American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-12, pp-244-251
www.ajer.org

Research Paper Open Access

Design and Hardware Implementation of a Digital Wattmeter

Md. Arafat Mahmud[1], Md. Tashfiq Bin Kashem[2],
Monzurul Islam Dewan[3], andMushfikaBaishakhi Upama[4]
[1]*Department of EEE, University of Asia Pacific, Dhaka, Bangladesh*
[2]*Department of EEE, University of Asia Pacific, Dhaka, Bangladesh*
[3]*Department of EEE, Ahsanullah University of Science and Technology, Dhaka, Bangladesh*
[4]*Research and Development Section, Energypac Engineering Ltd., Dhaka, Bangladesh*

Abstract :- Design and hardware implementation of a digital wattmeter has been presented in this paper. IC ADE7751, Microcontroller ATMEGA32 and a 16x2 LCD display are the major building blocks of the design. The real power information conveyed by the output signal from ADE7751 is extracted by necessary calibration process and finally displayed to LCD display using microcontroller coding. Obtained results show fair amount of accuracy which validates our circuit design and proves precise hardware implementation.

Keywords:- *Current coil, potential coil, IC ADE7751, microcontroller ATMEGA32, 16x2 LCD display*

I. INTRODUCTION

Wattmeter is a device for measuring real power of a load. In this paper, design and hardware implementation of a digital wattmeter have been presented with detailed functional description of individual component forming the total circuitry. In our design, the role of current and potential coil has been served by using IC ADE7751. The output from the IC is analyzed by a microcontroller, ATMEGA32 and the calculated power is displayed in a 16X2 LCD display through microcontroller coding and proper interfacing with the microcontroller port. Results obtained from our designed wattmeter shows fair amount of accuracy which proves the validity of our circuit design and hardware implementation.

II. WORKING PRINCIPLE

Real power of a load can be expressed as Eq. 1:

$$P=V_{rms}I_{rms}\cos\varphi \quad (1)$$

where, V_{rms} , I_{rms} and $\cos\varphi$ denote r.m.s. value of voltage, current and power factor respectively. In a wattmeter, Potential Coil (P.C.) and Current Coil (C.C.) give the measure of r.m.s. values of voltage and current respectively and the cosine of the phase angle difference between the voltage and current is multiplied with them to find the real power dissipated in the load[1]. Fig. 1 shows the basic circuit connection diagram of a wattmeter.

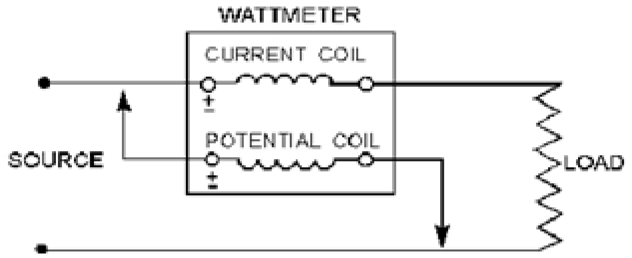

Fig. 1. Basic circuit connection diagram of a Wattmeter

In our design, both the voltage across and the current through the load have been taken in the form of a differential voltage using voltage and current transducers to IC ADE7751. The IC produces a square wave at its output whose frequency is proportional to the real power of the load. Detailed description of this functionality has been present in the circuit level description section. This square wave signal is sent to a input pin of a microcontroller port. The time period of the signal is measured using counter and thus its frequency is also determined. Through a calibration process described later in the paper, the dissipated real power is calculated. Finally, the calculated real power is displayed in a LCD display. In this regard, the LCD screen was properly interfaced with the pins of a port of the microcontroller. The whole process is guided by proper microcontroller coding.

III. FUNCTIONAL BLOCK DIAGRAM

Based on the working principle described in section II, the functional block diagram of the entire circuit can be presented as Fig. 2 which will give a better insight before going to circuit level description.

