IMPLEMENTATION OF A LOW COST PWM SINGLE PHASE INVERTER USING AN IRF3205 HEXFET POWER MOSFET

Omokere E. S[1] and Nwokoye A. O. C[2]

Department of Physics and Industrial Physics Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

[1] somokere@yahoo.com

[2] ositonyk@yahoo.com

***Abstract*— This work presents the development of a low cost but effective inverter using simple components. DC to AC inversion is successfully achieved without the use of complex circuitry for the design which is essentially focused upon low power electrical appliances such as personal computers, disc players and television sets. It has a feedback loop which regulates its output voltage irrespective of connected loads. The control circuit consists of a dedicated pulse width modulation (PWM) IC for triggering the MOSFETs arranged in a bridge configuration. The inverter output is regulated from 220Volts to 240Volts at 50Hz for a variation of tested load rated between 40W to 365W.**

Keywords: Inverter, Pulse Width Modulation (PWM), Metal Oxide Semiconductor Field Effect Transistor (MOSFET), Control Feedback, Bridge Circuit.

I. INTRODUCTION

With the increasing popularity of alternative power sources, such as solar and wind, the need for inverters which is usually a necessary interface to convert low dc to conventional high ac form has increased substantially. This conversion can be achieved by power transistors. There is a growing interest in development of cheaper reliable inverter systems. Pulse width modulation (PWM) is a technique that is gradually taking over the inverter market of control application. The technique combines both voltage and frequency control [1],[2]. The PWM circuit outputs a chain of constant amplitude pulses in which the pulse duration is modulated to obtain necessary specific waveform on constant output periods. [3]. Here, the controlled output voltage is easily obtained by switching the switches on and off within a cycle to generate output which is usually low in harmonic contents [1],[3].

Nowadays, there are dedicated PWM ICs that can perform pulse control of inverter switches thereby simplifying hardware with reduced components and improves the performance of inverter system implementation. Flexibility in control and cost effectiveness is a major advantage of a dedicated PWM IC system.

II. GENERAL DESCRIPTION OF THE DESIGN

The design is unique because it is implemented through a low cost PWM IC (SG3525A) as its controller and engages MOSFETs as the preferred power switches. The operating frequency supported by the device is approximately 50hz at its output. PWM signals can be generated using this controller. voltage regulation is an important features of the inverter that requires a feedback loop for monitoring the output voltage, and MOSFET switches is most preferred for such low voltage application [3],[4]. Our designed system parameters are as given:

Power rating 500W max

Output voltage ranges from 220V – 240V

Peak output current 2.27A

Inverter switching frequency is approximately 50Hz

Maximum load powered (tested) 365W

III. THEORETICAL BACKGROUND

PWM

In conventional pulse width modulation (PWM) control strategy a sinusoidal modulating signal is compared with a repetitive switching frequency triangular or saw tooth waveform as a carrier to generate the switching pulses [2],[3],[5]. The result of this comparison is used to operate inverter switches ON and OFF. A generalised sinusoidal wave through pulse width modulation (PWM) of inverter switching is as shown in figure 1 [9].

As is seen in figure 1, transistor device pair Q_1Q_3 is turned ON when the modulating voltage exceeds the carrier wave amplitude, whereas Q_2Q_4 is ON when the carrier amplitude is higher. The resulting pulse width modulation output voltage and its fundamental component are shown in the lower part of figure 1.

Dedicated PWM ICs are available that could convert DC level into pulses used to control inverter switches through pulse width modulation. The SG3525A is one of such.

