Nigerian Research Journal of Engineering and Environmental Sciences 2(1) 2017 pp. 91-99

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

# DESIGN AND IMPLEMENTATION OF AN OPEN CIRCUIT VOLTAGE DATA LOGGING SYSTEM

***Ogbeide, K.O. and Aikhoje, P.T.**

Department of Electrical/Electronics Engineering, Faculty of Engineering, University of Benin, Benin City, Nigeria
*kingsley.ogbeide@uniben.edu

**ARTICLE INFORMATION**

*Article history*:
Received 11 March 2017
Revised 23 March 2017
Accepted 27 March 2017
Available online 01 June 2017

*Keywords*:
Data-logging
Microcontroller
Solar
Sensor
Photovoltaic panel

**ABSTRACT**

*This paper presents the design and implementation of a microcontroller-based data logging system for the direct measurement of the open circuit voltage of a photovoltaic panel. The design and implementation of the proposed system employed a number of components and modules which included a PIC18F4620 microcontroller that formed the main signal processing element of the system. It also incorporated an electrically erasable programmable read only memory device (EEPROM) for the real time storage of the measured open circuit voltage. The different sub-units that made up the system were integrated using the C# programming language. The designed data logging system performed satisfactory as it gave an accuracy of up to 98% with respect to a calibrated commercially avaialable voltmeter.*



## 1. INTRODUCTION

Manufacturers of photovoltaic panels (PV) normally indicate the rated open circuit voltage of their panels under standard test conditions based on the environment of manufacture. However there is need to determine the actual open circuit voltage of such panels in the area of their deployment. Conventional use of the voltmeter device will be impossible to deploy in the site of installation of photovoltaic panels hence the need to deploy effective data logging system.

Photovoltaic panels are solid-state devices that generates electricity from sunlight. They do this silently with little or no maintenance, no pollution and no significant depletion of material resources (Mieke, 1998; Prasad and Snow 2014). However, PV panels' output voltage is a function of the atmospheric conditions (Tomas, 1999).

Data logging and recording is a very common measurement application. In its most basic form, data logging is the measurement and recording of physical or electrical parameters from sensors over a period of time (Sumon et al., 2006; Abdullah et al., 2013). Some of the data that can be logged include temperature, strain, pressure, voltage, current, resistance, power, or any of a wide range of other parameters. Real-world data logging applications are typically more involved than just acquiring and recording signals. It normally involves some combination of online analysis, offline analysis, display, report generation, and data sharing (Sumon et al., 2006). The stored records can then be transmitted using serial (RS-232 Communication port) links to personal computer for permanent storage (Nhivekar et al., 2011).

The design of this monitoring system involves various steps, starting with the selection of the requisite sensor that will sense physical parameter, design of signal conditioning circuit which support digital logic device, selection of central processing unit (CPU) and display unit (Nhivekar et al., 2011, Sumon et al., 2006). Sensors sense the physical parameters and the analog output of the sensor are given to on-chip analog to digital converter (ADC). The ADC converts analog voltage into corresponding digital form which is processed to get the actual physical parameter that is then displayed by the liquid crystal display (LCD) module interfaced to the ports of microcontroller (Nhivekar et al, 2011). An integrated LCD is also used for real time display of data acquired from various sensors (Madukar and Suryawanshi, 2016). The device also acts as a data logger, with the help of Real Time Clock (RTC) and multi media memory card (MMC) interfaced to microcontroller.

The data logging system used in this work is one designed to measure the open circuit voltage of the photovoltaic panel using an analog to digital converter in the microcontroller PIC18F4620, measure the temperature of the surrounding where the photovoltaic panel is installed using the LM35 temperature sensor and keeping track of time using DS1307 real time clock and all of these information are stored on the AT24C256 EEPROM. A data acquisition software written in C# programming language is installed in a personal computer as a graphical user interface program to allow the display of the logged data from the environment of installation. The means of communication between the data logging system and the data acquisition software is through the Bluetooth module, HC-05 found in the data logging system.

