* The magnetic field in the inductor collapses and induc Voltage which makes the current to flow through the circuit.
* Diode $D_1$ is forward biased.
* Capacitor C discharges through the load.

CONCLUSION

* When output voltage reduces, the ON time of the pulse is more which makes the capacitor to charge for more time, further increases the output voltage.

* When output voltage increases, the OFF time is more which makes the capacitor to discharge for more time, further decreases the output voltage.

$$\therefore \left\{ V_{out} = V_s \left[ \frac{T_{ON}}{T} \right] \right\}$$

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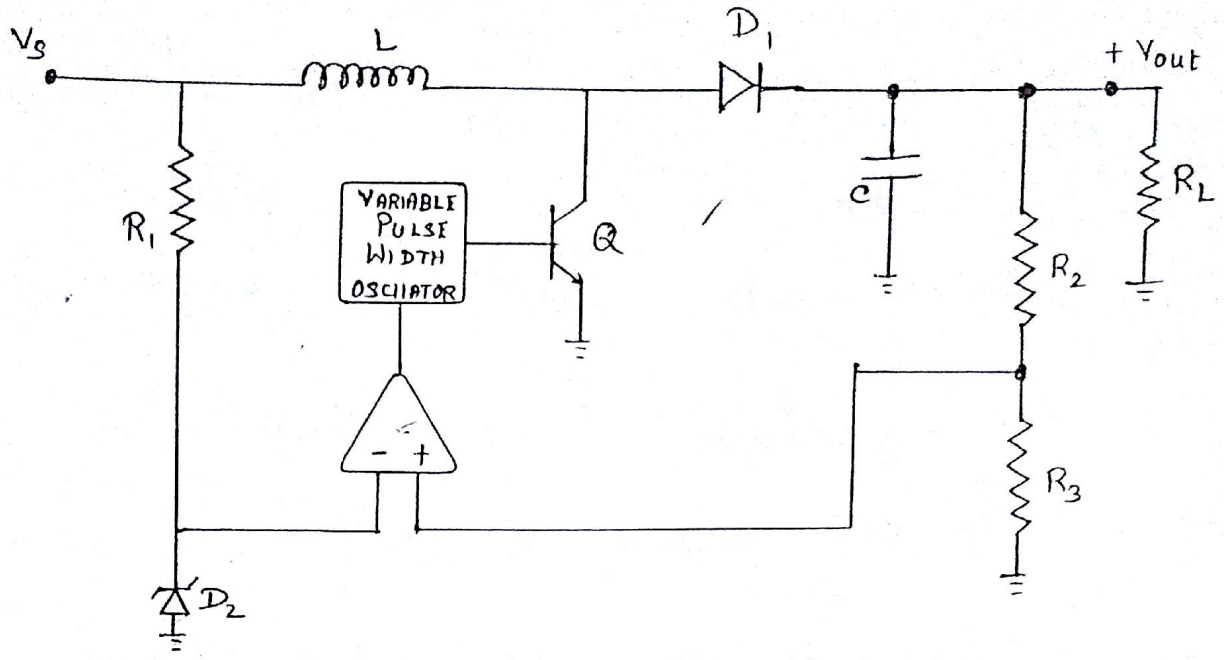
# STEP-UP SWITCHING REGULATOR




* Step up switching regulator are used to regulate the output voltage more than the supply voltage.

## CASE i - Transistor is ON

* When transistor is ON, the magnatic field in the inductor L expands. Which stores more energy.
* Since switch 'Q' is in Conducting state current will not flow through '$D_1$'
* During this period, the ~~output~~ ~~Voltage~~ current through $R_L$ will be taken care by the capacitor.

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## TRANSISTOR IS OFF.

* When transistor is OFF, the magnetic field in the inductor collapses and induces an emf which gets added with supply voltage.
* This additional voltage charges the capacitor to the maximum voltage.
* Due to this the output voltage gets increased above supply voltage 'Vs'

## CONCLUSION

* When ON time is more the average voltage is more, because the energy stored in the inductor is more.
* When off time is more the average voltage is less, because the energy stored in the inductor is less.

