4th IEEE International Conference On I-SMAC (IoT In Social, Mobile, Analytics And Cloud) (I-SMAC 2020) -- PRE-PRINT – Will be available at IEEE Xplore

Low Cost Voltage and Current Measurement Technique using ATmega328p

Fahad Faisal[1], Asif Karim[2], Md. Zahid Hasan[1], Bharanidharan Shanmugam[2*], Muntasir Mahdi[3], Nazmun Nessa Moon[1]

[1] Department of Computer Science and Engineering, Daffodil International University, Bangladesh
[2] College of Engineering, IT and Environment, Charles Darwin University, NT, Australia
[3] Department of Electrical and Electronic Engineering, University of Science and Technology, Chattogram, Bangladesh

Corresponding author: bharanidharan.shanmugam@cdu.edu.au

***Abstract*-This paper is mainly focused on the low cost technique to measure both AC and DC voltage along with current by using very low cost components. The system can also be easily monitored via a smartphone. The work is intended for the engineering students as most of the Voltmeter/Ammeter is very expensive. Not only that, the acquired data can be stored as per the requirements. New features can be added very easily with this ammeter/voltmeter as well. Whole task was implemented with the help of popular micro-controller ATmega328p to reduce the cost.**

Keywords- ATmega328p, Low cost, Voltmeter, Ammeter.

1. Introduction

Currently, lots of ammeter/voltmeter are available in the market but sometimes they fail to provide accurate reading due to their poor quality. It is very common to use different microprocessor based components in real life as well [1]. On the other hand, voltmeter/ammeter with very high accuracy is available in the market but they are too much expensive. A measurement device have been tried to build to measure both Alternating Current and Direct Current voltage along with the Current on the likely device. The voltage and current reading can be shown on the LCD display or via Smartphone. To display the values on Smartphone additional hardware like Bluetooth shield (HC-05) is required.

2. Literature Review

El Hammoumi *et. al* [2] in their research paper explained the low-cost solution of virtual materials for PV panels by three properties like the voltage, current, and power. They chose an ATMGA 328 microcontroller, an Arduino UNO board and a UART bus for a computer. According to this study, a mind-blowing benefit has been explained to show real-time data that the selected PV panel can present graphically. Several types of equipment such as two 100 watt artificial lamps and a PV panel have been used to achieve accurate results displayed on a computer screen.

A smart current and voltage monitoring system was developed by Mnati *et. al* [3] to monitor current and voltage. In their paper, they use the 3 phase electrical system and the Arduino platform as sensor microcontrollers and transmit it to the LCD via smartphone. After calculating this data, they use three current and voltage sensors to transmit via Bluetooth using a third-party application and are available in the Play Store.

The Caruso et al [4] study showed a real-time wireless Alternating Current and Direct Current monitoring system via a microcontroller which is Atmega 328P. This program works in a variety of client modes and can measure the amount of electricity consumed on their systems in real-time. They digitally convert analog AC and DC to convert 13 clock cycles using ADC integrated microcontrollers.

In their research paper, Nair et al [5] described the ATmega 328P microcontroller and Android as a cheap portable alternative to a system that uses a wireless device. This method detects the signal via Bluetooth by an Android device that converts it via a microcontroller. The system has disadvantages that can generate signals up to 5 volts but it has certain advantages that are easily affordable for all applications as well as signal generators. A number of features have been addressed such as signal saving, saved signal reproduction, signal analysis, etc.

Bouabana *et. al*, in their research article [6], described a universal sensor that adds three single sensor topologies, such as current, voltage and temperature, with a higher resolution accuracy that can easily control the current with the digital value and the F-PWM form of the digital output signal without loss of distance data through the sensor. On the other hand, the sensor has a low power consumption problem based on specific voltage, current or temperature sensors, a major advantage for control units that can regulate current and voltage, and a novel advantage is that all calculated values are directly coded with a digital value that can be decoded and used in control units.

Elizalde *et. al* [7] explained an automated wireless fire detection system using some techniques such as ATmega328p, smoke sensors, GSM modules, GPS and ZigBee module. The system is capable of detecting fire and sending an alert message to recipients via Bluetooth device, and saving data. The system has a servo motor that moves every 90 degrees but for every 10 degrees it takes 10 seconds delay and the fire and smoke sensor detects restricted area and sends data to ATmega328p. ATmega328p processed the required data, and an alert message sends to the cell phone receiver through the GSM module.

