

# Subject Name Solutions

1323202 – Summer 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Draw the symbol of (1)SCR (2)Diac(3)Triac

### Solution

#### Diagram:

SCR Symbol:

A  
|

DIAC Symbol:

A1  
|

TRIAC Symbol:

MT2  
|

|  
K  
/  
/  
G

|  
A2  
/  
/  
G

|  
MT1  
/  
/  
G

- **SCR (Silicon Controlled Rectifier)**: Three-terminal device with Anode, Cathode, and Gate
- **DIAC (Diode AC switch)**: Two-terminal bidirectional device with terminals A1 and A2
- **TRIAC (Triode AC switch)**: Three-terminal bidirectional device with MT1, MT2, and Gate

### Mnemonic

“AGK for SCR, AA for DIAC, MMG for TRIAC”

## Question 1(b) [4 marks]

Explain the term(1) CMRR (2) Slew rate

### Solution

Table 1: Op-Amp Parameters

Parameter	Definition	Significance
<b>CMRR (Common Mode Rejection Ratio)</b>	Ratio of differential gain to common mode gain expressed in dB	Higher CMRR means better rejection of common input signals
<b>Slew Rate</b>	Maximum rate of change of output voltage (V/ s)	Determines how fast op-amp responds to rapidly changing inputs

- **CMRR formula:**  $CMRR = 20 \log_{10}(Ad/Acm)dB$
- **Slew Rate importance:** Affects high-frequency performance and prevents distortion

## Mnemonic

“Common Mode Rejected Rapidly, Slew shows Signal Speed”

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

Draw and explain summing amplifier.

#### Solution

Diagram:

#### Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    V1 {"V1"} --> R1["R1"] --> A1["A1"]  
    V2 {"V2"} --> R2["R2"] --> A1  
    V3 {"V3"} --> R3["R3"] --> A1  
    A1 --> Rf["Rf"] --> B1["B1[Op-Amp]"]  
    B1 --> Vout["Vout"]  
    B1 --> A2["A2"]  
    A2 --> A3["A3"]  
    A3 --> Ground["Ground"]  
{Highlighting}  
{Shaded}
```

#### Operation of Summing Amplifier:

- **Circuit function:** Adds multiple input voltages with scaling
- **Output equation:**  $V_{out} = -(R_f/R_1 \times V_1 + R_f/R_2 \times V_2 + R_f/R_3 \times V_3)$
- **Inverting configuration:** Input signals undergo  $180^\circ$  phase shift
- **Gain control:**  $R_f/R_n$  determines weight of each input signal
- **Application:** Audio mixing, analog computation, signal processing
- **Key feature:** Virtual ground at inverting input simplifies analysis

## Mnemonic

“Sum with Weights:  $V_{out} = -R_f(V_1/R_1 + V_2/R_2 + V_3/R_3)$ ”

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

Draw and explain DA converter

#### Solution

Diagram:

#### Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    D0["D0"] --> R1["2^0R"] --> S1["S1"]  
    D1["D1"] --> R2["2^1R"] --> S2["S2"]  
    D2["D2"] --> R3["2^2R"] --> S3["S3"]  
    D3["D3"] --> R4["2^3R"] --> S4["S4"]  
    S1 \& S2 \& S3 \& S4 --> A1["A1[Summing Amp]"]  
    A1 --> Vout["Vout"]  
{Highlighting}  
{Shaded}
```

#### R-2R Ladder DAC Operation:

- **Function:** Converts digital binary input to analog output voltage

- **Working principle:** Weighted resistor network creates scaled currents
- **Binary weighting:** Each bit contributes voltage proportional to its position ( $2^n$ )
- **Resolution:** Determined by number of bits (N) as  $1/2$  of full scale
- **Advantages:** Simple design, good accuracy, fast conversion
- **Applications:** Audio equipment, signal generation, control systems

### Mnemonic

“Digital Bits to Analog Steps - R-2R makes the magic”

### Question 2(a) [3 marks]

Describe thermal run away of transistor.

