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Low Cost Uninterruptible Power Supply (UPS) With Pure Sine Wave Inverter Using Lithium Ion Battery Backup

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Abstract- Due to the power crisis in Pakistan, we had an issue in the growing market of inverters ranging from 500W to 5000W for household and different industrial applications. In household these inverters were normally used for short interval of time when the power from grid station is unavailable. Normally the inverters being sold in the market were based on square wave or modified sine wave output and the inverters having pure sine wave output were quiet expensive but in order to run the appliances quieter, cooler and safer we always require pure and clean sine wave output. So these cheap modified sine wave inverters reduce the life of our equipment. The idea of building this inverter is to provide clean and pure sine wave to our appliances as we receive from our grid stations and to increase the life of our appliances. In this inverter we have also used lithium-ion battery instead of conventional lead acetate batteries which have less charge density, less life and are less efficient than lithium-ion batteries. So this system would be less expensive and would be more reliable as compared to the systems which are being sold in the markets. The quantity of components in the circuits are kept as minimum as possible in order to increase reliability of this system.

Index Terms- Inverter, Micro-controller, Lithium ion, Converter, PWM, UPS and Charger

1. INTRODUCTION

THIS section describes different parts of Uninterruptable Power Supply (UPS) and builds the background for implementing pure sine wave inverter and charger for lithium-ion batteries.

A. Pure Sine Wave Inverter

First of all it is necessary to understand the concept of inverter. Basically the function of inverter is to convert DC power into AC power. The simple inverter is shown in Fig 1.

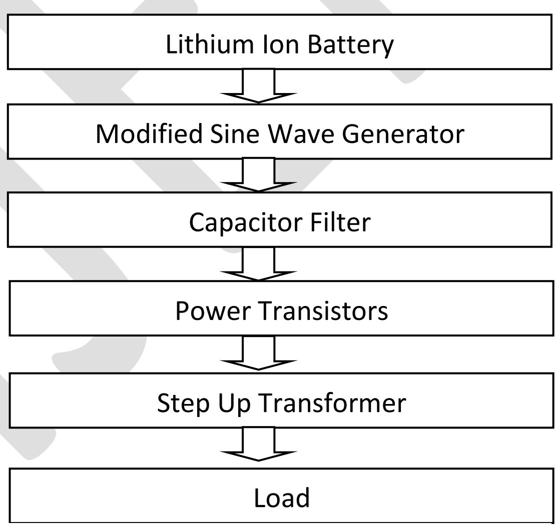

Figure 12: Modified Sine Wave Inverter Block Diagram

Fig. 1 shows the block diagram of a basic inverter which gives modified sine wave or square wave output at load. In these inverters first of all DC power is drawn from battery which is converted to pulsating DC by use of bridge rectifier than it is converted to modified AC sine wave by capacitor filter and finally by the use of power transistors and step transformer we get 220V output at load.

The inverter which we have designed consists of a programmable microcontroller (PIC 16F628A) whose function is to modulate the width of the pulses by using PWM technique to achieve clean and pure sine wave at output. The design of our inverter is shown in Fig 2.

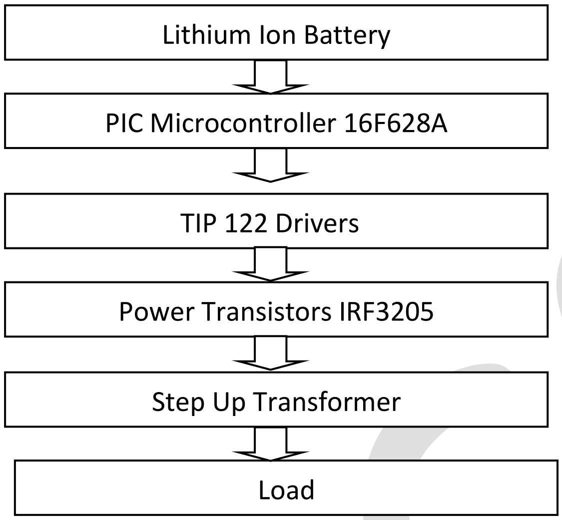

Figure 13: Block Diagram of Pure Sine Wave Inverter

In this design PWM pulse train output form the microcontroller gets amplified by the use of TIP 122 Driver and then they feed the power stage for driving the transformer.

