National University of Science and Technology Politehnica Bucharest

Doctoral School of Electrical Engineering

DOCTORAL THESIS

SUMMARY

Contributions regarding the analysis, design and realization of electrical devices used for indoor ambiental monitoring

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Bucharest

2023

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Keywords: electrical devices, quantitative studies, IoT technology, ambiental monitoring, sensors, pollution, arduino, user perception, smart spaces, air quality, consumption measurements, parameter analysis.

Introduction

Ambient monitoring is a especially current subject in the context of increasingly pressing concerns for protecting the health of the population and the environment. On the other hand, technological developments prove the great potential that smart spaces have, both for people's comfort and for protecting the environment. In this context, the realization of a research that responds to the need to monitor the ambient by capitalizing on the potential of an intelligent space is all the more appropriate.

This research followed two major steps, the first of which sought to understand the current situation regarding the use of electrical devices at the user level and the willingness to use them in the future, and the second, in the form of a concrete device solution to improve user activity.

In the first part of the doctoral research, several studies were carried out, the first being based on the specialized literature on IoT technology to know their principles, domains and applicability.

As a result, starting from the analysis of specialized literature, the following questions were outlined:

- What is the situation in Romania regarding the penetration of IoT devices into consumption?
- What is the perception of current and potential users about these devices?
- Are there areas where their use is of more interest? Are there categories of people who are more open to using these devices?

To answer these questions, the research was organized based on quantitative studies specific to the empirical research method and inductive reasoning.

A first study carried out in this regard was based on the analysis of statistical data available at European level, provided by Eurostat and available online for the period 2020-2022. This study aimed to determine whether:

- There are differences between the countries of the European Union regarding the use of IoT devices in individual homes and what is the situation of Romania in the group of EU countries;
- What are the factors influencing the degree of use of IoT devices in homes and whether there are significant differences between EU member countries.

The second quantitative study focused on the situation in Romania, to analyze whether in the case of electrical devices there are differences in use between personal and professional environments. The research method used in this study was the questionnaire survey applied in an entity in Romania chosen so that all employees could be questioned, regardless of their position, specialization, age or domicile. The aim of this study was to determine:

- If there are differences in the perception of the use of electrical devices in the professional environment versus the personal one and
- If these differences are influenced by certain user-specific variables (education, occupation, age, residence, gender).

A particular case of application of smart electrical devices is in the medical field. We are talking about such intelligent healthcare that involves the incorporation of new technologies, but also a different way of approaching and reporting on the medical act. The use of smartphones in combination with various applications in this field can provide greater access to knowledge and healthcare specific to each branch. Medical records, laboratory results and diagnostic interpretations can be easily communicated via a mobile device. Smartphones, wearable devices, sensors and communication systems have revolutionized medicine with the ability to contain artificial intelligence (AI). Several algorithms based on artificial intelligence have been approved by the Food and Drug Administration (FDA) in the last decade, so they will be able to be implemented, but medicine is not only based on artificial intelligence technologies, but also on other digital tools.

The third quantitative study aimed to analyze the extent to which potential users in Romania are open to the use of electrical devices in the medical field. From the multitude of potential users, the study focused on an analysis of students, as future specialists who will be faced with the decision to use such devices. Furthermore, the study was applied to two distinct groups of students, one from the medical field and another from the engineering field, so that we could analyze whether there are any differences in perception between them.

Another field in which electrical devices have a high applicability potential is that of ambiental monitoring. Smart electrical devices designed for modern homes can offer users more safety and comfort, but can also contribute to reducing energy consumption, reducing the presence of harmful substances and, implicitly, a healthier environment.

Because ambiental monitoring is a new field in Romania, little known by the Romanian public, in terms of advantages and implementation methods - all these things justify the opportunity to study how electrical ambiental monitoring devices are perceived by potential consumers.

The fourth quantitative study, also based on a questionnaire, aimed to analyze the perception of electrical ambient monitoring devices for three distinct scenarios:

1. In the personal space of each individual;
2. In the professional space where people work;
3. In the medical field.

Practically, among the fields in which electrical environmental monitoring devices can be applied in this study, the medical field was chosen, on the one hand due to the fact that many innovative advances have been made in this field and, on the other hand, due to the benefits what can be brought in this way for the whole society, given that each individual comes into contact with medical services both personally and in the situation of relatives or close ones who encounter health problems. The statistical collective to which the study was applied is formed by students of the electrical engineering specialization, the option for this category being justified by the fact that it is about people who have a minimum of notions regarding electrical devices.

