BMS INSTITUTE OF TECHNOLOGY AND MANAGEMENT

Department of Electronics and Communication Engineering

POWER ELECTRONICS AND INSTRUMENTATION_18EC36

B. E. (EC / TC) Choice Based Credit System (CBCS) and Outcome Based Education (OBE) SEMESTER – III			
POWER ELECTRONICS AND INSTRUMENTATION			
Course Code	**18EC36**	**CIE Marks**	**40**
Number of Lecture Hours/Week	**03**	**SEE Marks**	**60**
Total Number of Lecture Hours	**40 (8 Hours/ Module)**	**Exam Hours**	**03**
CREDITS – 03			

Course Learning Objectives: This course will enable students to:

- Study and analysis of thyristor circuits with different triggering conditions.
- Learn the applications of power devices in controlled rectifiers, converters and inverters.
- Understand types of instrument errors.
- Develop circuits for multirange Ammeters and Voltmeters.
- Describe principle of operation of digital measuring instruments and Bridges.
- Understand the operation of Transducers, Instrumentation amplifiers and PLCs.

Module-1	RBT Level
Introduction: History, Power Electronic Systems, Power Electronic Converters and Applications (**1.2, 1.3 1.5 & 1.6 of Text 1).** **Thyristors:** Static Anode-Cathode characteristics and Gate characteristics of SCR, Turn-ON methods, Turn-OFF mechanisms(**2.3, 2.6 without 2.6.1), 2.7, 2.9 of text 1**), Turn-OFF Methods: Natural and Forced Commutation – Class A and Class B types (**refer 2.10 without design considerations**), Gate Trigger Circuit: Resistance Firing Circuit, Resistance capacitance firing circuit (**refer 3.5 upto 3.5.2 of Text 1**), Unijunction Transistor: Basic operation and UJT Firing Circuit (**refer 3.6, upto 3.6.4, except 3.6.2**).	**L1, L2**

Module-2	
Phase Controlled Converter: Control techniques, Single phase half wave and full wave controlled rectifier with resistive and inductive loads, effect of freewheeling diode (**refer Chapter 6 of Text 1 upto6.4.1 without derivations**). **Choppers:** Chopper Classification, Basic Chopper operation: step-down, step-up and step-up/down choppers. (**refer Chapter 8 of Text 1upto 8.3.3**)	L1,L2, L3
Module-3	
Inverters: Classification, Single phase Half bridge and full bridge inverters with R and RL load (**refer Chapter 9 of Text 1 upto 9.4.2 without Circuit Analysis**). **Switched Mode Power Supplies**: Isolated Flyback Converter, Isolated Forward Converter(**only refer to the circuit operations in section 16.3 of Text 1upto 16.3.2 except 16.3.1.3 and derivations**). **Principles of Measurement:** Static Characteristics, Error in Measurement, Types of Static Error. (Text 2: 1.2-1.6) Multirange Ammeters, Multirange voltmeter. (Text 2: 3.2, 4.4)	L1,L2, L3

Module-4	
Digital Voltmeter: Ramp Technique, Dual slope integrating Type DVM, Direct Compensation type and Successive Approximations type DVM (Text 2: 5.1-5.3, 5.5, 5.6) **Digital Multimeter:** Digital Frequency Meter and Digital Measurement of Time, Function Generator. **Bridges:** Measurement of resistance: Wheatstone's Bridge, AC Bridges-Capacitance and Inductance Comparison bridge, Wien's bridge. (Text 2: refer 6.2, 6.3 upto 6.3.2, 6.4 upto 6.4.2, 8.8, 11.2, 11.8-11.10, 11.14).	**L1, L2**
Module-5	
Transducers: Introduction, Electrical Transducer, Resistive Transducer, Resistive position Transducer, Resistance Wire Strain Gauges, Resistance Thermometer, Thermistor, LVDT. (Text 2: 13.1-13.3, 13.5, 13.6 upto 13.6.1, 13.7, 13.8, 13.11). Instrumentation Amplifier using Transducer Bridge, Temperature indicators using Thermometer, Analog Weight Scale (Text 2: 14.3.3, 14.4.1, 14.4.3). **Programmable Logic Controller:** Structure, Operation, Relays and Registers (Text 2: 21.15, 21.15.2, 21.15.3, 21.15.5, 21.15.6).	**L1,L2, L3**

Course Outcomes: At the end of the course students should be able to:

- Build and test circuits using power electronic devices.
- Analyze and design controlled rectifier, DC to DC converters, DC to AC inverters and SMPS.
- Define instrument errors.
- Develop circuits for multirange Ammeters, Voltmeters and Bridges to measure passive component values and frequency.
- Describe the principle of operation of Digital instruments and PLCs.
- Use Instrumentation amplifier for measuring physical parameters.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

Text Books:

1. M.D Singh and K B Khanchandani, Power Electronics, 2nd Edition, Tata Mc-Graw Hill, 2009, ISBN: 0070583897

2.H. S. Kalsi, "Electronic Instrumentation", McGraw Hill, 3rd Edition, 2012, ISBN: 9780070702066.

Reference Books:

1. Mohammad H Rashid, Power Electronics, Circuits, Devices and Applications, 3rd/4th Edition, Pearson Education Inc, 2014, ISBN: 978-93-325-1844-5.
2. L. Umanand, Power Electronics, Essentials and Applications, John Wiley India Pvt. Ltd, 2009.
3. David A. Bell, "Electronic Instrumentation & Measurements", Oxford University Press PHI 2nd Edition, 2006, ISBN 81-203-2360-2.
4. A. D. Helfrick and W.D. Cooper, "Modern Electronic Instrumentation and Measuring Techniques", Pearson, 1st Edition, 2015, ISBN: 9789332556065.

Students will be able to		
CO1	Apply the concepts of mathematics and electronic principles in the design of electronic circuits	PO1
CO2	Analyze the working principle of electronic circuits for its application	PO2
CO3	Design the electronic devices based upon the given specification	PO3
CO4	Present in a team, the technical aspects of electronic devices used in real time applications	P08,PO9, 10,12

Module-1

- Introduction: History, Power Electronic Systems, Power Electronic Converters and Applications **(1.2, 1.3 1.5 & 1.6 of Te**
- Thyristors: Static Anode-Cathode characteristics and Gate characteristics of SCR, TurnON methods, Turn-OFF mechanisms**(2.3, 2.6 without 2.6.1), 2.7, 2.9 of text 1)**
- Turn-OFF Methods: Natural and Forced Commutation – Class A and Class B types **(refer 2.10 without design considerations)**
- Gate Trigger Circuit: Resistance Firing Circuit, Resistance capacitance firing circuit **(refer 3.5 upto 3.5.2 of Text 1)**
- Unijunction Transistor: Basic operation and UJT Firing Circuit **(refer 3.6, upto 3.6.4, except 3.6.2)**

Concept of Power Electronics

➢Power electronics belongs partly to power engineers & partly to electronic engineers.

Power electronics

Power engineering

Power engineering is mainly concerned with generation, transmission, distribution & utilization of electric energy at high frequency.

Based mainly on electromagnetic principles.

e.g. -semiconductor power switches such as thyristor, GTOs etc. work on the principle of movement of holes an electrons.

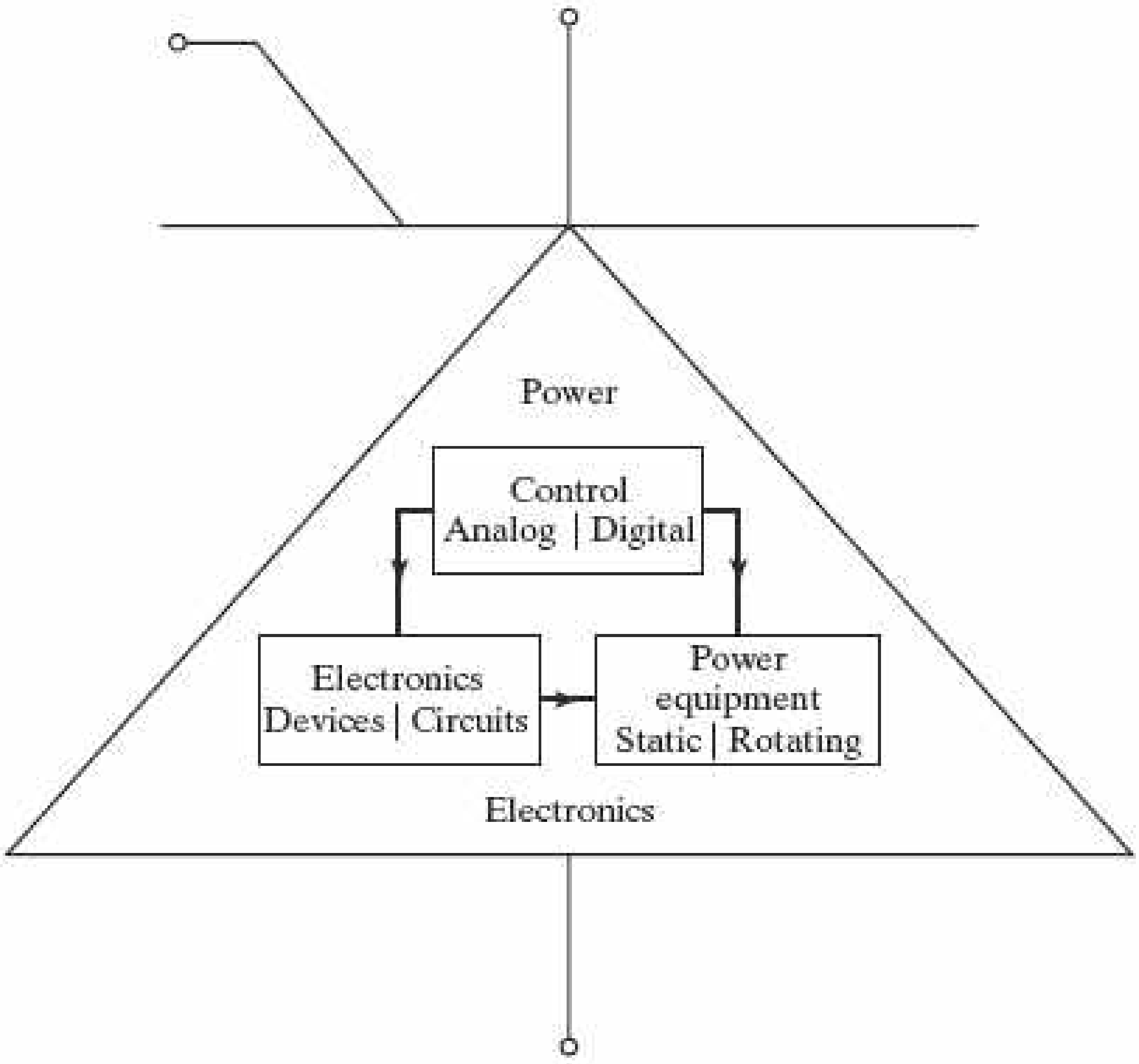
Electronics engineering

Electronics engineering is guided by distortionless production, transmission and reception of data & signals of vary low power levels of order of a few watts , or milliwatts without much consideration to the efficiency.

Based upon physical phenomena in vacuum, gases/ vapours & semiconductors.

e.g. –diodes, mercury-arc rectifier and thyratrons (gas-filled triode),high-power level devices that is based on physical phenomena in gases and

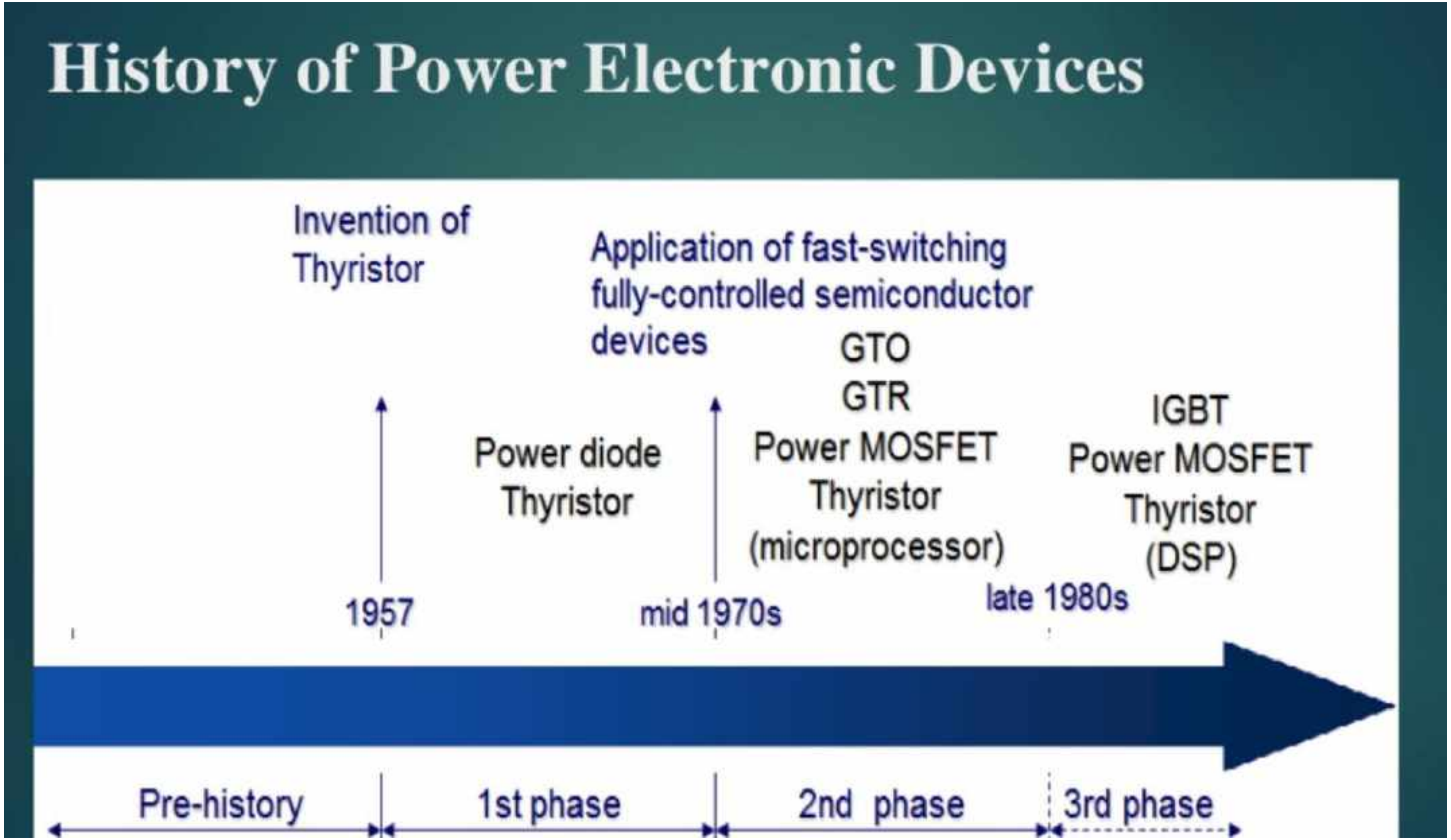
Vapours


Power
Control
Analog | Digital
Electronics
Devices | Circuits
Power
equipment
Static | Rotating
Electronics

Definition Power Electronics : is the electronics applied to conversion and control of electric power.

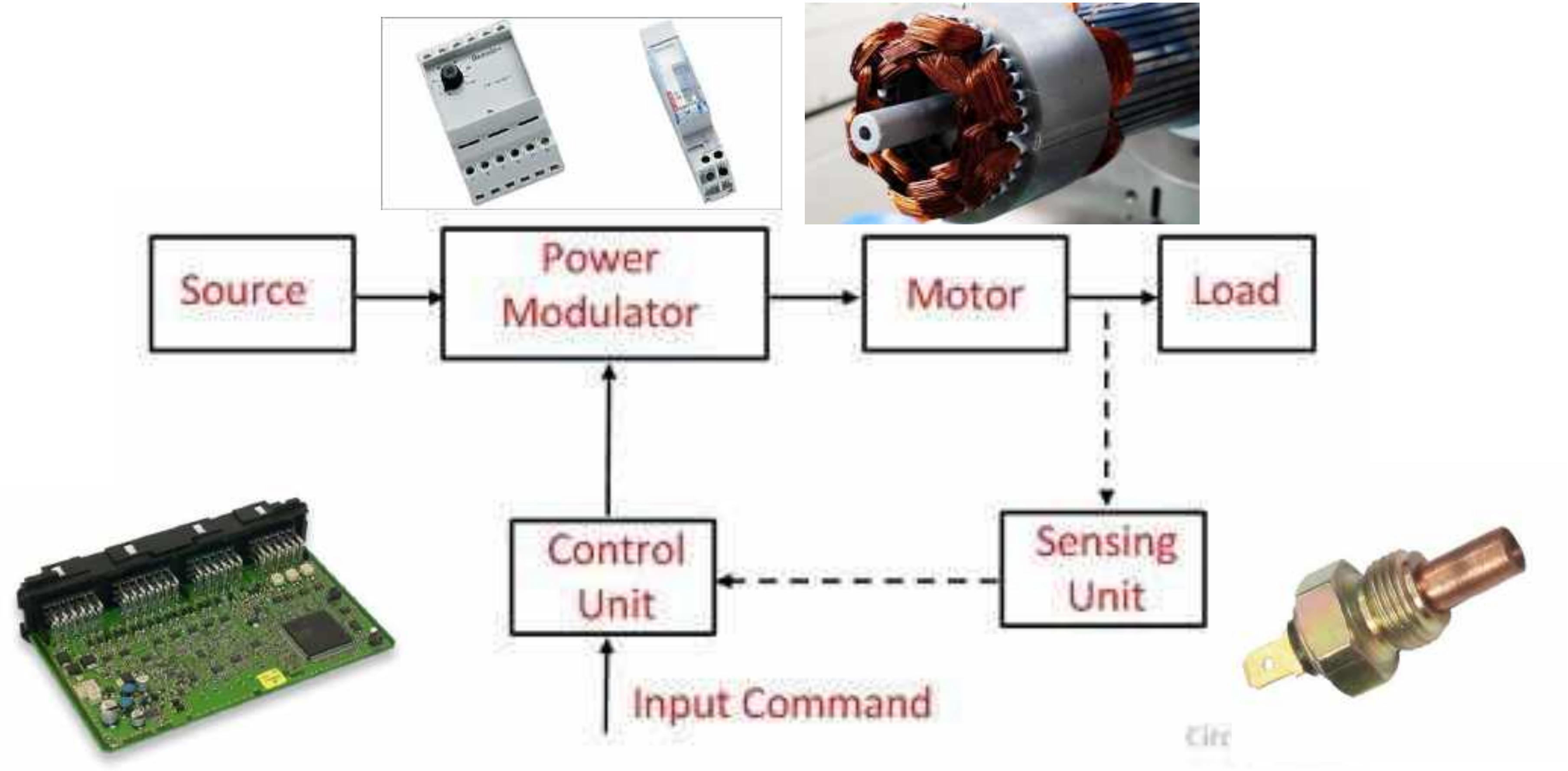
Power electronics is the application of solid-state electronics to the control and conversion of electric power.

Range of power scale : milliwatts(mW), megawatts(MW) ,gigawatts(GW)



- 1882: J. Jasmin (French) discovered semiconductance.
- 1892: L. Arons (German) invented the first mercury arc vacuum valve.
- 1901: P. C. Hewitt (U.S) developed the first arc valve.
- 1906: J. A. Fleming (U.S) invented the first vacuum diode.
- 1907: L. Forest (U.S) invented vacuum triode.
- 1921: F. W. Meyer (German) formulated the main principles of power electronics.
- 1948: J. Bardeen, W. H. Brattain and W. B. Shockley (U.S) invented transistor.
- 1960: J. Moll (U.S) & team invented silicon – based thyristors.
- 1975 – 90: MOSFET, UJT, GTO were developed.
- 1990s: IGBT was developed.

Power Electronic System



The main parts are
power modulator
motor
controlling unit
and sensing units

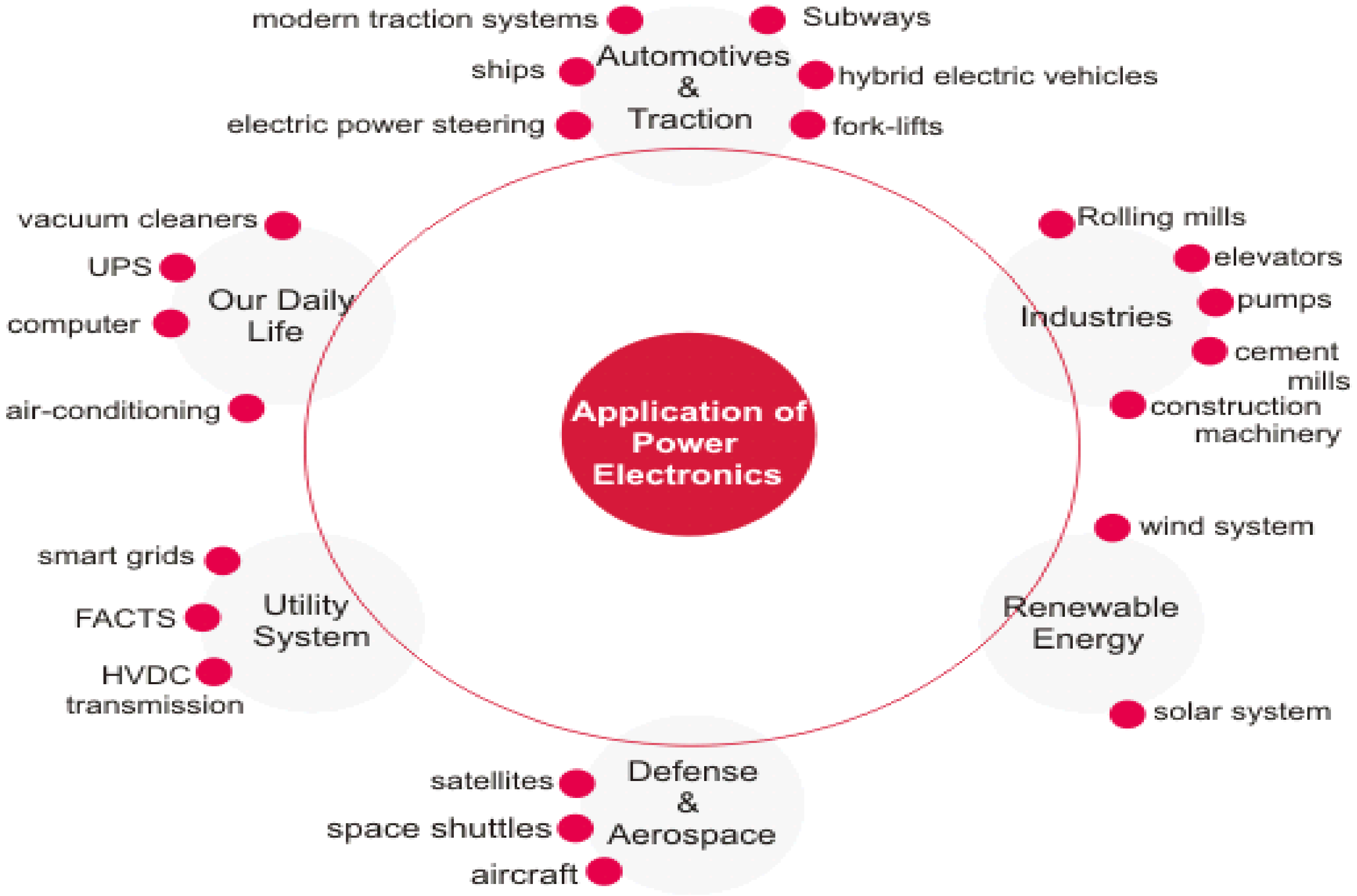
Power Modulator – Regulates the output power of the source.
Controls the power from the source to the motor in such a manner that motor transmits the speed-torque characteristic required by the load.
Hence the power modulator restricts the source and motor current.
Converts the energy according to the requirement of the motor e.g. if the source is DC and an induction motor is used then power modulator convert DC into AC.
It also selects the mode of operation of the motor(motoring or braking)

Control Unit – The control unit controls the power modulator which operates at small voltage and power levels.
Operates the power modulator as desired.
Generates the commands for the protection of power modulator and motor.

An input command signal which adjusts the operating point of the drive, from an input to the control unit.

Sensing Unit – Senses the certain drive parameter(motor current and speed).
Mainly required (protection/ closed loop operation)

Application of Power Electronics



•**Our Daily Life:** power electronics applications such as a fan regulator, light dimmer, air-conditioning, induction cooking, emergency lights, personal computers, vacuum cleaners, UPS (uninterrupted power system), battery charges, etc.

•**Automotives and Traction:** Subways, hybrid electric vehicles, trolley, fork-lifts, and many more. A modern car itself has so many components where power electronic is used such as ignition switch, windshield wiper control, adaptive front lighting, interior lighting, electric power steering and so on.

•**Industries:** industries are controlled by power electronic drives, for eg. Rolling mills, textile mills, cement mills, compressors, pumps, fans, blowers, elevators, rotary kilns etc. Other applications include welding, arc furnace, cranes, heating applications, emergency power systems, construction machinery, excavators etc.

•**Defense and Aerospace:** Power supplies in aircraft, satellites, space shuttles, advance control in missiles, unmanned vehicles and other defense equipments.

•**Renewable Energy:** Generation systems such as solar, wind etc. needs power conditioning systems, storage systems and conversion systems in order to become usable. For example solar cells generate DC power and for general application we need AC power and hence power electronic converter is used.

•**Utility System:** HVDC transmission, VAR compensation (SVC), static circuit breakers, generator excitation systems, FACTS, smart grids, etc.

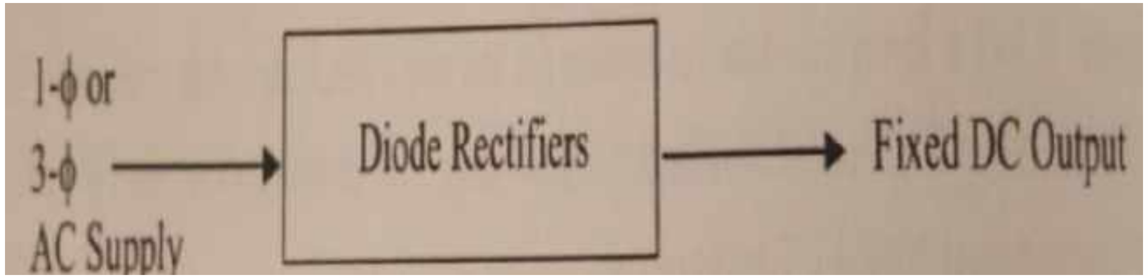
Classification of Converters (Based on Functions)

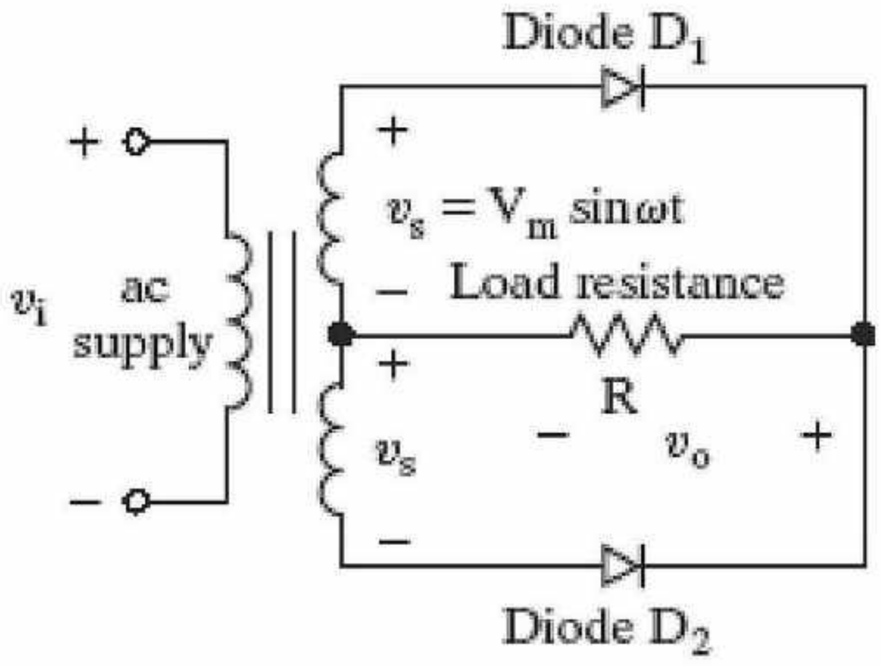
Converters	Input to Output Conversion
1. AC VOLTAGE CONTROLLER	Fixed to Variable ac (Line Commutation).
2. RECTIFIERS (Uncontrolled).	Fixed ac to Fixed dc (Line Commutation).
3. RECTIFIERS (Controlled).	Fixed ac to Variable dc (Line Commutation).
4. DC-to-DC (Chopper).	Fixed dc to Variable dc (Load or Forced Commutation).
5. INVERTERS (Uncontrolled).	Fixed voltage dc to Fixed ac (Line, Load, Forced).
6. INVERTERS (Controlled).	Fixed voltage dc to Variable ac (Line, Load, Forced).
7. CYCLO CONVERTERS.	Fixed ac voltage ac to Variable ac voltage & Frequency (Line or Forced).

