Subject Name Solutions

4331103 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

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

Solution

Symbol and Construction of SCR:

```
    Anode (A)
       |
       v
       \_
      | |
      | |
  G {-|\_|  }
      | |
      |\_|
       |
       v
   Cathode (K)
```

Construction:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Anode] {-{-}{-} P1[P{-}Layer]}
    P1 {-{-}{-} N1[N{-}Layer]}
    N1 {-{-}{-} P2[P{-}Layer]}
    P2 {-{-}{-} N2[N{-}Layer]}
    N2 {-{-}{-} K[Cathode]}
    G[Gate] {-{-}{-} P2}
{Highlighting}
{Shaded}
```

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

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "V{-I Characteristics"}
    style V{-I fill:\#f9f9f9,stroke:\#333,stroke{-}width:1px}

    MT2((MT2)) {-{-}{-} O[O]}
    O {-{-}{-} MT1((MT1))}

    V1[V] {-{-}{-} I1[I]}

    G[Gate Triggering]

    quad1[I quadrant] {-{-}{-} quad3[III quadrant]}
    breakover1[Breakover voltage +Vbo] {-{-}{-} breakover2[Breakover voltage {-}Vbo]}

    holding1[Holding current +Ih] {-{-}{-} holding2[Holding current {-}Ih]}
    end
{Highlighting}
{Shaded}
```

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
- **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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    G[Gate] {-{-}{-} E[Emitter]}
    E {-{-}{-} N+[N+ Layer]}
    N+ {-{-}{-} P[P Layer]}
    P {-{-}{-} N{-}[N{-} Drift Region]}
    N{- {-}{-}{-} N+B[N+ Buffer Layer]}
    N+B {-{-}{-} C[Collector]}
{Highlighting}
{Shaded}
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VCC[VCC] {-{-}{-} R1[R1] {-}{-}{-} E[Emitter]}
    E {-{-}{-} C[Capacitor] {-}{-}{-} GND[GND]}
    E {-{-}{-} UJT[UJT]}
    UJT {-{-}{-} B1[Base 1] {-}{-}{-} R2[R2] {-}{-}{-} GND}
    UJT {-{-}{-} B2[Base 2] {-}{-}{-} R3[R3] {-}{-}{-} VCC}
    B1 {-{-}{-} Output[Output]}
{Highlighting}
{Shaded}
```

Working principle:

- **Capacitor charging**: C charges through R1 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

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):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    DC\_Source[DC Source] {-{-}{-} SCR[SCR] {-}{-}{-} Load[Load]}
    SCR {-{-}{-} L[Inductor] {-}{-}{-} C[Capacitor]}
    C {-{-}{-} SW[Switch] {-}{-}{-} DC\_Source}
{Highlighting}
{Shaded}
```

Working principle:

- **Initial state**: SCR conducting, capacitor charged with polarity (+) on right
- **Commutation start**: When switch SW closed
- **Resonant circuit**: LC circuit forms resonant path
- **Reverse current**: Capacitor discharge creates reverse current through SCR
- **Turn-off**: SCR turns off when current falls below holding current
- **Recharging**: Capacitor recharges with opposite polarity

Applications:

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

Mnemonic

"SCCRRT" - 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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Anode] {-{-}{-} P1[P+ Anode Layer]}
    P1 {-{-}{-} N[N Base Layer]}
    N {-{-}{-} P2[P Base Layer]}
    P2 {-{-}{-} N2[N+ Cathode Layer]}
    N2 {-{-}{-} K[Cathode]}
    G[Gate] {-{-}{-} P2}
{Highlighting}
{Shaded}
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    SCR[SCR] {-{-}{-} R[Resistor] {-}{-}{-} C[Capacitor]}
    C {-{-}{-} SCR}
{Highlighting}
{Shaded}
```

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):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    DC\_Source[DC Source] {-{-}{-} SCR1[SCR1] {-}{-}{-} Load1[Load 1]}
    DC\_Source {-{-}{-} SCR2[SCR2] {-}{-}{-} Load2[Load 2]}
    SCR1 {-{-}{-} SCR2}
{Highlighting}
{Shaded}
```

Working principle:

- **Initial state**: SCR1 conducting, SCR2 off
- **Commutation start**: SCR2 is triggered
- **Load transfer**: Current transfers from SCR1 to SCR2
- **Voltage reversal**: Voltage across SCR1 becomes negative
- **Turn-off**: SCR1 turns off as current falls below holding current
- **Alternating operation**: SCR1 and SCR2 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

Advantage	Description
Higher efficiency	Lower power loss and better transformer utilization
Lower ripple factor	Smoother DC output requiring smaller filter components
Higher power handling	Can handle higher power levels than single phase
Better transformer utilization	Higher transformer utilization factor
Lower harmonic content	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:

Mermaid Diagram (Code)

```
{Shaded}
```

```
{Highlighting}[]
graph LR
    AC[AC Supply] {-{-}{-} D[Diode] {-}{-}{-} R[Load Resistor]}
    R {-{-}{-} AC}
{Highlighting}
{Shaded}
```

Waveform:

```
    Voltage
      \^{}
      |     /{      /      /}
      |    /  {    /      /  }
      |{-{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-} Time}
      |         {              }
      |          {              }
      |
   Input AC

    Voltage
      \^{}
      |     /{      /      /}
      |    /  {    /      /  }
      |{-{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-} Time}
      |
      |
      |
   Output DC (Pulsating)
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    DC[DC Source] {-{-}{-} S1[Switch S1] {-}{-}{-} S2[Switch S2] {-}{-}{-} DC}
    S1 {-{-}{-} Load[Load] {-}{-}{-} S3[Switch S3]}
    S2 {-{-}{-} Load}
    S3 {-{-}{-} S4[Switch S4] {-}{-}{-} DC}
{Highlighting}
{Shaded}
```

Working principle:

- **First half-cycle**: S1 and S4 ON, S2 and S3 OFF
- **Second half-cycle**: S2 and S3 ON, S1 and S4 OFF
- **Output waveform**: AC square wave across load
- **Control method**: Gate signals to switches with 180°$phaseshift$

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

Parameter	UPS (Uninterruptible Power Supply)	SMPS (Switched Mode Power Supply)
Primary function	Provides backup power during outages	Converts AC to regulated DC
Battery backup	Contains batteries for backup	No battery backup
Output	AC output (typically)	DC output (typically)
Efficiency	Lower (70-80%)	Higher (80-95%)
Size	Larger and heavier	Compact and lightweight
Applications	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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    R[R Phase] {-{-}{-} D1[Diode D1] {-}{-}{-} Load[Load]}
    Y[Y Phase] {-{-}{-} D2[Diode D2] {-}{-}{-} Load}
    B[B Phase] {-{-}{-} D3[Diode D3] {-}{-}{-} Load}
    Load {-{-}{-} N[Neutral]}
{Highlighting}
{Shaded}
```

Waveform:

```
Voltage
  \^{}
  |
  |    /{    /    /    /    /    /}
```

```
      |   /  {  /    /    /    /    /  }
      |{-{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-} Time}
      |   R    Y    B    R    Y    B    R
      |
   Input (Three phase)

    Voltage
      \^{}
      |
      |    /{    /    /    /    /    /}
      |   /  {  /    /    /    /    /  }
      |{-{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-} Time}
      |
      |
   Output DC (Less ripple)
```

Working principle:

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

Mnemonic

"CROP" - Conduction of 120°, $Ripplereduced, Outputsmoother, Pulsestripled$

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):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VS[DC Source] {-{-}{-} S1[Switch S1] {-}{-}{-} L[Inductor]}
    L {-{-}{-} Load[Load] {-}{-}{-} VS}
    Load {-{-}{-} D1[Diode D1] {-}{-}{-} S1}
    Load {-{-}{-} S2[Switch S2] {-}{-}{-} D2[Diode D2] {-}{-}{-} VS}
{Highlighting}
{Shaded}
```

Working principle:

- **First quadrant operation (forward motoring):**
  - S1 ON, S2 OFF: Energy flows from source to load
  - S1 OFF, S2 OFF: Current freewheels through D2
- **Second quadrant operation (forward regeneration):**
  - S1 OFF, S2 ON: Energy flows from load to source
  - S1 OFF, S2 OFF: Current freewheels through D1

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VS[Supply] {-{-}{-} SCR[SCR] {-}{-}{-} Load[Load]}
    GC[Gate Control] {-{-}{-} SCR}
{Highlighting}
{Shaded}
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    AC[AC Supply] {-{-}{-} TRIAC[TRIAC] {-}{-}{-} Load[Load]}
    AC {-{-}{-} R[Resistor] {-}{-}{-} C[Capacitor] {-}{-}{-} DIAC[DIAC] {-}{-}{-} G[TRIAC Gate]}
    G {-{-}{-} TRIAC}
{Highlighting}
{Shaded}
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    Power[AC Power Supply] {-{-}{-} Inv[High Frequency Inverter]}
    Inv {-{-}{-} Coil[Induction Coil]}
    Coil {-{-}{-} Workpiece[Metal Workpiece]}

    subgraph "Physical Process"
    Coil {-.{-} Magnetic[Alternating Magnetic Field]}
    Magnetic {-.{-} Eddy[Eddy Currents]}
    Eddy {-.{-} Heat[Heat Generation]}
    end
{Highlighting}
{Shaded}
```

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    VS[Supply] {-{-}{-} R1[Resistor R1] {-}{-}{-} LDR[LDR]}
    LDR {-{-}{-} GND[Ground]}
    R1 {-{-}{-} B[Transistor Base]}
    VS {-{-}{-} RC[Collector Resistor] {-}{-}{-} C[Transistor Collector]}
    C {-{-}{-} Relay[Relay Coil] {-}{-}{-} GND}
    E[Transistor Emitter] {-{-}{-} GND}
{Highlighting}
{Shaded}
```