The concrete objectives of this study were to know the opinion of future specialists regarding the use of electrical devices for ambiental monitoring in the three above-mentioned scenarios.

In the second part of the doctoral research, the issue of the use of electrical devices for the purpose of environmental monitoring was developed, the research method used in this case being of the constructivist type [1]. If in the first stage a series of analyzes were carried out based on statistical data (available through Eurostat or collected personally through surveys) in order to understand the manifestation of some phenomena (use of electrical devices, level of knowledge about electrical devices)), in the second stage, a solution for the use of these devices was proposed, starting from the needs resulting from European policies and the needs expressed at the level of potential users.

The objectives pursued in this stage were to establish:

- what are the most important indicators that ensure a good monitoring of the environment (Ob.1);
- what technical method can be used to measure these indicators so as to ensure a good accuracy of the data, but also ease of application of the device (Ob.2).

To answer the first objective (Ob1), *the research was completed with information from secondary sources*, namely specialized literature, articles and reports on the main polluting factors on human health and the environment, ways of manifestation, measurement methods, indicators and control levels. Then, based on the respective results, *an environmental monitoring device was designed and built, based on Arduino technology*.

In summary, the steps followed in the doctoral research approach are summarized in Fig. 1.

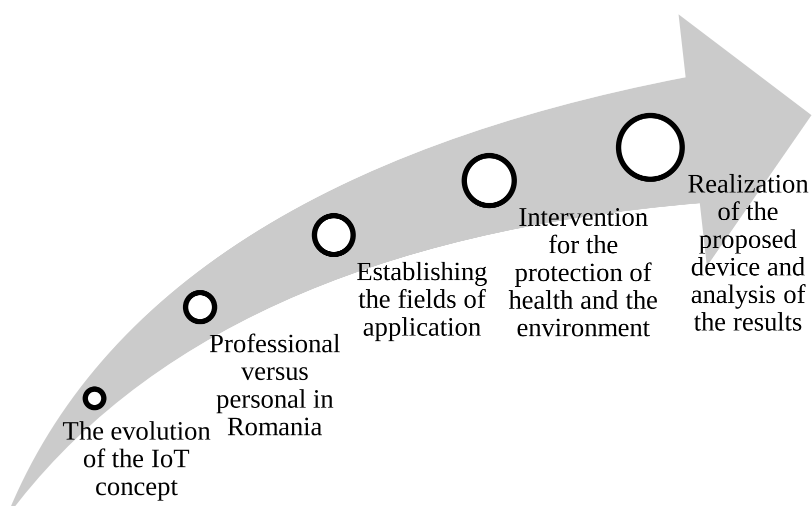

Fig. 1. The steps followed in the doctoral research approach

Chapter 1. Case study

This chapter includes four subchapters, each dedicated to one of the quantitative studies carried out:

- study on the description, evolution and use of IoT devices (Chap. 1.1);
- study on the use of electrical devices in smart spaces (professional environment versus personal environment) (Chap. 1.2);
- study on the importance of electrical devices in the medical field (in the perception of future specialists) (Chap. 1.3);
- study on the importance of electrical devices used for ambiental monitoring (Chap. 1.4).

1.1. IoT technology

1.1.1. Description of the IoT concept

The term Internet of Things (IoT Internet of Things) was coined by industry researchers, but it has only recently appeared in the view and language of the general public. Some experts in the field claim that the IoT will completely transform the way computer networks are used in the next 10 or 100 years, while others see the IoT as a blip that won't affect most people's daily lives [2] . The IoT creates an opportunity to assess, gather and analyze an ever-increasing selection of behavioral information.

1.1.3. Analysis of the degree of use of Internet of Things devices by individual users in European countries

1.1.3.1. Methodology

Taking into account the vast applicability of IoT, as well as its usefulness in both public and private space, *the thesis studied the degree of use of IoT devices in the private homes of individual consumers, aiming to answer the following questions:*

- Are there differences between the situation in the member countries of the European Union and other European countries, but between the 27 member states of the EU?
- What are the factors that influence the degree of use of IoT devices in homes and how do they manifest themselves: does their intensity differ from country to country, from one device category to another, or can certain similarities be established?

