Project Proposal - Habit Forming Key Station

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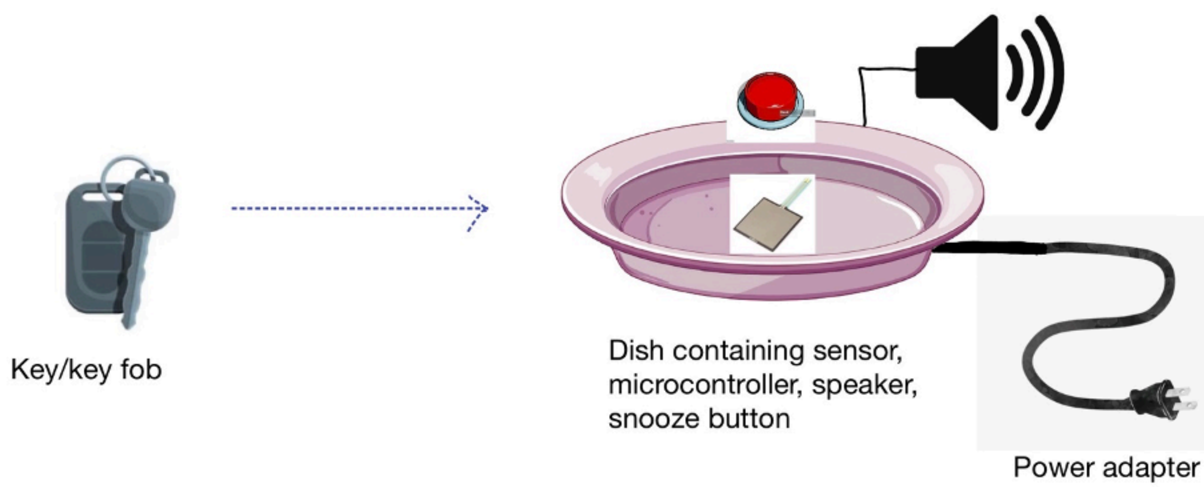
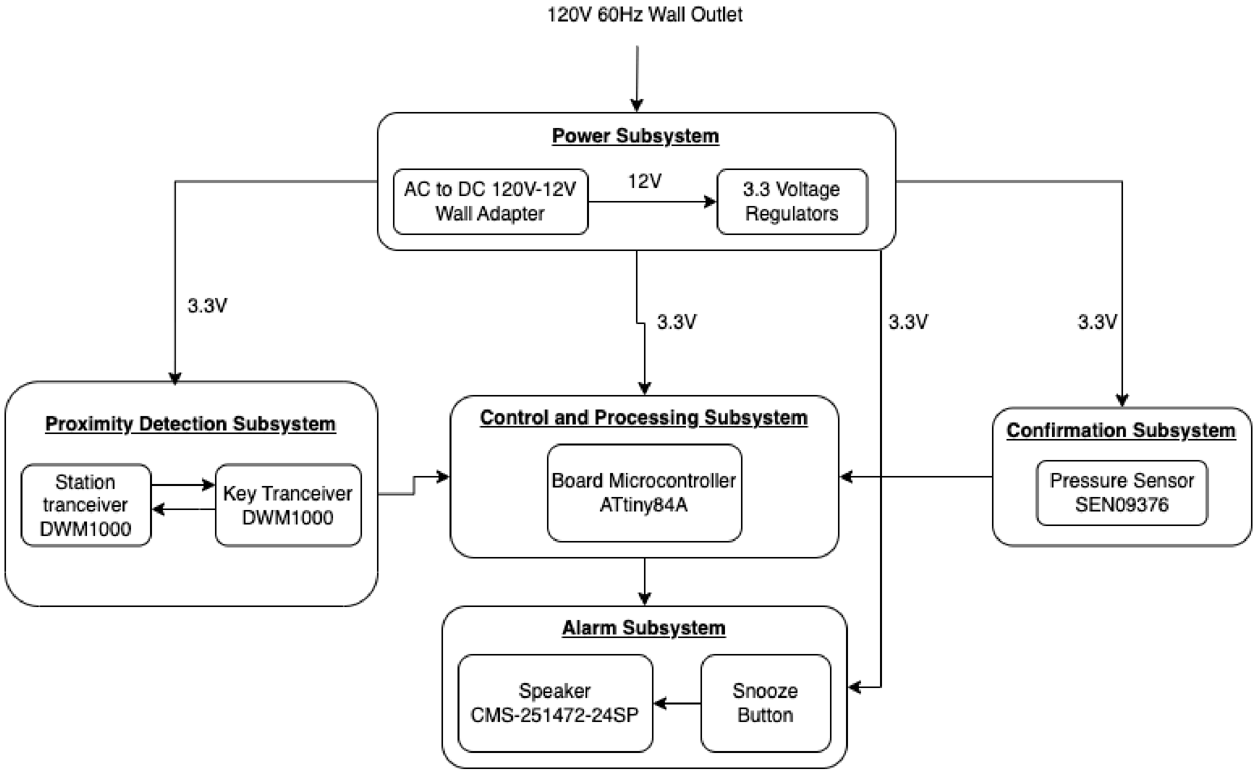
Introduction: People have a difficult time building good habits. A common issue that many people encounter is losing or misplacing their keys whenever they enter their home. People often leave their keys in random places around the house, leaving them scrambling to find them when it's time to leave. If they were accustomed to placing and grabbing their keys from a specific designated location, then the likelihood of losing their keys and wallet would be significantly low.