### Solution

**Thermal Runaway Process:**

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    A[Increased Temperature] --> B[Increased Collector Current]
    B --> C[More Power Dissipation]
    C --> A
{Highlighting}
{Shaded}
```

- **Definition:** Self-accelerating process where transistor heats up and draws more current
- **Cause:** Negative temperature coefficient of base-emitter voltage
- **Prevention:** Use proper heat sink and stabilization circuits

### Mnemonic

“Heat feeds Current feeds Heat - a dangerous loop”

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

Draw and explain voltage series negative feedback.

### Solution

**Diagram:**

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    Vin --> A[Amplifier]
    A --> Vout
    Vout --> Feedback Network
    Feedback Network --> B[Subtractor]
    B --> A
{Highlighting}
{Shaded}
```

**Voltage Series Negative Feedback:**

Parameter	Effect of Negative Feedback
<b>Gain stability</b>	Improved, less dependent on amplifier parameters

<b>Bandwidth</b>	Increased proportional to feedback factor
<b>Distortion</b>	Reduced significantly
<b>Input impedance</b>	Increased

- **Working principle:** Output voltage is sampled and fed back to input
- **Gain formula:** Closed-loop gain = Open-loop gain/(1 + A)

### Mnemonic

“Series says Sample Voltage, Stabilize Gain”

## Question 2(c) [7 marks]

Draw and explain DC load line for common emitter amplifier.

### Solution

#### Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    subgraph DC Load Line
        direction LR
        A[Point A: IC=0, VCE=VCC] --- B[Operating Point Q]
        B --- C[Point B: IC=VCC/RC, VCE=0]
    end
{Highlighting}
{Shaded}
```

#### DC Load Line Characteristics:

- **Definition:** Graphical representation of all possible operating points
- **Equation:**  $IC = VCC/RC - VCE/RC$
- **Key points:**
  - Saturation point ( $VCE \approx 0V, IC = VCC/RC$ )
  - Cutoff point ( $IC \approx 0mA, VCE = VCC$ )
  - Q-point (selected operating point for amplification)
- **Significance:** Determines biasing stability and output signal limits
- **Relationship:** DC load line is fixed by circuit components (VCC and RC)

### Mnemonic

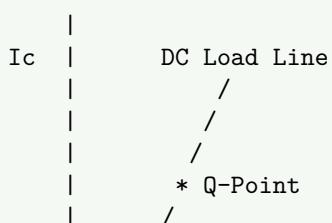
“Connect Cutoff to Saturation for DC Load Line”

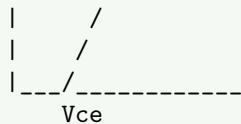
## Question 2(a OR) [3 marks]

Explain operating point(Q-point) in transistor

### Solution

#### Q-Point (Operating Point):





- **Definition:** Specific DC bias point where transistor operates in active region
- **Importance:** Determines output signal range without distortion
- **Selection criteria:** Center of load line for maximum swing

### Mnemonic

“Quality amplification needs Quiet bias at Q-point”

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

Draw and explain hartley oscillator.

### Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    A[Transistor] --{-}--> Feedback --{-}--> B[LC Tank Circuit]
    B --{-}--> A
    B --{-}--> L1, L2, C --{-}--> Output
{Highlighting}
{Shaded}
```

### Hartley Oscillator:

- **Configuration:** Common emitter with tapped inductor feedback
- **Frequency formula:**  $f = 1/[2 \sqrt{(C \times (L_1 + L_2))}]$
- **Phase shift:** Ensures  $360^\circ$  total phase shift for oscillation
- **Feedback:** Inductive voltage divider provides positive feedback

### Mnemonic

“Hartley Has two coils with inductance for LC oscillation”

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

Draw and explain AC load line for common emitter amplifier.

### Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    subgraph AC and DC Load Lines
        direction LR
        A[DC Load Line] --{-}--> B[Q{-}Point]
        B --{-}--> C[AC Load Line {-} Steeper]
    end
{Highlighting}
{Shaded}
```

### AC Load Line Characteristics:

- **Definition:** Represents dynamic operation during signal amplification
- **Equation:**  $i_c = (V_{CC} - V_{CEQ})/R'_c - v_{ce}/R'_c$  where  $R'_c = RC||RL$
- **Comparison with DC load line:**
  - AC load line is steeper than DC load line
  - Passes through Q-point
  - Determines voltage and current signal swings
- **Significance:** Defines maximum undistorted output signal
- **Limiting factor:** Avoiding saturation and cutoff regions

### Mnemonic

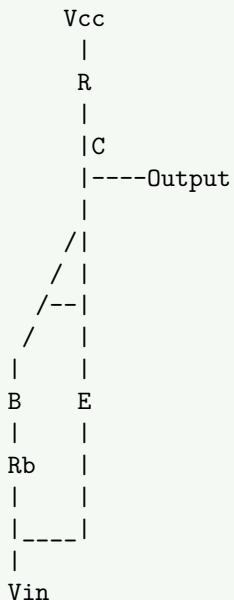
“AC Amplitude Controlled by Load line Angle”

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

Draw the fixed bias circuit and explain working of it

### Solution

#### Diagram:



- **Structure:** Base resistor connected to VCC, collector resistor for load
- **Operation:** Fixed base current biases transistor
- **Disadvantage:** Poor stability against temperature changes

### Mnemonic

“Fixed Bias Feeds Base from power supply”

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

In hartley oscillator  $L_1=5\text{mH}$ ,  $L_2=10\text{mH}$ ,  $C=0.01\mu\text{F}$ . Calculate frequency of oscillations.

### Solution

#### Solution:

- **Given:**  $L_1=5\text{mH}$ ,  $L_2=10\text{mH}$ ,  $C=0.01\mu\text{F}$
- **Frequency formula:**  $f = 1/[2 \sqrt{(C \times (L_1 + L_2))}]$
- **Calculation:**
  - Total inductance  $LT = L_1 + L_2 = 5\text{mH} + 10\text{mH} = 15\text{mH} = 15 \times 10^{-3}\text{H}$

- $C = 0.01\mu F = 1 \times 10^{-8} F$
- $f = 1/[2 \sqrt{(15 \times 10^{-3} \times 1 \times 10^{-8})}]$
- $f = 1/[2 \sqrt{(15 \times 10^{-11})}]$
- $f = 1/[2 \times 3.873 \times 10^{-6}]$
- $f = 1/[24.33 \times 10^{-6}]$
- $f = 41,101 \text{ Hz} \approx 41.1 \text{ kHz}$

### Mnemonic

"For Hartley's frequency, add coils then take square root"

## Question 3(c) [7 marks]

Draw and explain the frequency response curve of two stage RC coupled amplifier.

### Solution

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    subgraph Frequency Response
        direction LR
        A[Low Frequency] --> B[Mid Frequency]
        B --> C[High Frequency]
    end
{Highlighting}
{Shaded}
```

### Two-Stage RC Coupled Amplifier Frequency Response:

- **Low-frequency region:** Gain rises with frequency ( $< 50\text{Hz}$ )
  - Limited by coupling and bypass capacitors
- **Mid-frequency region:** Constant maximum gain ( $50\text{Hz}-20\text{kHz}$ )
  - Flat response, ideal operating region
- **High-frequency region:** Gain drops with frequency ( $> 20\text{kHz}$ )
  - Limited by transistor capacitances and Miller effect
- **Bandwidth:** Range of frequencies with gain  $\geq 70.7\% \text{ of maximum gain}$
- **Cutoff frequencies:** Points where gain drops by 3dB (0.707 times max gain)

### Mnemonic

"Low-flat-high: capacitors block, amplify well, then roll off"

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

Explain in detail barkhausen criterion for oscillation.

