Subject Name Solutions

4331103 – Summer 2023

Semester 1 Study Material

Detailed Solutions and Explanations

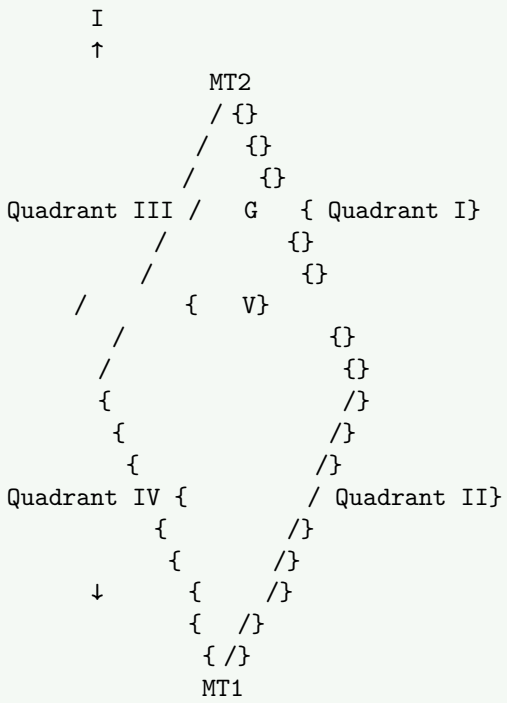
Question 1(a) [3 marks]

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:



- **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 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:

```
P


N


P


Cathode
```

- **Two-transistor structure**: PNP (Q1) and NPN (Q2) 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 Q2 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:

```
+Vcc


 R1


       LDR


B

C



 R2      Relay
```

```
GND
```

- **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 R1 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:

```
        +Vcc


         R1




             B2
        UJT

        B1


         R3


   C        SCR Gate


             GND
```

- **RC timing**: R1 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 R1 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

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):

```
                L1
    AC
Source


      SCR1          SCR2




                Load
```

- **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"

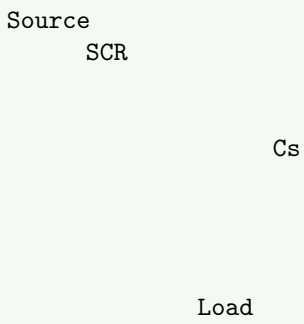
Question 2(c) [7 marks]

Draw and explain Snubber Circuit for SCR.

Solution

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

```
AC              Rs
```



- **RC network**: Series resistor (Rs) and capacitor (Cs) 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**: Cs based on load current, Rs 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

Mnemonic

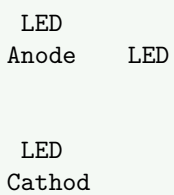
"Fault Current Causes Equipment Damage"

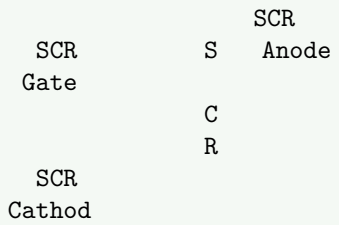
Question 2(b OR) [4 marks]

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:





- **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"

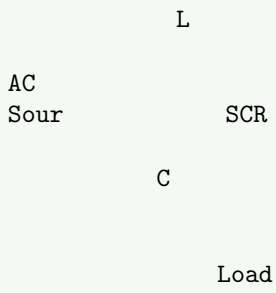
Question 2(c OR) [7 marks]

What is force commutation? Explain any two.

Solution

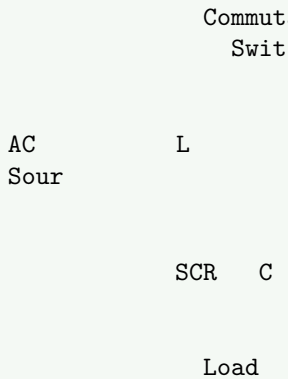
Force commutation is artificially turning OFF an SCR by reducing its anode current below holding level.

