FadeX: Automated Nicotine Tapering Device

By

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1 Introduction

1.1 Problem

Electronic cigarettes, originally conceptualized as smoking cessation tools, have evolved into a significant driver of nicotine dependency. Current nicotine replacement therapies (NRTs), such as nicotine patches or medicated gums, exhibit high failure rates primarily because they decouple the physiological delivery of nicotine from the sensorimotor reinforcement associated with vaping [1]. Specifically, NRTs fail to address the oral fixation and inhalation rituals, which are behavioral habits that are clinically shown to be as addictive as the substance itself [2].

Furthermore, current "manual tapering" strategies are fundamentally limited by commercial availability and human error. Users attempting to reduce intake must navigate discrete, infrequent concentration steps (e.g., a 40% drop from 5% to 3% nicotine), which often triggers acute withdrawal and subsequent relapse [3]. There is a distinct absence of a closed-loop or automated system capable of delivering a computationally linear taper while maintaining the user's behavioral routine. This gap in the cessation market represents a critical failure in public health and addiction science. A device that enables controlled, micro-dosed nicotine reduction while maintaining behavioral continuity may significantly reduce relapse rates and improve cessation outcomes.

1.2 Solution

FadeX is an automated fluidic delivery system with wireless communication capabilities designed to completely obfuscate the nicotine tapering process from the user. To achieve this without burdening the user with a heavy, complex handheld device, FadeX utilizes a two-part architecture: a stationary Batch-Mixing Base Station and a passive Handheld Vaporizer.

By mixing the non-nicotine and nicotine juices into a central container, the base station enables an imperceptible and customizable reduction curve (e.g., 5.0% to 4.95% to 4.90%) that is impossible to achieve with pre-mixed commercial liquids. The Base Station utilizes an ESP32 microcontroller to drive high-precision stepper peristaltic pumps, which meter fluid into an internal main reservoir. This homogenization is verified via a closed-loop gravimetric load cell to ensure strict volumetric accuracy.

Once the daily algorithmic ratio is prepared, the user docks their Handheld Vaporizer. A secondary transfer pump safely injects the custom-blended dose through a dry-break silicone septum into the handheld's internal "Daily Tank." To address safety and compliance, FadeX implements firmware-level dosage caps and thermal interlocks, preventing both user "cheating" and hardware failure. By maintaining the behavioral ritual in a sleek handheld format while the Base Station systematically reduces the chemical stimulus, FadeX provides a scientifically grounded, hands-off pathway to complete cessation.

1.3 Visual Aid:

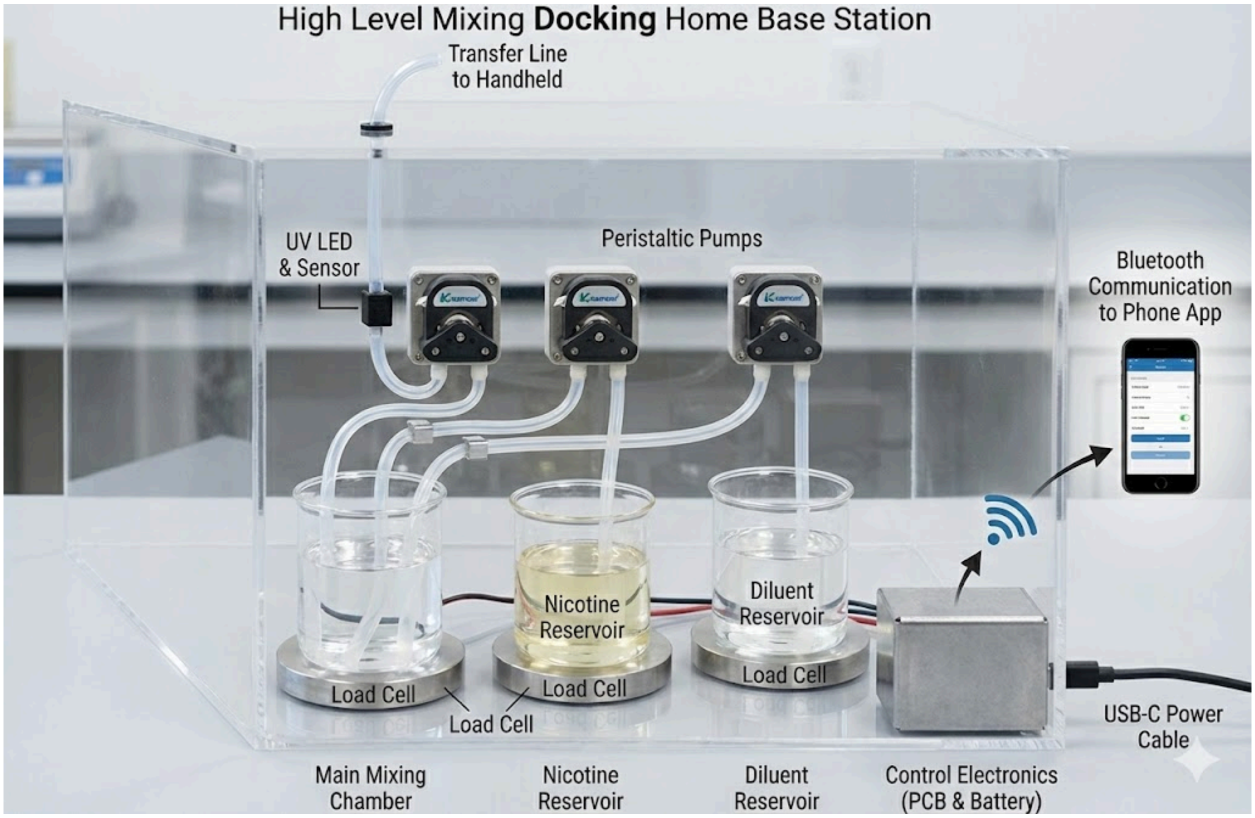

Figure 1: High-level diagram of the FadeX Home Base System.
***Note: resv. = reservoir**

