Shadow Wellness Platform: Wrist Wearable Watch Hardware Documentation

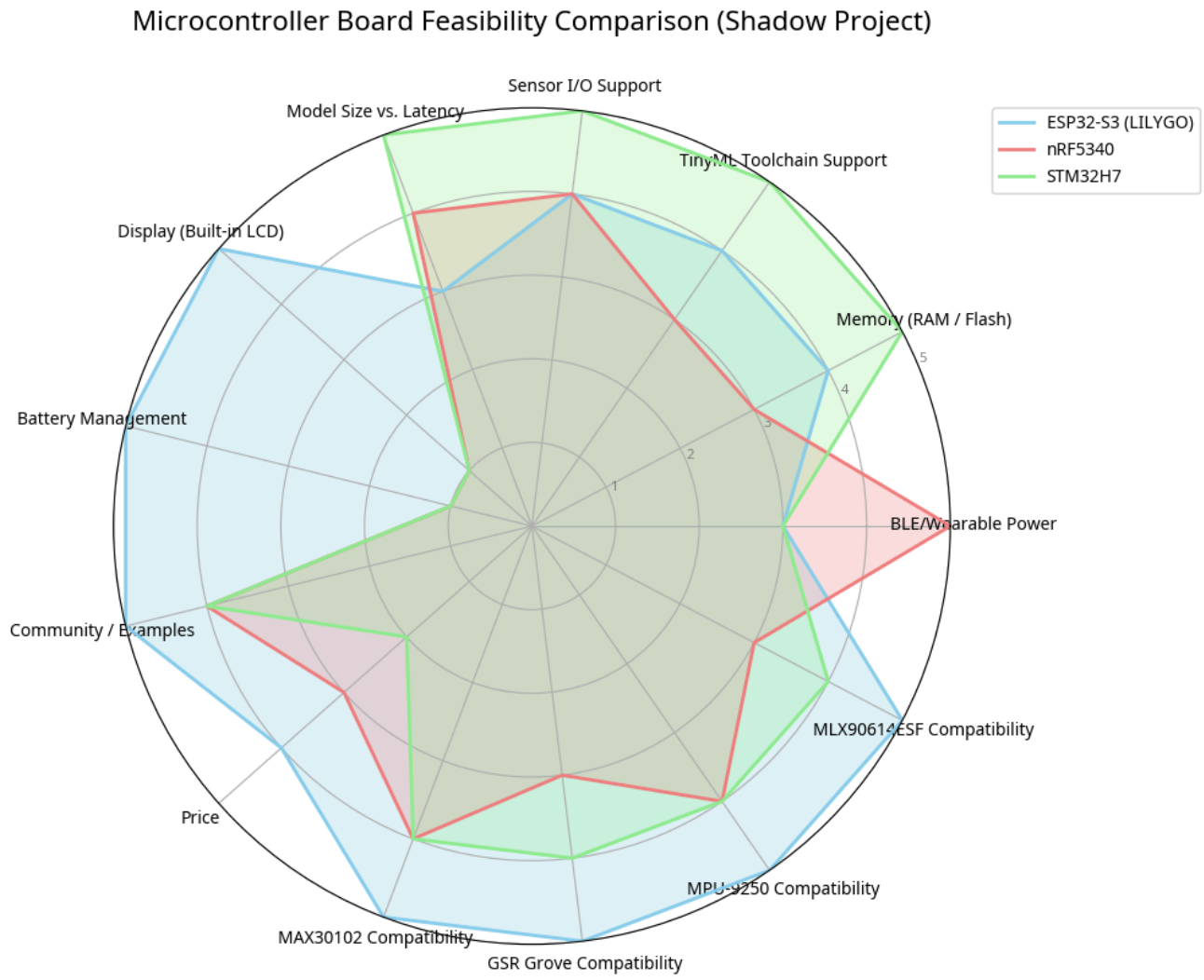
1. Introduction

This document provides a comprehensive overview of the hardware components selected for the Shadow Wellness Platform's wrist wearable watch device. It is intended for embedded software engineers and hardware developers, detailing each component's functionality, key specifications, and crucial connection information necessary for successful integration and system development. The design prioritizes a compact form factor, low power consumption, and the ability to collect diverse wellness data.

