A Wrist Worn Internet-of-Things Sensor Node for Wearable Equivalent Daylight Illuminance Monitoring

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***Abstract* — The Light openness assumes a pivotal part in directing human physiology and conduct. Notwithstanding, current wearable Web of-Things (I o T) gadgets need checking of light openness. This paper presents a wearable light sensor hub intended to fill this hole by giving observing of identical sunshine illuminance openness in certifiable settings. The framework plan, electronic execution testing, and precision of identical light illuminance estimations contrasted with an aligned unearthly source are introduced. Factors, for example, sensor arrangement on various pieces of the body and reasonable use north of seven days are additionally tended to. The gadget works for 3.5 days between charges, with an inspecting time of 30 seconds and 10 channels of estimation over the scope of 415-910 nm. Results show a mean outright mistake of under 0.07 log lx for estimated α-opic identical sunlight illuminance. This work gives a stage to future examinations concerning certifiable light openness checking and I o T-based lighting control.**

I. INTRODUCTION

The Light serves as a vital external stimulus that influences human physiology and behavior on a daily basis. It regulates various non-image forming responses, including the regulation of the circadian clock, melatonin secretion, alertness, sleep, mood, and cognitive performance. The amount and quality of light exposure have acute effects on alertness, mood, and cognitive performance, emphasizing the importance of accurately monitoring light exposure for individual health and well-being. While wearable Internet-of-Things (I o T) devices have become increasingly prevalent in monitoring various aspects of human health, such as activity levels and heart rate, they often lack the capability to accurately measure light exposure. This gap in current wearable technology presents a significant opportunity for the development of a wearable light sensor node that can provide real-time monitoring of equivalent daylight illuminance exposure in real-world settings. wearable technology presents a significant opportunity for the development of a wearable light sensor node that can provide real-time monitoring of equivalent daylight illuminance exposure in real-world settings. Prevalent in monitoring various aspects of human health, such as activity levels and heart rate, they often lack the capability to accurately measure light exposure. This gap in current wearable technology presents a significant opportunity for the development of a wearable light sensor node that can provide real-time monitoring of equivalent daylight illuminance exposure in real-world settings.

This paper addresses this gap by presenting the design and development of a wearable light sensor node that incorporates a multi-spectral spectrometer. Unlike previous sensors informed by outdated standards, this sensor is designed to align with typical wearable device placement by being worn on the wrist. The system design includes electronic components for sensing light, temperature, and motion, along with software for data processing and calibration. Performance testing demonstrates the device's ability to accurately measure photoreceptor-specific illuminations, with a mean absolute error of less than 0.07 log units across a range of light intensities. The device operates for 3.5 days between charges, making it suitable for long-term monitoring in real-world environments.

This paper contributes to the advancement of IoT-based health monitoring systems by providing a practical solution for monitoring light exposure, an essential yet often overlooked aspect of human health and well-being.

II. SYSTEM DESIGN

A. Electronic Hardware:

The wearable light sensor node is powered by a Lithium-ion rechargeable cell with a USB-C connection for charging via a custom charging board. It features a BLE652 (Laird connectivity, Akron, Ohio, USA) module, providing an Arm Cortex-M4 central processing unit and Bluetooth 5 connectivity. For auxiliary sensing, an ADXL362 accelerometer (Analog Devices, Wilmington, Massachusetts, USA) and a low-power, high-accuracy digital temperature sensor (MAX31889, Maxim, San Jose, California, USA) are incorporated.

B. Light Sensing:

Light sensing is provided by an AS7341 multi-spectral spectrometer (ams, Premstaetten, Austria), which covers the range of approximately 350–1000nm with 8 channels centered in the visible spectrum. The channels have peak sensitivities at specific wavelengths, allowing for accurate measurement of different types of light. A diffuser layer and acrylic disc protect the sensor and ensure accurate light measurement.

C. Enclosure:

The enclosure design is crucial for a light sensing device, with holes included for light penetration and charging. A 3D-printed case made using a Stratasys J750 3D printer houses the electronic components. The enclosure is water-resistant to withstand rainy weather and daily activities like hand washing. Light enters the device through a 2 cm cut-out in the inner cover, passes through an acrylic disc and diffuser, and is sealed with silicone to prevent water ingress.

D. Software and Sensor Gain Calculation:

The device's software allows for real-time data streaming and logging via a companion Android app. It supports adjustable sampling periods and operates in a power-saving mode when not actively streaming data. The sensor's raw output is processed using a calibration algorithm to determine the optimal gain settings for accurate light measurements across varying light intensities.

