



Government College of Engineering Kolhapur



(Affiliated to Dr. Babasaheb Ambedkar Technological University, Lonere)

Department of Electrical Engineering

Mini project II Report

single phase uncontrolled converter (Diode Rectifier)

(Power Electronics Lab Development initiative)

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Academic Year 2025-26



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Certificate

This is to certify that the Mini Project “single phase uncontrolled converter” has been successfully completed by following group of students in the Third Year (Semester V) B. Tech. (Electrical) of their study in Academic Year 2025-26

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Acknowledgment

We, the members of our project group, would like to express our sincere gratitude to all those who supported and guided us in the successful completion of our project on the Single-Phase Uncontrolled Converter (Diode Rectifier).

- **Faculty Guidance**

We are deeply thankful to our faculty and mentors for their valuable teaching and encouragement. Their insights into the principles of power electronics, rectifier circuits, and practical applications provided us with the technical foundation required for this project.

- **Institutional Support**

We acknowledge our institution for providing laboratory facilities, reference materials, and a collaborative environment that enabled us to carry out experiments, simulations, and analysis effectively.

- **Team Effort**

Each member of our group contributed with dedication—whether in circuit design, simulation, report writing, or performance analysis. This teamwork not only enhanced our technical knowledge but also strengthened our collaborative and problem-solving skills.

Abstract

A single-phase uncontrolled converter, commonly known as a diode rectifier, is an essential power electronic circuit used to convert alternating current (AC) into direct current (DC) without any external control. It operates using diodes, which conduct automatically based on the polarity of the input AC voltage. The

simplicity, reliability, and low cost of diode rectifiers make them widely used in power supplies, battery charging, and low-power industrial applications. This paper (or study) presents the working principle, circuit configuration, output characteristics, and performance analysis of a single-phase uncontrolled converter. The results highlight the influence of load type on the output voltage waveform and the efficiency of the conversion process. Overall, the single-phase uncontrolled converter remains a fundamental and efficient method for AC–DC power conversion.

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1.Introduction

1.1. Background of the Topic

A single-phase uncontrolled rectifier is an essential power electronics circuit used to convert alternating current (AC) into direct current (DC). It uses diodes as switching devices, which conduct automatically based on the polarity of the AC input. These rectifiers are widely used in low- and medium-power applications such as battery charging, DC power supplies, household electronics, and industrial control systems. Their simple construction, reliability, and low cost make them a fundamental building block in the study of power electronics.

1.2. Relevance and Motivation

In modern electrical systems, almost every device requires a stable DC supply. Since the main electrical grid provides AC power, rectification becomes a crucial process. Understanding how a single-phase uncontrolled rectifier works helps students gain practical knowledge of power conversion, waveform analysis, and electrical component behavior.

The motivation behind choosing this mini-project is to develop a strong foundation in power electronics, understand real-time load behavior, and explore how diodes influence current flow and voltage levels. This project also helps in preparing for advanced topics like controlled rectifiers, inverters, and DC-DC converters.

1.3. Objectives of the Mini-Project

The major objectives of this mini-project are:

To study the working principle of a single-phase uncontrolled diode rectifier.

To design and analyze the circuit using essential components such as transformer, diodes, and load.

To observe and compare input AC and output DC waveforms.

1.4. Scope and Limitations

Scope:

This project covers the design, construction, and testing of a single-phase diode rectifier. It includes waveform analysis, performance calculations, and discussion of different rectifier configurations such as half-wave and full-wave types.

1.5.Limitation (choose any one):

The circuit provides an unregulated DC output, which may contain a high ripple component.

2.Problem Definition

2.1. Clear Statement of the Central Problem

Most electronic devices and circuits require a stable DC supply for proper operation, whereas the power available from the electrical grid is AC. Therefore, converting AC to DC efficiently, safely, and economically becomes a major requirement.

The central problem addressed in this mini-project is to design, implement, and analyze a single-phase uncontrolled rectifier that converts AC power into usable DC output using diodes. The focus is on understanding its working behavior, output characteristics, and performance limitations.

