Industrial Electronics (4331103) - Summer 2023 Solution

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Question 1(a) [3 marks]

Draw and Explain the V-I Characteristics of TRIAC.

Solution

TRIAC (Triode for Alternating Current) is a bidirectional three-terminal semiconductor device that can conduct current in either direction when triggered.

Diagram:

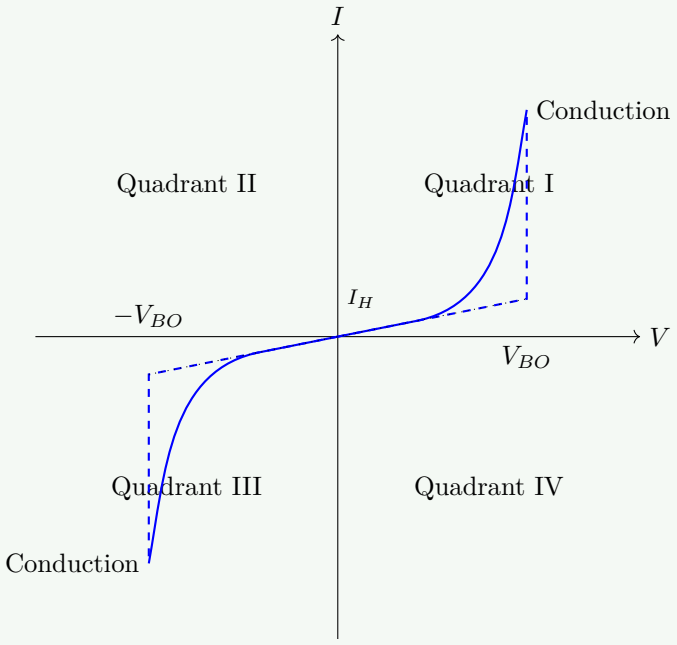

Figure 1. V-I Characteristics of TRIAC

- **Bidirectional operation**: TRIAC conducts in both directions (positive and negative half cycles)
- **Quadrant operation**: Functions in all four quadrants based on polarity of MT2 and gate
- **Triggering voltage**: Breakdown occurs at $\pm V_{BO}$ in either direction
- **Holding current**: Minimum current to maintain conduction

Mnemonic

Two Rectifiers In A Case

Question 1(b) [4 marks]

Explain working of SCR using two transistor analogy.

Solution

SCR (Silicon Controlled Rectifier) can be represented as interconnected PNP and NPN transistors.
Diagram:

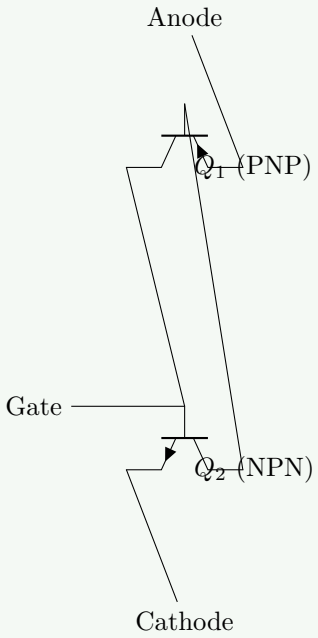

Figure 2. Two Transistor Analogy of SCR

- **Two-transistor structure**: PNP (Q_1) and NPN (Q_2) connected such that collector of each transistor drives the base of other
- **Regenerative feedback**: Once both transistors start conducting, they keep each other in saturation
- **Triggering**: Applying gate current to Q_2 base starts the regenerative process
- **Latching**: Once triggered, SCR remains ON even if gate signal is removed

Mnemonic

Pull Neat Path

Question 1(c) [7 marks]

Draw the circuit diagram of photo electric relay using LDR and explain it Working.

Solution

A photoelectric relay using LDR (Light Dependent Resistor) is a light-activated switching circuit.
Circuit Diagram:

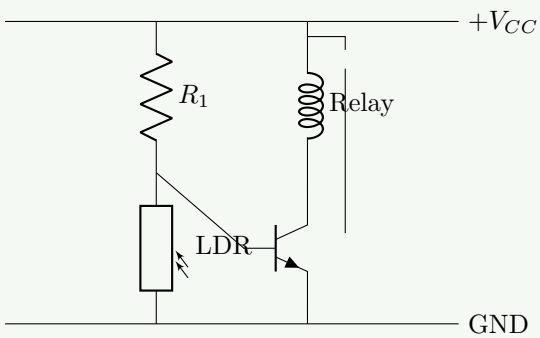

Figure 3. Photo Electric Relay Circuit

- **Light sensing**: LDR resistance decreases in presence of light
- **Transistor operation**: When light falls on LDR, voltage at transistor base changes
- **Relay switching**: Transistor conducts/cuts off based on light, activating/deactivating relay
- **Threshold adjustment**: Potentiometer R_1 sets light sensitivity level
- **Applications**: Automatic street lights, burglar alarms, automatic door openers