Figure 1 shows the Home Base system. It'll be used to mix our non-nicotine (diluent) and nicotine concentration fluids into a main chamber to create a tailored nicotine concentration. Once it is ready to go, it will be pumped out via the juice transfer line to the liquid container on the vape. More specifically, we plan to have a liquid container that can have its lid removed so that we can run a line that connects the new concentration mix to the container and have that be pumped in.

The handheld system in Figure 2 will externally seem similar to existing vape devices to the user. It will operate using some existing features implemented in it as well, such as LED indication, pressure sensor to detect inhalation and fire the coil, and a glass thermal chamber to house the e-cigarette juice (e-juice). Ours will add a PCB as a control unit for the system. It will manage and control power, house the charging module, and store and send data via bluetooth to a smart phone for the application.

Figure 2: High-level diagram of the FadeX Handheld Vaporizer System.

1.4 High Level Requirements:

- *Asynchronous Volumetric Mixing Precision:* The dual-pump fluidic subsystem must achieve a commanded nicotine-to-diluent ratio with a steady-state error of less than 15%. Given that industrial laboratory standards allow for a 10% tolerance, this requirement ensures medical-grade feasibility while accounting for the mechanical tolerances of micro-peristaltic tubing and PWM-driven DC motors.

- *Dynamic Usage-Responsive Tapering Algorithm:* The system must implement a closed-loop feedback algorithm that adjusts the nicotine concentration based on user data. The user will set a taper schedule and starting concentration, and the software developed by our group should calculate the tapering trajectory. This data would then be implemented on the firmware of the MCU in the docking system. The algorithm would also collect data during the trial phase of the user to predict future use and success with the current tapering trajectory and adjust if needed.

- *Wireless Communication of Data:* The system must maintain a Bluetooth Low Energy (BLE) link to the mobile application with a data synchronization interval of less than 500 ms. This ensures that usage analytics (puff duration, frequency, and current concentration) are reflected in the user dashboard in near real-time, and that algorithm setpoints from the app are pushed to the mixing station without much delay.

