Adherascent

ECE 445 Design Document - Spring 2026

Megan Shapland
Wenchang Qi

Professor: Craig Shultz
TA: Jiaming Xu

February 28, 2026

1 Introduction

1.1 Problem

Consistent medication adherence is a fundamental pillar of healthcare, yet it remains a significant challenge, particularly for the aging population. As individuals age, the reliability of cognitive functions, vision, and hearing often diminishes, making it increasingly difficult to manage complex daily medication regimens. While a variety of adaptive devices and digital reminders exist, they frequently fail to meet the needs of those most reliant on them. Traditional auditory or visual notifications are often lost within the pervasive "noise" of modern digital environments, where users are saturated with constant alerts and sounds.

Furthermore, many existing smart medical devices suffer from a high barrier to entry due to intimidating user interfaces and complex setup procedures, such as manual time setting. For a population that may be less familiar with modern technology, these design hurdles often lead to the abandonment of the device rather than improved health outcomes. There is a critical need for a non-intrusive, intuitive reminder system that bypasses the sensory fatigue of traditional notifications while ensuring a verifiable feedback loop for medication compliance.

1.2 Visual Aid

The pillbox in the image has 7 compartments, one for each day of the week. each compartment has its own magnet and sensor to detect if it is open or closed. The tall cylindrical stack will emit the scent when triggered. and there are buttons for time input, a space for indicator lights, and a USB-C to supply power, and a port for refilling the scent reservoir. If the pillbox is not opened by the appointed time, a scent will be emitted. The device also contains the capability to expand the function in later development via Wi-Fi and Bluetooth.

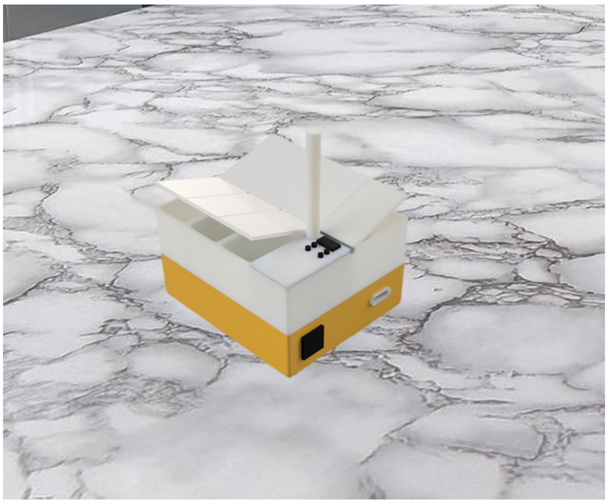

Figure 1: Visual-Aid

1.3 Solution

To address these challenges, we propose AdhereScent, an automated smart pill dispenser that utilizes scent as the primary notification mechanism. By leveraging the olfactory sense—which is less susceptible to the "notification fatigue" associated with sight and sound—AdhereScent provides a distinct, gentle, yet persistent reminder that a dose is due. The system is designed to minimize user frustration by automating technical tasks, such as time synchronization, which is handled via an integrated Real-Time Clock chip.

The device is centered around a custom-designed PCB featuring an ESP32 microcontroller, which manages the system logic, connectivity, and scheduling. When a scheduled dose is reached, the microcontroller triggers a modified ultrasonic aroma diffuser to release a scent. To ensure adherence rather than just notification, the scent persists until the user physically opens the specific medication compartment. This closed-loop feedback is achieved through the use of Hall Effect sensors and permanent magnets embedded in the pill box lids, allowing the system to detect the precise open/closed state of each compartment. This integration of olfactory actuation and magnetic sensing creates a seamless, "smart" environment that supports patient health with minimal technological friction.

1.4 High-Level Requirements

- The system must ensure the olfactory mechanism triggers within 5 seconds of the scheduled time. Furthermore, scent generation must be perceptible—producing visible mist within 2 seconds of activation—and must automatically cease within 1 second once the "Lid Open" state is detected by the sensing subsystem to ensure a tight feedback loop.
- Upon the initial user connection to the integrated Web server, the control subsystem must capture the client's local timestamp to synchronize the system clock within 1 minute of powering on. This synchronization must be maintained with sufficient stability to ensure the scheduling logic remains accurate throughout the device's operation.
- The power subsystem must provide stable, regulated rails to support simultaneous high-current demands, specifically delivering at least 300mA on the 3.3V logic rail to handle ESP32 transmission spikes and 800mA on the 5.0V actuator rail for the atomizer. To protect both the hardware and the user, the system must maintain a voltage ripple below 50mV to prevent brownouts and include a safety cutoff that disconnects the battery if the voltage drops below 2.5V.

