

ARTICLE**Design and Construction of A Single-Phase Power Factor Meter****A. A. Mukaila I. Olugbemi E. E. Sule***

Department of Electrical and Electronic Engineering, The Federal University of Technology Akure, Nigeria

ARTICLE INFO*Article history*

Received: 15 October 2019

Accepted: 26 October 2020

Published Online: 31 October 2020

Keywords:

Arduino nano

Zero crossing

Power factor

Inductive load

Capacitive load

ABSTRACT

It is known that the power consumption and efficiency of an equipment owes directly to its power factor. The lower the power factor of the equipment the more the energy consumption of such equipment and vice-versa. Hence, the need to develop an equipment to measure accurately the operating power factor of domestic and industrial equipment and appliances^[1]. The operating principle of this power factor meter design is based on Zero Crossing detection principle, the principle is utilized using Arduino Nano, instrument transformers, LM324 operational amplifier, generic resistor, generic XOR Gate 7488 and 2X16LCD. The input current and voltage signal is taken by the transformers and sent to the op- amp which carries out the zero crossing detection in order to get the time difference after which the microcontroller does the calculation to determine the power factor and the deficit reactive power which is then displayed on an interface^[2].

1. Introduction

There is a daily increase in the rate of power consumption which owes to the high demand of electric power for domestic, commercial and industrial use. In order to meet the demand of consumers, there is a need to increase the electric power generated, transmitted and distributed in the most efficient of ways. This will be accomplished by minimizing energy loss in the power system. Electric power is the measurement of energy transfer over time. There are various types of power at work to provide us with electrical energy^[3]. Working power or real power provides the power that performs actual work on the other hand reactive power is the power needed by equipment that generates magnetic fluxes. Apparent power is the vectorial summation of the real and reactive power^[4]. Power factor is the measure of how effective electricity is being consumed. Power factor is also defined as the ratio

of working power to apparent power^[5]. There is a large amount of current being transferred when transmitting at a lower power factor which leads to a loss in power transmitted hence the need for a suitable power factor meter in order to measure accurately the power factor at various points of the power system^[6].

Measuring the power factor is something that we often need to do when dealing with AC mains circuits. Ideally, every load connected to the mains supply should have a power factor of 1, but many devices like electric motors or old fluorescent tube ballasts are inductive and have a lower power factor. To correct the power factor, usually a capacitor of suitable value is connected in parallel. But to verify that the capacitor effectively corrects the power factor, there is no other way around than measuring it^[5]. It must be said that the opposite situation, even if not very frequent, is also possible: an AC load could have a low power factor due to its capacitance that could be fixed by

**Corresponding Author:*

E. E. Sule,

Department of Electrical and Electronic Engineering, The Federal University of Technology Akure, Nigeria;

Email: sule59002018db@futa.edu.ng

adding an inductor. Again, measuring the power factor is the only way to make sure we did a good job. So, it is very important to measure power of a system before we can know whether the equipment needs power factor improvement or not and also power consumption of any equipment, household, or an industry can be determined by measuring the power factor of the equipment.

2. Materials and Methods

The methodology of this research work is divided into 5 stages. (1) Power Stage (2) Load Stage (3) Zero Crossing Detection Stage (4) Computation Stage (5) LCD Display. Fig 1. illustrates the whole process in a block diagram.

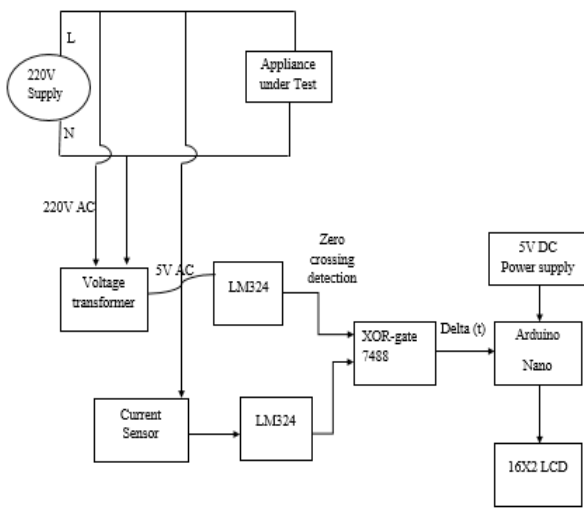


Figure 1. Block diagram representation of methodology

2.1 The Power Stage

Figure 2 shows Power supply unit. Power stage comprises of the AC side and the DC side. The 50Hz 220V/240V supply coming from the socket outlet into the design is converted to 5VDC which can easily be handled by micro controller. For the purpose of this design 5V AC to DC converter was used. Also, the incoming 50Hz, 220V AC from the AC source is sent through voltage transformer which step it down to 5Vac, this is then sent to zero crossing detection stage through first LM358 op-amp

