

# Smart Glasses for Hands-Free Datasheet Retrieval

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**ECE 445 Design Document – Fall 2026**

## **Project #6**

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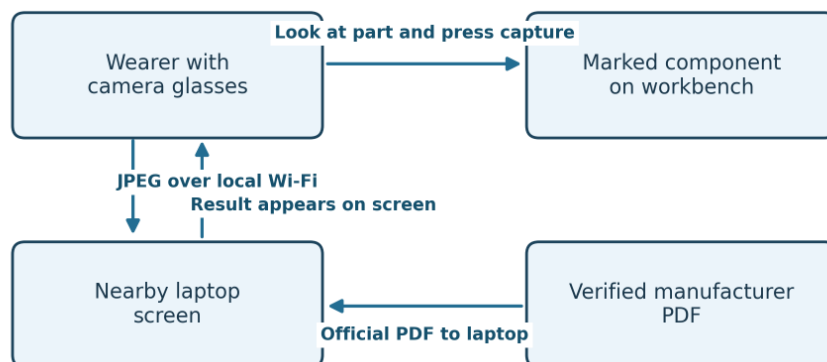
# 1. Introduction

## 1.1 Problem and solution

Looking up a component datasheet can interrupt work at an electronics bench. The user has to read a small marking, search for the part number, and then make sure the result is actually from the manufacturer. Similar markings and package suffixes can make this confusing, while laser-etched text, low contrast, and glare can also make the marking hard to capture with a head-mounted camera. Because of this, the system needs to produce a readable image at normal bench distances and avoid presenting an uncertain match as a definite answer.

Our solution uses camera glasses to capture the component and a nearby laptop to identify it. The user centers the component and presses a button on the glasses, after which a custom ESP32-S3 board sends an autofocus image over local Wi-Fi. The laptop reads the marking using OCR and compares it against a catalog of known parts. If one match is clearly supported, the system accepts it. If several parts are plausible, the user is shown those options and chooses between them. If the image is too uncertain, the system asks for another capture. Once a part is accepted, the laptop opens a reviewed manufacturer datasheet and shows the image and recognition evidence so the user can verify the result.

## 1.2 Visual aid



**Figure 1.** The laptop screen is the user display; no display is mounted in the glasses. The PDF is sourced from a reviewed manufacturer entry, then cached locally.

## 1.3 High-level requirements

- Across 100 blinded first-capture trials spanning at least 20 cataloged components with at least five trials per component, the system shall produce the correct final full part number in at least 80 trials and an incorrect final part number in no more than two trials. A correct final identification may be either an automatic unique accept or a user selection from a multiple-match candidate set; a candidate-selection screen by itself is an intermediate state and is not scored as an identification. All remaining trials shall end as recapture or explicit error.
- On the specified local 2.4 GHz Wi-Fi test network, the median time from button press to the first visible actionable result shall be about 10 s, and the 95th percentile shall be at most 20 s over

those 100 trials. An actionable result is an accepted result with its reviewed datasheet, a multiple-match candidate-selection screen containing reviewed datasheet choices, or an actionable recapture/error result.

- The complete head-worn assembly shall weigh at most 150 g and operate from its 1000 mAh battery for at least two hours at one capture per 5 minutes; wearer-accessible surfaces shall stay below 45 °C throughout the same two-hour run period.

The 45 °C surface-temperature criterion is a proposed prototype verification limit requiring TA review; passing it does not establish suitability for prolonged skin contact.

- Every accepted exact orderable part number shall map to one reviewed manufacturer PDF with manufacturer, exact orderable number, package, URL, retrieval date, and SHA-256 recorded; any displayed extracted specification shall identify its source page. Different exact part numbers may share the same reviewed family PDF, but each exact orderable number shall have its own manifest entry.

## 2. Design

### 2.1 Block Diagram

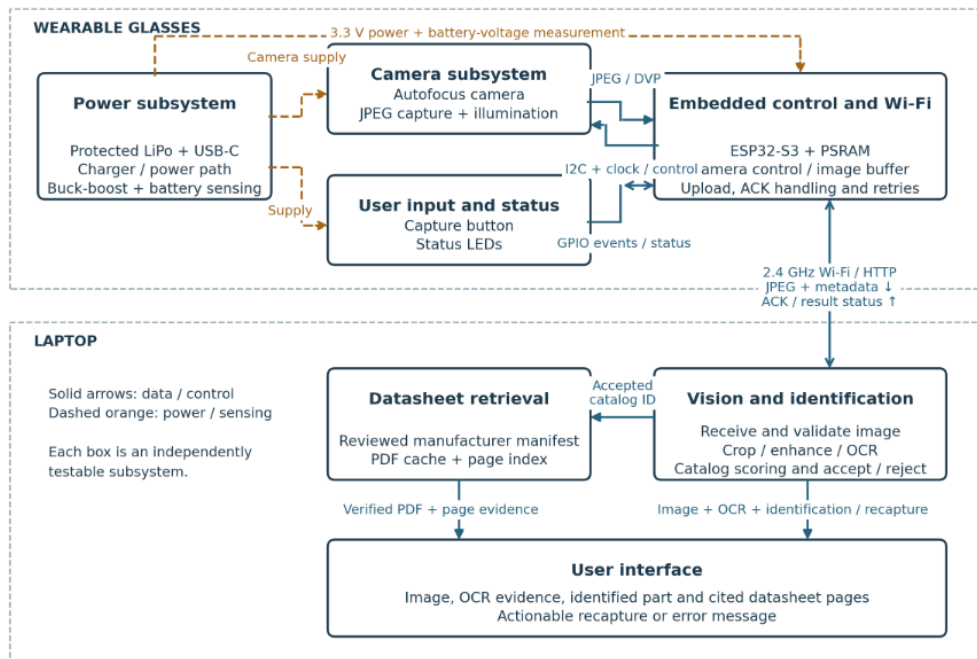


Figure 2 shows the main hardware on the glasses and the software running on the laptop. The power subsystem handles charging, regulation, and battery-voltage measurement. The camera subsystem captures the autofocus image, while the input and status subsystem handles the capture button and status indicators. The ESP32-S3 controls the camera, buffers the JPEG, and sends it to the laptop over Wi-Fi with acknowledgment and retry handling. On the laptop, the image is checked, preprocessed, passed through OCR, and compared against the part catalog. Accepted or user-selected results are then connected to the reviewed manufacturer PDF and shown in the user interface.

