CONTROLLER DESIGN THAT PROVIDES LIGHTING AUTOMATION FOR ENERGY EFFICIENCY IN BUILDINGS

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ABSTRACT
In this study, a DALI-2 compatible controller has been developed for lighting automation. A complete DALI lighting automation solution has been provided that can work together with all DALI peripherals, with the ability to integrate into different endpoints, will provide energy efficiency with scheduled functions and includes an embedded web interface customized with the concept of "human-centric lighting". Energy efficiency will be ensured in lighting places such as buildings, schools, hospitals where the automation solution will be used. At the same time, the physiological and psychological health of people who continue their daily lives in areas illuminated by "human-centric lighting" will be protected and their productivity will be increased.

Keywords: Green Building, Home Automation, Human-Centric Lighting, DALI, Dali Master

1. INTRODUCTION
As of today, technological developments are now developing even faster than in the past and are taking place in our daily lives. The shortcomings of technological products and solutions have become so widespread that they are seriously felt in our daily life. Technological developments have accelerated not only the Internet but also the electronics sector day by day. Devices that used to be difficult to imagine even in the past and their lower parts have become cheaper and cheaper. In particular, microcontrollers and similar tools that make devices smart are now appearing in all kinds of devices. With the development of production facilities, billions of devices are finding a place in our lives and are becoming more and more widespread. Of course, with technological developments, people's needs have increased and demands have been formed.
With the cheapening of technology, users have started using intelligent Building Automation Systems for savings purposes and end users, especially in the European Market, have started to demand automation systems. The impact of increasing energy prices and taxes on this situation is quite large. Consumers are becoming more aware of energy saving every day and tend to reduce inefficient consumption.
Energy efficiency in buildings according to the European Union and Turkish Legislation (Yuksekkaya, 2016), buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the European Union. New buildings usually need three to five liters of heating fuel per square meter per year, while older buildings consume an average of 25 liters. Some buildings can even consume up to 60 liters. Currently, 35% of the buildings in the EU are buildings older than 50 years. It is estimated that by increasing the energy efficiency of buildings, the implementation of energy efficiency measures in buildings can reduce the EU's total energy consumption by 5-6% by 2023 and create a lot of new job opportunities.
As in Turkey, as well as in Europe, studies have been conducted on the importance of building automation systems in the field of energy saving. The European Union obliges member states to have new public buildings starting in 2018, and all new buildings starting in 2020 to be energy-consuming buildings close to zero. In the report published by the European Commission in November 2017, it is seen that 20.8% of the energy consumed in buildings is consumed by lighting systems, and the same report states that as much as 60% of this energy can be saved when integrated with automation systems. This means that up to 12.5% of the total consumption can be saved. The biggest portion of this savings is the prevention of unnecessary consumption by automation. The concept of Smart Building could be defined as a set of communication technologies enabling different objects, sensors and functions within a building to communicate and interact with each other and also to be managed, controlled and automated in a remote way.
Together with lighting systems, air conditioning systems, they are among the most energy consuming systems in buildings. Especially in buildings such as residences, hospitals, public institutions, constantly burning lighting units make a serious amount of unnecessary energy consumption.
One of the goals of Turkey in 2023 is to reduce this non-essential consumption to a minimum and reduce energy imports with buildings close to zero energy. For this reason, building management systems are mandatory in newly constructed public buildings. Within the scope of the KABEV - Energy Efficiency In Public Buildings Project (P162769, 2019) carried out within the framework of the Ministry of Environment and Urbanization, it is aimed to reduce energy consumption in public buildings. The automation solution of the product to be designed within the scope of this study will be in a position to support the energy policy of our country and contribute to the goal of energy efficiency and savings.

2. DALI STANDARDS

The controller to be developed within the scope of the study will be compatible with DALI-2 standards, which are widely used all over the world in lighting automation, and will be able to integrate into systems running on network infrastructure with ethernet connectivity.

DALI (Digital Addressable Lighting Interface) communication standard was adopted as a standard in 2009 with IEC-62386 norm. It has entered among the international standards in the world in terms of home, building and emergency lighting control. This standard was designed and developed by the German society of electrical engineers (ZVEI) and, unlike other communication standards, it provided the possibility of communication with two cables without poles. Thus, it has brought a radical solution to the reverse binding problem experienced in the field. The priority feature in the messages brought with DALI-2 has increased the safety to the highest level in emergency lighting scenarios.