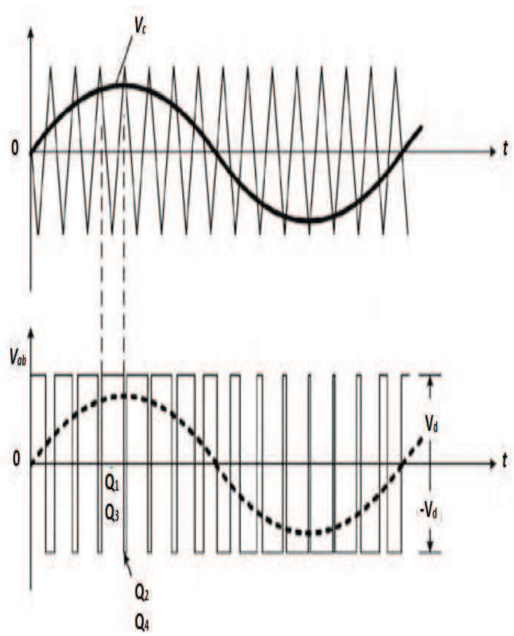


Figure 1: Production of sinusoidal wave through pulse width modulation of Inverter switching

IV. INVERTER APPROACH

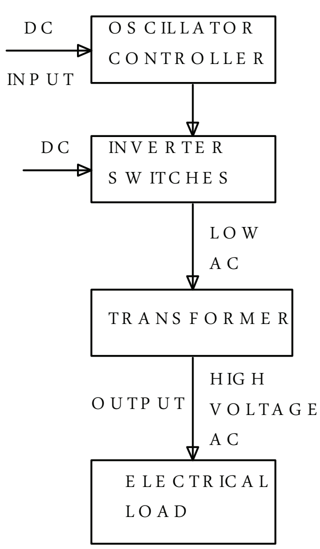


Figure 2: Inverter Block diagram

The block diagram of the inverter circuit is shown in figure 2. The operation starts by taking the 12V DC from the input supply. The 12V DC is given directly to the oscillator controller and the inverter switches which then produces low voltage AC signals. This AC signal is then step up to high voltage AC capable of powering electrical loads by the transformer. Emphasis is given only to the controller and inverter switches sections in our design consideration.

D. Control Circuit

The control circuit of the design consists of the SG3525 PWM IC as the chosen controller IC. The control circuit is used to produce the PWM pulses and the pulses that obtained from the controller is provided to the inverter switching circuit such that the inverter MOSFETs gates can be triggered ON and OFF [10].

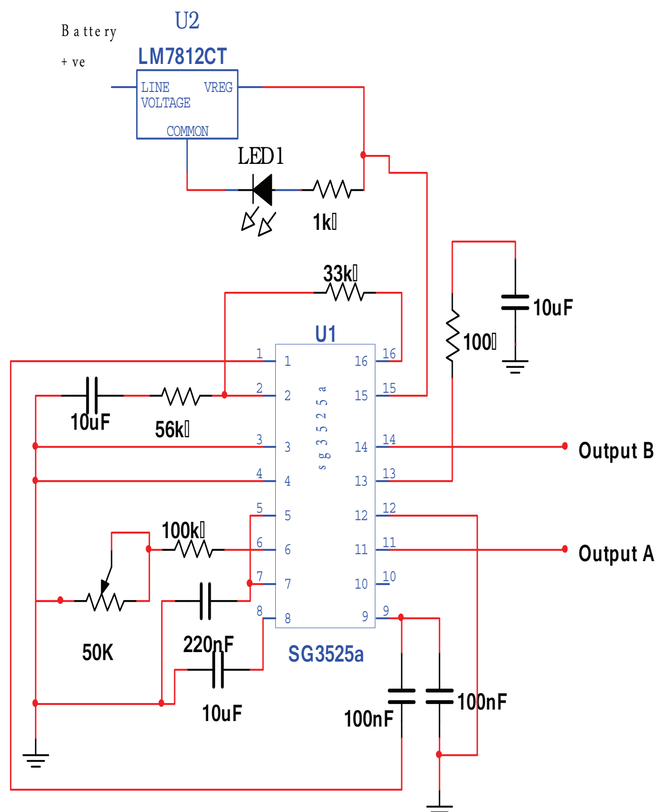
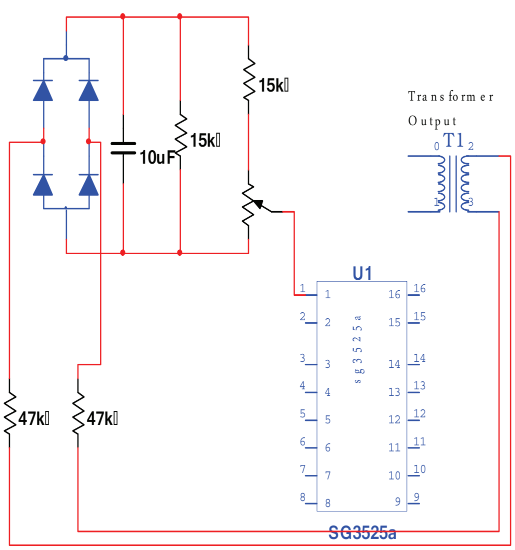