## 2.2 Physical design

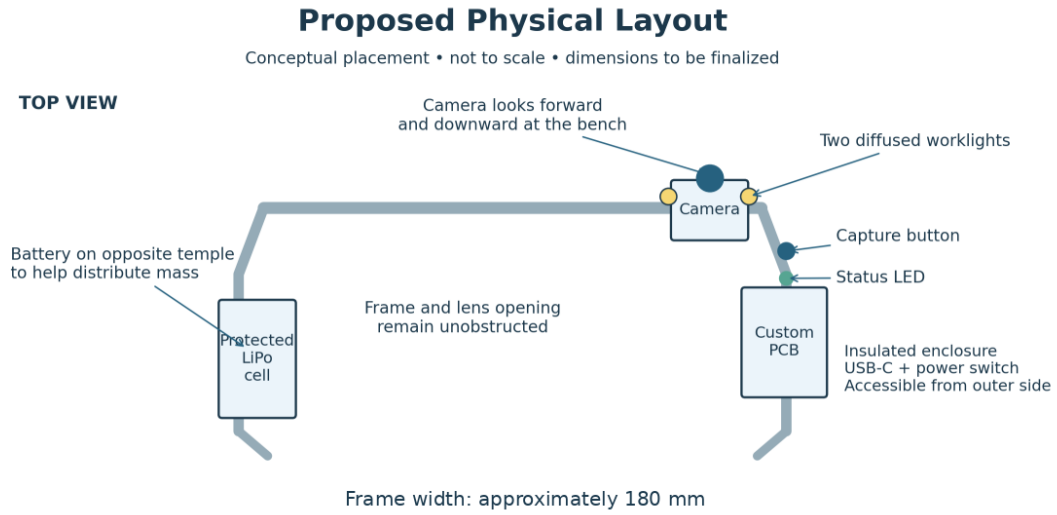


Figure 3 shows the proposed physical layout of the glasses. The autofocus camera is mounted near the front corner and the protected battery is placed on the opposite temple to balance the weight. The frame is expected to be about 180 mm wide. The selected Waveshare camera board is 35.70 mm × 23.90 mm, while the exact PCB enclosure and battery mounting dimensions will be finalized after the frame and PCB layout are complete. The capture button, status LED, USB-C connector, and power switch are placed so they can be reached while the glasses are worn. Camera and battery wiring will be secured to the frame with strain relief, and all exposed conductors will be enclosed.

## 2.3 Power Subsystem

The power subsystem is responsible for running the wearable for the required two hours. The selected battery is a protected DNK Power DNK603450 / LP603450 single-cell lithium-polymer pack rated at 3.7 V nominal and 1000 mAh [19]. Power enters through USB-C and is managed by a BQ24074 charger with power-path capability before reaching the TPS63070 buck-boost converter. Battery temperature is monitored using an external Semitec 103AT-2 NTC attached to the pack. The buck-boost converter is used because the battery voltage can fall below the required 3.3 V rail during discharge [1], [2].

The main regulated rail is 3.3 V and must stay between 3.20 V and 3.40 V. It powers the ESP32-S3 and compatible peripherals. The selected Waveshare OV5640 Camera Board (C) also runs from 3.3 V and handles its camera supply rails internally [17], [18]. Battery voltage is measured through a resistor divider connected to an ESP32-S3 ADC input. After calibration, that measurement must stay within  $\pm 50$  mV over a battery range of 3.3–4.2 V.

The charger uses  $R8 = 3.57$  k $\Omega$  at 1%, which gives a nominal fast-charge current of about 250 mA, or about 0.25 C for the 1000 mAh battery, before input-current and thermal limits. The USB-C input will be configured so normal charging is not limited to USB100. A compliant source must be used that can supply the programmed charge current along with the system load. The external NTC network will

enforce the charging-temperature window and should fail safely if the sensor is missing or shorted. A physical switch disconnects the system load while still allowing the battery to charge, and test points are provided for the USB input, battery, charger output, 3.3 V rail, camera supply, battery ADC, and ground.

| Requirement                                                                                                                                                                                                    | Verification procedure                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P1. The system rail shall remain between 3.20 V and 3.40 V for steady loads from 20 mA to 1.2 A.                                                                                                               | Connect an electronic load to the 3.3 V and GND test points and power the regulator from a current-limited bench source, not from the 1000 mAh battery. Sweep 20, 100, 300, 500, 800, and 1200 mA. Every measured rail voltage must remain between 3.20 V and 3.40 V.                                                                                                                                       |
| P2. During a 20-to-520 mA load step, the rail shall not remain below 3.10 V for more than 100 $\mu$ s.                                                                                                         | Apply the load step with an electronic load. Probe the ESP32-S3 supply pins with an oscilloscope using a short ground connection. Repeat ten times and save waveforms showing minimum voltage and time below 3.10 V.                                                                                                                                                                                        |
| P3. The wearable shall operate for at least 120 minutes at one capture per 5 minutes.                                                                                                                          | Fully charge the 1000 mAh battery, disconnect USB power, and execute one complete capture and identification cycle every 5 minutes for 120 minutes. Record battery voltage, successful cycles, and shutdown time. The system must remain operational for the full 120 minutes and complete at least 24 cycles.                                                                                              |
| P4. Wearer-accessible surfaces shall remain below the proposed 45 $^{\circ}$ C project limit throughout the same two-hour runtime test at $23 \pm 3$ $^{\circ}$ C ambient; this limit is subject to TA review. | Attach thermocouples to the battery enclosure and electronics enclosure. During the 120-minute P3 run, record ambient and wearer-accessible surface temperatures at least once per minute. Every measured accessible surface temperature must remain below 45 $^{\circ}$ C. Test charging separately off the wearer. Passing this test does not by itself establish suitability for prolonged skin contact. |
| P5. The complete head-worn assembly shall weigh no more than 150 g.                                                                                                                                            | Assemble the complete wearable including frame, PCB/enclosure, camera, battery, wiring, button, LEDs, and mounting hardware. Measure total mass on a calibrated digital scale with 1 g or better resolution. Record the result; pass if total mass is $\leq 150$ g.                                                                                                                                         |
| P6. Calibrated battery-voltage reporting shall agree with a reference DMM within $\pm 50$ mV from 3.3 V to 4.2 V.                                                                                              | Use a programmable bench supply at the battery input and test at 3.3, 3.5, 3.7, 3.9, 4.1, and 4.2 V. After the defined ADC settling delay and calibration, compare the reported battery voltage with a calibrated DMM at TP2 and TP14. Every battery-referred error must be within $\pm 50$ mV.                                                                                                             |

## 2.4 Camera Subsystem

The camera subsystem uses the Waveshare OV5640 Camera Board (C), which is a 5-megapixel autofocus module with its supplied autofocus lens. Images are captured at  $2592 \times 1944$  in JPEG format, which is supported by the OV5640 sensor [3]. The module runs from 3.3 V and includes the circuitry needed for its internal camera supply rails [17], [18].

The camera connects to the ESP32-S3 through its 8-bit parallel DVP interface using D0–D7, PCLK, HREF, VSYNC, XCLK, SCCB clock/data, RESET, and PWDN. Waveshare documents the board I/O as 3.3 V level and specifies the mating connector and pinout [17], [18]. These connections will be checked against the exact purchased module before the PCB is ordered.