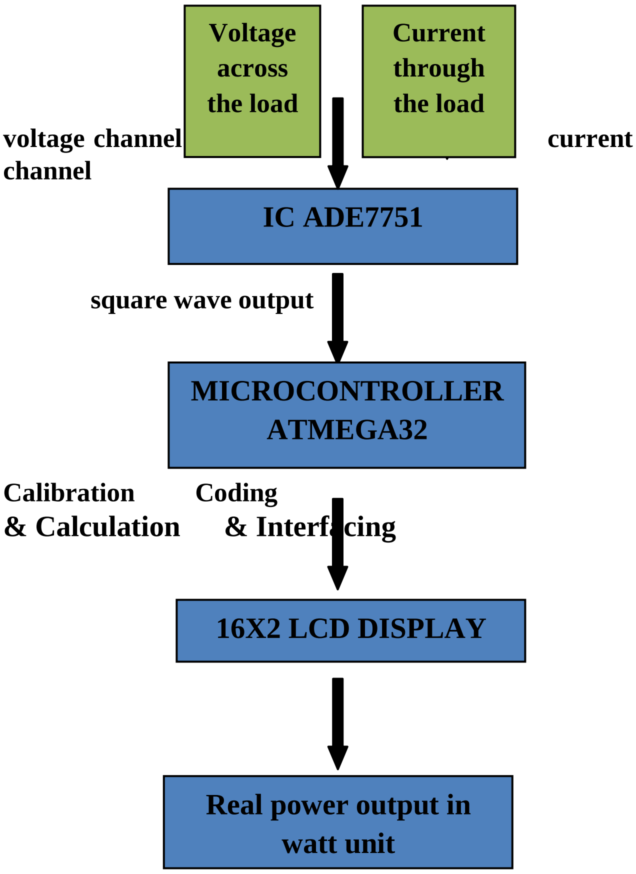

Fig. 2. Functional block diagram of the entire circuit design of wattmeter

IV. CIRCUIT LEVEL DESCRIPTION

In this section, circuit level description of the components is presented. Entire circuitry can be divided into three sections: IC ADE7751, Microcontroller ATMEGA32 and 16x2 LCD display.

A. IC ADE7751

The circuit connection diagram of IC ADE7751 has been shown in Fig. 3. Pin configuration description of various pins of the IC can be found at [2]. IC ADE7751 receives two analog inputs (load current and voltage) at its two channels (V1A and V1B as current channel and V2N and V2P as voltage channel)in the form of a differential voltage input using current and voltage transducers.

The output of the line voltage transducer is connected to the ADE7751 at voltage channel, V2. Channel

V2 is a fully differential voltage input. The maximum peak differential signal on Channel 2 is ± 660 mV. Fig. 4 illustrates the connection at ADE7751 Channel 2. Channel 2 must be driven from a common-mode voltage,i.e.the differential voltage signal on the input must be referenced to a common mode (usually AGND).

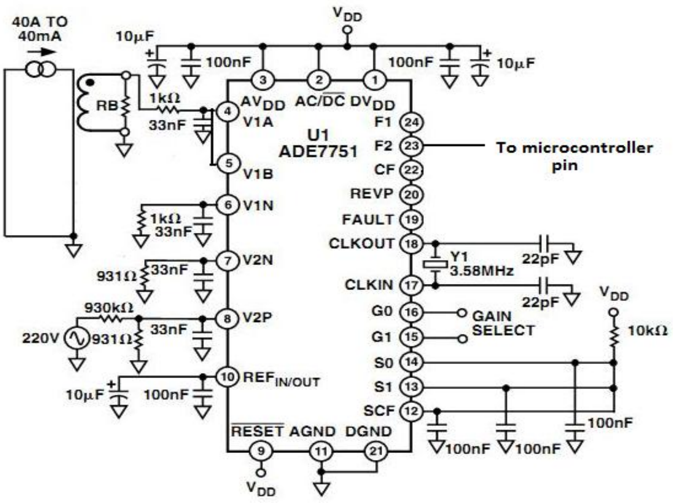

Fig. 3. Circuit connection diagram of IC ADE7751

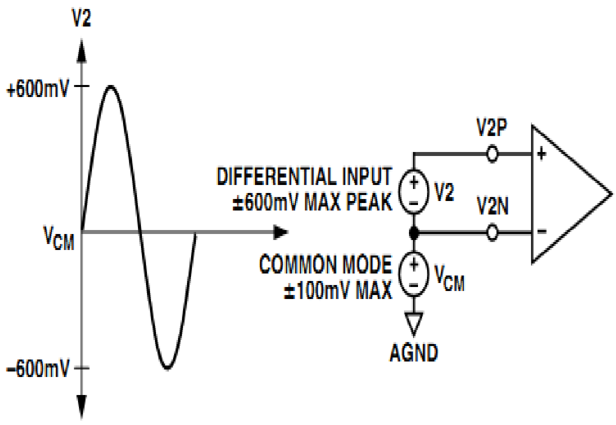

Fig. 4. Circuit connection at Channel 2 (V2N, V2P) of IC ADE7751 for load voltage measurement

