MINING AND METALLURGY INSTITUTE BOR
and
TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE

IOC2022
International October Conference

53rd International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:
Ana Kostov
Milenko Ljubojev

3 – 5 October 2022. Hotel "Albo" Bor, Serbia

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Editors: Ana Kostov, Milenko Ljubojev

Publisher: Mining and Metallurgy Institute Bor

Printed in: "GRAFOMED-TRADE" Bor

Text printing preparation: Vesna Simić

Disclaimer: Authors are responsible for the content, translation and accuracy.

Circulation: 100 copies

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)
669(082)

INTERNATIONAL October Conference on Mining and Metallurgy (53 ; 2022 ; Bor)
Proceedings / 53rd International October Conference on Mining and Metallurgy - IOC 2022, 3 % 5 October 2022, Bor ; [organizer] Mining and Metallurgy Bor and Technical Faculty in Bor, University of Belgrade ; editors Ana Kostov, Milenko Ljubojev. - Bor : Mining and Metallurgy Institute, 2022 (Bor : Grafomed-trade). - XV, 251 str. : ilustr. ; 25 cm

Tiraž 100. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7827-052-9

a) Рударство - Зборници b) Металургија - Зборници

COBISS.SR-ID 74763529

Bor, October 2022

Conference is financially supported by the
Ministry of Education, Science and Technological
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AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 1)

Viša Tasić[1], Tatjana Apostolovski-Trujić[1], Ivan Lazović[2], Nikola Mirkov[2], Zvonko Damnjanović[3]

[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia, visa.tasic@irmbor.co.rs
[2]Vinča Institute of Nuclear Science, Mike Petrovića Alasa 12-14, 11351 Vinča, Belgrade, Serbia
[3]Kompjuter centar Bor, Trg Oslobođenja 8, 19210 Bor, Serbia

Abstract

This work presents a portable device for temporary or continuous measurement the meteorological parameters and air quality parameters. In the basic variant, the device enables measurement the wind speed and direction, air temperature, relative air humidity, air pressure, and concentration of suspended particles (fractions PM_{10} and $PM_{2.5}$) in the air. In the extended version, in addition to the listed parameters, this device can be used for indicative measurements of carbon dioxide concentrations and concentrations of some easily volatile organic substances (formaldehyde, toluene) in the air. The device is based on the Arduino Mega 2560 microcontroller and low-cost sensors.

***Keywords**: measurement, meteorology, particulate matter, microcontroller, low-cost sensors*

1 INTRODUCTION

Meteorological measurement and observation are the instrumental measurement and/or determination the value of one or more meteorological elements. [1] Meteorological data are quantitative values of meteorological elements and phenomena, obtained by meteorological measurements, observations, and/or their processing at meteorological stations entered in the Register of the state meteorological and hydrological stations and additional networks of meteorological and hydrological stations. [1] A meteorological station is a place with appropriate facilities, instruments, and equipment for the execution of prescribed program of meteorological measurements and observations, including the program of air quality monitoring, determined by a special regulation. [1] For the purpose of systematic monitoring and research of the state and changes in weather, climate, and water, on the territory of the Republic of Serbia, the meteorological and hydrological observation system of the Republic of Serbia was established as an integral part of the European and global observation systems. [1]

In accordance with the Law on Air Protection (Official Gazette of RS, Nos. 36/09 and 10/13), the Serbian Environmental Protection Agency (SEPA) is responsible for the National Network for the Automatic Air Quality Monitoring (AAQM) in the Republic of Serbia [2]. The Automatic air quality monitoring is performed in accordance with the Decree on Establishment the Air Quality Control Programs in the State Network (Official Gazette of RS, No. 58/11) and the Decree on Conditions and Requirements for the Air Quality Monitoring (Official Gazette of RS, Nos. 58/11, 11/10, 75/10, and 63/13). SEPA started automatic monitoring of air pollution in the Republic of Serbia in 2006. Today, SEPA manages more than 40 AAQM stations. The spatial coverage of the Republic of Serbia with the AAQM is uneven because most of the stations are concentrated in the area of the city of

Belgrade. Because of that, there is a real need for instruments for temporary or continuous measurement the meteorological parameters in the field, in the observed microenvironment. Such instruments should be reliable enough that their results should be used to reduce the risk of exposure the population to high concentrations of air pollutants.

