

From working prototype to reliable product.

A two-hour hardware refresher for Lenny’s Bellhop founder interview. Eight lessons, 36 automatically graded questions, four spoken exercises, a component test matrix and a morning review sheet.

How to use your two hours

Follow the lessons in order. Each time allowance includes reading, the exercise and its checkpoint. Answer before grading; explanations appear after grading. Spend the final 15 minutes explaining your reasoning aloud. No equipment, account or internet connection is needed to take the course; external source links are optional further reading.

Timing: 10 + 15 + 20 + 15 + 15 + 15 + 15 + 15 = 120 minutes. If a topic is unfamiliar, finish the core route first and use your missed-question list for review. This is a technical refresher, not a substitute for supervised bench practice.

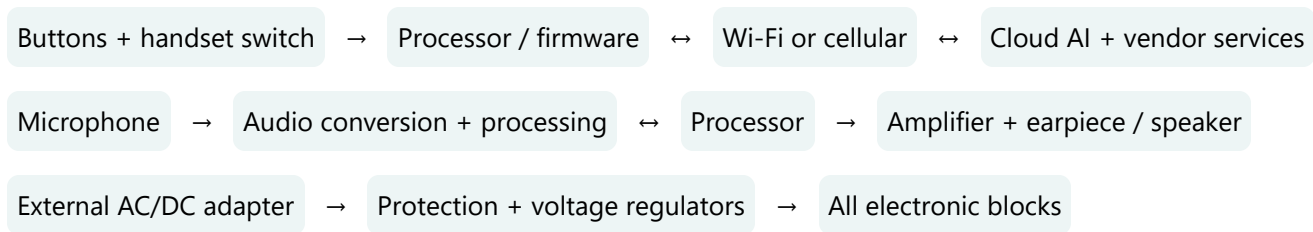
Grading: 36 equal-weight questions; unanswered = incorrect. 85–100%: strong recall; 70–84%: revisit misses; below 70%: repeat weak lessons. Those are study bands, not a hiring prediction. The spoken exercises are separately self-scored out of 16.

10 MINUTES · INCLUDES CHECKPOINT

1. Understand the whole product

Your job is to turn a user action into a reliable result—and know where that chain can break.

This course uses a **hypothetical corded, screenless voice device** with Talk, Ride and Food buttons. Your October 25 description is the source for the form, rendering, prototype, resin printers and possible hearing-aid/TV plans. Wall power is an assumption. Chips, voltages, board layout and test limits below are teaching examples, not Bellhop specifications. The original ad was not recovered in this lookup, so its exact tool requirements are unverified.



Walk through a Ride request

A switch changes voltage at a processor input. Firmware filters switch bounce and creates one event. The device provides a local acknowledgement, captures speech, and sends audio or recognized intent to its service. Software confirms destination and price, authorizes the transaction, and sends a booking request. The returned status becomes speech through the audio output. Later notifications must still reach the device and ring it while idle. There is no special “Uber chip”: the vendor integration is usually software.

Distinguish **input detected** → **request sent** → **booking confirmed**. A light or beep cannot truthfully mean “ride booked” before the service confirms it. Repeated presses and network retries must not make duplicate bookings; an **idempotent** request uses a stable operation identifier so a retry does not repeat the purchase.

Three plausible electronics approaches

Approach	Why use it?	Tradeoff to discuss
MCU: microcontroller with an RTOS (real-time operating system)	Controls buttons, streams audio, modest local processing	Limited RAM and compute; prove audio, security and connectivity requirements fit
Linux SoM: system-on-module on a carrier board	More compute, memory and existing software support	Power, boot time, storage corruption, updates and thermal management
Main processor plus audio/radio coprocessor	Offloads specialized jobs	More interfaces, firmware versions, cost and integration risk

A **SoC** is a system-on-chip; a **SoM** is a module containing a processor and supporting circuitry. An ESP32-S3-class MCU is an illustrative Wi-Fi/BLE option, not evidence of Bellhop’s design or a recommendation for hearing-aid audio. Its published feature list includes Wi-Fi and Bluetooth LE; that alone does not establish the audio profiles required here. [Espressif product overview](#).

Handset details that change the design

A **hook switch** detects whether the handset is on its cradle; it might be mechanical, magnetic (Hall sensor), or another sensor. The coiled cable might carry analog microphone/earpiece signals or power and digital signals. Do not infer its pinout from its telephone-like plug. Flex life, strain relief, connector retention, noise pickup and replacement availability matter. A handset microphone near the mouth is a different acoustic problem from a microphone across the room.

Say it aloud, 45 seconds: Trace “press Food” through input, firmware, network, service and spoken confirmation. Then name one failure at each boundary.

Checkpoint 1

1. What physically happens first when a simple mechanical Ride button is pressed?

- ☐ A. A new Wi-Fi network is created
- ☐ B. A voltage at an input changes
- ☐ C. The audio codec books a ride
- ☐ D. A cloud API runs inside the switch

2. What would establish whether a proposed processor can support the hearing-aid feature?

- ☐ A. The number of GPIO pins
- ☐ B. The required profiles, radio/controller features, software stack and tested hearing-aid models
- ☐ C. The word Bluetooth on its box
- ☐ D. Its clock speed alone

3. A user presses Ride twice because the first response was slow. What should the complete system prevent?

- ☐ A. All local acknowledgement
- ☐ B. All retries
- ☐ C. Two bookings for the same intended request
- ☐ D. Any logging

4. Which is the best first question about a prototype said to be almost finished?

- ☐ A. What color should the carton be?
- ☐ B. Can we skip testing because the demo works?
- ☐ C. Can we order production before reviewing it?
- ☐ D. Which measured requirements has this revision passed, and which are still open?

15 MINUTES · INCLUDES CHECKPOINT

2. Electronics and the parts you may find

Learn each part by its job, its connections and a way to prove it works.

The minimum electrical vocabulary

Voltage (V) is potential difference between two points. **Current (A)** is charge flow. **Resistance (Ω)** opposes current. For a resistor, $V = I \times R$; power $P = V \times I$. **Ground** is a circuit reference and return path, not automatically protective earth. An **open** is a broken path; a **short** is an unintended low-resistance path. A digital “1” means a voltage within the receiver’s specified high range, not universally 5 V. Check logic levels and absolute maximum ratings before connecting boards.