- **Ac-dc Converter (Rectifier) :**Two Types
  Diode Rectifier (uncontrolled rectifier)

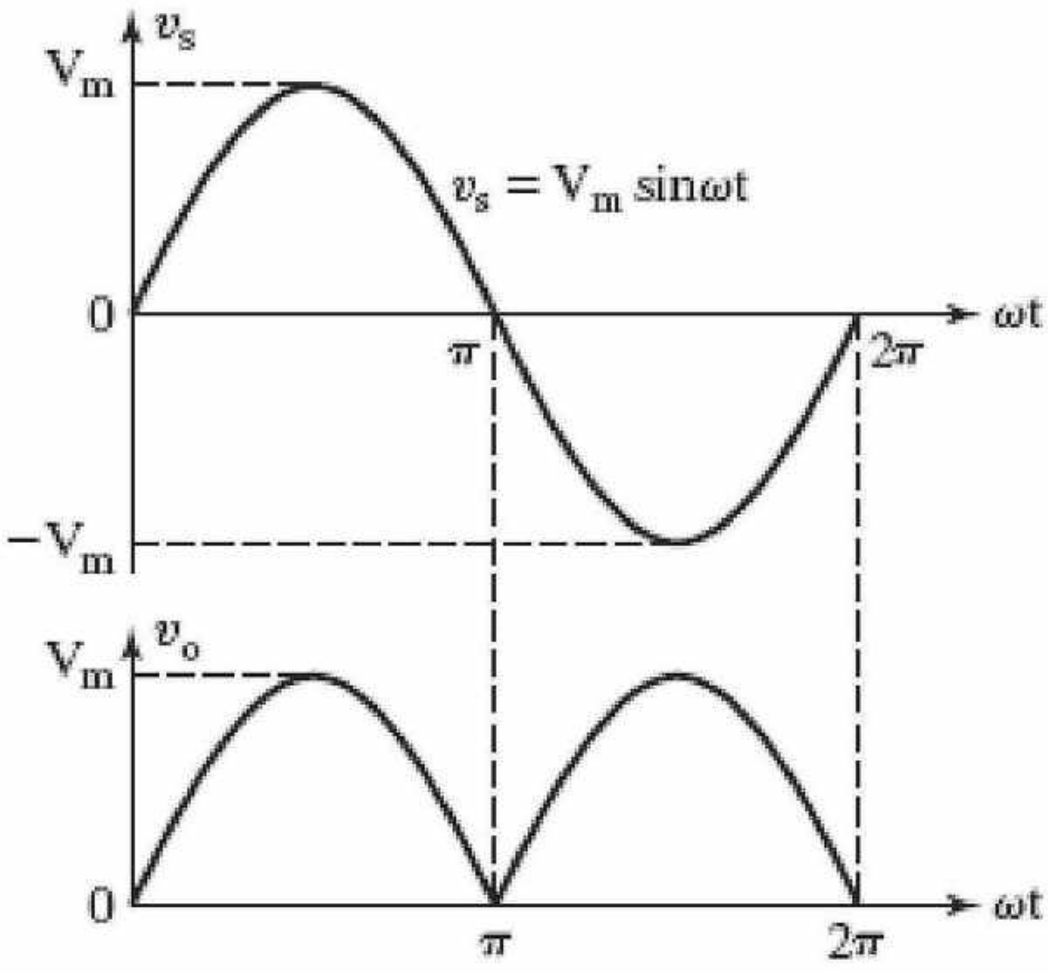
Ac-dc converters (controlled rectifiers)

Diode Rectifier (uncontrolled rectifier)



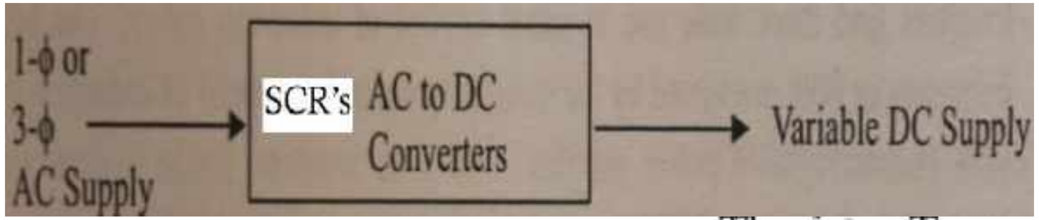


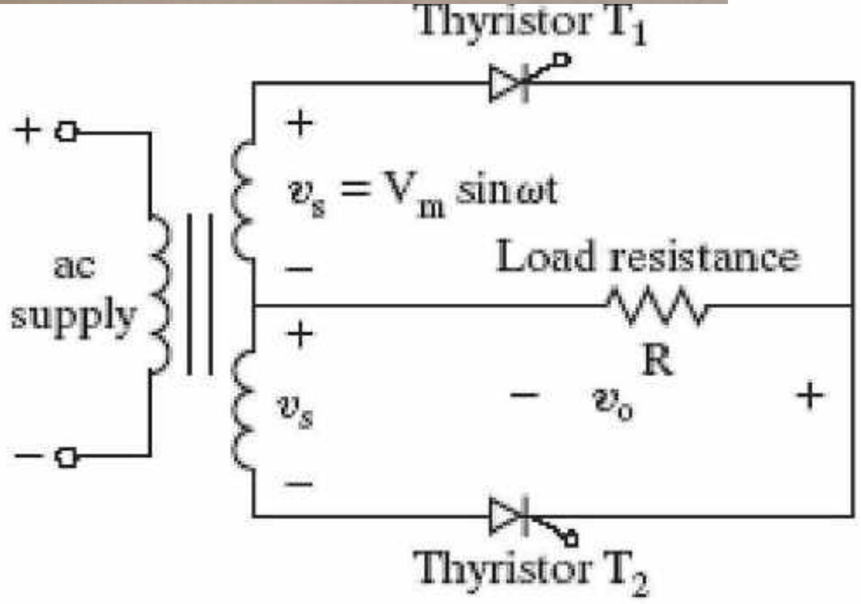
(a) Circuit diagram



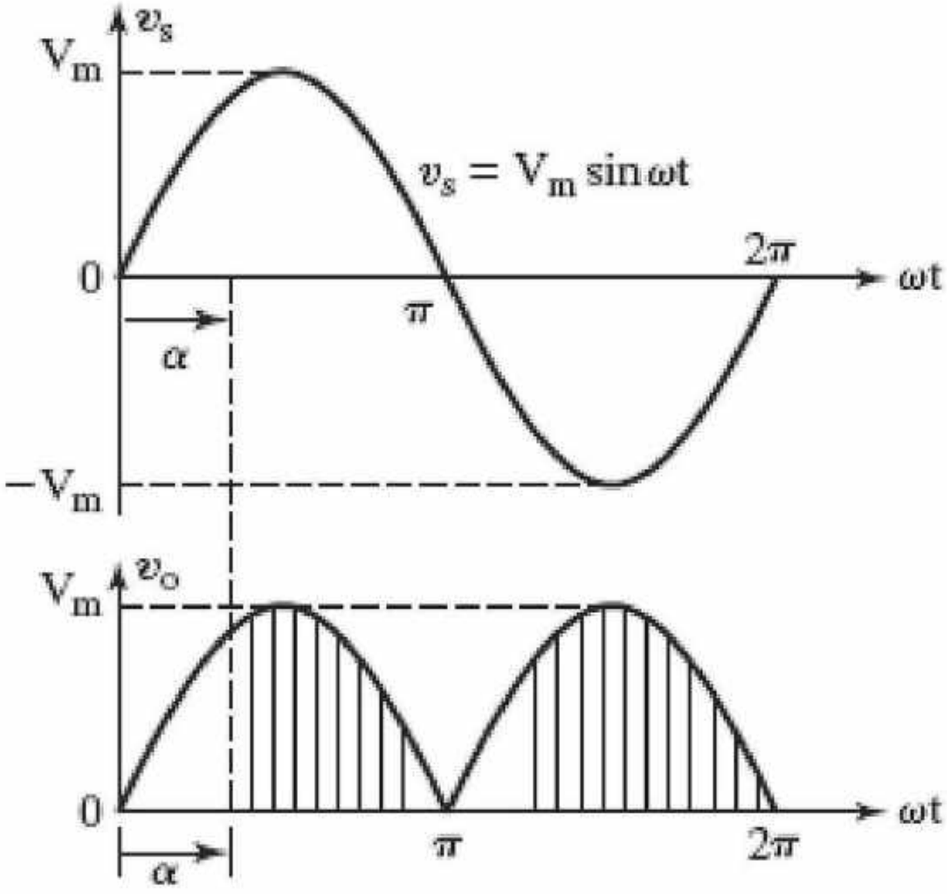
(b) Voltage waveforms

Ac-dc converters (controlled rectifiers)





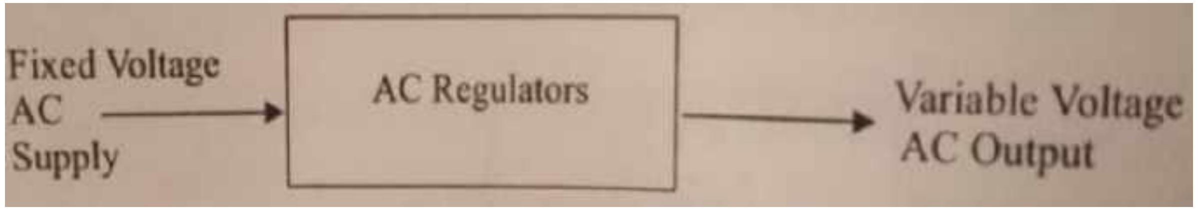
(a) Circuit diagram



(b) Voltage waveforms

Applications: DC drives, metallurgical etc.

Ac-ac Converter



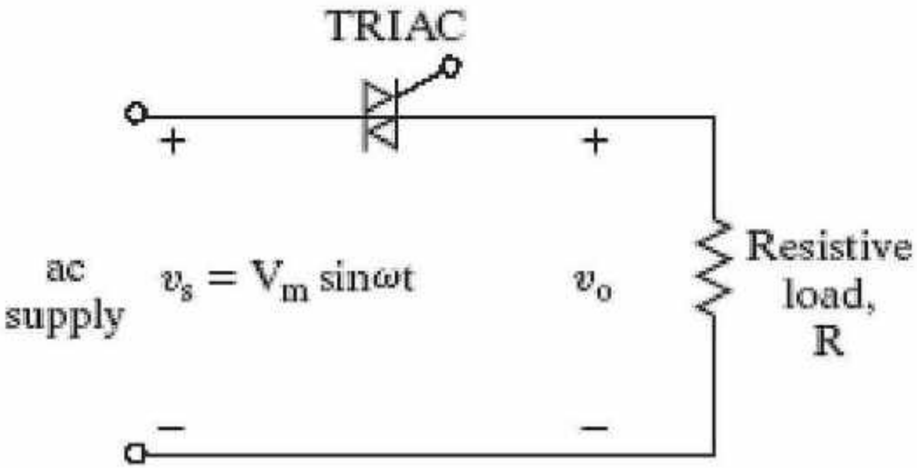
A. Output frequency is equal to input frequency (output rms voltage can be varied)

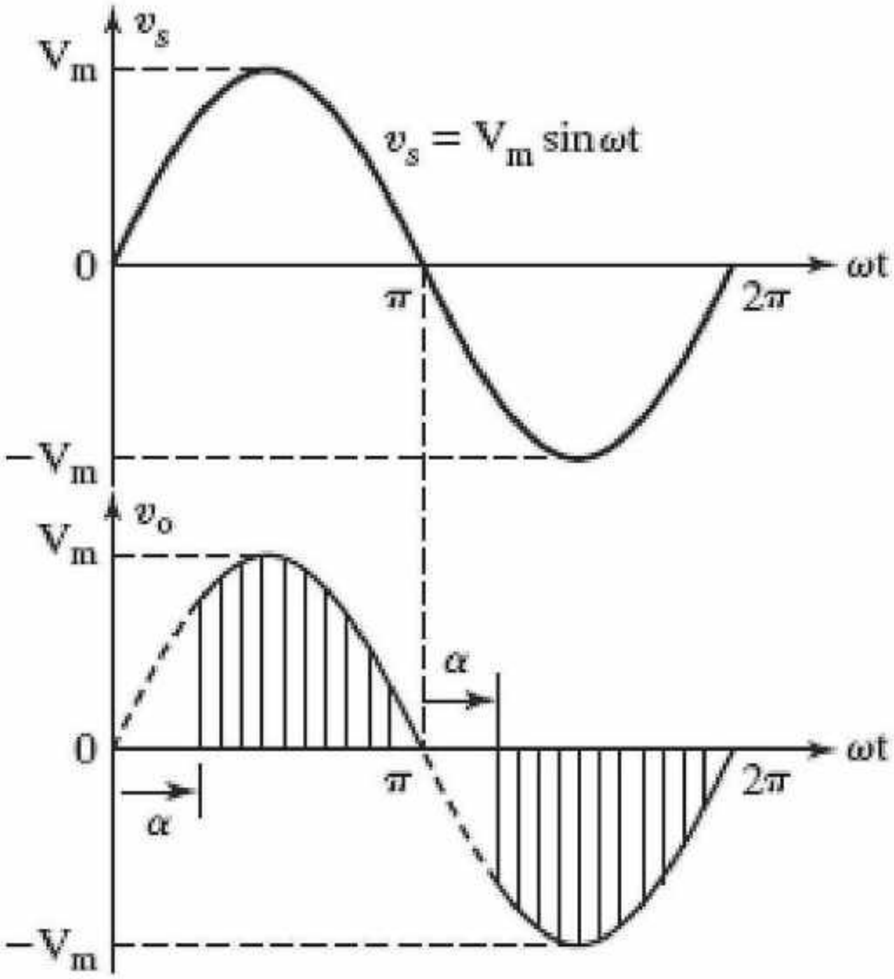
TRIAC based Ac Voltage regulator (low voltage and current rating)

Thyristor based AC voltage regulator (high voltage and current rating)

B. Output frequency is less than input frequency (output rms voltage can be varied)--

Cycloconverter



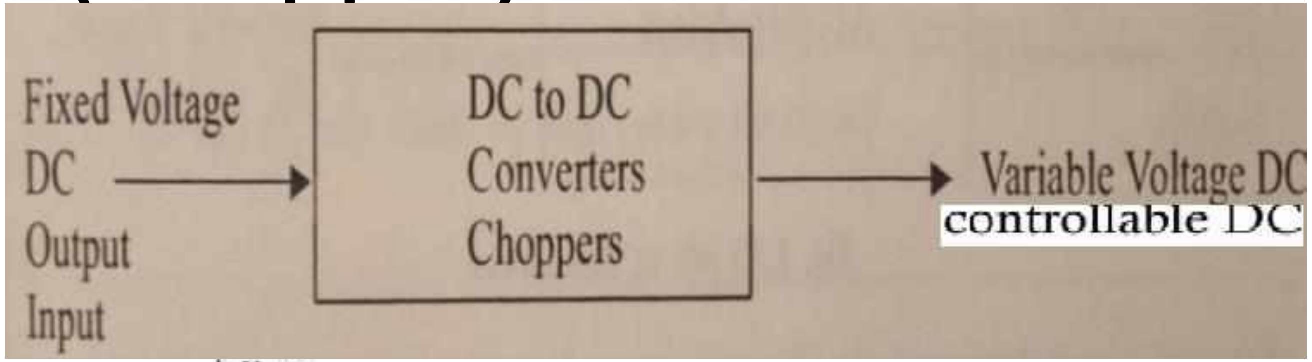


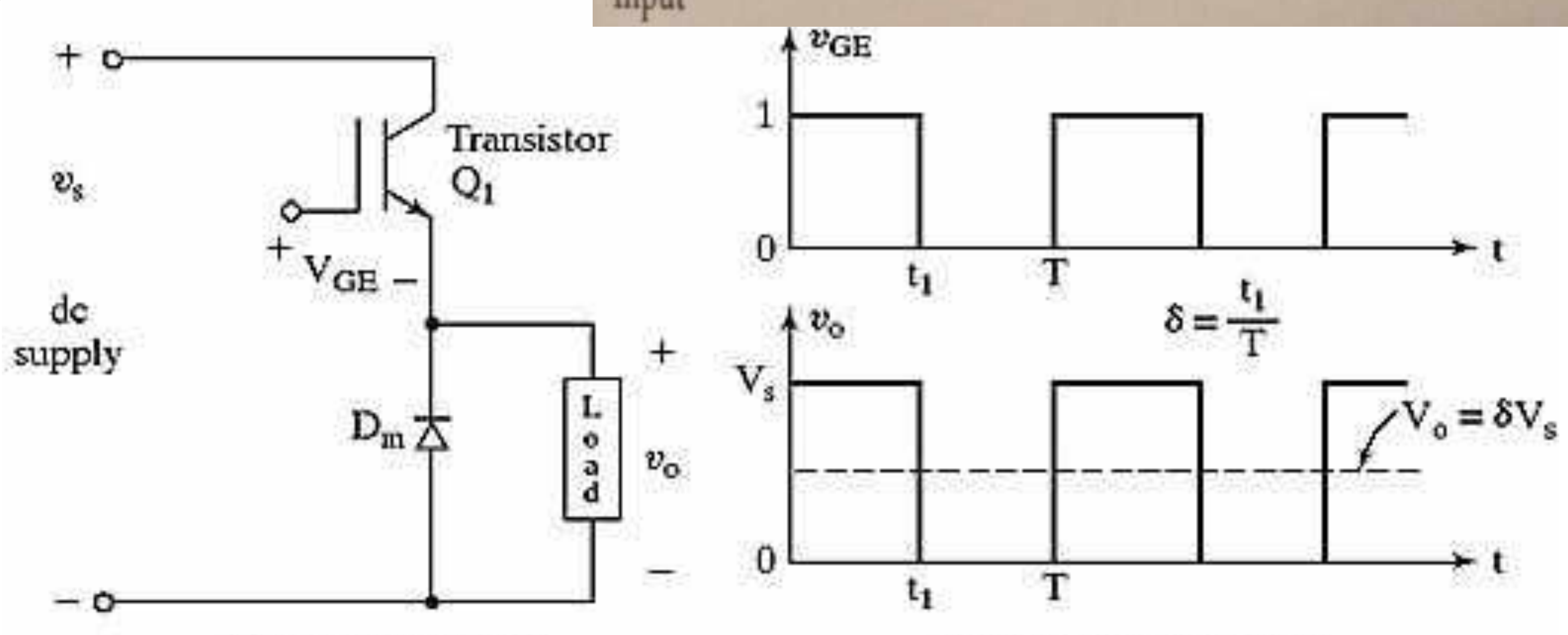
(b) Voltage waveforms

Applications: Speed control of fans and pumps

Dc-dc Converter (Chopper)

- Buck (step-down)
- Boost (step-up)
- Buck-boost



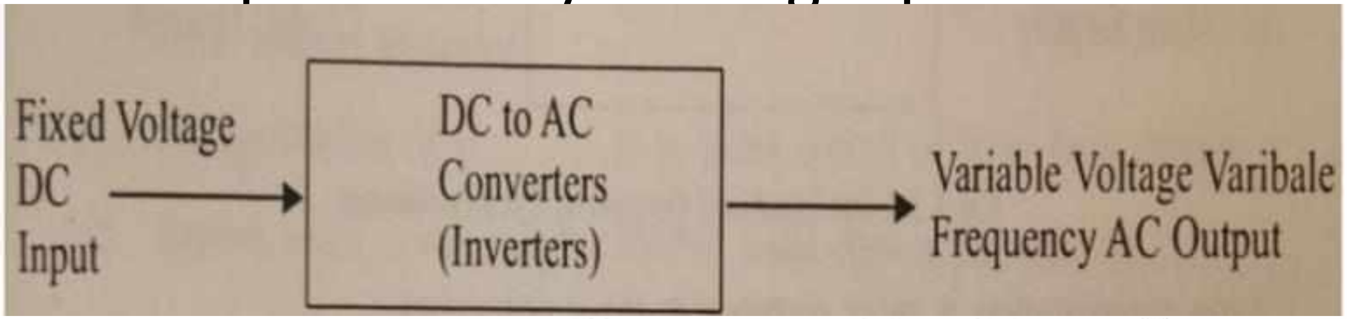


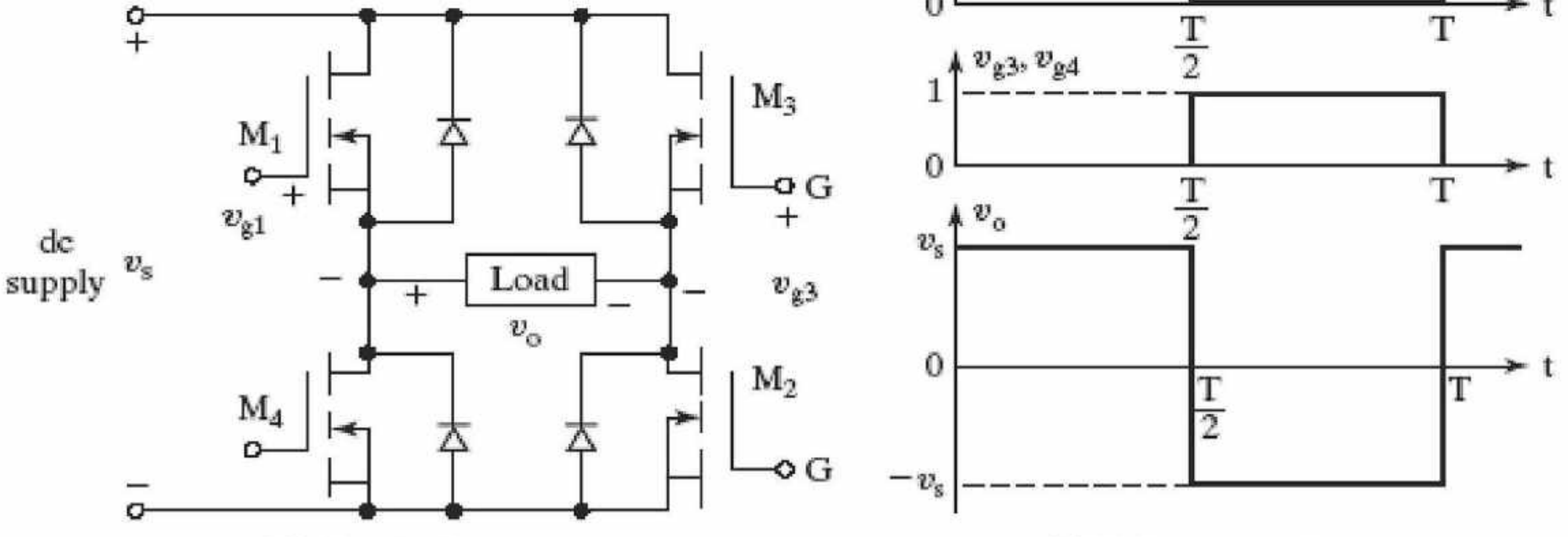
(a) Circuit diagram (b) Voltage waveforms

Applications: Subway cars, trolley trucks, DC drives

Dc-ac Converter (Inverter)

- Output AC may be Single-phase or three-phase.

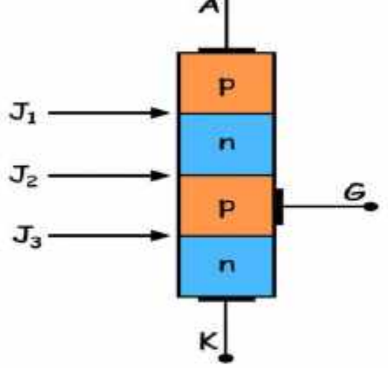


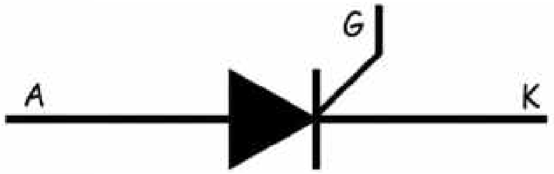


(a) Circuit diagram (b) Voltage waveforms

Applications: Speed control of induction motor, UPS, HVDC transmission

SCR OPERATION





- **Silicon Controlled Rectifier** (**SCR**) is a unidirectional semiconductor device made of silicon.
- solid state equivalent of thyratron and hence it is also referred to as **thyristor** or **thyroid transistor**.
- trade name given to the thyristor by General Electric Company.
- **SCR** is a three-terminal, four-layer semiconductor device consisting of alternate layers of p-type and n-type material.Hence it has three pn junctions J_1, J_2 and J_3.
- The figure above shows an SCR with the layers p-n-p-n. The device has terminals Anode(A), Cathode(K) and the Gate(G).

- The Gate terminal(G) is attached to the p-layer nearer to the Cathode(K) terminal.

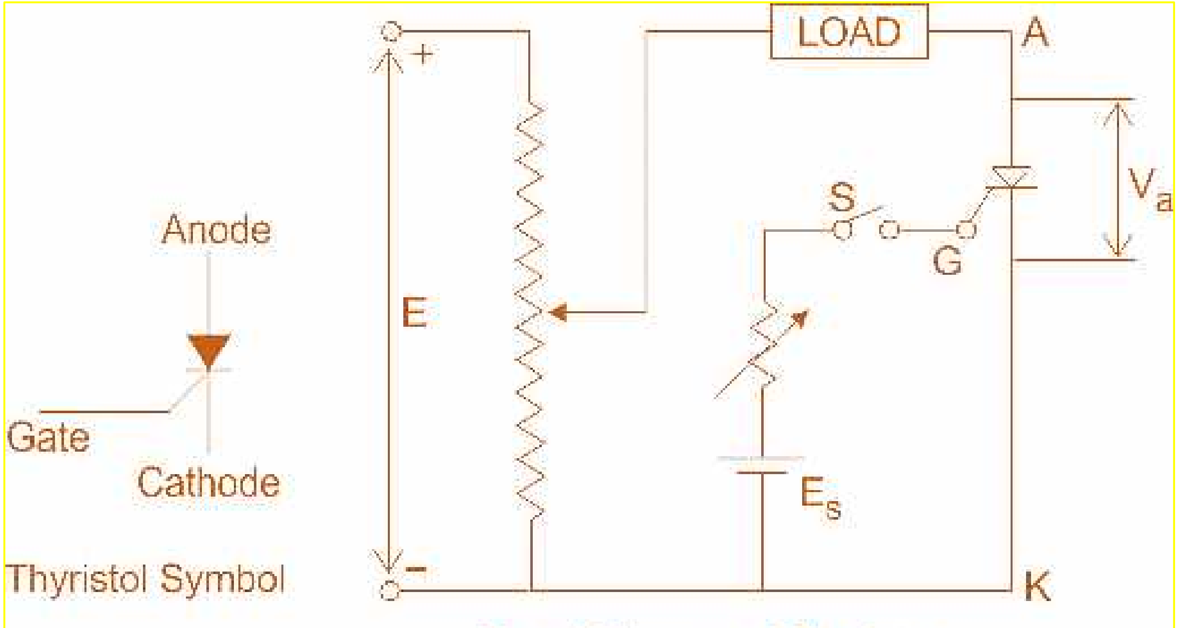
V-I Characteristics of a Thyristor

- On giving the supply, **V-I characteristics of a thyristor** can be described
- three basic modes of operation

reverse blocking mode,

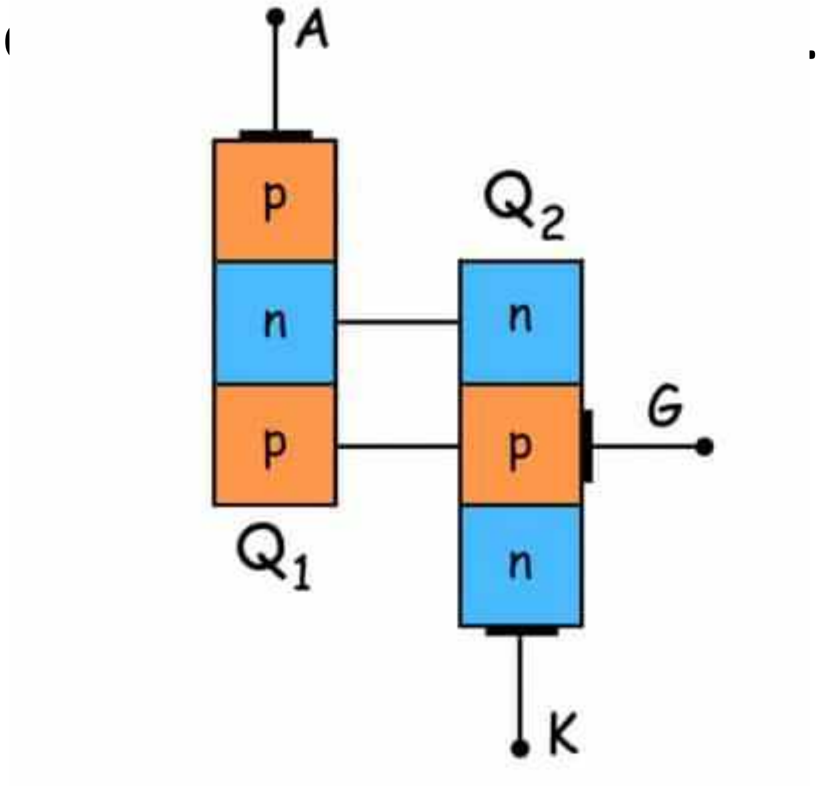
forward blocking (off-state) mode

forward conduction (on-state) mode



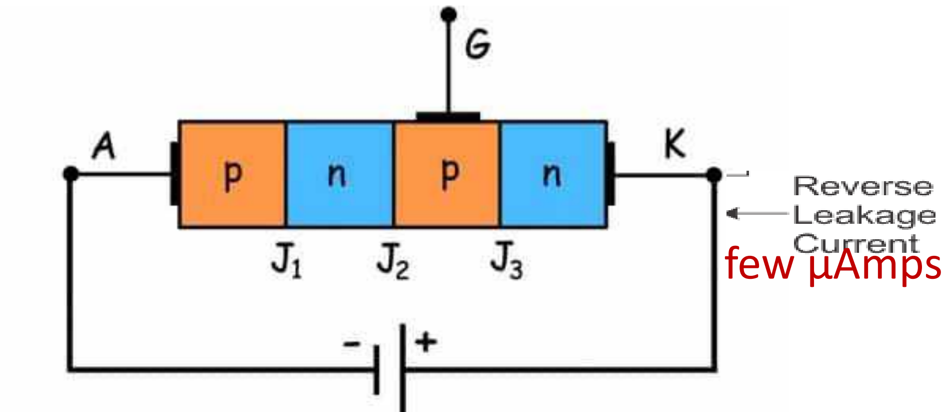
Circuit Diagram of Thyristor

- An SCR can be considered as two inter-connected transistors as shown below. single **SCR** is the combination of one pnp transistor (Q_1) and one npn transistor (Q_2).
- Here, the emitter of Q_1 acts as the anode terminal of the SCR while the emitter of Q_2 is its cathode. Further, the base of Q_1 is connected to the collector of Q_2 and the collector of Q_1 is connected to the base of Q_2. The gate terminal of the SCR is conne .