2. Microcontroller Unit (MCU) Selection: Why LilyGo T-Display-S3?

Choosing the right Microcontroller Unit (MCU) is paramount for the success of any embedded system, especially for a privacy-conscious wearable like the Shadow Wellness Platform. The selection process involved a thorough evaluation of several leading microcontroller boards against criteria critical to our project's requirements, including power efficiency, memory, TinyML support, sensor compatibility, cost, and community support.

To visualize this comparison, a radar chart was generated, assessing the feasibility of the ESP32-S3 (LILYGO), nRF5340, and STM32H7 microcontrollers across various parameters. This chart provides a clear overview of each board's strengths and weaknesses relative to our specific needs.



Rationale for Choosing LilyGo T-Display-S3 (ESP32-S3)

After careful consideration and based on the comparative analysis, the LilyGo T-Display-S3, featuring the ESP32-S3 microcontroller, emerged as the most suitable choice for the wrist wearable watch. The key reasons for this selection are:

1. **Integrated Display and Battery Management:** A significant advantage of the LilyGo T-Display-S3 is its integrated 1.9-inch LCD and built-in battery management circuitry. This significantly simplifies the hardware design, reduces the overall form factor, and

accelerates development for a wearable device that requires a visual interface and portable power.

2. **Robust Wireless Connectivity:** The ESP32-S3's integrated Wi-Fi and Bluetooth 5/BLE capabilities are fundamental to Shadow's peer-to-peer communication architecture. It provides the necessary flexibility for both higher-bandwidth data transfer (Wi-Fi) and low-power, continuous communication (BLE) with other devices in the ecosystem (e.g., Android phone).

3. **Strong TinyML Toolchain Support:** The ESP32-S3 benefits from excellent support within the TinyML ecosystem, particularly with TensorFlow Lite Micro and Espressif's optimized libraries (esp-nn). This ensures that our chosen machine learning models for stress recognition can be efficiently deployed and run on the device with minimal overhead.

4. **Versatile Sensor I/O:** The ESP32-S3 offers a rich set of GPIOs, I2C, and SPI interfaces, providing ample flexibility for integrating all our selected sensors (MAX30102, GSR Grove, MPU-9250, MLX90614ESF). Its analog-to-digital converter (ADC) capabilities are well-suited for the GSR sensor.

5. **Active Community and Extensive Examples:** The ESP32 platform boasts a massive and active developer community, along with a wealth of open-source examples and libraries. This significantly eases the development process, troubleshooting, and access to readily available solutions for common challenges.

6. **Cost-Effectiveness:** Compared to other high-performance microcontrollers, the ESP32-S3 offers a highly competitive price point, making it an economically viable option for a project aiming for open-source accessibility and potential wider adoption.

While other boards like the nRF5340 excel in ultra-low power BLE and the STM32H7 offers superior raw processing power and memory, the LilyGo T-Display-S3 strikes the optimal balance across all critical criteria for our specific wearable application. Its integrated features, robust connectivity, TinyML readiness, and strong community support make it the most practical and efficient choice for the Shadow Wellness Platform's wrist wearable.

3. Component Overview

This section details each primary hardware component of the wrist wearable watch.

3.1. LilyGo T-Display-S3

Description: The LilyGo T-Display-S3 is a compact and versatile development board featuring the ESP32-S3 microcontroller. It integrates a 1.9-inch LCD color screen and two programmable

buttons, making it an ideal choice for wearable applications requiring a display and user interaction. Its integrated Wi-Fi and Bluetooth capabilities are crucial for peer-to-peer communication within the Shadow ecosystem.

Functionality:

- **Microcontroller:** The ESP32-S3 acts as the central processing unit, handling sensor data acquisition, preliminary data processing, communication protocols (Wi-Fi, Bluetooth LE), and display management.
- **Display:** The 1.9-inch LCD provides a visual interface for displaying wellness insights, notifications, and user interface elements.
- **Connectivity:** Built-in Wi-Fi enables communication with the Android phone (for higher bandwidth data transfer) and other network-connected devices. Bluetooth 5 and Bluetooth Low Energy (BLE) are essential for low-power communication with other wearables and the Android phone.
- **Power Management:** Includes battery voltage detection and charging circuitry for LiPo batteries, critical for portable wearable applications.

