TECHNICAL REPORT – INCLUSIVE SCALE

Revision Control

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Table of Contents

1. Introduction
2. System Overview
3. Hardware Architecture
4. Software Architecture
5. Communication Interface
6. Target Weight Configuration
7. Tare Function
8. Weight Evaluation Algorithm
9. Weight Stability Control
10. Audible Guidance System
11. Human Machine Interface (HMI)
12. Power Management
13. Operational Safety and Reliability

List of Figures

Figure 1. Inclusive Scale, Side View
Figure 2. RS-232 Communication Port for Commercial Scale
Figure 3. Braille Keyboard and Touchscreen User Interface
Figure 4. HW-044 UART to RS-232 Communication Module
Figure 5. Matrix Membrane Keypad
Figure 6. PCF8574T I^2C Keyboard Interface Module
Figure 7. Braille Overlay Template
Figure 8. Electronic Circuit Schematic Diagram

List of Tables

Table 1. Software Functional Modules
Table 2. RTOS Task Allocation and Priorities

1. Introduction

This document describes the functional characteristics, hardware and software architectures, and operating principle of an electronic system designed to assist weighing operations for individuals with different disabilities through the use of real-time visual, tactile, and auditory feedback.
The implemented architecture provides robust and intuitive operation, facilitating compliance with dosing objectives while reducing operator-related errors.
The integration of stability control mechanisms, persistent storage of system parameters, multitasking management, and sequential auditory indications contributes to a high level of usability, accessibility, and operational reliability.

The system provides the following capabilities:

- Configuration of a target weight.
- Acquisition of weight measurements from an external commercial scale.
- Electronic tare compensation.
- Automatic determination of weighing status relative to the configured target weight.
- Operator guidance through graphical indicators and voice messages.
- Storage of operational parameters in non-volatile memory.

2. System Overview

The equipment is implemented on an embedded platform based on the **M5Stack TAB5 IoT** module, which integrates:

- Color touchscreen display.
- ESP32-P4 processor.
- microSD card storage.
- Integrated loudspeaker.
- RS-232 serial communication interface for external scale connection.
- External matrix Braille keyboard connected through an I^2C interface.

The system operates as a dedicated Human–Machine Interface (HMI) for weighing operations, providing both visual and auditory feedback to the operator.

The following figures illustrate the developed system:

