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Microprocessor controlled luxmeter with automatic operation and digital data recording for long-term measurements (not only) of low illuminance

Abstract*. This contribution deals with the instrumental support of long-term sensing of light technical data measured under the night sky. The objective of such measurements is the quantification of obtrusive light and its different levels comparison in populated industrial areas and outside. For long-term measurements of low illuminance levels (approx. 10^{-2} lux) and luminance (about 10^{-3} cd/m^2) it is necessary to use not only measuring devices with high sensitivity, but also completely autonomous with the possibility of saving the measured data.*

Streszczenie. *Artykuł dotyczy urządzeń pomagających przy długoterminowym skanowaniu technicznych danych oświetlenia obserwowanego nocnego nieba. Celem pomiarów jest analiza zanieczyszczenia świetlnego w zaludnionych obszarach przemysłowych oraz poza nimi. Dla długoterminowych pomiarów niskich poziomów natężenia oświetlenia (cca 10^{-2} lx) i luminancji (około 10^{-3} cd/m^2) powinny być wykorzystywane nie tylko urządzenia o wysokiej czułości, ale również urządzenia całkowicie autonomiczne z możliwością zapisywania danych pomiarowych.* ***(Mikroprocesorowy luksomierz z cyfrowym zapisem danych do długoterminowych pomiarów natężenia oświetlenia)***

Keywords: obtrusive light, luminance, microcontroller
Słowa kluczowe: światło przeszkadzające, luminancja, mikrokontroler

Introduction

This article describes proposal and execution of luxmeter that is suitable for long-term evaluation of the state of obtrusive light at night. Objective evaluation of obtrusive light is gathering information on its effects in different locations and weather conditions. It mainly concerns the effect of public lighting. However, not only this source affects the luminance of the night sky. It is necessary to take into account the influence of other light sources such as windows, neon signs, commercial and industrial centres, etc.

Luxmeter development which meets the requirements for long-term measurement of very low levels of illuminance was caused by the impossibility to obtain such device on the market of measuring instruments. Measuring instruments available on the market, meeting the requirements for measuring low levels of illuminance, did not meet other requirements, which were mainly related to long-term data collection. This means that they did not meet the requirements for measured data transmission, minimizing consumption, automatic range switching, built-in real time clock, etc. The above mentioned reasons therefore led to the design proposal and implementation of the luxmeter which meets the requirements above.

Specification of the main requirements for the digital luxmeter development

When designing the concept of digital luxmeter the following requirements were taken into account:

- The curve sensitivity of the human eye for photopic vision - although the luxmeter has been primarily designed for measuring low levels of illuminance, which may correspond to brightness circumstances in which the human eye is located in mesopic to scotopic vision, so the sensor evaluating the incident radiation has been chosen according to the sensitivity curve of the human eye for photopic vision. The reason for this fundamental decision was the possibility of comparing the measured data with other devices. The dominant part of the instruments for light measuring technology has this sensibility, even though visual organ operates at low levels of luminance with other transfer between the incident radiation and visual perception.
- Wide measuring range from 10^{-2} lx to 10^{5} lx - is usable in the long-term measurements for illuminance acquiring not only at night but also during daylight hours. This data can be currently applied in the field of the incident radiation for photovoltaic power plants.
- Possibility of zero calibration - set to zero when measuring low levels of illuminance is necessary in this type of device.
- Long-term unattended operation - long-term operation is understood to detect illuminance levels under the night sky in various weather conditions, which makes it necessary to use fully autonomous operation.
- Power supply from battery or mains supply - power supply from the battery is necessary for field measurements with operation, i.e. the short-term measurements.
- Automatic range switching - is directly related to the measurement of illuminance even under daytime sky, which has great dynamics and for correct long-term measurements is necessary.
- Possibility of saving the measured data in memory and their later transfer to a computer - this feature is very well utilized in conjunction with real time clock with outdoor measurements.
- Ability to measure together with sending the measured data to a PC – has appeared in requirements due to measuring of rapid changes of illuminance, especially when verifying start-up characteristics of light sources.
- LCD display - with the possibility of changing its luminance appeared in the requirements due to the display luminance adjustment to different lighting conditions in the daytime and at night and of course also due to a reduction in consumption of long-term autonomous measurements.
- Real time clock independent on luxmeter power supply - are very important in terms of comparing the measured data from different locations with the assumption that these locations are meteorologically near and presumably the same conditions reflecting the sky. By such a comparison can be observed the influence of terrestrial light sources on obtrusive light in different locations [1].

