

Development of a Microcontroller Based 12/24 Volts Push-Pull Inverter System

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Abstract : Conventional power inverter systems are normally specified to work with a single nominal battery voltage. This is somewhat restrictive and causes downtimes when d.c power sources of specified voltages are not available. In this work, a push-pull inverter circuit that generates its rated output voltage from either a 12Volts or 24 Volts d.c source was developed. The circuit, based on a PIC 16F877A microcontroller, determines the battery voltage and generates the required MOSFET gate drive signals required to generate a 240 volts r.m.s modified square wave output waveform. The developed circuit and the associated microcontroller firmware were designed and modelled using proteus® software and MicroC software respectively. The circuit was constructed, programmed and then tested. The circuit generated 240 volts r.m.s output waveforms when it was powered from either a 12 volts or a 24 volts d.c voltage sources.

Keyword:– Microcontroller, push-pull, Inverter, MicroC.

I. Introduction

Inverters are important components of power backup and renewable energy systems. Inverter systems, powered from sets of batteries, convert d.c power at a specified voltage level to a.c waveforms with minimal power loss. Common operating voltages for inverter systems are 12 volts, 24 volts and 48 volts, depending on the output power. A number of batteries are usually connected in series and parallel strings to generate the required d.c power at the specified inverter input voltage. In situations where the number of batteries and their terminal voltages are such that the available inverter input d.c voltage requirement cannot be met, either a suitably rated inverter or more batteries are needed. For example, in a typical 24 volts power backup system where two 12 Volts batteries are connected in series to generate the required 24 volts d.c, if one of the batteries fails, either the inverter must be replaced with one rated at 12V or the failed battery must be changed. Until either of these steps is taken, the entire system will be out of operation, resulting in down times.

In the above example, what is needed is an inverter system that can work with various battery voltages. This work seeks to develop such an inverter system that can operate with 12V or 24 V d.c voltages. The developed inverter circuit, based on a PIC 16F877A microcontroller, is a modified push-pull inverter that generates a 240v output waveform when powered from either a 12V or 24V d.c power source. It achieves this by effectively changing the voltage transformation ratio of a multi-tap output transformer.

II. Literature Review

Inverters are crucial energy conversion components in any renewable energy scheme which converts d.c power to a.c energy required by most electrical loads. The ideal inverter has hundred percent efficiency and produces a perfectly sinusoidal output waveform. Production of a perfect sinusoidal output waveform will require the inverter to operate as a linear amplifier which reduces the efficiency figure. To achieve reasonably high efficiency, inverters replace the temporal variations of a sinewave with waveforms that have square edges. Examples of such waveforms include squarewaves [1], modified squarewave, sinusoidal pulse width modulation (SPWM) synthesized sinewave [2], and multilevel waveforms [3].

The process of synthesizing a.c power from d.c sources is commonly achieved using two basic methods. In the first method, a high voltage d.c source whose average value equals the peak value of the a.c voltage to be synthesized is generated from the battery using high frequency d.c to d.c converters. The a.c waveform is then generated from the high voltage source using electronic switches [4,5]. This approach leads to a compact design because heavy 50Hz magnetics are not used. The other approach involves the direct generation of a.c power from the available d.c power using 50Hz step-up transformer and electronic switches [6]. Either of these methods can be used to make squarewave, modified sinewave and sinusoidal pulse width modulated sinewave inverters. A circuit block related to inverters is the d.c to d.c converter which converts input d.c power to an output d.c power at a different voltage level. A class of d.c to d.c converters, known as multi-input converters, have the ability to operate from more than one voltage sources have been developed and analysed in the literature [7, 8]. These converters are used in renewable energy conversion systems that have multiple sources of energy such as solar and wind energy sources, as exemplified by [9]. They adjust their voltage gain in relation to the input d.c voltage, as needed to generate the required output voltage using pulse-width modulation techniques.

