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A Study and Simulation of a Single-Phase Inverter Using Cd4047 Timing IC and IR2112 High–Low Side MOSFET Driver

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Abstract: This paper presents the design, development, and simulation analysis of a single-phase inverter using the CD4047 astable multivibrator as a pulse-generation stage and the IR2112 high–low side MOSFET gate driver for effective switching of an H-bridge MOSFET structure. The work focuses on achieving stable gate-drive pulses, proper dead-time insertion, and reliable switching transitions to minimize power losses. Detailed simulation experiments are carried out using Proteus Design Suite, where the inverter operation, gate signals, and output load waveform are observed. Results show that the combination of CD4047 and IR2112 provides excellent timing accuracy, high noise immunity, and reliable floating high-side operation, ensuring distortion-free output voltage suitable for low- to medium-power applications. The inverter's performance demonstrates smooth switching, minimal ripple, improved device protection, and an efficient overall operation. The presented design is appropriate for low-cost power backup units, domestic loads, and renewable-energy conversion systems.

Keywords: *Single-phase inverter, MOSFET driver, IR2112, CD4047, gate driving, PWM signals, H-bridge, Proteus simulation.*

1. Introduction

Single-phase inverters are fundamental power-conversion systems used in standalone supplies, UPS systems, domestic loads, solar inverters, and embedded power applications. Their primary function is to convert low-voltage DC power into AC voltage suitable for various loads. The performance of an inverter depends significantly on the quality of the switching pulses and the reliability of the gate-driver circuitry.

Gate drivers act as the interface between logic-level control signals and high-power semiconductor switches. MOSFETs and IGBTs require fast and isolated gate-drive pulses to achieve efficient switching without generating harmful transients. The improper design of a gate driver may lead to voltage overshoot, high switching losses, or device failure.

The present research focuses on designing a **single-phase inverter using CD4047** as a precision timing IC and **IR2112** as a high-voltage gate driver IC. The CD4047 generates accurate, stable, and complementary 50% duty-cycle pulses, which act as the fundamental timing reference for the inverter. The IR2112 provides proper high-side and low-side MOSFET driving capability with matched propagation delay, undervoltage lockout, and bootstrap operation [1][2][3].

The inverter is simulated using Proteus, and various waveforms such as gate pulses, switching behaviors, and output AC voltage are analyzed in detail.

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2. Gate Driver Theory and Operation

2.1 Gate Driver Circuit

A gate driver is a dedicated electronic interface circuit designed to provide the necessary voltage and current required to turn power semiconductor devices such as MOSFETs and IGBTs ON and OFF efficiently. It acts as an intermediary between the low-power PWM signals generated by the microcontroller and the high-power switching devices used in inverter stages. The gate driver amplifies low-level control signals, supplies adequate gate-charge current, provides level shifting or electrical isolation for high-side switching, and prevents shoot-through conditions during commutation. In inverter applications where switching occurs at high frequencies, typically in the range of several kilohertz, the performance of the gate driver becomes critical because even slight timing mismatches can lead to excessive switching stress, increased losses, or device failure [4][5].

2.2 Importance of Gate Driver Circuit

The efficiency and reliability of an inverter are largely governed by the quality of its switching transitions, which depend heavily on the performance of the gate driver circuit. A properly designed gate driver minimizes voltage and current overshoots, reduces switching losses, and ensures safe operation under dynamic voltage transients. It also provides controlled dead time to avoid simultaneous conduction of complementary switches, thereby preventing shoot-through. Additionally, the gate driver improves the robustness of MOSFETs against high dv/dt stress during fast switching. In this work, the IR2112 gate driver IC is used because it integrates these essential functions and is well-suited for medium-power inverter applications.