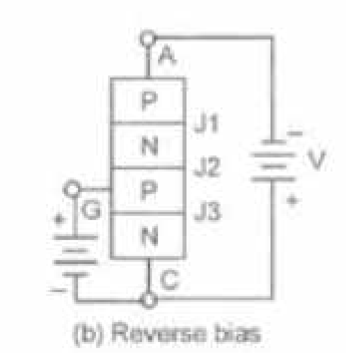


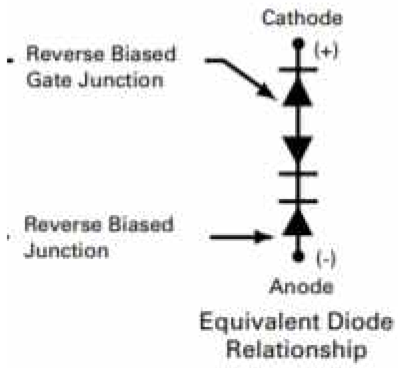
Reverse Blocking Mode of SCR/OFF STATE

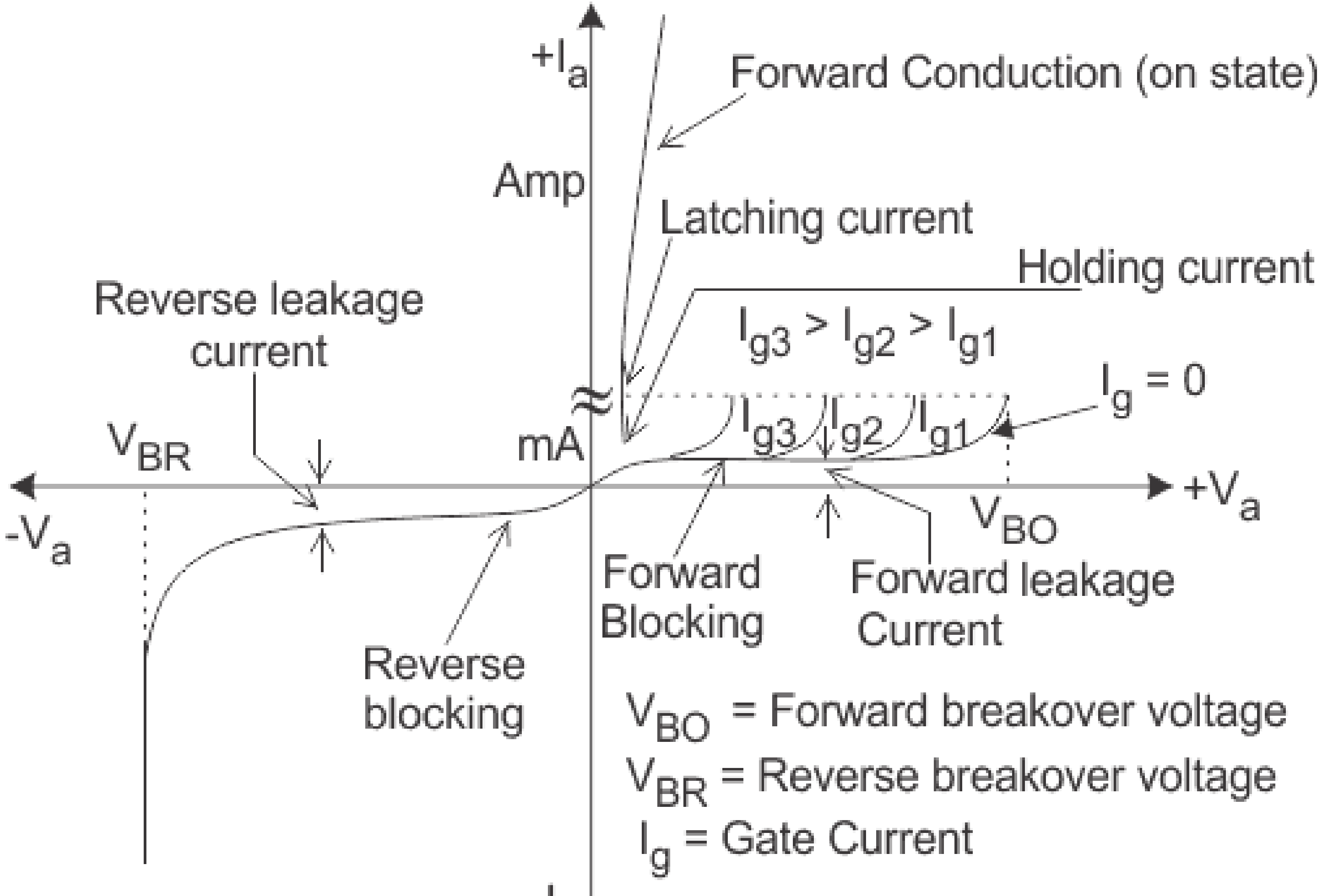
- Here Junctions J_1 and J_3 are reverse biased whereas the junction J_2 is forward biased.
- If the reverse voltage is now increased and as it reaches the critical breakdown voltage V_{BR}, an avalanche occurs at J_1 and J_3 and the reverse current increases rapidly.
- A large current gives rise to more losses in the SCR, which results in heating.further damaging the device.
- Must be ensured that maximum working reverse voltage across a [thyristor](#) does not exceed V_{BR}.
- When reverse voltage applied across a thyristor is less than V_{BR}, the device offers very high impedance in the reverse direction(open circuit).



few µAmps flows

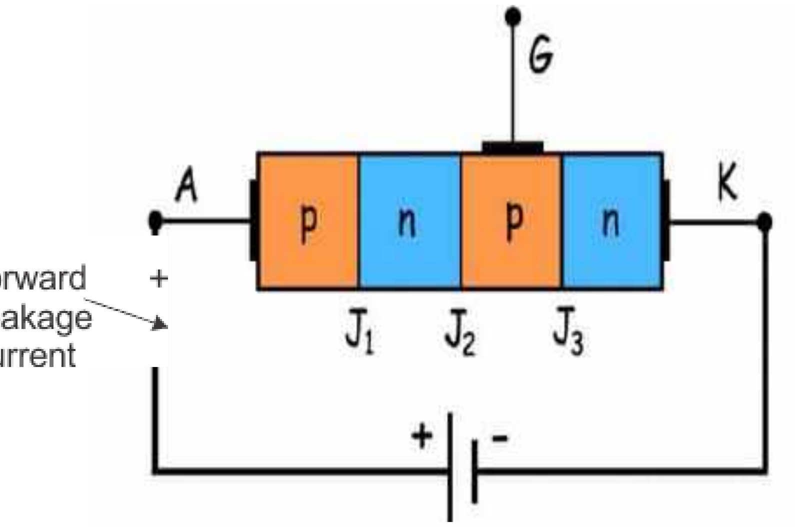


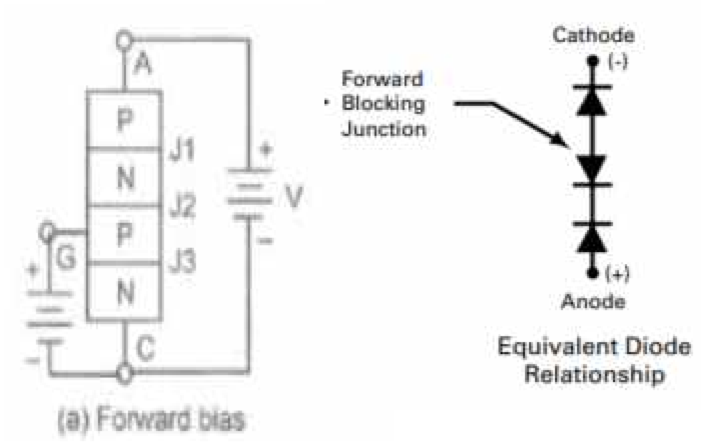




V I Characteristics of Thyristor

Forward Blocking Mode of SCR





Under this condition, the junction J_1 and J_3 get forward biased while junction J_2 gets reverse biased.

In this particular mode, a small current, called forward leakage current is allowed

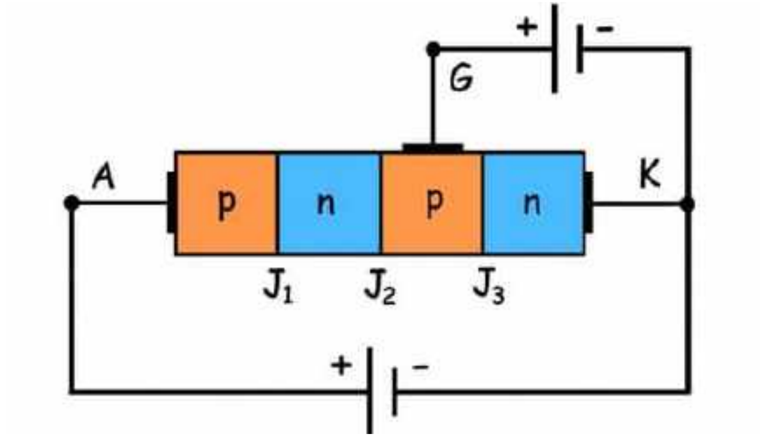
Now, if we keep on increasing the forward biased anode to cathode voltage.In this particular mode, the thyristor conducts currents from anode to cathode with a very small voltage drop across it.

A thyristor is brought from forward blocking mode to forward conduction mode by turning it on by exceeding the forward break over voltage or by applying a gate pulse between gate and cathode. In this mode, thyristor is in on-state and behaves like a closed switch.

Voltage drop across thyristor in the on state is of the order of 1 to 2 V

But, if we keep the forward voltage less than V_{BO}, the device offers a high impedance. Thus even here the thyristor operates as an open switch during the forward blocking mode.

Forward Conduction Mode of SCR



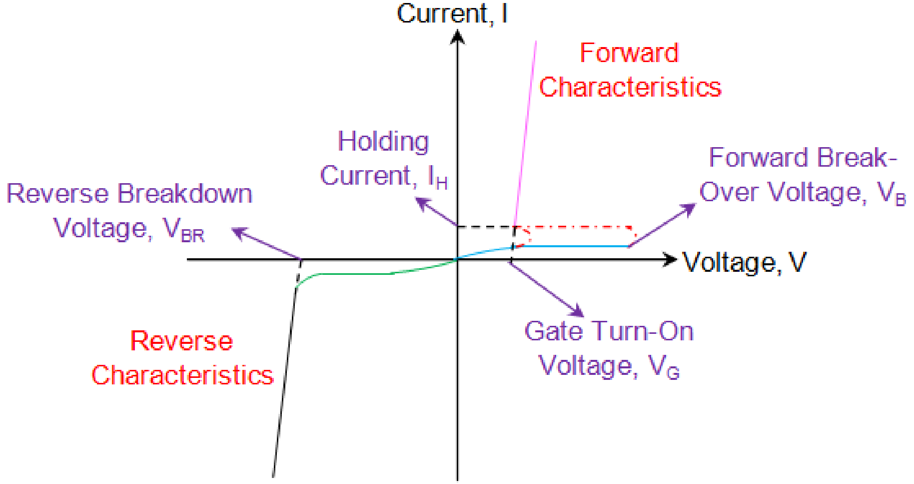


Figure 4 V-I Characteristics of SCR

- The SCR can be made to conduct either
  (i) By increasing the positive voltage applied at anode terminal (A) beyond the Break Over Voltage, V_B or
  (ii) By applying positive voltage at the gate terminal (G) as shown in the figure below.

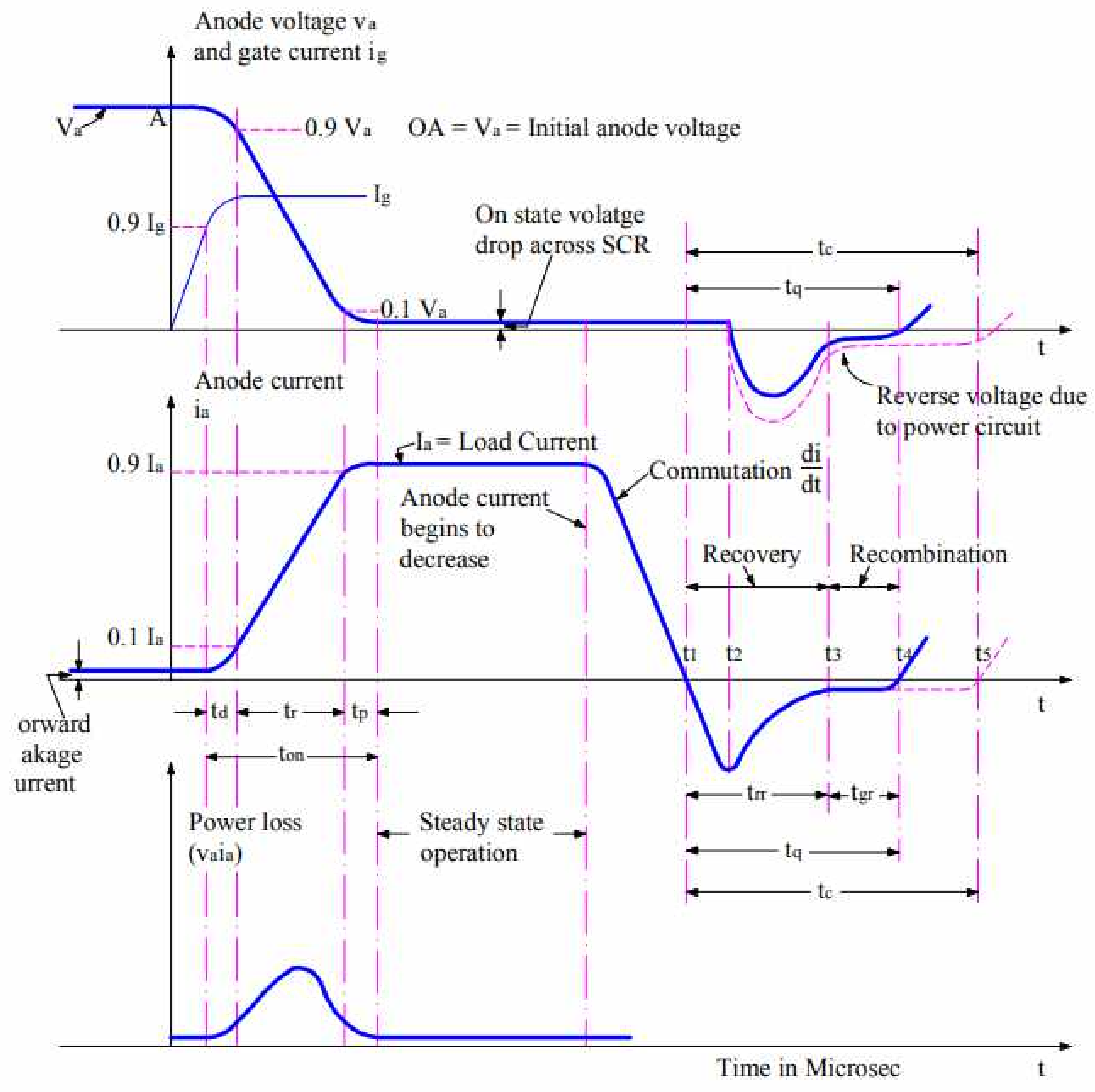
Forward Conduction Mode
When the anode to cathode forward voltage is increased, with gate circuit open, the reverse junction J_2 will have an avalanche breakdown at forward break over voltage V_{BO} leading to thyristor turn on.

In this mode of operation, the thyristor conducts maximum current with minimum voltage drop, this is known as the forward conduction forward conduction or the turn on mode of the thyristor.

Turn OFF Time of SCR

- Once the thyristor is switched on or in other point of view, the anode current is above latching current, the gate losses control over it. That means gate circuit cannot turn off the device.
- For turning off the SCR anode current must fall below the holding current. After anode current fall to zero we cannot apply forward voltage across the device due to presence of carrier charges into the four layers. So we must sweep out or recombine these charges to proper **turn off of SCR**.
- **turn off time of SCR** can be defined as the interval between anode current falls to zero and device regains its forward blocking mode.
- On the basis of removing carrier charges from the four layers, **turn off time of SCR** can be divided into two time regions,
- Reverse Recovery Time.
- Gate Recovery Time

- **Reverse Recovery Time**
- It is the interval in which change carriers remove from J_1, and J_3 junction.
- At time t_1, anode current falls to zero and it will continue to increase in reverse direction with same slope (di/dt) of the forward decreasing current. This negative current will help to sweep out the carrier charges from junction J_1 and J_3. At the time t_2 carrier charge density is not sufficient to maintain the reverse current hence after t_2 this negative current will start to decrease. The value of current at t_2 is called reverse recovery current. Due to rapid decreasing of anode current, a reverse spike of voltage may appear across the SCR. Total recovery time $t_3 - t_1$ is called **reverse recovery time**.
- After that, device will start to follow the applied reverse voltage and it gains the property to block the forward voltage.



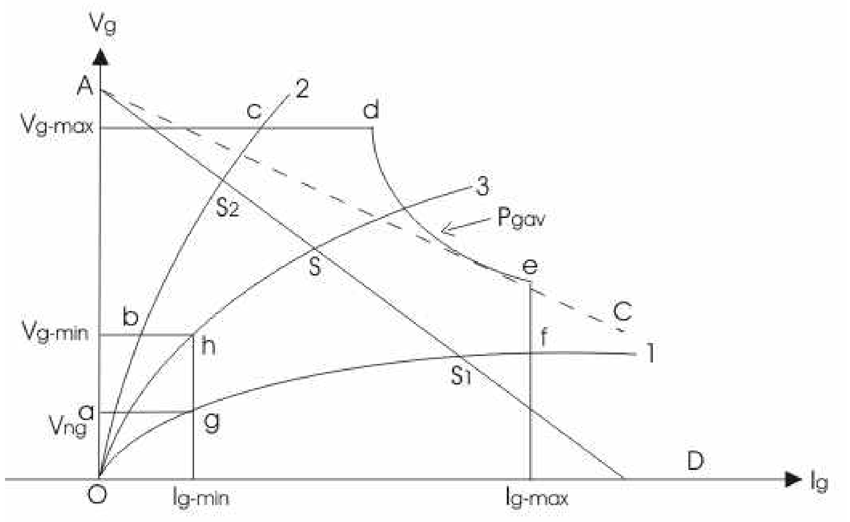
:ecovery Time

;weeping out the carrier charges from junction J_1 during **reverse recovery time**, there still remain :d charges in J_2 junction which prevent the SCR ›locking the forward voltage.

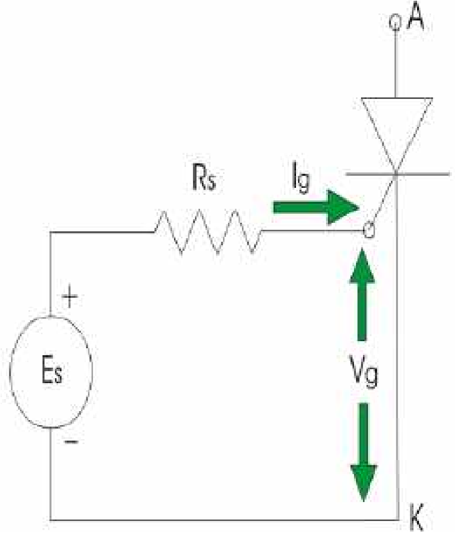
:apped charge can be removed by recombination nd the interval in which this recombination is done, **gate recovery time**.

Gate characteristic of thyristor or SCR

- briefs an idea to operate it within a safe region of applied gate voltage and current.
- So this is a very important characteristic regarding thyristor.
- At the time of manufacturing each SCR or thyristor is specified with the maximum gate voltage limit ($V_{g\text{-}max}$), gate current limit ($I_{g\text{-}max}$) and maximum average gate power dissipation limit (P_{gav}).
- These limits should not be exceeded to protect the SCR from damage and there is also a specified minimum voltage ($V_{g\text{-}min}$) and minimum current ($I_{g\text{-}min}$) for proper operation of a thyristor.



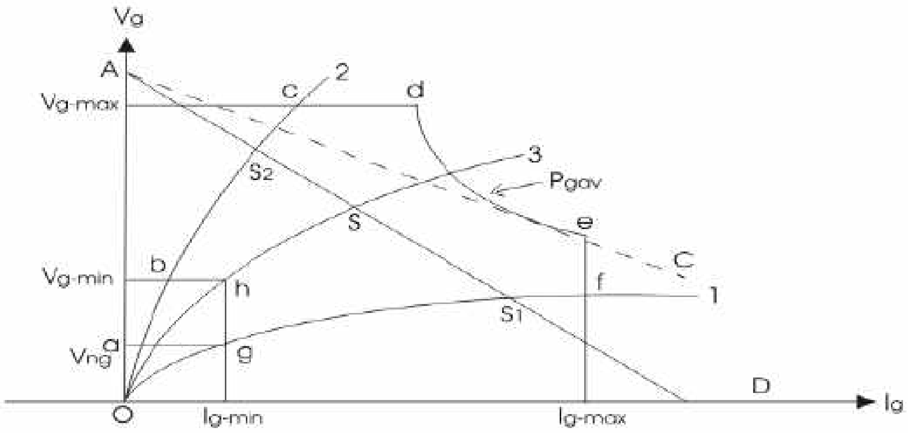
- Curve 1 represents the lowest voltage values that must be applied to turn on the SCR and curve 2 represents the highest values of the voltage that can safely applied.
- So from the figure we can see the safety operated area of SCR is bcdefghb.



- Now, from the triggering circuit, we get,

  $$E_s = V_g + I_g R_s$$

  Where,
  E_s = gate source voltage
  V_g = gate cathode voltage
  I_g = gate current
  R_s = gate source resistance



- A load line of gate source voltage is drawn as A

where OA = E_s and OD = E_s/R_s (trigger circuit short circuit current)

- Now, let a VI characteristic of gate circuit is given by curve 3.
- The intersection point of load line (AD) and curve 3 is called as operating point S.
- It is evident that S must lie between S_1 and S_2 on the load line.
- For decreasing the turn ON time and to avoid unwanted turn ON of the device, operating point should be as close to P_{gav} as possible.
- Slope of AD = source resistance R_s. Minimum amount of R_s can be determined by drawing a tangent to the P_{gav} carve from the point A.
- A gate non triggering voltage (V_{ng}) is also mentioned at the time of manufacturing of the device.
- All noises and unwanted signals should lie under this voltage to avoid unwanted turn on of the thyristor.

SCR Turn on methods are the techniques to bring an SCR in forward conduction mode from forward blocking mode.
An SCR in forward conduction mode is characterized by low impedance, low voltage drop across anode & cathode and high anode current.
The value of anode current is determined by the load. Thus it allows for the flow of current.
Therefore, an SCR in forward conduction mode is called its ON state and may be treated as a close switch.

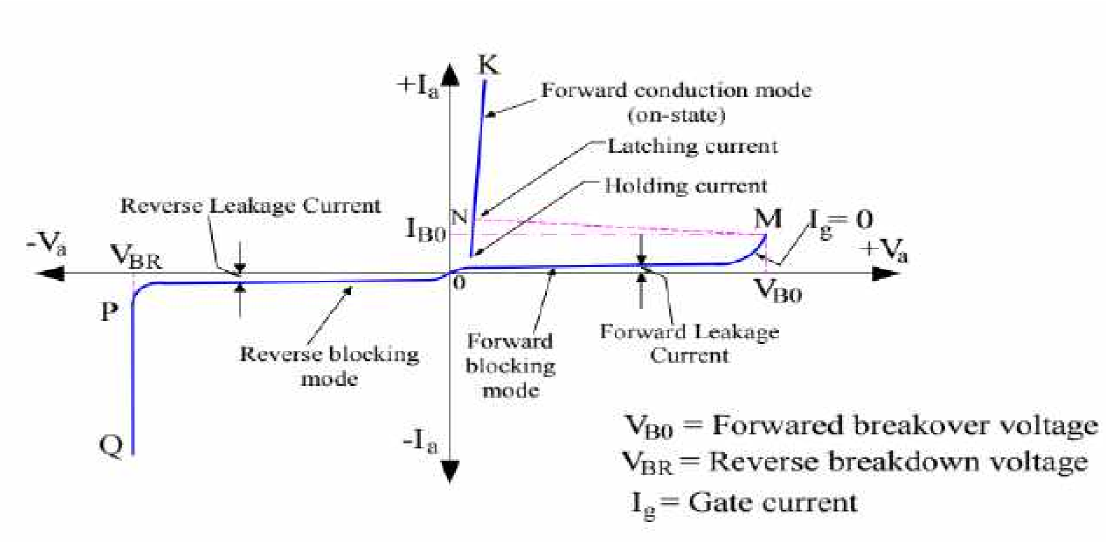
There is mainly five different methods turn on methods of SCR:

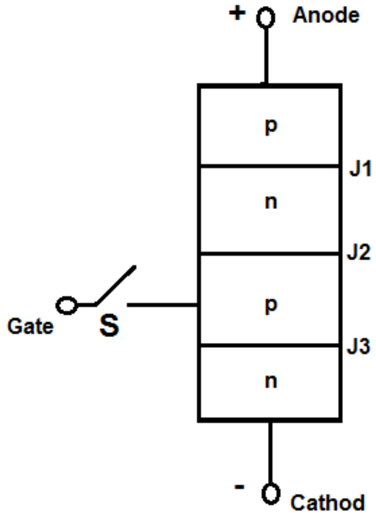
- Forward Voltage Triggering
- Gate Triggering
- dv/dt Triggering
- Temperature or Thermal Triggering
- Light Triggering

Forward Voltage Triggering

- forward biased and will increase this bias voltage till SCR gets ON.

- In a forward biased SCR or Thyristor, junction J1 and J3 are forward biased whereas junction J2 is reversed bias.
- Therefore, increasing this bias voltage will narrow down the width of the depletion region of junction J2 and at a particular voltage, this depletion region will vanish.
- At this stage, reversed biased junction J2 is said to have avalanche breakdown and this voltage is called the forward breakover voltage.
- The name forward breakover voltage is given as at this voltage the V-I characteristics of SCR breaks and shifts to its ON position

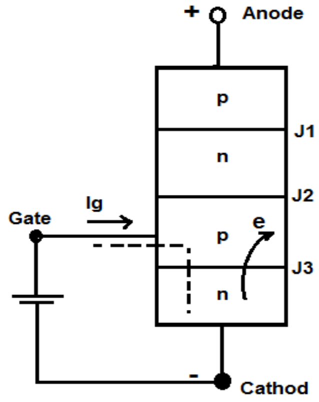


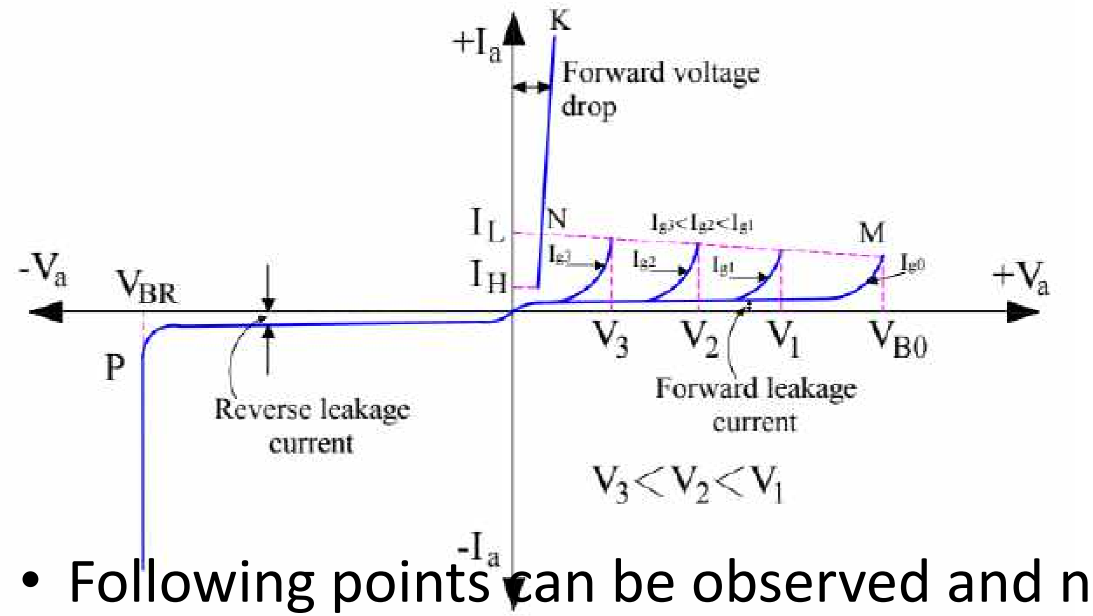


- You may notice that at forward breakover voltage V_{BO}, the V-I curve breaks at point M and shift to its On position N with forward breakover current I_{BO}. This is the reason; this critical voltage is called forward breakover voltage.
- As soon as avalanche breakdown at junction J2 occurs, current starts flowing from anode to cathode of SCR. The value of this anode current is only limited by the load. Thus SCR is now in its conduction mode in forward direction i.e. from anode to cathode. This is forward triggering method of turning SCR ON.
- Normally this method is not used to turn on SCR as it may damage it. Generally the forward breakover voltage is less than reverse breakdown voltage and hence reverse breadwon voltage is considered as final voltage rating while designing SCR. It must also be noted and bear in mind that, once avalanche breakdown take place at junction J2, the blocking capability of J2 is lost. Therefore if anode voltage is reduced below forward breakover voltage, the SCR will continue to conduct. The SCR can now be turned off by bringing its anode current below a certain value called the holding current.