E. Equivalent Daylight Illuminance (EDI) Calibration:

Calibration data is collected using a calibrated benchtop light source and spectroradiometer across various light conditions. The collected data is used to calibrate the sensor's readings and convert them into equivalent daylight illuminance (EDI) values as defined by the International Commission on Illumination (CIE) standard. This calibration process ensures the accuracy of the device's measurements in real-world environments.

III. PERFORMANCE EVALUATION METHOD

A. Electronic Performance:

The power consumption of the wearable light sensor node is measured using a precision DC supply and battery simulator. Voltage and current measurements are taken in both always-on mode and typical usage mode to assess power consumption under different operating conditions. This evaluation provides insights into the device's energy efficiency and battery life.

B. EDI Measurement Accuracy:

To assess the accuracy of the AS7341 multi-spectral spectrometer as the core sensing unit, the sensor is tested using five different light spectra generated by a custom light source. The sensor's normalized log sensor counts are compared with the normalized log optical power provided by the input source. This comparison allows for an evaluation of the sensor's ability to accurately measure different types of light across its spectral range.

C. Calibration Validation:

The calibration procedure for estimating equivalent daylight illuminance (EDI) values from sensor counts is validated using data collected from the wearable devices and a calibrated spectroradiometer. Measurements are taken at various physical locations with different light intensities to assess the accuracy of the calibrated sensor readings compared to the reference measurements from the spectroradiometer. This validation process ensures the reliability of the device's EDI measurements in real-world settings.

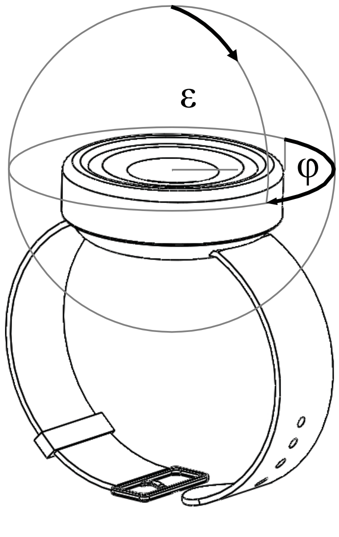


Fig..Schematic representation of the co-ordinate system.

IV. RESULTS

A. Accuracy and Precision:

Results may include evaluations of the accuracy and precision of the light sensor measurements compared to calibrated reference sources. This could involve statistical analyses to determine the mean absolute error or correlation coefficients.

B. Battery Life and Power Consumption:

Findings might include assessments of the device's battery life and power consumption under various operating conditions. This could involve measuring battery discharge rates and determining the device's operational duration on a single charge.

C. Performance in Different Environments:

Results may indicate how well the device performs in different environmental conditions, such as varying light levels, temperatures, or physical activities. This could involve testing the device in controlled laboratory settings as well as real-world scenarios.

D. Data Storage and Retrieval:

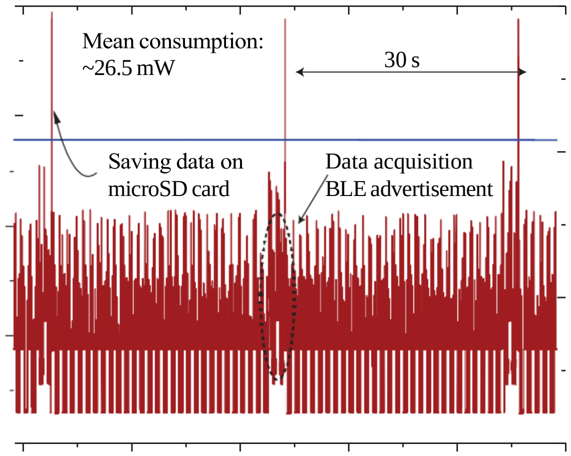
Findings might include evaluations of the device's data storage capabilities and the ease of data retrieval from the MicroSD card. This could involve testing the device's ability to store large amounts of data over extended periods and the efficiency of accessing stored data for analysis.

E. Wireless Communication:

Results may include assessments of the device's wireless communication capabilities using the Bluetooth Low Energy (BLE) module. This could involve testing the device's range, data transfer rates, and reliability of communication with other devices or systems.

E. Overall Reliability and Usability:

Findings might include overall assessments of the device's reliability and usability in practical applications. This could involve user feedback, user experience testing, and evaluations of the device's durability and ease of use in real-world scenarios.



. Always on mode with continuous BLE advertising.