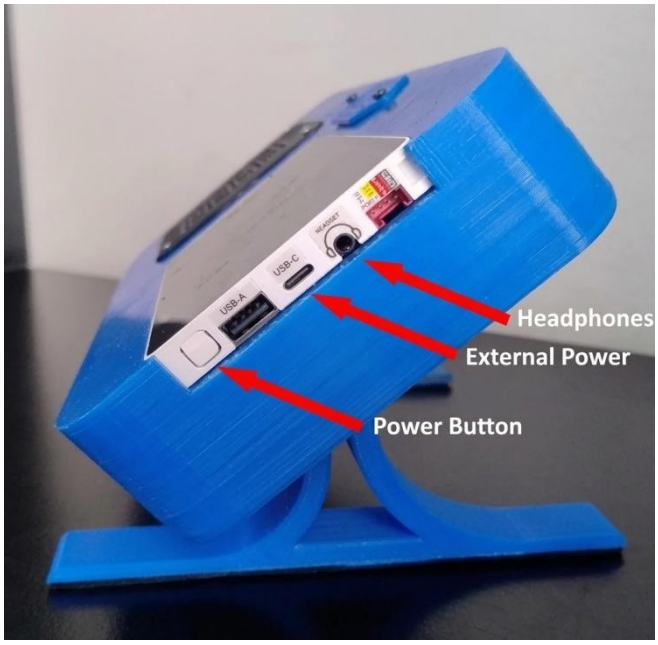


Figure 2. RS232 Communication Port for Commercial Scale

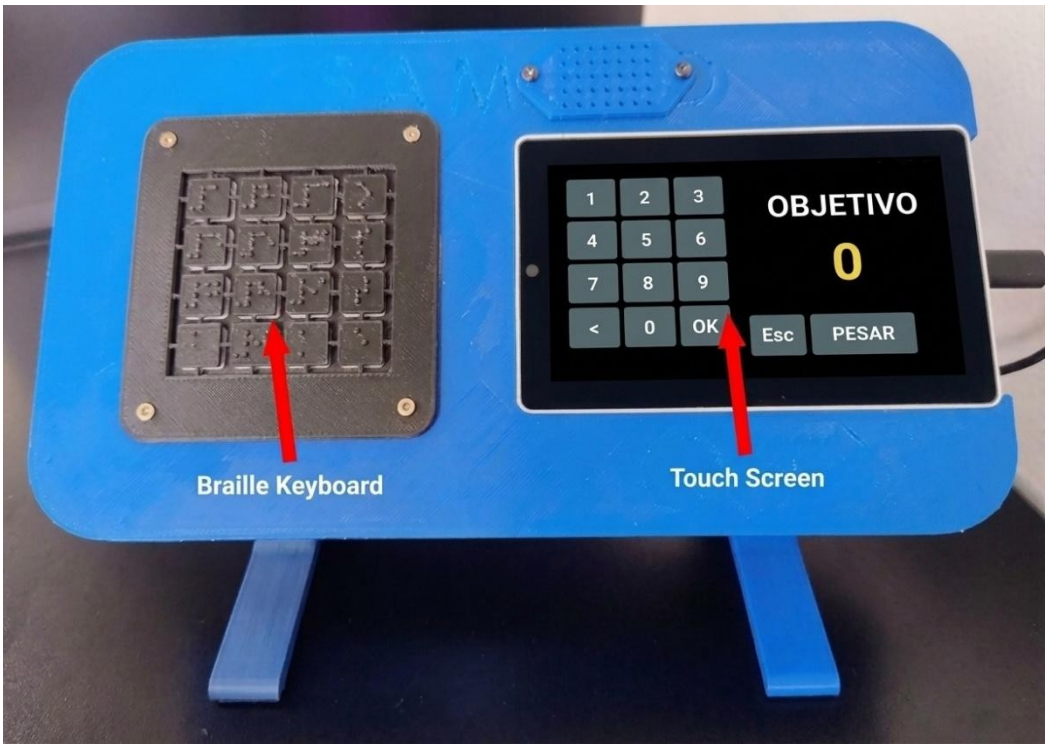


Figure 3. Braille Keyboard and Touchscreen User Interface

3. Hardware Architecture

The hardware architecture is based on the **M5Stack TAB5 IoT** module, which communicates through its M-Bus expansion interface with two external modules dedicated to serial communication and keyboard management.

3.1 Commercial Scale Communication Interface

Communication with the commercial weighing instrument is achieved using an **HW-044 UART-to-RS232 adapter module**, connected to GPIO pins G3 and G4 of the TAB5 module.



Figure 4. HW-044 UART-to-RS232 Interface Module

3.2 Braille Keyboard Interface

The Braille input system is implemented using the **HW-KB module based on the PCF8574T I/O expander**.
The TAB5 communicates with this module through an I²C bus to perform matrix keyboard scanning and key acquisition.

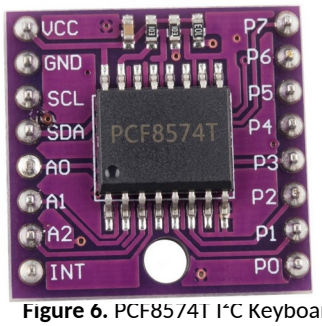


Figure 6. PCF8574T I²C Keyboard Interface Module



Figure Memb

A custom Braille overlay is installed over the keypad membrane to facilitate tactile interaction.