Solution: Our solution is the habit-forming key dish: a designated home for your valuable keys that trains you to keep them in the right place every time. This key dish utilizes negative reinforcement to build positive habits for its users. The key dish will be equipped with a pressure sensor, RF tracking, a speaker, and a snooze button. We utilize RF tracking to detect when the user has come home but hasn't put their keys in the dish. At this moment, we will sound an alarm on the speaker, notifying the user that they need to place their keys into the dish. The user can either place the keys into the dish or press the snooze button to turn off the alarm. This solution forces users to always keep their keys in their designated spot and prevents them from losing them in their home ever again.

Visual Aid:



Block Diagram



Subsystem Overview

Proximity Detection Subsystem

The Proximity Detection Subsystem serves as the initial point of user interaction with the system. It utilizes a transceiver on the dish to detect the presence of a corresponding transceiver attached to the user's keys. When the keys come within a specified range, the dish transceiver picks up the signal from the tag and communicates this data to the Control and Processing Subsystem. This subsystem is essential for determining whether the user has returned home and is in proximity to place the keys in the designated station.

Requirements and Tests

1. Accurately detect the key up to 15 feet range in diverse indoor environments, including those with potential electronic interference.
    a. Conduct detection tests across the specified range in environments mimicking common indoor settings with and without electronic devices active.
2. Achieve a detection accuracy of at least 95% in environments with active common household electronic devices.
    a. Evaluate detection accuracy in a controlled environment simulating household electronic interference, recording the success rate of detections.
3. Limit detection latency to under 2 seconds for key fob recognition within the effective range.

    a. Measure the latency from key fob entry into the detection range to system response, conducting multiple trials for statistical validity.

<u>Control and Processing Subsystem</u>

At the heart of the system is the Control and Processing Subsystem, which acts as the decision-making unit. Powered by the ATmega2560 microcontroller, it processes the input from the Proximity Detection Subsystem to determine the system's state — whether the user has arrived and if the keys are not yet placed in the dish. Based on these conditions, it sends control signals to the Alarm Subsystem to initiate the alert and waits for the Confirmation Subsystem to signal the cessation of the alarm. It is the central hub that orchestrates the behavior of the entire system.

Requirements and Testing:

1. Transition between four states when provided appropriate stimuli
    a. Simulate software stimuli to ensure sound control logic.
    b. Develop test harness which projects state to an LED. Provide stimuli to change states
    c. Test each path to ensure safety of state reachability
2. Read input from confirmation subsystem
    a. Write test harness to sound an alarm anytime pressure is added to the sensor
3. Provide output to the alarm subsystem and generate 80 dB waves
    a. Write test harness to provide square waves whenever a button is pressed
    b. Compare audible sound with known square wave to ensure correct sound is emitted
    c. Utilize decibel meter to measure loudness right next to the dish
4. Read input for proximity detection subsystem
    a. Write test harness to sound an alarm whenever the key fob comes within reading range (approximately 15 feet) of the proximity detection subsystem

<u>Alarm Subsystem</u>

The Alarm Subsystem is responsible for alerting the user to place their keys in the designated spot. It is activated by the Control and Processing Subsystem when the keys are detected but not yet placed in the dish. This subsystem employs a Piezo Buzzer to emit an audible alarm, ensuring the user is reminded to place their keys properly. Once the keys are placed, and the Confirmation Subsystem sends a signal, the Control and Processing Subsystem will then deactivate the alarm. Another feature to turn off unnecessary ringing when the user is carrying the keys and does not need to place it in the dish is a snooze button. It will send the system back to the timer state.

