Possible Impacts of Ion Balance in Indoor Environment with Practical Application

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***Abstract*—This study focuses on ionizers, with particular emphasis on their effects on the human body and the environment, as well as the generation and composition of ions. Initially, the basic principles of ionizer operation will be explained, including the effects of negative ions on the human body and microorganisms. Following this, a detailed analysis of various ion generation methods will be provided, such as cosmic rays, UV radiation, natural and artificial corona discharge, lightning, the Lenard effect, and the ion-producing role of plants.**

The second part of the study concentrates on the specific design and construction of ionizers. The article thoroughly discuss the application of cascade multiplication and high-voltage rectification, high-voltage measurement methods, and the design of an "ion emitter." Subsequently, the implementation steps, including the development of circuit designs, the design process, the execution of measurements, the measurement of outgoing ions, and the experiences gained during the project will be presented.

Keywords – air ionizer, NAI, negative air ions, negative ion cluster

I. INTRODUCTION

The various sources of electromagnetic radiation, such as computers, televisions, mobile phones, and other electrical devices, have become an indispensable part of human life. These radiation sources can affect the human body in various ways, both directly and indirectly. The direct effect falls under the concept of "human exposure to EM fields" resulting from electromagnetic radiation sources. The human body reacts to exposure to electromagnetic fields, and this reaction depends on several factors, such as the type, intensity, and duration of the radiation. In contrast, electromagnetic radiation sources can also indirectly affect human health. For example, these devices can influence sleep patterns, stress levels, and contribute to changes in cognitive performance. In the past, when people suffered from lung diseases or other respiratory problems, the solution often involved breathing clean air, such as mountain air. Today, we observe and feel that urban air is significantly polluted, primarily due to exhaust gases, factory smoke, and other harmful substances in the air. This is important to mention because the aforementioned devices, especially in enclosed spaces, increase the generation of positive ions, and poor air quality further exacerbates this issue. An ionizer is a device that emits negative ions (anions) into the air in our environment, neutralizing the polluting particles found in the air of enclosed spaces. The device's function is to restore the poor air quality in our environment to a state similar to natural, fresh air. The use of this device is particularly recommended in homes, places with many children, clinics, hospital wards, offices, educational institutions, etc. In other words, places where many people spend long periods of time and where cations are prevalent.

II. THEROTICAL BACKGROUND

A. Air ions

Air ions are electrically charged molecules or atoms found in the atmosphere. An air ion is formed when a gas-phase molecule or atom gains enough energy to expel an electron. Negative air ions gain electrons, while positive air ions lose them. Natural and artificial energy sources include cosmic or radiative (ionizing) rays in the atmosphere; sunlight, including ultraviolet light; natural and artificial corona discharges, including lightning and thunder; the separation of water (Lenard effect); and energy sources from plants.

Radioactive elements like radium, actinium, and thorium emit α, β, and γ rays during their decay, ionizing the air. Cosmic radiation ionization is responsible for about 20% of ion generation in terrestrial areas [1]. Over the oceans, these sources generate negative air ions, with concentrations reaching up to 500 ions/cm^3 on land and exceeding 1000 ions/cm^3 at an altitude of 15 km [2].

The Earth's atmosphere is affected by a natural electric field, whose intensity varies under local and global influences [3]. Local effects include geographic location and weather conditions, while global factors refer to daily variations [1]. Sharp points on tree leaves or branches can cause corona discharge at high potential differences, emitting NAI. In mountainous areas, high electric fields and low air pressure promote corona discharge [4, 5]. Thunderstorms and lightning create very high electric fields, resulting in corona discharge, but NAI decreases once the thunderstorms subside. In forests, changes in the electric field during fog formation and dissipation can also induce corona discharge and NAI generation [3].