Worked example: a 3.3 V output drives an LED with a 2.0 V forward drop at a teaching target of 5 mA. $R = (3.3 - 2.0) / 0.005 = 260 \Omega$; 270 Ω is a nearby standard value, giving about 4.8 mA. Confirm the actual LED and output ratings. A processor pin is not a power supply for a speaker or motor.

Part family	What it does here	What you check
Resistors; pull-ups/pull-downs	Limit current; define an input’s idle level; set gains	Value/tolerance, correct placement, input levels. In-circuit resistance may include parallel paths.
Capacitors	Local decoupling, bulk energy storage, filtering	Capacitance, voltage rating, polarity where applicable, placement, supply ripple. ESR is equivalent series resistance.

Inductors / ferrite beads	Energy storage in converters / high-frequency noise suppression	Current rating, saturation, heating, correct value; a bead is not a universal noise cure.
Diodes, TVS, fuse/eFuse	Direction control, transient protection, overcurrent protection	Polarity, ratings, voltage drop, response to defined fault conditions.
MOSFET / load switch	Electronically switches power, possibly reverse-polarity protection	Control voltage, on-state drop, leakage and heating; gate threshold is not the full-on voltage specification.
Buck / boost / LDO / PMIC	Step down / step up / linear regulation / power-management integration	Input and output rails, enable, startup sequencing, load response and temperature.
MCU / application processor	Runs firmware or an OS; manages the product	Supply, reset, clock, boot configuration, debug connection and known test firmware.
Flash / RAM / EEPROM	Persistent program / working memory / small retained settings	Read/write verification, memory test, power-cycle retention where relevant. RAM normally loses contents at power-off.
Crystal / oscillator; reset supervisor	Timing reference; holds reset until power is valid	Specified clock and reset behavior. Probing a crystal directly can stop it; use a buffered clock output or suitable low-capacitance probe.
Audio codec; microphone; amplifier	Converts audio; captures sound; drives the output load	Known audio in/out, noise, clipping, gain, clocks, channel routing, mute and speaker impedance compatibility.
Wi-Fi/Bluetooth module; optional cellular modem	Network and local wireless links	Antenna integration, real connection and data transfer, range, reconnects and peak current.
Secure element / watchdog (optional or integrated)	Protects identity keys / recovers from stalled firmware	Provisioning and authentication / deliberate hang and safe recovery. Never print production keys in logs.
Battery charger / protection / fuel gauge (only if battery exists)	Controls charging / interrupts faults / estimates remaining charge	Correct chemistry and limits, temperature sensing, switchover, runtime and state-of-charge behavior. A charger and protection circuit serve different jobs.

Power arithmetic you should be able to explain

A teaching example draws $5\text{ V} \times 1.2\text{ A} = \mathbf{6\text{ W}}$. An adapter rated $5\text{ V}, 2\text{ A}$ has a 10 W nominal output capacity; the device draws the current it requires, within limits. Extra current capacity does not force 2 A through the device. Wrong voltage can destroy it.

A linear regulator dropping 5 V to 3.3 V at 0.5 A dissipates approximately $(5 - 3.3) \times 0.5 = \mathbf{0.85\text{ W}}$. That can be significant heat. A buck is often more efficient but brings switching-noise/layout considerations. A USB-C connector does not itself negotiate extra power: source, sink configuration, cable and any USB Power Delivery implementation must match.

For an optional 3.7 V nominal, 2 Ah battery, nominal energy is 7.4 Wh. At a 2 W load with an assumed 80% usable conversion factor, illustrative runtime is $7.4 \times 0.8 / 2 \approx \mathbf{3 \text{ hours}}$. This is an estimate, not a qualification result; load peaks, cell age, temperature and cutoff affect it. No battery is established for Bellhop.

Recall: Why can a product have a perfectly adequate adapter and still reset? Think cable resistance, connectors, regulator response, local capacitors and peak load.

Checkpoint 2

1. A 5 V supply delivers 0.8 A. What is the input power?

- ☐ A. 0.16 W
- ☐ B. 4 W
- ☐ C. 40 W
- ☐ D. 6.25 W

2. What does a pull-up resistor do on a simple active-low button input?

- ☐ A. Amplifies microphone audio
- ☐ B. Stores the program
- ☐ C. Sets a defined high level while the switch is open
- ☐ D. Makes the switch waterproof

3. Which statement about a 5 V, 3 A adapter is correct?

- ☐ A. It always forces 3 A into the device
- ☐ B. It can supply up to its rated current under specified conditions; voltage and connection must also match
- ☐ C. It is interchangeable with any 12 V adapter
- ☐ D. It proves the downstream 3.3 V rail cannot sag

4. What is the approximate heat dissipated by a 5 V to 3.3 V LDO supplying 0.5 A?

- ☐ A. 3.3 W
- ☐ B. 0 W
- ☐ C. 0.85 W
- ☐ D. 8.5 W

20 MINUTES · INCLUDES CHECKPOINT

3. Bench tools and an oscilloscope refresher

A meter answers “how much?” A scope answers “what happened over time?” A logic analyzer answers “what digital conversation occurred?”

Tool	Use it for	Trap
DMM: digital multimeter	DC rails, resistance, continuity, diode checks, current	An averaged voltage reading can miss a short dip. Current mode across a supply creates a near-short.
Current-limited bench supply	Controlled first power-up; observe consumption	Set correct voltage/polarity and a reasoned limit before connection. Too-low limit can itself cause repeated startup failure.

Oscilloscope + appropriate probes	Rail droop, ripple, reset pulses, clocks, switch bounce, analog waveforms	Wrong ground connection can short the circuit. Probe loading and long ground leads can alter what you see.
Logic analyzer	Decode I ² C/SPI/UART and correlate digital events	A decoded bit does not establish analog edge quality or noise margin. Match input ratings and thresholds.
Electronic load	Exercise a supply at controlled steady and changing loads	Stay inside its power and voltage limits; it produces heat.
Function generator	Inject a known signal into an approved analog test point	Check amplitude, offset, impedance and shared ground before attaching.
Microscope, solder station, hot air, flux, wick	Inspect and repair accessible assembly defects	Heat can lift pads, damage connectors or move neighboring parts.
SWD/JTAG debugger; UART adapter	Program/debug supported chips; read serial logs	TTL UART is not RS-232. Match voltage; do not accidentally back-power a board.
Thermal camera, thermocouple, acoustic fixture, RF instruments	Find heat; measure audio repeatably; investigate radio/EMC	Touch is not a thermal qualification; a Wi-Fi connection is not an RF compliance test.