To answer these questions, the study based its analysis on primary statistical data provided by Eurostat and available online for the years 2020 and 2022. These are the data series on the use of IoT and those on the barriers to the use of IoT devices, on which we called "influence factors" [16], [17].

In a first step, the figures were analyzed using descriptive statistics, so that the degree of use of the devices could be compared, on the one hand between the EU27 (based on the average level of use, established statistically) and other European countries and, on the other on the other hand, between the level of use reached by each of the 27 member states. The application of the coefficient of variation allowed us to study whether the data indicated for the EU countries express a common trend or are sufficiently heterogeneous to be able to state that the differences between the countries are major. Then, the same descriptive approach was applied to statistical data on the factors influencing the use of IoT devices at the individual level in European states (EU and non-members). In the graphs made to show the comparative situation, the codes for the countries as they are recognized at the international level were used each time [18].

In the second step, the relationship between the factors that influence the use of IoT devices and the degree of household use of these devices was analyzed to determine how strong this influence is on each category of devices. In this sense, the Pearson linear correlation coefficient was chosen as an indicator, taking into account the distribution mode of the individual values of the series.

1.2. Use of electrical devices in smart spaces: professional versus personal environment

1.2.1. Study methodology

In order to understand people's willingness to use electrical devices, a study was carried out to compare the degree of use in professional activity with that in the personal life environment of Romanian employees. The study considered the specific devices of an "intelligent space", a concept that involves automation and remote control, aspects related to people's safety, environmental comfort and consumption reduction.

For the analysis, **a quantitative study was used**, based on a questionnaire, in which all 50 employees of an entity operating in Romania were included. The benefit of total, all-employee research is to provide a comprehensive picture of entity-wide perception of those devices.

1.3. The importance of electrical devices in the medical field in the perception of future specialists

1.3.1. Study methodology

Taking into account the potential and importance of electrical devices for the medical field, a study was carried out among future specialists, to know the perception they have about the possibilities of capitalizing on these devices, as a premise for the acquisition of new technologies and the availability to capitalize on them in the field of activity.

For the study we chose direct, quantitative, questionnaire-based research, so that a comparative analysis of the opinions between two groups of respondents could be carried out. The general population established for the analysis is that of first-year students from the Faculty of Medicine of the University of Medicine and Pharmacy "Carol Davila" Bucharest (hereinafter abbreviated UMF), and from the Faculty of Electrical Engineering, Electronics and Information Technology of the University "Valahia" from Târgoviște (hereinafter abbreviated UVT). These are two specializations which, by their very nature, must integrate developments in the field of electrical devices into specialized theory and practice. At the same time, the choice of two specializations is intended to allow us to perform a comparative analysis between the group of medical students and that of engineering students. We limited the application of the study to first-year students in order to observe their perception "a priori", before the exposure to the specialized information from the university curricula. The study sample was set at 100 subjects, 50 from each faculty, and the selection method was cluster type [22].

The resulting questionnaire contained a number of 15 questions and was applied online, between March 21-24, 2022, through the Microsoft Forms platform, and the in-depth analysis of the answers was carried out with the help of MS Excel functions.

The study falls under the category of exploratory research, which aims to understand the way a phenomenon manifests and formulate hypotheses and directions for further research.

1.4. Awareness raising among young Romanians regarding the importance of electrical devices used for ambiental monitoring

1.4.1. Study methodology

This study aimed to analyze how electrical environmental monitoring devices (hereinafter abbreviated as DEMA) are perceived by potential consumers, respectively the openness shown towards these innovative products and, on the other hand, the existing reluctance at the public level.

The specific objectives pursued in this study were:

- Knowledge of the opinion regarding the use of electrical devices for monitoring the environment in the personal space;
- Knowledge of the opinion regarding the use of electrical devices for monitoring the environment in the professional space;
- Knowledge of the opinion regarding the use of electrical devices for monitoring the environment in medical activity.

To carry out the research, a quantitative study was chosen, in the form of a survey that uses a questionnaire as a tool for collecting information. The advantage of this study is that it allows the measurement of results with the help of statistical indicators, as well as the establishment of correlations between certain analyzed variables.

The research sample was made up of students of the Faculty of Electrical Engineering of the Politehnica University of Bucharest. The option to carry out the study among this type of population is justified by the fact that it is about people who have a minimum of notions regarding electrical devices.

