XVII International Scientific Conference on Industrial Systems (IS'17)
Novi Sad, Serbia, October 4. – 6. 2017.
University of Novi Sad, Faculty of Technical Sciences,
Department for Industrial Engineering and Management
Available online at http://www.iim.ftn.uns.ac.rs/is17

Development and testing of Arduino-based Relative Humidity and Dry Bulb Temperature data logger

Milovan Medojevic
(Teaching Assistant and Researcher, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, 2100 Novi Sad, Serbia, medojevicmilovan@gmail.com)

Andrija Stojanovic
(Production planer, Robert Bosch Doo, Dositejeva 33, 22310 Šimanovci, Serbia, andija1991@gmail.com)

Milovan Lazarevic
(Associate Professor, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, 2100 Novi Sad, Serbia, laza@uns.ac.rs)

Ilija Cosic
(Professor Emeritus, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, 2100 Novi Sad, Serbia, ilijac@uns.ac.rs)

Nemanja Sremcev
(Assistant Professor, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, 2100 Novi Sad, Serbia, nextesla@uns.ac.rs)

Abstract

In this paper, an effort has been made to design and develop an 8-channel Relative Humidity and Dry Bulb Temperature data logger. Initially, the conceptual solution of data logger consists of several elements where the main components are Arduino Mega 2560, LM35 analogue temperature sensors, DHT22 digital temperature and humidity sensors, pull-up resistors, as well as Bluetooth HC05 communication module. Moreover, data logger testing was carried out under controlled climatic conditions. A digital multimileter DT9205M with the temperature probe TR-01A was used as a reference device, while the testing was performed for 2 specific cases. In the first case, both devices recorded measured values of air temperature in conditions with a relatively quiescent air stream. Subsequently, the second case involves testing in conditions with constant, forced hot air flow through a circular pipe. Lastly, the aim of this study was to determine shortcomings, possible measurement errors, and data logger reliability. Having this in mind, both of these cases are described in more detail below, while the relevant results were graphically interpreted and discussed.

Key words: *Arduino, Data Logger, Relative Humidity, Temperature*

1. INTRODUCTION

The need for collecting high quality data on temperature and relative humidity continuously increases [1], as better information on system performance could improve understanding of energy use [2], thermal comfort [3], indoor environmental quality (IEQ) [4,5], and even the microbiology of the built environment [6]. Such data are widely applicable in agriculture, energy sector, tourism, construction and many other aspects of everyday life. Having this in mind, a scientific interest emerged for the development and implementation of such solutions, while several studies have dealt with this topic. Likewise, Gasparesc used an Arduino Uno board connected to a PC with a graphical user interface (GUI) to monitor and measure temperature and relative humidity in various conditions [7], while Khairi et al. developed a wireless temperature monitoring system [8]. Similar studies were presented by Goswami et al., Ibrahim, Kumar et al., and Sigh and Sud [9-12]. Moreover, applications of portable and mobile data logging with sensors are also in demand [13-15]. Given the aforementioned, conceptual solution for development of Arduino-based, 8-channel Relative Humidity and Dry Bulb Temperature data logger was in focus of this research, while all relevant findings are explained hereafter.

2. CONCEPTUAL SOLUTION

The conceptual solution of Arduino-based data logger consists of several elements where the main components are Arduino Mega 2560 (a microcontroller platform based on Atmel's Atmega2560 8-bit microcontroller), 5 LM35 analogue temperature sensors (integrated-circuit temperature sensors with an output voltage linearly-proportional to the Centigrade temperature), 3 DHT22 digital temperature and humidity sensors (it uses a capacitive humidity sensor and a thermistor to measure the parameters of surrounding air, and spits out a digital signal on the data pin) and Bluetooth communication module HC05 (module has two operation modes, Command Mode where it can send commands and Data Mode where it transmits and receives data to another Bluetooth module). The connection of the sensors and communication modules to Arduino Mega was performed through a breadboard which is used to test the device operation in order to determine possible shortcomings (Figure 1).

