

# Industrial Electronics (4331103) - Winter 2023 Solution

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## Question 1(a) [3 marks]

Draw symbol and construction of SCR. Also write down applications of SCR.

### Solution

Symbol and Construction of SCR:

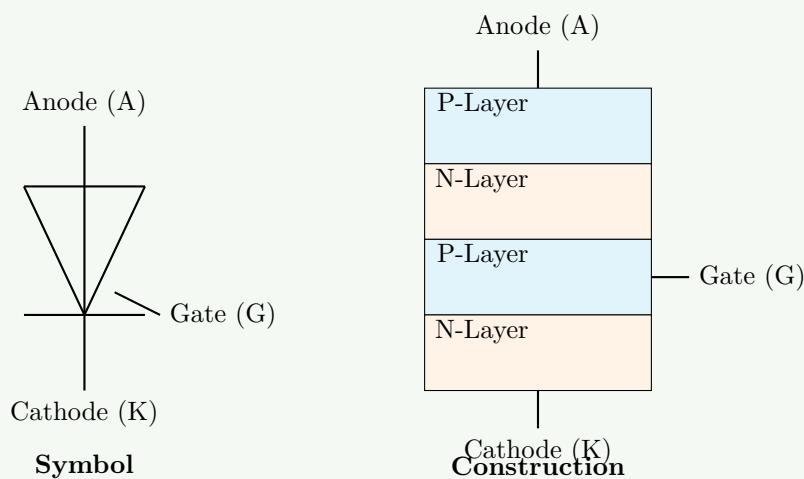


Figure 1. SCR Symbol and Construction

Applications of SCR:

- **Power control:** AC/DC power regulators
- **Motor drives:** Speed control of motors
- **Lighting control:** Dimmer circuits
- **Inverters:** DC to AC conversion

### Mnemonic

“PALS: Power control, Appliance control, Lighting systems, Speed regulators”

## Question 1(b) [4 marks]

State full form of (i) SCS (ii) LASCR (iii) MCT (iv) PUT.

### Solution

Table 1. Full Forms of Devices

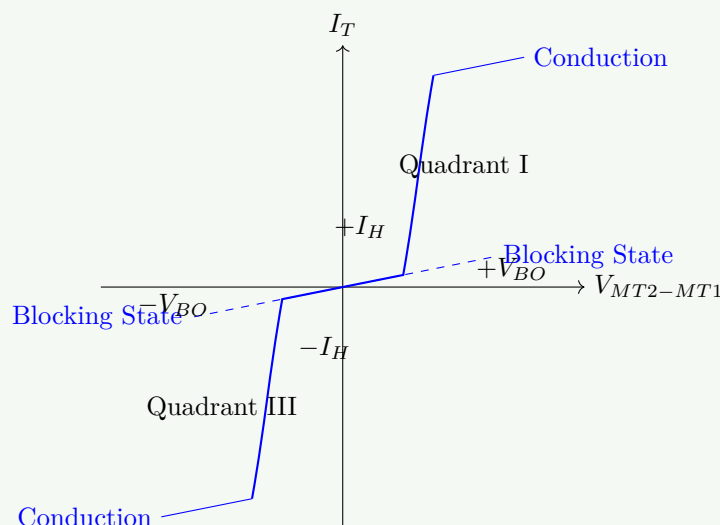
Device	Full Form
SCS	Silicon Controlled Switch
LASCR	Light Activated Silicon Controlled Rectifier
MCT	MOS Controlled Thyristor
PUT	Programmable Unijunction Transistor

**Mnemonic**

“SLaMP: Silicon controlled switch, Light activated SCR, MOS controlled thyristor, Programmable UJT”

**Question 1(c) [7 marks]**

Draw and explain V-I characteristics of TRIAC. Also write down applications of TRIAC.

**Solution****V-I Characteristics of TRIAC:**

**Figure 2.** V-I Characteristics of TRIAC

**TRIAC V-I characteristics explanation:**

- **Bidirectional device:** Conducts in both directions.
- **Quadrant operation:** Works in 1st and 3rd quadrants.
- **Breakover voltage:** Starts conducting when voltage exceeds  $\pm V_{bo}$ .
- **Holding current:** Minimum current to maintain conduction state.
- **Gate triggering:** Can be triggered with positive/negative gate voltage.

**Applications of TRIAC:**

- **AC power control:** Lamp dimmers, heater controls.
- **Motor speed control:** AC motor regulators.
- **Fan regulators:** Domestic fan speed control.
- **Light dimmers:** Adjustable lighting systems.

**Mnemonic**

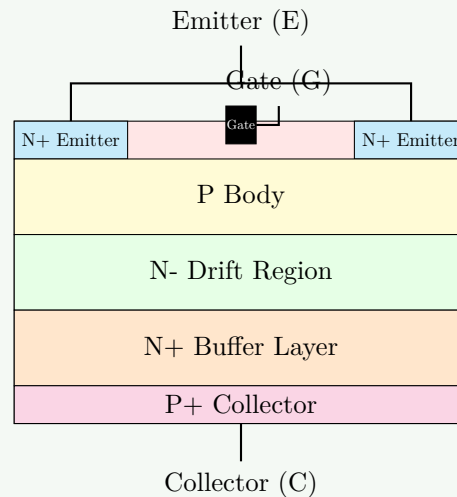
“HALF: Heaters, AC controls, Lighting systems, Fan regulators”

## Question 1(c OR) [7 marks]

Explain construction and working of IGBT in detail.

