

Smart Monitoring System of DC to DC converter for Photovoltaic Application

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ABSTRACT

This paper presents a new smart monitoring system designed based on dc to dc converter for photovoltaic application. This system design according two parts to monitor input-output voltages and currents for dc/dc converter, (a) control system: the control system using Arduino NANO as microcontroller to read the measuring voltage and current values from sensor circuits of voltage and current. The measuring data send by Bluetooth HC-05 to end user (monitor system). Bluetooth as wireless communication between the control system and monitoring system (end users). (b) monitoring system: The monitoring system application program as a new application designed to monitor the received data from control system from safety distance (around 10m). the application program designed by the open source AppyBuilder software. The AppyBuilder is an open source software for easily building Android smartphone application. The advantages of the final circuit can be used to monitor step-up or step-down topologies, low-cost, and high-efficiency performance.

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1. INTRODUCTION

Due to changes in technology, There is an ongoing evolution in the surveillance systems, especially in the medical, industrial and general services industry for individuals [1-9]. The purpose of these technologies and modern applications is to increase the reliability of the devices, provide convenience to consumers and ensure the safety of workers in the control and monitoring of electrical and electronic instrument.

In this paper a new smart monitoring system for DC/DC converter. This system is called here: "Smart Monitoring System of DC to DC converter for Photovoltaic Application" (SMS). Figure 1. Present the full monitoring system of DC/DC converter. The main objective of this paper is to achieve smart monitoring and control system based on an embedded solution. The SMS can be divided into two parts which are: control and monitoring circuit and Android smartphone monitoring application. A)The measuring and control circuit can be divided into four parts: 1) DC to DC converter circuit connected to photovoltaic cells or DC power supply[10-13], This circuit has been used for the purpose of measuring voltages and current on input and output. 2) Voltage/Current sensor circuit, this circuit used to measure DC voltage/current for the DC/DC converter. 3) An Arduino Nano 3.0 as a microcontroller unit. This microcontroller was used read data from sensors units then Arduino send measuring data to Android smartphone (end user) by using wireless communication system [1],[2],[14-18]. The main advantage of using this controller is because it is cheap unit as well as open source code application [19]. 4) HC-5 Bluetooth communication device [20-22], Bluetooth is one of the devices used for wireless communication. B) Android smartphone monitoring application, this application designed by using AppyBuilde [23]. The AppyBuilde is an open-source environment application to create android smartphone application. the advantage of this work is to describes

an open source evolution of that prototype, in order to obtain a new monitoring and control system at a lower cost and with increased reliability of the instrument [18][22].

The organized of this paper is: Section 2 Provide relevant work and research. Section 3 Presents the monitoring system of DC/DC converter(hardware and software). Section 4 discusses the practical system hardware and smartphone application. Finally, Section 5 shows conclusions and further works.

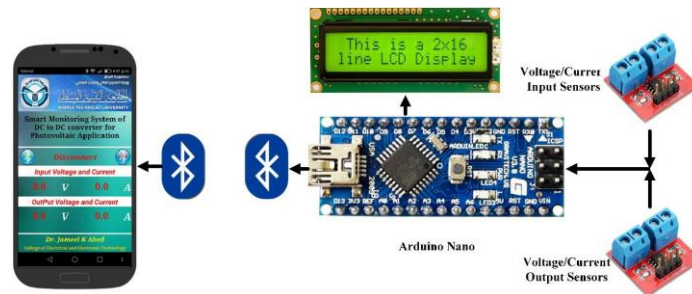


Figure 1. Full Monitoring System Diagram for DC to DC Converter

2. CURRENT RESEARCH WORKS

In this section, a similar research exhibition will be proposed in this research. In recent years, academic research on intelligent and smart monitoring and control techniques has increased in all fields as a result of these technologies of benefit to society. Reports in the United States indicate an increase the profits resulting from increased sales of equipment, sensors and applications related to smart monitoring and control technologies. The increase in equipment is mainly in smart grid sensor networks, smart homes and medical applications. In terms of software applications is how to monitor these devices by using smartphone application or computers software from long distance[5]. Table 1 Present the related work for the last three years according to field application, type of monitoring system, type of microcontroller, type of sensor and finely type of communication system.