Gate Triggering

- Gate triggering is the method in which positive gate current is flown in forward biased SCR to make it ON. Gate triggering is in fact the most reliable, simple and efficient way to turn on SCR. In this method, positive gate voltage between gate and cathode terminals are applied in forward biased SCR which establishes gate current from gate terminal to cathode.
- When positive gate current is applied, gate p layer is flooded with electrons from the cathode (n side). This is because the cathode n layer is heavily doped as compared to gate p layer. Since junction J1 and J3 are already forward biased, the injected electrons in gate p layer may reach junction J2 and hence reduces the width of depletion result is reduction of forward breakover voltage. In fact, the more the injecte in gate p layer, the more will be chance of electrons reaching J2. This means t the value of gate current, the more will be reduction in forward breakover vo gate current and forward breakover voltage are inversely proportional.
- Please refer the figure below. This is the V-I characteristics of DSCR for differe gate current I_g.

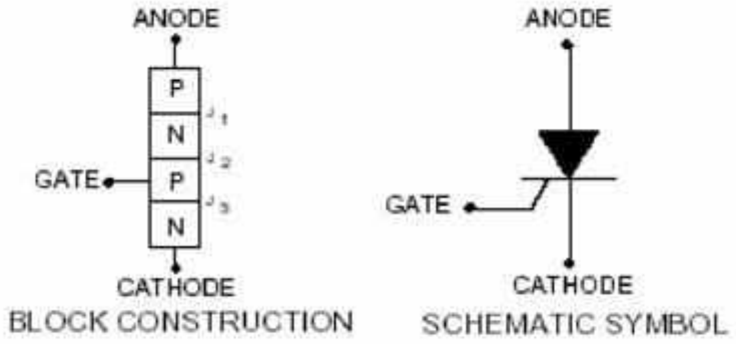


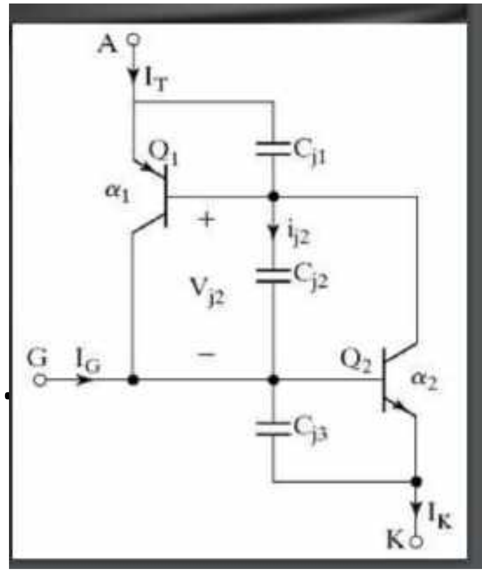


- Following points can be observed and noted from the above curve:
- When the gate current I_g is zero, the forward breakover voltage is V_{BO}.
- As gate current increases from zero to I_{g1}, the forward breakover voltage reduces from V_{BO} to V_1. Similarly, its value reduces from V_1 to V_3 as the gate current increases from I_{g1} to I_{g3}.
- Thus the SCR may be turned on by applying gate current. It should be noted that SCR is turning on due to forward breakover voltage though this voltage is reduced considerably due to positive gate current.
- Once SCR starts conducting in forward direction, reversed bias junction J2 no longer exists. Therefore, no gate current is required for SCR or thyristor to remain in ON state. Therefore if gate current is removed, the conduction of current from anode to cathode is not affected. However, if gate current is reduced to zero before the rising of anode current to a specific value called the latching current, the SCR or thyristor will turn off again. This means we should not make gate current off until anode current has crossed latching current.

- ***Latching current is defined as the minimum value of anode current which must be attained during turn on process of SCR to main the conduction even when gate current is removed.***
- Once SCR or thyristor starts conductiong, gate losses its control. The SCR or thyristor can now be turned OFF only if the anode current reaches below a specified value of anode current. This value of anode current below which SCR gets turned OFF is called Holding Current. As can be seen from the V-I characteristics of SCR, the value of latching current is more than the Holding Current.
- ***Holding Current is defined as the minimum value of anode current below which it must fall for turning OFF the SCR or Thyristor.***

dv/dt Triggering





- SCR is turned ON by changing the forward bias voltage with respect to time.
- dv/dt itself means rate of change of voltage w.r.t time.
- junction J2 is reversed biased in a forward blocking mode of SCR.
- A reversed biased junction may be treated as a capacitor due to presence of space charges in the vicinity of reversed biased junction. Let us assume its capacitance to be 'C' farad.
- The charge on capacitor, voltage across the capacitor and capacitance are related as below:

  $Q = CV$

  Differentiating both sides w.r.t time, we get

  $dQ/dt = C(dV/dt)$

  But current $I = dQ/dt$

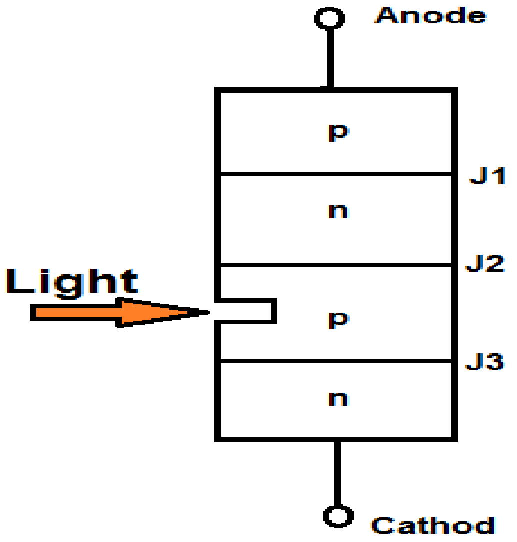
  $\Rightarrow I = C(dV/dt)$

- Thus the current through the reversed biased junction J2 is directly proportional to (dv/dt). Therefore if the rate of rise of forward voltage i.e. (dv/dt) is high, the charging current I will also be high. This charging current acts like gate current and turns ON the SCR or thyristor even though the gate current is zero. If should be noted that, it is rate of rise of voltage which is responsible for turning the SCR ON. It is independent of magnitude of voltage. The voltage may be low, but the rate of its rise should be high enough to turn SCR ON.

Temperature Triggering/ thermal triggering

- In reversed biased junction a reverse saturation current flows whose value depends on the temperature of the junction.
- In forward blocking mode of SCR or thyristor, there will be a flow of reverse saturation current across the junction J2.
- This current will increase the temperature of the junction which in turn will result in further increase in reverse leakage current.
- This increased leakage current will again increase the junction temperature and hence will further increase the reverse leakage current.
- Thus, this process is cumulative and will eventually lead to vanishing of depletion region of reversed biased junction J2 at some temperature.
- At this temperature, the SCR will get turn ON.

Light Triggering



- In light triggering, a pulse of light of suitable wavelength guided by optical fibers is irradiated to turn SCR ON.
- A recess or niche is made in the inner p layer for light triggered SCR as shown in figure.
- When this niche is irradiated, free charge carriers(electron and hole) pairs are generated.
- If the intensity of irradiated light is exceeds a certain value, forward biased SCR is turned ON.
- Irradiated light produces free charge carries which is just like in case of gate current. There charge carries move near the reversed biased junction J2 and reduces the forward breakover voltage. This is the reason, the SCR gets turned ON.
- The SCR which is turned ON by using light is called Light Activated SCR or LASCR

Sr. No.	Latching Current	Holding Current
1)	It is related with turn on process of SCR or thyristor.	It is related to turn off process.
2)	Minimum current above which gate losses its control.	Minimum value of anode current below which it must fall to stop conducting in forward direction.
3)	Value of latching current is more than that of holding current.	It is less than latching current.
4)	Latching current is generally 2 to 3 times of the holding current.	–

SCR triggering method

This is most widely used SCR triggering method. Three types .

1. DC Gate Triggering:-
2. 2. AC Gate Triggering:- I. Resistance triggering: II. RC Triggering
3. 3. Pulse Gate Triggering:-

DC gate triggering:-

- A DC voltage of proper polarity is applied between gate and cathode (Gate terminal is positive with respect to Cathode).
- When applied voltage is sufficient to produce the required gate Current, the device starts conducting.

Drawbacks :

- One drawback of this scheme is that both power and control circuits are DC and there is no isolation between the two.
- Another disadvantages is that a continuous DC signal has to be applied. So gate power loss is high. `

AC Gate Triggering:-

- oHere AC source is used for gate signals.
- This scheme provides proper isolation between power and control circuit.

Drawback: o
Drawback of this scheme is that a separate transformer is required to step down ac supply.
Two methods of AC voltage triggering namely (i) R Triggering (ii) RC triggering

Pulse Gate Triggering:-

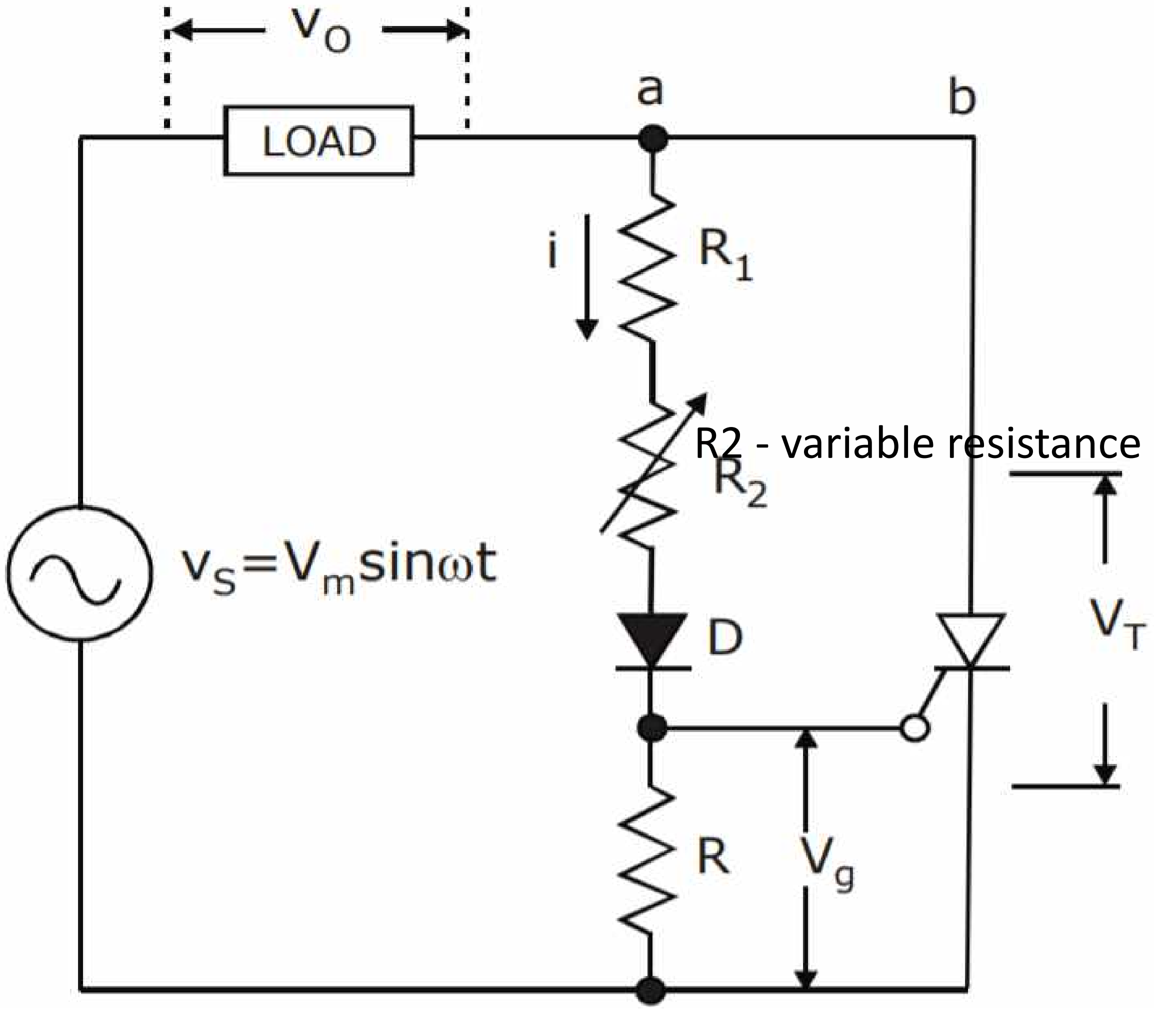
- In this method the gate drive consists of a single pulse appearing periodically (or) a sequence of high frequency pulses.

- This is known as carrier frequency gating.

Advantages

1. Low gate dissipation at higher gate current.
2. Small gate isolating pulse transformer
3. Low dissipation in reverse biased condition is possible.So simple trigger circuits are possible in some cases
4. When the first trigger pulse fails to trigger the SCR, the following pulses can succeed in latching SCR.

R Triggering Circuit



R2 - variable resistance R – stabilizing resistance

- The diode D is called as blocking diode. It prevents the gate cathode junction from getting damaged in the negative half cycle

- Simplest triggering circuit
- Limited triggering angle range (0° to 90°)
- Performance depends upon temperature & SCR characteristics
- In the above fig. R_1 is the current limiting resistor, R_2 is the variable resistor which controls the firing angle and R is the stabilizing resistor

- If $R_2 = 0$, then the current is limited by R_1.
- This current should not > max. permissible gate current I_{gm}. Therefore, R_1 can be found as follows

$$I_{gm} \leq \frac{V_m}{R_1} \Rightarrow R_1 \geq \frac{V_m}{I_{gm}}$$

- R is chosen s. t. max. voltage across it doesn't exceed max. forward gate voltage V_{gm}. Therefore,

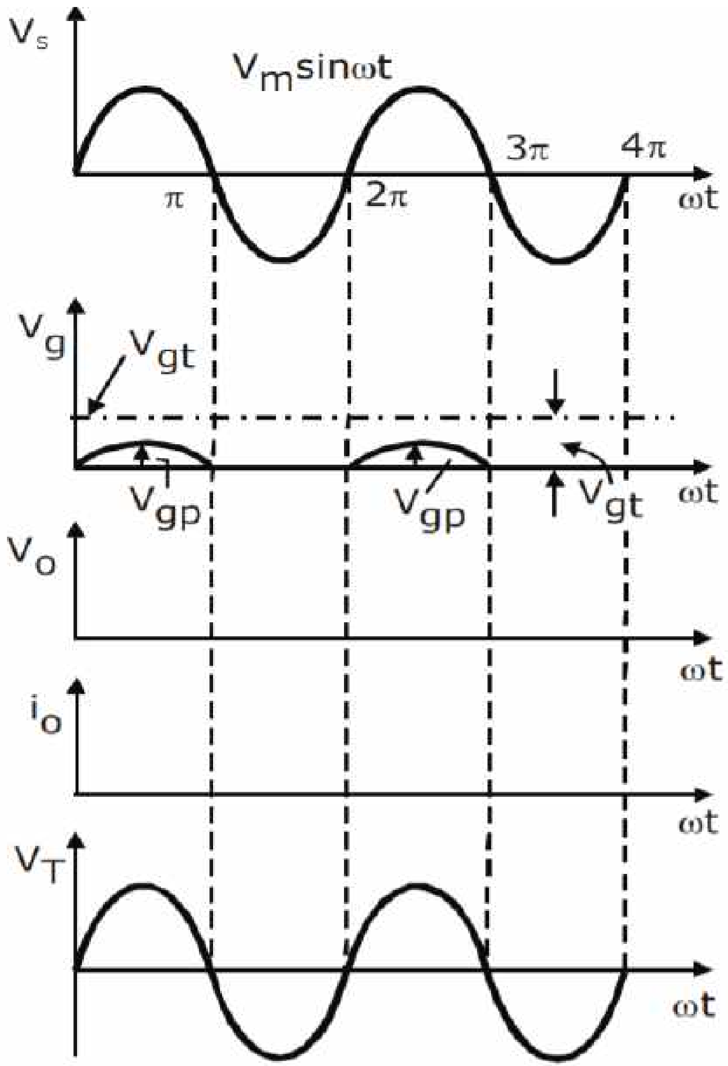
$$\frac{V_{\mathrm{m}}}{R+R_1} R \le V_{gm} \Rightarrow R \le \frac{V_{\mathrm{gm}} R_1}{V_{\mathrm{m}} - V_{\mathrm{gm}}}, \quad \left(R_2 = 0\right)$$

- Gate trigger ckt draws a small current due to large values of R_1 & R_2.
- Gate voltage v_g is a half wave pulse because diode D allows the flow of current only in +ve half cycle. Its amplitude is governed by R_2
- Next, we discuss cases for different values of R_2

Case 1: R_2 is large, No triggering

- When R_2 is large, current i is small and voltage $v_g = iR$ is also small
- If peak value of gate voltage $V_{gp} < V_{GT}$, SCR will not turn ON and accordingly there will be no O/P voltage or current and the supply voltage will appear ax the SCR

Case 1:
No Triggering

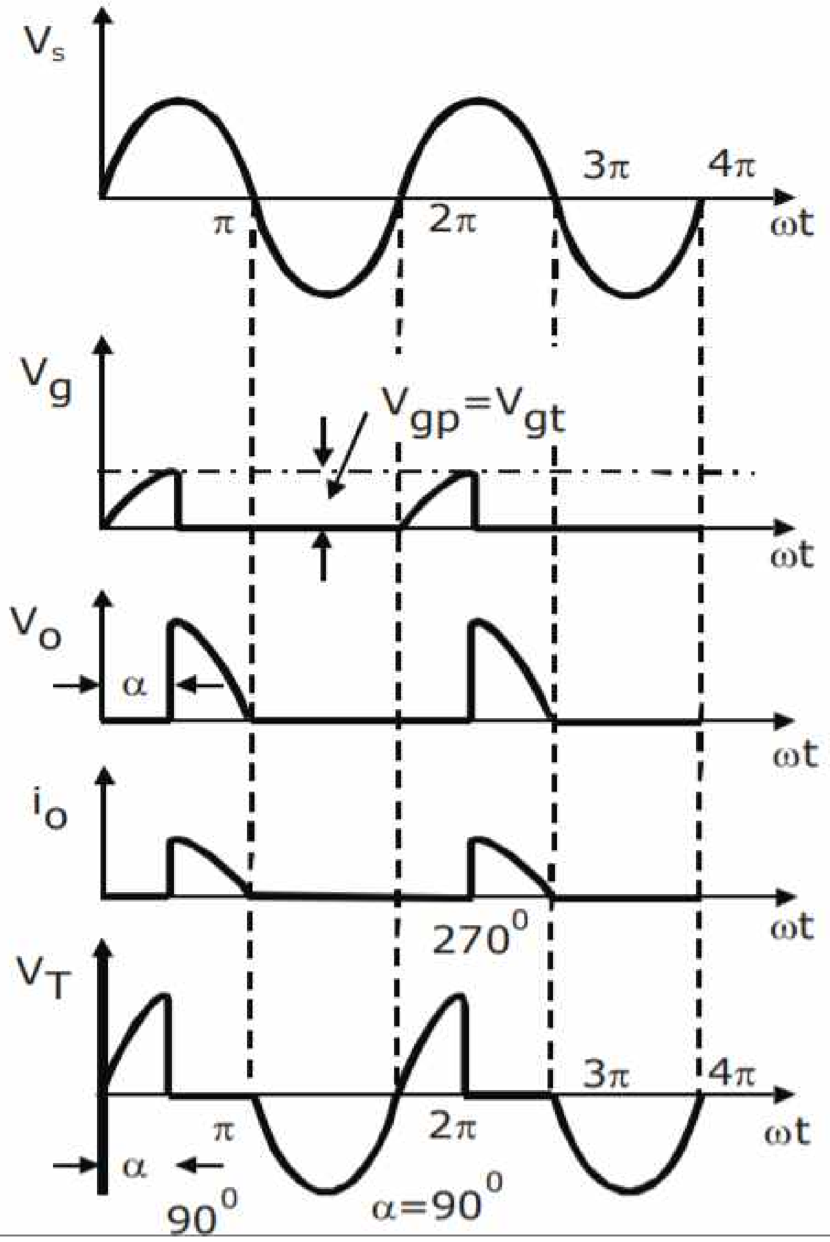


R2 Large

Case 2: $\alpha = 90°$

- When R_2 is decreased s. t. $V_{gp} = V_{GT}$, $\alpha = 90°$ is obtained which can't increase beyond this value
- This is because the thyristor latches into conduction as soon as V_{gp} becomes equal to V_{GT} for the first time

Case 2:
α = 90°



Vs
π
2π
3π
4π
ωt
Vg
Vgp=Vgt
ωt
Vo
α
ωt
io
ωt
270⁰
VT
α
90⁰
π
2π
α=90⁰
3π
4π
ωt

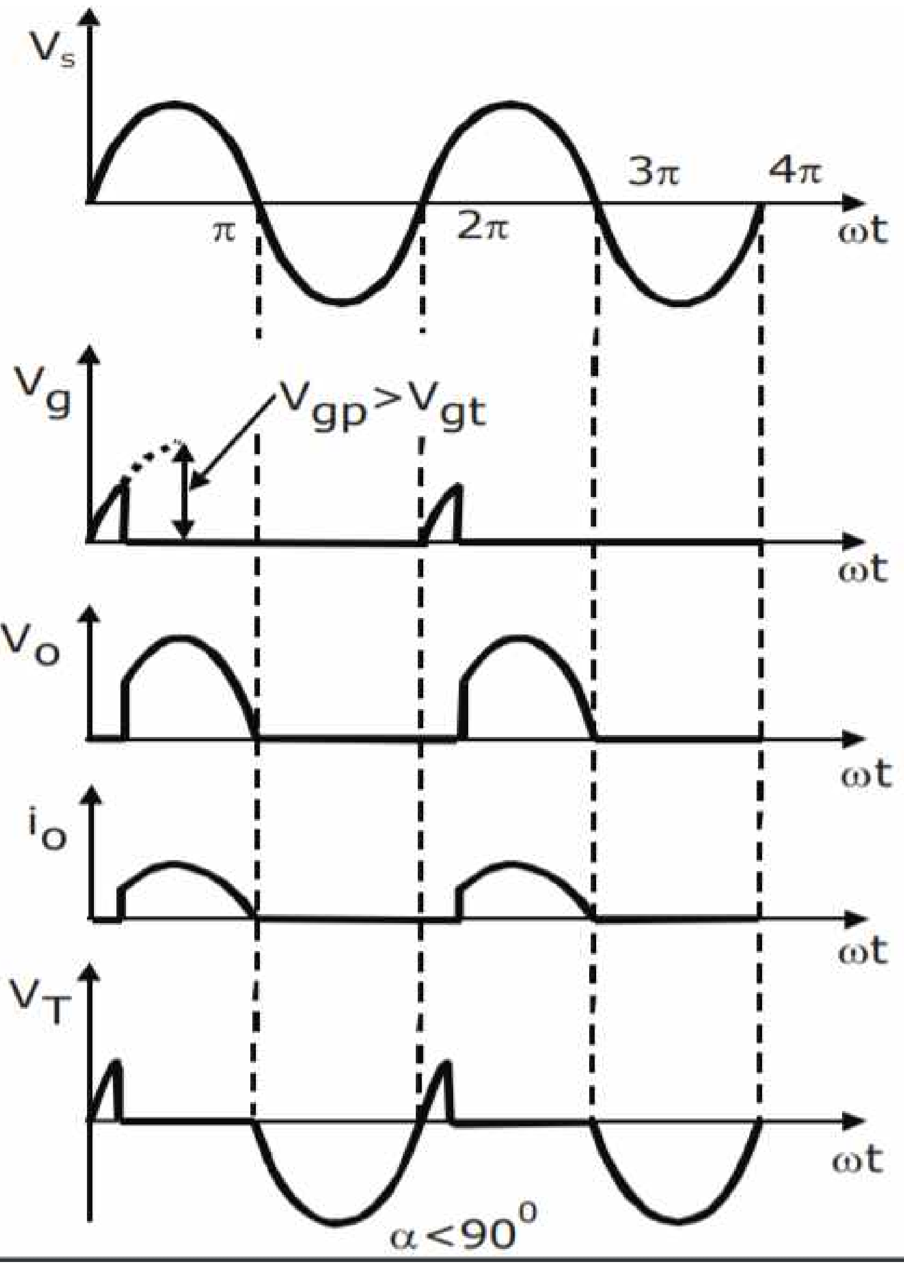
Case 3: $\alpha < 90°$

- When $V_{gp} > V_{GT}$, $\alpha < 90°$
- Also α can't be zero however large v_g may be.
- Min. value of α is about 2° – 4° (which is obtained when $R_2 = 0$)
- **Relationship between V_{gp} & V_{GT} is**