Artificial corona discharge is an effective method for generating NAI. Applying a high negative voltage to a conductor/electrode causes corona discharge if the electric field is strong enough [6]. The electric field is higher around the tip of a charged conductor with a sharp end, thus ionizing the air near the wire, creating negative air ions [7]. The intensity of the corona discharge depends on the shape, size of the wires, and the applied voltage. A sharp-pointed conductor results in more discharges, while larger diameter wires produce fewer; higher voltage generates more NAI [7]. NAI concentration is higher near the corona point, where an electron avalanche forms during corona discharge [8]. The application of electric fields and corona discharge to plants began in the 1960s [9]. Bachman and Hademenos (1971) demonstrated that high voltage resulted in more intense leaf tips, causing corona discharge and the formation of air ions and ozone [10]. The studies primarily focused on the biological effects, such as growth response, evaporation, plant damage, and the impact of produced ozone and negative air ions on growth [5].

B. *Composition of negative Air Ions*

Typically, negative air ions (NAIs) consist of several negatively charged molecules, and these negative ions can attach to multiple, or even 20-30 water molecules, forming negative ion clusters such as CO3−(H2O)n, O−(H2O)n, and O3−(H2O)n [11]. Mass spectrometry techniques have been widely used to determine the composition of NAIs from various sources [12]. Early measurements suggested that the majority of negative ions in the lower troposphere are O2−, CO3−, or NO3− and their (H2O)n clusters, as well as HSO4− core ions. Research has shown that atmospheric negative ions also contain additional ions such as OH−, NO2−, HCO3−, and their water clusters [13]. Fig. 1 and Fig. 2 summarizes the composition of NAIs from different sources and the evolution of oxygen-based NAIs.

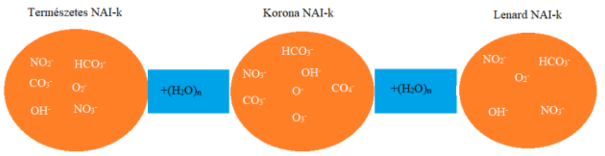

Figure 1: Composition of NAIs

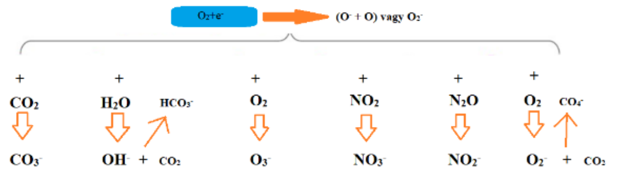

Figure 2: Development of oxygen-based negative air ions. Orange arrows indicate NAI transformation processes

C. *Mechanism of Action of Ionizers*

Ionizers used in homes produce negative and/or positive air ions (NAIs and PAIs), which can be generated simultaneously or separately. As a "side effect" of air purification, negative ions attract particles of dust, pollen, mold spores, tobacco smoke, and unpleasant odors in the rooms.

The ions produced by the ionizer are small and move at high speed, making them extremely effective. When these ions encounter pollutants, they transfer their charge to them. The resulting larger, charged particle is attracted to the nearest "grounded" surface, such as a wall or shelf where the ionizer is located. It is important for this surface to be washable, due to the "black wall effect."

As the ions move towards the interior of the room, their natural motion slows down. During this slowdown, the airborne pollutants (such as dust, pollen, cigarette smoke, and other gaseous pollutants) surround the ion, creating a "cluster." As a result, the ion's size increases significantly until it reaches a size that is too large and heavy to remain airborne, causing it to fall to the ground (Fig. 3).

The ionizer's ability to remove small particles from the air is particularly valuable for health. Recent research indicates that the smaller the pollutant particle size, the more difficult it is for the immune system to cope with it.

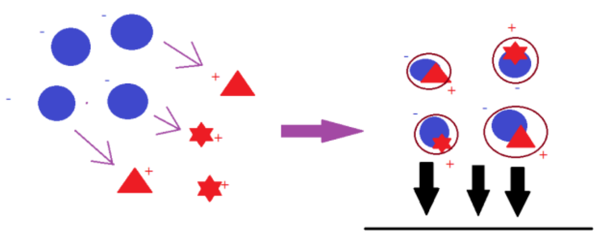

Figure 3: Size-dependent behavior of ions

D. *Ozone*

Ozone (O3) is a three-atom oxygen molecule that plays a significant role in the Earth's atmosphere. The ozone molecule consists of three oxygen atoms connected by strong bonds. It is a colorless gas but can appear bluish at high concentrations. It originates from both natural and human sources. Ozone was first discovered by its sharp smell and color; in 1840, Christian Friedrich Schönbein identified it while experimenting with oxygen and electrical sparks. The word "ozone" comes from the Greek "ozein," meaning to smell.

