

Electronic-paper material tags

Implementation and pilot guide | V0.3 | PCBA Partner | 4 October 2026

1. Purpose and evidence

This engineering trial combines a local material workbench, USB/BLE gateways, embedded label firmware and a passive interface carrier. The same platform supports electronics material stores, warehouse bins and production lineside replenishment. It is intended to make the task visible at the physical location and keep task confirmation distinct from display delivery.

The source and target builds are available for inspection. No physical board has been flashed, assembled or accepted for this trial. Screenshots show the local demonstration interface, and device messages in browser checks are simulated. No measured battery life, RF coverage, optical display quality or field reliability is claimed.

Current checks: 43 backend checks; 36 browser checks; 11 USB gateway checks; 11 BLE gateway host checks; 111 C-core assertions; 10,704 journal corruption/truncation cases; three complete ARM firmware targets. ERC, DRC, unconnected-net and schematic-parity counts are zero. Ignored KiCad defaults are listed in the reports. These checks do not establish assembly fit, radio behavior or manufacturing readiness.

Read the README, firmware README, docs/API.md, procurement CSV and site acceptance CSV before commissioning. The original detailed documents are mainly Chinese; this guide provides an English route through the package.

2. Material workflows and stock ownership

Electronics store: create a pick for a component and storage location with an optional work-order reference. For example, issue 30 resistors from A-01. Creation reserves stock; business completion deducts it. Component-lot, date-code, MSL, shelf-life and FIFO rules are not implemented and must be mapped before an ERP/WMS extension.

General warehouse: display article, location, task quantity and unit; use the locate LED to find the bin. For example, pick 12 fasteners from B-03. Quantities are integers. Weighing, fractional units, RFID and automatic quantity detection need additional interfaces and rules.

Lineside supply: button 2 requests replenishment. For example, a station calls for 20 terminals. A request does not add inventory. A delivery task and its business confirmation record the incoming material. Only one open replenishment task is allowed per label.

Only one selected pick is shown on a label; other open picks remain reserved. Completed or cancelled selected tasks cause the next eligible task to be selected. Cancellation releases the reservation without changing total stock. Workbench completion checks the exact part code and location plus an entered operator ID. A wrong scan is rejected. This operator identifier is not a login identity. Button 1 uses the specific task and display version previously reported as displayed; it provides no scan evidence. The compatibility API still allows an empty completion body, so a mandatory-scan policy needs extra controls.

3. Hardware target and wiring

Use the base Seeed XIAO nRF52840 (SKU 102010448), not Plus or Sense, and the Waveshare 2.9-inch black-and-white finished module (SKU 12956), V2 target revision. Verify the rear-board revision, 3.3 V supply/logic support and supplied cable pin sequence with the supplier. Color B/G/D variants and a bare panel require a different design. The driver target is GxEPD2_290_T94_V2, 296 x 128 pixels.

USB powers the XIAO. Connect panel VCC/GND to XIAO 3V3/GND. MOSI/DIN uses D10; SCK/CLK D8; CS D3; DC D4; RST D5; BUSY D6. Confirm button: D1 to switch to GND. Shortage button: D0 to switch to GND. Locate LED: D2 through 1 kohm to LED anode; cathode to GND. D7 and D9 are reserved. Follow signal names rather than cable colors. Do not wire USB VBUS to the panel or GPIO.

Start with the modules and short jumper wires. Confirm power and USB identity before adding the display. Check for short circuits and observe actual current, resets and heating. The 70 x 50 mm, two-layer carrier is a passive THT interface candidate with no mounting holes. Capacitor MPNs and some part envelopes remain open. Verify socket height, USB clearance, antenna distance from metal and enclosure fit before ordering samples. CAM files are for engineering review. The suggested enclosure envelope is not a released mechanical design.

4. Build, identity and BLE commissioning

The pinned target is Seeeduino:nrf52:xiaonRF52840, Seeed non-mbed core 1.1.13 and S140 7.3.0 (FWID 0x0123). Binary folders EL-001, WH-001 and LS-001 contain Intel HEX and Nordic DFU ZIP, not UF2. Verify the actual bootloader and SoftDevice, then use the vendor's upload flow. Do not substitute another board's image or perform a full-chip erase. build.py can compile a different ASCII label identifier; dependencies.lock.json records the tested versions and source archive checksums.

Run the workbench locally, add real locations and set each commissioned label to external-device mode. Over USB, record the label_id and the 16-hex-digit MCU device_id returned in hello. Configure the gateway with explicit expected identifiers. A BLE scan address on macOS is a host UUID, not the MCU identifier. An advertisement name alone is not authentication.

A USB commissioning command opens a 60-second pairing window. The SDK generates a dynamic PIN printed only over USB. The firmware requires authenticated encrypted mode and a 16-byte key; enrollment outside the window is denied, while existing bonds can reconnect. Use the documented OS pairing flow. Actual PIN negotiation, bonding persistence and security must be verified on hardware.

