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# MODULE FOR MEASURING INDOOR LIGHTING USING A GRAPHICAL INTERFACE IN VISUAL STUDIO AND ARDUINO BH1750 SENSORS

# MODULE FOR INDOOR LIGHTING MEASUREMENT USING A GRAPHICAL INTERFACE IN VISUAL STUDIO AND ARDUINO BH1750 SENSORS

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**Abstract:** The objective of this project is to design and develop a module for measuring indoor lighting, using low-cost materials and maintaining characteristics similar to or better than those of a commercial lux meter. Using reverse technology analysis, lighting measurement was improved, as the module has the ability to capture brightness level data and store it in an internal memory for later use, allowing it to provide a usage profile and be used in the study of luminaire selection. The interface displays lighting graphs over time, has the function to calculate the maximum average uniformity ratio (IC) based on NOM-025-STPS-2008, data capture and workspace selection functions, as well as the height at which the luminaires are located, so that the data acquired by the Arduino HB1750 sensor can be managed in a user-friendly manner. The module has the advantage of being affordable, as all its components are low-cost, and it is a system that can be easily reproduced and used for educational purposes in educational institutions.
**Keywords**: lighting measurement, educational module, educational lux meter, BH1750 digital sensor, Arduino UNO, Visual Studio, graphical interface, NOM-025-STPS-2008.

**Abstract:** The objective of this work is the design and development of a module to measure indoor lighting, using low-cost material and maintaining similar or improved characteristics to those that would be obtained with a commercial lux meter. Using reverse technology analysis, lighting measurement was improved since the module has the capacity to capture data on brightness levels and store them in an internal memory for later use, which allows them to provide a usage profile and be used in the luminaire selection study. The interface displays lighting graphs with respect to time, has the function for calculating the maximum average uniformity ratio (IC) based on NOM-025-STPS-2008, the data acquisition function, and the selection of the work area, in addition to the height at which the luminaires are located, so the data acquired by the Arduino HB1750 sensor can be managed in a user-friendly way. The module has the advantage of being affordable, as all its components are inexpensive. This system can be easily reproduced and used for educational purposes in educational institutions.
**Keywords**: illumination measurement, didactic module, educational luxmeter, digital sensor BH1750, Arduino UNO, Visual Studio, graphical interface, NOM-025-STPS-2008.

## INTRODUCTION

With the growing need to equip public university laboratories with efficient and economical measuring equipment, given that most have limited resources, a cost-benefit analysis was carried out to develop teaching modules for obtaining indoor lighting levels. These would aid in understanding the methodology of studying lighting systems, as well as being used for teaching purposes, mainly in classes on lighting systems, electrical installations, among others, taught in electrical engineering programs at technical institutes. The equipment that was designed has new features that others on the market do not have, such as taking measurements and graphing in real time, calculating the average lighting of a measured plane, as well as having a graphical interface and memory for readings. The proposed design has the advantage of being able to store readings by capturing measurements through the graphical interface and saving the information in a file that can be used in the calculation of lighting systems. It also has a visual aid that shows the measurements obtained from the sensors in real time. One of the extra functions available is the calculation of the area index (IC) and the uniformity ratio (Umax) based on NOM-025-STPS-2008.

General objective

To design and build a low-cost module for measuring indoor lighting, using BH1750 sensors and an Arduino UNO board, complemented by a graphical interface developed in Visual Studio, in order to represent and analyze the data captured in real time in accordance with current regulations on lighting conditions.

Specific objectives

- Investigate the operation of lux meters and the basic principles of illuminance measurement.
- Design and selection of the appropriate electronic components and materials for the construction of the module.
- Program the Arduino UNO microcontroller to capture, process, and transmit the lighting data obtained by the BH1750 sensors.

- Develop a graphical interface in Visual Studio that allows real-time data graphing and calculations related to average illumination, area index (AI), and uniformity ratio (Umax).
- Design the physical parts of the module using CAD software (SolidWorks) and print them using additive manufacturing technology (3D printing).
- Assemble and validate the operation of several units of the module for educational and practical measurement purposes.

