ECEN 5823 Spring 2025
Course Project Report
Team 8

Section 1 - Project Proposal

Section Author: Krishna Suhagiya

Student Names

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Project Overview

I chose to implement Option 1.

This product addresses the need for secure and efficient ambient light monitoring in indoor spaces. It reads ambient light levels and transmits them via BLE to the Si Connect app on a smartphone, acting as the central BLE client. To enhance security during data communication, the device uses BLE numerical pairing.

Use Case:

- Office/Classroom Buildings: This system can be used in offices to assess whether natural or artificial lighting meets ergonomic lighting standards for employee/student comfort and productivity.
- Smart Homes: This system can be used by homeowners to manually assess ambient light levels in different rooms, aiding decisions on when to open blinds or turn on lighting, without needing a fully automated lighting system.
- Retail Stores: This system can be used to evaluate the effectiveness of lighting on product displays, ensuring they are well-lit throughout the day to attract customers, while also avoiding unnecessary energy use.

High Level Requirements

- The product shall measure ambient light levels using the TEMT 6000 ambient light sensor.
- The product shall broadcast BLE advertisement packets periodically.
- The product shall allow the Si Connect app to establish a secure connection using BLE numerical pairing.
- The product shall expose a custom GATT service with a characteristic that notifies the client with light level percentage.
- The product shall display current light levels on an onboard LCD.
- The product shall operate in EM2 (Energy Mode 2) for low-power operation when idle.

High Level Design

The proposed solution is a low-power BLE server that reads ambient light values and transmits the percentage data to a BLE central client (Si Connect app). Numerical pairing is used to ensure secure communication.