The hardware part of the digital luxmeter

The basic part of luxmeter with high sensitivity (the ability to evaluate illuminance about 10^{-2} lx) is a quality sensor that is adapted by its sensitivity to the sensitivity curve of the human eye. If the sensor is not of sufficient quality, it is not possible to objectively evaluate illuminance not even by the best electronic circuit.

The Fig. 1 shows a block diagram of the luxmeter connection, which consists of the following main blocks:

- measurement block,
- microcontroller ATMEGA8,
- user interface,
- real time clock,
- EEPROM memory,
- USB communication,
- Power supply.

Measurement block consists of converter I/U, electronic switch of ranges and A/D converter. In order to ensure linear conversion of illuminance to electrical variable even from a very small values of illuminance, the current is evaluated at the output of the sensor, and if possible in a state short. This can be implemented by current-voltage converter with an operational amplifier. Currents, with whom the converter operates in the illuminances up to 1 lx are, however, very small, of the order of nA. To work with such small currents the operational amplifier must be able to evaluate very small input currents, preferably several orders smaller than the operating current. These requirements meet the operational amplifiers with FET inputs. Other important parameters, that must meet the operational amplifier is the smallest noise and drift. In order to operate the operational amplifier from a battery power, it must operate smoothly even at a low supply voltage. These requirements best suited operational amplifier AD822. Due to the maximum limit of external interference (ensuring sufficient accuracy) is the analogue part of the luxmeter shielded. To switch ranges the analog electronic switch ADG728 is used, whose five inputs and one output are connected in the feedback of operational amplifier AD822. Range switching is done through serially controlled I^2C interface which is served by ATMEGA8 microcontroller. The analog value from the operational amplifier is further converted to a digital value using the highly accurate 18-bit AD converter MCP3421, which is also controlled by the microcontroller through I2C serial interface.

Microcontroller ATMEGA8 by the ATMEL company ensures operation of the individual peripherals, which include electronic switch ranges, A/D converter, LCD display, four control buttons, real time clock, EEPROM memory and communication with the computer.

The user interface includes an LCD display and four control buttons. The LCD display is able to display a total of 64 characters, which are divided into four lines of sixteen characters. To be able to read the measured values even in poor visibility, it is possible for a LCD display to activate the backlight. Control buttons are used primarily to scroll through menu and for its settings.

Real time clock conveys current information that include the date and time and forms a circuit DS1338. To enable real-time clock to work even when the supply voltage is off, the DS1338 circuit is powered from the 3V stand-by battery. EEPROM memory – here is used serially programmable memory AT24C1024, which is organized as 131,072 words, each of which contains 8 bits. Memory is used here to store the measured illuminance values in certain time.

USB communication between the microcontroller and the computer is enabled by RS232/USB converter, which is formed by FT232RL circuit. Data communication between the microcontroller and the converter RS232/USB is galvanically isolated using two optocouplers. To the power supply circuit FT232RL is used 5V power from the computer, which is normally supplied through the USB cable [2].