The module uses its supplied autofocus lens, so there is no separate M12 lens in the design. The controlled operating distance for this project is 100–110 mm, and both C2 and the tolerance analysis use this same range. The older 150 mm and 200 mm distances are no longer acceptance conditions. Two diffused white LEDs are used to illuminate the target during focus and exposure, with each LED limited to no more than 20 mA.

| Requirement                                                                                                                                    | Verification procedure                                                                                                                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C1. The camera shall produce valid 2592 × 1944 JPEG images no larger than 2 MB under the defined test conditions.                              | Capture 100 images of the evaluation components. Decode each image using a laptop script and record dimensions, file size, and decoding success. All images must satisfy the resolution and size requirements.                                                                          |
| C2. Autofocus shall complete within 1.5 s at working distances of 100, 105, and 110 mm.                                                        | Position a marked target at 100, 105, and 110 mm using a ruler or translation fixture. Perform twenty captures at each distance. Log focus-start and focus-complete timestamps and inspect the saved images for readable markings. Every autofocus sequence must complete within 1.5 s. |
| C3. At least 90 of 100 evaluation images shall fully contain the selected component and its primary marking within the central 60% × 60% crop. | Overlay the crop boundary on the 100 evaluation images. Independently score whether the package and marking are fully contained. Record the count and retain annotated images.                                                                                                          |
| C4. Each worklight shall draw no more than 20 mA and shall be off outside focus and exposure.                                                  | Measure current through each LED branch with a DMM. Use an oscilloscope to compare the LED-enable signal with the capture-state signal over twenty cycles. Record current and timing traces.                                                                                            |

## 2.5 User Input and Status Subsystem

The input and status subsystem lets the wearer start a capture and see whether the system is ready, processing, accepted, asking for another image, or in an error state. A momentary button on the temple connects to an ESP32-S3 GPIO with a pull-up resistor and is active low. Firmware generates one capture event per valid press and requires the button to be released before another capture can begin.

A 250 ms lockout is used to handle switch bounce. The firmware also ignores button presses while a transaction is already active so that multiple images are not competing for the same buffer. Status LEDs show ready, processing, accepted, recapture, and error states. Each LED uses a current-limiting resistor, and a transistor driver is used if the current would be too high for the GPIO.

This keeps each button press tied to one image and gives the user clear feedback during the capture process.

## Requirement

## Verification procedure

- I1.** Each button press lasting 50 ms–1 s shall generate exactly one capture request capture-event debug signal using a logic analyzer. Compare press and event counts; require exactly one event per valid press.
- I2.** A held button or additional press during an active transaction shall not generate another capture. Hold the button for five seconds and press it repeatedly during twenty not active transactions. Inspect firmware logs and confirm that no additional capture is queued.
- I3.** The status indication shall update within 250 ms of a firmware state change. Trigger ready, processing, accepted, recapture, and error states. Measure the interval between a debug state-transition signal and the LED output with a logic analyzer. Record at least five transitions per state.

## 2.6 Embedded Control and Wireless Subsystem

The embedded subsystem controls the camera and sends the captured image to the laptop. The ESP32-S3-WROOM-1-N8R8 has 8 MB flash, 8 MB PSRAM, camera-interface peripherals, and 2.4 GHz Wi-Fi [4]. The PSRAM is used for the compressed image buffer and camera-driver allocations so the design does not depend only on the ESP32-S3's internal SRAM.

For each capture, the firmware creates a unique request ID, focuses the camera, captures the JPEG, and uploads it to the laptop using HTTP. The payload includes the image along with the request ID, image dimensions, byte count, battery voltage, and image checksum. The ESP32 keeps the image until the laptop confirms that it was received and validated.

Each upload attempt has a 5 s timeout. The ESP32 will retry no more than two times before entering a visible error state. The laptop ignores duplicate request IDs so a retry does not create a second identification task. This also prevents corrupted or old images from being treated as the current capture.

## Requirement

## Verification procedure

- E1.** The firmware shall buffer and transmit JPEGs up to 2 MB without corruption or reset. Upload 100 images, including files near the size limit. Compare device and receiver SHA-256 checksums, decode the received files, and record reset and memory-allocation errors. Require matching hashes and no unexpected resets.
- E2.** At least 80 of 100 uploads shall succeed on the first attempt, and all 100 shall succeed within three attempts on the defined test network. Place the wearable and laptop on the same local 2.4 GHz network at the recorded demonstration distance. Log transfer duration, attempt count, and acknowledgment for each image.
- E3.** Incorrect request identifiers shall never complete the active transaction; failure shall be reported after two retries. Inject acknowledgments with incorrect identifiers, then disable the receiver. Inspect the device logs and status indication. Require rejection of incorrect acknowledgments and exactly two retries before failure.

## 2.7 Vision and Identification Subsystem

The vision subsystem turns the received image into one of three outcomes: one accepted catalog entry, a list of multiple plausible entries for the user to choose from, or a recapture/error result. Before OCR, the receiver checks the request ID, checksum, file size, and JPEG decoding. Images above 2 MB or metadata above 16 kB are rejected before entering the OCR pipeline.

The software uses the central 60% of the image width and height. For a  $2592 \times 1944$  image, this gives a crop of about  $1555 \times 1166$  pixels depending on rounding. A fixed set of image-enhancement variants is then used to improve contrast and reduce noise before OCR. OCR output keeps the recognized text, bounding boxes, confidence values, and processing time.

The recognized marking is compared against a catalog containing exact orderable part numbers, manufacturers, package information, and documented aliases. The resolver uses score and separation thresholds that are chosen using a separate calibration set and then frozen before evaluation. If one candidate clearly passes the thresholds, it can be accepted automatically. If multiple candidates remain plausible, the system shows them to the user instead of guessing. During evaluation, the person making that selection must not know the ground-truth part number. Automatic accuracy, user-assisted accuracy, and overall final accuracy are reported separately.

### Requirement

### Verification procedure

**V1.** All malformed JPEGs, checksum mismatches, images over 2 MB, and metadata over 16 kB shall be rejected before OCR. Submit a documented set of valid, corrupted, and oversized payloads, including values immediately below and above each size limit. Record response codes and verify that rejected payloads produce no accepted part.

**V2.** Across 100 blinded first-capture trials, at least 80 shall end with the correct final full part number and no more than two shall end with an incorrect final part number.

**V3.** A result shall be automatically accepted only when the frozen acceptance criteria identify one clear candidate; if multiple plausible candidates remain, no part shall be accepted until the user selects one.

Use at least twenty cataloged components with at least five trials each. A correct automatic accept counts as correct. If a multiple-match screen appears, the person selecting a candidate must be blinded to the ground-truth part number. A correct selection counts as correct and a wrong selection counts as incorrect; the candidate screen itself is intermediate and is not separately scored. All other final outcomes are recapture or explicit error. Record and report automatic-only accuracy, user-assisted accuracy on candidate-selection cases, overall final-identification accuracy, incorrect finals, recaptures, and errors.

