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Design and Development of a Low-Power 12 V DC to 230 V AC Square-Wave Inverter Using CD4047 and Power MOSFETs

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***Abstract*— Frequent short power interruptions create a need for small, inexpensive backup sources that can run loads such as LED lighting, Wi-Fi routers and phone chargers. Commercial inverters are generally rated for much higher power and waste a noticeable amount of energy when they run such light loads. This paper describes the design and development of a low-power inverter that converts a 12 V DC battery supply into a 230 V, 50 Hz square-wave AC output. The CD4047 CMOS multivibrator, operated in astable mode, generates two complementary 50 Hz signals. These signals drive a pair of IRFZ44N N-channel power MOSFETs through 100 Ω gate resistors, and the MOSFETs switch the two halves of a 12-0-12 V centre-tapped transformer in a push-pull arrangement. The transformer secondary delivers the stepped-up AC output. The timing network, switching stage and transformer are designed for a 50 W load with a target conversion efficiency above 80 %. Design calculations for the oscillator frequency, device currents and conduction losses are presented along with the testing procedure. The circuit uses a small number of low-cost, easily available components, which makes it suitable for emergency lighting and similar low-power backup applications.**

Keywords—CD4047, centre-tapped transformer, DC-AC conversion, low-power inverter, MOSFET switching, push-pull topology, square-wave inverter

I. Introduction

Power cuts are still a routine problem in many parts of India, particularly in semi-urban and rural areas. Even a short outage switches off lighting, internet connectivity and phone charging, which people now depend on for work and study. A battery-backed inverter solves this by converting the DC energy stored in a battery into AC at mains voltage and frequency.

Most inverters on the market are built for household loads of several hundred watts or more. When such a unit supplies only a lamp or a router, its fixed internal losses make up a large share of the total drawn from the battery, so the backup time is shorter than it could be. Units with pure sine-wave output also need microcontroller-based control and more expensive power stages, which is hard to justify for basic lighting backup.

This work presents a compact inverter intended specifically for such low-power loads. The design keeps the component count as low as possible. A single CD4047 IC produces the complementary 50 Hz drive signals, two IRFZ44N MOSFETs switch a centre-tapped transformer in push-pull mode, and the transformer raises the voltage to 230 V AC. The rest of the paper is organised as follows. Section II states the problem and the objectives. Section III reviews the relevant inverter topologies. Section IV describes the system design, Section V presents the design calculations and the testing plan, and Section VI concludes the paper with directions for future work.

II. Problem Statement and Objectives

Three issues motivate this work. First, high-capacity commercial inverters draw a relatively large standby (quiescent) current, which becomes significant when the connected load is only a few watts. Second, pure sine-wave micro-inverters need more complex control electronics, which raises their cost. Third, switching high currents at low voltage produces conduction and switching losses that heat the devices unless the switches are chosen carefully. The need, therefore, is a low-cost, portable and reliable 12 V DC to 230 V AC inverter that delivers a stable 50 Hz output to small loads.

The objectives of the project are as follows:

1) Pulse driver design: to design an astable multivibrator around the CD4047 that delivers complementary 50 Hz square-wave outputs.

2) Power switching stage: to implement a push-pull stage using low-$R_{DS(on)}$ N-channel power MOSFETs for efficient DC-to-AC conversion.

3) Step-up and efficiency evaluation: to step the 12 V switched waveform up to 230 V AC with a centre-tapped transformer and to verify a conversion efficiency above 80 % at a 50 W load.

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III. Literature Review

Voltage-source inverters are commonly grouped by the shape of their output waveform: square wave, modified (quasi-) square wave and sine wave [1], [2]. A sine-wave output is obtained by sinusoidal pulse-width modulation (SPWM) followed by filtering. It gives the lowest harmonic distortion, but it needs a microcontroller or dedicated PWM controller and fast switching devices. A square-wave inverter is the simplest of the three. Each switch stays on for exactly half of the output period, so the switching frequency equals the output frequency and switching losses are small. The price paid is harmonic content: an ideal square wave contains all odd harmonics, with the nth harmonic having an amplitude of 1/n of the fundamental, giving a total harmonic distortion of about 48 % [1].

For the power stage, the half-bridge, full-bridge and push-pull topologies are the usual choices [2], [3]. Bridge circuits need high-side gate drivers or bootstrap supplies. In the push-pull converter, on the other hand, both switches are connected to the negative battery terminal, so they can be driven directly by a logic-level oscillator. This makes the push-pull topology well suited to low-voltage battery inputs. Its drawbacks are that each switch must block roughly twice the supply voltage, and that the transformer leakage inductance causes voltage spikes at turn-off [2], [4].

