PT. SOLUSI INTEK INDONESIA

POWER SUPPLY CIRCUIT

BASIC ELECTRONICS TUTORIAL #02

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CHAPTER 1

PHYSICS LAWS FOR ELECTRICITY

I. PHYSICS LAWS FOR ELECTRICITY

In electronics, several fundamental laws govern the behavior of electric circuits. These laws are essential for analyzing and designing circuits. Here, we'll discuss Ohm's Law, Kirchhoff's Laws, and a few other important principles.

I.1. Ohm's Law

Ohm's Law is one of the most fundamental principles in electronics. It relates the voltage (V), current (I), and resistance (R) in a circuit.

$$V = I \times R \tag{1. 1}$$

Where:

- V is the voltage across the resistor (in volts).
- I is the current flowing through the resistor (in amperes).
- R is the resistance (in ohms).

I.1.A. Applications Of Ohm's Law

- **Calculating Current**: If you know the voltage and resistance, you can find the current.

$$I = \frac{V}{R} \tag{1. 2}$$

- **Calculating Voltage**: If you know the current and resistance, you can find the voltage.

$$V = I \times R \tag{1. 3}$$

- **Calculating Resistance**: If you know the voltage and current, you can find the resistance.

$$R = \frac{V}{I} \tag{1. 4}$$

I.2. Kirchhoff's Laws

Kirchhoff's Laws are two principles that deal with the conservation of charge and energy in electrical circuits.

I.2.A. Kirchhoff's Current Law (Kcl)

KCL states that the total current entering a junction (or node) in a circuit equals the total current leaving the junction. This law is based on the principle of conservation of electric charge.

$$\sum I_{in} = \sum I_{out} \tag{1. 5}$$

I.2.B. Kirchhoff's Voltage Law (Kvl)

KVL states that the sum of all electrical voltages around any closed loop in a circuit is equal to zero. This law is based on the principle of conservation of energy.

$$\sum V = 0 \tag{1. 6}$$

I.2.C. Applications Of Kirchhoff's Laws

- **Analyzing Complex Circuits**: KCL and KVL are used to solve circuits with multiple loops and nodes.
- **Finding Unknown Values**: These laws help in finding unknown currents and voltages in a circuit.

I.3. Thevenin's And Norton's Theorems

These theorems simplify complex circuits to make analysis easier.

I.3.A. Thevenin's Theorem

Thevenin's Theorem states that any linear electrical network with voltage and current sources and resistances can be replaced by an equivalent circuit consisting of a single voltage source (Thevenin voltage, V_{th}) in series with a resistance (Thevenin resistance, R_{th}).

I.3.B. Norton's Theorem

Norton's Theorem states that any linear electrical network can be replaced by an equivalent circuit consisting of a single current source (Norton current, I_N) in parallel with a resistance (Norton resistance, R_N).

I.3.C. Conversion Between Thevenin And Norton

- **Resistance Conversion**

$$R_{th} = R_N \quad (1.7)$$

- **Voltage Conversion**

$$V_{th} = I_N \times R_N$$

- **Current Conversion**

$$I_N = \frac{V_{th}}{R_{th}} \quad (1.8)$$

I.3.D. Applications

- **Simplifying Analysis**: These theorems make it easier to analyze complex circuits by reducing them to simpler equivalent circuits.
- **Design and Testing**: Useful in designing and testing circuit components by focusing on essential characteristics.

I.4. Superposition Theorem

The Superposition Theorem states that in a linear circuit with multiple independent sources, the response (voltage or current) at any point in the circuit can be found by summing the responses caused by each independent source acting alone, with all other independent sources turned off (replaced by their internal impedances).

I.4.A. Applications

- **Analyzing Circuits with Multiple Sources**: This theorem is particularly useful for circuits with multiple voltage and current sources.
- **Simplifying Complex Calculations**: Allows for easier calculation of circuit behavior by considering one source at a time.

I.5. Maximum Power Transfer Theorem

The Maximum Power Transfer Theorem states that maximum power is delivered to a load when the load resistance (R_L) is equal to the Thevenin resistance (R_{th}) of the circuit supplying the power.

I.5.A. Application

- **Optimizing Power Delivery**: Used in designing power systems to ensure maximum efficiency.