### Solution

#### IGBT Construction and Working:



**Figure 3.** Structure of IGBT

#### Construction details:

- **Three-terminal device:** Gate, Emitter, Collector.
- **Multilayer structure:** N+, P, N-, N+ buffer, P+ substrate.
- **Hybrid device:** Combines MOSFET input with BJT output characteristics.

#### Working principle:

- **Gate control:** Positive voltage at gate forms inversion layer in P-region.
- **Channel formation:** Electrons flow from N+ emitter to N- drift region.
- **Conductivity modulation:** P-N- junction injects holes, lowering resistance.
- **Turn-off process:** Removing gate voltage stops electron flow.

#### Advantages of IGBT:

- **High input impedance:** Easy voltage control.
- **Low conduction losses:** Efficient power handling.
- **Fast switching:** Good for high-frequency applications.

### Mnemonic

“GIVE: Gate controlled, Input high impedance, Voltage driven, Efficient conduction”

## Question 2(a) [3 marks]

Discuss relaxation oscillator circuit using UJT.

### Solution

#### UJT Relaxation Oscillator:

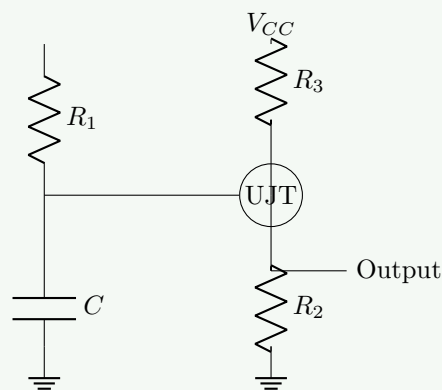


Figure 4. UJT Relaxation Oscillator Circuit

**Working principle:**

- **Capacitor charging:** C charges through  $R_1$  until reaching UJT firing voltage.
- **UJT fires:** When emitter voltage reaches peak point voltage.
- **Discharge cycle:** Capacitor discharges through emitter-base1 junction.
- **Oscillation:** Process repeats creating sawtooth waveform.

**Mnemonic**

“CROP: Capacitor charges, Reaches threshold, Oscillates, Produces sawtooth”

**Question 2(b) [4 marks]**

Discuss the triggering methods of SCR.

**Solution**

Table 2. SCR Triggering Methods

Triggering Method	Working Principle
Gate Triggering	Applying positive voltage between gate and cathode
Thermal Triggering	Temperature increase reduces breakover voltage
Light Triggering	Photons create electron-hole pairs in LASCR
dv/dt Triggering	Rapid voltage rise across SCR causes capacitive current
Breakover Triggering	Voltage exceeds breakover voltage without gate signal

**Key points:**

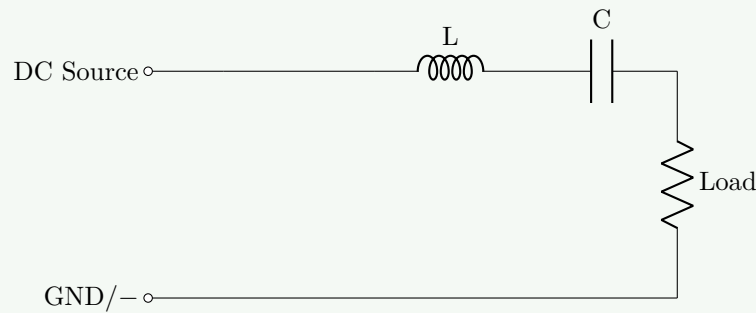
- **Gate triggering:** Most common method.
- **Light triggering:** Used in opto-isolators.
- **dv/dt triggering:** Often undesirable, requiring snubber circuits.

**Mnemonic**

“GLTDB: Gate, Light, Thermal, dv/dt, Breakover”

**Question 2(c) [7 marks]**

Explain class A type commutation method.

**Solution****Class A Commutation (Self-commutation by LC circuit):****Figure 5.** Class A Commutation Circuit**Working principle:**

- **Initial state:** SCR conducting, capacitor charged.
- **Resonant circuit:** LC circuit forms resonant path with Load.
- **Reverse current:** Capacitor discharge creates reverse current tendency.
- **Turn-off:** SCR turns off when current falls below holding current due to oscillation.
- **Recharging:** Capacitor recharges with opposite polarity.

**Applications:**

- **Inverter circuits:** DC to AC conversion.
- **Chopper circuits:** DC to DC conversion.

**Mnemonic**

“SCCRRRT: Switch closes, Capacitor discharges, Current reverses, SCR turns off, Recharging begins, Turn-off complete”

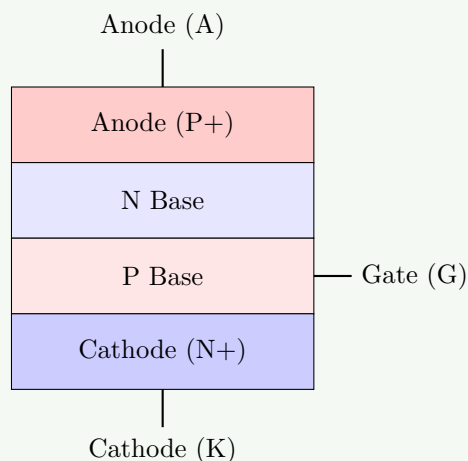
**Question 2(a OR) [3 marks]**

State full form of GTO and draw the structure of GTO.