### Solution

Barkhausen Criterion:

Condition	Requirement
<b>Loop Gain</b>	Must equal exactly 1 ( $A = 1$ )
<b>Phase Shift</b>	Must be $0^\circ$ or $360^\circ$ around loop

- **Purpose:** Ensures sustained oscillations without damping
- **Consequences:**
  - If  $A < 1$ : Oscillations die out
  - If  $A > 1$ : Oscillations grow until limited by nonlinearity
  - If  $A = 1$ : Stable oscillations maintained

### Mnemonic

“Barkhausen’s Balance: Loop Gain=1, Phase=360°”

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

Explain the effect of negative feedback on the gain of amplifier

### Solution

**Effect of Negative Feedback on Amplifier Gain:**

Parameter	Without Feedback	With Feedback
<b>Voltage Gain</b>	A	$A/(1+A)$
<b>Stability</b>	Less stable	More stable
<b>Bandwidth</b>	Lower	Higher
<b>Distortion</b>	Higher	Lower

- **Gain reduction:** Gain decreases by factor  $(1+A)$
- **Gain-bandwidth tradeoff:** Bandwidth increases as gain decreases
- **Gain stabilization:** Less affected by temperature and component variations

### Mnemonic

“Negative Feedback: Less Gain, More Stability”

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

Draw fan regulator circuit and explain how it will control the speed of fan.

### Solution

**Diagram:**

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    A[AC Supply] --> B[DIAC]
    B --> C[TRIAC]
    C --> D[Fan]
    E[Variable Resistor] --> F[RC Network]
    F --> B
{Highlighting}
{Shaded}
```

### Fan Regulator Operation:

- **Control method:** Phase angle control using TRIAC and DIAC
- **Working principle:** RC network creates variable phase shift
- **Speed control:** Variable resistor adjusts RC time constant
- **Operation sequence:**
  - RC network delays DIAC firing
  - DIAC triggers TRIAC at adjustable point in AC cycle
  - TRIAC conducts for remaining portion of AC half-cycle

- Less conduction time = lower power to fan = slower speed
- **Advantages:** Simple design, smooth control, energy efficient
- **Applications:** Ceiling fans, exhaust fans, cooling systems

### Mnemonic

“Delay the TRIAC firing, control fan’s speed”

## Question 4(a) [3 marks]

Write short note on natural commutation

### Solution

#### Natural Commutation:

- **Definition:** SCR turns off automatically when current falls below holding current
- **Process:** Occurs in AC circuits at each zero-crossing point
- **Requirements:** No external components needed, inherent to AC operation

### Mnemonic

“Natural Commutation: Zero Current Crossings Turn Off Thyristors”

## Question 4(b) [4 marks]

Explain the parameters gain and bandwidth of amplifier.

### Solution

#### Amplifier Parameters:

Parameter	Definition	Formula
<b>Gain (A)</b>	Ratio of output to input signal	$A = V_{out}/V_{in}$
<b>Bandwidth (BW)</b>	Frequency range with gain $\geq 70.7\% \text{ of maximum}$	$BW = f_H - f_L$

- **Gain-bandwidth product:** Remains constant ( $GBP = Gain \times Bandwidth$ )
- **Cutoff frequencies:** Lower ( $f_L$ ) and higher ( $f_H$ ) frequencies where gain drops by 3dB
- **Significance:** Determines amplifier's ability to handle different frequencies

### Mnemonic

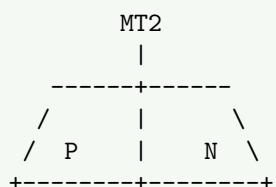
“Good Amplifiers Balance Width and Magnitude”

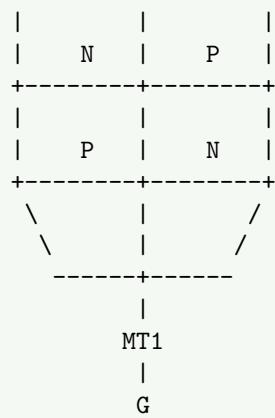
## Question 4(c) [7 marks]

Draw the construction and characteristics of triac and describe working of it, also write the application of triac.

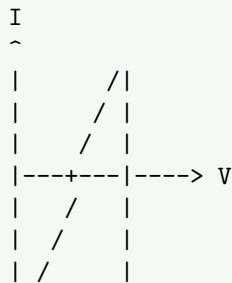
### Solution

#### TRIAC Construction and Characteristics:





### I-V Characteristics:



### TRIAC Operation:

- **Structure:** Five-layer PNPN bidirectional device
- **Switching:** Conducts in both directions when triggered
- **Triggering modes:** Four quadrant operation possible
- **Turn-off:** Natural commutation at current zero-crossing

### Applications:

- Light dimmers
- Fan speed controllers
- Heater controls
- Motor speed regulation
- AC power switching

### Mnemonic

"TRIAC Takes AC Control in Both Directions"

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

Write any three application of SCR.

### Solution

#### Applications of SCR:

Application	Function
<b>DC Motor Speed Control</b>	Provides variable DC to motors
<b>Battery Chargers</b>	Regulates charging current
<b>Power Inverters</b>	Converts DC to AC efficiently

- **Advantages:** High power handling, efficient control, robust operation
- **Limitations:** Requires forced commutation in DC circuits

## Mnemonic

“SCR Controls DC - Motors, Batteries, Inverters”

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

Explain holding current and latching current with reference to SCR

#### Solution

##### SCR Current Parameters:

Parameter	Definition	Typical Values
<b>Holding Current (IH)</b>	Minimum current to maintain conduction	5-40 mA
<b>Latching Current (IL)</b>	Minimum current to establish conduction	10-100 mA

- **Latching current:** Must be exceeded briefly after triggering for SCR to latch
- **Holding current:** Must be maintained to keep SCR in conduction
- **Relationship:** Usually  $IL > IH$
- **Significance:** Critical for reliable switching operation

## Mnemonic

“Latch with more, Hold with less, both keep SCR conducting”

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

Draw and explain in detail block diagram of operational amplifier.

#### Solution

##### Operational Amplifier Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    A[Input Differential Stage] {-{-}{}} B[Intermediate Stage]  
    B {-{-}{}} C[Output Stage]  
    D[Bias Circuit] {-{-}{}} A \& B \& C  
    E[Frequency Compensation] {-{-}{}} B  
{Highlighting}  
{Shaded}
```