Analogue sensors LM35 are connected to a 5V voltage, obtained from the Arduino board (AB), while their output signals are connected to the analogue inputs (A8, A9, A10, A11 and A12) on AB which allows the readout of the voltage received by sensors. Additionally, the Bluetooth module is also powered directly from the AB with standard 5V. As the module uses serial communication, its communication contacts (Tx, Rx) are connected to the 10th and 11th pin on AB which can be used for communication, i.e. to be (Tx, Rx). Lastly, DHT22 sensors are also powered by a 5V from AB, while connection is ensured via digital inputs to AB (2, 3, 4). However, in order to get a signal at the sensors output, 10 kΩ pull-up resistors should be installed. The connection diagram of the described components with Arduino Mega is given in the figure 2.

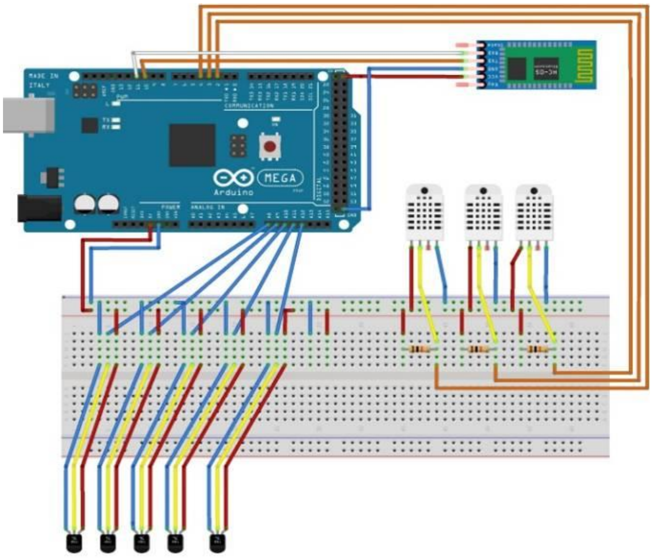

Figure 1. The connection of the sensors and communication module to Arduino Mega

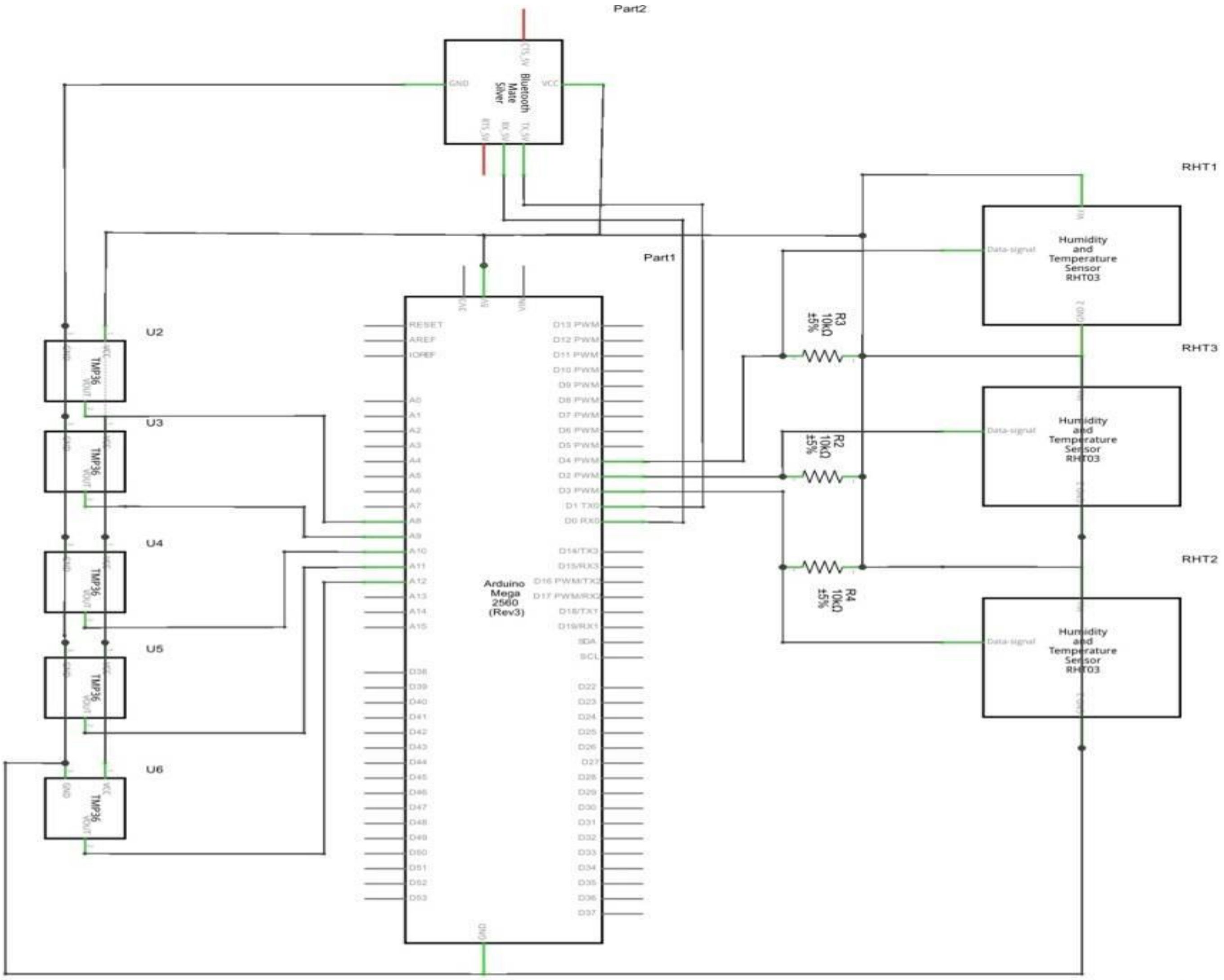

Figure 2. The connection diagram of components to AB

AB as a basic component has a microcontroller that needs to be programmed to perform the given function. In order to develop a program that reads data from sensors, processes data and sends data via serial connection using Bluetooth, the DHT22 sensor libraries were integrated. Moreover, *Average.h* a statistics library is implemented in the program. The reason for using the *Average.h* library is because it was determined that the values obtained over analogue sensors oscillate around the referent values. Having in mind that this library in a series of iterations performs interpolation between two successively measured values, it is possible to achieve more reliable and accurate data. Subsequently, an adequate program algorithm was determined and transferred to AB microcontroller. Key elements of program algorithm are given in the figure 3.

