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DESIGN AND DEVELOPMENT OF DEDICATED DATA LOGGER FOR PV SOLAR MODULES

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Abstract
A dedicated device for collect, store and record data from various sensors and the photovoltaic generator itself over the time is presented in this paper. The device is designed and developed for the laboratory of Renewable Energy of FTS needs, intended for laboratory testing of the influence of meteorological and electrical conditions on the efficiency of photovoltaic panel as the panel temperature, air humidity, air pressure, solar radiation, wind speed, wind direction, voltage and current.
The designed data logger prototype is based on the microcontroller (MCU) STM32F411 for sensor processing data, while for data store and recording is used portable storage device - SD card. The MCU's internall Real Time Clock (RTC) was implemented to record date and time, as administrative data, during an acquisition.
For storage and for recording acquired data the memory of Bluetooth enabled android mobile phone can be used also and with installed free application Serial Bluetooth Terminal. Namely, the data logger is equipped with Bluetooth transceiver for remotely monitoring of acquisition in the real time. The sampling time of the device is variable and can be adjusted during an acquisition using the phone application. The default value is 1000 ms. Mentioned application provides the Bluetooth connection terminal, data display terminal and data storage facility on a mobile phone.
The results obtained by recording data over a longer time interval, which are stored on the SD card in file form, will be used for various software analyzes and modeling the effect of the inclination angle on the efficiency of photovoltaic modules.

Keywords: MCU, solar radiation sensor, wind speed and direction sensor, RS485, I2C, Hall current sensor, SD card, Bluetooth, step-up converter, PV module.

INTRODUCTION

Recent data loggers, dedicated to PV modules represent reliable solution for monitoring of PV module performance, efficiency improvements identification and long-term yield evaluation in the real time [1], [2]. It collect, records and stores information such as power generation, voltage, temperature, solar radiation and other relevant parameters, enabling real time, targeted monitoring of the system.

Almost all the industrial process requires data logging [4]. However, cheap and feasible solution of data logging in industrial and scientific processes is a difficult task with factory-available data loggers because of the specific needs of users. Therefore, it is necessary to design an inexpensive and real special purpose data logger in accordance with user requirements [3]. A key criterion in designing is the choice of the precise sensors for measuring non-electrical and electrical quantities.

This article represents one of numerous solutions of solar PV data logger, [2], [3], [5], constructed in accordance with requirements of the laboratory of renewable energy of the Faculty of technical sciences in Kosovska Mitrovica. Special attention was paid to the installation of precise sensors of non-electrical quantities to monitor the influences of meteorological conditions on the efficiency of the photovoltaic module. In order to achieve high measurement precision this design is based exclusively on digital sensors of non-electrical and electrical quantities of interest.

PROJECT REQUIREMENTS

As already mentioned, this device is designed according to the requirements of the laboratory for Renewable Energy – FTS. The established basic requirements refer to the need to measure and store in real-time the following quantities:

1. measuring the operating temperature of the PV panel,
2. measuring the humidity of the ambient air,
3. measurement of absolute barometric pressure,
4. solar irradiance measurement as power per unit area (surface power density) received from the Sun,
5. DC current from PV module through the load,
6. DC voltage from PV panel on the load,
7. wind speed,
8. wind direction,
9. time and date stamp.

The proposed data logger should have the ability to change the sampling time in *ms* and display the measured quantities in real-time during the acquisition process.

HARDWARE SELECTION

After the approval of the project requirements, the appropriate hardware components were selected. The block diagram of the proposed data logger is shown in the Fig. 1. It consists of heart of the device – a STM32F411CEU6 microcontroller [10], that has an ARM Cortex-M4 core, a 512 KB flash, 128 KB SRAM memory, a floating point unit and a rich set of integrated peripherals such as multiple SPI, I^2C and USART interfaces, one 12-bit 2.4 MSPS ADC, low power RTC, six 16-bit and two 32-bit timers.

The popular BlackPill board with STM32F411CEU6 core was applied in this project, Fig. 2. The chosen 40-pin board has enough I/O lines as well as peripherals to meet the needs of the user.

