Hardware Development & Systems Integration for the LexiPal Dyslexia Assistant

Nerimen SAHLI

2025

Abstract

This report details my individual technical contributions to the **LexiPal** project, an innovative smart pen designed to assist children with dyslexia. My role focused on transforming the conceptual design into a functional hardware prototype. Key responsibilities included **3D mechanical design and modeling** of the pen enclosure, **designing and assembling the electrical system**, and **developing critical firmware** to solve a fundamental networking challenge. This work encompassed component specification, iterative testing, debugging, and systems integration, ensuring the core device operated reliably as a platform for the assistive software.

Project Overview

LexiPal is a portable assistive device that helps dyslexic children read printed text independently. It integrates a miniature camera, an ESP32 microcontroller, and a mobile application to provide real-time word scanning, text-to-speech feedback, and learning analytics. The project aimed to create an ergonomic, child-friendly tool that promotes active learning rather than passive assistance. **The project received the 3rd Place Award in the IEEE WIE, CIS & EMBS Technical Challenge.**

1 My Contributions & Technical Implementation

My involvement was central to the hardware realization and basic functionality of the smart pen. The following subsections break down my specific tasks and solutions.

1.1 3D Mechanical Design & Enclosure Modeling

I was solely responsible for creating the physical form factor of the LexiPal pen using **SolidWorks**.

- Designed a compact, ergonomic enclosure with target dimensions of **140 mm in length and 35 mm in diameter** to ensure a comfortable grip for children.
- Modeled precise internal compartments and mounting points to house all electronic components: the **ESP32-CAM module** at the tip for optimal text capture, the **LiPo battery**, and the **power management circuitry** (MT3608 boost converter) in the main body.
- Integrated a **USB-C port** for charging and a button for user control.
- The finalized 3D model served as the direct blueprint for 3D printing the first physical prototype, validating mechanical feasibility and component fit before assembly.

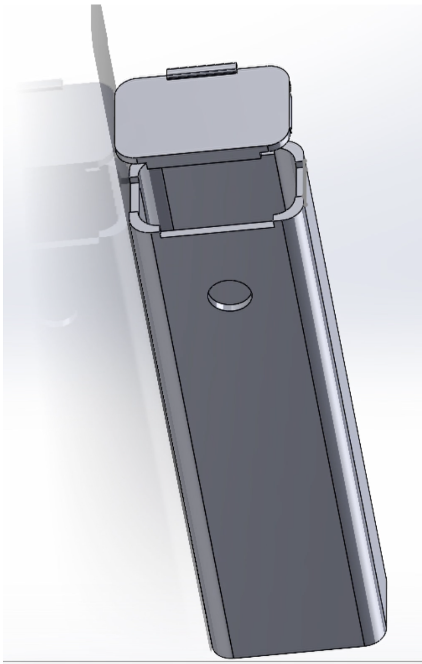

Figure 1: The finalized 3D model

1.2 Electrical Circuit Design, Assembly, and Power Management

I conceived the electrical architecture, sourced components, and performed the physical assembly and debugging.

- **Designed the Circuit:** Mapped the connections between the ESP32-CAM, battery, boost converter, and charging module to ensure stable voltage regulation and safe operation.
- **Initial Assembly & Critical Debugging:** After assembling the first prototype, system testing revealed instability and crashes. I diagnosed the root cause as **insufficient current supply** from the initial 3.7V 600mAh LiPo battery, which could not sustain the ESP32-CAM's peak power demand during Wi-Fi transmission and camera operation.
- **Implemented Solution:** I sourced and integrated a higher-capacity **3.7V 2000mAh LiPo battery**. This replacement provided the necessary current headroom, immediately resolving the instability and yielding a robust, reliable power system for extended use.

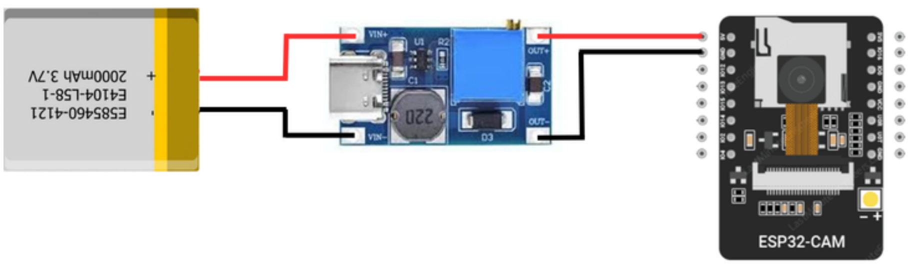

Figure 2: The connections between the ESP32-CAM, battery and boost converter

1.3 Firmware Development & Networking Solution

A major systems integration challenge arose: the mobile application required an internet connection for OCR processing, but the phone needed to connect to the ESP32-CAM's Wi-Fi to receive the video stream, cutting off internet access.

I solved this by programming the ESP32-CAM to operate in a **dual Wi-Fi mode (AP + STA)**.

