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Design and Construction of Digital Line Frequency Meter using PIC Microcontroller

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***Abstract:** In power transmission system, the line frequency matching from one end to another forms a very critical part of matching parameters at the receiving end. It can lead to serious implications if accuracy is not taken into account. Therefore the accuracy for line frequency measurement plays a major role in the power line transmission system. This paper describes a very simple and compact design of Digital Line Frequency Meter using PIC microcontroller. This line frequency meter having frequency measurement range from 10.00 Hz to 90.00 Hz, with a resolution of 0.01 Hz and accuracy ± 1%. Digital line frequency meter is a 4 digit type of digital meter; the usage of latest CMOS IC technology has helped in increasing the reliability, accuracy and making the unit light weight and compact.*

Keywords: Line Frequency, PIC 16F876 Microcontroller, BCD to Seven Segment Decoder, PIC C compiler, Zero Crossing Detector circuit.

1. Introduction

Accuracy of measuring instruments is increasing rapidly over the past few years. Unfortunately, their accuracies are mostly proportional to the time period. As time passes, they may function incorrectly and generate some errors. The mistaken results from such instruments can cause serious problems in economic system and life safety since they will be used for validating product standards in the importing and exporting industries. In order to ensure that they work perfectly, the calibration process is required. In the past, the calibration has to be performed manually, so they were prone to serious issues like human errors. Presently, fully automatic calibration systems have been used worldwide and they play an important role in the calibration of measurement instruments. They can improve measurement accuracy, repeatability and minimize routine jobs. This proposed system is to measure line frequency using PIC microcontroller. The whole process of the line frequency meter is controlled by PIC 16F876 microcontroller.

Frequency measurement is very important in many applications of alternating current, especially in AC power systems designed to run efficiently at one frequency and one frequency only. If the AC is being generated by an electromechanical alternator, the frequency will be directly proportional to the shaft speed of the machine, and frequency could be measured simply by measuring the speed of the shaft. If frequency needs to be measured at some distance from the alternator, though, other means of measurement will be necessary.

2. System Architecture

The system architecture has been shown below in Figure 1, which will give a detailed structure of the proposed system. The heart of this Line Frequency meter is PIC16F876A microcontroller with built-in CCP1 pin. The line frequency from the AC line is first converted to a train of pulses using zero crossing detector (ZCD). The output of the ZCD is almost twice the line frequency under measurement which will be given to the timer pin of the microcontroller. This timer will calculates the time between the two pulses, thus giving the frequency of the input line. After this manipulation, final measurement is displayed on the seven segment display through BCD to seven segment decoder chip.

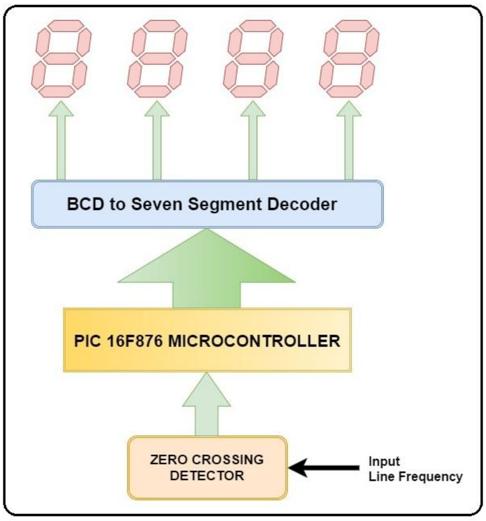

Figure 1: Block diagram representation for Line frequency meter using PIC 16F876

a) PIC 16F876 Microcontroller

The PIC16F876A-I/SP is an 8-bit enhanced Flash Microcontroller with low-power, high-speed flash/EEPROM 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. [2]

