AdheraScent: A Multi-Modal Medication Adherence System

Jonathan Liu (jliu268)
Hardhik Tarigonda (htarig2)
Dhiraj Bijinepally (ddb3)

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Contents

Abstract

Approximately 66% of adults in the United States take prescription medication, yet adherence remains one of the leading preventable sources of poor health outcomes. Even among individuals with chronic illnesses, up to half fail to take medications as prescribed. Forgetfulness, notification fatigue, and difficulty establishing routines contribute heavily to this problem.

AdheraScent addresses this gap through a three-part integrated system consisting of: (1) a mobile application for medication scheduling and adherence monitoring, (2) a pillbox equipped with a lid-contact sensing mechanism to confirm dosage events, and (3) a wearable scent-emitting device that provides escalation beyond traditional visual or auditory reminders.

When a scheduled medication becomes due, the system generates mobile notifications and monitors user response. If the individual does not take the medication within a configured window, the wearable activates an olfactory cue via a controlled heating mechanism. If the pillbox is opened, a signal is transmitted immediately to cease escalation.

This report presents the full system design, hardware implementation, software architecture, requirements and verification, cost analysis, safety and ethical considerations, and conclusions drawn from prototype evaluation.

Chapter 1

Introduction

Medication adherence is one of the most persistent obstacles in public health. More than two-thirds of Americans take at least one prescription medication, and many require strict schedules to maintain therapeutic effectiveness. However, maintaining adherence can be challenging, particularly for individuals managing complex regimens or adapting to new prescriptions.

Existing consumer solutions rely heavily on visual or auditory prompts: smartphone notifications, alarms, flashing indicators, or vibrating wristbands. These modalities often fail when users experience notification fatigue, have sensory limitations, or simply become desensitized to repetitive cues. Importantly, none of the mainstream consumer adherence systems incorporate olfactory stimuli, despite evidence that scent is one of the most direct pathways to cognitive recall.

AdheraScent introduces a novel multi-modal escalation model that integrates olfactory reminders. The system consists of:

- a mobile application for medication scheduling and initial reminders,
- a specialized pillbox that detects user interaction via a lid-contact mechanism,
- and a wearable scent-diffusing device that activates during missed reminders.

When medication becomes due, the user first receives app notifications. If unacknowledged, the system escalates and ultimately activates a wearable heater to melt scented wax, providing an attention-grabbing olfactory cue. Opening the pillbox interrupts escalation, enabling precise adherence tracking.

Throughout this report, Bluetooth Low Energy (BLE) refers to the wireless link between the mobile application, desktop gateway, and embedded devices, and lithium polymer (LiPo) refers to the rechargeable batteries that power the prototypes.

This chapter presents the motivation and system objectives. Chapter 2 describes the high-level design, Chapter 3 the detailed software and hardware design, Chapter 4 the comprehensive requirements and verification results, Chapter 5 the cost and schedule analysis, and remaining chapters cover safety, ethics, and conclusions.

Chapter 2

High-Level System Overview

AdheraScent consists of three highly integrated subsystems connected using BLE:

1. the mobile scheduling application,
2. the pillbox sensing unit,
3. and the wearable scent emitter.

The communication architecture is built using the Nordic UART Service (NUS) BLE protocol [6]. The mobile application generates the initial reminder signals based on stored schedules. If no confirmation is received, the app sends a command to the wearable, which escalates through LED patterns and ultimately triggers scent release.

Opening the pillbox closes the capacitive-contact circuit between two copper pads, indicating that medication has been accessed. This event is sent over BLE and immediately halts the escalation sequence.

Figure 2.1 shows the complete system architecture and the flow of information between the user, the mobile application, the pillbox, and the wearable.

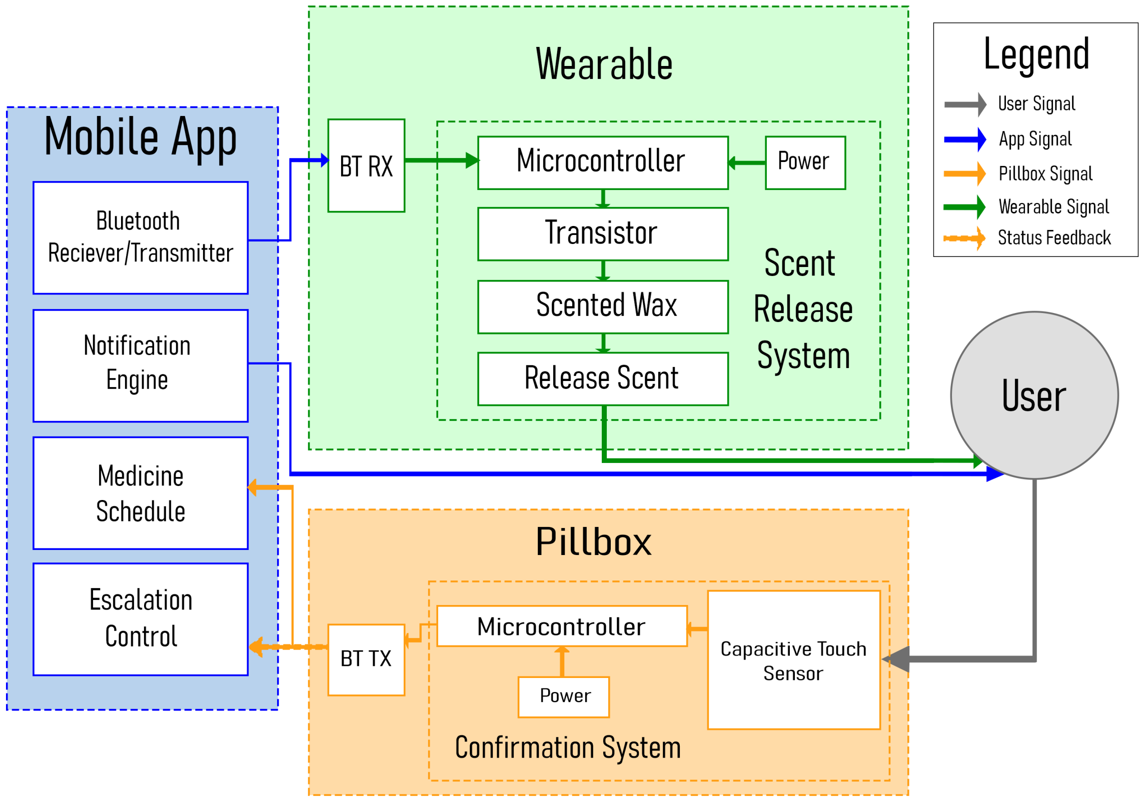

Figure 2.1: High-level system block diagram illustrating the interaction between the mobile application, pillbox sensing module, and wearable scent emitter.