Similarly, the voltage output from the current transducer is received at channel 1(V1A and V1B). The two ADCs at the IC digitize the voltage and current signals from the current and voltage transducers. These ADCs are 16-bit second order sigma-delta converters with an oversampling rate of 900 kHz. This analog input structure greatly simplifies transducer interfacing by providing a wide dynamic range for direct connection to the transducer and also by simplifying the anti aliasing filters design. The real power calculation is derived from the instantaneous power signal. The instantaneous power signal is generated by a direct multiplication of the current and voltage signals. In order to extract the real power component (i.e., the dc component), the instantaneous power signal is low-pass filtered. Fig. 5 illustrates the instantaneous real power signal and shows how the real power information can be extracted by low-pass filtering the instantaneous power signal. This scheme correctly calculates real power for non sinusoidal current and voltage waveforms at all power factors. All signal processing is carried out in the digital domain for superior stability over temperature and time. The low frequency output of the ADE7751 is generated by taking this real power information. This low frequency inherently means a long accumulation time between output pulses. The output frequency is therefore proportional to the average real power. Because of its high output frequency, and hence shorter integration time, the CF output is proportional to the instantaneous real power. This is useful for system calibration purposes that would take place under steady load conditions.

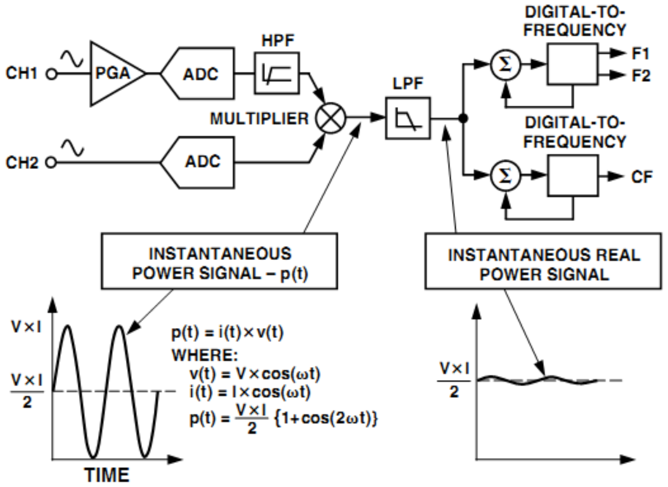

Fig. 5. Power information extraction from instantaneous power signal

The method used to extract the real power information from the instantaneous power signal (i.e., by low-pass filtering) is still valid even when the voltage and current signals are not in phase. If we assume the voltage and current waveforms are sinusoidal, the real power component of the instantaneous power signal (i.e., the dc term) is given by $\frac{VI}{2}\cos(60^{\circ})$. This is the actual real power calculation. Fig. 6 illustrates how dc component of instantaneous power signal conveys real power information for power factor less than 1 i.e. when there is a phase angle difference between load voltage and load current.

Frequency Outputs F1 and F2 of Fig. 2 calculate the product of two voltage signals (on Channel 1 and Channel 2) and then low-pass filters this product to extract real power information. This real power information is then converted to a frequency. The frequency information is output on F1 and F2 in the form of active low pulses. The pulse rate at these outputs is relatively low, e.g., 0.34 Hz maximum for ac signals with S0 = S1 = 0 as shown in Table 1.

The expression of frequency of the signal at pin 23 of ADE7751 which is sent to microcontroller pin is given below:

$$f=\frac{5.74V_1V_2GF_{1-4}}{V^2_{REF}} \quad (2)$$

where, V_1 = differential r.m.s.voltage signal on channel 1

V_2 = differential r.m.s.voltage signal on channel 2

G = gain depending on selection pins G_0 and G_1

V_{REF} =reference voltage (2.5V $\pm$ 8%)

F_{1-4} = one of four possible frequencies set by selection pins S_0 and S_1

TABLE I: FREQUENCY INFORMATION ON F_1 AND F_2 FOR DIFFERENT COMBINATION

S_0	S_1	F_{1-4}	XTAL freq.	Maximum frequency(ac input)
0	0	1.7	3.579 MHz/2^21	0.34
0	1	3.4	3.579 MHz/2^20	0.68
1	0	6.8	3.579 MHz/2^19	1.36
1	1	3.6	3.579 MHz/2^18	2.72

