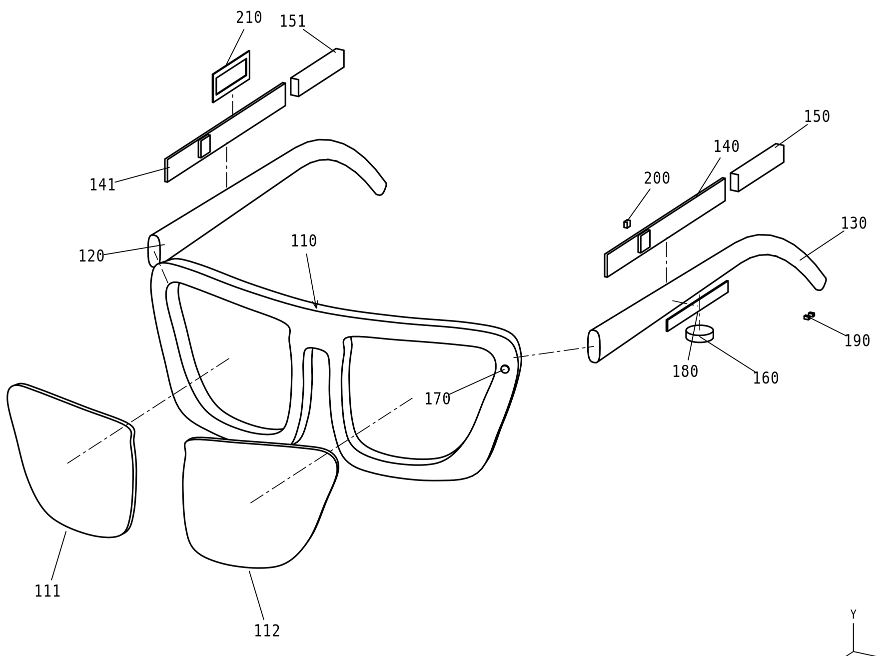
Kyra R1 EV1 - the escalation glasses engine

Design documentation package



110 FRAME FRONT   111/112 LENS, PLANO, NO DISPLAY   120 TEMPLE, CONTROLLER SIDE   130 TEMPLE, AUDIO SIDE
140 PCB, AUDIO SoC (BM83 CLASS)   141 PCB, CONTROLLER (nRF52840)   150/151 CELL, Li-Po   160 OPEN-EAR SPEAKER
170 MICROPHONE, POWER-SWITCHED   180 TOUCH STRIP, 3 CH + GUARD   190 CHARGING CONTACTS   200 MIC POWER SWITCH   210 NFC ANTENNA

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Document control

Revision history

Revision	Date	By	Description
3297c80	2026-09-02	animesh-chouhan	copperhead: create pipeline stage: part-selection
abad67f	2026-09-02	animesh-chouhan	copperhead: create pipeline stage: architecture
0c2f005	2026-09-02	animesh-chouhan	copperhead: create pipeline stage: spec-seed
9b73f9b	2026-09-02	animesh-chouhan	stageMaxTurns: part-selection 80 (I27 workaround)
ed41083	2026-09-02	copperhead-harness	workspace baseline: brief

Contents of this package

Part	Document	Source
XXIII	Tasks	`openspec/changes/seed-kyra-glasses-ev1-spec/tasks.md`
XXIV	Attempt 01 - FAIL (operator stop at the stage-4 boundary; stages 1 to 3 committed)	`/home/animesh/copperhead/kyra/run-logs/2026-09-02T06-56-19/attempt-01/REPORT.md`

Contents

PART I

Kyra R1 EV1 - the escalation glasses engine

Source: brief.md

Design the electronics for the **Kyra glasses**, the wearable escalation surface for the Kyra agent: the thing on your face that speaks when an open loop genuinely needs you, that takes the call you owe someone, and that listens only when you tell it to. Kyra's own words are "ambient glasses controlled by a ring: reply, dismiss or confirm with your thumb". This board is the glasses' electronics. The ring is a separate board with its own brief; the two are one system, and this board owes the ring a link.

The board specified here is **EV1**, the engineering-validation build. It carries the complete glasses architecture in packages that can be ordered, assembled and probed today. The production glasses are a rigid-flex assembly split across two temples in bare silicon; EV1 is their electrical twin, and every part below names its production equivalent. EV1 exists to answer four questions before anyone tools a frame, and those four questions are what every requirement in this brief serves.

Why glasses, and why these glasses

Kyra's software runs on Mac and iOS. The phone is the brain: it finds the open loops, decides what escalates, renders speech and transcribes replies. The glasses are the surface the escalation arrives on and the surface a reply leaves from, and nothing more.

Every smart glasses shipping today is either a **camera** (Ray-Ban Meta) or a **display** (Even, Halliday, Meta Display, Frame). A display costs an FPGA, a waveguide and a supply chain one vendor controls; a camera is a consent problem the product's whole claim argues against. Kyra's glasses are an **audio surface**: open-ear speakers, two microphones, no camera, no display, no wake word. They can take a phone call, because the founder's own first prototype did exactly that. Their differentiator is what they do not carry, and the one thing they do carry that could listen - the microphone - is powered by a switch the application controller owns, off by default, on only for a call or for a reply the wearer asked for. That is the direct hardware expression of "your data stays with you", and it is what lets a 250 mAh cell last a day.

What EV1 must prove

1. **Call legibility and pickup.** Does an open-ear speaker at temple position deliver a call and an eight-second spoken escalation legibly at street noise, and does the speaker leak into the microphones enough to break the echo canceller?
2. **Escalation latency.** From the phone's decision to the first audible sample, through the audio module leaving sniff and starting a stream: under one second? Under 500 ms?
3. **The power budget, measured.** Does the design hold 8 mA average over a defined day, on an instrument, not on a spreadsheet?
4. **The link.** Does a thumb gesture on the ring silence or answer the glasses within 200 ms with both devices on the phone, and is a direct glasses-to-ring link needed at all?

Every test point, jumper and connector on this board exists for one of those four. Nothing else is instrumented.

Scope and the parts budget

One board, one schematic sheet. Hold it to roughly **90 placed symbols** and never more than **110**, connectors, passives and test points included. Requirement text is free; only parts cost sheet area. Where a choice exists between an integrated part and a discrete block, take the integrated one unless a requirement below says otherwise. Do not add circuitry that is not listed as a board requirement; every block below is required and nothing else is.

Four assemblies are deliberately **off the board**, on connectors: the cell, the two speakers, the two microphones, and the touch electrodes. Microphone placement and electrode geometry are the experiment; a fixed copper pattern would defeat it.

Decisions closed

The product copy and the founder's prototype leave these open. A schematic needs a value, so each is closed here with its reason.

1. **Call audio is Bluetooth Classic, Hands-Free and A2DP, through a certified dual-mode audio module.** An iPhone carries a call over HFP; Apple has not enabled LE Audio for calls. A Bluetooth Low Energy radio alone cannot make the call the founder's V0 made. The module is the Microchip BM83 (`RF_Bluetooth:Microchip_BM83`): HFP 1.7.2, A2DP 1.3, two differential microphone inputs with bias, stereo DAC to headphone outputs, a DSP with echo cancellation and noise reduction, an integrated charger, and a host UART. Production: the IS2083BM silicon inside it, or a dual-mode SoC with an open application core, named in rationale and never in the part-number column.
2. **No display.** The prototype has none, the product copy says "ambient", not "shows", and a waveguide is not a PCB problem. Escalations are spoken.
3. **No camera.** It is the consent problem the product exists to avoid, and the prototype was demonstrated without one.
4. **Microphone power is a hardware state.** The microphones' supply goes through a high-side switch driven by the application controller, off by default, on only during a call or a reply window. The audio module's own microphone bias does not power them. "Microphone off" is therefore a state a probe can verify, not a firmware promise. The digital-microphone inputs are unpopulated: there is no wake word.
5. **Two radios on EV1: the audio module, and an application controller with its own Bluetooth Low Energy radio.** The audio module's processor runs the vendor's audio firmware; it cannot host the Kyra app's data profile and cannot act as a central toward the ring. The application controller is the nRF52840 in the Raytac MDBT50Q-1MV2 module (`RF_Module:MDBT50Q-1MV2`): pre-certified with its antenna, high-voltage supply mode so the cell connects directly, native USB for bring-up, and the same silicon Brilliant Labs' Frame proves in this seat. It holds two links (peripheral to the phone app, central to the ring), drives the sensors and the touch strip, owns the microphone switch, and controls the audio module over UART. Production: one dual-mode SoC with an open application core, once one has a symbol.
6. **Two open-ear speakers, one per temple, driven by two class-D amplifiers from the module's headphone outputs.** The headphone driver alone will not move an open-ear speaker legibly. The amplifiers' shutdown pins are on a controller output and held low between escalations.
7. **Two analog differential MEMS microphones on the audio module's inputs**, so the module's dual-microphone noise reduction has two channels. Off-board on a flat-flex tail: where they sit on the frame, and how much speaker leaks back into them, is question 1.
8. **A confirm is gated on the accelerometer, and not-worn means silent.** The same accelerometer as the ring, as an interlock: don and doff, and a nod as the confirm gesture when the ring is off. No activity data is derived and none leaves the glasses.
9. **A temple touch strip with the ring's three gestures.** Every shipping glasses with a ring keeps temple touch as well, and Kyra has not said the ring is required. The strip is the input when there is no ring on; the ring is preferred, not a dependency.
10. **One cell on EV1, charged by the audio module's own charger from 5 V on a USB-C receptacle.** The

production frame carries a cell per temple and charges from a case over contacts; EV1 carries one cell on a connector and takes 5 V from USB-C, which also gives the controller its native USB. No second charger part. Discrete cell protection on the board, because a bare pouch cell in a sealed product has no other protection.

11. **No discrete logic regulator.** The controller module takes the cell directly in high-voltage mode and its regulated output powers the sensors and the touch controller; the audio module has its own buck; the amplifiers take the cell. State the external load on the module's regulated output against its datasheet limit.
12. **No indicator light on the glasses.** A light on your face is a notification other people can read. EV1 carries exactly one charge-status light, in the instrumentation block, and it is not in the glasses build. Whether the product needs a microphone-active light for the people around the wearer is an open item.

Board requirements

1. Audio module and application controller

- **KYG-101.** Bluetooth 5.0 dual-mode stereo audio module with Hands-Free Profile, A2DP and AVRCP, two differential analog microphone inputs with bias, I2S, stereo DAC to headphone outputs, an audio DSP with echo cancellation and noise reduction, an integrated Li-ion charger, and a host UART: `RF_Bluetooth:Microchip_BM83`, footprint `RF_Module:Microchip_BM83`.
- **KYG-102.** Application controller: nRF52840 module with integrated antenna, `RF_Module:MDBT50Q-1MV2`, footprint `RF_Module:Raytac_MDBT50Q`. Its VDDH pin takes the protected cell node directly; DCCH inductor network per the module datasheet if the module requires it; native USB on VBUS, D+ and D-.
- **KYG-103.** Host UART between controller and audio module: TXD, RXD, RTS and CTS. The module's PWR (MFB) and ~RST pins are on controller outputs, so the controller can wake, configure and power down the audio module.
- **KYG-104.** The controller shall be able to hold **two concurrent Bluetooth Low Energy links**, peripheral to the phone and central to the ring, without a second radio. This is a firmware and stack requirement; the board's obligation is not to preclude it.
- **KYG-105.** Reset provision and a pull-up on the controller's reset pin. Crystals per the module: if the module variant lacks a 32.768 kHz crystal, fit one with its load capacitors, because the glasses keep time between connections.
- **KYG-106.** The audio module's I2S and line-in are not used and are terminated per its datasheet. Its LED1 output drives the single instrumentation light of decision 12.

2. Audio output

- **KYG-201.** Two mono class-D amplifiers, `Amplifier_Audio:PAM8302AAD`, one per speaker, fed AC-coupled and differentially from the module's AOHPL and AOHPR against AOHPM. Set the gain for the speaker of KYG-203 and state the calculation.
- **KYG-202.** Both amplifiers' ~SD pins on one controller output, held low when idle, so the amplifiers contribute nothing to the standby budget.
- **KYG-203.** Two open-ear micro speakers, `Device:Speaker`, off-board on two-way connectors. Target 8 ohm class; the part, impedance and rated power are an open item and the amplifier gain is restated when it closes.
- **KYG-204.** Keep the speaker leads and the microphone tail apart in layout intent, and note it in the documents; question 1 depends on it.

3. Microphones

- **KYG-301.** Two analog differential MEMS microphones, `Sensor_Audio:SPM0687LR5H-1`, into MICP1/MICN1 and MICP2/MICN2, with the module's MICBIAS network per its datasheet.

- **KYG-302.** The microphones are **not on this board**. They leave on an eight-way flat-flex connector (two of Vdd, OUT+, OUT-, plus two grounds), so placement can change without a board spin.
- **KYG-303. Microphone power is a hardware state.** The microphones' Vdd is switched by a high-side switch (`Transistor_FET:Q_PMOS_GSD` class, or a load switch) driven from a controller output, with a pull-up that holds it **off** at reset and while the controller is unpowered. The module's bias pin does not supply the microphones. State in the specification that "microphone off" is verifiable at the test point of KYG-803.
- **KYG-304.** The module's digital-microphone inputs (DMIC1_L, DMIC1_R, DMIC_CLK) are unpopulated and terminated per datasheet. No wake-word path exists; say so in the specification.
- **KYG-305.** Series resistors on every microphone line, close to the module, for electrostatic discharge and radiated-emissions control. Record the value and the reason.

4. Input and interlock

- **KYG-401.** Seven-channel burst-mode capacitive touch controller with I2C and a CHANGE output: `Sensor_Touch:AT42QT1070-M`. It scans autonomously and interrupts the controller; the controller does not poll it.
- **KYG-402.** Channel allocation, fixed: **three channels** as a linear strip along the outer temple (tap position and swipe direction), **one channel as the guard**, **one channel as the wear-detect electrode** on the inner temple. Two channels spare and terminated per the datasheet.
- **KYG-403.** The electrodes are off-board on a six-way flat-flex connector (three strip, one guard, one wear, one ground). Series resistors on every electrode line. Adjacent key suppression and the guard channel both enabled; the rain-and-sweat result is a measurement to be taken, not a claim.
- **KYG-404.** Three-axis accelerometer with an on-chip wake-up engine, single-digit microamp low-power current, I2C: `Sensor_Motion:KX022-1020`, interrupt to the controller. Accelerometer only; no gyroscope, no magnetometer.
- **KYG-405.** No motion data leaves the glasses. The accelerometer is the don/doff and nod-to-confirm interlock and is not logged, transmitted or aggregated. State this in the specification.
- **KYG-406.** Not worn gates the product: the glasses **shall not** play an escalation and **shall not** open a microphone window when they read as not worn. The rule is firmware and belongs in the specification; the hardware obligation is the wear electrode and the accelerometer.

5. Cell, protection and charging

- **KYG-501.** Single lithium-polymer cell, 250 mAh nominal, 3.7 V, `Device:Battery_Cell` on a two-way connector so cells can be swapped during the power study. Bare cell, no protection module of its own.
- **KYG-502.** Discrete cell protection on the board: over-charge, over-discharge and over-current, using `Battery_Management:AP9101CK` and a common-source pair of low on-resistance N-channel MOSFETs in the cell's negative leg. Non-negotiable.
- **KYG-503.** Charging by the audio module's integrated charger: ADAP_IN from the 5 V of KYG-601, BAT_IN to the protected cell node. Program the charge current for **0.5 C (125 mA)** by the datasheet's method and state both the setting and the method. Whether the cell permits more is an open item.
- **KYG-504.** Only the audio module is powered through its BAT_IN. Every other block is powered from the protected cell node or from the controller module's regulated output. Do not power external blocks from the audio module's regulators.
- **KYG-505.** Thermal check: state the charger's worst-case dissipation at 125 mA from 5 V, and confirm the module's rating handles it.
- **KYG-506.** State the total external load on the controller module's regulated output (touch controller, accelerometer, the microphone switch) against the datasheet limit.

6. Power input

- **KYG-601.** USB Type-C receptacle, USB 2.0, `Connector:USB_C_Receptacle_USB2.0_16P`, with 5.1 kilohm pull-downs on CC1 and CC2 so a source supplies 5 V. VBUS to ADAP_IN and to the controller module's VBUS; D+ and D- to the module. EV1 only: the glasses charge from a case over contacts and the receptacle is not in the glasses build.
- **KYG-602.** Transient-voltage suppression on VBUS, `Device:D_Zener` class or a dedicated TVS, and bulk capacitance per both modules' input requirements.

7. Pairing and identity

- **KYG-701.** Near-field communication tag antenna on the controller module's NFC pins, with the two tuning capacitors the vendor's reference requires, on a two-way connector so the antenna is a mechanical part. Out-of-band pairing: tap the glasses to the host.
- **KYG-702.** Where a host does not support near-field pairing, pairing is confirmed by a deliberate gesture on the temple strip. No extra hardware; state the flow.
- **KYG-703.** No advertisement payload, from either radio, carrying anything about the wearer. Rotating resolvable private address on the controller's radio. Specification requirement.
- **KYG-704.** The glasses store no message content: escalations arrive as opaque identifiers over the control link and as rendered audio over the audio link. Say that in the specification; it is a product claim.

8. Bring-up and instrumentation

- **KYG-801.** Serial wire debug for the controller on a 2x5 1.27 mm header, with the reset line included. EV1 only; the glasses have test pads.
- **KYG-802. A current-measurement jumper in series with the cell's positive leg**, so the average current of question 3 can actually be measured with an instrument. Two-way header, shorting link fitted for normal operation.
- **KYG-803.** Test points, minimum set: cell positive, VBUS, the controller module's regulated output, the audio module's BAT_IN, the **switched microphone Vdd**, both amplifier outputs, UART TXD and RXD, the touch CHANGE line, the accelerometer interrupt line, and ground. At least two ground test points, physically separated.
- **KYG-804.** The audio module's UART also on a four-pin header (TXD, RXD, GND, 3V3 sense) so the vendor's configuration tool can reach it without the controller. EV1 only.
- **KYG-805.** One charge-status LED with its resistor from the audio module's LED1, per decision 12. Not in the glasses build.
- **KYG-806.** I2C bus pull-ups, valued for the bus's total capacitance at the intended speed. One bus for the touch controller and the accelerometer; confirm the two addresses do not collide and record them in the pinout.

9. Power budget

- **KYG-901.** The design target is **8 mA average** and the ceiling is **12 mA**, over a 20-hour wearing day with this duty cycle: 40 escalations, each an earcon plus up to 8 s of streamed speech; 40 reply windows of 15 s with the microphones powered; one 30-minute call; the phone links held all day; standby otherwise. Twelve milliamps is 240 mAh usable from a 250 mAh cell over 20 hours.
- **KYG-902.** The specification shall carry an **itemised current table**, one row per device and operating mode, each citing a datasheet figure, summed against the duty cycle, with the margin against KYG-901 shown. The audio module's sniff, A2DP, HFP and deep-sleep figures come from its datasheet, DS70005402; the controller module's from Nordic's. An unitemised total is not a budget.
- **KYG-903.** Every part's quiescent, standby and leakage current is checked against KYG-901 during part

selection. A part whose standby current alone spends a tenth of the budget must be justified in its rationale or replaced.
- **KYG-904.** Audio energy is amortised into the budget: state the per-escalation charge, the per-reply-window charge, the assumed counts per day, and the resulting average.

Capture and sourcing rules

- Every part must resolve to a symbol installed on this machine. Confirm the symbol exists and confirm its pins before committing the part.
- Named parts indicate the reference implementation. Orderable equivalents are acceptable where a symbol or footprint is not available, provided the substitution is recorded with its reason.
- **The bill of materials is the EV1 build.** Its part numbers are the EV1 packages and modules: the ones that can be ordered from a major distributor and assembled on a rigid board. Where the production glasses use bare silicon, name that production part in the rationale column, not in the part-number column. A part number that does not match its footprint is a defect.
- Parts orderable from major distributors. Mostly 0402 passives, no smaller.

Mechanical

- EV1: two-layer board, **50 mm x 35 mm**, one edge carrying the USB-C receptacle, the debug header and the current jumper; the opposite edge carrying the cell and speaker connectors; the microphone and electrode flat-flex connectors on a third edge; the NFC antenna connector on the fourth. Two mounting holes.
- The board is not the glasses. It is sized to sit in a printed carrier that clips to a frame for wear testing, and its connector placement exists so the speakers, microphones and electrode flex can be routed to temple and end-piece positions as they will be in the glasses.
- Production glasses, for context and not for this board: rigid-flex across two temples through the hinges, one cell per temple, bare silicon, charging contacts at the temple tips.
- Keep both radios' antennas clear of the speaker leads and the microphone tail in layout intent, and note it in the documents.

Compliance

- EV1 is an engineering test unit and is not offered for sale. No certification is claimed or required for it. Both radios are pre-certified modules on EV1, which is why they were chosen; the production glasses with bare silicon need full intentional-radiator testing, and that is a known, budgeted cost to record in the specification.
- The glasses' frame is the only skin-contact material. EV1 makes no biocompatibility claim.
- Hearing-safety: the amplifier gain and the speaker's rated output shall be stated against the open-ear position; no claim of compliance is made on EV1.

Environment

- Operating: **0 to 45 degrees Celsius**, set by the cell's charge and discharge limits, not by the silicon. Every part must be rated for it.
- Storage: -20 to +60 degrees Celsius.
- EV1 carries no ingress rating. The production glasses are sealed against sweat and rain.

Not yet specified - record as explicit assumptions or open items

- The speaker part, impedance and rated power; the amplifier gain follows from it.
- The audio module's sniff, A2DP, HFP and deep-sleep currents from its datasheet.
- The cell's permitted charge rate. KYG-503 assumes 0.5 C is acceptable.
- Microphone placement on the frame, and therefore the flat-flex length.
- Whether the product needs a microphone-active light for bystanders.
- Whether the production audio path stays Bluetooth Classic or moves to LE Audio when the host supports it, and therefore which single SoC replaces the two modules.
- Whether the module variant carries a 32.768 kHz crystal.

Out of scope

- Any display, waveguide or optical component.
- Any camera.
- Any wake-word or always-listening path.
- A haptic actuator in the glasses; the haptic channel is the ring's.
- The charging case, its cell and its contacts.
- The frame, hinges, temples, lenses and sealing.
- The Mac and iOS software, the open-loop detection, speech rendering and transcription, and everything above the links.
- The ring. It has its own brief; this board owes it a link and nothing else.

PART II

Kyra R1 EV1 - Escalation Glasses Engine: Specification

Source: docs/SPEC.md

Status: seeded from `brief.md` (stage 1, requirements only - no schematic exists yet). All values marked **ASSUMED** are defaults proposed here, not stated by the brief; all items marked **OPEN** are unresolved and must close before the production frame is tooled.