**Solution**

**Full form of GTO:** Gate Turn-Off Thyristor

**Structure of GTO:**

**Figure 6.** Structure of GTO

**Mnemonic**

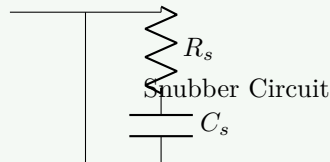
“PANG: P-anode, And, N-base, Gate-controlled thyristor”

**Question 2(b OR) [4 marks]**

Discuss the design and requirement of snubber circuit for SCR.

**Solution**

**Snubber Circuit for SCR:**



**Figure 7.** Snubber Circuit

**Design requirements:**

- **Resistor selection:** Limits discharge current of capacitor.
- **Capacitor selection:** Controls rate of voltage rise ( $dv/dt$ ).
- **RC time constant:** Determines response time.

**Purpose of snubber circuit:**

- **$dv/dt$  protection:** Prevents false triggering due to rapid voltage changes.
- **Voltage spike suppression:** Absorbs inductive voltage spikes.
- **Transient protection:** Protects SCR during switching.

**Mnemonic**

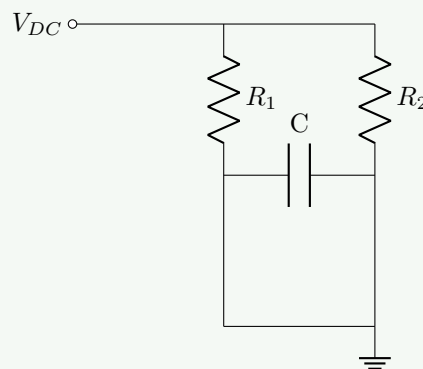
“RAPE: Resistor And capacitor Protect against Excessive voltage rise”

**Question 2(c OR) [7 marks]**

Explain class C type commutation method.

**Solution**

**Class C Commutation (Complementary commutation):**



**Figure 8.** Class C Commutation Circuit

**Working principle:**

- **Initial state:**  $SCR_1$  conducting,  $SCR_2$  off. Capacitor charges.
- **Commutation start:**  $SCR_2$  is triggered.
- **Load transfer:** Current path changes; detailed analysis of capacitor voltage polarity switching.
- **Voltage reversal:** Voltage across  $SCR_1$  becomes negative due to C.
- **Turn-off:**  $SCR_1$  turns off as current falls.
- **Alternating operation:**  $SCR_1$  and  $SCR_2$  conduct alternatively.

**Applications:**

- **Inverter circuits:** Used in bridge inverters.
- **Dual load systems:** Where alternate operation is required.

**Mnemonic**

“TACTOR: Triggering Alternate SCRs Creates Turn-Off and Reversal”

**Question 3(a) [3 marks]**

State the advantages of poly-phase rectifier over single phase rectifier.

**Solution**

**Table 3.** Advantages of Poly-phase Rectifier

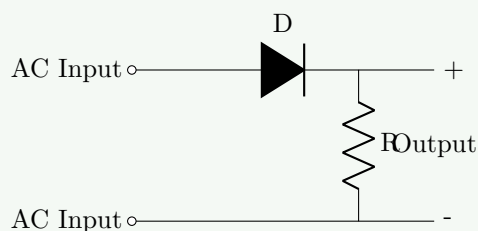
Advantage	Description
<b>Higher efficiency</b>	Lower power loss and better transformer utilization
<b>Lower ripple factor</b>	Smoother DC output requiring smaller filter components
<b>Higher power handling</b>	Can handle higher power levels than single phase
<b>Better transformer utilization</b>	Higher transformer utilization factor
<b>Lower harmonic content</b>	Reduced harmonic distortion in output

**Mnemonic**

“HELPS: Higher efficiency, Even output, Lower ripple, Power handling better, Smaller filter”

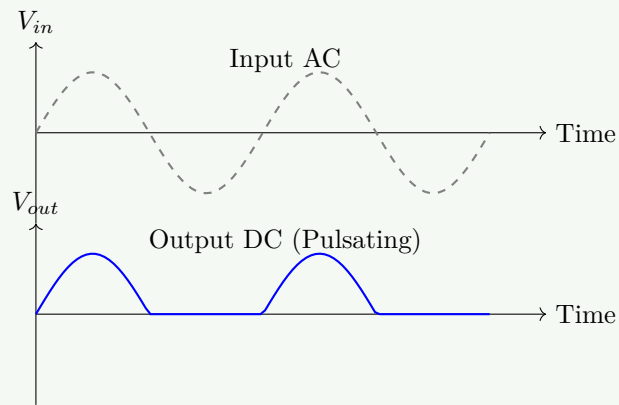
**Question 3(b) [4 marks]**

Draw and explain the circuit of single phase Half Wave rectifier. Draw the waveforms.