2 Design

2.1 Block Diagram

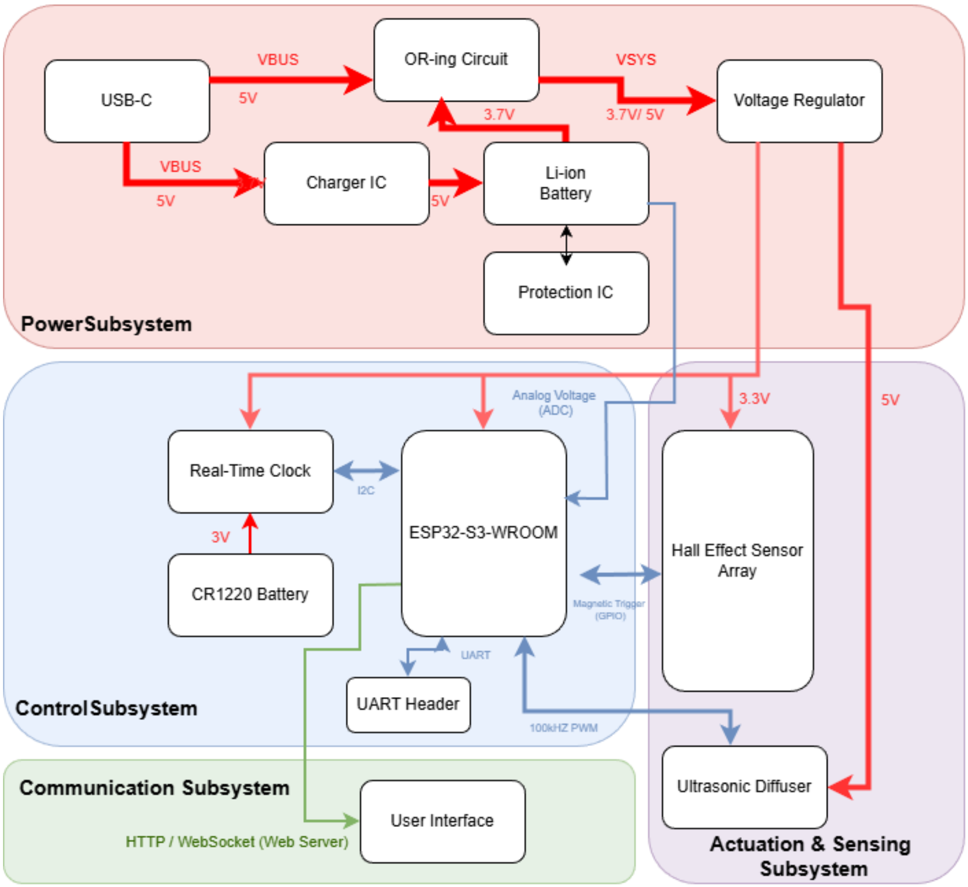

Figure 2: Block Diagram

2.2 Subsystem Descriptions, Requirements and Verifications

2.2.1 Power Subsystem

Functions:

- **Power Path Management (OR-ing):** Utilizes a Schottky diode (D2) and a P-Channel MOSFET (Q4) to automatically select between USB-C power (VBUS) and battery power (VBAT).

- **Battery Charging & Monitoring:** Employs an LTC4054 linear charger to safely charge the Li-ion battery. A voltage divider (R14, R15) provides an analog BAT_MONITOR signal.

- **Battery Protection:** Incorporates a DW01A protection IC alongside dual N-Channel MOSFETs (Q5A, Q5B) to protect the Li-ion cell from over-charge, over-discharge, and over-current conditions.

- **Voltage Regulation:** Converts the raw system voltage (VSYS) into two regulated rails. An XC6220 LDO regulator provides a clean 3.3V rail. An AP3012 Step-Up (Boost) converter provides a 5.0V rail.

Interactions with Other Subsystems:

- **Control Subsystem:** Supplies continuous 3.3V DC to the Control and Sensing Subsystems. Outputs the analog BAT_MONITOR signal to the ESP32's ADC. Receives the digital 5VCTRL GPIO signal from the ESP32 to enable or disable the 5.0V boost converter.
- **Olfactory Subsystem:** Supplies 5.0V DC to the Olfactory Subsystem to drive the ultrasonic atomizer.
- **Sensing Subsystem:** Supplies continuous 3.3V DC to the Sensing Subsystems.