2.1 Subsystem Overview

The three major subsystems provide distinct but coordinated roles:

2.1.1 Mobile Application

The mobile application:

- stores medication schedules,
- presents alerts when doses become due,
- interfaces with a desktop BLE gateway,
- and controls escalation timing.

2.1.2 Pillbox

The pillbox subsystem:

- uses two copper contacts to detect lid opening,
- contains an ESP32 microcontroller,
- transmits "pill taken" events over BLE,
- and draws power from a LiPo battery regulated through an LDO.

2.1.3 Wearable Scent Emitter

The wearable subsystem:

- receives escalation commands from the app via BLE,
- controls an LED indicator for visual cues,
- heats scented wax using a resistor-based heater,
- and ensures user safety using a PTC fuse in the heater path.

2.2 System Operation Summary

The complete operational flow is:

1. The app detects a scheduled medication time.
2. The user receives an app notification; a timer begins.
3. If the timeout expires with no confirmation, the desktop BLE gateway sends an escalation command to the wearable.
4. The wearable escalates LED states, then activates the heater to release scent.
5. Opening the pillbox triggers a BLE event that is logged by the app and immediately stops escalation.

Chapter 3

Detailed System Design

This chapter presents the complete hardware and software design for the AdheraScent system. All descriptions and figures correspond directly to the implemented prototype.

3.1 Mobile Application

The mobile application is implemented using React Native and Expo. It maintains local storage for medication schedules, user authentication data, and a queue of active alerts. Communication with the desktop BLE gateway is performed through a WebSocket channel using a lightweight command protocol.

The app performs four main tasks:

1. User authentication
2. Medication scheduling
3. Alert activation and dismissal
4. Communication with the BLE gateway

3.1.1 Authentication Module

User credentials are stored in the application's AsyncStorage. The app supports sign-up and login flows.

```
const handleAuth = async (mode) => {
  const raw = (await AsyncStorage.getItem(USERS_KEY)) || '{}';
  const users = JSON.parse(raw);
```

```
  if (mode === 'signup') {
    users[username] = { password };
    await AsyncStorage.setItem(USERS_KEY, JSON.stringify(users));
  } else {
    if (!users[username] || users[username].password !== password) {
      Alert.alert('Invalid credentials');
      return;
    }
  }
  onAuthenticated({ username });
};
```

3.1.2 Scheduling Engine

Medication reminders are triggered once per day or on selected weekdays. The application verifies whether the current time matches any scheduled reminder.

```
const hhmm = now.toLocaleTimeString([], {
  hour: '2-digit', minute: '2-digit', hour12: false
});
const today = now.getDay();
const times = schedule.times.split(',').map(t => t.trim());

if ((schedule.type === 'daily' || schedule.days.includes(today))
    && times.includes(hhmm)) {
  addAlert(med.id);
}
```

3.1.3 Alert Rendering

When an alert becomes active, it appears in a dedicated list in the UI.

```
function handleNotification(medication) {
  const item = document.createElement('div');
  item.innerHTML = `
    <span>Time to take your <strong>${medication.name}</strong></span>
    <button class="confirm-btn" data-id="${medication.id}">Dismiss</button>
  `;
  notificationsList.appendChild(item);
```

```
}
```

3.1.4 Communication With BLE Gateway

Alerts and acknowledgments are transmitted to the desktop BLE gateway through a WebSocket channel. The gateway forwards commands to the wearable or pillbox over BLE, acting as a bridge between the React Native front-end and the embedded devices.

3.2 Desktop Application

The desktop gateway is implemented using Electron. It displays adherence events and acts as an intermediary between the mobile app and BLE peripherals.

Its responsibilities include:

- Displaying real-time adherence notifications,
- Handling alert acknowledgments,
- Communicating with BLE devices via Python backend,
- Logging user behavior locally.

The renderer process listens for events from the main process:

```
function handleNotification(medication) {
  const item = document.createElement('div');
  item.innerHTML = `
    <span>Time to take your <strong>${medication.name}</strong></span>
    <button class="confirm-btn" data-id="${medication.id}">Dismiss</button>
  `;
  notificationsList.appendChild(item);
}
```

3.3 Python BLE Backend

BLE communication is handled using the `bleak` Python library. The backend exposes two key functions: sending wearable commands and processing pillbox notifications.

3.3.1 Sending Commands to Wearable

```
async def send_armband_command(command):
    if armband_client and armband_client.is_connected:
        await armband_client.write_gatt_char(
            UART_RX_CHAR_UUID,
            command.encode('utf-8')
        )
```

3.3.2 Handling Pillbox Events

```
if "Button␣pressed" in msg:
    print("EVENT:PILLBOX_BUTTON_PRESSED", flush=True)
```

3.4 Wearable Firmware

The wearable firmware is implemented on an ESP32 microcontroller. It handles BLE commands, LED escalation states, and heater activation.

```
if (rxValue == "LED_SOLID_RED") {
    currentMode = LED_MODE_SOLID;
    digitalWrite(LED_PIN, HIGH);
    digitalWrite(VBUS_CONTROL_PIN, HIGH);
}
```

The firmware exposes a BLE characteristic for receiving commands. Upon receiving escalation commands, the wearable transitions through LED patterns and ultimately activates the heater element by driving the MOSFET gate high.