III. Methodology

The developed inverter circuit, built around a PIC16F877A microcontroller, consist of a driver circuit that generates 12volt pulses from the 5 volts output pulses of the microcontroller; a set of power MOSFETs which acts as high power switches, a power supply unit that generates 5v and 12 V d.c required by the microcontroller and the driver circuits respectively; and a 50Hz multi-tap step-up transformer. The microcontroller, under software control, measures the battery voltage through one of its analogue channels. A 15 volt threshold was used in determining the nominal battery

voltage. The microcontroller also produces the required sequence of pulses needed to generate a modified square wave output waveform, using timer interrupts and delay techniques. A pushbutton switch, debounced using the hardware generated delays, is used to switch on or switch off the inverter. A LED indicator blinks every 100 ms and 400ms for nominal battery voltages of 12 volts and 24 volts respectively. The overall hardware circuit is shown in Fig. 1. The circuit was designed and simulated with proteus modelling software ; the software was developed and fine-tuned using MicroC software. A prototype was constructed on a general purpose printed circuit board, otherwise known as Veroboard®. The firmware developed was transferred to the program memory of the PIC16F877A microcontroller with a usbpicprog USB programmer unit.

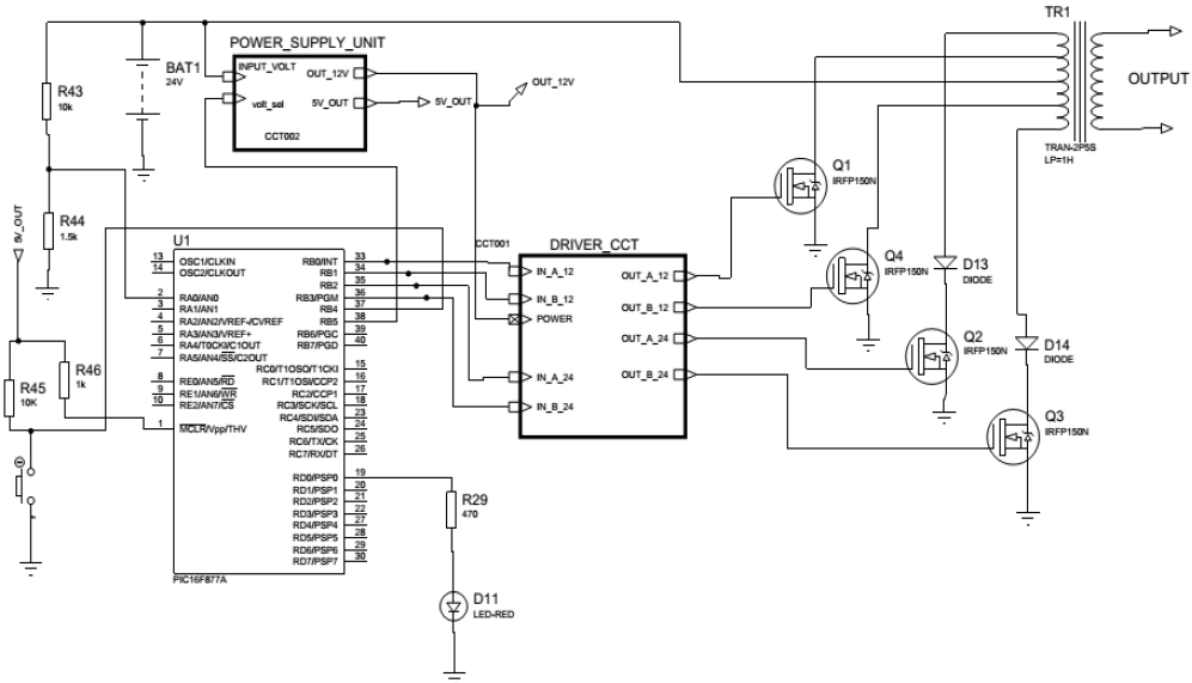


Fig. 1. 12V/24V Inverter Circuit

3.1 Driver Circuit.

The driver circuit interfaces between the microcontroller and the output stage power MOSFETs. It consists of four identical push-pull circuits, with each circuit generating a 12V logic level output signal from the 5 volts output logic signal of the microcontroller. A circuit diagram of one of the driver circuit implementations is shown in Fig 2.