Replay the evaluation logs and inspect the ranked candidates for every trial. Verify that automatic accepts satisfy the frozen score/separation criteria. For deliberately ambiguous or multiple-match images, verify that the interface presents the candidate set and that no candidate enters the accepted state before user selection.

## 2.8 Datasheet Retrieval Subsystem

The datasheet-retrieval subsystem maps each exact catalog part number to one reviewed manufacturer document. Every manifest entry stores the manufacturer, exact orderable part number, package, official source URL, retrieval date, SHA-256 hash, and local cache location. Even if multiple exact numbers share the same family PDF, each accepted exact orderable number still has its own manifest entry pointing to the correct reviewed document.

The laptop caches each PDF and indexes its extracted text by page number, which lets the interface open the original document even without internet access. Any specification shown to the user includes the page containing the supporting text or table row. Absolute-maximum ratings and recommended operating conditions are kept separate so they are not confused.

If a catalog entry does not have a reviewed mapping, or if the requested information is not supported by the document, the system returns an explicit unavailable result instead of filling in an answer.

| Requirement                                                                                                                    | Verification procedure                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| D1. Every exact catalog part number eligible for acceptance shall map to exactly one reviewed manufacturer PDF manifest entry. | Audit every exact orderable part number against the manufacturer source. Record manufacturer, exact orderable number, package, URL, retrieval date, SHA-256, and mapping count. Several exact part numbers may point to the same reviewed family PDF, but each exact number must have one manifest entry and no accepted exact number may be unmapped. |
| D2. Every cached PDF shall parse and open with internet access disabled.                                                       | Disable the laptop network connection and open every cached document. Record parser success and UI opening success for each file.                                                                                                                                                                                                                      |
| D3. Every displayed extracted specification shall cite a page containing its supporting evidence.                              | Ask a fixed set of pinout, absolute-maximum, and recommended-operating questions across at least five PDFs. Compare each answer with its cited page and record correctness. Unsupported questions must display an unavailable response.                                                                                                                |

## 2.9 User Interface Subsystem

The laptop interface shows the identification result and the evidence behind it. Each request moves through received, processing, candidate-selection, accepted, recapture, or error states while keeping the same request ID. An accepted result shows the original image, crop, OCR output, full part number, manufacturer, package, score, margin, and manufacturer PDF. If there are multiple plausible candidates, the interface shows the exact part numbers and manufacturer information so the user can choose the correct one.

Recapture results tell the user what to change, such as improving focus, reducing glare, centering the marking, or moving closer. A candidate is not treated as an accepted identification until it is either accepted automatically or selected by the user from the candidate list.

End-to-end latency is measured from the physical button press to the first visible actionable result. That result can be an accepted result with its datasheet, a multiple-candidate selection screen, an actionable recapture instruction, or an explicit error. This keeps the latency endpoint the same across the high-level requirement and U3.

#### **Requirement**

#### **Verification procedure**

U1. Every accepted result shall display the image, crop, OCR output, full part number, manufacturer, package, score, margin, and PDF link; a multiple-match result shall display all plausible candidate parts and their reviewed PDF choices before acceptance.

Inspect all accepted and multiple-match evaluation records and associated screens. Use a checklist for the required fields. For multiple-match cases, verify that each candidate shows enough identifying information and a reviewed manufacturer PDF option, and that one is not marked accepted until the user selects it.

U2. Every recapture result shall provide at least one actionable explanation, and every multiple-match result shall provide a clear user-selection action.

Test blurred, glare-obscured, off-center, unreadable, and ambiguous/multiple-match images. Verify that unusable images produce a relevant corrective action and that multiple plausible matches produce a candidate-selection screen rather than a guessed accepted part.

U3. Over 100 integrated trials, the median button-to-visible-result time shall be about 10 s and the 95th percentile shall be no more than 20 s.

Record button presses and the first visible actionable result using a shared video timebase or validated timing instrumentation. The endpoint is the first accepted result with datasheet, multiple-match candidate-selection screen with reviewed datasheet choices, or actionable recapture/error result. User decision time after a candidate-selection screen is logged separately and excluded from U3. Tabulate all 100 trial durations; the median should be about 10 s and the nearest-rank 95th percentile must be  $\leq 20$  s.

## **2.10 Tolerance Analysis**

Readable markings and stable camera/Wi-Fi operation are the main things that determine whether the system can identify a part correctly. The tolerance analysis checks optical sampling and power variation using the Rev A.2 schematic, PCB, and BOM. Those files contain design values but no measured hardware results, so any remaining estimates are called out below. The current R&V requirements are still the acceptance criteria. [6], [15], [16]

### **2.10.1 Camera and optical tolerance**

#### **Image geometry**

The selected Waveshare OV5640 Camera Board (C) uses its supplied autofocus lens and captures at 2592 × 1944. Waveshare specifies 3.3 V operation, the DVP/SCCB interface, autofocus support, and a 35.70

mm  $\times$  23.90 mm board size [17]. The actual horizontal framing still has to be measured on the purchased module. The old 45° lens target is kept only for comparison; the actual acceptance range is 100–110 mm.

For horizontal resolution  $N$ , marking dimension  $h$ , distance  $d$ , horizontal field of view  $\varphi$ , and tilt  $\alpha$  along the measured dimension:

$$W = 2d \tan(\varphi/2), \quad p \approx \frac{Nh \cos \alpha}{2d \tan(\varphi/2)} \quad (1)$$

This model assumes a small flat marking near the image center, square pixels, proper focus, and negligible local distortion. The 0.8 mm example still has to be checked against the smallest marking in the catalog. Cropping to the central 60% keeps the same original pixel density, and upsampling cannot recover optical detail that was never captured. See Sections 2.4 and 2.7.

| Distance | 45° HFOV, no tilt | 70° HFOV, no tilt | 70° HFOV, 15° tilt |
|----------|-------------------|-------------------|--------------------|
| 100 mm   | 25.031 px         | 14.807 px         | 14.303 px          |
| 105 mm   | 23.839 px         | 14.102 px         | 13.622 px          |
| 110 mm   | 22.755 px         | 13.461 px         | 13.002 px          |

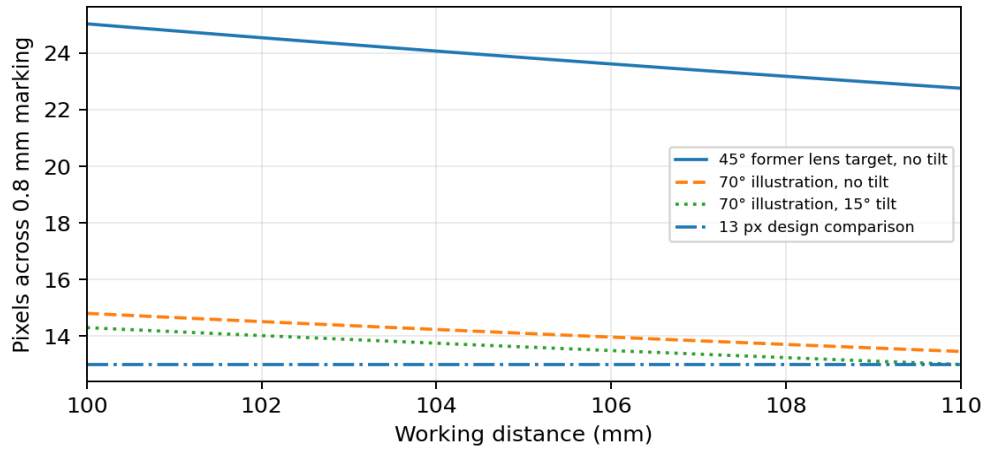


Figure 4. Calculated sampling comparison for the former 45° lens target and an illustrative wider-lens case over the controlled 100–110 mm operating range. The wider-angle and tilt values are sensitivity assumptions, not measured camera tolerances.