3.5 Pillbox Firmware

The pillbox microcontroller monitors the lid-contact pads and transmits BLE notifications when the user opens the pillbox.

```
bool currentButtonState = digitalRead(BUTTON_PIN);

if (deviceConnected && lastButtonState == HIGH &&
    currentButtonState == LOW) {
```

```
    pTxCharacteristic->setValue("Button␣pressed");
    pTxCharacteristic->notify();
}
```

3.6 Hardware Design Overview

The AdheraScent hardware consists of two ESP32-based PCBs: a wearable scent emitter and a pillbox sensing module. Both are powered by single-cell LiPo batteries regulated to 3.3 V using AP2112K-3.3 low-dropout regulators [3]. The ESP32 modules and power components follow manufacturer recommendations [2].

3.6.1 Wearable Hardware

The wearable scent emitter is powered by a LiPo cell. A low-dropout (LDO) regulator reduces battery voltage to 3.3 V for the ESP32 module. A power resistor embedded beneath an aluminum plate behaves as a controlled heating element for melting scented wax.

A PTC fuse protects the heater path, ensuring the current never exceeds 1.5 A. The AO3400 MOSFET drives the heater, ensuring safe switching within gate-drive limits [4].

Figure 3.1 shows the complete wearable schematic. Figure 3.2 shows the PCB layout with an antenna keep-out region and heater routing. Figure 3.3 illustrates the enclosure, including scent vents and strap guides.

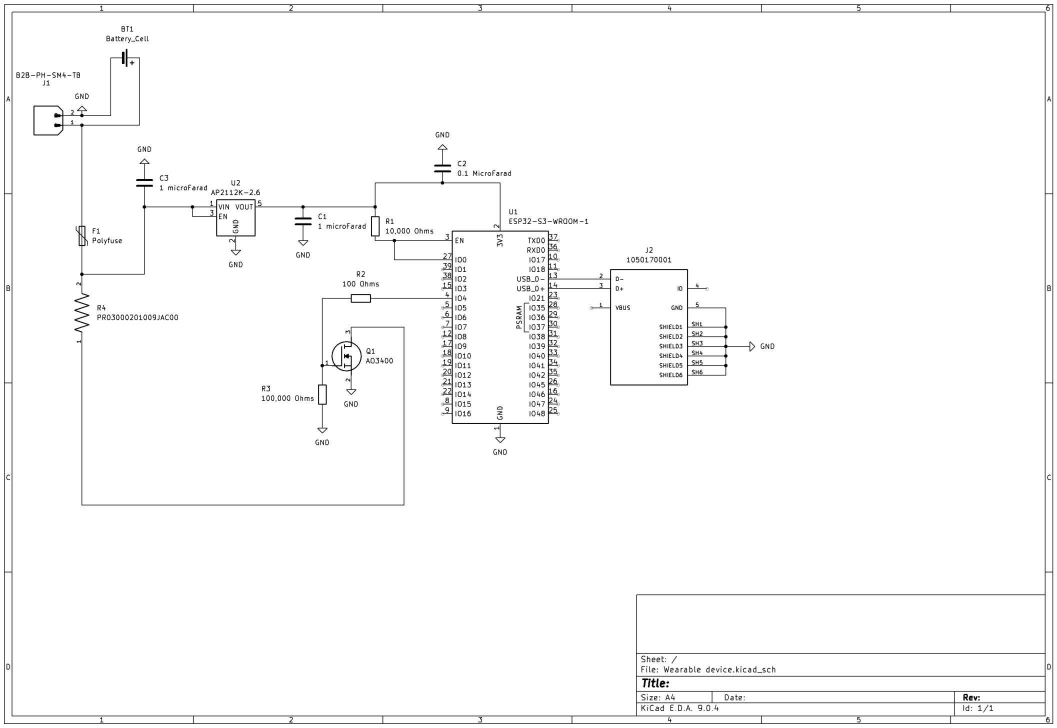

Figure 3.1: Wearable hardware schematic diagram.