Requirement	**Verification Procedure**	**Success Criterion**
1. Battery Charging Current: The LTC4054 charger IC must provide a constant charging current of 500 mA ± 50 mA to the battery when powered via USB-C.	1. Connect a partially discharged Li-ion battery (approx. 3.5V) to the battery terminal. 2. Connect a digital multimeter (DMM) in series to measure current. 3. Plug a 5V source into the USB-C receptacle.	The DMM measures a continuous current between 450 mA and 550 mA flowing into the battery.
2. Logic Voltage Regulation: The XC6220 LDO must output a stable logic voltage of 3.3V ± 0.15V under a continuous load of up to 300 mA.	1. Power VSYS using a bench power supply set to 3.5V. 2. Connect a 3.3V-compatible electronic load set to 300 mA to the +3V3 output. 3. Measure the +3V3 rail with a DMM.	The DMM reads a voltage strictly between 3.15V and 3.45V.
3. Actuator Power Control: The Boost Converter must maintain an output voltage of 5.0V ± 0.2V only when the 5VCTRL signal is logic HIGH (> 1.5V).	1. Apply 3.7V to VSYS. 2. Apply 3.3V (Logic HIGH) to the 5VCTRL pin and measure the +5V output. 3. Apply 0V (Logic LOW) to the 5VCTRL pin and measure the +5V output.	The rail measures 4.8V to 5.2V during Step 2. The rail is disabled during Step 3.
4. Over-Discharge Protection: The Battery Management System (BMS) must cut off power output if the battery voltage drops below 2.5V.	1. Connect a variable bench power supply to the battery input terminals. 2. Apply a 100 mA load to the VSYS rail. 3. Gradually decrease the power supply voltage from 3.7V down to 2.0V while monitoring the load current.	The load current drops to 0 mA exactly when the bench power supply voltage reaches between 2.4V and 2.6V.

Table 1: Power Subsystem Requirements and Verifications

Requirements and Verifications:

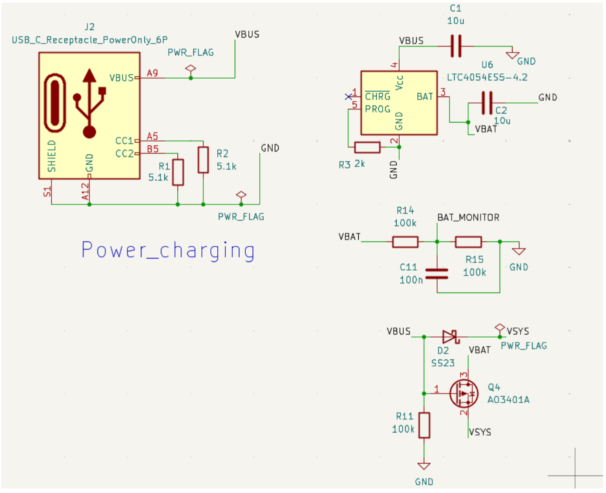

Figure 3: Charger IC Schemtic

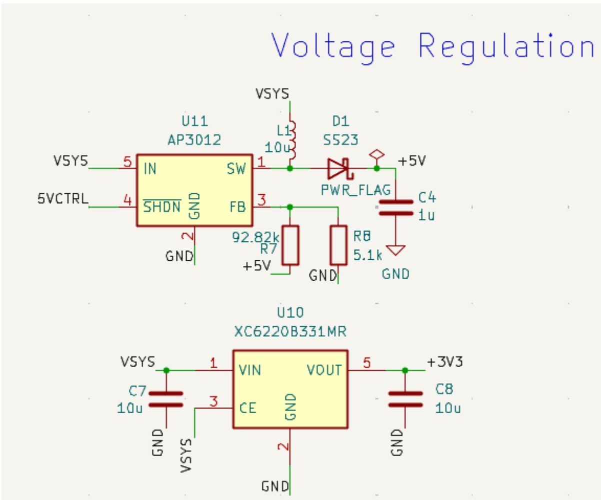

Figure 4: Voltage Regulator Schematic

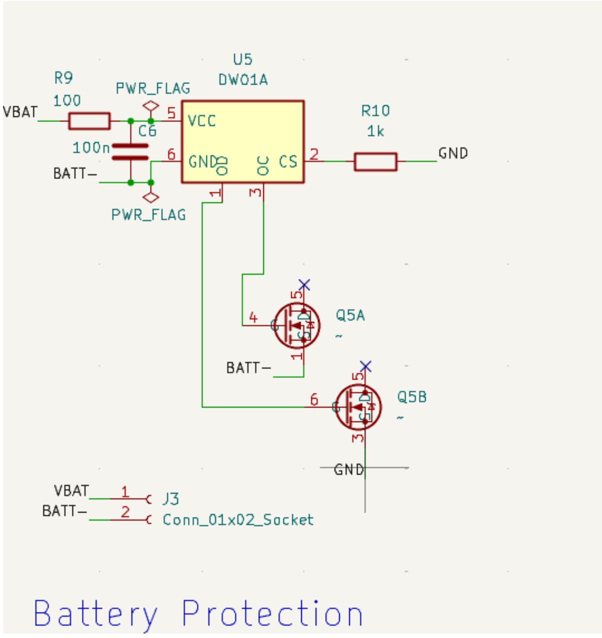

Figure 5: Protection IC Schematic

2.2.2 Control Subsystem

The Control Subsystem serves as the central processing unit of the AdhereScent device, centered around the ESP32-S3-WROOM-1 microcontroller module. It is responsible for orchestrating the timing schedule, processing sensor feedback, driving the notification hardware, and handling wireless connectivity. The subsystem uses an internal real-time clock synced via Captive Portal over Wi-Fi, complemented by an external hardware I2C RTC (with a CR1220 backup battery) to maintain schedule integrity during network or primary power outages.