I.6. Summary of Physics Laws for Electricity

Understanding these fundamental laws and theorems is crucial for anyone studying electronics. They provide the basis for analyzing, designing, and optimizing electrical circuits. Here is a quick recap:

1. **Ohm's Law**: Relates voltage, current, and resistance.
2. **Kirchhoff's Laws**: KCL (current conservation at nodes) and KVL (voltage conservation in loops).
3. **Thevenin's and Norton's Theorems**: Simplify complex circuits to single-source equivalents.
4. **Superposition Theorem**: Analyzes circuits with multiple sources by considering one source at a time.
5. **Maximum Power Transfer Theorem**: Ensures maximum power delivery to a load when load resistance equals source resistance.

CHAPTER 2

POWER SUPPLY OVERVIEW

II. POWER SUPPLY OVERVIEW

II.1. Introduction

What is a power supply? A power supply is an electronic device that provides electrical energy to an electrical load. The primary function is to convert electric current from a source to the correct voltage, current, and frequency to power the load.

Importance and applications Power supplies are crucial in virtually every electronic device, from household appliances and computers to industrial machinery and medical equipment.

a **b**

Figure 2. 1. (a). AC to DC Power Supply, (b). DC Power Supply

II.2. Types of Power Supply Circuits

II.2.A. By Operation Mode

- Linear Power Supplies
- Switch-Mode Power Supplies (SMPS)
- Uninterruptible Power Supplies (UPS)
- Programmable Power Supplies

II.2.B. By Output Type

- AC-DC Power Supplies
- DC-DC Converters
- AC-AC Converters
- Inverters (DC-AC Converters)

II.2.C. By Application

- High-Voltage Power Supplies
- Adjustable Power Supplies
- Battery Power Supplies
- Constant Current Power Supplies

II.3. Key Components and Their Functions

II.3.A. Transformers

- Purpose: Steps up or steps down AC voltage levels
- Operation: Uses electromagnetic induction to transfer energy between windings

II.3.B. Rectifiers

- Types: Half-wave, Full-wave, Bridge rectifiers
- Function: Converts AC voltage to pulsating DC voltage

II.3.C. Filters

- Purpose: Smooths the pulsating DC from the rectifier
- Types: Capacitor filter, Inductor filter, RC filter, LC filter

II.3.D. Voltage Regulators

- Purpose: Ensures a stable DC output voltage
- Types: Linear regulators (e.g., 7805), Switching regulators (e.g., buck converters)

II.4. Designing a Simple Linear Power Supply

- Selecting the transformer
    - Determine the required output voltage and current
    - Choose a transformer with appropriate voltage and current ratings
- Designing the rectifier circuit
    - Choose between half-wave, full-wave, or bridge rectifier
    - Use diodes (e.g., 1N4007) for rectification
- Adding filter capacitors:
    - Calculate the required capacitance to reduce ripple voltage
    - Use electrolytic capacitors for higher capacitance values
- Choosing and implementing voltage regulators:
    - Select a suitable linear regulator (e.g., 7805 for 5V output)
    - Implement heatsinking if necessary to manage heat dissipation
- Practical example:
    - Output requirement: 5V, 1A
    - Transformer: 230V to 9V, 1.2A
    - Rectifier: Bridge rectifier using 1N4007 diodes
    - Filter: 1000µF capacitor
    - Regulator: 7805 with heatsink

II.5. Applications of Power Supply Circuits

- Consumer electronics: Smartphones, laptops, TVs
- Industrial equipment: PLCs, motor drives, control systems
- Medical devices: Imaging equipment, patient monitoring systems
- Telecommunications: Routers, base stations, signal amplifiers

CHAPTER 3

LINEAR POWER SUPPLIES

III. LINEAR POWER SUPPLIES

III.1. Working Principles

Linear power supplies operate by using a series of components to convert an AC voltage to a stable DC voltage. The process involves the following steps:

1. **Transformer:** Steps down the high AC voltage from the mains to a lower AC voltage.
2. **Rectifier:** Converts the AC voltage to pulsating DC voltage.
3. **Filter:** Smooths the pulsating DC voltage to reduce ripple.
4. **Voltage Regulator:** Provides a stable DC output voltage by dissipating excess power as heat.

a b

Figure 3. 1. (a). Linear Power Supply HI FI Ultra-Low Noise (b). Embedded Linear Power Supply

III.2. Key Components

1. **Transformer:**
    - **Function:** Converts high AC voltage to a lower AC voltage suitable for the circuit.
    - **Types:** Step-down transformers are commonly used in linear power supplies.
2. **Rectifier:**
    - **Function:** Converts AC voltage to DC voltage.
    - **Types:**
        - **Half-Wave Rectifier:** Uses a single diode to convert AC to pulsating DC.
        - **Full-Wave Rectifier:** Uses a center-tapped transformer and two diodes to convert AC to DC.
        - **Bridge Rectifier:** Uses four diodes in a bridge configuration to convert AC to DC.

