ADHERECENT
AUTO TIME SETTING SCENT REMINDER

By

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Project Proposal for ECE 445, Senior Design, Spring 2026

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2/13/2026

Project No. 58

Introduction

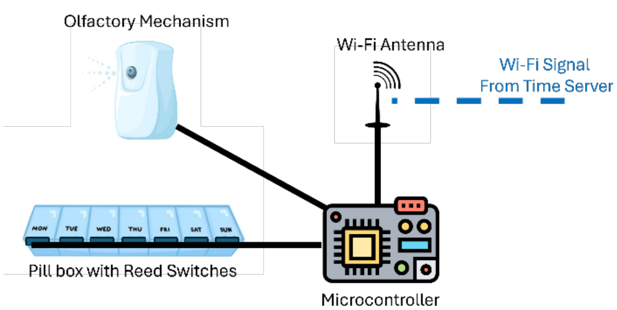
Problem

Daily Medication is imperative to health but is often easy to forget as we grow older and the reliability of our memories, sight, and sound decrease. Traditional medication reminders are lost in the frenzy of notifications and sounds that we experience daily. The population with the largest need for daily medication is also the population least familiar with technology. Many adaptive devices are not adopted due to the intimidation of new technologies, particularly with time setting and confusing user interfaces.

Solution

We propose a smart pill dispenser that utilizes scent as the primary notification mechanism. The system is built around a custom-designed PCB integrating an ESP32 microcontroller module. This allows for Wi-Fi connectivity, enabling time synchronization and remote scheduling potential. When a scheduled dose is due, the system triggers a scent release mechanism. The scent persists until the user opens the correct pill compartment. We will achieve the scent generation by electronically interfacing with and controlling a commercial aroma diffuser. The system will also employ magnetic sensors to detect the precise open/closed state of each medication compartment to close the feedback loop.

Visual Aid

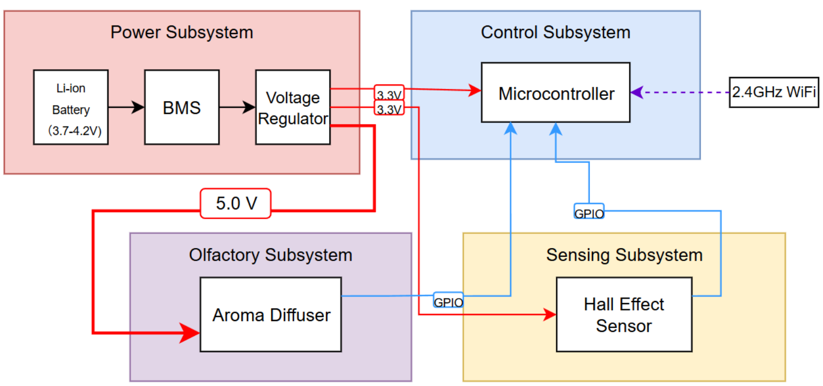


High-level requirements list

- **Scheduling Reliability**: The device must trigger the scent notification within 5 seconds of the scheduled medication time.
- **Scent Control**: The system must successfully turn on the external diffuser via the custom isolation circuit and turn it off automatically when the pill box is opened.
- **Sensor Accuracy**: The Hall Effect sensors must detect the Open and Closed states of the compartment with 100% accuracy across consecutive test trials.
- **PCB Functionality**: The custom-designed PCB must successfully power the ESP32 module and handle the logic levels without overheating or resetting due to power fluctuations.

Design

Block Diagram



Subsystem Overview:

1. Power Subsystem

- **Function Description:** Manages energy storage, charging safety, and voltage regulation for the entire device.
- **Major Components:**
  - o Li-ion Battery (Single Cell)
  - o BMS (Battery Management System)
  - o LDO Voltage Regulator
  - o 5V Boost Converter

- **Voltage Rails:**
    - **Input:** 5V (USB Charging)
    - **Output:** 3.3V DC & 5.0V DC
- **Input / Output Interfaces:**
    - **3.3V Rail:** Supplies Control & Sensing subsystems.
    - **5.0V Rail:** Supplies Olfactory subsystem.