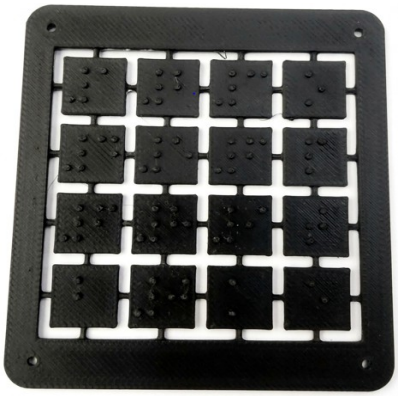
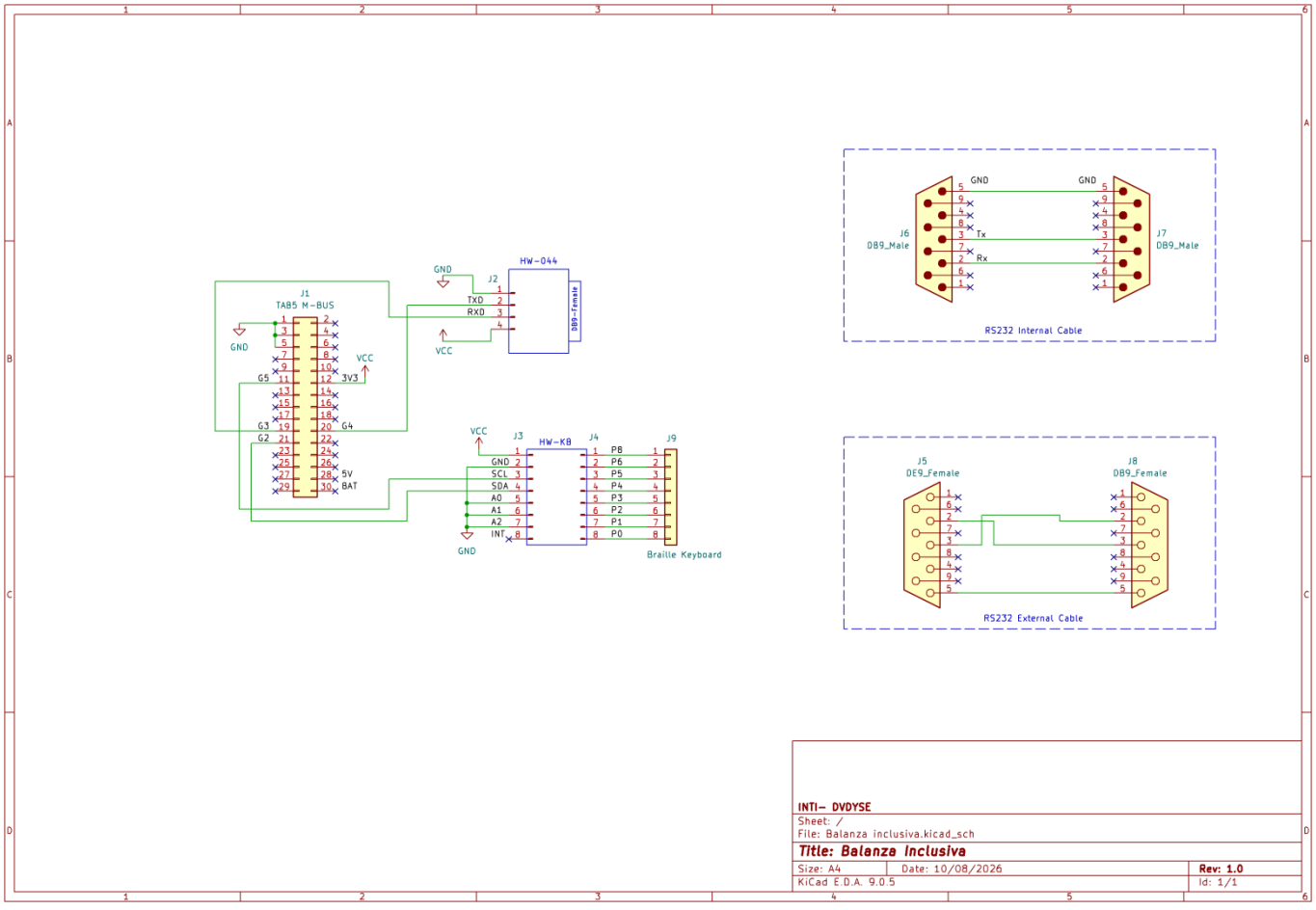


Figure 7. Braille Overlay Template

3.3 Electronic Circuit Diagram

The complete electronic interconnection architecture is illustrated in the following schematic



4. Software Architecture

The software has been developed in **C++** and executes under a **Real-Time Operating System (RTOS)**.
The application is organized into independent functional modules.

Module	Function
main.cpp	User interface, task management, and main application logic.
pesaje.cpp	Processing of data frames received from the commercial scale.
audios.cpp	Voice message playback management.

Table 1. Software Functional Modules

The software is divided into concurrent tasks assigned to the microcontroller cores, ensuring deterministic execution and responsiveness.

Task	Priority	Core	Main Function
WeighingTask	1	Core 0	Acquisition and interpretation of RS-232 frames
UITask	1	Core 0	Graphical interface, touchscreen management, I²C keyboard handling, and weight-stability logic
AudioTask	2	Core 1	Non-blocking PCM/WAV audio playback

Table 2. RTOS Task Allocation and Priorities

4.1 User Interface Task (UITask)

This task is responsible for:

- Braille keyboard acquisition.
- Touchscreen input processing.
- Graphical display updates.
- Operational state management.
- Energy-saving functions.

