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Chapter 2
The use of the Arduino and sensors to monitor environmental parameters

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Abstract: The article presents the analysis and the possibility of a wide use of the Arduino platform to monitor important environmental parameters with the help of low-cost sensors. Some sensors included in the conceptual design were tested for analysis. A statistical approach was applied in stable and dynamically changing environmental conditions using a computer program and the Arduino platform. The results obtained below make it possible to see the potential for using the project and confirm the usefulness, efficiency and repeatability of the data recorded by the sensors.

Keywords: air quality, sensors, the Arduino, microcontrollers

Introduction

In the modern world, we are dealing with enormous technological progress that contributes to the development of various types of industry. Thanks to this, humanity lives better, but sometimes forgets the huge impact it has on the surrounding environment and ecology. The industrial revolution is one of the most important factors through which large amounts of carbon dioxide, carbon monoxide, sulfur, nitrogen, dust and other gases began to enter the atmosphere. This aspect made it necessary to monitor environmental parameters in practically every possible industry for the sake of people's health and the environment. For this purpose, various companies use specialized programs, embedded systems and sensors that record and transmit data on relevant environmental parameters in real time. An important aspect is the price of such devices, especially sensors, which sometimes reach large amounts. It is required that such devices be as cheap and efficient as possible. Having an inexpensive embedded Arduino system and sensors for detecting e.g. temperature and various gases, this system can be defined as an economical solution to the problem.

There is a large number of low-cost electronic devices on the market, including sensors and embedded systems. With the right equipment and knowledge, one can monitor environmental parameters at a low cost, while achieving high performance of the measuring device. This solution is possible.

This article offers the authors' conceptual design and the results of the analysis, as well as the possibility of a wide application of the Arduino platform and sensors for monitoring environmental parameters.

Arduino – open source hardware/software

Arduino is an open source software / hardware used comprehensively to create independent interactive projects by professionals and hobbyists. Arduino manufactures different types of equipment for different purposes, making equipment use global (Fig. 2.1) [1]. The physical part of the hardware is a PCB of various sizes and functionalities depending on the type of embedded system. It usually contains a certain number of I/O pins, analog pins, power pins, I^2C and SPI pins, crystal oscillators, USB connectors, DC sockets, a RESET button and other components. Device programming is most often done via the Arduino IDE. This cross-platform application allows the use of such languages as Java, C, C ++ and Python, and is compatible with all Windows, Linux, MacOS systems.

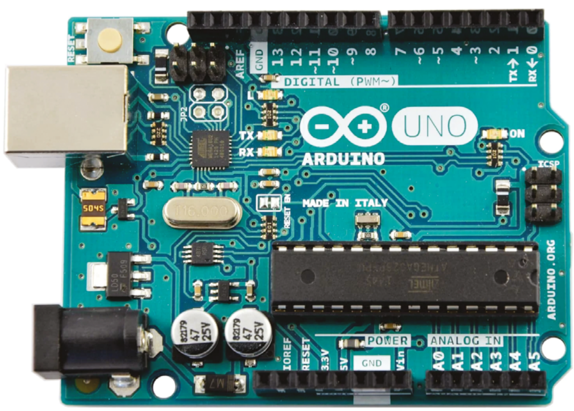

FIGURE 2.1. An example of the original Arduino UNO R3 board

Arduino programming has become greatly functional thanks to the possibility of extending libraries allowing for more efficient work with hardware and data manipulation. One of the main and important functionalities of the microcontroller is reading the signal output data from various types of sensors, e.g. temperature and humidity sensors, pressure sensors, sensors of various gases concentration in the air. For this, specific sensor libraries are used, which contain the control instruction and the type of signal being sent. The microcontroller reads the data sent from the sensor using an analog or digital method. The analog method consists in observing the change in the generated voltage produced by an analog sensor and processing it in such a way that it reflects the real data. In contrast, the digital method reads discrete values, i.e. 0 or 1, which are binary / digital signals from a digital sensor. Thanks to these methods, the Arduino microcontroller can handle various types of digital and analog sensors in a practical application.