Using the meter correctly

For voltage, connect across the two points. For current with a conventional DMM, break the path and insert the meter in series using the correct fused jack/range. Start conservatively and follow that meter's manual. Return the red lead to the voltage jack afterward. For resistance/continuity, remove power and discharge capacitors safely first. A beep indicates resistance below the meter's threshold, not that a complex circuit is healthy. [NI measurement fundamentals](#).

Scope controls translated

- **Volts/div:** vertical scale. At 1 V/div, three divisions represent 3 V.
- **Time/div:** horizontal scale. At 1 ms/div, a ten-division screen covers 10 ms.
- **Trigger:** the event that stabilizes or starts capture. Choose signal, rising/falling edge and threshold. Use single acquisition to catch a one-time event.
- **DC coupling:** displays DC level and changes. **AC coupling:** removes DC but can distort slow events; it is not the right starting point for absolute rail droop.
- **Bandwidth:** analog frequency response. **Sample rate:** samples per second. **Memory depth:** how much record you retain. Edge speed matters, not just a bus's nominal frequency.
- **10× passive probe:** attenuates the signal and often loads a node less than 1×. Match the channel setting; compensate compatible probes using the scope's calibration output.

Ground rule: conventional bench-scope probe ground clips are commonly tied together and to protective earth. Connect only to a verified appropriate reference. Never lift the scope's protective earth to "float" it. Do not probe the inside of a mains adapter. A bridge-tied speaker output has two driven terminals: neither is automatically ground.

Use a suitably rated differential measurement arrangement for that output. Read the instrument/probe ratings.
[Tektronix probe primer.](#)

Guided case: device resets when the ring sounds

1. Record the board revision, firmware, adapter, cable, volume and reproducible trigger. Obtain the rail's actual allowed range and reset threshold.
2. With a suitable 10× probe and short ground connection, measure the **processor supply at its local decoupling point**. Start DC-coupled. Choose scales around the expected voltage and event duration.
3. Trigger on a falling voltage near the suspected threshold; keep pre-trigger data. Use another channel for reset or an event marker when safely possible.
4. Reproduce the ring. Correlate the rail waveform, reset signal and reset-reason log. A drop suggests a power-path problem; it is evidence to investigate, not automatic proof of the root cause.
5. Compare input power and regulator output, swap one known-good cable or supply at a time, and exercise the load. If rails are stable, investigate watchdog, software crash, thermal or interference paths.
6. After a fix, repeat at demanding approved conditions and on several units. Adding a capacitor without understanding startup, stability and inrush can create a second problem.

Worked reading: a repeating signal's period occupies 2 divisions at 0.5 ms/div. $T = 1 \text{ ms}$, so $f = 1/T = 1 \text{ kHz}$. A meter showing "about 3.3 V" cannot exclude a 2 ms brownout.

Checkpoint 3

1. The unit resets briefly during loud playback, but its DMM reading is 3.3 V. Best next measurement?

- ☐ A. Scope the processor rail during the event and correlate reset/logs
- ☐ B. Order a new processor
- ☐ C. Increase adapter voltage
- ☐ D. Measure continuity while powered

2. Where can the ground clip of a conventional earth-referenced scope safely go?

- ☐ A. Any convenient metal point
- ☐ B. Anywhere if the scope power earth is removed
- ☐ C. Either speaker terminal
- ☐ D. A verified appropriate circuit reference, respecting the scope and circuit grounding

3. A waveform period is 4 divisions at 250 microseconds/div. Its frequency is:

- ☐ A. 1 MHz
- ☐ B. 4 kHz
- ☐ C. 250 Hz
- ☐ D. 1 kHz

4. You want to measure load current with a conventional DMM. What is correct?

- ☐ A. Put current mode directly across the supply
- ☐ B. Use the correct fused current input and connect in series
- ☐ C. Connect either jack; the meter automatically makes it safe
- ☐ D. Use resistance mode while powered

4. Boards, soldering and first power-up

Recognize the assembly, use a controlled repair process, and bring up one subsystem at a time.

PCB words without bluffing

PCB means the bare printed circuit board; **PCBA** is the assembled board. A **schematic** describes electrical connections; **layout** places parts and copper in physical space. A **net** is an electrically connected group; a **trace** is copper routing; a **via** connects copper layers; a **pad** receives a component termination. A **footprint** must match the actual package. **Solder mask** covers selected copper; **silkscreen** provides markings. A **stackup** specifies layer construction. Reference designators such as R12, C8, U3 and J1 identify resistor, capacitor, IC and connector locations.

Board or package type	Where it fits
Rigid FR-4, two-layer	Simple button or connector board; not automatically suitable for a dense radio/processor design.
Multilayer rigid board	Power/reference planes and complex routing; layer count follows signal, power, routing and cost needs.
Flex / rigid-flex	Thin interconnect between shaped assemblies. Bend radius, fatigue, stiffeners and assembly handling matter.
Main board, daughterboard, carrier board	Roles rather than materials. A carrier connects a compute module; separate button/audio boards may simplify mechanics and servicing.
Development board / module / custom PCBA	Fast experiments / integrated reusable subsystem / product-specific integration. A dev board is not automatically production-ready.
SMT / through-hole	Parts on surface pads / leads through holes. Some mechanical connectors use through-hole retention.
QFP / QFN / BGA	Visible gull-wing leads / underside-perimeter pads / solder-ball array. Hidden joints require different inspection and rework capability.

Soldering refresher: sequence matters

Use a practice board first if equipment is already available; do not learn on the only working prototype. Inspect under magnification. Remove power and disconnect batteries. Use appropriate ESD controls at the low-voltage bench, eye protection and fume extraction. Secure the work, choose electronics-compatible flux/solder and a tip sized to transfer heat to the joint.

1. Clean and lightly tin the tip. Apply suitable flux to the joint.
2. Heat both pad and lead, then feed solder into the heated joint. Look for wetting rather than a bead sitting on top.

3. Remove solder, then the iron; hold the joint still while it solidifies.
4. Inspect wetting, bridges, disturbed joints, lifted pads, polarity and adjacent parts. Lead-free joints can look less shiny; shine alone is not an acceptance criterion.
5. Clean residues according to the flux/process and product requirements, inspect again, then perform unpowered checks before a controlled functional test.