The transport is ordinary BLE Nordic UART Service GATT, not Bluetooth ESL or PAwR. RX and TX messages are newline-delimited JSON and can span multiple notifications. Gateways use 20-byte writes with response. An ATT response is only transport delivery. USB continues to supply power while BLE carries business data; a battery power/sleep architecture is not included.

5. Protocol, retries and data recovery

Each command contains `command_id`, `label_id`, `display_version`, `part` and `location` fields, `stock quantity`, `selected task ID/type/quantity` and `locate duration`. Commands are immutable snapshots with increasing display versions. Display receipts carry their own event UUID, command ID, version and driver result. BUSY observation establishes a driver report, not an optical readback. A display receipt does not complete a task or change stock.

Device business events retain the same event UUID until acknowledged. The gateway commits an event to the backend before sending accepted. A lost ACK can therefore retry without another stock deduction. Permanent rejections are recorded before a rejected ACK; temporary network or authentication errors leave the event pending. The device journal holds up to 16 unacknowledged events in CRC-protected dual slots. Damaged storage fails closed. Reboot preserves pending event identifiers but requires fresh display synchronization.

GET `/api/state` returns local state and a process CSRF token. POST `/api/tasks` creates pick/replenish tasks and may include `reference` and `request_id`. POST `/api/tasks/{id}/complete` accepts `scanned_item`, `scanned_location` and `operator` together. Device `command`, `heartbeat`, `receipt` and `button` endpoints are documented in `docs/API.md`. Heartbeat diagnostics include `transport`, `firmware`, `queued_events` and `storage_fault`. The token and Host/Origin checks are local browser controls, not an enterprise device-authentication system.

Use `app/manage.py` for integrity checks and consistent SQLite backups. Restore to a new path, never overwrite the active database. Reconcile movements after the backup and reboot normal tags for new display synchronization. The package does not contain your runtime database or machine credentials.

6. Procurement and pilot acceptance

Plan three working labels plus one core spare: four XIAO boards, four V2 display modules, ten buttons, five LEDs, resistors, short jumpers, breadboards, four USB data cables and suitable USB power. The English procurement CSV lists quantities, supplier references and receiving checks. Prices, availability, freight and tax must be confirmed with suppliers; no procurement order or firm BOM quotation is included.

Phase 1: prove one desk prototype with USB identity, complete text/quantity display, BUSY failure behavior, buttons, locate LED, repeated events and restart. Phase 2: enroll three labels, verify identity mismatch rejection, pairing-window behavior, bond reconnect and concurrent radio tasks. Phase 3: test power loss during display and after a button event, lost ACK after backend commit, backend restart, queue saturation and damaged journal slots. Record stock counts and screen photographs.

Phase 4: exercise each real workflow. Wrong-code workbench confirmation must leave stock unchanged; physical-button results must be distinguished from scan evidence. Phase 5: observe a week of operation and log task success, end-to-end delay, disconnections, unexplained resets and stock discrepancies. A useful proposed target is 100 operations with no duplicate deduction or cross-label task, and rejection of every deliberately wrong code. These are proposed targets, not achieved results. Establish RF coverage and refresh-latency targets from site measurements.

The site acceptance CSV contains pending physical cases. After module tests, freeze MPN/footprints, antenna and connector clearances, mounting and DFM/DFA before five carrier samples. Further product work includes power and RF/EMC qualification, flash endurance, safety and ESD, enclosure, fixtures, firmware revision records and project-specific EVT/DVT/PVT release criteria.

7. Customization brief, files and references

For a pilot or custom PCBA request, provide application and process owner, number of locations and simultaneous tasks, initial and future quantities, power and network, shelf/mounting photographs, viewing distance, update frequency, item/location/order-code samples, scan and account policies, ERP/WMS API details, required languages, acceptance targets and schedule. Agree which system owns stock and how interrupted or duplicate operations are reconciled.

V0.3 is a single-computer trial. ERP/WMS connectors, accounts and role permissions, production fleet provisioning, cloud operation, battery optimization, OTA, Bluetooth ESL/PAwR and product certification need separate scope. We can define electronics, firmware, gateway, enclosure integration and prototype verification around those requirements.

The complete archive contains the local app/web source, C core, Arduino firmware, USB/BLE gateways, commissioning/build tools, pinned upstream source archives, three firmware targets, native KiCad, BOM, drawings, CAM candidate, procurement and acceptance sheets, detailed docs and current/historical reports. Public packaging removes local machine paths and excludes runtime DBs, caches and environments. SHA256SUMS identifies the distributed files. Original upstream licenses and font notices remain applicable; combined Arduino firmware includes GPLv3 GxEPD2. See the licensing notice before redistribution or commercial integration.

Solution and inquiry: <https://pcbapartner.com/electronic-paper-material-tags.html>

Seed board and upload reference: https://wiki.seeedstudio.com/XIAO_BLE/

Waveshare module reference:

<https://www.waveshare.com/product/displays/e-paper/2.9inch-e-paper-module.htm>

Display-library source and license: <https://github.com/ZinggJM/GxEPD2>

Custom development: <https://pcbapartner.com/product-concept-appearance-structure-design.html>