Key Specifications:

- **MCU:** ESP32-S3 (Dual-core Xtensa LX7 processor)
- **Flash Memory:** Typically 16MB
- **PSRAM:** Typically 8MB
- **Display:** 1.9-inch LCD, 170x320 resolution (ST7789 driver)
- **Wireless:** Wi-Fi (802.11 b/g/n), Bluetooth 5, BLE
- **Interfaces:** USB-C, I2C, SPI, UART, GPIOs
- **Power:** 3.7V LiPo battery input, USB-C for power and programming.

Datasheet/Resources:

- LILYGO T-Display-S3 Product Page
- ESP32-S3 Datasheet (Espressif)

3.2. LiPo Battery

Description: A Lithium Polymer (LiPo) battery is chosen for its high energy density, lightweight nature, and flexible form factor, which are critical attributes for wearable devices.

Functionality:

- **Power Source:** Provides the necessary electrical energy to power the LilyGo T-Display-S3 and all connected sensors.

- **Rechargeable:** Allows for repeated charging and discharging cycles, making the device reusable.

Key Specifications (Typical for Wearables):

- **Voltage:** 3.7V (nominal)
- **Capacity:** Varies depending on desired battery life and physical size (e.g., 200mAh - 500mAh for a wrist device).
- **Form Factor:** Small, thin, and often rectangular or custom shapes to fit wearable designs.

3.3. MAX30102 (Pulse Oximeter and Heart-Rate Sensor)

Description: The MAX30102 is an integrated pulse oximetry and heart-rate monitor module. It combines two LEDs (red and infrared), a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry (SpO2) and heart rate (HR) signals. It is designed for wearable health applications due to its small size and low power consumption.

Functionality:

- **Heart Rate Measurement:** Detects changes in blood volume in the finger (or wrist) by emitting light and measuring the absorption, which correlates with heartbeats.
- **Pulse Oximetry (SpO2) Measurement:** Measures the oxygen saturation level in the blood by analyzing the differential absorption of red and infrared light by oxygenated and deoxygenated hemoglobin.

Key Specifications:

- **Operating Voltage:** 1.8V (typically on breakout boards, VCC can be 3.3V or 5V with onboard regulator)
- **Interface:** I2C (SDA, SCL)
- **LEDs:** Red and IR LEDs
- **Features:** Ultra-low shutdown current, fast data output, high sample rates, robust motion artifact resilience.

Datasheet/Resources:

- MAX30102 Datasheet (Analog Devices)

3.4. GSR Grove Skin Current Sensing Sensor

Description: The Grove - GSR (Galvanic Skin Response) sensor measures the electrical conductance of the skin, which varies with sweat gland activity. This activity is influenced by

emotional arousal, making GSR a common indicator for stress, excitement, or other strong emotions.

Functionality:

- **Skin Conductance Measurement:** Applies a small, safe voltage across two electrodes placed on the skin (typically fingers) and measures the resulting current, which is proportional to skin conductance.
- **Emotional Arousal Indicator:** Provides a physiological signal that can be correlated with a user's emotional state or stress levels.

Key Specifications:

- **Input Voltage:** 3.3V / 5V (compatible with LilyGo T-Display-S3 GPIO voltage levels)
- **Output:** Analog voltage output (proportional to skin conductance)
- **Interface:** Analog input (requires an ADC pin on the microcontroller)
- **Electrodes:** Comes with finger straps for easy attachment.

Datasheet/Resources:

- Grove - GSR Sensor Wiki (Seeed Studio)
- Grove - GSR Sensor Datasheet (Seeed Studio)

3.5. MPU-9250 (9-Axis Motion Tracking Sensor)

Description: The MPU-9250 is a 9-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer (compass) in a single small package. It is widely used for motion sensing, orientation tracking, and activity monitoring in wearable devices.