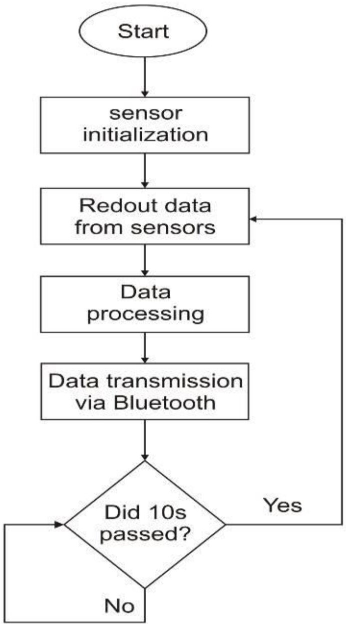

Figure 3. Simplified Program Algorithm

The first step program performs, is the initialization of sensors. Here the pins on which the sensors are located must be defined in order microcontroller can recognize them. Upon initialization of all sensors, the recoded values are sent are read. In this version, 100 readouts from each sensor are recorded for a period of one minute upon which program calculates the average value for each sensor. Then, using serial communication, these data are forwarded to the Bluetooth module that transfers information to the computer.

3. DEVICE TESTING

Device testing was carried out in controlled climatic conditions where a reference temperature of a room was 18 °C. In addition, a digital multimileter DT9205M with the temperature probe TR-01A was used as a reference device. The testing was performed for 2 specific cases. In the first case, both devices recorded measured values of air temperature at intervals of 10 seconds over a period of 5 minutes in conditions with a relatively quiescent air stream. Subsequently, the second case involves testing in conditions with constant, forced hot air flow through a 665 mm long and 110 mm in diameter circular pipe. Both of these cases are described in more detail below.

3.1 **Case 1**

In this case, all sensors were set at approximately uniform altitude from the ground (0.4 - 0.6 m), while air velocity values were determined by using the KIMO VT50 anemometer with a hot wire. The velocity of air flow at the aforementioned height ranges from 0.05 - 0.09 m/s. The obtained results for the previously described case are graphically depicted in Figures 4-6. Figure 1 is a graphic representation of the measured and averaged values from DHT22 and LM35 sensors in relation to the values recorded with the temperature probe TR-01A.

