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Air Monitoring System Based on Unmanned Aerial Vehicle Powered from the Ground †

Wojciech Walendziuk [1,*], Maciej Słowik [2] and Małgorzata Gulewicz [2]

[1] Faculty of Electrical Engineering, Bialystok University of Technology, Wiejska 45D, 15-351 Bialystok, Poland
[2] Faculty of Engineering Management, Bialystok University of Technology, 2 Ojca Tarasiuka Street, 16-001 Kleosin, Poland
* Correspondence: w.walendziuk@pb.edu.pl; Tel.: +48-85-7469397
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Abstract: This article presents a design of the prototype and experimental verification of an air quality measurement device that can be equipped with sensors such as CH4, CO_2, O_2, $PM_{2.5}$, and PM_{10}. The proposed solution allows for a long-term visual observation that is connected with the monitoring of air parameters, due to the power supply via a cable from the ground.

Keywords: unmanned aerial vehicle; tethered drone; air monitoring system; air pollution; air quality

1. Introduction

Recently, a rapid development of various types of unmanned aerial vehicle (UAV) applications in areas that are related to the environment protection can be observed. One example of this phenomenon is the use of UAVs for observation and monitoring using vision systems that are equipped with heads for daytime, infrared, thermal, and hyperspectral observations. These, among other things, enable the early detection of fires, smoke outbreaks, or plant disease conditions based on the analysis of the electromagnetic radiation that they reflect [1]. Another application is the detection of pollutants that are products of illegal waste incineration [2]. The main issue is that there are no commercially available shelf products for the integration with the tethered or free-flying UAVs. In this research, the design and development of hardware and software components of the AirLAB module are described. This description ranges from the phase of the 3D design of the module chassis, through a scheme of its electronic components, to the design of a measurement chamber, up to electro-compatibility tests.

The aim and scope of this research was to design a prototype and conduct an experimental verification of an air quality measurement device which was a module of the MISIO system, the unmanned aerial vehicle platform that is the result of an R&D project number POIR.01.02.00-00-0072/16, titled: "Modular surveying-inspecting system based on a flying multirotor platform powered from a ground station", which was co-financed by Moose spolka z ograniczona odpowiedzialnoscia and the Polish National Center for Research and Development. The proposed solution allows a long-term visual observation that is connected to the monitoring of air parameters, due to a power supply via a cable from the ground. The ControlBASE (ground control station (GCS) application) is the element of the system that used to ensure the safety of flight and allows the possibility to focus on observation instead of the control of the UAV. The GCS application is a dedicated application which is the central point of the MISIO system. The main features of the application are: the control of UAV movement with the proper safety margin, the verification of flight parameters that are typed by the user, steaming image from the cameras, and monitoring the air quality parameters that are measured by the AirLAB module that is mounted onboard the UAV platform.

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The device (Table 1) consists of a dedicated casing—inside which there is a closed chamber—into which the air is sucked for preheating and further analysis (shown in Figures 1 and 2). The air that is collected in the chamber goes to a set of electrochemical sensors and environmental parameters sensors are: methane concentration, oxygen concentration, carbon dioxide concentration, atmospheric pressure, relative humidity, temperature, and concentrations of dusts of diameters of 2.5 µm and 10 µm.