**Solution****Single Phase Half Wave Rectifier:**

**Figure 9.** Half Wave Rectifier Circuit

**Waveform:**



**Figure 10.** Half Wave Rectifier Waveforms

**Working principle:**

- **Forward bias:** Diode conducts during positive half-cycle.
- **Reverse bias:** Diode blocks current during negative half-cycle.
- **Output:** Pulsating DC with high ripple factor.
- **Frequency:** Output frequency same as input frequency.

**Mnemonic**

“PROF: Positive half conducts, Reverse half blocks, Output is pulsating, Frequency unchanged”

## Question 3(c) [7 marks]

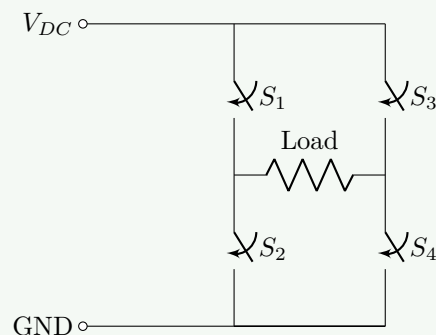
List all types of Inverters. Out of that explain single phase full bridge Inverter.

**Solution**

**Types of Inverters:**

1. Based on circuit: Series, Parallel, Bridge
2. Based on phases: Single-phase, Three-phase
3. Based on output: Square wave, Modified sine wave, Pure sine wave
4. Based on commutation: SCR-based, Transistor-based

**Single Phase Full Bridge Inverter:**



**Figure 11.** Single Phase Full Bridge Inverter

**Working principle:**

- **First half-cycle:**  $S_1$  and  $S_4$  ON,  $S_2$  and  $S_3$  OFF. Positive voltage across load.
- **Second half-cycle:**  $S_2$  and  $S_3$  ON,  $S_1$  and  $S_4$  OFF. Negative voltage across load.
- **Output waveform:** AC square wave across load.
- **Control method:** Gate signals to switches with  $180^\circ$  phase shift.



**Advantages:**

- **Higher output power:** Twice the output of half bridge.
- **Better voltage utilization:** Full DC bus voltage across load.
- **Lower current rating:** Each switch carries only load current.

**Mnemonic**

“SOAP: Switches Operate Alternately in Pairs”

**Question 3(a OR) [3 marks]**

Compare UPS and SMPS.

**Solution**

**Table 4.** Comparison of UPS and SMPS

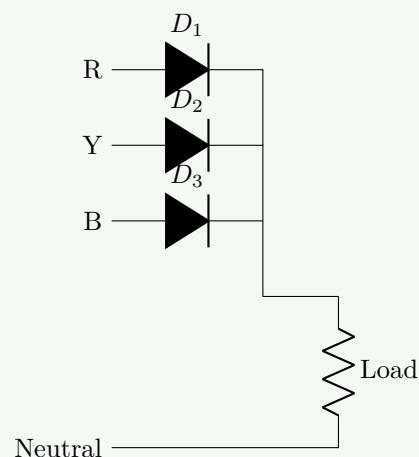
Parameter	UPS	SMPS
<b>Primary function</b>	Provides backup power during outages	Converts AC to regulated DC
<b>Battery backup</b>	Contains batteries for backup	No battery backup
<b>Output</b>	AC output (typically)	DC output (typically)
<b>Efficiency</b>	Lower (70-80%)	Higher (80-95%)
<b>Size</b>	Larger and heavier	Compact and lightweight
<b>Applications</b>	Computers, servers, critical equipment	Electronic devices, chargers

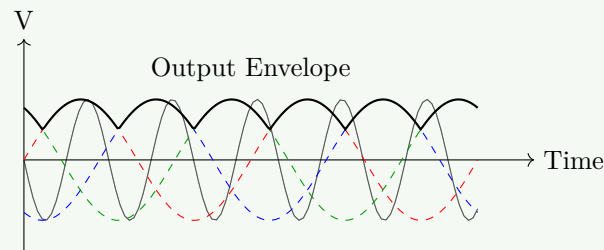
**Mnemonic**

“BBOSS: Backup Battery Only in UPS, Small Size in SMPS”

**Question 3(b OR) [4 marks]**

Draw and explain the circuit of three phase Half Wave rectifier. Draw the waveforms.

**Solution****Three Phase Half Wave Rectifier:**

**Figure 12.** Three Phase Half Wave Rectifier Circuit**Waveform:****Figure 13.** Output Voltage Waveform**Working principle:**

- **Conduction sequence:** Each diode conducts when its phase voltage is highest.
- **Conduction angle:** Each diode conducts for  $120^\circ$ .
- **Output ripple:** 3 pulses per cycle, lower ripple than single phase.
- **Ripple frequency:** 3 times the input frequency.

**Mnemonic**

“CROP: Conduction of  $120^\circ$ , Ripple reduced, Output smoother, Pulses tripled”

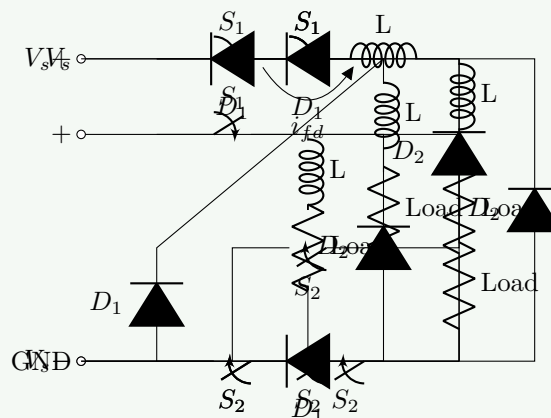
### Question 3(c OR) [7 marks]

Define chopper. With the help of circuit diagram explain class D chopper.