Mnemonic

Light Detects Readily

Question 1(c OR) [7 marks]

Draw the gate pulse trigger circuit using UJT for SCR and explain its working.

Solution

UJT (Unijunction Transistor) provides reliable trigger pulses for SCR.
Circuit Diagram:

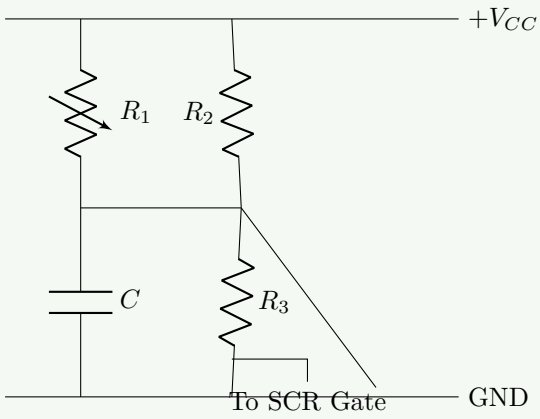

Figure 4. UJT Trigger Circuit for SCR

- **RC timing**: R_1 and C form charging circuit that determines pulse frequency
- **UJT operation**: UJT fires when capacitor voltage reaches peak point voltage
- **Pulse generation**: UJT discharges capacitor producing sharp trigger pulse
- **SCR triggering**: Pulse applied to SCR gate turns it ON at specific points in AC cycle
- **Frequency control**: Adjusting R_1 changes pulse frequency for phase control

Mnemonic

Uniform Junctions Trigger

Question 2(a) [3 marks]

State Triggering methods of SCR.

Solution

Triggering Method	Operating Principle	Advantages
Gate Triggering	Current applied to gate terminal	Most common, precise control
Thermal Triggering	Temperature rise causes leakage	Simple, no external circuit
Light Triggering	Photons create electron-hole pairs	Electrical isolation, used in LASCRs
dv/dt Triggering	Rapid voltage rise causes turn-on	Useful for protection circuits
Forward Voltage Triggering	Exceeding breakover voltage	No gate connection needed

Table 1. SCR Triggering Methods

Mnemonic

Good Triggers Let Devices Fire

Question 2(b) [4 marks]

What is Commutation of SCR? Explain class-E commutation.

Solution

Commutation is the process of turning OFF an SCR by reducing its anode current below holding current.
Class-E Commutation (Complementary Commutation):

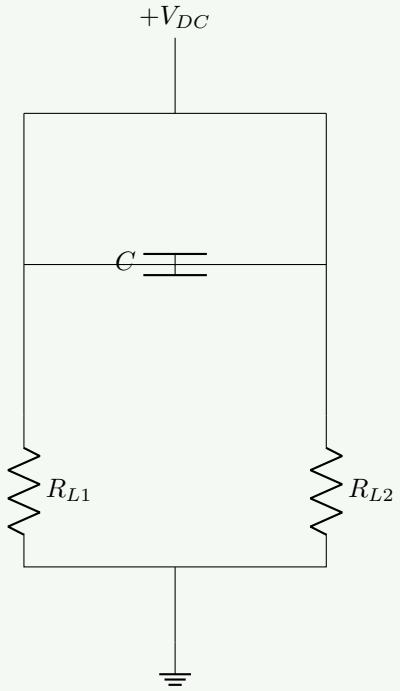

Figure 5. Class-E Commutation Circuit

- **Complementary switching**: Uses another SCR in opposite half-cycle
- **Natural commutation**: AC source crosses zero, anode current falls below holding current
- **Application**: AC power control circuits, cycloconverters
- **Advantage**: No additional commutation components required

Mnemonic

Complementary Elements

Question 2(c) [7 marks]

Draw and explain Snubber Circuit for SCR.