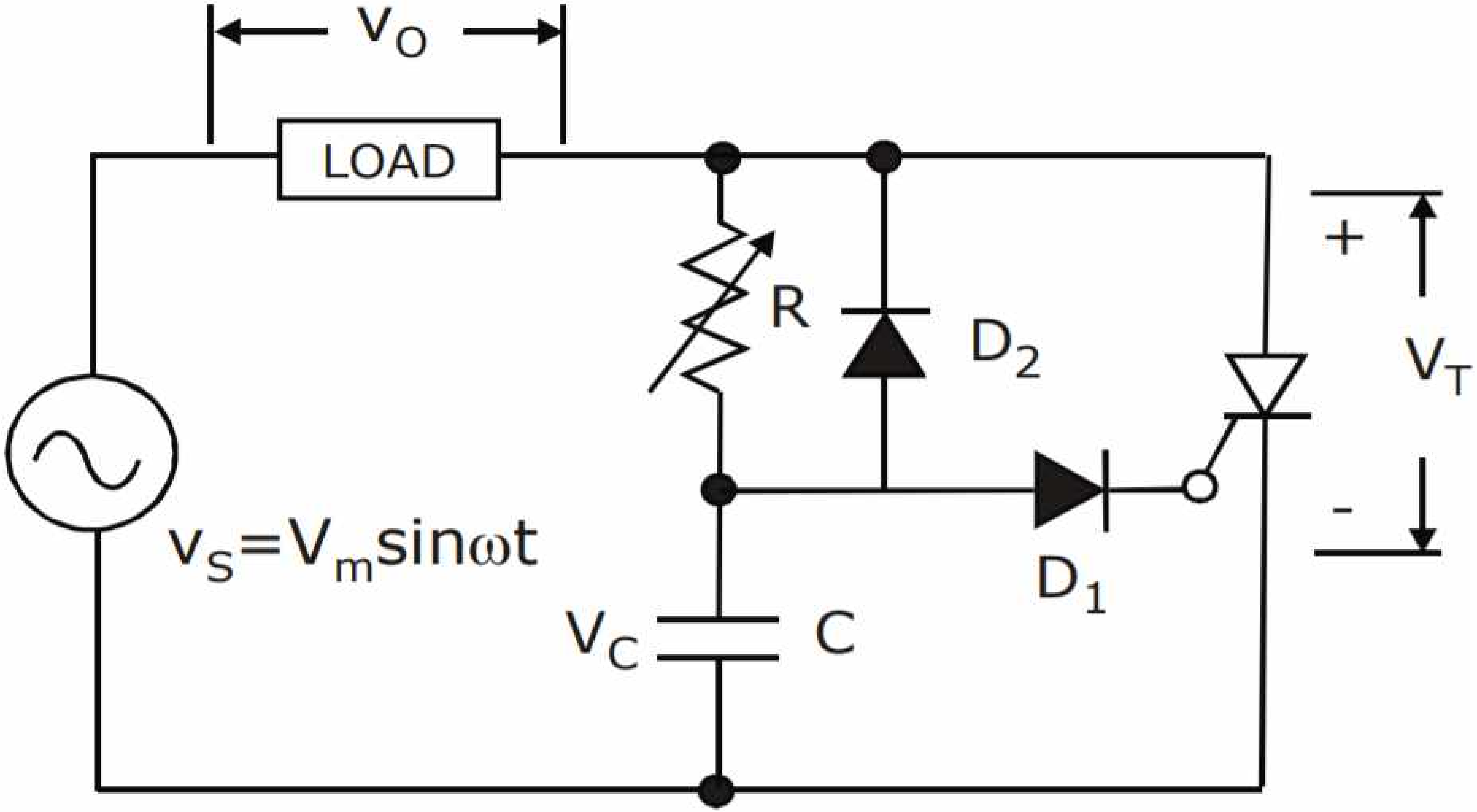
$$V_{gp} \sin\alpha = V_{GT}$$

$$\text{or, } \alpha = \sin^{-1} (V_{GT}/V_{gp})$$

Case 3:
α < 90°



RC Half Wave Circuit



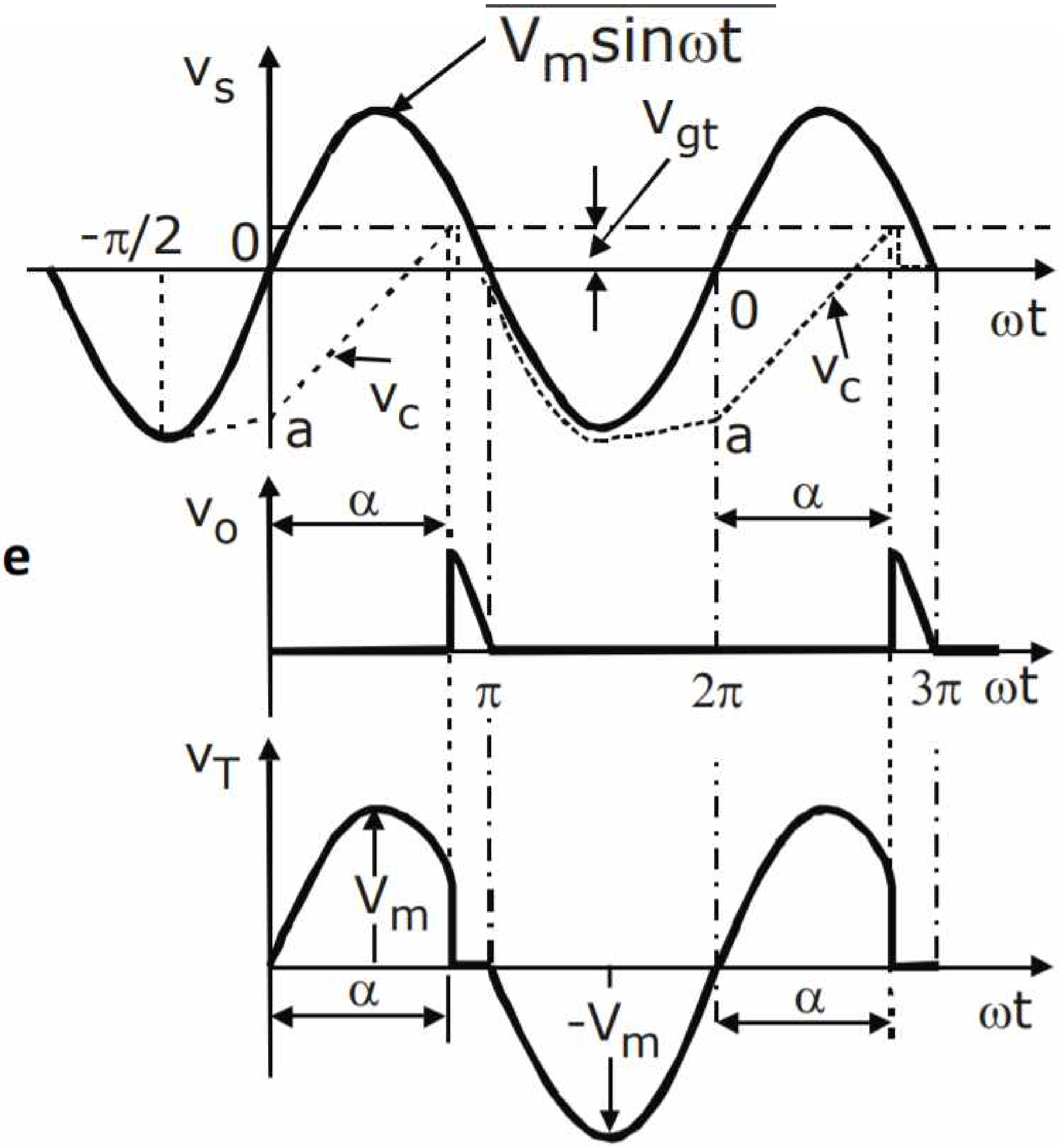
RC triggering circuit

- The limited range of firing angle control by resistance firing circuit can be overcome by RC firing circuit
- Several variations of RC trigger circuits are available
- In these cases the range of α is extendable beyond 90.

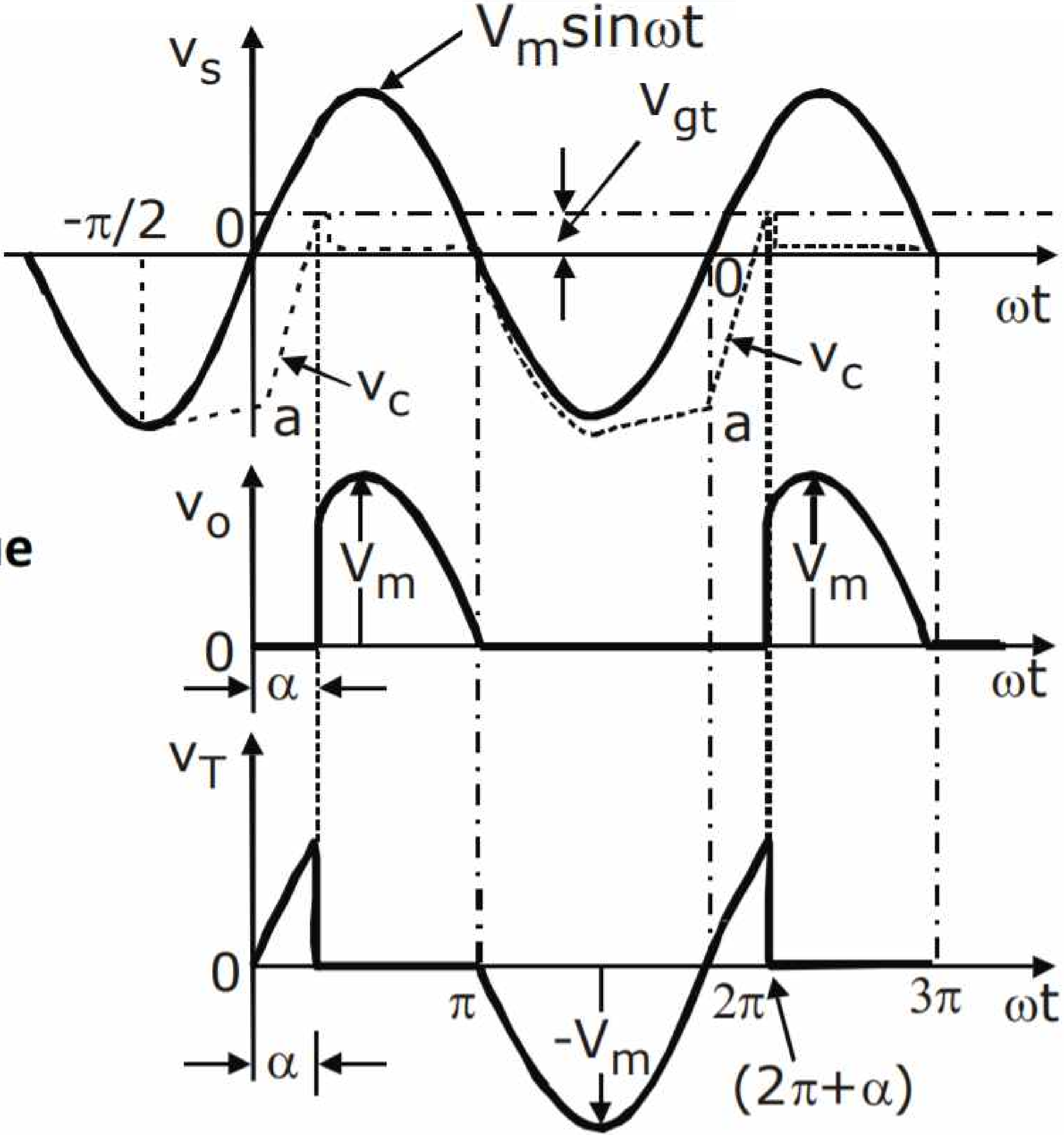
RC half wave triggering circuit

- By varying the value R, firing angle can be controlled from 0 to 180
- In the –ve half cycle capacitor C charges through D2 with lower plate +ve to the peak supply voltage Vm at ωt=-90
- After ωt=-90, source voltage Vs decreasing from –Vm at ωt=-90 to zero at ωt=0

High Value of R



Low Value of R



Working

- The limited firing angle range of R triggering ckt is overcome in RC ckt where the range is 0°-180° (controlled by the variable resistance)
- In the above ckt, capacitor gets charged (through D_2) to $-V_m$ in every –ve half cycle
- Upto the zero crossing of the AC supply wave, voltage may decrease to a lower value but can be assumed constant for simplicity
- In +ve half cycle C begins to charge through R

- As soon as the capacitor voltage rises to V_{GT}, SCR triggers
- Capacitor holds a small constant voltage after this
- D_1 serves to prevent breakdown of the G-K junction during –ve half cycle
- Observing the waveform it can be said that firing angle can never be exactly 0° & 180°

Empirical Relationships

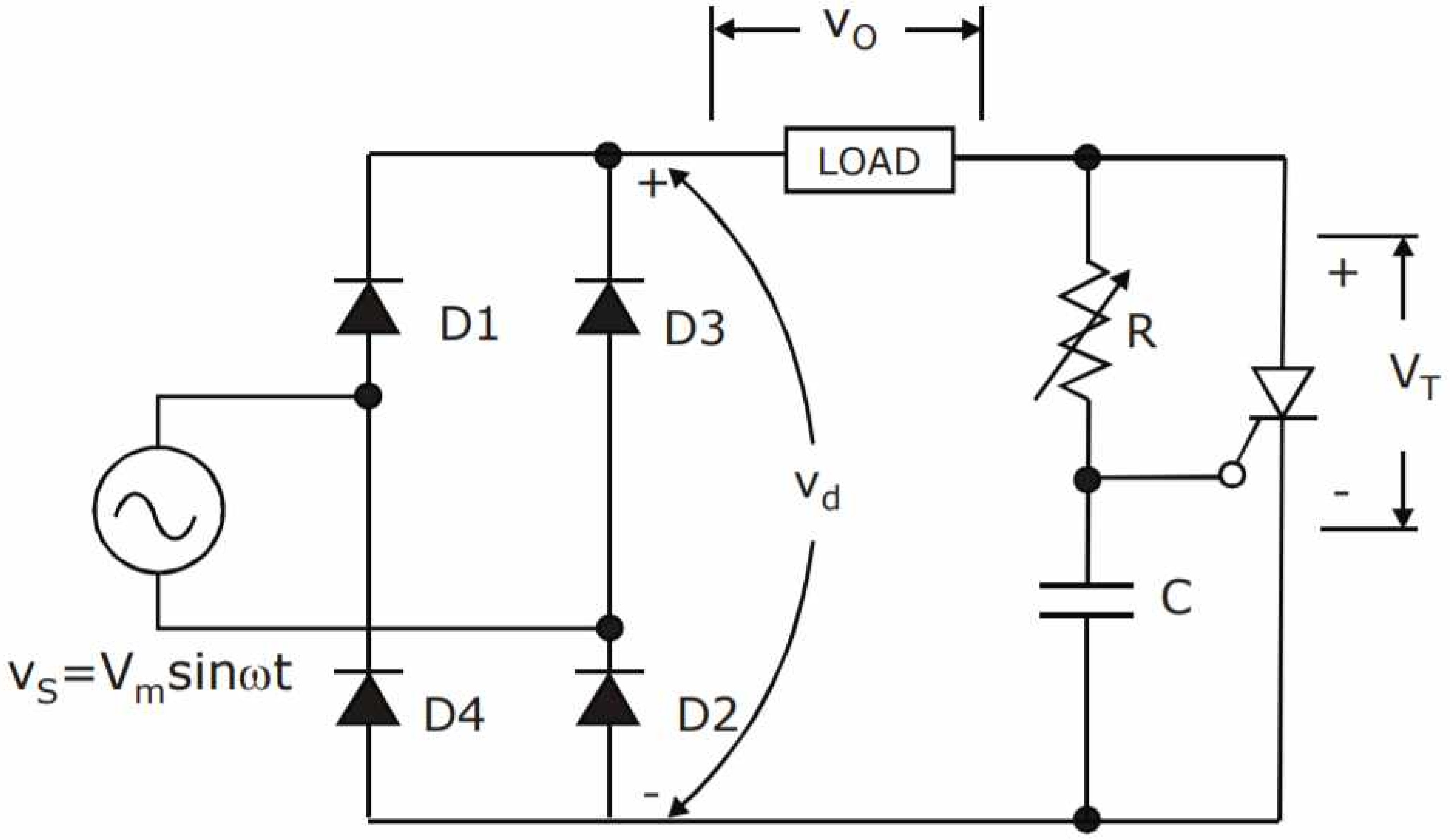
- In the range of power frequencies, it can be shown that the value of RC for zero o/p voltage is given by $RC \geq \frac{1.3T}{2} \cong \frac{4}{\omega}, \omega = 2\pi f$

$f = 1/T$ is the frequency of the AC line frequency

- At the triggering instant, $v_C = V_{GT} + V_{D1}$
- Max value of R can be found as follows

$$R \leq \frac{v_s - V_{GT} - V_{D1}}{I_{GT}}$$

RC Full Wave Circuit



Power Electronics

belongs partly to power engineers & electronic engineers

(220v to 240v) deals with generation, transmission & utilization of energy at high ...

... with the ... of electronic for ...ol & conversion of ...ge amount of electric power

mainly deals with distortionless production, Tx & reception of data at very low power levels (0-30V)

...wer electronics:

deals with the conversion & control of electric energy

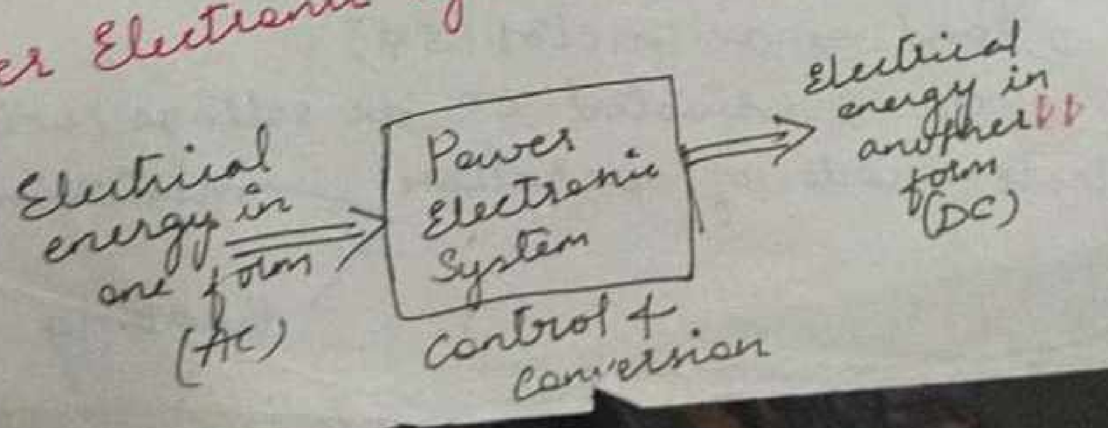
combines power, electronics & control

defined as the appln of solid state electronics for the control & conversion of electric power

is the appln of electronic principles into a situations that are rated at power levels instead of signal level

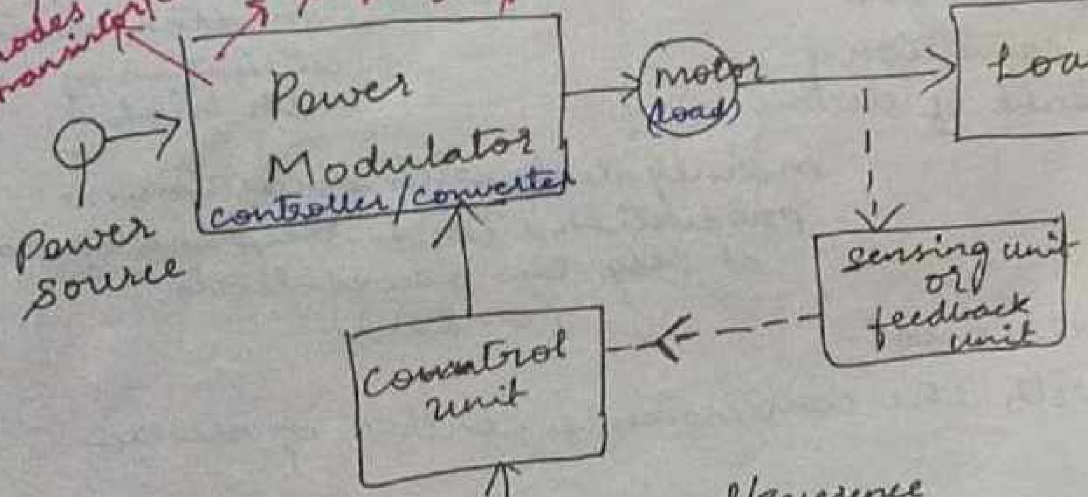
-> deals with use of electronics for the control & conversion of large amounts of electrical power

Power Electronic Systems



Cut off Region

switches, L, C, transformer
diodes transistor/SCR → matrix of power semiconductor switches to convert power at high ?



Power Source: AC / dc

AC → 1 φ (low power / 1000W) → lighting, heating, few large electric motors
AC → 3 φ (50 Hz) → 3 power → 120°

low power drives

aircraft, mobile towers, command s/m, manufact peaks → 90°/270° power m delivered at co one

Power Modulator:
→ converts electrical energy of the source as p the requirement of the load
Ex, load → dc motor
o/p → adjusted to dc voltage
2) load → ac motor (3φ)
dc → adjusted to ac voltage (with fu...
... operation ⟨ monitoring

modulat... to load ... It res... are wit... revers... motors ... DC ... Indu... Syn... Cont... →

modulates the power flow from source to load (as required by the load) ②

It restricts the source & motor currents are within permissible values during speed reversal

Motors

DC motor
Induction motor
Synchronous motor
Stepper motor
Brushless dc motor
Switched reluctance motor

Control unit (

→ controls power modulator
→ operates at lower power & vtg levels

Sensing unit

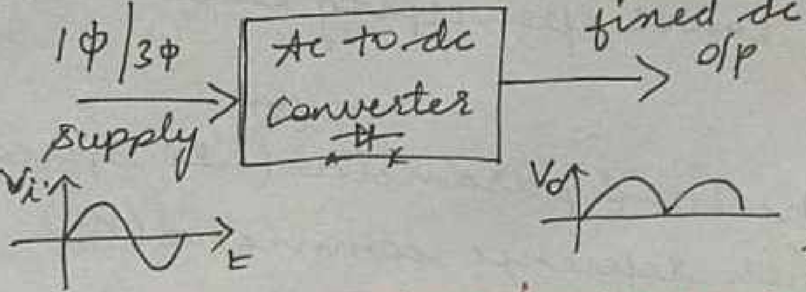
→ measures the load parameters (like speed) & compares with reference command (K_2)
→ Based on the difference ($K_1 - K_2$), the control unit controls the devices used in power modulator

Power Electronic converters / power electronic circuit or Power converters

classified as

1. diode rectifiers / uncontrolled rectifiers
2. ac - dc converters / controlled rectifiers
3. ac - ac converters / ac voltage controllers / AC regulator
4. dc - dc converters / dc choppers
5. dc - ac converters / inverters
6. ac - ac converters / cyclo converters

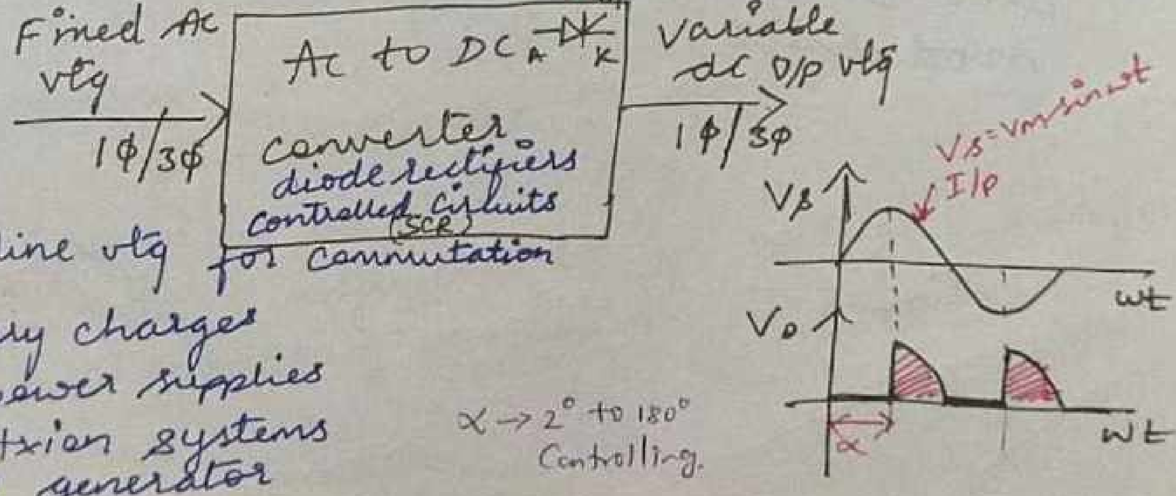
1. Diode rectifiers / uncontrolled rectifier



2. AC to DC converters / phase controlled Rectifiers

line commuted ac to dc Rectifiers

naturally —"—



→ uses line vtg for commutation

→ Battery charges
→ dc power supplies
→ dc txion systems
→ wind generator

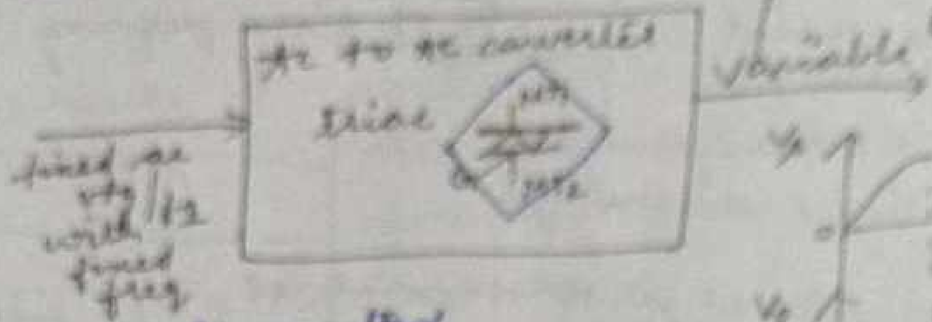
$\alpha \rightarrow 2^\circ$ to 180° Controlling.

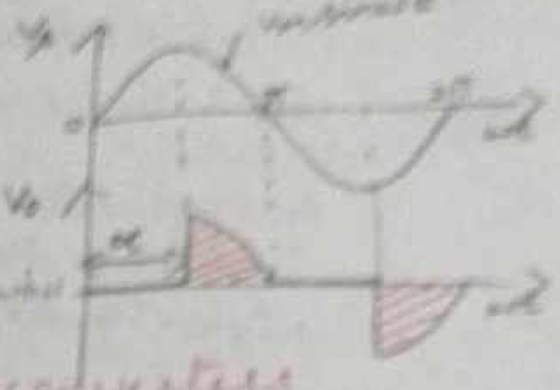
. . . 4 terminal device

③

③ AC to AC converters / AC regulators or AC vtg controller

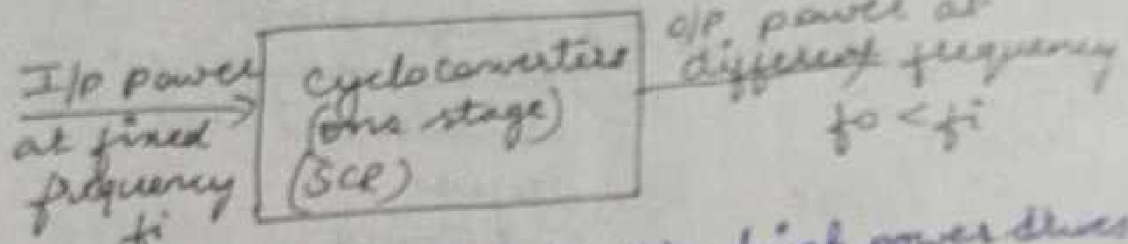
we can control both +ve and -ve cycle





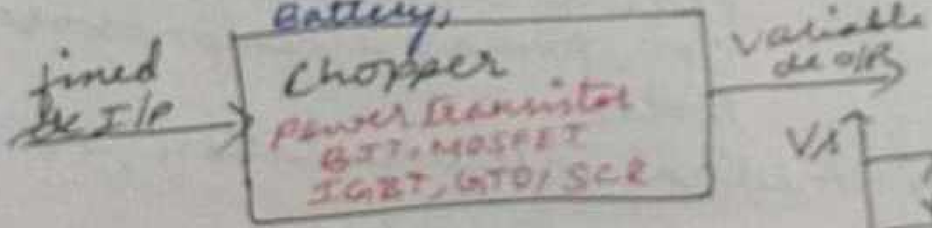
App: lighting control
Speed control of large fans
electronic chargers, AC drives/motors

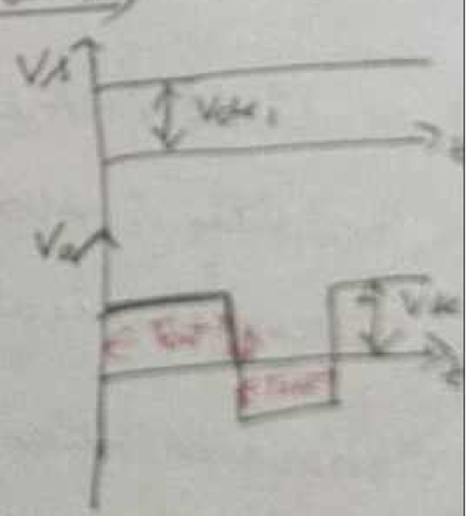
④ AC to AC converter / cycloconverters



→ used for slow speed, very high power drives
→ AC transaction drives

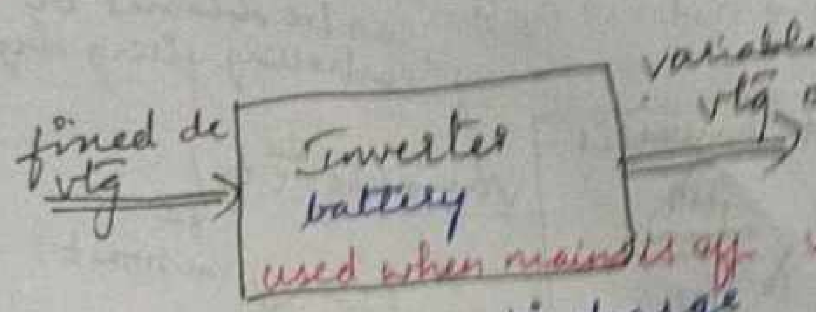
⑤ DC to DC converters / choppers

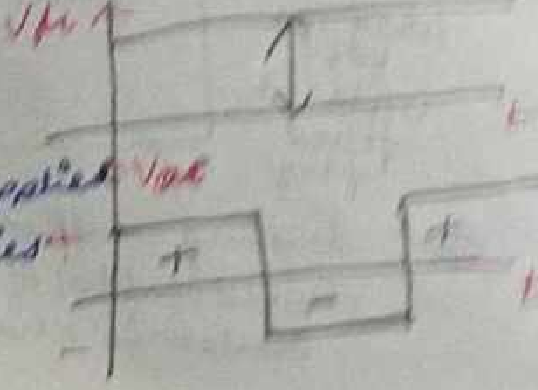




Appln: DC drives
Subway cars
Battery driven vehicles
SMP supplies

⑥ DC to AC converter/Inverter





Appn: flash light discharge
UPS
Aircraft + space power supplies
Induction heating supplies
high vtg dc trian s/m

Application of power electronics

① Home Appliances: Refrigerators
sewing machines
grinders/mixers
dryers
lightning
washing machine

② Industrial: welding equipment, press machinery, conveyors, dryers, elevators, electric drives, induction heating, UPS, pumps + compressors, machine tools,

③ Medical: medical instrumentation, Fitness m/c

④ Security: Alarm + security s/m's

⑤ Telecommunication: UPS, solar power supplies, VLF transmitters

⑥ Transportation: trains, trolly, subways

1 — 0 1 desh

aerospace: Aircraft power supplies, satellite (4)
Power system

(8) Automotive: audio & RF amplifiers, regulator

(9) Commercial: power tools, electric fans,
photocopies, vending machine
Advertising

