Luxímetro com Data Logger

Frederico Ferreira Pereira Alves Mimoso

Masters in Electronics Engineering

Instituto Superior Técnico (Taguspark), Av. Prof. Dr. Cavaco Silva 13, Porto Salvo, Lisboa, Portugal

Phone : +351-967315713, e-mail : fredericofpam@gmail.com

Abstract — This document regards the development of a light meter with a data logger, "Luxímetro com Data Logger". The intended device works as a tool for assessing the light quality on a space with an automated luminaire system which works based on human presence. This document gathers the procedures for building a light sensor and a motion sensor and for grouping these two sensors with a Raspberry Pi 3 model B resulting in a lux meter with data logger.

Keywords: Data Logger, light sensor, motion sensor, Raspberry PI 3, Light meter

I. INTRODUCTION

The light meter with a data logger was requested by ETAP Lighting. ETAP Lighting deals with the light management in workplaces and public spaces. In such places, ETAP installs automated luminaire systems that adapt the room illuminance regarding the circumstances and occupation. This device is intended to work as a tool for assessing this sort of automated light systems.

ETAP Lighting shown interest in a device that records illuminance measures with a certain frequency that increases when there is any person nearby the device. While human motion is detected, the device should also capture images alongside with the illuminance measures. Moreover, the device shall be also able to increase its sampling frequency when it detects a variation on successive illuminance measures higher than a configurable value.

II. DEVELOPMENT

i. Project Overview

The device was specified according to ETAP Lighting needs and conditions. The instrument will help certify that the light intensity is behaving accordingly to the desired light system configuration. The main light meter with data logger characteristics are:

Controller: Raspberry PI 3 model B

Camera: Camera V2 Raspberry PI of 8 MPX

Motion sensing: PIR (IRA-S210ST01)

Light sensor: Phototransistors TEPT5700 and BPW85

Light sensor range and resolution: 0-2000 lx; 10 lx

The device must measure illuminance, in lux with a configurable sampling time. The instrument shall operate in one of two possible monitoring modes:

• Normal mode: device collects illuminance with a standard sampling frequency.

• Intensive mode: The sampling frequency increases, the device takes pictures as the same time it measures illuminance.

The device should change from normal mode to intensive mode when it detects human motion or a variation between successive illuminance samples above a configurable limit.

The light sensor is designed with two phototransistors, the motion detector is designed with a PIR. An ADC is required for the interaction of these two sensors with the RPI. The chosen camera just needs to be plugged to the RPI for allowing software interaction.

The data saved into the SD card. The user interface is made with a VNC connection that allows access to the RPI operating system. The RPI is programmed to define the system behavior, to allow some configurations and data access.

ii. Photosensor

The photosensor is built with two phototransistors for measuring light emitted from different types of light sources [2] [3] [4].

The two chosen phototransistors must have a different response in light spectrum [1]. They should be selected to produce a response like the shown in Figure 1. The selected phototransistors, TEPT 5700 and BPW 85, have a similar response to the photodiodes Channel 0 and Channel 1, named in Figure 1, respectively [5] [6].

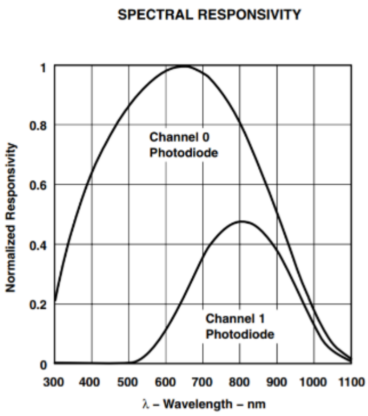

Figure 1- TSL 2561 – Photoelements spectral responsivity.

Each phototransistor must be polarized at the active zone. This way, the produced output current will have an almost linear response from 10 to 10000 lx to the illuminance that irradiates the phototransistor [7].