There is no universal correct iron temperature: alloy, tip, joint mass and station behavior matter. Use the process recommendation and lowest effective setting; poor wetting is a reason to inspect cleanliness, flux and heat transfer, not simply keep increasing heat. HAKKO soldering/rework guidance. Wick removes molten solder by capillary action; do not drag it off a cold joint. Hot-air rework needs controlled airflow/heat, protection for nearby plastics and a suitable process. BGA repair is a specialist capability, not something to imply from hand-soldering experience.

First-board bring-up checklist

1. Get the correct schematic, BOM, assembly drawing, board revision, expected rails and programming instructions.
2. Inspect orientation, connector pinouts, missing parts and solder bridges.
3. With no power, check for suspicious rail-to-ground shorts. Capacitors charge from a meter and some processor rails naturally read low; compare the circuit and a known-good unit rather than applying a universal resistance cutoff.
4. Disconnect optional loads where designed to permit it. Apply the specified voltage with a justified current limit; stop for unexpected current or heating.
5. Verify rails, sequence, reset and clocks. Use suitable probes.
6. Connect the supported debugger or serial console; run minimal known firmware and establish boot behavior.
7. Exercise buttons, audio, radios and peripherals separately, then together at realistic load. Save measurements and defects by serial/revision.

What you can honestly say: distinguish production ownership, enclosure/interconnect work and hands-on assembly from schematic design, PCB layout, RF engineering and firmware. A refresher prepares you to discuss a process; it does not establish recent bench proficiency.

Checkpoint 4

1. A component footprint is:

- ☐ A. A complete factory test
- ☐ B. The board's shipping dimensions
- ☐ C. The pad pattern and mechanical accommodation for a component package
- ☐ D. The software driver

2. What should happen before applying power to a new PCBA?

- ☐ A. Full-volume audio testing
- ☐ B. Visual/polarity checks and appropriate unpowered short checks
- ☐ C. A firmware update over Wi-Fi
- ☐ D. Connecting every external load

3. Solder will not wet the pad. Best response?

- ☐ A. Increase temperature to maximum
- ☐ B. Hold the iron there indefinitely
- ☐ C. Assume any dull joint is bad
- ☐ D. Check oxidation, flux, contact area and heat transfer

4. Which claim about BGA packages is correct?

- ☐ A. They eliminate the need for functional tests
- ☐ B. A top-down photo proves every joint is good
- ☐ C. Their hidden solder joints may need X-ray inspection and specialized rework
- ☐ D. They are always hand-soldered with a large iron

15 MINUTES · INCLUDES CHECKPOINT

5. Audio, buses, hearing aids and connectivity

A product that connects to Wi-Fi can still be unable to hear, speak or recover reliably.

Follow both audio directions

Input: sound → microphone → analog preamp/ADC or digital mic interface → processor → network. **Output:** network or local audio → processor → DAC/codec or digital-input amplifier → earpiece/speaker. An ADC converts analog to digital; a DAC does the reverse. An audio **codec IC** commonly combines converters and routing; that is different from a compression codec such as LC3 or Opus. The TI TLV320AIC3204 is one example with ADC/DAC channels, digital audio interfaces and a separate control interface—not a known Bellhop part. [TI codec reference](#).

A **MEMS microphone** may output analog, PDM (pulse-density modulation) or another digital format. It needs the correct supply, clock if applicable, acoustic port alignment and sealing. A speaker needs an amplifier appropriate to its impedance and power. Class-D amplifiers switch efficiently; their output needs an appropriate measurement method. A headphone driver, line output and speaker-power output are not interchangeable.

Interface	Recognize it	Typical diagnostic
GPIO	Individual input/output; buttons, LEDs, enables	Correct idle/pressed voltage and firmware event.

I ² C (“eye squared see”)	SDA data + SCL clock; addressed devices, usually pull-ups	Power/reset, address, pull-ups, idle level, start/address/ACK. An ACK proves response, not complete operation.
SPI	Clock, chip select, data in/out; variants exist	Correct chip select, clock polarity/phase, bit order and voltage levels.
UART	Asynchronous TX/RX; agreed baud rate and format	TX to RX, shared reference, correct voltage and baud; garbled text often means a setting mismatch.
I ² S (“eye squared ess”)	Digital audio samples, bit clock, word/frame clock and data; sometimes master clock	Clock ownership, sample/slot format, channel alignment, data activity and configuration.
PDM	Clocked stream from some digital microphones	Clock and data, selected channel and processor conversion/filtering.
USB	Power/data with device/host roles and enumeration	Cable capability, roles, power negotiation where used, enumeration and logs.

Why clear speech is a system test

SNR is signal-to-noise ratio. **Clipping** is signal overload and distortion. **AEC**, acoustic echo cancellation, reduces the device’s own playback leaking into its microphone; it needs a usable playback reference and tuning. **AGC**, automatic gain control, adjusts level; it cannot restore clipped audio. **Beamforming** combines microphones to favor directions. **VAD** detects voice activity. **Endpointing** decides when the person has finished speaking. **Full duplex** means listening and playing simultaneously; it must be tested with both people/device speaking, not only one at a time.

Test handset and speaker modes separately, quiet and TV-noisy rooms, near/far speech where required, soft voices, long pauses, ringing, mute, maximum allowed volume and switching modes. Use a repeatable acoustic setup for production limits, then representative users and rooms for validation. Loudness alone is not intelligibility.

Hearing aids and TV: important unknowns

Classic Bluetooth audio, vendor-specific hearing-aid paths, LE Audio and telecoil/inductive coupling are different approaches. Establish supported hearing-aid models, direction of audio, pairing/setup and fallback. LE Audio includes hearing-aid support; the Hearing Access Profile defines interoperability requirements. [Bluetooth SIG HAP](#). **Auracast is broadcast audio; it does not by itself establish a microphone return channel.** A hearing aid containing a microphone does not prove the device can access that microphone. [Bluetooth SIG Auracast FAQ](#).

A TV accessory could use analog line audio, optical S/PDIF, HDMI ARC/eARC or a wireless path; these are alternatives, not confirmed features. Ask whether it only sends TV sound to hearing aids or also handles voice interaction. Measure latency/lip sync, supported formats, volume behavior, reconnection and switching back to a call. Do not add all these ports to an assumed design.