Architecture: `docs/SUBSYSTEMS.md` (stage 2) decomposes this spec into nine subsystems (S1–S9), and is the binding source for the net-naming contract, the control-ownership rules (the controller owns `MIC_EN_N` and `AMP_SD_N`; the BM83 owns only the charger and the audio path), the single-`GND` topology, and the per-subsystem power and symbol ledgers. It restates no value that is not derived here; where the two disagree, this document governs.

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1. What the device is

The Kyra glasses are the **escalation surface** for the Kyra agent: an audio-only wearable that speaks when an open loop needs the wearer, takes a phone call, and listens only when explicitly asked. The phone is the brain (it detects open loops, decides what escalates, renders speech, transcribes replies); the glasses are the surface an escalation arrives on and a reply leaves from, and nothing more.

This document specifies **EV1**, the engineering-validation board: the complete glasses architecture in orderable, probeable packages on one 50 × 35 mm two-layer board. EV1 is the electrical twin of the production rigid-flex temples, not the product.

EV1 exists to answer four questions. Every test point, jumper and connector serves one:

Q	Question	Instrumented by
Q1	Is an open-ear speaker at temple position legible at street noise, and does it leak into the microphones enough to break the echo canceller?	Speaker connectors J3/J4, microphone FFC J5, amplifier-output test points
Q2	Escalation latency: phone decision → first audible sample, through the audio module leaving sniff. < 1 s? < 500 ms?	UART TXD/RXD test points + audio-module UART header J9
Q3	Does the design hold 8 mA average over a defined day, **measured on an instrument**?	Current-measurement jumper J10 in the cell's positive leg
Q4	Does a ring thumb gesture silence or answer the glasses within 200 ms, and is a direct glasses↔ring link needed at all?	Controller BLE (two concurrent links), SWD header J8

1.1 Scope walls (these are requirements, not preferences)

On the board: dual-mode audio module, BLE application controller, two class-D amplifiers, two analog microphone channels with a hardware power switch, capacitive touch controller, accelerometer, discrete cell protection, USB-C 5 V input, NFC pairing antenna connector, bring-up instrumentation.

Deliberately off the board, on connectors (placement is the experiment; fixed copper would defeat it): the cell, the two speakers, the two microphones, the touch electrodes, the NFC antenna.

Forbidden - do not add, in any revision, without reopening this spec:

- any display, waveguide or optical component;
- any camera;
- any wake-word, voice-activation or always-listening path (the digital-microphone inputs are unpopulated for exactly this reason);
- a haptic actuator (that channel belongs to the ring);
- a second charger, or a discrete logic regulator;
- any indicator light in the glasses build (EV1's single charge LED is instrumentation only);
- any circuitry not named in a KYG requirement.

Parts budget: target ≈ 90 placed symbols, hard ceiling 110, including connectors, passives and test points. Current architecture estimate: ≈ **82 symbols** (§9).

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2. Architecture

```
      USB-C (5V, EV1 only)
          |  VBUS -- TVS -- bulk
          |            |
          |            +--------------------------> MDBT50Q VBUS (native USB, D+/D-)
          |            |
          +-- ADAP_IN -+-> BM83 audio module --> BAT_IN --> VBAT_PROT
                            (integrated charger, 125 mA)

Cell 250 mAh -- J2 -- AP9101CK + 2xNFET (negative leg) -- J10 (current jumper) -- VBAT_PROT

VBAT_PROT --+--> BM83 BAT_IN            (audio module only, per KYG-504)
            +--> MDBT50Q VDDH  --REG0--> VDD_3V0 (module regulated output)
            +--> PAM8302A x2 VDD        (amplifiers take the cell directly)

VDD_3V0 --+--> AT42QT1070 (touch)   -I2C-+
          +--> KX022-1020 (accel)   -I2C-+--> MDBT50Q
          +--> Q1 PMOS high-side switch --> MIC_VDD --> J5 --> 2x SPM0687LR5H-1
               (gate pull-up to VDD_3V0 = OFF at reset)

BM83 AOHPL/AOHPR/AOHPM --AC-coupled--> PAM8302A x2 --> J3/J4 --> 2x open-ear speaker
BM83 MICP1/N1, MICP2/N2 <-- 100 ohm <-- J5 <-- microphones
MDBT50Q --UART (TXD/RXD/RTS/CTS) + PWR(MFB) + ~RST--> BM83
MDBT50Q P0.09/P0.10 --NFC--> J7 --> antenna (off-board)
```

Two radios, on purpose. The BM83's processor runs Microchip's audio firmware; it cannot host the Kyra data profile and cannot act as a central toward the ring. The nRF52840 holds both BLE links (peripheral → phone, central → ring), owns the sensors, the touch strip and the microphone switch, and commands the BM83 over UART.

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3. Parts (EV1 build)

`docs/BOM.md` **(stage 3) is the binding part list.** It carries one row per refdes for all 90 placed symbols with values, footprints, UNVERIFIED MPNs and per-part rationale, plus the confirmed `lib_id` and pin numbers for every active part. The table below is the architectural summary of the principal parts only; where the two disagree on a *part*, BOM.md governs, and where they disagree on a *budget or constraint*, this document governs.

Every lib_id below was confirmed present in the installed KiCad libraries before being written here. Footprints marked *(confirm)* must be verified against the symbol default at capture - **a part number that does not match its footprint is a defect**.

Ref	Part (EV1, orderable)	lib_id (verified installed)	Footprint	Production equivalent	Idle / standby current
U1	Microchip BM83 dual-mode audio module	`RF_Bluetooth: Microchip_BM83`	`RF_Module: Microchip_ BM83`	IS2083BM bare silicon, or one dual-mode SoC with an open app core	3.0 mA sniff **ASSUMED**, 10 μA off **ASSUMED**
U2	Raytac MDBT50Q-1MV2 (nRF52840)	`RF_Module: MDBT50Q-1MV2`	`RF_Module: Raytac_ MDBT50Q`	nRF52840 bare die / single dual-mode SoC	$\approx$ 200 μA with 2 BLE links (§6)
U3	AT42QT1070 7-channel touch, QFN-20	`Sensor_Touch: AT42QT1070-M`	QFN-20 4×4 *(confirm)*	same	40 μA low-power scan **ASSUMED**
U4	Kionix KX022-1020 accelerometer	`Sensor_Motion: KX022-1020`	LGA-12 2×2 mm *(confirm)*	same (identical part to the ring)	5.7 μA wake-up mode
U5	AP9101CK Li-ion protection	`Battery_ Management: AP9101CK`	SOT-23-5 *(confirm)*	same	3.0 μA operating, 0.1 μA power-down
U6, U7	PAM8302A class-D amplifier ×2	`Amplifier_ Audio: PAM8302AAD`	MSOP-8-EP *(confirm)*	same	0.5 μA shutdown, 2.6 mA enabled
MK1, MK2	SPM0687LR5H-1 analog diff. MEMS mic ×2	`Sensor_Audio: SPM0687LR5H-1`	off-board, on J5	same	250 μA each, **only when MIC_VDD is on**
Q1	P-MOSFET high-side microphone switch	`Transistor_FET: Q_PMOS_GSD`	SOT-23 *(confirm)*	integrated load switch	< 1 μA off-leakage
Q2, Q3	Low-R_DS(on) N-MOSFETs, cell negative leg	`Transistor_FET: Q_NMOS_GSD` ×2	SOT-23 *(confirm)*	dual FET in one package	leakage only
LS1, LS2	Open-ear micro speaker, 8 Ω class	`Device:Speaker`	off-board, on J3/J4	same	- (**OPEN-1**)
BT1	Li-Po cell 250 mAh / 3.7 V, bare	`Device: Battery_Cell`	off-board, on J2	one cell per temple	-
J1	USB-C receptacle, USB 2.0, 16P	`Connector:USB_ C_Receptacle_ USB2.0_16P`	16P SMD *(confirm)*	**not in the glasses build** (case contacts)	-
D1	Unidirectional TVS on VBUS	`Device:D_TVS`	SOD-323 *(confirm)*	same	leakage only, and 0 V whenever USB is unplugged
D2	Charge-status LED (instrumentation only)	`Device:LED`	0603	**not in the glasses build**	driven by BM83 LED1

Passives: 0402 minimum size, no smaller. All parts must be rated 0 to +45 °C operating and −20 to +60 °C storage

(§8).

---

4. Power tree and the rails

Rail	Source	Nominal	Loads
`VBUS`	USB-C J1 (EV1 only)	5.0 V	BM83 ADAP_IN, MDBT50Q VBUS
`VBAT`	cell J2, before protection	3.0–4.2 V	AP9101CK sense only
`VBAT_PROT`	after protection FETs and current jumper J10	3.0–4.2 V	BM83 BAT_IN, MDBT50Q VDDH, both PAM8302A
`VDD_3V0`	MDBT50Q REG0 output (nRF52840 high-voltage mode)	3.0 V **ASSUMED setting**	AT42QT1070, KX022, I2C pull-ups, Q1 source (→ MIC_VDD)
`MIC_VDD`	Q1 high-side switch from `VDD_3V0`	3.0 V, **off by default**	two microphones, via J5

Why the microphone rail comes from REG0 and not from the cell (a hard electrical constraint, not a style choice): the SPM0687LR5H-1 supply maximum is 3.6 V. `VBAT_PROT` reaches 4.2 V on a full cell and higher during charge. Switching the microphones from the cell would exceed the microphone's absolute maximum. The switch is therefore fed from the 3.0 V REG0 output, which also keeps the whole switched load inside the REG0 budget (§5.4).

KYG-504 is absolute: only the BM83 is powered through its own BAT_IN, and nothing external is powered from the BM83's regulators (SYS_PWR carries its decoupling capacitor and nothing else).

---

5. Design calculations (stated, not asserted)

5.1 Amplifier gain (KYG-201, KYG-203)

PAM8302A gain is set by the input resistor against the internal feedback network: `Av = 2 x (142 kohm / R_in)` **ASSUMED** (confirm the internal value against the datasheet at capture).

- BM83 headphone output full scale: **0.6 Vrms ASSUMED** (AOHPL/AOHPR against AOHPM).
- Speaker: 8 Ω class, part **OPEN-1**.
- Chosen EV1 target: **0.25 W into 8 Ω = 1.41 Vrms**, deliberately conservative for an open-ear position and hearing safety.
- Required gain = 1.41 / 0.6 = **2.36**. With `R_in = 120 kohm`: `Av = 2 x 142/120 = 2.37` (7.5 dB) → 1.42 Vrms → **0.25 W** into 8 Ω.
- BTL headroom check at the cell's low end: peak differential swing ≈ 2 × 3.0 V = 6.0 Vpp → 2.12 Vrms available. 1.42 Vrms fits with margin, so the gain does not clip at end-of-charge.
- Input coupling: `C = 220 nF` with 120 kΩ → `f_c = 1/(2pi.120k.220n) = 6.0 Hz`, far below the voice band.
- **If Q1 shows the escalation is not legible at street noise**, the gain rises to 3.46 (`R_in = 82 kohm`, 0.54 W) - a resistor change, not a spin. The gain is **restated when OPEN-1 closes**.
- Hearing safety: gain and rated output are stated here against the open-ear position. **No compliance claim is made on EV1.**

5.2 Microphone and electrode series resistors (KYG-305, KYG-403)

- **100 Ω, 0402, on each of MICP1, MICN1, MICP2, MICN2**, placed close to the BM83. Reason: the microphone tail is an unshielded flex antenna next to two transmitters; 100 Ω limits ESD current from the connector and, with the module's input capacitance, forms a low-pass that attenuates rectified RF, while adding < 1 dB into the module's high-impedance differential inputs.
- **10 Ω on the MIC_VDD feed** (not 100 Ω): at 500 μA for two microphones the drop is 5 mV, and the resistor still damps the flex-cable resonance without disturbing the mic supply.
- **1 kΩ on each of the five electrode lines** (three strip, guard, wear) at the connector: standard AT42QT1070 practice for ESD and radiated emissions on a user-touchable electrode.

5.3 I2C pull-ups and addresses (KYG-806)

One bus: AT42QT1070 + KX022-1020 + two test points. Estimated bus capacitance **Cb ≈ 50 pF ASSUMED**, target **400 kHz**.

- `Rp(max) = t_r / (0.8473 .  Cb) = 300 ns / (0.8473 x 50 pF) = 7.08 kohm`
- `Rp(min) = (VDD - VOL) / IOL = (3.0 - 0.4) / 3 mA = 0.87 kohm`
- **Chosen: 4.7 kΩ** → `t_r = 0.8473 x 4.7 kohm x 50 pF = 199 ns` ✓
- `~CHANGE` (open-collector) gets its own **10 kΩ** pull-up - not 4.7 kΩ - because only 300 μA flows while it is asserted and the line is idle-high all day (§6).
- KX022 `INT1` is push-pull: **no pull-up fitted**, and that absence is intentional.

Addresses - no collision: AT42QT1070 = **0x1B fixed** (it has no address pin, so it has no freedom); KX022-1020 = **0x1E** with SDO/ADDR tied low (0x1F if tied high). Recorded in PINOUT.md at capture.

5.4 External load on the controller's regulated output (KYG-506)

nRF52840 REG0 current available for external circuitry: **25 mA ASSUMED** (confirm against the nRF52840 product specification and the Raytac module datasheet at capture).

Load on `VDD_3V0`	Worst case
AT42QT1070 (fast scan)	0.50 mA
KX022-1020 (high-performance)	0.15 mA
Two microphones via Q1, while MIC_VDD is on	0.50 mA
I2C pull-ups, both lines low	1.28 mA
~CHANGE pull-up, asserted	0.30 mA
Q1 gate pull-up (R17, 100 kΩ), while MIC_EN_N is asserted	0.03 mA
Total	**2.76 mA - 11 % of the 25 mA limit** ✓

The gate-pull-up row was added at stage 3 (`docs/BOM.md` §3.3) when R17 got a value: it is the one load a part-selection stage can add without noticing, so it is booked explicitly. It draws nothing in standby (no potential across the resistor while `MIC_EN_N` is high), and averaged over the day's 2,400 s of microphone windows it is 0.001 mA - it does not move the 4.77 mA day average.

5.5 Charge current and its programming (KYG-503)

- **0.5 C = 125 mA** for the 250 mAh cell.
- **Method:** the BM83 charger current has no external programming resistor; it is set in the module's configuration (Microchip Config Tool / EEPROM parameter) and written over the audio-module UART header **J9** - which is

why KYG-804 exists. **ASSUMED** that the configuration granularity permits 125 mA; if not, the nearest step **below** 125 mA is taken and recorded at bring-up. Whether the cell permits more than 0.5 C is **OPEN-3**.

5.6 Charger thermal check (KYG-505)

Worst case is the constant-current phase at the lowest cell voltage:

```
P = (V_ADAP_IN - V_BAT) x I_charge = (5.0 - 3.0) V x 0.125 A = 250 mW
```

With θ**JA** $\approx$ **100 °C/W ASSUMED** for the module on a two-layer board, the rise is $\approx$ 25 °C. At the 45 °C ambient ceiling the junction sits near 70 °C, inside the module's rating. Charging is in any case permitted only from 0 to 45 °C, set by the cell (§8). Confirm θJA and the module's maximum junction temperature at capture.

---

6. Power budget (KYG-901 … KYG-904)

Target 8 mA average, ceiling 12 mA, over a 20-hour wearing day (72,000 s). Twelve milliamps is 240 mAh from a 250 mAh cell; eight is 160 mAh.

Duty cycle, as specified: 40 escalations (earcon + up to 8 s of speech, budgeted at 10 s each); 40 reply windows of 15 s with microphones powered; one 30-minute call; phone links held all day; standby otherwise.

6.1 Per-device standby current

Device	Mode	Current	Source
BM83	sniff, HFP/A2DP link held	**3.00 mA**	DS70005402 **ASSUMED**, **OPEN-2**
MDBT50Q-1MV2	2 BLE links (100 ms + 200 ms intervals) + System ON idle	0.20 mA	Nordic nRF52840 PS **ASSUMED**
AT42QT1070	low-power scan	0.040 mA	datasheet **ASSUMED**
KX022-1020	wake-up engine, low power	0.006 mA	datasheet (5.7 μA)
AP9101CK	operating quiescent	0.003 mA	datasheet
PAM8302A $\times$2	~SD held low	0.001 mA	datasheet (0.5 μA each)
Q1 + microphones	switch off, MIC_VDD = 0 V	0.001 mA	leakage
Standby total		**3.25 mA**	

6.2 Day rollup

Mode	Seconds/day	Current	Charge
Standby (links held, mics off, amps shut down)	69,200	3.25 mA	62.5 mAh
Escalation playback: BM83 A2DP 22 mA + amps 5.2 mA quiescent + 12.7 mA speaker drive + controller	400 (40 $\times$ 10 s)	40.4 mA	4.49 mAh
Reply window: BM83 HFP 28 mA + microphones 0.5 mA + controller (amps stay shut down)	600 (40 $\times$ 15 s)	29.0 mA	4.83 mAh
Call: BM83 HFP + microphones + both amplifiers + controller	1,800	47.0 mA	23.50 mAh
Total	**72,000**		**95.3 mAh**

Average = 95.3 mAh / 20 h = 4.77 mA.

- Margin against the 8 mA target: **64.7 mAh spare, 40 % headroom.**
- Margin against the 12 mA ceiling: **60 % headroom.**
- The day consumes 38 % of a 250 mAh cell.

6.3 Audio energy, amortised (KYG-904)

Item	Charge each	Count/day	Contribution to the average
Escalation (earcon + 8 s speech, 10 s budgeted)	0.112 mAh	40	0.22 mA
Reply window (15 s, microphones powered)	0.121 mAh	40	0.24 mA
Call (30 min)	23.5 mAh	1	1.18 mA
Standby	-	-	3.12 mA

6.4 The budget's single risk, stated plainly (KYG-903)

A part whose standby current alone spends a tenth of the budget (**0.8 mA**) must be justified or replaced. **Exactly one part crosses that line: the BM83 at 3.00 mA in sniff - 66 % of the day's charge.**

Justification: it is held in sniff rather than powered down because Q2 requires the first audible sample within 1 s (goal 500 ms) of the phone's decision. A powered-down BM83 needs seconds to boot and reconnect, which fails Q2 outright. Sniff is the cost of the latency requirement, and it is bought knowingly.

Sensitivity, so the measurement has a pass/fail line before it is taken:

- 8 mA target is met while measured sniff current $\leq$ **6.6 mA**;
- 12 mA ceiling is met while measured sniff current $\leq$ **10.8 mA**.

If the measured figure exceeds 6.6 mA, the escape is a longer sniff interval or a phone-side wake over BLE (the controller wakes the BM83 through PWR/MFB), and the latency cost of that escape is itself a Q2 measurement.

---

7. Privacy and product-claim requirements (firmware, stated here because they are claims)

- **KYG-303 - microphone off is a hardware state.** MIC_VDD is switched by Q1, whose gate is pulled up to `VDD_3V0`, holding the switch **off at reset and while the controller is unpowered**. The BM83's MICBIAS does not power the microphones. **"Microphone off" is verifiable with a probe at the MIC_VDD test point (KYG-803)** - it is not a firmware promise.
- **KYG-304 - no wake word exists.** DMIC1_L, DMIC1_R and DMIC_CLK are unpopulated and terminated per the BM83 datasheet. There is no always-listening path in the hardware.
- **KYG-405 - no motion data leaves the glasses.** The KX022 is a don/doff and nod-to-confirm interlock only. Motion is not logged, transmitted or aggregated, and no activity metric is derived from it.
- **KYG-406 - not worn means silent.** When the wear electrode and the accelerometer read "not worn", the glasses **shall not** play an escalation and **shall not** open a microphone window. Firmware rule; the hardware obligation is the wear electrode and the accelerometer.
- **KYG-703 - no wearer information in any advertisement**, from either radio. The controller uses a rotating resolvable private address.

- **KYG-704 - the glasses store no message content.** Escalations arrive as opaque identifiers over the control link and as rendered audio over the audio link.
- **Decision 12 - no indicator light in the glasses.** A light on your face is a notification other people can read. EV1's single charge LED is instrumentation and is not in the glasses build. Whether bystanders need a microphone-active light is **OPEN-5**.

---

8. Mechanical, environment, compliance

Item	Value
Board	50 mm $\times$ 35 mm, **two layers**, two mounting holes
Edge A	USB-C receptacle, SWD header, current-measurement jumper
Edge B (opposite)	cell connector, two speaker connectors
Edge C	microphone FFC, electrode FFC
Edge D	NFC antenna connector
Operating temperature	**0 to +45 °C**, set by the cell's charge/discharge limits, not the silicon; every part must be rated for it
Storage temperature	−20 to +60 °C
Ingress	none claimed on EV1 (production glasses are sealed against sweat and rain)
Skin contact	the frame is the only skin-contact material; **EV1 makes no biocompatibility claim**
Certification	EV1 is an engineering test unit, not offered for sale; no certification claimed or required. Both radios are pre-certified modules - that is why they were chosen. **The production glasses with bare silicon require full intentional-radiator testing: a known, budgeted cost.**
Hearing safety	gain and rated output stated in §5.1 against the open-ear position; no compliance claim on EV1

8.1 Layout intent (binding on the board stage)

- **Keep the speaker leads and the microphone tail apart** - physically separated connectors on different regions, no parallel runs. Q1 (acoustic and electrical leakage into the echo canceller) depends on it.
- **Keep both radio antennas clear of the speaker leads and the microphone tail.** Both modules' integrated antennas need their datasheet keepout: no copper, no ground pour, no routing under or beside the antenna region.
- The board is not the glasses. It sits in a printed carrier clipped to a frame; connector placement exists so speakers, microphones and electrode flex reach temple and end-piece positions as they will in the glasses.

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9. Parts-count check

Group	Count
ICs and modules (U1–U7)	7
MOSFETs (Q1–Q3)	3
Connectors (USB-C, cell, 2 speakers, mic FFC, electrode FFC, NFC, SWD, audio UART, current jumper)	10
Test points (KYG-803, incl. 2 separated grounds)	13
LED + resistor (D2, R1)	2
DC/DC inductor (L1, DCCH)	1
Passives (R2–R26, C1–C28, D1 TVS: decoupling, CC pull-downs, I2C and reset pull-ups, gain network, series resistors, NFC tuning, protection network)	54
Total	**90** (target 90, ceiling 110) ✓

This is now an exact count enumerated in `docs/BOM.md`, not an estimate: 90 placed symbols, 20 below the hard ceiling. The rise from the stage-2 estimate of ≈ 82 is eight passives the architecture implied but had not enumerated - the second amplifier decoupling capacitor, the KX022's separate `IO_VDD` capacitor, the AT42QT1070 `~RESET` pull-up, the BM83 reset pull-up and line-in terminations, and the pseudo-differential amplifier input return capacitors.