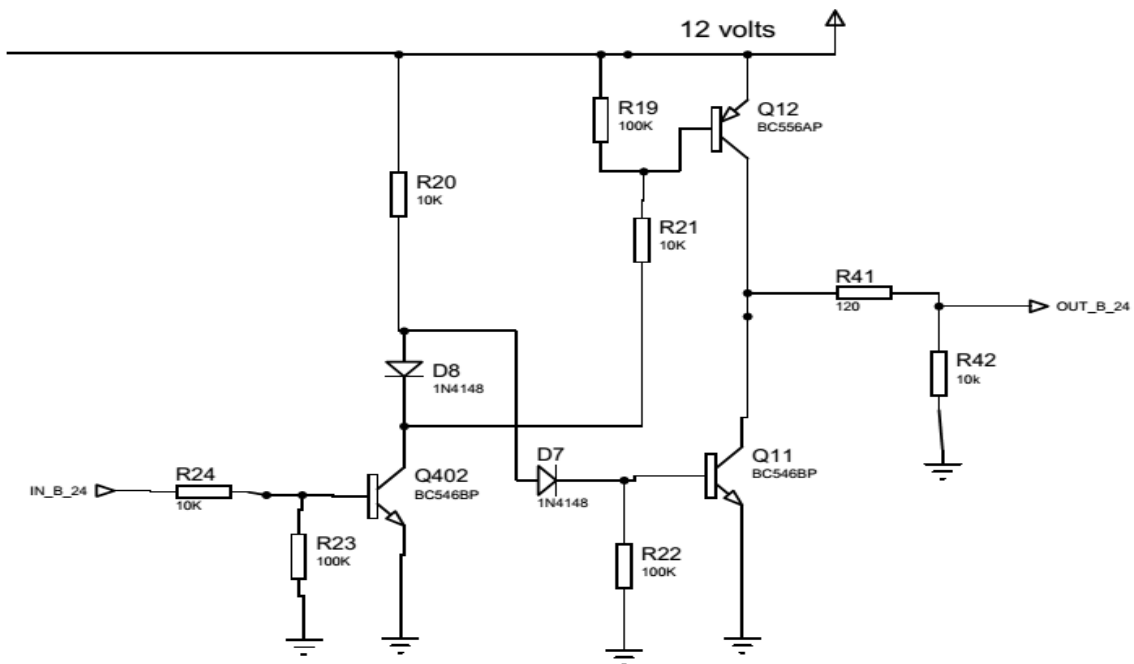


Fig. 2: The driver circuit

3.2 The Output Stage

The output stage of the inverter is comprises of four switching mosfets, namely Q1 ,Q2, Q3 and Q4, and a multi-tap output step-up transformer TR1, as shown in Fig. 1. The output stage is a simple push-pull power conversion topology modified to have two voltage transformation ratios. Only two of the four output stage Mosfets are active for a given battery voltage. With a 12 volts battery voltage, drive pulses are applied to the gates of Mosfets Q4 and Q1, and with a 24 volts supply, they are applied to Q2 and Q3. Thus, the effective voltage transformation ratio of the transformer depends on which set of Mosfets is being switched.

3.3 Software Design

The software controls the operation of the inverter. It generates the drive pulses and directs them to the appropriate output pin of the microcontroller, depending on the battery voltage. The control pulses are generated using timer0 resource on the PIC chip. The timer is configured to generate an interrupt every 5ms. A finite state machine that runs in the timer0 interrupt service routine enables the appropriate pins of the microcontroller for a given time duration, as required to generate a 240V r.m.s, 50Hz modified square wave output waveforms. The pushbutton switch is debounced in hardware using timer0-generated delays, with a debounce period of 20ms. When a switch press is detected, the inverter state is changed from on state to off state or vice versa. The software flowchart is shown in Fig. 3.