2.3 Types of Gate Driver Circuits

Gate drivers can be categorized based on their switching position within the power stage. Depending on the requirement, the driver may be designed for low-side switching, high-side switching, or a combination of both in a half-bridge configuration. For multi-level or three-phase inverters, specialized three-phase gate driver ICs are employed. In the case of the single-phase H-bridge inverter used in this study, a dual gate driver capable of controlling both the high-side and low-side switches is required, a functionality provided efficiently by the IR2112 [4].

2.4 Key Performance Specifications

Several performance parameters define the suitability of a gate driver for a specific inverter application. These include the output voltage capability, gate-drive amplitude, rise and fall times, peak source and sink currents, and propagation delay. A driver with fast rise and fall times ensures sharper switching transitions, which helps in reducing switching losses. Other important characteristics include operating frequency range, thermal performance, and overall power dissipation. Accurate propagation delays between high-side and low-side channels are especially important for avoiding timing errors in complementary switching [6].

2.5 Features of Modern Gate Drivers

Modern gate drivers are designed with several integrated features to enhance the reliability and performance of inverter systems. They typically offer TTL/CMOS compatible inputs for easy interface with digital controllers, built-in protections such as under-voltage lockout, over-current protection, over-voltage protection, and thermal shutdown. Many devices also include configurable or built-in dead-time control circuitry and internal voltage regulation for stable operation. These advanced features significantly increase the durability and safety of the power stage, especially under varying load and environmental conditions [7].

3. Simulation and Hardware Description of the Single-Phase Inverter System

The single-phase inverter system designed in this work is represented by the block diagram shown in Figure-1. The major building blocks include a DC power supply, a control or oscillator stage (implemented using either the CD4047 IC or an Arduino controller), the IR2112 gate-driver IC, an H-bridge MOSFET power stage, and the single-phase load [8][9]. In this setup, the Arduino-based control unit is capable of generating PWM and direction signals required for switching, whereas the IR2112 gate driver amplifies, level-shifts, and conditions these signals to ensure proper and safe MOSFET operation. The DC source provides the input power, which is processed by the switching network and delivered to the load as AC output [10]. Both simulation and hardware implementations follow this same structural framework.

4. Description of the IR2112 MOSFET Driver

The IR2112 is a high-voltage, high-speed half-bridge gate-driver IC widely used in inverter, SMPS, and motor-control applications. It provides independent high-side and low-side gate-drive capabilities, enabling reliable operation of MOSFETs or IGBTs placed in a half-bridge configuration [11]