Functions:

- **Logic & Scheduling:** Executes the primary state machine to monitor the current time against the user's medication schedule and trigger alarms accordingly.
- **I/O Processing:** Utilizes GPIO pins to monitor up to 7 independent medication compartments (HALL_1 through HALL_7) and manage the actuation of the scent diffuser.
- **Connectivity:** Leverages the ESP32-S3's integrated 2.4GHz Wi-Fi to fetch network time (NTP) and host a lightweight web server (HTTP/WebSocket) for user scheduling.
- **Battery Monitoring:** Uses an analog-to-digital converter (ADC) pin to continuously read the BAT_MONITOR voltage divider signal, tracking the battery's state-of-charge.
- **System Debug & Flashing:** Includes a standard UART header (TX/RX) and an automated boot/reset button circuit (SW1, SW2) for firmware programming and diagnostics.

Interactions with Other Subsystems:

- **Power Subsystem:** Receives regulated 3.3V power. Reads the analog BAT_MONITOR signal to determine battery voltage. Outputs the 5VCTRL digital signal to enable the 5.0V Boost Converter only when actuation is needed.

- **Sensing Subsystem:** Reads digital logic levels from the Hall Effect Sensor Array via pins HALL_1 to HALL_7 to detect if a specific pill box lid has been opened, forming the adherence feedback loop.
- **Olfactory Subsystem:** Outputs a digital trigger signal (DIFF_TRIG) through a 100 Ω current-limiting resistor to actuate the ultrasonic diffuser's isolation circuit.

Requirements and Verifications:

Requirement	Verification Procedure	Success Criterion
1. Sensor Input Latency: The microcontroller must register a state change (Logic HIGH to LOW) on any HALL_X pin and execute the corresponding interrupt/callback within 200 ms.	1. Power the system and connect an oscilloscope to the HALL_1 input and a designated debug output pin. 2. Configure the firmware to toggle the debug pin immediately upon detecting a falling edge on HALL_1. 3. Manually pull HALL_1 to GND and measure the time delta between the falling edge of HALL_1 and the rising edge of the debug pin.	The measured time delta on the oscilloscope is $\leq$ 200 ms for 10 consecutive trials.
2. Actuation Control Signals: Upon reaching a scheduled medication time, the MCU must assert both 5VCTRL and DIFF_TRIG to a logic HIGH level (3.3V $\pm$ 0.15V) to activate the diffuser.	1. Connect a digital multimeter (DMM) to the 5VCTRL pin and another to the DIFF_TRIG pin (after R12). 2. Use the Web UI or UART interface to force a "medication due" event. 3. Record the voltage levels on both pins.	Both DMMs record a voltage strictly between 3.15V and 3.45V during the active notification period.
3. I2C RTC Communication: The ESP32 must successfully communicate with the external RTC via I2C (I2C_SCL on pin 21, I2C_SDA on pin 22) operating at a standard 100 kHz $\pm$ 5 kHz clock frequency.	1. Connect a logic analyzer to the I2C_SCL and I2C_SDA lines. 2. Trigger a manual time-sync read from the RTC via the firmware. 3. Analyze the captured I2C waveform.	The I2C_SCL frequency measures between 95 kHz and 105 kHz, and the SDA line shows valid Acknowledge (ACK) bits from the RTC device.
4. Wi-Fi & Client-Side Time Synchronization: From a cold boot, the MCU must establish a 2.4GHz Wi-Fi Access Point (AP). Upon the first connection from a client device (e.g., a smartphone) to the hosted web server, the system clock must be synchronized via a client-injected timestamp within 1 minute of the user accessing the web interface.	1. Configure the ESP32 to start in Access Point (AP) mode. 2. Connect the UART header to a PC and open a serial terminal. 3. Press the Reset button (SW1) and start a stopwatch. 4. Open the hosted web page in a browser. 5. Stop the stopwatch when the serial terminal prints the "System Time Synchronized from Client" (or equivalent) log.	The stopwatch reads $\leq$ 1 minute from the moment the web page is loaded for 5 consecutive cold boots.
5. Battery Voltage Measurement: The ADC must interpret the BAT_MONITOR signal accurately, computing the raw battery voltage within $\pm$ 0.1V of the true value.	1. Connect a bench power supply set to exactly 3.8V to the VBAT input. 2. Read the software-calculated battery voltage output over the UART debug interface. 3. Compare the UART output to the bench power supply value.	The UART outputs a calculated battery voltage between 3.7V and 3.9V.