### Justification

Effective teaching of concepts related to lighting measurement in indoor spaces faces significant limitations when the available instrumental resources are scarce. In the case of the Electrical Engineering laboratory at the National Technological Institute of Mexico, Ciudad Juárez Campus, the availability of only two lux meters hinders the active participation of all students in experimental practices, especially in large groups. This situation compromises the quality of learning and limits the development of practical skills essential for their professional training. In view of this problem, the development of a low-cost, easy-to-manufacture, and intuitive lighting measurement module is proposed, which can be reproduced in multiple units. These modules are designed to be operated by the students themselves, promoting a more interactive and equitable learning experience. Unlike commercial lux meters, the proposed devices integrate a graphical interface that allows data to be recorded, displayed, and analyzed in real time, facilitating a better understanding of variations in lighting levels.

In addition, they incorporate multiple sensors that allow simultaneous measurements to be taken at different points on a surface, reducing manual intervention and improving the accuracy of the results obtained. This functionality represents a significant improvement over traditional instruments, which require manual movement of the sensor and only display specific values on the screen. Together, these features make the proposed module an efficient, accessible teaching tool that can be adapted to different educational environments, thereby strengthening students' technical training.

## DEVELOPMENT

This study was developed using a quantitative and applied approach, in that it sought to design, implement, and validate a functional indoor lighting measurement system using low-cost technology. This is an experimental type of research, as it involved the direct intervention of the researcher on controlled variables (electronic components, software, lighting conditions), in order to observe the effects generated by the proposed solution (Hernández, Fernández & Baptista, 2014).

The methodological design was cross-sectional and laboratory-based, as the data were collected at a single point in time during the prototype testing, without manipulating the conditions over time. The nature of the design can also be considered constructivist-instrumental, since the purpose was to create a functional teaching resource aligned with specific educational needs, as proposed by the educational technological innovation approaches developed by González and Escudero (2003). As a basis for the implementation of the prototype, previous contributions by Ortiz Villicaña (2023) were revisited, who proposed a functional module for measuring indoor lighting using BH1750 sensors and an interface in Visual Studio, fundamentals that were expanded upon in this study.

As mentioned by Francisco Quintanilla et al. (2025) in their article "Prototype for measuring light in laboratories and classrooms (PMLLA)," the use of prototypes for measuring lighting levels in classrooms and laboratories can be developed through programming and the use of readily available electronic components.

The study population consisted of the interior environments of the Electrical Engineering laboratory at the National Technological Institute of Mexico, Ciudad Juárez Campus. The sample was intentional and corresponded to different points of measurement of light intensity in specific areas of the laboratory.

Structured observation techniques were used to obtain real-time lighting data using a module built with BH1750 sensors connected to an Arduino UNO board (Arduino, n.d.), programmed in the Arduino IDE development environment using C language (Rao, 2021). The data was sent to a graphical interface developed in Visual Studio 2022 with C# language, which allowed the measurements to be visualized and recorded in the form of graphs and numerical values. As mentioned by José Ignacio Aguilar Carrasco et al. (2023) in their article "Development of a lux meter mobile application considering the minimum lighting levels established in NOM-025-STPS-2008," as pointed out by Aguilar Carrasco, Cuevas Torres, and García López (2023), the quality of the measurements obtained from a prototype can be comparable to those obtained by a commercial lux meter, with improvements possible in the form of data acquisition.

The test data was obtained using the measurement prototype consisting of hardware (sensors, I2C TCA9548A multiplexer, Arduino UNO) and customized software. Official Mexican technical standards (NOM-025-STPS-2008) were also used as a reference to validate the acceptable values of illuminance, area index (IC), and uniformity ratio (Umax) obtained by the system (STPS, 2008; CONUEE, 2018).

The BH1750 sensor, widely documented by ROHM Semiconductor (n.d.) for its accuracy and sensitivity, allowed reliable data to be captured at different points in the laboratory. Figure 1 shows the user interface displaying the graphs obtained in real time from the data collected by the module.