1. Class A Commutation (Self-Commutation):



- **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):



- **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

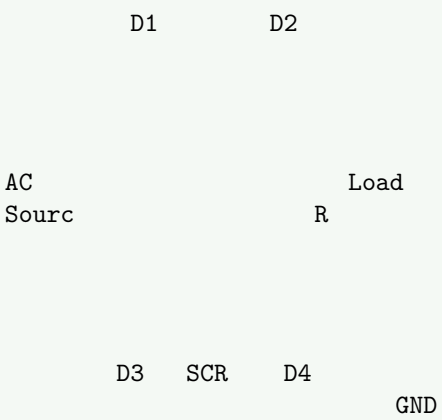
"Force Circuit Reversal"

Question 3(a) [3 marks]

Explain 1- 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:



- **Bridge configuration**: Four diodes arranged in bridge with one replaced by SCR
- **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

Mnemonic

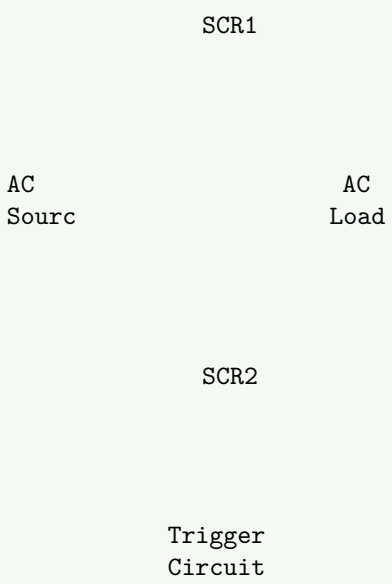
"Chops Current Perfectly"

Question 3(c) [7 marks]

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

Solution

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



- **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 $\times Dutycycle$

Mnemonic

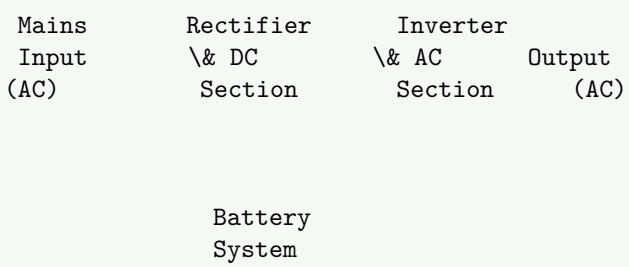
"Direct Current Control"

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:



- **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

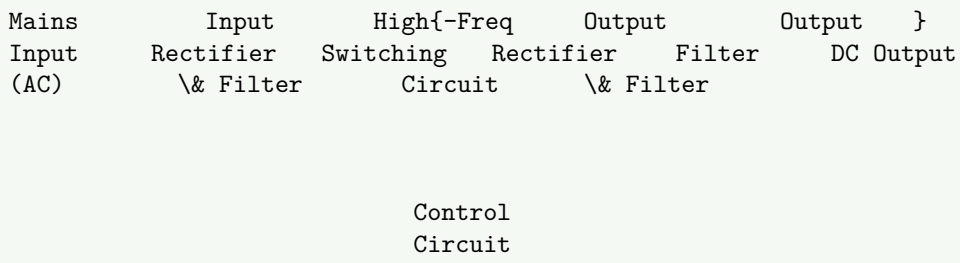
"Uninterrupted Power Securely"

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:



- **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

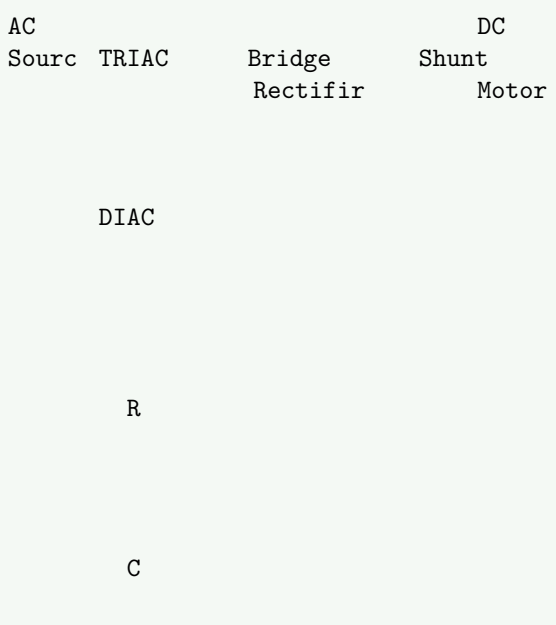
"Switch Mode Power System"

Question 4(a) [3 marks]

