Oxlo Project Spectre: A Portable Security Research Platform for Wireless Environments

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***Abstract*—Oxlo Project Spectre is a custom-built, pocket-sized hardware platform that integrates an ESP32 dual-core system-on-chip with a 2.8 in TFT touchscreen (240×320), resistive touch input, microSD storage, an onboard audio amplifier, and USB-to-UART programming in a 3D-printed enclosure. It is powered at 5 V via either Micro-USB or USB-C, offering flexibility in mobile scenarios. The goal is a reproducible device for wireless environment research, rapid embedded prototyping, and educational use. This paper details the architecture, board capabilities, design trade-offs, and use cases; provides initial evaluation data; and outlines limitations, ethics, and future Oxlo hardware directions.**

***Index Terms*—embedded systems, ESP32, Wi-Fi, Bluetooth, BLE, portable devices, open hardware, security research, touch-screen UI**

I. Introduction

Portable, self-contained tools that integrate compute, display, input, and storage are valuable for wireless research and embedded education. Many development kits provide strong silicon but lack cohesive mechanicals and on-device UX. Oxlo Project Spectre addresses this gap with an ESP32-based core, SPI TFT + touch, microSD logging, USB programming, audio output, and a printable Oxlo-branded case. Contributions include an integrated hardware design, reproducible build documentation, and an evaluation of field usability.

II. Related Work

Work spans bare ESP32-based development modules and SDKs [1]–[3], handheld network instruments, and open-source UIs. Oxlo Project Spectre positions itself between general-purpose boards and fixed-function tools: pocketable, interactive, and reproducible with commodity parts. Technical details of the ESP32 architecture and radios are documented by Espressif [4]; relevant wireless standards include IEEE 802.11 [5] and Bluetooth Core v4.2 [6]. LCD specifications derive from the JC2432A028N documentation [7], while board-level characteristics follow the ESP32-2432S028R specification [8].

III. System Architecture

A. Overview

The core of the system is the ESP32-2432S028R module, based on the ESP32 dual-core MCU running up to 240 MHz with 520 KB SRAM, 448 KB ROM, and 4 MB embedded Flash [4], [8]. The SoC integrates IEEE 802.11 b/g/n Wi-Fi and Bluetooth v4.2 radios. The board drives a 2.8 in TFT LCD (JC2432A028N) with 240×320 resolution and an ILI9341V controller over SPI [7], [9]. The display supports 65K colors (16-bit RGB), a 12 o'clock viewing direction, and uses a four-LED backlight rated around 80 mA typical [7]. Resistive touch sensing is provided via an XPT2046-compatible controller [10].

A push–push microSD slot enables removable logging. Auxiliary circuits include a small speaker amplifier, RGB LED, and a photosensor input for adaptive brightness; a DHT11 header is available for basic temperature and humidity sensing. BOOT/RESET buttons provide flashing control. The system is powered at 5 V, with input available through either Micro-USB or USB-C. Typical current consumption is approximately 115 mA under nominal operation [8]. The module's nominal outline is 50 mm $\times$ 86 mm.

B. Compute and Connectivity

The ESP32 provides dual-core LX6 processors, integrated Wi-Fi MAC/PHY, Bluetooth radios, on-chip RAM, and rich peripherals [4]. SDKs support STA/AP modes and security features for IEEE 802.11 [5], along with classic Bluetooth and BLE GATT roles [2], [6].

C. Display and Touch

The JC2432A028N LCD module provides a 2.8 in diagonal active area, $240\times\text{RGB}\times320$ resolution, an ILI9341V controller, and a resistive touch overlay driven over SPI [7], [9], [10]. Partial updates and double buffering maintain interactivity for on-device UI.

D. Storage

Removable storage is supported via a microSD slot. FAT file systems implemented in ESP-IDF or Arduino cores enable buffered writes and rolling logs [2], [3].

E. Audio and Indicators

An SC8002B-class audio amplifier drives a 4 ■, 2 W speaker for tones and alerts [11]. An RGB LED provides multicolor status indication, while a photosensor can be used for adaptive brightness or environment-aware features.

F. Power

The board accepts 5 V input via either Micro-USB or USB-C connectors, simplifying power selection in the field and ensuring compatibility with common cables and chargers [8]. Typical operating current is on the order of 115 mA under nominal UI/activity.

G. Enclosure

The Oxlo 3D-printed enclosure prioritizes pocketability, durability, and protection. It incorporates tolerance allowances for the TFT bezel, screw-boss reinforcement, USB clearance, and surface texture for grip. The design includes cavities for heat-set threaded inserts, enabling secure repeated assembly with metal fasteners, which extends the enclosure's lifetime compared to plastic-only fastening. Design files are provided in both `.3mf` and Autodesk Fusion 360 (`.f3d`) formats, allowing for direct 3D printing or parametric modification.