Description of the structure and elements of the measurement system

To check and evaluate the usefulness and efficiency of cheap sensors monitoring environmental parameters, a temporary measurement system was made, consisting of thermal and gas sensors based on the Arduino Nano V3 microcontroller (Fig. 2.2) [2].

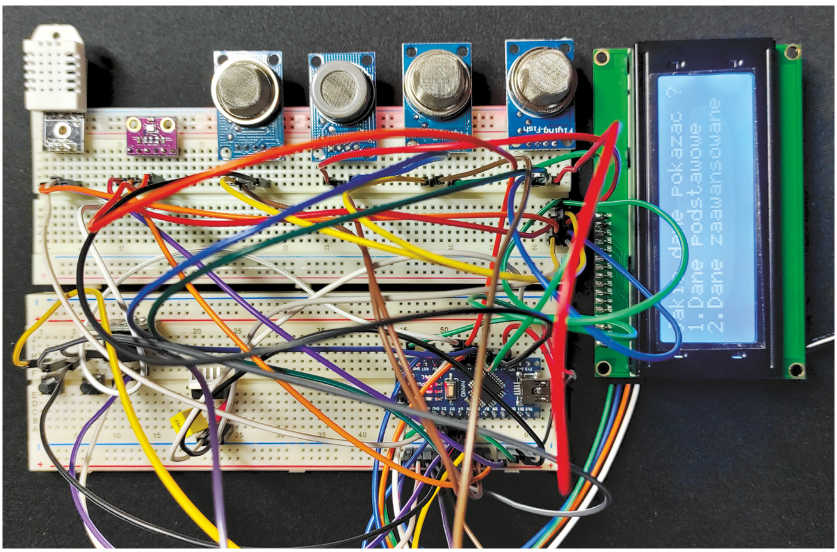

FIGURE 2.2. **Prototype measurement system based on the Arduino Nano V3 microcontroller**

The construction of the station was designed in such a way as to ensure a constant and stable propagation of current and voltage to the elements of the electric circuit, thanks to which the noise and errors during the operation of the equipment can be reduced. Contact plates, which are a passive element, became the temporary base on which the electronic components were placed. Finally, the project was made on a designed PCB with dimensions of 12×8 cm in the popular engineering program Eagle by Autodesk (Fig. 2.3).

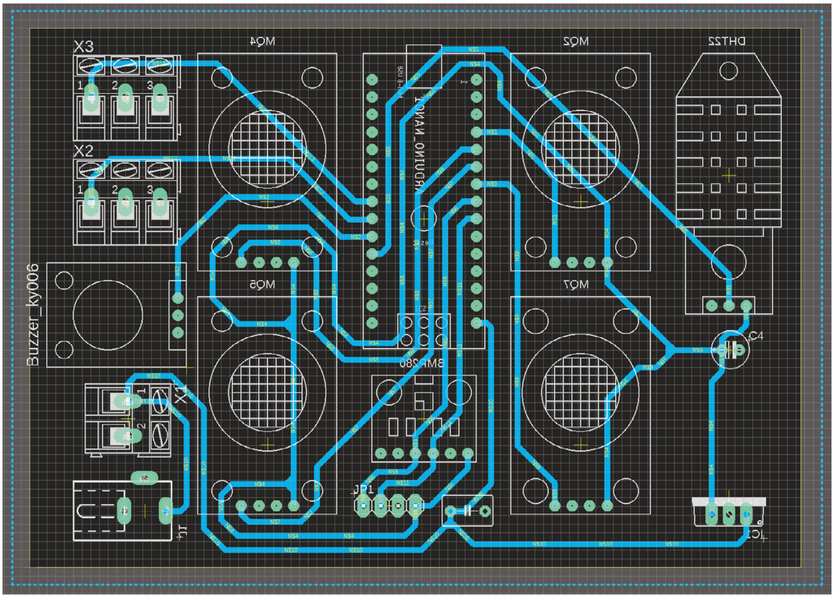

FIGURE 2.3. **Visualization of the PCB with connections between system components**