3. HUMAN-CENTRIC LIGHTING

Configurating and managing the light obtained from the artificial light sources in a way that it would support human morale, motivation and especially circadian biorhythm by controlling light in terms of spreading, severity and color tone called as “Human Centric Lighting”

Light is one of the most important regulators, influencers of the human life and hormonal order. From sunrise to sunset, seasonal changes have been searched in terms of characteristics of the geographic regions lived over the world and impacts created by these on the people living in these regions and after those evaluations striking effects/results have been found by the scientists over the years. (Memiş, 2019)

Color temperature is a characteristic of visible light that can significantly impact a space’s ambiance and functionality. It is measured in degrees Kelvin (K) on a scale that ranges from warm (yellow/orange) to cool (blue) and is an essential factor to consider in lighting design, photography, and other fields. The color temperature of a light source is determined by the amount of heat required to produce the light. For example, a candle flame has a color temperature of about 1900K, considered warm, while the midday sun has a color temperature of around 5500K, regarded as cool.

When people wake up in the morning, human body mechanism starts the day by trying to adapt itself to Kelvin (CCT) value of the daylight, which is at 2200 Kelvin level. This adaptation mechanism continues working in order to adapt itself depending on white light Kelvin (CCT) values provided by the artificial lighting applications in offices, schools, hospitals, workplaces, houses and similar places, where we may be at for a variety of purposes during the day. (Figure-1) Human-centrci lighting can adjust the light temperature and intensity according to our daily rhythm.

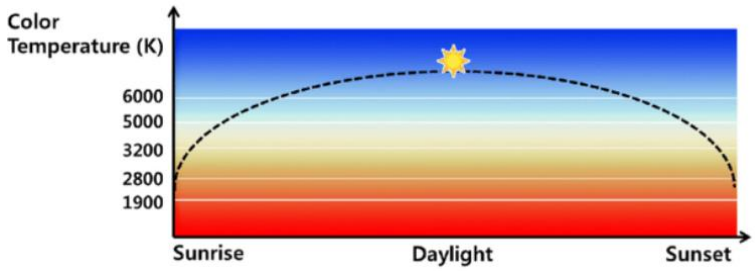

Fig.1. Color temperature variation throughout a single day

4. MOTIVATION

The main reason for this study is that digital methods are gaining importance in terms of energy efficiency in lighting automation in the Smart Building systems sector. Along with the automation solution provided by the DALI - 2 standard compatible controller, the focus will be on the title of "Human-Centric Lighting", which has been studied academically in recent years. The place, time, etc. located inside the controller. lighting automation will be made intelligent with parameter-dependent data sets and scheduling possibilities. In this way, both energy savings will be realized and the comforts of people living in illuminated areas will be provided.

In the study, a DALI-2 compatible controller designed for such purposes as easy control, easy fault detection and energy efficiency in lighting automation and interoperable with all DALI peripherals will be developed. With the ability to integrate into different endpoints, a complete DALI lighting automation solution will be provided, which will ensure energy efficiency with scheduled functions and include an embedded web interface customized with the concept of "human-centric lighting". Together with the multi-master feature it supports, it is possible to use DALI input/output and DALI sensor products together. In this way, it has been ensured that a complete solution can be offered only with DALI without the need for other automation systems.

5. CONTROLLER DESIGN STUDIES

At the beginning of the study, the studies in the literature (Maaspuro, 2015; Robinson, 2015; Matijevics, 2011; Sysala et al., 2016; Qipeng et al., 2014) and the products that may be similar were examined in detail. In similar product reviews, criteria such as mechanical and hardware designs of products, user interfaces have been taken into account.

According to the standards (IEC 62386-101) for the controller, in accordance with the electrical data, the circuit design was made so that the line voltage will be 18V DC and 250mA current capacity. Timing calculations have been made for data receiving and data sending structures, including 24-bit, 16-bit, 8-bit. Experiments have been conducted using DMA and Timer peripherals for the microcontroller to manage these timings. During the design process, additional windings were added to the basic transformer designs for additional output values requirements, and the appropriate number of windings and wire cross-sections were determined. With the technical data obtained and the experience gained from the preliminary trials, hardware and mechanical design and software development studies were carried out.

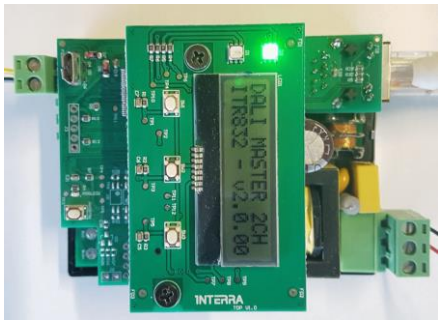

Fig.2. PCB Design

In hardware design studies; Schematic designs of the physical layer required for DALI-2 and the isolation-protected communication layer required for DALI-2 communication and the design of the supply source that will feed the 2 x DALI line were made. In the mechanical design studies; case design was made for the installation of the developed hardware and in accordance with IP protection standards. In embedded software design studies; The software algorithm of the communication protocols determined for DALI communication and DALI communication objects and parameters are designed to be compatible with the RTOS (Real-Time Operating System) system.