B. Charging Circuit (Converter)

In order to charge the Lithium-ion Batteries this system need efficient charger because lithium-ion batteries are quite sensitive as far as charging is concerned. Keeping in mind the plan to reduce charging time of our battery, we designed a charger with "Boost Charging" option. The designed charger will charge the battery at C/5 till 80% charge than it will switch to slow charging and will charge at C/10. A comparator circuit is used to monitor the voltages of the battery and as the voltage reaches 80% of the rated voltage the charger switch to slow charging mode.

The block diagram of the charger/converter is shown in figure 3.

The charger takes the 220V AC input from the socket which is step down by the transformer into 16V AC then these 16V are converted to pulsating DC by the use of bridge rectifier which is further smoothen by use of capacitor filter. Then LM317 voltage regulator regulates the voltage which is parallel to TIP2955 MOS transistors which is used for current amplification because LM317 can handle 1A current but our requirement is 40A which is fulfilled by TIP2955 which is used in such configuration that it will give 5A current. The comparator circuit will monitor that when to have fast charging and when to have slow, when our battery is at 80% charge it will switch to slow charging else fast charging and this all process will be done with the help of the control circuitry which will switch our current between C/10 and C/5 and hence this charger will be smart charger with boost charging capability.

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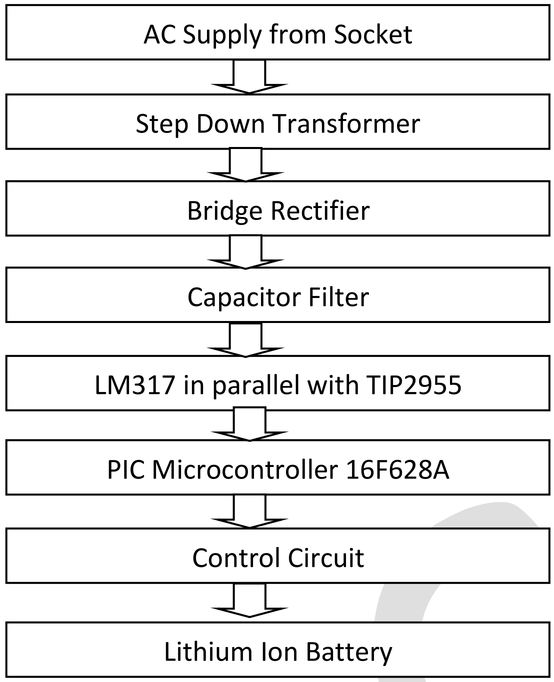

Figure 14: Block diagram of Charging Circuit

In our today's world the most common batteries that are being used commercially are Lead Acid Batteries because they are cheap and can be used to fulfil low load requirements but these batteries have a lot of disadvantages like they are heavy weight, have less charge density, less efficient and most importantly have less life of about 500charge and discharge cycles. The use of lithium ion batteries will enhance the performance of this project because lithium batteries are up to 90% efficient and give more backup than lead acid batteries. Most importantly lithium batteries have charge ad discharge cycles of 10 times as lead acid batteries, so they can last longer. And also lithium batteries charge faster than lead acid batteries and give much longer backup over heavy current requirements, so the use of lithium ion batteries in this project will show the alternate for conventional lead acid batteries and will improve the performance of battery backup over heavy loads.

2. Implementation:

A. Pure Sine Wave Inverter:

The design of pure sine wave inverter is pretty simple in which most of the working is done by PIC Microcontroller which generates our desired PWM at pin no 9 and 10. Than this PWM is fed to TIP122 driver where we provide PWM with current gain because PIC directly cannot meet the requirement of power stage which consists of IRF 3205 in low side push pull configuration where they sink the current. At a time only one IRF 3205 is on, so IRF 3205 in pair continuously alters the direction of the current which result in change in flux at primary side of transformer. Hence EMF is generated at the secondary side which is still not a pure sine wave than this wave is filtered with the help of RC filter in which 2.2µF capacitor and 1k resistance is used to give clean and pure sine wave at the output. This design is very much simple and component level is kept less a possible which will increase the reliability of the system. This also gives us the advantage of less cost and easy trouble-shooting of the circuit of inverter as shown in figure 4.