2.2 Why the Problem Is Important

- Almost all electronic systems—such as chargers, adapters, sensors, control panels, and communication devices—depend on DC power.
- Without rectifiers, AC power from the mains cannot be used directly in these systems.
- Uncontrolled diode rectifiers are the simplest and most widely used rectifying circuits, making them essential for learning the fundamentals of power electronics.
- Understanding this conversion process helps students analyze voltage waveforms, current flow, ripple, efficiency, and the effects of load variations.
- This knowledge forms the foundation for advanced power electronic devices like controlled rectifiers, converters, and inverters.

2.3 Existing Solutions

Several types of rectifier circuits already exist for AC-to-DC conversion, including:

a) Half-Wave Diode Rectifier

Uses a single diode to allow current during only one half-cycle. Simple but low efficiency and high ripple.

b) Full-Wave Center-Tap Rectifier

Uses two diodes and a center-tap transformer to produce DC during both half-cycles. Better efficiency and lower ripple.

c) Full-Wave Bridge Rectifier

Uses four diodes to produce continuous rectification without requiring a center-tap transformer. Most commonly used due to higher efficiency and lower ripple.

3.Methodology / Project Stages

Stage 1:

3.1 Requirement Analysis

The first step of the project is to understand the need for converting AC power into DC using an uncontrolled diode rectifier. This involves identifying the electrical parameters, understanding circuit behavior, and selecting appropriate components. Requirement analysis helps ensure that the designed system meets performance expectations such as output voltage level, ripple content, and load handling capability

3.2 User Needs

The primary users of this project are students, beginners in power electronics, and small-scale electronic applications that need a simple DC supply. The essential user needs include:

A low-cost and easy-to-construct rectifier circuit.

A stable and reliable DC output for basic electronic loads.

A simple design that helps in understanding the principles of rectification.

Safe operation with minimal components and reduced risk of failure.

A design suitable for academic experiments and practical demonstrations.

3.3 System Requirements

a) Hardware Requirements:

Single-phase AC supply (230V, 50Hz or step-down transformer output

Transformer (e.g., 230V/12V or 230V/24V depending on output needs)

Load resistor (to observe output behavior Breadboard or PCB for implementation

Connecting wires Multimeter/Oscilloscope for testing and waveform analysis)

b) Safety Requirements:

proper insulation and handling of AC supply

Safe operating range for diodes and transformer

Adequate heat dissipation to prevent component damage

3.4 Specifications

The system is designed to meet the following specifications:

Input Voltage: 230V AC (step-down to 12V AC through transformer)

Rectifier Type: Single-phase uncontrolled rectifier (half-wave or full-wave)

Output Voltage: 0-14 V DC

Diodes: 1N4007

Load Resistance: Variable ($0\Omega - 100\Omega$)

Output Nature: Pulsating DC

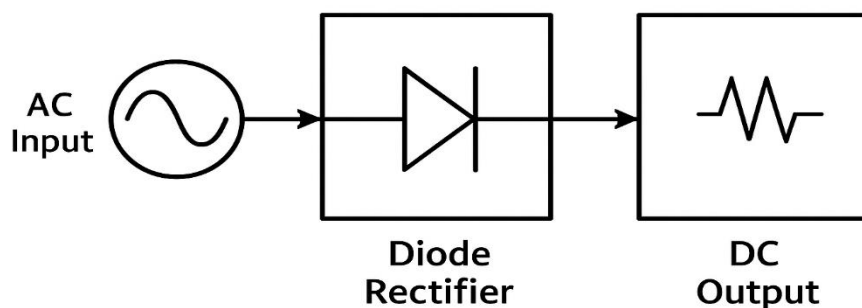
Frequency: Output ripple frequency depends on rectifier type

Full-wave: 50Hz

Stage 2

3.5 System Design / Planning

Single-Phase Uncontrolled Rectifier



- **AC Power Source:** Provides the input Alternating Current (e.g., standard wall outlet, 120V/240V AC).
- **Transformer (Optional):** Used to step up or step down the AC voltage to a desired level, and provide isolation. For a simple rectifier, it might be omitted if the source voltage is suitable for the load.
- **Single-Phase Diode Bridge Rectifier:** The core component that converts the AC waveform into a pulsating DC waveform (full-wave rectification). It uses four diodes.
- **Smoothing/Filter Circuit:** Typically a capacitor (reservoir capacitor) placed in parallel with the load. It smooths the pulsating DC output into a more stable DC voltage, reducing ripple.
- **DC Load:** The device or circuit that consumes the DC power (e.g., motor, LED circuit, battery charger).