Prototype products have been developed with the data obtained as a result of design studies. The schematic designed has been turned into a Printed Circuit Board (PCB) design by taking into account the EMC (Electromagnetic Compatibility) and LVD (Low Voltage Directive) compatibility. When designing the PCB, it was drawn taking into account its suitability for the plastic box to be used in the product. (Figure-2).

5. APPLICATION OF THE CONTROLLER

The controller developed in the study has found many application areas in residential projects, shopping malls and office campuses. As an example, lighting and mechanical automation have been carried out for energy efficiency at JustWork Istanbul office campus, which is located in Meydan shopping center in Umraniye, Istanbul and has about 100 offices of different sizes. JustWork is a 24/7 open shared workspace designed as a counterpart to the office campuses of technology companies such as Google, Facebook, Amazon in America. There are about 300 automation devices in this project based on the productivity of employees.

In the project, scenarios suitable for the human-centric lighting concept have been applied in all working offices for energy efficiency. With the help of sensors placed in each office separated by glass partitions to detect the entire room, unnecessary lighting of the lights has been prevented when there are no people in the room. Especially in the evening, with the sensors located in the corridors, DALI Master controller's gradual dimming function enabled energy savings without creating a dark environment by reducing it to 100% first, then 50% for the desired time and 10% after a while when people enter the corridor. In the daylight areas of the office, with constant light control, the lights are turned off in unnecessary cases and the desired target value of lighting is provided by dimming in necessary cases. By constantly preventing the lights from burning to the maximum, the life of lighting products has been extended. In addition, with the intelligent error notification of the DALI Master product, malfunctioning drivers and LEDs can be detected in the field. This contributes to the sustainability of the building and reduces maintenance costs. (Figure-3)

In the measurements made, it was determined that 20% savings were achieved in lighting and 30% savings in air conditioning as energy consumption values.

Fig.3. JustWork office campus

7. CONCLUSIONS

Intelligent building lighting control will be carried out with the DALI-2 standard compatible controller with ethernet, web interface developed within the scope of the study (Figure-4). In the places where the automation solution is used, a high contribution to energy efficiency will be made by performing intelligent building lighting control due to the web interface customized with the centralized control, imaging and human-centric lighting concept offered by the controller device

The lighting automation solution revealed within the scope of the study will be able to be used in health centers, offices, educational institutions and areas where greenhouse and farm animals are raised, which are important items in the agricultural sector. Energy savings will be achieved with the automation opportunity offered by the controller.

Fig.4. Controller

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REFERENCES

Yuksekkaya, T., (2016). Binalarda Enerji Verimliliği: AB ve Türk Mevzuatı. Binalarda Enerji Verimliliğinin Artırılması İçin Teknik Yardım Projesi El Kitabı

European Commission, (2017). Smart Building: Energy Efficiency Application. Digital Transformation Monitor, October

Kabakçı, O.K., (2020). Energy Efficiency In Buildings. T.C. Ministry of Energy and Natural Resources, Enerji Verimliliği ve Çevre Dairesi Başkanlığı

The World Bank Project, (2019). Turkey Energy Efficiency in Public Buildings. Project ID 162762, Envıronmental and Social Management Framework, November 5

IEC 62386, DALI and DALI-2 Standard

Memiş, Ö., (2019). İnsan odaklı aydınlatmanın farklı ortamlar için incelenmesi, insan üzerindeki fizyolojik ve psikolojik etkilerinin araştırılması. Yüksek Lisans Tezi, Marmara Üniversitesi

Maaspuro, M., (2015). DALI Master Controller Unit with a Wireless Connection and Application Software. Journal of Engineering and Applied Sciences, November

Robinson, T., (2015). Digital Addressable Lighting Interface (DALI)

Matijevics, E., (2011). KNX Controlled Lighting Over The DALI Network. Acta Technica Corviniensis - Bulletin of Engineering

Sysala, T. and Pribyslavsky, J. and N.eumann, P., (2016). Using MicroComputers for Lighting Appliance Control Using a DALI Bus. 20th International Conference on Circuits, Systems, Communications and Computers, October

Qipeng, H. and Xiaoyang, H., (2014). Mobile Lighting Control Scheme Based on DALI Protocol. Applied Mechanics and Materials (Volume 734), p970-974