Design of Digital Voltmeter for AC Voltage Measurement Using PIC Microcontroller

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Abstract: ***This article describes the design of a digital voltmeter for AC voltage measurement using PIC microcontroller. This design uses the PIC microcontroller, rectifier, voltage divider and seven segment displays to complete the desired measurement. We are using our microcontroller programming skills as well as our circuit designing expertise for the required design. This meter is calibrated for the measurement of upto 500 volts AC. Here we are using PIC microcontroller because this is having an internal ADC, however any other microcontroller can be used with or without internal ADC. But separate ADC is required if microcontroller used is without internal ADC.***

Keywords: PIC 16F876 Microcontroller, Seven Segment Display, AC to DC Conversion, Voltage Divider

1. Introduction

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. Analog voltmeters have a pointer across a scale in proportion to the voltage of the circuit; digital voltmeters give a numerical display of voltage by use of an analog to digital converter. A digital voltmeter (DVM) measures an unknown input voltage by converting the voltage to a digital value and then displays the voltage in numeric form. DVMs are usually designed around a special type of analog-to-digital converter called an integrating converter. The first digital voltmeter was invented and produced by Andrew Kay of Non-Linear Systems (and later founder of Kaypro) in 1954 [6]. DVM measurement accuracy is affected by many factors, including temperature, input impedance, and DVM power supply voltage variations. However this implementation is quite rugged and very much reliable.

2. Objectives

The objective for this project is to design a digital voltmeter for AC measurement upto 500 volts, which is one of the general requirements for any electrical circuit. In order to increase accuracy and repeatability this circuit is designed using a microcontroller which also minimize the other electronic circuitry. Thus this design will improve the overall performance of the voltmeter.

3. System Architecture

This paper will describe how to make a simple digital voltmeter using a PIC16F876 microcontroller. The range of this DVM is 0-500V, but the range can be decreased based on the requirements by using the hardware circuit needs described in this project. The PIC microcontroller reads the input voltage through one of the 5 analog channels and converts it to a 10-bit digital number using the internal ADC. By manipulating the output of the ADC this value can be calibrated to the actual measured voltage. This voltage is displayed through a 7- segment LED display unit.

The system architecture of a Digital Voltmeter (DVM) is shown below (Figure 1) through a simplified block diagram. It consists of a microcontroller module which regulates the entire reading of value and display activity for the system. This proposed system also having few more hardware sections like voltage divider, rectifier, and switching of seven segment displays.

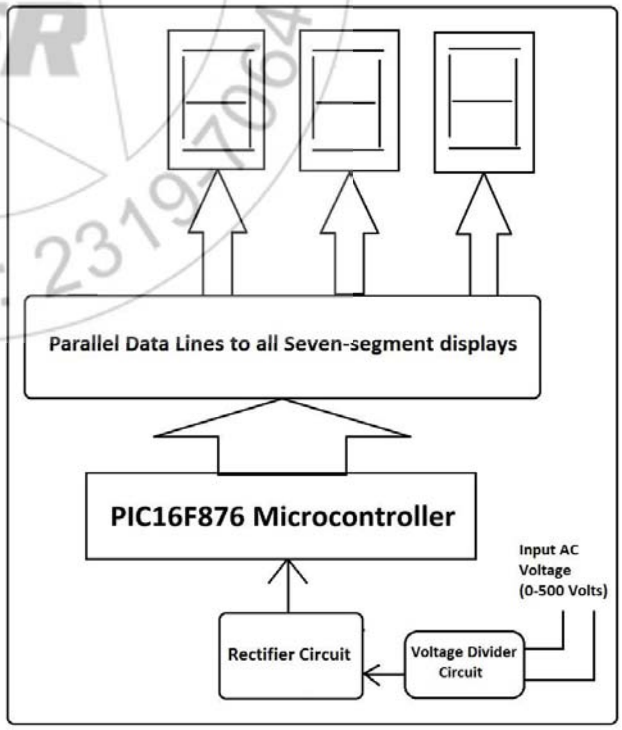

Figure 1: Block Diagram of Digital Voltmeter

a) PIC 16F876 Microcontroller

The PIC16F876A-I/SP is an 8-bit enhanced Flash Microcontroller with low-power, high-speed flash/EEPROM

ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

technology. It features 256bytes of EEPROM data memory, self programming, an ICD, 2 comparators, 5 channels of 10-bit Analogue-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire serial peripheral Interface (SPI) or the 2-wire inter-integrated circuit (I²C) bus and a universal asynchronous receiver transmitter (USART). The data EEPROM, flash program memory is readable and writable during normal operation (over the full VDD range). This memory is not directly mapped in the register file space. Instead, it is indirectly addressed through the special function registers. All devices have a host of features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection.

- Synchronous serial port (SSP) with SPI (master mode) and I²C (master/slave)
- Universal synchronous asynchronous receiver transmitter (USART/SCI) with 9-bit address detection
- Brown-out detection circuitry for brown-out reset (BOR)
- 10-bit/up to 8-channel Analogue-to-digital converter (A/D)
- 100,000 Erase/write cycles enhanced flash program memory typical
- 1,000,000 Erase/write cycles data EEPROM memory typical
- >40 Years Data EEPROM retention
- Self-reprogrammable under software control
- In-circuit serial Programming (ICSP) via two pins
- Single-supply 5V in-circuit serial programming
- Programmable code protection
- Power saving sleep mode

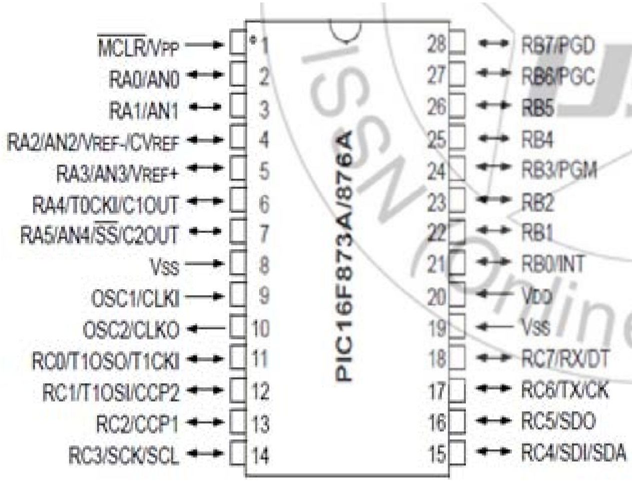

Figure 2: PIC 16F876 Microcontroller

This system is having three seven segment displays for displaying of voltages ranging from 00.0volt to 500 volts AC. This voltmeter has been calibrated with 0.1volt of resolution upto 99.9 volts and of 1volt of resolution from 100 volts onwards.

b) Seven Segment Display

Generally seven segment displays are available in 10 pin package. The pin diagram of seven segment display is shown in the Figure 3. Seven segment display is an electronic circuit consisting of 10 pins. Out of 10 pins 8 are LED pins and these are left freely. 2 pins in middle are common pins and these are internally shorted. Depending on either the common pin is cathode or anode seven segment displays can be either named as common cathode or common anode display respectively.

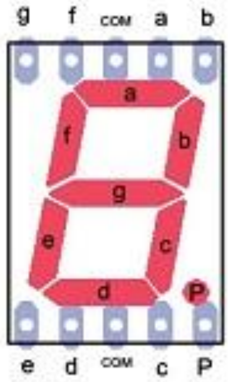

Figure 3: Pin Diagram of Seven Segment Display

Types of Seven Segment Displays:

Common Anode (CA): In common anode type, all the anodes of 8 LED’s are connected to the common terminal and cathodes are left free. Thus, in order to glow the LED, these cathodes have to be connected to the logic „0“ and anode to the logic ‘1’.