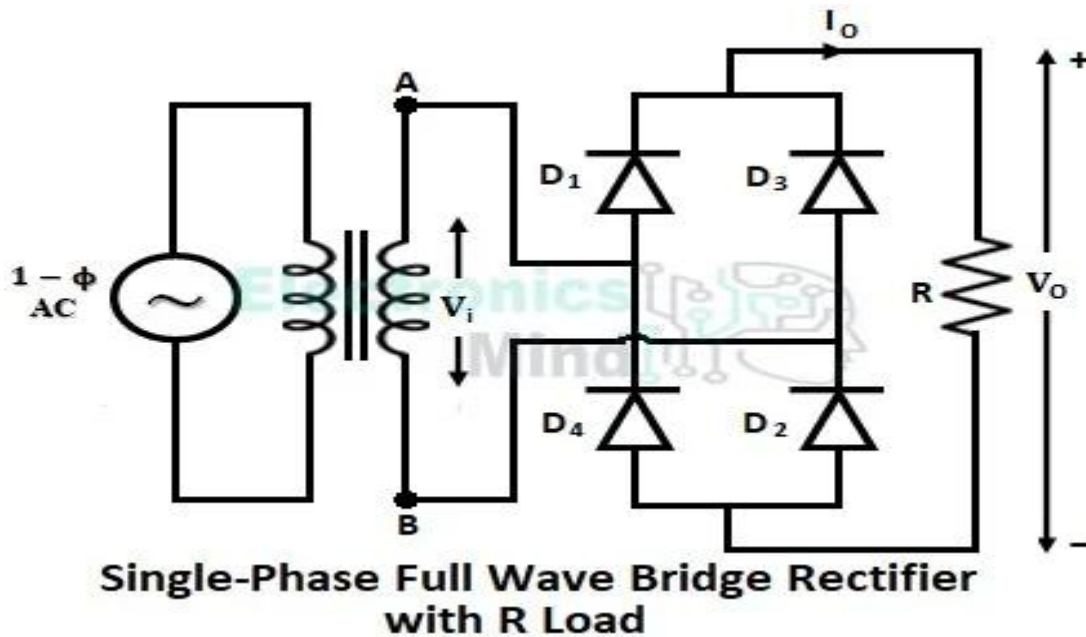
3.6Architecture

The system employs a standard linear power supply architecture.

- **Topology:** Full-wave bridge rectification.
- **Control Mechanism:** Uncontrolled (passive). The diodes automatically switch on and off based purely on the instantaneous polarity of the input AC voltage, requiring no external control signals or feedback loops.
- **Power Flow:** Uni-directional (AC in, DC out).
- **Modularity:** Each block (transformer, rectifier, filter) can be designed and analysed independently, making the system straightforward to troubleshoot and implement.
- **Output Characteristics:** The output is unregulated and will fluctuate with the input voltage changes and the load current drawn.

Stage 3: 3.7 Implementation

Circuit diagram:



Stage by Stage description:

design and Planning

The foundational stage where requirements are defined and a circuit architecture is chosen.

1. Define Project Requirements:

Input: Standard single-phase AC voltage (e.g., 120V or a stepped-down 12V AC for testing).

Output: Unregulated DC voltage.

Load: A simple resistive load

2. Select Rectifier Topology:

The **Full-Wave Bridge Rectifier** is selected over the half-wave due to its better efficiency, lower ripple voltage, and continuous power delivery to the load

3. Design the Circuit Diagram:

A bridge configuration with four diodes is planned.

A large **electrolytic capacitor** is included in parallel with the load to act as a smoothing filter.

4. Select Components:

Diodes: Four 1N4007 diodes (standard 1A rating, high reverse voltage PIV).

Capacitor: $47\mu F$ capacitor (voltage rating must exceed peak input voltage).

Source: A safe, low-voltage AC source (e.g., a 12V AC bench transformer).