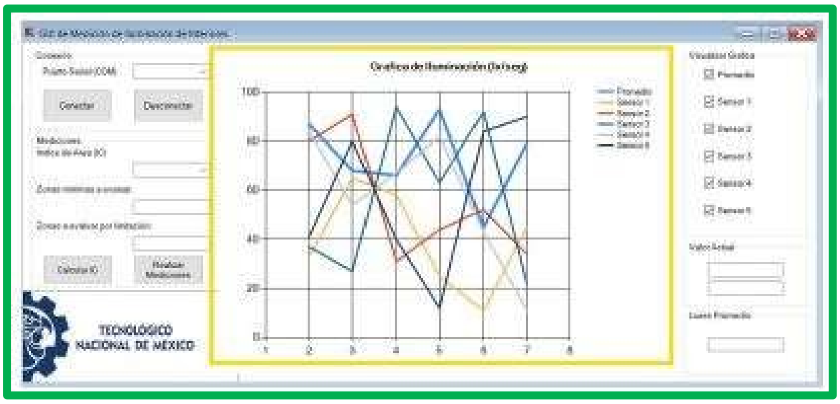


**Figure 1**. *User interface*.

**Source**: Own work (2025).

The area index (AI) and uniformity ratio (Umax) are calculated using a calculator programmed into the interface, which is shown in Figure 2.

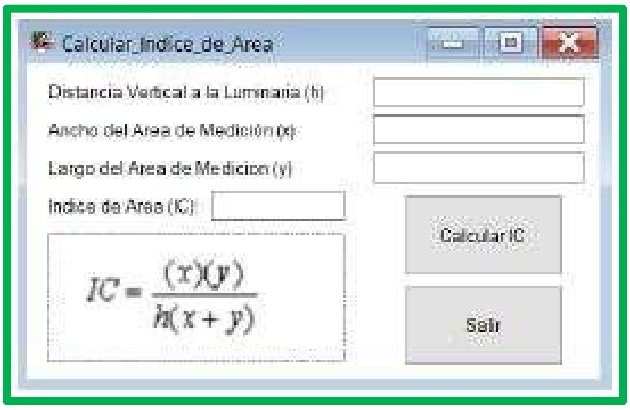


**Figure 2**. *Calculator for the area index (AI).*

**Source**: Own work (2025).

The study was conducted under the principles of transparency, scientific responsibility, and exclusive academic use.

Among the main limitations are the dependence on a commercial lux meter as a reference for validation, as well as the failure to evaluate the module in adverse environmental conditions, such as dust, vibration, or humidity, which restricts its current use to controlled indoor spaces.

## DISCUSSION AND ANALYSIS OF RESULTS

The implementation of the lighting measurement module developed in this study allowed us to verify its functional and pedagogical viability as an alternative to conventional lux meters. Based on the electronic design with BH1750 sensors, Arduino UNO, and a TCA9548A I2C multiplexer, reliable data on indoor illuminance levels was collected, with real-time visualization and analysis capabilities through a graphical interface developed in Visual Studio.

During field tests in indoor spaces at the electrical engineering laboratory of the Tecnológico Nacional de México, Ciudad Juárez Campus, the lighting values obtained by the module remained within an acceptable margin of error when compared to the data provided by a certified commercial lux meter. This behavior confirms that, despite its low cost, the system meets the technical requirements established by the NOM-025-STPS-2008 standard in terms of measurement and analysis of illuminance and its spatial distribution. In addition, a qualitative comparison was made between the developed module and two certified commercial lux meters (Extech and Mastech brands), commonly used in academic settings. Although commercial equipment offers superior accuracy and is more portable, the proposed system stands out for its low cost, integrated graphical interface, data storage, and real-time display capability. These features make it particularly suitable for educational purposes, with a margin of error of less than 10% compared to professional devices. Table 1 shows a comparison of the developed lux meter and commercial ones.