Solution

A snubber circuit protects SCR from voltage transients and dv/dt turn-on.
Circuit Diagram:

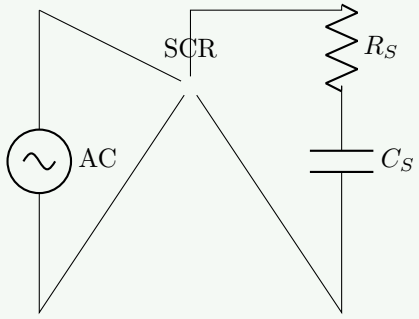

Figure 6. Snubber Circuit for SCR

- **RC network**: Series resistor (R_S) and capacitor (C_S) connected across SCR
- **Transient suppression**: Capacitor absorbs voltage spikes that could damage SCR
- **dv/dt protection**: Prevents false triggering due to rapid voltage rise
- **Turn-off assistance**: Helps in commutation by providing alternate current path
- **Component selection**: C_S based on load current, R_S limits discharge current

Mnemonic

Safely Neutralizes Unwanted Breakover

Question 2(a OR) [3 marks]

Explain over current protection method of SCR.

Solution

Protection Method	Working Principle	Applications
Fuses	Melts when current exceeds rating	Simple, economical protection
Circuit Breakers	Trips on overload, can be reset	Reusable protection
Current Limiting Reactors	Limits fault current magnitude	Industrial power control
Electronic Current Limiting	Senses current and controls gate	Precise protection
Crowbar Circuit	Shorts power supply on overload	Protects sensitive loads

Table 2. SCR Overcurrent Protection Methods

Mnemonic

Fault Current Causes Equipment Damage

Question 2(b OR) [4 marks]

Explain the working of opto-SCR.

Solution

An opto-SCR (or Light Activated SCR) combines a light source and SCR in an isolated package.
Diagram:

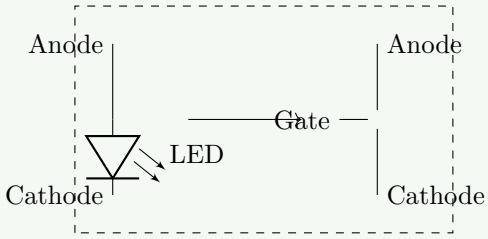

Figure 7. Opto-SCR Structure

- **Electrical isolation**: LED optically triggers SCR without electrical connection
- **Noise immunity**: Immune to electrical noise and interference
- **High-voltage isolation**: Separates control and power circuits
- **Applications**: Industrial control, high-voltage switching

Mnemonic

Light Activates Silicon Control

Question 2(c OR) [7 marks]

What is force commutation? Explain any two.

Solution

Force commutation is artificially turning OFF an SCR by reducing its anode current below holding level.
1. Class A Commutation (Self-Commutation):

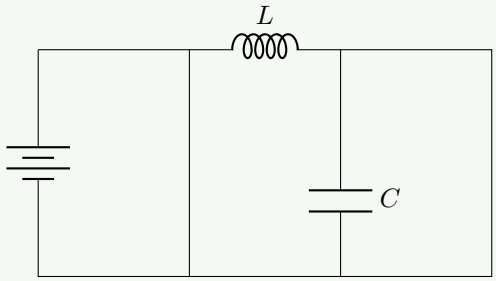

Figure 8. Class A Commutation

- **LC resonant circuit**: Parallel L-C across SCR creates oscillations
- **Reverse current**: L-C circuit forces reverse current through SCR
- **Applications**: Inverters, choppers

2. Class B Commutation (Resonant Pulse Commutation):

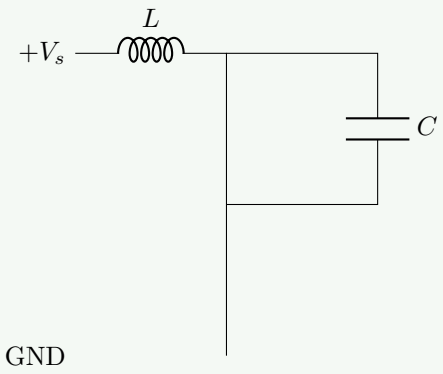

Figure 9. Class B Commutation

- **External switch**: Additional SCR or switch triggers commutation
- **Energy storage**: L-C circuit stores energy then reverses SCR current
- **Applications**: DC choppers, controlled rectifiers

Mnemonic

Force Circuit Reversal

Question 3(a) [3 marks]

Explain 1-ϕ full Wave bridge-controlled rectifier using four diodes & one SCR.