3. **Filter:**
    - **Function:** Reduces the ripple in the DC output.
    - **Types:**
        - **Capacitor Filter:** Uses capacitors to smooth the output.
        - **Inductor Filter:** Uses inductors to smooth the output.
        - **RC (Resistor-Capacitor) and LC (Inductor-Capacitor) Filters:** Combine resistors, capacitors, and inductors for improved smoothing.
4. **Voltage Regulator:**
    - **Function:** Maintains a constant output voltage regardless of variations in input voltage or load conditions.
    - **Types:**
        - **Series Regulator:** Uses a pass transistor in series with the load.
        - **Shunt Regulator:** Uses a pass element in parallel with the load.
        - **Integrated Circuit (IC) Regulators:** Common examples include the 78xx series for positive voltage regulation and the 79xx series for negative voltage regulation.

III.3. Design Considerations

1. **Voltage and Current Requirements:**
    - Determine the required output voltage and current for the load.
    - Choose a transformer with appropriate voltage and current ratings.
2. **Heat Dissipation:**
    - Linear regulators dissipate excess power as heat.
    - Ensure adequate heatsinking and ventilation to manage thermal performance.
3. **Efficiency:**
    - Linear power supplies are less efficient than switch-mode power supplies, especially when the difference between input and output voltage is large.
    - Efficiency is typically around 30-60%.

4. **Noise and Ripple:**
   - Use appropriate filtering to minimize noise and ripple in the output.
   - Consider additional filtering stages if necessary.

III.4. Advantages

1. **Simplicity:** Simple design and easy to implement.
2. **Low Noise:** Produce very low electromagnetic interference (EMI) and noise.
3. **High Precision:** Provide highly stable and precise output voltage.

III.5. Disadvantages

1. **Inefficiency:** Lower efficiency due to power dissipation as heat.
2. **Heat Generation:** Significant heat generation requires proper heatsinking.
3. **Bulkiness:** Larger and heavier due to transformers and heatsinks.

III.6. Applications

1. **Audio Equipment:** Low noise is crucial for audio amplification.
2. **Analog Circuits:** Stable voltage is essential for analog signal processing.
3. **Laboratory Power Supplies:** Precision and stability are required for testing and experimentation.
4. **Consumer Electronics:** Used in devices where efficiency is less critical but stability is important.

III.7. Practical Example: Designing a Linear Power Supply

Let's design a simple linear power supply with the following specifications:

- **Output Voltage:** 5V
- **Output Current:** 1A

III.7.A. Selecting the Transformer

- **Requirement:** Output of 5V DC, 1A.
- Choose a transformer with an output of 9V AC (considering rectifier and dropout voltage of the regulator) and a current rating of at least 1.2A.
- Example: 230V AC primary to 9V AC secondary transformer.

III.7.B. Designing the Rectifier Circuit

- Use a bridge rectifier configuration for full-wave rectification.
- Diodes: 1N4007 diodes (4 pieces).

III.7.C. Adding Filter Capacitors

- Calculate the required capacitance to smooth the rectified output.
- Use the formula

$$C = \frac{I}{2} \cdot f \cdot V_r$$

Equation 3. 1

  where I is the load current, f is the frequency (50Hz for mains), and V_r is the acceptable ripple voltage.

- For a ripple of 1V:

$$C = \frac{1A}{50Hz \cdot 1V} = 20000\mu F$$

Equation 3. 2

- Choose a 2200µF capacitor for practical purposes.

III.7.D. Choosing and Implementing Voltage Regulators

- Use an LM7805 linear regulator for 5V output.
- Add a heatsink to the regulator to dissipate heat.

III.7.E. Assembling the Circuit

- Connect the transformer secondary to the bridge rectifier.
- Connect the rectifier output to the filter capacitor.
- Connect the filtered output to the input of the LM7805 regulator.
- Connect the output of the regulator to the load

III.7.F. Circuit Diagram

This example illustrates the basic process of designing a simple linear power supply. Adjustments can be made based on specific requirements and constraints.