### Camera variation and design limits

Inside the controlled 100–110 mm range, the worst optical detail happens at the longest distance, widest field of view, largest tilt, and smallest marking. Sampling increases with marking size and decreases with distance. The previous 150 mm and 200 mm points are not acceptance conditions anymore. Before the calibration set is frozen, we will measure the actual horizontal field of view, smallest usable marking, usable tilt, autofocus behavior, glare sensitivity, and OCR performance on the purchased camera.

Let  $p_{\text{req}}$  be the minimum detail established using separate OCR calibration images. The limits follow from:

$$d_{\text{allow}} = \frac{N_{h_{\min}} \cos(\alpha_{\max})}{2p_{\text{req}} \tan(\varphi_{\max}/2)} \quad (2)$$

$$\varphi_{\text{allow}} = 2 \arctan\left(\frac{N_{h_{\min}} \cos(\alpha_{\max})}{2d_{\max}p_{\text{req}}}\right) \quad (3)$$

For the controlled test range, we use 100–110 mm distance, measured HFOV  $\leq 70^\circ$ , tilt  $\leq 15^\circ$ , and marking size  $\geq 0.8$  mm. At 110 mm in the illustrative  $70^\circ/15^\circ$  case, the model gives 13.002 pixels across a 0.8 mm marking. These are design limits, not a guarantee that OCR will work. The actual camera still has to pass measured framing and OCR calibration, followed by C1–C4 and V2. There is no longer a 150 mm or 200 mm acceptance requirement.

### Camera verification

Camera verification will measure framing, image scale, minimum marking size, usable tilt, focus, distortion, glare, motion blur, and compression on the purchased Waveshare OV5640 Camera Board (C). The board is powered from 3.3 V and includes onboard camera supply regulation [17], [18]. C1–C4 then require 100 valid full-resolution JPEGs  $\leq 2$  MB; twenty autofocus trials at 100, 105, and 110 mm with completion  $\leq 1.5$  s; at least 90/100 packages and markings inside the central crop; and worklights  $\leq 20$  mA each and off outside focus/exposure. Settings and thresholds are frozen before V2's 100 blinded trials across at least twenty components. Final performance must be at least 80 correct identifications with no more than two incorrect identifications, with user-assisted selections scored according to V2.

### 2.10.2 Power subsystem tolerance

#### Steady rail and feedback resistor variation

Rev A.2 used  $R_{23} = 312 \text{ k}\Omega$  and  $R_{24} = 100 \text{ k}\Omega$  at 0.1%, with PS/SYNC high for PWM/PFM power-save operation. The proposed PCB revision changes these to  $R_{23} = 31.2 \text{ k}\Omega$  and  $R_{24} = 10.0 \text{ k}\Omega$ , both 0.1%, and holds PS/SYNC low for forced PWM. The nominal output stays at 3.296 V, but the lower resistor values reduce the error caused by feedback leakage. These are still proposed values until they are confirmed in the released schematic/BOM and then measured on the assembled board. P1 requires 3.20–3.40 V from 20 mA to 1.2 A.

For resistor tolerance  $t = 0.001$  and feedback accuracy factors  $a_{\min}$  and  $a_{\max}$ , the divider extremes are:

$$V_{\min} = 0.800a_{\min}\left(1 + 3.12\frac{1-t}{1+t}\right), \quad V_{\max} = 0.800a_{\max}\left(1 + 3.12\frac{1+t}{1-t}\right) \quad (4)$$

The TPS63070 datasheet specifies  $-1\%/+3\%$  feedback accuracy in PFM for input  $\geq 3$  V and  $\pm 1\%$  in forced PWM. The 100 nA feedback-leakage limit can contribute up to 31.232 mV with the old 312 k $\Omega$  upper resistor, but only about 3.124 mV with the proposed 31.2 k $\Omega$  resistor. Both leakage directions are included below. Line/load regulation, board loss, ripple, and resistor temperature drift are still additional error sources. [2, Secs. 7.5, 9.2.2.1]

| Mode | Accuracy and divider only | Including feedback leakage |
|------|---------------------------|----------------------------|
|------|---------------------------|----------------------------|

| Mode                                                 | Accuracy and divider only | Including feedback leakage |
|------------------------------------------------------|---------------------------|----------------------------|
| Rev A.2 PFM baseline                                 | 3.258102–3.400027 V       | 3.226871–3.431259 V        |
| Forced-PWM sensitivity comparison                    | 3.258102–3.334007 V       | 3.226871–3.365239 V        |
| Proposed revision:<br>forced PWM, 31.2/10 k $\Omega$ | 3.258102–3.334007 V       | 3.254979–3.337131 V        |

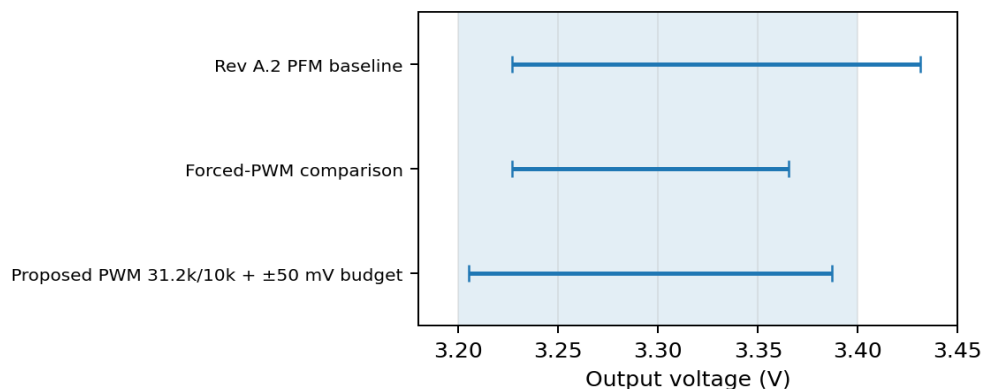


Figure 5. Conservative output-voltage bounds comparing the Rev A.2 PFM configuration with the proposed forced-PWM 31.2 k $\Omega$ /10.0 k $\Omega$  revision. The proposed design also reserves  $\pm 50$  mV for remaining steady-state error within P1's 3.20–3.40 V range.

