Design and Implementation of Single Phase Inverter

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Abstract: ***A microcontroller based advanced technique of generating sine wave with lowest harmonics is designed and implemented in this paper. The main objective of our proposed technique is to design a low cost, low harmonics voltage source inverter. In our project we used PIC16F73 microcontroller to generate 4 KHz pwm switching signal. The design is essentially focused upon low power electronic appliances such as light, fan, chargers, television etc. In our project we used STP55NF06 NMOSFET, which is a depletion type N channel MOSFET. For driving the MOSFET we used TLP250 and totem pole configuration as a MOSFET driver. The inverter input is 12VDC and its output is 220VAC across a transformer. The complete design is modeled in proteus software and its output is verified practically.***

Keywords: Inverter, Totem pole, Microcontroller, Data acquisition box.

1. Introduction

Energy crisis are of special attention now-a-days. A need for power rating inverter is required to smoothly operate electrical and electronic appliances. Most of the commercially available UPS or IPS is actually square wave or quasi square wave inverters. Electronic devices run by this inverter will damage due to harmonic contents [1]. Available sine wave inverters are expensive and their output is not so good. For getting pure sine wave we've to apply sinusoidal pulse width modulation (SPWM) technique. The pulse width modulation inverter has been the main choice in power electronics because of its simplicity [2]. Sinusoidal pulse width modulation is the mostly used method in motor control and inverter application [3, 4, 5]. To generate this signal, triangular wave is used as a carrier signal is compared with sinusoidal wave at desired frequency [2].

The proposed alternative approach is to replace the conventional method with the use of microcontroller [2]. In our project we used PIC16F73 microcontroller. It is low cost and reduces the complexity of the circuit for the single phase full bridge inverter. The microcontroller has built in dead time control circuit [6].

2. General Description Of The Proposed System

The basic block diagram of the inverter is shown in fig. 1.

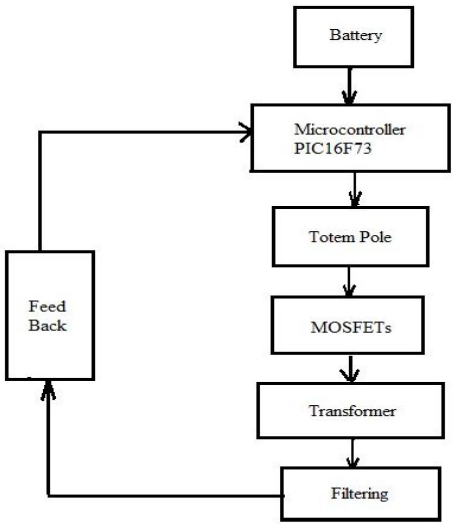


Figure 1. Block diagram of PIC pure sine wave inverter.

The basic single phase full bridge inverter circuit is shown in fig. 2

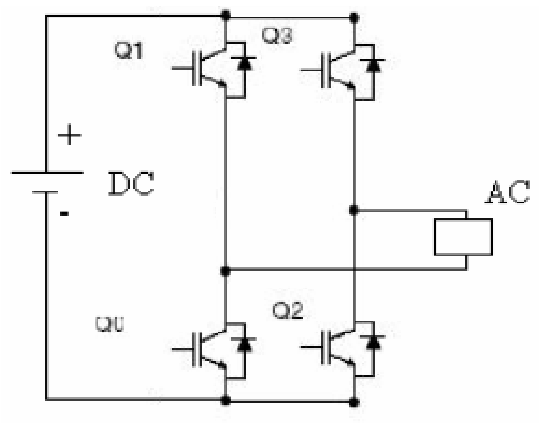


Figure 2. Single Phase full bridge inverter [7]

The heart of this system is a PIC microcontroller. This microcontroller is specially developed for the generation of Sinusoidal PWM (SPWM). The PIC16F73 microcontroller generates two PWM signal and two rectangular pulse signals i.e. it is modified SPWM signal. RC4, RC5 are output pin for sinusoidal pulse width modulation and RC0, RC1 are output pin for rectangular pulse signal. RC4 and RC5 pin goes to MOSFET driver and RC0, RC1 goes to totem pole configuration. The MOSFET driver IC is TLP250 is used in the high side of the MOSFET to isolate the ripple content of the high side to microcontroller. In low side we used totem-pole configuration, before totem pole configuration we used a inverting transistor so that totem pole bypass 12V to low side MOSFET when the signal is off, inverting transistor is used for protection purposes. To operate microcontroller we used 20MHz crystal oscillator.