- **Wrote & Flashed Custom Firmware:** Developed Arduino C++ code for the ESP32-CAM (View code file).
- **Implemented AP+STA Mode:** Configured the device to:
  1. Act as a Wi-Fi **Access Point (AP)** (SSID: `ESP32_CAM_AP`), broadcasting the MJPEG video stream server on a local IP.

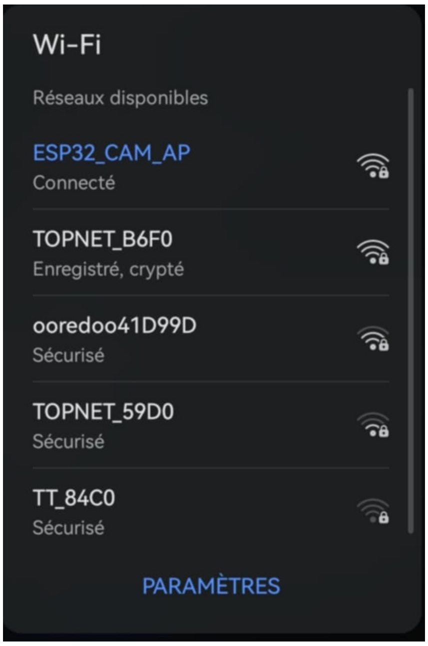

Figure 3: Mobile phone Wi-Fi settings showing the ESP32-CAM Access Point

  2. Simultaneously connect as a **Station (STA)** to an existing Wi-Fi network (e.g., a mobile hotspot or home router) using static IP configuration, granting the *device itself* internet access for future cloud services.

- **Enabled Camera Streaming:** Implemented an HTTP server on the ESP32 to serve a live MJPEG video feed accessible at `http://[ESP-IP]:81/stream`.
- **Validated Functionality:** Successfully tested the stream by connecting a computer to the ESP32's AP and viewing the live camera feed in a web browser, confirming the core capture-and-transmit functionality.

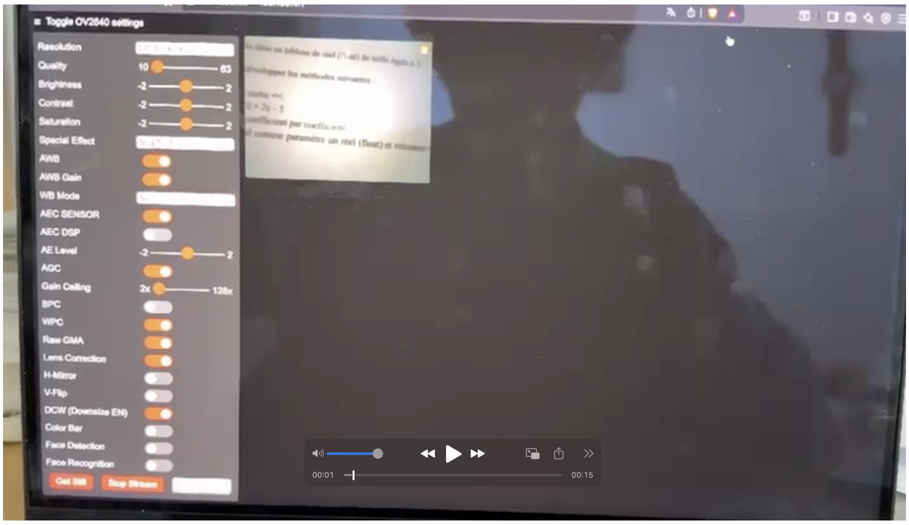

Figure 4: Viewing the live camera feed in a web browser

2 Impact & Outcomes

- **Delivered a Functional Prototype:** My work translated the project from concept into a tangible, working device. The 3D model ensured ergonomics, the power system debugging guaranteed reliability, and the firmware solved a critical connectivity block.
- **Enabled Software Development:** The stable hardware platform and the functional video stream server provided the essential foundation upon which the mobile application team could build and integrate their OCR and UI features.
- **Demonstrated Problem-Solving:** The process of diagnosing the battery issue and architecting the dual-Wi-Fi firmware showcased analytical and iterative engineering skills in embedded systems.

Figure 5: Final Prototype

3 Skills Demonstrated

- **Mechanical CAD:** SolidWorks (3D modeling, tolerancing, design for manufacturing).
- **Embedded Hardware:** Circuit design, component sourcing, soldering, power management, debugging.
- **Embedded Software/Firmware:** Arduino C/C++, ESP32 framework, Wi-Fi networking (AP/STA modes).
- **Systems Integration & Testing:** Prototyping, iterative testing, diagnosing hardware-software interaction issues.

Conclusion

My contributions to the LexiPal project covered the full hardware stack—from mechanical design and electrical assembly to low-level firmware programming. I tackled key engineering challenges related to power delivery and network architecture, directly enabling the prototype's core functionality. This experience honed my skills in end-to-end embedded system development and reinforced the importance of iterative testing and cross-disciplinary problem-solving in creating effective assistive technology.