- 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

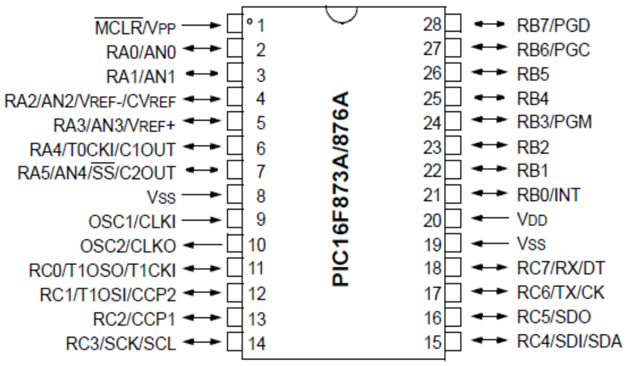

Figure 2: PIC 16F876 Microcontroller

b) BCD to Seven Segment Decoder (4511)

The 74HC/HCT4511 are high-speed Si-gate CMOS devices and are pin compatible with "4511". The 74HC/HCT4511 are BCD to 7-segment latch/decoder/drivers with four address inputs (D1 to D4), an active LOW latch enable input (LE), an active LOW ripple blanking input (BI), an active LOW lamp test input (LT), and seven active HIGH segment outputs (Qa to Qg).

When LE is LOW, the state of the segment outputs (Qa to Qg) is determined by the data on D1 to D4. When LE goes HIGH, the last data present on D1 to D4 are stored in the latches and the segment outputs remain stable. When LT is LOW, all the segment outputs are HIGH independent of all other input conditions. With LT HIGH, a LOW on BI forces all segment outputs LOW. The inputs LT and BI do not affect the latch circuit.

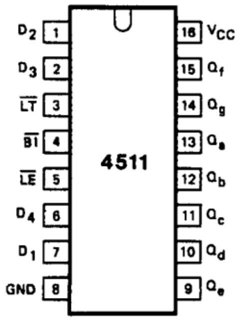

Figure 3: BCD to Seven Segment Decoder

c) 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 4. 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.

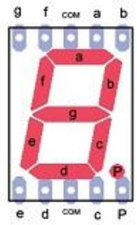

Figure 4: Pin Diagram of Seven Segment Display

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.

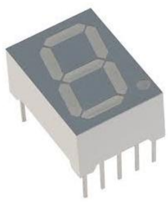

Figure 5: Seven Segment Display Top View

d) Zero Crossing Detector (ZCD) Circuit

As the name indicates the zero crossing detector is a device for detecting the point where the voltage crosses zero in either direction. As shown in the circuit diagram (Figure 6) the first section is a rectifier using diode provides half wave rectified output. This is applied to the base of the transistor through a base resistor, R2. The capacitor charges to maximum of the rectified output through the diode. This charge is available to the transistor as VCC. The capacitance value is kept large in order to minimize ripple and get perfect dc. The transistor remains OFF until the Cut-in voltage VBE is reached. During the OFF period of the transistor the output will be high and approximately equal to VCC. Once the transistor is ON and IB increases according to the input wave, the transistor moves slowly towards saturation where the output reduces to the saturation voltage of the transistor which is nearly equal to zero. [6]

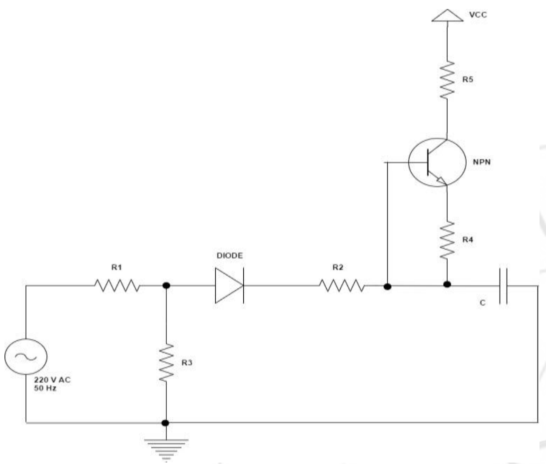

Figure 6: Zero Crossing Detector Circuit

Initially VBE = Cut-in voltage of diode, the capacitor will charge through the diode Vm where Vm is the maximum amplitude of the rectified wave. Now the diode is reverse biased and hence does not provide a discharging path for the capacitor, which in turn has two effects, a) Variation in VCC, b) it will provide base current to the transistor in the region where both diode and transistor are OFF.