On the other hand, since we aimed to study whether the level of education in the field has an influence on the perception of the analyzed subject, we introduced a filter question in the questionnaire to find out whether or not the respondents studied in college about electrical devices for environmental monitoring.

The questionnaire was distributed online to all students, with analysis to determine whether there were differences in responses between students based on their level of information on the subject. The study took place between 12.01.2023-31.01.2023 through the Microsoft Forms platform.

As a result of the survey, 155 valid questionnaires were obtained, the collected data being analyzed based on descriptive statistics, as well as by using the chi-square significance test on sub-groups (Sub-group SG1 - "students who studied" and Sub- group SG2 - "students who have not studied" about electrical devices for ambient monitoring) to establish whether the specialist knowledge acquired by respondents influences their perception of electrical devices for ambient monitoring [23].

Chapter 2. The impact of air pollution on health and the environment

2.1. General aspects regarding air pollution

Air pollution is a social problem that can be defined as the contamination of the air with excessive concentrations of gases, liquid droplets or solid substances that tend to harm living organisms and lead to undesirable changes in the natural environment.

Specifically, air pollution is any change in the natural composition and characteristics of the atmosphere. These substances that lead to unwanted changes in the environment and exert adverse effects on the biosphere are called air pollutants. Air pollutants are usually grouped into two classes, including primary and secondary pollutants.

The doctrine refers to air pollution as the release of pollutants into the air, the parameters of which are harmful to the health of human beings and the environment. According to the World Health Organization (WHO), annually, air pollution is the main cause of approximately 7 million deaths globally. Nine out of ten people currently breathe air that exceeds WHO limits for pollutants, with those living in low-income countries particularly suffering the most [24].

The effects of air pollution on the human body vary depending on the type of pollutant and the duration and level of exposure, as well as other factors, including a person's individual health risks and the cumulative impact of multiple pollutants or stressors.

However, human activities do not have a positive effect on the environment by polluting water, air and soil. Even though the industrial revolution was significantly successful in terms of society, technology and the provision of multiple services, this technological progress also provided the production of huge amounts of pollutants emitted into the air, which are harmful to human health.

2.8. The impact of air pollutants on the environment

Air pollution has negative effects on both terrestrial and aquatic ecosystems, degrading environments and reducing biodiversity. This chapter examines the exposure of vegetation to key air pollutants. It is based on both modeled estimates of total exposure and measurements from monitoring stations in rural areas.

Ground-level ozone damages agricultural crops, forests and plants by reducing growth rates, decreasing yields and by affecting biodiversity and ecosystem services.

Certain atmospheric pollutants deposit on the Earth's surface, thus degrading the receiving ecosystems. Nitrogen oxides and ammonia from the air are deposited on land and in water bodies, resulting in the introduction of excessive amounts of nitrogen. In bodies of water, this contributes to eutrophication, whereby excess nutrients cause algal blooms and reduce oxygen availability. In sensitive terrestrial ecosystems such as grasslands, exceeding critical nitrogen deposition loads can lead to loss of sensitive species, increased growth of species that benefit from high nitrogen levels, and changes in ecosystem structure and function.

The deposition of sulfur dioxide, nitrogen oxides and ammonia leads to changes in the chemical composition of soils, lakes, rivers and seawater through a process known as acidification, which disrupts ecosystems and leads to the loss of biodiversity. As sulfur dioxide emissions have declined significantly in recent decades, the relative contribution of ammonia and nitrogen oxides to surface water and soil acidification has increased.

Heavy metals are toxic pollutants that travel long distances in the atmosphere and are deposited in ecosystems, leading to the accumulation of these contaminants in soil and their subsequent bioaccumulation and biomagnification in the food chain [42].

According to the UNECE Air Convention, the critical ozone exposure level for forest protection is set at 10,000 μg/m3 per hour. Any concentration in the atmosphere above this critical level can have direct negative effects on plants and ecosystems.

2.9. The impact of air pollution on health

Exposure to high levels of air pollution can cause a variety of negative health outcomes. It increases the risk of respiratory infections, heart disease and lung cancer. Both short-term and long-term exposure to air pollutants have been associated with health effects. More severe effects affect people who are already ill. Minors, the elderly and social cases are more susceptible. The most harmful pollutants, closely associated with excessive premature mortality, are the fine PM2.5 particles that penetrate deep into the pulmonary pathways.

