Evaluating the Performance of a Single Phase PWM Inverter Using 3525A PWM IC

Omokere, E. S and Nwokoye, A. O. C

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

Abstract

This paper presents the development of control circuit for single phase inverter using a pulse width modulation (PWM) IC. The attractiveness of this configuration is the elimination of a complex circuitry to generate oscillation pulses for transistor switches. The 3525A controller is able to generate the necessary waveforms to control the frequency of the inverter through proper use of switching pulse. The DC to AC inversion was successfully achieved alongside the switching signals; the controller produced inverter output of frequency nearly 50Hz.

1. Introduction

Pulse width modulation (PWM) is a way of digitally encoding analog signal levels. It is a technique that is now gradually taking over the inverter market of control application. The technique combines both frequency and voltage control **[3,4,7,10].** The PWM circuit gives a chain of constant amplitude pulses in which the pulse duration is modulated to obtain the necessary specific waveform on the constant pulsing period. In PWM, the controlled output voltage is easily obtained by switching the transistors ON and OFF many times within a cycle to generate a variable voltage output which is normally low in harmonic content **[1,3,7]**. The performance of a PWM converter significantly depends on the control method and the type of modulation. Pulse width modulators are now available in a variety of designs and integrated circuits, which greatly simplifies the design and implementation.

To achieve the control system, the 3525A PWM IC was used, and it brings simplicity with its low cost implementation and has a small size of control circuit for the single phase bridge inverter.

2. The Single Phase Full Bridge Inverter

The inverter, also known as DC to AC converter converts dc power to ac power at desired output voltage and frequency. The output voltage of an inverter has a periodic waveform that is not sinusoidal but can be made to closely approximate this desire waveform. It is an electronic power converter that is necessary as an interface between the power input and the load **[1,5,7,11]**.

The full bridge (single phase) inverter is built from two half bridges connected to form what is known as a full bridge or H-bridge inverter. Its arrangement is shown in figure 2. It comprises of DC voltage source, 4 power switches (usually bipolar junction transistors-BJTs, metal-oxide semiconductor field effect transistors-MOSFETs, insulated gate bipolar transistors- IGBTs or gate turned on transistors-GTOs) and the load **[1,8,11]**.
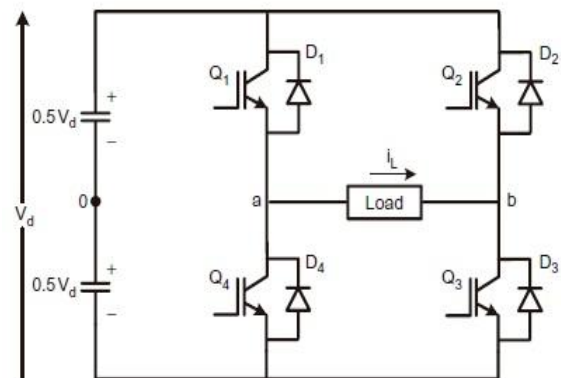

Figure 1: Full bridge single phase inverter [Curled from Bose B. K. 2006]

To create a square-wave output voltage, the device pairs Q_1Q_3 and Q_2Q_4 are switched alternatively at a delay of 180 degrees. When Q_1 and Q_3 are ON with Q_2Q_4 OFF for a duration t, also with Q_2Q_4 ON and Q_1Q_3 OFF at t. Assuming there is a sinusoidal load current, the load will absorb power when Q_1Q_3 and Q_2Q_4 pairs are conducting alternatively whereas feedbacking occurs when the diode pairs are conducting **[1,4,5]**. For a complete operation in time, the output is as shown in figure 2.
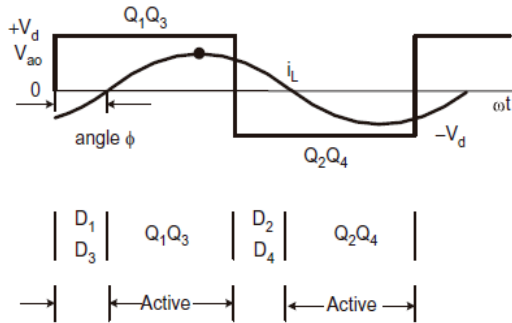
Figure 2: Load voltage and current wave in full bridge [Curled from Bose B. K. 2006]