IV. Capabilities

Wireless: Wi-Fi scanning/measurement and BLE/BT discovery through ESP-IDF and Arduino cores [2], [3].
On-device UI: Touchscreen menus, dashboards, and controls without a host.
Logging: SD-card storage for CSV/binary logs; USB serial for debug.
Extensibility: GPIO/I^{2}C/SPI/UART breakouts, RGB LED, photosensor, DHT11 interface.
Power: Accepts 5 V input via either Micro-USB or USB-C, improving flexibility in portable setups.

V. Use Cases

A. Education

Hands-on labs for MCU peripherals, SPI display pipelines, touch input, BLE scanning, and Wi-Fi measurement.

B. Security Research (Ethical)

With explicit authorization, Oxlo Project Spectre supports environment-assessment tasks such as device discovery and controlled testbed experiments. This paper does not prescribe offensive workflows; we emphasize legal and ethical use [12].

C. Rapid Prototyping

Self-contained HMI + logging makes Oxlo Project Spectre a convenient front end for IoT demos, portable loggers, and sensor-UX experiments.

VI. Evaluation

A. Methodology

Firmware was built with ESP-IDF and Arduino. Benchmarks included redraw latency, BLE advertisement throughput, Wi-Fi scan frequency, SD write rate, and idle current.

B. Results

Prototype testing indicated that partial UI redraws averaged roughly 16 ms per updated region; BLE scanning processed approximately 120 advertisements per second; a full sweep of the 2.4 GHz band could be performed about eight times per minute; sequential microSD writes reached on the order of 1.8 MB/s; and idle current with the display active measured about 115 mA.

VII. Discussion

Strengths include portability, integrated UX, and reproducibility. Limitations include resistive-touch responsiveness, modest 320×240 resolution, and no integrated battery. The 115 mA operating point enables practical portable use with external packs, but motivates future power domain work.

VIII. Future Work

Planned directions: integrated battery/charging, higher-resolution capacitive display, modular accessory header, secure element, and a unified Oxlo UI/data schema across devices.

IX. Conclusion

Oxlo Project Spectre demonstrates that a compact, touch-screen ESP32 platform with flexible power input can effectively support wireless research, education, and prototyping. Open mechanicals and schematics make it practical to reproduce and extend.

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References

[1] Espressif Systems, *ESP32 Datasheet*, 2025, module specifications and electrical characteristics. [Online]. Available: https://www.espressif.com/en/support/documents/technical-documents
[2] ——, "Esp-idf programming guide," https://docs.espressif.com/projects/esp-idf/en/latest/, 2025.
[3] I. Grokhotkov and Contributors, "Arduino core for the esp32," https://github.com/espressif/arduino-esp32, 2025.
[4] Espressif Systems, *ESP32 Technical Reference Manual*, 2025, architecture, peripherals, and subsystem details. [Online]. Available: https://www.espressif.com/en/support/documents/technical-documents
[5] *IEEE Std 802.11-2020: Wireless LAN MAC/PHY Specifications*, IEEE Std., 2020.
[6] *Bluetooth Core Specification v4.2*, Bluetooth SIG Std., 2014. [Online]. Available: https://www.bluetooth.com/specifications/specs/core-specification-4-2/
[7] Jiangsu Chimei Electronic, *JC2432A028N 2.8-inch TFT LCD Module Datasheet*, 2024, internal PDF: JC2432A028N.pdf.
[8] Ai-Thinker / AiTrip, *ESP32-2432S028R Specifications (EN)*, 2025, internal PDF: ESP32-2432S028 Specifications-EN.pdf.
[9] Ilitek, *ILI9341 TFT LCD Single Chip Driver*, 2012. [Online]. Available: https://www.displayfuture.com/Display/datasheet/controller/ILI9341.pdf
[10] XPTek / Texas Instruments, *XPT2046 Resistive Touch Screen Controller (ADS7846 Compatible)*, 2011. [Online]. Available: https://www.ti.com/lit/ds/symlink/ads7846.pdf
[11] Silan Microelectronics, *SC8002B Audio Power Amplifier Datasheet*, 2018. [Online]. Available: https://www.silan.com.cn
[12] J. Lin, W. Yu, N. Zhang, X. Yang, H. Zhang, and W. Zhao, "A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications," *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1125–1142, 2017.

Appendix A
Bill of Materials (Representative)

The representative bill of materials includes:

- ESP32-2432S028R module with Wi-Fi + Bluetooth SoC and 4 MB Flash.
- JC2432A028N 2.8 in TFT LCD (240×320, ILI9341V controller, four-LED backlight).
- XPT2046 resistive touch controller.
- microSD push–push socket for removable storage.
- SC8002B-class audio amplifier and 4 , 2 W speaker.
- CH340C USB–UART bridge for programming and serial I/O.
- RGB LED and photosensor for indication and adaptive brightness.
- DHT11 header for temperature/humidity sensing.
- BOOT and RESET tactile buttons.
- Passive components, headers, and fasteners.

Appendix B
Mechanical Design Files

The enclosure design is released as:

- `.3mf` files for direct slicing and 3D printing.
- `.f3d` (Autodesk Fusion 360) files for parametric editing.

Mounting points support heat-set threaded inserts, ensuring durable assembly and disassembly over the device lifetime.