Sleep Environment & Recovery Monitor
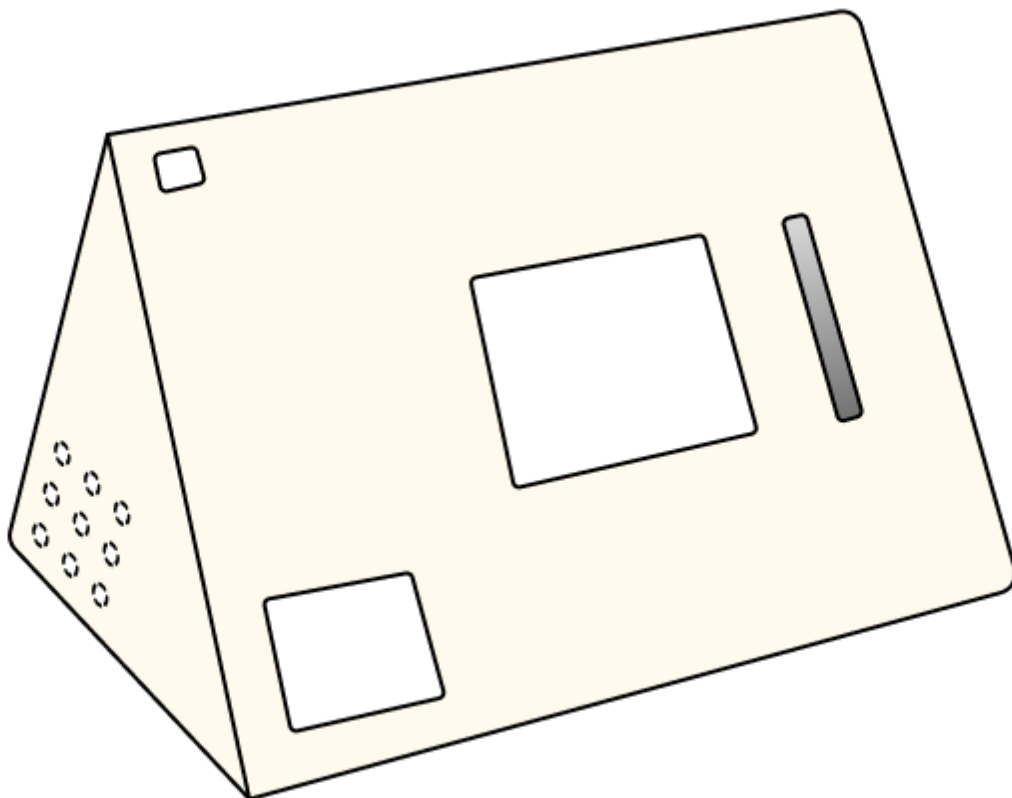
Project Overview

What it does

The Sleep Environment & Recovery Monitor evaluates overnight sleep conditions — light, sound, temperature — and translates them into a simple, physical recovery score visible in the morning. Instead of tracking the body, the system focuses on environmental quality to encourage healthier sleep habits without medical claims.

What it looks like

The system consists of two devices:

- A sensor unit placed on a nightstand that quietly monitors the sleep environment overnight

- A display unit resembling a small alarm clock with an OLED screen and soft LED indicator that communicates the sleep quality score at a glance.
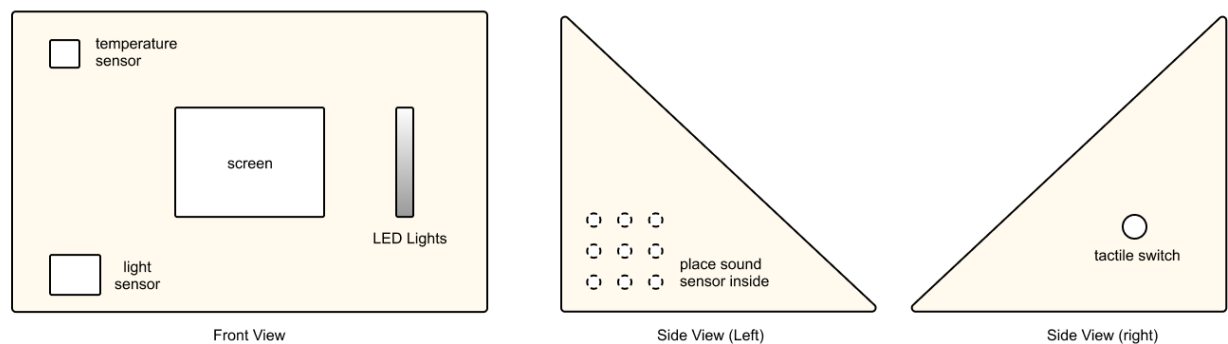
Sensor Device (Sleep Environment Monitor)