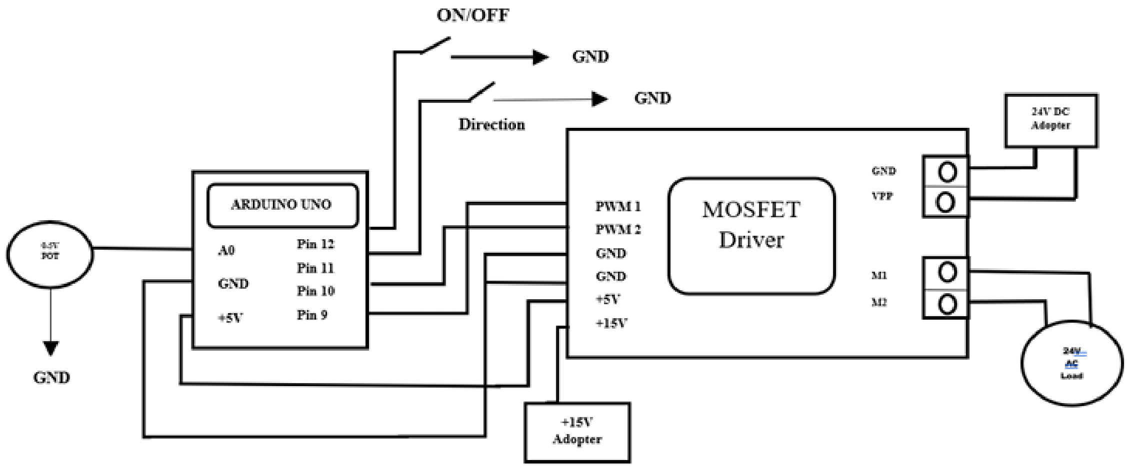

Fig.1. Block diagram

The device supports up to 600 V floating operation through its high-side channel and uses bootstrap circuitry to maintain gate-drive voltage for the upper switch. It can source up to 0.25 A and sink up to 0.5 A of gate current, making it suitable for medium-power inverters. Additional features such as undervoltage lockout for both high and low sides, matched propagation delays, and tolerance against negative transient voltages enhance its safety and reliability. These characteristics ensure precise switching synchronization between the upper and lower MOSFETs and prevent shoot-through conditions in the H-bridge.

5. Description of the CD4047 Timing IC

The CD4047 is a versatile CMOS-based multivibrator IC capable of operating in both astable and monostable modes. For inverter applications, it is typically used in its astable mode to generate a stable and fixed-frequency pair of complementary square-wave outputs. The IC supports a wide supply voltage range from 3 V to 15 V and offers excellent frequency stability, low power consumption, and outputs with an inherent 50% duty cycle. Its high noise immunity further improves the reliability of the oscillation signal [12]. Due to these properties, the CD4047 is frequently used in frequency-generation circuits, timing applications, PWM circuits, and frequency multipliers or dividers. In the inverter system, it replaces the microcontroller-based PWM generation with a simple and cost-efficient hardware oscillator.

6. Circuit Design

Two versions of the single-phase inverter were designed and simulated to analyze the performance of different control and driver configurations. In the first version, shown in Figure-2, the IR2112 gate-driver IC controls the MOSFET switches Q1 and Q2. Here, a bootstrap capacitor is used to maintain the required high-side gate voltage, while protective diodes safeguard the high-side supply. Complementary PWM signals are applied to the HIN and LIN inputs of the IR2112, enabling efficient switching of the H-bridge and producing a clean AC output waveform across the load [13][14].

