# Integrated Spectroradiometer: Utilizing FLAME-VIR with Single Board Computer

**Keywords:** Spectroradiometer, Raspberry Pi, Single Board Computer, Automatic-Calibration Method, Integrated System.

## 1. Introduction

Single-board computers (SBCs) are utilized for processing and controlling data across various systems, such as spectroradiometers. These compact and highly integrated devices offer an efficient and versatile solution for a range of monitoring and analysis applications, regardless of the specific field of study. The utilization of SBCs significantly simplifies the design and implementation of control systems, enabling seamless integration with spectroradiometer components. A key benefit of this approach is its capacity to deliver robust computational performance in a compact and energy-efficient format, ideal for mobile, field, or remote applications (Álvarez, Mozo, Durán, 2021). The SBC reduces implementation and maintenance costs but also expands the possibilities for research and monitoring across a variety of scientific and industrial contexts.

It is crucial to highlight that utilizing conventional spectroradiometers frequently encounters considerable hurdles, primarily due to their high cost. Conventional spectroradiometers tend to be complex and expensive, limiting their accessibility and applicability in many research and monitoring contexts. In addition to the initial acquisition costs, traditional spectroradiometers may also require substantial investments in infrastructure and maintenance over time. These financial barriers can restrict the use of these devices in areas where resources are limited, hindering the conduct of important studies and large-scale data collection (Mancini, Frontoni, Zingaretti, 2016). In this regard, single-board computers (SBC) offer an attractive alternative, providing a more affordable and efficient solution for spectroradiometer control, which can democratize access to these technologies and expand their applications in a variety of scientific and industrial fields. It is recommended to read Ghael, Solanki and Sahu (2020).

## 2. Background

Spectroradiometers are instruments used to measure the spectral distribution of electromagnetic radiation at different wavelengths. These devices are fundamental in different areas, including remote sensing, atmospheric studies, and materials analysis. However, the process of developing, acquiring, and maintaining spectroradiometers can be expensive and challenging. Firstly, the development of a high-quality spectroradiometer requires significant technical expertise and substantial financial resources. The design and manufacture of precise optical components, sensitive detectors, and sophisticated electronics entail significant investments in research and development. Additionally, ensuring the accuracy and proper calibration of the instrument requires deep knowledge of optics, spectroscopy, and electronics, as well as access to specialized testing and calibration facilities (Mancini, Frontoni, Zingaretti, 2016; Pacheco-Labrador et al., 2019).

High-quality spectroradiometers are often manufactured in limited quantities. These may be produced by specialized companies, resulting in high prices due to the scarcity of supply and demand for high-precision instruments. Periodic calibration is essential to ensure the accuracy and reliability of measurements over time. This may involve sending the instrument to specialized laboratories or hiring qualified technicians to perform calibration procedures on-site (Feister et al., 2005; Pacheco-Labrador et al., 2019).

Radiometric calibration aims to correct any deviations or irregularities in the spectral data obtained by the FLAME-NIR spectrometer, ensuring that the measurements accurately reflect the spectral characteristics of the object or material being analyzed. This process demands correcting effects, such as detector sensitivity variation across the spectrum, compensating for distortions caused by optical components, reducing noise, and ensuring a linear dark current. A fundamental part of radiometric calibration is the use of high-quality and reliable reference standards. These standards may include reference light sources with known spectra and reference materials with well-characterized spectral properties (Mancini, Frontoni, Zingaretti, 2016; Natesan et al., 2017). By comparing the measurements obtained by the spectrometer with the reference standards, it is possible to determine and correct any deviation or systematic error in the measurements. Therefore, this study aims to develop an automatic calibration system for a spectroradiometer. Additionally, methods will be proposed for the calibration and automation of the measurement processes involved. One notable aspect pertains to the necessity of calibrating the spectrometer through its interface. Nevertheless, the current study endeavors to formulate a methodology aimed at minimizing reliance on said interface. This methodology seeks to streamline the process by utilizing only essential components for real-time data visualization.

## 3. Materials and methods

A system was constructed for obtaining and calibrating the FLAME-NIR spectroradiometer, which by within the range of 950nm – 1650 nm, with signal-to-noise ratio 6000:1 and optical resolution of 10nm (25 microns slit) (Ocean Optics, 2016). The equations presented below were derived based on the procedure that OceanView would automatically perform. Thus, the following system of equations is established, and ultimately, the aim is to obtain the reflectance factor value.

$$Op_1 = R - B \quad (1)$$
$$Op_2 = O - B \quad (2)$$
$$Op_3 = Op_2 / Op_1 \quad (3)$$
$$Op_4 = Reflection(K \times Op_3) \quad (4)$$

Where $R$ and $B$ are the reference and background measurements in digital numbers, respectively, that will be used for calibration. $O$ represents the original signal, i.e., the measurement being performed, and finally, reflection is a conversion operation from digital number to reflectance values, where $K$ is a constant with the value of 1000. It is noteworthy that the process described in

Equation 1 is performed only during the calibration of measurements, while the other equations are applied to all measurements. And the result is given by the variable $Op_4$.