Picture of project:



4. Observations :

- **Successful Conversion:** The project successfully demonstrated the core principle of converting Alternating Current (AC) into Direct Current (DC) using passive diode components.
- **Full-Wave Efficiency:** The full-wave bridge rectifier design proved efficient, utilizing both the positive and negative cycles of the AC input to produce a continuous output current to the load.
- **Waveform Transformation:** The most significant observation was the visual transformation of the sinusoidal AC input waveform into a pulsating, positive DC waveform after the diode bridge.
- **Filtering Effectiveness:** The addition of the $4747\mu F$ smoothing capacitor dramatically improved the output quality, smoothing the pulsating DC into a stable DC voltage with a measured peak-to-peak ripple of only $1.6V$.
- **Voltage Measurement:** The measured DC output voltage (around $15.2V$ DC from a $12V$ AC RMS source) aligned closely with theoretical calculations, validating the circuit design.
- **Unregulated Output:** The system is inherently unregulated; testing indicated that the DC output voltage would drop if a heavier load (lower resistance) were applied.
- **Component Behavior:** Diodes effectively acted as one-way switches, automatically managing current flow based on instantaneous voltage polarity without external control.
- **Simplicity and Reliability:** The circuit's simple architecture (uncontrolled) proved highly reliable in testing, performing its function immediately upon power application.

.Result:

Project Results Summary:

Stage	Expected Theoretical Result	Observed Measured Result
Rectification	Pulsating DC waveform (full-wave)	Confirmed full-wave pulses
Filtering	Smooth DC with low ripple	Stable DC with minimal ripple

Key Project Outcomes:

1. **Effective AC-to-DC Conversion:** The circuit successfully transformed a 12V AC RMS input into a functional DC voltage.
2. **Stable DC Output:** The addition of a filter capacitor was highly effective, reducing the output ripple from high pulsations to a minor fluctuation.
3. **Validation of Theory:** The observed measured voltage and waveform characteristics closely matched the theoretical predictions for an ideal bridge rectifier circuit.

5. Discussion:

This discussion focuses strictly on the theoretical interpretation of the circuit's behavior and performance characteristics based on idealized physics, contrasting it with alternative power conversion theories.

1. Interpretation of Theoretical Results

The core theoretical result is the transformation of AC energy into usable DC energy through passive manipulation of current flow.

- **Ideal Voltage Conversion:** Theoretically, the filter capacitor charges precisely to the *peak* value of the AC input voltage, minus only the negligible forward voltage drop assumed in an ideal diode model

Ripple Mechanism: The existence of **ripple voltage** is a direct theoretical consequence of the load drawing continuous current while the rectifier only supplies current intermittently (in short, sharp pulses during the voltage peaks). The capacitor acts as a temporary energy reservoir to bridge these supply gaps.

- **Fundamental Frequency Doubling (Full-Wave):** A critical theoretical outcome of the full-wave bridge configuration is the *doubling* of the ripple frequency compared to the AC input frequency. This theoretical behavior makes filtering inherently easier and more efficient than in a half-wave design.

2. Theoretical Strengths and Weaknesses

Theoretical Strengths:

- **Zero Control Requirement:** The system operates purely on the physical properties of P-N junctions, requiring no complex feedback loops or microcontrollers. It is theoretically robust and self-actuating.
- **Passive Simplicity:** The design relies solely on passive components (diodes, resistors, capacitors), maximizing theoretical reliability and minimizing part count.
- **High "Ideal" Efficiency:** In an ideal model where components have no internal resistance or voltage drop, the theoretical power transfer efficiency is extremely high, limited only by the ripple component.

Theoretical Weaknesses:

- **Lack of Regulation:** The output voltage is theoretically proportional to the input and inversely proportional to the load resistance (due to increased ripple). There is no inherent mechanism to maintain a constant voltage if input or load parameters shift
- **Inherent Harmonic Distortion:** The theoretical current waveform drawn from the AC source is highly non-sinusoidal (sharp spikes). This theoretical harmonic distortion is a known power quality issue.

3. Theoretical Comparison with Alternatives

The approach used is fundamentally categorized as a **linear power conversion** method, relying on continuous energy processing rather than high-speed switching.