Description

The sensor device continuously monitors environmental conditions during sleep using a low-power duty cycle. Data is aggregated overnight and transmitted wirelessly to the display device in the morning.

Sensors & Parts (part numbers)

Function	Part Number	Quantity	Description
MCU + Wireless	Seeed Studio XIAO ESP32-C3	1	BLE, low power
Ambient Light Sensor	VEML7700	1	High-sensitivity ambient light sensor (I²C)
Microphone	SPH0645LM4H-B	1	I²S MEMS microphone, RMS only
Temperature	TMP117	1	High-accuracy temperature sensing
Battery Charger	MCP73831	1	LiPo charging IC
LiPo Battery	3.7V 1000-2000mAh	1	Power supply

Front View

Side View (Left)

Side View (right)

How it works

- The device wakes on a scheduled interval during sleep hours.
- Light, sound RMS, temperature are sampled.
- Audio is processed locally (no recording or storage).
- All data is time-weighted and stored in local memory.
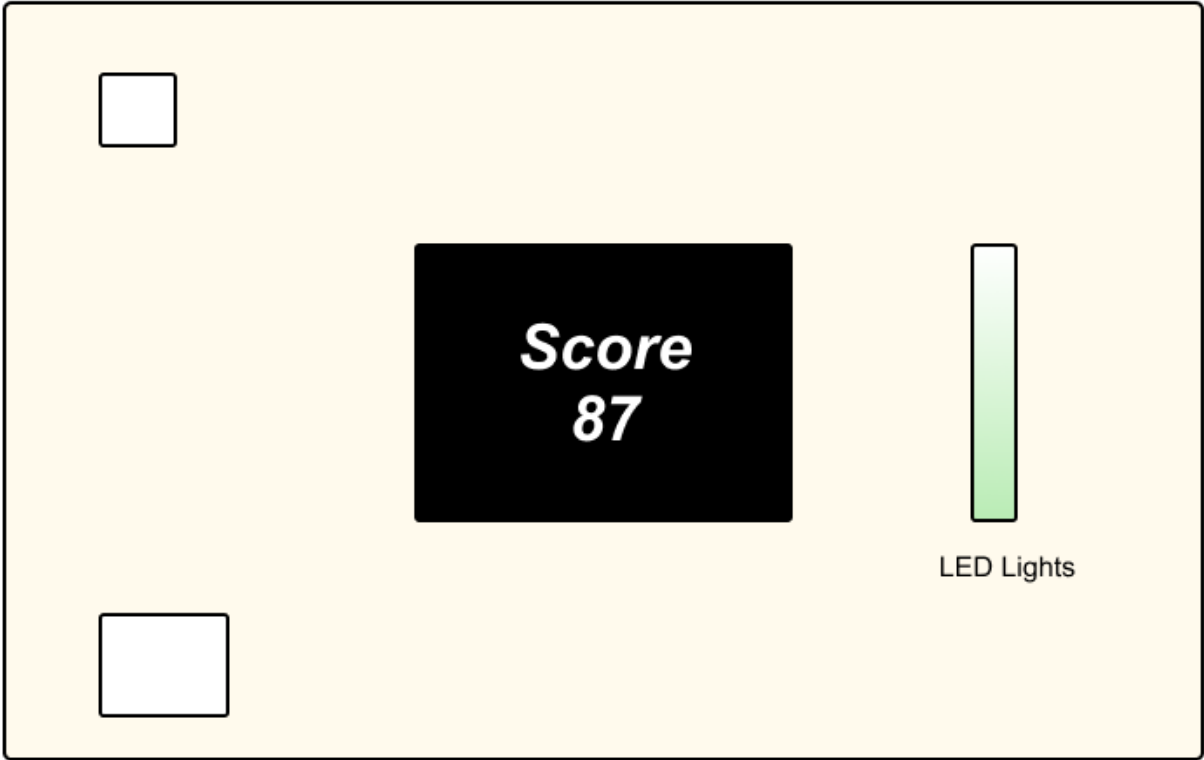- At wake time, a summary packet is transmitted to the display device.