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10. Pin and strapping notes for the capture stage

These are checked **before** any pin is assigned:

- **P0.09 / P0.10 default to NFC (NFCT), not GPIO.** They are reserved for the NFC antenna connector J7 and must not be assigned any other function. Using them as GPIO would require a UICR change; the design does not.
- **P0.18 is configured as nRESET** and carries a 10 kΩ pull-up (KYG-105), and appears on the SWD header.
- **P0.00 / P0.01 are XL1 / XL2. ASSUMED**: the MDBT50Q-1MV2 carries the 32.768 kHz crystal on-module, so none is fitted on EV1 (**OPEN-7**). These two pins are therefore left unassigned rather than used as GPIO, so a crystal can be added on a spin if the assumption is wrong. **The absence of a crystal here is intentional, not an omission.**
- **SWDIO / SWDCLK** are dedicated and go to the 2×5 1.27 mm header with reset (KYG-801).
- **KX022 SDO/ADDR tied low** → address 0x1E; **AT42QT1070 address 0x1B is fixed**.
- **AT42QT1070 MODE pin tied for I2C comms mode** (**ASSUMED** polarity - confirm against the datasheet at capture); `~RESET` carries a pull-up.
- **BM83 VDD_IO (pin 25) is** `no_connect` in the installed symbol, and **LED1 (pin 32) is typed** `input` although it sinks the status LED. Both will need explicit handling at capture so ERC reflects reality rather than being silenced.
- **BM83 I2S (DR1/DT1/RFS1/SCLK1/MCLK1) and line-in (AIL/AIR) are unused** and terminated per the datasheet (KYG-106).

---

11. ASSUMED (defaults proposed here, not stated by the brief)

#	Assumption	Why it is safe / what breaks if wrong
A1	BM83 sniff 3.0 mA, A2DP 22 mA, HFP 28 mA, off 10 μA	The whole budget rests on these; §6.4 gives the pass/fail line (sniff $\leq$ 6.6 mA)
A2	REG0 set to **3.0 V**, external draw limit **25 mA**	3.0 V suits both sensors and keeps the mic rail under the SPM0687's 3.6 V max
A3	MDBT50Q-1MV2 carries the 32.768 kHz crystal; none fitted	If wrong, RTC accuracy between connections degrades; XL1/XL2 left free for a spin
A4	REG0 high-voltage DC/DC enabled: 10 μH from DCCH to VDDH + 4.7 μF	Lowers standby; if the module datasheet forbids it, fall back to LDO mode (costs $\approx$ 100 μA)
A5	PAM8302A gain law `2 x (142 k / R_in)`; BM83 HP output 0.6 Vrms	Sets `R_in = 120 kohm` for 0.25 W; restated when OPEN-1 closes
A6	I2C bus capacitance 50 pF at 400 kHz $\rightarrow$ 4.7 kΩ pull-ups	Recompute if the electrode flex adds load
A7	100 Ω mic series / 10 Ω mic Vdd / 1 kΩ electrode series	ESD and RF control; adjust after the Q1 measurement
A8	Charger θJA $\approx$ 100 °C/W; 125 mA is a reachable configuration step	Confirm at bring-up; take the nearest step below 125 mA if not
A9	Escalation budgeted at 10 s (earcon + 8 s speech)	Conservative against the brief's "up to 8 s"
A10	BLE connection intervals: 100 ms phone, 200 ms ring	Sets the 0.20 mA controller figure; Q4 will measure the real cost
A11	AT42QT1070 MODE polarity for I2C mode	Confirm at capture; wrong polarity means no bus

12. OPEN items (must close; none blocks stage 1)

#	Open item	Closes by
OPEN-1	Speaker part, impedance and rated power - the amplifier gain follows from it	Q1 measurement; §5.1 restated
OPEN-2	BM83 sniff / A2DP / HFP / deep-sleep currents from DS70005402	Datasheet read + Q3 measurement
OPEN-3	Whether the cell permits more than 0.5 C charge	Cell datasheet
OPEN-4	Microphone placement on the frame, and therefore the flex length	Q1
OPEN-5	Whether the product needs a microphone-active light for bystanders	Product decision
OPEN-6	Whether production audio stays BT Classic or moves to LE Audio, and therefore which single SoC replaces the two modules	Host support + symbol availability
OPEN-7	Whether the MDBT50Q-1MV2 variant carries the 32.768 kHz crystal	Raytac datasheet
OPEN-8	Whether a direct glasses$\leftrightarrow$ring link is needed at all	Q4

13. Requirement traceability

Requirement	Where satisfied
KYG-101, 103, 106	§2, §3 (U1), §10
KYG-102, 104, 105	§2, §3 (U2), §10, A3, A4
KYG-201 … 204	§5.1, §8.1, §3 (U6/U7, LS1/LS2)
KYG-301 … 305	§4, §5.2, §7, §3 (MK1/MK2, Q1)
KYG-401 … 406	§3 (U3, U4), §5.2, §5.3, §7, §10
KYG-501 … 506	§2, §4, §5.4, §5.5, §5.6, §3 (U5, Q2/Q3, BT1)
KYG-601, 602	§2, §4, §3 (J1, D1)
KYG-701 … 704	§7, §10 (P0.09/P0.10 reserved), §3 (J7)
KYG-801 … 806	§5.3, §5.5, §9, §10, Q3 instrumentation
KYG-901 … 904	§6 in full

PART III

Kyra R1 EV1 - Subsystem architecture

Source: docs/SUBSYSTEMS.md

Stage 2 (architecture). This document decomposes the EV1 board defined by `docs/SPEC.md` into blocks, fixes what crosses between them, and states what each block owes the power budget. **No value here is new.** Every number is carried from `docs/SPEC.md` (§ references given inline) or from `.copperhead/constraints.json`; where SPEC.md marks a figure **ASSUMED** or **OPEN**, this document carries the mark forward rather than quietly promoting it to fact.

No schematic and no board exist yet, so ERC, DRC and legibility gates are **not applicable at this stage** - they are owed by stage 3 (capture) and stage 4 (layout). What stage 3 inherits from this document is: the subsystem partition, the net-naming contract (§11), the ownership rules (§10), and the per-subsystem symbol allocation (§12).

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1. The board in one paragraph

EV1 is a two-radio wearable audio endpoint on a 50 × 35 mm two-layer board (constraint `mech.board_outline`). A 250 mAh Li-Po cell arrives on a connector, passes through discrete protection and a current-measurement jumper, and becomes the single unregulated system node `VBAT_PROT`. Three things hang off that node directly: the BM83 audio module (which also contains the charger), the nRF52840 module's high-voltage input, and the two class-D amplifiers. The nRF52840's internal REG0 makes the board's only regulated rail, `VDD_3V0`, which feeds the two sensors, the I^2C pull-ups, and - through a single P-channel high-side switch - the microphone rail. Audio flows one way through the BM83 (phone → speakers) and the other way through the microphones (mics → BM83 → phone); control flows from the nRF52840 to everything, over UART to the BM83 and over I^2C to the sensors. Nothing regulated leaves the BM83, and nothing analog leaves the board except on an explicitly separated connector edge.

---

2. Block diagram in prose

Power domains, in the order energy moves through them:

1. `VBUS`**, 5.0 V, EV1 only.** Enters at the USB-C receptacle J1, is clamped by D1, and goes to exactly two places: the BM83's `ADAP_IN` (charger input) and the nRF52840 module's `VBUS` pin (native USB device, `USB_DP`/`USB_DM`). It powers nothing else. In the production glasses this domain does not exist on the temple board at all - charge arrives through case contacts (SPEC §3, J1 row).
2. `VBAT`**, 3.0–4.2 V, unprotected.** The bare cell node between connector J2 and the protection FETs. Its only load is the AP9101CK's sense input. Nothing else may touch it; a load here is a load the protection cannot disconnect.
3. `VBAT_PROT`**, 3.0–4.2 V, protected.** `VBAT` after the two series N-FETs in the **negative** leg and after the current-measurement jumper J10. This is the system node. Loads: BM83 `BAT_IN`, nRF52840 `VDDH`, both PAM8302A `VDD`. Placing J10 here rather than in a downstream rail is what makes Q3 (§Q3 of SPEC §1) a single-instrument measurement: every milliamp the board spends crosses that jumper.

4. `VDD_3V0`, **3.0 V regulated.** The nRF52840's REG0 output in high-voltage mode (SPEC A2, **ASSUMED** setting). Loads: AT42QT1070, KX022-1020, the I^2C and `~CHANGE` pull-ups, and Q1's source. External draw is budgeted at **2.73 mA of a 25 mA limit** (SPEC §5.4, constraint `rail.reg0_external_load_mA`, limit **ASSUMED**).
5. `MIC_VDD`, **3.0 V switched, off by default.** `VDD_3V0` through the P-MOSFET Q1, whose gate pull-up to `VDD_3V0` holds it **off at reset and while the controller is unpowered** (SPEC §7, KYG-303). Loads: the two microphones, off-board via J5.

Signal domains, and who owns each crossing:

- **Control, nRF52840 → BM83.** Four-wire UART (`BT_UART_TXD`, `BT_UART_RXD`, `BT_UART_RTS`, `BT_UART_CTS`) plus `BT_PWR` (MFB) and `BT_RST_N`. Every state change in the audio module - leave sniff, answer a call, start playback - is a controller command. The BM83 never initiates.
- **Control, nRF52840 → sensors.** One I^2C bus (`SDA`, `SCL`) with two devices and two test points, plus two interrupt lines back: `TOUCH_CHG_N` (open-collector, pulled up) and `ACC_INT1` (push-pull, deliberately not pulled up).
- **Control, nRF52840 → analog power.** Two GPIO: `MIC_EN_N` to Q1's gate and `AMP_SD_N` to both amplifiers' `~SD`. These are the two nets that make privacy and quiet a hardware state rather than a firmware promise.
- **Audio out, BM83 → speakers.** `AOHPL/AOHPR` against `AOHPM`, AC-coupled into the two PAM8302A inputs, out as four BTL nets `SPK_L_P/N`, `SPK_R_P/N` to connectors J3/J4.
- **Audio in, microphones → BM83.** Two differential pairs from FFC J5, each through 100 Ω series resistors, into `MICP1/MICN1` and `MICP2/MICN2`. **These pairs never touch the nRF52840.** The controller can switch the microphones off but cannot hear them.
- **RF.** Two module-integrated antennas (BM83, MDBT50Q) plus one off-board NFC loop on `NFC1/NFC2` from J7. All three need keepout (SPEC §8.1).

The one crossing that does not exist, on purpose: there is no audio path between the nRF52840 and the microphones, and no digital-microphone path at all (SPEC §7, KYG-304). The application processor is architecturally incapable of listening.

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3. S1 - USB input and charge path

Role. Accept 5 V on EV1, clamp it, hand it to the BM83's integrated charger, and expose the nRF52840's native USB for firmware and instrumentation.

Why this shape. The BM83 already contains a Li-ion charger; adding a second one is a forbidden block (`scope.forbidden_blocks`). The charge current is therefore **not** set by an external resistor - it is a configuration parameter written over the audio-module UART header J9 (SPEC §5.5, constraint `charge.current_mA`). That is the entire reason J9 exists as a populated header rather than test pads.

Key values.

Item	Value	Source
Input	5.0 V nominal on `VBUS`	SPEC §4
Charge current	**125 mA (0.5 C)** for the 250 mAh cell, set in BM83 config over J9	SPEC §5.5
Worst-case charger dissipation	**250 mW** = $(5.0 - 3.0)$ V $\times$ 0.125 A, CC phase at the lowest cell voltage	SPEC §5.6

Item	Value	Source
Thermal rise	≈ 25 °C at θJA ≈ 100 °C/W **ASSUMED**; ≈ 70 °C junction at the 45 °C ambient ceiling	SPEC §5.6
Charge temperature window	0 to +45 °C, set by the cell, not the silicon	SPEC §8
CC pull-downs	5.1 kΩ ×2 on `CC1`/`CC2` (sink advertisement)	SPEC §9 passives
Status LED	D2 + resistor, driven by BM83 LED1 - **instrumentation only, not in the glasses build**	SPEC §3, §7 decision 12

Interface nets. `VBUS`, `GND`, `USB_DP`, `USB_DM`, `CC1`, `CC2`, `LED_CHG`.

Standby contribution. Zero when unplugged (D1 leakage only). This subsystem is not in the day budget.

Open. Whether the cell permits more than 0.5 C (OPEN-3) and whether the BM83's configuration granularity lands exactly on 125 mA (SPEC A8) - if not, the nearest step **below** 125 mA is taken and recorded at bring-up.

4. S2 - Cell and protection

Role. Hold the 250 mAh cell on a connector, protect it against over-charge, over-discharge and over-current, and give the day-budget measurement a single place to happen.

Why this shape. The cell is off-board on J2 because cell placement in the temple is itself an experiment. Protection is discrete (AP9101CK + two N-FETs) rather than a protected cell assembly so that the FETs sit in the **negative** leg, which keeps the positive leg a clean, uninterrupted node for J10 to break. The current jumper is in the cell's positive leg for exactly one reason: an ammeter there reads the whole board, which is what Q3 asks for.

Key values.

Item	Value	Source
Cell	250 mAh nominal, 3.7 V Li-Po, bare, on a 2-way connector	SPEC §3, constraint `power.cell_capacity_mAh`
Node voltage range	3.0–4.2 V	SPEC §4
Protection quiescent	3.0 μA operating, 0.1 μA power-down	SPEC §6.1
Usable charge at the ceiling	240 mAh over 20 h = 12 mA (the ceiling's arithmetic)	constraint `power.average_current_ceiling_mA`
Day consumption, as budgeted	95.3 mAh = **38 % of the cell**	SPEC §6.2

Interface nets. `VBAT` (protection sense only), `VBAT_PROT` (system), `GND`.

Standby contribution. **0.003 mA** (AP9101CK operating quiescent), plus FET leakage.

5. S3 - Rail distribution

Role. Get from one unregulated node to one regulated rail and one switched rail, with no discrete regulator anywhere on the board.

Why this shape. A discrete logic regulator is a forbidden block (`scope.forbidden_blocks`); the nRF52840's REG0 in high-voltage mode already produces a 3.0 V rail from `VBAT_PROT` with enough headroom for the whole sensor and microphone load. The choice of 3.0 V is not arbitrary and not a style preference - it is the one setting that simultaneously suits both I^2C sensors **and** keeps the switched microphone rail under the SPM0687LR5H-1's 3.6 V supply maximum (constraint `rail.mic_vdd_max_V`). Feeding Q1 from `VBAT_PROT` instead would put 4.2 V on the microphones at full charge and more during charge: an absolute-maximum violation, not a margin question. That is why the amplifiers (rated for the cell) take `VBAT_PROT` directly while the microphones do not.

Key values.

Rail	Source	Nominal	Loads
`VBAT_PROT`	S2	3.0–4.2 V	BM83 `BAT_IN`, nRF52840 `VDDH`, U6/U7 `VDD`
`VDD_3V0`	nRF52840 REG0, HV mode (**ASSUMED** setting, SPEC A2)	3.0 V	U3, U4, pull-ups, Q1 source
`MIC_VDD`	Q1 from `VDD_3V0`	3.0 V, **off by default**	MK1/MK2 via J5

REG0 external-load ledger (SPEC §5.4 - the limit is **ASSUMED**, the loads are not):

Load	Worst case
AT42QT1070, fast scan	0.50 mA
KX022-1020, high-performance	0.15 mA
Two microphones through Q1, `MIC_VDD` on	0.50 mA
I^2C pull-ups, both lines low	1.28 mA
`~CHANGE` pull-up, asserted	0.30 mA
Q1 gate pull-up (R17, 100 kΩ), `MIC_EN_N` asserted	0.03 mA
Total	**2.76 mA - 11 % of the 25 mA limit ✓**

The gate-pull-up row entered the ledger at stage 3, when R17 acquired a value (`docs/BOM.md` §3.3). It costs nothing in standby - the gate sits at `VDD_3V0` with no potential across the resistor - and 0.001 mA averaged over the day.

DC/DC. REG0's high-voltage buck needs 10 μH from `DCCH` to `VDDH` plus 4.7 μF (SPEC A4). If the module datasheet forbids buck mode, the fallback is LDO mode at a cost of $\approx$ 100 μA - which the 40 % standby margin absorbs without redesign.

KYG-504 is absolute: nothing external is powered from the BM83's regulators. `SYS_PWR` carries its decoupling capacitor and nothing else.

6. S4 - Application controller (MDBT50Q-1MV2 / nRF52840)

Role. The board's only decision-maker. Holds two concurrent BLE links (peripheral → phone, central → ring), owns both sensors, owns the microphone switch and the amplifier shutdown, commands the BM83 over UART, and provides the regulated rail.

Why a second radio at all. The BM83's processor runs Microchip's audio firmware; it can neither host the Kyra data profile nor act as a central toward the ring, and a BLE-only radio cannot carry a phone call over HFP. One radio cannot cover both roles today. Both collapse into a single dual-mode SoC with an open application core when one has a symbol (OPEN-6).

Key values.

Item	Value	Source
Standby	**0.20 mA** with two BLE links + System ON idle	SPEC §6.1 (**ASSUMED**)
Connection intervals	100 ms phone, 200 ms ring	SPEC A10 (**ASSUMED**)
Ring gesture response	$\leq$ **200 ms**	constraint `latency.ring_gesture_response_ms`
Reset	P0.18 as `nRESET`, 10 kΩ pull-up, on the SWD header	SPEC §10
NFC	P0.09/P0.10 **reserved for NFCT** - not available as GPIO	SPEC §10
32.768 kHz crystal	**none fitted**; XL1/XL2 (P0.00/P0.01) left unassigned	SPEC §10, OPEN-7

Strapping and pin facts checked before any assignment (SPEC §10): P0.09/P0.10 default to NFCT and using them as GPIO would need a UICR change the design does not want; P0.18 is the reset pin; SWDIO/SWDCLK are dedicated. XL1/XL2 are left free rather than reused as GPIO precisely so a crystal can be added on a spin if the on-module-crystal assumption (A3) is wrong - **that absence is intentional.**

Interface nets. `VBAT_PROT`, `VDD_3V0`, `GND`, `VBUS`, `USB_DP`, `USB_DM`, `BT_UART_TXD/RXD/RTS/CTS`, `BT_PWR`, `BT_RST_N`, `SDA`, `SCL`, `TOUCH_CHG_N`, `ACC_INT1`, `MIC_EN_N`, `AMP_SD_N`, `SWDIO`, `SWDCLK`, `nRESET`, `NFC1`, `NFC2`.

Standby contribution. 0.20 mA - 6 % of the standby total, well under the 0.8 mA justify threshold (`power.part_standby_justify_threshold_mA`).

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7. S5 - Audio link (BM83)

Role. Dual-mode Bluetooth Classic audio: A2DP for rendered speech, HFP for calls, plus the integrated charger. It is a peripheral of S4, not a peer.

Why it is held in sniff, and what that costs. This is the board's single budget risk and it is bought deliberately. The BM83 draws **3.00 mA in sniff** (**ASSUMED**, OPEN-2) - 66 % of the day's charge, and the only part on the board that crosses the 0.8 mA justify-or-replace threshold. It is not powered down between escalations because a powered-down module needs **seconds** to boot and reconnect, and `latency.escalation_to_first_sample_ms` allows **1000 ms** (goal 500 ms) from the phone's decision to the first audible sample. Sniff is the price of that latency requirement.

The pass/fail line exists before the measurement is taken (SPEC §6.4):

- 8 mA target holds while measured sniff current $\leq$ **6.6 mA**;
- 12 mA ceiling holds while measured sniff current $\leq$ **10.8 mA**.

If the measured figure exceeds 6.6 mA, the escape is a longer sniff interval or a phone-triggered wake over BLE (S4 pulses `BT_PWR`/MFB) - and the latency cost of that escape is itself a Q2 measurement, not an assumption.

Key values.

Mode	Current	Source
Sniff, link held	3.00 mA	SPEC §6.1 (**ASSUMED**, OPEN-2)
A2DP playback	22 mA	SPEC §6.2 (**ASSUMED**)
HFP call	28 mA	SPEC §6.2 (**ASSUMED**)
Off	10 μA	SPEC §3 (**ASSUMED**)

Unused pins, terminated not floated (SPEC §10, KYG-106): I^2S (`DR1`, `DT1`, `RFS1`, `SCLK1`, `MCLK1`) and line-in (`AIL`, `AIR`) are unused and terminated per the datasheet. `DMIC1_L`, `DMIC1_R`, `DMIC_CLK` are **unpopulated** - that is KYG-304, the absence of any always-listening path, expressed in copper. Two symbol quirks need explicit handling at capture so ERC reflects reality rather than being silenced: `VDD_IO` (pin 25) is `no_connect` in the installed symbol, and `LED1` (pin 32) is typed `input` although it sinks the status LED.

Interface nets. `VBAT_PROT`, `VBUS` (as `ADAP_IN`), `GND`, `BT_UART_*`, `BT_PWR`, `BT_RST_N`, `AOHPL`, `AOHPR`, `AOHPM`, `MICP1`, `MICN1`, `MICP2`, `MICN2`, `LED_CHG`, `SYS_PWR` (decoupling only).

Standby contribution. 3.00 mA - 92 % of the 3.25 mA standby total.

8. S6 - Audio output

Role. Two PAM8302A class-D amplifiers driving two open-ear speakers on connectors J3/J4.

Why this shape. Open-ear position at the temple means the speaker is not sealed to the ear, so legibility at street noise is an open question (Q1) - which is why the speakers are on connectors and the gain is a resistor. The gain chosen is deliberately conservative for hearing safety in an open-ear position.

Key values (SPEC §5.1; gain law and BM83 output level are **ASSUMED**, A5):

Item	Value
Gain law	`Av = 2 x (142 kohm / R_in)`
`R_in`	**120 kΩ** → `Av = 2.37` (7.5 dB)
Input coupling	**220 nF** → `f_c = 6.0 Hz`, far below the voice band
Output	1.42 Vrms → **0.25 W into 8 Ω**
Headroom at end-of-charge	2.12 Vrms available at a 3.0 V cell vs 1.42 Vrms required - **does not clip**
Shutdown	0.5 μA each, `~SD` held low
Enabled quiescent	2.6 mA each

If Q1 shows the escalation is not legible at street noise, the gain rises to 3.46 (`R_in = 82 kohm`, 0.54 W) - a resistor value change, not a board spin. The gain is restated when the speaker part closes (OPEN-1).