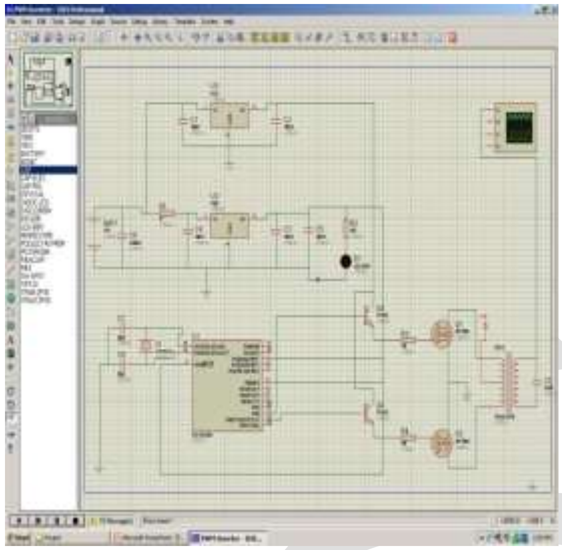

Figure 15: Inverter Schematic

B. Smart Charger:

The smart charger was really easy to implement because it is concept based on simple regulated power supply with a modification that TIP2955 increase the current capability of this supply to 40amp as shown in figure 5.

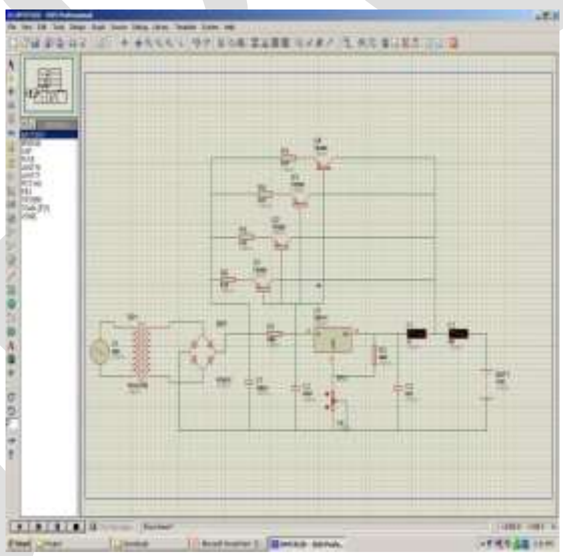

Figure 16: Charger Schematic

3. RESULTS

The low cost pure sine wave inverter was successfully implemented and tested. The photograph of implemented inverter is shown in figure 6, 7 and 8.