Ozone is present in different layers of the Earth. The ozone layer in the stratosphere absorbs the sun's harmful UV radiation, protecting terrestrial life from skin cancer and other health issues. In the atmosphere, ozone is found 10% in the troposphere (10-200 ppb) and 90% in the stratosphere (200-10000 ppb). The ozone shield absorbs a small portion of UV-B radiation and all UV-C radiation, enabling the sustenance of life.

Ozone is formed from oxygen under the influence of UV radiation, particularly UV rays with wavelengths shorter than 242 nm. Large amounts of ozone are produced around lightning strikes due to corona discharge. Tanning lamps filter out UV-C radiation with a special glass coating, as it also generates ozone. According to the World Health Organization, the maximum permissible concentration of ozone is 0.1 ppm [14].

Ozone is a highly oxidizing, toxic gas with a slightly unpleasant odor. Its byproducts are dangerous and carcinogenic, causing symptoms such as weakened immune system, reduced lung capacity, respiratory inflammations, and irritation. Ozone also acts as a greenhouse gas, preventing heat from returning to the sun. However, due to its disinfectant properties, it is beneficial as well, as its strong oxidizing ability effectively destroys viruses and bacteria. This property of O3 was discovered in 1886.

III. IMPLEMENTATION

A. *Circuit*

The method had been chosen involved a single pointed surface (formed from a pointed welding rod) connected to a potential ranging between -4 and -10 kV relative to ground. Due to the corona effect, the strong electric field that appears at the tip ionizes the air, as mentioned in previous chapters. It was necessary to ensure that the value did not exceed approximately -7 kV, because above this voltage, excessive corona discharge generates uncontrolled ozone, whose dangers have been previously discussed. It will be shown that the device did not exceed this value.

Among the solutions used here, the simplest possible one, which directly generates the desired voltage value from the alternating current network using a voltage multiplier (see at Fig. 4.).

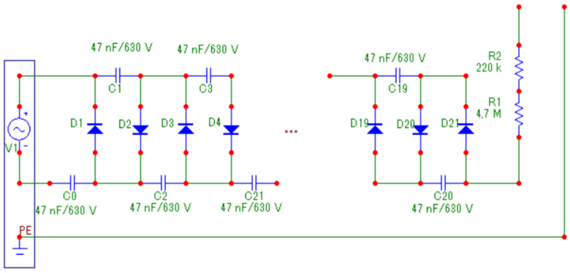

Figure 4: The schematic draw of the driver circuit

This construction is an 11-stage cascade multiplier (Fig. 5.), theoretically producing approximately -7 kV from the network (calculated value), and then stabilizing around -6 kV. Since higher voltages are generated at each stage, it was important for the capacitors to have a voltage tolerance of 630 V. The approximately 5 MΩ connected to the output was necessary to increase the internal resistance to ensure that any not intentional touch would be harmless. This approach is recommended for other circuits as well, and it is important that these resistors extend longitudinally and consist of more than just two parts, preferably several.

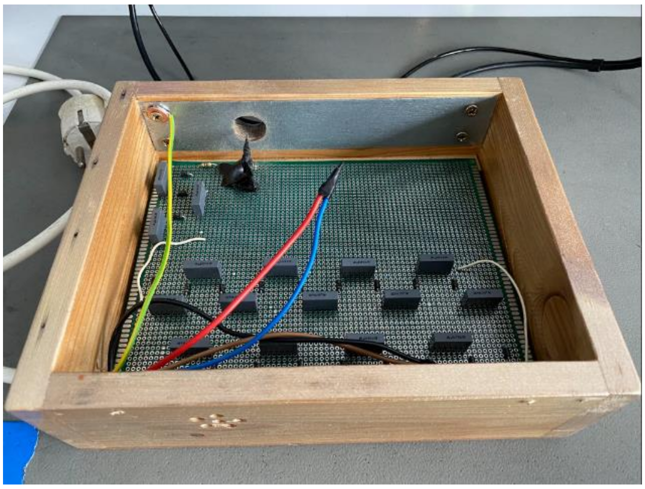

Figure 5: Physical appearance of the device

B. Measurement

The execution of the measurement required great attention due to the high voltage. Simple multimeters are not suitable for measuring high voltage, so a series resistor must be used to ensure the appropriate voltage for the instrument. An important characteristic of multimeters is the input resistance, which is dependent from the measurement range, and detailed in the datasheet.