A method of controlling the output voltage of the inverter in figure 2 called phase shift control (also called phase shift pulse width modulation) is shown in figure 3.
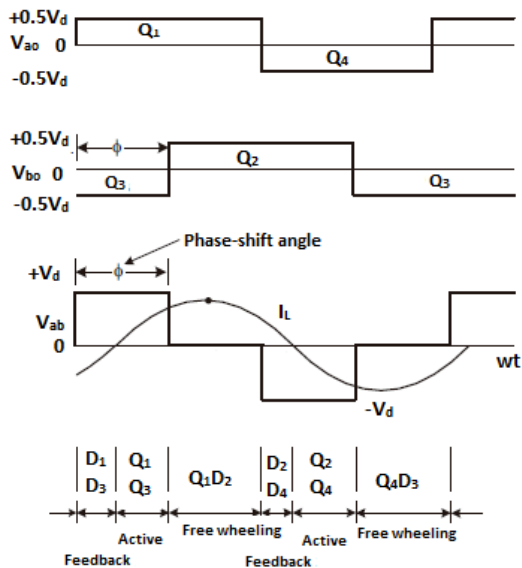

Figure 3: Phase shift voltage control [Curled from Bose B. K. 2006]

Here, both half-bridges of the inverter are made to operate in square-wave mode, but the right side half bridge operates at a phase shift angle φ as shown in the figure. The output voltage $V_{ab} = V_{ao} - V_{bo}$. To achieve a high practical sinusoidal output, a low pass filter is connected at the inverter output terminals to minimise high frequency harmonics distortion that is found in the square wave output [2,3,5]. The switching ON and OFF

operation by the switches is controlled by control circuitry.

3. Approach and Method

Figure 4 is the block diagram that describes the hardware development for controller circuit combined with the inverter switches. The arrow shows the signal flow through the inverter to the load.
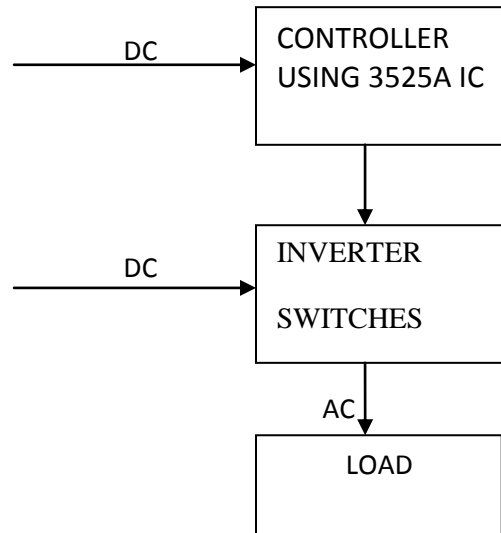

Figure 4: Signal flow of Inverter hardware

The switching frequency used in this project is 50Hz. It is desired to control the inverter with proper switching signals. The turn on and turn off time of the switches is determined by this PWM control signal generated by the 3525A IC controller. Before this control signal is being generated, proper calculation is done to determine the suitable switching pulses conditions (frequency) [6] for the switches.

Figure 5 shows the approach in which the controller outputs are connected with the inverter MOSFET switches as used in this work. The turn ON and OFF for Q1 and Q3 are controlled by PWM A generated at pin 11. While the turn ON and OFF for Q2 and Q4 are controlled by PWM B generated at pin 14.

Both PWM A and PWM B used the same control signal generated by the IC. With PWM A signal leading PWM B by half cycle or 180 degree of the switching signal.
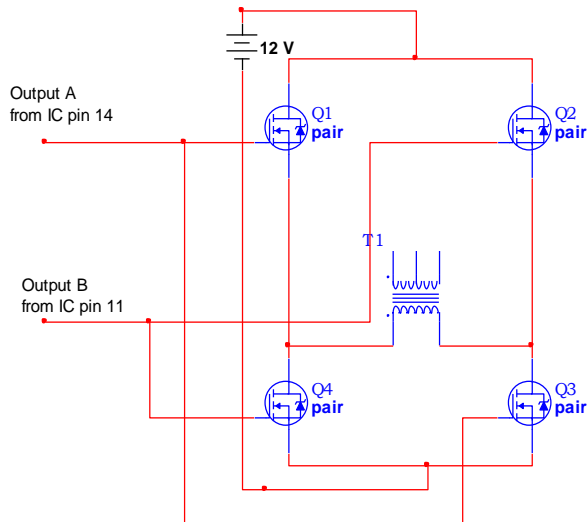
Figure 5: MOSFET switch arrangement