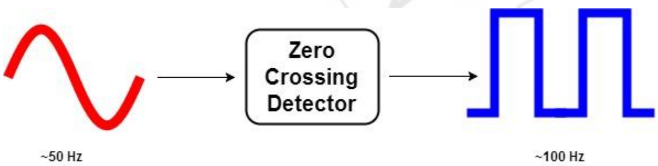

Figure 7(a): Conversion Trough Zero Crossing Detector

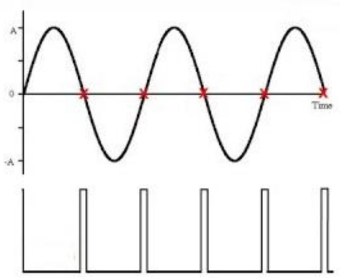

Figure 7(b): Zero Crossing Detector Waveforms

Thus an output square wave is produced whenever the input voltage crosses zero thereby acting as a zero crossing detector as shown in Figure 7(a) and 7(b).

e) PIC C Compiler

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:

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

3. Design Methodology

Our system has two input terminals known as L and N (since it only measures AC input). The frequency of the AC signal is connected to the Zero crossing detector (ZCD) input as explained in section 2(d). The operation of ZCD is to convert line voltage (~220V AC) into square wave equivalent to the double of the line frequency. For example, in India line frequency is 50Hz, therefore we will get frequency output ~100Hz. The frequency output is captured by the interrupt pin of the microcontroller and displayed on the seven segment display of the meter.

Operational flow chart:

Software routines that are programmed on the microcontroller are explained here with the help of a simple flowchart (Figure 8). The program is designed in embedded C and compiled on CCS compiler. Timer 1 in the capture mode is used in this application for the measurement of line frequency. At the start we configure the timer 1 in capture mode. The capture event is recorded on the timer interrupt. At the event of the edge detection on the timer interrupt, the interrupt counts the difference between two high pulses. The captured value is manipulated and displayed on the seven segment display.

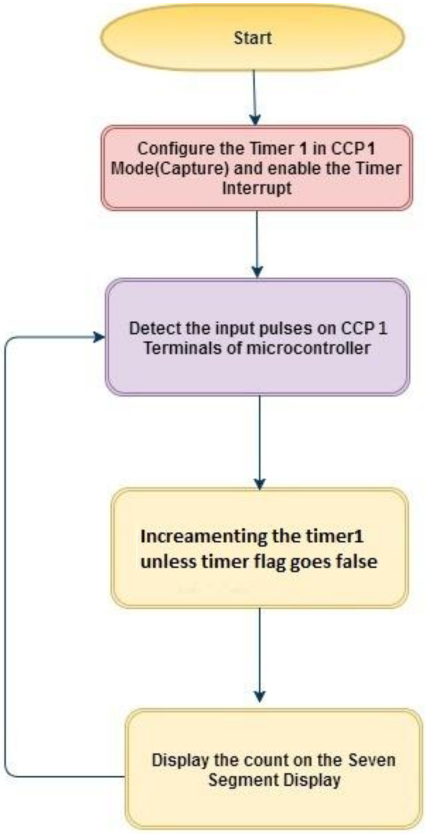

Figure 8: Flow chart of line frequency measurement

4. Test and Results

In this system, the digital line frequency meter has been designed to measure line frequency of AC supply. The operation of the digital line frequency meter will display on seven segment display as shown in Figure 9. As we can see, the frequency observed on the meter is around 50 Hz and within the claimed accuracy.

Figure 9: Test and result of line frequency measurement (at the testing stage)

5. Conclusion

This project has been successfully designed, constructed and also tested for the specified range. This frequency meter has been tested with 0.01 Hz of resolution from 10.00 Hz to 90.00 Hz. It is relatively cheaper version of meter to measure line frequency, comparing to those present in the market. This research will enhance the possibility of using digital meters to improve micro, small and medium scale industries in the country.

6. Future Scope

Moving on with our continuous endeavour to upgrade the existing system, we propose to sense the line frequency using a wireless technology like Wi-Fi, Bluetooth, etc. Using this system frequency of the line voltage can be accessed wirelessly.

7. 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 of the company.

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