Table 2: Control Subsystem Requirements and Verifications

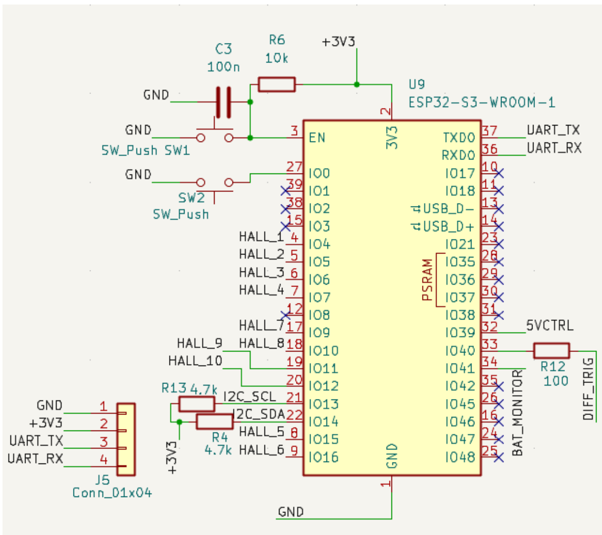

Figure 6: ESP32 Schematic

2.2.3 Actuation & Sensing Subsystem

The Actuation & Sensing Subsystem combines the physical notification hardware (olfactory mechanism) and the adherence tracking hardware (magnetic switches). It is responsible for releasing the scent upon receiving a command and continuously monitoring the medication compartments to close the feedback loop once the user retrieves their medication.

Functions:

- **Mist Generation:** Utilizes an ultrasonic atomizer connected via header J16 to generate the scent. The actuator is driven by an AO3422 N-Channel MOSFET (Q2) functioning as a low-side switch.
- **High-Frequency Filtering:** Incorporates an LC filter network (L2 at 100 uH, alongside C9 and C10) on the 5.0V rail to stabilize the power supply and suppress high-frequency switching noise generated by the ultrasonic atomizer.
- **Fail-Safe Triggering:** Employs a 10 kOhm pull-down resistor (R5) at the MOSFET gate to ensure the actuator remains completely off if the DIFF_TRIG signal is floating during boot or reset states.
- **Compartment Monitoring:** Interfaces with up to 10 independent Hall Effect sensors via dedicated 3-pin headers (J1, J6-J14). These sensors detect the magnetic fields of permanent magnets embedded in the pill box lids to verify the precise open/closed state of each compartment.

Interactions with Other Subsystems:

- **Power Subsystem:** Draws high-current 5.0V DC for the mist maker circuit and clean 3.3V DC to power the Hall Effect sensor array.
- **Control Subsystem:** Receives the 3.3V logic DIFF_TRIG signal to activate the N-channel MOSFET. Outputs digital logic signals (HALL_1 through HALL_7) back to the ESP32 GPIO pins to trigger the software interrupt that stops the scent release.

Requirements and Verifications:

Requirement	Verification Procedure	Success Criterion
1. Actuator Switching Reliability: The AO3422 MOSFET must fully saturate when driven by a 3.3V logic HIGH signal, allowing sufficient current flow to the atomizer.	1. Apply 5.0V to the +5V net and connect an equivalent load resistor (e.g., 5 Ohms) across J16. 2. Apply 3.3V to the DIFF_TRIG net. 3. Measure the voltage drop across the Drain and Source of Q2 (V_DS) using a DMM.	The measured V_DS is $\leq$ 0.15V, indicating the MOSFET is fully saturated and not dissipating excess heat.
2. Spurious Trigger Prevention: The 10 kOhm pull-down resistor (R5) must keep the MOSFET gate voltage below its threshold limit when the control line is disconnected or high-impedance.	1. Apply 5.0V to the +5V net. 2. Disconnect the ESP32 microcontroller (leave DIFF_TRIG floating). 3. Measure the voltage at the MOSFET gate relative to GND.	The gate voltage measures $\leq$ 0.1V, and no current flows through the J16 load.
3. Sensor Detection Accuracy: Each Hall Effect sensor must correctly detect lid state transitions with 100% accuracy across consecutive trials to ensure adherence tracking.	1. Power the sensor array with 3.3V. 2. Connect an oscilloscope to the HALL_1 signal pin. 3. Simulate lid opening by moving a test magnet away from the sensor 50 separate times using a mechanical jig.	The oscilloscope captures exactly 50 distinct logic level transitions matching the movement, with 0 false positives or missed events.
4. LC Filter Stability: The passive LC network (L2, C9, C10) must suppress power supply ripples on the +5V line caused by the atomizer's high-frequency draw to prevent interference with the Control Subsystem.	1. Connect the fully assembled Mist Maker to J16. 2. Apply a continuous 100 kHz PWM signal to DIFF_TRIG. 3. Connect an oscilloscope across the +5V net (before the inductor) with AC coupling enabled.	The peak-to-peak voltage ripple on the +5V line remains $\leq$ 150 mV during continuous actuation.