**Solution**

**Definition of Chopper:** A chopper is a DC to DC converter that converts fixed DC input voltage to variable DC output voltage using high-frequency switching.

**Class D Chopper (Two-quadrant chopper):**

**Figure 14.** Class D Chopper Circuit**Working principle:**

- **First quadrant operation:**  $S_1$  ON,  $S_2$  OFF. Energy flows from source to load.
- **Second quadrant operation:**  $S_1$  OFF,  $S_2$  ON. Current freewheels through  $D_1$  and  $D_2$ . Energy flows from load to source.

**Applications:**

- **DC motor drives:** Providing forward motoring and regenerative braking.

- **Battery charging:** Controlling charging current.
- **Renewable energy:** Interfacing with solar panels.

### Mnemonic

“FRED: Forward motoring, Regenerative braking, Energy flow control, Dual quadrant operation”

## Question 4(a) [3 marks]

Describe the use of SCR as a static switch.

### Solution

SCR as Static Switch:

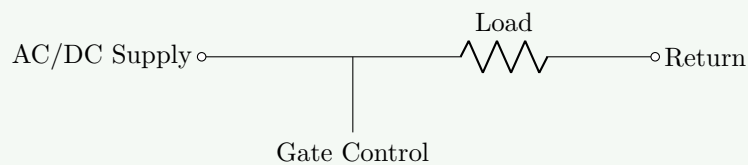


Figure 15. SCR Static Switch Application

Key features:

- **No moving parts:** Purely electronic switching.
- **Fast switching:** Microsecond response time.
- **High reliability:** Longer lifetime than mechanical switches.
- **Controlled turn-on:** Precise control via gate signal.

Advantages over mechanical switches:

- **No arcing:** No contact bounce or wear.
- **Silent operation:** No mechanical noise.
- **EMI reduction:** Less electromagnetic interference.

### Mnemonic

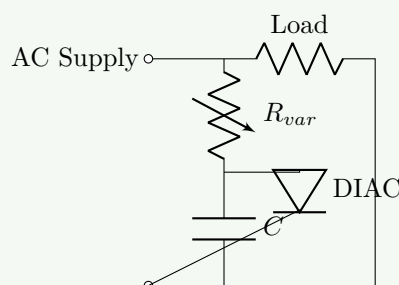
“FANS: Fast switching, Arc-free operation, No mechanical wear, Silent operation”

## Question 4(b) [4 marks]

Draw the circuit diagram of A.C. Power control using DIAC and TRIAC and explain its working.

### Solution

AC Power Control using DIAC and TRIAC:



**Figure 16.** AC Power Control Circuit**Working principle:**

- **RC network:** Controls firing angle by delaying gate pulse.
- **Capacitor charging:** C charges through R during each half-cycle.
- **DIAC breakdown:** When capacitor voltage reaches DIAC breakover voltage.
- **TRIAC triggering:** DIAC conducts and triggers TRIAC.
- **Power control:** Varying R changes firing angle and thus power delivered.

**Applications:**

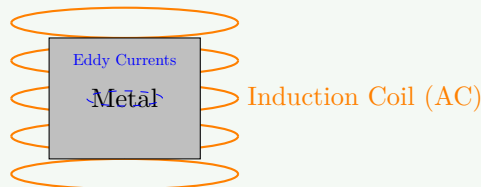
- **Light dimmers:** Controlling brightness of lamps.
- **Fan speed control:** Regulating fan speed.
- **Heater control:** Adjusting heating elements.

**Mnemonic**

“CRAFT: Capacitor charges, Reaches breakover, Activates DIAC, Fires TRIAC, Transfers power”

**Question 4(c) [7 marks]**

Explain the working principle of induction heating also write the applications of induction heating.

**Solution****Working Principle of Induction Heating:****Figure 17.** Induction Heating Principle**Working principle:**

- **High-frequency current:** Passes through induction coil.
- **Electromagnetic induction:** Creates alternating magnetic field.
- **Eddy currents:** Induced in workpiece.
- **Resistance heating:** Eddy currents generate heat due to resistance.
- **Skin effect:** Heat concentrated near surface.
- **Non-contact heating:** No physical contact between coil and workpiece.

**Applications of Induction Heating:**

- **Metal heat treatment:** Hardening, annealing, tempering.
- **Metal melting:** Foundry operations.
- **Welding and brazing:** Joining metal components.
- **Forging:** Heating before forming.
- **Domestic cooking:** Induction cooktops.
- **Semiconductor processing:** Crystal growth.

**Mnemonic**

“MASTER: Magnetic field, Alternating current, Surface heating, Temperature control, Eddy currents, Resistance heating”

### Question 4(a OR) [3 marks]

Explain working of photo relay circuit using LDR.