Table 1. Related work for the last Three years

Related Work Reference	Type of Monitoring System	Type of Communication system	Type of Sensors	Type of Microprocessor	Field Application
Mohammad Jabbar Mnsati et al. [1], 2017	Smartphone	Bluetooth	Voltage and Current	Arduino Nano	Power application
Matti Satish Kumar et al [9], 2016	LEDS	---	Soil Moisture	Arduino UNO	Agricultural Applications
Hanady S. Ahmed et al. [3], 2015	PC	NRF24L01	ECG	Arduino UNO	Medical Applications
Salorise Vyas B.E et al. [16], 2016	Smartphone	Bluetooth	---	Arduino UNO	DC Motor Control
Kyukswang Kim et al. [5], 2015	Smartphone	Wi-Fi	Camera	Intel® Edison	Biomedical applications

3. SMART MONITORING SYSTEM DESCRIPTION

The smart monitoring system of DC/DC converter in Figure 1 can be divided into two parts, measuring and control system(practical system design) and monitoring application software (smartphone monitoring application).

3.1. Measuring and Contro System (Practical System Design)

The measuring and control system in the Figure 1a , it has been designed to measure and control the voltage and current of DC/DC converter system. Then the Arduino Nano was used as a microcontroller to read voltage/current from the input and output sensors of DC/DC converter circuit. After reading data, the microcontroller present the measuring result on LCD and send the same data by using Bluetooth to end monitoring user.

The practical circuit of the measuring and control system includes the following main units:

1. DC/DC Converter unit
2. Voltage/current sensor unit
3. HC-5 Bluetooth unit

4. Arduino Nano 3.0 unit

The main units of the practical system are shown in Figure 2.

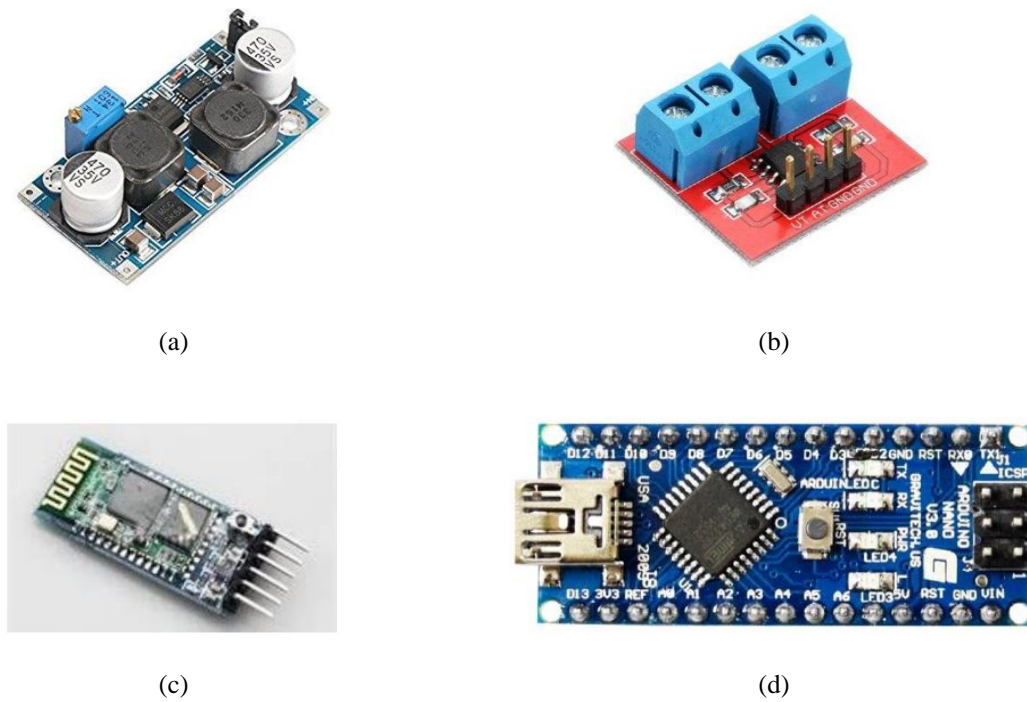


Figure 2. Main Practical Unites: (a) DC/DC Converter Unit, (b) Voltage/Current Sensor Unit, (c) Bluetooth HC-05, (d) Arduino Nano 3.0

3.1.1. DC/DC Converter Unit

The circuit diagram of DC to DC converter unite in the Figure 2a is present in the Figure 3. This circuit is designed base on XL6009E1 as a regulator circuit [25]. The XL6009E1 designed as a special regulator can be used in back and boost converter. The main advantage of The XL6009E1 , the output result of voltage and current is stable due to the current mode architecture. The main properties of the XL6009E1 is presented in the Table 2.