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**Table 1**. *Comparative table of the educational lux meter versus commercial lux meters.*

| Característica | Luxómetro Didáctico | Extech LT300 | Mastech MS6612 |
|---|---|---|---|
| Precio estimado | $800 – $1,200 MXN (materiales + impresión 3D) | $5,500 – $6,500 MXN | $2,000 – $2,500 MXN |
| Rango de medición (Lux) | 1 – 65,535 Lux (según sensor BH1750) | 0 – 400,000 Lux | 0 – 200,000 Lux |
| Unidades | Lux | Lux / Fc (Foot-candles) | Lux / Fc |
| Interfaz gráfica | ✓ Visual Studio, con gráficas en tiempo | ✗ Solo pantalla LCD | ✗ Solo pantalla LCD con barra |
| Almacenamiento de datos | ✓ En archivo .txt o base de datos | ✗ No almacena datos | ✗ No almacena datos |
| Portabilidad | ✗ Depende de PC | ✓ Compacto y portátil | ✓ Compacto y portátil |
| Sensor | BH1750 (digital, I2C, sensible y económico) | Fotodiodo de silicio con filtro óptico | Sensor fotoeléctrico con corrección CIE |
| Precisión | ±10 % aprox. respecto a comercial | ±5 % lectura + 0.5 % escala | ±3 % lectura (lámpara incandescente) |
| Retención de datos (Hold) | ✓ (por programación) | ✓ | ✓ |
| Pico / Máx / Mín | ✓ (implementable vía software) | ✓ Máx / Mín / Pico 10µs | ✓ Máx / Mín / Pico |
| Medición | ✓ (programable) | ✓ | ✓ |
| Alimentación | PC + Arduino UNO + 5V USB | Batería 9V | Batería 9V |
| Apagado | ✗ No incluido | ✓ | ✓ |
| Ventajas | Bajo costo, didáctico, visual, expandible | Alta precisión, robusto, confiable | Económico, práctico, buena precisión |
| Desventajas | No portátil, depende de PC, no calibrado | Alto costo, sin almacenamient | Precisión media, sin interfaz visual |
| Ideal para: | Educación, enseñanza práctica, proyectos DIY | Profesionales de iluminación, laboratorios | Estudiantes, técnicos, arquitectura |

**Source**: Own work (2025).

A significant finding was the effectiveness of the I2C multiplexer in expanding the number of sensors connected to a single Arduino board without loss of accuracy, which allowed simultaneous measurements to be taken in different areas of the work surface. This approach solved a common limitation in low-cost devices and represents a practical improvement over traditional lux meters that require manual movement.

From the perspective of constructivist theory applied to technology education (Jonassen, 1999; Papert, 1980), the possibility for each group of students to use their own module facilitates active learning and the development of skills in analysis, data interpretation, and the application of technical standards. In contrast to previous studies focused on industrial automation, this work stands out for its focus on educational accessibility (García & Pérez, 2019; Martínez & Sánchez, 2020). The project is part of the line of research on smart measurement systems and digital teaching resources, proposing a replicable, economical solution that can be adapted to various educational contexts. Its novelty lies in the effective integration of low-cost commercial components with a functional pedagogical design, opening up the possibility of future applications in light industrial environments, or as a base platform for more complex environmental monitoring using sensor networks. In contrast to previous studies focused on industrial automation, this work stands out for its focus on educational accessibility, making it a novel contribution to the field of educational instrumentation with emerging technologies.

## CONCLUSIONS

The development of a lighting measurement module based on Arduino UNO and BH1750 sensors shows that it is technically possible to partially replace commercial lux meters in educational contexts without compromising the quality or functionality required by official Mexican standards. Following the implementation of the system, it was found that the accuracy of the measurements is consistent with the expected theoretical values and those obtained by commercial devices, provided that the electrical and physical design parameters established during the development phase are respected.

The integration of multiple sensors using the I2C protocol and a TCA9548A multiplexer efficiently solved the addressing problem, allowing simultaneous captures at different points on the work plane. This represents a methodological improvement over the traditional procedure with single-point lux meters. In pedagogical terms, the system allows each group of students to have a functional unit, facilitating active participation in measurements and analysis of real data, which promotes discovery learning and the appropriation of normative concepts such as the area index (AI) and the uniformity ratio (Umax).

However, questions remain regarding the stability of measurements in conditions of high humidity or dust, as well as the behavior of the system in the face of electromagnetic interference present in certain industrial environments. The portability of the module was also identified as an area for improvement, as it currently depends on a computer for its operation. It is therefore proposed that future research delve deeper into the environmental robustness of the system and its possible energy and operational autonomy, integrating local storage or wireless data transmission to expand its applicability beyond the educational context.