The proposed fix is to hold PS/SYNC low for forced PWM and change R23/R24 to 31.2 k $\Omega$ /10.0 k $\Omega$ , both 0.1%. Including feedback leakage, the calculated range is 3.254979–3.337131 V. Reserving another  $\pm 50$  mV for the other steady-state errors gives 3.204979–3.387131 V, which stays inside the P1 range of 3.20–3.40 V. This is still a design calculation, not a measured result. Before PCB order, the released schematic/BOM has to be checked to make sure these values are actually implemented, and P1–P3 then have to be repeated on hardware. [2, Secs. 6, 7.5, 9.2.2]

### Load transient and component limits

The proposed output network uses C12–C14 = 22  $\mu$ F X7R, 10 V, 1206 capacitors, with Murata GRM31CR71A226KE15L selected for the BOM, and L1 = Coilcraft XAL5030-122MEC at 1.2  $\mu$ H. The nominal output capacitance is 66  $\mu$ F, while the design target is at least 18  $\mu$ F effective after tolerance and DC-bias derating. The exact Murata DC-bias curve still needs to be checked during PCB-release review, so the nominal 66  $\mu$ F value is not treated as guaranteed effective capacitance. [2, Sec. 9.2.2]

Using the stated derating expression without counting the same derating twice, the 18  $\mu$ F target requires at least 27.28% of the nominal 66  $\mu$ F bank to remain effective. For example, 20% tolerance with 50% DC-bias retention gives 26.4  $\mu$ F before any extra temperature effect. This is only a screening example, not the selected capacitor's guaranteed value. The final effective capacitance and inductance still need to be checked against the converter guidance and worst-case load. [2, Sec. 9.2.2]

$$C_{\text{eff,min}} C_{\text{nom}} t_c k_{\text{bias}} k_{\text{temp}}$$

P2 permits no more than **100  $\mu$ s** below 3.10 V during a **20-to-520 mA** step. The approximate capacitor contribution is:

$$\Delta V \approx \Delta I \cdot R_{\text{ESR}} + \frac{\int I_{\text{deficit}}(t) dt}{C_{\text{eff}}} \quad (5)$$

Starting from the P1 minimum of 3.20 V, an example allocation of 50 mV for ESR and 50 mV for capacitor discharge gives  $\text{ESR} \leq 0.100 \Omega$ . If the full 0.500 A load step had to come only from the capacitor bank, the 50 mV discharge allowance would last about 6.6  $\mu$ s with 66  $\mu$ F or 1.8  $\mu$ s with 18  $\mu$ F. Supplying that full deficit for 100  $\mu$ s would take about 1000  $\mu$ F, but that is only a hold-up comparison and not a recommended capacitor value or a P2 requirement. The real result depends on converter response, local capacitance, and layout, so those still have to be tested. Inductor saturation and current derating also have to be checked at minimum input voltage because switch-current rating does not directly equal guaranteed output current.

### Runtime and battery variation

The runtime analysis uses the selected protected DNK603450 1000 mAh battery [19]. P3 requires two hours of operation with one capture every 5 minutes, which means at least 24 complete capture-and-identification cycles. The pack is rated for 1.0 A maximum continuous discharge. Because of that, the 1.2 A regulator sweep in P1 is done from a current-limited bench supply instead of the battery. For usable charge  $Q_{\text{usable}}$  and active/idle currents  $I_a$  and  $I_i$ :

$$I_{\text{bat,avg}} \leq \frac{Q_{\text{usable}}}{2 \text{ h}}, \quad I_{\text{bat,avg}} = \frac{I_a t_a + I_i(300 \text{ s} - t_a)}{300 \text{ s}} \quad (6)$$

An ideal 1000 mAh battery allows 500 mA average current for two hours with no reserve. If only a fraction  $f$  of the nominal capacity is usable, the limit becomes  $500f$  mA. The selected pack is specified as 1000 mAh with a 1.0 A continuous-discharge limit and built-in protection [19]. Aging, cable loss, converter cutoff, and temperature will reduce the real margin. The measured current waveform therefore needs to include autofocus, camera operation, lights, uploads, retries, and idle current.

Battery current is not the same as 3.3 V rail current. For the converter, it is approximately  $I_{\text{bat}} = 3.30 I_{\text{out}}/(\eta V_{\text{bat}})$ , before adding auxiliary losses. At low battery voltage, the 1.2 A P1 regulator test can require more than the battery's 1.0 A continuous rating, which is why P1 is a bench-supply test. During normal battery-powered capture and upload, the measured battery current must stay within the verified pack limit [19].

### Battery sensing charging and temperature

R38 and R39 are both 100 k $\Omega$  at 0.1%, so the nominal divider ratio is 0.5 and the resistor-tolerance range is 0.4995–0.5005. Before calibration and drift, that gives about  $\pm 0.1\%$  scale error, or  $\pm 4.2$  mV when the battery is at 4.2 V. P6 allows a calibrated battery-referred error of  $\pm 50$  mV. The Rev A.2 sensing network is documented in the project design records [16, sheet 03].

$$E_{\text{bat}} \leq V_{\text{bat}} |\epsilon_k| + \frac{E_{\text{ADC}}}{k} \leq 0.050 \text{ V} \quad (7)$$

At 4.2 V, the resistor error leaves 45.8 mV of the  $\pm 50$  mV battery-referred budget, which corresponds to 22.9 mV at the ADC. The rest of the budget has to cover settling, leakage, ADC gain/offset/nonlinearity,

quantization, and temperature drift. With  $C25 = 100 \text{ nF}$  and a  $50 \text{ k}\Omega$  divider source resistance, the time constant is  $5 \text{ ms}$ . Five time constants still leave about  $28.3 \text{ mV}$  battery-referred settling error after a  $4.2 \text{ V}$  step. The firmware delay before sampling will be chosen from the full error budget and calibration will be checked from  $3.3\text{--}4.2 \text{ V}$ .