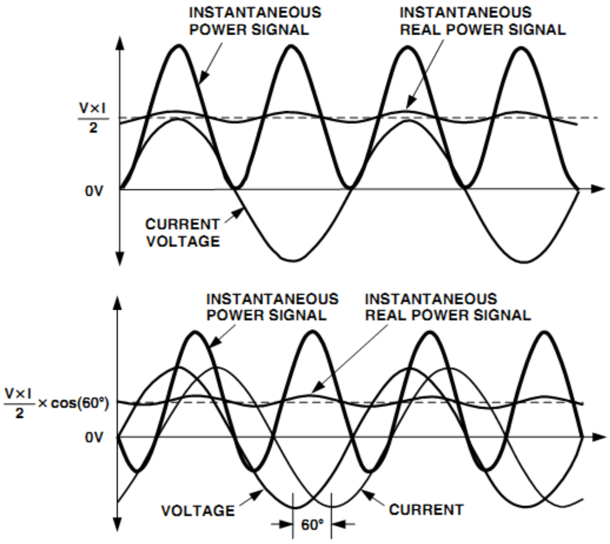

Fig. 6. Real power determination when there is a phase angle difference between load voltage and load current

B. Microcontroller ATMEGA32

Output pin 23 from IC ADE7751 which carries real power information through its signal frequency is taken as input to 3rd pin of port B of Microcontroller ATMEGA32.. Using a calibration process, the real power information is extracted from the signal. Using counter, at first the time period of the signal at PB3 is measured and from that, frequency is determined. Same process is repeated for a number of loads. Simultaneously, the readings of real power of the same loads are taken using standard commercially available analog wattmeter. Using the data obtained in this process, a curve of real power as a function of frequency in MATLAB is plotted and corresponding equation of power along with the values of the liner co-efficient were derived. This equation is used in microcontroller coding to show real power in LCD display. Port D pins of the microcontroller are interfaced with a 16x2 LCD display to show the real power in watt unit. The microcontroller code algorithm is given in Fig. 7.

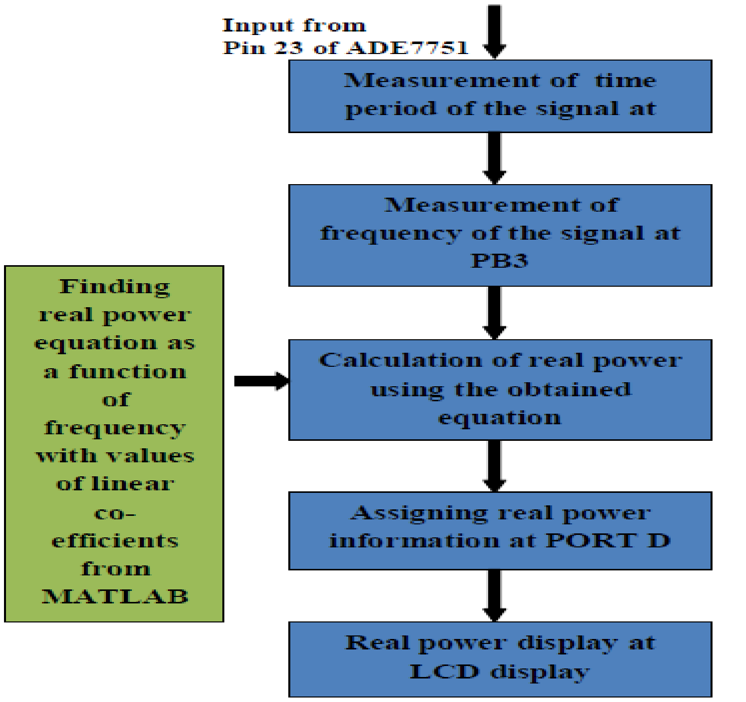

Fig. 7. Microcontroller code algorithm

C. 16x2 LCD display

The 16x2 LCD display is interfaced with PORT D of ATMEGA32 in 8 bit operating mode, i.e. LCD commands are sent through data line D0 TO D7. 8 bit data is sent at a time and data strobe is given through E pin of the LCD display. The interfacing between ATMEGA32 and LCD display are shown in Fig. 8. Pin configuration of Microcontroller ATMEGA32 and 16x2 LCD display can be found at [3]and [4].

V. HARDWARE IMPLEMENTATION

The circuit described above has been implemented in hardware level. Fig. 9-10 shows our implemented digital wattmeter. We have used several lamps having watt ratings of 40, 60 and 100Watt as loads and measured real power dissipated at those loads using our designed digital wattmeter. Simultaneously, watt readings using a standard commercially available analogue wattmeter were also taken. It has been observed that our digital wattmeter shows good accuracy and very minimal amount of error percentage. For instance, we obtained 98 watt reading from our digital wattmeter and 99 watt from the standard analogue wattmeter. So, percentage error can be expressed as:

$$\text{Percantage Error} = \frac{\text{Actual watt value-Obtained watt value}}{\text{Actual watt value}} \text{x}100\% \qquad (3)$$