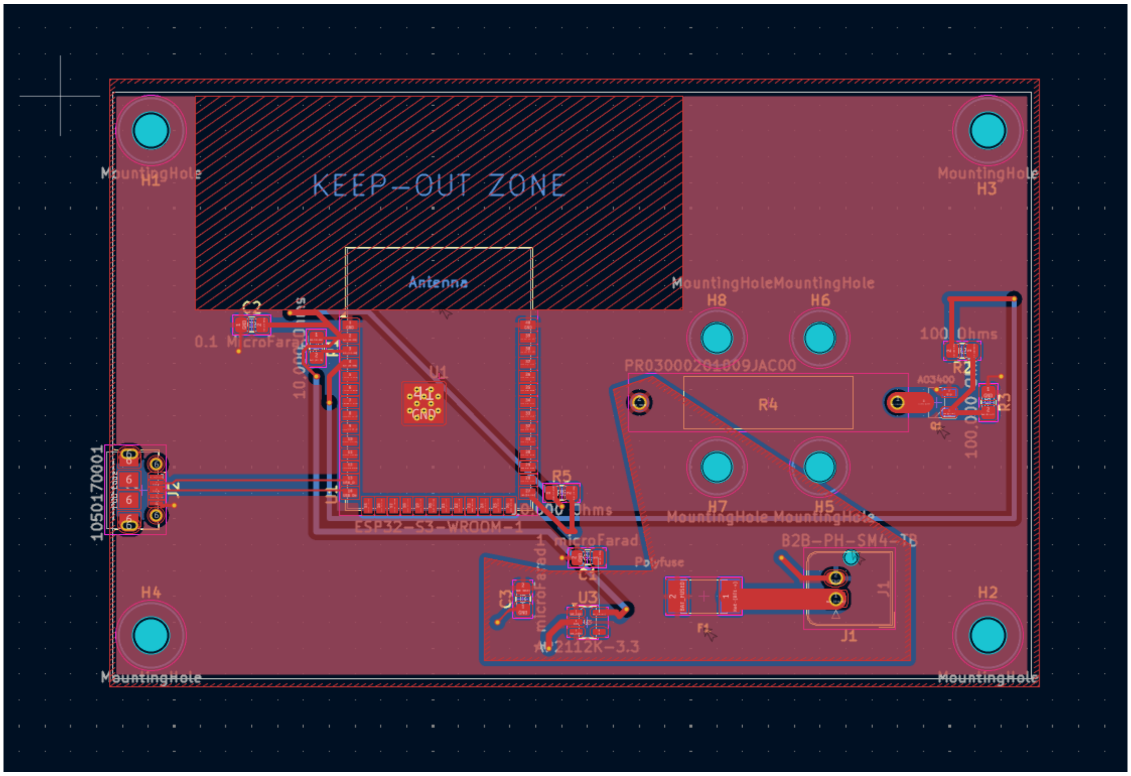

Figure 3.2: Wearable PCB layout.

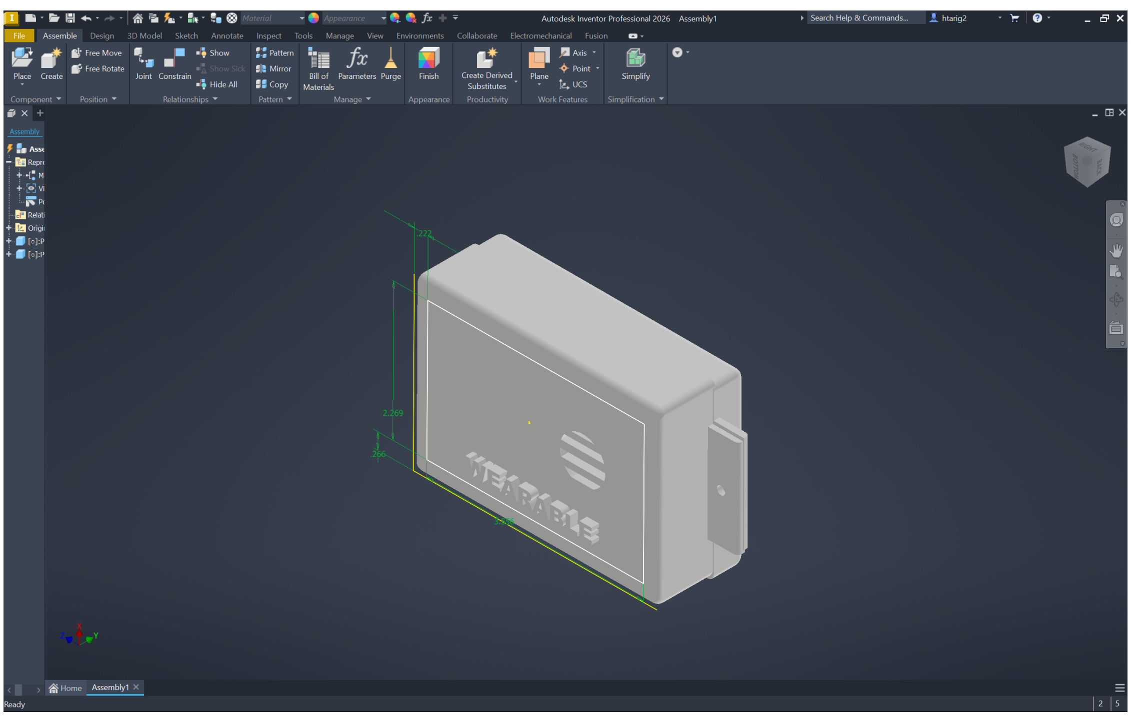

Figure 3.3: Wearable enclosure CAD rendering.

Heater Electrical Analysis

Let the battery voltage range from 3.7 V to 4.2 V. The heater resistor is approximately 10 Ω, yielding:

$$I_{\text{heater}} = \frac{V_{\text{battery}}}{R_{\text{heater}}} = \frac{4.2}{10} \approx 0.42 \text{ A} \tag{3.1}$$

Power dissipation:

$$P_{\text{heater}} = I_{\text{heater}}^2 R_{\text{heater}} = (0.42)^2 \times 10 \approx 1.76 \text{ W} \tag{3.2}$$

This ensures adequate wax melting while remaining below the PTC fuse limit.

MOSFET Operation

With a gate drive of approximately 3.2 V, the AO3400 MOSFET operates in saturation, allowing the required heater current while maintaining low conduction losses [4].

3.6.2 Pillbox Hardware

The pillbox senses lid-state closure through two copper pads that complete a circuit when the box is opened. Its ESP32 is powered through the same LiPo + LDO arrangement as the wearable. The pads are connected to a GPIO configured for capacitive-style detection, treated in firmware as a digital event.

Figure 3.4 shows the full pillbox schematic, and Figure 3.5 shows the PCB layout mounted underneath the pill compartments. Figure 3.6 presents the enclosure design.