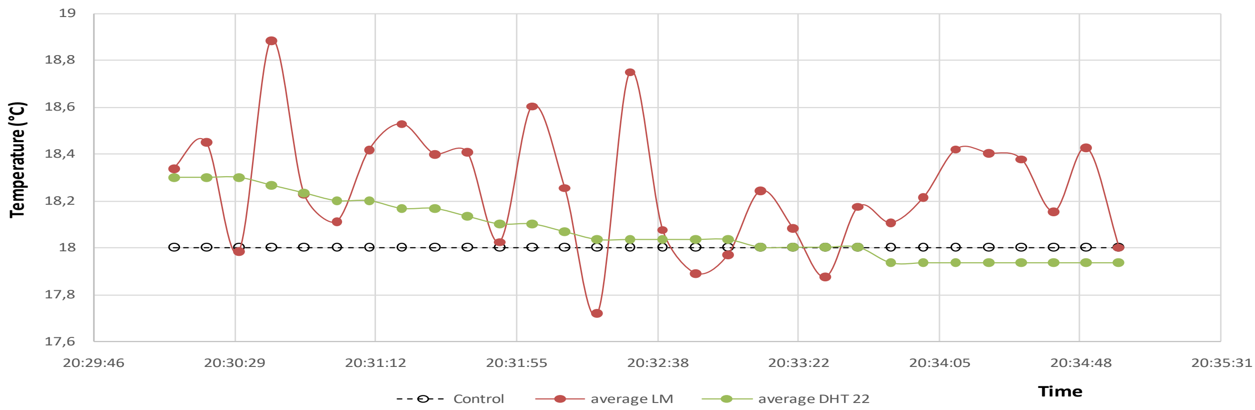

Figure 4. Measured and averaged values from DHT22 and LM35 sensors in relation to the values recorded with the temperature probe TR-01A (Case 1)

In addition, from the Fig. 4, it is possible to perceive the unevenness of the measurement results. The maximum deviation of the LM35 sensor relative to the reference value is recorded to be ± 1 °C. On the other hand, after 2 min and 20 sec from the beginning of the measurement, DHT22 sensors show relatively accurate temperature values with a deviation of 0.1 °C in compared to the reference values. Subsequently, figure 5 shows the measured values for the 5 LM35 sensors.

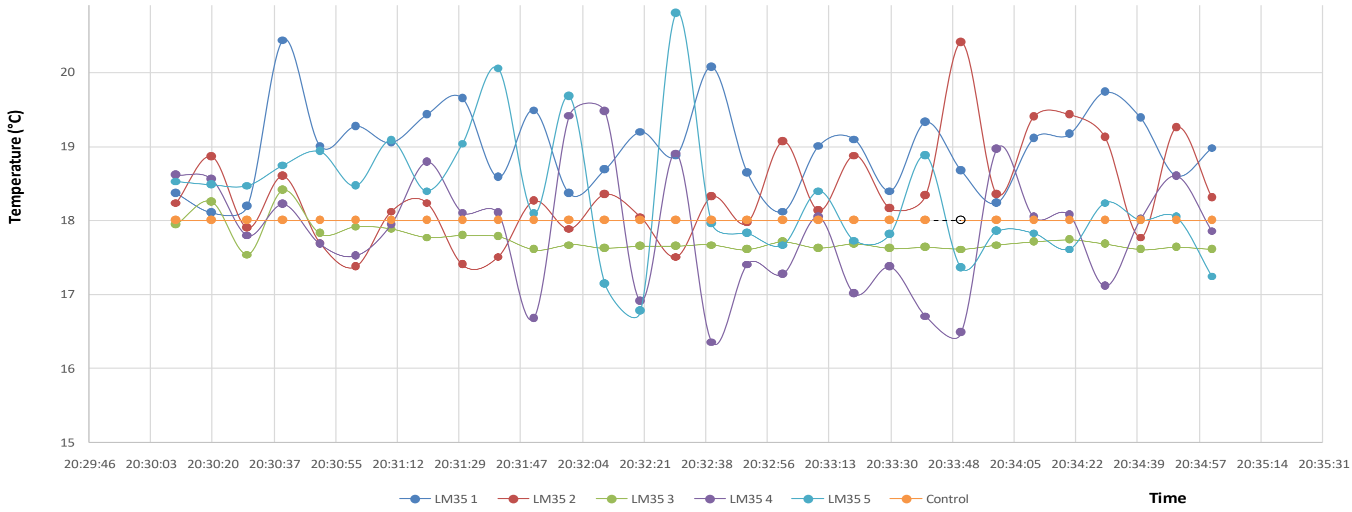

Figure 5. Individual values of 5 LM35 sensors relative to the TR-01A (Case 1)

From the graph given in the figure 5, it is possible to discern that the maximum deviation of values recorded by the LM35 sensors is ± 3 °C, while most of the points shown on the graph indicate a deviation of ± 2 °C. Similarly, individual values of 3 DHT22 sensors compared to TR-01A were given in the figure 6.