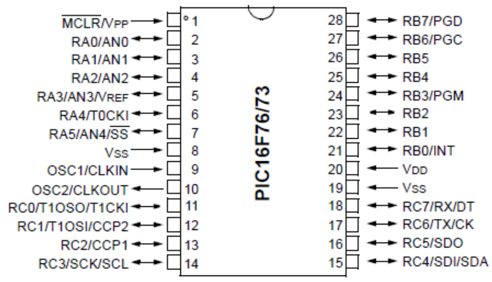


Figure 3. PIC16F73 pin diagram for the generation of the SPWM signal for single phase inverter

3. PIC Microcontroller Architecture

PIC16F73 has RISC Harvard architecture. Harvard architecture is a newer concept than von Neumann. It rose out of the need to speed up the work of a microcontroller. In Harvard architecture data bus and address bus are separate. Thus a greater flow of data is possible through the central processing unit and of course a greater speed of work. Separating a program from data memory makes it further possible for instructions not to have to be 8-bits for instructions which allows for all instructions to be one word instructions. It is also typical for Harvard architecture to have fewer instructions than von-Neumann's, and to have instructions usually executed in one cycle. Microcontrollers with Harvard architecture are also called "RISC microcontrollers". Fig. 4 presents the internal block of the PIC16F73.

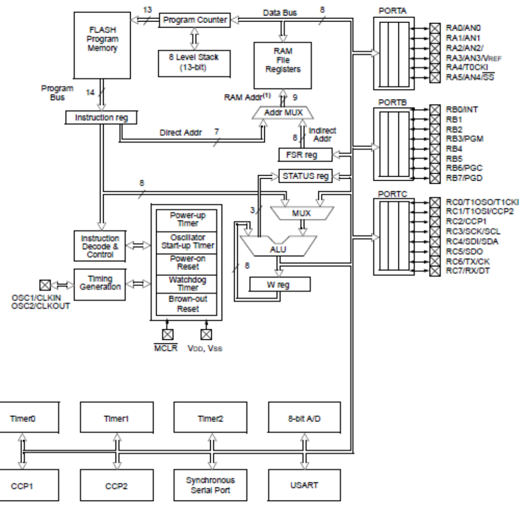


Figure 4. Internal block diagram of the PIC16F73

RISC stands for Reduced Instruction Set Computer. Microcontrollers with von-Neumann's architecture are called 'CISC microcontrollers', which stands for Complex Instruction Set Computer. PIC16F73 is a RISC microcontroller that means it has a reduced set of instructions; more precisely 35 instructions. PIC16F73 perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices. It is also ideal for smart cards as well as for battery-supplied devices because of its low power consumption [8].