Functionality:

- **Accelerometer:** Measures linear acceleration along X, Y, and Z axes, used for detecting movement, steps, and orientation changes.
- **Gyroscope:** Measures angular velocity (rotation) along X, Y, and Z axes, used for detecting rotational movements and gestures.
- **Magnetometer:** Measures magnetic field strength along X, Y, and Z axes, used for providing heading information (compass) and correcting gyroscope drift.
- **Motion Tracking:** By combining data from all three sensors, it can provide comprehensive 9-axis motion tracking, enabling precise orientation and movement analysis.

Key Specifications:

- **Operating Voltage:** 2.4V to 3.6V (typically 3.3V on breakout boards)
- **Interface:** I2C (SDA, SCL) or SPI
- **Features:** Digital-output 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer; Digital Motion Processor (DMP) for complex motion fusion algorithms.

Datasheet/Resources:

- MPU-9250 Datasheet (TDK InvenSense)

3.6. MLX90614ESF (Infrared Thermometer)

Description: The MLX90614ESF is a digital plug-and-play infrared thermometer for non-contact temperature measurements. It integrates a low-noise amplifier, 17-bit ADC, and a powerful DSP unit, achieving high accuracy and resolution. It is suitable for measuring skin temperature without direct contact.

Functionality:

- **Non-Contact Temperature Measurement:** Measures the infrared radiation emitted by an object (e.g., skin) to determine its temperature without physical contact.
- **High Accuracy:** Provides precise temperature readings, crucial for health monitoring applications.

Key Specifications:

- **Operating Voltage:** 2.6V to 3.6V (typically 3.3V on breakout boards)
- **Interface:** SMBus (I2C compatible) (SDA, SCL)
- **Accuracy:** Typically ±0.5°C in medical range (0°C to 50°C)
- **Measurement Range:** -40°C to 85°C (ambient), -70°C to 380°C (object)

Datasheet/Resources:

- MLX90614 Datasheet (Melexis)

4. Connection Diagram

This section provides a detailed connection diagram illustrating how the specified hardware components are interconnected with the LilyGo T-Display-S3. The connections primarily utilize the I2C communication protocol for the sensors, as it allows multiple devices to share the same bus, simplifying wiring.

Assumptions:

- All sensors are assumed to be on breakout boards that provide necessary voltage regulation and pull-up resistors for I2C communication.
- The LilyGo T-Display-S3 will provide the 3.3V power supply for the sensors.
- The specific GPIO pins for I2C (SDA, SCL) and the analog input for GSR on the LilyGo T-Display-S3 will be used as per its pinout.

LilyGo T-Display-S3 Pinout (Common I2C and Analog Pins):