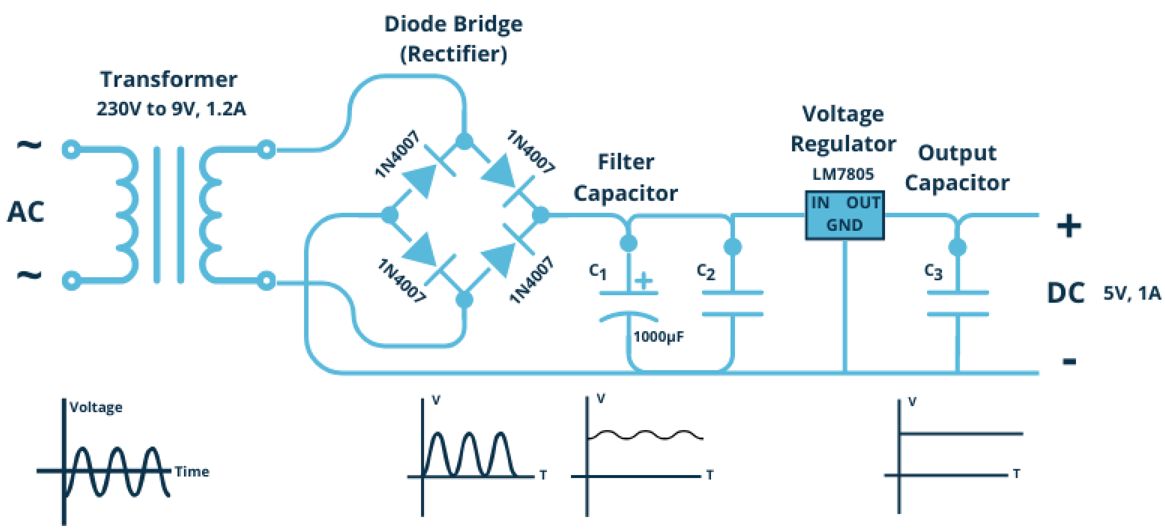

Figure 3. 2. Linear Power Supply Circuit Diagram

CHAPTER 4

SWITCHING POWER SUPPLIES

IV. SWITCHING POWER SUPPLIES

IV.1. Overview

Switching power supplies, or switch-mode power supplies (SMPS), are crucial in modern electronics due to their efficiency and flexibility. They convert electrical energy efficiently by switching elements (typically transistors) on and off at high frequencies, reducing energy loss compared to linear power supplies.

Figure 4. 1. Switching Power Supply

IV.2. Types of Switching Power Supplies

Switching power supplies come in various types, each suited for different applications. The primary types are:

1. **Buck Converter (Step-Down Converter)**
    - **Function:** Reduces the input voltage to a lower output voltage.
    - **Operation:** Uses an inductor, diode, and a switching element (usually a MOSFET) to regulate the output voltage.
    - **Applications:** Voltage regulation in microprocessors, LED drivers, and other low-voltage applications.
    - **Example:** Converting 12V DC to 5V DC for microcontroller power supply.
2. **Boost Converter (Step-Up Converter)**
    - **Function:** Increases the input voltage to a higher output voltage.
    - **Operation:** Utilizes an inductor, diode, and switching element to step up the voltage.
    - Applications: Battery-powered devices, where a higher voltage is needed from a lower battery voltage.
    - **Example:** Boosting a 3.7V lithium-ion battery to 5V for USB devices.
3. **Buck-Boost Converter**
    - **Function:** Can either step up or step down the input voltage.
    - **Operation:** Combines the principles of both buck and boost converters, allowing the output voltage to be either higher or lower than the input voltage.
    - **Applications:** Power management in systems with variable input voltage, such as solar power systems.
    - **Example:** Regulating power in portable devices with fluctuating battery levels.

4. **Flyback Converter**
   - **Function:** Provides electrical isolation and can generate multiple output voltages.
   - **Operation:** Uses a transformer to store energy during the switch-on phase and release it during the switch-off phase, providing voltage transformation and isolation.
   - **Applications:** Power adapters, chargers, and industrial power supplies.
   - **Example:** AC to DC converters in power adapters for laptops.