Table 3: Actuation & Sensing Subsystem Requirements and Verifications

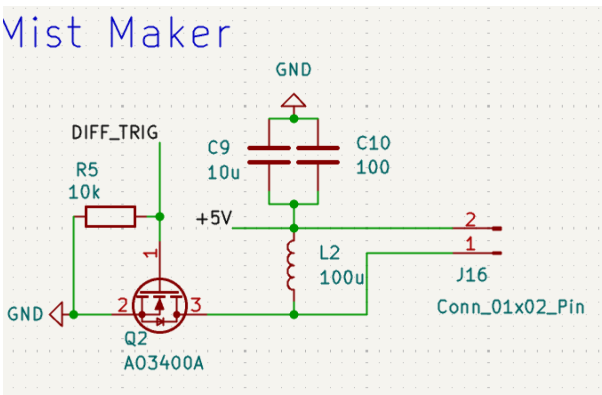

Figure 7: Ultrasonic Mist Generation Schematic

2.2.4 Communication Subsystem

The Communication Subsystem acts as the primary user interface for the AdhereScent device, fulfilling the need for an accessible, technology-friendly scheduling method. Rather than relying on external mobile applications or complex cloud infrastructure, the ESP32 microcontroller operates in Soft Access Point (SoftAP) mode to host a local web server. Users can connect their personal smartphone or computer directly to the device's localized Wi-Fi network to access a simple, embedded HTML/JavaScript webpage. This interface allows caregivers or users to intuitively input medication schedules, which are then parsed and saved to the device's non-volatile storage.

Functions:

- **SoftAP Hosting:** Configures the ESP32's 2.4 GHz radio to broadcast a localized Wi-Fi SSID (e.g., "AdhereScent_Setup"), providing an isolated network for configuration without requiring internet access.
- **Web Server Execution:** Runs a lightweight HTTP server to serve the User Interface (HTML/CSS/JS) to any connected client browser.
- **Data Parsing & Scheduling:** Receives HTTP POST requests containing user-defined medication times, sanitizes the payload, and updates the active scheduling logic.
- **State Persistence:** Writes the updated scheduling arrays to the ESP32's flash to ensure alarm configurations survive power cycles.

Interactions with Other Subsystems:

- **Control Subsystem:** Acts as a software layer operating on the Control Subsystem's ESP32 hardware. Modifies the global scheduling variables that the main firmware loop evaluates against the current RTC time.

Requirements and Verifications:

Requirement	Verification Procedure	Success Criterion
1. SoftAP Initialization: The ESP32 must successfully establish the local Wi-Fi network and begin broadcasting its SSID within 5 seconds of the system booting.	1. Power cycle the device. 2. Use a smartphone with a Wi-Fi analyzer app to scan for the designated SSID. 3. Start a stopwatch at the exact moment of power-on and stop it when the SSID appears.	The stopwatch records a time of $\leq$ 5 seconds across 5 consecutive boot cycles.
2. Web Server Latency: The embedded HTTP server must respond to a standard HTTP GET request and serve the full HTML interface payload in under 500 ms to ensure a responsive user experience.	1. Connect a laptop to the ESP32's SoftAP network. 2. Open a web browser's Developer Tools (Network tab). 3. Navigate to the local IP address and record the "Load Time" of the primary HTML document.	The measured document load time is $\leq$ 500 ms for 10 consecutive page refreshes.
3. Schedule Data Integrity: Time values submitted via the web interface must be correctly parsed and saved to the microcontroller's Non-Volatile Storage (NVS) without data corruption.	1. Access the web interface and submit a specific medication schedule (e.g., 08:30 AM). 2. Power cycle the device to force it to reload parameters from NVS. 3. Read the stored schedule via the UART debug terminal.	The UART terminal outputs the exact times matching the original web submission.
4. Concurrent Connection Handling: The SoftAP and web server must remain stable when accessed by at least two distinct client devices simultaneously.	1. Connect two separate smartphones to the AdhereScent Wi-Fi network. 2. Simultaneously attempt to load the scheduling webpage on both devices. 3. Submit a timer update from Device A while Device B is actively refreshing the page.	Both devices load the interface without connection timeouts (HTTP 200 OK), and the schedule is successfully updated.

Table 4: Communication Subsystem Requirements and Verifications

2.3 Tolerance Analysis

The critical function of the project is the ultrasonic mist generation based on the Actuation Subsystem. The subsystem generates a transient high-voltage peak ($V_{pk} \geq 30$V) to drive the piezoelectric micro-porous atomizer from a low-voltage 5V DC rail. The circuit employs a single-inductor boost topology driven by a logic-level MOSFET. To ensure high reliability and optimal atomization, the switching MOSFET was explicitly selected as the AO3422, which features a Drain-Source Breakdown Voltage (V_{ds}) of 55V.

The feasibility of the design is mathematically proven through the principle of inductive energy transfer. Let $V_{in} = 5$V, $L = 100\ \mu$H (inductance of L_2), and $C_p \approx 3$ nF be the equivalent parasitic capacitance of a standard 16mm/20mm piezoelectric disc. The microcontroller outputs a PWM signal with frequency $f_s = 110$ kHz and a nominal duty cycle $D_{nom} = 0.4$.