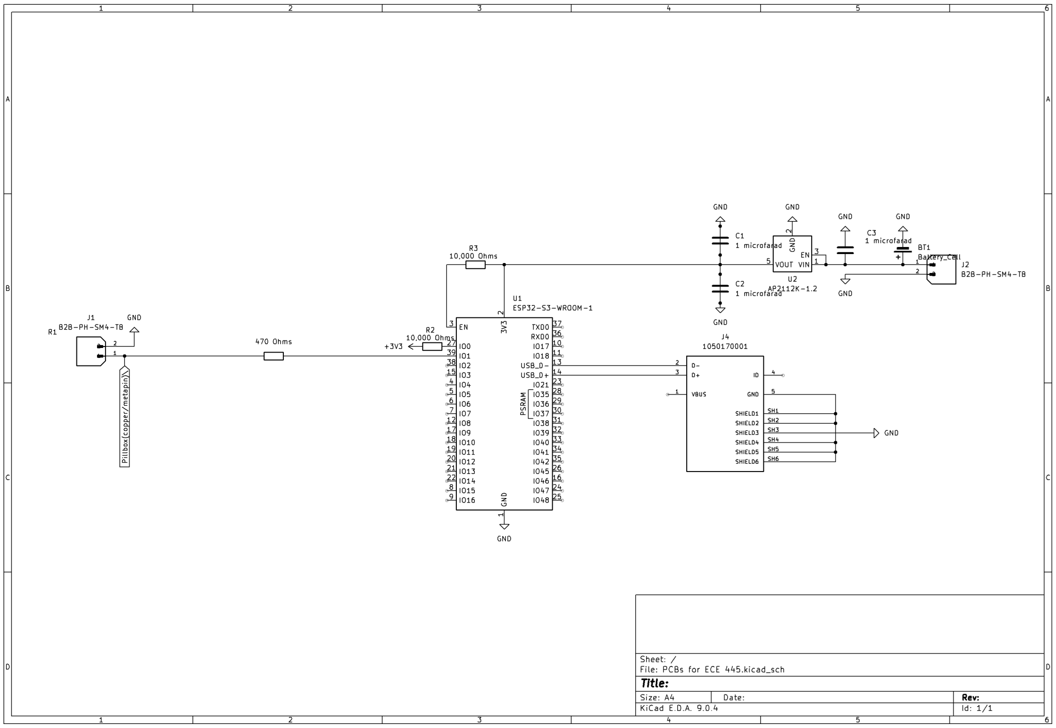

Figure 3.4: Pillbox schematic diagram.

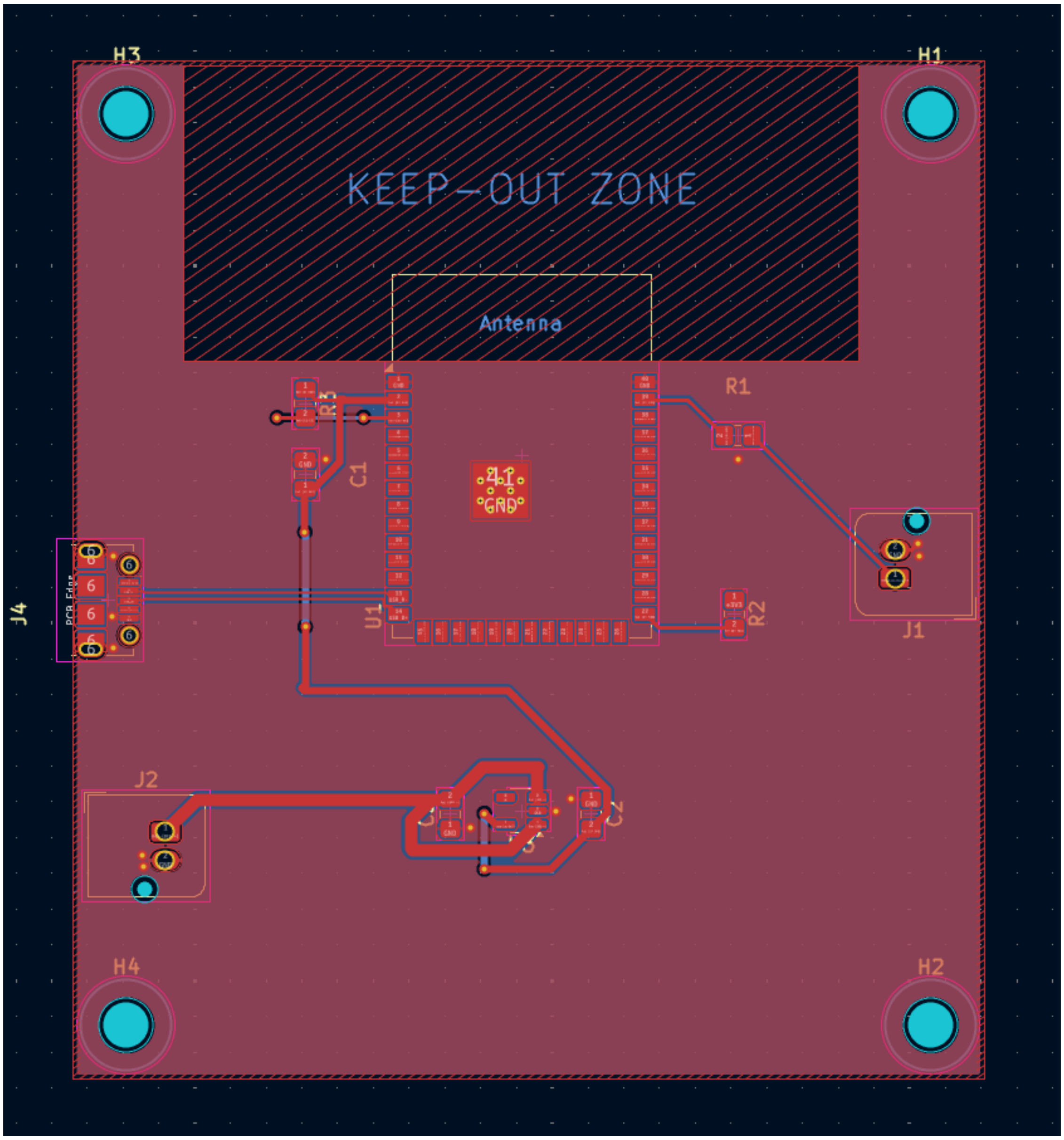

Figure 3.5: Pillbox PCB layout.