2. Design

2.1 Block Diagram

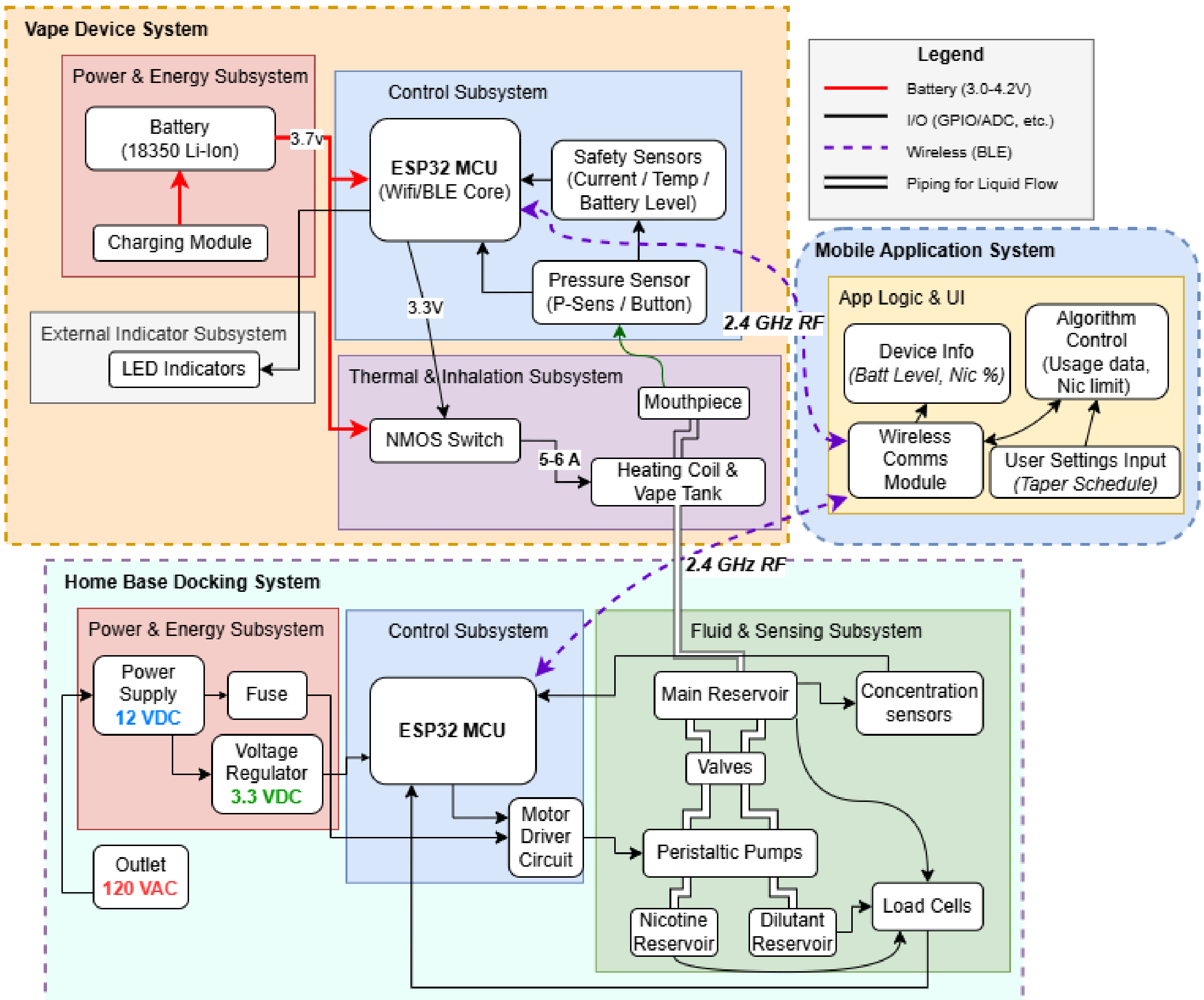

Figure 3: Block diagram of the FadeX Vape, Home Base, and Software Systems design

2.2 Power & Energy Management Subsystem

The Power & Energy Management System is critical to satisfying the overarching design requirement of delivering a highly accurate, automated nicotine taper. The Home Base power system ensures that high-current inductive loads (stepper pumps) do not cause voltage droop or reset the logic circuits governing the volumetric algorithm. Concurrently, the Handheld power system must guarantee safe, high-current discharge for aerosolization while maintaining a stable logic rail for the ESP32 and Bluetooth communication, even as the battery voltage sags near depletion.

Home Base

- **Inputs:** 120VAC wall power converted to 12VDC, 2A via a USB-C PD or barrel jack power supply.
- **Outputs (Logic Rail):** 3.3V ± 0.05V (via AP2112K LDO or Buck Converter) to provide stable power to the ESP32 and ADCs.
- **Outputs (Pump Rail):** 12VDC direct for the stepper drivers and peristaltic pumps.

Handheld Device

- **Inputs:** Single-cell 18350 Li-ion battery (3.6V nominal, 4.2V max).
- **Outputs:** Battery-direct NMOS switching (8A-12A peak) for the heating coil.
- **Requirements**

Requirements	Verifications
Home Base	
The 12V rail must include a fuse connected to the MOSFET that safely opens the circuit to prevent fire hazards in the event of a pump motor stall or short circuit.	Test a dummy circuit that does not contain important components and in a safe manner while measuring voltage and current data to verify safe shutdown.
12V rail gets stepped down via buck converter (MP1584EN) to a steady and reliable 3.3v.	Measure with oscilloscope during trial run with pumps powering on.
Handheld Device	
The circuit battery must be connected to an LDO which then provides a stable 3.3v to the ESP32.	Check output from the LDO and make sure that it's 3.3 V exactly.
Make sure the the user is aware of the battery being low by lighting an LED indicator	Having a diode connected signal to an I/O pin that once it goes low (at 3.3 volts), the MCU recognizes the battery level is below the acceptable threshold and lights the LED indicator.

To determine which power supply and battery we needed we calculated what the maximum power consumption for each component would be. For the home base we calculated that the pumps could consume a maximum of about 12W each based on the data sheet saying that they normally will run at a max of 500mA but might require up to an amp momentarily to get started. We decided to double count 12W in our final power consumption for the home base to keep the possibility of running both reservoir pumps at the same time in our pump algorithm. The ESP32 in both circuits consumes about 1.8W. The load cell with the load cell amplifier consumes 15mW. The flyback diode will consume 0.21W when active. In all for the Home base it will consume 28.8W at full capacity. The Vapes coil is a 12W coil, combine that with the ESP32 and the circuit consumes 13.65W. The pressure sensor's power consumption compared to the coil and ESP is negligible.

2.3 Control, Safety Logic, & Connectivity Subsystem

This subsystem serves as the central intelligence of the hardware. The Home Base calculates and executes precision fluid mixing, while the Handheld ensures responsive, sensor-driven vaporization with strict thermal safety cutoffs. The mobile application acts as the central BLE hub, eliminating the need for complex device-to-device relaying. Concentration algorithms must reside in the Home Base non-volatile memory (NVM) to ensure the tapering schedule is not lost during power cycles. The Home Base ESP32 requires a highly stable 3.3V logic rail to process ADC signals and maintain BLE connectivity without brownouts (damage or errors due to low-voltage stress). This is achieved by stepping down the 12V main rail using a buck converter, ensuring high efficiency and low thermal output.

Home Base

- **Inputs:** Load cell data (via HX711) to determine available liquid mass, and BLE configuration data from the mobile app (target concentration).
- **Outputs:** STEP/DIR signals to the A4988 stepper drivers for accurate mixing, and PWM to the DC transfer pump.

Handheld Device

- **Inputs:** Puff pressure sensor signal indicating user inhalation.
- **Outputs:** Gate signal to the IRLB3034 MOSFET to fire the coil, and BLE puff-data payloads sent to the smartphone.

