Research Article

Design and Construction of a Pure Sine Wave Inverter

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Abstract. This research is a design and implementation of a sine wave inverter circuit developed to run AC appliances at a low cost which high efficiency. The design consists of two stages i.e. the DC-DC step up stage and a DC-AC Inverter stage. The DC-DC step up converter is based on a push-pull design to step 24 VDC to 300 VDC. Pulse width modulation was used i.e. the SG3525 pulse width Modulator. The DC-AC inverter stage comprised of four power mosfets in an H-bridge configuration, driven by a 40 kHz square wave encoded/modulated by a 50 Hz sine wave that was derived from a TL084 quad op amp sine wave oscillator. An output voltage range of about 240-260 VAC from 300 VDC input was obtained. A low pass filter was used to filter out the high frequencies and thus isolate the harmonics so a 50 Hz fundamental frequency was retained.

Keywords. Inverter; Sine wave; Oscillator; Transformer

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1. Introduction

Electricity is one of the greatest inventions man has ever made, due to its very important role in socio-economic and technological development (Owen and Edward, 1996) [7]. Electricity can

be transmitted in two different ways namely: alternating currents (AC) or Direct current (DC). Alternating current is the form obtained from power outlets in homes and offices. It consists of a sinusoidal voltage source in which a continuous change in the direction of flow of voltage (and current) can be used to employ magnetic components (Cooks et al., 2001) [1]. Direct current is electricity flowing in a constant direction, and/or possessing a voltage with constant polarity and is appropriate for short-range transmission. Direct current is the form stored up in batteries. It uses is limited and it depends on AC power (Owen and Edward, 1996) [7].

A common difference between AC and DC involves the amount of energy that each can carry. Direct current has a voltage level and cannot travel very far until it losses energy. Ac is safer to transmit over long distance (Nergaard et al., 2001) [5]. DC is preferred over AC because of its portability hence the introduction of the inverter that are mobile AC source from a portable DC battery. An inverter is an electrical device that converts DC to AC; the converted AC can be at any required voltage frequency with the use of appropriate transformers, switching and control circuits. There are three types of DC-AC inverters, the square wave, the modified sine wave and pure sine wave.

Pure sine wave inverters are the most affluent in terms of efficiency and accurate timing output. They use batteries to generate power and it's important to have a means of recharging (Cunningham, 1999) [3]. Various methods can be adopted such as solar panels, wind turbine etc. Pure sine wave inversion is obtained by taking a DC voltage source and switching it across a load using an H-bridge. If this voltage needs to be boosted from the DC source in the inverter, it can be accomplished either before the AC stage by using a DC-DC boost converter, or after AC stage by using a Boost transformer (Crowley and Leung, 2001) [2]. The inverted signal is composed of a pulse width-modulated signal which encodes a sine wave. The duty cycle of the output is changed such that power transmitted is exactly that of a sine wave. This output can be used as it is or, alternatively, can be filtered easily into a pure sine wave (Nuzhat et al., 2010) [6].

This report documents the design of a pure sine wave inverter, focusing on the inversion of a DC high voltage source (Gurdjian and Maxwell, 2000) [4]. The various applications of the inverter are Wind/solar electrical systems, Back-up for power cells, Generator support systems, Remote homes, Telecommunications, Computers, Tools, Security applications, Mobile power, Boats and yachts, Airplane, Monitoring equipment, Emergency power and lighting etc.

2. Method

2.1 Power Supply and Transformer Selection

This unit of the system is responsible for powering the entire system. The input voltage of the system is 24 V, but this voltage was too high for some of the ICs used in the design hence a voltage regulator 7812 was used to regulate the 24 V input into 12 V and 5 V. For this design a high frequency transformer was required hence ETD49 was chosen. ETD49 has high frequency range of 20 KHZ-500 KHz. The number of primary turns was 16 turns while the number of secondary turns was 252 turns.