3. Experimental Method

To implement the whole process, a concept model has been developed based on several steps. At first, Arduino UNO [9] is connected with a voltage sensor. Usually, the voltage sensor operates within the range of 0-5 Volt. But the sensor is capable of measuring higher voltage within the range of 0-25 Volt [10] [11]. To measure the current, needed to use the ACS712 current sensor. Based on the requirements, it is possible to measure the current or voltage. The acquired data is displayed with the help of external display like 16×2 LCD. Not only that, with the help of bluetooth module (HC-05) [12], measurement data is monitored remotely. The whole process can be described with the following diagram shown in Fig. 1:

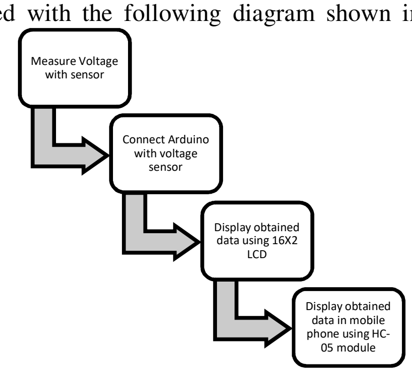

Figure 1: Overall data acquisition process

For each step, the relevant code is needed to add as well. To measure the voltage the following sketch has been used:

Sketch for voltage sensor:

```
int voltage_sensor_pin = A0;
float sensor_value = 0.0 *f;
float vout = 0.0;
float vin = 0.0;
float R1 = 30000;
float R2 = 7500;
void setup( )
{
sensor_value = analogRead(voltage_sensor_pin);
vout = (sensor_value*5)/1024;
vin = vout / (R2/(R1+R2));
}

void loop( )
{

}
```

The above code is intended for only single time execution. For continuous data acquisition, the sensor value must be acquired by using the loop function.

To acquire the data via Bluetooth, the following sketch must be included:

Sketch for Bluetooth Device (HC-05)

```
#include <SoftwareSerial.h>
 int bluetoothTx = 9;
 int bluetoothRx = 8;
SoftwareSerial bluetooth(bluetoothTx, bluetoothRx);

void setup()
{
 bluetooth.begin(9600);
 bluetooth.println("");
 bluetooth.println("Welcome to the measurement system.");
}

void loop()
{

}
```

In this regard, would like to add that, there are several reasons to choose Arduino Uno instead of other available options. The Table-I below explains the comparison of micro-controllers:

Table I: Choice of ATmega328p over others

Micro-controller	**ATmega328P**	**STM32 (Cortex)**	**MSP430 (Texas Inst.)**
Cost	Low	High	Low
Architecture	Advanced RISC architecture	Power Architecture technology designed for embedded applications	Older, von-Neumann architecture
Power Consumption	Low, more efficient power consumption	Medium, higher clock speed may result in higher consumption power	Low
Performance	Medium, lower bit but suitable for complex projects	High, fast processing speed, packs more power. Running 32 bit ARM processor core with sufficient RAM	Low, more suitable for only simple projects
Ease of Usage	Easy to use, 8 bit and high compatibility with Arduino	Complicated due to its nature of being a 32-bit	Complex relative to Arduino

	boards	microcontroller	boards

4. Implementation, cost estimation and comparison

Before implementing the system practically, a complete circuit setup was done using Tinkercad virtual simulator. As it is the best available simulator in the market now. The complete diagram is shown below in Fig. 2.

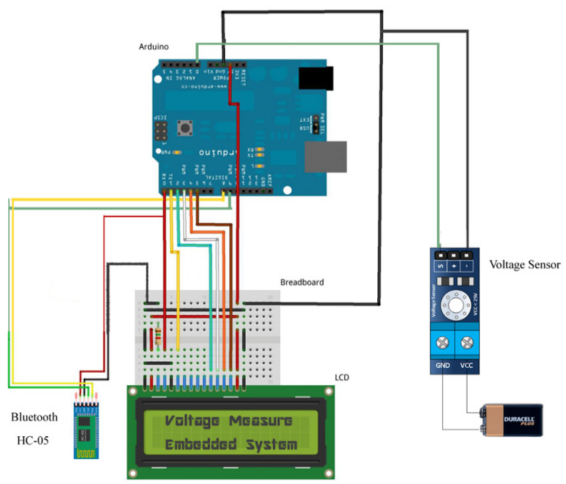

Figure 2: Complete Circuit Diagram

As can be seen from the above figure that the complete setup consists of Arduino UNO, 16×2 LCD, Bluetooth module and a voltage sensor.
To get the value of the voltage, at first- needed to connect the desired device with the battery/source where the positive terminal of the source will be connected to (V_{cc}) terminal of the voltage sensor and the negative terminal of the source will be connected with the (GND) terminal of the voltage sensor. The signal pin of the voltage sensor is connected with an analog pin “A0” of Arduino. Apart from that, the Bluetooth module is connected with the “Tx-Rx” pins of Arduino to access the data remotely. The system draws the power from Arduino Uno. The measured value can be seen instantly.