$$\left\{ V_0 = V_S \Big/ \left[ \frac{T_{OFF}}{T} \right] \right\}$$

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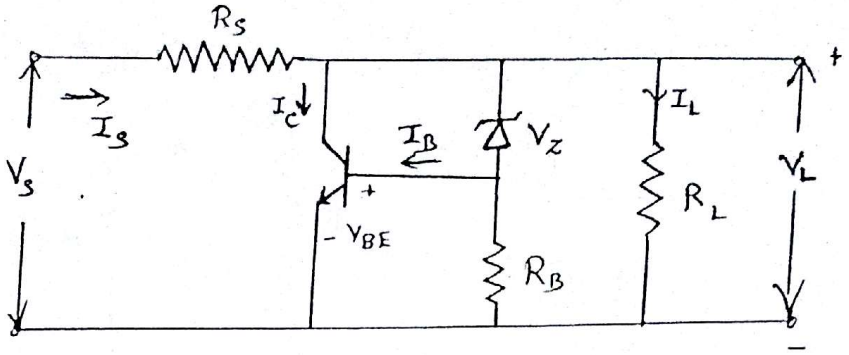
# TRANSISTOR SHUNT REGULATOR




* Since transistor switch is parallel to the supply voltage it is called as transistor shunt regulator.

* From the circuit, it is understood that load voltage is equal to the sum of $V_Z$ and $V_{BE}$

$$\therefore \boxed{V_L = V_Z + V_{BE}}$$

* If supply voltage $V_S$ increases, ultimately load voltage $V_L$ also increases which inturn increases $V_{BE}$, so that Base current increases which increases the collector current $I_C$, so that $I_S$ also increases which increases the drop across $R_S$ and maintains the output voltage $V_L$ constant.

$$\therefore \boxed{V_S = I_S R_S + V_L}$$

$$V_S \uparrow \rightarrow V_L \uparrow \rightarrow V_{BE} \uparrow \rightarrow I_C \uparrow \rightarrow V_{RS} \uparrow \rightarrow V_L \downarrow$$

* Similarly, If supply voltage decreases $V_{BE}$ decreases, which decreases the $I_C$ so that drop across $R_S$ decreases which maintains the output voltage constant

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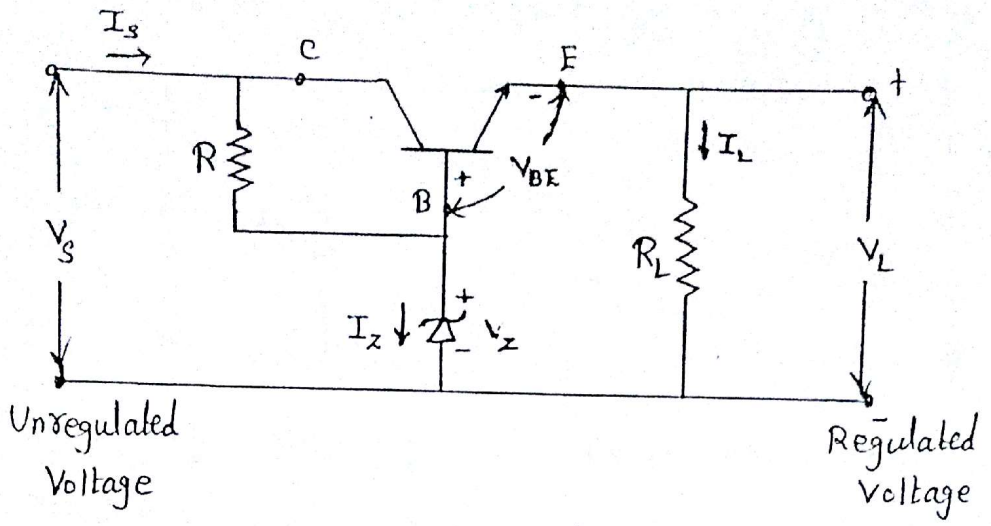
# TRANSISTOR SERIES REGULATOR




* Since transistor is connected in series with load, it is called as transistor series regulator.
* This circuit is also called as emitter follower (since its resistance varies with base current $I_B$)
* Here, $V_L = V_Z - V_{BE}$
* If load resistance increases, $I_L$ decreases which increases the drop across resistance $R_L$ (i.e, $V_L$), so that $V_{BE}$ decreases because the zener voltage is fixed. So that the conduction of the transistor is slightly blocked so that the output voltage is maintained constant
* The same thing happens if the output voltage decrea which increases the $V_{BE}$ so that transistor conduction increases which maintains the output voltage constant.

$$V_L \downarrow \rightarrow V_{BE} \uparrow \rightarrow I_E \uparrow \rightarrow I_L \uparrow \rightarrow V_L \uparrow$$

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