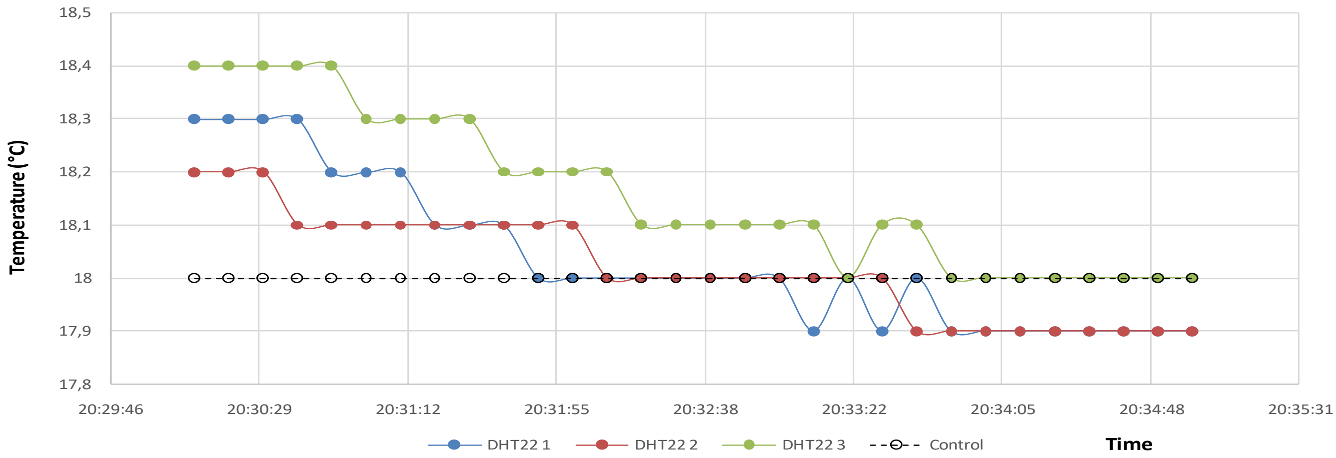

Figure 6. Individual values of 3 DHT22 sensors compared to TR-01A (Case 1)

As it can be seen from the graph shown in figure 6, a maximum deviation of values recorded by DHT22 sensors, in comparison to TR-01A, amounts ± 0.4 °C.

3.2 **Case 2**

As previously mentioned, , the second case involves testing in conditions with constant, forced hot air flow through a 665 mm long and 110 mm in diameter circular pipe, which illustratively given in the figure 7. An ordinary hair dryer was used in order to simulate the flow of hot air, wherein a velocity of hot air reaches 1.85 m/s at the end of circular pipe. In addition, LM35 sensors are located at a distance of ¼ the length of the tube from the heat source and 25 mm from the inner wall of the pipe. On the other hand, the DHT22 sensors (not shown in Figure 3) are placed on the lower inner wall of the same tube, due to their dimensions, but at the same distance from the heat source as the LM35 sensors. Also, the temperature probe TP-01A is set at an angle of 90 ° opposite to the central LM35 sensor (fig. 7). In this case, the duration of the measurement is 10 minutes after the simulation start, while the results are graphically depicted in Figures 8-10.