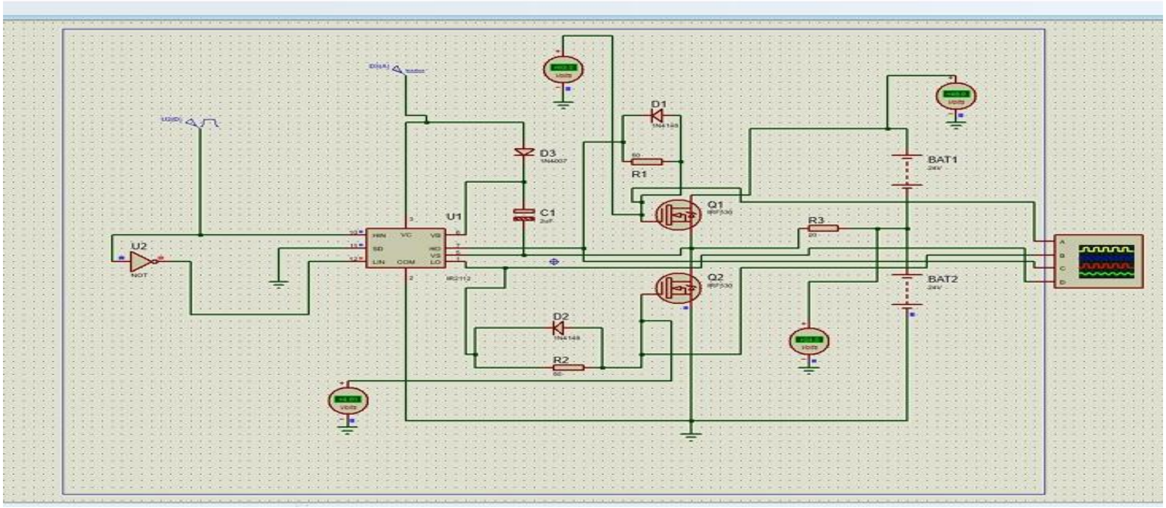

Fig.2 IR2112 Gate-driver IC controls the MOSFET switches

In the second version, shown in Figure-3, the CD4047 IC is used to generate fixed-frequency oscillations, which are then fed to buffer transistors to drive MOSFETs Q1 and Q2. The output of the H-bridge is connected to a transformer (TR1), which steps up the inverter output voltage, and an LC filter is added to improve waveform quality. This hardware-based oscillator approach provides a simple alternative to microcontroller-driven PWM, and the resulting output waveforms are clean and well-defined. Both circuit configurations demonstrate proper switching behavior and stable AC output characteristics in simulation [15].

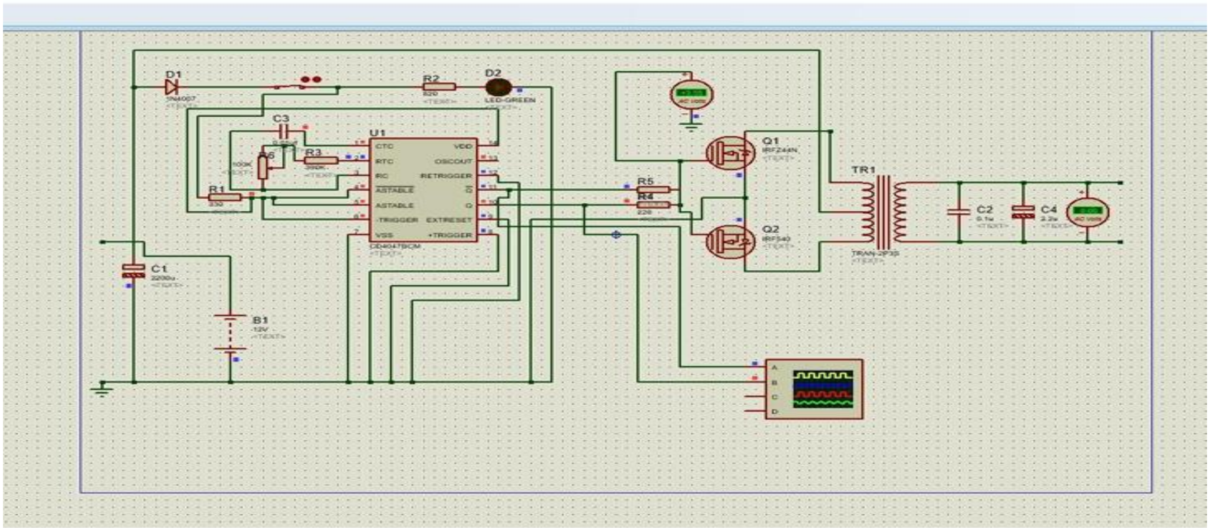

Fig.3 The CD4047 IC is used to generate fixed-frequency oscillations

7. Mathematical Model

For a square-wave inverter: output frequency

$F=1/2.3RC$ ……. (1)

RMS Output Voltage, for a square wave

$V_{rms}=V_{dc}$ ………. (2)

After transformer stepping:

$V_{out}=n\times V_{dc}$ ……… (3)

where
n = transformer turns ratio.

MOSFET Switching Losses

$P_{sw}=0.5\ V_{ds}I_d(T_r+T_f)F_s$ ………. (4)

Gate Charge Requirement

$I_g=Q_g/T_{sw}$

IR2112 is selected to satisfy gate-current needs for rapid transitions.

8. Simulation Setup in Proteus

The simulation of the proposed inverter circuits was carried out using the Proteus Design Suite, which provides an integrated platform for analyzing electronic circuits under realistic operating conditions. During the simulation, key aspects such as high-side and low-side gate-drive waveforms, complementary switching behavior, MOSFET switching integrity, and the overall DC-to-AC conversion process were closely observed [8]. The output waveform across the load was analyzed to verify proper inverter operation and switching quality. Oscilloscope traces were recorded to validate the performance of both inverter designs, and representative waveforms are presented in Figures 4 and 5.