Solution

This circuit combines diodes and an SCR for controlled single-phase full-wave rectification.
Circuit Diagram:

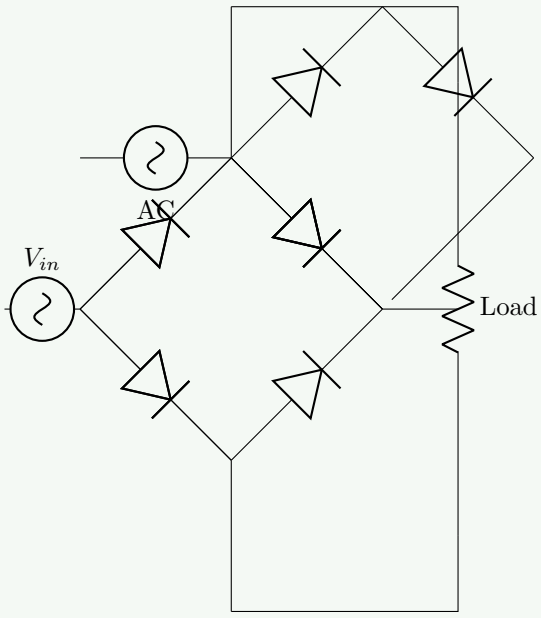

Figure 10. 1-ϕ Full Wave Rectifier with 4 Diodes and 1 SCR

- **Bridge configuration**: Four diodes arranged in bridge with one replaced by SCR (or SCR in series)
- **Variable output**: SCR controls conduction angle and thus output voltage
- **Economical design**: Uses only one SCR instead of two or four
- **Efficiency**: Higher than half-wave controlled rectifier

Mnemonic

Blend Diodes Smartly

Question 3(b) [4 marks]

What is Chopper? What are its application?

Solution

Aspect	Description
Definition	DC-DC converter that converts fixed DC input to variable DC output
Working Principle	Periodically switches DC input ON/OFF at high frequency
Types	Step-down (Buck), Step-up (Boost), Buck-Boost, Cuk
Control Methods	PWM, Frequency modulation, Current-limit control
Applications	DC motor speed control, Battery chargers, UPS, Solar systems, Electric vehicles

Table 3. Chopper Basics and Applications

Mnemonic

Chops Current Perfectly

Question 3(c) [7 marks]

Draw and explain the circuit diagram of static switch using SCR for 1-ϕ A.C. Load.

Solution

A static switch using SCR provides non-mechanical switching for AC loads.
Circuit Diagram:

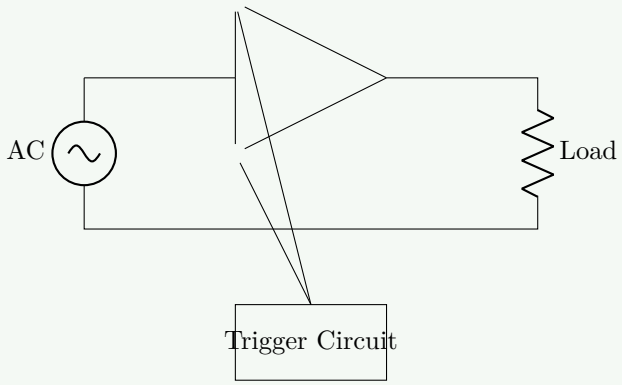

Figure 11. Static AC Switch using SCRs

- **Antiparallel SCRs**: Two SCRs connected in inverse parallel for bidirectional conduction
- **Gate control**: Properly timed gate signals control power to load
- **Zero-crossing switching**: SCRs naturally turn OFF at zero crossing
- **Applications**: Heater control, motor soft-starting, lighting control
- **Advantages**: No moving parts, silent operation, long life

Mnemonic

Solid Switching Technology

Question 3(a OR) [3 marks]

Explain basic principle of DC Chopper.

Solution

Component	Function
Switching Device	SCR, MOSFET, IGBT switches DC at high frequency
Control Circuit	Generates PWM gate signals to control ON/OFF time
Duty Cycle	Ratio of ON time to total time period determines output
Output Filter	Smooths chopped output to reduce ripple
Working Principle	Average voltage = Input voltage × Duty cycle

Table 4. DC Chopper Principle

Mnemonic

Direct Current Control

Question 3(b OR) [4 marks]

Write short note on: Un-interrupted Power Supply (UPS).