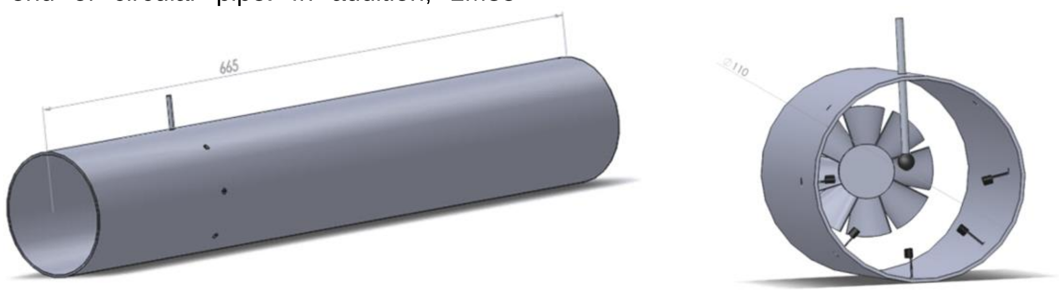

Figure 7. Experiment setup for Case 2

Figure 8 is a graphic representation of the measured and averaged values from DHT22 and LM35 sensors in relation to the values recorded with the temperature probe TR-01A in a conditions characteristic for the case 2. After 3 min and 30 sec of measurement, the data representation became relatively stabilized. What is interesting to note is the different sensitivity and response speed of the LM35 and DHT22 sensors compared to the temperature probe TP-01A. Also, the recorded values of LM35 and DHT22 sensors are lower (LM35 (5 °C), DHT22 (3 °C)) than the values recorded by the TP-01A probe after stabilization period, indicating an increased measurement error due to air flow. Similarly to the first case, figure 9 provides an indication of the measured individual values for the 5 LM35 sensors relative to the TP-01A probe under constant, forced airflow conditions, while figure 10 gives an indication of the measured values of the DHT22 sensors under the same conditions.

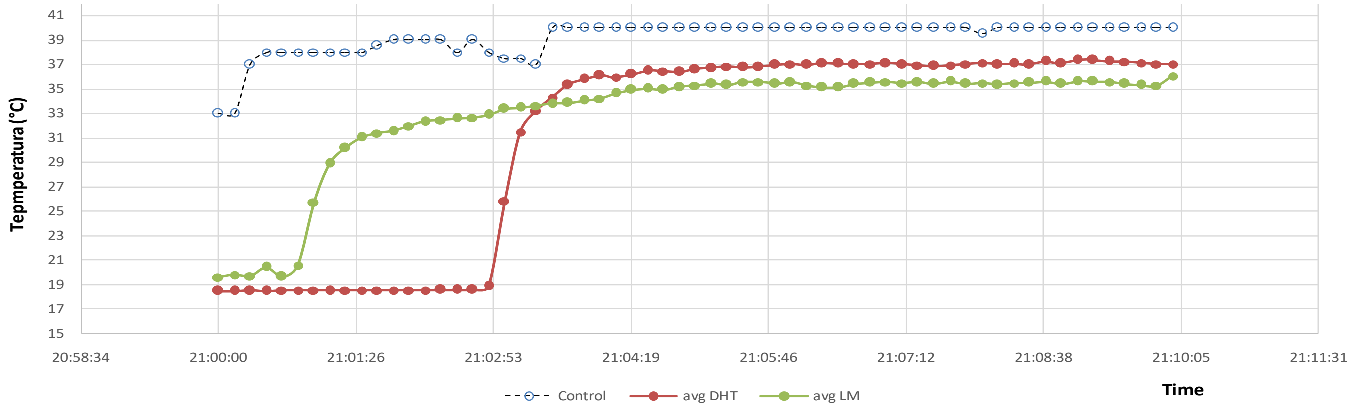

Figure 8. Measured and averaged values from DHT22 and LM35 sensors in relation to the values recorded with the temperature probe TR-01A (Case 2)