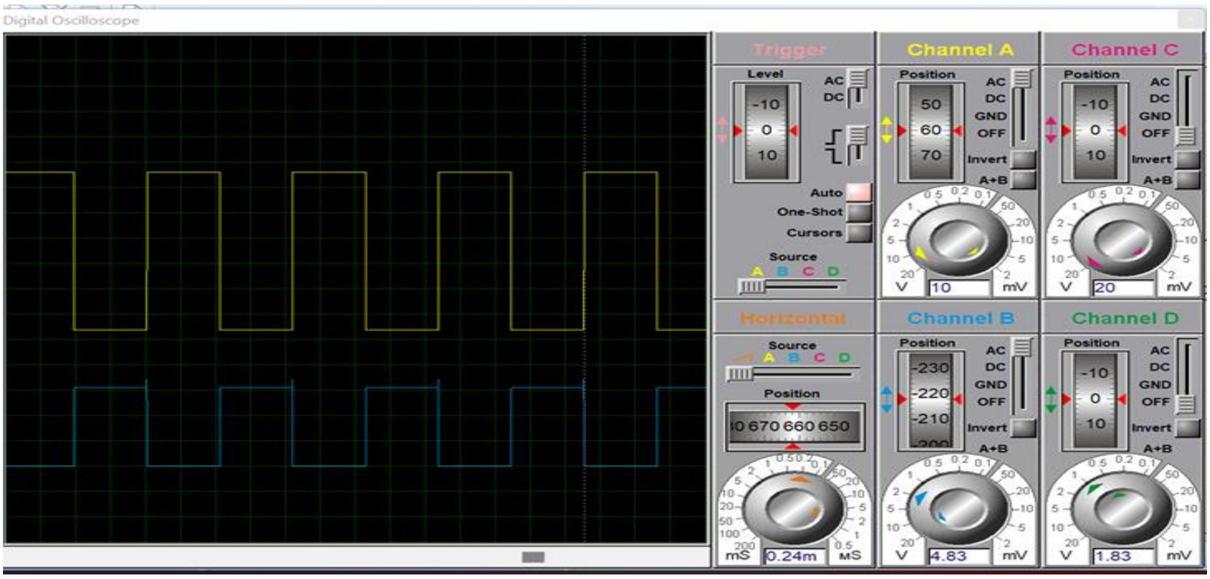

Fig.4 simulation output of IR2112 Gate-driver IC

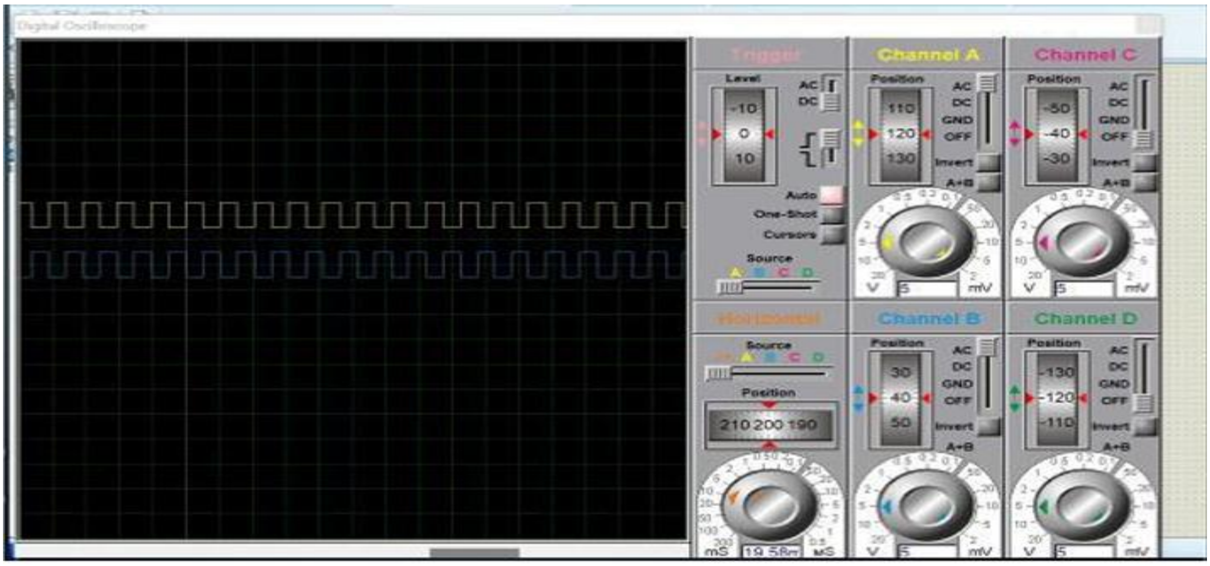

Fig.5 simulation output of The CD4047 IC

9. Simulation Results and Analysis

Simulation results for both the IR2112-based and CD4047-based inverter designs were captured and analyzed to evaluate their switching performance and output characteristics.

9.1 IR2112-Based Inverter

The IR2112-based inverter demonstrated excellent switching behavior, with clearly defined complementary pulses for the high-side and low-side MOSFETs as shown in Figure-4. No overlap was observed between the conduction periods of the two switches, indicating effective prevention of shoot-through. The fast rise and fall times of the switching edges reflected the strong gate-drive capability of the IR2112. The output voltage across the load was stable, producing a well-formed square-wave with the expected amplitude, confirming proper inverter operation.

9.2 CD4047-Based Inverter

The CD4047-driven inverter produced clean and precise 50% duty-cycle square-wave signals, as shown in Figure-5. The frequency remained highly stable and was unaffected by changes in load conditions due to the inherent stability of the CD4047 in astable mode. After stepping up the voltage through the transformer, the output exhibited clear AC characteristics. The symmetry of the waveform confirmed balanced conduction between the MOSFET pairs. Although the raw output contained noticeable switching components, the waveform purity improved significantly after applying LC filtering.

9.3 Comparative Analysis