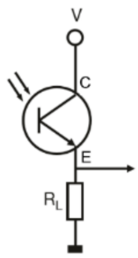

Figure 2 - Phototransistor in a common collector topology.

When applying the topology presented by the Figure 2, the resistor will force a voltage, at its terminals, that is proportional to the phototransistor incident light [7]. The circuit is configured with resistors that allow the best combination of sensitivity (voltage variation / lux) and linearity for each phototransistor.

To allow the RPI acquire the amplitude value of the analog signal produced by the photodetector, it is mandatory to introduce an ADC converter. Then, to improve the conversion accuracy, the output voltage at the output of each phototransistor emitter, configured as in Figure 2, is adapted to the input voltage range of the ADC using an amplifier, in an inverting topology, as suggested by Figure 3.

The voltage produced by the phototransistor TEPT 5700 from 0-4000 lx is fitted to the ADC input voltage range to increase the conversion resolution up to 1 lx per output code. The BPW 85 circuit, as it should produce an output with half of the sensitivity of the TEPT 5700 circuit, has its output voltage adapted, with the other amplifier in Figure 3, to fit the ADC input voltage range from 0-8000lx.

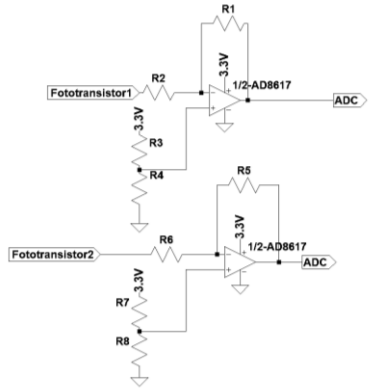

Figure 3 – Topology for amplifying the output signal of the circuit present in Figure 2.

Figures 4 and 5 show the output voltages of the TEPT 5700 and BPW 85 circuits, when exposed to lights emitted from two different lamps types. When the output voltages from the two phototransistors circuits are combined to obtain illuminance values, the result does rely on the light wavelength, making then possible to measure correctly illuminance from different light sources.

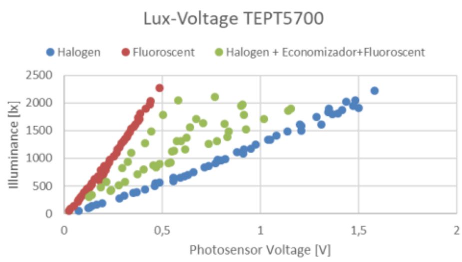

Figure 4 – Lux-Voltage Relation for TEPT5700 circuit. This shows the TEPT 5700 circuit voltage acquired with the ADC for different light types.

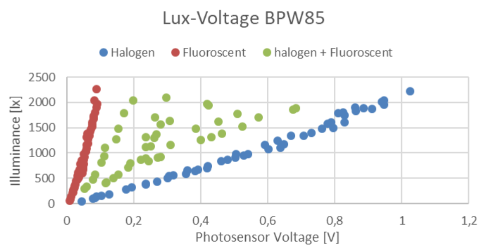

Figure 5 - Lux-Voltage Relation for BPW 85 circuit. This shows the TEPT 5700 circuit voltage acquired with the ADC for different light types.

The phototransistor with the lowest half-sensitivity angle limits the angular response of the photosensor. It is designed a case for the sensor that equalizes the angular response of the two phototransistors, through windows that cut the incident light from angles above than those imposed by the phototransistor with the lowest angular response, which in this case 25º [7].

ii. Motion Sensor

The motion detector is made from a PIR (Pyroelectric Infra-Red) sensor. This sensor detects human presence by sensing the body thermal radiation [10] [11].

The circuit to build a motion sensor with a PIR has two purposes: to amplify the weak signal presented at PIR's output and to filter the signal from disturbances that could lead to a false detection.

Figure 6 shows the circuit schematic for motion detection application with a PIR [9].