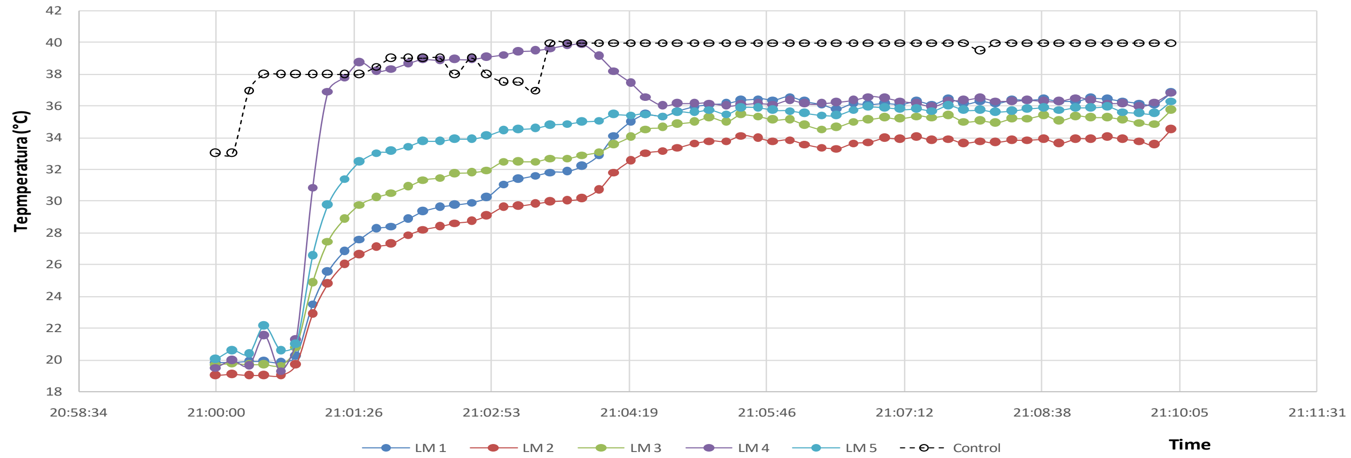

Figure 9. Individual values of 5 LM35 sensors relative to the TR-01A (Case 2)

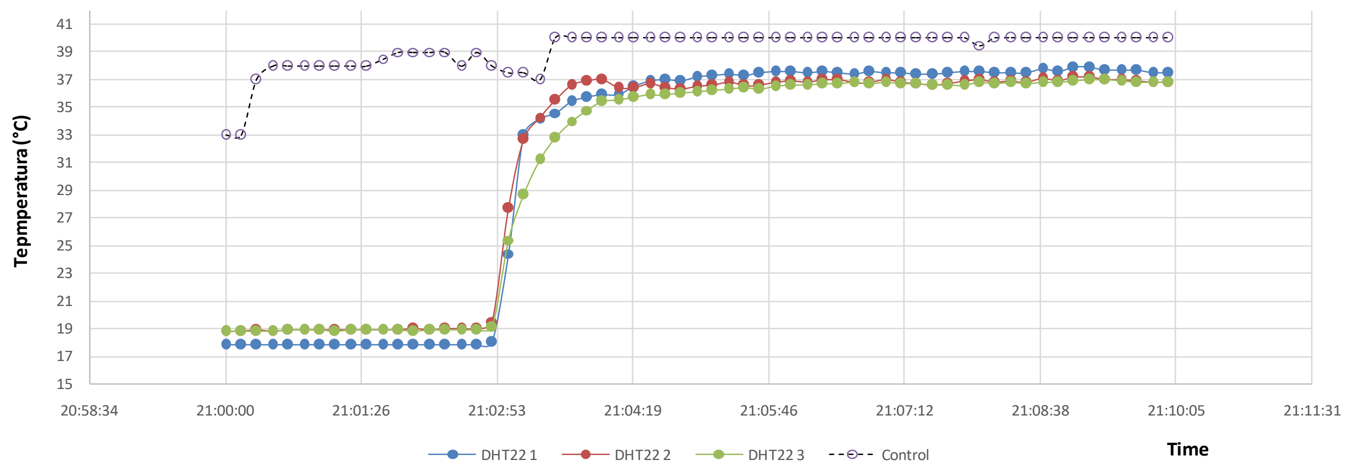

Figure 10. Individual values of 3 DHT22 sensors compared to TR-01A (Case 2)

In the second case, all DHT22 sensors are characterized by the same trend, i.e. their mutual absences for the given conditions is ± 1 °C, while in relation to the values recorded by the probe TP-01A the maximum deviation, after the stabilization period, is 5 °C. On the other hand, the 4 LM35 sensors are characterized by a similar trend with a higher interdependence, while the maximum recorded deviation in comparison to the values recorded by the probe is 7 °C.

4. CONCLUDING REMARKS

In this article a conceptual solution and realization of a Arduino-based Relative Humidity and Dry Bulb Temperature data logger was successfully carried out.

The indoor testing results showed that the developed device satisfactorily performed the required measurements and data logging. All components worked properly at an acceptable speed.