The World Health Organization highlighted in 2018 that approximately 7 million deaths were recorded each year due to exposure to fine airborne particles that penetrate deep into the lungs and cardiovascular system, causing significant conditions such as stroke , heart disease, lung cancer, chronic obstructive pulmonary disease and respiratory infections.

The organization states that ambient air pollution caused approximately 4.2 million deaths in 2016, while indoor air pollution from cooking with polluting fuels and technologies caused approximately 3.8 million deaths during the same period [43].

2.12. Analysis of the characteristics of some devices for monitoring the indoor ambient

In order to better understand the way of operation and the components that make up the devices built for monitoring the indoor environment, in the lines below is presented an analysis that was carried out with the aim of exposing the technical specifications of several equipment of this type [67].

Chapter 3. Design and practical realization of the device

3.1. Device design

Starting from the analysis carried out in the previous chapters, the approach to design and practically realize a device that fulfills the following objectives is fully justified:

- the use of a minimum number of sensors for the acquisition of ambiental parameters (temperature, humidity and particles in the air, concentration of CO, CO_2, TVOC and noise);
- monitoring the environmental parameters and storing them in a database;
- maintaining the environmental parameters in predetermined areas (below their risk values) through an alarm and control circuit;
- implementation of an interactive interface with digital screen and clock function;
- the use of an internal consumption monitoring circuit.

3.2. Practical realization of the device

The proposed indoor environment monitoring device is based on a monitoring and control block made up of two microcontrollers that collect data from sensors and manage alarm cases and communication with the outside. The block diagram of this device is shown in Fig. 3.3.

The ATmega328p microcontroller communicates with the ambient sensors (for temperature, humidity, airborne particles, carbon monoxide, carbon dioxide, TVOC and noise), the consumption monitoring sensor, the clock module and the physical user interface. The data from the sensors is passed on to the ESP8266 microcontroller which compares the received values with a series of preset thresholds by which alarm cases are determined. It also communicates with a web interface via the local WiFi network.

The user interface consists of an OLED screen and three buttons. The buttons are used to control the values displayed on the screen. Initially, the display shows the time (hh:mm), date (DD/MM/YYYY), temperature and humidity.

Buttons 1 and 2 toggle between the display:

- temperature and humidity;
- concentration of CO and CO_2;
- airborne particles, TVOC and noise.

Button 3 allows setting the date and time.

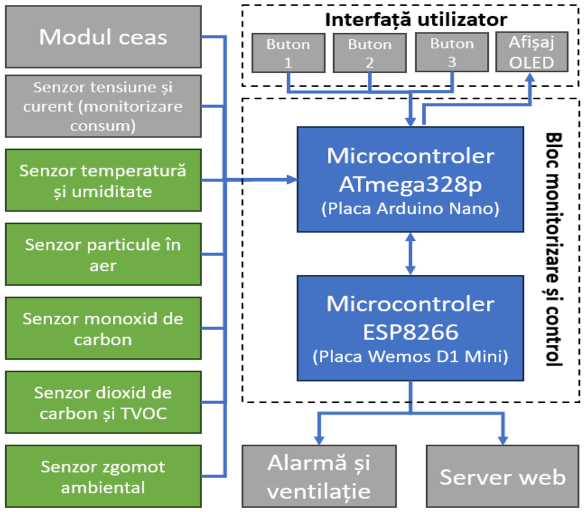

Fig. 3.3. Block diagram of the proposed device

3.4. Device programming

The device made is based on two microcontrollers: ATmega328p from the Arduino Nano prototyping board and ESP8266 (from the Wemos D1 board) (Fig. 3.27) [87].

The ATmega328p interface has enough pins and communication modules to allow the connection of the chosen sensors, but it has limited memory (32 KB flash memory, 2 KB RAM memory). The ESP8266 microcontroller does not have this problem, but its interface is much more limited (a single analog pin, 8 digital pins and 2 dedicated pins for the UART module). The solution developed was to use the ATmega328p microcontroller to communicate with the clock module (including time setting and alarm functions), retrieve data from sensors and manage the physical user interface.

The ESP8266 microcontroller receives the data from the other microcontroller, transmits the data to the database and manages the alarm case (monitoring air quality parameters, controls the external fan, window opening, triggers visual and audio signals).

