Subject Name Solutions

4321103 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

What is transistor biasing? What is its need?

Solution

Transistor biasing is the process of establishing a stable DC operating point (Q-point) for proper amplification of AC signals.

Table 1: Need for Transistor Biasing

Aspect	Importance
Stability	Maintains stable Q-point despite temperature variations
Linearity	Ensures operation in linear region for distortion-free amplification
Efficiency	Prevents signal clipping and maximizes signal swing
Reliability	Avoids thermal runaway and protects the transistor

Mnemonic

"SOLE operation" (Stability, Operating point, Linearity, Efficiency)

Question 1(b) [4 marks]

Explain load line for CE amplifier

Solution

Load line is a graphical representation of all possible operating points of a transistor circuit.

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[DC Load Line] {-{-}{-} B[CE Amplifier]}
    B {-{-}{-} C[AC Load Line]}
    C {-{-}{-} D[Q{-}point]}

    style A fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style B fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style C fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style D fill:\#bfb,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

- **DC load line**: Drawn between saturation point (Ic=Vcc/Rc, Vce=0) and cutoff point (Ic=0, Vce=Vcc)
- **AC load line**: Passes through Q-point with slope = -1/rc (rc = AC collector resistance)
- **Q-point**: Operating point where DC biasing conditions are established

Mnemonic

"SCQ points" (Saturation, Cutoff, Q-point)

Question 1(c) [7 marks]

List various biasing method of transistor and explain any one of them.

Solution

Various biasing methods for transistors include:

Table 2: Transistor Biasing Methods

Method	Key Feature
Fixed bias	Single resistor for base bias
Collector-to-base bias	Self-stabilizing due to negative feedback
Voltage divider bias	Most stable due to voltage divider network
Emitter bias	Provides excellent stability with emitter resistor
Combination bias	Uses multiple feedback paths for optimal stability

Explanation of Voltage Divider Bias:
Diagram:

```
     +Vcc
       |
       R1
       |
       +{-{-}{-}{-}{-}{-}+}
       |      |
       R2     Rc
       |      |
       |      C
  +{-{-}{-}{-}+      |}
  |   B  +{-{-}{-}{-}+{-}{-}{-}{-}+ Output}
  +{-{-}{-}{-}{-}|    |     |}
        |    |     |
  Input +{-{-}+ |     |}
        | C  E     |
        |    |     |
        +{-{-}{-}{-}+    |}
             |     |
             Re    |
             |     |
             +{-{-}{-}{-}{-}+}
             |
            GND
```

- **Operation**: R1 and R2 form a voltage divider to set base voltage
- **Stability**: Excellent thermal stability due to stiff voltage divider
- **Efficiency**: Most widely used due to independence from variations
- **Calculation**: Base voltage = Vcc $\times R2/(R1 + R2)$

Mnemonic

"VISE grip" (Voltage divider, Independent of , Stable, Efficient)

Question 1(c) OR [7 marks]

Explain voltage divider biasing method with help of circuit diagram

Solution

Voltage divider biasing is the most stable method to bias a transistor.
Diagram:

```
     +Vcc
       |
```

```
      R1
      |
      +{-{-}{-}{-}{-}{-}+}
      |      |
      R2     Rc
      |      |
      |      C
+{-{-}{-}{-}+      |}
|   B  +{-{-}{-}{-}+{-}{-}{-}{-}+ Output}
+{-{-}{-}{-}{-}|    |     |}
       |    |     |
Input +{-{-}+ |     |}
       | C  E     |
       |    |     |
      +{-{-}{-}{-}+     |}
            |     |
           Re     |
            |     |
           +{-{-}{-}{-}+}
            |
           GND
```

Table 3: Features of Voltage Divider Biasing

Component	Function
R1, R2	Creates stable base voltage independent of
Rc	Limits collector current and develops output voltage
Re	Provides stability via negative feedback
Bypass capacitor	Bypasses AC signal around Re to increase gain

- **Working principle**: R1 and R2 form a voltage divider that sets the base voltage
- **Thermal stability**: Re provides negative feedback for excellent thermal stability
- **Advantage**: Q-point remains stable despite variations in temperature and

Mnemonic

"BEST bias" (Base voltage, Emitter stability, Stiff divider, Temperature stable)

Question 2(a) [3 marks]

Write methods of cascading amplifiers

Solution

Cascading amplifiers means connecting multiple amplifier stages in series to increase overall gain.