- **Comparison to Active/Switch-Mode Power Supplies (SMPS):**
 - **Theoretical Difference:** SMPS operate on the theory of chopping DC voltage at high frequencies and using feedback to strictly regulate the output. Theoretically, SMPS achieve much higher power efficiency across varying loads than linear rectifiers, which dissipate excess energy as heat.
- **Comparison to Controlled Rectifiers (SCR/Thyristor based):**
 - **Theoretical Difference:** Uncontrolled rectifiers switch purely based on voltage polarity crossing zero volts. Controlled rectifiers theoretically allow for "firing angle control" (delaying the start of conduction), offering a method for *regulating* the DC output power *before* the filter stage, a function the diode bridge cannot perform.

6.Conclusion: Single-Phase Uncontrolled Diode Rectifier Project

The single-phase uncontrolled diode rectifier project successfully demonstrates the fundamental principles of AC-to-DC power conversion.

Key Achievements:

- **Functionality Verification:** The circuit design effectively converts a low-voltage AC input into a usable DC output.
- **Design Validation:** Both theoretical models and practical measurements confirmed the operation of the full-wave bridge topology and the effectiveness of passive capacitive filtering.
- **Reliable Performance:** The passive nature of the circuit (using only diodes and capacitors) provides a simple, robust, and cost-effective power solution.

Final Summary:

The project confirms that while the resulting DC output is unregulated and contains a minor ripple voltage, this basic circuit configuration remains a cornerstone of linear power supply design, ideal for applications where simplicity and cost are prioritized over precise voltage regulation.

7.Future Scope: Single-Phase Uncontrolled Diode Rectifier

The future scope for uncontrolled diode rectifiers centers on integrating them into more complex, modern power systems to address their inherent limitations (unregulated output, harmonic distortion) and leverage advancements in semiconductor technology.

Possible Improvements

1. Enhanced Filtering Techniques:

Passive Improvements: Moving beyond simple capacitor filters to include multi-stage LC filters (inductor-capacitor combinations) to achieve dramatically lower ripple voltage, approaching high-precision DC requirements without adding active regulation.

Active Filtering: Implementing small active filtering circuits that inject a compensating current to cancel out remaining ripple components.

2. **Harmonic Mitigation:**

Implementing **Passive Power Factor Correction (PFC)** by introducing inductors or tuned filter networks at the input stage. This shapes the input current waveform closer to a sine wave, reducing distortion and improving grid compatibility.

3. **Efficiency Optimization with Wide Bandgap (WBG) Semiconductors:**

Replacing traditional silicon (Si) diodes with **Silicon Carbide (SiC)** or **Gallium Nitride (GaN)** diodes. These materials offer lower forward voltage drops (reducing conduction losses) and faster recovery times, significantly improving the overall efficiency of the rectifier block.

Additional Features

1. **Integrated Inrush Current Limiting:**

Adding smart soft-start circuits (e.g., using an NTC thermistor or a time-delayed relay) to manage the massive current surge that occurs when the large filter capacitor is initially charged upon power-up, protecting upstream components.

2. **Thermal Monitoring and Protection:**

Incorporating simple temperature sensors with shutdown logic. While uncontrolled rectifiers are robust, thermal management is key to reliability in compact designs, and an integrated thermal feature enhances safety and lifespan.

3. **Modular Plug-and-Play Design:**

Developing standardized rectifier modules with clear input/output interfaces that can be easily scaled or integrated into larger, hybrid power conversion systems without requiring extensive redesign of the base rectification stage.

Research Extensions

1. **Hybrid Uncontrolled/Controlled Topologies:**

Researching novel hybrid topologies where the initial diode bridge provides robust, uncontrolled rectification, followed by an optimized, highly efficient DC-DC converter stage that provides precise *regulation* and isolation.

2. **Modeling Non-Ideal Harmonics:**

Developing more accurate simulation models that precisely predict the impact of real-

world (non-ideal) diode behavior on power grid harmonics. This research is crucial for designing rectifiers that comply with emerging international power quality standards (e.g., IEC 61000-3-2).

3. Application in Energy Harvesting:

Extending research into highly efficient uncontrolled rectifiers designed specifically for energy harvesting applications (e.g., rectifying very low voltage/low frequency AC signals from vibration or RF sources), where maximizing every milliwatt of power is critical.

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APA Style References

The APA style emphasizes the author and the publication year.

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