(10) Utility systems: supplementary energy systems
(solar, wind)

History of power electronics

till 1956 → confined to low power ckts → light current engineering

sep 1956 → four scientist of Bell lab's, USA → "PNPN transistor switches" paper

1957 → Gordon Hall of GE, USA → SCR

Continuous modification & improvement made
more economical & commercial

Digital Voltmeters

* measuring instruments that convert analog voltage to digital/numeric readout
  ↓
  on front panel

* measures analog dc vtges

* along with signal conditioner & DVM, it can be used to measure ac vtges, Ω, dc & ac current, temperature, pressure

* various features are speed, automation, programability

* Variety of DVM are available based on
  - No of digits
  - No of measurements
  - Accuracy
  - speed of reading

* numeric read out reduces
  → human error
  → eliminates parallax error
  → ↑ses reading speed
  → o/p form produced will be suitable for processing & recording

Perfomance characteristic of DVM

* I/p range from + 1.0V to 1000V with automatic range selection & overload indicat

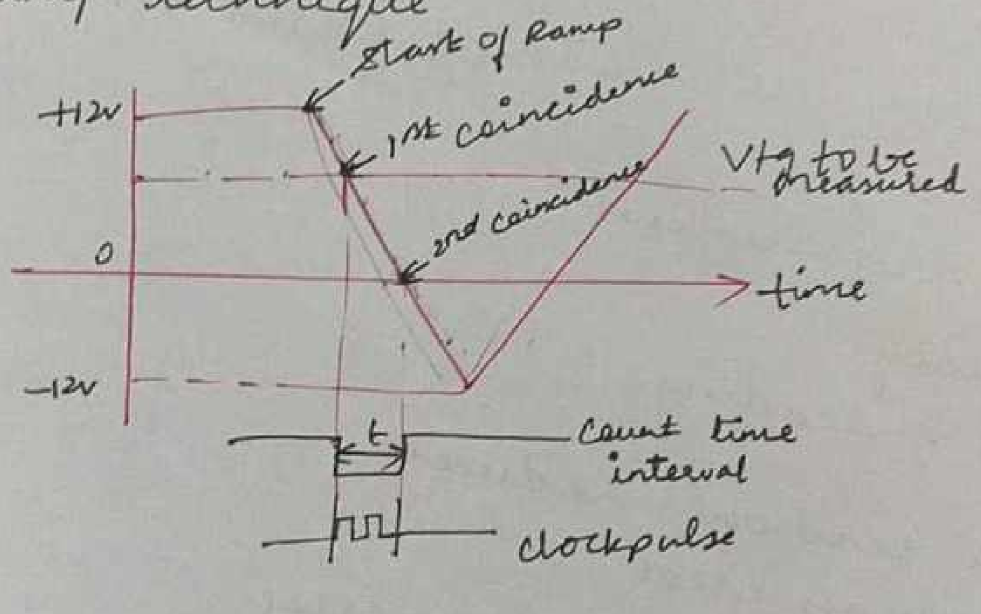
* Absolute accuracy is high

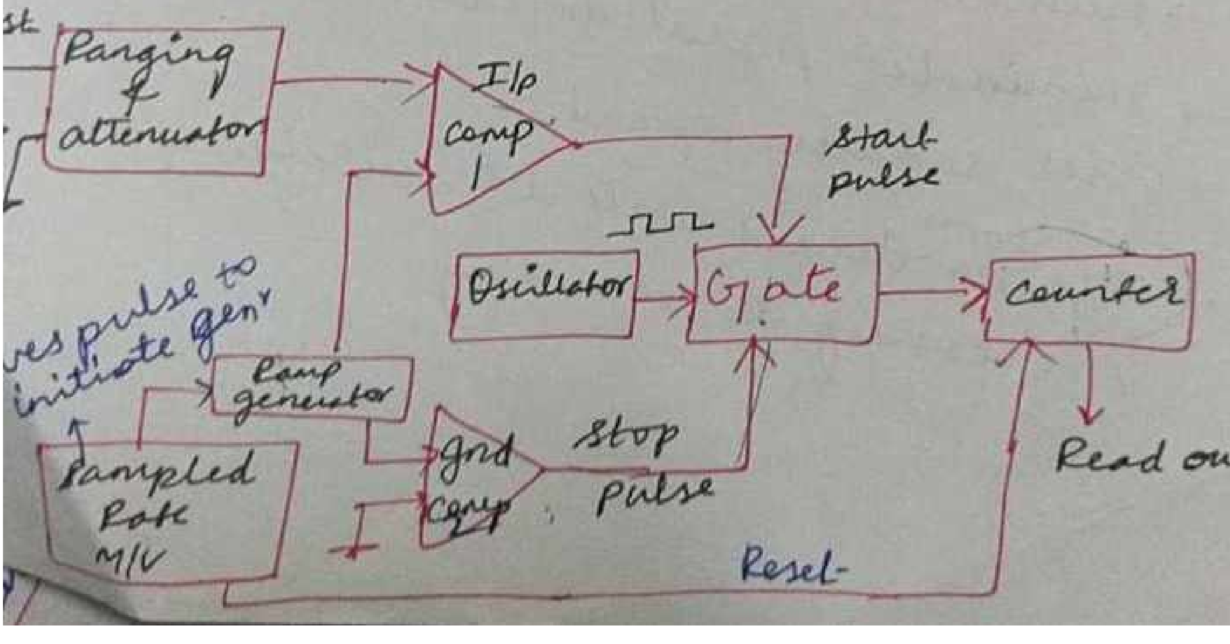
* Resolution 1 part in million (~~±~~V

* I/p resistance 10MΩ, Cin = 40PF

* O/P in BCD form.

Ramp technique





Principle

measure the time that a linear ramp takes to change the I/p level to gnd level & vice versa

* This time period is measured with counter

* Ramp → +ve/-ve

* At the start of the measurement a ramp voltage is initiated

* The ramp voltage is continuously compared with the voltage that is being measured

* At the instant these two voltage become e[qual] a coincidence circuit generates a pulse which opens a gate ie the I/p comp generates start pulse.

* The ramp continues until the second comparator circuit senses that ramp has reached zero value.

The gnd comp compares the ramp with gn[d] when ramp vtg equals zero / reaches gn[d] potential, the gnd comp generates a pulse which closes the gate.

* The time duration of the gate opening [is proportional to] I/p vtg value

* In the time interval b/w the sto[p] [&] start pulse, the gate opens & the o[scillator] ckt drives the counter
* The magnitude of the count ⇒ mag[nitude of] I/p voltage

Advantages

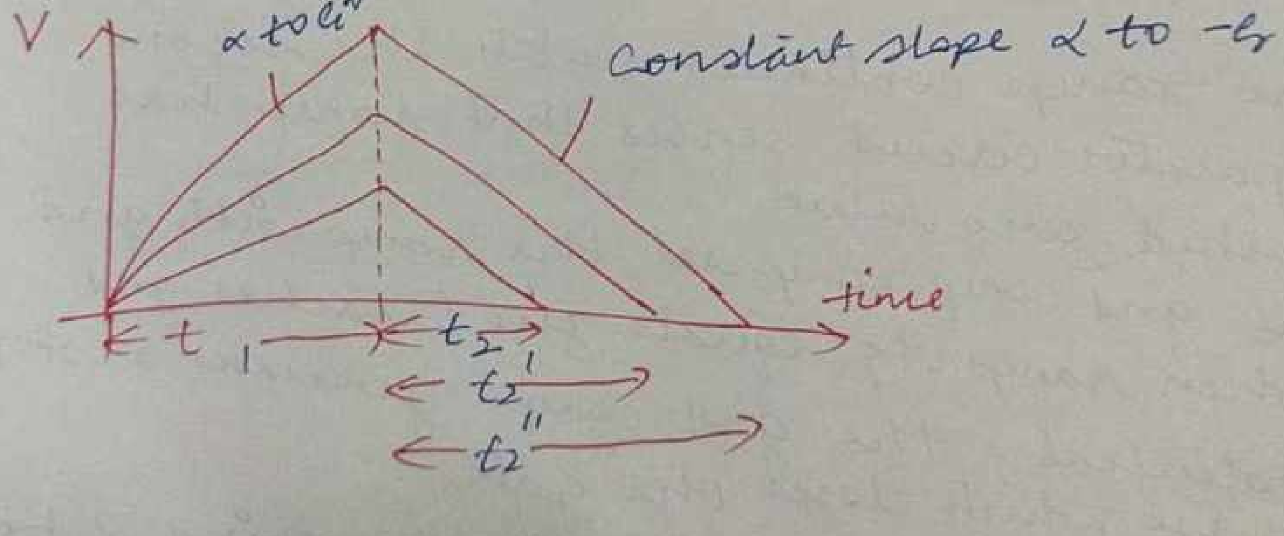
* Easy to design, cost is low
* O/p pulse can be transmitted over long feeder lines

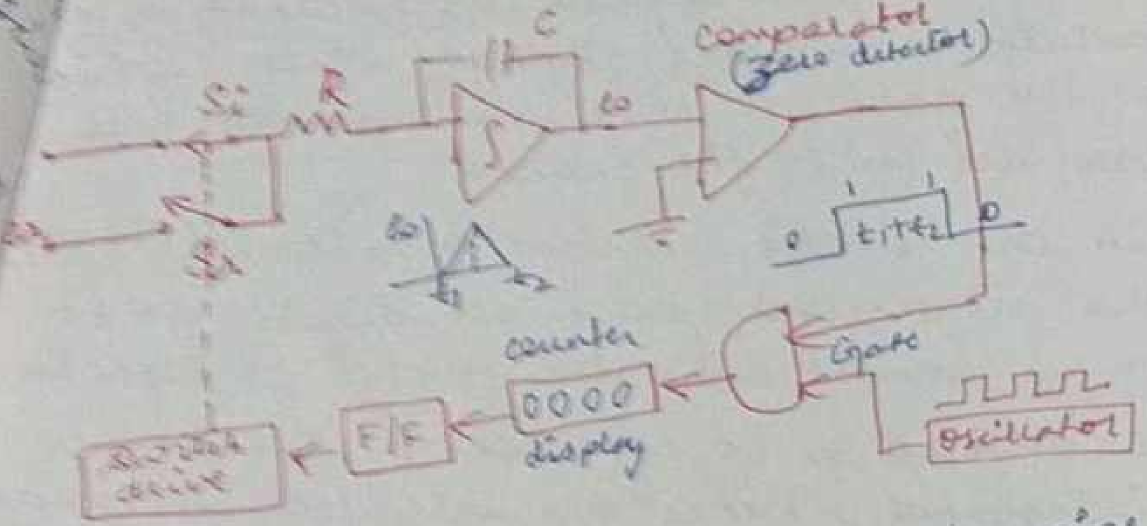
Disadvantages

* Large errors are possible when noise i[s] superimposed on the I/p signal

Dual slope integrating type DVM

[voltage to time conversion]





In ramp techniques, superimposed noise can cause large errors.

In the dual ramp technique, noise is averaged out by the +ve & -ve ramps using the process of integration

Principle

* I/P voltage ei is integrated, with slope of the integrator O/P ∝ to I/P voltage
* After a fixed time, equal t1, ei is dis-connected & -er is connected
* hence integrator will have -ve slope which is constant & ∝ to magnitude of the I/P voltage
* At the start a pulse resets the counter & F/F O/P to logic level '0'
* Si closed, Sr open
* capacitor begins to charge

* In this ...
* As soon as the integrator o/p exceeds 0, comparator o/p voltage changes state, which opens the gate so that the oscillator clk pulses are fed to the counter
* When the counter reaches max count (9999) on the next clock pulse all digits go to 0000 & counter activates the F/F to logic level
* hence switch S_r is connected, $-e_r$ is given to integrator, hence o/p will be -ve slope ie o/p ↓ses linearly to zero
* Hence comp o/p state changes & locks the gate & C discharges.
* The discharge time t_2 ∝ to Vin
* As soon as e_0 is 0, counter stops.
* The pulses counted by counter = Vin
*

During charging

$$e_0 = \frac{-1}{RC}\int_0^{t_1} e_i\,dt = -\frac{e_i t_1}{RC} \quad ①$$

During discharging

$$e_0 = +\frac{1}{RC}\int_0^{t_2} -e_r\,dt = -\frac{e_r t_2}{RC} \quad ②$$

① = ②

$$\frac{e_i t_1}{RC} = \frac{e_r t_2}{RC}$$

$$\boxed{e_i = \left(\frac{t_2}{t_1}\right) e_r}$$

whole ... (margin, cut off)

oscillator period equals T of digital counter indicates n_1 & n_2 counts

$$e_i = \frac{n_2 T}{n_1 T} e_r$$

$$e_i = \frac{n_2}{n_1} e_r$$

An integrator contains a 100kΩ & 1µF capacitor. If the voltage applied to the ∫ I/P is 1V, what voltage will be present at the integrator after 1s

$$e_o = \frac{e_i \times t_1}{RC} = \frac{1 \times 1}{100K \times 1\mu} = \frac{1}{0.1} = 10V$$

Now if reference voltage is applied to ∫ of the above example at t_1 is 5V in amp, what is the time interval of t_2

$$\frac{e_i \cdot t_1}{RC} = \frac{e_r \times t_2}{RC}$$

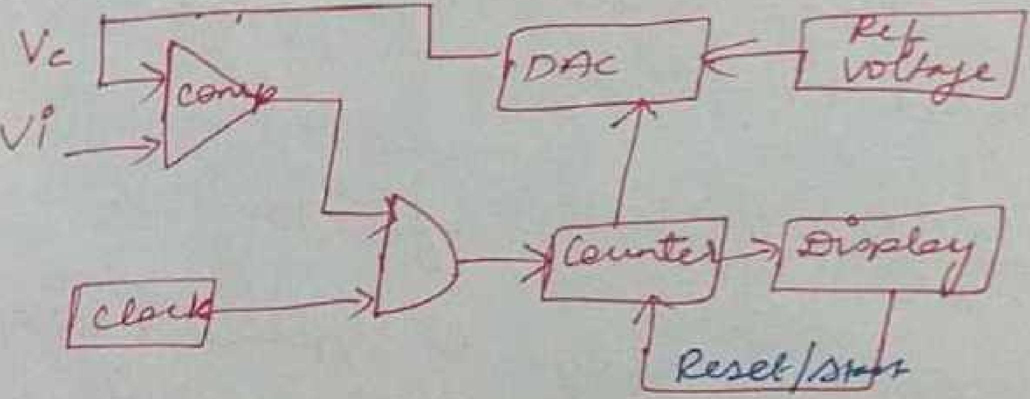
$$t_2 = \frac{e_i}{e_r} \times t_1 = \underline{\underline{0.2s}}$$

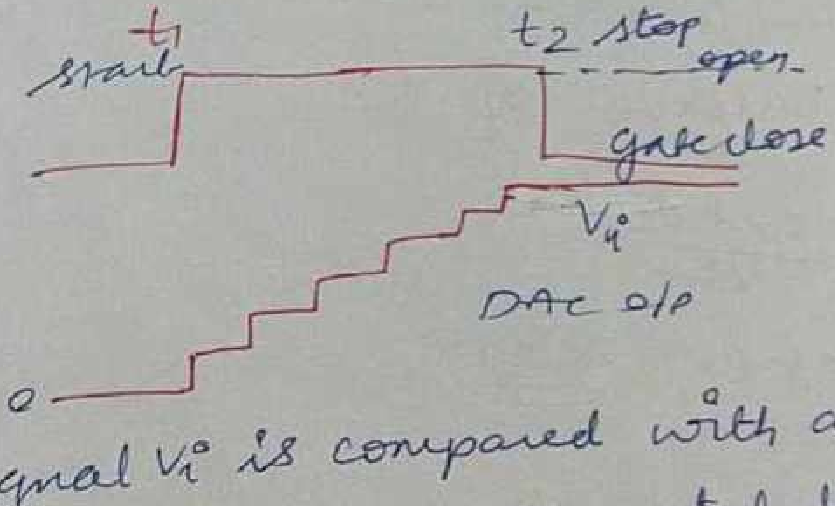
Principles of ADC (A D C)

Direct compensation

* The I/p signal is compared with an internal generated voltage which ↑sed in steps staircase from zero.
* The no of steps needed to reach the full compensation is counted

The staircase Ramp





I/p signal Vi is compared with an internal staircase voltage VC, generated by a series ckt (clock, counter, DAC)
As soon as VC is equal to Vi, the I/p amp closses the gate, counter stops & it displays

ration of ckt

* clock generates pulses continuously
* At start of measurement, the counter is reset to 0 at time t1 so that o/p of DAC is also "0"
* If $V_i \neq 0$, the I/P comparator applies an o/p voltage that opens gate and clk pulse are counted by the counter
* As the counter starts counting, DAC starts to produce an o/p voltage ↑sing by one step at each count of the counter
* The result is a staircase vtg applied to second I/P of the comparator.
* This process continues until the staircase voltage is equal to / slightly > than Vc
At that instant t2, V0 of comparator changes state & hence gate closes & the counter is stopped
* No of counts ∝ Vc & Vi

Advantages

① Zin of DAC high
② accuracy does not depend on clk

Disadvantage

① reading not stable
② Zin can influence accuracy

Successive Approximations

Suppose the converter can measure a max ie 5V corresponds to max count 11111111.
test voltage $V_{in} = 1V$,

$$V_O = \frac{V_{ref}}{2}\left[\frac{d_0}{2^7} + \frac{d_1}{2^6} + \dots + \frac{d_7}{2^0}\right]$$

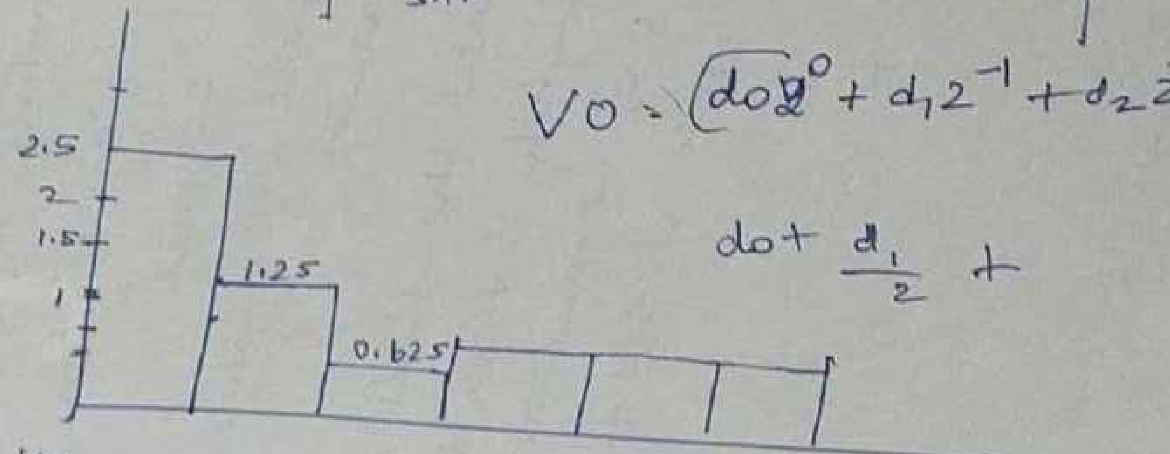
	D7	D6	D5	D4	D3	D2	D1	D0	Compare	O/P	V
$D_7=1$	1	0	0	0	0	0	0	0	$V_{in} < V_o$	$D_7 = 0$	2
$D_6=1$	0	1	0	0	0	0	0	0	$V_{in} < V_o$	D_6 0	1.2[illegible]
$D_5=1$	0	0	1	0	0	0	0	0	$V_{in} > V_o$	D_5 1	0.6[illegible]
$D_4=1$	0	0	1	1	0	0	0	0	$V_{in} > V_o$	$D_4=1$	0.93
$D_3=1$	0	0	1	1	1	0	0	0	$V_{in} > V_o$	D_3 0	"
$D_2=1$	0	0	1	1	0	1	0	0	$V_{in} > V_o$	$D_2=0$	"
$D_1=1$	0	0	1	1	0	0	1	0	$V_{in} > V_o$	$D_1=1$	0.977
$D_0=1$	0	0	1	1	0	0	1	1	$V_{in} > V_o$	$D_0=1$	0.997

SAR

$$V_O = (d_0 2^0 + d_1 2^{-1} + d_2 2^{-2} \dots d_7 2^{-8}]$$

$$d_0 + \frac{d_1}{2} + \dots \frac{d_7}{2^7}$$

V_{in} & V_o,



$$V_o = V_{ref}\left[D_7 + D_1 2^{-1} + D_2 2^{-2} \dots\right]$$

$$V_{ref}(d_7 + d_6 2^{-1} + d_5 2^{-2} \dots + D_7 2^0]$$

...ring the first clock pulse, ... control circuit sets the D_7 to 1, $V_{out} = \frac{...}{2}$

SAR → 10000000

if $V_{out} > V_{in}$ → comp o/p → -ve → D_7 to 0

if $V_{out} < V_{in}$ → comp o/p → +ve → D_7 to 1

III^ly all bits are tested for complete 8 pulses

- Done at the begining, a start pulse applied to the start/stop M/V → D_7 → 1 & hence $V_{out} = \frac{1}{2} V_{ref}$

↓

is compared to V_{in} (unknown)

if $V_{in} > V_{out}$ ⟹ comp o/p → +ve

⟹ D_7 → 1 (retained)

The converter continues to supply its reference o/p voltage of $\frac{1}{2} V_{ref}$

- The ring counter then advances one count, shifting a 1 in the second MSB of the control register & its reading becomes 11000000

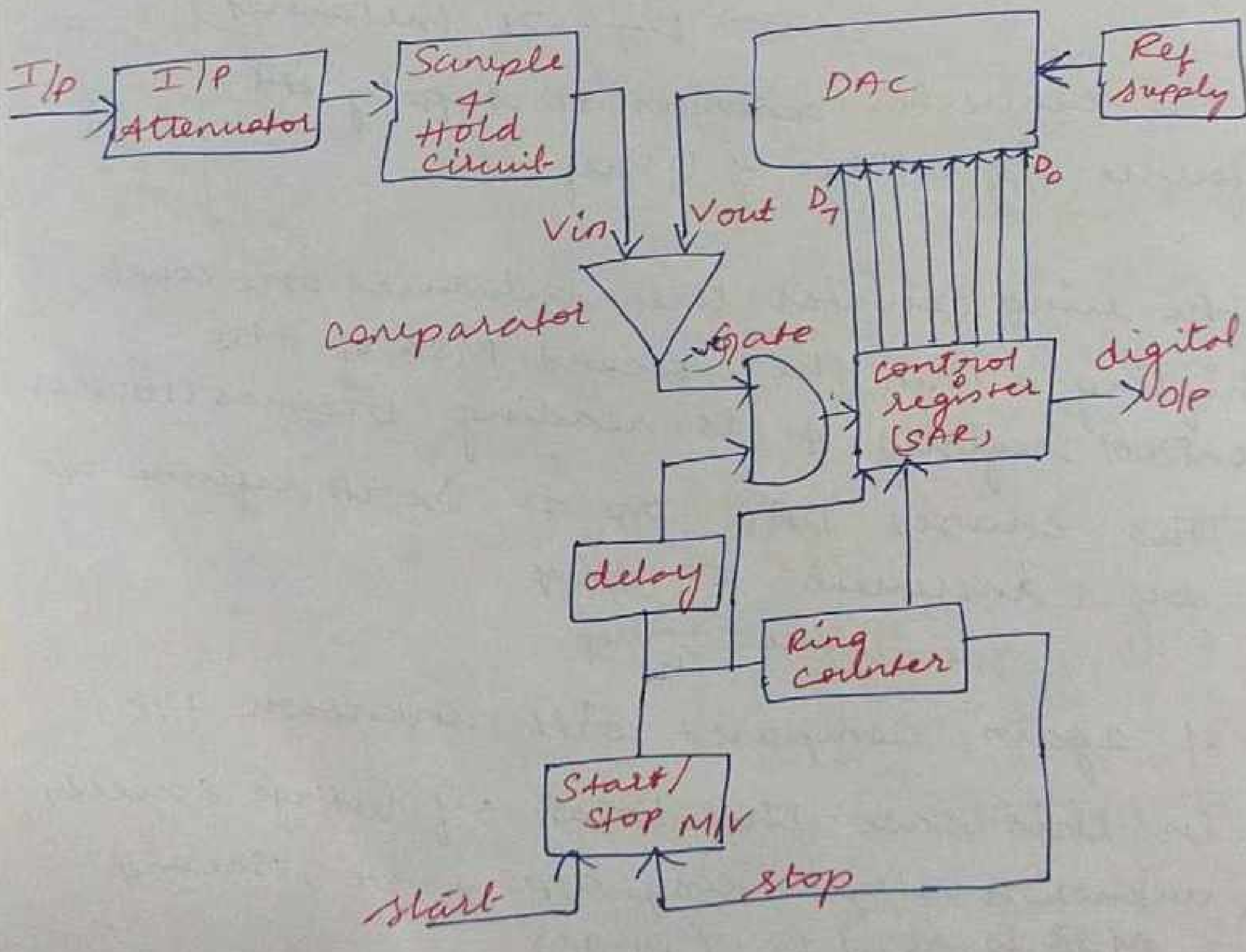
. This causes DAC o/p to rise its reference o/p by 1 increment to $\frac{1}{4} V_{ref}$

i.e. $\frac{1}{2} V_{ref} + \frac{1}{4} V_{ref}$

& again compared with unknown I/p,

* If in this case the total ref voltage exceeds the unknown voltage, comp o/p → -ve, second ... is reset to 0 (D_6 → 0)

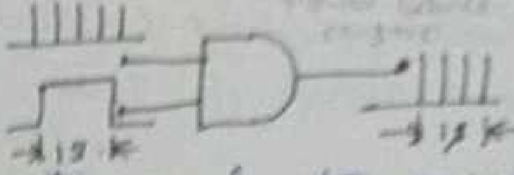
* The converter o/p then returns to its previous value of $\frac{1}{2}V_{ref}$ & awaits another input from the SAR.
* When the ring counter advances by 1, $D_5 \rightarrow 1$ & converter o/p rises by the next increment of $\frac{1}{2}V + \frac{1}{8}V$
* The cycle proceeds, finally ring counter reaches its final count, measurement cycle stops & the digital o/p of the control register represent final o/p of unknown I/p voltage



(A)

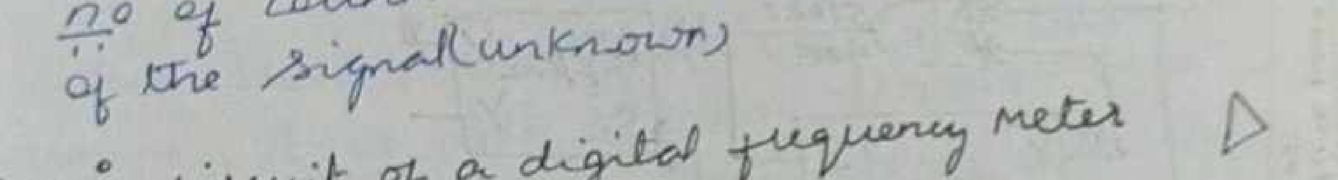
* III^lar to determination of the wt of an objec
* By using a balance + placing the obje on one side + an approximate wt on the other side, the weight of the object is determined
* If the weight placed is more than the unknown weight, wt is removed + anoth weight of smaller value is placed + agai the measurement is performed.
* Now if it is found that the wt plac is less than that of the object, another wt of smaller value is added to wt alrea Present + wt is determined
* If it is found to be greater than the unknown wt the added wt is removed + another wt of smaller value is added
* In this manner, by adding + removing + appropriate weight, the weight of the unknown object is determined. Using the above principal, successive appro works
* In the fig, if the start pulse, activates control circuit, SAR is cleared, D/A Vout = 0 the comparator O/P is -
* Now, if Vin > Vout,

Digital Frequency Meter

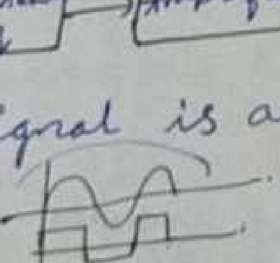


* signal is converted to trigger pulses & applied continuously to an AND gate
* A pulse of 1s is applied to the other terminal & no. of pulses counted during this period indicates the frequency
* The signal whose frequency is to be measured is converted into a train of pulses, one pulse for each cycle of the signal
* The no of pulses occurring in definite interval of time is then counted by counter
* no of counts → direct indication of frequency of the signal (unknown)

Basic circuit of a digital frequency meter



* signal is amplified & applied to schmitt trigger



converts sine to square & differentiated & clipped & o/p is train pulses

* o/p pulses are fed to start/stop Gate
* when this gate is enabled, I/P pulses pass through this gate & are fed directly to counter, which counts the no of pulses
* when this gate is disabled, the counter stops counting the incoming pulses.