Most of the available current and voltage meter is capable of displaying the value only. But in our developed system, the data can be stored and use for it for further processing as well. The estimated cost of our system is shown in Table-II below:

Table II: Estimated Cost

Sl	Component	Cost (BDT)
1	Arduino UNO	430
2	Voltage Sensor (AC)	350
3	Voltage Sensor (DC)	80
4	Bluetooth module (HC05)	260
5	LCD Display	120
6	USB Cable	30
	Total	1240 BDT (≈ 15 $)

Not only that, but the existing available meters are pretty expensive as well. Here a brief comparison of different systems along with our developed model are shown in Table-III:

Table III: Comparison of cost with existing devices

Sl	Available Model	Cost ($)
1	Fluke 8808A [13]	898
2	KEYSIGHT 34461A Digital Multimeter [14]	~1000
3	Siglent Technologies SDM3055 [15]	~ 449
4	B&K Precision 5491B True RMS Bench [16]	489
5	Tenma 72-1055 Bench top Digital Multimeter [17]	113
6	Our developed system	15

So the table above explains that our system is minimum 7 times cheaper than the available equipment on the market.

5. Output and Result Analysis

As described already, our system is capable of displaying the value either in LCD or via smartphone. The initial display for the measurement is shown below in Fig. 3. As both voltage and current can be measured. Initially, it shows the voltage as 0.00 and current as infinity. The display of the text changes automatically.

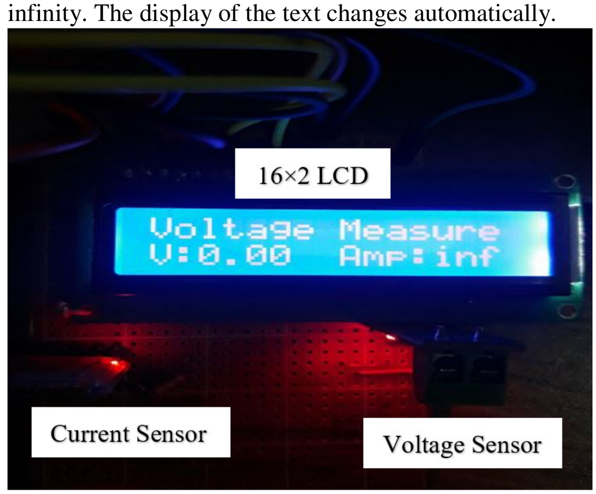

Figure 3: Initial display of the system

Once connected it with any sources, the measured voltage and current will be displayed immediately which is shown in Fig. 4:

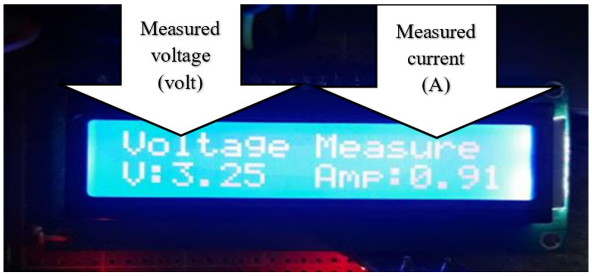

Figure 4: Voltage and current measurement

As our goal is to provide maximum flexibility, the whole system have been connected even with the smartphone using bluetooth module. Although IoT [18] is very prominent and available technology nowdays it has some limitations as well. The wifi enabled ESP8266 is ok, but it requires connectivity with local internet or router which increases the overall cost of our proposed systems as well. So for this kind of simple task Bluetooth is preferred over so-called IoT devices. The whole connection and data acquisition process is shown in Fig. 5 below:

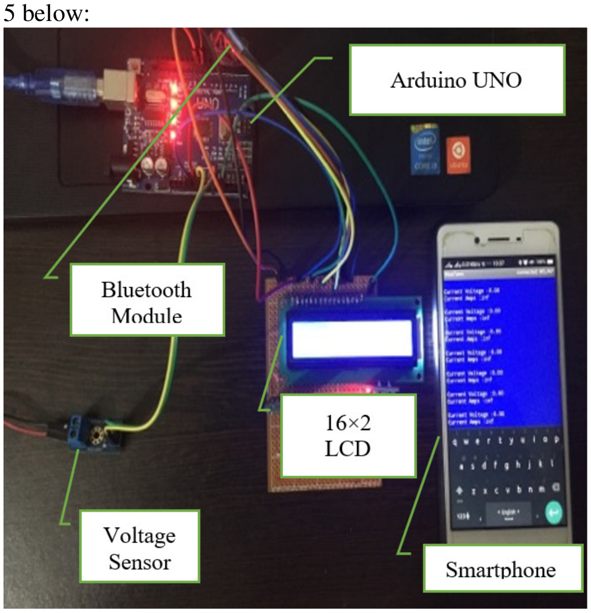

Figure 5: Data acquisition using a smartphone

To compare the accuracy of the proposed system, different cell phone batteries have been tested to measure the voltage and current level to check the performance. In this case, five popular mobile phone brands have been selected to check accuracy. They are Walton, Sony, Samsung, Symphony and Nokia. The results for measured voltage and current are shown below in Table IV and Table V respectively.

Table IV: Result of voltage measurement

SL	Brand	Model	Measured Value (V)
1	Walton	MH12	3.25
2	Sony	BST-33	3.70
3	Samsung	SCHA790	3.85
4	Symphony	M90	3.20
5	Nokia	BP5M	3.37

Table V: Result of current measurement

SL	Brand	Model	Measured Value (A)
1	Walton	MH12	910×10^{-3}
2	Sony	BST-33	960×10^{-3}
3	Samsung	SCHA790	1005×10^{-3}
4	Symphony	M90	1400×10^{-3}
5	Nokia	BP5M	940×10^{-3}

Now the relative error is calculated for the voltage between the measured value and original values, using the following formula:

$$Relative\ Error\ (\%) = \frac{|Absolute\ error|}{Original\ Value} \times 100 \,..(1)$$

The following results is got as shown in Table VI:

Table VI: Relative error for voltage measurement

SL	Brand	Original Value (V)	Measured Value (V)	Relative Error (%)
1	Walton	3.7	3.25	12.16
2	Sony	3.6	3.70	2.77
3	Samsung	3.7	3.85	4.05
4	Symphony	3.7	3.02	13.51
5	Nokia	3.7	3.37	8.91

After getting the result, can be seen that the relative error for any standard battery with our measurement system is maximum of 12.16%. On the other hand, if the relative error for current measurement is calculated using the equation (1), the following results shown in Table VII is got.

Table VII: Relative error for current measurement

SL	Brand	Original Value (mA)	Measured Value (mA)	Relative Error (%)
1	Walton	1100	910	17.27
2	Sony	1000	960	4
3	Samsung	1100	1005	8.63
4	Symphony	1800	1400	22.22
5	Nokia	900	940	4.44

As can be seen from the table-V that the local batteries are producing more prone to relative error as the rating might not be as accurate as other international brands.

6. CONCLUSION

A cost-efficient way is demonstrated to measure both AC & DC voltage along with current by using very low-cost components. The proposed system can also be easily monitored via a smartphone. Although the system has a sensitivity issue while measuring the current for any battery- but it can be neglected as it performs well with any battery of standard rating. Apart from that, the system can be upgraded as per the clients need and cost can be reduced if have gone for mass production. In future, having the intention to make it IoT enabled [19] and deploy machine learning [20] based auto fault detection mechanism, as machine learning-based enhancements [21, 22] showed promise in several fronts.

REFERENCE

[1] C. N. Cabaccan, F. Reidj and G. Cruz, "Power Characterization of Raspberry Pi Agricultural Sensor Nodes Using Arduino Based Voltmeter," 2018 3rd International Conference on Computer and Communication Systems (ICCCS), Nagoya, 2018, pp. 349-352, doi: 10.1109/CCOMS.2018.8463240.

[2] A. El Hammoumi, S. Motahhir, A. Chalh, A. El Ghzizal, and A. Derouich, "Low-cost virtual instrumentation of PV panel characteristics using Excel and Arduino in comparison with traditional instrumentation," Renewables: Wind, Water, and Solar, 5(1). doi:10.1186/s40807-018-0049-0.

[3] M. Mnati, A. Van den Bossche, and R. Chisab, "A Smart Voltage and Current Monitoring System for Three Phase Inverters Using an Android Smartphone Application," Sensors: 17(4), 872.

[4] M. Caruso, V. Castiglia, A. Del Pizzo, R. Miceli, M. Salles, G. Schettino and F. Viola, " Low-cost smart energy managment based on ATmega 328P-PU microcontroller," IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), 2017. doi:10.1109/icrera.2017.8191244.

[5] V. S. Nair, and A. S. Nair, "Portable Wireless Multipurpose Signal Viewer, Analyzer and Generator Using ATMEGA328P MCU and Android," 3rd International Conference for Convergence in Technology (I2CT), 2018.

