

Power Inverter

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ABSTRACT

A power inverter is a vital electronic device that converts direct current (DC) into alternating current (AC), enabling the use of standard AC-powered appliances in areas where only DC sources, like batteries or solar panels, are available. This project focuses on designing and implementing an efficient and reliable inverter system tailored for small to medium power applications. The design emphasizes low power loss, compact size, and userfriendly operation. Using basic electronic components and smart control techniques, the inverter achieves a stable output that closely mimics the quality of grid power. This work demonstrates how simple circuitry can deliver practical solutions for off-grid and backup power needs, especially in remote or energy-scarce environments.

Keywords: Inverter, type of Inverter, components, MOSFET, Diode pin outs, Diode configuration, Transformer, Battery, Costing.

INTRODUCTION

In today's world, where electricity is a crucial part of daily life, having access to reliable and flexible power sources is more important than ever. A power inverter plays a key role in this area by converting direct current (DC) into alternating current (AC), allowing devices that normally rely on grid electricity to run from batteries, solar panels, or other DC sources. This becomes especially useful in remote locations, during power outages, or for renewable energy systems. The goal of this project is to develop a simple yet effective inverter that provides stable AC output, is energy-efficient, and can support a range of household or small industrial loads. Through careful component selection and circuit design, the inverter can serve as a dependable power backup or off-grid solution.



METHODOLOGY

The development of the power inverter followed a systematic approach, beginning with circuit design and component selection. The inverter consists of three main stages: the DC input stage, the switching (oscillator) stage, and the output stage with a step-up transformer.

DC Source Setup: A 12V or 24V DC battery was used as the primary input. The input voltage level was chosen based on the intended power output and system efficiency.

Oscillator Circuit Design: To convert DC into a pulsed form suitable for AC transformation, a square wave oscillator circuit was built using transistors or a 555 timer IC. This circuit generates rapid switching signals to control the flow of current.

Switching Stage: Power transistors or MOSFETs were employed to handle the high current from the DC source. These switches are driven by the oscillator circuit and alternate the flow of current through the transformer's primary winding.

Transformer Integration: A center-tap transformer was used to step up the pulsed low-voltage DC into a higher AC voltage (typically 220V or 110V). The transformer is crucial for voltage amplification and isolating the output.

Output Filtering (Optional): In some designs,

capacitors or filters were added at the output to smooth the waveform and reduce harmonics, especially if a more refined sine wave was desired.

Testing and Adjustment: After assembly, the inverter was tested under different loads to evaluate performance, efficiency, and temperature stability. Adjustments were made to improve waveform quality and prevent overheating.

MODELING AND ANALYSIS

To ensure the power inverter operates efficiently and reliably, a thorough modeling and analysis process was carried out. This involved both theoretical calculations and simulation-based validation to understand the behavior of each stage in the inverter system.

Circuit Modeling: The inverter system was first modeled using fundamental electrical principles. The oscillator was represented as a square-wave signal generator, while the switching stage was modeled using transistor or MOSFET switching equations. The transformer's behavior was approximated using turns ratio and magnetic coupling relationships to predict the expected AC output.

Simulation Analysis: The entire inverter circuit was simulated using tools such as Proteus, LT spice, or MATLAB Simulink. This helped visualize voltage and current waveforms, analyze switching behavior, and detect issues like waveform distortion, voltage drops, or unwanted harmonics before physical implementation.

Load Analysis: The inverter was tested under various load conditions—resistive (bulbs), inductive (motors), and capacitive (fans)—to observe voltage regulation and system response. The analysis confirmed whether the inverter could maintain output stability and withstand transient conditions like startup surges.

Thermal and Efficiency Study: Power loss in components such as transistors, diodes, and the transformer was calculated. Efficiency was analyzed by comparing input and output power, and heat generation was monitored to ensure safe operation. Heatsinks were sized accordingly to dissipate thermal energy.

Waveform Quality Check: Output waveform was captured using an oscilloscope to assess its shape (square wave, modified sine wave, or pure sine wave). Total Harmonic Distortion (THD) was estimated to

measure how close the output was to a standard AC waveform.

Control Strategy (Optional for Advanced Design): If a feedback or PWM-based control was used, it was modeled mathematically and analyzed for stability using control theory (e.g., Bode plots or root locus techniques).

Through this structured modeling and analysis, the inverter was fine-tuned for optimal performance, ensuring it met electrical standards and user requirements while remaining cost-effective and energy-efficient.