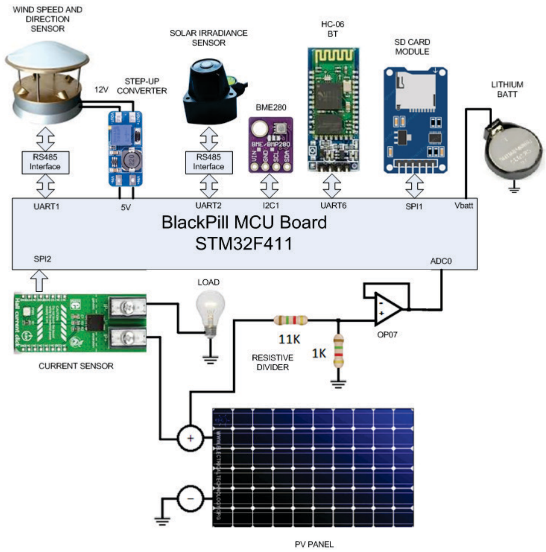


Fig. 1. *Block diagram of proposed data logger*

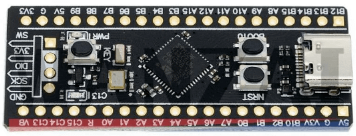


Fig. 2. *BlackPill board with STM32F411CEU6 core*

The BOSCH digital multi-sensor BME280 was chosen to measure panel temperature, air humidity and atmospheric pressure with excellent accuracy, Fig. 3. The sensor provides both SPI and I^2C serial communication interfaces and can operate in three modes: sleep, normal and forced mode. More details about this sensor can be found in [6].

Fig. 3. *BME280 multi-sensor board*

Calibrated PYR20 pyranometer or solar radiation sensor, Fig. 4, is used for global radiation measurement of both direct and diffusion of solar irradiance and offers excellent accuracy and consistency. The internal temperature compensation minimizes the error caused by heating of the sensor.

Output interface of the sensor is RS485 modbus-RTU, measurement range up to 2000 W/m^2 and spectral range 400-1100 nm [7]. Operating DC voltage is 3.9-30 V.

Fig. 4. *PYR20 pyranometer with RS485 modbus-RTU interface*

Hall current click board [9] represent a plug and play solution containing the integrated circuit TLI4970-D050T4 with 16-bit SPI output from *Infineon Technology*. A differential measurement principle allows effective stray field suppression with a highly linear output signal without hysteresis. Signal processing, compensation and calibration are already integrated. The full scale measurement range is ±50 A. This sensor is used for DC current measurement through the load.

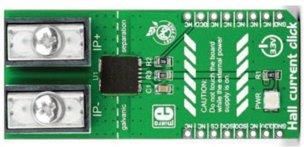


Fig. 5. *Hall current click board*

A resistive voltage divider with unity gain operational amplifier was used to measure the output DC voltage of the photovoltaic module. This voltage divider is set to its maximum output of 3.3 V for a maximum input voltage from the PV module of 36 V. The output of the low offset unity gain operational amplifier OP07 is directly connected to channel 0 of the ADC peripheral of the MCU.

In accordance with the requirements of the project, an ultrasonic digital wind speed and direction sensor QYCG-09 [8] was selected, Fig. 6. It collects ultrasonic data of wind speed and direction at the same time.

Fig. 6. *Ultrasonic wind speed and direction sensor with RS485 modbus-RTU interface*

The sensor has no moving parts and can accurately detect wind in difficult conditions, as well as very low wind speeds of around 0 m/s. The measurement range is 0-30 m/s for wind speed and 0-360 degrees for wind direction with an absolute error of ±0.2 m/s and ±1 degree, respectively. The output interface of the sensor is RS485 modbus-RTU, while the operating DC voltage is 7-17 V.

Finally, a record of the exact time and date for each sample was obtained with the help of a real-time clock-calendar. Namely, the selected MCU contains an integrated RTC peripheral with very low consumption. For the continuous operation of this peripheral even when the MCU is not operating, it is necessary to provide an uninterrupted power supply to the line V_B of the MCU with the help of an external 3V lithium battery.

On the memory SD card, the firmware creates a file system and specifically a file named *PV_Data.txt*. In this text file, the measured values of the samples and time stamp are recorded in several columns separated by the tab delimiter.

In order to reduce the costs of the data logger implementation, instead of a display for displaying the measured values of samples in real time, a bluetooth transceiver module HC-06 was added to the logger. Such an approach allows real-time display of measured samples values on a free mobile phone application – *Serial Bluetooth Terminal*, as well as wireless change of sampling rate. Despite the fact that the measured data is stored on a memory SD card, the adopted concept with the help of the mentioned mobile application offers an additional possibility of storing and saving data on a mobile phone.

Figure 7 shows the data logger realized on PCB with above mentioned modules.

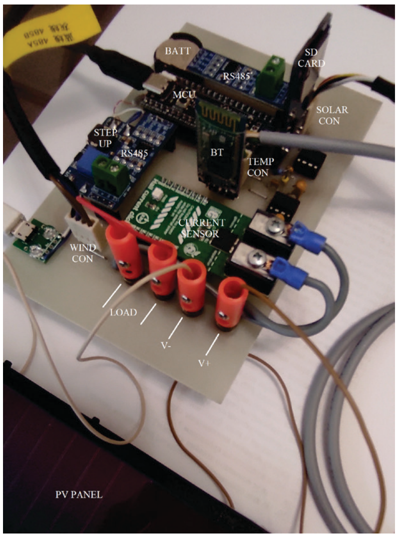
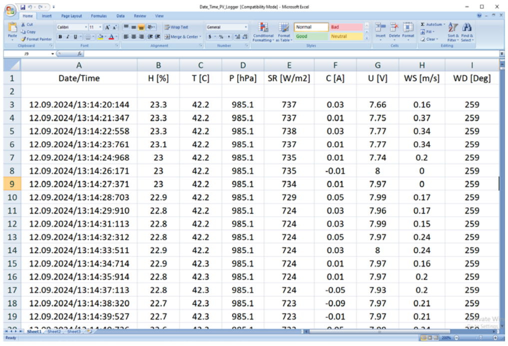