Table 4. 1

Type	Function	Common Applications
Buck Converter	Steps down voltage	Voltage regulation in devices
Boost Converter	Steps up voltage	Battery-powered devices
Buck-Boost	Steps up or down voltage	Power management in complex circuits
Flyback	Isolation and multiple outputs	Power adapters, industrial power supplies

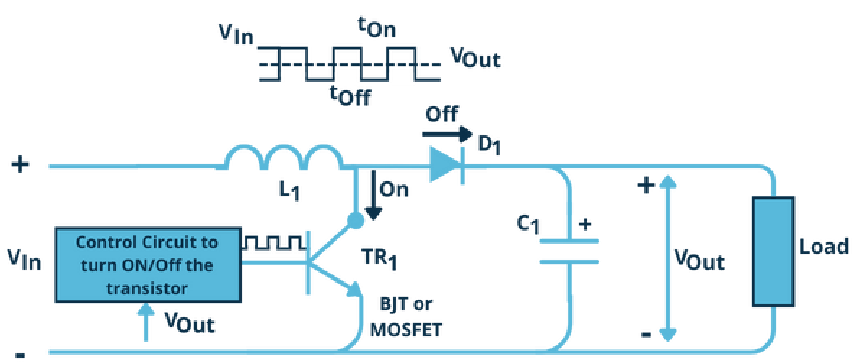

Figure 4. 2. Boost Switching Regulator

IV.3. Components of Switching Power Supplies

Switching power supplies consist of several key components that work together to regulate and convert electrical energy:

1. **Inductors**
   - **Function:** Store energy in a magnetic field during the switch-on phase and release it during the switch-off phase.

- **Selection Criteria:** Inductance value (H), current rating, core material, and DC resistance (DCR).
- **Example:** An inductor with 22µH inductance, 3A current rating, ferrite core.

2. **Capacitors**
   - **Function:** Smooth out voltage fluctuations, store energy, and filter noise.
   - **Selection Criteria:** Capacitance value (F), voltage rating, equivalent series resistance (ESR), and type (ceramic, electrolytic, tantalum).
   - **Example:** A 100µF, 25V electrolytic capacitor for output smoothing.
3. **Switching Elements (Transistors)**
   - **Function:** Rapidly switch on and off to control current flow.
   - **Selection Criteria:** Type (MOSFET, BJT), voltage and current rating, on-resistance (RDS(on)), switching speed.
   - **Example:** An N-channel MOSFET with 30V, 10A rating, and 10mΩ RDS(on).
4. **Controllers**
   - **Function:** Manage the switching elements to regulate the output voltage.
   - **Selection Criteria:** Type (PWM controller, PFM controller), operating frequency, features like synchronization, soft start, overcurrent protection.
   - **Example:** A PWM controller IC with 100kHz switching frequency and built-in protections.

IV.4. Advantages and Disadvantages

Switching power supplies offer several advantages over linear power supplies, but they also have some drawbacks.

Advantages:

- **High Efficiency:** Can reach efficiencies of 80-90% or higher due to reduced energy dissipation.
- **Compact Size:** Smaller components and less heat generation allow for a more compact design.
- **Wide Input Voltage Range:** Can operate over a broad range of input voltages, making them versatile for different applications.

Disadvantages:

- **Complex Design:** More intricate design and control mechanisms compared to linear power supplies.
- **Electromagnetic Interference (EMI):** Rapid switching can generate noise, requiring careful layout and filtering.
- **Higher Cost:** More expensive components and design complexity can increase the overall cost.

Table 4. 2

Advantages	Disadvantages
High efficiency	Complex design
Smaller size and weight	Generates EMI
Wide input Voltage range	Higher cost

IV.5. Design and Implementation

Designing a switching power supply involves several steps, including selecting the appropriate components and ensuring stability and efficiency.

1. **Determine Specifications**
   - Define the input voltage range, desired output voltage, and current requirements.
   - Example: Input voltage 9-18V, output voltage 5V, output current 2A.
2. **Select Topology**
   - Choose the appropriate converter type based on application requirements (buck, boost, buck-boost, flyback).
   - Example: Choose a buck converter for stepping down 12V to 5V.
3. **Component Selection**
   - Select inductors, capacitors, switching elements, and controllers based on calculated values.
   - Example: Choose a 22µH inductor, 100µF capacitor, N-channel MOSFET, and PWM controller IC.
4. **Circuit Design**
   - Create a detailed schematic diagram, considering layout best practices to minimize noise and EMI.
   - Example: Design a PCB with short, wide traces for high current paths and proper grounding.
5. **Simulation and Testing**
   - Simulate the circuit using software tools (e.g., SPICE) to verify performance and stability.
   - Build a prototype and test under various conditions to ensure reliable operation.
   - Example: Simulate transient response and load regulation, then validate with a physical prototype.