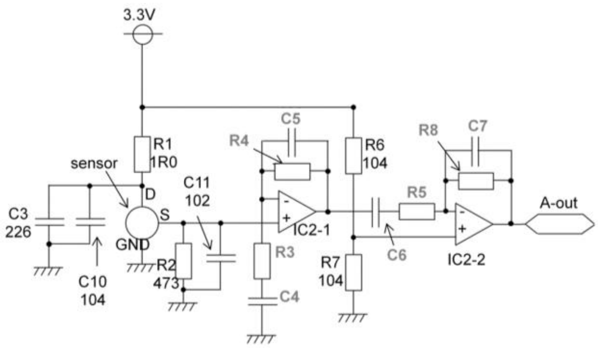

Figure 6 – Schematic for applying a PIR sensor as a motion detector [5].

The output voltage presented by the circuit, shown in Figure 7, is related with the presence of a human body under its detection zone. If the sensor's zone of action is unoccupied by people, its output voltage will remain constant. By the time that someone occupies the PIR action zone, it will sense the presence and it will produce a positive or negative output voltage variation [8] [10] [11].

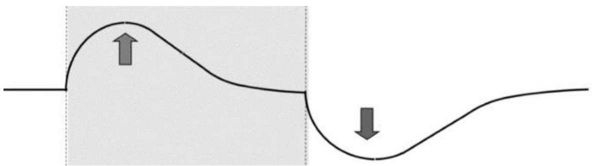

Figure 7 – PIR sensor - output voltage representation [9].

The voltage output positive or negative variation depends on the side that senses the body interference in first [10] [11]. Even though it is possible to define two thresholds (upper and lower) for the sensor's output voltage that allow the human presence detection.

The values for the resistors and capacitors in Figure 6 are obtained by choosing the gain that would allow a reasonable detection sensitivity for the application and the filter's cutoff frequencies that could reduce false detections.

iii. ADC

An ADC is needed for acquiring analog signals with the Raspberry Pi 3 model B. The circuit developed to operate the ADC regards the suggestion presented by the manufacturer.

A program is developed in the RPI operating system to configure and acquire samples of the different ADC channels. Figure 8 shows the results for 1000 ADC acquisitions with 512 samples and 2048 samples of two known values. With 2048 samples per acquisition, no standard deviations above 0.0001 were observed.

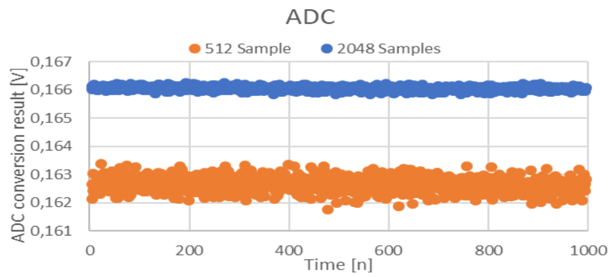

Figure 8 – AD7091R-5 - Result for 1000 conversions of two different DC, these voltages were acquired with a different number of samples per acquisition.

The number of samples per acquisition is determined by the required conversion accuracy. The light sensor, being used to quantify a very sensitive physical phenomenon, presents greater vulnerability to the conversion accuracy. It was concluded that it is required 2048 samples per acquisition to convert the light sensor voltage, and 512 samples per acquisition to acquire the motion detector voltage.

iv. Program

The RPI operating system is programmed in Language C. The RPI is connected to a network that provides Internet access and it facilitates a VNC connection that allows the interaction between the used and the RPI Linux workspace.

Light meter with Data Logger provides on its operating system, Raspbian, a configuration file and a folder with the illuminance logfiles, each one relative to a different day light activity. It also provides access to a folder where the pictures are stored, sorted by day and named by the hour of the photoshoot.

The program running on RPI, consists of six main routines each for:

- Time management: obtains date and time and determines when the light measurements and photographs are taken.

• Motion Detection: is always active, comparing if the motion sensor voltage exceeds the threshold limits. If so, signal's the system to the intensive mode.