#### Solution

Photo Relay Circuit using LDR:

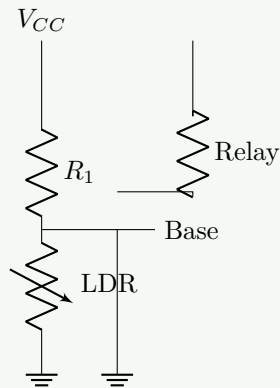


Figure 18. LDR Photo Relay Circuit

Working principle:

- **Light-dependent resistor:** Resistance decreases with increasing light.
- **Voltage divider:** LDR and  $R_1$  form voltage divider.
- **Transistor switching:** Base voltage controls transistor conduction.
- **Relay operation:** Transistor drives relay coil.
- **Threshold adjustment:** Can be set using variable resistor.

Applications:

- **Automatic street lighting:** Turns on lights at dusk.
- **Day/night switching:** Controls devices based on ambient light.
- **Security systems:** Light-activated alarms.

#### Mnemonic

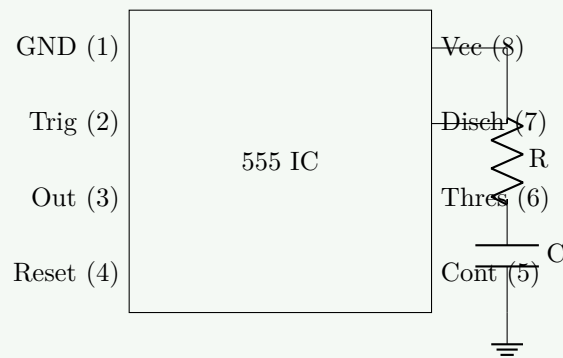
“LARK: Light controls, Activates transistor, Relay switches, Keeps circuit automated”

### Question 4(b OR) [4 marks]

Explain the operation of timer circuit using 555 timer IC.

#### Solution

555 Timer Circuit (Monostable):



Standard Monostable Configuration

**Figure 19.** 555 Timer Block Diagram**Working principle:**

- **Trigger input:** Active low trigger at pin 2.
- **Timing components:** R and C determine timing period ( $T = 1.1RC$ ).
- **Output high:** When triggered, output goes high.
- **Capacitor charging:** C charges through R.
- **Threshold detection:** When voltage reaches  $2/3 V_{CC}$ , output goes low.
- **Timer reset:** Circuit can be reset using pin 4.

**Applications:**

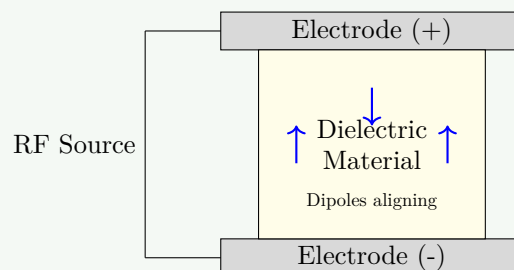
- **Delay circuits:** Creating time delays.
- **Pulse generation:** Generating precise pulses.
- **Timing control:** Sequential timing operations.

**Mnemonic**

“TRACT: Trigger activates, Resistor-capacitor timing, Accurate delay, Capacitor charges, Threshold detection”

**Question 4(c OR) [7 marks]**

Explain the working principle of dielectric heating also write the applications of dielectric heating.

**Solution****Working Principle of Dielectric Heating:****Figure 20.** Dielectric Heating Principle**Working principle:**

- **High-frequency electric field:** Applied between electrodes.
- **Dielectric material:** Placed between electrodes.
- **Molecular polarization:** Dipoles align with electric field.
- **Field oscillation:** Rapid reversal of field direction.

- **Molecular friction:** Dipoles rotate rapidly causing friction.
- **Volumetric heating:** Heat generated throughout material.
- **Frequency range:** Typically 10-100 MHz.

**Applications of Dielectric Heating:**

- **Food processing:** Baking, drying, pasteurization.
- **Wood industry:** Gluing, drying timber.
- **Textile drying:** Removing moisture from fabrics.
- **Plastic welding:** Joining thermoplastics.
- **Medical applications:** Therapeutic diathermy.
- **Paper industry:** Drying paper products.

**Mnemonic**

“DIPOLE: Dielectric material, Intense electric field, Polarization of molecules, Oscillation causes, Linkage of heat, Even heating throughout”

### Question 5(a) [3 marks]

Define AC drive. State applications of AC drives.

**Solution**

**Definition of AC Drive:** An AC drive is an electronic device that controls the speed, torque, and direction of an AC motor by varying the frequency and voltage supplied to the motor.

**Applications of AC Drives:**

**Table 5.** Applications of AC Drives

Application Area	Examples
<b>Industrial</b>	Conveyor systems, pumps, fans, compressors
<b>HVAC</b>	Blowers, cooling towers, air handling units
<b>Water treatment</b>	Pumps, mixers, aerators
<b>Mining</b>	Crushers, conveyors, pumps
<b>Textile</b>	Spinning machines, looms, winders
<b>Material handling</b>	Cranes, elevators, escalators