$R8 = 3.57 \text{ k}\Omega$  at  $1\%$  sets the charge current using  $I_{\text{CHG}} = K/R8$ . With  $K = 797\text{--}975 \text{ A}\Omega$  and nominal  $890 \text{ A}\Omega$  from the datasheet, the calculated current is  $249.300 \text{ mA}$  nominal and  $221.038\text{--}275.868 \text{ mA}$  at the extremes under unconstrained fast-charge conditions. For a  $1000 \text{ mAh}$  battery, that is about a  $0.25 \text{ C}$  nominal charge rate. Input-current limits, system load, and thermal regulation can all reduce the actual charging current. Normal charging will not use the USB100 limit; the USB-C source and charger input-current mode must support the programmed charging current plus the system load. R9 does not override the active USB input-current limit. [16], [1, Secs. 7, 8.5, 9.3.5] $I_{\text{chg}}$

The external Semitec 103AT-2 NTC circuit uses R14–R18 at  $0.1\%$  and U9 TLV7042. The nominal cold and hot switching resistances are  $14.684 \text{ k}\Omega$  and  $5.848 \text{ k}\Omega$ , with resistor-tolerance ranges of  $14.640\text{--}14.729 \text{ k}\Omega$  and  $5.830\text{--}5.866 \text{ k}\Omega$ . The intended charging window is about  $15\text{--}40 \text{ }^\circ\text{C}$ , but the exact limits still depend on the NTC curve and tolerance, comparator offset, and thermal lag from mounting. Both cutoff points and the behavior for a missing or shorted sensor must be checked against the selected battery's allowed charging range. [16, sheet 03 and README.md]

P4 uses  $45 \text{ }^\circ\text{C}$  as the proposed prototype limit for any surface that can touch the wearer during the same two-hour battery test at  $23 \pm 3 \text{ }^\circ\text{C}$  ambient. At the highest allowed ambient of  $26 \text{ }^\circ\text{C}$ , that leaves less than a  $19 \text{ }^\circ\text{C}$  temperature rise. This limit still needs TA review and does not by itself prove that the device is safe for prolonged skin contact. The battery charge cutoff also does not prove the enclosure stays below this temperature. Battery-enclosure and electronics-enclosure temperatures will be measured throughout the full two-hour run, while charging is tested separately off the wearer and under supervision. See Section 4.5 and requirement P4.

P1 is tested at  $20, 100, 300, 500, 800,$  and  $1200 \text{ mA}$  using a current-limited bench source at the regulator input; the  $1000 \text{ mAh}$  battery is not used for the  $1.2 \text{ A}$  sweep. TP4 and the ESP32 supply pins are used to measure rail voltage and ripple, TP2 measures battery voltage, and TP14 measures the ADC node. P2 is repeated ten times while recording minimum voltage, time below  $3.10 \text{ V}$ , load slew, and probe setup. P3 and P4 are then run together for 120 minutes with one complete capture-and-identification cycle every 5 minutes, for at least 24 cycles total. During that run we record battery voltage, cycle success, shutdown behavior, battery current, ambient temperature, and wearer-accessible surface temperatures at least once per minute.

The proposed forced-PWM change fits inside the P1 error budget on paper, but it still has to be implemented in the schematic/BOM and verified on hardware. The camera range is now consistently  $100\text{--}110 \text{ mm}$  in Section 2.4, C2, the tolerance analysis, and the schedule. The  $1000 \text{ mAh}$  battery and exact camera module are both identified in the BOM. Final acceptance still depends on measured runtime, temperature, battery current, ADC accuracy, camera performance, and OCR results, not just schematic review or a clean PCB DRC.

**The sources used in this tolerance analysis are included in the numbered reference list in Section 5.**

### 3. Cost and Schedule

#### 3.1 Cost Analysis

##### Labor

We estimate labor using an hourly rate of \$57.24, based on the University of Illinois reported average starting salary of \$119,064 for Computer Engineering graduates and an assumed 2,080 working hours per year. Each team member is budgeted for 90 hours covering implementation, integration, testing, and documentation [5].

The estimated labor cost is calculated using the required multiplier:

Labor cost = Hourly rate  $\times$  2.5  $\times$  Estimated hours

Cost per team member = \$57.24/hour  $\times$  2.5  $\times$  90 hours = **\$12,879.00**

Total labor cost = \$12,879.00  $\times$  3 team members = **\$38,637.00**

| Team member | Hourly rate | Estimated hours | Labor cost including 2.5 multiplier |
|-------------|-------------|-----------------|-------------------------------------|
|-------------|-------------|-----------------|-------------------------------------|

|                  |         |    |             |
|------------------|---------|----|-------------|
| Hridik Hingorani | \$57.24 | 90 | \$12,879.00 |
|------------------|---------|----|-------------|

|           |         |    |             |
|-----------|---------|----|-------------|
| Shiv Bahl | \$57.24 | 90 | \$12,879.00 |
|-----------|---------|----|-------------|

|                 |         |    |             |
|-----------------|---------|----|-------------|
| Preity Varanasi | \$57.24 | 90 | \$12,879.00 |
|-----------------|---------|----|-------------|

|                    |  |            |                    |
|--------------------|--|------------|--------------------|
| <b>Total labor</b> |  | <b>270</b> | <b>\$38,637.00</b> |
|--------------------|--|------------|--------------------|

##### Parts, Equipment, and Services

The parts estimate below is based on the current proposed BOM. Part numbers are fixed where the electrical or mechanical design depends on them. The frame and enclosure are currently expected to use lab stock or 3D-printed material, so their incremental cost is listed as \$0 for now.

| Part description                                     | Manufacturer or supplier | Part number or specification             | Quantity | Estimated total cost |
|------------------------------------------------------|--------------------------|------------------------------------------|----------|----------------------|
| Autofocus camera module                              | Waveshare                | OV5640 Camera Board (C), autofocus, 5 MP | 1        | \$17.50              |
| Two-layer PCB fabrication, five boards with shipping | JLCPCB                   | Custom PCB                               | 1 batch  | \$10.00              |

| Part description                                                     | Manufacturer or supplier       | Part number or specification                                                                          | Quantity | Estimated total cost |
|----------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------|----------|----------------------|
| Protected 1S LiPo battery + external NTC                             | DNK Power / Semitec            | DNK603450 / LP603450, protected 3.7 V 1000 mAh; external Semitec 103AT-2 NTC                          | 1 set    | \$9.95               |
| Buck-boost converter                                                 | Texas Instruments              | TPS63070RNMR                                                                                          | 1        | \$3.80               |
| Microcontroller module                                               | Espressif Systems              | ESP32-S3-WROOM-1-N8R8                                                                                 | 1        | \$3.50               |
| Power inductor and 22 $\mu$ F bulk capacitors                        | Coilcraft / Murata             | XAL5030-122MEC, 1.2 $\mu$ H; 3 $\times$ GRM31CR71A226KE15L, 22 $\mu$ F 10 V X7R 1206                  | 1 set    | \$3.50               |
| Power-path charger                                                   | battery Texas Instruments      | BQ24074RGTR                                                                                           | 1        | \$2.45               |
| USB-C receptacle and ESD protection diode                            | GCT / Nexperia                 | USB4105-GF-A USB-C receptacle; PESD1USB3B D+/D- ESD protection                                        | 1 set    | \$1.60               |
| Camera FPC connector                                                 | Hirose                         | FH12-24S-0.5SH(55), 24-position 0.5 mm, 2.0 mm height; verify bottom-contact orientation against flex | 1        | \$1.20               |
| Passives, LEDs, button, switch, connectors, frame/enclosure material | Lab stock / course 3D printing | Final PCB BOM plus frame/enclosure; no paid service assumed                                           | 1 set    | \$0.00 (provisional) |
| <b>Estimated parts subtotal</b>                                      |                                |                                                                                                       |          | <b>\$53.50</b>       |

The selected camera is the Waveshare OV5640 Camera Board (C) with its supplied autofocus lens and 24-position, 0.5 mm FPC interface [17]. The selected battery is the protected DNK603450 3.7 V, 1000 mAh pack [19]. The exact connector orientation and battery lead polarity still have to be checked against the parts that are actually purchased before PCB release.