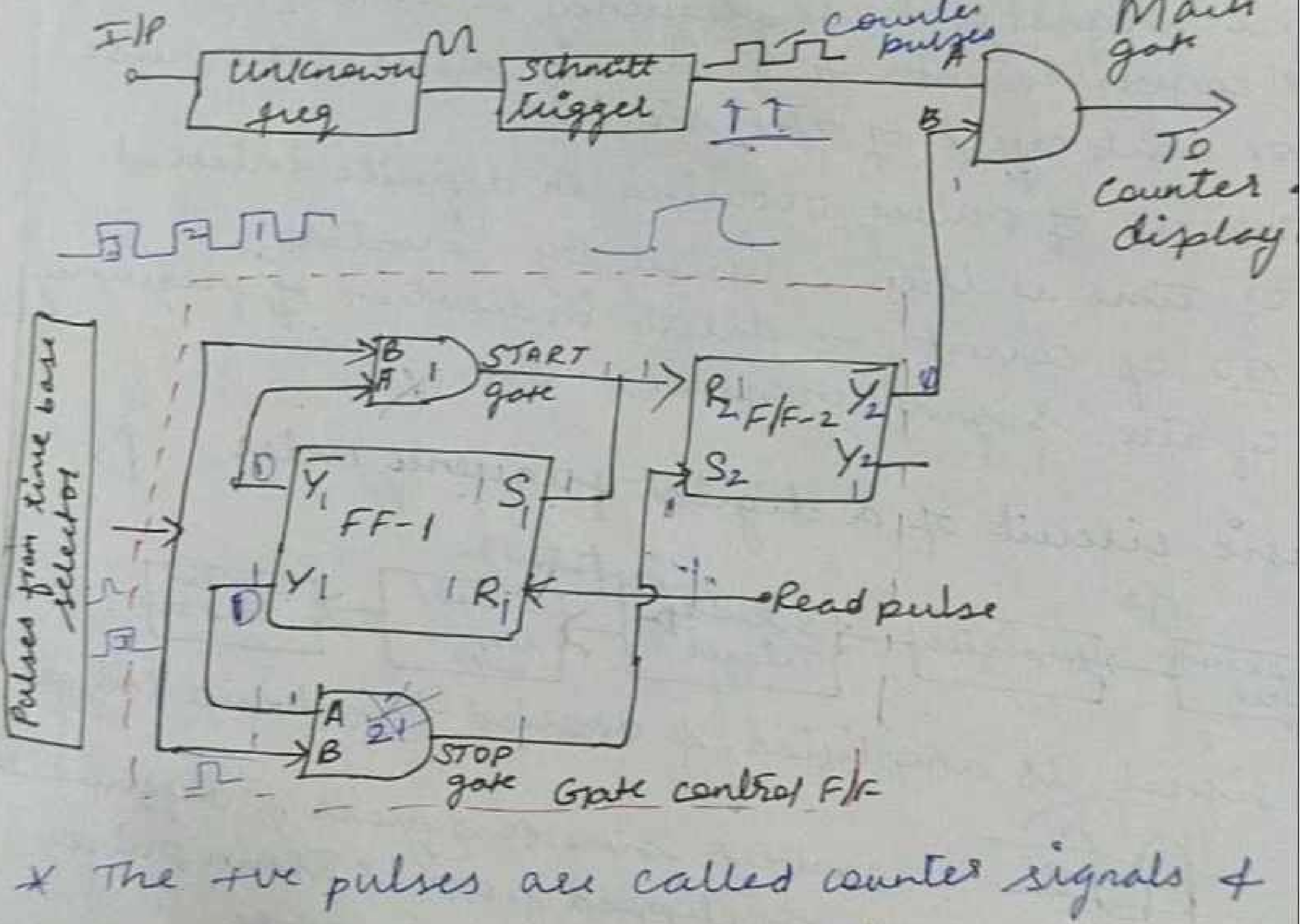
* The counter displays the no. of pulses ... have passed through it in the time ... b/w start & stop.

gives ... frequency

*

Basic circuit for frequency Measurement

* The o/p of the unknown frequency is applied ... Schmitt trigger, producing +ve pulses at the ... counter pulses



* The +ve pulses are called counter signals & are present at pt 'A' main gate.

* +ve pulses from time base selector are p... at B of start gate & pt 'B' of stop g...

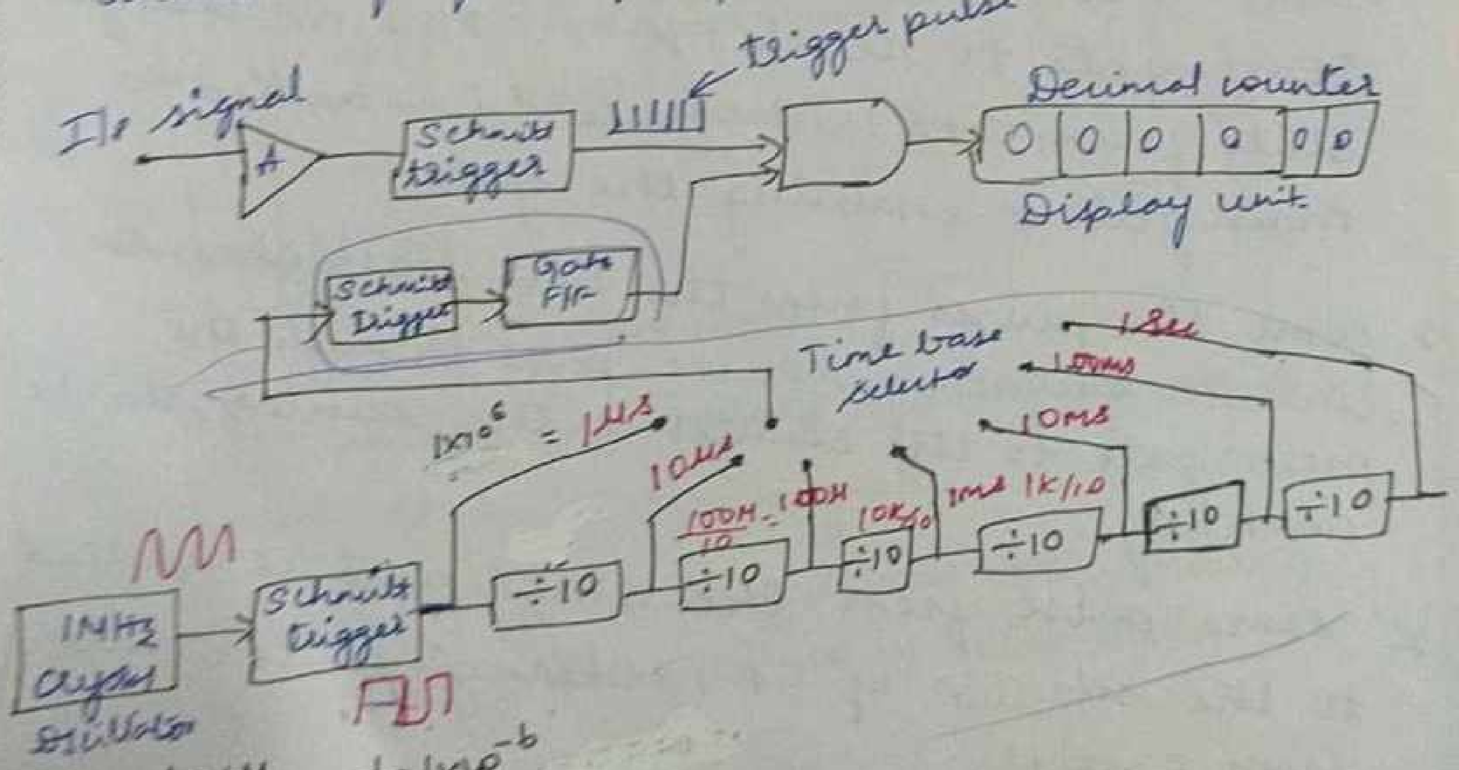
* Initially FF-1 is at logic 1 stat...

* O/p of Y_1 is applied to A of stop gate

* However, till the main gate is enabled, ... from the unknown frequency continue to pass through the main gate of the counter.

* The next pulse from the time base selector passes through the enabled STOP gate to the set I/P terminal of F/F-2, changing its o/p back to 1 & $\bar{Y}=0$.

∴ main gate is disabled, disconnecting the unknown freq signal from the counter. The counter counts the no of pulses occuring b/w two successive pulses from the time base selector is 1sec, then the no of pulses counted within this interval is the freq of the unknown frequency of source

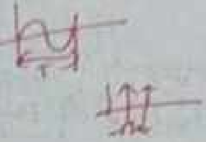


$f = 1M$ $t = 1\times10^{-6}$

10^{6} $f = 1\times10^{6}$ $t = \frac{1}{f}$

81

I/p signal is amplified, converted to square wave, differentiated + clipped to produce a train of pulses, each pulse seperated by the period of I/p signal ⟹



Digital Measurement of time

Operation

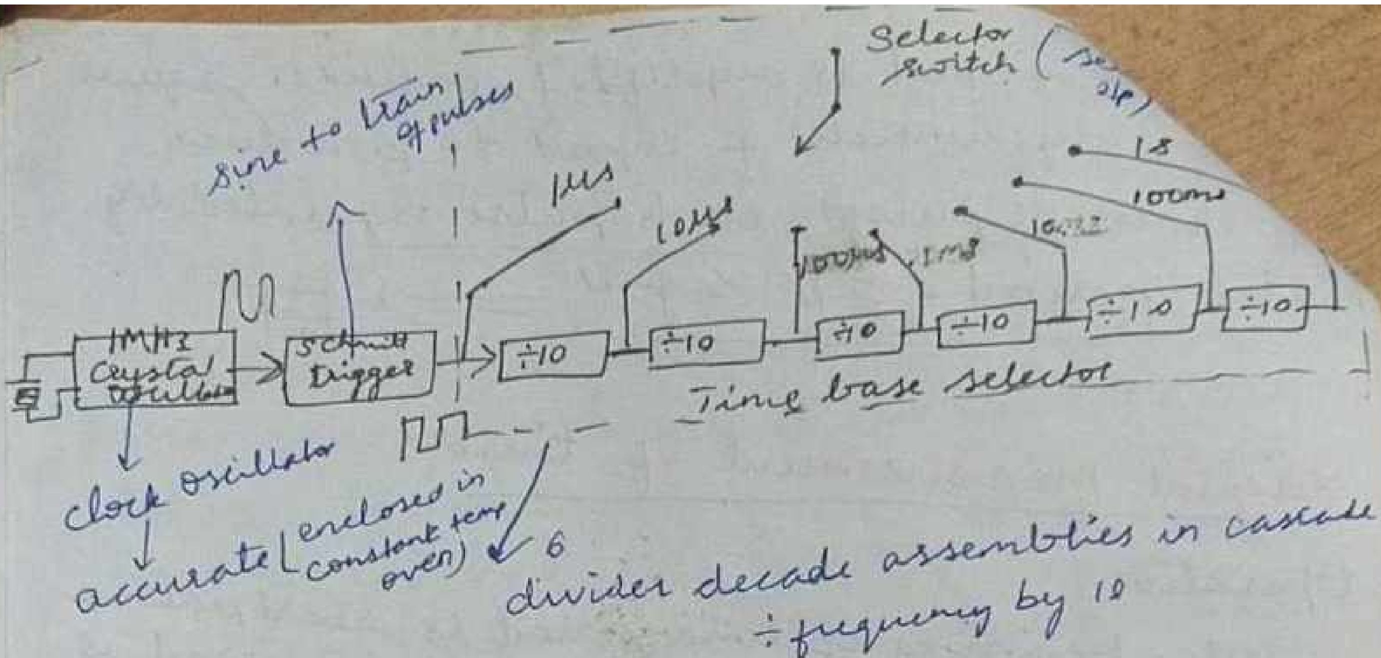
The begining of time period is start pulse + originating from I/p1 + end of the time period is the stop pulse coming from I/p 2

The oscillator runs continuously, but the oscillator pulses reach the o/p only during the period when the control F/F is in the 1 state.

The no of o/p pulses counted is a measure of the time period

Time base selector

* To know the value of freq of the I/p signal, the time interval b/w the start + stop of the gate must be accurately known., called time base

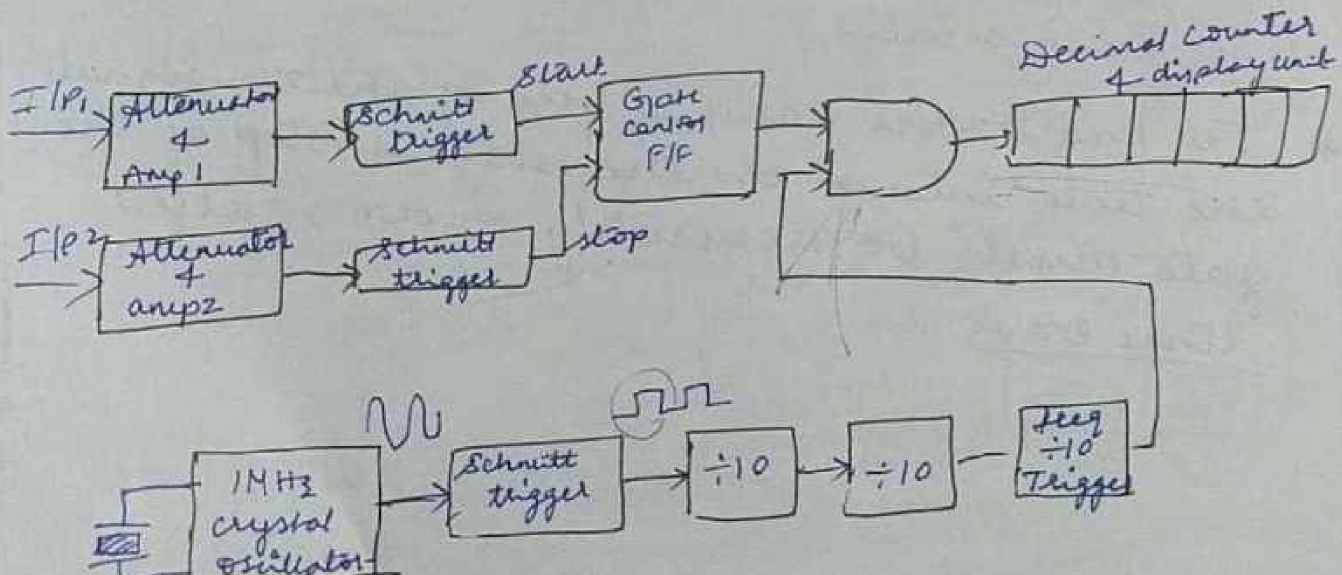


measurement of time period

→ measure time period

→ for low frequency measurement in order to obtain accuracy

→ to implement, gating & counted signal can be interchanged



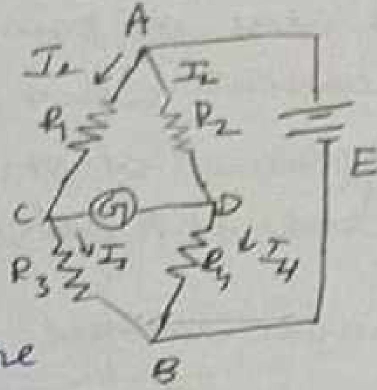
* frequency can be controlled by varying the magnitude of current

0.01Hz to 100k

dges

(1)

...implest form consists of a network of four resistance arms forming a closed circuit, with dc source of current applied to two opposite junctions & a current detector connected to the other two junctions



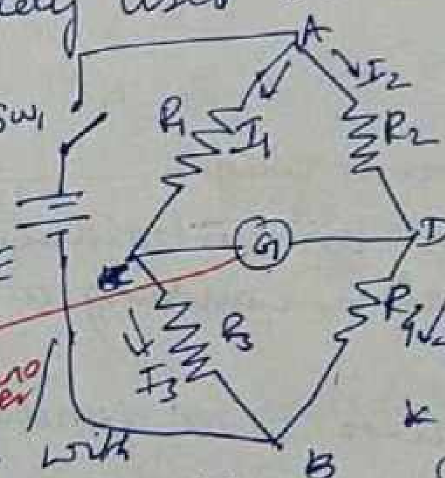
* measures R, L & C

Bridges circuit compares the value of an unknown component with the accurately known component

* Basic dc bridge is used for accurate measurement of resistance & it is called as Wheatstone bridge

Wheatstone bridge (measurement of resistance)

* accurately used to measure resistance



sensitive current indicating meter / Galvanometer / μammeter with zero scale (midscale)

* src EMF & switch is connected A & B
* meter b/w C & D
* when no current, G pointer to rest at "0"
* current in one direction causes the pointer to deflect in one ~~directio~~ side, & in opp direction to the other side

* when S_1 is closed, current flows 4 ÷ two arms at point A, I_1 & I_2
* Balanced when no current in the meter/ vtg difference at pt C & D is equal ie potential across the galvanometer is zero

* under balanced $V_C = V_D$

$$I_1 R_1 = I_2 R_2 \Rightarrow \frac{E}{R_1+R_3}(R_1) = \frac{E(R_2)}{R_2+R_4}$$

$$\Rightarrow R_1R_2 + R_{2}R_1 = R_1R_2 + R_2R_3$$

$$I_1 = I_3 = E/R_1+R_3$$

$$I_2 = I_4 = \frac{E}{R_2+R_4}$$

$$\boxed{R_4 = \frac{R_2 R_3}{R_1}}$$

Eqn for balanced bridge

In practical, wheatstone bridge, at least one of the resistance is made adjustable, to permit balancing

The bridge consists of $R_1 = 10K$, $R_2 = 15K$, $R_3 = 40K$, $R_x = ?$

$$\boxed{R_x = 60K\Omega}$$

Sensitivity of wheatstone bridge

-> when the bridge is in an unbalanced condition current flows through meter, causing a deflection of its pointer

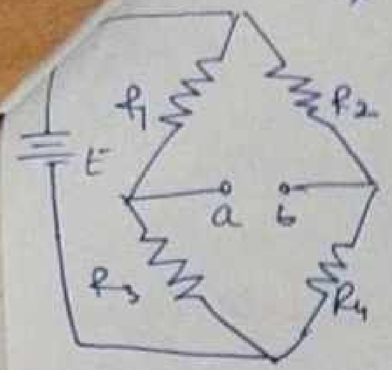
-> The amount of deflection is a function of the sensitivity

S = deflection per unit current

$$\boxed{S = D/I} = mm/\mu A \;/\; deg/\mu A \;/\; rad/\mu A$$

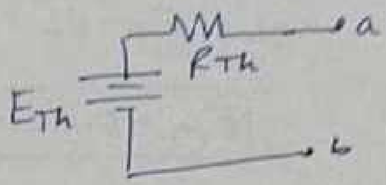
S↑, deflection more

...nced Wheastone bridge



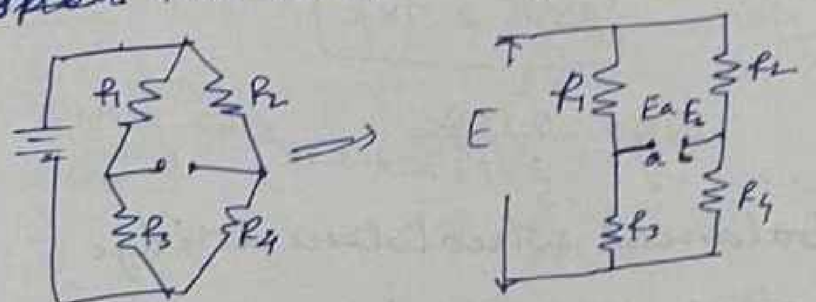
* To determine the unbalanced condn Thevenins theorm is applied
* In order to find the current thro the meter, thevenin equivalent ckt to be found

thevenin equivalent circuit



To determine ETh

@ Open the load/meter, determine the vtg across it



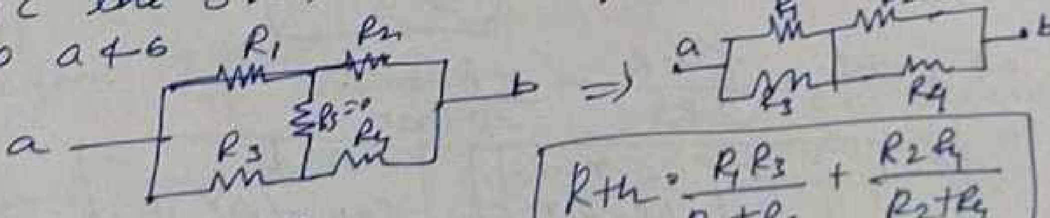
$$E_a = \frac{E R_3}{R_1+R_3} \quad , \quad E_b = \frac{R_4 E}{R_4+R_2}$$

$$E_{th} = E_a - E_b = E\left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_2+R_4}\right)$$

$$\boxed{E_{th} = E\left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_2+R_4}\right)}$$

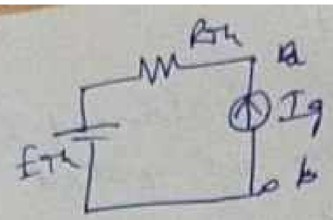
To determine Rth

@ SC the src, calculate equal resistance looking into a & b



$R_{th} = R_1 \| R_3 + R_2 \| R_4 \longrightarrow$

$$\boxed{R_{th} = \frac{R_1 R_3}{R_1+R_3} + \frac{R_2 R_4}{R_2+R_4}}$$

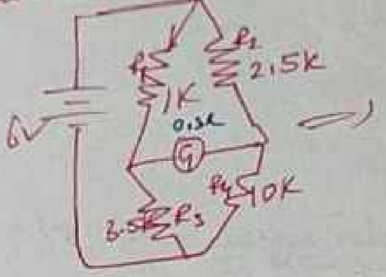


$\Longrightarrow$ $I_g = \frac{E_{Th}}{R_{Th}}$

if meter has internal resistance

$I_g = \frac{E_{Th}}{R_{Th} + R_g}$

An unbalanced wheatstone's bridge, calculate I_g



$E_{Th} = E_a - E_b = E\left(\frac{R_4}{R_2+R_4} + \frac{R_3}{R_1+R_3}\right)$

$E_{Th} = 0.132V$

$R_{Th} = \frac{R_1R_3}{R_1+R_3} + \frac{R_2R_4}{R_2+R_4}$

$R_{Th} = 2.78K$

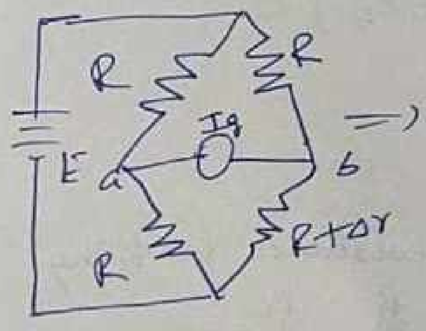
$I_g = \frac{0.132V}{2.78K + 0.5K} = 42.88 \mu A$

Slightly unbalanced wheatstone bridge

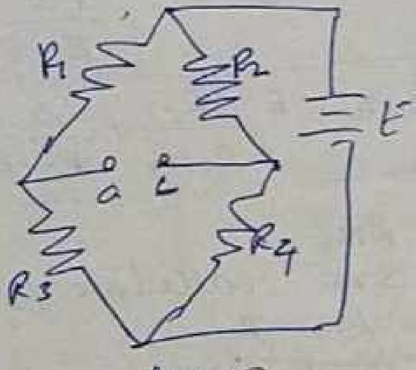
* 3 Resistance are equal

$R_1 = R_2 = R_3 = R$

R_4 = differs by 5%/less



$\Longrightarrow$



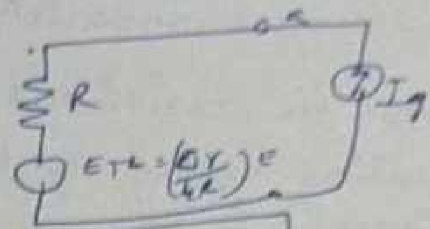
$E_{Th} = E_a - E_b = \frac{E \times R}{2R} - \frac{E(R+\Delta r)}{2R+\Delta r}$

$E_{Th} = E\left[\frac{\Delta r}{4R + 2\Delta r}\right]$

$\Delta r \downarrow$

$E_{Th} = \left(\frac{\Delta r}{4R}\right)E$

$$= \frac{R \times R}{R + R} + \frac{R(R+\Delta r)}{R + R + \Delta r}$$



$$R_{Th} = \frac{R}{2} + \frac{R(R+\Delta r)}{2R+\Delta r}$$

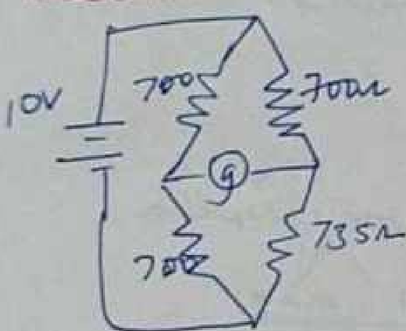
Δr = small

$$R_{Th} = R$$

$$I_g = \frac{E_{Th}}{R} = \frac{\Delta r E}{(4R)R}$$

if $\Delta r \leq 0.05R$, Eqn are approximate

Given a centre zero 200-0-200 μA ammeter movement having an internal resistance of 125 Ω calculate the current through the meter by approximation method



$$E_{Th} = \frac{E(\Delta r)}{4R} = \frac{10 \times 35}{4 \times 700} = 0.125V$$

$$R_{Th} = R = 700\Omega$$

$$I_g = \frac{E_{Th}}{R_{Th} + R_g} = 151.5 \mu A$$

Application of wheatstone bridge

* used to measure DC resistance of various type of wire, motor windings, transformers, solenoids & relay coils
* used by telephone companies to locate cable faults (two lines shorted, single line shorted to gnd)
* impedance of AF/RF can be measured

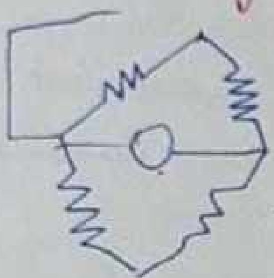
Limitations of bridge

* cannot measure low resistance like resistance of leads, & contacts (try to measure → error become significant

* cannot measure high resistance becau[se]
meter becomes insensitive
* change in resistance of the bridge becom du[e]
to heating effect of current through the
resistance

temp ↑ses ⇒ R changes → I ↑ → permanent ~~error~~ change in I

A C bridges



→ ||| lar to DC bridges, except that the bridge arms are impedance
→ excited by ac source.
→ o/p measured by headphone (detects AC)

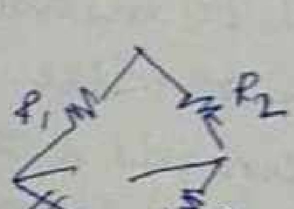
when the ~~bri~~ bridge is balanced

$$\frac{Z_1}{Z_3} = \frac{Z_2}{Z_4}$$

Z_1, Z_2, Z_3, Z_4 } → impedance of arms, vector complex (φ, mag) → adjust the balance

Capacitance comparison bridge

* The ratio arms are R_1, R_2
* known standard C_3 in series R_3 (varies)
* C_x → unknown capacitor, R_x } small leakage resistance of the capacitor
* $C_x < C_3$



$Z_1 = R_1$

$Z_2 = R_2$

$Z_3 = R_3$ in series $C_3 = R_3 - j/\omega C_3$

$Z_x = R_x$ in series $C_x = R_x - j/\omega C_x$

...der balanced

$$Z_1 Z_x = Z_2 Z_3$$

$$R_1\left(R_x - \frac{j}{\omega C_x}\right) = R_2\left(R_3 - \frac{j}{\omega C_3}\right)$$

$$\boxed{R_1 R_x = R_2 R_3} \qquad \boxed{\frac{R_1}{\omega C_x} = \frac{R_2}{\omega C_3}}$$

$$\boxed{R_x = \frac{R_2 R_3}{R_1}} \qquad \boxed{C_x = \frac{C_3 R_1}{R_2}}$$

A capacitance comparison bridge is used to m... a capacitance impedance at a freq of 2KHz. ... bridge constant at Balance are $C_3 = 100\mu F$, R_1 ... $R_2 = 50K\Omega$, $R_3 = 100K\Omega$

Find the Equivalent series circuit of the u... impedance

$$R_x = \frac{R_2 R_3}{R_1} = 500K\Omega$$

$$C_x = \frac{C_3 R_1}{R_2} = \frac{10K}{50K} \times 100 \times 10^{-6} = 20\mu F$$

In the measurement of capacitance using capacitance bridge.

R_1 in branch BC → 2000Ω

R_2 in branch CD → 2850Ω

R_4 in branch DA → 52Ω in series with C_4 = ...