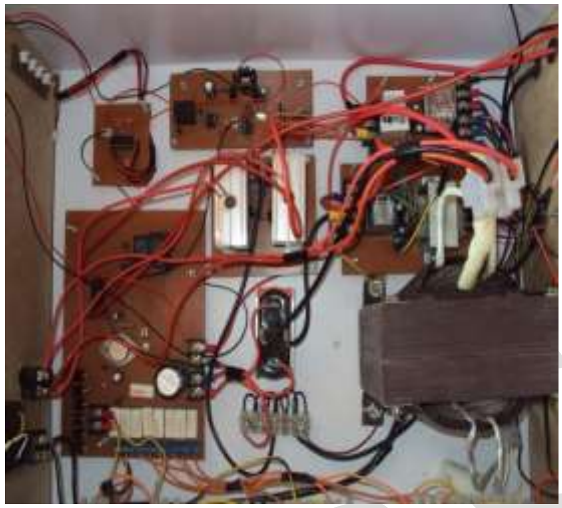

Figure 17: Picture of the Implemented UPS

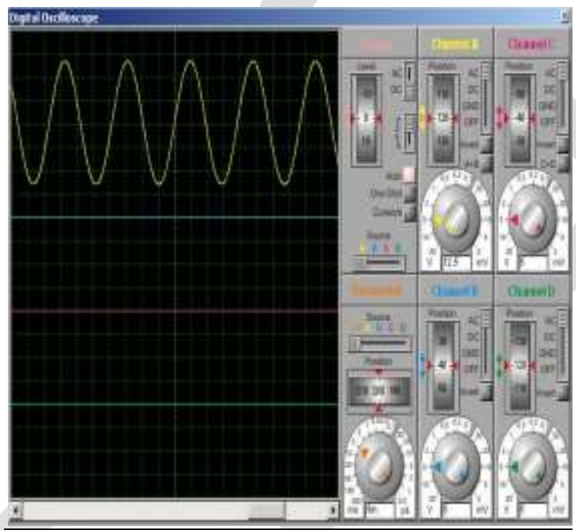

Figure 18: Inverter Output (Simulated)

Figure 19: Inverter Output (Real Time)

4. CONCLUSION

In this paper low cost uninterruptible power supply with pure sine wave inverter has been implemented successfully which is in reach of a common man and can be made in cost of modified sine wave inverter.

5. FUTURE RECOMMENDATIONS

1. Tune the filter as finer as possible.
2. Improve the appearance of the package.
3. Attempt to reduce costs.
4. Closed Loop feedback system in order to monitor PWM and output voltages continuously can greatly improve performance of the system.

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7. PCB LAYOUTS:

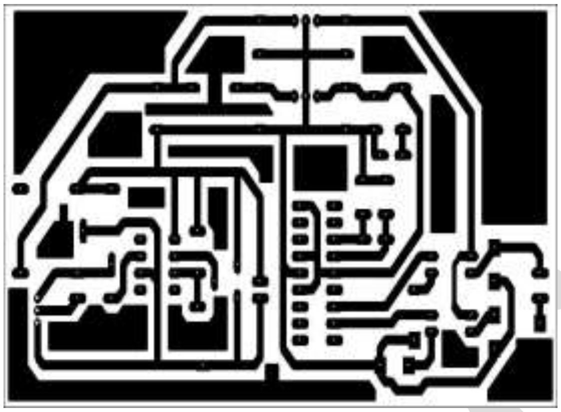

Figure 20: Inverter Driver Stage Layout

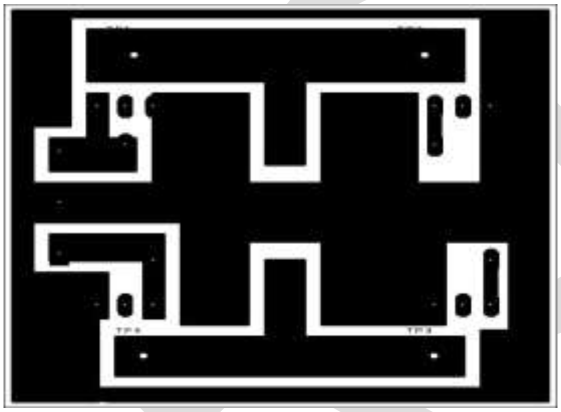

Figure 21: Inverter Power Stage Layout

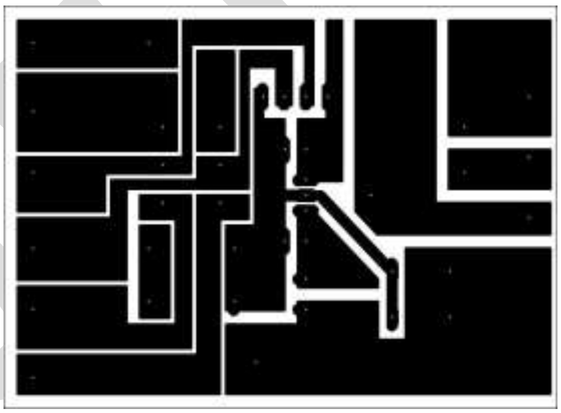

Figure 22: UPS Change-over Circuit Layout