engineering proceedings

MDPI

Proceeding Paper

Development and Design of Low-cost DIY Acoustic Sensor †

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† Presented at The 11th International Electronic Conference on Sensors and Applications (ECSA-11), 26–28 November 2024; Available online: https://sciforum.net/event/ecsa-11.

Abstract: In this paper, it is presented the development of a low-cost acoustic sensor based on an import-substituting element base as a cheap alternative to professional sensors or analog sensors. An Arduino board, a microphone module, a microSD card module and other modules were used. To improve the accuracy of the data taken from the microphone, it was calibrated using a reference noise meter, using a logarithmic smoothing method to calculate the sound level in decibels, and obtained an equation for converting the obtained ADC values into decibels. The code of the program executed by the sensor was developed and sewn into the device. The data captured from the microphone is stored in a CSV file with the date and time of the captured data.

Keywords: DIY; sensors; acoustic sensors; noise sensors

Citation: Golovkov, T.; Novichkova, M.; Saifutdinov, T.; Levik, A.; Matasov, V.; Vikulov, A. Development and Design of Low-cost DIY Acoustic Sensor. *Eng. Proc.* **2024**, *5*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s):

Published: 26 November 2024

1. Introduction

Ambient noise is one of the aggressors in the environment, which has a negative effect on the human body. Constant suffering from noise can cause the following consequences [1]:

- Hearing loss or impairment;
- Problems with the cardiovascular system;
- Decreased sleep quality;
- Memory impairment and deterioration of cognitive skills;
- Deterioration of attention concentration.

In modern society, not enough attention is paid to the problem of the influence of noise and its consequences, therefore, in order to solve the problem, it is necessary to regulate its level and time of exposure. Special measurement methods are used to assess the noise level in various rooms or in an open area. One of the most common methods is the use of sound sensors used at the measurement location. The sensor registers the ambient noise level with a certain frequency using the built-in microphone and displays it on the screen.

Our goal is to simplify this process by eliminating the need for manual measurements. To do this, we have developed an autonomous noise sensor made of components that are easily available in electronics stores and that do not require large material costs. Our sensor will be useful in both enclosed and open spaces, as it has an IP65 protection class. The sensor is easy to assemble, it is convenient to hang it both outside and inside thanks to specially designed fasteners. Moreover, device's microphone doesn't record all the sound and is only used to get voltage level on it to get noise level, so it is impossible to get any confidential data via this sensor.

2. Materials and Methods

2.1. Requirements for Components and Their Selection

Due to our striving to reduce costs we must define requirements for the components:

- Motherboard with integrated microcontroller, supporting plenty of different components and with ability to write a program using simple development environment. As a result, we chose Arduino Uno R3 board, which contains 14 digital and 6 analog pins, which is enough to our project. Also, we can write programs to it with Arduino IDE, which can be installed almost on any computer;
- Microphone module with integrated fixed amplifier. It must have ability to be connected to Arduino board and have sensitivity range 20 Hz–20 kHz. We chose electret microphone module with MAX9812L amplifier with low quiescent current and high gain factor as 20 dB;
- MicroSD card module with ability to connect to Arduino board. So, MicroSD card module with SPI interface and 5 V supply is chosen;
- For data storage, MicroSD card with 32 GB volume was chosen;
- Device, which can provide current date and time information with ≈1 s accuracy and store that data without any external power supply. As a result, RTC module based on DS1302 chip was chosen. It has a battery place for independent supply, battery in low price on most markets and enough accuracy for our project;
- Power supplies for motherboard with high capacity and ability to recharge. So, three 3.7 V 1500 mAh the 18,650 format accumulators were chosen. With special battery compartment they will provide ≈ 11.1 V which is in required voltage range by Arduino Uno R3 board through DC input;
- Case for three 18,650 accumulators with DC output connector;
- Case with water and dust resistance. Gainta G2105 [2] case was chosen because of its IP65 protection class and dimensions that provide tight components layout; moreover, it has holes for convenient PCB installation by screws;
- Two-positional key switch with rubber seal. We chose one with IP65 protection class;
- Water-resistant and air-transparent membrane. It will provide a hole for microphone and keep water protection class for case. So, we chose air-transparent self-adhesive membrane with IP68 protection class that is used to keep air pressure in car's headlights;
- Printed circuit board 70 × 90 mm to set on it RTC and MicroSD modules;
- Screws 2 × 6 mm 4 pieces to fix printed circuit board;
- Heat shrink tubes—they will provide safe connections between wires;
- Last part of this assembly—wires for parts connection. We chose 0.14 cupper wire with PVC insulation.

