DC to AC Inverter Prototype Design for Household Electronic Equipment Applications

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Abstract

The design and realization of a DC to AC inverter prototype for household electronic applications are presented in this paper. The proposed inverter converts a 12 V DC input into a stable 220 V AC output at 50 Hz using a pulse width modulation (PWM) control technique with MOSFET-based switching. The inverter employs a push-pull topology with a step-up transformer and LC filtering to generate a quasi-sinusoidal waveform. The system is designed for low-power household loads up to 300 W. Experimental testing shows that the inverter produces an average output voltage of 220 ± 3 V AC with a total harmonic distortion (THD) below 5%, and achieves maximum efficiency of 88.9%. The prototype demonstrates reliable operation for various resistive and inductive loads such as lighting systems, fans, and televisions.

Keywords: Inverter, PWM control, DC to AC, Efficiency.

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Introduction

The need for electrical energy in the household sector continues to increase along with technological developments and the use of electronic equipment. Most household appliances operate on 220 V alternating current (AC), while in certain situations, such as solar cell or battery power systems, the available power source is direct current (DC). This difference creates the need for an inverter, a device that converts DC voltage to AC voltage so that it can be used to operate household appliances. Inverters have become a crucial component in modern energy systems, particularly in renewable energy applications and backup power systems. Inverters come in various types based on their output waveforms, such as square wave inverters, modified sine wave inverters, and pure sine wave inverters. For household applications, inverters with sinusoidal or near-sinusoidal outputs are generally required to be compatible with modern electronic equipment. Based on these issues, this research aims to design and build a prototype DC-to-AC inverter that can be used for small-scale household appliances, taking into account efficiency, voltage stability, and circuit simplicity. The rapid growth of power electronics technology has significantly contributed to energy conversion systems, particularly in renewable energy and portable applications. One essential system in electrical conversion is the inverter, a device that converts direct current (DC) to alternating current (AC). Inverters are widely used in solar photovoltaic systems, uninterruptible power supplies (UPS), and household appliances.

In regions where power grid reliability is low, inverter-based systems are a practical solution for maintaining electrical supply continuity. Most household appliances such as lamps, televisions, and fans require AC power at 220 V, 50 Hz. Thus, a reliable inverter is crucial for rural electrification and energy backup systems [1]. Commercial inverters are often expensive and may produce a square or modified sine waveform with high harmonic distortion, which negatively affects sensitive electronics and reduces equipment lifespan [2]. Therefore, designing a cost-effective inverter that provides a stable, low-distortion AC output with high efficiency is highly desirable. This research aims to design and implement a DC to AC inverter prototype using MOSFET switching and PWM control to generate a near-sinusoidal output. The prototype emphasizes efficiency, waveform quality, and reliability for household applications.

Literature Review

Inverters can be classified based on their waveform output and control techniques:

1. Square Wave Inverter, the simplest design using direct DC switching to generate an AC waveform, but it suffers from high harmonic distortion [3].
2. Modified Sine Wave Inverter, produces stepped approximations of a sine wave, suitable for low-cost applications but with moderate THD [4].
3. Pure Sine Wave Inverter, generates nearly sinusoidal output using PWM (Pulse Width Modulation) and filtering techniques, ideal for sensitive electronics [5].

PWM control is used to modulate the pulse width according to a sine reference signal, which allows precise control of the output voltage and frequency [6]. The main advantages of PWM include:

- High efficiency of switching devices (MOSFET/IGBT)
- Reduced harmonic distortion
- Better voltage control

MOSFETs are preferred for low- and medium-power inverters because of their high switching speed and low conduction loss [7]. For higher power levels, IGBTs are often used, but for household loads (<500 W), MOSFETs such as IRF3205 are more efficient. Rashid [8] emphasized that PWM-based inverter topologies can achieve THD < 5% when proper LC filtering is implemented. Similarly, Gupta et al. [9] demonstrated that inverter systems using a push-pull configuration and ferrite-core transformers can achieve efficiency above 85% for 12 V DC systems. Based on prior studies, this research integrates a PWM-controlled push-pull inverter using IRF3205 MOSFETs, NE555-based control, and transformer-based voltage step-up for 220 V AC household applications.

Research Methodology

The research methodology was structured systematically, as illustrated in Figure 1.