4. Algorithm

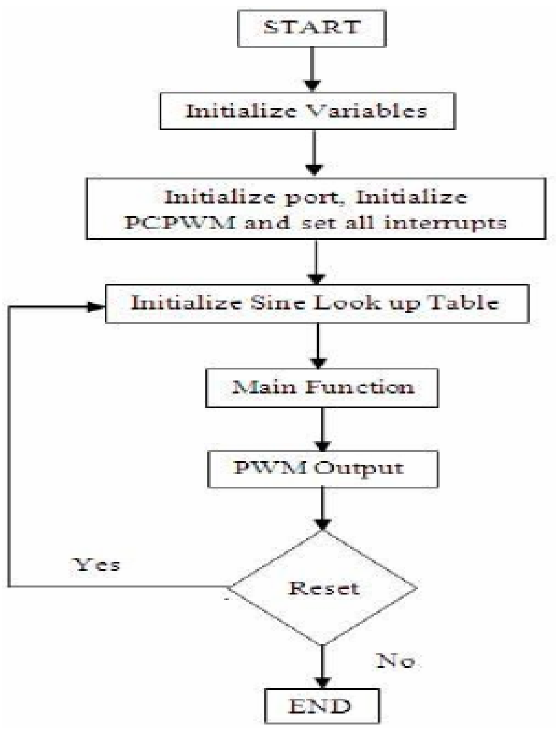


Figure 5. Flow chart for the Single Phase SPWM signal [6].

Fig. 5 shows the flow chart of single phase sinusoidal PWM signal. In this flow chart "initialize variables" means initialize the user defined memory cell; "initialize port" initializes the ports in software by which the ports work as output ports. After that "Initialize PCPWM" initializes the modules which are used to generate PWM. Then "set all interrupts" initializes all interrupts which are associated with all kinds of desired interrupts. Then "Initialize Sine Look up Table" stores the sampling value of sine wave. Those sampling value will go in PDC register. And the PTMR register will generate the Triangular wave. Then the signal becomes Sinusoidal PWM signal with dead time. The microcontroller checks whether the generation is completed or not, if yes, take another sampling of the sine wave table, if not, it waits until completion [2]. For generating sinusoidal pulse width modulated signal we divide each half cycle of sine wave into 32 parts and then we measure the value of sine wave at every interval to find out the duty cycle of every pulse. The duty cycle determine the width of the pulse [9] . The calculations of duty cycle for generating pulse are given below:

Carrier frequency $f_c = 4000$Hz

Highest PWM value for PIC16F73 is=255 (i.e. 100% duty)

Interval from one point to another point is, $\Delta\theta = {}^{1}/_{180} = 5.625^0$

The equation for determining the duty cycle is, $y = 255 \sin wt = 255 \sin n\Delta\theta$

$n = 0,1,2,3......................31$

5. Gate Driver

For driving the gate of the MOSFET there are basically two fundamental categories, are low side driver and high side driver. High side means the source of the MOSFET of the power element can float between the ground and high voltage power rail and the low side means the source of the MOSFET is always grounded [2]. For driving the high side MOSFET we used TLP250 and a capacitor of 50V, 100µfarad in output of TLP250, this capacitor is called boost strip capacitor. The capacitor in the output of TLP is used for $\frac{dv}{dt}$ protection. The Gate driver circuit pin diagram is shown in fig. 6

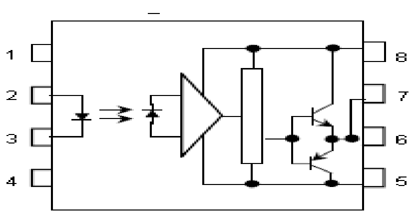


Figure 6. Pin diagram of the High side driver circuit TLP250

The pin out description is:

1: N.C, 2: Anode,

3: Cathode, 4: N.C,

5: GND, 6: V_0 (output),

7: V_0 and 8: V_{CC}.

For driving the low side of the MOSFET we used totem-pole configuration. The totem-pole circuit diagram is:

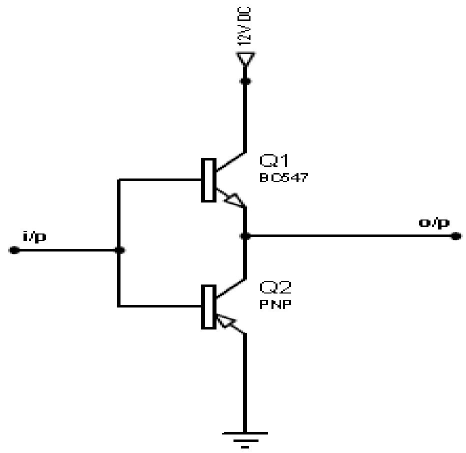


Figure 7. Circuit diagram of the totem-pole configuration.