The CD4047 is a CMOS multivibrator that provides complementary Q and $\overline{Q}$ outputs with a 50 % duty cycle from a single RC timing network, and it draws very little supply current [5]. Its outputs can swing up to the 12 V supply rail, which is enough to turn a standard power MOSFET fully on. The IRFZ44N offers a low on-resistance of 17.5 mΩ and a 55 V drain-source rating [6], giving enough voltage margin for a 12 V push-pull stage. Taken together, these properties make the CD4047 with IRFZ44N combination a practical and inexpensive basis for a low-power inverter.

IV. System Design and Methodology

A. Block Diagram

Fig. 1 shows the block diagram of the inverter. The 12 V battery supplies the oscillator and the centre tap of the transformer primary. The CD4047 generates two 50 Hz signals that are 180° out of phase. Each signal drives one MOSFET through its gate resistor, and the two MOSFETs connect alternate ends of the primary winding to ground. The resulting alternating flux in the core induces the stepped-up output at the secondary.

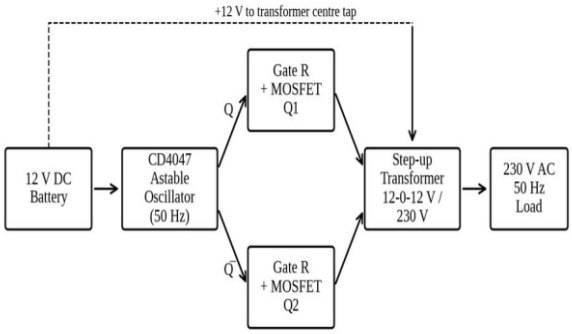


Fig. 1. Block diagram of the proposed low-power inverter

B. Oscillator Stage

The CD4047 is wired in astable mode, with an external resistor R and capacitor C setting the timing. For the complementary Q and $\overline{Q}$ outputs, the output period is about 4.40RC [5], so the output frequency is

$$f \approx 1 / (4.40\ R\ C) \quad (1)$$

With C = 100 nF and R = 45 kΩ, (1) gives f ≈ 50.5 Hz. In practice, R is made up of a fixed resistor in series with a trimmer potentiometer, so that component tolerances can be corrected and the output set to exactly 50 Hz during testing.

C. Gate Drive and Switching Stage

The Q and $\overline{Q}$ outputs have a 50 % duty cycle and are complementary, so the two MOSFETs conduct in alternate half-cycles. A 100 Ω resistor in series with each gate limits the peak current that charges and discharges the gate capacitance. It also damps high-frequency ringing formed by that capacitance and the wiring inductance. Because the CD4047 runs directly from the 12 V battery, the gate-source voltage is close to 12 V when a device is on. This is above the 10 V at which the IRFZ44N on-resistance is specified [6], so the devices are fully enhanced and conduction losses stay low.

When one MOSFET turns off, the other half of the primary induces about twice the battery voltage across it, plus a spike caused by leakage inductance. The 55 V rating of the IRFZ44N covers the nominal 24 V stress with reasonable margin. An RC snubber or a TVS diode across each drain can be added to clamp the spikes further.

D. Step-Up Transformer

A 12-0-12 V centre-tapped transformer with a 230 V secondary is used in reverse as a step-up transformer. The battery positive terminal is connected to the centre tap. When Q1 conducts, current flows through one half of the primary. When Q2 conducts, current flows through the other half in the opposite direction.

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This reversal of the magnetising current produces an alternating flux in the core, which induces a 50 Hz square-wave voltage in the secondary. The ideal gate signals and output waveform are shown in Fig. 2, and the circuit schematic is given in Fig. 3.

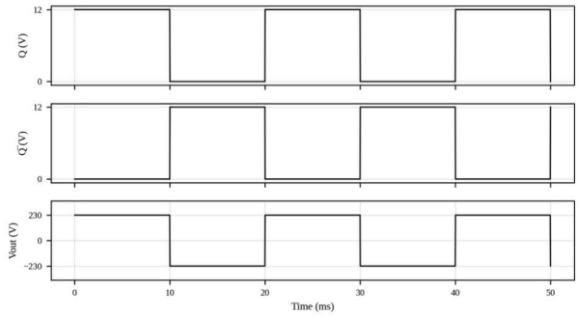


Fig. 2. Ideal waveforms: complementary gate signals Q and $\bar{Q}$, and the square-wave output voltage

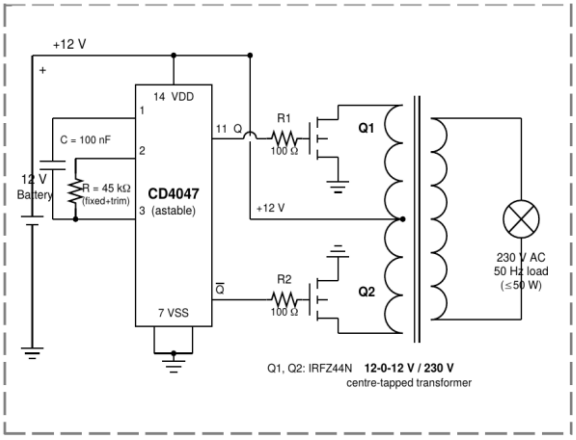


Fig. 3. Circuit diagram of the CD4047-based push-pull inverter

V. Design Calculations and Results

The main design parameters are summarised in Table I.