Common Cathode (CC): As the name indicates cathode is the common pin for this type of seven segments and remaining 8 pins are left free. Here, logic low is applied to the common pin and logic high to the remaining pins.

Working:

Seven segment display works, by glowing the required respective LEDs in the numeral. The display is controlled using pins that are left freely. Forward biasing of these pins in a sequence will display the particular numeral or alphabet. Depending on the type of seven segment the segment pins are applied with logic high or logic zero and in the similar way to the common pins also.

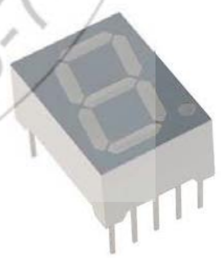

Figure 4: Seven Segment Display Top View

c) Voltage Divider

A simple voltage divider is shown below in Figure 5, using two different valued resistors with values of several kΩ each. Use voltage supply which is under measurement. Observe the Vout, according to the voltage divider formula Vout = Vs x R2/(R1 +R2).

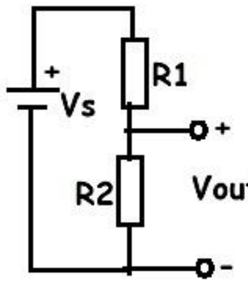

Figure 5: Voltage Divider Network

d) Software Implementation

CCS developed the first C Compiler for Microchip microcontrollers over 20 years ago and continues to provide software solutions to developers of embedded applications using PIC MCU and PIC24/dsPIC DSC devices. CCS compilers are easy to use and quick to learn.

CCS compiler include pro-level optimization, the largest library of built-in functions, powerful PIC MCU specific pre-processor commands, and ready-to-run example programs to quickly jump-start any project. [5]

Key Compiler Features:

- Easily migrate between all Microchip PIC MCUs devices
- Minimize development time with: peripheral drivers and standard C constructs
- C++ style input/output streams with full data formatting to any device or for strings
- Use CCS libraries and object code royalty free
- Convenient functions like #bit and #byte allow C variables to be placed at absolute addresses
- The integral one-bit type (Short Int) permits the compiler to generate very efficient Bit-oriented code
- Easily define, set-up and manage interrupts.

4. Proposed System

The project is divided into two parts- software part and the hardware part. Software part is basically the algorithm/code compiled using a compiler as explained above. In the hardware part a great bit of work is done as because the required measurement has been divided into three broad sections, (1) voltage divider, (2) analog to digital conversion, (3) reading data at ADC channel and displaying of voltage on seven segment display.

Operation of the proposed system:

The flow chart of the voltmeter system is shown below (Figure 6). At the start of the program, PIC needs to be initialized the I/O pins assigned and clock frequency. Initialization of ADC port should be done at which voltage will be read by the microcontroller. Since microcontroller is a digital device it can read/measure DC voltages upto 5volts only. Therefore, we should have divided the input voltage by a factor of 100 so that we could measure 500volts in terms of 5volts.

After the voltage divider network we should convert AC voltage into DC so that our microcontroller can read it efficiently. We use ordinary diodes for this purpose. This process is known as rectification. Once the rectification is done the voltage under measurement should be given to the specified ADC channel pin of the microcontroller, since our PIC microcontroller is having internal ADC.