Moreover, this low-cost portable data logger meets the accuracy requirements of majority of monitoring systems. The system design features easy-to-obtain hardware and open access software, making it accessible to any researcher or user for the development of systems of their own design and use. This flexibility makes the system more suitable for each intended application, such as the monitoring of manufacturing plants, households and buildings, as well as the collection of data at remote locations in developing countries. The cost of the proposed system is considerably lower than commercially available devices, with negligible loss of accuracy and precision. Last but not the least, the data logger developed in this study achieves a cost of approximately 60 €, with 5 analogue and 3 digital inputs within a low voltage range, which makes it quite efficient in terms of energy consumption. Lastly, the device can be improved by introducing additional sensors, for example sensors for wind speed and wind direction determination, which could stimulate a wider range of application. However, subsequent improvements are subject of further research.

5. REFERENCES

[1] Guerra-Santin, O., Tweed, C.A., (2015), "*In-use monitoring of buildings: An overview of data collection methods*", Energy and Buildings, Vol. 93, pp. 189 - 207.

[2] Babaei, T., Abdi, H., Lim, C.P., Nahavandi, S., (2015), "*A study and a directory of energy consumption data sets of buildings*", Energy and Buildings, Vol. 94, pp. 91 - 99.

[3] Langevin, J., Wen, J., Gurian, P.L., (2015), "*Simulating the human-building interaction: Development and validation of an agent-based model of office occupant behaviors*", Building and Environment, Vol. 88, pp. 27 - 45.

[4] Ramos, T., Dedesko, S., Siegel, J.A., Gilbert, J.A., Stephens, B., (2015), "*Spatial and Temporal Variations in Indoor Environmental Conditions, Human Occupancy, and Operational Characteristics in a New Hospital Building*", PLoS One, Vol. 10, https://doi.org/10.1371/journal.pone.0118207

[5] Heinzerling, D., Schiavon, S., Webster, T., Arens, E., (2013), "*Indoor environmental quality assessment models: A literature review and a proposed weighting and classification scheme*", Building and Environment, Vol. 70, pp. 210 - 222.

[6] Ramos, T., Stephens, B., (2014), "*Tools to improve built environment data collection for indoor microbial ecology investigations*", Building and Environment, Vol. 81, pp. 243 - 257.

[7] Gasparesc, G., (2013), "*Development of a low-cost system for temperature monitoring*", Proceedings of 36th International Conference on Telecommunications and Signal Processing, TSP 2013, Rome, Italy, pp. 340-343.

[8] Khairi, N.A., Jambek, A.B., Boon, T.W., Hashim, U., (2013) "*Design and analysis of a wireless temperature monitoring system*", Proceedings of IEEE Regional Symposium on Micro and Nano Electronics 2013, RSM 2013, 25-27 September 2013, Langkawi, Malaysia, pp. 105-108.

[9] Goswami, A., Bezboruah, T., Sarma, K.C., (2011), "*An embedded design for automatic temperature controller*", International Journal of Advanced Engineering & Application. Vol. 1 (2011), pp. 88-93.

[10] Ibrahim, D. (2002), Microcontroller based temperature monitoring and control, Elsevier Science & Technology Books.

[11] Kumar, A., Singh, I.P., Sud, S.K., (2010), "*Design and development of multi-channel data logger for built environment*", International Multi Conference of Engineers and Computer Scientists 2010, IMECS 2010, Hong Kong, 17-19 March, 2010, pp. 993-998.

[12] Singh, N.M., Sarma, K.C., (2012), "*Design and development of low cost pc based real time temperature and humidity monitoring system*", International Journal of Electronics and Computer Science Engineering, Vol. 1 (2012), pp. 1588 - 1592.

[13] Snur, H.M., Suhaimizan, W.Z., Joret, A., Mahadi, A.J., (2013), "*Design and development of wireless stethoscope with data logging function*", Proceedings of 2013 IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2013, Penang, Malaysia, pp. 132-135.

[14] Ross, P.S., Bourke, A., Fresia, B., (2013), "*A multi-sensor logger for rock cores: Methodology and preliminary results from the Matagami mining camp, Canada*", Ore Geology Reviews, Vol. 53, pp. 93-111.

[15] Khan, T.H., Wahid, K.A., (2014), "*A portable wireless body sensor data logger and its application in video capsule endoscopy*", Microprocessors and Microsystems. Vol. 38, pp. 42-52.