2 EXPERIMENTAL

Automatic meteorological stations consist of sensors for measuring temperature, humidity, air pressure, precipitation, wind speed and direction, devices for collecting and processing data, and devices for communication and power supply. Figure 1 shows a professional automatic meteorological station manufactured by UIT-gmbh [3]. Such meteorological stations are equipped with a LogTrans 6 data acquisition device with the GPRS equipment for remote data transmission via the public mobile telephony network service. The price of a professional automatic meteorological station in full configuration (as in Figure 1) can be up to 10,000 euros. In the national networks of automatic air quality monitoring, the automatic meteorological stations of different types and manufacturers are used to measure the meteorological parameters in the ambient air. In the Republic of Serbia, more than 20 AAQM stations have an automatic meteorological station type LUFFT WS500 [4]. The sensor head is shown in Figure 2. The price of this meteorological station, including the mast for mounting the sensor head, is around 3,000 euros. Operation and calibration of such meteorological stations are performed in accordance with the prescribed quality assurance and control procedures (QA/QC).

Figure 1 *Automatic weather station with solar power supply produced by UIT -gmbh [3]*

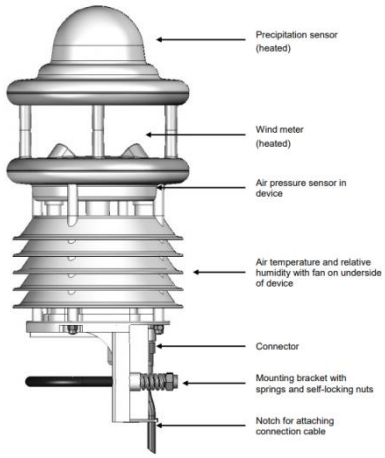

Figure 2 *LUFFT WS500 meteorological station sensor head [4]*

The high cost of professional automatic meteorological stations is a limiting factor for their wider application. On the other hand, to better assessment the impact of air pollution on human health, it is necessary to continuously monitor the air quality and meteorological parameters in real-time in different microenvironments (part of the residential area, school environment, kindergartens, hospitals, factories). In the last ten years, devices for monitoring the meteorological parameters that use the low-cost sensors have been available on the

market. Such meteorological stations consist of a number of low-cost sensors, microcontrollers, communication modules, and power supply modules. Such sensors have the low electricity consumption, small size and are significantly cheaper than the professional meteorological sensors. Due to this reason, they are easier to obtain and install. Some low-cost automatic weather stations and sensors, available on the market, are shown in Figure 3.

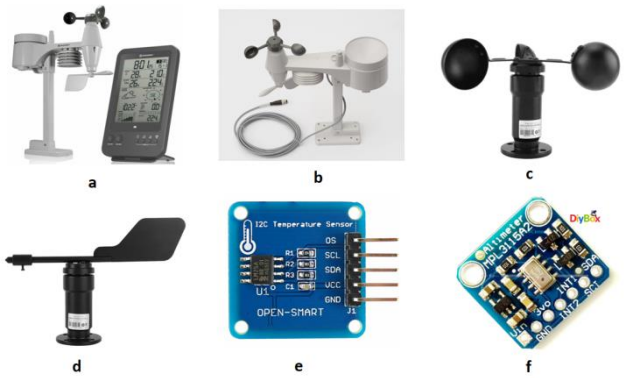

Figure 3 *Low-cost sensors and stations for measuring meteorological parameters*

Low-cost meteorological sensors and meteorological stations have several times lower prices than the professional ones (the prices of low-cost weather stations can vary from 200 to 1500 euros, while the prices of low-cost meteorological sensors vary from a few euros to a few hundred euros). However, the service life of low-cost meteorological stations and sensors is significantly lower compared to the professional ones, as well as the accuracy of measuring meteorological parameters (temperature ± 1°C, air humidity ± 5%). Cheap commercially available automatic meteorological stations (shown in Figures 3.a and 3.b) generally do not have the ability to network and store measurement results.

3 RESULTS AND DISCUSSION

The realized automatic meteorological station AMS/2022 is primarily intended for measuring the meteorological parameters: wind speed (0-30 m/s), wind direction (0-360 angular degrees), temperature (-10 ÷ 40°C), relative humidity (RH) of ambient air (10 ÷ 90% RH), air pressure in the range of 300 to 1100 hPa, and suspended particles PM_{10} and $PM_{2.5}$ in the range of 0 - 1000 µg/m^3. In addition to the listed parameters, there is a possibility to install theadditional sensor modules in the device. With the addition of the NDIR S8 CO_2 module [5], the device can be used for indicative measurements of CO_2 concentrations in the air in the range from 400 to 2000 ppm. With the addition of the VOC module [6], the device can be used for indicative measurement of formaldehyde concentrations in the air in the range from 0 to 70 ppm. The AMS/2022 device consists of the control module, sensor module, and previously listed sensors.