4.2 Weighing Task (WeighingTask)

This task is responsible for:

- Receiving data from the commercial scale through the serial interface.
- Data-frame assembly and decoding.

- Thread-safe updating of the global weight variable.

4.3 Audio Task (AudioTask)

This task is responsible for:

- Receiving audio playback events.
- Sequential reproduction of voice prompts.
- Memory management of WAV audio files.

5. Communication with the Commercial Scale

Weight acquisition is performed through an RS-232 serial interface using UART1 operating at **9600 bps** via the M-Bus expansion pins G3 and G4.

Received data frames follow the format:

Weight: <valor> kg

The software performs the following operations:

1. Frame integrity verification.
2. Numeric value extraction.
3. Conversion from kilograms to grams.
4. Tare offset compensation.
5. Update of the global weight variable.

This strategy guarantees continuous acquisition while maintaining complete independence from the operator interface.

6. Target Weight Configuration

The system allows the operator to enter the target weight using:

- The touchscreen interface.
- The external matrix Braille keyboard connected through I^2C.

Main characteristics include:

- Valid operating range: 0 g to 30,000 g.
- Automatic input validation.
- Visual indication of invalid entries.
- Permanent storage in ESP32 Non-Volatile Storage (NVS).

Upon system restart, the last valid target weight is automatically restored.

7. Tare Function

The system incorporates an electronic tare function.

When activated:

1. The current gross weight value is stored.
2. The stored value becomes the tare offset.
3. Subsequent measurements are corrected relative to this value.

This feature enables the use of bowls, containers, or trays without compromising dosing accuracy.

8. Weight Evaluation Algorithm

The software continuously compares the current measured weight against the configured target value.
A tolerance band of **±1 g** is applied.

Possible states are as follows:

State 1 – Underweight Condition

Condition: Current Weight < Target Weight − Tolerance

Actions:

- Green upward arrow.
- Proportional progress bar.
- Voice message: “Add”.

State 2 – Overweight Condition

Condition: Current Weight > Target Weight + Tolerance

Actions:

- Red downward arrow.
- Red status bar.
- Voice message: “Remove”.

State 3 – Correct Weight

Condition: Target − Tolerance ≤ Weight ≤ Target + Tolerance

Actions:

- Green confirmation bar.
- Voice message: “Perfect”.

9. Weight Stability Control

To prevent false indications caused by scale fluctuations, the system implements a stability-detection algorithm.

Main characteristics:

- Weight must remain stable for at least 2 seconds.
- Audio playback is enabled only after stability is confirmed.
- Repetitive announcements are prevented for identical measurements.

This feature significantly improves usability and reduces operator distraction.

Sistema de Indicaciones Auditivas

Los mensajes audibles son almacenados en una tarjeta microSD en formato WAV.

El sistema puede reproducir:

10. Audible Guidance System

Audio prompts are stored on a microSD card in WAV format.

The system supports playback of:

- **Numerical Values**

  Files:
  /0.wav
  /1.wav
  ...
  /30000.wav

- **Operational Messages**

  Files:
  /objetivo.wav

/agrega.wav
/saca.wav
/perfecto.wav
/error.wav

Playback is performed in a non-blocking manner using dynamically allocated audio buffers to ensure uninterrupted system operation.

11. Human–Machine Interface (HMI)

The graphical interface consists of three primary screens.

Home Screen

Provides access to:

- Target weight configuration.
- Weighing mode.

Target Weight Configuration Screen

Allows:

- Entry of target weight values.
- Confirmation of settings.
- Correction of input errors.

Weighing Screen

Displays:

- Target weight.
- Current measured weight.
- Graphical status indicators.
- Battery level.
- Access to target configuration functions.

12. Power Management

To maximize battery autonomy, several power-saving mechanisms have been implemented:

- Processor frequency reduction to 80 MHz.
- Wireless radio deactivation.

- Display brightness control.
- Automatic display shutdown after inactivity.

The display automatically enters low-power mode after a period of inactivity and is reactivated through user interaction.

13. Operational Safety and Reliability

The software incorporates several mechanisms to ensure reliable operation:

- RTOS semaphore protection of shared variables.
- Inter-task communication through message queues.
- Received-frame integrity verification.
- Input range validation.
- Safe memory management for audio resources.
- Prevention of overlapping audio playback events.