Network isolation

Separate “radio associated” from “received an IP address” (DHCP), “resolved a service name” (DNS), “secure connection established” (TLS), and “service accepted the request.” Wrong device time or credentials can break TLS even with strong Wi-Fi. Test router restart, wrong password, internet loss, server failure and recovery without duplicate transactions. No screen means the recovery instructions must be understandable through the remaining controls and audio.

Checkpoint 5

1. I²C and I²S are:

- ☐ A. A control bus and a digital audio interface, respectively
- ☐ B. Both analog speaker cables
- ☐ C. Only used for batteries
- ☐ D. Two names for the same audio bus

2. Audio works when the device is silent but fails while it speaks. What deserves investigation?

- ☐ A. Whether the LED is green
- ☐ B. Only flash capacity
- ☐ C. Only the carton
- ☐ D. Echo cancellation, clipping and the playback reference/path

3. What does Auracast support establish by itself?

- ☐ A. Access to a hearing aid’s raw microphone
- ☐ B. A two-way microphone path from every hearing aid
- ☐ C. Compatibility with all Bluetooth products
- ☐ D. A broadcast-audio capability, subject to compatible implementations

4. Wi-Fi association succeeds but the cloud service is unreachable. Next step?

- ☐ A. Replace the microphone
- ☐ B. Check IP/DNS/TLS/service errors and credentials before blaming RF
- ☐ C. Assume the cloud is working
- ☐ D. Raise speaker gain

15 MINUTES · INCLUDES CHECKPOINT

6. Resin prototypes, assembly and reliability

A beautiful rendering, a working printed prototype and a qualified production enclosure are three different milestones.

Resin printing vocabulary

Vat photopolymerization cures liquid photopolymer with light. SLA commonly uses a scanning laser; DLP projects an image; MSLA uses an LCD mask. People also use “SLA” broadly. Unlike FDM/FFF filament printing, these processes use liquid resin. Ask what printer, resin and post-process they actually use.

Orientation determines supports, visible surfaces and loading during printing. **Supports** hold features during the build but leave marks. **Peel/separation forces** can distort thin geometry. Hollow parts need suitable drainage and cleaning access. Small layer height is not a promise of overall dimensional accuracy. Measure critical features after the specified post-process.

Wash off uncured resin using the material’s specified process; dry and post-cure as required. Post-curing changes material properties, so test the final processed condition. Use the resin/solvent safety instructions, suitable gloves/eye protection and ventilation; do not treat liquid resin or wash waste as sink-safe. [Formlabs post-processing guide](#).

What to test in this handset enclosure

Feature	Evidence to collect
Cradle / hook sensing	Reliable detection through tolerance extremes, gentle placement, misplacement and repeated cycles.
Talk/Ride/Food buttons	Actuation force, travel, tactile differentiation, off-axis press, sticking and life cycles; verify electrical and firmware event together.
Coiled cord / connectors	Pinout, continuity while flexing, strain relief, pull/retention and mating cycles. Specify force, angle, cycles and pass criteria before testing.
Microphone / earpiece / speaker	Port alignment, gaskets, acoustic leaks, rattles, grille blockage, assembly-dependent frequency response.
Screw bosses / inserts / seams	Torque window, stripping/cracks, repeated service access, gap/flushness and tolerance stack.
Base stability and user handling	One-handed lift without dragging base; cord tug; tabletop slips; foreseeable drops and liquid spills.
Surface and material	Cleaning-agent compatibility, skin contact suitability, scratching, aging and heat exposure appropriate to the use case.

From resin to injection-molded plastic

A cured resin prototype is generally not the same material or process as a molded ABS/PC part. Do not transfer drop, snap-fit or heat results automatically. **Draft** lets a part release from a mold; a **parting line** is where mold halves meet; **undercuts** may require side actions. Near-uniform walls help avoid shrink and sink. **Ribs** add stiffness; **bosses** support fasteners; thick sections can sink or warp. Tool gates, ejector marks, weld lines, texture and shrink allowances affect appearance and strength. Agree actual geometry with the selected material and toolmaker. [Protolabs Network molding guide](#).

Assembly sequence for the hypothetical device

1. Verify kit, drawings, revisions and component lots; inspect molded/printed parts and PCBA.
2. Load approved firmware, identity and configuration at a controlled station; record success without exposing secrets.
3. Install boards and hardware with specified supports/torque; fit buttons, microphone seals, speaker and hook sensor.
4. Route and secure cables, avoid pinches, keep antenna clearance, connect keyed harnesses and inspect polarity.
5. Perform accessible subassembly checks, close the housing, then run the final test in its assembled state.

6. Record serial, firmware, measurements and result; verify labels, adapter, accessories, packaging and shipment configuration.

Risk-based validation: temperature/humidity operation, thermal cycling, drops, vibration/shipping, ESD, cable/button life, power interruption and prolonged operation may all matter. Set a use case, severity, sample size and acceptance rule with the relevant engineers/lab. Never invent “industry standard” drop heights or guarantee a lifetime from a few prototypes.

Checkpoint 6

1. A resin prototype survives a drop. What can you conclude?

- ☐ A. That sample survived that defined test; production material/geometry need validation
- ☐ B. The shipping package is qualified
- ☐ C. The PCB needs no tests
- ☐ D. All future molded parts will survive

2. What is draft in injection molding?

- ☐ A. An unfinished drawing only
- ☐ B. A solder defect
- ☐ C. A cloud API timeout
- ☐ D. A taper that assists removal from the mold

3. What is the best check for an intermittent handset cable?

- ☐ A. Monitor continuity/function while applying a defined flex and movement test
- ☐ B. Replace the cloud service
- ☐ C. Look only at the cable color
- ☐ D. Measure one stationary continuity reading and stop

4. When should critical resin-print dimensions be accepted?

- ☐ A. Immediately after slicing the model
- ☐ B. Only from the rendering
- ☐ C. After the specified wash/dry/cure process, against tolerances
- ☐ D. From layer height alone

15 MINUTES · INCLUDES CHECKPOINT

7. Component tests, factory gates and shipment evidence

You do not retest semiconductor wafers. You prove purchased parts are suitable, assembled correctly and functioning in the product.

Supplier qualification and traceability address component quality. Board tests address assembly faults. Functional tests exercise useful behavior. Design validation challenges requirements and use conditions. Reliability testing explores degradation over time/stress. Compliance testing addresses applicable obligations. These overlap, but none substitutes for all the others.