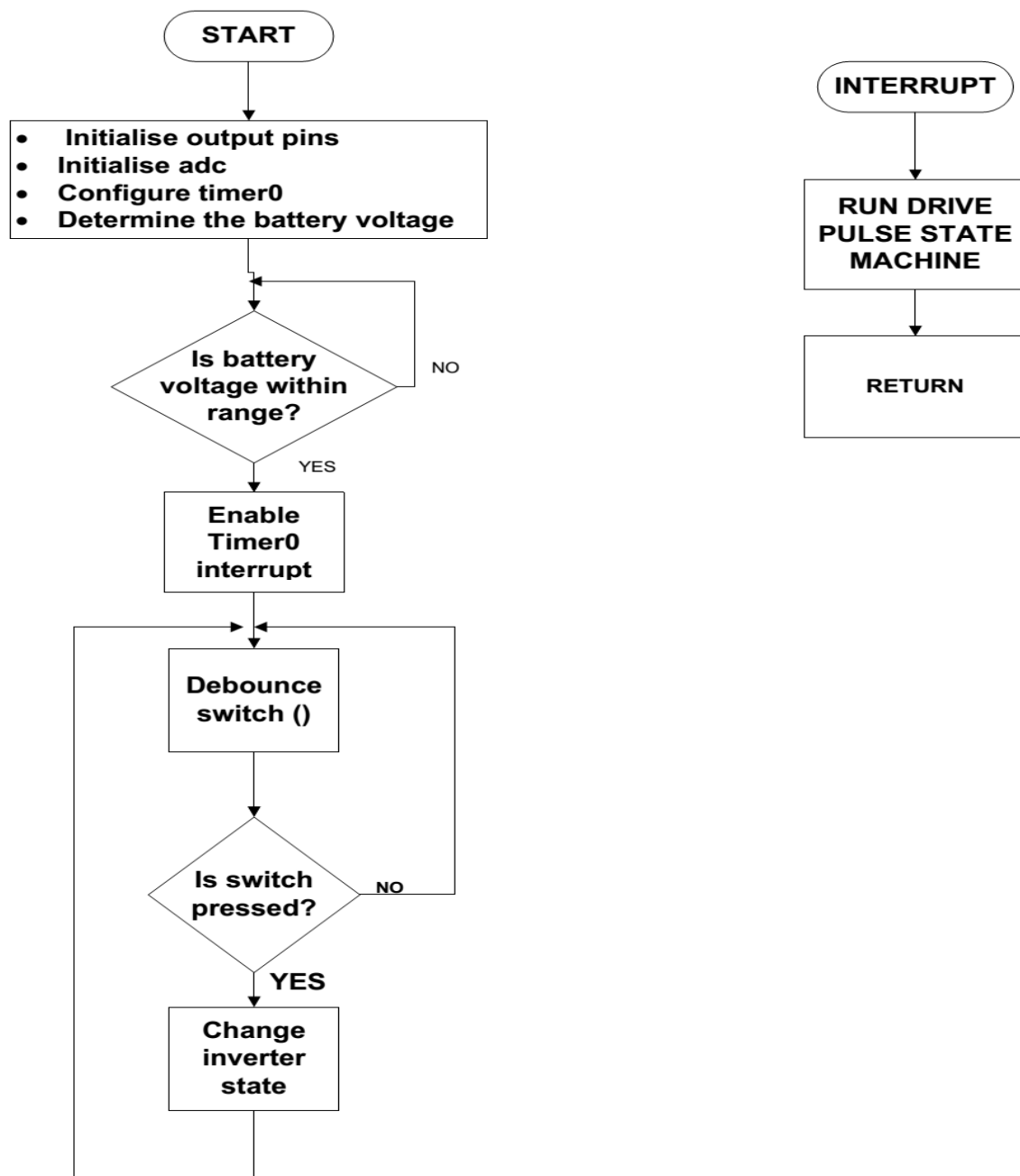


Fig. 3: Flowchart of the Inverter Software.

IV. Results And Discussion

Figure 4, consisting of two cascaded virtual oscilloscope pictures, shows the Mosfet gate drive waveforms produced by the proteus model of the inverter. In Fig. 4, the pictures on the left and right show the gate drive pulses applied to the output stage Mosfets when the inverter is powered from a 12 V and a 24 V d.c source respectively. The constructed circuit is shown in Fig. 5.