2. Control Subsystem

- **Function Description:** Central processing unit responsible for logic execution, Wi-Fi connectivity, and task scheduling.
- **Major Components:**
    - Microcontroller (ESP32 Module)
    - Integrated Wi-Fi/BT Radio
- **Voltage Rails:**
    - **Input:** 3.3V DC (Regulated)
- **Input / Output Interfaces:**
    - **Input:** Digital Signal (from Hall Sensor).
    - **Output:** GPIO Control Signal (to Olfactory).
    - **Data:** 2.4GHz Wi-Fi (NTP Time Sync).

3. Olfactory Subsystem

- **Function Description:** Actuation mechanism that generates the scent notification upon receiving a trigger signal.
- **Major Components:**
    - Ultrasonic Aroma Diffuser (Modified)
    - Driver Circuit (MOSFET/Optocoupler)
- **Voltage Rails:**
    - **Input:** 5.0V DC (Boosted)
- **Input / Output Interfaces:**
    - **Input:** Digital Trigger (GPIO) from Control Subsystem.
    - **Action:** Atomizes liquid to release scent.

4. Sensing Subsystem

- **Function Description:** Feedback loop system that detects the physical state (Open/Closed) of the medication compartment.
- **Major Components:**
    - Hall Effect Sensor
    - Permanent Magnet (Lid-mounted)
- **Voltage Rails:**
    - **Input:** 3.3V DC (Regulated)

- **Input / Output Interfaces:**
    - **Output:** Digital Logic Level (High/Low) to Control Subsystem indicating lid status.

Subsystem Requirements:

1. Power Subsystem

Block Description The Power Subsystem is responsible for energy storage, battery management, and voltage regulation. It accepts a 5V input via USB Type-C for charging a single-cell Li-ion battery (3.7V nominal). It utilizes a dedicated Battery Management System (BMS) IC to handle charging logic and protection. The raw battery voltage is processed by two separate regulators: an LDO to provide a clean 3.3V rail for logic components, and a Boost Converter to step up the voltage to 5.0V specifically for the olfactory actuator.

Contribution to High-Level Design This subsystem enables the "portability" and "wireless" requirements of the pill box, allowing the device to operate without being tethered to a wall outlet while ensuring safety through over-charge and over-discharge protection.

Interfaces

- Input: USB Type-C Standard (5.0V DC at 500mA to 1A).
- Output 1 (Logic Rail): 3.3V DC to Control and Sensing Subsystems.
- Output 2 (Actuator Rail): 5.0V DC to Olfactory Subsystem.

Critical Requirements

1. The subsystem must supply a continuous current of at least 300mA on the 3.3V rail to support ESP32 Wi-Fi transmission spikes without voltage droop.
2. The subsystem must supply a continuous current of at least 800mA on the 5.0V rail to drive the ultrasonic atomizer.
3. The voltage ripple on the 3.3V rail must not exceed 50mV peak-to-peak to prevent microcontroller brownouts.
4. The Battery Management System (BMS) must cut off power output if the battery voltage drops below 2.5V to prevent permanent cell damage.
5. The Boost Converter must maintain an output voltage of 5.0V +/- 0.2V even as the battery voltage drops from 4.2V to 3.0V.

2. Control Subsystem

Block Description The Control Subsystem centers around the ESP32 microcontroller module. It executes the firmware responsible for maintaining the system time (via NTP), storing the medication schedule, and processing the logic state machine. It interfaces with the Sensing Subsystem to monitor adherence and drives the Olfactory Subsystem to generate notifications via GPIO signals.

Contribution to High-Level Design This block fulfills the "Smart" and "Connectivity" requirements. It ensures medication reminders occur at the exact scheduled time and processes the logic to stop the alarm only when compliance is verified by the sensors.