2.2 DC-AC Inversion

The DC-AC inverter design is the most integral part of this thesis as its functionality determined the success of the design of the entire system. A similar design to that used by Crowley and Leung (2001) [2] was adopted for the design. Some modifications were made to this design such as adjusting the Sine wave frequency to 50 Hz and the entire pulse width modulation design was changed. Sine wave was first generated with the use of quad Op-Amp TL084. This DC-AC inversion was obtained with the use of an H-Bridge. The H-bridge consists of four MOSFETs that cannot operate efficiently with sine. Wave hence the sine wave had to be embedded in a square wave with the use of PWM IC SG3525. The process is explained in the next subsection.

2.2.1 Pulse Width Modulation

Pulse width modulation is a digital modulation technique whereby the width of a pulse carrier is made to vary in accordance with the modulation voltage. The pulse width modulation technique is shown in Figure 1. This output is then sent into the MOSFET driver IC IR2110 to drive the MOSFETs used in the H-Bridge.
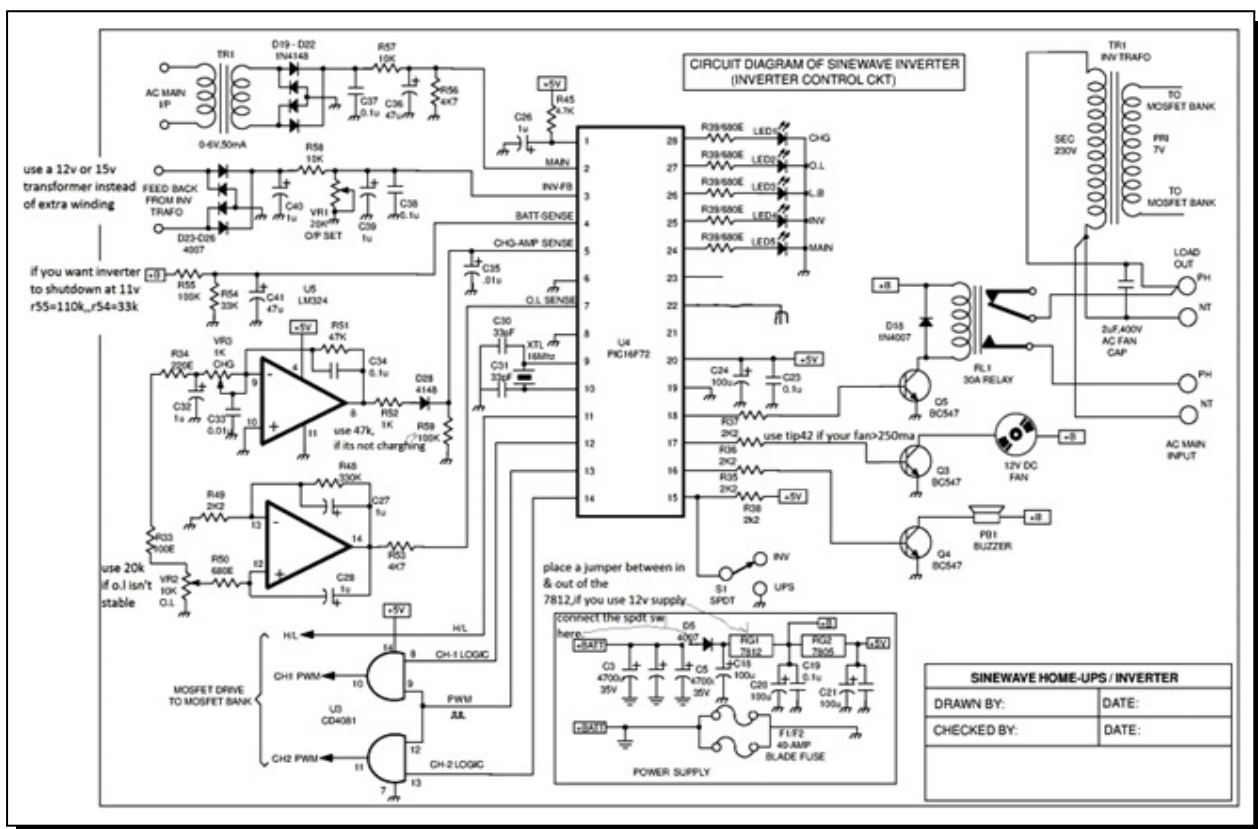