Male-male and female-male cables were used to connect each electronic element into a whole. In the design, the popular LM7805 linear voltage stabilizer was used for the stable propagation of the current and voltage to each sensor [3]. The power supply system is a simple 9 V/1 A DC power supply, which supplies voltage in parallel to the microcontroller and the voltage regulator. The control system of the measurement system consists of the used Arduino Nano V3 microcontroller powered by 9 V voltage, which provides data reading and two Tact Switch buttons, which are programmed to switch between displaying specific data of subsequent sensors on the display. For convenient analysis of the results, the universal HD44780 LCD 4x20 display was used, which presents readable measurement data, e.g. in a numerical manner, supplied with 5 V [4]. The measuring system consists of such sensors as MQ2, MQ4, MQ5, MQ7, DHT22 and BMP280. Optionally, a small buzzer with a generator was added to the design to signal the achievement of a certain level of gas concentration. Each element (Fig. 2.4) used to create the measuring station was checked before starting the measurements. Additionally, capacitors with a capacity of 330 nF and 100 nF were used, which help to stabilize the voltage in the LM7805 stabilizer.

The DHT22 temperature and humidity sensor was selected for this project as it is one of the most widely used low-cost sensors in engineering projects [5]. The operating temperature of this sensor is from – 40°C to 80°C with an accuracy of 0.1°C, while the humidity measurement range is 0–100% with a resolution of 0.1% and an accuracy of 2–5% RH. The MQ2, MQ4, MQ5 and MQ7 sensors are a class of cheap gas sensors with high measurement efficiency [6–9]. They are similar to each other with regard to the range of gas detection, which is between 10–10,000 ppm units. Their operating temperature is – 20°C to 50°C. The BMP280 sensor is a popular atmospheric pressure sensor that allows measurements in the range from 300 hPa to 1100 hPa [10]. Its operating temperature range is from 40°C to 85°C and the measurement accuracy is 1 hPa. The nominal supply voltage of all sensors is 5 V. The sensor communication system between the Arduino is based on one analog and digital signal bus, while the HD44780 display and the BMP280 sensor are based on two SCL and SDA buses, clock signal and data line in turn. The MQ2, MQ4, MQ5 and MQ7 sensors were connected to the Arduino in turn to the analog pins A0, A1, A2, A3. The DHT22 sensor was connected to the digital pin D2, while the BMP280 sensor and the HD44780 display were connected to two I^2C pins, i.e. SCL and SDA, which correspond to Arduino pins A5 and A4, respectively. The buzzer is connected to the digital pin D3, while the Tact Switch buttons are connected to the digital pins D4 and D5.