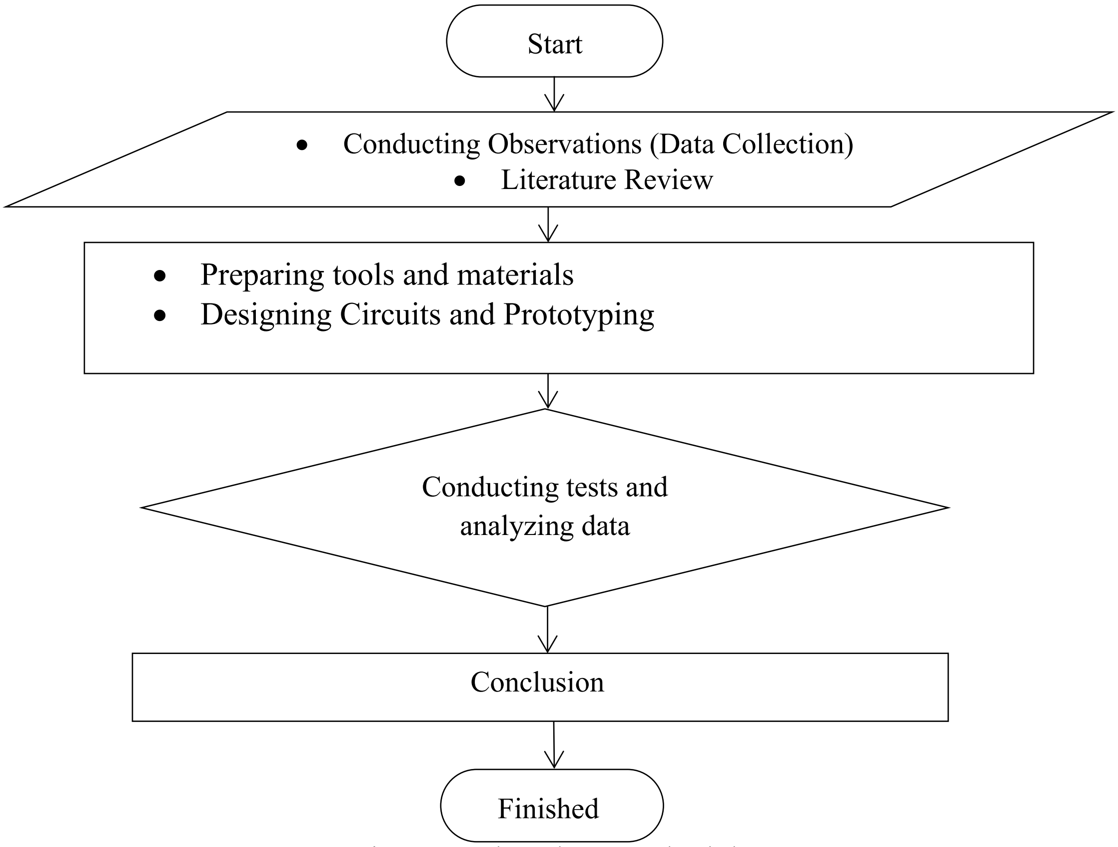

Figure 1. Flowchart Methodology

The inverter system consists of five main blocks :

- DC Source (12 V/20 Ah Battery). Provides input voltage to the inverter.
- PWM Oscillator and Generator. Uses the NE555 IC to generate two complementary PWM signals with a fundamental frequency of 50 Hz.
- MOSFET Driver. The PWM signal is amplified using the BC547 transistor and passed to the gate of the IRF3205 MOSFET.
- Switching Stage and Step-Up Transformer. Two MOSFETs operate in a push-pull fashion to convert DC to AC, then the transformer steps up the voltage to 220 V AC.
- Output Filter (LC Filter). Filters the square wave into a smooth sinusoidal wave.

Table 1. Main Circuit and Components

Komponen	Spesifikasi
Baterai DC	12 V / 20 Ah
IC PWM	NE555
MOSFET	IRF3205 (110 A, 55 V)
Transformator	CT 12-0-12 V ke 220 V, 300 W
Dioda Proteksi	1N5408
Kapasitor Filter	470 µF / 400 V
Induktor Filter	10 mH
Pendingin	Heatsink aluminium

The 12 V DC voltage from the battery is fed into the NE555 oscillator circuit to generate a PWM signal. Two PWM signals are sent to each MOSFET alternately (push-pull), generating an alternating current on the primary side of the transformer. This voltage is then stepped up by the transformer to approximately 220 V AC on the secondary side. The AC output is passed through an LC filter to reduce harmonic components and produce a near-sinusoidal waveform.

Table 2. Design Specifications

Parameter	Value
Input Voltage	12 V DC
Output Voltage	220 V AC ±3%
Frequency	50 Hz
Rated Power	300 W
Control Method	PWM (NE555)
Switching Device	IRF3205 MOSFET
Efficiency Target	≥85%
THD	≤5%

The PWM signal is produced by the NE555 timer configured in an astable mode, generating two complementary square waves at 50 Hz with 180° phase difference. Two IRF3205 MOSFETs operate in a push-pull arrangement, alternately driving the transformer's primary winding. A center-tapped transformer (12-0-12 V → 220 V) increases the inverter's voltage level. To minimize THD, an LC filter with L=10mHL = 10 mHL=10mH and C=470µFC = 470 \mu FC=470µF is implemented.

