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Microcontroller Based Digital Power Factor and Phase Angle Meter

Kareem A. Hamad
B.Sc, M.Sc, Ph.D AL – Rafidain University College, Computer Communication Eng. Dept Baghdad – Iraq

Abstract: *This paper deals with the development of an electronic power factor and phase angle meter using pic Microcontroller. The design is based on generating two signal values, the first is proportional to the peak value (I_m) of the line current i(t), the second is proportional to the instantaneous value of the line current at the instant of $v(t)=V_m$, i.e. $I_m$cosø, where I_m is the peak value of the line current and ø is the phase angle between line voltage and line current. These two components are inserted into PIC16F877A by means of analog circuit. The power factor is calculated by division of these two components and the phase angle is then calculated as Cos^{-1}ø.The calculated values will provide a realization and displayable form on LCD screen.*
Keywords: *Microcontroller, Power factor, Phase angle Measurements.*

I. Introduction

It is usually necessary to measure the power factor and phase angle of a power distribution system to assess its economy of transmission. The electro – dynamic power meters are sensitive to reliance on flux variation. The electronic design suffers from the problem of analog multiplication and division[1].

There are a lot of studies in this subject. M.F. Wagdy et al presents very simple method in phase measurement error compensation technique for automation [2]. Shu-Chen Wang and Chi-Jui Wu present accurate power factor measurement approach using FPGA [3]. Claudia A. da Silva et al. presents Power Factor Calculation by the Finite Element Method [4]. Mr. A Kumar Tiwari et al illustrates development of power factor controller using pic microcontroller [5]. Md. Shohe Rana et al proposes automatic power factor improvement by using ATmega8 microcontroller [6]. Ren Kaichun et al. presents Matlab simulations for power factor correction of switching power.

The digital power factor and phase angle meters described in this paper employs generation of two values by means of analog circuit, these values are proportional to I_m and $I_m$cosø thus division by using microcontroller will result in cosø i.e power factor, the phase angle is then calculated as Phase angle = Cos^{-1}ø.

II. Principle of Operation

Assuming the voltage and current waveforms are purely sinusoidal. Thus the instantaneous voltage *v(t)* and current *i(t)* are given as follows:

$$v(t) = V_m \sin(\omega t) \quad (1)$$

$$i(t) = I_m \sin(\omega t \pm \phi) \quad (2)$$

And the power factor of the load is

$$\text{P.F} = (\cos\phi) \quad (3)$$

Where V_m is the peak value of the line voltage, I_m is the peak value of line current, and ø is the phase angle between line voltage and line current (leading or lagging).

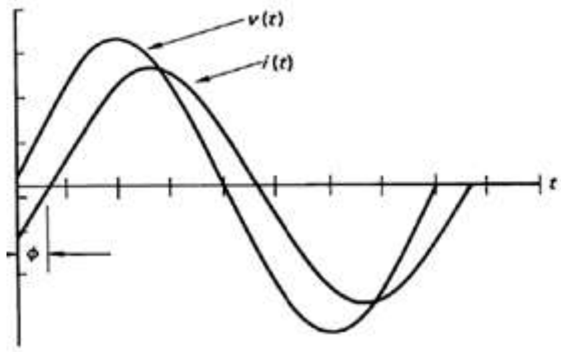

Fig (1) Voltage and current signals

From Fig (1) : at $\omega t = \pi/2$, then

$$v(t) = V_m \qquad (3)$$

$$i(t) = I_m \sin(\pi/2 + \phi)$$

$$i(t) = I_m \cos\phi \qquad (4)$$

Thus division of eqn. (4) by I_m will give cos ø, i.e. power factor, Then

$$\text{Phase angle} = \phi = Cos^{-1}\phi$$

III. Hardware description

The design aims to monitor power factor and phase angle on LCD display continuously. The circuit diagram and corresponding timing waveforms of the system are shown in Figs. 2 and 3 respectively. The basic point in the proposed technique is to generate two values using ADC contained in the microcontroller, these values are proportional to I_m and $I_m$cosø. This has been achieved by taking the ADC values from current signals at its maximum value, i.e I_m and at the instant of peak voltage V_m , i.e. $I_m$cosø. To achieve this aim electronically, We have used the step down arrangement of the transformer for voltage. Current signal can be acquired by using current transformer connected at main AC line. The line voltage V_1 and line current I_1 are shifted 90^o, squared V_2 and V_3 respectively and reduced ON time with monostable V_4 and V_5. Both I_m and I_1 current signals are converted in to digital signals with ADC of microcontroller, at the positive edges of V_4 and V_5, both signals of i(t) i.e I_m and $I_m$cosø are held, providing two components. Thus a division scheme between these two components is implemented to perform digital power factor (P.F = $I_m$cosø/I_m). The required division has been achieved with microcontroller PIC16F877A, the phase angle is then calculated as Cos^{-1}ø. These two outputs is digitized and displayed on LCD accordingly.