We plan to use the normal course-lab equipment for assembly and testing: soldering equipment, an oscilloscope, digital multimeter, current-limited bench supply, electronic load, and temperature-measurement equipment. Since the lab equipment and laptop are already available, the project assigns them an incremental cost of \$0. No paid machine-shop work is currently planned.

### Total Estimated Cost

| <b>Cost category</b>                                             | <b>Estimated cost</b> |
|------------------------------------------------------------------|-----------------------|
| Labor                                                            | \$38,637.00           |
| Parts and PCB fabrication                                        | \$53.50               |
| Additional equipment and shop services, assuming existing access | \$0.00                |
| <b>Provisional grand total</b>                                   | <b>\$38,690.50</b>    |

The grand total will be updated if the frame, enclosure, final component choices, or any other procurement costs change.

### 3.2 Schedule

The schedule below uses the controlled 100–110 mm camera range and the proposed Rev B power changes. Before the PCB is released, we will verify the purchased Waveshare module's FPC orientation, confirm the forced-PWM resistor values in the schematic/BOM, and check the exact battery and connector parts.

| <b>Week beginning</b> | <b>Hridik Hingorani</b>                                                                | <b>Shiv Bahl</b>                                                                                             | <b>Preity Varanasi</b>                                 |
|-----------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| <b>September 21</b>   | Freeze the 20-part test set; record markings and character heights.                    | Order the Waveshare OV5640-C module; verify the supplied autofocus lens and obtain module documentation.     | Stand up the laptop receiver and image logging.        |
| <b>September 28</b>   | Camera bring-up, I <sup>2</sup> C register configuration, and autofocus sequence.      | Power budget, charger, and converter schematic.                                                              | OCR pipeline on saved images and enhancement variants. |
| <b>October 5</b>      | Capture at 100, 105, and 110 mm; measure pixels per character and framing.             | USB-C, protection, and ADC battery-sensing schematic.                                                        | Catalog schema and scoring function version 1.         |
| <b>October 12</b>     | Freeze the exact camera SKU/FPC orientation, measured framing, and electrical pin map. | Full schematic review: verify proposed forced-PWM TPS63070 values, exact BOM MPNs, and two-layer PCB layout. | Datasheet manifest and PDF cache.                      |
| <b>October 19</b>     | Firmware capture and HTTP upload path.                                                 | Submit the PCB order; design the enclosure and mount.                                                        | Threshold calibration on held-out images.              |
| <b>October 26</b>     | Retry, request-ID, and status-LED state machine.                                       | Board bring-up: test rails using a current-limited supply.                                                   | Page index and grounded extraction.                    |

| <b>Week beginning</b> | <b>Hridik Hingorani</b>                            | <b>Shiv Bahl</b>                         | <b>Preity Varanasi</b>                         |
|-----------------------|----------------------------------------------------|------------------------------------------|------------------------------------------------|
| <b>November 2</b>     | Camera on the custom board and end-to-end capture. | Charger and thermal characterization.    | Interface screens and stage timing.            |
| <b>November 9</b>     | Integration and latency tuning.                    | Mechanical assembly, mass, and fit.      | Blinded-trial harness and randomization.       |
| <b>November 16</b>    | Full-system integration and firmware freeze.       | Runtime and thermal verification.        | Freeze software and run the calibration check. |
| <b>November 30</b>    | Blinded evaluation: 100 trials.                    | Rail-integrity and wearability tests.    | Confusion matrix and results write-up.         |
| <b>December 7</b>     | Mock-demo fixes.                                   | Final demo and presentation preparation. | Final paper.                                   |

## 4. Societal impact, standards, ethics, and safety

### 4.1 Societal Impact

The glasses are meant to reduce interruptions during electronics work by making it faster to get to the correct manufacturer datasheet. A wrong identification could still damage hardware, so unreadable images cause a recapture instead of a guess, while ambiguous images show the user a short candidate list. The final result still points back to the original manufacturer document. Using a nearby laptop keeps the wearable simpler and cheaper, but it also means the system depends on the user having a computer. Local processing and cached PDFs reduce internet dependence, and a replaceable battery and repairable enclosure can reduce electronic waste. The first version is limited to the selected component catalog and would need more work to support other languages or a wider range of parts.

### 4.2 Engineering Standards

The main standards and references for this project are IEEE 802.11 for Wi-Fi [7], the USB-IF Type-C specification for charging [8], and IEC 62133-2 for rechargeable lithium-battery safety [9]. We will also review FCC Part 15 and the ESP32-S3 module's RF integration and exposure requirements because the device is worn near the head [10], [4]. Using a certified wireless module does not automatically certify the complete glasses.

### 4.3 Ethics and Privacy

The design follows the IEEE guidance on safety, privacy, and honest reporting, along with ACM Code sections 1.2, 1.3, and 1.6 [11], [12]. We will report incorrect identifications, recaptures, errors, and multiple-match selections instead of only reporting successful trials, and we will not present an uncalibrated score as a probability. Since the camera can also capture people, screens, or private circuit

designs, every capture requires a button press, processing is kept local, and saved images and logs can be removed. These choices also follow the ECE 445 ethics guidelines [13].

#### **4.4 Safety Concerns**

The main safety concerns are battery damage, incorrect charging, electrical shorts, heat against the skin, and loose or sharp mechanical parts. We will follow the ECE 445 lab and battery-safety guidelines [14]. The design uses a protected battery, charging settings matched to the selected pack, enclosed conductors, secure mounts, and strain relief. We also need to check heat buildup inside the enclosure and make sure the camera does not block the wearer's view. The worklights point toward the bench and stay off outside focus and exposure.

#### **4.5 Safety Procedures**

Before using the battery, we will inspect the PCB for shorts, verify polarity with a multimeter, and test the rails from a current-limited bench supply. Charging will be done off the wearer and under supervision. Any battery showing swelling, damage, unusual heating, odor, or abnormal behavior will be removed from use and reported to course staff.

Mechanical fit will first be checked with the power off, followed by powered bench testing before anyone wears the system. The full two-hour battery test will also track the proposed 45 °C limit for wearer-accessible surfaces during the entire run. That threshold still requires TA review and should not be treated as proof of safe prolonged skin contact. We will also check that the mounts stay secure, the wearer's vision is not blocked, and the power switch remains accessible. The results will be documented and reviewed with the TA. If course staff classify the project as high risk, we will prepare the required Safety Manual and show compliance at demo time.

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