Interface nets. `VBAT_PROT`, `GND`, `AOHPL`, `AOHPR`, `AOHPM`, `AMP_SD_N`, `SPK_L_P`, `SPK_L_N`, `SPK_R_P`, `SPK_R_N`.

Standby contribution. 0.001 mA (both amplifiers in shutdown). The amplifiers are the second-largest active draw on the board and they are held off every second they are not playing - including during reply windows, where the day rollup credits them nothing.

Layout obligation (binding on stage 4): speaker leads and the microphone tail are physically separated onto different connector regions with no parallel runs. Acoustic and electrical leakage into the echo canceller is half of what Q1 measures.

9. S7 - Microphone channel and the privacy switch

Role. Two analog differential MEMS microphones, off-board on FFC J5, powered through a single high-side switch that is **off unless the controller explicitly turns it on**.

Why this shape - this is a product claim implemented in hardware. KYG-303 says "microphone off" is a hardware state, not a firmware promise. Q1's gate is pulled up to `VDD_3V0`, so the switch is off at reset **and while the controller is unpowered**; the BM83's MICBIAS does not power the microphones; and the state is verifiable with a probe at the `MIC_VDD` test point (KYG-803). A reviewer who finds the microphones dead on a fresh board is looking at the design working.

Why the rail is `VDD_3V0` and not `VBAT_PROT`. The SPM0687LR5H-1 supply maximum is **3.6 V** (`rail.mic_vdd_max_V`). `VBAT_PROT` is 4.2 V on a full cell and higher during charge. Sourcing the switch from the cell would exceed the microphones' absolute maximum - a destroyed part, not a degraded one.

Key values (SPEC §5.2):

Item	Value	Reason
Series R on `MICP1/MICN1/MICP2/MICN2`	**100** Ω each, 0402, close to the BM83	The mic tail is an unshielded flex antenna between two transmitters; limits ESD current and low-passes rectified RF at < 1 dB cost into high-impedance differential inputs
Series R on `MIC_VDD`	**10** Ω, not 100 Ω	At 500 μA, 100 Ω would drop 50 mV of supply; 10 Ω drops 5 mV and still damps the flex resonance
Microphone current	250 μA each, **only while `MIC_VDD` is on**	SPEC §3
Q1 off-leakage	< 1 μA	SPEC §3
Duty	40 reply windows × 15 s + one 30-min call per day	SPEC §6.2

Interface nets. `VDD_3V0`, `MIC_EN_N`, `MIC_VDD`, `GND`, `MIC1P`, `MIC1N`, `MIC2P`, `MIC2N` (connector side) → `MICP1`, `MICN1`, `MICP2`, `MICN2` (module side, after the 100 Ω).

Standby contribution. 0.001 mA - switch off, `MIC_VDD` at 0 V.

Deliberately absent: no digital-microphone path, no wake-word engine, no voice-activation detector, no audio connection of any kind to the application controller (KYG-304). The hardware cannot listen without the controller asserting `MIC_EN_N`.

10. S8 - Touch, interlock and the ownership rules

Role. A three-electrode capacitive strip plus guard and wear electrodes on the AT42QT1070, and a KX022-1020 accelerometer for don/doff and nod-to-confirm. Both on one I^{2}C bus.

Why this shape. The electrodes are off-board on an FFC because electrode geometry and position on the temple is an experiment. The accelerometer is the identical part used in the ring, which removes one driver from the firmware's surface.

Key values (SPEC §5.3):

Item	Value
Bus	one I^{2}C, 400 kHz target, `Cb ~= 50 pF` **ASSUMED**
Pull-up window	`Rp(min) = 0.87 kohm`, `Rp(max) = 7.08 kohm`
Chosen pull-ups	**4.7 kΩ** on `SDA/SCL` → `t_r = 199 ns` ✓
`TOUCH_CHG_N`	separate **10 kΩ** pull-up - open-collector, idle-high all day, so 300 μA when asserted instead of 640 μA
`ACC_INT1`	**no pull-up fitted** - the KX022 INT1 is push-pull. The absence is intentional
Addresses	AT42QT1070 = **0x1B fixed** (no address pin); KX022-1020 = **0x1E** with SDO/ADDR tied low - **no collision**
Electrode series R	**1 kΩ** on each of the five lines at the connector, for ESD and emissions on a user-touchable node
MODE pin	tied for I^{2}C comms mode - polarity **ASSUMED** (A11), confirm at capture or there is no bus

Interface nets. `VDD_3V0`, `GND`, `SDA`, `SCL`, `TOUCH_CHG_N`, `TOUCH_RST_N`, `ACC_INT1`, `TOUCH_E1`, `TOUCH_E2`, `TOUCH_E3`, `TOUCH_GUARD`, `TOUCH_WEAR`.

Standby contribution. AT42QT1070 **0.040 mA** (low-power scan) + KX022-1020 **0.006 mA** (wake-up engine) = **0.046 mA**.

Privacy obligation carried by this subsystem: the KX022 is a don/doff and nod-to-confirm interlock only. No motion data is logged, transmitted or aggregated, and no activity metric is derived from it (KYG-405). When the wear electrode and the accelerometer read "not worn", no escalation plays and no microphone window opens (KYG-406) - the hardware obligation is the electrode and the accelerometer; the rule is firmware's.

Ownership rules (binding on capture)

1. **The controller owns `MIC_VDD`.** Only S4 drives `MIC_EN_N`. The BM83 has no path to the microphone rail. Privacy must not depend on a module running vendor firmware.
2. **The controller owns `AMP_SD_N`.** One active-low net from one GPIO shuts both amplifiers. "Quiet" is one pin, so it cannot be half-true.
3. **The BM83 owns only the charger and the audio path.** It initiates nothing; every state change is a UART command from S4.

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11. S9 - Pairing, identity and instrumentation

Role. Out-of-band NFC tap pairing, and the test points and headers that let EV1 answer its four questions.

NFC. P0.09/P0.10 are reserved for NFCT and carry the antenna to connector J7 with its tuning capacitors. They are not available as GPIO (SPEC §10). No wearer information appears in any advertisement from either radio, and the controller uses a rotating resolvable private address (KYG-703). The glasses store no message content: escalations arrive as opaque identifiers on the control link and as rendered audio on the audio link (KYG-704).

Instrumentation, mapped to the question each item answers:

Item	Question
J10 current jumper in the cell's positive leg	Q3 - the whole board's current, on an instrument
`MIC_VDD` test point	KYG-803 / KYG-303 - microphone-off is probeable
UART TXD/RXD test points + J9 audio-module UART header	Q2 latency, and the charge-current configuration write
J8 SWD 2×5 1.27 mm header with reset	Q4, firmware, and controller instrumentation
Amplifier-output test points, J3/J4, J5	Q1 legibility and mic leakage
13 test points including **two separated grounds**	probe return without a shared-impedance artefact

Standby contribution. Zero.

12. Net-naming contract for stage 3

Capture uses these names exactly; no synonyms, no local variants.

Domain	Nets
Power	`VBUS`, `VBAT`, `VBAT_PROT`, `VDD_3V0`, `MIC_VDD`, `SYS_PWR`, `GND`
USB	`USB_DP`, `USB_DM`, `CC1`, `CC2`
BM83 control	`BT_UART_TXD`, `BT_UART_RXD`, `BT_UART_RTS`, `BT_UART_CTS`, `BT_PWR`, `BT_RST_N`
Audio out	`AOHPL`, `AOHPR`, `AOHPM`, `AMP_SD_N`, `SPK_L_P`, `SPK_L_N`, `SPK_R_P`, `SPK_R_N`
Audio in	`MIC1P`, `MIC1N`, `MIC2P`, `MIC2N` (connector side); `MICP1`, `MICN1`, `MICP2`, `MICN2` (module side)
Mic power	`MIC_EN_N`, `MIC_VDD`
Sensors	`SDA`, `SCL`, `TOUCH_CHG_N`, `TOUCH_RST_N`, `ACC_INT1`
Electrodes	`TOUCH_E1`, `TOUCH_E2`, `TOUCH_E3`, `TOUCH_GUARD`, `TOUCH_WEAR`
Debug	`SWDIO`, `SWDCLK`, `nRESET`
NFC	`NFC1`, `NFC2`
Instrumentation	`LED_CHG`

Ground is one net. On a two-layer board with two integrated antennas, a split analog / digital ground creates a slot the return current has to detour around, which is worse for both the microphone tail and the radios than a single plane. Probe-return separation is provided by two dedicated ground test points, not by cutting copper.

13. Budget ledger by subsystem

Standby, against the 3.25 mA figure of SPEC §6.1:

Subsystem	Standby	Share
S5 audio link (BM83, sniff)	3.000 mA	92.3 %
S4 controller (2 BLE links, System ON idle)	0.200 mA	6.2 %

Subsystem	Standby	Share
S8 touch + accelerometer	0.046 mA	1.4 %
S2 cell protection	0.003 mA	0.1 %
S6 amplifiers (shutdown)	0.001 mA	< 0.1 %
S7 microphone switch (off)	0.001 mA	< 0.1 %
S1, S3, S9	≈ 0	-
Total	**3.25 mA**	

Day rollup, against SPEC §6.2 (20 h = 72,000 s): standby 62.5 mAh + escalation playback 4.49 mAh + reply windows 4.83 mAh + one 30-minute call 23.50 mAh = **95.3 mAh**, i.e. **4.77 mA average**.

- Against the **8 mA target** (`power.average_current_target_mA`): 64.7 mAh spare, **40 % headroom** ✓
- Against the **12 mA ceiling** (`power.average_current_ceiling_mA`): **60 % headroom** ✓
- Cell consumed per day: **38 % of 250 mAh** ✓

Parts crossing the 0.8 mA justify-or-replace threshold: exactly one, S5's BM83 at 3.00 mA in sniff, justified in §7 above against `latency.escalation_to_first_sample_ms`, with the sensitivity line (≤ 6.6 mA / ≤ 10.8 mA) stated before the measurement.

REG0 external load: 2.73 mA of a 25 mA limit (§5), 11 % ✓

14. Symbol allocation

Against `parts.placed_symbol_count`: target ≈ 90, **hard ceiling 110**.

Subsystem	Symbols	Contents
S1 USB + charge	8	J1, D1 (TVS), D2 + resistor, 2× CC pull-down, VBUS bulk + decoupling
S2 cell + protection	8	J2, J10, U5, Q2, Q3, protection network (2 R + 1 C)
S3 rails	5	10 µH DC/DC inductor, DCCH 4.7 µF, VDDH bulk, rail decoupling
S4 controller	6	U2, J8, 3× decoupling, 10 kΩ `nRESET` pull-up
S5 audio link	10	U1, J9, R7/R8 line-in termination, R9 `BT_RST_N` pull-up, C11–C15 (`BAT_IN` bulk + HF, `ADAP_IN`, `SYS_PWR`, `MICBIAS`)
S6 audio output	13	U6, U7, J3, J4, R10/R11 120 kΩ gain, C16–C19 220 nF input coupling + return, C20/C21 per-amp decoupling, C22 shared `VBAT_PROT` bulk
S7 microphones	9	Q1, J5, 4× 100 Ω, 10 Ω, gate pull-up, `MIC_VDD` cap
S8 touch + interlock	15	U3, U4, J6, 5× 1 kΩ electrode, 2× 4.7 kΩ I^2C, 10 kΩ `TOUCH_CHG_N`, 10 kΩ `TOUCH_RST_N`, C24–C26 (U3 `VDD`, U4 `VDD`, U4 `IO_VDD`)
S9 pairing + instrumentation	16	J7, 2× NFC tuning cap, 13 test points
Total	**90**	✓ at target 90, 20 under the ceiling of 110 (SPEC §9)

This is now an **exact count enumerated row-by-row in** `docs/BOM.md` (stage 3), not the stage-2 estimate of 82. The eight added symbols are passives this architecture implied but had not enumerated: the second amplifier decoupling cap, the amplifiers' shared bulk cap, the two pseudo-differential input return caps to `AOHPM`, the KX022's separate

IO_VDD cap, the AT42QT1070 ~RESET pull-up, the BM83 BT_RST_N pull-up, and one line-in termination. None of them is a new function - all are decoupling, termination or bias parts the subsystem prose above already required.

Cross-check against the SPEC §9 categories, which this table must reproduce exactly and does: 7 ICs (U1–U7), 3 MOSFETs (Q1–Q3), 10 connectors (J1–J10), 13 test points, LED + resistor, 1 DC/DC inductor, 54 passives (R2–R26, C1–C28, D1). Off-board parts - BT1, LS1/LS2, MK1/MK2 - are **not** counted; they live on connectors and are not placed symbols.

The ceiling is a real constraint, not a slogan: the design has 20 symbols of collective slack before it stops being an EV1 and starts being a different design.

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15. Deliberately absent - read none of these as an omission

Absent	Why
Camera; display, waveguide or any optic	Forbidden by scope (`scope.forbidden_blocks`). This is an audio-only surface
Wake-word / voice-activation / always-listening path	KYG-304. `DMIC1_L`, `DMIC1_R`, `DMIC_CLK` are unpopulated and terminated
Any audio path to the application controller	The controller can silence the microphones but architecturally cannot hear them
Haptic actuator	That channel belongs to the ring
Second charger	The BM83 contains one; a second is forbidden
Discrete logic regulator	REG0 makes `VDD_3V0`; a discrete regulator is forbidden
Indicator LED in the glasses build	A light on your face is a notification other people can read. D2 is EV1 instrumentation only. Whether bystanders need a microphone-active light is OPEN-5
32.768 kHz crystal	**ASSUMED** on-module (A3, OPEN-7). XL1/XL2 left unassigned so it can be added on a spin
Pull-up on `ACC_INT1`	KX022 INT1 is push-pull; a pull-up would be redundant
Load on `VBAT` (pre-protection)	Any load there is a load the protection cannot disconnect
Anything powered from BM83 regulators	KYG-504 is absolute; `SYS_PWR` carries decoupling only
Fixed copper for cell, speakers, microphones, electrodes, NFC antenna	Placement is the experiment; fixed copper would defeat it

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16. What each subsystem owes the next stage

Stage	Owed
Stage 3 capture	Symbols per §14, nets per §12, ownership rules per §10, strapping facts per §6 (P0.09/P0.10 NFCT, P0.18 nRESET, XL1/XL2 free), BM83 symbol quirks per §7, `verify_symbols` + ERC clean, legibility clean

Stage	Owed
Stage 4 layout	50 × 35 mm, two layers, two mounting holes, connector edges A–D per SPEC §8; speaker leads separated from the mic tail; datasheet keepout around both module antennas and the NFC loop; DRC clean
Bring-up	Q1 legibility and mic leakage (closes OPEN-1, restates §8 gain); Q2 latency (closes the sniff-vs-wake question); Q3 day current on J10 (closes OPEN-2 against the $\leq$ 6.6 mA line); Q4 ring gesture (closes OPEN-8)

All parts must be rated **0 to +45 °C operating, −20 to +60 °C storage** (`env.operating_temp_C`, `env.storage_temp_C`) - set by the cell's charge/discharge limits, not by the silicon. That check is owed at BOM close, per part, and is deferred there deliberately.

PART IV

Kyra R1 EV1 - Bill of Materials

Source: docs/BOM.md

Stage 3 (part selection). This is the **binding part list** for stage 4 capture: one row per refdes, every symbol confirmed present in the KiCad libraries installed on this machine (`search_symbols` + `symbol_pins`, pin numbers read from the real symbol, not assumed).

Every MPN below is UNVERIFIED - proposed here from catalogue knowledge, not read off a datasheet in this run. Each row's Rationale states the specific, datasheet-verifiable claim that must be checked before parts are ordered. A row whose claim fails is a part change, not a design change, unless the Rationale says otherwise.

Derived from `docs/SPEC.md` §3–§6 and `docs/SUBSYSTEMS.md` §3–§14. Where this table and SPEC.md disagree on a *part*, this table governs; where they disagree on a *budget or constraint*, SPEC.md governs.

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1. The table

Refdes	Value	Footprint	MPN	Rationale
U1	BM83	RF_Module:Microchip_BM83	BM83SM1-00AA	S5 audio link. Dual-mode BT Classic module with integrated Li-ion charger - A2DP for rendered speech, HFP for calls, and the charger that KYG-503 needs without a second charger IC (a forbidden block). Pre-certified radio, chosen for that reason (SPEC §8). Verify: 3.0 mA sniff / 22 mA A2DP / 28 mA HFP against DS70005402 - this single figure is 92% of the standby ledger and OPEN-2. Verify pin 25 VDD_IO handling and that the charge current is configurable at or just below 125 mA over the J9 UART.

Refdes	Value	Footprint	MPN	Rationale
U2	MDBT50Q-1MV2	RF_Module:Raytac_MDBT50Q	MDBT50Q-1MV2	S4 controller. nRF52840 module: two concurrent BLE links, both sensors, both privacy nets, and REG0 supplies the board's only regulated rail so no discrete regulator is needed (forbidden block). Pre-certified. Verify: REG0 external draw limit $\geq$ 25 mA and 3.0 V setting (SPEC A2); whether the -1MV2 variant carries the 32.768 kHz crystal (OPEN-7 - none is fitted, XL1/XL2 left free deliberately).
U3	AT42QT1070	Package_DFN_QFN:QFN-20-1EP_4x4mm_P0.5mm_EP2.6x2.6mm	AT42QT1070-MMHR	S8 touch. 7-channel charge-transfer controller: 3 strip electrodes + guard + wear, on the one I^2C bus at fixed address 0x1B. 40 μA low-power scan is 1.2% of standby, well under the 0.8 mA justify threshold. Verify: MODE pin polarity for I^2C comms mode (SPEC A11 - wrong polarity means no bus); QFN-20 4$\times$4 EP dimensions against the -MMHR package drawing.
U4	KX022-1020	Package_LGA:LGA-12_2x2mm_P0.5mm	KX022-1020	S8 interlock. Don/doff and nod-to-confirm only (KYG-405 - no motion is logged or transmitted). Identical part to the ring, which removes a driver from firmware's surface. 5.7 μA wake-up mode. Verify: LGA-12 2$\times$2$\times$0.9 mm land pattern against the Kionix drawing, and that SDO/ADDR tied low gives 0x1E (no collision with U3's 0x1B).
U5	AP9101CK	Package_TO_SOT_SMD:SOT-23-5	AP9101CK5-AATRG1	S2 protection. Over-charge / over-discharge / over-current for the bare cell, driving Q2+Q3 in the negative leg. 3.0 μA operating quiescent is 0.1% of standby. Verify: **the package suffix must map to the SOT-23-5 pinout the 5-pin symbol carries (VM/VDD/VSS/DO/CO)** - the AP9101C family also ships 6-pin variants, and a 6-pin part against this symbol is a defect, not a substitution.

Refdes	Value	Footprint	MPN	Rationale
U6	PAM8302A	Package_SO:MSOP-8-1EP_ 3x3mm_P0.65mm_ EP1.68x1.88mm	PAM8302AADCR	S6 left amplifier. 2.5 W-class filterless class-D run deliberately at 0.25 W for an open-ear position (SPEC §5.1). 0.5 μA in shutdown, and ~SD is held asserted every second it is not playing. Verify: internal feedback resistor is 142 kΩ so `Av = 2x(142k/R_in)` (SPEC A5 - R10 follows from it), and MSOP-8-EP thermal pad dimensions.
U7	PAM8302A	Package_SO:MSOP-8-1EP_ 3x3mm_P0.65mm_ EP1.68x1.88mm	PAM8302AADCR	S6 right amplifier. Identical to U6; both are shut by the one `AMP_SD_N` net so "quiet" cannot be half-true. Same verification as U6.
Q1	DMG2301L	Package_TO_SOT_SMD:SOT-23	DMG2301L-7	S7 microphone high-side switch - the part that makes KYG-303 a hardware claim. P-channel, -20 V, logic-level: must be fully on at Vgs = -3.0 V from `VDD_3V0`. Verify: Rds(on) at Vgs = -2.5 V (drop at 500 μA must be $\ll 5$ mV) and **Idss $\leq$ 1 μA**, which is the leakage the standby ledger books against `MIC_VDD` off.
Q2	SI2302	Package_TO_SOT_SMD:SOT-23	SI2302CDS-T1-GE3	S2 cell protection, charge FET in the negative leg. N-channel, logic-level, driven from the AP9101CK at cell voltage. Verify: Rds(on) at Vgs = 2.5 V (worst case near the 3.0 V discharge floor) - two in series must not add meaningful drop at the 47 mA call current; and Idss, which the ledger books as leakage only.
Q3	SI2302	Package_TO_SOT_SMD:SOT-23	SI2302CDS-T1-GE3	S2 cell protection, discharge FET. Identical to Q2; discrete pair rather than a protected cell assembly so both FETs sit in the **negative** leg, leaving the positive leg a clean node for J10 to break. Production collapses these to one dual FET.

Refdes	Value	Footprint	MPN	Rationale
D1	PESD5V0L1BA	Diode_SMD:D_SOD-323	PESD5V0L1BA,115	S1 VBUS clamp. Unidirectional ESD/TVS on a user-facing connector. Verify: **stand-off voltage $\geq$ 5.25 V** so it does not conduct on a high-side USB source, and reverse leakage at 5 V - it sees 0 V whenever USB is unplugged, so it contributes nothing to the day budget. Replaces the generic Zener named in SPEC §3: a Zener's soft knee wastes charge current on VBUS.
D2	Green	LED_SMD:LED_0603_1608Metric	LTST-C191KGKT	S1 charge status, sunk by BM83 LED1. **Instrumentation only - not in the glasses build** (SPEC §7 decision 12: a light on your face is a notification other people can read). Anode is fed from `VBUS` through R1, so it is dark and draws nothing whenever USB is unplugged. Verify: Vf $\approx$ 2.0 V at 3 mA, which sets R1.
L1	10uH	Inductor_SMD:L_0805_2012Metric	LQM2HPN100MG0L	S3. REG0 high-voltage buck inductor, `DCCH` to `VDDH` (SPEC A4). Verify: Isat $\geq$ 150 mA and DCR low enough not to eat the buck's advantage; if the module datasheet forbids buck mode the fallback is LDO mode at $\approx$ 100 μA, which the 40% standby margin absorbs without a respin.
J1	USB-C 16P	Connector_USB:USB_C_Receptacle_USB2.0_16P	USB4105-GF-A	S1 input, **EV1 only** - the production glasses charge through case contacts and have no USB domain on the temple board. USB 2.0 16-pin part (no SuperSpeed pairs needed). Verify: 16P land pattern and that the shield tab scheme matches the KiCad footprint.
J2	Conn_01x02	Connector_JST:JST_SH_BM02B-SRSS-TB_1x02-1MP_P1.00mm_Vertical	BM02B-SRSS-TB(LF)(SN)	S2 cell connector. The cell is off-board because cell placement in the temple is itself an experiment. Verify: current rating $\geq$ 1 A (covers the 125 mA charge and any fault current up to the protection trip).