Practical component and subsystem test matrix

Every row needs a requirement ID, setup, stimulus, measured result, approved limit, serial/revision, firmware, instrument/fixture version and disposition. The examples below are test methods, not released production limits.

Block	Stimulus + observation	Typical failure isolated
Adapter, input connector, protection	Approved supply and load range; input voltage/current, retention, startup and recovery	Wrong adapter, cable drop, poor contact, protection tripping
Regulators and power passives	Measure every rail at idle and defined peak load; capture transients and temperature	Wrong value, unstable converter, insufficient margin, short
Processor, clocks, reset	Known boot image, debug/ID access, reset logs and controlled restart tests	Power sequencing, boot straps, clock/reset faults
Memory	Known-pattern read/write/verify in a safe test region; retention and interrupted-update tests	Bad assembly, addressing issue, corruption or recovery failure
Buttons, LEDs, hook switch	Exercise each input/output; measure transitions and confirm exactly one intended event	Wrong pin, swapped button, bounce, stuck switch, wrong polarity
Microphone path	Known acoustic stimulus in repeatable geometry; record level/noise/distortion and compare channels	Blocked port, bad seal, wrong gain/clock, damaged mic
Codec and amplifier	Known digital/analog test signal where supported; verify routing, mute, output and clipping	Configuration, bus clock, soldering or power fault
Speaker and earpiece	Controlled tones/speech and acoustic measurement; check rattles and correct routing	Reversed routing, damaged driver, loose mount, blocked grille
Radio and antenna	Controlled link/data test plus intended-enclosure range/coexistence validation	Antenna/cable issue, shielding/detuning, configuration or coexistence failure
Hearing-aid/TV link, if present	Model-by-model pairing, audio direction, latency, reconnection and handoff matrix	Unsupported profile, missing return path, incompatible formats
Optional battery system	Approved charging, temperature sensing, backup transfer and representative runtime tests	Wrong pack/sensor, poor contact, unsafe limits, unexpected shutdown
Housing, cord, connectors	Fit, torque, acoustic checks, flex/retention/life tests and controlled visual inspection	Pinch, tolerance issue, poor strain relief, inaccessible service part
Security and firmware lifecycle	Unique identity, authorized update, rejected invalid image, power-loss recovery, factory reset	Shared credentials, bricked update, leftover customer data, open production debug access
Complete service	Test accounts/sandbox: Talk/Ride/Food, repeat presses, network loss, notification and recovery	False confirmation, duplicate request, lost notification or stale session

Factory-test vocabulary

SPI can mean solder-paste inspection in manufacturing (different from the serial bus). **AOI** uses cameras to inspect assembly. **X-ray** examines hidden joints. **ICT** checks electrical properties/connections in circuit; **flying probe** uses moving probes and reduces fixture investment. **FCT** powers the unit and exercises functions; **EOL** means end-of-line. A **pogo-pin fixture** contacts designed test pads. **DFT** means designing test access, isolation and test firmware before the board is frozen.

Validate the fixture too: use controlled known-good and known-fault samples to check false passes/rejects. Calibrate instruments as needed, track fixture wear, and protect reference samples from uncontrolled changes. A golden sample is a reference, not the sole acceptance standard. A fixture that declares every unit "pass" proves nothing until fault detection is demonstrated.

Production gates and the package a factory needs

EVT: demonstrate engineering functions. **DVT**: validate the intended design against requirements. **PVT**: prove the manufacturing process and test system can build it consistently. Companies expand/name these gates differently; agree their exit criteria. A few working prototypes do not establish a finished design.

Request controlled schematics, layout/fabrication files and stackup, BOM with exact manufacturer part numbers and approved alternates, placement and assembly files, mechanical drawings/tolerances, firmware/programming package, work instructions, test specifications, labels and packaging. Define an **ECO** (engineering change order) path so a supplier cannot quietly substitute a part. Confirm ownership of tooling/files and how revisions are identified.

First-pass yield: if 90 of 100 units pass without rework, FPY is 90%. If 8 are repaired, eventual yield is 98%, but FPY stays 90%. Track failure categories, retest/rework, station time, escapes and field returns. **Takt time** follows demand; **cycle time** is how long a process takes. A cheap test that misses defects is not economical.

At interview level, plan RF/EMC pre-scans and a competent lab review early. A certified radio module does not automatically authorize the assembled host: integration conditions and remaining host requirements still apply. Exact obligations depend on markets and design. FCC module/host guidance. Ask the lab to scope electrical safety, ESD/immunity, materials and any battery-related obligations; do not claim compliance from a demo.

Checkpoint 7

1. 100 units enter a line; 90 pass immediately; 8 more pass after rework. First-pass yield is:

- ☐ A. 90%
- ☐ B. 100%
- ☐ C. 8%
- ☐ D. 98%

2. AOI reports no visible defects. What does this establish?

- ☐ A. Every hidden BGA joint is good
- ☐ B. All firmware and audio functions work
- ☐ C. The whole product is certified
- ☐ D. The assembly passed that optical inspection; other coverage is still needed

3. A factory proposes a cheaper regulator with the same output voltage. Best response?

- ☐ A. Let the factory change it without revision tracking
- ☐ B. Approve by voltage alone
- ☐ C. Review electrical/thermal/layout behavior, validate and release through change control
- ☐ D. Reject every alternate forever

4. What does using a certified wireless module mean for the host product?

- ☐ A. Integration conditions and remaining host obligations still need assessment
- ☐ B. Any antenna is allowed
- ☐ C. No product testing can ever be required
- ☐ D. Labels and user instructions no longer matter

15 MINUTES · INCLUDES CHECKPOINT

8. Technical interview rehearsal and final check

Answer with a hypothesis, a measurement, an interpretation and a verification step.

This is a study assessment, not proof of professional qualification. A realistic objective tonight is to explain the product clearly, choose sensible tests and identify where you need an electrical, firmware, acoustic or RF specialist. Two hours cannot replace years of circuit-design practice.

Use this five-part structure

Clarify the symptom and requirement → isolate a subsystem → choose a safe measurement → interpret evidence → prove the fix. Describe one first test before listing ten possible causes. Say what result would change your hypothesis. Do not call an unmeasured guess the root cause.