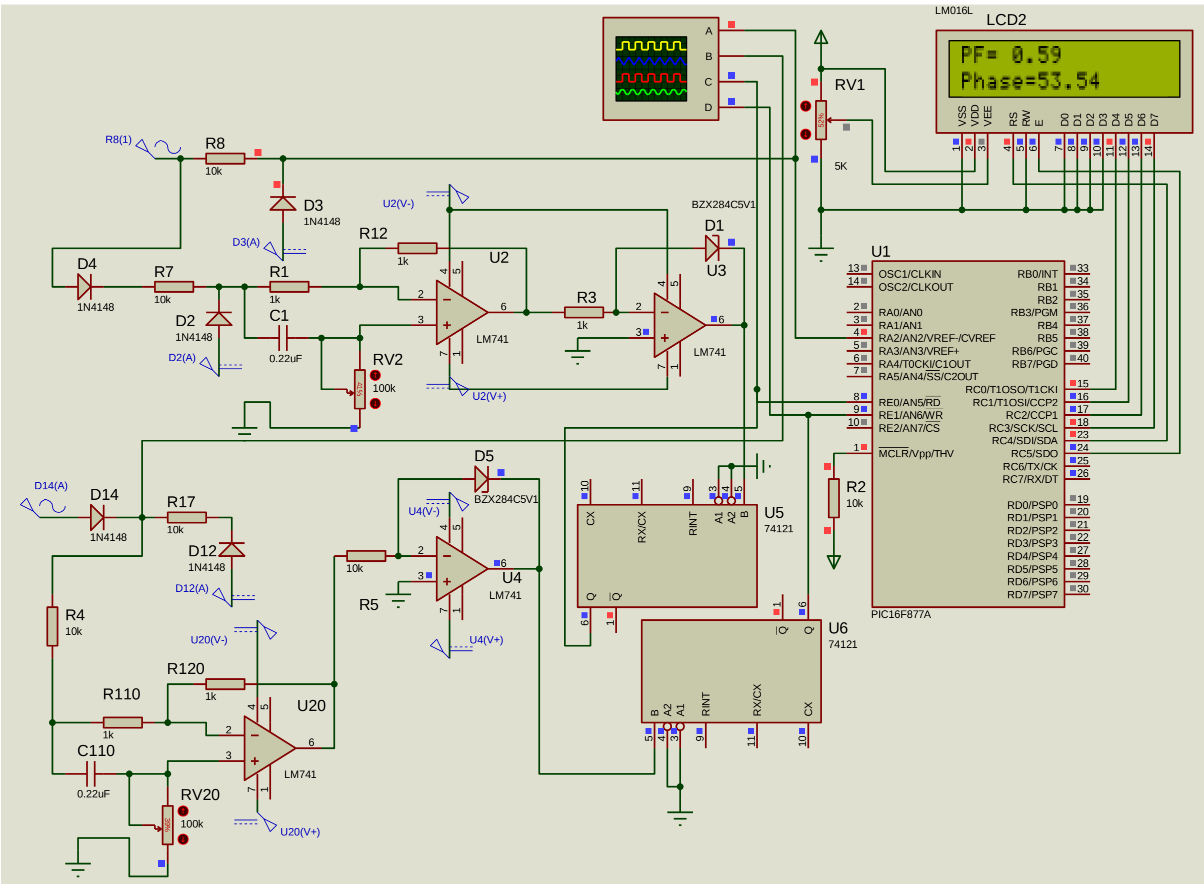

Fig (2) Schematic diagram of measuring system

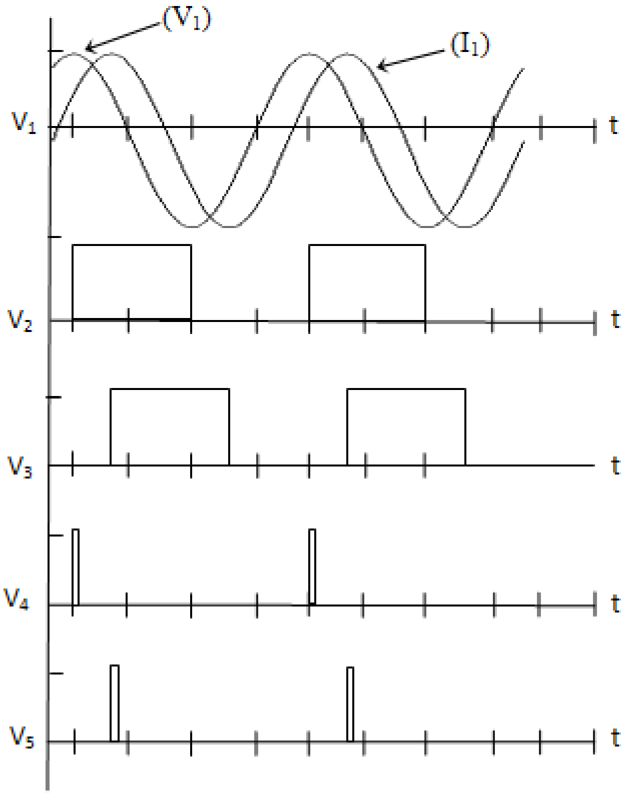

Fig (3) Timing waveforms

PIC16F877A Microcontroller

The PIC16F877A is a microcontroller from Microchip in a chip type of 40-pin DIP packages. The principal characteristics by which this PIC was used are: digital I/O ports, analog inputs, analog to digital converter of 10 or 8-bit resolution, serial communication USART, memory storage EEPROM [7]. The PIC16F877A, has programmed routines process or features, such as analog to digital conversion to get the values from the sensors, storage of historic data in the internal EEPROM when an alert happened generates a detection range of values which can determinate whether the system suffered acceleration that cause an alert [8]. The circuit used in this work operates of 20 MHz clock frequency and runs each instruction as fast as 200 ns.

The program for the PIC16F877A microcontroller is written in Micro C and is compiled into Hex program. Microcontroller is programmed to calculate power factor and phase angle. The flow chart of this calculation in Hex is shown in Fig. 4. The input of the current and voltage signals are connected to pin 4, 8 and 9 as shown in Fig. 2.

IV. Software Components

This section presents the software's used in the design of the measuring system

A. Micro C: Micro C is powerful, feature rich development tool for PIC micros. It designed to provide the programmer with the easiest possible for developing applications for embedded systems, without compromising performance or control [8].

B. Proteus 7 Professional: is an interactive system level simulator. Which combines mixed mode circuit simulation, micro-processor models and interactive component models to allow the simulation of complete micro-controller based designs [9].