• Light measuring: when it has permission from Time management, reads values from the light detector ADC Channel, writes down the time of acquisition and illuminance value on the relative daily logfile.

• Image capturing: waits for permission to shoot, when permission is given, sets the camera and captures a picture.

• Updates system parameters: searches for changes in system configuration file.

• Memory self-management: obtains the available memory space and ensures that the occupancy never gets over 95% by deleting older files.

The developed program allows user manipulation on the following settings: Motion detector threshold setting; Time between samples for the normal and intensive mode; Scheduling; Photo quality; Minimum illuminance value for taking a picture; Activate detection of light variation; Activate detection of light limit trespassing; Reset.

v. Calibration

To calibrate the instrument, a UNI-T UT 383 light meter is placed next to the developed light sensor. While changing light intensity, the phototransistors voltages and the light meter illuminance values are registered.

The responses of the two phototransistors circuits as a function of the light emitted by a halogen lamp and a fluorescent lamp are presented in Figures 4 and 5.

The relation between voltage of the two phototransistors and the illuminance of 0-2000 lux is approximately linear. Then the illuminance values are calculated from,

$$lux_{estimated} = a + b \times V_{phototransistor1} + c \times V_{phototransistor2} \qquad (7)$$

Where the coefficients A, B and C are obtained from a fit technique. The fit result is optimized if a methodology regarding the measurement error is applied.

III. Results

Light meter with Data Logger is submitted under tests in a standard environment, indicated by ETAP Lighting.

Light Meter Test

The developed light meter is compared to a DALI MSensor and a UNI-T UT 383 light meter. The sensor and both light meters are positioned to measure light illuminating the same area. The illuminance measured with the 3 instruments was registered for several instants. The results are presented in Figure 9.

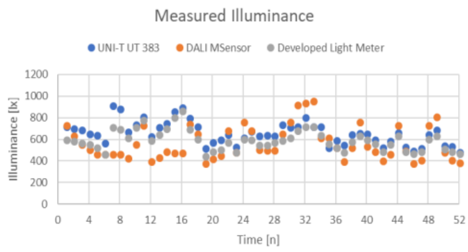

Figure 9 – Representation of measures made with the developed light meter, UNI-T UT 383 and the DALI MSensor.

In figure 9, the values presented by the UNI-T UT 383 are the most correct and accurate. From the three light meters this is the one that produces the lowest error, given by 4% + 5dgts. The DALI Msensor has a significant error and low accuracy. The produced light meter has better precision and accuracy to the UNI-T UT 383 illuminance measures than DALI MSensor.

Data Logger Test

On the second test, the light meter with data logger was put into work alongside with DALI MSensor, with both instruments recording light intensity. The results for the motion detector and the light meter registers are presented in Figures 10 and 11.

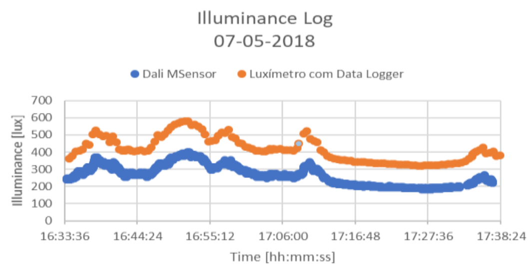

Figure 10 – Results for illuminance measures along time for the DALI MSensor and the developed light meter.

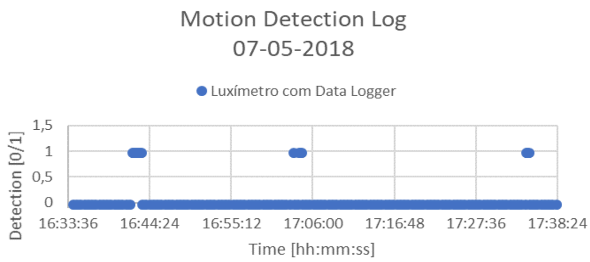

Figure 11 – Motion detection result for the Figure 10 time period.