**Mnemonic**

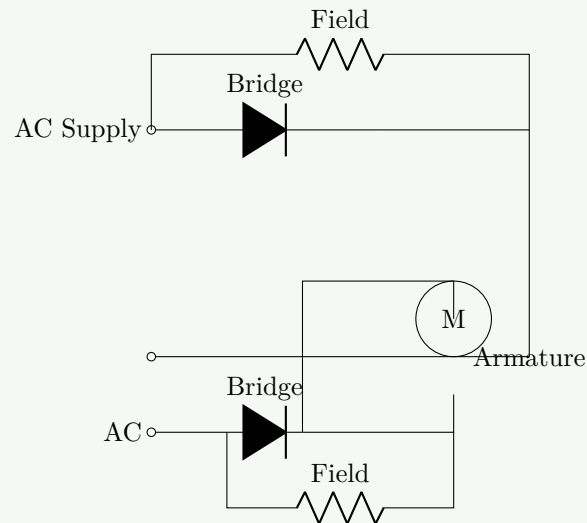
“PITCHW: Pumps, Industrial machinery, Textile machines, Conveyor systems, HVAC systems, Water treatment”

### Question 5(b) [4 marks]

Draw and explain any one method for speed control of DC shunt motor.

**Solution**

**Armature Voltage Control Method for DC Shunt Motor:**



**Figure 21.** Armature Voltage Control Circuit

**Working principle:**

- **Constant field current:** Field supply maintained constant.
- **Variable armature voltage:** Controlled by SCR.
- **Speed equation:**  $N \propto (V_a - I_a R_a) / \Phi$ .
- **Speed control:** By changing armature voltage  $V_a$ .
- **Torque control:** Armature current controls torque.

**Advantages:**

- **Wide speed range:** Can achieve speeds below and above base speed.
- **Smooth control:** Continuous speed adjustment.
- **High efficiency:** Low power loss in control circuit.

**Mnemonic**

“SAVE: SCR controls, Armature voltage varies, Velocity changes, Efficient operation”

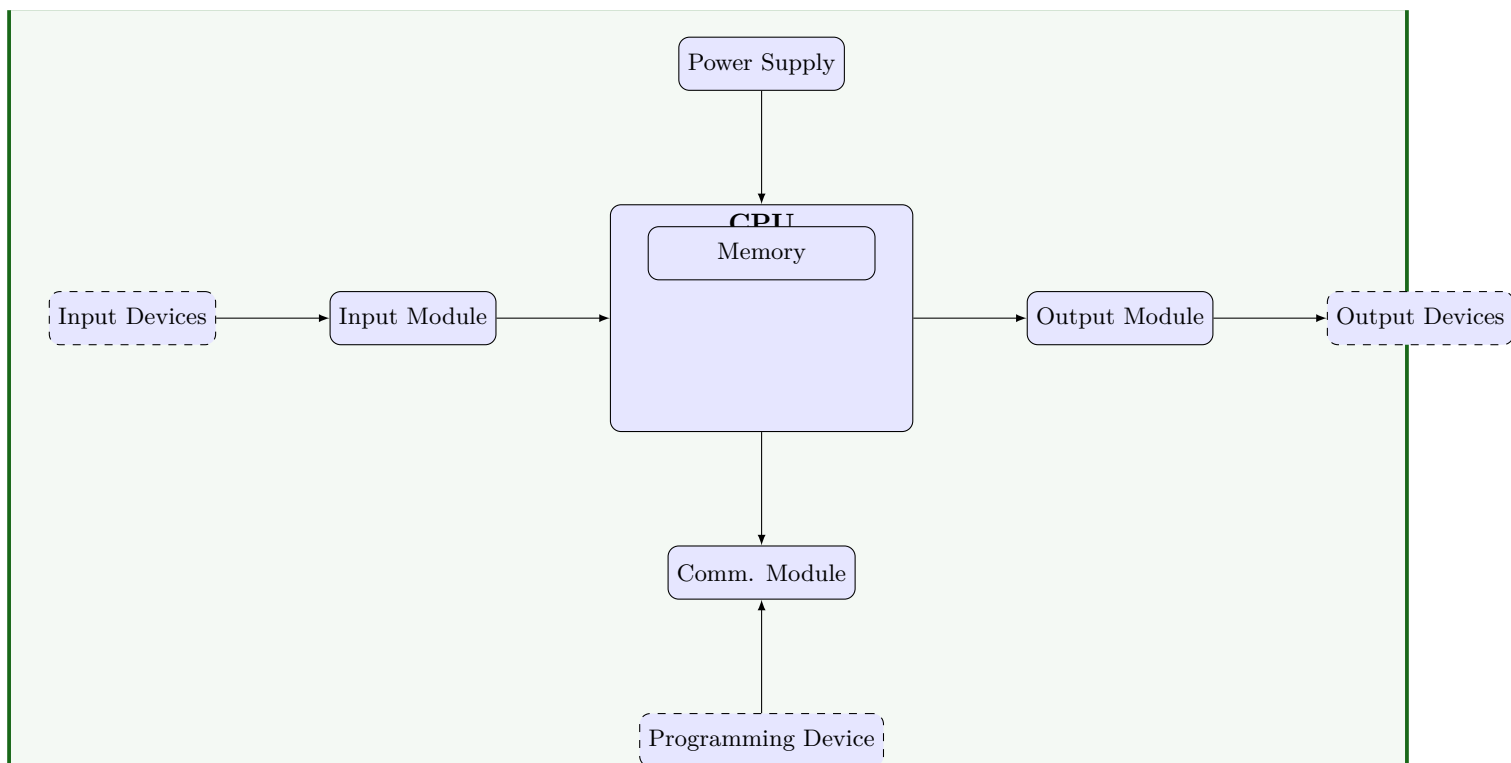
## Question 5(c) [7 marks]

Draw the block diagram of PLC and explain the function of each block.