Refdes	Value	Footprint	MPN	Rationale
J3	Conn_01x02	Connector_JST:JST_SH_BM02B-SRSS-TB_1x02-1MP_P1.00mm_Vertical	BM02B-SRSS-TB(LF)(SN)	S6 left speaker, BTL pair `SPK_L_P`/`SPK_L_N`. On a connector because open-ear legibility at temple position is Q1 - fixed copper would defeat the experiment. Verify: contact rating at 180 mA peak BTL current into 8 Ω.
J4	Conn_01x02	Connector_JST:JST_SH_BM02B-SRSS-TB_1x02-1MP_P1.00mm_Vertical	BM02B-SRSS-TB(LF)(SN)	S6 right speaker, `SPK_R_P`/`SPK_R_N`. Same as J3. Layout obligation: this connector and J5 sit on different board regions with no parallel runs (SPEC §8.1).
J5	Conn_01x06	Connector_FFC-FPC:Molex_505110-0692_1x06-1MP_P0.50mm_Horizontal	505110-0692	S7 microphone FFC: `MIC_VDD`, `GND`, and the two differential pairs. Six ways, 0.5 mm. This tail is an unshielded flex antenna between two transmitters, which is the whole reason R12–R16 exist. Verify: contact count/pitch and that the mating flex thickness is 0.30 mm.
J6	Conn_01x06	Connector_FFC-FPC:Molex_505110-0692_1x06-1MP_P0.50mm_Horizontal	505110-0692	S8 electrode FFC: three strip electrodes, guard, wear, and `GND`. Off-board because electrode geometry on the temple is an experiment. Same part as J5 - one flex connector type on the BOM instead of two.
J7	Conn_01x02	Connector_JST:JST_SH_BM02B-SRSS-TB_1x02-1MP_P1.00mm_Vertical	BM02B-SRSS-TB(LF)(SN)	S9 NFC antenna, `NFC1`/`NFC2` from P0.09/P0.10. Off-board loop for tap pairing (KYG-701). Verify: the loop's inductance lands where C27/C28 can tune it to 13.56 MHz.
J8	Conn_02x05	Connector_PinHeader_1.27mm:PinHeader_2x05_P1.27mm_Vertical_SMD	FTSH-105-01-L-DV-K	S9 SWD debug, 2×5 1.27 mm with reset (KYG-801). Serves Q4 and all controller firmware work. Verify: the Cortex Debug pinout assignment at capture (SWDIO, SWDCLK, nRESET, VDD_3V0 sense, grounds) - pin numbering is `Conn_02x05_Odd_Even`, so odd/even column order must be checked against the physical part.

Refdes	Value	Footprint	MPN	Rationale
J9	Conn_01x04	Connector_PinHeader_2.54mm:PinHeader_1x04_P2.54mm_Vertical	61300411121	S5 audio-module UART header. **This header is the only way the 125 mA charge current gets set** - the BM83 charger has no programming resistor, so the value is written into module configuration over these pins (SPEC §5.5). That is why it is a populated header and not test pads. Carries `GND`, `BT_UART_TXD`, `BT_UART_RXD`, `BT_RST_N`.
J10	Conn_01x02	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical	61300211121	S2 current-measurement jumper in the cell's **positive** leg - Q3's instrument point. 2.54 mm so a standard ammeter clip or shunt fits; shipped shorted with a jumper. Every milliamp the board spends crosses it, which is what makes the day-current measurement a single reading. Verify: contact resistance low enough not to disturb a 3–50 mA measurement.
R1	1k	Resistor_SMD:R_0402_1005Metric	RC0402FR-071KL	S1 LED series resistor, `VBUS` to D2 anode: $(5.0 - 2.0)/1\text{k} = 3$ mA. Fed from VBUS, not a battery rail, so the status LED can never discharge the cell.
R2	5.1k	Resistor_SMD:R_0402_1005Metric	RC0402FR-075K1L	S1 `CC1` pull-down: advertises the board as a USB-C sink. 5.1 kΩ is the specified Rd value, not a chosen one.
R3	5.1k	Resistor_SMD:R_0402_1005Metric	RC0402FR-075K1L	S1 `CC2` pull-down. Both CC lines need one or the board is a dead port in one cable orientation.
R4	330R	Resistor_SMD:R_0402_1005Metric	RC0402FR-07330RL	S2 AP9101CK VDD sense series resistor: with C3 it forms the input filter the protection IC needs to survive the ESD and di/dt of a bare-cell connector. Verify value against the AP9101CK application circuit.
R5	2k	Resistor_SMD:R_0402_1005Metric	RC0402FR-072KL	S2 AP9101CK VM resistor - limits current into the VM pin during a charger-overvoltage or short event. Verify value against the AP9101CK application circuit.
R6	10k	Resistor_SMD:R_0402_1005Metric	RC0402FR-0710KL	S4 `nRESET` pull-up on P0.18 (KYG-105). Idle-high, so it draws nothing in standby; only the debug probe pulls it down.

Refdes	Value	Footprint	MPN	Rationale
R7	10k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-0710KL	S5 `AIL` line-in termination to GND. The BM83 line-in is unused (KYG-106) and terminated rather than floated, so an unused high-impedance analog input next to two radios cannot rectify RF into the audio path.
R8	10k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-0710KL	S5 `AIR` line-in termination to GND. Same reason as R7.
R9	100k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100KL	S5 `BT_RST_N` pull-up **to `VDD_3V0`, not to** `SYS_PWR` - holds the BM83 out of reset while the controller's GPIO is high-Z at boot, and keeps the pull-up in the same logic domain as the pin that drives it. Sourcing it from the BM83's own regulator would breach KYG-504. Idle-high: 0 μA in standby, 30 μA only while reset is asserted.
R10	120k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07120KL	S6 left gain resistor: `Av = 2x(142k/120k) = 2.37` (7.5 dB) → 1.42 Vrms → **0.25 W into 8 Ω**, deliberately conservative for an open-ear position and hearing safety (SPEC §5.1). If Q1 shows the escalation is not legible at street noise this becomes 82 kΩ (Av 3.46, 0.54 W) - a resistor change, not a spin. Restated when OPEN-1 closes.
R11	120k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07120KL	S6 right gain resistor. Must match R10 to 1% or the two channels differ audibly; both are 1% parts for that reason.
R12	100R	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100RL	S7 series on `MICP1`, placed close to U1. Limits ESD current from the FFC and, with the module's input capacitance, low-passes rectified RF; costs < 1 dB into a high-impedance differential input.
R13	100R	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100RL	S7 series on `MICN1`. Must equal R12 - an imbalance between the two legs converts common-mode RF into differential signal, which is exactly what the pair is there to reject.
R14	100R	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100RL	S7 series on `MICP2`. Same as R12.

Refdes	Value	Footprint	MPN	Rationale
R15	100R	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100RL	S7 series on `MICN2`. Must equal R14, same balance argument.
R16	10R	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-0710RL	S7 series in the `MIC_VDD` feed - **10 Ω, not 100 Ω**: at 500 μA for two microphones 100 Ω would drop 50 mV of supply, while 10 Ω drops 5 mV and still damps the flex-cable resonance.
R17	100k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-07100KL	S7 Q1 gate pull-up to `VDD_3V0` - **this resistor is the privacy claim**. It holds the microphone switch off at reset and while the controller is unpowered (KYG-303), so a fresh board has dead microphones by construction. 100 kΩ against Q1's Ciss gives ≈ 50 μs turn-off; it costs 30 μA from REG0 only while `MIC_EN_N` is asserted (§3 below), and 0 μA in standby.
R18	1k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-071KL	S8 series on `TOUCH_E1` at the connector - standard AT42QT1070 practice for ESD and radiated emissions on a user-touchable electrode.
R19	1k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-071KL	S8 series on `TOUCH_E2`. Same as R18.
R20	1k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-071KL	S8 series on `TOUCH_E3`. Same as R18.
R21	1k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-071KL	S8 series on `TOUCH_GUARD`. Same as R18.
R22	1k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-071KL	S8 series on `TOUCH_WEAR` - the electrode half of the not-worn-means-silent interlock (KYG-406).
R23	4.7k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-074K7L	S8 `SDA` pull-up. Inside the computed window (Rp 0.87 k–7.08 kΩ for Cb ≈ 50 pF at 400 kHz) giving t_r = 199 ns (SPEC §5.3). Recompute if the electrode flex adds bus capacitance.
R24	4.7k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-074K7L	S8 `SCL` pull-up, same window and same value as R23.
R25	10k	Resistor_SMD:R_0402_ 1005Metric	RC0402FR-0710KL	S8 `TOUCH_CHG_N` pull-up - **10 kΩ, deliberately not 4.7 kΩ**: the line is open-collector and idle-high all day, so 10 kΩ halves its asserted current to 300 μA against the REG0 ledger.

Refdes	Value	Footprint	MPN	Rationale
R26	10k	Resistor_SMD:R_0402_1005Metric	RC0402FR-0710KL	S8 TOUCH_RST_N pull-up on the AT42QT1070 ~RESET (SPEC §10). Idle-high: 0 μA in standby.
C1	10uF	Capacitor_SMD:C_0805_2012Metric	GRM21BR61C106KE15L	S1 VBUS bulk, X5R 16 V. Holds the rail through the 125 mA charge current step at plug-in. 16 V rating against a 5 V rail keeps usable capacitance after DC-bias derating.
C2	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S1 VBUS high-frequency decoupling, X7R 16 V.
C3	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S2 AP9101CK VDD–VSS filter capacitor, X7R. With R4 it is the protection IC's input filter; the AP9101CK is the one part that must not be fooled by a transient.
C4	4.7uF	Capacitor_SMD:C_0603_1608Metric	GRM188R61A475KE15D	S3 DCCH capacitor for the REG0 high-voltage buck (SPEC A4), X5R 10 V.
C5	10uF	Capacitor_SMD:C_0805_2012Metric	GRM21BR61A106KE19L	S3 VBAT_PROT bulk at the module's VDDH, X5R 10 V. Supplies the 47 mA call-current step without dragging the cell node.
C6	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S3 VDDH high-frequency decoupling, X7R.
C7	4.7uF	Capacitor_SMD:C_0603_1608Metric	GRM188R61A475KE15D	S3 VDD_3V0 rail bulk on the REG0 output, X5R 10 V.
C8	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S4 VDD decoupling at the module's pin 28, X7R.
C9	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S4 VBUS decoupling at the module's USB pin 32, X7R 16 V.
C10	4.7uF	Capacitor_SMD:C_0603_1608Metric	GRM188R61C475KAAJ	S4 VBUS bulk for the nRF52840's native USB peripheral, X5R 16 V.
C11	10uF	Capacitor_SMD:C_0805_2012Metric	GRM21BR61A106KE19L	S5 BAT_IN bulk at U1, X5R 10 V. The BM83's transmit bursts are the largest current steps on the board.
C12	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S5 BAT_IN high-frequency decoupling, X7R.
C13	1uF	Capacitor_SMD:C_0402_1005Metric	CL05A105KA5NQNC	S5 ADAP_IN decoupling at the charger input, X5R 16 V.

Refdes	Value	Footprint	MPN	Rationale
C14	4.7uF	Capacitor_SMD:C_0603_1608Metric	GRM188R61A475KE15D	S5 SYS_PWR capacitor. **This capacitor is the only thing on SYS_PWR** - KYG-504 is absolute: nothing external is powered from the BM83's regulators, and a reviewer should read this single load as deliberate.
C15	1uF	Capacitor_SMD:C_0402_1005Metric	CL05A105KA5NQNC	S5 MICBIAS decoupling per the BM83 datasheet. Note the microphones are **not** powered from MICBIAS - they are powered from MIC_VDD through Q1, which is what makes microphone-off a hardware state.
C16	220nF	Capacitor_SMD:C_0402_1005Metric	CL05B224KO5NNNC	S6 left input coupling, AOHPL into U6 IN+. With R10's 120 kΩ, f_c = 6.0 Hz - far below the voice band, and it blocks the BM83 output's DC bias from the amplifier input.
C17	220nF	Capacitor_SMD:C_0402_1005Metric	CL05B224KO5NNNC	S6 left input return, U6 IN− to AOHPM. Referencing IN− to the BM83's headphone common through a matched capacitor - rather than grounding it - keeps the amplifier input pseudo-differential and rejects the common node's DC offset and its noise. Grounding IN− would leave the source reference floating.
C18	220nF	Capacitor_SMD:C_0402_1005Metric	CL05B224KO5NNNC	S6 right input coupling, AOHPR into U7 IN+. Same as C16.
C19	220nF	Capacitor_SMD:C_0402_1005Metric	CL05B224KO5NNNC	S6 right input return, U7 IN− to AOHPM. Same as C17.
C20	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S6 U6 VDD decoupling, X7R 10 V, placed at the pin - a class-D output stage switching into 8 Ω needs it local.
C21	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S6 U7 VDD decoupling. Same as C20.
C22	10uF	Capacitor_SMD:C_0805_2012Metric	GRM21BR61A106KE19L	S6 shared VBAT_PROT bulk for both amplifiers, X5R 10 V. Supplies the 180 mA peak BTL current so it is not drawn through the cell connector and J10.

Refdes	Value	Footprint	MPN	Rationale
C23	1uF	Capacitor_SMD:C_0402_1005Metric	CL05A105KA5NQNC	S7 `MIC_VDD` reservoir downstream of Q1 and R16, X5R. Small on purpose: this rail must **collapse quickly** when Q1 turns off, so that microphone-off is fast as well as true.
C24	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S8 U3 `VDD` decoupling, X7R.
C25	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S8 U4 `VDD` decoupling, X7R.
C26	100nF	Capacitor_SMD:C_0402_1005Metric	CL05B104KO5NNNC	S8 U4 `IO_VDD` decoupling - the KX022 has a separate I/O supply pin that needs its own capacitor even though both are tied to `VDD_3V0`.
C27	100pF	Capacitor_SMD:C_0402_1005Metric	GJM1555C1H101JB01D	S9 NFC tuning capacitor on `NFC1`, C0G/NP0. C0G is mandatory here, not preferred: an X7R part's capacitance drifts with temperature and bias and detunes the 13.56 MHz loop. Value is a placeholder until the antenna's inductance is known.
C28	100pF	Capacitor_SMD:C_0402_1005Metric	GJM1555C1H101JB01D	S9 NFC tuning capacitor on `NFC2`, C0G/NP0. Matched pair with C27.
TP1	GND	TestPoint:TestPoint_Pad_D1.0mm	-	S9 probe-return ground A. Two separated ground test points exist **instead of** splitting the ground plane: on a two-layer board with two integrated antennas a ground split is a slot the return current must detour around, which is worse for the mic tail and the radios than any shared-impedance it would cure.
TP2	GND	TestPoint:TestPoint_Pad_D1.0mm	-	S9 probe-return ground B, physically separated from TP1 so a differential measurement does not create its own artefact.
TP3	VBAT_PROT	TestPoint:TestPoint_Pad_D1.0mm	-	S9. System-node voltage during the Q3 day-current measurement, so current and voltage are read at the same instant.
TP4	VDD_3V0	TestPoint:TestPoint_Pad_D1.0mm	-	S9. Confirms REG0 is at 3.0 V and not 1.8 V - the setting the microphone's 3.6 V absolute maximum depends on.

Refdes	Value	Footprint	MPN	Rationale
TP5	MIC_VDD	TestPoint:TestPoint_Pad_D1.0mm	-	S9, **KYG-803 / KYG-303**: this is where "the microphone is off" stops being a firmware promise and becomes a probe reading of 0 V.
TP6	BT_UART_TXD	TestPoint:TestPoint_Pad_D1.0mm	-	S9, Q2 latency: timestamps the controller's command to the BM83.
TP7	BT_UART_RXD	TestPoint:TestPoint_Pad_D1.0mm	-	S9, Q2 latency: timestamps the BM83's acknowledgement, closing the phone-decision-to-first-sample interval against the 1 s ceiling.
TP8	SPK_L_P	TestPoint:TestPoint_Pad_D1.0mm	-	S9, Q1: amplifier output level and the leakage path into the echo canceller.
TP9	SPK_R_P	TestPoint:TestPoint_Pad_D1.0mm	-	S9, Q1: right channel, and channel-to-channel matching against R10/R11.
TP10	SDA	TestPoint:TestPoint_Pad_D1.0mm	-	S9. Bus rise time against the 199 ns computed from R23 and Cb - the assumption most likely to be wrong once the electrode flex is attached.
TP11	SCL	TestPoint:TestPoint_Pad_D1.0mm	-	S9. Clock integrity at 400 kHz, same reason as TP10.
TP12	MIC_EN_N	TestPoint:TestPoint_Pad_D1.0mm	-	S9. Proves the controller - not the BM83 - is what asserts microphone power, which is the ownership rule KYG-303 rests on.
TP13	AMP_SD_N	TestPoint:TestPoint_Pad_D1.0mm	-	S9. Proves both amplifiers are shut by one net, so "quiet" can be observed as a single state rather than inferred from two.

Row count: 90 placed symbols - target ≈ 90, hard ceiling 110 (`parts.placed_symbol_count`) ✓

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2. Symbol lib_ids for stage 4

Every lib_id below was confirmed on this machine with `search_symbols` and its pins read with `symbol_pins`. All are single-unit symbols; net endpoints use plain package pin numbers.

Refdes	lib_id	Pins confirmed
U1	`RF_Bluetooth:Microchip_BM83`	52 pins. `ADAP_IN` 22, `BAT_IN` 23, `SYS_PWR` 24, `VDD_IO` 25 (typed `no_connect`), `PWR(MFB)` 26, UART_RXD 29 / UART_TXD 30 / UART_RTS 31 / UART_CTS 48, `LED1` 32 (typed `input` though it sinks D2), `~{RST}` 43, `AOHPR` 6 / `AOHPM` 7 / `AOHPL` 8, `MICN2` 9 / `MICP2` 10, `MICN1` 13 / `MICP1` 14, `MICBIAS` 15, GND 16/50/56/57
U2	`RF_Module:MDBT50Q-1MV2`	61 pins. `VDD` 28, `VDDH` 30, `DCCH` 31, `VBUS` 32, `D-` 34, `D+` 35, `P0.18` 40, `SWDIO` 51, `SWDCLK` 53, `P0.09` 52, `P0.10` 54, `P0.00` 17 / `P0.01` 18 (XL1/XL2, **left unassigned**)
U3	`Sensor_Touch:AT42QT1070-M`	21 pins. KEY0 5 … KEY4 1, `VSS` 8 + 21, `VDD` 9, `MODE` 11, `SDA/OUT0` 12, `~{RESET}` 13, `~{CHANGE}/OUT4` 14 (open_collector), `SCL/OUT3` 15, `OUT1/KEY5` 17, `OUT2/KEY6` 16
U4	`Sensor_Motion:KX022-1020`	11 pins (no pin 8). `SDO/ADDR` 1, `SDI/SDA` 2, `IO_VDD` 3, `INT1` 5, `VDD` 7, `GND` 9, `~{CS}` 10, `SCLK/SCL` 12
U5	`Battery_Management:AP9101CK`	5 pins. `VM` 1, `VDD` 2, `VSS` 3, `DO` 4, `CO` 5
U6, U7	`Amplifier_Audio:PAM8302AAD`	8 pins. `~{SD}` 1, `NC` 2, `IN+` 3, `IN-` 4, `OUT+` 5, `VDD` 6, `GND` 7, `OUT-` 8
Q1	`Transistor_FET:Q_PMOS_GSD`	3 pins. G 1, S 2, D 3
Q2, Q3	`Transistor_FET:Q_NMOS_GSD`	3 pins. G 1, S 2, D 3
D1	`Device:D_TVS`	2 pins. `A1` 1, `A2` 2
D2	`Device:LED`	2 pins. `K` 1, `A` 2
L1	`Device:L`	2 pins
J1	`Connector:USB_C_Receptacle_USB2.0_16P`	17 pins, alphanumeric: `A1/A12/B1/B12` GND, `A4/A9/B4/B9` VBUS, `A5` CC1, `B5` CC2, `A6/B6` D+, `A7/B7` D−, `SH` shield
J2, J3, J4, J7, J10	`Connector_Generic:Conn_01x02`	2 pins
J5, J6	`Connector_Generic:Conn_01x06`	6 pins
J8	`Connector_Generic:Conn_02x05_Odd_Even`	10 pins, 1–10
J9	`Connector_Generic:Conn_01x04`	4 pins
R1–R26	`Device:R`	2 pins
C1–C28	`Device:C`	2 pins
TP1–TP13	`Connector:TestPoint`	1 pin

Two BM83 symbol quirks must be handled explicitly at capture so ERC reflects reality instead of being silenced: pin 25 `VDD_IO` is typed `no_connect` in the installed symbol, and pin 32 `LED1` is typed `input` although it sinks D2's current.

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3. Power check - every part against the budget

Budget: **8 mA average target, 12 mA ceiling** over a 20 h day; **3.25 mA** standby ledger (SPEC §6.1). Threshold for justify-or-replace: **0.8 mA** standby for any single part (`power.part_standby_justify_threshold_mA`).

3.1 Standby contributors

Part	Standby	Against the 0.8 mA threshold
U1 BM83, sniff	3.000 mA	**Over.** The board's only part above the line, at 92% of standby. Justified in SPEC §6.4: powering it down costs seconds of boot-and-reconnect and fails the 1 s escalation-latency ceiling outright. Pass/fail line set before measurement: $\leq$ 6.6 mA keeps the 8 mA target, $\leq$ 10.8 mA keeps the 12 mA ceiling.
U2 MDBT50Q, 2 BLE links	0.200 mA	Under ✓
U3 AT42QT1070, low-power scan	0.040 mA	Under ✓
U4 KX022-1020, wake-up engine	0.006 mA	Under ✓
U5 AP9101CK, operating	0.003 mA	Under ✓
U6+U7 PAM8302A, `~SD` asserted	0.001 mA	Under ✓
Q1 off-leakage + MK1/MK2 unpowered	0.001 mA	Under ✓
Q2, Q3 Idss	≈ 0	Under ✓
Total	**3.25 mA**	matches SPEC §6.1 exactly - no part added in this stage changes it

3.2 Parts added at this stage that draw nothing in standby

This is the check that matters for a part-selection run: nothing selected here quietly spends the budget.