Solution

UPS provides emergency power when main supply fails.
Block Diagram:

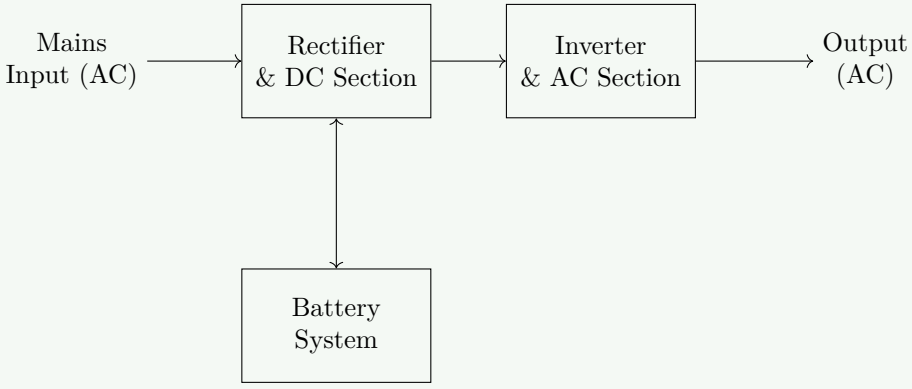

Figure 12. UPS Block Diagram

- **Backup power**: Provides continuous power during outages
- **Types**: Online, Offline, Line-interactive UPS
- **Protection**: Against power surges, sags, and frequency variations
- **Applications**: Computers, medical equipment, telecommunications

Mnemonic

Uninterrupted Power Securely

Question 3(c OR) [7 marks]

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

Solution

Switched-Mode Power Supply converts AC to regulated DC efficiently.
Block Diagram:

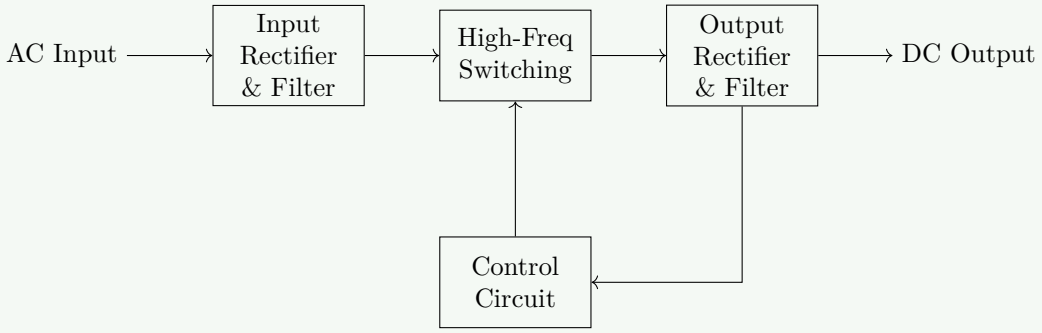

Figure 13. SMPS Block Diagram

- **Input rectifier**: Converts AC to unregulated DC
- **High-frequency switching**: Converts DC to high-frequency AC using transistors
- **Transformer**: Provides isolation and voltage scaling
- **Output rectifier**: Converts high-frequency AC to DC
- **Filter**: Smooths DC output to reduce ripple
- **Control circuit**: Regulates output through feedback

Mnemonic

Switch Mode Power System

Question 4(a) [3 marks]

Draw the circuit diagram using TRIAC for speed control of 1-ϕ DC Shunt motor and Explain its working.

Solution

TRIAC-based speed control for a DC shunt motor provides efficient variable speed.
Circuit Diagram:

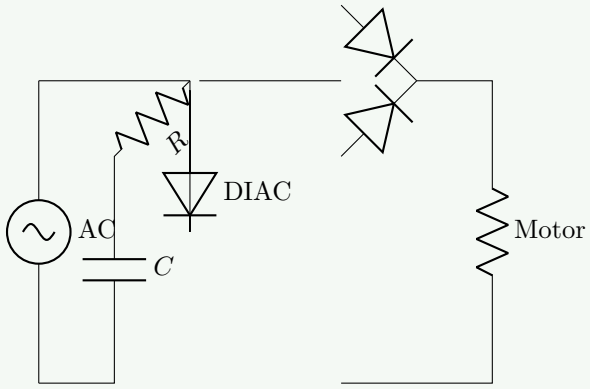

Figure 14. TRIAC Speed Control for DC Motor

- **Phase control**: TRIAC varies effective voltage through phase angle control
- **Rectification**: Bridge rectifier converts AC to DC for motor
- **Speed variation**: Motor speed proportional to applied voltage
- **RC timing**: RC network determines firing angle of TRIAC

Mnemonic

TRIAC Regulates Speed

Question 4(b) [4 marks]

Draw and explain the circuit diagram four stage sequential timer using IC-556.