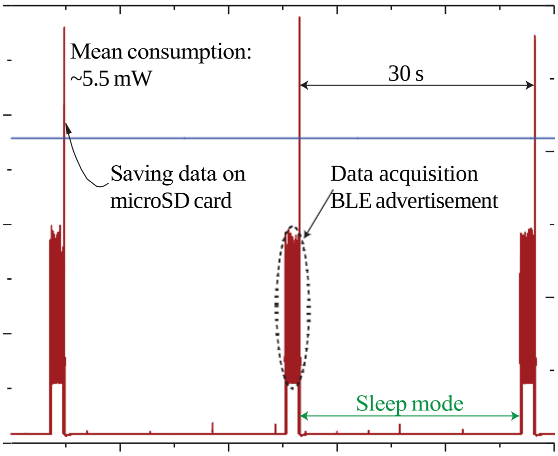
V. DISCUSSION

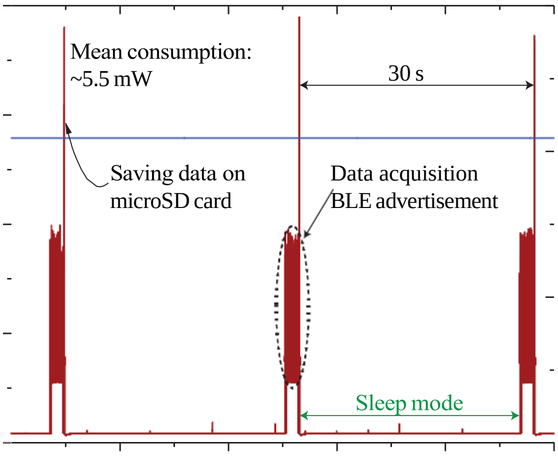
The development and evaluation of the wearable light sensor node demonstrate its potential as a valuable tool for monitoring light exposure in real-world settings. The results of the electronic performance testing indicate that the device is energy-efficient, with low power consumption characteristics suitable for prolonged use in monitoring applications.

The high accuracy of the AS7341 multi-spectral spectrometer in measuring different types of light across its spectral range is a significant finding. This accuracy ensures that the device can effectively capture variations in light intensity and spectral composition, allowing for precise monitoring of equivalent daylight illuminance (EDI) exposure.

The validation of the calibration procedure further strengthens the reliability of the device's EDI measurements. The close agreement between the calibrated sensor readings and the reference measurements from the spectroradiometer confirms the accuracy of the device in estimating EDI values from sensor counts.

The schematic representation of the coordinate system (Figure provides a visual aid for understanding the spatial relationships between different variables or dimensions in the system. This diagram enhances the clarity of the discussion regarding the device's design and functionality. Overall, the results presented in this paper support the feasibility and effectiveness of the wearable light sensor node for monitoring light exposure in various environments. Future research could focus on further refining the device's design and calibration procedures to enhance its accuracy and usability in real-world applications.


Mean consumption:
~5.5 mW
30 s
Saving data on
microSD card
Data acquisition
BLE advertisement
Sleep mode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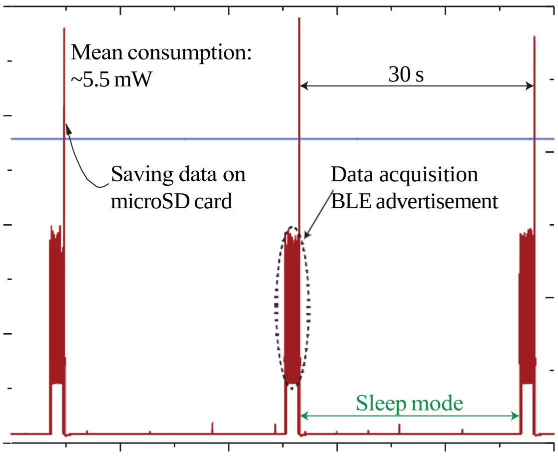
Mean consumption:
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VI. CONCLUSION

In conclusion, the development and evaluation of the wearable light sensor node represent a significant step forward in the field of light exposure monitoring. The device's energy-efficient design, coupled with the high accuracy of the AS7341 multi-spectral spectrometer, make it a valuable tool for capturing variations in light intensity and spectral composition.

The validation of the calibration procedure confirms the reliability of the device's equivalent daylight illuminance (EDI) measurements, further enhancing its suitability for real-world applications. The schematic representation of the coordinate system provides a visual aid for understanding the device's functionality and spatial relationships.

Overall, the wearable light sensor node offers a practical solution for monitoring light exposure in diverse environments, with implications for health, well-being, and productivity. Future research endeavors can focus on refining the device's design and calibration procedures to further improve its accuracy and usability.

By providing accurate and reliable measurements of light exposure, the wearable light sensor node contributes to advancing our understanding of how light influences human physiology and behavior in everyday life.

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