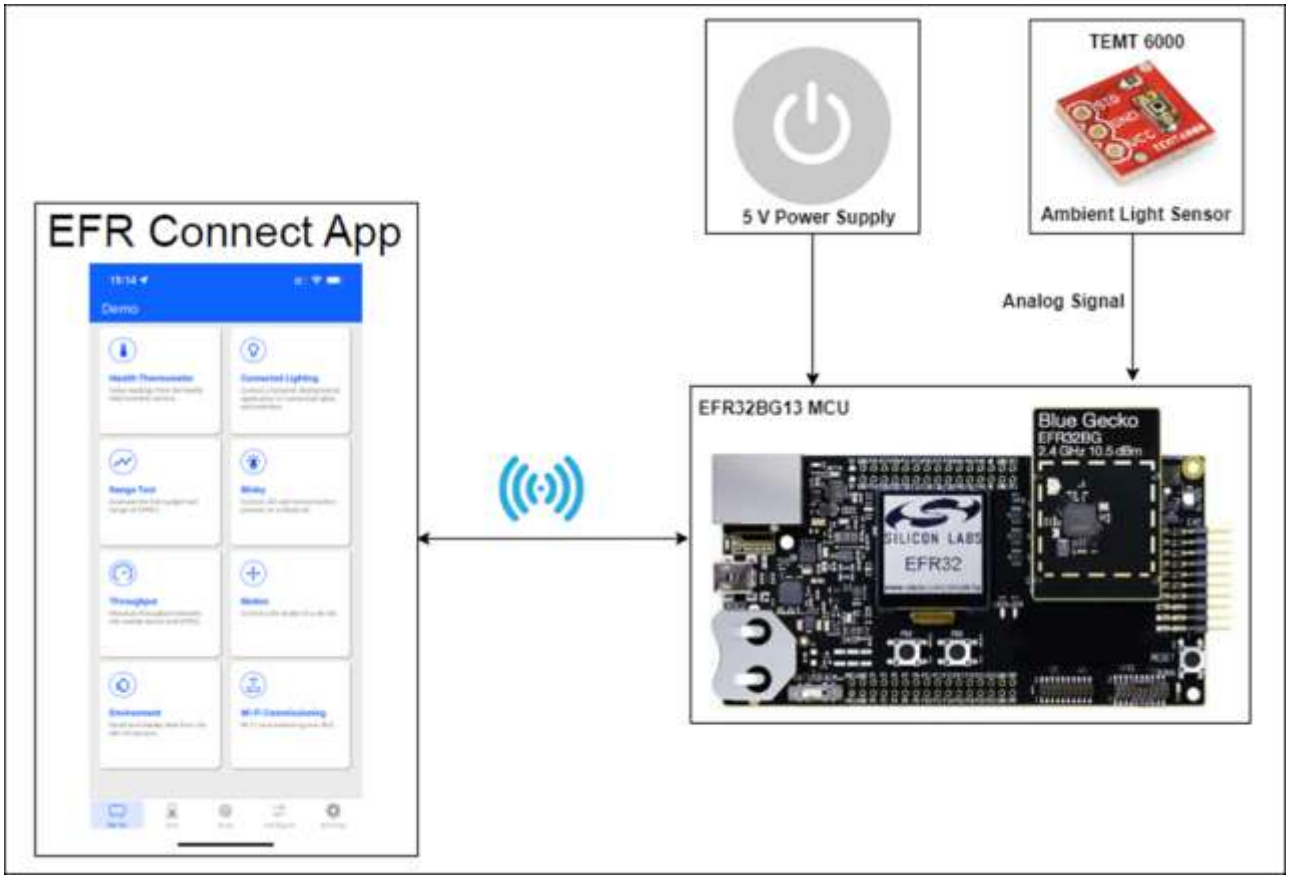
Table 1 : Data Types

Measurement	Units	Data Type	Valid/Allowed Values (Range)	Update Rate
Light Level	Percentage	Uint8_t	0 to 100	0.33 Hz
Button State	None	Uint8_t	0 or 1	On user action

Wireless Communication

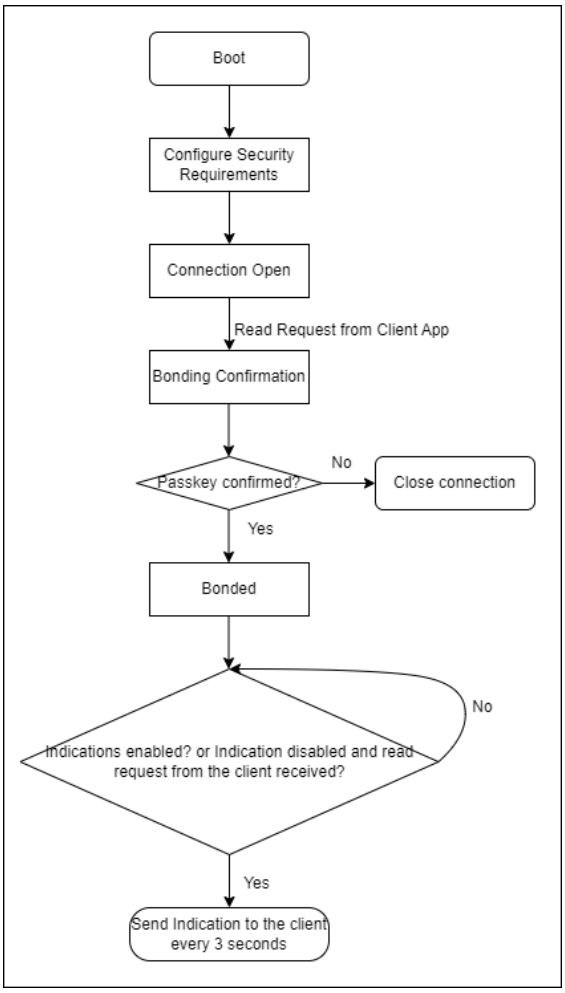
GATT Service Name	Characteristic ID	Length (Bytes)	Characteristic UUID
ECEN5823 Light Level Test	light_level_percentage	1	00000004-058f-49af-b3f8-5d8b4f7f885f
ECEN5823 Encryption Test	button_state	1	00000002-38c8-433e-87ec-652a2d136289