During the MOSFET ON-time (t_{on}), the inductor current ramps linearly:

$$I_{pk} = \frac{V_{in}}{L} \cdot \left(\frac{D_{nom}}{f_s} \right) = \frac{5\text{V}}{100\ \mu\text{H}} \cdot 3.63\ \mu\text{s} = 0.1815\ \text{A} \tag{1}$$

Upon MOSFET turn-off, the stored inductive energy (E_L) forms an LC resonance with the atomizer's parasitic capacitance (E_C), transferring the energy:

$$\frac{1}{2}LI_{pk}^2 = \frac{1}{2}C_pV_{pk}^2 \implies V_{pk} = I_{pk}\sqrt{\frac{L}{C_p}} \tag{2}$$

Under nominal conditions, the peak resonant voltage across the atomizer is:

$$V_{pk(nom)} = 0.1815 \text{ A} \cdot \sqrt{\frac{100 \ \mu\text{H}}{3 \text{ nF}}} \approx 33.1 \text{ V} \tag{3}$$

Tolerance and Worst-Case Margin Analysis:
To validate the system's robustness, we analyze the worst-case scenario where software latency or timer drift causes an unintended extension of the duty cycle to $D_{max} = 0.5$ (50%). Under this fault condition, the ON-time increases to 4.54 μs, resulting in a higher peak current $I_{pk(max)} = 0.227$ A.

The resultant worst-case transient voltage peak becomes:

$$V_{pk(max)} = 0.227 \text{ A} \cdot 182.57 \approx 41.4 \text{ V} \tag{4}$$

The selected AO3422 MOSFET has a maximum V_{ds} rating of 55V. Even under the worst-case duty cycle drift, the system maintains a secure voltage margin of 13.6V (55V − 41.4V). This analysis confirms that the optimized design is technically sound, eliminating the need for aggressive TVS clamping that would otherwise suppress the atomization efficiency, thereby achieving a perfect balance between mechanical actuation performance and electronic reliability.

3 Cost Analysis

Mfr	Part #	Desc	Price	Qty	Total	URL
ADI	LTC4057ES5-4.2#TRMPBF	-40°C˜+85°C 1 200uA...	5.39	1	5.40	Link
Diodes	AP3012KTR-G1	-40°C˜+85°C 1 1.5M...	0.11	1	0.11	Link
Torex	XC6220B331MR-G	-40°C˜+85°C 1 1A 3.3V...	0.47	1	0.48	Link
ESPRESSIF	ESP32-S3-WROOM-1-N16R8	-103.5dBm -40°C˜+65°...	5.74	1	5.74	Link
Slkor	DW01A	-40°C˜+85°C 1 1.5V˜...	0.02	1	0.02	Link
MAXIM	DS3231MZ+	-40°C˜+85°C 2.3V˜...	3.68	1	3.69	Link
SM Switch	SMG-01-H050A1	12V 2.5N 50mA 5mm 6...	0.03	2	0.06	Link
VISHAY	CRCW08055K10FKEA	-55°C˜+155°C 125mW...	0.01	3	0.03	Link
VISHAY	CRCW08052K00FKEA	-55°C˜+155°C 125mW...	0.01	1	0.01	Link
VISHAY	CRCW08054K70JNEA	-55°C˜+155°C 125mW...	0.01	2	0.02	Link
VISHAY	CRCW080510K0JNEA	-55°C˜+155°C 10kΩ 12...	0.01	2	0.02	Link
VISHAY	CRCW080593K1FKEA	-55°C˜+155°C 125mW...	0.02	1	0.03	Link
VISHAY	CRCW0805100KFKEA	-55°C˜+155°C 100kΩ ...	0.01	3	0.03	Link
VISHAY	CRCW08051K00FKEA	-55°C˜+155°C 125mW...	0.01	1	0.01	Link
VISHAY	CRCW0805100RFKEA	-55°C˜+155°C 100Ω 1...	0.01	2	0.02	Link
FUXINSEMI	FS8205A	-55°C˜+150°C 1.2V 1.5...	0.07	1	0.08	Link
AOS	AO3401A	1 P-Channel 14nC@10V...	0.06	1	0.06	Link
AOS	AO3422	-55°C˜+150°C 1 N-chan...	0.08	1	0.08	Link
TECHFUSE	SL1265-101M	100uH 138mΩ 2A 3.5...	0.44	1	0.45	Link
TECHFUSE	SL0420-100M	10uH 2.5A 200mΩ 2A...	0.12	1	0.13	Link
KINGHELM	KH-2.54PH180-1X4P-L11.5	-40°C˜+105°C 1 1x4P ...	0.03	1	0.04	Link
JST	B2B-PH-K-S-GW	-25°C˜+85°C 1 100V 1...	0.13	2	0.27	Link

Mfr	Part #	Desc	Price	Qty	Total	URL
GCT	USB4125-GF-A	-30°C˜+85°C 1 3A 48V...	0.95	1	0.95	Link
Keystone	3000	- ROHS	0.33	1	0.34	Link
onsemi	SS23	-65°C˜+125°C 1 Indepen...	0.38	2	0.76	Link
KEMET	C0805C105J3RECAUTO	1uF 25V X7R ±5% 0805...	0.08	1	0.09	Link
muRata	GRM21B7U1A104JA01L	100nF 10V U2J ±5% 08...	0.15	5	0.76	Link
KEMET	C0805C106J8RACAUTO	10V 10uF X7R ±5% 080...	0.19	3	0.59	Link
Generic	Mist Maker Atomizer Film	Humidifier Repair Parts	7.49	1	7.49	Link
0						