Display Device (Score Interface)

Description

The display device presents the overnight Sleep Environment Score using a low-power OLED screen combined with a soft ambient LED indicator. The OLED screen provides clear, numerical feedback in the morning, while the LED glow offers an immediate, non-intrusive visual sense of sleep quality. A single button allows the user to cycle through secondary metrics such as light exposure, noise level, and temperature.

Components & Parts

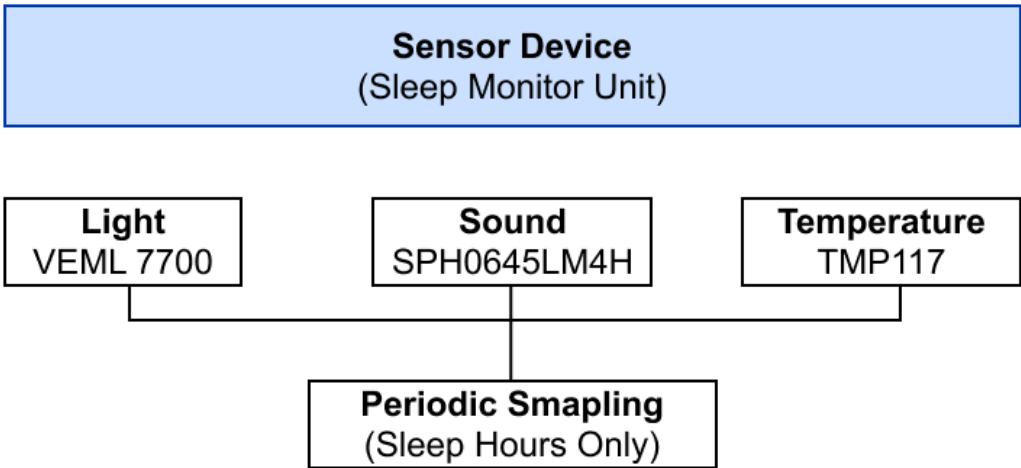| Function	Part Number	Quantity	Notes
MCU + Wireless	Seeed Studio XIAO ESP32-C3	1	Wireless receiver
Display	SSD1306 OLED (128×64)	1	Low-power I²C screen
LED	Warm White Diffused LED	1	Ambient sleep quality indicator
Button	Tactile Momentary Switch	1	Metric navigation
Battery	LiPo 2000 mAh	1	Multi-day operation
Resistor	220Ω	1	LED current limiting

A single button on the right side cycles through detailed metrics: light exposure, noise levels, and temperature trends.