Figure 3: Integrated Circuit (IC) Pin connections of IC 3525A

With a built in totem pole drivers at pin 11 and 14 outputs, the PWM IC can be configured with the MOSFET switches directly, thereby driving the MOSFET gate to turn ON and OFF [6]. The low source impedance of the output drivers provides rapid charging of the MOSFETs, this minimizes the need for external components (MOSFET drivers) as is found in other transistor switch implementations [7].

1.) Control Feedback: The PWM IC can be connected with a feedback as shown in figure 4 from the inverter AC outputs in order to regulate the output AC voltage to the desired value. The inverter output at the transformer is tapped from 2 points and connected to a bridge rectifier setup which rectifies the AC voltage to a voltage that is proportional to the inverter output and ripples are removed by using capacitor. This voltage signal is supplied to pin 1 of the IC (inverting input of the internal error amplifier inside the PWM IC) through R1, R2, VR1 and this voltage is compared with the internal reference voltage regulator. The regulator uses reference voltage of 5.1V [6]. The error amplifier output provides input for the PWM comparator whose output determines the pulse width. This error voltage is proportional to the variation of the output voltage from the desired value and the IC adjusts the duty cycle of the drive signals at pin 14 and pin 11 in order to bring the output voltage to the desired voltage value. VR1 is used for adjusting the inverter output voltage to 240V as it directly control the amount of voltage fed back from the transformer output to the error amplifier section inside the IC. If the output voltage decreases, the DC voltage also decreases and is fed back to the controller. The feedback control system is applied so that whenever DC voltage decreases or increases, duty cycle of PWM varies to regulate the output voltage.



V.

Figure 4: Control feedback circuit

E. Inverter Switch Circuit

The Inverter switch circuit consists of MOSFETs arranged in a bridge circuit as shown in figure 5. The circuit contains IRF3205 advanced MOSFET as a power switches. MOSFET is used as a switch due to its low voltage applications [3],[4],[9]. Depending on the voltage of the output required at the output, the gates of the MOSFETs are triggered with proper pulse sequence. The gate pulses are obtained from the control circuit.