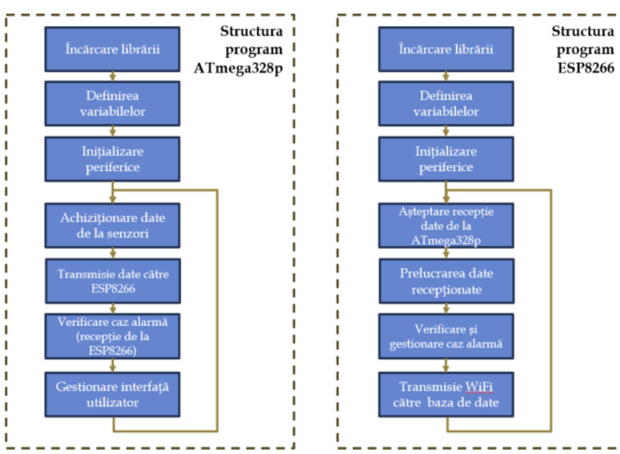

Fig. 3.27. Block diagrams for ATmega328p and ESP8266 code

In Fig. 3.27 shows the general structure of the indoor environment monitoring programs used by the proposed device. Both codes have the same initialization structure: the used libraries are loaded, the variables are defined, and the peripherals needed to communicate with external modules are initialized. The program on the ATmega328p acquires data from all used sensors and the clock module. It processes the received data, then transmitting it to the ESP8266 microcontroller via UART. After transmission, it checks if an alarm case has been received from the ESP8266 (in which case it activates the audio alarm). Finally, it checks if the user pressed the buttons in the physical interface, acting on the detected command. The code then returns to the purchasing side. It is important to note that the step through all the repetitive steps is done in the order of tens of milliseconds to ensure a quick response to the alarm and to the push of a button, in the acquisition step the reading is done only at a predetermined step of the order of seconds.

3.6. The cost of the device

The objective of this chapter is to estimate the cost for the realization of the device built for the monitoring of environmental parameters.

Fig. 3.36. The fully assembled ambient monitoring prototype device (left) and its internal circuitry (right)

The estimation of the cost of making the device was made taking into account some general aspects, which are presented in the following lines.

The cost of the components used to make the device are averages of spot prices charged by different suppliers.

In the estimate of the cost of realization, the cost of transporting the components was not taken into account.

Chapter 4. Device testing and measurement analysis

4.1. Device testing

The three commercially purchased pieces of equipment that will be presented in the following lines were used for testing and calibrating the device, which were factory calibrated and tested.

T-Z01 Pro. Air quality detector

The T-Z01 air quality monitor is a high-performance home air quality detector, mainly used to monitor gas concentrations of PM2.5, HCHO, TVOC, CO and CO_2, as well as temperature and humidity.

This device is suitable for testing air concentration in confined spaces such as home, wooden furniture, leather goods, office and indoor spaces.

T-Z05. Digital noise meter

This high-quality sound level meter allows easy measurement of ambient noise for noise and quality management. which can be used for noise engineering, quality control, health prevention and various environmental noise measurements. Such as factories, offices, roads, families, audio and other occasions. It is a fantastic noise measurement unit for accurate and high quality sound measurements with a dynamic range of 30dB to 130dB.

Multimeter Gw Instek GDM-8341

The GDM-8341 is a dual measurement multimeter that has exceptional features, having the capacity of 50,000 counts, a VFD quality dual display, DC voltage base accuracy of 0.02% and a USB protocol connector to provide users measurement precision, clear data observation and an easy possibility to connect to personal computer.

4.3. Making consumption measurements

The aforementioned multimeter, Gw Instek GDM-8341, was used to perform the measurements, the results being presented in the following lines.

4.3.1. General consumption of the circuit

Fig 4.11 shows the total consumption of the circuit.

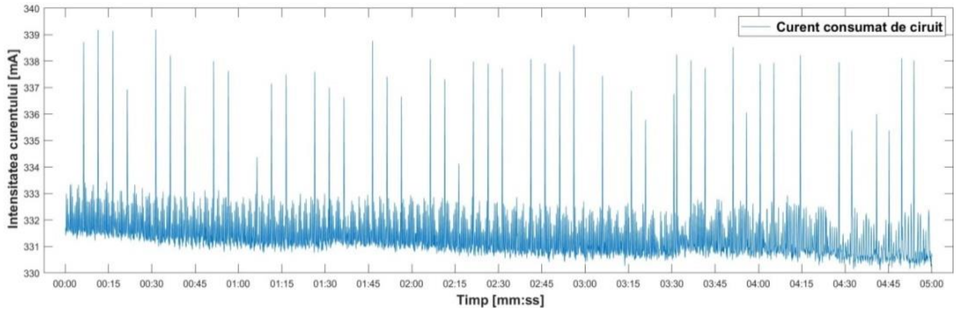

Fig. 4.11. Current consumed by the circuit

In Fig. 4.12 the supply voltage of the circuit is presented.