Table 4: Methods of Cascading Amplifiers

Method	Key Feature
RC Coupling	Uses capacitor and resistor for interstage coupling
Transformer Coupling	Uses transformer for impedance matching and isolation
Direct Coupling	No coupling components, direct connection between stages
LC Coupling	Uses inductor-capacitor for high-frequency applications

Mnemonic

"RTDL connection" (RC, Transformer, Direct, LC)

Question 2(b) [4 marks]

Compare CE and CB amplifiers

Solution

Table 5: Comparison of CE and CB Amplifiers

Parameter	Common Emitter (CE)	Common Base (CB)
Input Impedance	Medium ($\approx 1k$)	Low (≈ 50)
Output Impedance	High ($\approx 50k$)	Very high ($\approx 500k$)
Voltage Gain	High (≈ 500)	High (≈ 500)
Current Gain	Medium ( )	Less than 1 ( )
Phase Shift	180°	0°
Applications	Voltage amplification	High-frequency amplification

Mnemonic

"PIVOT differences" (Phase shift, Impedance, Voltage gain, Output impedance, Throughput)

Question 2(c) [7 marks]

Draw the circuit of RC coupled amplifier. Give the frequency response and explain

Solution

RC coupled amplifier uses resistor-capacitor network for interstage coupling.
Diagram:

```
     +Vcc
       |
       +{-{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}+}
       |   |        |   |
       Rc1 |        Rc2 |
       |   |        |   |
       +{-{-}{-}+        +{-}{-}{-}+}
       |            |
       C            +{-{-}{-}+ Output}
       |            |   |
   +{-{-}{-}+{-}{-}{-}+    +{-}{-}{-}+{-}{-}{-}+}
   |   |   |    |   |   |
   | B |   |    | B |   |
   | | C   |    | | C   |
   +{-+ |   |    +{-}+ |   |}
   |   |   |    |   |   |
Input   |   |    |   |   |
   +{-{-}{-}+{-}{-}{-}+    +{-}{-}{-}+{-}{-}{-}+}
       |            |
       Re1          Re2
       |            |
       +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
       |
      GND
```

Frequency Response:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Low Frequency] {-{-}{-} B[Mid Frequency]}
    B {-{-}{-} C[High Frequency]}

    style A fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style B fill:\#bbf,stroke:\#333,stroke{-width:1px}
```

```
    style C fill:\#f9f,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

- **Low frequency region**: Gain drops due to coupling and bypass capacitors
- **Mid frequency region**: Flat response with maximum gain
- **High frequency region**: Gain falls due to transistor internal capacitances
- **Bandwidth**: Determined by the lower and upper cutoff frequencies

Mnemonic

"LMH regions" (Low, Mid, High frequency regions)

Question 2(a) OR [3 marks]

Write definition of gain, Bandwidth and Gain Bandwidth product of an amplifier.

Solution

Table 6: Key Amplifier Parameters

Parameter	Definition
Gain (A)	Ratio of output signal to input signal (voltage, current, or power)
Bandwidth (BW)	Frequency range between lower and upper cutoff frequencies ($f_2 - f_1$)
Gain-Bandwidth Product (GBW)	Product of gain and bandwidth, remains constant for a given amplifier

Mnemonic

"GBP constants" (Gain, Bandwidth, Product constants)

Question 2(b) OR [4 marks]

Explain frequency response of single stage amplifier and indicate its cutoff frequencies.

Solution

Frequency response shows variation of gain with frequency in a single stage amplifier.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Frequency Response] {-{-}{} B[Low f Region]}
    A {-{-}{} C[Mid f Region]}
    A {-{-}{} D[High f Region]}
    B {-{-}{} E[f_{1}: Lower Cutoff]}
    D {-{-}{} F[f_{2}: Upper Cutoff]}
    C {-{-}{} G[Maximum Gain]}

    style A fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style B fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style C fill:\#bfb,stroke:\#333,stroke{-width:1px}
    style D fill:\#f9f,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

- **Cutoff frequencies**: Points where gain drops to 0.707 times maximum gain

- **Lower cutoff frequency (f_1)** : $Determinedbycouplingandbypasscapacitors$
- **Upper cutoff frequency (f_2)** : $Limitedbytransistorjunctioncapacitances$
- **Bandwidth: Frequency range between $f_1 andf_2 (BW = f_2 - f_1)$**

Mnemonic

"LUG points" (Lower cutoff, Upper cutoff, Gain maximum)