Solution

IC-556 dual timer can be configured as a multi-stage sequential timer.
Circuit Diagram:

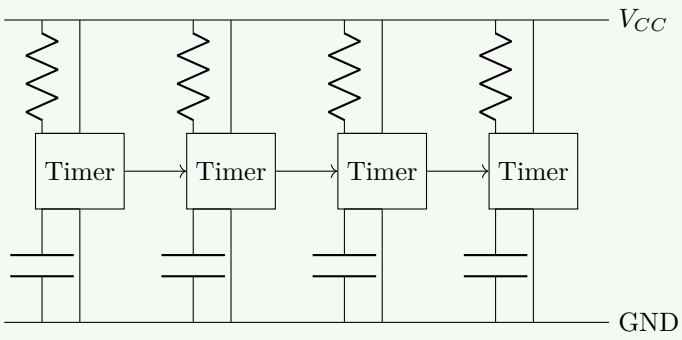

Figure 15. Sequential Timer Schematic Concept

- **Dual timer IC**: IC-556 contains two 555 timer circuits
- **Cascaded configuration**: Output of one stage triggers the next
- **Timing control**: RC time constants determine duration of each stage
- **Applications**: Industrial sequencing, process control, automation

Mnemonic

Sequential Steps Timed Precisely

Question 4(c) [7 marks]

Explain induction heating.

Solution

Induction heating is a non-contact heating process using electromagnetic induction.
Diagram:

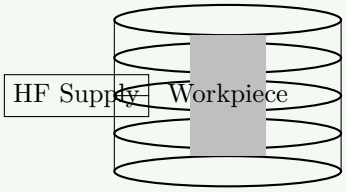

Figure 16. Induction Heating Setup

Principle	Description
Electromagnetic Induction	AC in coil creates alternating magnetic field
Eddy Currents	Magnetic field induces currents in workpiece
Resistive Heating	Eddy currents generate heat due to material resistance
Skin Effect	Current concentrates near surface at high frequencies
Applications	Heat treatment, melting, forging, brazing, cooking

Table 5. Induction Heating Principles

Mnemonic

Induced Heating Efficiently

Question 4(a OR) [3 marks]

Draw and explain three stage IC555 timer circuit.

Solution

A three-stage timer using IC555 provides sequential timing operations.
Circuit Diagram:

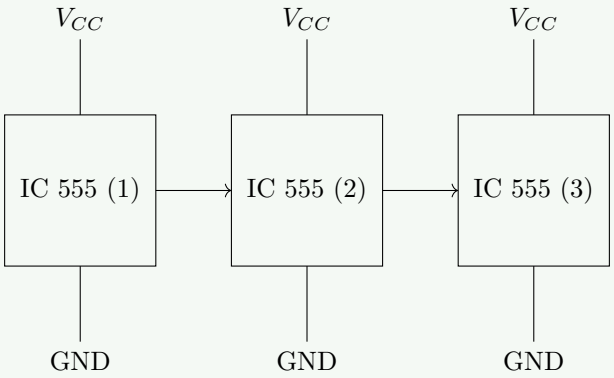

Figure 17. Three Stage IC555 Timer

- **Monostable mode**: Each stage operates in monostable mode with fixed time delay
- **Cascaded connection**: Output of first timer triggers second, and so on

- **Timing components**: R-C network determines time delay of each stage
- **Applications**: Automatic sequencing, process timing, industrial control

Mnemonic

Time Intervals Created

Question 4(b OR) [4 marks]

Explain the principle of dielectric heating.

Solution

Principle	Description
High-Frequency Electric Field	Material placed between electrodes with RF voltage (1-100 MHz)
Molecular Friction	Dipole molecules vibrate/rotate trying to align with alternating field
Heat Generation	Internal friction between molecules generates heat uniformly
Non-Conductive Materials	Effective for heating non-conductive materials (plastics, wood, food)
Applications	Plastic welding, wood drying, food processing (microwave ovens)

Table 6. Dielectric Heating Principles

Mnemonic

Dielectric Energy Heats

Question 4(c OR) [7 marks]

Make comparison between Induction heating and Dielectric heating.