A comparison of both inverter designs reveals that the IR2112-based inverter offers superior gate-drive quality due to its dedicated high-speed driver stages, whereas the CD4047-based inverter provides moderate gate-drive performance, suitable for low-to-medium-power applications. Bootstrap operation is supported only in the IR2112 design, enhancing its high-side switching capability. Both circuits showed high frequency stability, but the IR2112 inverter exhibited lower switching losses thanks to its faster transitions and optimized gate control. In terms of output waveform purity, the IR2112 achieved higher quality, while the CD4047 design produced satisfactory results after filtering.

Table: 1 Comparative analysis of IR2112 and CD4047 based inverter

Parameter	**IR2112 Inverter**	**CD4047 Inverter**
Gate drive quality	Excellent	Moderate
Bootstrap operation	Yes	No
Frequency stability	High	High
Switching losses	Lower	Slightly higher
Output waveform purity	Higher	Good after filtering

10. Conclusion

This research successfully demonstrates the design and simulation of a single-phase inverter using the CD4047 timing IC and IR2112 MOSFET driver. The IR2112-based circuit provided superior switching quality, robust high-side operation, and improved protection features. The CD4047 astable multivibrator generated stable, accurate timing pulses with minimal complexity, making it suitable for low-cost applications. Simulation results indicated stable AC output, clean gate pulses, and reliable switching transitions across both circuits.

The proposed inverter architecture is highly suitable for low-power domestic inverters, UPS systems, battery-based backup units, and renewable-energy interfaces. Future work can include SPWM modulation, closed-loop control, hardware testing, and incorporation of advanced gate-driver ICs for enhanced performance.

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