Figure 1. The pulse width modulation technique

2.2.2 H-Bridge

This is an electronic device that consists of four switching elements that allow voltage to be applied across a load in either direction. IRFP260N was chosen in this design, on the right side the two transistors are connected in a way that one is high and the other is low hence

they cannot be 'on' at the same time. The transistor at the left side are also connected like that. Only Adjacent transistors are allowed to come 'on' at the same time allowing voltage across the load. The switches are turned on in pairs, either high left and lower right, or lower left and high right, but never both switched on the same "side" of the bridge. If both the switches on one side of a bridge are turned on it creates a short circuit between the battery plus and battery minus terminals. This phenomenon is called shoot through in the Switch-Mode Power Supply (SMPS) this will cause the bridge to drain the battery rapidly. Generating a sine wave centered on Zero volts requires both a positive and negative voltage across the load, for the positive and negative parts of the wave, respectively. This can be achieved from a single source using four MOSFET switches arranged in an H-Bridge configuration. To minimize power loss and utilize higher switching speeds, N-Channel MOSFETs were chosen as switches in the bridge. Level translation between PWM signals and voltages required to forward bias high side N-Channel MOSFETs, the IR2110 MOSFET driver integrated circuit was chosen. A diagram of the H-Bridge circuit with MOSFET and drivers is shown in Figure 2.
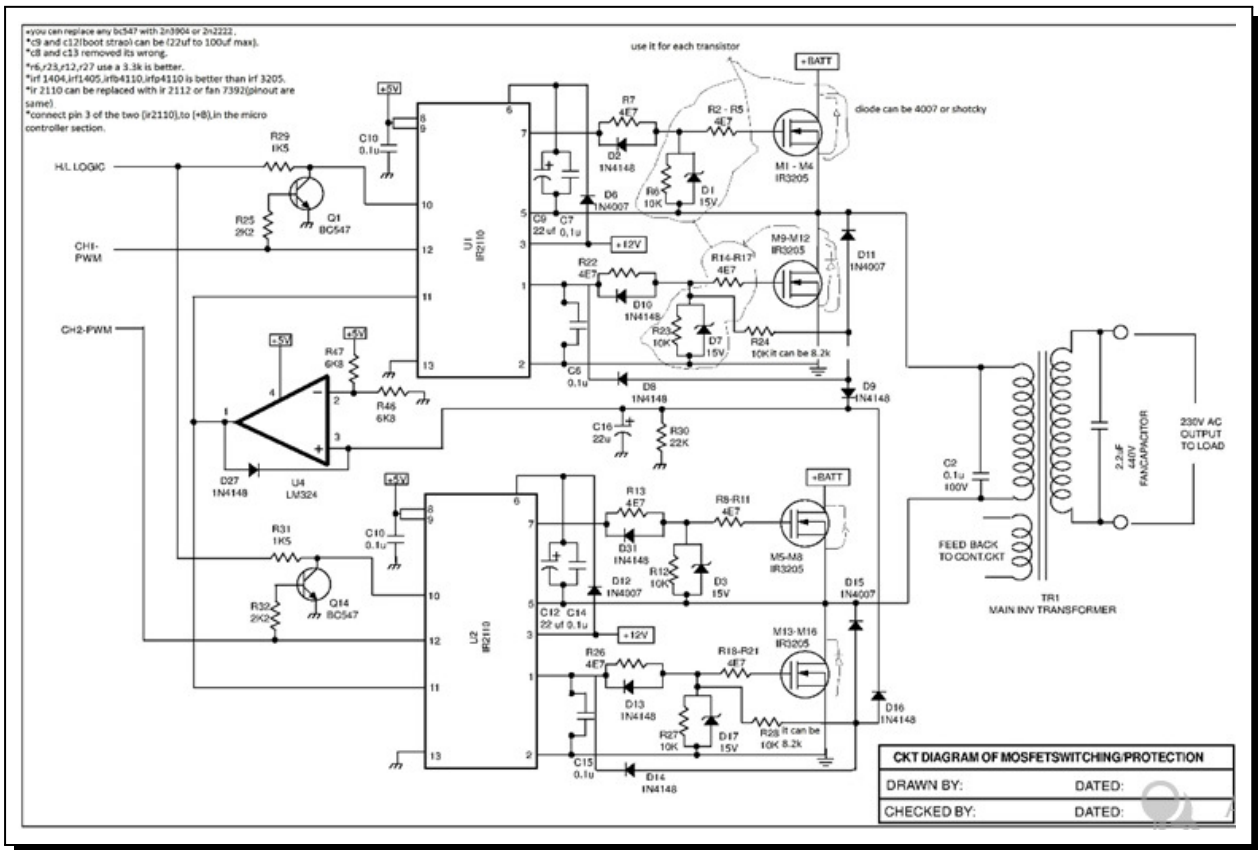