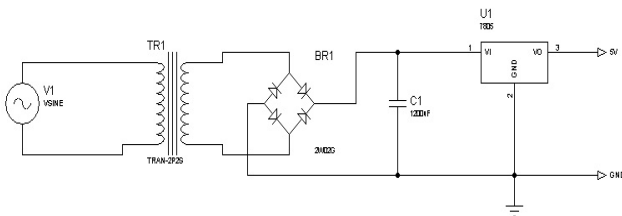


Figure 2. Power Supply Unit

2.2 Load Stage

This stage receives the load in which the power factor is to be measured using the instrument. The main component used in this stage is current transformer. The load is connected to the instrument through current transformer. The input current signal is gotten using a current transformer and sent to the second LM358 op-amp.

2.3 Zero Crossing Detection Stage

This stage comprises of two operational amplifiers which is tagged the first and the second LM358 op-amp. At this stage calculation of the phase lag between the voltage and current signal gotten from power and load stage is done, two detectors (LM324) are used to find the arrival instance of each signal. Then the difference in the arrival instance calibrated to angle gives the phase angle lag. The LM324 IC is used as the comparator circuit to function as zero crossing detector.

2.4 Computational Stage

This stage comprises of XOR gate (4030), Arduino Nano and 16X2 Liquid-crystal display. (LCD). Both signals from Zero crossing detectors is sent to the XOR gate where computational comparison between the current and voltage is done. The output signals from zero crossing detectors are in analogue form, these signals are converted to digital signal that Arduino can work with. XOR gate produces output only if there is phase difference in the two signals. The working principle is illustrated in Table 1.

Table 1. Working Principle of XOR Gate (4030)

SIGNAL A	SIGNAL B	OUTPUT
1	0	1
1	1	0
0	0	0
0	1	1

The information gotten is sent to Arduino Nano for calculation of the phase angle (Θ) and the corresponding power factor using $\cos(\Theta)$ and the resulting power factor and phase shift is the displayed by 16X2 Liquid- crystal display.

The information gotten is sent to Arduino Nano for calculation of the phase angle (Θ) and the corresponding power factor using $\cos(\Theta)$ and the resulting power factor and phase shift is the displayed by 16X2 Liquid- crystal display.

2.5 LCD Display

For the display of the designed power factor meter, LCD

16x2 JHD162A is selected due to its voltage compatibility and ease of connectivity with Arduino Uno [7]. The output interface circuit between Arduino and LCD display is shown in Figure 3, using resistor and potentiometer to adjust the LCD brightness.

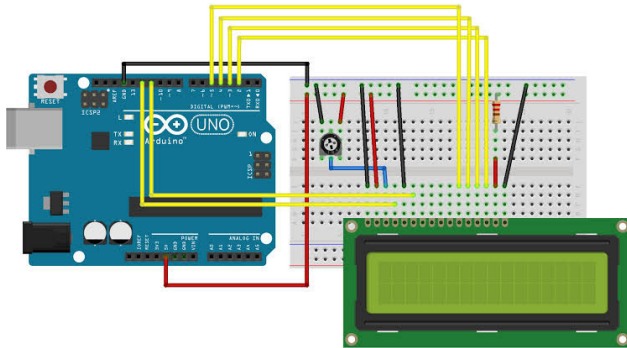


Figure 3. Output Interface between Arduino and LCD display

3. System Assembly and Results

The implementation of this project focuses on the hardware construction and the implementation of the firmware on the hardware.

Hardware Construction

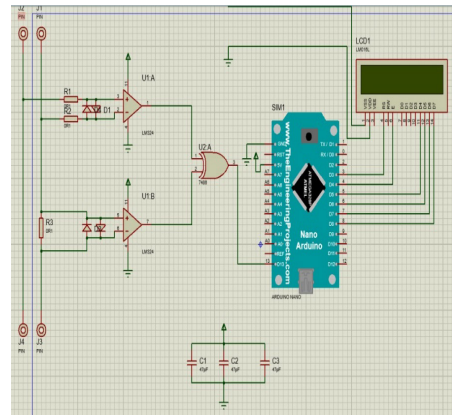
(1) Assembly of Component

After selecting the components as described in the methodology section of this project, I then proceed to assemble them on a Vero board following the schematics developed in chapter three. Components placed on the board were reinforced with soldering led to ensure the copper lines could withstand the current. The number and size of components determines the size of the Vero board and the allowance between them. The step taking in this procedure include:

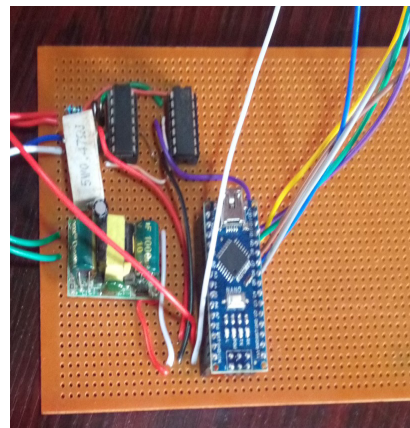
- (1) Drilling the Vero board to the preferred size of the arrangement used.
- (2) Thinning the components led to the required length.
- (3) Arranging the components on the Vero board.

(2) Soldering of Components and Packaging

Soldering involves the joining of the conductors or components terminals to the circuit board by means of soldering iron and soldering lead. This process was carried out after the terminals of the components have been thinned and tested. The construction of the Arduino based power factor meter was done as designed in the methodology section. The tools and equipment used in designing the Testbed The tools and equipment used in designing the hardware include; cutters, long nose plier, soldering iron and lead, lead sucker, screw drivers/ precision set, drilling machine, multimeter, veroboard, PVC (or insulated) cable and jumper wires, razor blade and power supply.



(a)



(b)



(c)

Figure 4. Circuit Design on Proteus (b) Circuit on Veroboard (c) Constructed Power Factor Meter

After every objective have been executed. The constructed power factor meter was tested by measuring the power factor of some loads whose results were compared with the standard power factor of the loads. Figure5a shows the load being measured which is a standing fan and Figure5b shows the measured power factor of the load on the meter. Figure5c shows the power factor reading of a rechargeable lamb.



(a)



(b)



(c)

Figure 5. (a) Power factor meter measuring the power factor of standing fan (b) Showing the power factor reading of standing fan (c) Power factor reading of Rechargeable Lamp

The comparison of the power factor of the loads measured and the standard power factor of the certain loads is shown in the Table 2.

Table 2. Showing the measured power factor reading of tested load and standard power factor reading as given by manufacturer

S/N	LOAD TESTED	STANDARD POWER FACTOR	MEASURED POWER FACTOR
1	Television	0.93-0.96	0.95
2	Rechargeable lamp	0.98-1.0	0.99
3	Drilling machine	0.80-0.89	0.89
4	Blender	0.79-0.81	0.82
5	DVD	0.93 -0.96	0.98
6	Printer	0.80-0.82	0.85
7	Soldering iron	0.90-0.96	0.92
8	Standing fan	0.94-0.96	0.98
9	Iron	0.91-0.96	0.92

4. Conclusion

After series of test, it was discovered that the operating power factor of a load depends on the type of load being measured either inductive or resistive load. The values of the power factor gotten is close to the standard power factor of the load. However, due to human errors the accuracy might be affected.

Acknowledgment

Our sincere gratitude goes to the staffs of the department of electrical/electronic engineering department, The Federal University of Technology, Akure Nigeria for their support and encouragements.

References

- [1] M. Abdul-Karim, D. Boghosian. Digital power factor design based on binary rate multiplicatio techniques. *Journal of IEEE Transaction on Instrumentation and Measurement*, 2002, 20: 51-84.
- [2] K. Yasin, M. M. Yusuf. Automated power factor correction and energy monitoring system. *International Journal of Electronics*, 2007: 5-11.
- [3] T. M. Chung, H. Daniyal. Arduino based power meter using instanteneous power. *ARPN Journal of Engineering and Applied Science*, 2015: 10-21.
- [4] S. Ranaj, N. Miah, H. Rahman. Automatic power factor improvement by using microcontroller. *Global Journal of Research in Engineering*, 2013: 4-9.
- [5] K. A. Hamad. Microcontroller based digital power factor and phase angle. *IOSR Journal of Electrical and Electronics(IOSR-JEEE)*, 2016: 1-2.
- [6] A. Biswes. Power factor measurement and correction using digital controller implemented on FPGA. *International Journal of Microelectronics Engineering (IJME)*, 2015: 154-541.
- [7] 16x2 LCD display module," *Circuit Digest*, 2019. [Online]. Available: <https://circuitdigest.com/article/16x2-lcd-display-module-pinout-datasheet> [Accessed 24 October 2019].