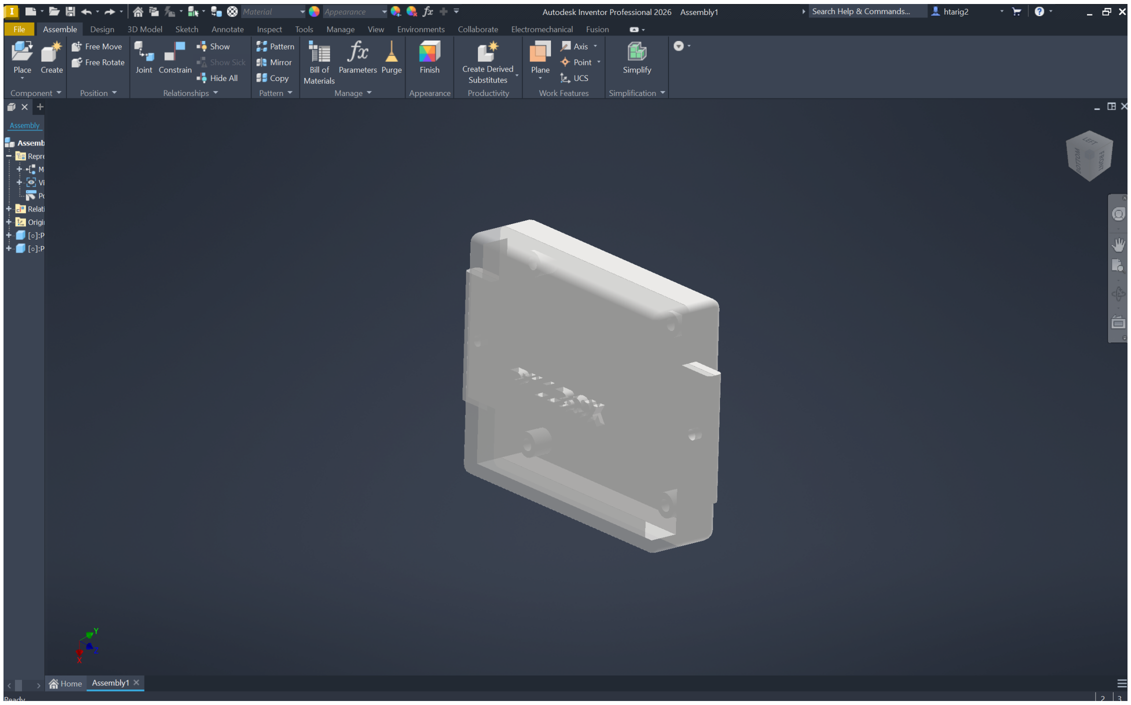

Figure 3.6: Pillbox enclosure CAD model.

3.7 Design Issues and Alternatives

Several design choices evolved over the semester as we refined both the sensing approach and the constraints imposed by safety, manufacturability, and usability.

The pillbox initially relied on a discrete mechanical pushbutton mounted near the lid. Mechanical alignment challenges and concerns about long-term durability led us to replace this with a simpler copper-contact sensing method. By placing copper pads on the lid and enclosure base, the ESP32 could detect lid openings directly through a capacitive-touch GPIO. This solution eliminated moving parts, improved reliability, and reduced the overall mechanical complexity of the subsystem.

For the wearable device, early iterations considered increasing heater power to achieve higher temperatures. Hotplate trials demonstrated that the internal heater assembly reached approximately 80 °C after ten seconds, which was sufficient to melt wax and release scent but approached thresholds associated with burn risk and enclosure softening. Rather than increasing thermal output further, the team shifted focus toward identifying wax formulations that produced stronger scent emission at lower temperatures. This approach provided adequate functionality while reducing safety risk and improving thermal margins.

Software escalation strategies also underwent iteration. An initial design emphasized longer, more persistent visual or audio prompts. However, this conflicted with the project's goal of exploring olfactory cues as the primary escalation vector. The team ultimately adopted a streamlined notification chain: the mobile application provides the initial reminder, and if unacknowledged, the wearable triggers the scent release. This better aligned with the project's objectives and reduced user alert fatigue.

A significant hardware issue also emerged during PCB development and impacted the semester timeline. Our PCBs were submitted during the second departmental ordering round in early October, but due to delays on the department's side, they did not arrive until the day before Fall Break. This left minimal time for assembly and hardware bring-up before major milestones.

After soldering the boards, we discovered that the design omitted a USB-to-UART programming interface. The ESP32-S3-WROOM-1 cannot be programmed over its USB pins without a dedicated bridge IC or an exposed UART header. As a result, the microcontrollers on our assembled PCBs could not be flashed directly.

With insufficient time remaining in the semester to redesign and reorder new PCBs, we implemented a recovery strategy: we programmed identical ESP32-S3 modules on our development breadboard, which included the necessary UART interface. Once flashed, the modules were desoldered from the breadboard and resoldered onto the custom PCBs. Although labor-intensive, this approach allowed us to deliver fully functional hardware for both the Final Demo and Final Presentation.

This experience highlights the importance of incorporating a dedicated programming header or USB–UART interface into early PCB revisions. Doing so ensures reliable firmware flashing, simplifies debugging, and allows rapid iteration during development.

Chapter 4

Requirements and Verification

This chapter presents all functional, electrical, thermal, and timing requirements for the AdheraScent system. Each requirement includes its tolerance, verification procedure, equipment used, quantitative result where available, and pass/fail determination.

The requirements are grouped by subsystem: Wearable (W), Pillbox (P), and Software/Application (S).

4.1 Wearable Requirements and Verification

The wearable scent emitter must operate safely, respond quickly to command signals, and maintain controlled thermal behavior during wax melting.

Table 4.1 summarizes all wearable requirements and their verification.