Four spoken questions: 60–90 seconds each

Answer before opening each model answer. Award yourself one point per criterion, 4 points per answer (16 total). These are self-assessed; the course cannot judge spoken competence.

1. "It boots, but there is no sound. What do you do?"

Clarify which output and whether all sounds fail. Play a known local tone to remove the cloud from the test. Check mute/routing/volume, speaker connection and amplifier power/enable. Verify digital clocks/data or analog input at the correct boundary, using safe probes. Compare with a known-good unit and change one thing at a time. Once repaired, test actual speech, volume range and assembled acoustics.

Score: local known stimulus; boundary-by-boundary checks; safe/appropriate measurements; complete-system retest.

2. "The button sometimes orders twice. Hardware or software?"

It could involve both. Capture the GPIO waveform and firmware event log for one press. If there are rapid edges, review hardware input conditioning and firmware debounce. If one clean event creates two requests, trace retries and transaction identifiers through the service. Also distinguish a deliberate second press from switch bounce. Verify one physical action gives one intended outcome under slow network/retry conditions.

Score: distinguishes bounce/repeated presses/retries; capture plus logs; separates input from transaction; verifies deduplication end to end.

3. "We have a working prototype. How do you get it onto shelves?"

First establish the design revision, target cost/volume/date, measured requirements and open defects. Review supply risk, factory build files, DFM/DFA/DFT and production materials. Agree EVT/DVT/PVT evidence and compliance plan, qualify a pilot line and fixtures, and track first-pass yield and failure causes. Release controlled production only when agreed gates pass. Include provisioning, packaging, support, spares, updates and field-return feedback.

Score: challenges readiness with evidence; controlled production package; pilot/test/yield ownership; lifecycle and release gates.

4. "How strong are you on board design and bench work?"

Use your actual boundaries: manufacturing/assembly, enclosure and interconnect work, sourcing and bringing products into production are your established strengths. You said soldering has not been recent; say that directly. Your existing profile does not establish PCB layout or firmware authorship. Explain the bench refresh and safe diagnostic process you can discuss, and ask which electrical-design responsibilities must be owned personally versus supported by another engineer. Do not describe this course as hands-on work you have already performed.

Score: accurate experience; explicit gap; concrete learning/test approach; clarifies the role's required ownership.

Questions worth asking the founder

- Which functions work today on the integrated prototype, and what are its three largest unresolved technical risks?
- What is the current processor/module, audio architecture and connectivity plan? May I see the block diagram?
- Who owns schematic/layout, firmware, acoustics and RF today? What must this hire personally design?
- Does hearing-aid support mean playback only or two-way conversation, and which models/profiles are committed?
- What validation has the current revision passed? Are tooling, manufacturer, test fixtures and compliance labs selected?
- What are the first production quantity, cost target, schedule and release criteria?

Morning review: five minutes

Draw the three paths: power, audio and request/response. Explain DMM versus scope versus logic analyzer. Rehearse the “ring causes reset” diagnosis. Recall I²C versus I²S, PCB versus PCBA, and EVT/DVT/PVT. End with your real manufacturing story and the boundary of your electronics experience.

Useful pushback: production ownership is not “just calling factories.” Test coverage, revision control, supply changes, yield, provisioning and field failures are part of the technical work. Present that strength with evidence while staying clear about board-design gaps.

Checkpoint 8

1. The speaker is silent. What is the most useful first isolation test?

- ☐ A. Buy new cloud credits
- ☐ B. Play a known local tone and inspect the local output path
- ☐ C. Change the carton design
- ☐ D. Replace every IC

2. An I²C device gives no ACK. Which checks come first?

- ☐ A. The font on its label
- ☐ B. An immediate PCB reorder
- ☐ C. Speaker impedance only
- ☐ D. Power/reset, address, wiring, pull-ups and bus waveform

3. A 10× probe is used but the scope is configured for 1×. What is the problem?

- ☐ A. The clock frequency changes by ten
- ☐ B. The physical signal becomes ten times larger
- ☐ C. No consequence
- ☐ D. Displayed voltage scaling is wrong

4. A headset-like device has a microphone and receives audio. Can you assume microphone audio returns to Bellhop?

- ☐ A. No; verify the supported upstream path and profiles on actual devices
- ☐ B. Yes, if both devices say Bluetooth
- ☐ C. Yes, every microphone is always exposed
- ☐ D. Only the enclosure color matters

5. Which test most directly distinguishes a bent microphone gasket from a cloud speech-recognition fault?

- ☐ A. A controlled local audio recording compared with a known-good unit
- ☐ B. A supplier quote
- ☐ C. A processor clock-speed increase
- ☐ D. An LED inspection

6. A product passes its bench test but fails after the lid closes. What do you consider?

- ☐ A. Only billing
- ☐ B. Only user error
- ☐ C. Nothing: bench pass is conclusive
- ☐ D. Cable pinching, acoustic seals, antenna detuning, thermal changes and assembly stress

7. What is the strongest evidence that a production fixture detects faults?

- ☐ A. It is expensive
- ☐ B. Every unit passes
- ☐ C. It uses many pogo pins
- ☐ D. Controlled known faults are rejected and known-good units pass repeatably

8. You are asked for a chip model you do not know. Best answer?

- ☐ A. Invent a plausible part number
- ☐ B. State the function and selection criteria, then say you would verify the exact part and datasheet
- ☐ C. Claim the factory selects everything without review
- ☐ D. Change the subject

The one-page recall sheet

Three paths: power → protection/regulation → loads; microphone → conversion/processing → network and back → amplifier/speaker; button → firmware event → service → confirmed outcome.

Three instruments: DMM = levels/continuity; scope = waveform/time; logic analyzer = digital transactions. Voltage in parallel; current in series. Resistance/continuity unpowered. Verify scope ground; never lift protective earth.

Power: $V = IR$; $P = VI$; LDO heat $\approx$ voltage drop $\times$ current; battery energy $\approx$ nominal volts $\times$ amp-hours. Measure load transients, not just idle.

Interfaces: GPIO controls; I²C configures; I²S carries audio; SPI carries fast peripheral data; UART gives serial logs; SWD/JTAG supports debug on compatible chips.

Audio: ADC in, DAC out, amplifier drives the load. Codec IC $\neq$ compression codec. Check ports/seals, gain, clipping, clocks and routing. AEC handles playback leakage; AGC cannot undo clipping. Auracast does not imply microphone return.