Figure 2. The H-Bridge Circuit with MOSFET and drivers

2.3 Battery

Storage batteries are the heart of all standalone wind pv or inverter electrical systems. This is how much electrical energy the battery can deliver and is measured in ampere hours (AC) when uniformly discharged over a given period of time. e.g. 120 AC at 100 hr rate battery

will be fully discharged at a higher rate by a higher current then battery capacity is reduced considerably. Max charge/discharge current should be less than 10% of battery AC capacity. Lower temperatures significantly reduce battery capacity the older a battery becomes the lower will be the capacity that can be obtained from it.

2.4 The Main

The main is the direct power supply which is 240 volts and is the power supply to the inverter, where there's is no main the inverter switch power supply to the battery, this is all control by the microcontroller pic16f72.

2.5 Feedback

The feedback steps down input voltage of 350volts from the transformer and steps it down to12volts then steps up to 240 volts is finally by the help of a variable resistor.

2.6 Battery Sense

The battery sense is responsible for shutting down the inverter when the battery is too low. This is done by the help of the microcontroller.

2.7 Overload Sense

Operational amplifiers are used here, two operational amplifiers which are the LM324, when there is overload of above 120% signal is read by the operational amplifiers and sends signal to the microcontroller which shuts down the inverter for safety.

2.8 Arduino Bluetooth

In this section, Arduino is used for controlling the whole process. Here we have used Bluetooth wireless communication for controlling the inverter. We download and install the application led controller and connect to the Arduino Bluetooth signal and so on for controlling inverter. After receiving from the android device connected, Arduino send signal to relays, to switch ON or OFF the inverter using a relay driver. HC 05/06 works on serial communication (Mayoogh, 2016) [8]. Here the android app is designed to send serial data to the Bluetooth module when a certain button is pressed. The Bluetooth module at other end receive the data and send to Arduino through the TX pin of Bluetooth module (RX pin of Arduino). The Code fed to Arduino check the received data and compares. If received data is 1 the LED turns on turns OFF when received data is 0.

3. Results and Discussions

The study has one main part DC-AC inversion stage. The design was first constructed and tested on a breadboard as shown in Figure 3 below, after proper testing it was transferred to a printed circuit board and tested to have the same results as the initial testing. The output waveforms were observed and the inferences made are recorded.