Table 4.1: Wearable Requirements and Verification

ID	Requirement (with tolerance)	Verification Procedure	Equipment	Result	Pass?
W1	Wearable must receive BLE command from the application within **0.5 s**.	Trigger BLE command from the app and measure time to firmware receipt using debug timestamps in the Python backend and firmware logs.	Laptop, BLE backend logging	0.3 s delay	Yes
W2	Heater activation must begin within **0.5 s** after BLE command receipt.	Send a command, monitor MOSFET gate on an oscilloscope, and record heater onset delay.	Oscilloscope, ESP32 debug output	0.3–0.5 s delay	Yes
W3	Heater current must remain below the PTC fuse trip point of **1.5 A**.	Measure current draw at maximum battery voltage (4.2 V) using an inline ammeter during heater activation.	Multimeter (ammeter mode)	0.42 A	Yes
W4	Wearable resting current must be below **10 A**.	Place device in idle mode with radio inactive and measure quiescent current.	Multimeter, power analyzer	0.1 A	Yes
W5	External surface temperature must stay below **45 °C** during heater operation.	Attach a thermocouple to the wearable enclosure surface and record temperature during a full heating cycle.	Thermocouple, thermometer	25–27 °C	Yes
W6	Internal heater assembly temperature must remain within safe bounds while still melting wax.	Measure internal heater temperature via embedded probe while observing scent emission and verify that it does not exceed 80 °C.	Thermocouple, hotplate test	80 °C with adequate scent release	Yes
W7	MOSFET must saturate properly at gate voltage of approximately **3.2 V**.	Monitor gate-source voltage and drain current under load to confirm operation in the saturation region.	Oscilloscope, multimeter	Saturation behavior observed at 3.2 V gate drive	Yes

4.2 Pillbox Requirements and Verification

The pillbox relies on a lid-contact sensing mechanism built from copper pads. It must detect real openings accurately, avoid false-positive events, and transmit BLE notifications to the application quickly.

Table 4.2 summarizes all pillbox requirements and their verification.

Table 4.2: Pillbox Requirements and Verification

ID	Requirement (with tolerance)	Verification Procedure	Equipment	Result	Pass?
P1	BLE transmission of lid-contact event must occur within **0.5 s** of detection.	Open the pillbox repeatedly and measure BLE event arrival time in logs.	Laptop, BLE backend logging	0.3 s delay	Yes
P2	Full detection pipeline (touch → BLE → app update) must complete within **1.0 s**.	Perform repeated opening events and measure time from lid contact to visible GUI update.	Laptop timer, BLE logs, app UI	0.8 s delay	Yes
P3	Touch detection accuracy must be at least **95%**.	Open the lid 100 times and count missed detections.	Manual testing, logging backend	100/100 detected (100%)	Yes
P4	False-positive rate must be **0%** during idle periods.	Monitor the pillbox for 10 minutes with no interaction and verify that no events are generated.	Logging backend	0 false positives	Yes
P5	Application must correctly log and display pillbox events.	Trigger multiple lid-open events and verify that each event appears in both the log and application UI.	App UI, BLE logs	All events logged and displayed	Yes

4.3 Software Requirements and Verification

The software system spans the mobile application, desktop BLE gateway, and backend BLE communication layer. Its responsibilities include schedule management, escalation logic, and real-time reflection of adherence data.

Table 4.3 summarizes all software requirements and their verification.

Table 4.3: Software Requirements and Verification

ID	Requirement (with tolerance)	Verification Procedure	Equipment	Result	Pass?
S1	Scheduler must trigger reminders within **±10 s** of the programmed time.	Compare scheduled time and actual alert time across multiple trials.	System clock, mobile app	Typical offset ±2–3 s	Yes
S2	Escalation must activate the wearable if the user does not confirm a reminder within the configured timeout.	Trigger a scheduled reminder, do not confirm on the app, and observe whether the wearable transitions through LED escalation and heater activation sequence.	App + BLE gateway, wearable device	Escalation sequence observed in repeated tests	Yes
S3	BLE reconnection must succeed after disconnection.	Manually disconnect wearable and pillbox from BLE and verify that the gateway and app reconnect and resume event handling.	Laptop BLE interface, app UI	Reconnection successful in repeated tests	Yes
S4	All BLE events must be correctly logged and displayed in the UI.	Perform multiple pillbox openings and wearable triggers and verify that each event appears in log output and in the desktop UI.	App UI, gateway backend logs	All events logged and rendered correctly	Yes

Chapter 5

Cost and Schedule

This chapter presents the cost of prototype development, including the bill of materials and labor calculation using the ECE 445 formula. A detailed schedule summarizing weekly progress is also included.

5.1 Bill of Materials

Table 5.1 contains all electrical and mechanical components used in the wearable and pillbox prototypes. Prices reflect small-quantity prototype orders rather than bulk production.

Table 5.1: Bill of Materials for the AdheraScent Prototype

Item	**Qty**	**Cost ($)**	**Supplier**
ESP32-S3-WROOM-1 Module	2	11.84	Digi-Key
LiPo Battery (3.7 V)	2	27.22	Digi-Key
AP2112K-3.3 Low Dropout Regulator	2	0.44	Digi-Key
AO3400 N-Channel MOSFET	2	0.46	Digi-Key
PTC Resettable Fuse (PR0300)	2	0.71	Digi-Key
10 Power Resistor (Heater Element)	1	0.59	Mouser
100 k Resistor (MOSFET Gate Pulldown)	1	0.10	Digi-Key
10 k Resistors (ESP32 Pull-ups)	3	0.25	Digi-Key
100 Gate Resistor	1	0.06	Digi-Key
1 µF Ceramic Capacitors (LDO Input/Output)	4	0.32	Digi-Key
0.1 µF Ceramic Bypass Capacitors	4	0.12	Digi-Key
JST Battery Connectors (2-pin)	2	0.10	Digi-Key
Copper Touch Contacts (Pillbox Lid Sensors)	1	7.99	Amazon
Aluminum Heater Plate (Wearable)	1	4.50	McMaster
Thermal Paste	1	6.99	Amazon
Scented Wax Cartridge	1	14.99	Amazon
Threaded Brass Inserts (M3)	1 pkg	9.49	Amazon
Machine Screws (M3)	1 pkg	8.99	Amazon
3D Printed Enclosures (Wearable + Pillbox)	2	6.00	UIUC Lab
PCB Fabrication	2	0.05	PCBWay
Total Parts Cost		**110.00**	

5.2 Labor Cost

ECE 445 specifies the following labor cost formula:

$$\text{Labor Cost} = 3 \times (40\$/\text{hr}) \times (8\ \text{hr/week}) \times (14\ \text{weeks}) \tag{5.1}$$

Substituting:

$$\text{Labor Cost} = 3 \times 40 \times 8 \times 14 = 13{,}440\ \text{USD} \tag{5.2}$$

Thus, total prototype development cost is:

$$\text{Total Cost} = 92.01 + 13{,}440 = 13{,}532.01\ \text{USD} \tag{5.3}$$

5.3 Project Schedule

Table 5.2 summarizes the work completed by each team member throughout the semester. This table reflects actual project progress, including Fall Break (November 22–30), and updated milestone dates: Mock Demo (12/1), Final Demo (12/3), and Final Presentation (12/10).