**Solution**

**PLC Block Diagram:**





**Figure 22.** Block Diagram of PLC

**Functions of each block:**

**Table 6.** Functions of PLC Blocks

Block	Function
<b>Power Supply</b>	Converts main AC supply to DC required for internal circuits
<b>CPU</b>	Executes program, processes I/O, performs calculations
<b>Memory</b>	Stores program, data, and I/O status (RAM, ROM, EEPROM)
<b>Input Module</b>	Interfaces with input devices, provides isolation, signal conditioning
<b>Output Module</b>	Drives output devices, provides isolation and protection
<b>Communication Module</b>	Connects PLC to networks, other PLCs, and programming devices
<b>Programming Device</b>	Used to develop, edit, and monitor PLC programs

**Advantages of PLC:**

- **Reliability:** Solid-state components with high MTBF.
- **Flexibility:** Easily reprogrammable for different applications.
- **Communication:** Network capabilities for distributed control.
- **Diagnostics:** Built-in diagnostics and troubleshooting.

#### Mnemonic

“PRIME-C: Power supply, RAM/ROM memory, Input module, Microprocessor (CPU), Execution of program, Communication interface”

## Question 5(a OR) [3 marks]

State the applications of stepper motor.

## Solution

Table 7. Applications of Stepper Motor

Application Area	Examples
Precision positioning	CNC machines, 3D printers, robotic arms
Office equipment	Printers, scanners, photocopiers
Medical devices	Surgical robots, fluid pumps, sample handlers
Automotive	Headlight adjustment, idle control, mirror control
Aerospace	Satellite positioning, antenna control
Consumer electronics	Cameras (focus/zoom), gaming controllers

## Mnemonic

“POMAC: Positioning systems, Office equipment, Medical devices, Automotive controls, Consumer electronics”

## Question 5(b OR) [4 marks]

Draw and explain the circuit to control speed of a DC series motor.

## Solution

Speed Control of DC Series Motor using SCR:

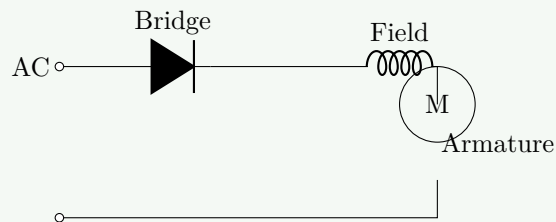


Figure 23. DC Series Motor Speed Control

Working principle:

- **Series connection:** Field winding in series with armature.
- **SCR control:** Phase-controlled SCR regulates average voltage.
- **Speed equation:**  $N \propto (V - I(R_a + R_f))/I\Phi$ .
- **Speed-torque relation:** Non-linear relationship.
- **Application:** Used when high starting torque required.

Advantages:

- **High starting torque:** Ideal for traction applications.
- **Simple control:** Basic circuit design.
- **Cost-effective:** Fewer components than other methods.

## Mnemonic

“SCAT: Series connection, Current controls flux, Average voltage controlled by SCR, Torque highest at low speeds”

## Question 5(c OR) [7 marks]

Discuss the BLDC motor in brief.

## Solution

### BLDC Motor (Brushless DC Motor):

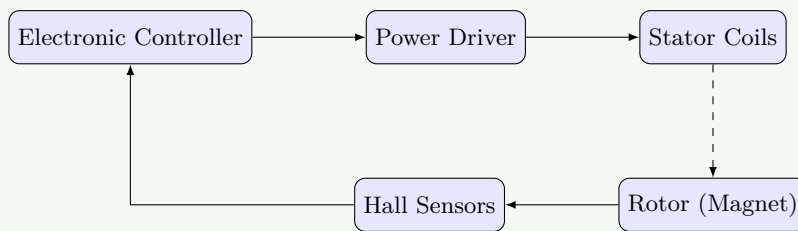


Figure 24. BLDC Motor Control System

#### Construction:

- **Stator:** Contains windings (typically 3-phase).
- **Rotor:** Permanent magnets on rotor.
- **Position sensing:** Hall effect sensors or encoders.
- **Controller:** Electronic commutation controller.

#### Working principle:

- **Electronic commutation:** Replaces mechanical brushes.
- **Sequencing:** Controller energizes stator coils in sequence.
- **Position feedback:** Hall sensors determine rotor position.
- **Phase energizing:** Proper phase energized based on rotor position.

#### Advantages:

- **High efficiency:** No brush friction losses.
- **Low maintenance:** No brush wear.
- **Longer lifespan:** Reliable operation.
- **Better speed-torque characteristics:** Flat curve.
- **Low noise:** Quiet operation.
- **Better heat dissipation:** Windings on stator.

#### Applications:

- **Computer cooling fans:** CPU/GPU coolers.
- **Hard disk drives:** Spindle motors.
- **Electric vehicles:** Propulsion systems.
- **Drones:** Propeller motors.
- **Home appliances:** Washing machines, refrigerators.
- **Industrial automation:** Precision control systems.

## Mnemonic

“COPPER: Commutation electronic, Operation efficient, Permanent magnets, Position sensors, Electronic control, Reliable performance”