Functional Hardware Block Diagram

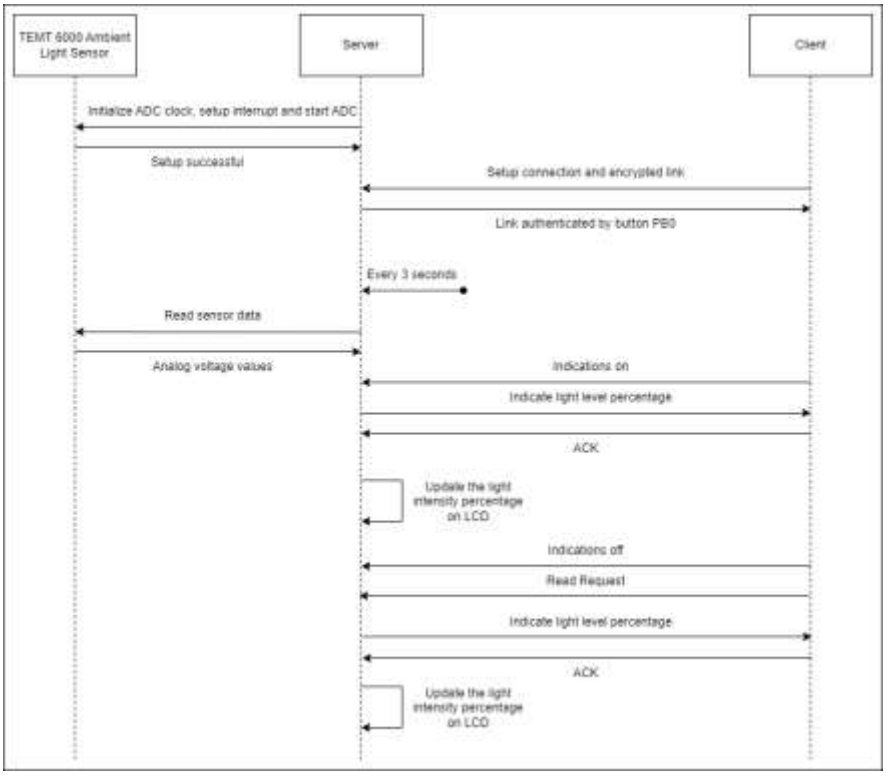


Functional Software Block Diagram

The following is the software block diagram representing the server-side architecture. On the client side, the Si Connect mobile application is used to interact with the BLE server.



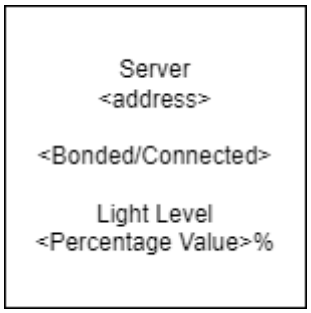
Data Flow Diagram



Division of Labor

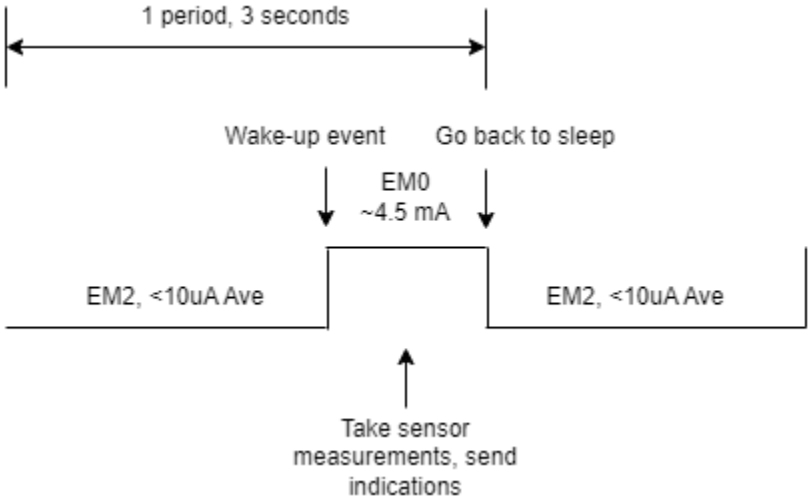
- Hardware: Sensor measurement, LCD display
- Software: BLE stack management, data acquisition, display control, low power modes

LCD Display design for Server



Energy Mode Targets

- EM0: Sensor Read + BLE notification
- EM2: Default idle mode



Subsystem Summary

Subsystem	Description
Light Level Measurement Subsystem	Reads the analog voltage (light) level from the light sensor every 3 seconds
BLE Communication Subsystem	Manages advertisements, connections, GATT services, and security pairing
LCD Display Subsystem	Shows real-time light intensity percentage
Power Management Subsystem	Switches between EM0 and EM2 for efficient power use
User Interaction Subsystem	Handles push button for initiating pairing process

Test Plan Approach

- **Unit Tests**:
  - Verify correct voltage (light) level read from the ambient light sensor.
  - Verify BLE service/characteristic UUIDs and pairing flow.
  - Check LCD displays correct data.
- **System Tests:**
  - Secure connection established with numerical pairing.
  - Correct data sent to Si Connect App over BLE.
  - Product enters and wakes from EM2 appropriately.

Proposed Schedule

Task	Student Responsible	Target Completion Date	Expected Completion Date
Light Level Detection Subsystem Design and Test	Krishna	April 18	
BLE GATT Service and Notify Implementation	Krishna	April 20	
Passkey security setup and Low-Energy Mode Integration (EM2 Sleep)	Krishna	April 24	
System Integration & Final Testing	Krishna	April 28	
Project Demonstration	Krishna	April 29 / May 1	
Final Report	Krishna	May 1	

GitHub repository URL(s) = https://github.com/CU-ECEN-5823/ecen5823-courseproject-krishna-cuboulder

Section 2 - Update 1

Section Author: Krishna Suhagiya

Status

The project has experienced some schedule shifts due to a major design change early in the development process. The original proposal was based on a GPIO-based PIR motion sensor, but it was determined that this implementation would not sufficiently meet the expectations for the course in terms of technical complexity. As a result, the entire project direction was revised.