Requirements	Verifications
Home Base	

Requirements	Verifications
Logic Power Stability: The MP1584EN buck converter must supply a steady 3.3V ± 5% (3.135V to 3.465V) to the Home Base ESP32 while the Wi-Fi/BLE radio is actively transmitting.	Power the Home Base via the 12V adapter. Connect a multimeter to the output pin of the MP1584EN. Flash a test script forcing the ESP32 to continuously broadcast a BLE signal. Verify the multimeter reading remains within the 3.135V - 3.465V window.
Handheld	
Watchdog Safety: The Handheld ESP32 must terminate the MOSFET gate signal (0V) at exactly 10.0 ± 0.5 seconds of continuous activation, regardless of continuous sensor input.	Connect an oscilloscope probe to the ESP32 pin driving the MOSFET gate. Apply a continuous 3.3V signal to the pressure sensor input pin to simulate a stuck/continuous puff. Measure the pulse width on the oscilloscope. Verify the signal drops to 0V between 9.5s and 10.5s.
BLE Latency: The Handheld must transmit a "puff completed" payload to the Smartphone App within 500 ms of the pressure sensor signal dropping LOW.	Connect the Handheld to a serial monitor via USB. Connect the Smartphone App to the Handheld via BLE. Trigger and release the pressure sensor. Compare the serial monitor timestamp of the sensor dropping LOW to the app's timestamp of payload receipt. Verify $\Delta t < 500$ ms over 10 consecutive trials.

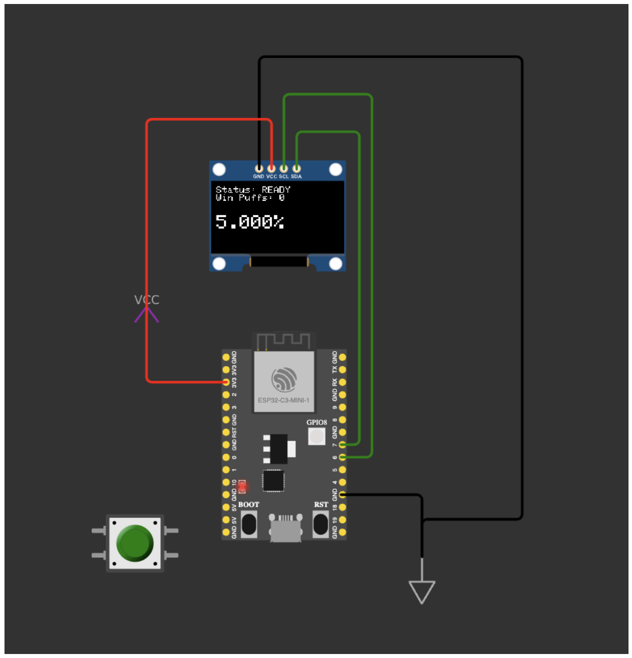

Figure 4: Full 5.000% Concentration Logic Inhalation

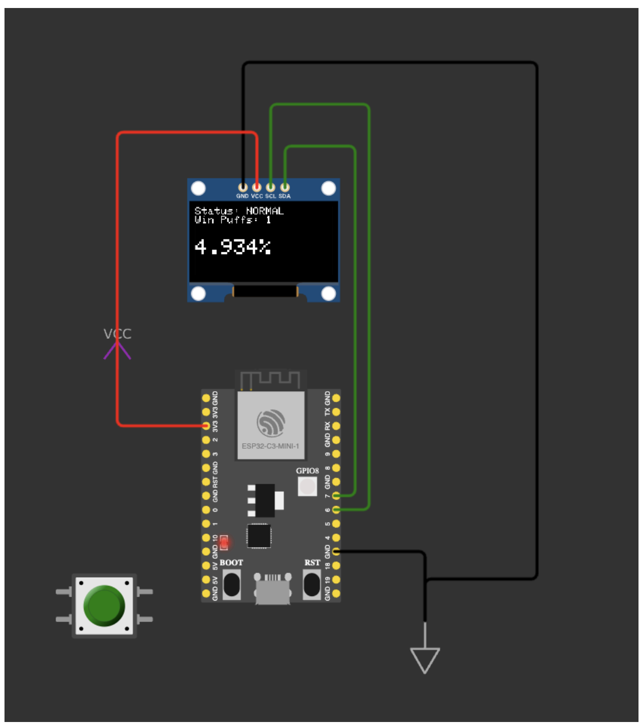

Figure 5: Adaptive Trajectory Reduction to 4.943%

# TIME(s)	PUFFS	WINDOW_PUFFS	CONC(%)	STATUS	Session ID	Notes
1	1	1	4.99	NORMAL	S001	Initial state
3	2	2	4.98	NORMAL	S001	Second puff recorded
3	3	3	4.97	NORMAL	S001	Rapid succession
4	4	4	4.969	ADJUSTED_SLOW	S001	Concentration drop observed
5	5	5	4.968	ADJUSTED_SLOW	S001	Continued slow adjustment
5	6	6	4.967	ADJUSTED_SLOW	S001	Stable low conc
15	7	7	4.966	ADJUSTED_SLOW	S001	Long pause between puffs
15	8	8	4.965	ADJUSTED_SLOW	S001	No time change
85	9	1	4.955	NORMAL	S002	New session started (Window reset)
91	10	2	4.945	NORMAL	S002	Puff count increasing
93	11	3	4.935	NORMAL	S002	Standard operation
98	12	4	4.934	ADJUSTED_SLOW	S002	Window limit approached