The Gate driver is required to pass 12V DC to MOSFET gate. There are various methods to generate *gate* voltage (V_{bs}) *supply* [3, 10].

6. Practically Implemented Circuit

The connection diagram of the power circuit is shown in fig. 8 respectively.

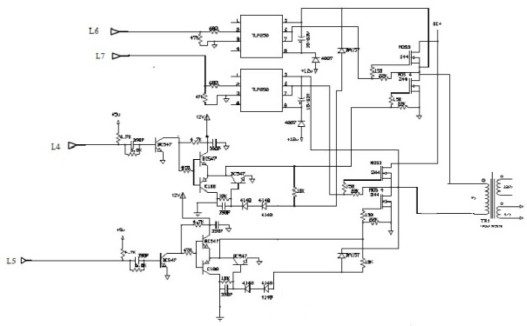


Figure 8. Connection diagram of power circuit

The power circuit is a full bridge inverter circuit. In our circuit we use four MOSFET connecting in series at each leg of H bridge. Four MOSFET is used to increase the current rating of circuit. Total 16 n channel MOSFET is used in our project. As microcontroller output is in maximum 5V which is direct to MOSFET gate but MOSFET is not active until 12V that why we need MOSFET driver for our circuit. For driving the high side MOSFET we used TLP250 and a capacitor of 50V, 100µfarad in output of TLP250, this capacitor is called boost strip capacitor. The capacitor in the output of TLP is used for $\frac{dv}{dt}$ protection. For the low side of inverter we used totem pole configuration, where totem pole passes 12V to MOSFET gate [26]. There should be a resistance between nMOSFET gate and source as gate resistance to drive the MOSFET otherwise MOSFET can't be on. There are used many protection diode in every stage of connection so that reverse current can't hamper to other circuit component such as TLP250, BJT, microcontroller. As MOSFET is very heat sensitive so for cooling purpose we used four heat sinks at four lags of Hbridge inverter. The drain of the MOSFET is mounted to heat sink. The output of the inverter is then passed to the transformer. The output is taken from the two lower MOSFETs drain as upper MOSFET source is connected to the drain of lower MOSFET.

7. Experimental Result

Fig. 9 and fig. 10 show our practical circuit and its testing setup.

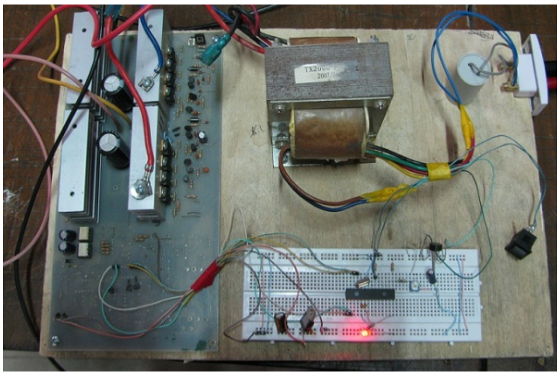


Figure 9. Our complete circuit setup

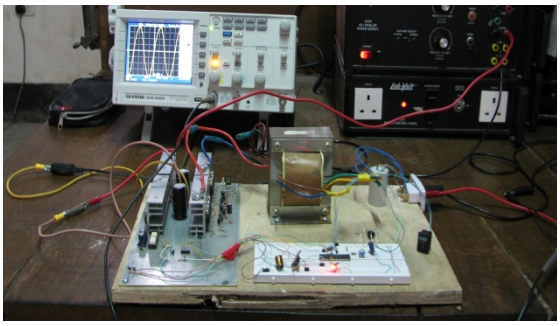
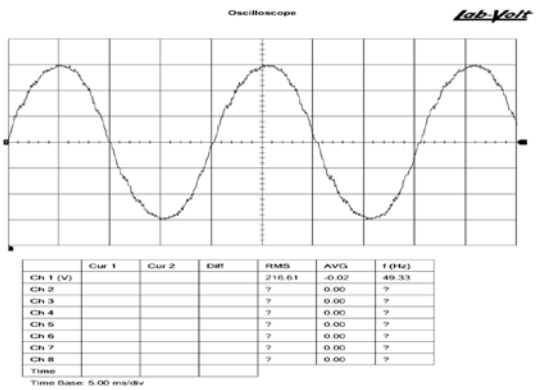