Table 5.2: Project Schedule by Week and Team Member

Week	**Jonathan**	**Hardhik**	**Dhiraj**
Week 1 (8/26–9/1)	Brainstorming, system architecture	Brainstorming, requirements drafting	App architecture, BLE feasibility
Week 2 (9/2–9/8)	Draft Design Doc	Power system research, heater feasibility	UI wireframes
Week 3 (9/9–9/15)	Pillbox sensing concept	MOSFET + heater calculations	BLE protocol draft
Week 4 (9/16–9/22)	Pillbox schematic	Wearable schematic	Scheduler logic design
Week 5 (9/23–9/29)	Pillbox PCB layout	Wearable PCB layout rev A	BLE backend (rev A)
Week 6 (9/30–10/6)	Pillbox enclosure CAD	Wearable enclosure CAD	Renderer + main integration
Week 7 (10/7–10/13)	DR preparation	DR preparation	DR preparation
Week 8 (10/14–10/20)	Firmware tuning (pillbox)	Firmware tuning (wearable)	Scheduler rev B
Week 9 (10/21–10/27)	PCB reorder follow-ups	PCB reorder follow-ups	BLE testing
Week 10 (10/28–11/3)	Assemble pillbox PCB	Assemble wearable PCB	Integration testing prep
Week 11 (11/4–11/10)	Touch detection refinement	Thermal cycle tests	App–pillbox BLE validation
Week 12 (11/11–11/17)	Enclosure revisions	Heater duty-cycle tests	Escalation logic verification
Week 13 (11/18–11/24)	System integration before Fall Break	System integration before Fall Break	System integration before Fall Break
Week 14 (11/25–12/1)	Fall Break (11/22–11/30), remote coordination and Mock Demo prep (12/1)	Fall Break (11/22–11/30), remote coordination and Mock Demo prep (12/1)	Fall Break (11/22–11/30), remote coordination and Mock Demo prep (12/1)
Week 15 (12/2–12/8)	Final Demo (12/3)	Final Demo (12/3)	Final Demo (12/3)
Week 16 (12/9–12/12)	Final Presentation (12/10)	Final Presentation (12/10)	Final Presentation (12/10)

Chapter 6

Safety and Standards

AdheraScent incorporates electrical, thermal, and ergonomic safety measures.

6.1 Electrical Safety

- The heater pathway includes a PTC fuse rated at 1.5 A, preventing overcurrent conditions.
- The MOSFET operates within its safe operating area, ensuring reliable, low-loss switching [4].
- All power paths are regulated through the AP2112K-3.3 LDO, ensuring stable microcontroller operation [3].

6.2 Thermal Safety

- Internal heater temperatures reach approximately 80 °C, but the aluminum plate and enclosure insulation limit external temperatures to 25 °C to 27 °C.
- Vent slots in the wearable enclosure allow scent dispersion without trapping heat.

6.3 Applicable Standards

While formal certification is beyond prototype scope, the following standards informed design choices:

- UL 2054 — Lithium Battery Safety [5]

- IEEE 802.15.1 — BLE communication guidelines
- ISO 10993 — Biocompatibility considerations for skin-contacting polymers

Chapter 7

Ethics and Privacy

AdheraScent adheres to the IEEE Code of Ethics [1]. Key considerations include:

7.1 User Safety

The heater subsystem is thermally isolated, and all enclosures prevent contact with hot elements. All electronics operate on low-voltage DC, consistent with good engineering practice.

7.2 Data Privacy

No medical data is collected or transmitted. All schedule information resides locally on the user's device. No cloud storage or third-party analytics are used.

7.3 Accessibility

By integrating visual, tactile, and olfactory cues, the system aims to support users with diverse sensory needs.

Chapter 8

Conclusion

The AdheraScent system demonstrates a functional proof-of-concept combining a pillbox sensing module, a wearable scent-release device, and a mobile application that manages medication schedules, reminders, and escalation logic. Hardware testing validated safe heater operation, stable BLE performance, and accurate lid-open detection using copper contact pads. Software testing confirmed correct scheduling behavior, event logging, and full end-to-end communication throughout the system.

Limitations and Development Uncertainties

One significant technical limitation encountered was the lack of a USB-to-UART programming interface on the initial PCB revision. This prevented in-system flashing of the ESP32 modules and required us to program them externally on a breadboard, then desolder and resolder the modules onto the custom PCBs. This workaround introduced uncertainty related to rework reliability and significantly limited the amount of firmware debugging and iteration we could perform late in the semester.

Additional uncertainties include incomplete long-term testing of wax performance across repeated heat cycles, limited characterization of battery life under real-world usage patterns, and BLE performance that was evaluated only in controlled indoor environments.

Future Work

Future improvements may include:

- adding a dedicated UART programming header or USB–UART bridge to the PCB,
- implementing replaceable scent cartridges for long-term usage,

- improving thermal monitoring and power management,
- expanding the mobile app to support analytics and cross-platform releases.

Overall, despite several development challenges, the prototype validates the feasibility of using olfactory cues as a novel escalation method to improve medication adherence.

References

1. IEEE Code of Ethics, IEEE Standards Association. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

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