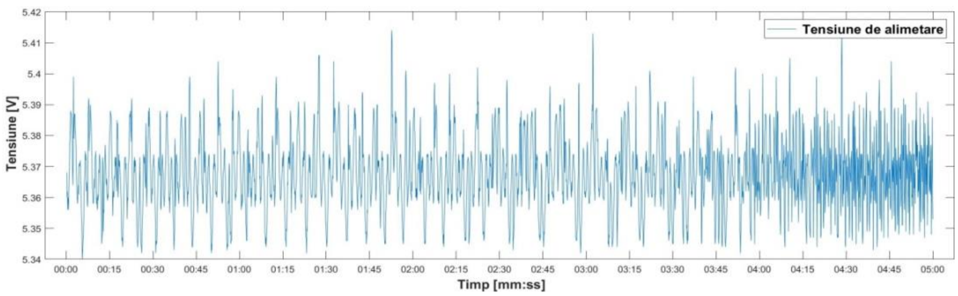

Fig. 4.12. Circuit supply voltage

4.3.2. Determination of the electrical parameters of the circuit in normal operation mode

In this subchapter, the electrical parameters of the prototype circuit built for monitoring the indoor ambient will be determined. During consumption monitoring, the monitored parameters are kept below the alarm limits. Consumption in alarm mode is discussed in chapter 4.3.3. The individual current consumption for the components that make up the circuit (the two prototyping boards, the OLED display, the clock module and the sensors used) is also investigated. Measurements were made with a GW Instek GDM-8341 digital multimeter. The data was acquired from the multimeter in Microsoft Excel by means of an Add-in provided by GW Instek that communicates with the measuring device via the USB interface. The results below were obtained from 10 measurements per second for 5 minutes, so each graph contains 3000 points.

Conclusions

1. General conclusions

The present doctoral research aimed to address the issue of devices used to monitor the indoor environment and was organized in two stages, the first aimed at analyzing the degree of use of electrical monitoring devices and the availability of potential beneficiaries to use them in the future and the second, focused on building a device for ambiental monitoring.

The concern for the introduction of IoT devices into individual consumption is manifested at the European level and through the adoption of indicators to track the state in which each country is. In this sense, six categories of IoT devices have been defined for which data is collected at the level of each country: "connected devices for energy management in the personal space", "connected devices for safety/security in the personal space", "connected household appliances", " using a virtual assistant", "using TV / internet connections for personal use", "using internet connection for game console in personal space".

Regarding the availability of Romanians to use these devices specific to the "intelligent space", the study we carried out shows people's openness to using these devices, especially at work, the interest in using them at home being held back especially by the perception regarding the scope of the investment. The analysis by socio-demographic categories indicates the existence of some segments of employees that show a greater openness towards devices specific to the "intelligent space", aspects that can be capitalized in the context of campaigns to promote the advantages of these devices on different market segments. As a limitation of this study, we mention the selection method of the analyzed entity, which we cannot consider statistically representative at the national level, the results having an exclusively exploratory character.

Regarding the readiness to apply electrical devices in the medical field, the study conducted on medical and engineering students, as future specialists faced with decisions related to this equipment, highlighted the fact that both categories are open regarding the usefulness and applicability of the devices.

Regarding the use of electrical devices for ambiental monitoring (abbreviated DEMA), the results of the study that was carried out among electrical engineering students, future specialists in the field, show that they attribute an important "average" to "high" DEMA regardless of whether it is about their application in the personal, professional or medical environment. The analysis of the answers on the two sub-groups of students - "those who studied in college" about DEMA and "those who did not study" - revealed large, statistically significant differences for two of the analyzed items:

- "importance attributed to DEMA for personal housing": those who studied about DEMA assigning them a greater importance;
- "disadvantages of DEMA at home": those who studied about DEMA, indicating in a higher proportion the high level of investment, the difficulty of implementation and the difficulty of use from a technical point of view, while those who did not study about DEMA evoked high consumption and even distrust of efficiency.