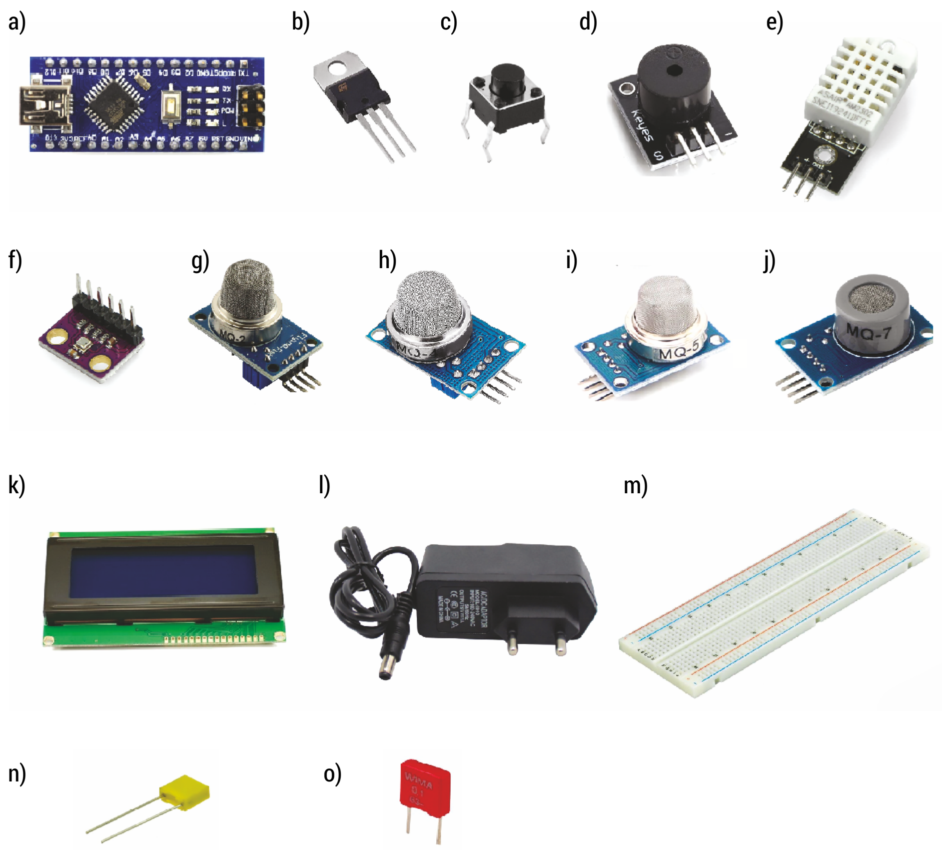

FIGURE 2.4. Arduino Nano V3 (a), LM7805 (b), Tact Switch (c), Buzzer (d), DHT22 sensor (e), BMP280 sensor (f), MQ2 sensor (g), MQ4 sensor (h), MQ5 sensor (i), MQ7 sensor (j), HD44780 display (k), power supply (l), contact plate (m), capacitor 330 nF (n), capacitor 100 nF (o)

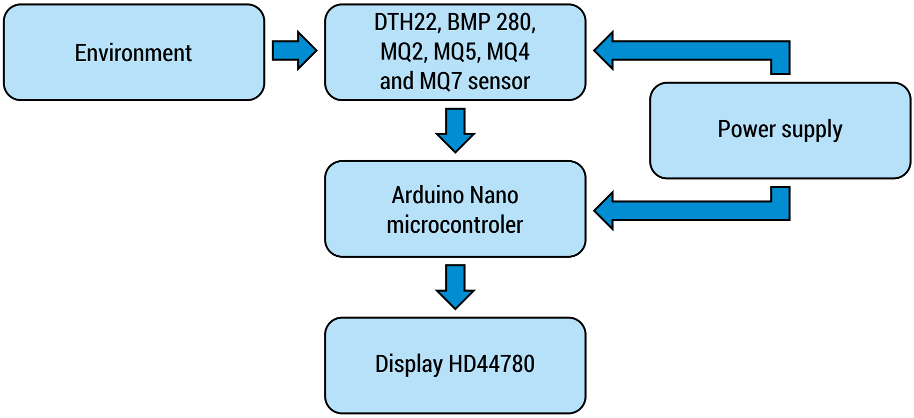

FIGURE 2.5. **Block diagram of the measurement system**

To fully understand the idea of operation and the way of communication of each electronic element (Fig. 2.5), a simple block diagram was made, which includes connections between the most important segments of the mechanism.

Analysis of the results

The MQ7 sensor and the DHT22 sensor were selected from among several sensors to check the usability and functionality of the design idea. The program that supports the entire system was written in the Arduino IDE programming environment in C [11], where the functions were compliant with the Arduino program guidelines. The idea of the code (Fig. 2.6) is presented in the form of a simple diagram that explains how the program performs its task and controls various activities.

The main task of the MQ7 sensor is to record the concentration of carbon monoxide in the surrounding environment. Its presence pollutes the air and causes damage to human health, even in small amounts [12]. This compound is odorless, hence such a sensor should be used that is capable of detecting this gas. As part of the experiment to assess the usefulness, precision and repeatability of measurements, the MQ7 sensor was subjected to an attempt to read the content of carbon monoxide CO in the air in an office room, but with a variable and constant value of this compound at room temperature. The first day shows CO concentration in a ventilated environment, while the next day shows CO concentration in a slightly polluted but constant environment. The graph (Fig. 2.7) clearly shows that the repeatability precision of this sensor is at a very high level. It has been found that a cheap environmental sensor under stable conditions can withstand and display data that is identical throughout the experiment.