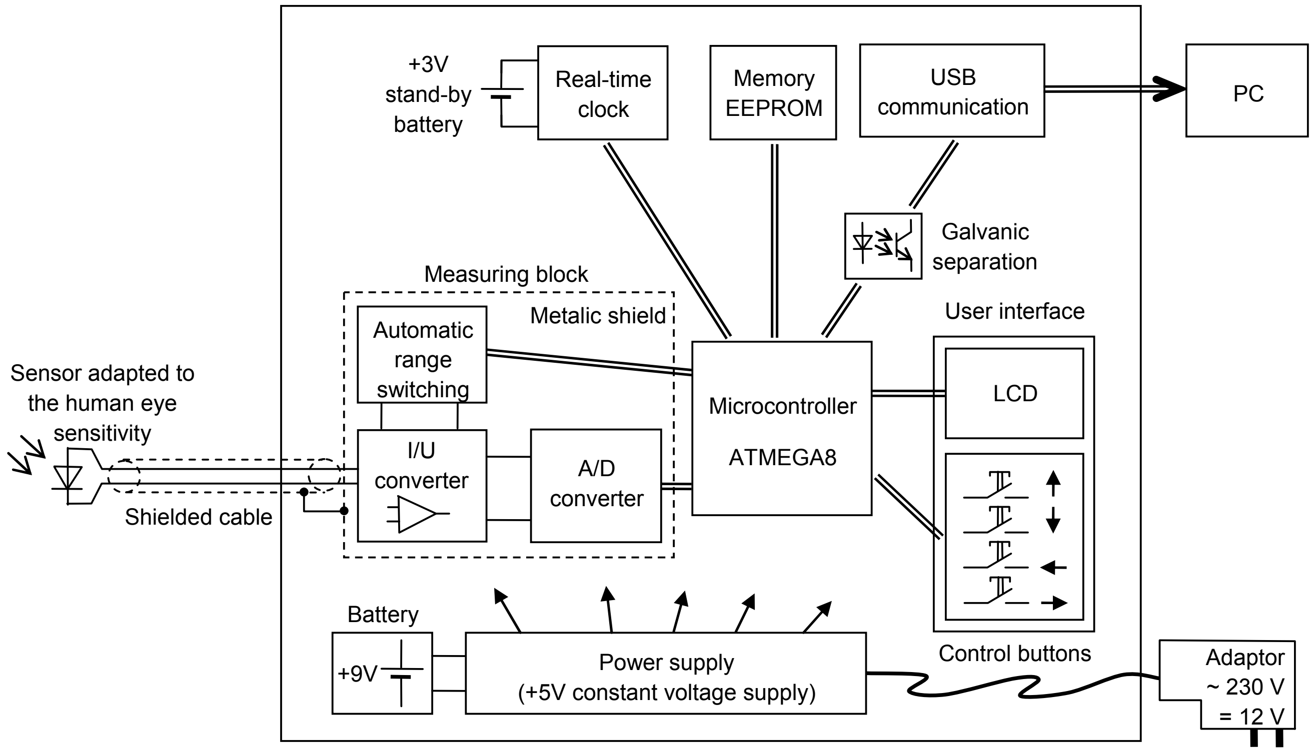

Fig.1. Block diagram of luxmeter connection

The software part of a digital luxmeter

Luxmeter can be connected to a computer through USB interface, which is nowadays the most widespread. The communication itself, however, is via the so-called "virtual serial port", which is created on the USB bus. It is a common method used in many measuring devices, GPS receivers and similarly. Communication between the luxmeter and the computer is in characters. For example, the value of 35.7 lx translates as ":35,7 lx<CR>", where CR is in this case ASCII value 13 (enter). To receive these measured data from a virtual serial port an application in LabVIEW system was created, which at certain time intervals stores the received data to a text file. It is possible, depending on the lighting, to cycle on and off selected appliance, which may be for instance a lamp. Output file consists of a text table containing the time and illuminance level. A new file is automatically created for each day. Output files can be easily imported for example into Excel and further processing here.

User menu of digital luxmeter

When you first turn the luxmeter on the LCD screen shows the value of lighting in Auto mode and also information about the current time and date. By using the Up/Down button it is possible to switch from the auto mode switching ranges on to a mode of manual settings with ranges up to 3 lx, 30 lx, 300 lx, 3 klx, 30 klx, 100 klx. By using the Left key we see the user menu containing the following menu:

- Offset cal.
- Set backlight
- Set date
- Set time
- Datalog period
- Start Datalog
- Stop Datalog
- Measured data
- USB communication

Shift the cursor to a specific menu in the user menu is done by using the Up/Down buttons. To confirm the selected menu the Right key is used, which also has the function of the Enter button.

<u>A detailed description of each menu of user menu:</u>

<u>Offset cal.:</u>

When selecting menu Offset cal., it automatically performs offset calibration for all ranges. Offset calibration must be carried out in a total darkness, which is possible only with the protective cap sensor.

<u>Set backlight:</u>

Time backlight of LCD display can be set in the Set backlight menu. The user can choose one of the following menus:

- none
- 1 s
- 2 s
- 5 s
- 10 s
- 30 s
- 1 min
- permanent

<u>Set date, Set time:</u>

The menu Set date or Set time is used to set the current date or time.

<u>Datalog period:</u>

Setting the period of the automatic storage of measured data to the EEPROM memory.

<u>Start Datalog, Datalog Stop:</u>

The menu Start datalog and Stop Datalog is used to begin or end the automatic storage of measured data to the EEPROM memory.

<u>Measured data:</u>

In the menu Measured data can be viewed the measured data stored in the EEPROM memory.

<u>USB communication</u>:

This menu allows USB communication when requesting storage of measured data from the EEPROM memory to the computer.

Photodocumentation of the implemented digital luxmeter

The Fig.2 shows the shouldered printed circuit board of digital luxmeter when viewed from top layer. LCD display shows the first part of menu of the user menu.