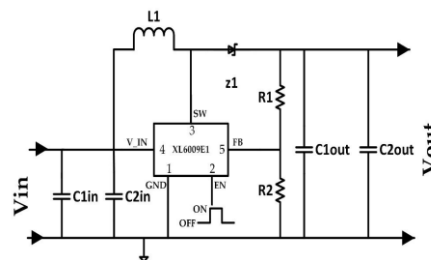


Figure 3. DC to DC Converter Circuit

Table 2. The Main Properties of the XL6009E1 [25]

Parameter	Value
Input Voltage Range	5V to 32V
Switching Frequency	400KHz
Maximum Current	4A
Efficiency	Up to 94%

3.1.2. Voltage/Current sensor unit

The voltage/current measuring circuit of D to Dc converter in Figure 2b is shown in the Figure 4 . This circuit is designed based on the MAX471 [26]. The MAX471 IC is a bidirectional amplifier for high current sense is used to measure dc voltage and current. The Main properties of MAX471 IC is present in Table 3.

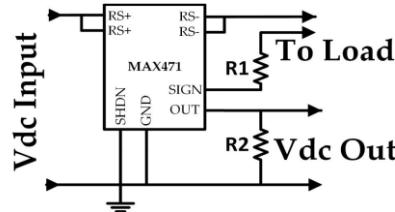


Figure 4. Voltage/Current Operation Circuit

Table 3. The Main Properties of the MAX471[24]

Parameter	Value
Supply Operation	3V to 36V
Max. supply Current	100µA
Max. Shutdown Mode	18µA
Accuracy Over Temperature	2%

3.1.3. HC-5 Bluetooth Unit

The Bluetooth HC-05 device is shown in the Figure 2c was used to communicate between the measuring circuit according the microcontroller and monitoring circuit application(end user). The main properties of Bluetooth HC-05 is, ISM frequency band (2.4GHz), Power supply (3.3Vdc 50mA), working temperature (-25 ~ +75)°C, the synchronous (1Mbps/1Mbps) and the transmit power (Class 2, ≤4dBm).

3.1.4. Arduino Nano 3.0 Unit

The Arduino Nano 3.0 in the Figure 2d is the main unit in the control circuit to read data from sensors and send the measuring results. The Arduino Nano is from a family of ATmega328 microcontroller that has 6 PWM pins , 8 analog I/O Pins, 22 digital input/output pins, 16 MHz as Clock Speed, flash Memory, EEPROM and SRAM (32KB,1KB and 2KB), 40mA DC Current per I/O Pins and 5V as an Operating Voltage. Figure 5. shows the main window used to programs all types of Arduino microcontrollers by using the C language.

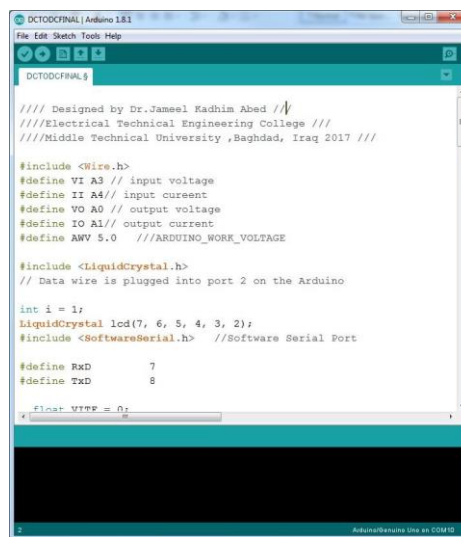


Figure 5. Main screen of Arduino Platform]

3.2. Monitoring Application Software (Smartphone Monitoring Application)

Monitoring System application software is designed to be installed on an Android smartphone instrument. This application is designed by using Appybuilder. Appybuilder or called AILiveComplete is an Development Environment for Android Applications. The main screen of AppyBuilder in the Figure 6. is an open source software for easily building Android smartphone application. The web site screen has spatial parameter in left side like (text box, Common button, timer, label ...etc.) ,main design screen in the middle of window and the properties of parameter like (font, color, size ..etc.) in right.