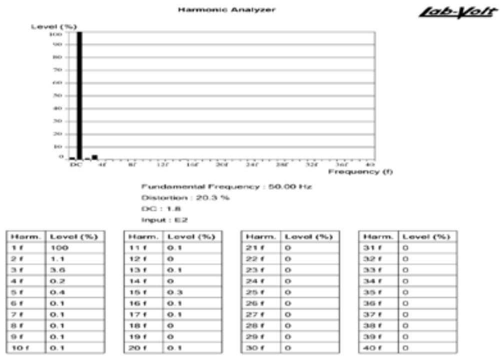
Figure 10. Observation setup of the pure sine wave inverter

The output of our inverter is shown in fig. 11 and fft of the output voltage is shown in fig.12. All these output is taken from laptop synchronizing with data acquisition box connected with inverter.



	Cur 1	Cur 2	Diff	RMS	AVG	f (Hz)
Ch 1 (V)				216.61	-0.02	49.33
Ch 2				?	0.00	?
Ch 3				?	0.00	?
Ch 4				?	0.00	?
Ch 5				?	0.00	?
Ch 6				?	0.00	?
Ch 7				?	0.00	?
Ch 8				?	0.00	?
Time						

Figure 11. Output voltage from the laptop synchronizing with data acquisition box



Harm.	Level (%)	Harm.	Level (%)	Harm.	Level (%)	Harm.	Level (%)
1 f	100	11 f	0.1	21 f	0	31 f	0
2 f	1.1	12 f	0	22 f	0	32 f	0
3 f	3.6	13 f	0.1	23 f	0	33 f	0
4 f	0.2	14 f	0	24 f	0	34 f	0
5 f	0.4	15 f	0.3	25 f	0	35 f	0
6 f	0.1	16 f	0.1	26 f	0	36 f	0
7 f	0.1	17 f	0.1	27 f	0	37 f	0
8 f	0.1	18 f	0	28 f	0	38 f	0
9 f	0.1	19 f	0	29 f	0	39 f	0
10 f	0.1	20 f	0.1	30 f	0	40 f	0

Figure 12. FFT of output voltage showing THD, from Laptop synchronizing with data acquisition box

The output data on tested condition are:

Load = 5W (lamp)
Input voltage = 11.3V
Input current = 2.58A
Output from inverter = 7.13V
Output from transformer = 224.6V
Trans ratio of transformer = 2:63
THD for voltage: THD = 20.3%,
Output current = .07A

8. Conclusion

In this work, a single phase PWM inverter has been implemented with PIC16F73 microcontroller and gate driver's IC TLP250, totem-pole. Several outstanding features of the developed Sinusoidal PWM inverter are: fewer harmonic, low cost, simple and compact. The implemented inverter is for low power and low voltage application.

9. Future Work

In our project we didn't do any work for power factor improvement. But in our regular uses power factor is vital factor. Low power factor causes huge problem such as increase the reactive power, loss will increase, harmonics may generate, short circuit of line may arises and the total system may collapse. So there is a future scope for power factor correction. Besides we've done no work for voltage regulation. So in this sector there has also opportunity for future scope. Besides these, our project work is not tested on high voltage. We just work on 220 volts which is in household range. Now a day there is a high demand on DC power transmission. For industrial and high voltage DC voltage conversion will be a good future work. It needs the further enhancement of the system. It needs a huge transformer. Of course the requirements will cause huge amount of expenses. Finance is a critical issue for further enhancement.

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Abdulla Al Mamun received the B.Sc. degree in Electrical and Electronic Engineering from Chittagong University of Engineering & Technology in 2012.