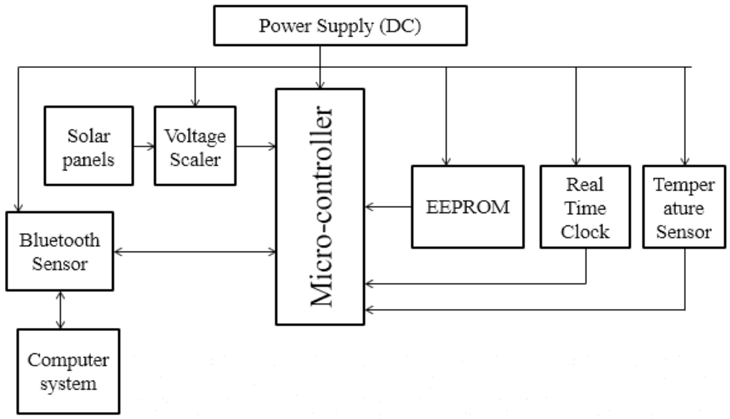


**Figure 1**: Block diagram designed data logger

Figure 1 shows the block diagram of the designed data logging system. It comprises of the different sub-units making up the entire system. As seen from the diagram, the different sub-systems are powered from a DC power source except the solar panels (PV panels) and computer. The voltage scalar scales down the voltage from the PV panels. The Microcontroller is the main processing component. The EEPROM stores the output voltage while the real time clock provide the timing signal for the system. A Bluetooth sensor transmits the stored data to the computer system.

## 2. MATERIALS AND METHODS

This data logging system which is designed to suit the purpose of measuring the open circuit voltage of PV panels is basically divided into the hardware and software components.

### 2.1. Hardware Component

A 12 V battery was the primary source of the power supply for all the components. The AC mains was the secondary power source which was used to charge the 12V battery through a 19 V power pack (switch mode power supply). A set of 8 diodes in series was connected in series with the battery and the power pack to drop part of the 19 V from the power pack. When the device is powered on, the initialized microcontroller ensures that the RTC counts periodically. The time read is compared with the pre-stored time in the program. If there is a match, the microcontroller reads the voltage from the two PV panels, the temperature and stores in the next available space in the EEPROM. If there is an interrupt from the universal asynchronous receiver transmitter (UART), it analyzes the data received then carries out the requested operation such as setting the time or date, request to send time and date and request to send stored data in the EEPROM.

## 2.2. Software Realisation

A software named "Solar Data" for the purpose of retrieving the stored data was developed using the C# programming language based on the .NET 4.5 framework with "windows form". The goal of the software is for easy retrieval of data from the data logging circuitry. Figure 2 is low is the program flow chart of the microcontroller.

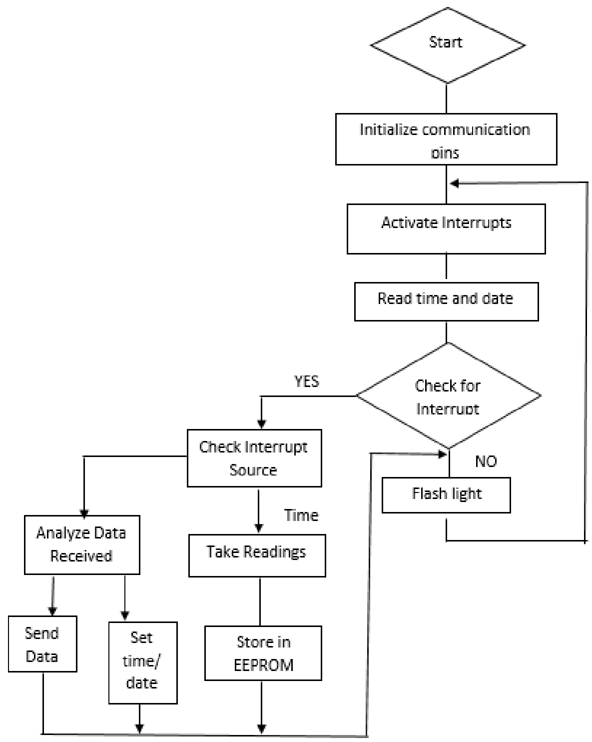


**Figure 2**: The program flow chart of the microcontroller

Communication between the computer software and the data logging circuitry was done through a bluetooth module HC-05. The HC-05 bluetooth module implements serial port communication in its architecture and as a result, serial port communication was used for communicating between the computer software and the data logging device taking readings from the solar panels. The communication protocol used the RS-232 standard for serial communication. A number of self-defined protocols were also used for communication.