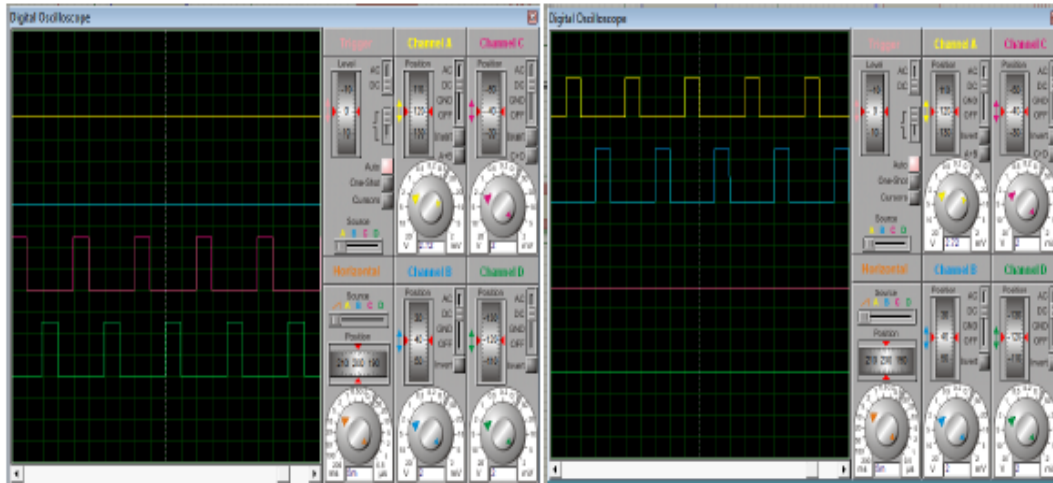


Fig. 4: Mosfet gate drive pulses for 12 Volts and 24 Volts operation

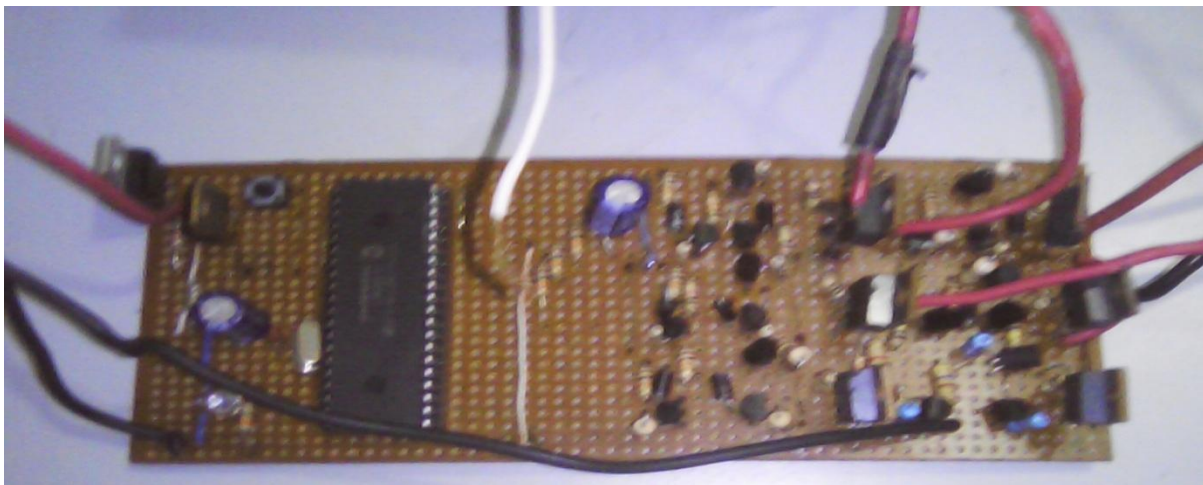


Fig. 5: The Constructed 12V/24V Inverter circuit

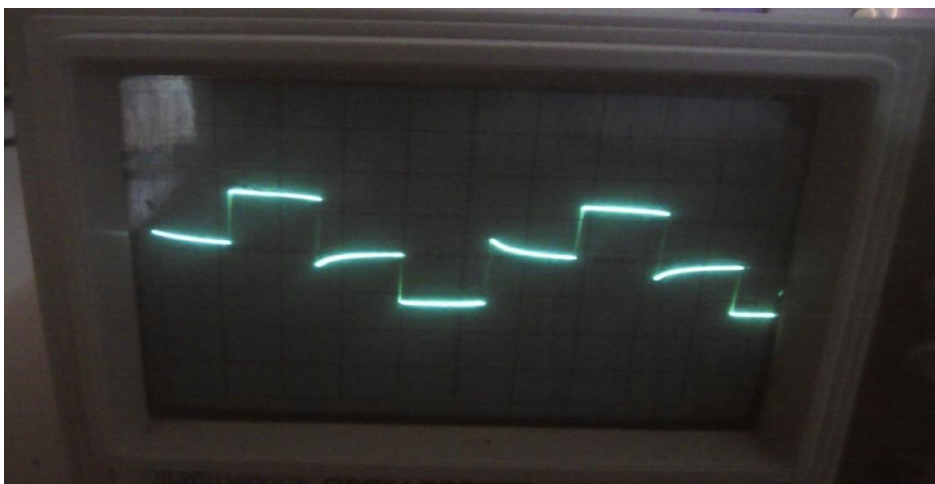


Fig. 6: The output waveform of the inverter

Fig. 6 shows a sample of the output waveform of the inverter circuit when it was powered from either a

12V or 24V d.c source. The inverter successfully determines the nominal battery voltage and adjusts its operation accordingly to generate the required output voltage.

V. Conclusion

An inverter system that can operate on either a 12V or 24V battery voltage has been successfully designed and constructed. The constructed circuit produced a 240 V r.m.s, 50Hz modified squarewave output from either a 12V or 24V d.c source. The inverter was tested by using it to power a 60 W filament lamp, and it was found to work well. The developed circuit can be further refined by using pulse width modulation techniques to generate a low distortion sinusoidal output waveform.

References

- [1]. Abolarinwa, J. and Gana, P., Design and Development of Inverter with AVR Using Switch Mode Square Wave Switching Scheme ,AU J. T. 13(4), 2010.
- [2]. Thangam, P. and Kanna, R. R., Effectiveness of Increased and Efficient Sinewave in PWM Architecture, International Journal for Trends in Engineering and Technology, Vol. 4, Issue 2, 2015.