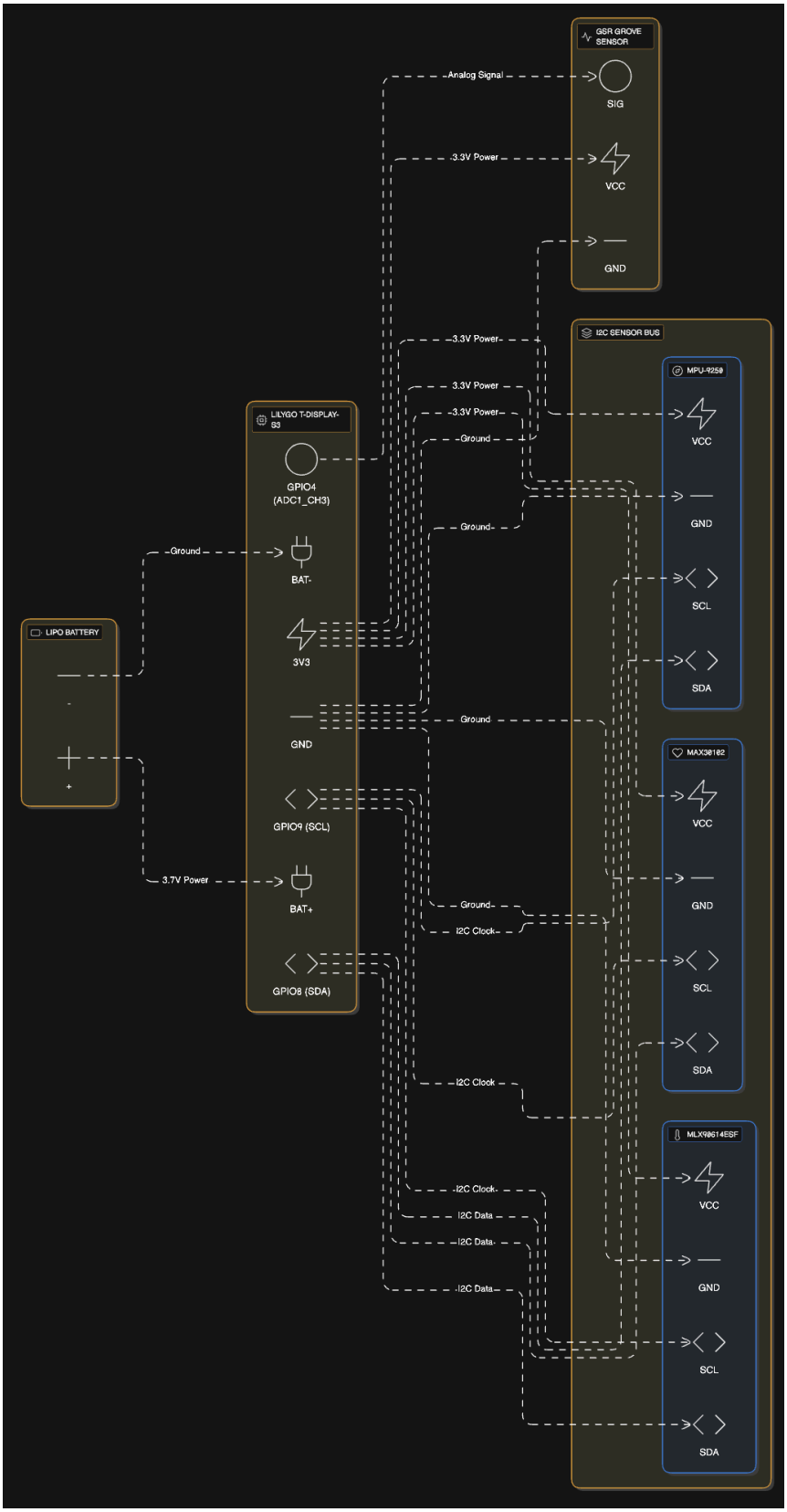
- **SDA (Data):** GPIO 8 (or other designated I2C SDA pin)
- **SCL (Clock):** GPIO 9 (or other designated I2C SCL pin)
- **Analog Input (GSR):** GPIO 4 (or other designated ADC pin)
- **3.3V:** 3V3 pin
- **GND:** GND pin

Connection Table:

Component	**Pin on Component**	**Connects to LilyGo T-Display-S3 Pin**	**Notes**
LiPo Battery	VCC	BAT+	Connects to battery input connector
	GND	BAT-	
MAX30102	VCC	3V3	Power supply for the sensor
	GND	GND	Ground connection
	SDA	GPIO 8 (SDA)	I2C Data Line
	SCL	GPIO 9 (SCL)	I2C Clock Line
GSR Grove Sensor	VCC	3V3	Power supply for the sensor
	GND	GND	Ground connection
	SIG (Analog Out)	GPIO 4 (ADC1_CH3)	Analog input for skin conductance measurement

Component	Pin on Component	Connects to LilyGo T-Display-S3 Pin	Notes
MPU-9250	VCC	3V3	Power supply for the sensor
	GND	GND	Ground connection
	SDA	GPIO 8 (SDA)	I2C Data Line
	SCL	GPIO 9 (SCL)	I2C Clock Line
MLX90614ESF	VCC	3V3	Power supply for the sensor
	GND	GND	Ground connection
	SDA	GPIO 8 (SDA)	I2C Data Line (SMBus compatible)
	SCL	GPIO 9 (SCL)	I2C Clock Line (SMBus compatible)

Connection Diagram:



5. Conclusion

This document provides a detailed hardware specification and connection guide for the Shadow Wellness Platform's wrist wearable watch. By carefully integrating these components, developers can build a robust and functional device capable of collecting essential wellness data for the privacy-focused platform.