## 2.3. Principle of Operation

The power supply consisted of a 12V, 7.5Ah lead acid battery, a 9V, 3A regulated power supply and a bulk converter (LM2576) 5V 3A regulator. It is required that the logging device be able to work continuously without any interruptions. From the data sheets of the individual ICs, the device is expected to draw a maximum current of 50mA ($I_{max}$). Using this maximum current requirement, a 7.5Ah battery can continuously supply this maximum current of 50 Ma for 6.25 days as shown in Equation 1.

$$\frac{7.5\text{Ah}}{50\times10^{-3}\text{A}} = 150 \text{ hours } = 6.25 \text{ days} \quad (1)$$

The data logger was expected to operate continuously above the 6.25 days supply limit of the battery. Therefore a secondary power source was required to supply the device and also charge the battery. The 220V AC supply was chosen as the secondary power source which would supply the required power for the device and also charge the battery through a 19V 3A regulated power supply. The battery to be charged is a 12V lead acid battery and the charging source voltage is 19V. From the battery's specification, the full charge voltage is 13.3V and a constant charge is recommended, thus a system was required to drop the 19V of the charging source to the 13V required for the battery for charging. Due to the forward voltage drop property of a diode (about 0.7V), it was decided to use a diode to drop the excess voltage of the charging source.

Excess voltage to be dropped, $V_{ex}$ = 19-13=6V

Forward voltage drop per diode, $V_f$ = 0.7 V

Number of diode (U) required to drop excess voltage

$$U = \frac{V_{ex}}{V_f} = \frac{6}{0.7} = 8.57 \cong 8 \text{ diodes} \quad (2)$$

The 8 diodes (D1, D8, D2, D9, D10, D3, D4, D11) were placed in series with the charging source.

Thus, the charging voltage v was obtained as follows:

$$v = 19 - (8 \times 0.7) = 13.4V$$

This is almost same as that specified by the battery manufacturers.

Every active component in the logging device operated on a voltage of 5V, therefore, the battery supply is further regulated to 5 V using the 7805 regulator.

Furthermore the open voltage produced by the PV panels is rated $22V_{max}$ but the microcontroller has an input range of 0-5 V range. In order not to destroy the microcontroller with the voltage from the PV panel, the voltage is first scaled down using a potential divider. Figure 3 shows the voltage divider diagram which consist of resistors R2 and R3 with the voltage measured across R3.

The scaling factor was calculated for each of the potential divider

$$\text{Scaling down factor} = \frac{R3}{R3+R2} \quad (3)$$

$$R3 = 22k\Omega, R2 = 100k\Omega$$

K.O. Ogbeide and P.T. Aikhoje / Nigerian Research Journal of Engineering and Environmental Sciences
2(1) 2017 pp. 91-99

$$\text{Scaling down factor} = \frac{22 \times 10^3}{(22 + 100) \times 10^3} = 0.1803$$

After the measurement of the scaled voltage, the original voltage can be recovered by multiplying by the inverse of the scaling factor.

$$\text{Scaling up factor} = \frac{1}{\text{scaling down factor}} = \frac{1}{0.1803} = 5.545 \quad (4)$$

This was implemented in the written program of the microcontroller.