IV.6. Practical Examples

Switching power supplies are used in various applications, including:

Table 4. 3

Application	Description
Computers	PSUs providing multiple regulated output voltages
Mobile Devices	Efficient chargers and battery management systems
Power Adapters	External adapters for laptops with multiple outputs

IV.7. Summary

Switching power supplies are crucial in modern electronic devices due to their high efficiency, versatility, and compact size. Understanding the different types, components, and design principles is essential for developing reliable and efficient power supplies.

CHAPTER 5

POWER SUPPLY DESIGN CONSIDERATIONS

V. Power Supply Design Considerations

V.1. Introduction

Designing a power supply involves various considerations to ensure reliable performance, efficiency, and safety. This chapter delves into critical design aspects such as thermal management, electromagnetic interference (EMI), protection mechanisms, and regulatory compliance.

V.2. Thermal Management

Effective thermal management is crucial to maintain the reliability and longevity of power supplies. Excessive heat can degrade components, reduce efficiency, and lead to failure.

1. **Heat Dissipation**
   - **Methods:** Heat sinks, fans, and thermal interface materials (TIMs) are commonly used to dissipate heat.
   - **Design Considerations:** Ensure adequate ventilation, select appropriate heat sink size and material, and consider forced cooling for high-power applications.
   - **Example:** Using a heat sink with a thermal resistance of 2°C/W for a MOSFET dissipating 10W of power.
2. **Thermal Protection**
   - **Methods:** Thermal shutdown circuits, temperature sensors, and derating.
   - **Design Considerations:** Implement thermal shutdown to protect against overheating and use temperature sensors to monitor critical components.
   - **Example:** Integrating a thermal shutdown circuit that activates at 150°C to protect a buck converter.

Table 5. 1

Thermal Management Method	Details	Example
Heat Dissipation	Heat sinks, fans, TIMs	Heat sink with 2°C/W for MOSFET dissipating 10W
Thermal Protection	Thermal shutdown, temperature sensors	Thermal shutdown at 150°C for buck converter

V.3. Electromagnetic Interference (EMI)

Switching power supplies can generate EMI, which may interfere with other electronic devices. Controlling EMI is essential for compliance with regulatory standards and ensuring reliable operation.

1. **Sources of EMI**
   - **Switching Transients:** Rapid switching of transistors generates high-frequency noise.
   - **Magnetic Components:** Inductors and transformers can emit electromagnetic fields.
   - **PCB Layout:** Poor layout can lead to noise coupling and radiation.
2. **Mitigation Techniques**
   - **Filtering:** Use input and output filters to attenuate high-frequency noise.
   - **Shielding:** Enclose the power supply in a metal case to contain EMI.
   - **PCB Layout:** Optimize layout to minimize loop areas and use ground planes.
   - **Example:** Implementing a π-filter at the output of a buck converter to reduce high-frequency noise.
3. **Regulatory Compliance**
   - **Standards:** Compliance with standards such as CISPR 22, FCC Part 15, and EN 55022.
   - **Testing:** Conduct EMI testing in an anechoic chamber to ensure compliance.
   - **Example:** Designing a power supply to meet CISPR 22 Class B limits for conducted and radiated emissions.

Table 5. 2

EMI Mitigation Technique	Details	Example
Filtering	Input/output filters	π- Filter at the output of a buck converter
Shielding	Metal enclosures	Metal case for SMPS
PCB Layout	Minimize loop areas, ground planes	Optimized layout reduced noise

V.4. Protection Mechanisms

Incorporating protection mechanisms is vital to safeguard power supplies and connected loads from faults and abnormal conditions.

1. **Overcurrent Protection (OCP)**
   - **Methods:** Current limiting, foldback current limiting, and current sense resistors.
   - **Design Considerations:** Select appropriate current limit threshold and method for the application.
   - **Example:** Using a current sense resistor and comparator to implement OCP in a boost converter.
2. **Overvoltage Protection (OVP)**
   - **Methods:** Crowbar circuits, zener diodes, and feedback control.

- **Design Considerations:** Ensure rapid response to overvoltage conditions to protect sensitive components.
- **Example:** Implementing a crowbar circuit with an SCR to clamp the output voltage in case of overvoltage.