Button Interaction

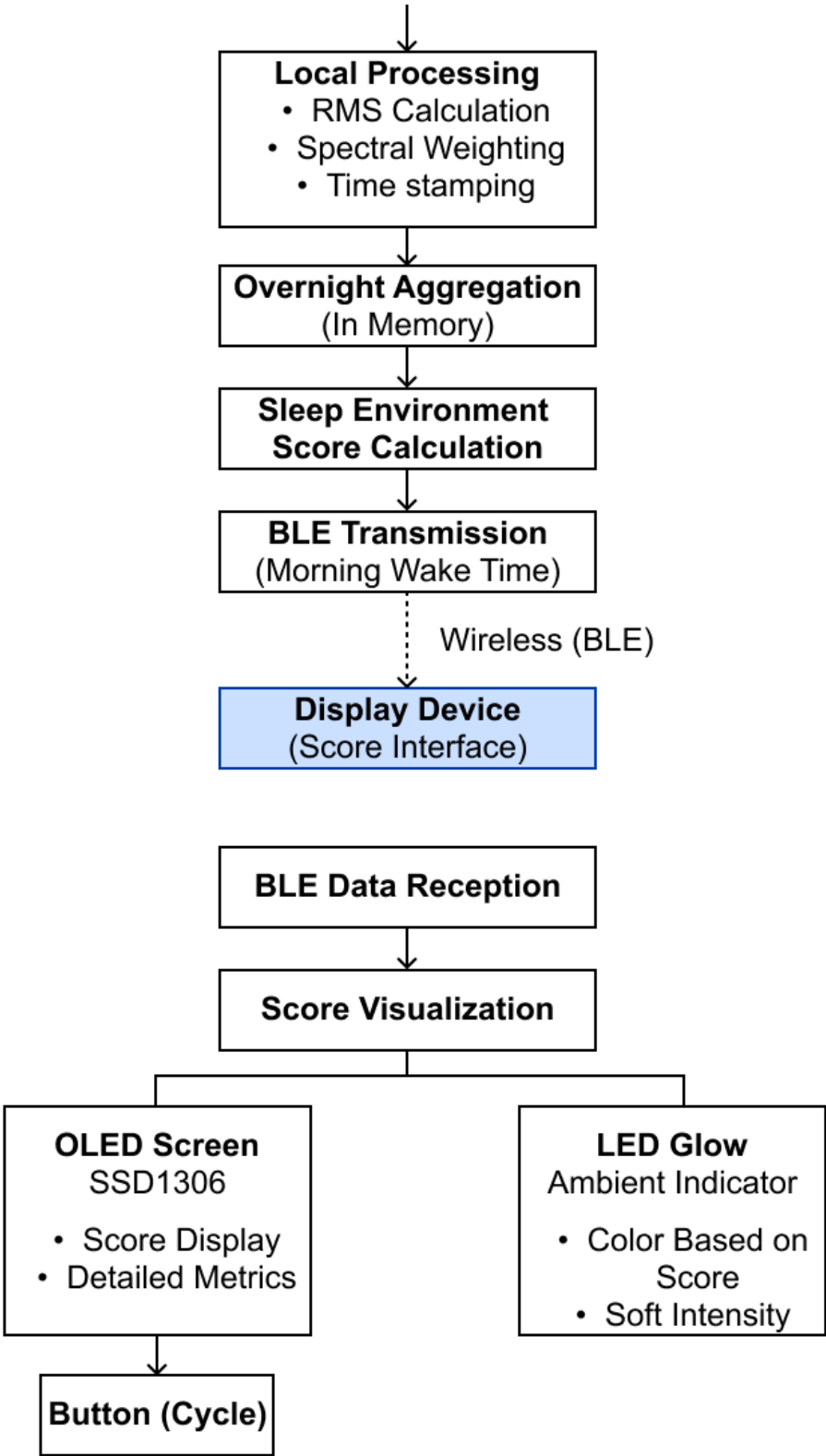| Main Score | Light Exposure | Sound Level | Temperature |

System Communication & Data Flow

Figure: Complete data pipeline from sensors through processing to display outputs.

System Communication

The system consists of two standalone devices: a sleep environment sensor device and a display device. The sensor device operates independently overnight, collecting and aggregating environmental data. In the morning, a single summary packet is transmitted wirelessly to the display device using BLE or Wi-Fi.

Communication between the sensor device and the display device is implemented using BLE. BLE is selected due to its low power consumption and suitability for short-range, infrequent data transmission in a sleep environment context.

Data Flow & Processing Pipeline

During the sleep period, the sensor device periodically samples ambient light, sound level, and temperature. Audio data is processed locally using RMS calculation and basic spectral weighting to emphasize disruptive noise patterns. All sensor readings are time-weighted and aggregated into a single overnight dataset.

After aggregation, the data is converted into a normalized Sleep Environment Score. This score is transmitted to the display device, where it is visualized on a low-power screen. A soft ambient LED glow provides an additional non-screen feedback channel, reinforcing the overall sleep quality without requiring focused attention.

Future Work

- Optional Wi-Fi connectivity to support long-term data logging or remote visualization