2.2. Electrical Circuit Design

Device's electrical circuit design is shown in Figure 1. All the components are powered by Arduino's 5 V pin. Arduino, in turn, is powered by case with three 18,650 accumulators. In this circuit design seven digital and one analog pins were used, so there are a lot of free pins to use more modules, for example, NBIoT SIM module to send data to the server by mobile connection.

It it important to note that there are two states of sensor operations: on and off. Key switch, which is installed in wire break of accumulators case, allows to turn on and off power supply of Arduino board. In case of the sensor is turned off, all of components, excluding RTC module, are deprived of power. This state allows to save accumulators power while RTC module keeps renewing time and date data, getting power by it's cell. So, in case of the sensor is turned on, all the parts are being given the power and device is recording noises from the outside.

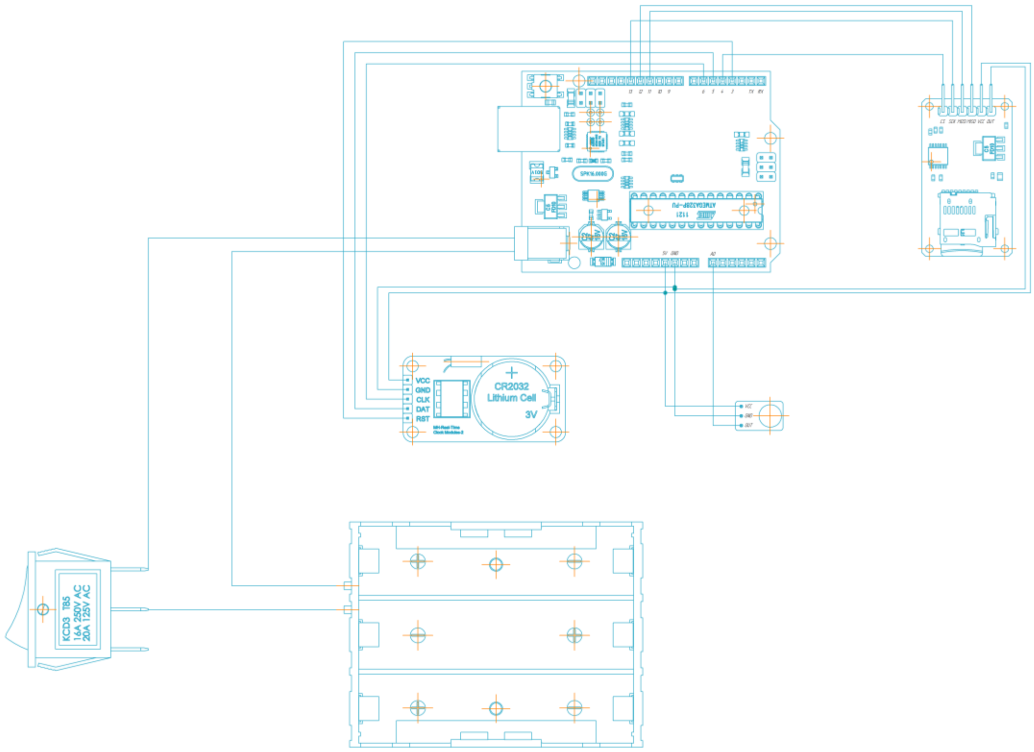
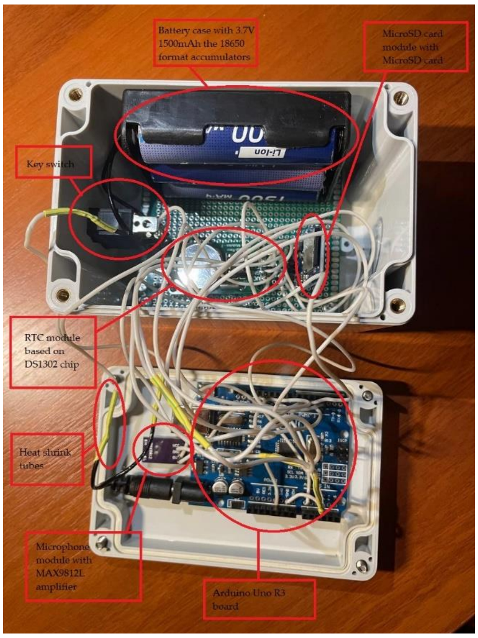


Figure 1. Electrical circuit design.