To achieve a higher voltage range, the total resistance must be increased. In the case of high voltage, the internal resistance of the instrument is negligible, but it must be considered in lower ranges.Based on calculations, the appropriate shunt resistor was 2.7 MΩ, which achieved a 1:10 division. For the measurements, the Siglent SDM 3055 digital multimeter was available in the laboratory. The value measured at the output is shown in Fig. 6.

Figure 6: The measured value with shunt

Since it is on a 1:10 scale, the real value is multiplied by ten times, the number indicated by the device, so we get about -6kV (actually a negative voltage, which it was aiming for), perfectly matching expectations. This value should be higher, but the circuit has a high internal resistance, so the calculated value will differ from the measured value. Worth to note, that the described measurement method can only be a used for a well approximated indication.

C. Ion detector

To detect the emitted negative air ions, a simple circuit had been used (see on Fig. 7.). In this implementation, the leg of resistor R_3 serves as an antenna, which is sufficient for proper operation. The accumulation of ions on the antenna causes a small negative current, which flows to the base of transistor T_1.

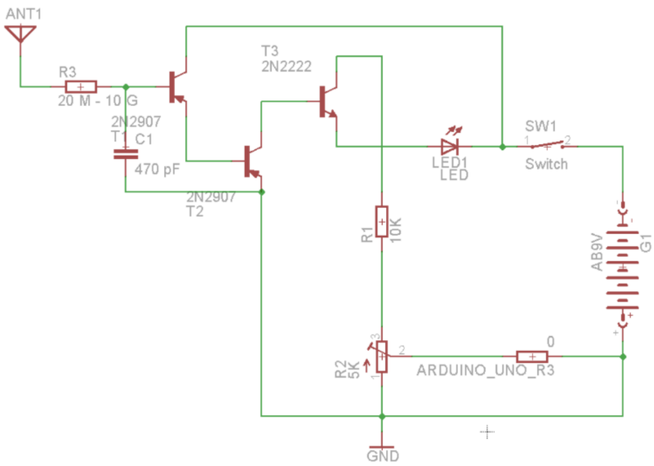

Figure 7: The scheamtic of ion detector

The capacitor C_1 and resistor R_3 function as an RC network, eliminating rapid fluctuations. If the negative current is large enough, it switches on T_1, which connects the negative pole of the B_1 battery (a TOE-8951 laboratory power supply during measurements) to the base of T_2, biasing and switching on T_2. This connects the base of T_3 to the positive pole of the battery, biasing and turning on T3. When T3 is switched on, the Arduino UNO R3, with the help of a shunt resistor and the internal ADC periphery, indicates the level of ion current, while LED lights up, indicating a strong ion field. Proper grounding is generally necessary for the unit to function correctly, which will be connected to the ionizer's ground - in this case, a portable PSU is proposed.

After connecting the microcontroller and using the appropriate shunt resistor (in a similar way as in [15-18]), and then used the built-in serial plotter in the Arduino IDE (Fig. 8) to display the measured values in graph form. The previous measurements confirmed that it was possible to obtain adequate results, as first, the circuit current was measured with a digital multimeter. The measured range is in microamperes, so it had been selected the shunt resistor accordingly and wrote the code for the microcontroller. Similar control systems are detailed in [19, 20]. The applications of these control systems extend to advanced engineering fields [21, 22].

It is logical that the value changes as a function of distance; in this case, when the power of the ionizer was increased, the current also increased. This can be explained by the fact that there is a higher concentration of negative charges near the tip of the needle, resulting in a higher current flowing through the circuit. Fig. 9. shows an input power based measurement. As an opportunity for further development, it would be useful to collect spatial data, process it and graphically visualize the 3D environment for optimization [23, 24].