Question 2(c) OR [7 marks]

Draw and Explain circuit diagram of common collector amplifier

Solution

Common collector (CC) amplifier is also known as emitter follower.
Diagram:

```
   +Vcc
     |
     Rc
     |
     +
     |
     |    C
     |    |
  +{-{-}{-}+    |}
  |  |    |
  | B |    |
Input{-+ |    |}
  |  |    |
  |  |    |
  |  C    |
  |  |    |
  +{-{-}{-}+{-}{-}{-}{-}+{-}{-}+ Output}
     |    |
     Re   |
     |    |
     +{-{-}{-}{-}+}
     |
    GND
```

Table 7: Features of Common Collector Amplifier

Parameter	Characteristic
Voltage Gain	Approximately 1 (less than 1)
Current Gain	High ( )
Input Impedance	Very high ($\approx \times Re$)
Output Impedance	Very low ($\approx 1/gm$)
Phase Shift	$0°(nophaseinversion)$
Applications	Impedance matching, buffer stages

- **Working principle**: Output is taken from emitter, collector is common to input and output
- **Key feature**: Voltage follower with output voltage following input voltage
- **Main advantage**: High input impedance and low output impedance

Mnemonic

"BIVOP characters" (Buffer, Impedance matching, Voltage follower, One gain, Phase matched)

Question 3(a) [3 marks]

Draw transistor two port network and describe h-parameters for it.

Solution

Transistor can be represented as a two-port network with h-parameters.
Diagram:

```
     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
     |                     |
     |    Two{-Port         |}
Input|    Network     +{-{-}{-}{-}+{-}{-}{-} Output}
   +{|                |    |}
     |    Transistor  |    |
     |                v    |
     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Table 8: h-parameters

Parameter	Description
h_{11}(h_i)	Input impedance with output short-circuited
h_{12}(h_r)	Reverse voltage transfer ratio with input open-circuited
h_{21}(h_f)	Forward current transfer ratio with output short-circuited
h_{22}(h_o)	Output admittance with input open-circuited

Mnemonic

"IRFO parameters" (Input impedance, Reverse transfer, Forward transfer, Output admittance)

Question 3(b) [4 marks]

Explain voltage gain Av, current gain Ai and Power gain Ap for CE amplifier

Solution

Table 9: Gain Expressions for CE Amplifier

Gain Type	Expression	Relation to h-parameters
Voltage Gain (Av)	V_o/V	Av = -h_fe × R_L/h_ie
Current Gain (Ai)	I_o/I	Ai = h_fe / (1 + h_oe × R_L)
Power Gain (Ap)	P_o/P	Ap = Av × Ai = (voltagegain × currentgain)

- **Voltage gain**: Typically 500-1000 for CE amplifier
- **Current gain**: Approximately equal to h_fe ( ) of transistor
- **Power gain**: Product of voltage gain and current gain

Mnemonic

"VIP gains" (Voltage, Input-output current, Power)

Question 3(c) [7 marks]

Explain Darlington pair, its features and applications

Solution

Darlington pair consists of two transistors connected to act as a single high-gain transistor.
Diagram:

```
     +Vcc
```

```
       |
       Rc
       |
       +{-{-}{-}{-}{-}{-}{-}{-}{-}+}
       |        |
       |        | Output
       |        |
       | +{-{-}{-}{-}{-}{-}{-}+}
       | |
       | C
  +{-{-}{-}{-}{-}+{-}+}
  |    | |
  |  +{-+ |}
  |  |    |
  |  | C |
  |  | | |
Input  | | |
  +{-{-}{-}{-}{-}+{-}+ |}
       |   |
       +{-{-}{-}+}
       |
      GND
```

Table 10: Features of Darlington Pair

Feature	Description
Current Gain	Very high ($_1 \times _2$)
Input Impedance	Extremely high
Voltage Drop	Higher $(\approx 1.4V) due to two B-E junctions$
Switching Speed	Slower than single transistor
Thermal Stability	Poorer than single transistor

- **Applications**: Power amplifiers, motor drivers, touch switches, sensors
- **Advantages**: Very high current gain, high input impedance
- **Limitations**: Higher saturation voltage, slower switching

Mnemonic

"CHIPS application" (Current amplification, High impedance, Increased gain, Power handling, Slower switching)

Question 3(a) OR [3 marks]

Discuss applications of LDR.

Solution

Light Dependent Resistor (LDR) is a photoresistor whose resistance decreases with increasing light intensity.

Table 11: Applications of LDR

Application	Working Principle
Automatic Street Lights	Turns on lights when ambient light level falls
Camera Exposure Control	Adjusts aperture/shutter based on light intensity
Light Beam Alarms	Triggers alarm when light beam is interrupted
Solar Trackers	Helps orient solar panels toward maximum sunlight
Automatic Brightness Control	Adjusts display brightness based on ambient light

Mnemonic

"CASAL applications" (Camera, Alarm, Street light, Automatic control, Light measurement)

Question 3(b) OR [4 marks]

Comparison of clipper and clamper

Solution

Table 12: Comparison between Clipper and Clamper

Parameter	Clipper	Clamper
Function	Limits/clips signal amplitude	Shifts DC level of signal
Output	Removes portions beyond threshold	Adds DC component
Components	Diode + Resistor	Diode + Capacitor + Resistor
Wave Shape	Changes wave shape	Preserves wave shape
Applications	Noise removal, wave shaping	TV signal processing, DC restoration

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Signal] {-{-}{} B[Clipper]}
    A {-{-}{} C[Clamper]}
    B {-{-}{} D[Amplitude Limited]}
    C {-{-}{} E[DC Level Shifted]}

    style A fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style B fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style C fill:\#bfb,stroke:\#333,stroke{-width:1px}
    style D fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style E fill:\#bfb,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

Mnemonic

"CLIPS vs CLAMPS" (Cut Levels In Peak Signal vs Change Level And Maintain Peak Shape)

Question 3(c) OR [7 marks]

Describe h-parameters circuit for CE amplifier.

Solution

h-parameters provide a simple way to analyze CE amplifier performance.

Diagram:

```
     +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
     |                     |
  Ii |    +{-{-}{-}{-}{-}{-}{-}{-}{-}+     | Io}
   +{|    |          |     |+}
     |    |   h\_ie   |     |
  Vi |    +{-{-}{-}{-}{-}{-}{-}{-}{-}+     | Vo}
   +{|    |          |     |+}
     |    | h\_re.Vi  |     |
     |    |          |     |
     |    |  h\_fe.Ii |{-{-}{-}{-}|}
     |    |          |     |
     |    |   h\_oe   |     |
     |    +{-{-}{-}{-}{-}{-}{-}{-}{-}+     |}
```

```
    |                         |
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Table 13: h-parameters for CE Configuration

Parameter	Symbol	Typical Value	Physical Significance
Input impedance	h_ie	1-2 kΩ	Base-emitter input impedance
Reverse voltage ratio	h_re	10^{-4}	Feedback from output to input
Forward current gain	h_fe	50-300	Current gain ( )
Output admittance	h_oe	$10^{-6}S$	Output conductance

- **Circuit analysis**: Uses h-parameters to calculate voltage gain, current gain, input/output impedance
- **Equivalent circuit**: Combines h-parameters in a two-port network representation
- **Advantage**: Simplifies complex transistor behavior into linear parameters

Mnemonic

"FIRO parameters" (Forward gain, Input impedance, Reverse feedback, Output admittance)

Question 4(a) [3 marks]

Write short note on Darlington pair.

Solution

Darlington pair combines two transistors to create a super-high gain transistor.
Diagram:

```
       +{-{-}{-}+}
       |   |
  +{-{-}{-}{-}+{-}{-}{-}+{-}{-}{-}{-}+}
  |    |        |
  |    +        |
  |  E/ {C      |}
  |   /B {      |}
Input + {-{-}+     |}
  |    |        |
  |    +        |
  |  E/ {C      |}
  |   /B {      |}
  |    |        |
  +{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
       |
     Output
```

- **Configuration**: Two transistors where first transistor's emitter drives second transistor's base
- **Total gain**: $_1 \times _2 (product of individual transistor gains)$
- **Input impedance**: Extremely high ($_2 \times R\_e1$)

Mnemonic

"HIS properties" (High gain, Impedance boost, Sandwich configuration)

Question 4(b) [4 marks]

Explain Zener diode as a voltage regulator.

Solution

Zener diode provides a constant voltage reference when operated in reverse breakdown.