- [3]. Bhargava, R. and Shrivastava, A, Cascaded H-Bridge Multilevel Inverter Using Microcontroller for Single-Phase Induction Motor, International Journal of Emerging Technologies 3 (2), 2012, 101-108.
- [4]. Menon, A. and Madhumitha, R., Design and Simulation of Solar –Micro Inverter with Multiple Loads , International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 5, 2014. pp. 9612-9620.
- [5]. Dandin, S and Khumari, A, Highly Efficient Pure Sine-Wave Inverter for Photovoltaic Applications with MPPT Technique , International Journal of Engineering Research and Technology, Vol. 3, Issue 5, 2014. pp 1837-1842.
- [6]. Kayabasi, A. and Akkaya, R., The Design and Implementation of a Microcontroller-Based Single Phase On-Line Uninterrupted Power Supply With Power Factor Correction, International Conference on Electrical and Electronics Engineering (ELECO 2009.), I-442, I-446, pp. 2009.
- [7]. Matsuo, H., Lin, W., Kurokawa, F., Shigemizu, T., and Watanabe, N., Characteristics of Multiple-Input DC-DC Converters, IEEE Transaction on Industrial Electronics, Vol. 51, No. 3. 2004. pp. 625-631.
- [8]. Srinivas, V. S., Kumar, E. V., and Bhavya, K., A Two-Input Output Z-Sourced DC-DC Converter for Renewable Applications, International Journal of Modern Engineering Research, Vol. 2, Issue 5. 2012. pp. 3861-3868.
- [9]. Sivakumar, N. and Sumathi, A. , Control of Hybrid System Using Multi-input Inverter and Maximum Power Point Tracking , International Journal of Engineering Research and Applications, Vol. 3, Issue 4, 2013. pp. 77-81.