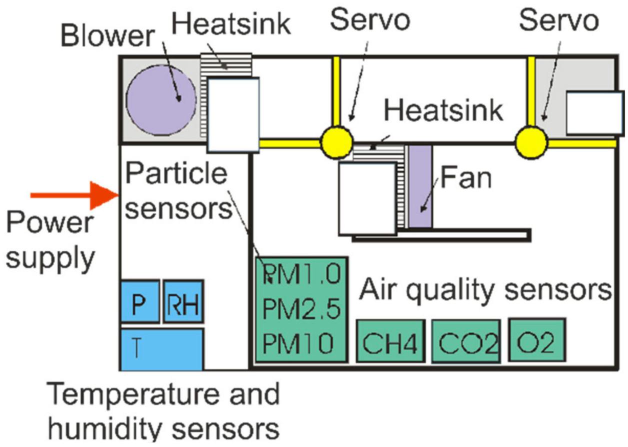
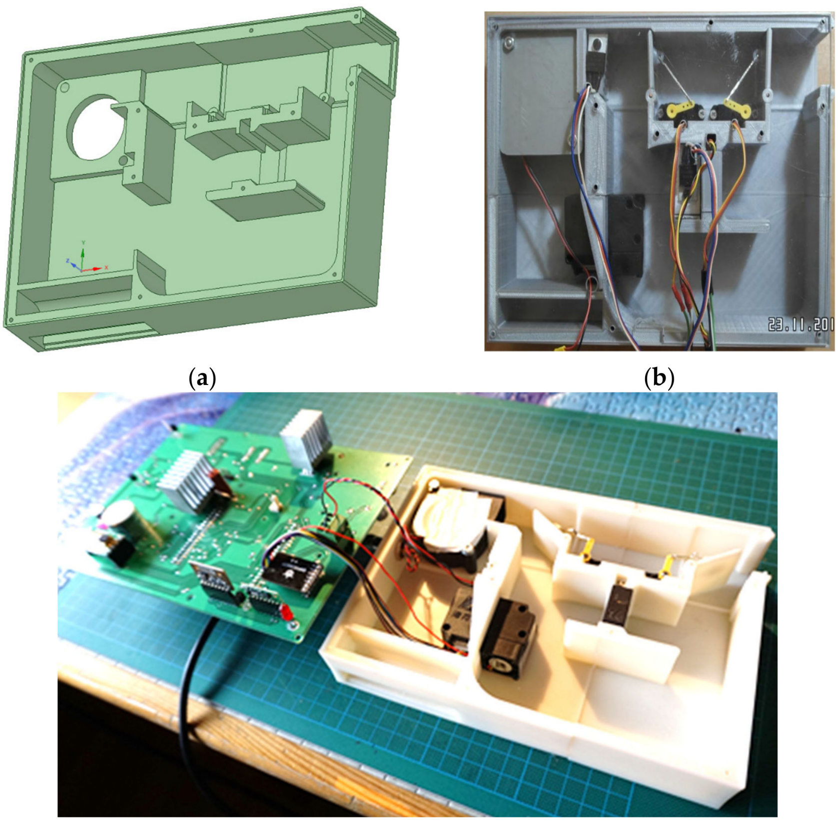


Figure 1. Air quality meter functional components diagram.



(**a**) (**b**)

(**c**)

Figure 2. Visualization of the chassis 3D model: (**a**) a view of the chassis prototype; (**b**) inner side of the meter with functional component arrangement (**c**).

Table 1. Technical properties of the device.

Power Requirements	Voltage	20 V DC–32 V DC
Power consumption	Maximum consumption	40 W
Communication	Wired	USB, [emulated COM 115200/N/8/1]
	Wireless	WiFi, USART [115200/N/8/1]
Memory	Number of samples	4091

2. The Air Monitoring Platform

The verification of the design was conducted by experimental tests in laboratory conditions and by successful electromagnetic compatibility verification which was performed in a certified laboratory. During the tests, among other elements, the communication between the AirLAB module and the GCS station computer was positively verified. The data link was critical for a proper operation of the platform and monitoring the measurement sensors. The GCS application—the ControlBASE—is shown in Figure 3.