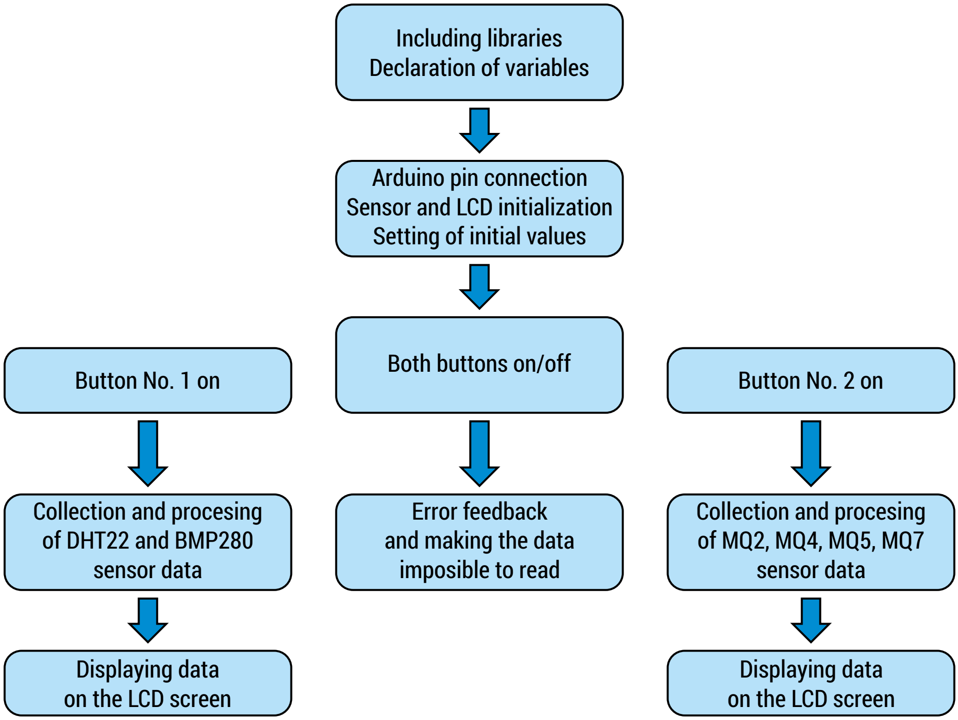

FIGURE 2.6. **Block diagram of the program operation**

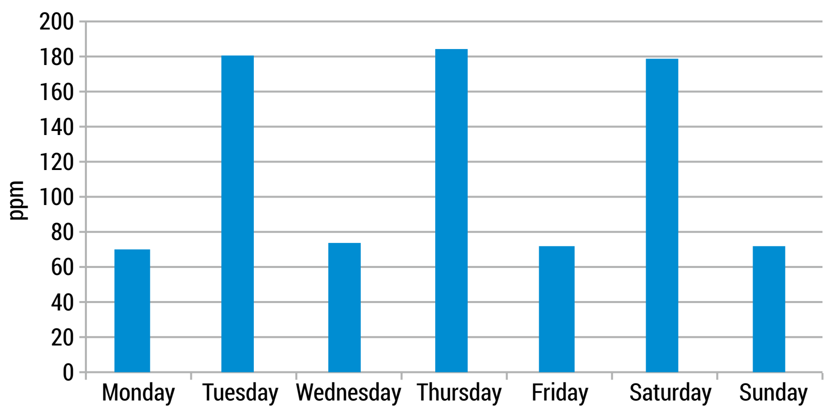

FIGURE 2.7. **Daily diagram of average concentration of CO carbon monoxide in stable environmental conditions read by the MQ7 sensor within 7 days**

The graph below (Fig. 2.8) shows changes in the concentration of CO in the air in an environment where the concentration of this compound changes dynamically. From the moment the carbon monoxide CO is injected close to the sensor head, an increase in the content of a harmful chemical compound in its surroundings was immediately read, and thus the program triggered the alarming loudspeaker.