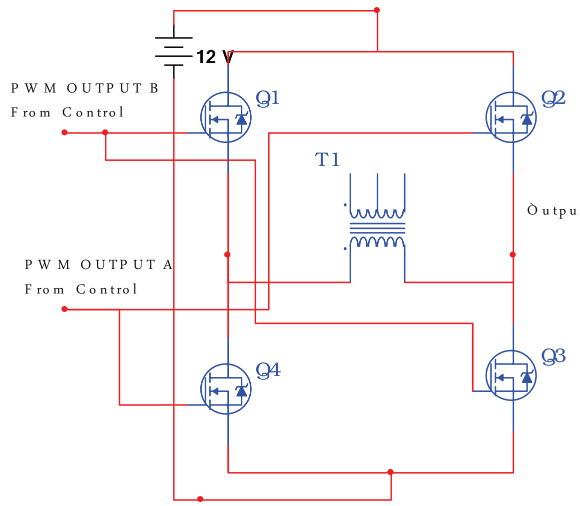


Figure 5: Single phase full bridge inverter

Inverters are supposed to perform the DC to AC conversion very efficiently so that very little energy is wasted in the form of heat as it is being drawn from the battery to be converted into AC mains voltage. We employed full bridge configuration of our inverter switches which generates the highest output power amongst all converter types. The DC from the battery is converted into AC by using a pair of power MOSFETs $Q_{1,}Q_3$ and Q_2Q_4 which are acting as very efficient electronic switches. By switching the pair $Q_{1,}Q_3$, the battery current is made to flow through the primary and to ground through pair $Q_{1,}Q_3$. Equally by switching on pair Q_2Q_4 instead, the current is made to flow the opposite way through the primary and to ground. Therefore switching the two pairs of MOSFETs ON alternatively, the current is made to flow first in one direction of the primary and then in the other direction, thus producing an alternating magnetic flux in the transformer's core. As a result a corresponding AC voltage is induced in the transformer's secondary winding [10].

V. SELECTING COMPONENTS

In selecting our components, a number of considerations were made with respect to controller frequency and power MOSFET. Also the peak current and power dissipation are taken into consideration. The major components used are given:

SG3525A PWM IC, MOSFET IRF3205, Voltage regulator IC7812 and Output transformer 500W.

A. *Controller Frequency*

Timing components ***R_T* AND *C_T***, determine the inverter frequency and maximum duty cycle of the switches. The selection of these component values is a critical consideration. The values of ***R_T* AND *C_T*** helps to determine the output frequency for the inverter which is represented by [6]:

$$F_{OSC} = \frac{1}{C_T(0.7R_T)} \quad \text{----1}$$

R_T is a timing resistor connected to pin 6 of the controller

C_T is a timing capacitor connected to pin 5 of the controller.

B. *MOSFET*

The MOSFET utilized in this work is an IRF3205 HEXFET power MOSFET which has an ultra low ON resistance with fast switching speed. It has a rugged device design and is suitable for low profile application. With a number of characteristics [8]:

Gate threshold $V_{GS(th)}$ = 2V min and 4Vmax

Drain to Source ON resistance $R_{DS(on)}$ = 8mΩ

Drain current I_D = 75A

V_{DSS} = 55V.

The $R_{DS(on)}$ for the MOSFET is an important parameter in choosing it because the lower this resistance of a transistor switch is, the less power they are going to dissipate when switching [4]. The peak current and power dissipation are other important parameters when selecting switching transistors for practical applications

For an inverter, the maximum average current will occur at minimum input voltage

$$I = \frac{P_{out}}{V_{in}} \quad \text{---- 2}$$

The power dissipated by the MOSFETs during conduction is as given by [4] and expressed as in equation (3)

$$P = d\, R_{DS(on)}\, I_o^2 \quad \text{----3}$$

VI. TESTING AND DISCUSSION

Testing was carried out on our inverter using various loads of varying power ratings their operation and various voltage output values of the device were observed. Our testing loads included commonly available electrical appliances such as television set, ceiling fan, audio amplifier, personal computer and light bulbs of different wattage. These devices were operated individually from inverter output and also combined in turn. They were observed to work optimally. A summary of our test loads and results are shown in Tables I and II.

TABLE I: TEST LOADS AND THEIR POWER CONSUMPTION USED FOR TESTING THE INVERTER

Test Appliance	Power (Watt, W)
14"TV set	43
Audio amps + 2 speakers	175
Personal Computer	65
Light Bulbs	100
	200

A comparison of the output voltage and connected load rating as gotten from our test results in Table II is shown graphically in figure 6.

