

REVIEW

by Assoc. Prof. Eng. Slavi Yassenov Lyubomirov, PhD
Plovdiv University "Paisii Hilendarski"

of dissertation for awarding the educational and scientific degree "Doctor"

in the field of higher education 5 Technical sciences

professional field 5.3. Communication and computer equipment

doctoral program "Automation of areas of the intangible field (medicine, education, science, administrative activities, etc.)"

Author: MEng. Stanislav Mitkov Assenov

Topic: "Design, research and optimization of wireless sensor units with low power consumption".

Supervisor: Assoc. Prof. Dimitar Mihailov Tokmakov, PhD, Paisii Hilendarski University of Plovdiv.

1. General description of the submitted materials

With order №P33-3478 from 19.07.2021. of the Rector of Plovdiv University "Paisii Hilendarski" (PU), I have been appointed a member of the scientific jury under the procedure for defense of a dissertation on the topic "Design, research and optimization of wireless sensor units with low energy consumption" for obtaining an educational and scientific degree "Doctor" in field of higher education 5 Technical sciences, professional field 5.3 Communication and computer engineering, doctoral program "Automation of areas of the intangible field (medicine, education, science, administrative activity, etc.)" The author of the dissertation is M.Sc. Stanislav Mitkov Assenov - PhD student in full-time education at the Department of Electronics, Communications and Information Technologies with supervisor Assoc. Prof. Dimitar Mihailov Tokmakov, PhD, from Paisii Hilendarski University of Plovdiv.

The presented by Mag. eng. Stanislav Mitkov Assenov set of materials, includes the following documents:

- application to the Rector of PU ent. № K1-62 / 20.07.2021 for opening the procedure for defense of dissertation;
- CV in European format;

- transcript-extract from the Minutes of the Department Council at the Department of EKIT (PU) № 31 / 30.06.2021, item 1 Preliminary discussion of the dissertation of Stanislav Assenov;
- dissertation work;
- abstract in the volume of 32 pages;
- list of scientific publications on the topic of the dissertation - 8 issues;
- list of noticed citations - 7 pieces;
- declaration of originality and authenticity of the attached documents.

2. Brief biographical data about the doctoral student

The doctoral student mag. Eng. Stanislav Mitkov Assenov in 2006 graduated from secondary special education with a degree in Electronic Computing at the Professional High School of Engineering and Technology "Hristo Botev" in Smolyan. Later, he acquired a bachelor's degree in Computer Systems and Technologies at the Technical University of Sofia, Plovdiv branch in 2010. He received a Master's degree in the same specialty in 2014 at the University of Food Technology in Plovdiv.

In 2019 he was enrolled in a doctoral program by order №P33-573 from 01.02.2019 of the Rector of Plovdiv University "Paisii Hilendarski".

His career began as a teacher of disciplines in the field of "Computer Systems" at PGTT "Hristo Botev" in Smolyan. In 2017 he became an assistant at the Faculty of Physics and Technology at Paisii Hilendarski University of Plovdiv.

3. Relevance of the topic and expediency of the set goals and objectives

The topic of this dissertation is related to the design, research and optimization of wireless sensor units with low power consumption. It is specified on the methods and hardware for optimizing the energy consumed by the wireless sensor nodes.

In the last decade, wireless communication networks have become widespread and research has focused on broadband wireless networks. In solving many problems related to industrial monitoring, the construction of the "Smart Home" system, distributed data collection systems and others, networks with information transmission up to 1 Mbit / s become relevant.

In recent years, there has been a desire to achieve higher quality in terms of supplies and services provided by wireless sensor networks and nodes. This is a prerequisite for the expansion and implementation of additional low-energy end sensor nodes to the networks.

The object of the dissertation is the design and research of wireless sensor nodes with low energy consumption, and the subject of the dissertation is the optimization of the energy consumption of the nodes.

The overall theoretical and practical research reflected in the dissertation is focused on the design and implementation of wireless sensor units with low power consumption. Various circuit solutions and ways to reduce the energy consumed by the wireless sensor nodes are proposed.

In this context, the dissertation focuses on the impact of hardware, software and total power consumption of wireless sensor units.

The peer-reviewed dissertation is related to a topical issue from a scientific and scientific-applied point of view.

The tasks set in the dissertation work directly correspond to the main goal. An energy efficient LoRaWAN protocol is presented. The design and research of wireless sensor units with low power consumption and the conducted experimental research are essential.

The topic of the dissertation is relevant because it is dedicated to problems related to the improvement of wireless sensor nodes, performed experimental studies of their conventional implementations and their optimized hardware and software solutions in order to achieve low power consumption and extend the life of power supplies batteries.

Solving these problems is a rather complex task as it requires a precise choice of hardware and software and research in real conditions.