TABLE I
DESIGN PARAMETERS OF THE INVERTER

Parameter	Value
Input supply	12 V DC (lead-acid battery)
Output	230 V AC, 50 Hz, square wave
Oscillator IC	CD4047 (astable mode)
Timing resistor, R	45 kΩ (fixed + trimmer)
Timing capacitor, C	100 nF
Calculated frequency	50.5 Hz
Power switches	2 × IRFZ44N (55 V, 49 A)
RDS(on) (max, 25 °C)	17.5 mΩ
Gate resistors	100 Ω
Transformer	12-0-12 V / 230 V, centre-tapped
Rated load	50 W
Target efficiency	> 80 %

A. Transformer Ratio

For a square wave, the RMS value equals the peak value. A 12 V square wave across each half of the primary is therefore stepped up to 230 V with a turns ratio of about

$$N = V_s / V_p = 230 / 12 \approx 19.2 \quad (2)$$

In practice, the output will be slightly lower than 230 V under load because of winding resistance and the voltage drop across the conducting MOSFET.

B. Input Current and Device Losses

At the rated output of 50 W and the target efficiency of 80 %, the input power is 62.5 W, so the average battery current is

$$I_{in} = P_{out} / (\eta V_{dc}) = 50 / (0.8 \times 12) \approx 5.2 \text{ A} \quad (3)$$

Each MOSFET carries this current for half of every cycle, so its RMS current is $5.2/\sqrt{2} \approx 3.7$ A. Using the maximum on-resistance of 17.5 mΩ, the conduction loss per device is

$$P_{cond} = I_{rms}^2 R_{DS(on)} \approx 3.7^2 \times 0.0175 \approx 0.24 \text{ W} \quad (4)$$

The total conduction loss of the switching stage is therefore under 0.5 W at room temperature. On-resistance increases with junction temperature, so a small heat sink on each device is still advisable. Since the MOSFETs switch only 100 times per second, switching losses are negligible. Most of the loss is therefore expected in the transformer, through copper and core losses. On the output side, a 50 W load draws about 50/230 ≈ 0.22 A from the secondary. With a 12 V, 7 Ah battery, the ideal backup time at full load would be around 1.3 h. The actual figure will be lower once battery discharge characteristics are taken into account.

C. Testing and Measured Performance

The project has been planned in five phases. The literature review and topology selection are complete. Circuit simulation in LTspice/Proteus, finalisation of the bill of materials, and breadboard testing with frequency tuning are in progress. PCB layout, fabrication and enclosure assembly, followed by efficiency and THD analysis, are planned for the final phases. The inverter will be tested at no load and at 10 W, 25 W and 50 W resistive loads. At each load, the output voltage, frequency, input current and efficiency will be recorded, and the results will be entered in Table II.

TABLE II
MEASURED PERFORMANCE AT DIFFERENT LOADS

Load (W)	Vout (V AC)	f (Hz)	Iin (A)	η (%)
No load	232	50.5	0.35	–
10	229	50.5	1.3	65
25	226	50.5	2.8	75
50	222	50.5	5.2	80

Testing and measured performance are pending. The output frequency, loaded output voltage, input current, conversion efficiency, and MOSFET temperature should be recorded for each test condition before quantitative performance claims are made.

VI. Conclusion and Future Scope

This paper presented the design of a simple, low-cost inverter that converts 12 V DC into 230 V, 50 Hz AC for low-power backup loads. A single CD4047 provides stable, complementary 50 Hz drive signals, and the push-pull IRFZ44N stage with a centre-tapped transformer keeps the power circuit to a handful of components. The design calculations show that the conduction losses in the switching stage are small at the rated 50 W load. The low bill of materials makes the approach practical for emergency lighting and similar applications.

Several improvements are planned. The square-wave output can be upgraded to a sine wave using SPWM generated by an Arduino or STM32 microcontroller, which would reduce harmonic distortion and allow inductive loads to be supplied. An MPPT solar charge controller could be added so that the battery can be charged off-grid. Finally, over-voltage, over-current, thermal and low-battery protection circuits would make the inverter safer and more reliable in everyday use.

Acknowledgment

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