Bring-up: drawings/revision → inspect → unpowered checks → current-limited correct supply → rails/reset/clock → known firmware → individual functions → combined load → record evidence.

Production: PCB $\neq$ PCBA. DFM/DFA/DFT = manufacture/assembly/test. EVT = engineering; DVT = design requirements; PVT = repeatable production. AOI $\neq$ complete functional coverage. FPY excludes repaired passes. Control alternates and revisions.

Answer pattern: clarify → isolate → measure → interpret → verify. Name the first measurement. Separate demonstrated experience from refreshed theory. Ask who owns schematic/layout, firmware, acoustics and RF.

Evidence and limits

Prepared October 25, 2026. Product description: your message today. Role context and experience boundaries: the saved Bellhop role record and application profile. Prior feedback: the October 23 mock-interview coaching record. The first-round recording was located but has not been transcribed or assessed for this course. The exact current ad and actual Bellhop architecture remain unverified.

The technical examples are educational engineering scenarios. Numerical test thresholds, quantities, components and architectures are not company specifications. Source links within lessons point to manufacturer documentation or the relevant standards/regulatory organization. They support the named concepts, not claims about Bellhop's implementation. Optional external reading is outside the two-hour route.

Answer key and explanations

1. Understand the whole product

1. **B. A voltage at an input changes** — The electrical input changes first. Firmware interprets it and software performs subsequent actions.
2. **B. The required profiles, radio/controller features, software stack and tested hearing-aid models** — Compatibility is a complete-system question, including the actual receiving devices.
3. **C. Two bookings for the same intended request** — Debouncing handles electrical chatter; transaction deduplication handles repeated user actions and retries.
4. **D. Which measured requirements has this revision passed, and which are still open?** — A successful demo is evidence of some functions, not of manufacturing or field readiness.

2. Electronics and the parts you may find

1. **B. 4 W** — $P = V \times I = 5 \times 0.8 = 4 \text{ W}$.
2. **C. Sets a defined high level while the switch is open** — The switch can pull the node low when closed; the resistor prevents it floating when open.
3. **B. It can supply up to its rated current under specified conditions; voltage and connection must also match** — Current rating is capacity, not a command. Downstream wiring and regulation still matter.
4. **C. 0.85 W** — The regulator burns the voltage drop times current: $1.7 \times 0.5 = 0.85 \text{ W}$, ignoring its small operating current.

3. Bench tools and an oscilloscope refresher

1. **A. Scope the processor rail during the event and correlate reset/logs** — Capture the transient at the load. A DMM can average over the event.
2. **D. A verified appropriate circuit reference, respecting the scope and circuit grounding** — The ground clip may create an earth connection and a short. Never defeat protective earth.
3. **D. 1 kHz** — $4 \times 250 \mu\text{s} = 1 \text{ ms}$; $1 / 0.001 \text{ s} = 1,000 \text{ Hz}$.
4. **B. Use the correct fused current input and connect in series** — Current measurement requires the current to flow through the meter, within its ratings.

4. Boards, soldering and first power-up

1. **C. The pad pattern and mechanical accommodation for a component package** — A correct symbol in the schematic does not guarantee a correct physical footprint.
2. **B. Visual/polarity checks and appropriate unpowered short checks** — Avoid preventable damage before the first controlled power-up.
3. **D. Check oxidation, flux, contact area and heat transfer** — A systematic process avoids heat damage and addresses the actual wetting problem.

4. **C. Their hidden solder joints may need X-ray inspection and specialized rework** — Optical inspection cannot directly see all underside joints; different tests cover different defects.

5. Audio, buses, hearing aids and connectivity

1. **A. A control bus and a digital audio interface, respectively** — A codec may use I²C for configuration and I²S for audio samples.
2. **D. Echo cancellation, clipping and the playback reference/path** — Playback can swamp the mic or expose incorrect AEC integration. Reproduce double-talk with measured audio.
3. **D. A broadcast-audio capability, subject to compatible implementations** — Broadcast reception does not imply an upstream microphone path or universal compatibility.
4. **B. Check IP/DNS/TLS/service errors and credentials before blaming RF** — Network layers have separate failure modes. Use evidence to isolate the failing boundary.

6. Resin prototypes, assembly and reliability

1. **A. That sample survived that defined test; production material/geometry need validation** — Material, geometry, process and sample variation can change the result.
2. **D. A taper that assists removal from the mold** — Draft is a manufacturing feature whose amount depends on geometry, texture, material and tooling.
3. **A. Monitor continuity/function while applying a defined flex and movement test** — A static pass can miss an intermittent conductor or connector failure.
4. **C. After the specified wash/dry/cure process, against tolerances** — The processed part is what must fit and function; layer height is only one process parameter.

7. Component tests, factory gates and shipment evidence

1. **A. 90%** — Rework improves eventual output but does not change the original first-pass result.
2. **D. The assembly passed that optical inspection; other coverage is still needed** — Optical, electrical and functional tests detect different failure classes.
3. **C. Review electrical/thermal/layout behavior, validate and release through change control** — Output voltage alone does not establish pin, stability, transient, current or thermal compatibility.
4. **A. Integration conditions and remaining host obligations still need assessment** — Modular authorization is conditional; the complete integration must be reviewed.

8. Technical interview rehearsal and final check

1. **B. Play a known local tone and inspect the local output path** — A local tone separates cloud/service issues from the device playback path.
2. **D. Power/reset, address, wiring, pull-ups and bus waveform** — Establish basic electrical and addressing conditions before concluding the IC is bad.
3. **D. Displayed voltage scaling is wrong** — Probe attenuation and channel configuration must agree.

4. **A. No; verify the supported upstream path and profiles on actual devices** — A built-in microphone is not proof of an accessible two-way audio service.
5. **A. A controlled local audio recording compared with a known-good unit** — Inspect captured audio before the cloud boundary and reproduce the mechanical condition.
6. **D. Cable pinching, acoustic seals, antenna detuning, thermal changes and assembly stress** — The enclosure is part of the electrical, RF, thermal and acoustic system.
7. **D. Controlled known faults are rejected and known-good units pass repeatably** — Test the test system and its measurement repeatability; passing everything can indicate a broken test.
8. **B. State the function and selection criteria, then say you would verify the exact part and datasheet** — Technical honesty plus a competent verification method is stronger than false specificity.

Private interview preparation · Course works offline · No answers are sent anywhere.