Fig. 7. *Complete proposed data logger connected with small PV panel*

EXPERIMENTAL RESULTS

After designing and implementing the proposed data logger, several successful tests were performed. The data recorded on the SD card in the form of a *PV_Data.txt* file were pasted into the *Excel* editor after reading, Fig. 8. As shown in Figure 8, the first column shows the date/time for each sample, the second column shows the relative humidity of the environment, the third panel temperature, the fourth absolute ambient air pressure, the fifth solar radiation, the sixth current through the load, the output voltage of the seventh PV panel and the last two columns of wind speed and azimuth.

The same data recorded on the SD card, but not all (except for air humidity and air pressure), was transferring successfully to the Bluetooth-enabled android phone via the HC-06 Bluetooth module and was storing in the mobile phone memory thanks to the free *Serial Bluetooth Terminal* application, Fig. 9. This application can be used for the change of the data logger sampling rate in *ms*, also. The data logger was programmed under STM32CubeIDE software.



	A	B	C	D	E	F	G	H	I
1	Date/Time	H [%]	T [C]	P [hPa]	SR [W/m2]	C [A]	U [V]	WS [m/s]	WD [Deg]
2									
3	12.09.2024/13:14:20:144	23.3	42.2	985.1	737	0.03	7.66	0.16	259
4	12.09.2024/13:14:21:347	23.3	42.2	985.1	737	0.01	7.75	0.37	259
5	12.09.2024/13:14:22:558	23.3	42.2	985.1	738	0.03	7.77	0.34	259
6	12.09.2024/13:14:23:761	23.1	42.2	985.1	737	0.01	7.77	0.34	259
7	12.09.2024/13:14:24:968	23	42.2	985.1	735	0.01	7.74	0.2	259
8	12.09.2024/13:14:26:171	23	42.2	985.1	735	-0.01	8	0	259
9	12.09.2024/13:14:27:371	23	42.2	985.1	734	0.01	7.97	0	259
10	12.09.2024/13:14:28:703	22.9	42.2	985.1	729	0.05	7.99	0.17	259
11	12.09.2024/13:14:29:910	22.8	42.2	985.1	724	0.03	7.96	0.17	259
12	12.09.2024/13:14:31:113	22.8	42.2	985.1	724	0.03	7.99	0.15	259
13	12.09.2024/13:14:32:312	22.8	42.2	985.1	724	0.05	7.97	0.24	259
14	12.09.2024/13:14:33:511	22.9	42.2	985.1	724	0.03	8	0.24	259
15	12.09.2024/13:14:34:714	22.9	42.3	985.1	724	0.01	7.97	0.16	259
16	12.09.2024/13:14:35:914	22.8	42.3	985.1	724	0.01	7.97	0.2	259
17	12.09.2024/13:14:37:113	22.8	42.3	985.1	724	-0.05	7.93	0.2	259
18	12.09.2024/13:14:38:320	22.7	42.3	985.1	723	-0.09	7.97	0.21	259
19	12.09.2024/13:14:39:527	22.7	42.3	985.1	723	-0.01	7.97	0.21	259

Fig. 8. *Data collected on SD card and converted to xls format*

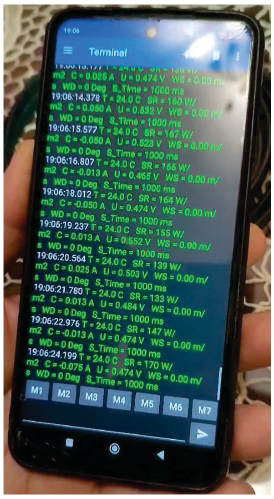


Fig. 9. *Bluetooth data transfer to the android mobile phone*

CONCLUSION

The designed data logger is a reliable and relatively inexpensive solution for collecting of electrical and meteorological parameters important for photovoltaic solar panels. The direct interfacing of carefully selected calibrated sensors to the rest of the data logger makes this device efficient and useful for many PV solar panel tests. Remote monitoring of the acquisition and changing of the sample rate are enabled with a Bluetooth transceiver.

Finally, some improvements can be made, such as installation of more temperature sensors, taking into account the larger area of the PV solar panel.

Acknowledgements

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