##### Op-Amp Blocks and Functions:

- **Input differential stage:**
  - High input impedance
  - Rejects common-mode signals
  - Provides differential voltage gain
- **Intermediate stage:**
  - Additional voltage gain
  - Level shifting
  - Frequency compensation
- **Output stage:**
  - Low output impedance
  - Current amplification
  - Power capability for driving loads
- **Bias circuit:**
  - Establishes proper operating points

- Temperature stability
  - **Frequency compensation:**
    - Prevents oscillation
    - Controls frequency response

## Mnemonic

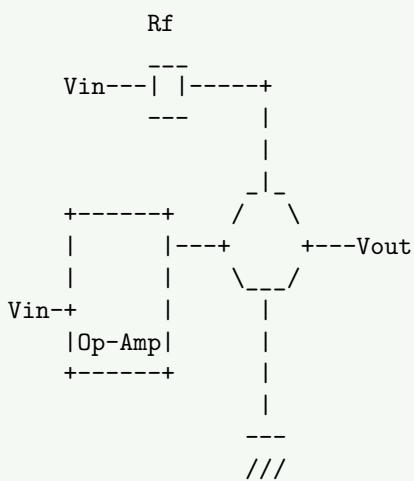
“Differential Input, Gain in Middle, Power at Output”

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

**Draw and explain in brief inverting amplifier.**

## Solution

### Inverting Amplifier Circuit:



- **Gain formula:**  $V_{out} = -(R_f/R_{in}) \times V_{in}$
  - **Operation:** Input signal inverted with amplification
  - **Virtual ground:** Inverting input maintained at 0V

## Mnemonic

“Inverting means Negative Gain equals  $-R_f/R_{in}$ ”

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

Draw and explain the block diagram of regulated power supply.

### Solution

#### Regulated Power Supply Block Diagram:

## Mermaid Diagram (Code)

```

{Shaded}
{Highlighting} []
graph LR
    A[Transformer] --> B[Rectifier]
    B --> C[Filter]
    C --> D[Regulator]
    D --> E[Output]
    F[Reference] --> D
    G[Feedback] --> D
{Highlighting}

```

{Shaded}

#### Regulated Power Supply Stages:

- **Transformer:** Steps down AC voltage to required level
- **Rectifier:** Converts AC to pulsating DC (diode bridge)
- **Filter:** Smooths pulsating DC (capacitors)
- **Regulator:** Maintains constant output despite variations
- **Reference:** Provides stable comparison voltage
- **Feedback:** Monitors output and adjusts regulation

#### Mnemonic

“Transform, Rectify, Filter, Regulate for Stable DC”

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

Draw and explain astable multivibrator.