Interfaces

- Power Input: 3.3V DC +/- 5% (from Power Subsystem).
- Input Signal: Digital GPIO Logic (Logic High: >2.0V, Logic Low: <0.8V) from Sensing Subsystem.
- Output Signal: Digital GPIO Control Signal (3.3V Logic) to Olfactory Subsystem.
- Wireless Interface: 2.4 GHz 802.11 b/g/n Wi-Fi.

Critical Requirements

1. The microcontroller must successfully connect to a pre-defined Wi-Fi network and synchronize time via NTP within 30 seconds of system boot.
2. The subsystem must have a deep-sleep current consumption of less than 10mA when not actively notifying or syncing, to preserve battery life.
3. The control logic must respond to a "Lid Open" signal change (High to Low transition) within 200ms to immediately cease scent generation.
4. The subsystem must provide a 3.3V logic level signal capable of sourcing at least 10mA to drive the optocoupler isolation circuit.

3. Olfactory Subsystem

Block Description This subsystem acts as the user notification interface. It consists of a modified commercial ultrasonic aroma diffuser and a custom isolation interface. The isolation circuit (Optocoupler) receives low-voltage signals from the Control Subsystem and bridges them to control the power flow to the atomization unit, effectively simulating a physical button press electronically.

Contribution to High-Level Design This is the core differentiator of the project, satisfying the requirement for a "non-intrusive, olfactory-based notification system" rather than a loud auditory alarm.

Interfaces

- Power Input: 5.0V DC (from Power Subsystem).
- Control Input: Digital Logic Signal (Active High or Low depending on optocoupler configuration).

Critical Requirements

1. The subsystem must generate visible mist or scent within 2 seconds of receiving the activation signal from the Control Subsystem.
2. The isolation circuit must provide at least 1500V of electrical isolation between the Control Subsystem (3.3V logic) and the Diffuser power circuit to prevent high-voltage feedback.
3. The atomizer must automatically cease operation if the control signal is removed, with a spin-down time of less than 1 second.
4. The total power consumption of this subsystem must not exceed 4.5 Watts (900mA at 5V) to stay within the capabilities of the Power Subsystem's boost converter.

4. Sensing Subsystem

Block Description The Sensing Subsystem utilizes Hall Effect sensors positioned near the pill compartment lid and a permanent magnet embedded in the lid itself. It acts as a digital switch: when the magnet is close (Lid Closed), the sensor outputs a specific logic state; when the magnet moves away (Lid Open), the state flips.

Contribution to High-Level Design This subsystem fulfills the requirement for "verifiable adherence," ensuring the scent alarm only stops when the user has physically accessed the medication, rather than just pressing a button or waiting for a timeout.

Interfaces

- Power Input: 3.3V DC (from Power Subsystem).
- Signal Output: Digital Logic (Active Low/High) to Control Subsystem GPIO.

Critical Requirements

1. The sensor must trigger a state change (Closed to Open) when the magnet is moved more than 10mm away from the sensor face.
2. The sensor must exhibit hysteresis to prevent rapid signal toggling (bouncing) when the lid is partially open or vibrating.
3. The sensor output must be compatible with 3.3V CMOS logic levels without requiring external level shifting components.

4. The sensor must operate reliably (no false positives) in a temperature range of 0 degrees Celsius to 50 degrees Celsius to simulate typical home environments.

Tolerance Analysis:

A risk to our project is significant interference, or power instability which could cause issues with signal processing.

As long as our power supply maintains 2.2V–3.6V and can provide up to 1 A for transmission spikes we should be well within operating parameters.

Ethics, safety and societal impact

When building the scent distribution mechanism, fire is a concern due to some methods of dispersal using flammable or hot substances that pose a fire risk.

Spraying and releasing substances into the air can also be dangerous to animals, or in areas where food is consumed. Extra care will be needed to make sure all of these risks are averted.

Since we will be using a time server connected to a Wi-Fi network, data privacy for the end user is also pertinent to adhere to the ACM code of ethics.

The societal impact of the product should be a positive one. Less missed medications should result in better outcomes for patients and less trips to the emergency room for patients who miss critical medications.