Figure 6: Tabulated Algorithm Verification Data Points

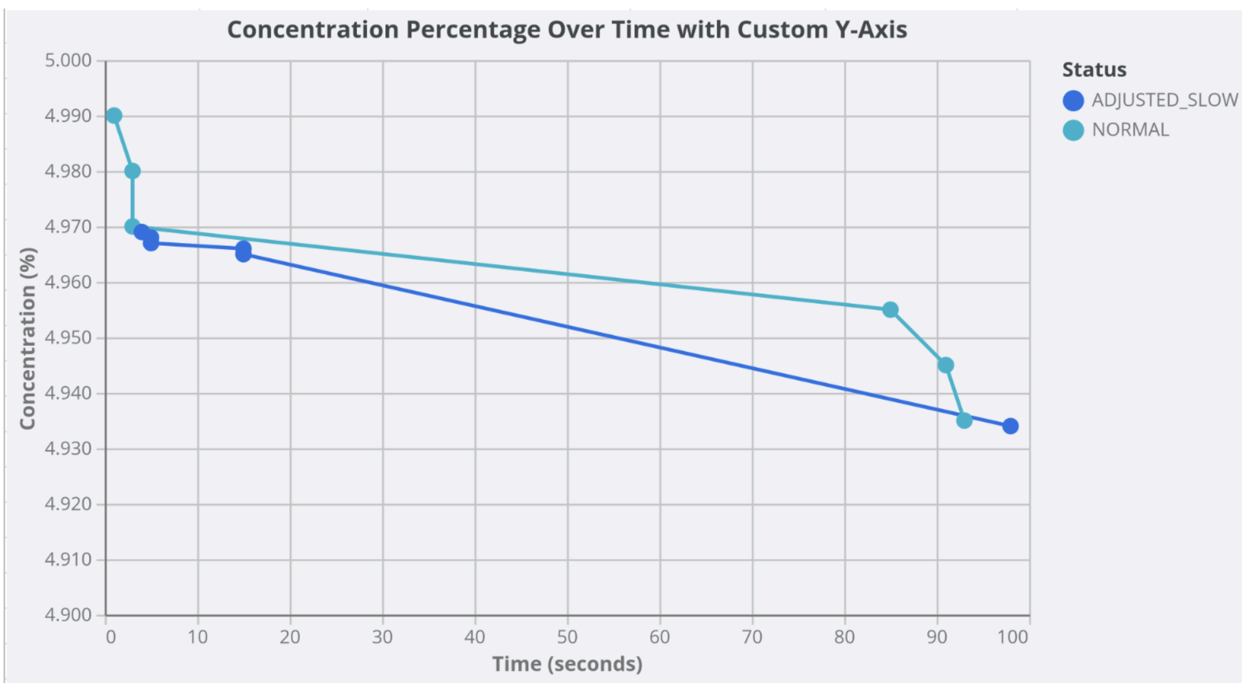

Figure 7: Nicotine Concentration (%) vs. Time (s)

The verification begins with the logic initialization at a 5.000% baseline (Fig 3), confirming the ESP32 has correctly loaded the user's cessation parameters into active memory. As the user interacts with the device, the sliding window algorithm monitors puff density; when rapid intake is detected, the system executes an adaptive state transition to 4.943% (Fig 4), proving it can pivot the nicotine delivery slope mid-session to prevent withdrawal. This entire behavioral log is captured in the comprehensive data table (Fig 5), which provides the quantitative "Truth" signal for every 30-second window. Finally, the concentration vs. time plot (Fig 6) visually maps these pivots, providing a high-level proof that the handheld device successfully maintains a usage-responsive trajectory as required by the project goals.

2.4 Fluid, Mixture & Sensing Subsystem

This subsystem houses the raw liquids, meters them to precise fractional volumes, verifies the mixture optically, and safely transfers the daily dose to the docked handheld device. It utilizes three 500g micro load cells paired with HX711 24-bit ADCs. 500g load cells were selected because 100mL of dense e-liquid (PG/VG) we would use in the home base weighs up to 126g. Using 100g load cells would physically max out the sensors. These continuously measure reservoir weight to ensure algorithmic accuracy and prevent overflow. The 12V peristaltic stepper pumps (driven by A4988 logic) must be PWM-calibrated to deliver liquid with a volumetric accuracy of ±2%. The mixed concentration is verified using a 265nm UVC LED shining through FEP (Fluorinated Ethylene Propylene) or Quartz Glass tubing. FEP is strictly required because standard silicone tubing blocks UVC light. The transmitted light is detected by a UVC photodiode and amplified by an OPA320 Transimpedance Amplifier (TIA) to output a 0-3.3V analog signal to the ESP32.

Home Base

- **Inputs:** 12V DC Power, 5.0% nicotine base liquid, and 0.0% nicotine diluent liquid.
- **Outputs:** A homogenized, custom-ratio mixture delivered via the transfer pump to the docked vaporizer. The load cells measures the weight of the reservoirs to ensure accuracy and prevent overflow.

Handheld Device

- **Inputs:** Fluid transferred from the Base Station.
- **Outputs:** Safely storing the liquid in the internal "Daily Tank" that holds 5 mL to allow for one whole day of at minimum.