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

Solution

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



- **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

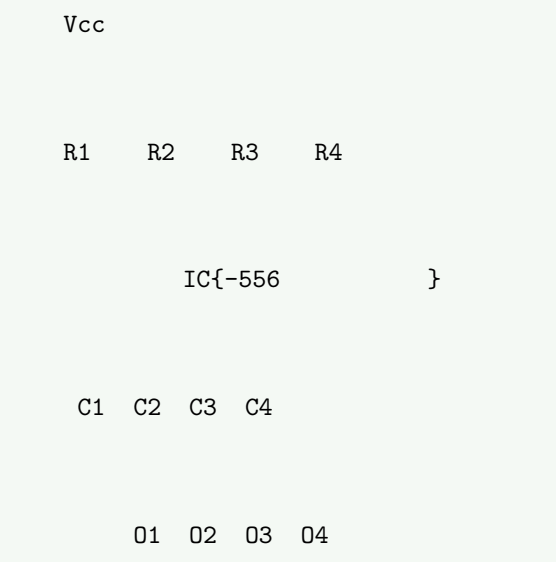
"TRIAC Regulates Speed"

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:



- **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

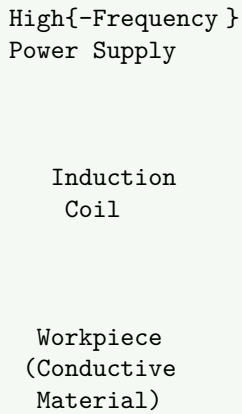
"Sequential Steps Timed Precisely"

Question 4(c) [7 marks]

Explain induction heating.

Solution

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



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

Mnemonic

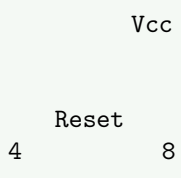
"Induced Heating Efficiently"

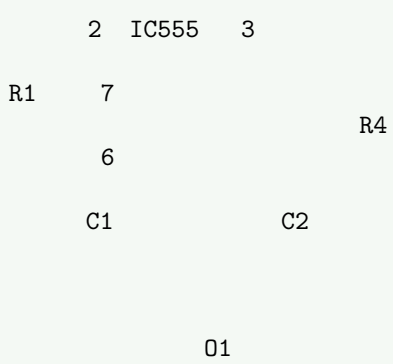
Question 4(a OR) [3 marks]

Draw and explain three stage IC555 timer circuit.

Solution

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





- **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)

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

Mnemonic

"ICED" - Induction Conductive, Eddy currents; Dielectric, Dipoles

Question 5(a) [3 marks]

Explain Construction and working of Universal Motor.

Solution

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

- **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:

```
Encoder
Feedback
```

- **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:

```
Input              Central              Output
Modules          Processing           Modules
                     Unit


Memory           Programming            Power
Unit               Device               Supply
```

- **CPU (Central Processing Unit)**: 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:

```
Stator
```

- **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

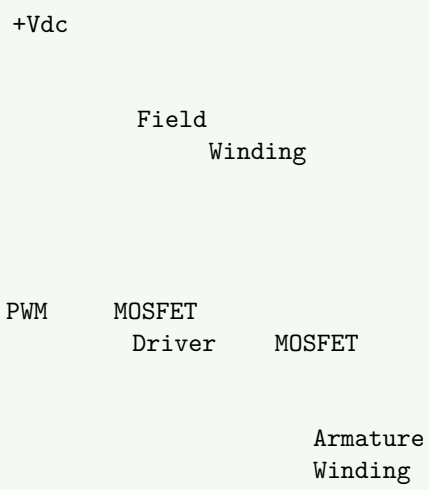
"Steps Precisely Moved"

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:



- **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

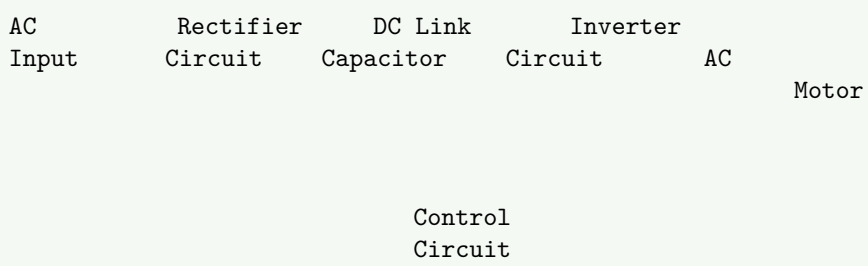
"Power With MOSFET"

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:



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

- **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"