4. Results and Discussion
The Controller Circuit using 3525A PWM IC

This serves as the controller. It produces PWM pulses and these pulses are provided to the MOSFET switches such that the MOSFET gates can be triggered ON and OFF. This is responsible for generating oscillating signals that controls the ON and OFF action of the MOSFET switches.
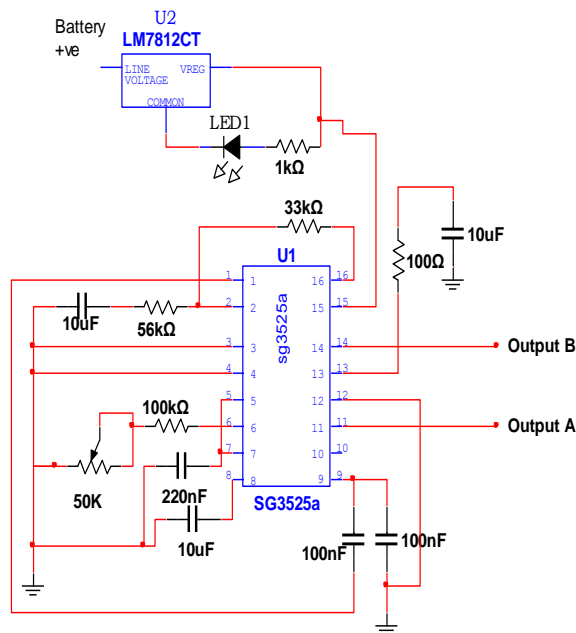

Figure 6: Pin configuration for controller

The control circuit as a whole was made with a 3525A PWM IC and combination of some passive components. The oscillation from its output pins is

controlled by a timing resistor and capacitor connected to pins 5 and 6 terminal of the IC.

The 3525A is a 16-pin device and included in it are all the control necessary for PWM. They include reference voltage regulator, an error amplifier, a comparator, an oscillator, under-voltage lockout, soft start circuit, and output drivers [6,9].

It uses negative feedback to force the voltage at the inverting input (pin 1) of the error amp to be equal to the voltage at the non-inverting input (pin 2) of the error amp. The internal oscillator drives a flip flop. Each half-cycle of the flop puts on the NOR gate for a full PWM cycle. It has an internal pair of complementary BJT gate drivers that deliver high and low output voltages necessary to adequately drive power switches [6,9].

The soft start circuit is necessary for limiting the pulse width produced when the IC initially starts operating, and the soft-start time is governed by the following relation.

$$t \text{ (sec)} = C_{ss} \times V_{out} / I \qquad \text{---1}$$

where t is soft-start delay time in seconds
C_{ss} is charging capacitor connected to pin 8. In this work 10uF is used as shown in figure 1 to obtain a 0.50 sec delay during turn ON.

V_{out} is the soft start threshold voltage at which value the inverter starts from the device datasheet, this value is 2.5V max
I is the soft-start current as provided by the internal current source in the IC (50uA).

It has an under-voltage lockout component which has a threshold at $7V\pm1V$ to shut down its output at a voltage below its normal input voltage V_{cc} range.

The reference regulator supplies all other internal sub circuits of the IC a reference of 5V for operation.

The comparator creates PWM signals based on the difference between the internal oscillator signal and the carrier signal which comes from pin 9 and pin8.