Solution

Parameter	Induction Heating	Dielectric Heating
Basic Principle	Electromagnetic induction	High-frequency electric field
Suitable Materials	Conductive materials (metals)	Non-conductive materials (plastics, wood)
Frequency Range	1 kHz to 1 MHz	1 MHz to 1 GHz
Heating Mechanism	Eddy currents and hysteresis	Molecular friction (dipole rotation)
Heat Distribution	Surface heating (skin effect)	Volumetric (uniform throughout)
Efficiency	80-90% for magnetic materials	50-70% depending on material
Applications	Metal melting, forging, heat treatment	Plastic welding, food processing, drying
Equipment	Induction coil, work piece	Electrodes, dielectric material

Table 7. Comparison of Induction vs Dielectric Heating

Mnemonic

ICED

Question 5(a) [3 marks]

Explain Construction and working of Universal Motor.

Solution

Universal motor operates on both AC and DC power sources.
Diagram:

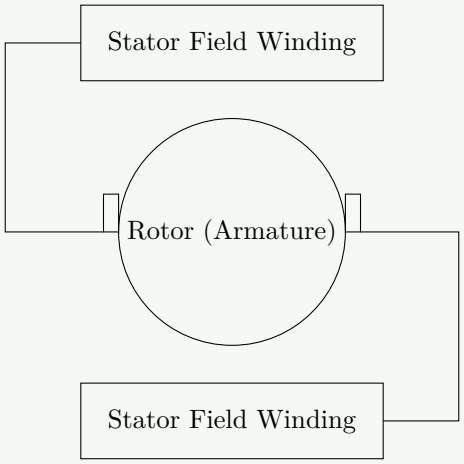

Figure 18. Universal Motor Construction

- **Series connection**: Field winding in series with armature winding
- **Construction**: Stator with field winding, rotor with commutator and brushes
- **Operating principle**: Same direction torque on both AC and DC
- **Characteristics**: High starting torque, high speed at low load
- **Applications**: Portable tools, household appliances, blenders

Mnemonic

Universally Motorized

Question 5(b) [4 marks]

Draw and explain the construction of DC servo motor.

Solution

DC servo motor provides precise position or speed control.
Diagram:

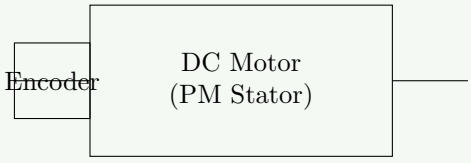

Figure 19. DC Servo Motor

- **Construction**: Permanent magnet stator, lightweight rotor, feedback device
- **Control system**: Closed-loop control with position/velocity feedback
- **Low inertia**: Allows quick response and precise positioning
- **Applications**: Robotics, CNC machines, positioning systems
- **Features**: High torque-to-inertia ratio, fast response, accuracy

Mnemonic

Servo System Control

Question 5(c) [7 marks]

Draw the block diagram of Programmable logic Control (PLC) and explain the Function of each block.

Solution

PLC is an industrial digital computer for automation control.
Block Diagram:

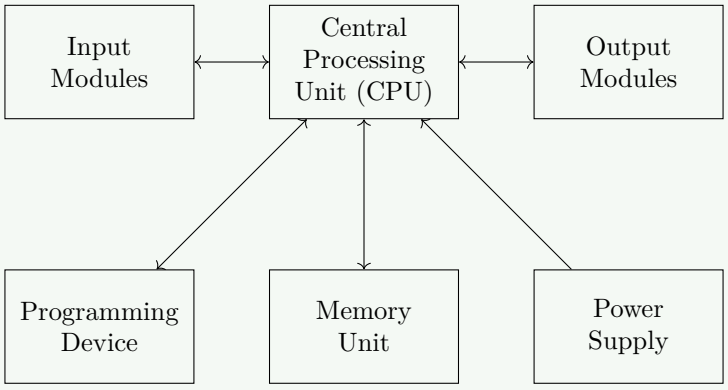

Figure 20. PLC Block Diagram

- **CPU**: Executes program, processes I/O data, makes decisions
- **Input modules**: Convert field signals (sensors, switches) to digital signals for CPU
- **Output modules**: Convert CPU commands to actuator signals (motors, valves)
- **Memory unit**: Stores program and data (ROM for OS, RAM for user program)
- **Programming device**: PC or console for program development and monitoring
- **Power supply**: Provides regulated power to PLC components

Mnemonic

Programs Logic Completely

Question 5(a OR) [3 marks]

Draw and explain the construction of Stepper motor.