Working principle:

- **Light-dependent resistor**: Resistance decreases with increasing light
- **Voltage divider**: LDR and R1 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):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    VCC[+VCC] {-{-}{-} R[Resistor R] {-}{-}{-} D8[Pin 8 VCC]}
    D8 {-{-}{-} D4[Pin 4 Reset]}
    D8 {-{-}{-} D7[Pin 7 Discharge]}
    R {-{-}{-} D7}
    D7 {-{-}{-} C[Capacitor C] {-}{-}{-} GND[Ground]}
    Trigger[Trigger Input] {-{-}{-} D2[Pin 2 Trigger]}
    D3[Pin 3 Output] {-{-}{-} Output[Output]}
    D1[Pin 1 GND] {-{-}{-} GND}
    D5[Pin 5 Control] {-{-}{-} CC[Control Capacitor] {-}{-}{-} GND}
    D6[Pin 6 Threshold] {-{-}{-} D7}
{Highlighting}
{Shaded}
```

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 VCC, 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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    RF[RF Generator] {-{-}{-} Electrodes[Electrodes]}

    subgraph "Material Between Electrodes"
    Electrodes {-{-}{-} Electric[Alternating Electric Field]}
    Electric {-{-}{-} Dipoles[Molecular Dipoles]}
    Dipoles {-{-}{-} Oscillation[Dipole Oscillation]}
    Oscillation {-{-}{-} Friction[Molecular Friction]}
    Friction {-{-}{-} Heat[Heat Generation]}
    end
{Highlighting}
{Shaded}
```

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:

Application Area	Examples
Industrial	Conveyor systems, pumps, fans, compressors
HVAC	Blowers, cooling towers, air handling units
Water treatment	Pumps, mixers, aerators
Mining	Crushers, conveyors, pumps
Textile	Spinning machines, looms, winders
Material handling	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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    AC[AC Supply] {-{-}{-} B[Bridge Rectifier]}
    B {-{-}{-} SCR[SCR] {-}{-}{-} A[Armature]}
    A {-{-}{-} B}
    AC {-{-}{-} F[Field Circuit]}
    F {-{-}{-} Field[Field Winding]}
    GC[Gate Control] {-{-}{-} SCR}
{Highlighting}
{Shaded}
```

Working principle:

- **Constant field current**: Field supply maintained constant
- **Variable armature voltage**: Controlled by SCR
- **Speed equation**: N $(V_a - I_a R_a)/$
- **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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    PS[Power Supply] {-{-}{-} CPU[Central Processing Unit]}
    CPU {-{-}{-} MEM[Memory]}
    CPU {-{-}{-} INP[Input Module]}
    CPU {-{-}{-} OUT[Output Module]}
    CPU {-{-}{-} COM[Communication Module]}
    INP {-{-}{-} Input[Input Devices]}
    OUT {-{-}{-} Output[Output Devices]}
    COM {-{-}{-} Network[Network/HMI]}
    PROG[Programming Device] {-{-}{-} COM}
{Highlighting}
{Shaded}
```

Functions of each block:

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

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:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    AC[AC Supply] {-{-}{-} B[Bridge Rectifier]}
    B {-{-}{-} SCR[SCR] {-}{-}{-} A[Armature]}
    A {-{-}{-} SF[Series Field]}
    SF {-{-}{-} B}
    GC[Gate Control] {-{-}{-} SCR}
{Highlighting}
{Shaded}
```

Working principle:

- **Series connection**: Field winding in series with armature
- **SCR control**: Phase-controlled SCR regulates average voltage
- **Speed equation**: $N \quad (V - I(R_a+R_f))/I\Phi$
- **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):

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "BLDC Motor Construction"
    Stator[Stator with Windings]
    Rotor[Rotor with Permanent Magnets]
    Hall[Hall Sensors]
    end

    subgraph "Control System"
    Controller[Electronic Controller]
```

```
    Driver[Power Driver]
    Feedback[Position Feedback]
    end

    Controller {-{-}{-} Driver}
    Driver {-{-}{-} Stator}
    Hall {-{-}{-} Feedback}
    Feedback {-{-}{-} Controller}
{Highlighting}
{Shaded}
```

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