Requirements	Verifications
Home Base	

Requirements	Verifications
Pump Volumetric Accuracy: The 12V peristaltic stepper pumps must deliver target liquid volumes with an accuracy of ±2% (e.g., dispensing 10.0 mL must yield between 9.8 mL and 10.2 mL).	Place a dry, empty beaker on a calibrated lab scale and tare it to 0.00g. Send a command to the ESP32 to dispense exactly 10.0 mL of distilled water (density = 1.0 g/mL). Weigh the dispensed water on the scale. Verify the final mass is between 9.80g and 10.20g. Repeat 3 times for both the nicotine and diluent pumps.
Optical Verification Sensor: The UVC photodiode and TIA must output a distinct analog voltage differential of at least Δ0.2 V between a 0.0% nicotine solution and a 5.0% nicotine solution.	Fill the transfer tubing with 0.0% diluent. Connect a DMM to the output pin of the TIA and record the baseline voltage. Flush the tube and fill it with 5.0% nicotine base. Record the new voltage. Verify that
Load Cell Resolution: The 500g load cells and HX711 ADCs must detect changes in reservoir mass with a resolution and accuracy of ±0.5 grams to ensure the mixing algorithm receives valid data.	Place an empty reservoir on the load cell and run the ESP32 HX711 tare script. Output the serial weight data to a monitor. Place a certified 50.0g calibration weight into the reservoir. Verify the serial monitor reads between 49.5g and 50.5g

stock solution amount (ml)	stock solution perecnt (mg/ml)	stock solution mol	stock solution concentartion (mol/l)				
30	50	0.0003082	0.000308201				
	5%						
	conc (mol/L) in 1L	mol	mg/ml	diff conc	amount needed of stock (ml)	amount of juice needed (ml)	final amount (ml)
	6.164E-05	6.164E-05	10	1%	2	8	10
	9.246E-05	9.246E-05	15	1.50%	3	7	10
	0.00012328	0.00012328	20	2%	4	6	10
	0.0001541	0.0001541	25	2.50%	5	5	10
	0.00018492	0.00018492	30	3%	6	4	10
	0.00021574	0.00021574	35	3.50%	7	3	10
	0.00024656	0.00024656	40	4%	8	2	10
	0.00027738	0.00027738	45	4.50%	9	1	10
	0.0003082	0.0003082	50	5%	10	0	10

Figure 8: Nicotine concentration calculations

Figure 7 shows the required amounts of nicotine and non-nicotine juices to achieve certain concentration percentages. This math also demonstrates that we'll be able to achieve these concentrations within an acceptable range because our pumps will be able to control the volume in the uL range.

To achieve the precise tapering ratios required by the user, the system's algorithm calculates fluid delivery using standard volumetric dilution kinetics. The Home Base stores a primary stock solution of 5.0% nicotine (C_{stock}) and a 0.0% nicotine diluent.

When the Mobile Application requests a specific target concentration (C_{target}) for the Handheld Device's daily 10.0 mL capacity (V_{total}), the ESP32 calculates the exact required volume of the nicotine stock solution (V_{stock}) using the following relationship:

$$C_{stock} * V_{stock} = C_{target} * V_{total}$$

Rearranging for the unknown stock volume:

$V_{stock} = C_{target} * V_{total}/C_{stock}$

Once V_{stock} is determined, the required volume of zero-nicotine diluent $V_{diluent}$ is simply the remainder of the total volume:

$V_{diluent} = V_{total} - V_{stock}$

The microcontroller then translates these target volumes (in mL) into exact step-counts for the A4988 motor drivers to execute via the peristaltic pumps. Table X below demonstrates the calculated volumetric ratios required to achieve various tapering milestones for a standard 10.0 mL daily dose.

2.5 Thermal & Vapor Generation Subsystem

This subsystem is entirely localized to the portable Handheld Device and is responsible for the rapid, safe vaporization of the e-liquid and real-time usage tracking. It utilizes an IRLB3034 NMOS transistor to switch high-amperage current (8A-12A) directly from the 18650 battery to a sub-ohm Kanthal heating coil. This specific logic-level MOSFET was chosen for its extremely low on-resistance, ensuring minimal power loss and preventing the device casing from overheating. A puff pressure sensor detects user inhalation, acting as the trigger for the ESP32 to drive the MOSFET gate. To monitor user habits and system status, the ESP32 identifies when the vaporizer is being used and calculates the exact duration of each MOSFET firing event to log the total number of puffs. Additionally, because the Handheld utilizes a 5.0 mL internal daily tank, the MCU must algorithmically estimate the remaining fluid volume based on the cumulative coil firing time, triggering a "Refill Required" flag via BLE when the tank nears depletion.

Handheld Device

- **Inputs:** Mixed liquid from the internal tank, 8A-12A current from the 18650 cell, and the trigger signal from the Puff Pressure Sensor.
- **Outputs:** Inhalable aerosol (vapor) delivered to the user, and usage data payloads (puff duration, count, and volume estimation flags) transmitted via BLE.

Requirements	Verifications
Handheld Device	
The IRLB3034 MOSFET must successfully switch 8A-12A of current to the heating coil upon sensor activation without the transistor package exceeding a safe operating temperature of 60°C.	Apply a continuous signal to the MOSFET gate for a maximum standard puff duration (e.g., 5 to 8 seconds) while connected to the 0.35-ohm coil and a fully charged 18650 battery, using a thermocouple taped to the transistor package to verify the temperature remains below 60°C.

Requirements	Verifications
Usage Tracking Accuracy: The ESP32 must accurately log the duration of the MOSFET firing event to within ±0.1 seconds of the physical pressure sensor activation..	Trigger the pressure sensor using a controlled syringe of air for exactly 3.0 seconds, then verify via the serial monitor or BLE payload that the ESP32 records a firing duration between 2.9 and 3.1 seconds.
Volume Estimation & Refill Flag: The MCU must trigger a "Refill Required" BLE flag after a cumulative firing time that corresponds to the complete depletion of the 5.0 mL tank.	Run a test script to simulate continuous puffing until the cumulative firing time reaches the predetermined 5.0 mL depletion threshold (based on coil wattage testing), and verify using the companion app or a serial monitor that the "Refill Required" status flag is successfully transmitted.