The data obtained are important due to the fact that the youth segment is the most open to accepting innovative technologies, as shown by the Startcom study conducted recently in Romania.

The results obtained in this way show us that it is necessary that both the characteristics and the implementation method of EDEM be popularized primarily among specialists in the field of electrical engineering, but also among the general public who can become a user - beneficiary of these devices. Practically, only through an understanding of the main technical and environmental implications can the prerequisites be created for the integration of these devices in different professional fields and overcoming the reservations related to their use in the personal living space.

Regarding environmental pollution and its impact on health and ecosystems, studies have highlighted the negative influence of ground-level ozone, nitrogen oxides and ammonia, sulfur dioxide, nitrogen oxides and ammonia deposition, as well as heavy metals. Specialized bodies have established critical levels regarding the presence of these pollutants, and exceeding them has adverse effects on health and terrestrial and aquatic ecosystems. In the case of human health, atmospheric pollution is responsible for respiratory diseases, heart diseases, lung cancer, these also cause deaths, especially in low and middle income countries (such as those in Asia, Africa, the Eastern Mediterranean region or Europe). Numerous studies, internationally, have highlighted the relationship between air pollution and non-accidental mortality (such as that caused by exposure to ozone, sulfur dioxide, fine particles $PM_{2.5}$). While not leading to mortality, these polluting factors can affect the central nervous system through neuroimmune or neuroinflammatory reactions, can generate physiological changes.

The practical realization of the device, the collection of data and the performance of measurements regarding the environment and energy consumption were carried out in the cities of Târgoviște and Bucharest, both located in Romania. After connecting the components from which the equipment was built, in order to achieve the proposed results, it became necessary to calibrate the sensors, a very important step for achieving correct monitoring.

In the research carried out, the measurement results were established by comparisons with the real-time measurement values of some factory-calibrated and tested devices, this process being essential to significantly reduce the probability of making erroneous readings of the data from the sensors from which it is made up the created device. Considering the way in which the research was carried out, it is expected that the results obtained regarding the ambient measurements fall within the allowed limits.

The working method, the components that make up the device and the equipment used to test it in carrying out this research serve to strengthen the data validation and to confirm the calibration results.

The objective of this research is to emphasize the importance of continuous monitoring of the environment, this process having a significant impact because it gives engineers, scientists and decision makers the opportunity to take the necessary measures based on correct information to manage and improve the quality of life and the environment surrounding.

C2. Original contributions

In this doctoral research, **several studies were aimed**:

- *The importance of technology and the Internet of Things in both personal and professional life;*
- *Awareness of the need to carry out permanent monitoring of the ambient and the impact of pollution on health and the environment,* ***the final goal being the construction of an electrical device that has the ability to obtain correct results in real time in terms of monitoring the indoor ambient and its own energy consumption.***

The research has an interdisciplinary character through the prism of the areas addressed.

In the research carried out, we studied the degree of use and the opportunities for the application of electrical devices both in the personal space of individuals and in the professional one and, as fields, we deepened the situation in the medical and environmental fields.

Another original contribution lies in the methodology used during the research. The research combined the empirical research method, based on inductive reasoning, with the constructivist research method that led to the design of an ambiental monitoring device.

Regarding the practical part, a device that has the ability to monitor the indoor ambient was built, and after several sets of measurements were made, the results obtained and the operating parameters of the equipment were well analyzed, and modeling and optimization were carried out them, closely related to energy consumption.

To justify this research, which led to the practical realization of the equipment, **the following studies were carried out**:

- Statistical analysis of Internet of Things (IoT) penetration in individual consumption in EU countries.
- Use of electrical devices in smart spaces: professional environment versus personal environment;
- The importance of electrical devices in the medical field in the perception of future specialists;
- Awareness raising among young Romanians regarding the importance of electrical devices used for ambiental monitoring;

Other original contributions are:

- designing the device based on the studies carried out;
- practical realization (prototype) of the device based on the proposed project;
- device calibration;
- device programming;
- device testing;
- the analysis of the costs of purchasing the components;
- performing of measurements sets of the device's ambiental and electrical parameters;
- analysis of the results and mathematical modeling using the Matlab programming environment.

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