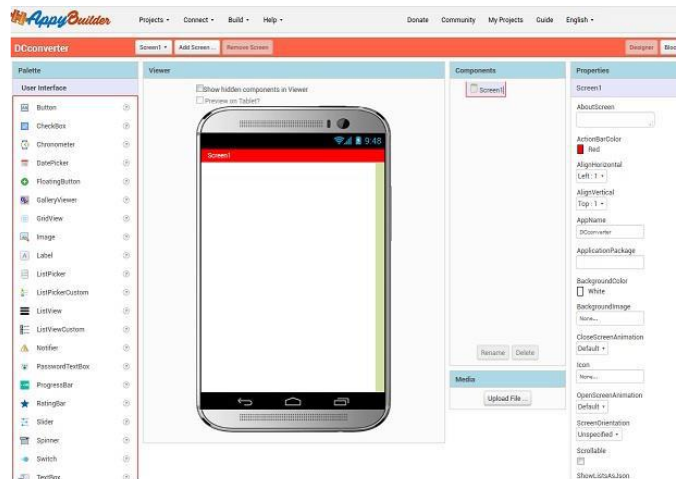


Figure 6. Main Screen of Appybuilder Website

4. EXPERIMENTAL RESULTS

The Final hardware system of DC to DC converter with photovoltaic application is shown in the Figure 7, the system consists of six units, which are: (1) DC/DC converter circuit, (2) Arduino Nano, (3) HC-5 Bluetooth communication system, (4) Voltage and Current sensors, (5) LCD 2/16, (6) photovoltaic cells and Simple resistive load. Figure 9. Shows the full connection of all components connected together and how can work, in order to read the data from sensors unit's and show how the results presents by the LCD unit before send it by the HC-5 Bluetooth.

The device has been tested by checked the sensors values (measuring values) of current and voltage, as well as compare the results on the LCD screen with the data sent to the smartphone application. The monitoring data were taken by the smartphone application from a distance of less than 10 meters due to the HC-5 Bluetooth device.

Figure 8. present the flowchart of DC/DC converter. Figure 8a is show how the microcontroller system send the information results by HC-5 Bluetooth after the Arduino Nano read data (DC voltage and current) from input and output sensors unites, Normally the HC-5 Bluetooth device connected automatically to microcontroller to make it as available. Before sending data by Bluetooth the measuring results presented on LCD unite. Figure 8b shows the flowchart of monitoring system, the monitoring system or the monitoring program is a smartphone application program, this program reads the data sent by the control system of voltage and current for input and output of DC/DC converter. Before the data presented on the smartphone application, the application program firstly need to search and connect to Bluetooth will be available of the control system. Figure 8a. Present the HC-5 Bluetooth searching window of the smartphone application.

Figure 9. present the final windows of DC/DC converter monitoring program. In Figure 9(a) show the HC-5 Bluetooth search window, this window used to locking and connect with available Bluetooth of control system. Figure 9(b) and (c) is present the final window of monitoring application before and after connected to Bluetooth respectively to monitor the measuring values of voltage and current was send from control system. The main window of the smart monitoring application of DC/DC converter in the Figure 9(b)and(c) content fields to voltage and current reading values of input and output of control system, two bottom for Bluetooth connected and disconnected, Finely some information about the Author and his work place was added in main window.