Part	Why it costs zero in standby
R6, R9, R25, R26 (pull-ups)	All four lines idle **high**. A pull-up only draws current when something pulls the line down, and none of these is asserted in standby.
R17 (Q1 gate pull-up)	The gate sits at `VDD_3V0` with `MIC_EN_N` either driven high or high-Z - no potential across the resistor. Draws 30 μA **only** while the microphones are on.
R23, R24 (I^2C pull-ups)	Bus idle-high between transactions; the 1.28 mA figure is a both-lines-low worst case, already in the REG0 ledger.
R1, D1, D2	All sit on `VBUS`, which is 0 V whenever USB is unplugged. The status LED cannot discharge the cell.
R2, R3 (CC pull-downs)	Referenced to `VBUS`/CC, not to a battery rail.
R2–R5, R7, R8, R10–R16, R18–R22	Series or termination resistors in signal paths that are idle or unpowered in standby.
C1–C28	Ceramic X7R/X5R/C0G; insulation resistance puts total leakage well under 1 μA.
L1	DCR only, no static loss.
J1–J10, TP1–TP13	Passive interconnect.

3.3 REG0 external-load ledger (limit 25 mA, `rail.reg0_external_load_mA`)

Load on `VDD_3V0`	Worst case
U3 AT42QT1070, fast scan	0.50 mA
U4 KX022-1020, high-performance	0.15 mA

Load on `VDD_3V0`	Worst case
MK1+MK2 through Q1, while `MIC_VDD` is on	0.50 mA
R23+R24 I^2C pull-ups, both lines low	1.28 mA
R25 `~CHANGE` pull-up, asserted	0.30 mA
R17 Q1 gate pull-up, `MIC_EN_N` asserted	**0.03 mA**
Total	**2.76 mA - 11% of the 25 mA limit ✓**

R17's 30 μA is new to this ledger - it is the one load a part-selection stage can add without noticing, and it is now booked. Averaged over the day (2,400 s of microphone windows out of 72,000 s) it is **0.001 mA**, which does not move the 4.77 mA day average.

3.4 Temperature rating

Every part above is a commercial or industrial part rated at least **−40 to +85 °C**, which covers the board's **0 to +45 °C operating / −20 to +60 °C storage** window (`env.operating_temp_C`, `env.storage_temp_C`). That window is set by the cell's charge/discharge limits, not by the silicon - the silicon has margin to spare; the cell does not. Confirm per part at order time against the datasheets, together with each row's UNVERIFIED claim.

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4. Off-board, on connectors - not BOM rows

These are real parts of the product but are **not placed symbols**, so they are deliberately absent from the table above. Placement is the experiment; fixed copper would defeat it.

Item	Part	Lands on	Note
BT1	250 mAh / 3.7 V Li-Po, bare cell	J2	Sets the 0–45 °C window and the 12 mA ceiling arithmetic (240 mAh over 20 h)
LS1, LS2	Open-ear micro speaker, 8 Ω class	J3, J4	**OPEN-1** - the amplifier gain (R10/R11) is restated when this part closes
MK1, MK2	SPM0687LR5H-1 analog differential MEMS mic	J5	250 μA each, only while `MIC_VDD` is on. **3.6 V supply maximum** - the reason `MIC_VDD` comes from REG0 and not from the 4.2 V cell node
-	Touch electrode flex (3 strip + guard + wear)	J6	Geometry is an experiment; **OPEN-4**
-	NFC loop antenna	J7	Tuned by C27/C28 once its inductance is known

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5. Deliberately not on this BOM

A missing part can look like a mistake, so each absence is recorded with its reason.

Absent	Why
Charge-current programming resistor	The BM83 charger has none - 125 mA is a configuration value written over J9 (SPEC §5.5). Its absence is why J9 is a populated header.
Second charger IC	The BM83 contains one; a second is a forbidden block (`scope.forbidden_blocks`).
Discrete logic regulator	REG0 makes `VDD_3V0`; a discrete regulator is forbidden.
32.768 kHz crystal + 2 load caps	**ASSUMED** on-module (SPEC A3, OPEN-7). XL1/XL2 (pins 17/18) are left unassigned rather than reused as GPIO so a crystal can be added on a spin.
Pull-up on `ACC_INT1`	The KX022 INT1 is push-pull. A pull-up would be redundant, and its absence is intentional.
Any part on `VBAT` (pre-protection)	A load there is a load the protection cannot disconnect. Only U5's sense input touches that node.
Any load on `SYS_PWR` except C14	KYG-504 is absolute: nothing external is powered from the BM83's regulators.
Digital-microphone parts, wake-word engine, VAD	KYG-304. `DMIC1_L`, `DMIC1_R`, `DMIC_CLK` are unpopulated - the hardware has no always-listening path.
Indicator LED in the glasses build	SPEC §7 decision 12. D2 is EV1 instrumentation only.
Output LC filter on the class-D outputs	The PAM8302A is filterless into an inductive speaker load; if EMC at the speaker leads proves troublesome, ferrites are added at J3/J4 as a footprint change at layout.
Series resistors on `SPK_*`	A series resistor in a BTL output path burns the power the 0.25 W budget just spent.

PART V

DECISIONS

Source: docs/DECISIONS.md

- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Feed the microphone high-side switch (Q1) from the controller's 3.0 V REG0 output (VDD_3V0), not from the protected cell node VBAT_PROT. | why: The SPM0687LR5H-1 supply maximum is 3.6 V; VBAT_PROT reaches 4.2 V on a full cell and higher during charge, so switching the mics from the cell would exceed their absolute maximum. REG0 also keeps the whole switched load inside the 25 mA REG0 budget. | affects: Q1, MIC_VDD, MK1/MK2, docs/SPEC.md §4 and §5.4, openspec/specs/microphone-privacy/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Hold the BM83 in Bluetooth sniff mode all day (3.0 mA) rather than powering it down between escalations, and state the sniff current at which the budget breaks: 6.6 mA for the 8 mA target, 10.8 mA for the 12 mA ceiling. | why: It is the only part crossing the KYG-903 one-tenth-of-budget line (66% of the day's charge), but a powered-down module needs seconds to boot and reconnect, which fails the sub-1 s escalation latency of Q2 outright; sniff is the price of the latency requirement and is bought knowingly, with a documented escape (longer sniff interval or BLE-triggered wake via PWR/MFB) whose latency cost is itself a Q2 measurement. | affects: U1, docs/SPEC.md §6.1/§6.4, openspec/specs/power-budget/spec.md, openspec/specs/audio-link/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Fit no 32.768 kHz crystal on EV1, on the assumption that the MDBT50Q-1MV2 carries it on-module, and leave P0.00/P0.01 (XL1/XL2) unassigned rather than reusing them as GPIO. | why: KYG-105 requires a crystal only if the module variant lacks one (OPEN-7); keeping XL1/XL2 free means the crystal can be added on a spin if the assumption proves wrong. The absence is intentional, not an omission - recorded so a reviewer does not read it as a missing part. | affects: U2 P0.00/P0.01, docs/SPEC.md §10 and A3/OPEN-7, openspec/specs/application-controller/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Set the PAM8302A gain with R_in = 120 kΩ (Av = 2.37, 7.5 dB) for 1.42 Vrms = 0.25 W into an 8 Ω open-ear speaker, with 220 nF input coupling (6.0 Hz corner). | why: Deliberately conservative for an open-ear position and hearing safety, and it does not clip at end-of-charge (2.12 Vrms available at a 3.0 V cell against 1.42 Vrms required); if Q1 shows the escalation is not legible at street noise the gain rises to 3.46 via an 82 kΩ resistor, a value change rather than a board spin. Restated when the speaker part (OPEN-1) closes. | affects: U6, U7, LS1, LS2, docs/SPEC.md §5.1, openspec/specs/audio-output/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Use 100 Ω series resistors on each of MICP1/MICN1/MICP2/MICN2, 10 Ω on the MIC_VDD feed, and 1 kΩ on each of the five electrode lines. | why: The microphone tail is an unshielded flex antenna between two transmitters: 100 Ω limits ESD current from the connector and low-passes rectified RF against the module's input capacitance while costing under 1 dB into high-impedance differential inputs; MIC_VDD gets only 10 Ω because 100 Ω at 500 μA would drop 50 mV of supply; electrodes get 1 kΩ as standard AT42QT1070 practice for a user-touchable node. | affects: U1 mic inputs, Q1/MIC_VDD, U3 electrode lines, J5, J6, docs/SPEC.md §5.2, openspec/specs/microphone-privacy/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Fit 4.7 kΩ I2C pull-ups, a separate 10 kΩ pull-up on the AT42QT1070 ~CHANGE line, and no pull-up at all on the KX022 INT1 line. | why: 4.7 kΩ sits inside the computed Rp window (0.87 k–7.08 kΩ for 50 pF at 400 kHz) giving a 199 ns rise time; ~CHANGE is open-collector and idle-high all day, so 10 kΩ cuts its asserted current to 300 μA against the standby budget; KX022 INT1 is push-pull and needs no pull-up - that absence is deliberate, not a missed part. | affects: U3 ~CHANGE, U4 INT1, SDA/SCL nets, docs/SPEC.md §5.3, openspec/specs/instrumentation/spec.md
- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Carry two radios on EV1 (BM83 audio module + MDBT50Q-1MV2 application controller) rather than a single SoC, and set the controller's REG0 to 3.0 V in high-voltage mode with no discrete logic regulator. | why: The BM83's processor runs Microchip's audio firmware and can

neither host the Kyra data profile nor act as a central toward the ring, so one radio cannot cover both roles; an iPhone carries calls over HFP, which a BLE-only radio cannot do at all. 3.0 V on REG0 suits both sensors and, critically, keeps the switched microphone rail under the SPM0687's 3.6 V maximum, which a cell-fed rail would breach. Production collapses to one dual-mode SoC with an open application core once one has a symbol (OPEN-6). | affects: U1, U2, VDD_3V0 rail, docs/SPEC.md §2 and §4, openspec/specs/application-controller/spec.md, openspec/specs/audio-link/spec.md

- 2026-09-02 [run 2026-09-02T01-26-19-846Z] Reserve P0.09/P0.10 exclusively for the NFC antenna connector, and configure P0.18 as nRESET with a 10 kΩ pull-up onto the SWD header. | why: On the nRF52840 P0.09/P0.10 default to NFCT rather than GPIO; assigning them any other function would require a UICR change the design does not need, and KYG-701 needs them for out-of-band tap pairing anyway. P0.18 as nRESET satisfies the KYG-105 reset provision and lets the debug probe reset the part. Both are strapping-table facts checked before any pin was assigned. | affects: U2 P0.09/P0.10/P0.18, J7 NFC connector, J8 SWD header, docs/SPEC.md §10, openspec/specs/pairing-and-identity/spec.md
- 2026-09-02 [run 2026-09-02T01-54-37-204Z] Shut both PAM8302A amplifiers from a single active-low net AMP_SD_N driven by one controller GPIO, rather than giving each amplifier its own ~SD line. | why: "Quiet" must be a single, indivisible hardware state - one pin means it cannot be half-true (one channel silent, one channel live) through a firmware bug or a partially-initialised GPIO port; the amplifiers are never used independently (both play the same escalation or neither does), so per-channel control buys nothing and costs a pin plus a failure mode, and it keeps the 0.001 mA shutdown figure in §6.1 a property of one net. | affects: U6, U7, U2 GPIO, AMP_SD_N net, docs/SUBSYSTEMS.md §8 and §10, docs/SPEC.md §6.1
- 2026-09-02 [run 2026-09-02T01-54-37-204Z] Use one continuous GND net across the whole board - no split analog/digital ground, no moat under the microphone tail - and provide probe-return separation with two dedicated ground test points instead. | why: On a two-layer board carrying two module-integrated antennas plus an NFC loop, a ground split creates a slot that return current must detour around, degrading both the unshielded microphone flex and the radios more than any shared-impedance coupling it would cure; the measurement need behind a split (clean probe return for Q1/Q3) is met with two separated ground test points, which costs two symbols instead of a plane discontinuity. | affects: GND net, 13 test points (2 ground), U1/U2 antenna keepouts, J5 microphone tail, docs/SUBSYSTEMS.md §12, docs/SPEC.md §8.1 and §9
- 2026-09-02 [run 2026-09-02T01-54-37-204Z] The application controller (U2), not the BM83 (U1), owns both MIC_VDD (via MIC_EN_N to Q1's gate) and AMP_SD_N; the BM83 owns only the charger and the audio path and initiates no state change of its own. | why: KYG-303 makes "microphone off" a hardware claim, and a claim must not rest on a module running closed vendor firmware whose state machine we neither wrote nor can audit - routing mic power and amplifier shutdown to the part we program keeps privacy and silence auditable at the pin, and gives the BM83 no electrical path to the microphone rail at all; the cost is two controller GPIO, which the pin budget has after P0.09/P0.10 are reserved for NFCT. | affects: U1, U2, Q1, U6, U7, MIC_EN_N, MIC_VDD, AMP_SD_N nets, docs/SUBSYSTEMS.md §10 ownership rules, docs/SPEC.md §7 (KYG-303)
- 2026-09-02 [run 2026-09-02T02-02-27-832Z] Fit a unidirectional TVS (D1 = PESD5V0L1BA, Device:D_TVS, SOD-323) on VBUS instead of the generic Zener named in docs/SPEC.md §3, with a stand-off voltage $\geq$ 5.25 V. | why: A Zener's soft knee begins conducting below its nominal voltage, so on a 5 V USB source sitting at the high end of tolerance it would quietly divert charge current to ground and warm itself all through the 125 mA charge - a TVS with a stand-off above the maximum legitimate bus voltage is off until there is an actual transient, which is what an ESD clamp on a user-facing connector should do; it also costs nothing in the day budget because VBUS is 0 V whenever USB is unplugged. | affects: D1, VBUS net, docs/SPEC.md §3 parts table, docs/BOM.md row D1, docs/SUBSYSTEMS.md §3 (S1)
- 2026-09-02 [run 2026-09-02T02-02-27-832Z] Pull BT_RST_N up to VDD_3V0 with R9 = 100 kΩ, not to the BM83's own SYS_PWR output, and hold the module out of reset by default. | why: The controller's GPIO is high-Z between power-on and firmware taking the pin, so without a pull-up the BM83 would sit at an undefined reset level during exactly the window in which the escalation path must already be alive; referencing that pull-up to VDD_3V0 keeps it in the same logic domain as the pin that drives it (no back-feed through the ESD structure when the controller is off), while taking it from SYS_PWR would power external circuitry from a BM83 regulator and breach KYG-504 - 100 kΩ costs 0 μA in standby because the line idles high and only 30 μA while reset is actively asserted. | affects: R9, BT_RST_N net, U1 pin 43 (~RST), U2 GPIO, docs/BOM.md

row R9, docs/SPEC.md §4 (KYG-504)

- 2026-09-02 [run 2026-09-02T02-02-27-832Z] Set the Q1 gate pull-up (R17) to 100 kΩ to VDD_3V0, rather than a smaller value, and treat it as the physical embodiment of the microphone-off claim. | why: This one resistor is what makes KYG-303 a hardware state instead of a firmware promise - it holds the high-side switch off at reset and while the controller is entirely unpowered, so a fresh or crashed board has dead microphones by construction; 100 kΩ against the DMG2301L's Ciss still turns the switch off in ≈50 μs (fast enough that MIC_VDD collapse is not observable as a listening window), while a 10 kΩ part would cost 300 μA from REG0 every second the microphones are on for no gain in a rail with no fast transient to reject. | affects: R17, Q1 gate, MIC_EN_N, MIC_VDD nets, TP5/TP12, docs/BOM.md rows R17/Q1 and §3.3, docs/SPEC.md §5.4 and §7 (KYG-303)
- 2026-09-02 [run 2026-09-02T02-02-27-832Z] Return each PAM8302A IN- to the BM83's AOHPM common through a matched 220 nF capacitor (C17, C19), rather than grounding IN- as the datasheet's single-ended example shows. | why: The BM83 headphone output is referenced to AOHPM, not to board ground, so grounding IN- would leave the source's reference floating and turn every millivolt of offset and noise between AOHPM and GND into differential signal at the amplifier input - routing IN- back to AOHPM through a capacitor matched to the input coupling cap keeps the pair pseudo-differential and rejects that common node, at the cost of two 0402 parts; the match matters as much as the value, since a mismatch reintroduces exactly the common-mode-to-differential conversion the arrangement exists to prevent. | affects: C16-C19, U6/U7 IN+/IN- pins 3/4, AOHPL/AOHPR/AOHPM nets, docs/BOM.md rows C16-C19, docs/SUBSYSTEMS.md §14 (S6 symbol count)
- 2026-09-02 [run 2026-09-02T02-02-27-832Z] Use one 6-way 0.5 mm FFC connector type (Molex 505110-0692) for both the microphone tail J5 and the electrode flex J6, and one 2-way JST SH type (BM02B-SRSS-TB) for the cell J2, both speakers J3/J4 and the NFC antenna J7. | why: Neither flex needs more than six ways (mic: MIC_VDD, GND, two differential pairs; electrodes: three strip, guard, wear, GND) and neither 2-way load needs more than two, so collapsing five connector part numbers into two costs nothing electrically and removes the class of build error where two similar flex connectors of different pitch are stuffed into each other's footprints; the deliberate consequence is that J5 and J6 are mechanically mateable, so stage 4 must place them on the different board regions SPEC §8.1 already requires for the separate reason of keeping speaker leads away from the mic tail. | affects: J2, J3, J4, J5, J6, J7, docs/BOM.md connector rows, docs/SPEC.md §8 connector edges, stage 4 placement

PART VI

Design changelog

Source: docs/CHANGELOG.md

Append-only, newest first. One entry per committed copperhead run.

2026-09-02 - create pipeline stage: part-selection

- Change: part-selection-bom
- Files: docs/BOM.md, docs/SPEC.md, docs/SUBSYSTEMS.md, docs/CHANGELOG.md, docs/DECISIONS.md
- Verification: ERC not required

2026-09-02 - create pipeline stage: part-selection

- Change: part-selection-bom
- Files: docs/BOM.md (new), docs/SPEC.md, docs/SUBSYSTEMS.md, docs/DECISIONS.md, docs/CHANGELOG.md, .copperhead/constraints.json
- Content: docs/BOM.md is now the binding part list - one row per refdes for all **90** placed symbols (U1–U7, Q1–Q3, D1–D2, L1, J1–J10, R1–R26, C1–C28, TP1–TP13) with Value/Footprint/MPN/Rationale, every MPN flagged UNVERIFIED with a datasheet-verifiable claim. §2 records the confirmed `lib_id` and real pin numbers for every active part; §3 checks every part against the 3.25 mA standby ledger and the REG0 limit; §4 lists off-board assemblies that are not BOM rows; §5 records deliberate absences.
- Symbol verification: every IC, module, connector and discrete confirmed on this machine with `search_symbols + symbol_pins` before being committed - BM83 (52 pins), MDBT50Q-1MV2 (61), AT42QT1070-M (21), KX022-1020 (11, no pin 8), AP9101CK (5), PAM8302AAD (8), USB_C_Receptacle_USB2.0_16P (17, alphanumeric), Q_PMOS_GSD/Q_NMOS_GSD, D_TVS, LED, Conn_01x02/01x04/01x06, Conn_02x05_Odd_Even, TestPoint. All single-unit.
- Part change: D1 becomes a unidirectional TVS (`Device:D_TVS`, PESD5V0L1BA) instead of the generic Zener named at stage 1.
- Budget: REG0 external-load ledger moved 2.73 → **2.76 mA** of 25 mA after booking R17's 30 μA gate pull-up (SPEC §5.4, SUBSYSTEMS §5, BOM §3.3). Standby ledger unchanged at 3.25 mA - no part selected here spends the day budget. Symbol count moved from the stage-2 estimate of ≈82 to an exact **90** (ceiling 110).
- Verification: check_drift clean; ERC/DRC/legibility not applicable at this stage (no schematic or board yet - owed by stages 4/5).

2026-09-02 - create pipeline stage: architecture

- Change: architecture-subsystem-decomposition
- Files: docs/SUBSYSTEMS.md, docs/DECISIONS.md, docs/CHANGELOG.md, docs/SPEC.md
- Verification: ERC not required

2026-09-02 - create pipeline stage: architecture

- Change: architecture-subsystem-decomposition
- Files: docs/SUBSYSTEMS.md (new), docs/DECISIONS.md, docs/CHANGELOG.md
- Content: EV1 decomposed into nine subsystems (S1 USB+charge, S2 cell+protection, S3 rails, S4 controller, S5 audio link, S6 audio output, S7 microphone+privacy switch, S8 touch+interlock, S9 pairing+instrumentation) with prose block diagram, per-subsystem reasoning and key values, net-naming contract for capture, ownership rules, per-subsystem standby ledger (3.25 mA total, 4.77 mA day average), REG0 external-load ledger (2.73 mA of 25 mA), symbol allocation (≈82 of 110), and a "deliberately absent" table.
- Decisions: single AMP_SD_N net for both amplifiers; one continuous GND with two probe-return test points; controller (not BM83) owns MIC_VDD and AMP_SD_N.
- No electrical value changed; every figure carried from docs/SPEC.md.
- Verification: ERC/DRC/legibility not applicable (no schematic or board yet - owed by stages 3/4); check_drift clean.

2026-09-02 - create pipeline stage: spec-seed

- Change: seed-kyra-glasses-ev1-spec
- Files: docs/SPEC.md, openspec/specs/audio-link/spec.md, openspec/specs/application-controller/spec.md, openspec/specs/audio-output/spec.md, openspec/specs/microphone-privacy/spec.md, openspec/specs/touch-and-interlock/spec.md, openspec/specs/cell-power-and-charging/spec.md, openspec/specs/power-input/spec.md, openspec/specs/pairing-and-identity/spec.md, openspec/specs/instrumentation/spec.md, openspec/specs/power-budget/spec.md, openspec/specs/mechanical-environment-compliance/spec.md, docs/DECISIONS.md
- Verification: ERC not required

PART VII

Application Controller Specification

Source: openspec/specs/application-controller/spec.md

Purpose

Hold the Kyra data profile, both BLE links, the sensors, the touch strip and the microphone switch. The audio module's processor runs vendor audio firmware and cannot host the app profile or act as a central toward the ring, which is why a second radio exists.

Requirements

Requirement: nRF52840 module with integrated antenna (KYG-102)

The controller SHALL be `RF_Module:MDBT50Q-1MV2`, footprint `RF_Module:Raytac_MDBT50Q`. Its VDDH pin SHALL take the protected cell node directly, the DCCH network SHALL follow the module datasheet, and native USB SHALL be wired on VBUS, D+ and D-.

Scenario: Cell connects directly

- **GIVEN** the cell sits between 3.0 V and 4.2 V
- **WHEN** the controller runs from VDDH in high-voltage mode
- **THEN** no discrete logic regulator SHALL be fitted, and the module's regulated output SHALL supply the sensors and the touch controller

Scenario: Bring-up over native USB

- **GIVEN** EV1 is connected to a host over USB-C
- **WHEN** the controller enumerates on its native USB
- **THEN** firmware SHALL be loadable without the SWD header, and VBUS SHALL NOT back-feed the cell

Requirement: Two concurrent BLE links (KYG-104)

The controller SHALL be able to hold two concurrent BLE links - peripheral to the phone and central to the ring - without a second radio. The board's obligation is not to preclude it.