#### Solution

#### Astable Multivibrator Using 555 Timer:

##### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    subgraph 555 Timer
        A[Threshold] --> B[Flip{-}Flop]
        C[Trigger] --> B
        B --> D[Output]
    end
    E[R1] & F[R2] & G[C] --> A
    {Highlighting}
{Shaded}
```

#### Operation of Astable Multivibrator:

- **Configuration:** Free-running oscillator with no stable states
- **Timing components:** External R1, R2, and C
- **Oscillation process:**
  - Capacitor charges through R1+R2
  - Capacitor discharges through R2
  - Continuous charging/discharging cycle
- **Output waveform:** Rectangular with duty cycle based on R1/R2 ratio
- **Frequency formula:**  $f = 1.44 / ((R1 + 2R2))$
- **Applications:** Clock generation, LED flashers, tone generators
- **Advantages:** Simple design, stable frequency, adjustable duty cycle

#### Mnemonic

“Always Switching, Time set by RC, Both states Least stable”

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

In an op amp non-inverting amplifier  $R_1=2k\Omega$  and  $R_f=200k\Omega$ . Find the voltage gain of non-inverting amplifier.

#### Solution

##### Solution:

- **Given:**  $R_1 = 2k\Omega$ ,  $R_f = 200k\Omega$

- Non-inverting amplifier gain formula:  $A = 1 + (R_f/R_1)$
- Calculation:
  - $A = 1 + (200k\Omega/2k\Omega)$
  - $A = 1 + 100$
  - $A = 101$
- Result: Voltage gain of non-inverting amplifier is 101
- Significance: Output voltage will be 101 times the input voltage

### Mnemonic

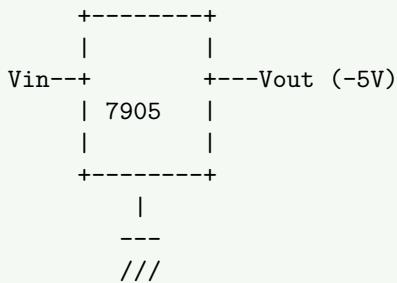
“Non-inverting amplifier gain: One plus Feedback over Ground”

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

Draw and explain in brief circuit to get -5V regulated dc output voltage.

### Solution

**Negative Voltage Regulator Circuit:**



### Circuit Operation:

- Key component: 7905 negative voltage regulator IC
- Input requirement: Negative DC voltage (typically -7V to -25V)
- Filtering: Input and output capacitors for stability
- Regulation method: Series pass element with feedback control
- Output characteristics: Fixed -5V with current up to 1A

### Mnemonic

“79XX for Negative, 78XX for Positive regulated voltage”

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

Draw and explain the block diagram of SMPS.

### Solution

**SMPS Block Diagram:**

Mermaid Diagram (Code)

```

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

H {-{-}{} I}  
{Highlighting}  
{Shaded}

#### **SMPS Operation:**

- **Input stage:** Filters EMI, rectifies AC to high-voltage DC
- **Switching stage:** Converts DC to high-frequency AC (20-100 kHz)
- **Transformer:** Provides isolation and voltage transformation
- **Output stage:** Rectifies and filters to produce clean DC
- **Feedback control:** Regulates output by adjusting switching duty cycle

#### **Advantages of SMPS:**

- **High efficiency** (80-90%) due to switching operation
- **Small size and weight** from high-frequency transformer
- **Wide input voltage range** with stable output
- **Multiple output voltages** possible from single transformer

#### **Applications:**

- Computer power supplies
- Electronic device chargers
- Industrial power systems

#### **Mnemonic**

“Switch More Power Smartly: High frequency saves size and energy”