To calculate how much vapor is made each puff, we had to learn about how vapor production is tied to the work done by the electrical power across the coil. The first step in calculating the amount of juice in mL that was vaporized was getting the power calculated to be consumed by the coil, which was found to be 12W in the power and energy section earlier. Then we had to pick a standard amount of time to run the vape to model a "hit", which we chose 3 seconds for. This allowed us to calculate the amount of heat generated by the coil to be 48 Joules. From there the amount of vapor per puff was calculated as the amount of heat times the assumed heat transferred efficiency of 0.7, divided by the typical PG/VG latent heat of vaporization of 700 J/g to get 0.048grams of liquid.

2.6 Mobile Application Subsystem (Software)

This software subsystem acts as the central hub for user configuration, system monitoring, and data logging across both physical devices. To ensure a seamless user experience and a consistent tapering schedule, the Mobile Application connects to the Home Base and Handheld Device via Bluetooth Low Energy (BLE). For the Home Base, the application processes the user's desired tapering goal and algorithmically converts it into specific stepper-motor pulse counts, which are then transmitted to the base station to execute the physical mix. It simultaneously monitors the Base Station, displaying critical statuses such as connection state, fluid reservoir levels, and AC power activity. For the Handheld Device, the app synchronizes usage data by receiving and logging puff duration and frequency, allowing the system to track behavioral habits over time. It also provides real-time UI updates on the "Vape Status," alerting the user to the 18650 battery percentage and the estimated remaining fluid volume in the daily tank.

Home Base Interaction Inputs: User-defined tapering goals and schedule parameters entered via the GUI.

- **Outputs:** Algorithmically calculated stepper-motor pulse counts and target concentration payloads transmitted via BLE, along with a UI display of "Base Status" (Connected, Fluid Levels OK, AC Power Active).

Handheld Device Interaction

- **Inputs:** Puff duration, frequency data, battery voltage readings, and remaining tank volume estimates received via BLE.
- **Outputs:** A logged history of user behavioral habits and a real-time UI display of "Vape Status" (Battery Percentage, Estimated Tank Volume).

Requirements	Verifications
Home Base	
Adaptive Tapering Precision: The control logic must adjust the nicotine reduction decrement based on puff density. For "Normal" density (<=3 puffs/30s), the decrement must be 0.010% += 0.001%. For "High" density (> 3 puffs/30s), the decrement must be 0.001% += 0.0002%	Open the Wokwi simulation and clear the Serial Monitor. Send a sequence of 3 puff commands within 10s; verify the concentration drops from 5.000% to 4.970% (+= 0.001%). Send a 4th command within the same 30s window; verify the next concentration value is 4.969% (+= 0.0002%). Repeat the test sequence 3 times to ensure software flag consistency.
Handheld Device	
Data Sync Reliability: The application must receive and log puff duration and frequency data from the Handheld Device with zero dropped packets over a continuous sequence of 20 simulated puffs.	Trigger the Handheld device's pressure sensor 20 consecutive times to simulate user puffs, then check the application's history log to verify it accurately displays exactly 20 distinct entries matching the duration of each triggered event.

2.7 Tolerance Analysis

The difficulty of the design will lie in the accuracy of delivery of the concentration of a nicotine-like liquid within the device's reservoir. The e-cigarette liquid (e-juice) in commercial e-cigarettes usually lies within a housing that surrounds the heating coil. This design for the housing will have to allow insertion of liquid from another source within the device and not allow liquid to flow backwards, possibly contaminating the dilutant. There could also be an issue with the user inhalation causing unwanted forward flow, disturbing the precision of the mixture in the main reservoir.

Feasibility was analyzed through research of different components involved in the fluid subsystem. This includes micro-pumps, valves, pump drivers, and sensors that rely on controls from the microcontroller and feedback signals that are given to the microcontroller as well. Mainly, the addition of valves between the pump and central chamber will allow us to control the flow of fluids regardless of the inhalation pressure that is posed when the device is being used. To mitigate the risks of backflow and uncommanded forward flow, we have selected micro-peristaltic pumps. The fundamental mechanism of a peristaltic pump involves a rotor compressing a flexible silicone tube against the pump housing. This mechanical compression creates a continuous point of occlusion, effectively acting as a "normally closed" check valve when the motor is stationary.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Name	Role / Primary Focus	Est. Hours	Total Cost
Malik Kelly	**Algorithm Development & App Integration**	**150**	**$16,875**

Justin Leith	**Project Management & Mechanical Design**	**150**	**$16,875**
Ian Zentner	**MCU Logic & Hardware Integration**	**150**	**$16,875**
Total Labor		**450**	**$50,625**

3.1.2 Parts List

Description	Manufacturer	Qty	Total	Link
MCU Development Board	**Espressif**	**2**	**$22**	**ESP**
Peristaltic Pump (12V)	**Adafruit Industries**	**3**	**$74.85**	**PP**

Mini Load Cell - 500g	**SparkFun Electronics**	**3**	**46.50**	Load Cell
UVC-Specific Gallium Nitride (GaN) Photodiode	**Genicom Co., Ltd.**	**1**	**$18.23**	Digikey
Load Cell Amplifier HX711	**SparkFun**	**3**	**34.50$**	Load cell amplifier
120VAC - 12VDC 3A power supply	**Arkare**	**1**	**$9.59**	Power supply
Li-ion Battery 18350	**Vapcell**	**1**	**$16.35**	16350
Charging IC	**HiLetGo**	**5**	**$9.99**	TP4057