Cost Category	**Description**	**Unit Price (USD)**	**Quantity**	**Total (USD)**
Hardware (BOM)	Electronic Components	$27.73	5 units	$277.30
Hardware (BOM)	PCB (99x80mm, 2-layer)	$5.00	5 units	$25.00
Labor (NRE)	UIUC ECE Engineer A	$60.00/hr	130 hrs	$7800.00
Labor (NRE)	UIUC ECE Engineer B	$60.00/hr	130 hrs	$7800.00
			Estimated Total Project Cost:	**$1,5763.65**

Table 6: Project Cost Analysis Simulation (13-Week Part-time)

4 Schedule

The following schedule defines the project's progression for the Spring 2026 semester. It balances hardware fabrication, software development, and the mandatory verification phases required for the ECE 445 Design Document and Final Demo.

Week	Megan Shapland	Wenchang Qi	Everyone
2/16	Initial Product 3D model.	Initial PCB design.	Component Ordering
2/23	Refine enclosure for sensor mounting.	Finalize PCB layout and sub-circuits.	Design Document
3/02	3D print initial prototypes for fit testing.	Solder Power Subsystem and verify rails.	Subsystem Verification
3/09	Fabricate internal support structures for atomizer.	Develop ESP32 Wi-Fi SoftAP and NTP sync logic.	Hardware/Software Sync
3/16	Integrate Hall Effect sensors into the pill box lid.	Implement I2C communication with Hardware RTC.	Mid-term Progress Report
3/23	Test mechanical durability of the hinge system.	Write ADC logic for battery voltage monitoring.	Peer Review Phase
3/30	Optimize airflow for scent distribution.	Develop interrupt-driven sensing for 10 compartments.	Integration Testing
4/06	Design labeling and accessibility features.	Optimize power consumption and sleep modes.	System Debugging
4/13	Finalize Product 3d model.	Finalize User Interface.	Mock Demo
4/20	Assemble final unit and verify aesthetic finish.	Perform stress testing on web server connections.	Finalize Assembly; potential bug fix
4/25	Prepare presentation visual aids.	Document verification results and tolerances.	Final Demo
5/04	Complete mechanical sections of paper.	Complete electrical/software sections of paper.	Final Paper

Table 7: Spring 2026 Project Schedule and Task Distribution

4.1 Ethics, Safety, Societal Impact, and Engineering Standards

Medication nonadherence is a critical public health challenge that significantly degrades patient outcomes and inflates unnecessary healthcare costs annually [1]. This project addresses this societal issue by replacing abrasive traditional alarms with a gentle, closed-loop ultrasonic aroma diffuser, reducing technological friction and actively supporting patient health through physical verification. In strict alignment with the IEEE Code of Ethics, which mandates holding public health, safety, and privacy paramount [2], the system is intentionally designed to process and store all user medication schedules and adherence data locally on the ESP32 microcontroller. By relying exclusively on a local HTTP/WebSocket interface rather than third-party cloud services, the design inherently eliminates the risk of cloud-based data breaches, fully justifying the system's architecture to protect patient confidentiality. To guarantee operational safety, the device strictly adheres to rigorous engineering and safety standards. The wireless communication subsystem complies with the IEEE 802.11 standard for robust local networking and FCC Part 15 regulations to ensure its electromagnetic emissions do not interfere with other household or medical electronics [3]. Furthermore, the power subsystem incorporates a dedicated Protection IC for the Li-ion battery, adhering to UL 1642 standards to mitigate thermal and fire hazards during operation and charging [4]. Finally, drawing upon general OSHA electrical safety principles, the design utilizes isolated low-voltage DC power (3.7V/5V) for the actuation subsystem, ensuring absolute user safety during daily physical interactions and liquid refilling [5].

References

[1] M. T. Brown and J. K. Bussell, "Medication adherence: WHO cares?" *Mayo Clinic Proceedings*, vol. 86, no. 4, pp. 304–314, 2011.

[2] Institute of Electrical and Electronics Engineers, "IEEE code of ethics," https://www.ieee.org/about/corporate/governance/p7-8.html, 2020, accessed: 2026-02-27.

[3] Federal Communications Commission, "Title 47 of the code of federal regulations (CFR), part 15: Radio frequency devices," https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15, 2023.

[4] Underwriters Laboratories, *UL 1642: Standard for Lithium Batteries*, 5th ed. Northbrook, IL: Underwriters Laboratories, 2012.

[5] Occupational Safety and Health Administration, "Standard 1910 subpart s - electrical," 29 CFR 1910.301-399, 2007, available at: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910SubpartS.