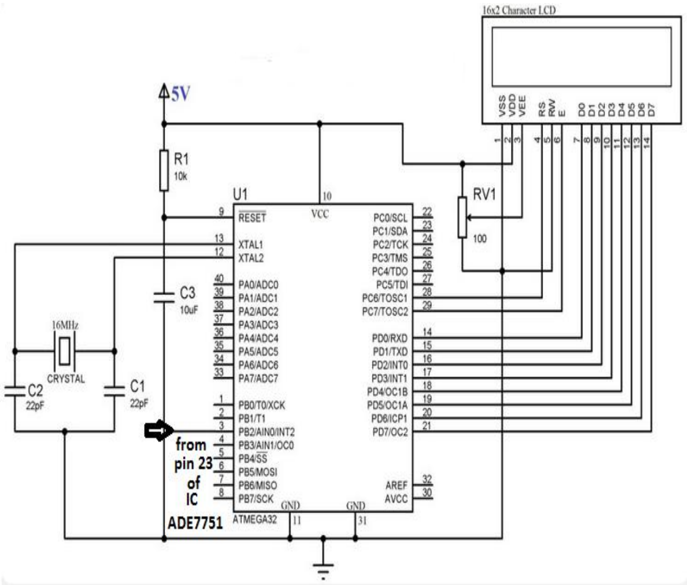

Fig. 8. Interfacing of ATMEGA32 with 16x2 LCD display

Fig. 8. Hardware implemented digital wattmeter device

Fig. 10. Amplified view of LCD display showing real power information

$$\text{So, percentage error } = \left(\frac{99-98}{99} \text{x}100\right)\%$$

$=1.01\%$

So, the accuracy of our digital wattmeter is 98.99% which proves the validity of circuit design and hardware level implementation.

VI. SPECIFICAIONS

General and Electrical specifications of the digital wattmeter have been presented in Table II and Table III respectively.

Table Ii: General Specifications of The Digital Wattmeter

Properties	Specifications
Display	16 x 2 (16 columns, 2 rows) LCD (Liquid Crystal Display)
Measurement	Watt (real power)
Polarity	Uni- polar
Zero Adjust	External adjustment for zero of the display
Operating Temperature	0°C to 50°C (32°F to 122°F).
Operating Humidity	Less than 80% RH.
Power Supply	Digital Circuitry: DC 5V battery, Analog Circuitry: 220V (line to neutral)
Power Consumption	Approx. DC 6 mA
Weight	250g (including battery)

TABLE III: ELECTRICAL SPECIFICATIONS OF THE DIGITAL WATTMETER

Signal	Specifications
AC voltage	Range : 220V Resolution : 0.2VRange : 660V Resolution : 0.6V Frequency Characteristics : 45 Hz - 65 Hz Input Impedance: 1 Mega ohm. Converter Response : Average responding, calibrated to display RMS value
AC current	Range : 10A Resolution : 10mAVoltage drop (in case of full scale) : 250 AC mVFrequency Characteristic : 45 Hz -65 Hz Converter Response :calibrated to display RMS value of sine wave
DC voltage	Range : 4V to 5.3VInput Impedance : 1 Mega ohm
DC current	Range : 10A Resolution : 10mAMaximum Input Current : 10A Input Impedance : 1 Mega ohm Voltage drop (in case of full scale) : 250 DC mV

VII. CONCLUSION

A circuit level design and hardware implementation of a digital wattmeter has been presented in this paper. The wattmeter has shown remarkable accuracy for measuring a number of different loads. This proves the precision of our design and hardware level implementation. Also, as the device is guided by microcontroller coding, more features like energy measurement and electricity bill generation in local currency can also be added to this digital wattmeter.

ACKNOWLEDGMENT

We would like to express our gratitude to our respected teacher Mr. Ahmad Zubair, Lecturer, Department of EEE, BUET, who inspired and motivated us to get ourselves involved in innovative circuit design especially involving microcontroller coding and hardware implementation of those designs.

REFERENCES

[1] M. Rehman, M. R. Saad, S. Ahmad, and M. S. Ansari, "Development of an analogue electronic wattmeter," IEEE region 10 conference on Tencon, pp. 1-2, November 2005.

[2] US Patent 5,745,323; 5,760,617; 5,862,069; 5,872,469, Energy metering IC with on-chip fault detection: ADE7751, Analog devices Inc., USA.: 2002.

[3] ATMEL corporation, 8 bit AVR microcontroller with 32Kbytes in system programmable flash: ATMEGA32 and ATMEGA32L, USA, 2011.

[4] Revolution Education Ltd., Alpahanumeric LCD display(16x2),UK.