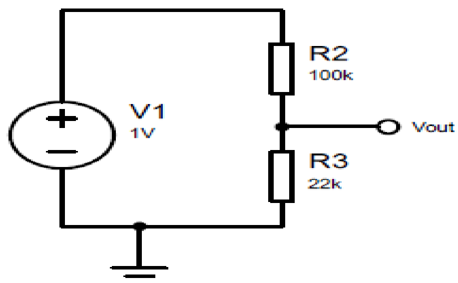

**Figure 3**: Voltage divider network

$$\text{Source Resistance}, Rs = \frac{R2 \times R3}{R2 + R3} = \frac{100 \times 22}{100 + 22} X10^3 = 18k\Omega$$

The EEPROM AT24C256 was required to store the measurements taken by the microcontroller, and it was used because it has the ability to retain its data in the event of power loss. The bluetooth was chosen as the means of data retrieval. The bluetooth device used in this work was HC-05 module. During data retrieval, the logging system is paired with a bluetooth enabled computer. Figures 4 shows the pictorial depiction of the designed data logging circuit while the complete circuit diagram is as shown in Figure 5.

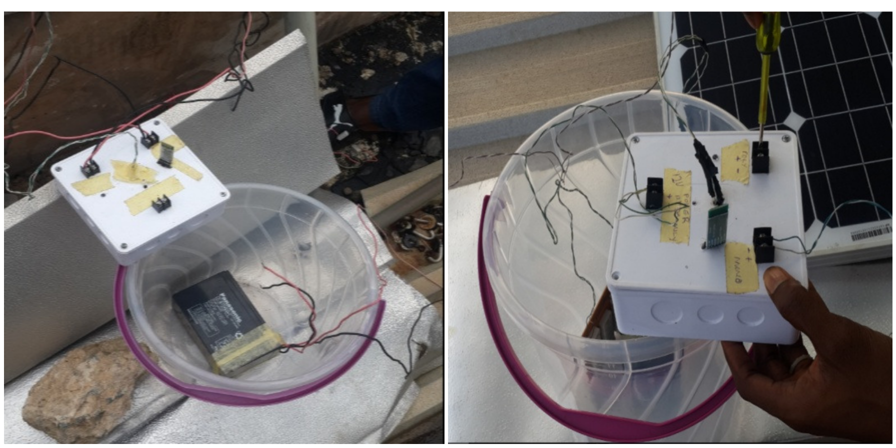
**Figure 4**: Pictorial depiction of the designed data logging circuit

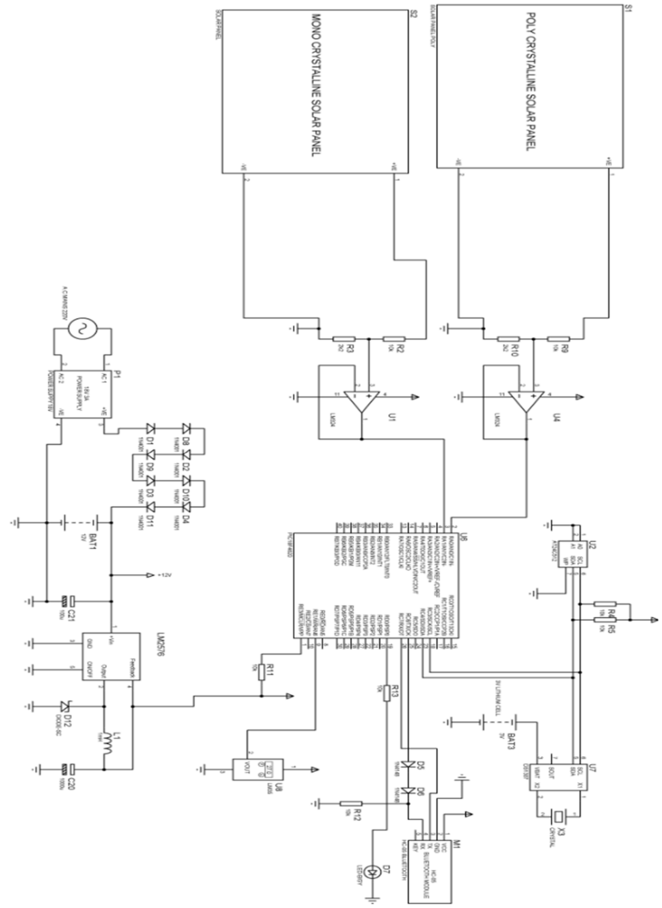

**Figure 5**: Circuit diagram of the data logging.

## 3. RESULTS AND DISCUSSION

Both the designed open circuit voltage data logging device and a calibrated voltmeter were used to take measurement of a typical PV panel and the results are presented in Figure 6. Figure 6 shows a graphical representation of the obtained reading during a measurement test of a 100W monocrystalline photovoltaic panel. Figure 6 clearly shows the closeness of the values measured by the data logger compared with values obtained from the conventional voltmeter.