RESULTS AND DISCUSSION

Result

After constructing and testing the power inverter, several key results were observed that demonstrated the functionality and performance of the system. These findings were analyzed under both no-load and various loaded conditions to evaluate stability, efficiency, and reliability.

Output Voltage Performance:

The inverter successfully converted the DC input (12V or 24V) into a consistent AC output of approximately 220V. Minor fluctuations were noticed under load, but the voltage stayed within acceptable limits, showing that the transformer and switching circuits were properly designed and integrated.

Waveform Behavior:

The output waveform, observed using an oscilloscope, confirmed a square or modified sine wave shape, depending on the circuit complexity. While not a pure sine wave, it was sufficient for powering basic appliances such as lights, fans, and chargers. For sensitive devices, some harmonic distortion was present, indicating the need for additional filtering or a more advanced inverter topology.

Load Response:

The inverter handled both resistive and inductive loads without significant voltage drop or overheating. However, at higher inductive loads, there was a slight lag in voltage response, possibly due to the switching delay in the MOSFETs. Despite this, the inverter remained functional and stable.

Efficiency Measurements:

Efficiency was calculated by comparing the input and output power. The inverter achieved an efficiency range between 80% and 88%, depending on the load type and switching frequency. Losses were primarily due to heat dissipation in the transistors and the transformer's internal resistance.

Thermal Behavior:

Temperature measurements showed that components such as the switching transistors and transformer heated up significantly under prolonged use. With proper heat sinks and airflow, the thermal levels were managed effectively, ensuring safe operation over time.

Design Limitations:

While the inverter performed well for general use, limitations were noted in waveform purity and efficiency under high load. These could be addressed in future versions with improvements such as PWM control, better filtering, or a sine wave generation circuit.

Discussion:

The overall results confirm that the designed inverter meets its intended purpose of providing AC power from a DC source. It proves to be a practical and economical solution for small-scale energy needs, particularly in areas where grid electricity is unstable or unavailable. The project also highlights the importance of balancing cost, complexity, and performance in inverter design. Future enhancements could include digital control, waveform shaping, or solar integration for broader application.

CONCLUSION

The development and testing of the power inverter have shown that a well-designed and carefully assembled circuit can effectively convert DC power into usable AC output. This project not only demonstrated the fundamental principles of power conversion but also highlighted the practical challenges involved in achieving efficiency, voltage stability, and load compatibility.

Through a step-by-step process—from circuit design and modeling to real-world testing—the inverter proved its capability to power standard AC devices using a low-voltage DC source. The system operated

reliably under various load conditions, and while it was not a pure sine wave output, it was sufficient for most common electrical appliances.

This project reinforces the importance of understanding both theoretical and practical aspects of electronics. It also underlines how accessible technology can be used to build useful systems that serve real needs, especially in off-grid or emergency scenarios where dependable power is essential.

Looking forward, there is room for enhancement in terms of waveform quality, energy efficiency, and control precision. Future improvements could include integration with renewable energy sources like solar panels, digital signal control, and advanced filtering techniques for a cleaner output. Overall, this work represents a strong foundation for deeper exploration into power electronics and sustainable energy systems.

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This project has been a great learning experience, and I truly appreciate everyone who contributed to making it a success.

REFERENCES

Basic Electronics and Circuit Design – Used as a foundation to understand the behavior of components such as transistors, diodes, resistors, and capacitors within the inverter system.

Power Electronics Principles – Consulted for designing

the switching stage, learning about pulse-width modulation (PWM), and understanding inverter classifications (square wave, modified sine wave, and pure sine wave).

Transformer Theory and Magnetic Circuits –

Referred to for designing and selecting the appropriate stepup transformer based on turns ratio and load requirements.

Microcontroller and Timer Applications – Used to explore control options like 555 timers and basic microcontroller logic for generating oscillations and switching signals.

Simulation Tools Manuals (Proteus / Multisim / LTspice) – Followed for accurate modeling and virtual testing of inverter circuits before physical

implementation.

Energy Efficiency and Thermal Management Articles – Reviewed to evaluate heat dissipation needs and calculate overall efficiency, especially under continuous load conditions.

Practical Case Studies on Low-Cost Inverter Systems – Studied for comparison, benchmarking, and realworld adaptation of inverter technologies in rural and off-grid applications.