The control module of the AMS/2022 device is housed in a standard metal housing (250x250x150 mm), attached to a metal mast with a square cross-section of 30x30 mm, 2 mm thick and 2 m high. The sensor module dimensions 125x80x32 mm, with sensors for measuring the temperature, air pressure and relative humidity is attached to spacers on the underside of the control module housing, as shown in Figure 4. Sensors for wind

direction and speed are mounted on a 1 m long bracket of a square cross-section of 30x30 mm, 2 mm thick, attached in the middle to the supporting mast of device, as shown in Figure 4. The weight of complete device with the mast is about 6.5 kg.

Figure 4 *The exterior of the AMS/2022*

4 CONCLUSION

The AMS/2022 is a portable device for the temporary or continuous measurement of meteorological parameters and air quality parameters. The advantages of this device are in a fact that it is very easy to handle, the costs of making the device are lower compared to similar products that can be found on the market, and easy to install, calibrate and maintain.

ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, [Grants Nos. 451-03-68/2022-14/200052 and 451-03-9/2021-14/200017].

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AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 2)

Viša Tasić[1], Tatjana Apostolovski-Trujić[1], Ivan Lazović[2], Nikola Mirkov[2], Zvonko Damnjanović[3]

[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia, visa.tasic@irmbor.co.rs

[2]Vinča Institute of Nuclear Science, Mike Petrovića Alasa 12-14, 11351 Vinča, Belgrade, Serbia

[3]Kompjuter centar Bor, Trg Oslobođenja 8, 19210 Bor, Serbia

Abstract

This work presents a portable device for temporary or continuous measurement the meteorological parameters and air quality parameters based on thelow-cost sensors. The device consists of the control module, keyboard, sensor module, and low-cost sensors for measurements the wind speed and direction, air temperature, relative air humidity, air pressure, and concentration of suspended particles (fractions PM_{10} and $PM_{2.5}$) in the air. The control board of device is based on the Arduino Mega 2560 microcontroller.

***Keywords**: measurement, meteorology, particulate matter, microcontroller, low-cost sensors*

1 INTRODUCTION

The automatic meteorological stations consist of sensors for measuring temperature, air humidity, air pressure, speed and direction of wind and precipitation, data collection and processing devices, and communication and power supply devices. The automatic meteorological stations, with the addition of appropriate data transmission equipment, can be connected and be the integral elements of various systems for early warning (alarm) of meteorological disasters. On the other hand, in order to better assessment the impact of air pollution on human health, it is necessary to carry out continuous monitoring of the air quality and meteorological parameters in real-time in different microenvironments (part of a residential area, around schools, kindergartens, hospitals, factories).

Figure 1 *AMS/2022 module layout inside the housing*
(1. Control module, 2. PM module, 3. LCD module, 4. Keyboard, 5. ON/OFF switch)

The AMS/2022 device, presented in this paper, enables the measurement of wind speed and direction, air temperature, relative humidity, air pressure, and the concentration of suspended particles (PM_{10} and $PM_{2.5}$ fractions) air with the ability to display and store the measurement results. Unlike professional weather stations, this station uses the low-cost sensors.

2 AMS/2022 HARDWARE

The AMS/2022 device is powered by a + 5V DC via AC/DC adapter 240V/5V, 2A, 50 Hz. The power consumption of device is up to 5W, depending on the number of connected sensor modules. The device control module, keyboard, and display are attached to the housing using a 200x200x2 mm sheet steel support plate. The layout of module inside the device housing is shown in Figure 1, while Figure 2 shows the external appearance of the sensor module of the AMS/2022 device. The control module is located on a double-sided printed circuit board (PCB) of EUROPA format (100x160 mm) to which all components of the control module and signals from the sensor module are connected via the appropriate connectors, as shown in Figure 3. It consists of the Arduino Mega microcontroller board [1], MicroSD Card module [2], real-time clock (RTC module) [3], booster module [4], and connectors for connection to the sensor board. In addition to the control module, the device housing also houses the PM module [5], DHT22 module [6], LCD module [7], 16-key keyboard, and ON/OFF switch, as shown in Figure 1.