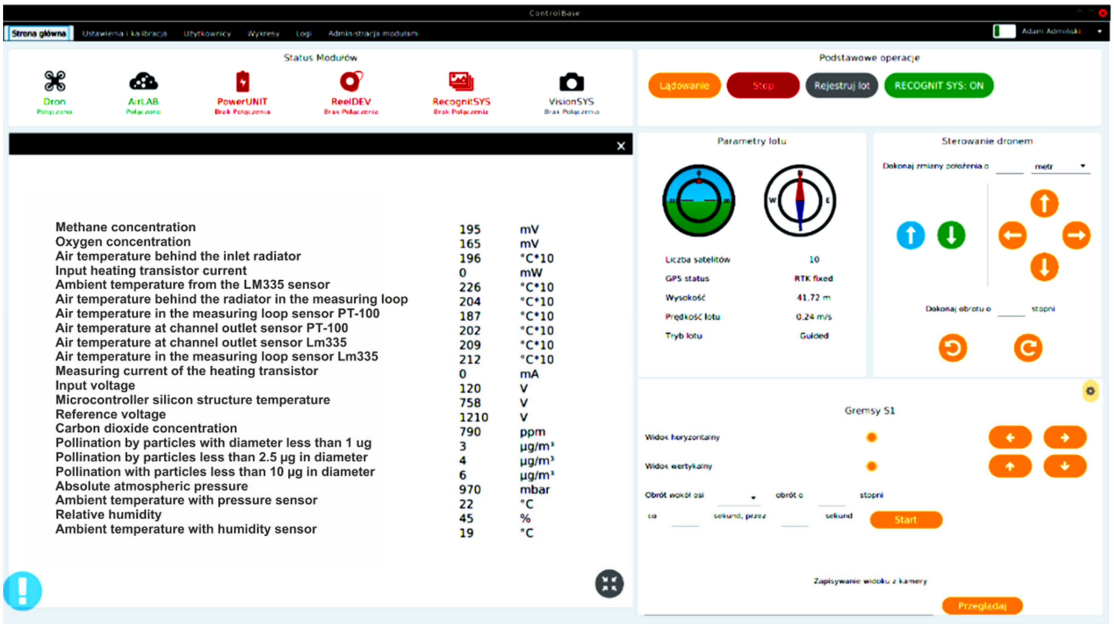


Figure 3. The simulated parameters read from the AirLAB module are shown in the ground control station application ControlBASE.

3. Results and Conclusions

The first prototype was developed with the use of 3D printing of the housing with air ducts for testing the air sample. The electronic part of the project and software for controlling the device were developed parallelly. Then, the communication interface between the AirLAB module and the ControlBASE application was created. The presented solution, with both the AirLAB measurement device and ControlBASE (the ground control station that is application linked with developed interfaces) allows for the remote measurement of air quality parameters and gas detection.

The final stage of work was preparing a prototype of the AirLAB module for testing the compliance with the 2014/30/EU EMC Directive. Due to the close proximity of the UAV, driving tests were conducted on the susceptibility of the AirLAB module to electromagnetic interference. Positive results confirmed the correctness of our assumptions and the realization of the gas detection module; the results are shown in Figure 4.

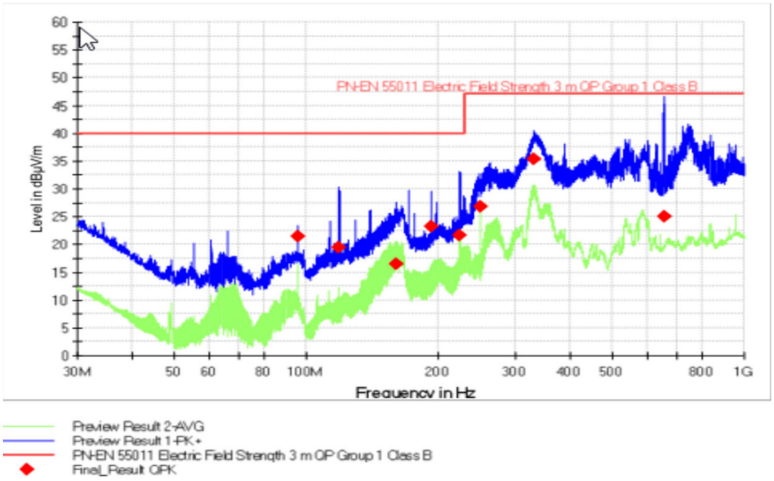


Figure 4. Confirmation of positive EMC tests results of AirLAB module.

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