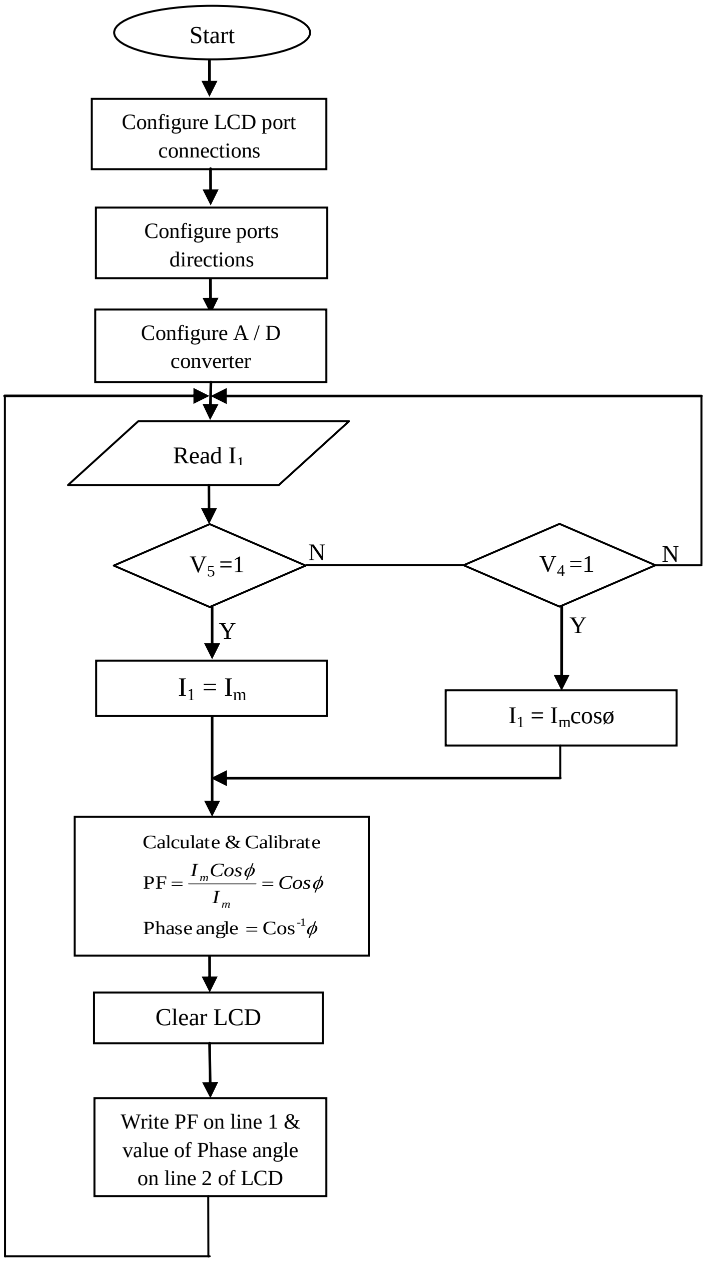

Fig (4) Flowchart of power factor and phase angle measurement. Hex program

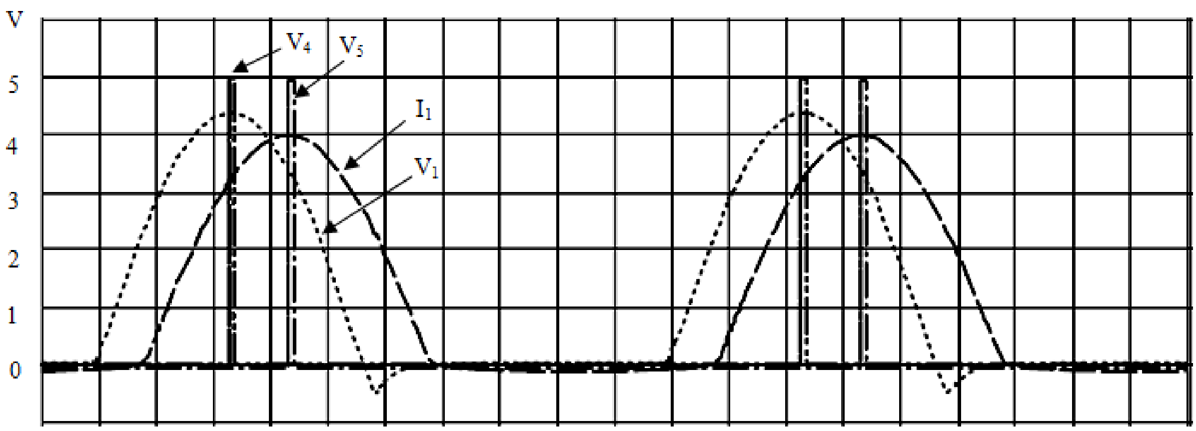

Fig (5) The microcontroller inputs of the current and voltage signals

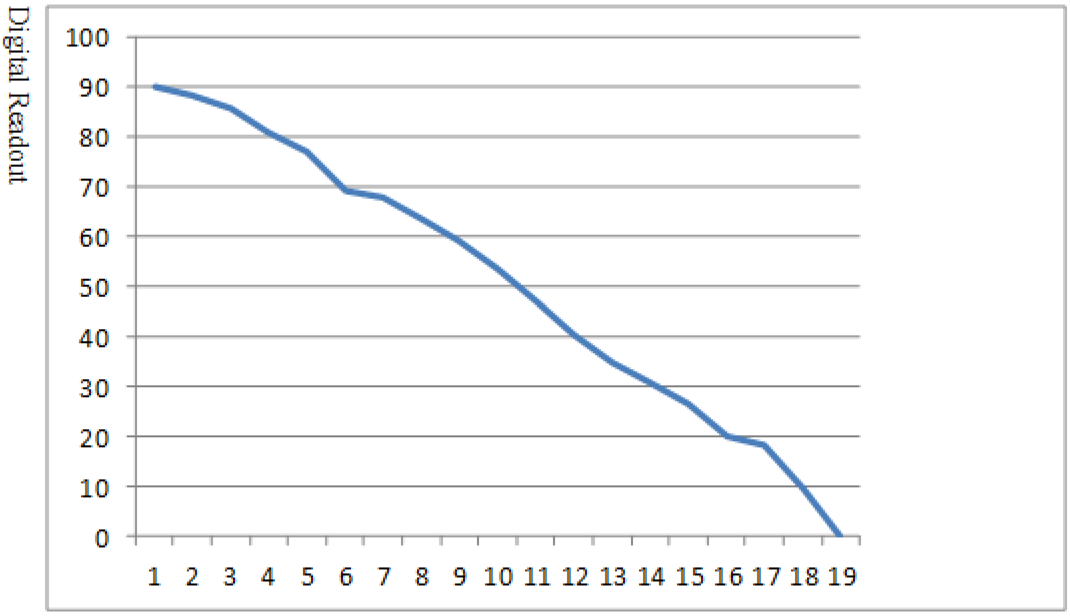

Fig (6) System linearity curve

V. Conclusion

This paper presented a simple approach to realize a digital power factor and phase angle meter based on PIC microcontroller. Which can be implemented in the various fields of industry and education. The circuit is designed to display PF and phase angle of the load connected the network. Calculation process is achieved by PIC16F877A. This approach is so straight forward that the hardware is very simple. The system has been tested under different loading conditions using proteus simulator and has shown linear behavior under those conditions, as shown in Fig.6

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