Additionally, commonly for its use, the software automatically finds a suitable exposure time. However, this study aims to eliminate the need for any graphical interface, proposing instead a methodology based on the curve behavior for validation. Upon analyzing the computational curve, it is expected that the peak of the energy curve obtained lies between 20 and 25% below its maximum potential, with the maximum value determined from the manual. Therefore, the Raspberry Pi can autonomously determine the most suitable integration time. Moreover, to ensure redundancy in the system, each measurement will be conducted a minimum of 10 times, with proper labeling of all data. This approach facilitates data recovery in the event of calculation issues, enabling manual analysis when necessary.

Furthermore, aiming to enable field use and facilitate visualization, it is proposed to create a mobile hotspot for access via cellphone or laptop. From this hotspot, access via NGINX is made possible. NGINX is an open-source web server and reverse proxy known for its high performance, stability, and low resource consumption. Thus, with an understanding of all requirements for utilization on a Raspberry Pi 4B, considering resource and energy consumption, it is anticipated that all measurements can be made available in the field. This will enable validation and verification in case any issues arise. The proposed system is depicted in Figure 1.

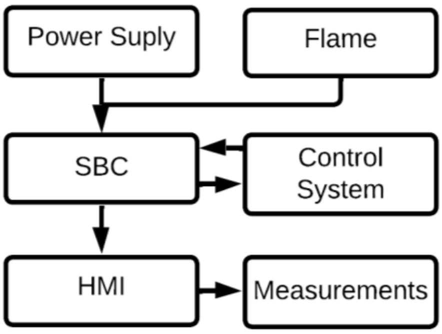


Figure 1. Scheme for the automatic system calibration.

## 4. Results and discussion

The construction of all the hardware to be used has been completed. The proposed system includes LEDs for signaling whether the process is occurring correctly or if any issues occurred. In the latter case, the system automatically restarts. Additionally, it features four buttons that interface with the user and are only activated when pressed for a few seconds. These buttons are responsible for obtaining the reference measurement, the dark target measurement, the target measurements based on the reference and dark target, as per the previously demonstrated equations, and finally, the button to shut down the system, preventing it from being disconnected from power and risking data corruption. Moreover, the system can display all acquired data organized by measurement time on the web page accessible when connecting to its mobile hotspot. Numerous tests have been conducted to ensure the proposed system's reliability and integrity, particularly due to the absence of a graphical interface. From the measurements performed, it was observed that the system is functional. Thus, the constructed system can be seen in Figure 2.

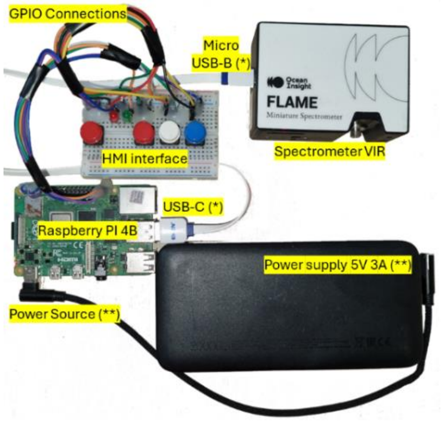


Figure 2. Proposed hardware layout.

## 5. Conclusion and next steps

It was possible to propose a system for the automatic calibration of the spectroradiometer, allowing the automatically obtained value to be sufficient for measurements, even in the presence of greater issues such as non-numeric values or outliers. Furthermore, it enables the provision of all information locally for system validation. As the next steps, intercalibration and validation with other hyperspectral sensors are planned to ensure measurement accuracy and value redundancy, from dark current measurements to reflectance acquirements. Additionally, a series of tests with different types of targets are intended to validate and study their spectral behavior. Due to the utilization of the SBC, it still allows for usage in various real-time data collection applications, in addition to providing greater control over information triggering and calibration processes. Furthermore, it may enable integration with mobile devices such as agricultural machinery for crop studies, backpacks for soil data acquisition, and even drones for aerial surveys.

## Acknowledges

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