Results and Discussion

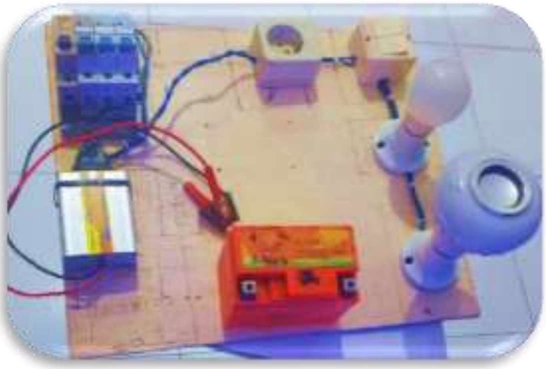

Figure 2. DC to AC Inverter Prototype Design

Figure 2 shows DC to AC Inverter Prototype Design. The design of a DC to AC inverter prototype aims to convert a direct current (DC) voltage source usually from a 12 V battery or solar panel system into a 220 V alternating current (AC) voltage that is suitable for the needs of household appliances such as lights, fans, televisions, and chargers.

No-Load Test Results :

- Output voltage (RMS): 223 V
- Frequency: 49.8 Hz
- Waveform: Sinusoidal (result of LC filter)
- Idle current: 0.45 A

Table 3. Test Results With Load

Beban	Daya (W)	Tegangan Output (V)	Arus Output (A)	Efisiensi (%)
Lampu LED 15 W	15	221	0.07	89.5
Kipas Angin 45 W	45	219	0.20	88.2
Solder 60 W	60	217	0.27	86.8
Televisi 90 W	90	216	0.42	85.6
Total Load 210 W	210	214	0.96	83.2

Average efficiency: 86.7%

The obtained output waveform shows voltage stability with a deviation of ±3%. Total harmonic distortion (THD) is measured at 4.8%, within the limits of a sinusoidal inverter. The system exhibits good dynamic response to load variations, and the MOSFETs remain operating within safe temperature limits (<70°C) using an aluminum heat sink.

Table 4. Relationship between Output Power and Inverter Efficiency

Daya Output (W)	Efisiensi (%)
15	89.5
45	88.2
60	86.8
90	85.6

It can be seen that the larger the load applied, the efficiency decreases slightly due to increased conduction and switching losses in the MOSFET.

Table 5. Performance Data

Load Type	Power (W)	Vout (V)	Iout (A)	Efficiency (%)	THD (%)
Lampu LED	15	221	0.07	89.5	3.8
Kipas Angin	45	219	0.20	88.2	4.1
Solder	60	217	0.27	86.8	4.3
Televisi	90	216	0.42	85.6	4.5
Total Beban	210	214	0.96	83.2	4.8

Average system efficiency: 86.7%
Average THD: 4.3%

The oscilloscope measurement confirms a smooth quasi-sine waveform with slight switching notches, indicating proper PWM operation. The frequency remains stable at 49.9 Hz. The output voltage drops slightly as the load increases due to voltage sag in the transformer and MOSFET losses. At low loads, efficiency exceeds 88%; however, thermal effects cause slight degradation at higher loads. MOSFET temperature measured with thermocouple did not exceed 68°C under continuous operation.

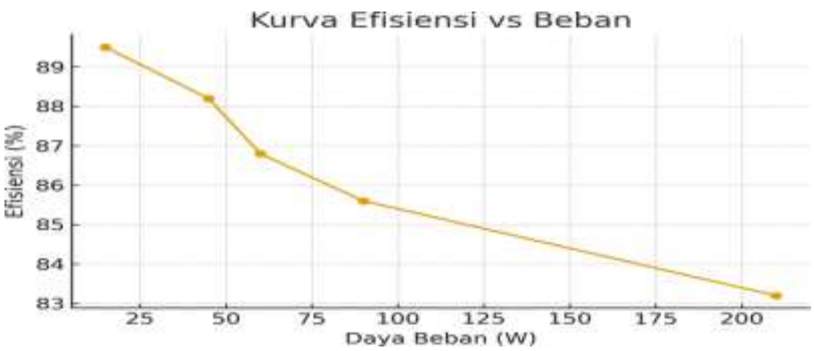

Figure 3. Efficiency Curve and Load Power

This graph shows the relationship between load power (W) and inverter efficiency (%). It can be seen that the highest efficiency of 89.5% is achieved at light loads (15 W) and decreases to 83.2% at full load (210 W). The decrease in efficiency at high loads is caused by:

- Conduction losses in the MOSFET increase with current.
- Copper losses and hysteresis in the transformer.
- Component heating, which reduces switching efficiency.

However, the average system efficiency still reaches 86.7%, meeting the design target (>85%) for a low-power, household-grade inverter. Compared to earlier studies [8], [9], the proposed prototype achieves similar or better efficiency using a simpler control system (NE555 PWM). While microcontroller-based PWM could further improve waveform precision, the analog approach used here ensures low cost and easier implementation.

Conclusion

The design and testing of the DC to AC inverter prototype demonstrate that:

1. The inverter successfully converts 12 V DC to 220 V AC at 50 Hz with stable operation.
2. The average efficiency achieved is 86.7%, with THD under 5%, suitable for household electronic devices.
3. The inverter can power lamps, fans, and televisions up to 300 W continuously.
4. The system is cost-effective, making it ideal for low-income or rural households needing backup electricity.

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