The ion detector can quickly signal the presence of a negative ion field, help identify its source, and indicate its relative strength, but it is not designed to measure absolute flux intensity. The ion detector can be used to filter out residual ion fields, check for ion leakage (e.g., during shielding tests), or test for static charges (in people's clothing, fluorescent tubes, plastic containers, certain winds, etc.), as well as for numerous other applications.

Figure 8: The measured values with Arduino

D. Current Measurement Instead of Voltage Measurement

The system is powered by the 230V public network. The microcontroller receives power from a 5V DC adapter. The power regulation of the ionizer is solved with a closed feedback loop, where the intervenor is a phase-splitting power regulator realized with a triac, galvanically isolated from the microcontroller by an optodiac, and the sensor is the circuit already presented (see the results in Fig. 10.). Comparable control loops and embedded systems are described in [25-27].

The output of the sensor is connected to the ADC of the microcontroller through the outputs of the terminals of a shunt. The current flowing through the shunt drops the voltage, which is measured by the microcontroller and displayed on the development interface of the serial plotter see on Fig. 11.

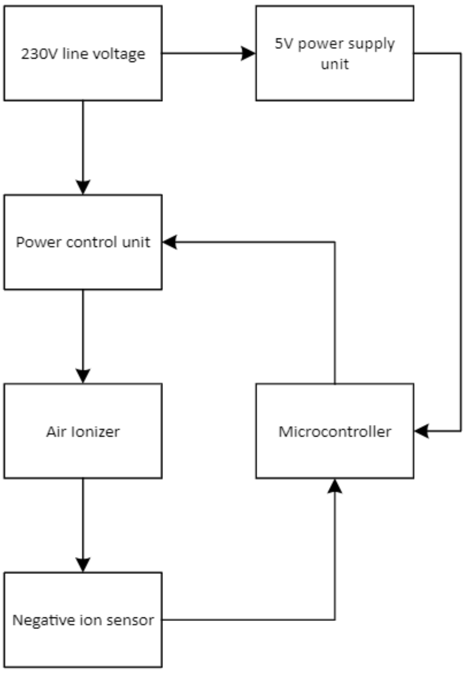

Figure 9: The block diagram of the project

Figure 10: Measured voltage, displayed in microamps

E. Measurement and Operational Experiences of the Ionizer

After measured the other stages as well and observed that the multiplication provided by the circuit is offset by the loss of each section. It had been measured roughly the same values at each stage. It is likely that the diy soldering is not optimal, and some voltage leaks from the system, resulting in reduced performance.

The device effectively collects positively charged particles, as shown in Fig. 11. This stage was made in a wooden box. The device works as expected, and the so-called ion breeze, mentioned in previous chapters, is noticeable. It produces a minimal amount of ozone, which is difficult to avoid, but plans include its detection and regulating the incoming voltage.

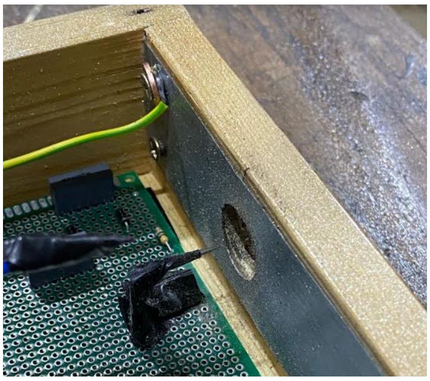

Figure 11: The result of the operation. As expected, the dust particles collect on the metal plate opposite the tip of the needle.

Conclusion

The study focused on the design, implementation, and effects of the ionizer, which plays a crucial role in air purification by generating negative and/or positive air ions. The ionizer, constructed using a simple yet effective 11-stage cascade multiplier, successfully generated the desired voltage of approximately -6 kV from the network. This was achieved despite the challenges posed by the high internal resistance of the circuit, which required careful measurement and calibration activities.