The IC operates at a voltage range of 8V to 35V. The recommended operating conditions as gotten from the manufacturer datasheet are [6,9]:

- Supply voltage V_{cc} 8V to 35V
- Collector supply voltage V_c 4.5V to 35V
- Oscillator frequency range 100Hz to 400 KHz
- Oscillator Timing Capacitor C_T 1nF to 0.2µF
- Oscillator timing Resistor R_T 2KΩ to 150kΩ
- Operating Ambient Temperature Range is 0 – 70ºC

The approximated frequency output of the oscillator is governed by the following equation [6,9]:

Oscillator Frequency

$$F_{OSC} = \frac{1}{CT(0.7RT + 3Rd)} \qquad \text{----2}$$

Where F_{osc} is the operating frequency of the IC
C_T is the timing capacitor connected at pin 5
R_T is the timing resistor value connected to pin 6
R_d is the discharge resistance value at pin 7
For a frequency output of approximately 50Hz as required for our testing, the Oscillator timing resistor and timing capacitor values were respectively chosen to be R_T = 129kΩ C_T = 0.22µF and R_d = 0

$$\text{Thus, } F_{OSC} = \frac{1}{0.22*E-06\,(0.7*129000)} \approx 50Hz$$

The 3525A is employed as the controller circuit to make the design of the controller simpler, more reliable and the most important to reduce the components. This component can perform the function of a whole circuit, being dependent on the project to be implemented.

Figure 6 shows the output waveform of the full bridge single phase inverter during testing. A National oscilloscope VP-5100B was used experimentally to observe the inverter output. The frequency of the output waveform from experimental results is approximately 50 Hz. This frequency is exactly equal to mains frequency. The inverter wave as observed and compared with known works on inverters is known to be a pulse width modulated wave **[3,8,10]**. The width of pulse train was notice to increase on increasing the value of loads connected at the H-bridge output. This, our investigations revealed was to compensate on the output voltage of the inverter.

Figure 7: Inverter output wave on oscilloscope

5. Conclusion

The main task in this work is a control circuit was been developed for single phase full bridge inverter using 3525A IC. In general, DC to AC inversion was successful. It is found from the results experimentally that the PWM switching scheme was achieved. The controller is able to produce the inverter output frequency at nearly 50 Hz through proper selection of components. The method used to control the inverter switches is pulse width modulation (PWM).

6. References

[1] Bose B. K., Power Electronics and Motor Drives, Academic Press, Burlington, MA, USA, 2006.

[2] Jahmeerbacus M. I., Oolun M. K. and Soyjaudah K. M. S, A Dual-Stage PWM DC to AC Inverter with Reduced Harmonic Distortion and Switching Losses, Science and Technology – Research Journal, University of Mauritius, Reduit, Mauritius, Vol. 5, 2000, pp. 79-91.

[3] Jahmeerbacus M. I. and Soyjaudah K. M. S, Comparative Study of Single-Pulse tri-State and Sinusoidal Pulse Width Modulation DC to AC Inverters, International Journal of Electrical Engineering Education, Vol. 37, No.3, 2000, pp. 259-267.

[4] National Program on Technology Enhanced Learning (NPTEL), Power Electronic, Funded by Government of India, 2007.

[5] Salam Z., Power Electronics and Drives, Ver2, [online ebook] http://encon.fke.utm.my/courses/see_5433/ accessed June 29, 2011.

[6] STMicroelectronics http://www.st.com/internet/com/TECHNICAL_RESOUR CES/TECHNICAL_LITERATURE/DATASHEET/CD00 000958.PDF accessed March 2, 2011.

[7] Vodovozov V., Introduction to Power Electronics, Ventus Publishing, UK, 2010.

[8] Hanif A., Mukhtar A., Farooq U. And Javed A., Comparative Analysis of Voltage Control Signal Techniques for Single Phase Inverter, International Journal of Computer and Electrical Engineering, Vol. 3, No. 6, 2011, pp. 762-770.

[9] Fairchild Semiconductor International. http://www.fairchildsemi.com/ds/KA/KA3525A.pdf Accessed March 2, 2011.

[10] Islam S. M. M., Sharif G. M, Microcontroller based Sinusoidal PWM Inverter for photovoltaic application, 1st International Conference on Developments in Renewable Energy Technology (ICDRET), 2009, pp 1-4.

[11] Senthikumar R. and Singaaravelu M., Design of Single Phase Inverter using dsPIC30F4013, International Journal of Engineering Science and technology, Vol.2, No. 11, 2010, pp 6500 – 6506.