Figure 2 *The exterior of the AMS/2022 sensor module*

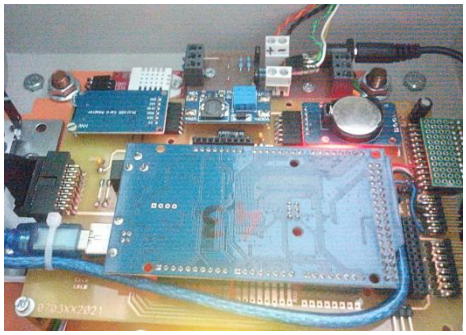

Figure 3 *The appearance of the AMS / 2022 control module*

The sensor module of the AMS/2022 device is housed in a plastic housing 128x80x32 mm. The sensor module is protected from precipitation and solar radiation by a 250x200x5 mm plastic canopy to which it is attached by spacers, as shown in Figures 2 and 4. The sensor module canopy is attached to the spacers using the control module housing spacers, as shown in Figure 2.

Figure 4 *The appearance of the AMS/2022 sensor module*

The sensor module serves as an interface module between the control module and sensors themselves. A connector for connection with the control module and sensors for measuring the air pressure and air humidity are placed on the raster board of the sensor module, 80x50x1.5 mm (Figure 4). The wind speed and wind direction sensors are also connected via the sensor module connector to the control module. Depending on the user need, the sensors for measuring CO_2 concentrations [8] and formaldehyde [9] can be installed on this sensor module. The AMS/2022 is powered from the mains by a 220 V AC/ 5V DC adapter, current 2A [10]. For the operation of the wind speed and wind direction modules, a voltage of + 12V DC is required, obtained by the voltage lifter module (5V/12V DC). The electrical connection diagram of the AMS/2022 device is shown in Figure 5. In the rural areas with no electrical network, it is possible to power the AMS/2022 device using a 12V DC battery of appropriate capacity.

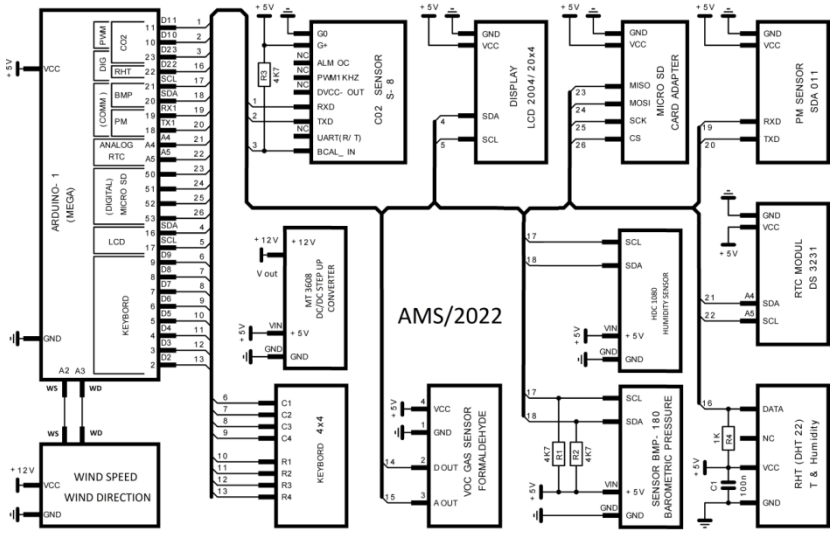

Figure 5 *AMS/2022 connection diagram*

3 AMS/2022 SOFTWARE

The programming of the Arduino Mega microcontroller built into AMS/2022 was performed using the Arduino IDE (Integrated Development Environment) [11]. The main reason for choosing the Arduino development platform is the fact that programming microcontrollers within this platform is simple and requires only a USB cable and PC. In addition, the Arduino programming language is a simplified version of the C ++ programming language, which further simplifies the microcontroller programming. Also, a large number of examples and libraries for connecting the Arduino platform with various sensor modules can be found on Internet.

4 CONCLUSION

The AMS/2022 is a portable device for temporary or continuous measurement the meteorological parameters and air quality parameters. The advantages of this device is in fact that it is very easy to handle, the costs of making the device are lower compared to similar products that can be found on the market, and easy to install, calibrate and maintain. The AMS/2022 device was tested in the field and showed very good stability and reliability. Hence, it can be concluded that the AMS/2022 is applicable for temporary or continuous indicative measurements of meteorological parameters and air quality parameters.

ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, [Grants No. 451-03-68/2022-14/200052 and 451-03-9/2021-14/200017].

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