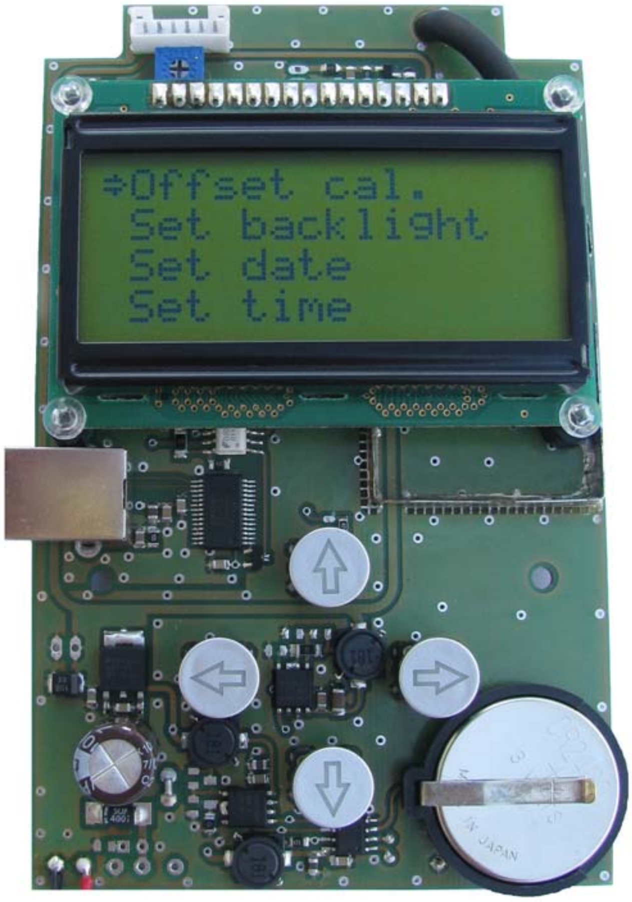

Fig.2. Shouldered printed circuit board of digital luxmeter when viewed from top layer

The Fig. 3 shows the shouldered printed circuit board of digital luxmeter when viewed from bottom layer. In the upper left part is in a tinned shielding box located main measuring unit of luxmeter. This measuring unit contains a double operational amplifier, digitally controlled analog switch, which is involved in the feedback of input operational amplifier.

A/D convertor is also part of this block. Supply of all integrated circuits is due to limitations of interference filtered using LC filters. Detail of the shielded analog-digital section of luxmeter is shown in the Fig. 4.

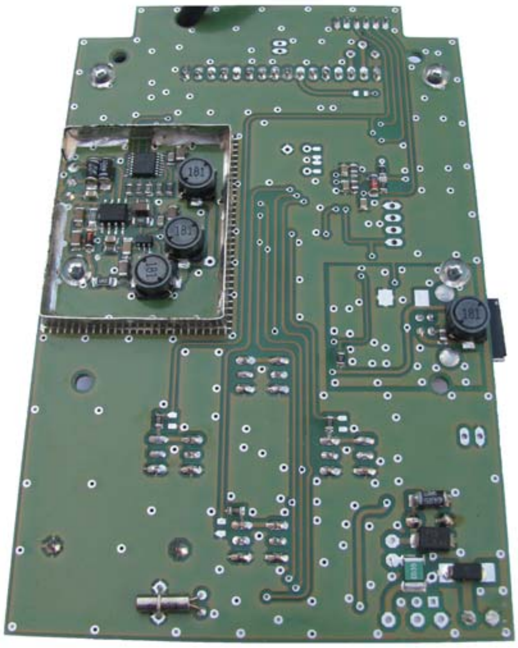

Fig.3. Shouldered printed circuit board of digital luxmeter when viewed from bottom layer

Fig.4. Detail of the shielded analog-digital section of luxmeter

Conclusion

By using the above mentioned luxmeter and its accessories can be measured and evaluated light-technical parameters of the night sky. A wide range of illuminance measurements is usable in long-term measurements for long-term unattended operation with the possibility of saving the measured data in memory and their further transfer to a computer. Due to the fact that the luxmeter includes a real time clock that is independent of the luxmeter power supply, it is possible to compare the measured data from different locations with the assumption that these locations are meteorologically near and the same conditions reflecting the sky can be assumed. With such a comparison the influence of terrestrial light sources for obtrusive light in different locations can be observed.

Acknowledgements

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REFERENCES

[1] Sokansky, K., Novak, T., Zavada, P., Kolar, V., Hrbac, R., Development of measuring instruments for long-term measurement of low level illuminances and luminances, *International Conference on Environment and Electrical Engineering*, Prague, (2010), 89-92, ISBN 978-1-4244-5374-0.

[2] Novak, T., Sokansky, K., Závada, P., Kolar, V., Hrbac, R., Pristroje pro dlouhodobe mereni nizkych urovni osvetlenosti a jasu, *Svetlo 2010*, (2010), 40-42. ISSN 1212-0812.

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