[6] A. Bouabana, E. Sanal and C. Sourkounis, "Development of a low cost universal sensor for an accurate measurement of current, voltage and temperature," IEEE International Conference on Renewable Energy Research and Applications (ICRERA), 2016. doi:10.1109/icrera.2016.7884367.

[7] D. Q. R. Elizalde, R. J. P. Garcia, M. M. S. Mitra, and R. G. Maramba, "Wireless Automated Fire Detection System on Utility Posts Using ATmega328P," IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 2018.

[8] S Smys, JIZ Chen, "Special Section on Innovative Engineering Solutions for Future Health Care Informatics", Journal of Medical Imaging and Health Informatics 6, no. 7 (2016), 1570-1571

[9] O. E. Amestica, P. E. Melin, C. R. Duran-Faundez and G. R. Lagos, "An Experimental Comparison of Arduino IDE Compatible Platforms for Digital Control and Data Acquisition Applications," 2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), Valparaiso, Chile, 2019, pp. 1-6.

[10] J. Kaur et al., "Paradigm and performance anatomization of automatic indoor solar energy harvesting system exerting sensors," 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon), Bangalore, 2017, pp. 64-68.

[11] R. Khwanrit, S. Kittipiyakul, J. Kudtonagngam and H. Fujita, "Accuracy Comparison of Present Low-cost Current Sensors for Building Energy Monitoring," 2018 International Conference on Embedded Systems and Intelligent Technology & International Conference on Information and Communication Technology for Embedded Systems (ICESIT-ICICTES), Khon Kaen, 2018, pp. 1-6.

[12] S. Banerjee, S. Laskar, A. Chowdhury, S. Sarkar, A. Roy and A. Das, "Real-Time Monitoring and Control of Consumed Power for Household Appliances using Arduino Uno through Bluetooth and Android Application," 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, 2019, pp. 529-533.

[13] K. Xia, H. Su, J. Ni, B. Liu, Y. Ye and H. Li, "Smart pen-shaped digital multimeter system based on IoT and cloud," in IEEE Instrumentation & Measurement Magazine, vol. 22, no. 6, pp. 27-32, Dec. 2019, doi: 10.1109/MIM.2019.8917900.

[14] Milardović, S., Ivanišević, I., Rogina, A., and Kassal, P. (2018). "Synthesis and Electrochemical Characterization of AgNP Ink Suitable for Inkjet Printing", International Journal of Electrochemical Science, vol 13, pp. 11136-11149. doi:10.20964/2018.11.87

[15] W. Zhang, X. Yang, J. An, L. Zhang, B. Cai, and K. Yang, "Effect of Side Substituents Incorporated into π-Bridges of Quinoxaline-Based Sensitizers for Dye-Sensitized Solar Cells," Energy Technol., vol. 8, no. 5, p. 2000032, 2020.

[16] V. Dabbagh, A. A. D. Sarhan, J. Akbari, and N. A. Mardi, "Design and manufacturing of ultrasonic motor with in-plane and out-of-plane bending vibration modes of rectangular plate with large contact area," Measurement, vol. 109, pp. 425–431, 2017.

[17] A. D. Milne and C. A. Brousseau, "Effects of battery type and age on performance of rechargeable laryngoscopes," J. Anesth., vol. 27, no. 5, pp. 781–784, 2013.

[18] M Duraipandian, R Vinothkanna, "Cloud Based Internet of Things for Smart Connected Objects", Journal of ISMAC 1 (2), 111-119

[19] A. Ahmed, M. M. Parvez, M. M. R., M. H. Hasan, F. N. Nur, N. N. Moon, A. Karim, S. Azam, B. Shanmugam and M. Jonkman, "An Intelligent and Secured Tracking System for Monitoring School Bus," 2019 International Conference on Computer Communication and Informatics (ICCCI), 2019.

[20] A. Karim, S. Azam, B. Shanmugam, K. Kannoorpatti, M. Alazab, "A Comprehensive

Survey for Intelligent Spam Email Detection," IEEE Access, 2019, 7, 168261–168295.

[21] S. Manlangit, S. Azam, B. Shanmugam, and A. Karim, "Novel Machine Learning Approach for Analyzing Anonymous Credit Card Fraud Patterns," International Journal of Electronic Commerce Studies, 10(2), 2019. doi: 10.7903/ijecs.1732.

[22] M. F. A. Foysal, M. S. Islam, A. Karim, and N. Neehal, "Shot-Net: A Convolutional Neural Network for Classifying Different Cricket Shots," Communications in Computer and Information Science Recent Trends in Image Processing and Pattern Recognition, pp. 111–120, 2019.