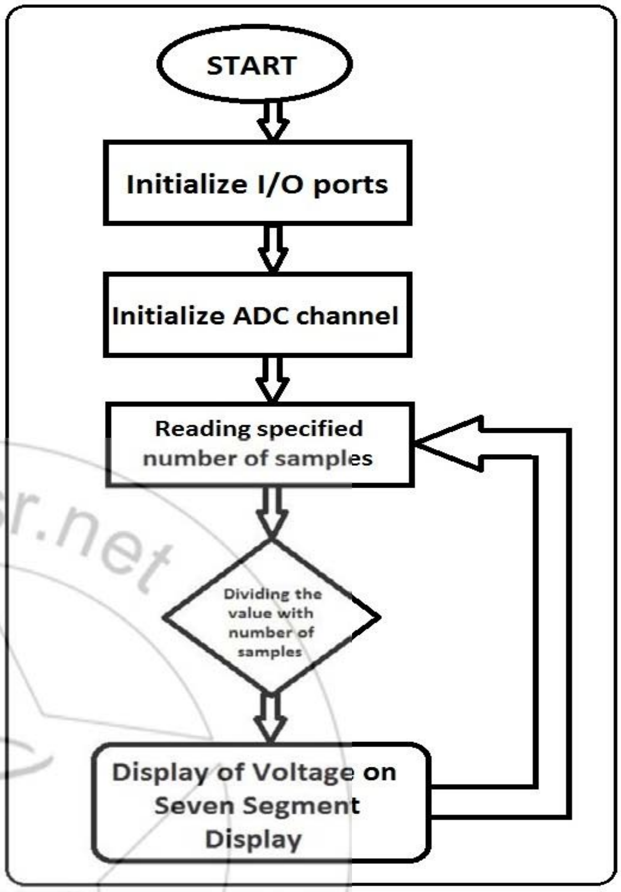

Figure 6: Flow chart for the proposed Digital Voltmeter

A number of samples/reading will be read by the microcontroller as per our algorithm. By averaging the measured value by number of samples, we get the exact voltage reading under measurement. Here 8-bit data pins have been directly connected to the each seven segment display in parallel. By using the switching property of the transistors, we are enabling the display unit to show the desired reading on the seven segment display.

Our voltmeter is designed in such a way that it shows the reading with 0.1volt of resolution upto 99.9volts and with 1volt of resolution after 100volts. This is done by automatic range selection of the meter, i.e. by removing the decimal from the seven segment display as shown in the test images (Figure 7).

5. Test and Result photos of the system

This image is taken when the voltage was measured at the line voltage 223V AC (around 220V). This voltmeter has been tested for different voltages ranging from 0-500 Volts AC. Therefore the project is successful. Now the voltmeter is ready to measure any voltage ranges from 0-500V.

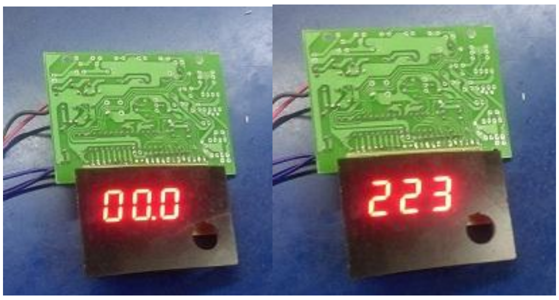

Figure 7: Digital voltmeter with 7-segment display (at the testing stage)

6. Conclusion

This project has been successfully designed, constructed and also tested for the specified range. This voltmeter is calibrated with 0.1volt of resolution upto 99.9 volts and of 1volt of resolution from 100 volts onwards. It is relatively cheaper voltmeter, comparing to those present in the market. This research will enhance the possibility of using digital voltmeters to improve micro, small and medium scale industries in the country.

7. Future Scope

We can extend this voltmeter to measure DC voltage also, so that this voltmeter could be used for both types of measurements AC voltages as well as DC voltages. Further such meters can be interfaced with a complex measurement system using serial interface or wireless mode so that data could be utilized for control purposes.

8. Acknowledgment

We take this opportunity to thank all those who motivate us to think innovative and design such a circuit which is usable largely in the engineering field of measurement. We also want to thank Mr. Vinod Verma, Director Vinytics Peripherals Pvt. Ltd, New Delhi and the other staff members especially from the production department of the company.

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Shagun Malhotra received his B.Tech degree from Guru Gobind Singh Indraprastha University, New Delhi and M.Tech degree from Maharshi Dayanand University, Rohtak. He is having a wide industrial experience of working with private as well as government organization. He has published various papers in International journals. He is now working as Electronics Design Engineer with Vinytics Peripherals Pvt. Ltd. Delhi.

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