Mini MP1584EN Buck Converter Module	**MTDELE**	**6**	**$8.99**	**Buck converter**
Power MOSFET (Coil)	**BOJACK**	**5**	**$9.99**	**MSFT**
AP2112K-3.3TRG1 **(LDO for vape)**	**DigiKey**	**1**	**$0.22**	**LDO**
IPS TFT LCD Display (1.54")	**Fermion**	**1**	**$15.00**	**FERM**
UVC LED	**Lite-On**	**1**	**$25.75**	**Lite**

Custom PCB Fabrication	**JLCPCB/PCBWay**	**1**	**$25.00**	
3D Printing Material	**Hatchbox**	**1**	**$25.00**	
Total Parts			**$296.15**	

3.2 Schedule

Week	Phase	Ian (MCU Logic & Hardware)	Justin (Project Management & M	Malik (Algorithm & App Integr
Week 7(Mar 2)	Design Finalization &	Finalize custom PCB schematic and layout for fabrication.	Finalize Design Document. Order all raw components,	Draft the core tapering algorithm logic in
Week 8(Mar 9)	Prep & Prototyping	Write initial ESP32 test scripts for the I2C sensors and PWM motor drivers.	Begin CAD modeling for the Home Base acrylic housing and Handheld device tank.	Develop the BLE transmission protocol and define the data payload structure between the App and ESP32.
Week 9(Mar 16)	Assembly & Subsystem Check	Receive and solder the PCBs. Perform basic continuity and power rail testing (3.3V / 12V / 5V).	3D print the first iteration of the Home Base housing. Route the FEP tubing for the peristaltic pumps.	Build the user interface (UI) dashboard for "Base Status" and "Vape Status".
Week 10(Mar 23)	Mock-Up / Individual Testing	Wire the ESP32 to the A4988 motor drivers and HX711 load cells. Verify pump activation.	Calibrate the micro-peristaltic pumps for volumetric accuracy (±2%). Assemble Handheld vape housing.	Successfully pair the Mobile App with the ESP32 via BLE. Send dummy concentration data to the UI.
Week 11(Mar 30)	Integration Phase 1: Home Base	Integrate the load cell feedback loop with the motor drivers to achieve accurate mixing.	Mount all reservoirs, pumps, and the PCB into the physical Home Base housing. Check for fluid leaks.	Push the volumetric dilution algorithm to the Home Base ESP32. Test algorithm response to simulated data.
Week 12(Apr 6)	Integration Phase 2: Handheld	Wire the IRLB3034 MOSFET, heating coil, and pressure sensor. Test the 10-second thermal watchdog.	Integrate the Handheld PCB and 18350 battery into the portable casing. Ensure the silicone septum is leak-proof.	Sync Handheld puff duration/frequency data to the mobile app. Test the "Refill Required" flag.
Week 13(Apr 13)	Full System Integration	Establish two-way BLE comms (App to Base, Handheld to App) without packet loss.	Perform the first physical fluid transfer from the Home Base to the docked Handheld vaporizer.	Finalize app UI and historical data logging charts. Debug any BLE latency issues.
Week 14(Apr 20)	Refinement & R&V Testing	Run through every single R&V table check. Tune the optical UV sensor thresholds.	Perform full mechanical stress tests. Polish the physical presentation of the prototype.	Run the adaptive state transition tests (simulating "High" and "Normal" puff density).
Week 15(Apr 27)	Final Demo Prep	Finalize firmware comments. Prepare hardware for the TA demonstration.	Draft the Final Presentation slides and begin the Final Paper.	Polish the app GUI for the live demo. Generate sample user data for the presentation.

4.1 Ethics, Safety, Engineering Standard, and Societal Impact

For this project, nicotine will not be used for this iteration's demonstration, so there is less of a risk toward using it. However, we may choose to work with it at some point in the future, and the safety of using it should be emphasized. Nicotine is a highly addictive, toxic substance that can be fatal if swallowed or in contact with skin. It is very possible that we can work with it in the proper environment with proper PPE. The design involves a heating element at greater than 200℃, and it implements thermal safety protocols aligned with UL 8139 standards for heating element cutoff. The device uses wireless communication, so it must maintain Bluetooth communications with encrypted pairing (Security Mode 1, Level 4) to prevent unauthorized schedule modifications, ensuring data integrity as outlined in the IEEE Code of Ethics (Canon 1) regarding public safety.

This project provides a societal impact through the public health domain, which directly aligns with IEEE Code of Ethics (1.1). Tobacco remains a leading cause of preventable death globally. This design uses a state-of-the-art device paired with a customized tapering algorithm to take away the difficulties of going through withdrawal symptoms. FadeX has the potential to significantly increase the success rate of cessation, reducing the burden of smoking-related illnesses on the healthcare system. Regarding economic benefits, the cost of vaping (or smoking) is high, but the cost of healthcare for smokers is higher. A device that successfully weans a user off nicotine entirely generates a massive long-term economic benefit for the individual and society. Traditional disposable vapes create massive e-waste, sending millions of lithium batteries and plastic to landfills and local streets annually. FadeX is a refillable, reusable device designed for a long lifecycle. Our product would have a positive environmental impact by significantly reducing plastic and battery waste.

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