3.1 DC-AC Inversion

The DC-AC inverter design is the most integral part of this study as its functionality determined the success of the design of the entire system. Sine wave frequency is 50Hz and the entire pulse width modulation was generated. Sine wave was generated with the use of quad Op-Amp TL084. For the scope of this DC-AC inversion was obtained with the use of an H-Bridge. The H-bridge consists of forty MOSFETs that operate efficiently to produce a sine wave.
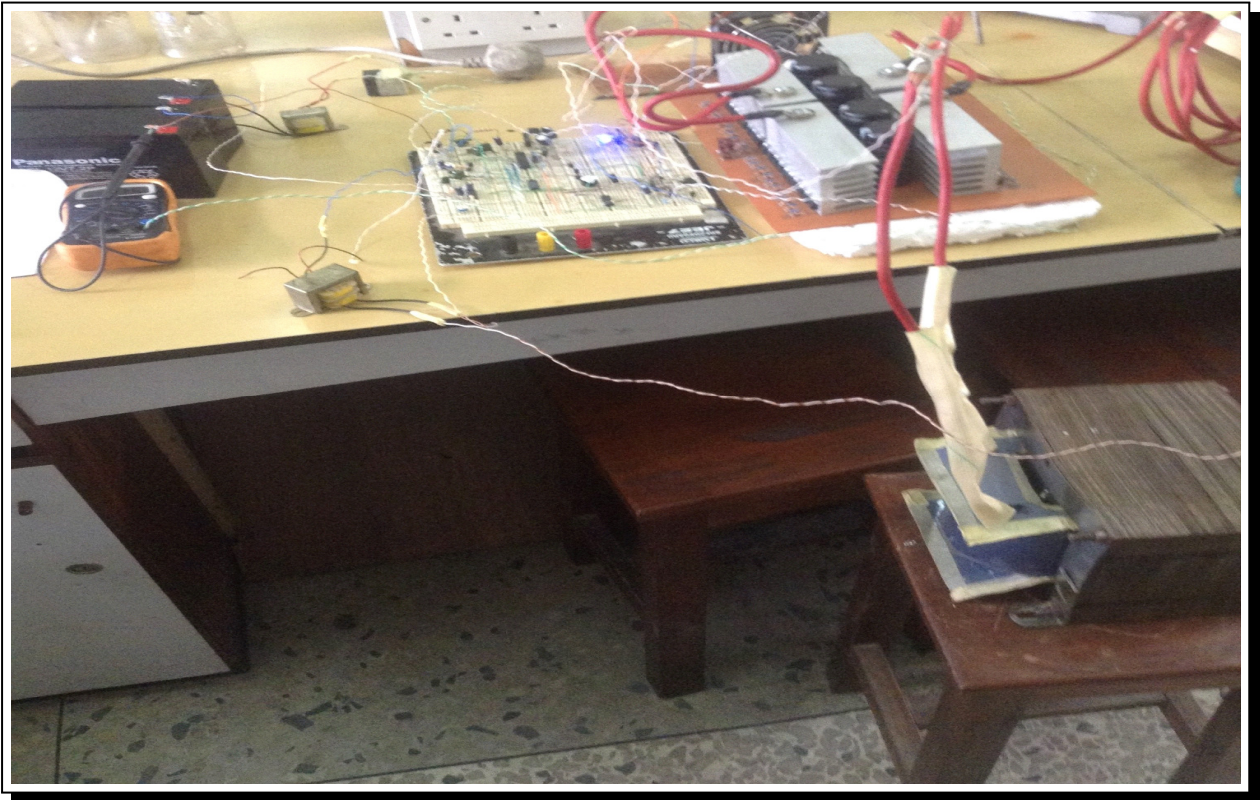

Figure 3. Testing the design on breadboard

3.2 Pulse Width Modulation

Pulse width modulation is a digital modulation technology whereby the width of a pulse carrier is made to vary in accordance with the modulation voltage. A pulse width modulation IC SG3525 was used in the design. SG3525 was programmed to switch at a frequency of 40 KHz. The input of SG3525 IC was the half wave, this signal was the compared with its in-built saw tooth. This comparison produces a square wave output to switch the H-bridge MOSFETs.Theoutput waveform is shown in Figure 4.

3.3 H-Bridge

The output of the SG3525 was sent as input into two MOSFET drivers IR2110. Operation of the IR2110 device will be controlled through generated PWM signal. The PWM signal was fed into the HIN and LIN pins simultaneously. If the internal logic detects a logic high, the HO pin will be driven; if a logic low is detected, the LO pin will be driven. The HO and LO pins of

the MOSFET driver is connected to adjacent MOSFETs The IC also produced complementary waveforms from its two output pins. The H-bridge was later tested with an input voltage of 12 volts without connecting the low pass filter and the output waveform is shown below. The output voltage from the H-bridge was 12.3 volts.

Figure 4. Sine wave obtained from PWM

4. Conclusion

The result revealed that the inverter design was successful and the objectives were also achieved. The inverter produced a pure sine wave and had no challenges operating under load. The feedback network from the pulse width modulator kept the output voltage constant at maximum and minimum input voltage.

Acknowledgement

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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