The accuracy level of the designed voltmeter was 98% as calculated from Equation (4). Thus the designed logger can be relied upon for on- site and automatic logging of open circuit voltage information of photovoltaic panels.

$$\text{Accuracy} = \frac{[E_C - E_L]}{E_C} \tag{4}$$

$E_C$ is the voltage measured by a calibrated voltmeter and $E_L$ is the voltage measured by the designed logging device.

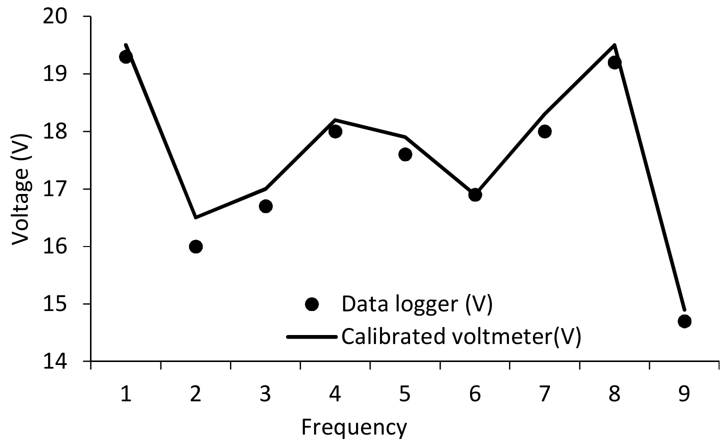


**Figure 6**: Accuracy curve for designed logger and calibrated voltmeter

## 4. CONCLUSION

The work which is design and implementation of an open voltage circuit data logging system employed a number of discrete and modular electronic components to realize a direct and automatic measurement of the open circuit voltages of photovoltaic panels. This is an alternative to the conventional voltmeter which cannot be deployed in site of PV installations. The designed data logger attained an accuracy level of up to 98% with respect to the conventionally calibrated voltmeter.

## 5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

## REFERENCES

Abdullah, A.M., Kenneth S., Ahmed N., Matiur, R. and Nizam U. A. (2013). Design and development of a PC-Based Automated Data Logging System for Measuring Temperature, *ARPN Journal of Engineering and Applied Sciences,* 8(11), pp. 960-968.

Madukar S.C. and Suryawanshi V.S. (2016). AVR Microcontroller Based Temperature Control System with Real Time Data Logger. *International Journal for Research in Applied Science & Engineering Technology,* 4(11), pp. 245-250

Mieke, W. (1998). Hot climate performance comparison between poly-crystalline and amorphous silicon cells connected to a utility mini-grid. *Proceedings of Solar 98, 36th Annual Conference of the Australian and New Zealand Solar Energy Society, Christchurch, New Zealand,* pp. 464-470.

Nhivekar, G.S. and Mudholker, R.R. (2011). Data Logger and Remote Monitoring System for Multiple Parameter Measurement Applications. e -*Journal of Science & Technology (e-JST)* 3(6), pp. 276-283.

Prasad, D. and Snow M. (2005), Designing with Solar Power: A Source Book for Building Integrated Photovoltaics (BiPV), Images, pp. 23

Sumon, S., Tofiqul I. and Zakir H. (2006), Design of a Low Cost Multi Channel Data Logger, *ARPN Journal of Engineering and Applied Sciences,* 1(1), pp. 26-32

Tomas M. (1999). Solar Electricity. West Sussex: John Wiley & Sons, 2nd Ed. pp. 67-75.