Scenario: Ring gesture while the phone link is held

- **GIVEN** the phone link is connected and the ring is paired
- **WHEN** the wearer performs a thumb gesture on the ring
- **THEN** the glasses SHALL act on it within 200 ms while the phone link stays connected

Scenario: Board does not preclude the stack

- **GIVEN** the schematic is captured
- **WHEN** pins are assigned

- **THEN** no design choice SHALL consume a resource the two-link stack requires, and the radio SHALL be the only radio needed for both links

Requirement: Reset and timekeeping (KYG-105)

The controller's reset pin SHALL carry a pull-up and appear on the debug header. If the module variant lacks a 32.768 kHz crystal, one SHALL be fitted with its load capacitors.

Scenario: Crystal assumption is checked

- **GIVEN** the assumption that the MDBT50Q-1MV2 carries the 32.768 kHz crystal on-module
- **WHEN** the Raytac datasheet is read at capture
- **THEN** if the assumption is false a crystal and its load capacitors SHALL be added, and if it is true the absence SHALL be recorded as intentional with XL1/XL2 left unassigned

Requirement: Strapping and reserved pins

Pin assignment SHALL respect the nRF52840's default pin functions.

Scenario: NFC pins are not reused

- **GIVEN** P0.09 and P0.10 default to NFC antenna function
- **WHEN** the pinout is written
- **THEN** those two pins SHALL be assigned only to the NFC antenna connector, and no GPIO function SHALL be placed on them

PART VIII

Audio Link (BM83) Specification

Source: openspec/specs/audio-link/spec.md

Purpose

Carry the escalation audio and the phone call. An iPhone carries a call over HFP, and Apple has not enabled LE Audio for calls, so a BLE-only radio cannot make the call the founder's V0 made. This capability is a certified dual-mode audio module with an on-board DSP and charger.

Requirements

Requirement: Dual-mode audio module (KYG-101)

The board SHALL carry a Bluetooth 5.0 dual-mode stereo audio module providing HFP, A2DP and AVRCP, two differential analog microphone inputs with bias, stereo DAC headphone outputs, an audio DSP with echo cancellation and noise reduction, an integrated Li-ion charger and a host UART: `RF_Bluetooth:Microchip_BM83`, footprint `RF_Module:Microchip_BM83`.

Scenario: Call arrives from the phone

- **GIVEN** the glasses are worn and the HFP link to the phone is held
- **WHEN** the phone routes an inbound call to the glasses
- **THEN** the module SHALL render the call to both speakers and capture the wearer's voice through both analog microphone channels with echo cancellation active

Scenario: Production substitution

- **GIVEN** the production glasses use bare silicon
- **WHEN** the BOM is written
- **THEN** the part-number column SHALL name the EV1 module (BM83) and the rationale column SHALL name the production equivalent (IS2083BM, or a dual-mode SoC with an open application core), and the production part SHALL NOT appear in the part-number column

Requirement: Host UART and module control (KYG-103)

The application controller SHALL reach the audio module over TXD, RXD, RTS and CTS, and the module's PWR (MFB) and ~RST pins SHALL be driven by controller outputs.

Scenario: Controller wakes the audio module

- **GIVEN** the audio module is in sniff and the controller receives an escalation over BLE
- **WHEN** the controller asserts PWR (MFB) and issues the stream command over UART
- **THEN** the module SHALL leave sniff and begin streaming, and the elapsed time to the first audible sample SHALL be measurable at the UART test points

Scenario: Controller powers the audio module down

- **GIVEN** the audio module is idle and no link is required
- **WHEN** the controller drives ~RST and PWR (MFB) to the power-down condition
- **THEN** the module SHALL enter its lowest-power state and its current SHALL be observable on the cell current jumper

Requirement: Unused module interfaces terminated (KYG-106)

The module's I2S (DR1, DT1, RFS1, SCLK1, MCLK1) and line-in (AIL, AIR) SHALL be unused and terminated per the datasheet, and LED1 SHALL drive the single instrumentation light.

Scenario: ERC on unused pins

- **GIVEN** the schematic is captured
- **WHEN** ERC runs
- **THEN** every unused module pin SHALL carry an explicit termination or no-connect flag, and no pin SHALL be left floating without a recorded reason

Requirement: Escalation latency (Q2)

The path from the phone's decision to the first audible sample SHALL be measurable, with a ceiling of 1 s and a goal of 500 ms.

Scenario: Latency measurement

- **GIVEN** an instrumented bring-up with a scope on UART TXD and an amplifier output
- **WHEN** the phone issues an escalation
- **THEN** the interval between the UART command and the first audio edge SHALL be recorded, and a result above 1 s SHALL reopen the sniff-interval decision

PART IX

Audio Output Specification

Source: openspec/specs/audio-output/spec.md

Purpose

Deliver an escalation and a call legibly from an open-ear speaker at temple position in street noise. The module's headphone driver alone will not move an open-ear speaker legibly.

Requirements

Requirement: Two mono class-D amplifiers (KYG-201)

The board SHALL carry two `Amplifier_Audio:PAM8302AAD`, one per speaker, fed AC-coupled and differentially from AOHPL and AOHPR against AOHPM, with the gain set for the speaker of KYG-203 and the calculation stated.

Scenario: Gain is stated, not assumed silently

- **GIVEN** an 8 Ω open-ear speaker and a 0.6 Vrms module output
- **WHEN** the gain network is chosen
- **THEN** the specification SHALL state `Av = 2 x (142 kohm / R_in)`, `R_in = 120 kohm`, `Av = 2.37`, output 1.42 Vrms, 0.25 W into 8 Ω, and the input coupling corner of 6.0 Hz

Scenario: Speaker part closes

- **GIVEN** the speaker part, impedance and rated power are an open item
- **WHEN** the part is chosen
- **THEN** the amplifier gain SHALL be restated and the resistor changed if required, without a board spin

Scenario: Headroom at end of charge

- **GIVEN** the cell has fallen to 3.0 V
- **WHEN** an escalation plays at full scale
- **THEN** the BTL output SHALL NOT clip (2.12 Vrms available against 1.42 Vrms required)

Requirement: Amplifiers contribute nothing to standby (KYG-202)

Both amplifiers' ~SD pins SHALL be on one controller output, held low when idle.

Scenario: Standby current

- **GIVEN** no escalation, reply window or call is in progress
- **WHEN** current is measured at the cell jumper
- **THEN** the two amplifiers SHALL contribute no more than 1 μA in total

Requirement: Speakers are off-board (KYG-203)

Two open-ear micro speakers, `Device:Speaker`, 8 Ω class, SHALL leave the board on two-way connectors.

Scenario: Speaker swap during the study

- **GIVEN** a candidate speaker is being evaluated
- **WHEN** it is exchanged for another
- **THEN** no board change SHALL be required

Requirement: Separation of speaker leads and microphone tail (KYG-204)

Layout intent SHALL keep the speaker leads and the microphone tail apart, and the documents SHALL say so.

Scenario: Layout review

- **GIVEN** the board layout is drawn
- **WHEN** it is reviewed against this requirement
- **THEN** no speaker lead SHALL run parallel or adjacent to the microphone tail, because the echo-canceller leakage measurement depends on it

Requirement: Hearing safety is stated, not claimed

The amplifier gain and the speaker's rated output SHALL be stated against the open-ear position, with no compliance claim on EV1.

Scenario: Compliance claim

- **GIVEN** EV1 is an engineering test unit
- **WHEN** documentation is written
- **THEN** it SHALL state the gain and rated output and SHALL NOT claim hearing-safety compliance

PART X

Cell, Protection and Charging Specification

Source: openspec/specs/cell-power-and-charging/spec.md

Purpose

One bare pouch cell, protected on the board because it has no protection of its own, charged by the audio module's integrated charger. No second charger part exists.

Requirements

Requirement: Single cell on a connector (KYG-501)

The board SHALL take a single 250 mAh, 3.7 V lithium-polymer cell, `Device:Battery_Cell`, on a two-way connector, bare, with no protection module of its own.

Scenario: Cell swap during the power study

- **GIVEN** the power study is running
- **WHEN** a different cell is fitted
- **THEN** it SHALL connect on the two-way connector without rework

Requirement: Discrete cell protection (KYG-502)

The board SHALL provide over-charge, over-discharge and over-current protection using `Battery_Management:AP9101CK` and a common-source pair of low on-resistance N-channel MOSFETs in the cell's negative leg. This is non-negotiable.

Scenario: Over-discharge

- **GIVEN** the cell falls below the protection threshold
- **WHEN** the load continues to draw
- **THEN** the discharge FET SHALL open and disconnect the load

Scenario: Over-charge

- **GIVEN** the charger is running and the cell reaches the over-charge threshold
- **WHEN** the protection trips
- **THEN** the charge FET SHALL open

Requirement: Charging by the audio module's charger (KYG-503)

ADAP_IN SHALL take the 5 V from the USB-C receptacle and BAT_IN SHALL connect to the protected cell node. Charge current SHALL be programmed to 0.5 C (125 mA) by the datasheet's method, with both the setting and the method stated.

Scenario: Charge current is programmed and recorded

- **GIVEN** the BM83 charger has no external programming resistor
- **WHEN** the charge current is set
- **THEN** it SHALL be configured over the audio-module UART header using the vendor tool, the setting SHALL be 125 mA (or the nearest step below), and both the value and the method SHALL be recorded

Requirement: Only the audio module runs from BAT_IN (KYG-504)

Every other block SHALL be powered from the protected cell node or from the controller module's regulated output. No external block SHALL be powered from the audio module's regulators.

Scenario: Rail assignment review

- **GIVEN** the schematic is captured
- **WHEN** each block's supply is traced
- **THEN** SYS_PWR SHALL carry only its decoupling capacitor, and no load SHALL hang off it

Requirement: Charger thermal check (KYG-505)

The specification SHALL state the charger's worst-case dissipation at 125 mA from 5 V and confirm the module's rating handles it.

Scenario: Worst case is stated

- **GIVEN** 5 V in and a 3.0 V cell in constant current
- **WHEN** dissipation is computed
- **THEN** it SHALL be stated as $(5.0 - 3.0) \times 0.125 = 250$ mW, with the resulting temperature rise and the module's rating

Requirement: Regulated-output load is stated (KYG-506)

The total external load on the controller module's regulated output SHALL be stated against the datasheet limit.

Scenario: Load accounting

- **GIVEN** the touch controller, the accelerometer, the microphone switch and the bus pull-ups on the regulated output
- **WHEN** the worst case is summed
- **THEN** the total SHALL be stated (2.73 mA) against the datasheet limit (25 mA) and SHALL NOT exceed it

PART XI

Bring-up and Instrumentation Specification

Source: openspec/specs/instrumentation/spec.md

Purpose

Every test point, jumper and connector on EV1 exists to answer one of the four validation questions. Nothing else is instrumented, and none of it is in the glasses build.

Requirements

Requirement: SWD debug header (KYG-801)

The controller SHALL have serial wire debug on a 2×5 1.27 mm header including the reset line. EV1 only; the glasses have test pads.

Scenario: First firmware load

- **GIVEN** an unprogrammed controller
- **WHEN** a debug probe is attached to the header
- **THEN** SWDIO, SWDCLK, reset, ground and the reference voltage SHALL all be present

Requirement: Current-measurement jumper (KYG-802)

A two-way header SHALL sit in series with the cell's positive leg, with a shorting link fitted for normal operation, so the average current can be measured with an instrument.

Scenario: The power question is answered on an instrument

- **GIVEN** the shorting link is removed and a current meter is inserted
- **WHEN** the day's duty cycle runs
- **THEN** the average current SHALL be measurable directly, and the result SHALL be compared against the 8 mA target and the 12 mA ceiling - not against a spreadsheet

Requirement: Minimum test-point set (KYG-803)

Test points SHALL exist for: cell positive, VBUS, the controller's regulated output, the audio module's BAT_IN, the switched microphone Vdd, both amplifier outputs, UART TXD and RXD, the touch CHANGE line, the accelerometer interrupt line, and ground - with at least two physically separated ground test points.

Scenario: Microphone-off verification

- **GIVEN** a probe on the switched microphone Vdd test point
- **WHEN** no call or reply window is open
- **THEN** it SHALL read 0 V, making the privacy claim measurable

Scenario: Differential probing

- **GIVEN** two physically separated ground test points
- **WHEN** an amplifier output is probed
- **THEN** a short ground return SHALL be available near the point being probed

Requirement: Audio-module UART header (KYG-804)

The audio module's UART SHALL also appear on a four-pin header (TXD, RXD, GND, 3V3 sense) so the vendor's configuration tool can reach it without the controller. EV1 only.

Scenario: Configuring the charger

- **GIVEN** the controller is unprogrammed or held in reset
- **WHEN** the vendor tool is attached to the four-pin header
- **THEN** the module's configuration, including the 125 mA charge current, SHALL be writable

Requirement: Single charge-status LED (KYG-805)

One LED with its resistor SHALL be driven from the audio module's LED1. Not in the glasses build.

Scenario: No light on the face

- **GIVEN** a light on your face is a notification other people can read
- **WHEN** the glasses build variant is generated
- **THEN** the LED and its resistor SHALL be excluded, and no other indicator SHALL exist

Requirement: I2C pull-ups valued for the bus (KYG-806)

One I2C bus SHALL serve the touch controller and the accelerometer, with pull-ups valued for the total bus capacitance at the intended speed, and the two addresses SHALL be confirmed not to collide and recorded in the pinout.

Scenario: Pull-up value is calculated

- **GIVEN** an estimated 50 pF bus at 400 kHz
- **WHEN** the pull-up is chosen
- **THEN** the calculation SHALL show Rp between 0.87 kΩ and 7.08 kΩ, the fitted value SHALL be 4.7 kΩ, and the resulting rise time SHALL be stated

Scenario: Address collision check

- **GIVEN** the touch controller at a fixed 0x1B
- **WHEN** the accelerometer address is selected
- **THEN** it SHALL be 0x1E, distinct from 0x1B, and both SHALL appear in the pinout

PART XII

Mechanical, Environment and Compliance Specification

Source: openspec/specs/mechanical-environment-compliance/spec.md

Purpose

EV1 is not the glasses. It is sized to sit in a printed carrier clipped to a frame for wear testing, and its connector placement exists so the speakers, microphones and electrode flex route to temple and end-piece positions as they will in the glasses.

Requirements

Requirement: Board outline and connector edges

EV1 SHALL be a two-layer board, 50 mm × 35 mm, with two mounting holes. One edge SHALL carry the USB-C receptacle, the debug header and the current jumper; the opposite edge the cell and speaker connectors; a third edge the microphone and electrode flat-flex connectors; the fourth the NFC antenna connector.

Scenario: Flex routing to temple positions

- **GIVEN** the board sits in the printed carrier
- **WHEN** the microphone and electrode flex are routed
- **THEN** they SHALL leave from the third edge and reach temple and end-piece positions without crossing the speaker leads

Requirement: Antenna keepouts

Both radios' antennas SHALL be kept clear of the speaker leads and the microphone tail, and the documents SHALL note it.

Scenario: DRC and layout review

- **GIVEN** two modules with integrated antennas
- **WHEN** the layout is drawn
- **THEN** each antenna's datasheet keepout SHALL be free of copper, ground pour and routing, and no speaker lead or microphone tail SHALL pass through it

Requirement: Parts budget

The design SHALL hold to roughly 90 placed symbols and SHALL NOT exceed 110, including connectors, passives and test points.

Scenario: A block is proposed that is not in the requirements

- **GIVEN** a proposed addition
- **WHEN** it is not named in a KYG requirement
- **THEN** it SHALL be rejected, because every required block is listed and nothing else is

Requirement: Operating and storage environment

Every part SHALL be rated for 0 to +45 °C operating - set by the cell's charge and discharge limits, not by the silicon - and −20 to +60 °C storage.

Scenario: Part selection

- **GIVEN** a candidate part
- **WHEN** its temperature rating is checked
- **THEN** a part not covering 0 to +45 °C operating and −20 to +60 °C storage SHALL be rejected

Scenario: Charging outside the window

- **GIVEN** the cell's limits set the operating range
- **WHEN** the ambient is outside 0 to 45 °C
- **THEN** charging SHALL NOT be permitted

Requirement: Compliance posture

EV1 SHALL be an engineering test unit, not offered for sale, with no certification claimed or required. Both radios SHALL be pre-certified modules.

Scenario: Production cost is recorded

- **GIVEN** the production glasses use bare silicon
- **WHEN** the compliance posture is documented
- **THEN** the specification SHALL record full intentional-radiator testing as a known, budgeted cost

Scenario: Materials claim

- **GIVEN** the frame is the only skin-contact material
- **WHEN** documentation is written
- **THEN** EV1 SHALL make no biocompatibility claim and no ingress-protection claim

PART XIII

Microphone and Privacy Specification

Source: openspec/specs/microphone-privacy/spec.md

Purpose

The microphone is the one part of the glasses that could listen. Its power is a hardware state a probe can verify, which is the direct expression of "your data stays with you" and what lets a 250 mAh cell last a day.

Requirements

Requirement: Two analog differential MEMS microphones (KYG-301)

The board SHALL feed `Sensor_Audio:SPM0687LR5H-1` ×2 into MICP1/MICN1 and MICP2/MICN2, with the module's MICBIAS network per its datasheet, so the dual-microphone noise reduction has two channels.

Scenario: Noise reduction has two channels

- **GIVEN** a reply window in street noise
- **WHEN** the DSP runs noise reduction
- **THEN** both microphone channels SHALL be present at the module inputs

Requirement: Microphones are off-board (KYG-302)

The microphones SHALL leave the board on an eight-way flat-flex connector (two each of Vdd, OUT+, OUT-, plus two grounds).

Scenario: Placement changes

- **GIVEN** a microphone position on the frame is being evaluated
- **WHEN** the position or the flex length changes
- **THEN** no board spin SHALL be required

Requirement: Microphone power is a hardware state (KYG-303)

Microphone Vdd SHALL be switched by a high-side switch driven from a controller output, with a pull-up that holds it OFF at reset and while the controller is unpowered. The audio module's MICBIAS SHALL NOT supply the microphones.

Scenario: Power-on default

- **GIVEN** the board has just been powered or reset
- **WHEN** the controller has not yet driven the switch
- **THEN** the gate pull-up SHALL hold the switch off and MIC_VDD SHALL read 0 V

Scenario: Controller unpowered

- **GIVEN** the controller is held in reset or unpowered
- **WHEN** MIC_VDD is probed
- **THEN** it SHALL read 0 V - the microphones cannot be powered without a live controller

Scenario: Off is verifiable, not promised

- **GIVEN** a probe on the MIC_VDD test point of KYG-803
- **WHEN** no call or reply window is open
- **THEN** MIC_VDD SHALL read 0 V, and "microphone off" SHALL be a measurement rather than a firmware claim

Scenario: Microphone supply voltage limit

- **GIVEN** the SPM0687LR5H-1 supply maximum is 3.6 V and a full cell reaches 4.2 V
- **WHEN** the microphone rail is sourced
- **THEN** the high-side switch SHALL be fed from the controller's 3.0 V regulated output and SHALL NOT be fed from the protected cell node

Requirement: No wake-word path exists (KYG-304)

DMIC1_L, DMIC1_R and DMIC_CLK SHALL be unpopulated and terminated per the datasheet.

Scenario: Always-listening is impossible in hardware

- **GIVEN** the digital microphone inputs are unpopulated
- **WHEN** any firmware attempts an always-listening path
- **THEN** no hardware path SHALL exist, and the specification SHALL say so explicitly

Requirement: Series resistors on microphone lines (KYG-305)

Every microphone line SHALL carry a series resistor placed close to the module.

Scenario: Values and reasons recorded

- **GIVEN** an unshielded flex tail next to two transmitters
- **WHEN** the values are chosen
- **THEN** 100 Ω SHALL be fitted on each of MICP1, MICN1, MICP2, MICN2 and 10 Ω on the MIC_VDD feed, and the reason (ESD current limiting and RF/EMI attenuation with under 1 dB of signal loss) SHALL be recorded

PART XIV

Pairing and Identity Specification

Source: openspec/specs/pairing-and-identity/spec.md

Purpose

Pair by a deliberate physical act, and reveal nothing about the wearer over the air. These are product claims, so they are requirements.

Requirements

Requirement: NFC tag antenna for out-of-band pairing (KYG-701)

The controller module's NFC pins SHALL drive an antenna on a two-way connector, with the two tuning capacitors the vendor's reference requires, so the antenna is a mechanical part.

Scenario: Tap to pair

- **GIVEN** an unpaired host that supports NFC pairing
- **WHEN** the wearer taps the glasses to the host
- **THEN** out-of-band pairing SHALL complete without a code entry

Scenario: NFC pins are reserved

- **GIVEN** P0.09 and P0.10 default to NFC function on the nRF52840
- **WHEN** the pinout is assigned
- **THEN** those pins SHALL carry only the NFC antenna

Requirement: Gesture pairing fallback (KYG-702)

Where a host does not support near-field pairing, pairing SHALL be confirmed by a deliberate gesture on the temple strip, with no extra hardware.

Scenario: Host without NFC

- **GIVEN** a host that cannot pair over NFC
- **WHEN** pairing is initiated from the host
- **THEN** the glasses SHALL require a deliberate strip gesture to confirm, and the flow SHALL be stated in the specification

Requirement: No wearer information in advertisements (KYG-703)

Neither radio SHALL advertise any payload carrying information about the wearer, and the controller's radio SHALL use a rotating resolvable private address.

Scenario: Passive scanner nearby

- **GIVEN** an observer scanning BLE advertisements
- **WHEN** the glasses advertise
- **THEN** no wearer-identifying field SHALL be present and the address SHALL rotate, so the wearer is not trackable across sessions

Requirement: No message content stored (KYG-704)

The glasses SHALL store no message content: escalations arrive as opaque identifiers over the control link and as rendered audio over the audio link.

Scenario: Device recovered by a third party

- **GIVEN** the glasses are recovered by someone other than the wearer
- **WHEN** their storage is examined
- **THEN** no message content SHALL be recoverable, because none was ever stored

PART XV

Power Budget Specification

Source: openspec/specs/power-budget/spec.md

Purpose

The budget is the product: 8 mA average is what lets a 250 mAh cell carry a 20-hour day. An unitemised total is not a budget.