Solution

Stepper motor rotates in discrete steps for precise positioning.
Diagram:

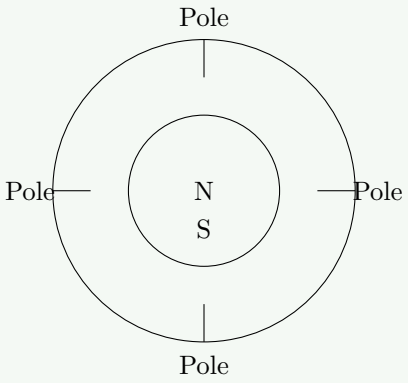

Figure 21. Stepper Motor Construction

- **Stator**: Contains multiple coil windings (phases)
- **Rotor**: Permanent magnet or variable reluctance type
- **Types**: Permanent magnet, variable reluctance, hybrid
- **Step angle**: Typically 1.8° (200 steps/rev) or 0.9° (400 steps/rev)
- **Applications**: Printers, disk drives, robotics, CNC machines

Mnemonic

Steps Precisely Moved

Question 5(b OR) [4 marks]

Draw explain solid state circuit to control DC shunt Motor Speed.

Solution

Solid-state circuit provides efficient and smooth DC motor speed control.
Circuit Diagram:

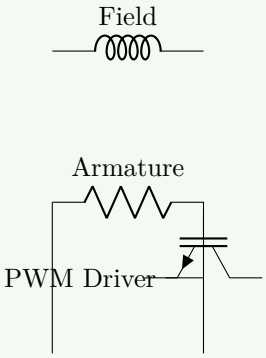

Figure 22. Solid State DC Motor Control

- **PWM controller**: Generates variable duty cycle pulses to control speed
- **MOSFET driver**: Provides gate drive to power MOSFET
- **Power MOSFET**: Controls current through armature winding
- **Feedback**: Tachogenerator or encoder provides speed feedback
- **Advantages**: Efficient, smooth control, wide speed range

Mnemonic

Power With MOSFET

Question 5(c OR) [7 marks]

Explain the Working of VFD (Variable Frequency Drive).

Solution

VFD controls AC motor speed by varying frequency and voltage.
Block Diagram:

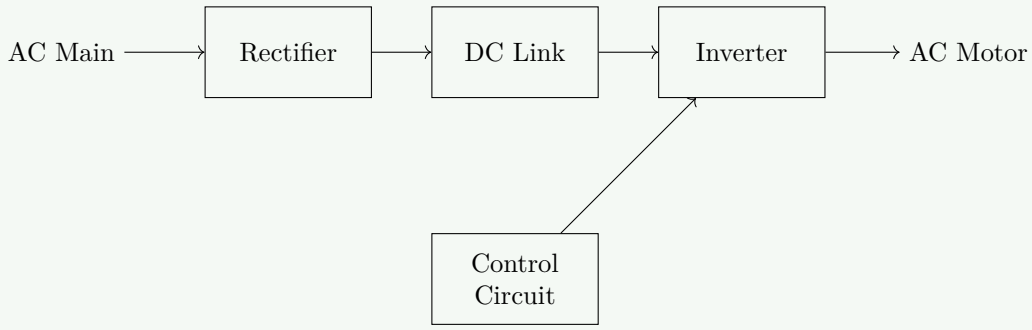

Figure 23. VFD Block Diagram

Component	Function
Rectifier	Converts AC input to DC (diode bridge or active front end)
DC Link	Filters DC and stores energy (capacitors, sometimes inductors)
Inverter	Converts DC to variable frequency AC (IGBTs with PWM)
Control Circuit	Regulates frequency/voltage based on speed requirement
Braking Circuit	Dissipates regenerative energy during deceleration

Table 8. VFD Components

- **Speed control**: Motor speed proportional to frequency ($RPM = 120f/P$)
- **Torque control**: Maintains V/f ratio for constant torque
- **Energy savings**: Reduces energy consumption at lower speeds
- **Applications**: Pumps, fans, conveyors, process control
- **Features**: Soft start, overcurrent protection, regenerative braking

Mnemonic

Vary Frequency, Drive motor