The light record shows a similar behaviour of both instruments along time. As the light meter with data logger produces closer measures to a calibrated and more reliable light meter, it can be used to correct the DALI Msensor measures.

Light Variation Test

Lastly, the configuration that makes the Light meter with Data Loggerincrease its sampling frequency when the light varyies above a configurable value is tested. A threshold of 40% has been set for the light variation. As it can be seen on the results presented in Figures 12 and 13, a higher variation that 40% occurred between 19:59:31 and 20:04:47 leading the device to the intensive mode as it should be.

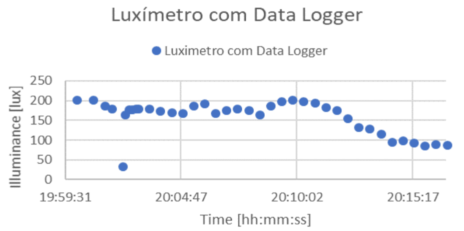

Figure 12 – “Luxímetro com Data Logger”, illuminance results.

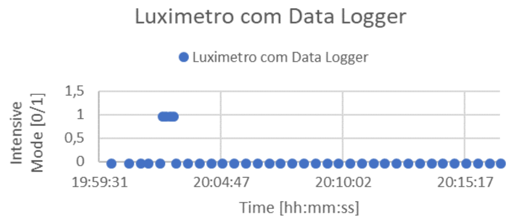

Figure 13 – “Luxímetro com Data Logger” – Intensive mode activity register for the time period of Figure 12 period.

Conclusion

The device has passed the submitted tests successfully. It behaves as ETAP Lighting’s specifications required. This device can be used to qualify and correct the DALI MSensor measures in comparison with the UNI-T UT 383. The final technical characteristics are presented in Table 1.

Max Resolution (light meter)	1 lx
Max Error (light meter)	37+8%*(ReadingValue)
Aperture Angle (light meter)	50º
Dynamic Range (light meter)	0-2000 lx
Distance Range (motion detector)	>2 m
Aperture Angle (motion detector)	>90º
Minimum time between samples (data logger)	7 s
Maximum time between samples (data logger)	48 h
Memory size (data logger)	>10 GiB
Picture Output format (camera)	.jpeg

Table 1 – “Luxímetro com Data Logger” characteristics

References

[1] Bahaa E. A. Saleh, Malvin Carl Teich; “Fundamentals of Photonics”, John Wiley & Sons, Inc., 2007.

[2] J.S Botero, F. E. López G. e J. F. Vargas B., “Characterization of photodetectors using a monochromator and a broadband light source in the xyz color space”, Facultad de Ingénierías, Instituto Tecnológico Metropolitano, Colombia, 5-Jan-2016.

[3] Intersil, Datasheet: Light to Digital Sensor ISL29020; Intersil, 20-Aug-2009.

[4] TAOS, Datasheet: phototransistor Light to Digital Sensor TSL2561; TAOS - Texas Advanced Optoelectronic Solutions, Mar-2009.

[5] Vishay Semiconductors, Datasheet: phototransistor TEPT 5700; Vishay, 08-Feb-2017.

[6] Vishay Semiconductors, Datasheet: phototransistor BPW 85; Vishay, 4- Aug-2014.

[7] Vishay Semiconductors, Application Note: Optical Sensors; Vishay; 10-Dec-2012.

[8] Jaeseok Yun e Sang-Shin Lee, “Human Movement Detection and Identification Using Pyroelectric Infrared Sensors”, Sensors 2014, 5-May-2014.

[9] Murata, Datasheet: IRA-S210ST01, Murata, 14-May-2018.

[10] Murata, Application Note: Pyroeletric Infrared Sensor Frednel Lens, Murata, 2-Nov-2017.

[11] David Van Ess, Application Note: Pyroelectric Infrared Motion Detector, Cypress MicroSystems, 5-Aug-2013.