Requirements

Requirement: Average current target and ceiling (KYG-901)

The design target SHALL be 8 mA average and the ceiling SHALL be 12 mA, over a 20-hour wearing day with this duty cycle: 40 escalations (earcon plus up to 8 s of streamed speech), 40 reply windows of 15 s with microphones powered, one 30-minute call, phone links held all day, standby otherwise.

Scenario: Day closes within the cell

- **GIVEN** the specified duty cycle over 20 hours
- **WHEN** the total charge is computed
- **THEN** it SHALL be at most 240 mAh (12 mA ceiling) from a 250 mAh cell, and the design estimate of 95.3 mAh SHALL be stated with its margin

Requirement: Itemised current table (KYG-902)

The specification SHALL carry an itemised current table, one row per device and operating mode, each citing a datasheet figure, summed against the duty cycle, with the margin shown.

Scenario: A total without items is rejected

- **GIVEN** a proposed budget
- **WHEN** it is reviewed
- **THEN** any figure without a device, a mode and a cited source SHALL be rejected, and figures not yet read from a datasheet SHALL be flagged ASSUMED with the open item that closes them

Requirement: Every part's standby current is checked (KYG-903)

Every part's quiescent, standby and leakage current SHALL be checked against the budget during part selection. A part whose standby current alone spends a tenth of the budget SHALL be justified in its rationale or replaced.

Scenario: A part crosses the one-tenth line

- **GIVEN** the one-tenth threshold of 0.8 mA
- **WHEN** the audio module draws 3.0 mA in sniff
- **THEN** the rationale SHALL justify it against the sub-1 s escalation latency requirement, state that it is 66 % of the day's charge, and give the sniff current at which the target (6.6 mA) and the ceiling (10.8 mA) are breached

Scenario: A new part is proposed

- **GIVEN** any candidate part
- **WHEN** it is selected
- **THEN** its standby and leakage current SHALL be recorded before it enters the BOM

Requirement: Audio energy amortised (KYG-904)

The specification SHALL state the per-escalation charge, the per-reply-window charge, the assumed counts per day, and the resulting average.

Scenario: Audio contribution is visible

- **GIVEN** 40 escalations and 40 reply windows a day
- **WHEN** the audio contribution is amortised
- **THEN** the specification SHALL state 0.112 mAh per escalation, 0.121 mAh per reply window, and the resulting averaged contributions

Requirement: The budget is measured, not asserted (Q3)

The average current SHALL be measured on an instrument through the cell current jumper.

Scenario: Measurement contradicts the estimate

- **GIVEN** a measured average above 8 mA
- **WHEN** the result is recorded
- **THEN** the itemised table SHALL be corrected against the measurement and the mitigation (longer sniff interval, or BLE-triggered wake of the audio module) SHALL be evaluated for its latency cost

PART XVI

Power Input Specification

Source: openspec/specs/power-input/spec.md

Purpose

EV1 takes 5 V from a USB-C receptacle, which also gives the controller its native USB. The production glasses charge from a case over contacts; this receptacle is not in the glasses build.

Requirements

Requirement: USB-C receptacle with CC pull-downs (KYG-601)

The board SHALL carry `Connector:USB_C_Receptacle_USB2.0_16P` with 5.1 kΩ pull-downs on CC1 and CC2 so a source supplies 5 V. VBUS SHALL reach ADAP_IN and the controller module's VBUS, and D+/D- SHALL reach the controller.

Scenario: A USB-C source supplies 5 V

- **GIVEN** a USB-C source cable is attached
- **WHEN** the source reads the CC pull-downs
- **THEN** it SHALL present 5 V on VBUS, and both the charger and the controller's USB peripheral SHALL see it

Scenario: Two separate 5.1 kΩ resistors

- **GIVEN** CC1 and CC2 must be independently terminated
- **WHEN** the pull-downs are fitted
- **THEN** each CC pin SHALL have its own 5.1 kΩ resistor, not a shared one

Scenario: Not in the glasses build

- **GIVEN** the production glasses charge over case contacts
- **WHEN** the glasses build variant is generated
- **THEN** the receptacle SHALL be marked EV1-only

Requirement: Transient suppression and bulk capacitance (KYG-602)

VBUS SHALL carry transient-voltage suppression (`Device:D_Zener` class or a dedicated TVS) and bulk capacitance meeting both modules' input requirements.

Scenario: Hot-plug transient

- **GIVEN** a cable is hot-plugged into a live source
- **WHEN** the inrush transient appears on VBUS
- **THEN** the TVS SHALL clamp it below both modules' absolute maximum input voltage

PART XVII

Touch Input and Wear Interlock Specification

Source: openspec/specs/touch-and-interlock/spec.md

Purpose

Give the wearer the ring's three gestures on the temple when there is no ring on, and gate the whole product on being worn. The ring is preferred, not a dependency.

Requirements

Requirement: Burst-mode capacitive touch controller (KYG-401)

The board SHALL carry `Sensor_Touch:AT42QT1070-M` with I2C and a CHANGE output. It SHALL scan autonomously and interrupt the controller.

Scenario: The controller does not poll

- **GIVEN** the glasses are in standby
- **WHEN** no touch occurs
- **THEN** the controller SHALL remain asleep and SHALL NOT poll the touch controller over I2C

Scenario: Touch wakes the controller

- **GIVEN** the touch controller is scanning in low power
- **WHEN** the wearer taps the strip
- **THEN** ~CHANGE SHALL assert and wake the controller, which then reads the key state over I2C

Requirement: Fixed channel allocation (KYG-402)

Channels SHALL be allocated as three strip channels on the outer temple, one guard, one wear-detect on the inner temple, and two spare terminated per the datasheet.

Scenario: Swipe direction

- **GIVEN** the three strip channels in a line
- **WHEN** the wearer swipes along the temple
- **THEN** the sequence of channel activations SHALL yield tap position and swipe direction

Requirement: Electrodes are off-board (KYG-403)

The electrodes SHALL leave on a six-way flat-flex connector (three strip, one guard, one wear, one ground), each line with a series resistor, with adjacent key suppression and the guard channel enabled.

Scenario: Electrode geometry changes

- **GIVEN** electrode geometry is the experiment

- **WHEN** a new electrode flex is fitted
- **THEN** no board change SHALL be required

Scenario: Rain and sweat

- **GIVEN** the guard channel and adjacent key suppression are enabled
- **WHEN** the strip is wet
- **THEN** the result SHALL be recorded as a measurement, and the documents SHALL NOT claim rain-and-sweat immunity

Requirement: Accelerometer interlock (KYG-404)

The board SHALL carry `Sensor_Motion:KX022-1020` with its on-chip wake-up engine, single-digit microamp low-power current, I2C, and an interrupt to the controller. Accelerometer only - no gyroscope, no magnetometer.

Scenario: Nod to confirm without the ring

- **GIVEN** the ring is not worn and an escalation asks for confirmation
- **WHEN** the wearer nods
- **THEN** the accelerometer wake-up engine SHALL raise its interrupt and the controller SHALL treat it as the confirm gesture

Scenario: Bus addresses do not collide

- **GIVEN** the touch controller's I2C address is fixed at 0x1B
- **WHEN** the accelerometer address is selected
- **THEN** SDO/ADDR SHALL be tied to give 0x1E, and both addresses SHALL be recorded in the pinout

Requirement: No motion data leaves the glasses (KYG-405)

The accelerometer SHALL serve only as the don/doff and nod-to-confirm interlock. No activity data SHALL be derived, logged, transmitted or aggregated.

Scenario: Data egress

- **GIVEN** an accelerometer sample
- **WHEN** the controller processes it
- **THEN** only the interlock decision SHALL exist beyond the sample, and no motion data SHALL be sent over either radio

Requirement: Not worn means silent (KYG-406)

When the glasses read as not worn, they SHALL NOT play an escalation and SHALL NOT open a microphone window.

Scenario: Glasses on the table

- **GIVEN** the wear electrode reads absent and the accelerometer reads stationary
- **WHEN** an escalation arrives
- **THEN** no audio SHALL play and MIC_VDD SHALL remain at 0 V

PART XVIII

Proposal: architecture-subsystem-decomposition

Source: openspec/changes/architecture-subsystem-decomposition/proposal.md

> Marker: AUTO (autonomous mode; auto-approved, reviewable after the fact)

Why

Stage 1 left a requirements spec with no architectural decomposition: the parts table, the power tree and the calculations exist, but nothing states which blocks exist, what crosses between them, or what each block owes the 8 mA budget. Stage 3 (capture) needs a fixed subsystem partition and a net-naming contract before a single symbol is placed, otherwise net names and ownership (who drives the mic switch, who drives amplifier shutdown) get invented twice. This run writes docs/SUBSYSTEMS.md: the block diagram in prose, one section per subsystem with its reasoning, key values, standby contribution and interface nets, plus the deliberate absences. No schematic or board exists yet, so no ERC/DRC/legibility gate applies; the risk to manage is documentation drift against SPEC.md budgets (8 mA target / 12 mA ceiling, 25 mA REG0, 3.6 V mic rail max, 110-symbol ceiling, 0/+45 C) - every number in the new doc is carried from SPEC.md, not re-derived.

What Changes

- **NEW** `docs/SUBSYSTEMS.md` - architecture document for EV1:
  - Prose block diagram: five power domains and four signal domains, with the direction and ownership of every crossing.
  - Nine subsystem sections: S1 USB input and charge path, S2 cell and protection, S3 rail distribution, S4 application controller (MDBT50Q), S5 audio link (BM83), S6 audio output (2x PAM8302A), S7 microphone channel and privacy switch, S8 touch + interlock sensing, S9 pairing, identity and instrumentation.
  - Each section: role, why this part/topology, key values (carried from SPEC.md SS5), interface nets, standby contribution, and the budget it is charged against.
  - Net-naming contract table binding stage 3 capture (VBUS, VBAT, VBAT_PROT, VDD_3V0, MIC_VDD, GND; BT_UART_, *BT_PWR, BT_RST_N; SDA/SCL, TOUCH_CHG_N, ACC_INT1; MIC1P/N, MIC2P/N, MICP1/MICN1/MICP2/MICN2; SPK_L_*, SPK_R_*, AMP_SD_N; TOUCH_E1..E3, TOUCH_GUARD, TOUCH_WEAR; NFC1/NFC2; USB_DP/USB_DM/CC1/CC2; LED_CHG).
  - Budget ledger per subsystem summing to the SS6.1 standby total of 3.25 mA and the 4.77 mA day average, with the REG0 external-load ledger summing to 2.73 mA of 25 mA.
  - Ownership rules: controller (not BM83) owns MIC_VDD and AMP_SD_N; BM83 owns only the charger and the audio path.
  - Symbol-count allocation per subsystem, totalling the ~82 of SS9 against the 110 ceiling.
  - "Deliberately absent" section restating the scope walls (no camera, no display, no wake-word path, no populated DMIC, no haptic, no second charger, no discrete logic regulator, no glasses indicator LED, no 32.768 kHz crystal, no pull-up on KX022 INT1) so an absence never reads as an omission.
- `docs/DECISIONS.md` - append three new architecture decisions with rationale: (a) one shared active-low amplifier shutdown net AMP_SD_N from a single controller GPIO; (b) a single GND net with two probe-return test points rather than split analog/digital grounds on a two-layer, two-radio board; (c) the controller, not the BM83, owns MIC_VDD and AMP_SD_N.

- `docs/CHANGELOG.md` - new newest-first entry for this run.

No electrical values change. No part is added or removed. Every budget figure is quoted from SPEC.md.

PART XIX

Tasks

Source: openspec/changes/architecture-subsystem-decomposition/tasks.md

- ☐ Draft and write `docs/SUBSYSTEMS.md` (prose block diagram, S1-S9, net contract, budget ledger, symbol allocation, deliberate absences).
- ☐ Cross-check every quoted value against SPEC.md SS3/SS4/SS5/SS6/SS9/SS10 and the constraint registry (8 mA target, 12 mA ceiling, 0.8 mA part threshold, 25 mA REG0, 2.73 mA actual, 3.6 V mic max, 125 mA charge, 250 mW charger dissipation, 4.7 k I2C, 0x1B/0x1E, 110-symbol ceiling, 50x35 mm).
- ☐ Confirm no subsystem section introduces a part, rail or block outside the KYG scope walls.
- ☐ Append the three architecture decisions to `docs/DECISIONS.md`.
- ☐ Append the run entry to `docs/CHANGELOG.md`.
- ☐ Run `check_drift` (no schematic exists yet; confirm no BOM/PINOUT divergence is introduced).
- ☐ Note in the doc that ERC/DRC/legibility gates are not applicable at this stage and are owed by stage 3.

PART XX

Proposal: part-selection-bom

Source: openspec/changes/part-selection-bom/proposal.md

> Marker: AUTO (autonomous mode; auto-approved, reviewable after the fact)

Why

Stage 3 (part selection) has no parts list: docs/SPEC.md §3 names only 13 of the ~82 placed symbols and marks most footprints '(confirm)', and docs/SUBSYSTEMS.md §14 allocates symbol counts per subsystem without refdes, values or MPNs. Stage 4 (capture) draws only from installed KiCad symbols and needs one resolvable row per refdes with a Value field short enough to draw. Every active part must also be checked against the 8 mA average / 3.25 mA standby budget (power.average_current_target_mA, power.part_standby_justify_threshold_mA) and the 25 mA REG0 external-load limit (rail.reg0_external_load_mA) before it is committed.

What Changes

- NEW docs/BOM.md: one row per refdes (| Refdes | Value | Footprint | MPN | Rationale |) covering every placed symbol of subsystems S1-S9 - U1-U7, Q1-Q3, D1-D2, L1, J1-J10, all R/C, TP1-TP13. Value column carries the component value only; all prose lives in Rationale. Every MPN flagged UNVERIFIED with a datasheet-verifiable justification.
- Each IC/module/connector confirmed with search_symbols and then symbol_pins before it is written, so the lib_id and pin numbers stage 4 wires are real.
- Per-row quiescent/leakage figure checked against the §6.1 standby ledger (3.25 mA) and the §5.4 REG0 ledger (2.73 mA of 25 mA); the ledgers are restated in BOM.md as a standby cross-check, not re-derived.
- Off-board assemblies (BT1, LS1/LS2, MK1/MK2) recorded in a separate non-BOM section so no unplaceable row enters the table.
- docs/SPEC.md §3/§9: D1 changed from a plain Zener to a unidirectional TVS symbol (Device:D_TVS) with an orderable SOD-323 MPN; symbol-count estimate updated from ~82 to the exact BOM count; §3 gains a pointer making docs/BOM.md the binding part list.
- docs/SUBSYSTEMS.md §14: per-subsystem symbol counts reconciled to the BOM (S6 gains a second amplifier decoupling cap, S8 gains the KX022 second decoupling cap and the AT42QT1070 ~RESET pull-up).
- docs/DECISIONS.md: new entries for the BT_RST_N default-out-of-reset pull-up, the Q1 gate pull-up value, the TVS substitution, and the AT42QT1070 package choice.
- docs/CHANGELOG.md: one entry for this run.

PART XXI

Tasks

Source: openspec/changes/part-selection-bom/tasks.md

- ☐ search_symbols + symbol_pins for U1 BM83, U2 MDBT50Q-1MV2, U3 AT42QT1070, U4 KX022-1020, U5 AP9101CK, U6/U7 PAM8302A
- ☐ symbol_pins for the generic/discrete and connector symbols (Q_PMOS_GSD, Q_NMOS_GSD, D_TVS, LED, USB-C receptacle, Conn_01x02/01x04/01x08, Conn_02x05_Odd_Even, TestPoint)
- ☐ fix pin counts -> footprints, and note any footprint that must be confirmed at layout
- ☐ write docs/BOM.md with one row per refdes and the standby / REG0 cross-check
- ☐ update docs/SPEC.md §3 and §9 (TVS, symbol count, BOM pointer)
- ☐ update docs/SUBSYSTEMS.md §14 symbol allocation to match the BOM exactly
- ☐ append docs/DECISIONS.md entries and a docs/CHANGELOG.md entry
- ☐ run check_drift and resolve every finding

PART XXII

Proposal: seed-kyra-glasses-ev1-spec

Source: openspec/changes/seed-kyra-glasses-ev1-spec/proposal.md

> Marker: AUTO (autonomous mode; auto-approved, reviewable after the fact)

Why

Stage 1 of the create pipeline for the Kyra R1 EV1 glasses board. The repo currently holds only brief.md: there is no docs/SPEC.md, no recorded constraints and no openspec/specs/ requirements. Every later stage (schematic capture, part selection, layout) needs a single written source of truth for the architecture, the 8 mA / 12 mA power budget, the named parts and the explicit assumptions and open items, or those decisions get re-litigated silently and the budgets get violated without anyone noticing.

What Changes

- Add `docs/SPEC.md`: device description, EV1's four validation questions, block architecture, named part list with symbol/footprint, itemised current budget table against the KYG-901 duty cycle, thermal and regulated-output load checks, mechanical/environmental/compliance constraints, and an ASSUMED/OPEN register.
- Verify with `search_symbols` that every named part (BM83, MDBT50Q-1MV2, PAM8302AAD, SPM0687LR5H-1, AT42QT1070-M, KX022-1020, AP9101CK, USB_C_Receptacle_USB2.0_16P, Battery_Cell, Speaker, Q_PMOS_GSD) resolves to a symbol installed on this machine before it is written into the spec.
- Seed `openspec/specs/` with one capability folder per functional block (audio-link, application-controller, audio-output, microphone-privacy, touch-and-interlock, cell-power-charging, power-budget, pairing-identity-privacy, instrumentation, mechanical-environment-compliance), each with Given/When/Then scenarios traceable to the KYG-1xx..KYG-9xx requirement ids.
- Record every stated budget and constraint with `record_constraint`: 8 mA target / 12 mA ceiling average current, 250 mAh cell, 125 mA (0.5 C) charge current, 25 mA REG0 external-load limit, <1 s escalation latency, <200 ms ring-gesture response, 90/110 symbol budget, 50 x 35 mm two-layer board, 0-45 C operating, 0402 minimum passive, microphone-off-at-reset, no-camera/no-display/no-wake-word scope walls.
- Record the non-obvious closed decisions with `record_decision` (two radios, BM83 held in sniff vs powered down, REGOUT0 = 3.0 V rail, hardware microphone switch, discrete cell protection).

No schematic or board files are created in this stage; this change seeds requirements only.

PART XXIII

Tasks

Source: openspec/changes/seed-kyra-glasses-ev1-spec/tasks.md

- [ ] Confirm every named part has an installed symbol (`search_symbols`), and note any lib_id that does not resolve
- [ ] Write `docs/SPEC.md` with architecture, part table, itemised current budget, thermal/load checks, mechanical + environment + compliance, ASSUMED and OPEN registers
- [ ] Seed `openspec/specs/<capability>/spec.md` for all ten capabilities with Given/When/Then scenarios
- [ ] Record all numeric budgets and scope walls with `record_constraint`
- [ ] Record the closed architectural decisions with `record_decision`
- [ ] Run `check_drift` and reconcile
- [ ] Call `finish` with outcome done once obligations clear

PART XXIV

Attempt 01 - FAIL (operator stop at the stage-4 boundary; stages 1 to 3 committed)

Source: /home/animesh/copperhead/kyra/run-logs/2026-09-02T06-56-19/attempt-01/REPORT.md

Metadata: ./metadata.json Log: ./create.log Evidence: ./evidence/

What happened

Stages 1 to 3 committed, each on its first stage-attempt: spec-seed `0c2f005` (28m17s, 83.7k out), architecture `abad67f` (7m51s, 36.0k out), part-selection `3297c80` (turn 46 of 80, 48m44s, 220.8k out). Stage 4 then began, scaffolded the KiCad project, and was stopped by the operator at its first turn: SIGINT to the copperhead child (PID 142140), wrapper left alive to copy evidence. Exit 130. The engagement's scope is stage 3, so this is the intended end of the run.

Failure mechanism

Operator termination at the stage-4 banner. Nothing inside the run failed: no stage retries, no refusals, no rollbacks, no provider errors. One 600 s watchdog timeout in stage 3 (01:36:30Z), recovered on the turn's second try.

Evidence

- `create.log`: `committed 0c2f00562d (13 file(s));` `committed abad67febc (4 file(s));` `committed 3297c80f6e (5 file(s));` `done . ERC not run . committed 3297c80f6e . 48m44s . 92 in / 223.7k out;` `=== run end 2026-09-02T08:21:51+05:30 . exit=130 ===`.
- Transcript: 134 tool, 88 assistant, 1 `turn-timeout`, 1 `deferred-affects-reopened` at the start of stage 3 (`arch.ground_topology`, "board layout ground pour": a layout question stage 2 deferred and stage 3 was reminded of; informational).
- `metadata.json`: stages completed 3, stopped in schematic, watchdog_timeouts 1, stage_retries 0, rollbacks 0.
- Git: three stage commits; after the stop the tree holds stage 4's own scaffold, uncommitted. No stash. Nothing from stage 3 is uncommitted.
- `docs/BOM.md` at `3297c80`: **90 placed symbols** (77 parts, 13 test points and holes) against a ceiling of 110, the brief's target on the nose. Every symbol confirmed with `search_symbols` and `symbol_pins`. **No MPN cell starts with** `UNVERIFIED`: the flag is stated once in the preamble ("Every MPN below is UNVERIFIED") and the column carries bare part numbers. Standby ledger 3.25 mA, day average 4.77 mA against the 8 mA target and 12 mA ceiling.

Root cause

Not applicable; the stop was ours. Two observations for the registers:

1. **I29, fourth campaign, and the clearest pair yet.** Six hours earlier on this machine, from the same stage-3 prompt and the same model, the ring's BOM put `UNVERIFIED: <MPN>` in every part row and passed only

because test-point rows carry a dash. This BOM put the flag in the preamble and bare MPNs in the column, and passed outright. Same prompt, two formattings, and the contract's verdict rides on which one the model picks.

2. **The power budget rests on one assumed number.** The BM83's sniff current is entered as 3.00 mA and marked `ASSUMED` (SPEC OPEN-2): 92 % of the standby ledger and the only part above the 0.8 mA justify-or-replace line. The datasheet could not be fetched during the engagement's research either (engagement OI-16). Everything else in the ledger is datasheet-cited. Not a pipeline defect; the agent did exactly what the brief asked (KYG-902: cite, or mark assumed) and said so.

New or recurrence

- **I29 recurrence**, fourth campaign, passed by formatting.
- No new issue. No new recommendation: R21 and R22 from the ring session cover what this run would have added.

Action taken

None on copperhead. Registers updated: I29, CURRENT-STATE.

Validated

Not applicable.

Next attempt

None for this brief within the engagement's scope: stage 3 is committed. If stage 4 is ever run, resume is automatic from `3297c80`. The first measurement to make on the glasses EV1 is the BM83's sniff current through the jumper, because the budget's margin is that number.