At the time when the content of CO carbon monoxide in the environment was generally determined, the information obtained from the sensor was not sudden and it was necessary to wait several seconds for the sensor to notice any increase in the concentration of the harmful agent, which was shown by slight fluctuations in the graph. It has been noticed that the sensor reacts very quickly to changes in environmental parameters. Its repeatability in this case is also good. The stability of the sensor's operation was observed after many fatigue tests despite drastically changing environmental parameters, which proves its usefulness and high efficiency. In both environmental cases, the results of the other gas sensors, i.e. MQ2, MQ4 and MQ5, were identical.

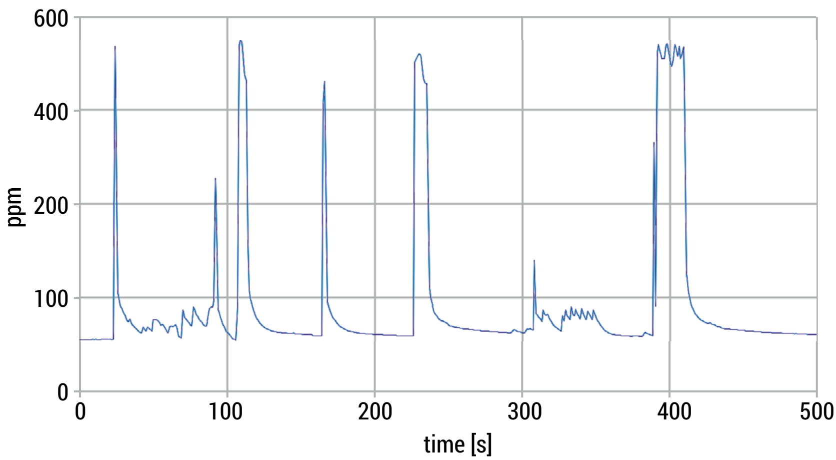

FIGURE 2.8. Graph of CO concentration under dynamic environmental conditions read by the MQ7 sensor during 5 minutes

The DHT22 sensor checks the temperature and humidity of the environment in which it is located. These are parameters that should be read virtually anywhere, especially the temperature value, e.g. in a building / room, laboratory, production hall, etc. In order to estimate the precision and accuracy of the measurements of the DHT22 sensor, an experiment was performed consisting in placing the sensor at room temperature and outside temperature for 7 days without interruption. The temperature data from the DHT22 sensor was compared with a professional Ferroli home automation sensor (Fig. 2.9) and a normal sensor intended for outdoor use (Fig. 2.10) [13]. It has been observed that the values indicated by the cheap temperature sensor are identical to the sensors from the higher price range. Despite the low temperature environment, the sensor was as good as the sensor intended for this environment.

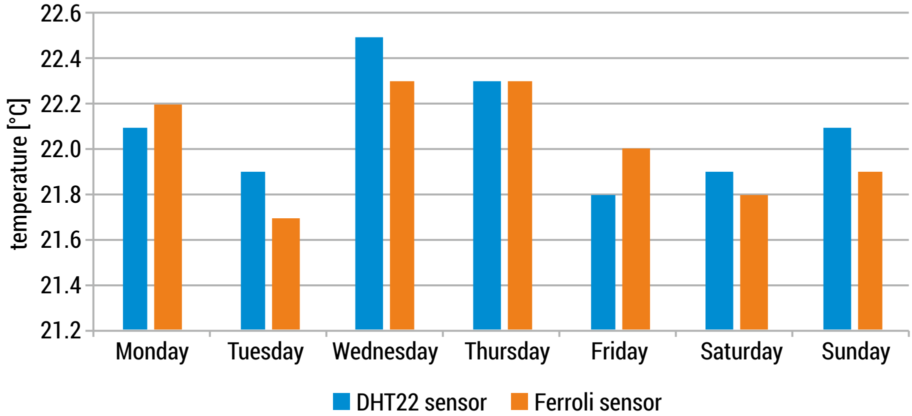

FIGURE 2.9. A graph comparing the average daily room temperature of the DHT22 sensor and the Ferroli sensor over 7 days