The fact that a significant number of publications on the researched problem continue to be presented demonstrates the topicality of the dissertation work. All this determines the relevance of the problem developed in the dissertation. It is also of great importance on a global scale.

4. Knowledge of the problem

The doctoral student has studied a significant volume of literature sources related to the technologies and methods for the implementation of wireless sensor units with low power consumption. The paper analyzes the relevant specialized literature. It can be assessed that the dissertation proceeds to formulate the goal and the tasks arising from it after a thorough acquaintance and critical evaluation of scientific information in the field of the problem.

The cited 165 sources and the achieved results are proof of the good knowledge of the problem and its creative solution.

5. Research methodology

Mag. Eng. Stanislav Mitkov Assenov conducts his research methodologically correctly. The research methodology chosen by the doctoral student allows to achieve the set goal and to obtain an adequate answer to the tasks solved in the dissertation.

Numerous measurements of the energy consumption of designed and implemented wireless sensor units with low energy consumption have been performed. The measurements were performed using the method of direct current measurement, using an oscilloscope, which has a high class of accuracy. This method was chosen using a shunt resistor to measure the power consumption of the wireless sensor units. The energy consumption for each phase of the activity of the sensor unit is measured, as the phases of activity and the modes of operation and consumption are determined by their applications.

In the first chapter covers the conducted literary research and the defined problems. The purpose and tasks of the dissertation are formulated as well.

The second chapter of the dissertation presents an optimized energy model of sensor units using LoRa / LoRaWAN technologies. This model allows the analysis of various modes and scenarios for specific applications in the Internet of Things, based on LoRaWAN class A end devices. The energy consumption of a wireless LoRaWAN sensor node was evaluated through different action scenarios. A model that allows to study the impact of the hardware and the choice of software on the autonomy of the node has been developed.

The third chapter of the dissertation presents the designed, implemented and researched: LoRaWAN wireless sensor node with microcontroller ATMEGA328, Wi-Fi wireless sensor node with microcontroller ESP8266, LoRaWAN wireless sensor node with microcontroller and PLAM10NTMTM wireless sensor unit with ESP32 microcontroller. For each of the presented wireless sensor units, experimental studies of their conventional implementations and their optimized hardware and software solutions were performed in order to achieve low power consumption and extend the life of their batteries.

A mathematical model has been developed in Chapter Four, which has applicability for determining the capacitance values of capacitors depending on the magnitude of the harvester current. Approaches for mathematical calculation of the values of the capacitors, which are useful in optimizing the time interval of the low-energy state of the sensor unit are proposed. A simulation model of a battery-free sensor unit, developed in the middle of MATLAB, is presented in order to simulate the dependence of the capacitor capacity on the magnitude of the current generated by the harvester.

The data obtained confirm the correct approach of the doctoral student in conducting his research. The results also prove the authenticity of the material on which the contributions in the dissertation are based.

6. Characteristics and evaluation of the dissertation

The dissertation presented to me for review has a volume of 165 pages, including 96 figures (schemes, graphics and photographs), 47 formulas and 26 tables. 165 literature sources are presented, the predominant number of titles are from the last five years, which shows a high degree of knowledge of the current state of the problem.

It is structured as follows, an introduction, a literature review on the topic of the dissertation and three chapters with conclusions to each chapter. The dissertation is formatted according to the requirements.

The emphasis is put on the peculiarities of the operation of wireless sensor units with low power consumption. An overview and classification of wireless sensor units with low power consumption has been made. The architectural features of the wireless sensor nodes, the technologies for data transmission from the wireless sensor nodes are presented.

The conceptual aspect of the dissertation is in the direction of designing and researching the following:

- wireless sensor unit with ATMEGA328 microcontroller, LoRaWAN transceiver and ultra low power consumption;
- wireless sensor unit with LoraWan transceiver and ultra low power consumption;
- WI-FI sensor unit with low power consumption;
- LoRaWAN sensor unit with ultra low power consumption, with FRAM memory and nano timer.
- wireless sensor unit with LoraWan transceiver and ESP32.

The dissertation has shown research and practical skills in the design, development and research of wireless sensor units with low power consumption.

The data obtained confirm the correct approach of the doctoral student in conducting his research. The results also prove the authenticity of the material on which the contributions in the dissertation are built.

The results of the dissertation of mag. eng. Stanislav Assenov have been published in eight scientific journals.

7. Contributions and significance of development for science and practice

The reviewer has no objections to the claims for contributions made by the doctoral student.

I accept the contributions of the dissertation that they are scientifically applied and applied.