Diagram:

```
       Rs
    +{-{-}www{-}{-}+}
    |         |
 Vi |      | | Vz    RL   Vo
 +{-{-}+      | +{-}{-}{-}+{-}{-}{-}www{-}{-}+}
    |      |/|   |         |
    |      |{|   |         |}
    |         |   |         |
    +{-{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
              |
            GND
```

Table 14: Zener Voltage Regulator

Parameter	Description
Principle	Maintains constant voltage in reverse breakdown region
Series Resistor (Rs)	Limits current and drops excess voltage
Load Resistor (RL)	Represents the circuit being powered
Regulation	Maintains constant output despite input voltage fluctuations

- **Working**: Zener operates in breakdown region, maintaining fixed voltage
- **Limitation**: Power dissipation capability limits maximum current

Mnemonic

"ZEBRA" (Zener Effect Breakdown Regulates Accurately)

Question 4(c) [7 marks]

Explain Optocoupler with advantages and disadvantages.

Solution

Optocoupler (also called optoisolator) uses light to transfer signals between isolated circuits.

Diagram:

```
   +{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}+}
   |        |          |
   |    +{-{-}{-}+{-}{-}{-}+       |}
   |    |       |       |
   |    |  LED  |       |
   |    |       |       |
   |    +{-{-}{-}+{-}{-}{-}+       |}
Input   |   |          | Output
   |    |   |     +{-{-}{-}{-}+{-}{-}{-}+}
   |    |   |     |     |    |
   |    |   +{-{-}{-}{-}|     |    |}
   |    |         |Photo|    |
   |    |         |sensor|   |
   |    |         |     |    |
   |    |         +{-{-}{-}{-}+{-}{-}{-}+}
   |    |           |        |
   +{-{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
```

Table 15: Advantages and Disadvantages of Optocoupler

Advantages	Disadvantages
Complete electrical isolation	Relatively slow response time
High noise immunity	Limited bandwidth
No ground loops	Temperature sensitive
High voltage isolation	Aging effects
Protection against transients	Requires current to drive LED

- **Working**: Input signal drives LED, which emits light detected by photodetector
- **Applications**: Medical equipment, industrial control, power supplies, signal isolation
- **Types**: Photoresistor, photodiode, phototransistor, photo-SCR based

Mnemonic

"LIGHT transfer" (Linked Isolated Galvanic-free High-voltage Transfer)

Question 4(a) OR [3 marks]

Draw Half Wave Voltage Doubler.

Solution

Half-wave voltage doubler uses diodes and capacitors to produce DC output approximately twice the peak input voltage.

Diagram:

```
          D1
   +{-{-}{-}{-}{-}{-}{-}{-}+{-}{-}||{-}{-}{-}{-}{-}{-}{-}{-}+}
   |                       |
   |                       |
   |                       |
  \_|\_                     \_|\_
  { / D2                  {-}{-}{-} C2}
   |                       |
   |                       |
Vin |        +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}+ Vout(2Vin)}
   |        |
   |        |
   |       \_|\_
   |       {-{-}{-} C1}
   |        |
   +{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

- **Components**: Two diodes and two capacitors
- **Output**: Approximately twice the peak input voltage

Mnemonic

"DC2" (Doubles input using Capacitors and 2 Diodes)

Question 4(b) OR [4 marks]

Explain the working and applications of OLED.

Solution

Organic Light Emitting Diode (OLED) uses organic compounds that emit light when current flows through them.

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[OLED Structure] {-{-}{} B[Cathode]}
    A {-{-}{} C[Organic Layer]}
    A {-{-}{} D[Anode]}
    A {-{-}{} E[Substrate]}

    style A fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style B fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style C fill:\#bfb,stroke:\#333,stroke{-width:1px}
    style D fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style E fill:\#bfb,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

Table 16: Working and Applications of OLED

Aspect	Description
Working	Electron-hole recombination in organic layer produces light
Efficiency	High efficiency, low power consumption
Viewing Angle	Excellent (nearly 180°)
Applications	Smartphones, TVs, wearable devices, lighting
Advantages	Thin, flexible, better contrast, faster response

Mnemonic

"VIEWS technology" (Vibrant colors, Incredible contrast, Excellent angle, Wide application, Self-emitting)

Question 4(c) OR [7 marks]

Explain working of solar battery charger circuits.

Solution

Solar battery charger converts solar energy to electrical energy to charge batteries.
Diagram:

```
+{-{-}{-}{-}{-}{-}{-}{-}+       +{-}{-}{-}{-}{-}{-}{-}{-}{-}+       +{-}{-}{-}{-}{-}{-}{-}{-}{-
|         |         |           |         |          |         |         |
| Solar   |         | Charge    |         | Voltage |          | Battery|
| Panel   |{-{-}{-}{-}{-}{-}{-}|Controller|{-}{-}{-}{-}{-}{-}{-}|Regulator|{-}{-}{-}{-}{-}{-}{-}|
|         |         |           |         |          |         |         |
+{-{-}{-}{-}{-}{-}{-}{-}+       +{-}{-}{-}{-}{-}{-}{-}{-}{-}+       +{-}{-}{-}{-}{-}{-}{-}{-}{-
                      |                                       |
                      |                                       |
                      v                                       v
                  +{-{-}{-}{-}{-}{-}{-}{-}{-}+                          +{-}{-}{-}{-}{-}{-}{-}{-
                  |Indicator|                             |  Load   |
                  | Circuit |                             |         |
                  +{-{-}{-}{-}{-}{-}{-}{-}{-}+                          +{-}{-}{-}{-}{-}{-}{-}{-
```

Table 17: Components and Their Functions

Component	Function
Solar Panel	Converts sunlight to DC electricity
Charge Controller	Prevents overcharging and deep discharge
Voltage Regulator	Stabilizes voltage to appropriate charging level
Battery	Stores electrical energy
Indicator Circuit	Shows charging status and battery level

- **Working principle**: Photovoltaic effect converts sunlight to electricity
- **Regulation**: Prevents overcharging using voltage/current regulation
- **Protection**: Includes reverse current protection to prevent battery discharge at night
- **Types**: PWM (Pulse Width Modulation) and MPPT (Maximum Power Point Tracking)

Mnemonic

"SCORE system" (Solar Conversion, Overcharge protection, Regulation, Energy storage)

Question 5(a) [3 marks]

Draw a block diagram of regulated power supply.

Solution

Regulated power supply provides stable DC output voltage despite variations in input or load.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Transformer] {-{-}{} B[Rectifier]}
    B {-{-}{} C[Filter]}
    C {-{-}{} D[Voltage Regulator]}
    D {-{-}{} E[Output]}

    style A fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style B fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style C fill:\#bfb,stroke:\#333,stroke{-width:1px}
    style D fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style E fill:\#bbf,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

- **Components**: Transformer, rectifier, filter, voltage regulator
- **Function**: Converts AC to stable DC regardless of load changes

Mnemonic

"TRFO blocks" (Transformer, Rectifier, Filter, Output regulator)

Question 5(b) [4 marks]

Describe Transistor shunt Voltage Regulator.

Solution

Transistor shunt regulator maintains constant output voltage by diverting excess current through a transistor in parallel with the load.
Diagram:

```
    +{-{-}{-}{-}{-}{-}{-}+}
    |       |
    |      \_|\_
    |      { / Zener}
    |       |
    |       |
    +{-{-}{-}+{-}{-}{-}+}
        |
```

```
        |   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
        +{-{-}{-}| Base      |}
            |           |
 Vin    Rs  | Transistor|  RL   Vout
 +{-{-}{-}+{-}{-}www{-}+          +{-}{-}{-}www{-}{-}{-}+}
            | Collector |         |
            |           |         |
            +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+        |}
                |                 |
                +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
                |
               GND
```

Table 18: Transistor Shunt Regulator

Component	Function
Zener	Provides reference voltage
Transistor	Shunts excess current
Series Resistor (Rs)	Drops excess voltage
Load Resistor (RL)	Represents circuit being powered

- **Working**: Transistor conducts more when output tries to increase
- **Advantage**: Simple circuit with good regulation

Mnemonic

"ZEST circuit" (Zener reference, Excess current, Shunt transistor, Tension-free output)

Question 5(c) [7 marks]

Draw and explain SMPS block diagram with its advantages and disadvantages.

Solution

Switched Mode Power Supply (SMPS) uses switching regulation for high efficiency.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[EMI Filter]}
    B {-{-}{} C[Rectifier \& Filter]}
    C {-{-}{} D[Switching Circuit]}
    D {-{-}{} E[Transformer]}
    E {-{-}{} F[Output Rectifier]}
    F {-{-}{} G[Output Filter]}
    G {-{-}{} H[DC Output]}
    I[Feedback \& Control] {-{-}{} D}
    H {-{-}{} I}

    style A fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style D fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style E fill:\#bfb,stroke:\#333,stroke{-width:1px}
    style H fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style I fill:\#bbf,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

Table 19: Advantages and Disadvantages of SMPS

Advantages	Disadvantages
High efficiency (80-95%)	Complex circuit design
Small size and lightweight	Generates high-frequency noise
Wide input voltage range	EMI/RFI interference
Good regulation	Higher cost for low power
Lower heat generation	Difficult troubleshooting

- **Working principle**: Rapidly switches power on/off at high frequency
- **Size reduction**: Higher switching frequency allows smaller transformers
- **Applications**: Computers, TVs, mobile chargers, LED drivers

Mnemonic

"SWEEP advantages" (Small size, Widerange input, Efficient, Economical, Precise regulation)

Question 5(a) OR [3 marks]

Draw voltage regulator using three terminal IC 7812.

Solution

Three terminal IC 7812 provides fixed +12V regulated output voltage.
Diagram:

```
     +{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
     |       |       |
Vin  |       |       |  Vout
+{-{-}{-}{-}|  IN   OUT  |{-}{-}{-}{-}+ (+12V)}
     |       |       |
+{-{-}{-}{-}|  GND       |{-}{-}{-}{-}+}
|    |       |       |
|    +{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}+}
|        |
|       \_|\_
|       {-{-}{-} C1}
|        |
+{-{-}{-}{-}{-}{-}{-}{-}+}
        GND
```

- **Components**: 7812 regulator IC and filter capacitors
- **Pin configuration**: Input, Ground, Output
- **Features**: Internal current limiting and thermal shutdown

Mnemonic

"IGO pins" (Input, Ground, Output)

Question 5(b) OR [4 marks]

Describe Transistor series Voltage Regulator

Solution

Transistor series regulator controls output voltage by varying the conductivity of a series transistor.
Diagram:

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|          |
|         \_|\_
|         { / Zener}
```

```
   |          |
   |          |
   +{-{-}{-}{-}{-}+{-}{-}{-}{-}+}
         |
         |   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
         +{-{-}{-}| Base      |}
             |           |
  Vin        | Transistor|     Vout
  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}| Collector |{-}{-}{-}{-}{-}+}
             |           |      |
             | Emitter   |      |
             +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
                 |              |
                 |            \_|\_
                 |            {-{-}{-} C}
                 |              |
                 +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
                            GND
```

Table 20: Features of Series Voltage Regulator

Feature	Description
Control Element	Transistor acts as variable resistor in series
Reference	Zener diode provides stable reference voltage
Regulation	Feedback adjusts transistor conductivity
Efficiency	Better than shunt regulator for high current loads

- **Working principle**: Transistor conductivity changes to maintain constant output
- **Advantage**: More efficient than shunt regulators for higher currents

Mnemonic

"CERT circuit" (Control transistor, Efficient design, Reference voltage, Transistor in series)

Question 5(c) OR [7 marks]

Draw and explain UPS block diagram with its advantages and disadvantages.

Solution

Uninterruptible Power Supply (UPS) provides emergency power when main supply fails.
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Input] {-{-}{} B[Surge Protector]}
    B {-{-}{} C[Rectifier/Charger]}
    C {-{-}{} D[Battery]}
    C {-{-}{} E[Inverter]}
    D {-{-}{} E}
    E {-{-}{} F[Output Filter]}
    F {-{-}{} G[AC Output]}
    H[Control Circuit] {-{-}{} C}
    H {-{-}{} E}
    H {-{-}{} D}

    style A fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style C fill:\#bbf,stroke:\#333,stroke{-width:1px}
    style D fill:\#bfb,stroke:\#333,stroke{-width:1px}
```

```
    style E fill:\#f9f,stroke:\#333,stroke{-width:1px}
    style H fill:\#bbf,stroke:\#333,stroke{-width:1px}
{Highlighting}
{Shaded}
```

Table 21: Advantages and Disadvantages of UPS

Advantages	Disadvantages
Provides backup power	Limited backup time
Protects from voltage fluctuations	Regular battery maintenance
Surge protection	Initial high cost
Smooth power transition	Noise during operation
Power conditioning	Lower efficiency in standby

- **Types**: Offline/Standby, Line-interactive, Online/Double-conversion
- **Applications**: Computers, medical equipment, data centers, telecommunications
- **Working**: Normally passes main power while charging battery; switches to battery power during outage

Mnemonic

"POWER backup" (Protection from Outages, Waveform conditioning, Emission-free, Reliability boost)