2.3. Building a Prototype and Writing a Program

After checking the operability of the sensor on the breadboard, the measuring modules were soldered to the Arduino and the printed circuit board using soldering wires. The printed circuit board is located on special racks at the bottom of the case and is attached to it with 2 × 5 mm screws. Holes were drilled and processed in the case for the output of the microphone and the key switch. It is assumed that in preparation for mass production, its own case will be designed with special racks for attaching an Arduino board and a battery compartment to it, as well as with holes for installing a microphone and a switch. A self-adhesive water-resistant membrane is located on the outside of the microphone output hole, the microphone module and the switch are glued to the housing using sealed BF-2 glue [3]. The program that the sensor executes is written in the Arduino IDE development environment. The code of the program executed by the sensor was sewn into the device. The data captured from the microphone is stored in a text file with the date and time of the captured data.



(**a**)

(**b**)

Figure 2. Device's components layout. (**a**) Inner layout; (**b**) External layout.

3. Results and Discussion

So, we got the physical prototype of our device. To improve the accuracy of the data captured from the microphone, the assembled sensor was calibrated. The method of direct calibration of noise values using a professional noise level meter was used. A noise level corresponding to 39 dB was taken as the level of silence in the laboratory, and a white noise generator was used as the source. As the volume of the noise generated by the generator gradually increased, 5 values were taken from our sensor and the reference noise meter at each volume level. Thus, 12 experiments were conducted, as a result of which the standard deviations were calculated and a table of correspondence between the readings of the voltage value by microphone and the reference noise meter was obtained. Using the capabilities of MATLAB, the following equation of dB dependence on voltage readings was obtained:

$$dB = 34.2\lg(U) + 102.48. \quad (1)$$

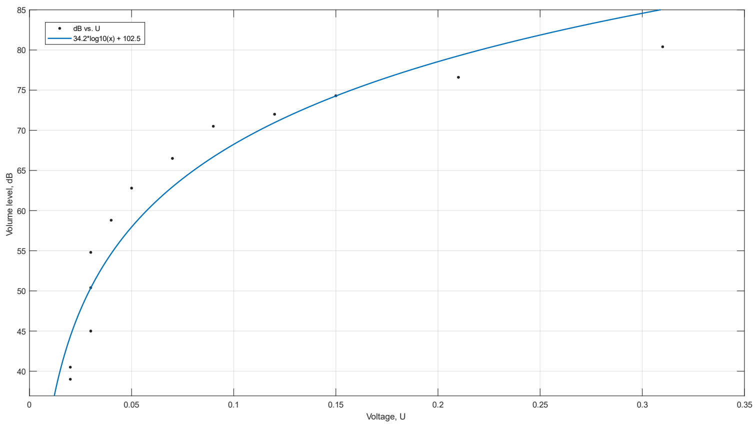


Figure 3. Graph of linearization of data obtained during calibration.

4. Conclusions

A prototype of the DIY noise sensor was designed for use in production and in the workplace. All available components have been selected for it and the IP65 dust and moisture protection level has been achieved. Moreover, we performed primary calibrations and got the results that can be used to increase the sensor accuracy.

The sensor is ready for further improvement, namely the addition of NB-IoT module, a user interface, easier access to data, the development of its own housing, and eventually mass production.

One of the key prospects for further development of the project is to enhance the accuracy and sensitivity of the noise sensor. The sensor is now ready for field testing and verification of its readings against already calibrated and proven devices.

Also, there is a great perspective for installing a self-developed motherboard with custom microcontroller and built-in high-quality microphone that could provide more accuracy and power efficiency.

Author Contributions: Conceptualization, A.V., A.L. and V.M.; methodology, A.L.; software, T.S. and M.N.; validation, A.L., T.G. and T.S.; formal analysis, A.V.; investigation, T.S., T.G. and M.N.; resources, A.V.; data curation, A.V.; writing—original draft preparation, T.S. and M.N.; writing—review and editing, T.S.; visualization, T.S.; supervision, A.V.; project administration, T.S.; funding acquisition, A.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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