The main mechanism of the ionizer involves ionizing particles in the air through a high-voltage conductor. This process effectively attracts and neutralizes airborne contaminants, including dust, pollen, and smoke, thus purifying the air. Although the device produced a small amount of ozone, which is a known byproduct of ionization, the ozone levels were regulated and remained within safe limits. The presence of ozone highlights the need for further refinement in the design to minimize ozone production without compromising the efficiency of the ionizer.

Practical experiments and measurements confirmed that the ionizer effectively collects positively charged particles, reinforcing theoretical expectations. Despite some potential issues with soldering and voltage leakage in the circuit, the overall performance of the device was satisfactory.

In conclusion, the ionizer presents a promising solution for air purification, particularly in indoor environments. Its ability to remove fine particles from the air is beneficial not only for general cleanliness but also has significant health impacts, especially in areas with poor air quality. Future work should focus on optimizing the design of the ionizer to reduce ozone production and further improve the efficiency and safety of the device.

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References

[1] Hoppel W.A., Anderson R.V., Willet J.C. „Atmospheric Electricity in the Planetary Boundary Layer.” The Earth’s Electrical Environment. Washington, DC, USA: NAS Press, 1986. 195–205.

[2] Ermakov V.I., Bazilevskaya G.A., Potrevsky P.E., Stozhkov Y.I. „Ion balance equation in the atmosphere.” J. Geophys. Res. 102 (1997): 23413–23419.

[3] Borra J.P., Roos R.A., Renard D., Lazar H., Goldman A., Goldman M. „Electrical and chemical consequences of point discharges in a forest during a mist and a thunderstorm.” J. Phys. D: Appl. Phys. 30 (1997): 84–93.

[4] Harrison R.G., Carslaw K.S. „Ion-aerosol-cloud processes in the lower atmosphere.” Rev. Geophys. (2003): 41.

[5] Aubrecht L., Stanek Z., Koller J. „Corona discharge on coniferous trees—Spruce and pine.” Europhys. Lett. 53 (2001): 304–390.

[6] Altamimi G., Illias H.A., Mokhtar N., Mokhlis H., Bakar A.H.A. „Corona discharges under various types of electrodes.” Kuching Sarawak, Malájzia: Proceedings of the 2014 IEEE International Conference on Power and Energy (PECon), 2014.

[7] Berendt A., Budnarowska M., Mizeraczyk J. „DC negative corona discharge characteristics in air flowing transversely and longitudinally through a needle-plate electrode gap.” J. Electrostat. 92 (2018): 24-30.

[8] Manabe Y., Shimazaki T. „Formation mechanism of surface corona on dielectric plates under negative impulse voltage in atmospheric air.” IEEE Trans. Dielectr. Electr. Insul. 11 (2004): 631–637.

[9] L.E., Murr. „Plant growth response in a simulated electric field-environment. .” Nature 200 (1963): 490-491.

[10] Bachman C.H., Hademenos D.G. „Ozone and air ions accompanying biological applications of electric fields.” J. Atmos. Terr. Phys. 33 (1971): 497–505.

[11] Iwama H., Ohmizo H., Furuta S., Ohmori S., Watanabe K., Kaneko T., Tsutsumi K. „Inspired superoxide anions attenuate blood lactate concentrations in postoperative patients.” Crit. Care Med. 30 (2002): 1246–1249.

[12] J.G., Dillard. „Negative ion mass spectrometry.” Chem. Rev. 73 (1973): 589–643.

[13] Cabane M., Playe P. „Mass spectra of negative ions in air-like gas mixtures at atmospheric pressure.” J. Aerosol Sci. 11 (1980): 475–482.

[14] WHO, „National Library of Medicine,”National Center of Biotechnology Information, 2015. [Online 2023]. https://www.ncbi.nlm.nih.gov/books/NBK574591/#ch3.s4.

[15] S. Alsarayreh and Z. Sütő, "Power Converter Half-bridge Models in the Light of Real-time FPGA Implementation," *2021 IEEE 19th International Power Electronics and Motion Control Conference (PEMC)*, Gliwice, Poland, 2021, pp. 153-160, doi: 10.1109/PEMC48073.2021.9432622.