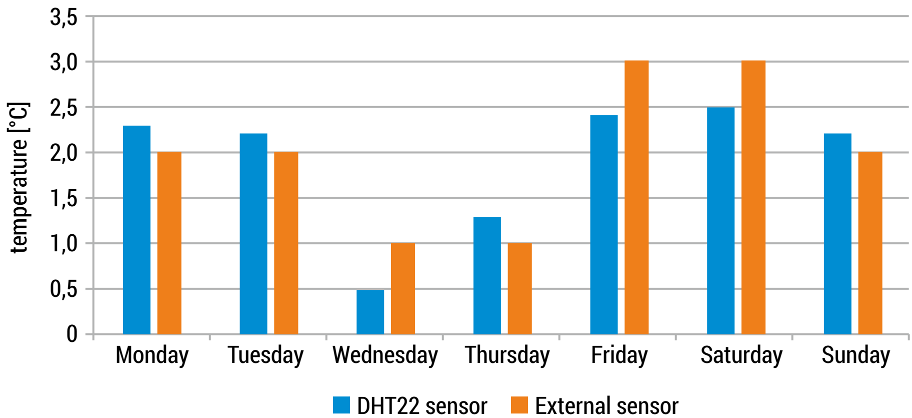

FIGURE 2.10. A graph comparing the average daily outside temperature of the DHT22 sensor and the Ferroli sensor over 7 days

Summary and Conclusions

The article presents the results of measuring the effectiveness of the conceptual design of a handheld or stationary measurement system for recording important environmental parameters using an Arduino microcontroller and sensors. The purpose of the analysis was proving a practical and cheap solution of obtaining data on environmental conditions, practically anywhere.

The obtained results show the real precision, reliability and significant measurement performance that occurs in inexpensive electronic sensors available on the market, in a stable and dynamically changing environment. Under the assumed project conditions, the values shown in the charts confirm the fact that it is possible to create a cheap, precise and universal device for measuring environmental parameters. The speed of the program and sensors that read analog signals from the surrounding environment show the great potential of the above design in practical application.

In order to improve the mobility of the device, it is possible to connect the system to a compact battery. Thanks to this solution, the equipment can be used for a long time without access to energy from the grid. Thanks to the miniaturization of the design with the simultaneous use of many sensors, the device opens up many possibilities. It can be used in drones checking the composition of smoke coming from chimneys, e.g. home, industrial factories. Sensors can be successfully used to regulate air parameters in a home heat recovery system. The project enables the use of wireless communication, e.g. Wi-Fi, thanks to which it will be possible to connect many such devices and multiply the range of applicability of the entire system on a larger scale. With proper calibration, this system is able to detect very small amounts of harmful chemical compounds, e.g. in a laboratory.

Research work on the project will be continued taking into account the location, durability, precision and miniaturization of the entire project.

Streszczenie: Artykuł przedstawia analizę i możliwość szerokiego wykorzystania platformy Arduino do monitoringu ważnych parametrów środowiska przy pomocy niskobudżetowych czujników. W celu analizy przetestowano niektóre czujniki wchodzące w skład koncepcyjnego projektu. Zastosowano podejście statystyczne w stabilnych i dynamicznie zmieniających się warunkach otoczenia przy pomocy programu komputerowego oraz platformy Arduino. Uzyskane niżej wyniki pozwalają dostrzec potencjał wykorzystania projektu oraz stwierdzają użyteczność, wydajność oraz powtarzalność danych zarejestrowanych przez czujniki. (Wykorzystanie Arduino i czujników do monitorowania parametrów środowiskowych)

Słowa kluczowe: jakość powietrza, czujniki, Arduino, mikrokontrolery

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