The scientific-applied ones are:

1. A developed and implemented energy efficient LoRaWAN protocol is proposed, through which the consumed energy is reduced by up to 35% compared to the conventional protocol.
2. A mathematical model of the energy life cycle of a battery-free wireless sensor unit has been developed. Approaches for mathematical calculation of the values of the capacitors are proposed, which are useful in optimizing the time interval of the low-energy state of the sensor unit.
3. A simulation model of a battery-free sensor unit in the middle of MATLAB has been created.
4. Innovative circuit solutions are proposed to reduce the power consumption of LoraWan wireless sensor units in low-energy mode - "deep sleep" by using a nano timer and FRAM memory to record the parameters of the LoraWan connection during power off of the microcontroller and the radio transceiver.

The applications are:

1. The parameters influencing the energy consumed by the wireless LoRaWAN sensor units have been determined and proven.
2. A sensor unit with LoRaWAN interface and ATMEGA328 microcontroller with low power consumption has been designed, developed and tested.
3. Class A LoRaWAN sensor unit with ATMEL SAM D21 microcontroller, TPL5110 nano timer and FRAM memory, characterized by ultra low power consumption, was designed, developed and tested.
4. Designed, developed and tested Wi-Fi sensor unit with microcontroller ESP 8266MOD with low power consumption.
5. LoraWAN wireless sensor unit with ESP32 microcontroller with ultra low power consumption is designed, developed and tested.
6. Two battery-free wireless LoRaWAN end sensor nodes for IoT applications have been developed and tested.

8. Evaluation of dissertation publications

Mag. Eng. Stanislav Mitkov Assenov has presented on his dissertation eight publications. The publications reflect the essence of the work and to a large extent the independence of the author.

Six articles have been published in refereed and indexed in the world-famous Scopus database and two in refereed editions. One of them is a separate article, which was published in the Scientific Papers of the Union of Scientists in Bulgaria - Plovdiv. All publications are in English. The doctoral student has presented a report on six citations from Bulgarian and foreign publications.

They reflect the research in the dissertation and coincide in subject matter with it. This shows that the results of the research on the dissertation have become available to the scientific community.

9. Personal participation of the doctoral student

From the dissertation submitted for review and the publications attached to it, it is clear that the doctoral student has independently performed the design, research and optimization of wireless sensor units with low energy consumption. This shows that the student has acquired during his training skills for independent solving of scientific and practical tasks.

10. Abstract

The review of the dissertation abstract shows full compliance with the requirements for its preparation, as well as the adequacy of reflecting the main points and contributions of the dissertation.

11. Critical remarks and recommendations

As a reviewer in the preliminary discussion procedure before the Extended Department Council at the EKIT Department at the University of Plovdiv, the doctoral student has complied with the remarks and recommendations and they are reflected in the final version of the dissertation.

The notes on the dissertation are of an editorial nature and do not diminish the significance of the proposed research and the formulated contributions.

My recommendation to the doctoral student for his next research and development is to justify his choice, while also taking into account the technical and economic parameters of the problem.

12. Personal impression

I know Stanislav Assenov since he started working as an assistant in the Department of Power Engineering and Communications at the Faculty of Physics and Technology at the University of Plovdiv "Paisii Hilendarski". My personal impression as a department head for the doctoral student is positive. He has always performed conscientiously and dealt on time with the tasks set by the department. He approaches his teaching activity responsibly, while constantly updating the content of the teaching material in the disciplines he teaches. He participates in the program accreditations of the professional fields 5.2. Electrical engineering, electronics and automation and 5.3. Communication and computer equipment very actively. He is part of the team that prepares the curriculum for the Bachelor's degree in Hardware and Software Systems, Computer and Communication Systems and for the Master's degree in Hardware and Software Systems and Information Security.

13. Recommendations for future use of dissertation contributions and results

Regarding the future use of the scientific and scientific-applied contributions of the dissertation research, no guidelines are presented in the final part of the dissertation.

CONCLUSION

The dissertation contains **scientific-applied and applied** results, which represent an original contribution to science and meet all the requirements of the Law for Development of the Academic Staff in the Republic of Bulgaria (ZRASRB), the Regulations for application of ZRASRB and the respective Regulations of Paisii Hilendarski University.

The dissertation shows that the doctoral student **mag. Eng. Stanislav Mitkov Assenov** has in-depth theoretical knowledge and professional skills in the scientific specialty 5.3 Communication and computer technology by demonstrating qualities and skills for independent research.

Due to the above, I confidently give my positive assessment of the research presented in the above reviewed dissertation, abstract, results and contributions, and I suggest to the esteemed scientific jury to award the educational and scientific degree "Doctor" to Mag. Eng. Stanislav Mitkov Assenov in the field of higher education: 5 Technical sciences, professional field 5.3 Communication and computer engineering, doctoral program "Automation of areas of the intangible field (medicine, education, science, administrative activities, etc.)

31.08.2021

Reviewer:

(Assoc. Prof. Dr. Eng. Slavi Lyubomirov)