[16] Snezana Dragicevic, Aleksandar Peulic, Miroslav Bjekic, Radojka Krneta. Measurement and Simulation of Energy Use in a School Building. Acta Polytechnica Hungarica Vol. 10, No. 2, 2013. ISSN: 1785-8860

[17] Mosavi Amirhosein, Bertalan Beszedes, Imre Felde, Nadai Laszlo, Gorji Nima E. Electrical characterization of CIGS thin-film solar cells by two- and four-wire probe technique. MODERN PHYSICS LETTERS B 2020 p. 2050102 , 16 p. (2020)

[18] György Györök, Baklanov Alexander E, Bertalan Beszédes. Extension of Nodal Voltage Method with the Thermosensing. In: Orosz, Gábor Tamás (szerk.) AIS 2017 - 12th International Symposium on Applied Informatics and Related Areas organized in the frame of Hungarian Science Festival 2017 by Óbuda University : Proceedings. Székesfehérvár, Magyarország : Óbudai Egyetem (2017) 204 p. pp. 201-204. , 4 p.

[19] György Györök, András Dávid, Nikoletta Tolner, Bertalan Beszédes, Dániel Cseh. Supervision of the operation of digital circuits by Embedded Microcontroller. In: Orosz, Gábor (szerk.) AIS 2018 - 13th International Symposium on Applied Informatics and Related Areas. Székesfehérvár, Magyarország : Óbudai Egyetem, Alba Regia Műszaki Kar (2018) pp. 29-35. , 7 p.

[20] Györök György, Tihomir Trifonov, Alexander E. Baklanov, Bertalan Beszédes, Svetlana V. Grigoryeva, Aizhan Zhaparova. A Special Robust Solution for Battery Based Power Supply. In: Orosz, Gábor Tamás (szerk.) 11th International Symposium on Applied Informatics and Related Areas (AIS 2016). Székesfehérvár, Magyarország : Óbudai Egyetem (2016) pp. 32-35. , 4 p.

[21] Attila Sáfár, Bertalan Beszédes. Educational Aspects of a Modular Power Management System. In: Orosz, Gábor Tamás (szerk.) AIS 2019 : 14th International Symposium on Applied Informatics and Related Areas organized in the frame of Hungarian Science Festival 2019 by Óbuda University. Székesfehérvár, Magyarország : Óbudai Egyetem (2019) pp. 163-166. , 4 p.

[22] György Györök, Bertalan Beszédes. Artificial Education Process Environment for Embedded Systems. In: Orosz, Gábor Tamás (szerk.)

9th International Symposium on Applied Informatics and Related Areas - AIS2014. Székesfehérvár, Magyarország : Óbudai Egyetem (2014) pp. 37-42. , 6 p.

[23] A.Krasavin, M.Tolykbayeva, A.Kussaiyn-Murat, A.Kadyroldina, D.Alontseva. Surface restoration based on scanning data. 18th International Symposium on Applied Informatics and Related Areas, AIS, Óbuda University November 16, 2023 Székesfehérvár, Hungary, pp 68-72.

[24] A.Kadyroldina, A.Kussaiyn-Murat, A.Krasavin, D.Alontseva. A new laser stripe detection algorithm for 3D scanning applications. Международный симпозиум Applied Informatics and Related Areas, AIS, Óbuda University November 17, 2022 Székesfehérvár, Hungary. - pp 93-97.

[25] Alexander Baklanov, Svetlana Grigoryeva, György Györök. Control of LED Lighting Equipment with Robustness Elements, Acta Polytechnica Hungarica (1785-8860 1785-8860): 15 3 pp 105-119 (2016)

[26] G. Gyorok and M. Mako, "Configuration of EEG input-unit by electric circuit evolution," 2005 IEEE International Conference on Intelligent Engineering Systems, 2005. INES '05., Spain, 2005, pp. 255-258, doi: 10.1109/INES.2005.1555168.

[27] Aizhan Zhaparova, Dimitry Titov, Alexander Y. Baklanov, Gyorgy Gyorok. Study of the Effectiveness of Switching-on LED Illumination Devices and the Use of Low Voltage System in Lighting. Acta Polytechnica Hungarica (1785-8860 1785-8860): 12 5 pp 71-80 (2015)