In addition to the above, the developed system not only meets the technical requirements for lighting measurement, but also represents a viable and accessible educational alternative. Thanks to its low cost, ease of construction, and improved functionality compared to traditional devices, this module contributes significantly to practical teaching in electrical engineering. Its implementation can democratize access to measuring instruments in institutions with limited resources, promoting active and meaningful learning.

## FUTURE WORK

Based on this research, the aim is to adjust the interface in the future so that outdoor measurements, taking into account the applicable regulations for this type of calculation and allowing the type of measurement to be selected, in addition to complying with NOM-013-ENER-2013 (SENER, 2013), and providing the module with a screen for reading the measurement in progress.

## REFERENCES

Arduino. (n.d.). *Arduino UNO Rev3*. https://www.arduino.cc/en/Main/ArduinoBoardUno

Aguilar Carrasco, J. I., Cuevas Torres, O. M., & García López, I. F. (2023). Development of a luxmeter-type mobile application considering the minimum lighting levels established in Mexican Official Standard 025 STPS 2008. *Transdigital, 4*(7), 1–23. https://doi.org/10.56162/transdigital183

ROHM Semiconductor. (n.d.). *BH1750 datasheet: Digital ambient light sensor IC*. https://www.mouser.com/datasheet/2/348/bh1750fvi-e-186247.pdf

National Commission for the Efficient Use of Energy (CONUEE). (2018). *Technical guide for the evaluation of illuminance in work areas*. https://www.gob.mx/conuee

García, J., & Pérez, L. (2019). Development of educational prototypes with sensors and microcontrollers for teaching electronics. *Electronic Journal of Technology Education, 18*(3), 45–58.

González, F., & Escudero, T. (2003). *Evaluation of educational innovations*. Morata.

Hernández, R., Fernández, C., & Baptista, P. (2014). *Research methodology* (6th ed.). McGraw-Hill.

Jonassen, D. H. (1999). *Designing constructivist learning environments*. Educational Technology Publications.

Martínez, A., & Sánchez, D. (2020). Measuring illuminance in indoor spaces using digital sensors and microcontrollers. *Ibero-American Journal of Educational Technology, 10*(1), 21–35.

Ortiz Villicaña, A. A. (2023). *Design of a module for measuring indoor lighting using a Visual Studio graphical interface and the Arduino BH1750 sensor* [Bachelor's thesis, National Technological Institute of Mexico, Ciudad Juárez Campus].

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Quintanilla Moreno, F. J., Meza Espinosa, J. J., & Reynoso Gómez, B. L. (2025). Prototype for measuring light in laboratories and classrooms (PMLLA). *RECIBE, 14*(1), E1–E17. https://doi.org/10.32870/recibe.v14i1.356

Rao, R. P. (2021). *C Programming for Arduino*. Packt Publishing.

Ministry of Labor and Social Welfare (STPS). (2008). *NOM-025-STPS-2008: Lighting conditions in workplaces*. https://www.gob.mx/stps

Ministry of Energy (SENER). (2013). *NOM-013-ENER-2013: Energy efficiency in lighting systems for outdoor roads*. https://www.gob.mx/sener

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| Software | Ortiz Villicaña Aaron |
| Validation | Miriam Magdalena González Muñoz, Gerardo López Fierro, Aarón Ortiz Villicaña Alejandro |
| Formal Analysis | Ríos Fernández Nancy Esperanza |
| Research | González Muñoz Miriam Magdalena, López Fierro Gerardo, Ortiz Villicaña Aarón Alejandro |
| Resources | Castañeda Fierro Francisco, Ortiz Villicaña Aarón Alejandro |
| Data curation | Ríos Fernández Nancy Esperanza |
| Writing - Preparation of the original draft | Castañeda Fierro Francisco, González Muñoz Miriam Magdalena, López Fierro Gerardo |
| Writing - Revision and editing | Ríos Fernández Nancy Esperanza |
| Visualization | González Muñoz Miriam Magdalena, López Fierro Gerardo, Ortiz Villicaña Aaron Alejandro |
| Supervision | Castañeda Fierro Francisco |
| Administration of Project | Castañeda Fierro Francisco |
| Fund Acquisition | Castañeda Fierro, Francisco; Ortiz Villicaña, Aaron Alejandro |