The new concept Smart Lighting Advisor involves the integration of an ambient light sensor and BLE communication using numerical pairing for added security. While this new design meets the expectations for complexity and learning outcomes, it also required a complete redesign of both the hardware and software components, which delayed the overall schedule.

In addition to the redesign, initial delays were encountered due to sensor selection. These challenges resulted in the second milestone slipping by a few days.

Task	Student Responsible	Target Completion Date	Expected Completion Date
Light Level Detection Subsystem Design and Test	Krishna	April 18	April 18
BLE GATT Service and Notify Implementation	Krishna	April 20	April 20
Passkey security setup and Low-Energy Mode Integration (EM2 Sleep)	Krishna	April 24	April 24
System Integration & Final Testing	Krishna	April 28	April 28
Project Demonstration	Krishna	April 29 / May 1	April 29 / May 1
Final Report	Krishna	May 1	May 1

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Section 3 - Update 2

Section Author: Krishna Suhagiya

Status

The project is currently on schedule and progressing smoothly. Major milestones have been completed as planned. The BLE GATT service has been successfully implemented along with notification support, enabling real-time data transmission. Additionally, passkey-based pairing security has been configured to ensure secure device communication. Integration of Low-Energy Mode (EM2 sleep) has also been completed, optimizing power consumption during idle periods. So far, no significant issues or design changes have been encountered, and the development remains aligned with the initial timeline.

Task	Student Responsible	Target Completion Date	Expected Completion Date
Light Level Detection Subsystem Design and Test	Krishna	April 18	April 18
BLE GATT Service and Notify Implementation	Krishna	April 20	April 20
Passkey security setup and Low-Energy Mode Integration (EM2 Sleep)	Krishna	April 24	April 25
System Integration & Final Testing	Krishna	April 28	April 28
Project Demonstration	Krishna	May 1	May 1

Final Report	Krishna	May 1	May 1

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Section 4 - Final Report

Section Author: Krishna Suhagiya

Status

I successfully implemented all the project requirements as planned. Initially, I intended to run the system in EM0 during sensor sampling and transition to EM2 otherwise. However, since the ADC operates down to EM3 but the Bluetooth stack requires EM2 or higher, I simplified the design by always keeping the system in EM2. This ensured reliable BLE operation while maintaining low power consumption. The resulting energy mode behavior is shown in the Energy Profiler screenshots below.

Energy Profiler screenshot for average current per period (387.36 uA):

Energy Profiler screenshot when the system is idle (not taking light level measurements) (348.46 uA):

Final Schedule:

Task	Student Responsible	Target Completion Date	Expected Completion Date
Light Level Detection Subsystem Design and Test	Krishna	April 18	April 18
BLE GATT Service and Notify Implementation	Krishna	April 20	April 20
Passkey security setup and Low-Energy Mode Integration (EM2 Sleep)	Krishna	April 24	April 25
System Integration & Final Testing	Krishna	April 28	April 28
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Distribution of Work

I completed 100% of the work on this project independently, which gave me full responsibility for hardware configuration, BLE integration, secure pairing, and system optimization.

File Name	Author
adc.c/.h	Krishna Suhagiya
ble.c/.h	Krishna Suhagiya
irq.c/.h	Krishna Suhagiya
oscillators.c/.h	Krishna Suhagiya
scheduler.c/.h	Krishna Suhagiya
timers.c/.h	Krishna Suhagiya

What Was Learned

Krishna Suhagiya:
Working on this project taught me several valuable lessons beyond the scope of regular coursework. First, I learned how to work with ADCs through interrupt handling. This gave me hands-on experience with configuring it using datasheets and reference manuals. Second, I developed a stronger understanding of power-efficient embedded design, especially how single-shot ADC sampling and timed BLE updates (every 3 seconds) help conserve energy in low-power systems.

Originally, the proposal focused on continuous ADC sampling and more frequent BLE updates, but I had to reduce the update rate and switch to single-shot ADC mode after testing showed unnecessary power usage. Also, I initially planned for dynamic sensor calibration but found that fixed scaling (after testing the sensor under varied light conditions) was both simpler and sufficient for the application.

The most important part was configuring the ADC and understanding how to map analog voltage to a consistent 0-100% light level. It required calibration and multiple iterations of testing. What I really enjoyed was seeing the system come together end-to-end—reading from hardware, processing the data, and securely sending it over BLE.

GitHub repository URL(s) = https://github.com/CU-ECEN-5823/ecen5823-courseproject-krishna-cuboulder
Demo Video Link = demo_video.mp4