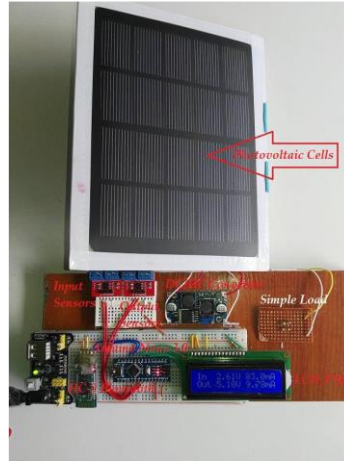


Figure 6. Final Headwear System of Monitoring DC/DC Converter with Photovoltaic Cell

5. CONCLUSIONS AND FUTURE WORK

The smart monitoring system(SMS) of DC/DC converter in this paper is designed and implemented the final circuit to measure voltage/current input and output of low power DC/DC converter. In this paper, HC-5 Bluetooth was used as a communication system between the control system(final circuit of DC/DC converter) and end user (smartphone application user). New smartphone application design by AppyBuilder software, AppyBuilder software is an open source program to design Android smart instrument application. The advantages of the final circuit can be used to monitor step-up or step-down topologies, low-cost, and high-efficiency performance. The monitoring system uses a new android smartphone application designed by MIT App Inventor 2. This application receives the three phase RMS voltage and current data from the Bluetooth device (HC-05). The SVCMS has been tested successfully.

The future work of the system in this paper (SMS) are,(1) to apply the same system to measure and monitor high voltage and current off DC/DC converter by replace the measuring sensors ,(2) replace the communication system (Bluetooth) by Internet of Things (IOT) or LoRa Communication technology. These technologies is the future of communication of smart monitoring systems.

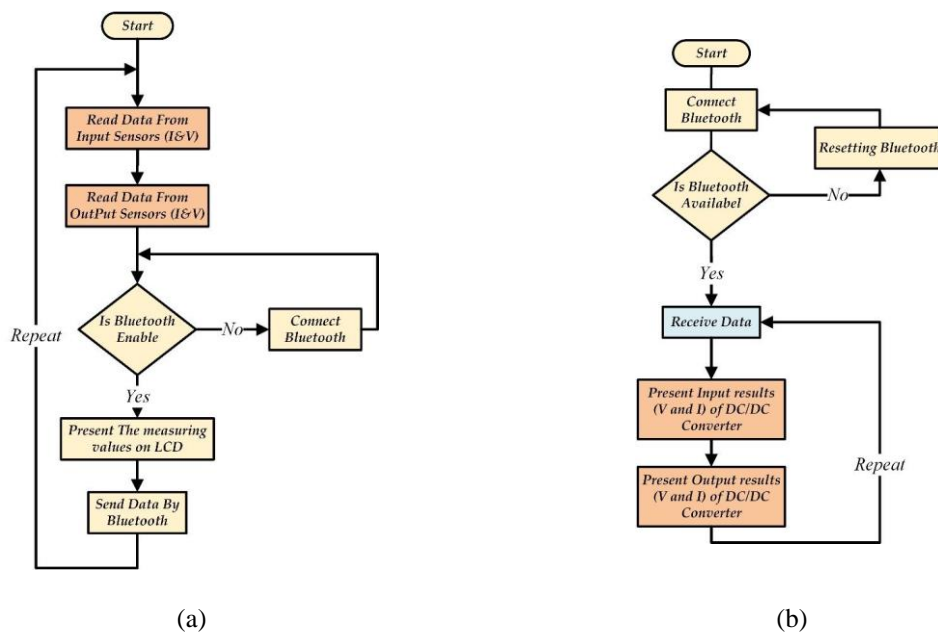


Figure 7. Flowchart of Control System of DC/DC Converter: (a) Control System Flowchart; (b) Smartphone Application Flowchart



Figure 9. Windows of DC/DC Converter Application: (a) HC-5 Bluetooth Searching Window; (b) Main Application Window Before Bluetooth Connected; (c) Main Application Window with Results after Bluetooth Connected

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Jameel Kadhim Abed received his MSc and PhD degree in power system, machine and power electronics from the University of Baghdad in 1985 and 2003 respectively. He has worked at the Foundation of Military Production since 1988 as Head Master of the Development and Research Department in the field of power electronics (power supply and inverters). Currently he works in the Middle Technical University as Head Master of the Mechatronics Department and as lecturer in power electronics for undergraduate and postgraduate students as well as supervisor of master and high diploma students in the field of high frequency inverter and renewable energy. His research is on electrical drives and power electronics on various inverter types, and he is interested in renewable energy.