3. **Undervoltage Protection (UVP)**
    - **Methods:** Undervoltage lockout (UVLO) circuits and monitoring ICs.
    - **Design Considerations:** Set appropriate undervoltage thresholds to prevent malfunction due to insufficient voltage.
    - **Example:** Using a UVLO circuit to disable a buck converter when the input voltage drops below 8V.
4. **Short-Circuit Protection (SCP)**
    - **Methods:** Current limiting, foldback current limiting, and crowbar circuits.
    - **Design Considerations:** Ensure fast response to short-circuit conditions to prevent damage.
    - **Example:** Implementing foldback current limiting in a linear regulator to protect against short circuits.

Table 5. 3

Protection Mechanism	Method	Example
Overcurrent Protection	Current limiting, current sense resistors	OCP using current sense resistor in boost converter|
Overvoltage Protection	Crowbar circuits, zener diodes	Crowbar circuit with SCR for overvoltage protection
Undervoltage Protection	UVLO circuits, monitoring ICs	UVLO circuit in buck converter
Short-Circuit Protection	Current limiting, foldback current limiting |	Foldback current limiting in linear regulator

V.5. Regulatory Compliance

Designing power supplies to comply with regulatory standards ensures safety and reliability while facilitating market acceptance.

1. **Safety Standards**
    - **Agencies:** Underwriters Laboratories (UL), International Electrotechnical Commission (IEC), and others.
    - **Design Considerations:** Ensure insulation, spacing, and component ratings meet safety standards.
    - **Example:** Designing a power supply to comply with UL 60950-1 for information technology equipment.
2. **EMI/EMC Standards**
    - **Agencies:** Federal Communications Commission (FCC), European Committee for Electrotechnical Standardization (CENELEC).
    - **Design Considerations:** Implement EMI mitigation techniques to meet standards.

- **Example:** Designing a power supply to comply with FCC Part 15 for electromagnetic compatibility.

3. **Environmental Standards**
    - **Agencies:** Restriction of Hazardous Substances (RoHS), Waste Electrical and Electronic Equipment (WEEE).
    - **Design Considerations:** Ensure materials and processes meet environmental regulations.
    - **Example:** Selecting RoHS-compliant components for a power supply design.

Table 5. 4

Regulatory Area	Agency	Example Standard
Safety	UL, IEC	UL 60950-1 for IT equipment
EMI/EMC	FCC, CENELEC	FCC Part 15 for electromagnetic compatibility
Environmental	RoHS, WEEE	RoHS-compliant components

V.6. Practical Design Example

To illustrate the design considerations discussed, let's walk through a practical example of designing a buck converter for a specific application.

1. **Specifications**
    - Input Voltage: 12V ± 10%
    - Output Voltage: 5V
    - Output Current: 2A
2. **Component Selection**
    - Inductor: 22µH, 3A current rating, ferrite core
    - Capacitor: 100µF, 25V electrolytic capacitor
    - MOSFET: N-channel, 30V, 10A, 10mΩ RDS(on)
    - Controller: PWM controller IC with 100kHz switching frequency
3. **Circuit Design**
    - Create a schematic with the selected components, ensuring proper placement and connections.
    - Optimize the PCB layout to minimize EMI and ensure good thermal performance.
4. **Simulation and Testing**
    - Simulate the circuit using SPICE software to verify stability and performance.
    - Build a prototype and test under different load conditions and temperatures.
5. **Compliance Testing**
    - Conduct EMI testing in an anechoic chamber to ensure compliance with FCC Part 15.
    - Verify safety standards by ensuring proper insulation and spacing per UL 60950-1.

By following these steps, you can design a reliable and efficient buck converter that meets all necessary specifications and regulatory standards.

Table 5. 5

Design Step	Details	Example
Determine Specifications	Input voltage, output voltage, and current	Input 12V, Output 5V, Current 2A
Component Selection	Inductor, capacitor, MOSFET, controller	22µH inductor, 100µF capacitor, N-channel MOSFET
Circuit Design	Schematic and PCB layout	Optimized layout for reduced EMI
Simulation and Testing	Simulate and test prototype	SPICE simulation, prototype testing
Compliance Testing	EMI and safety testing	SPICE simulation, prototype testing

V.7. Summary

Designing a power supply involves careful consideration of thermal management, EMI control, protection mechanisms, and regulatory compliance. By addressing these aspects, engineers can create robust and efficient power supplies suitable for various applications.