R_x in series with C_x in branch AB, f = 400Hz

$$R_x = \frac{R_1 R_4}{R_2} = 36.2\Omega = \frac{2850 \times 52}{2000} = 36.5\Omega$$

$$C_x = \frac{R_2}{R_1} \times C_4 = 0.715$$

loss angle of the capacitor (a series ...
defined as the angle by which current d...
an exact quadrature from the applied vtt

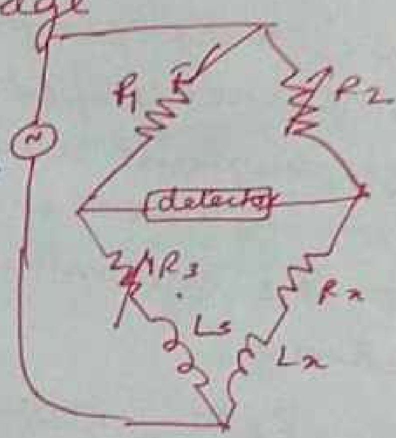
'δ' is loss angle of the capacitance

$$\tan\delta = \frac{R_x}{X_x} = \omega C_x R_x = 2\pi f C_x R_x$$

$\tan\delta = 0.06573$

$\delta = 3°76'$

Inductance Comparison bridge



Unknown R_x, L_x can be obtained by comparison with standard inductor & resistance

Balance Eqn

$Z_1 Z_x = Z_2 Z_3$

$$L_x = \frac{L_3 R_2}{R_1}$$

$$R_x = \frac{R_2 R_3}{R_1}$$

$R_2 \rightarrow$ inductive balance control

$R_1 \rightarrow$ ~~capacitive~~ resistance balance

* Balance is obtained by alternately varying L_3 & R_3

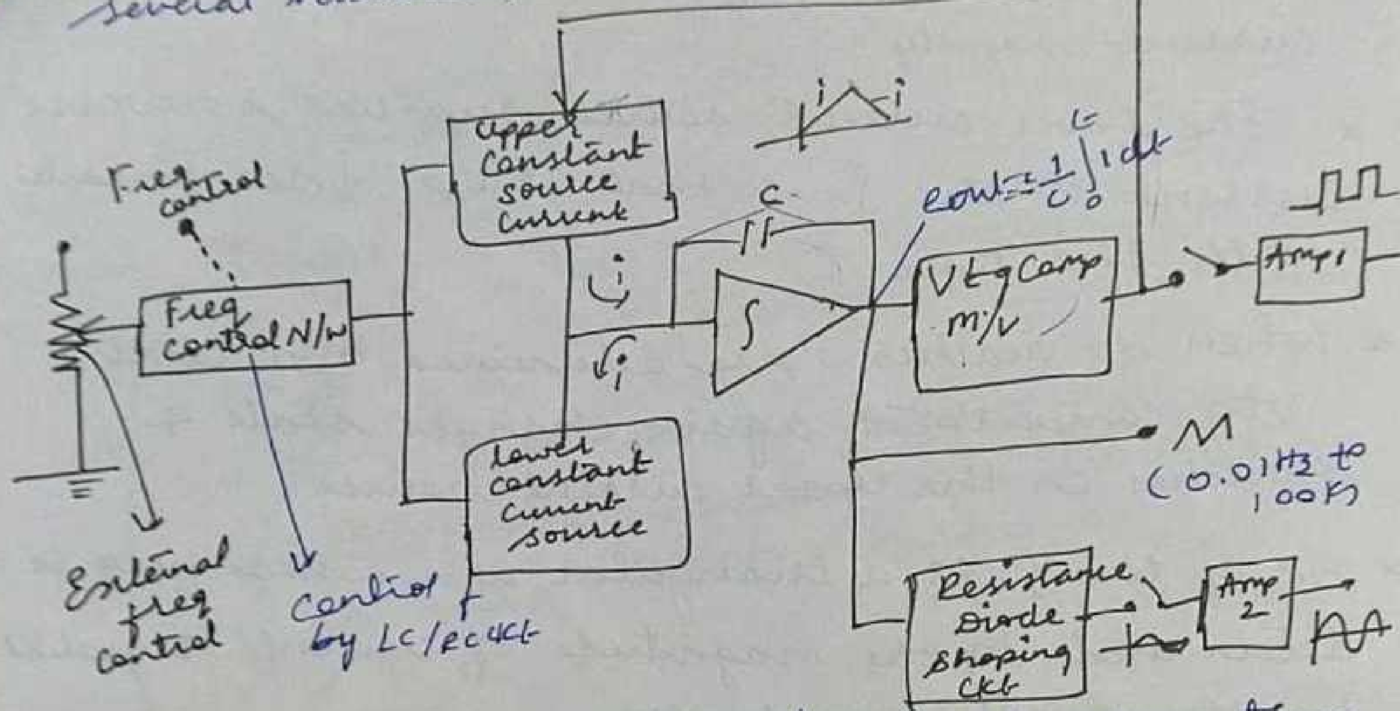
* if $Q/_{L_x, R_x} > Q/_{L_3, R_3} \Rightarrow$ variable R has to be placed by with R_x to obtain balance

~~* if Q/L,~~

An inductance comparison bridge is used to measure inductive capacitance at a freq 5kHz The bridge constants at balance are $L_3 = 10mH$ $R_1 = 10k\Omega$, $R_2 = 40k\Omega$, $R_3 = 100k\Omega$, Find the equivalent series ckt of the unknown impedance

~~~on generator (20M)

produces different (sine, square, triangular, sawtooth) W/F of adjustable freq (fraction to several hundreds) (white & pink noise)



* Various o/p's can be produced at same time
  Eg a square wave → test linearity of amplifier
  a sawtooth → drives the horizontal deflection amp of CRO
* the frequency is controlled by varying the magnitude of current which drives the ∫
* The frequency controlled vtg regulates two current sources.
* upper current source supplies constant current to integrator whose o/p vtg ↑ses linearly with time,
* ↑se/↓se in the current ↑ses/↓ses the slope of the o/p vtg & hence controls the freq

*
~~~

* The voltage comparator multivibrator changes states at a predetermined max level of the ∫ o/p vtg. This changes cut-off the upper current supply & switches on the lower current supply

* The lower current source supplies a reverse current to the ∫, so that it o/p ↓ses linearly with the time

* when o/p reaches a pre-determined min level vtg comparator again changes state & switches on the upper current source

* o/p of the ∫ is a triangular W/F whose freq is determined by the magnitude of current supplied by the const current source

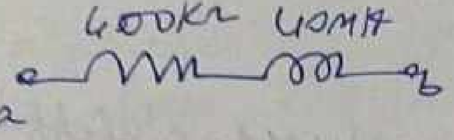
* The comparator deliver ⊓ wave
* Resistance diode N/w alters the slope of the Δle wave & produces W/F with less than 1%. distortion

Tektronics
FG502
0.1Hz to 11MHz
10V.
AM/PM/FM
Z0 50Ω

J
e
/
R1
*
*
Ar
ne
Th.
R1
Fi
in

$\frac{R_2 R_3}{R_1} = 400k\Omega$

$L_x = \frac{R_2 L_3}{R_1} = 40mH$

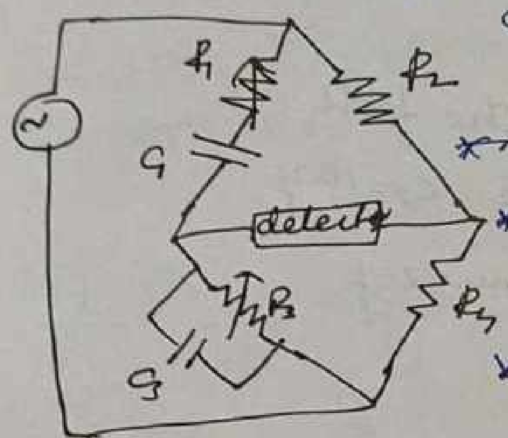


$R_1 + jX_L$

$R_1 + j\omega L$

Wien's bridge

* has series combination R … one arm & ||el … in … arm
* measures frequency
* unknown capacitor with great accuracy



$Z_1 = R_1 - j/\omega C_1$ $\quad Z_3 = R_3 || C_3 = \frac{R_3(-j/\omega C_3)}{R_3 - j/\omega C_3}$

$\frac{1}{Z_3} = Y_3 = \frac{1}{R_3} + j\omega C_3$

under balance

$Z_1 Z_4 = Z_2 Z_3$

$Z_2 = Z_1 Z_4 Y_3$

$R_2 = R_4\left(R_1 - \frac{j}{\omega C_1}\right)\left(\frac{1}{R_3} + j\omega C_3\right)$

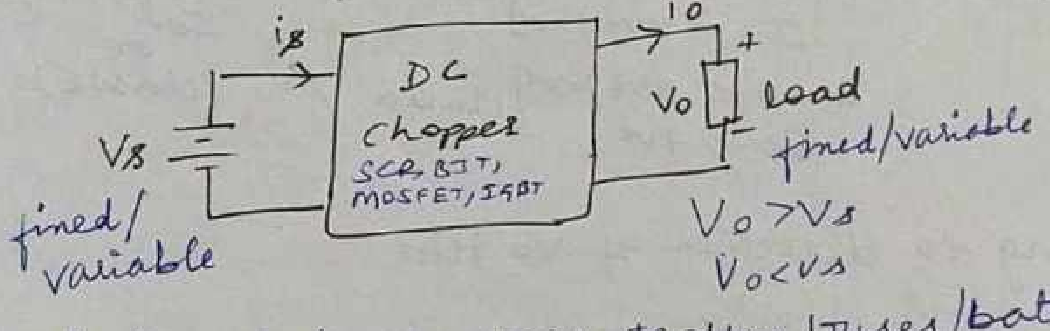
$R_2 = \frac{R_1 R_4}{R_3} + \frac{C_3 R_4}{C_1}$ & $\rightarrow$ $\boxed{\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}}$

$\frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4 = 0 \Rightarrow \boxed{f = \frac{1}{2\pi\sqrt{C_1 R_1 C_3 R_3}}}$

1

CHOPPERS / DC to DC converters

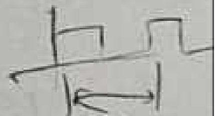
* converts I/p DC to fixed/variable DC o/p (controlled by on & off period)



* used in subway cars, trolley buses/battery operated Vehicles
* offer greater efficiency, faster response, lower maintaince, smooth control

Basic chopper classification

* According to I/p & o/p vg levels



- step-up chopper: $V_o > V_i$
- step down chopper: $V_o < V_i$

* According to commutation method or Direction of o/p vg and current
  - Voltage Commutated choppers
  - current commutated choppers
  - Load commutated chopper
  - Impulse commutated chopper

* According to circuit operation

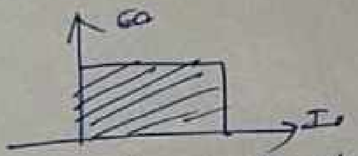
First quadrant chopper
- V_0, I_0 are +ve

Two quadrant chopper
- $V_0 \rightarrow$ +ve, $I_0 \rightarrow$ +ve/-ve } class C
- $V_0 \rightarrow$ +ve/-ve, $I_0 \rightarrow$ +ve } class D

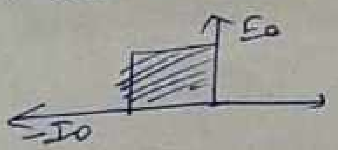
Four quadrant chopper
- V_0, I_0 } $\rightarrow$ +ve/-ve or (class E)

* According to direction of V_0 & I_0

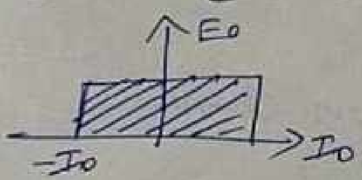
→ class A (type A) chopper



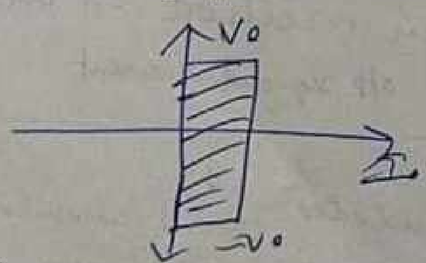
→ Class B (type B) chopper



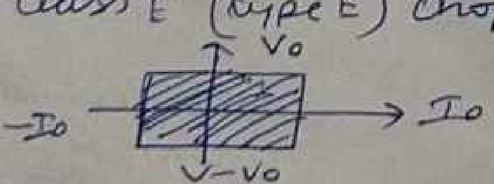
→ class C (type C) chopper



→ Class D (type D) chopper

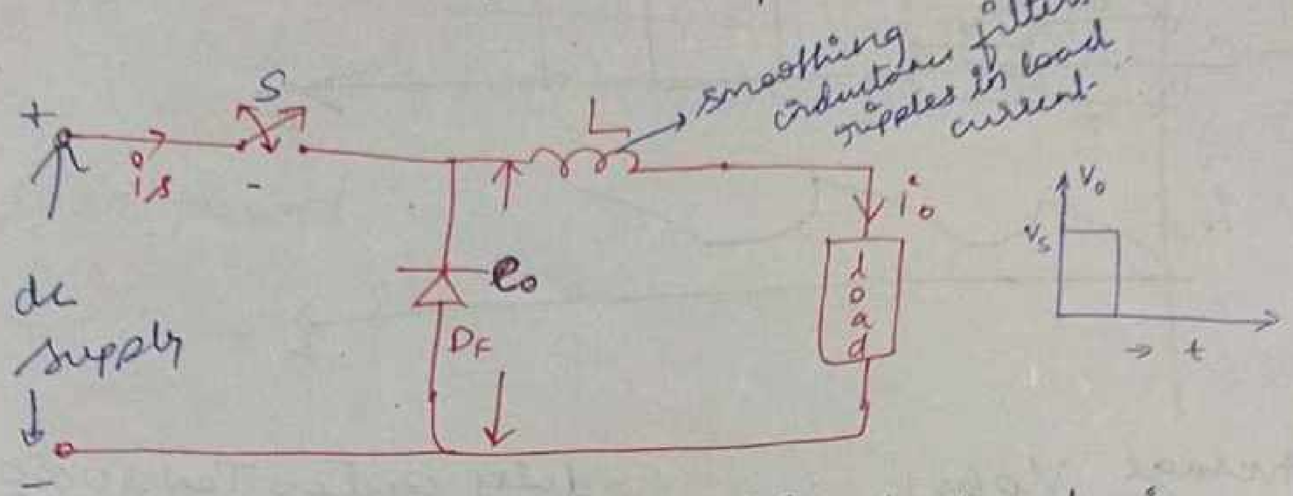


→ class E (type E) chopper



Basic chopper classification

Principle of step down operation



Chopper has power semiconductor devices

R, L, C

I/P dc supply

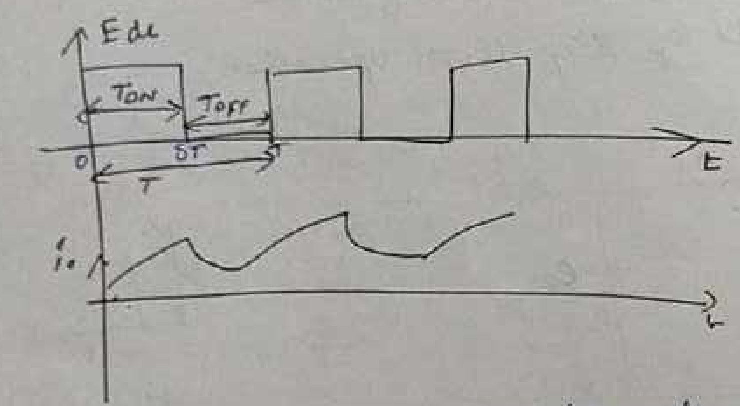
V_0

* Power diode D_F operates in freewheeling -mode to provide a path to load current when switch is off

* S is kept conducting for T_{ON}, 4 blocked for period T_{off}

* During the period T_{on}, when the chopper is on, the supply terminals are connected to load terminals

* During the period T_{OFF}, when the chopper is OFF, load current flows through the freewhee diode D_F



Average $V_{o(av)}$

δ = duty cycle = $\frac{T_{on}}{T}$, $0 \le \delta \le 1$

$$V_{o(av)} = \frac{1}{T}\int_0^T V_o(t)\,dt$$

$$= \frac{1}{T}\left[\int_0^{\delta T} V_s(t)\,dt + 0\right]$$

$$= \frac{1}{T}\left[V_s \cdot \delta T\right]$$

$$\boxed{V_{o\,av} = V_s\,\delta} \quad \boxed{I_{o\,av} = \frac{V_{o\,av}}{R} = \frac{V_s\delta}{R}}$$

RMS o/p voltage

$$V_{orms} = \sqrt{\frac{1}{T}\int_0^T v_o^2(t)\,dt}$$

$$= \sqrt{\frac{1}{T}\int_0^{\delta T} V_s^2\,dt}$$

Chopp...

$$\eta = \frac{\text{load power (o/p ...)}}{\text{Supply power (i/p power)}}$$

load power

$$P_o = \frac{1}{T}\int_0^{\delta T} \frac{V_o^2}{R}\,dt$$

$$= \frac{1}{T}\int_0^{\delta T} \frac{(V_s - V_{ch})^2}{R}\,dt$$

$$\frac{1}{RT}\cdot(V_s - V_{ch})^2\left[t\right]_0^{\delta T}$$

$$\boxed{P_o = \delta\frac{(V_s - V_{ch})^2}{R}}$$

$V_s = V_o$

$i_s = i_o$

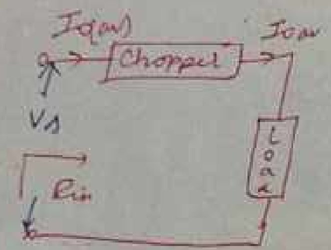
$$P_i = \frac{1}{T}\int_0^{\delta T} V_s \cdot i_s\,dt$$

$$= \frac{1}{T}\int_0^{\delta t} V_o \cdot i_o\,dt$$

$$= \frac{1}{T}\int_0^{\delta t} V_s\frac{(V_s - V_{ch})}{R}\,dt$$

$$\boxed{P_i = \frac{\delta V_s(V_s - V_{ch})}{R}}$$

$$\eta = \frac{P_o}{P_i} = \frac{\delta(V_s - V_{ch})^2}{R} \times \frac{R}{\delta V_s(V_s - V_{ch})}$$



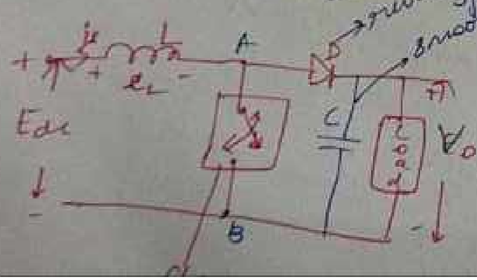
$$R_{in} = \frac{V_s}{I_{o(av)}} = \frac{V_s}{\frac{V_{o(av)}}{R}} = \frac{1}{\delta} R$$

$$\boxed{R_{in} = \frac{R}{\delta}}$$

Principle of step up choppers

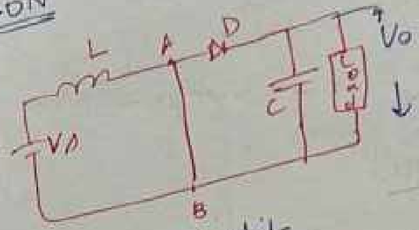
* step up chopper gives mean voltage higher than i/p supply v/t

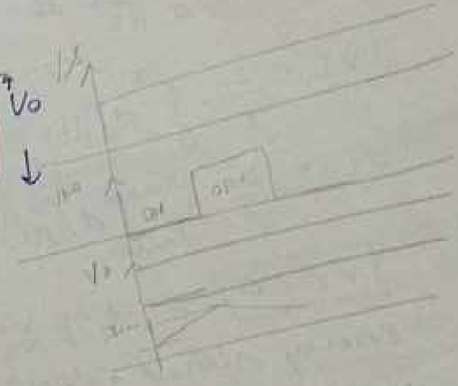
$V_0 \geq V_s$



The

S→ON





$$V_L = L \frac{di_L}{dt}$$

$V_{AB} = 0$

$V_0 = V_B$

D → off

S → off

inductor current is forced to flow through the diode & load

$$V_0 = V_{dc} + L\frac{di}{dt}$$

$\therefore V_0 > V_s$

Average load voltage

$V_0 =$

$V_{AB} = V_L + V_s$

$$V_{AB} = \frac{1}{T} \int_0^T V_{AB}(t)\, dt$$

44 15

① - ㉑ Pages

Electronic instrumentation
- H S KALSI
3rd Edition.

Qualities of Measurements

(a) Measurement errors:

Introduction :-

* what is an instrumentation?

It is a technology of measurement which serves not only science but all branches of engg, medicine & (Electrical, civil, electronics, mechanical) (temp, pressure) &

→ The indepth knowledge of any parameter can be easily understood by the use of measurement

→ measuring is basically used to monitor a process or operation or as well as the controlling process

Reactor temp.

Ex :- Thermometers, Barometers, anemometer are used (atmospheric pressure) (wind speed) to indicate environmental conditions.

petrol indicator.

→ H_2O meter, gas meter, electric meter, Voltmeter, Ammeter, ohmmeter (utility)
Spectrometer: samples of the steel are taken and analysed.

Borewell Richter

→ There is always a need for improvements and development of new equipment to solve measurement problems.

→ The major problem encountered with any measuring instrument is the error. Therefore it is obviously necessary to select the appropriate measuring instrument and measurement method which minimizes error.

→ The basic concern of any measurement is that the measuring instrument should not effect the Quantity being measured

performance characteristics (PC):-

A knowledge of PC of an instrument is essential for selecting the most suitable instrument for specific measuring jobs.

It consists of two basic characteristics

1. Static.
2. Dynamic.

Static characteristics :-

The SC of an instrument are in general considered for instruments which are used to measure an unvarying process condition.

There are a number of related definitions or characteristics such as

1. Instrument :- A device or ~~instrume~~ mechanism used to determine the present value of the quantity under measurement.
2. Measurement :- The process of determining the amount, degree, or capacity by comparison (Direct or indirect) with the accepted standards of the s/m units being used.
3. Accuracy :- The degree of exactness (closeness) of a measurement compared to the expected (desired) value.

Scanned with CamScanner

0.0001V Higher resolution
0.10V Lower Resolution

* 4. Resolution :- The smallest change in a measured variable to which an instrument will respond.

5. Precision :- A measure of the consistency or repeatability of measurements i.e successive reading do not differ.
1. 1.5 → 2 → 2.5 → 3 = 0.5

Target
Android Application.

6. Expected value :- after simulation.
The most probable value that calculations indicate one should expect to measure.

Mixing different materials.

7. Error :-
set point → ⊗ → error ↑ measured variable.
The deviation of the true value from the desired value.

Thermometer
Cold H_2O
Hot H_2O

* 8. Sensitivity :-
The ratio of the change in output (response) of the instrument to a change of input or measured variable.

ERROR IN MEASUREMENT :-

* Measurement is the process of comparing an unknown quantity with an accepted std. quantity.
* It involves connecting a measuring instrument into the system under consideration and observing the resulting response on the instrument.
* Any measurement is affected by many variables therefore the results rarely reflect the expected value.

Ex :- Connecting a measuring instrument into the ckt under consideration always disturbs the circuit causing the measurement to differ from the expected value.

MEMS
Micro electro mechanical System (Made up of components 1 to 100 μ meters) → M Sensors
Size : 20 μmeter to 1 millimeter

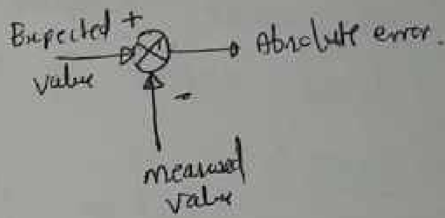
Scanned with CamScanner

* The degree to which a measurement nears the expected value is expressed in terms of the error of measurement.

* Error may be expressed either as absolute or as percentage of error.

* Absolute error may be defined as the difference b/w the expected value of the variable and the measured value of the variable,

$$e = Y_n - X_n$$



where,
e = absolute error.
Y_n = expected value.
X_n = Measured value

$$\therefore \quad \% \text{ Error} = \frac{\text{Absolute value}}{\text{Expected value}} \times 100 = \frac{e}{Y_n} \times 100$$

$$* \quad \therefore \quad \% \text{ Error} = \left(\frac{Y_n - X_n}{Y_n} \right) \times 100$$

It is more frequently expressed as a accuracy rather than error.

$$* \quad A = 1 - \left| \frac{Y_n - X_n}{Y_n} \right|$$

where, A is the relative accuracy.

Accuracy is expressed as % Accuracy.

$$a = 100\% - \% \text{ error}.$$

OR

$$a = A \times 100\%$$

{ what is the percentage error out of 100%. }

Where, a is the % accuracy.

Scanned with CamScanner

① The expected value of the voltage across a resistor is 80V However the measurement gives a value of 79V. calculate (i) absolute error (ii) % error (iii) Relative accuracy (iv) % of accuracy.

Soln :-

(i) Absolute error $e = Y_n - X_n = 80 - 79 = 1V$

(ii) % Error = $\frac{Y_n - X_n}{Y_n} \times 100 = \frac{80-79}{80} \times 100 = 1.25\%$

(iii) Relative accuracy.

$$A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right| = 1 - \left|\frac{80-79}{80}\right|$$

$$\therefore \quad A = 1 - \frac{1}{80} = \frac{79}{80} = 0.9875$$

(iv) % of Accuracy $a = 100 \times A = 100 \times 0.9875 = 98.75\%$

or $a = 100\% - \%$ of error $= 100\% - 1.25\% = 98.75\%$

② The expected value of the current through a resistor is 20mA. However the measurement yields a current value of 18mA. calculate (i) absolute error (ii) % Error. (iii) Relative accuracy (iv) % accuracy.

Soln :-

Step 1 :- Absolute error.

$$e = Y_n - X_n = 20mA - 18mA = 2mA$$

Step 2 :- % error.

$$\%\ error = \frac{Y_n - X_n}{Y_n} \times 100 = \frac{20mA - 18mA}{20mA} \times 100 = \frac{2mA}{20mA} \times 100$$

$$= 10\%$$

Scanned with CamScanner

Step 3 :- Relative Accuracy.

$$A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right| = 1 - \left|\frac{20mA - 18mA}{20mA}\right| = 1 - \frac{2}{20} = 1 - 0.1$$
$$= 0.90$$

Step 4 :- % Accuracy

$a = 100\% - \%\ error = 100\% - 10\% = 90\%$

$a = A \times 100\% = 0.90 \times 100\% = 90\%$

If a measurement is accurate, it must also be precise. (Accuracy means precision). However, a precision measurement may not be accurate. precision can also be expressed mathematically as

$$P = 1 - \left|\frac{X_n - \overline{X_n}}{\overline{X_n}}\right|$$

X_n → value of the nth measurement

$\overline{X_n}$ → Avg. set of measurement.

Ex :- Table 1 gives the set of 10 measurement that were recorded in the laboratory. calculate the precision of the 6th measurement.

Table 1:

Measurement numb.	Measurement value X_n
1	98
2	101
3	102
4	97
5	101
6	100
7	103
8	98
9	106
10	99

Scanned with CamScanner

Sol^n:- The avg value for the set of measurements is

$$\overline{X_n} = \frac{\text{Sum of the 10 measurement values}}{10}$$

$$= \frac{1005}{10} = 100.5$$

$$\text{Precision} = 1 - \left| \frac{X_n - \overline{X_n}}{\overline{X_n}} \right|$$

For the 6th reading

$$\text{Precision} = 1 - \left| \frac{100 - 100.5}{100.5} \right| = \frac{100}{100.5} = 0.995$$

The accuracy and precision of measurements depend not only on the quality of the measuring instrument but also on the person using it.

Types of Static error:-

True value = Expected value.

The static error of a measuring instrument is the numerical difference b/w the true value of a quantity and its value as obtained by measurement.

→ Static errors are categorised as gross errors or human errors, systematic errors and random errors.

* Gross errors:-

→ These errors are mainly due to human mistakes in reading or in using instruments or errors in recording observations.

→ Errors may also occur due to incorrect adjustment of instruments and computational mistakes.

...alog ...nm. ...experiments.

Scanned with CamScanner

* The complete elimination of gross errors is not possib but one can minimize them.

* One of the basic gross errors that occurs frequently is the improper use of an instrument. The error can be minimized by taking proper care in reading and recording the measurement parameter.

Systematic Errors :-

These errors occur due to short comings of the instrument (Instrumental errors) such as defective or worn parts or ageing or effects of the environment on the instrument (Irregular spring tensions, stretching of the spring, reduction in tens due to improper handling or overloading of the

* A constant uniform deviation of the operation of an instrument is known as a systematic error.

There are basically three types of systematic errors.

1. Instrumental errors
2. Environmental errors
3. Observational errors.

* Environmental errors are due to conditions external to the measuring device such as the effects of change in temp, humidity, barometric pressure or of magnetic or electrostatic fields.

These errors can also be avoided by

(i) air conditioning (ii) using magnetic shields

* Observational errors are errors introduced by the observe. These errors are caused by the habits of individual obser (error introduced in reading a meter scale and error of estimation when obtaining a reading form a meter scale

Scanned with CamScanner

ID
ntroller

③ Random Errors

* These are errors that remain after gross and systematic errors.
* Random errors are generally an accumulation of a large number of small effects. (It is concerned only in measurements requiring a high degree of accuracy).
* These are normally small and follow the laws of Probability. So, random errors can be treated mathematically.

Ex:- A voltage is being monitored by a voltmeter which is read at 15 minutes intervals. The instrument gives readings that vary slightly over the period of observation. This variation can't be corrected by any method of calibration.

Sources of Error :-

① Insufficient knowledge of process parameters and design conditions.
② poor design
③ poor maintenance.
④ Errors caused by person operating the instrument or equipment.
⑤ certain design limitations.

Dynamic characteristics :-

The Dynamic characteristics of an instrument are.

① Speed of Response :- It is the rapidity with which an instrument responds to changes in the measured quantity.
② Lag :- It is the delay in the response of an instrument to changes in the measured variable.

Scanned with CamScanner

Error is changing frequently not stationary.

→ Frequently changing not stationary.

(3) Dynamic error :- It is the difference b/w the true value of a Quantity changing with time and the value indicated by the instrument, if no static error is assumed.

(4) Fidelity (The Quality) :- It is the degree to which an instrument indicates the changes in the measured variable without dynamic error. (Faithful reproduction).

Measurement is accurate means fidelity is more

Scanned with CamScanner