TABLE II: CONNECTED LOAD INVERTER OUTPUT READINGS

Test Appliance	Load rating (Watts)	Inverter Voltage output (Volts)
14" TV	43	230
PC	65	230
Electric bulb	100	233
14"TV + 100W bulb	143	231
Electric bulb + PC	165	231
Electric bulb	200	236
14"+200W bulb	243	236
100W bulb + PC	265	235
300W bulbs (100+200)W	300	234
300W bulbs + 14"TV	343	225
300W bulbs + PC	365	225

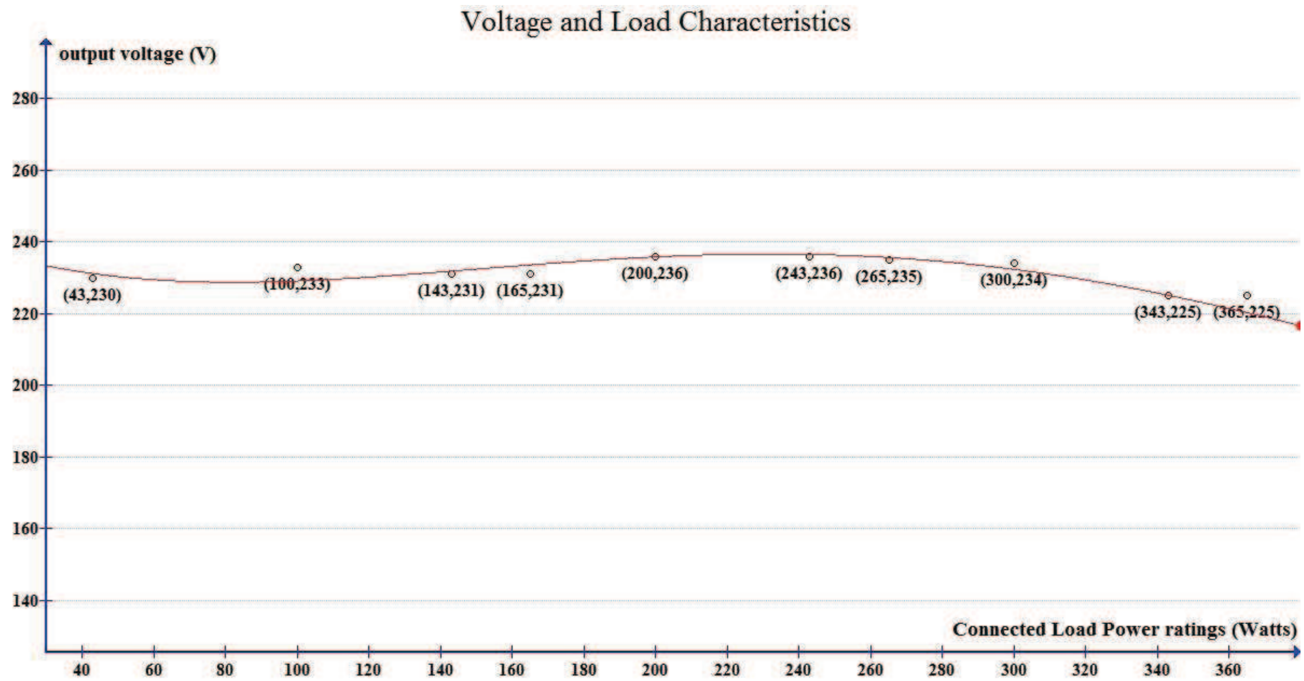


Figure 6: Voltage against Load observation of the inverter

During performance evaluation carried out on the device, testing was made using a 12V DC battery as DC input source to power various loads. Figure 6 shows a plot of our output voltage and the tested load ratings. It can be seen from figure 6 that at different connected load ratings, the inverter is able to sustain an AC output voltage within the range of 220V – 240V which is equivalent to AC mains voltage value.

VII. CONCLUSION

The design and implementation of a low cost single-phase inverter that produces an ac output voltage of desired magnitude and frequency was achieved. Due to the use of the H-bridge connection of the IRF3205 MOSFETs the inverter showed good performance when tested with common loads. Moreover the use of PWM IC allowed us to achieve simple control of the MOSFET to implement the DC-AC stage and to provide an AC output. We utilized a DC battery as its input voltage source during testing. The inverter output is regulated from 220Volts to 240Volts at 50Hz for a variation of tested load rated between 40W to 365W. Finally, the circuit during testing performed optimally and in the manner desired.

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