Requirements:

1. The alarm must be audible at 80 dB SPL at 1 meter.
    a. Test with a sound level meter at 1 meter.
    b. Confirm SPL meets/exceeds 80 dB
2. Speaker power consumption should not exceed 2W.
    a. Measure power usage with a multimeter

    b. Ensure it is within 2W during operation
3. Accurate timing for the snooze duration before re-activating the alarm
    a. Measure the interval between snooze activation and alarm re-activation.

<u>Confirmation Subsystem</u>

This subsystem confirms the placement of the keys in the station. It features a pressure sensor that detects the weight of the keys when placed in the dish. Once the keys are detected, the Confirmation Subsystem sends a signal back to the Control and Processing Subsystem to terminate the alarm sequence. This feedback loop is crucial for ensuring that the habit of placing the keys in the dish is reinforced through the cessation of the alarm.

Requirements:

1. Detect placement of objects weighing between 45g to 55g, simulating key weight, with a tolerance of ±5g.
    a. Conduct a series of tests using calibrated weights to validate the sensor's accuracy in identifying key placement within the defined weight range.
2. Response time from weight detection to confirmation signal activation must not exceed 500 milliseconds.
    a. Utilize a timing device to capture the interval from the moment weight is applied to the sensor to the activation of the confirmation signal.
3. Ensure consistent sensor performance across temperature variations from 15°C to 35°C, to account for typical indoor temperature fluctuations.
    a. Test the sensor's functionality at various temperatures within the specified range, ensuring accuracy remains within the required tolerance.

<u>Power Subsystem</u>

The Power Subsystem provides necessary electrical power to all other subsystems. It utilizes a 9V battery to ensure that the device can operate for several weeks without the need for recharging or battery replacement. This subsystem is connected to each of the other subsystems, supplying them with the power required to perform their functions.

Test and Verification: Monitor operational lifespan on a 9V battery against expected duration. Record voltage and current draw to validate system efficiency.

Requirements:

1. Provide a stable 5V output under load.
    a. Conduct load testing with a multimeter
    b. Ensure voltage remains within 5% of 5V
2. Support total current draw of 500mA without overheating
    a. Execute a continuous operation test.
    b. Monitor temperature to stay within safe limits
3. Accommodate varying voltage and current needs of components.
    a. Perform audio frequency analysis.
    b. Verify output is within 500 Hz to 4 kHz.

High-Level Requirements:

1. The microcontroller waits 2 - 4 minutes after removing the keys from the pressure plate before enabling the proximity subsystem to detect the keys
2. The proximity subsystem should detect the key fob at a minimum of 15 feet from the dish. Upon detecting the keys, it should wait 30-90 seconds before sounding the alarm.
3. The alarm turns off by either placing the keys in the dish or pressing the snooze button within 5 seconds of either method

Subsystem Requirements

Proximity Detection Subsystem:

1. The system must include two DWM1000 transceivers, ensuring they can detect each other within veteran ranges.
2. The subsystem must implement a protocol for communication that can decode the unique identification signals transmitted by RFID transceiver, ensuring accurate and reliable key detection.
3. The subsystem must include an antenna design optimized for a clear signal within the specified range and minimal interference from common household materials such as wood, glass, and cement.
4. <u>Testing</u>: This subsystem's effectiveness is evaluated through range tests DWM1000 RFID Transceivers in the operational distance Additionally, communication protocol accuracy is assessed by differentiating unique identifiers from multiple tags, alongside antenna optimization tests that measure signal integrity through common materials, confirming minimal interference and optimized design.

Control and Processing Subsystem:

1. The ATTiny85V-10SU microcontroller must process the RFID input within 200 milliseconds to trigger the alarm system.
2. The subsystem must maintain a control algorithm can handle debounce logic for the RFID reader, pressure sensor inputs, and the snooze button functionality
3. Despite the ATTINY85V-10SU's lower power consumption, the firmware must be optimized for power efficiency, especially when connected to an outlet power source, with considerations for safe power management.
4. <u>Testing</u>: Testing focuses on measuring the RFID input processing time to ensure it falls within the required 200 milliseconds, utilizing high-resolution timing tools for accuracy. The debounce logic is validated through simulated rapid inputs, ensuring the system accurately filters out noise and false triggers. Power efficiency is also scrutinized, monitoring consumption in various operational states to confirm the system's power management meets efficiency standards, particularly in idle states.

Alarm Subsystem:

1. The CMS-251472-24SP buzzer must emit a sound at 80-90dB, which must be audible from at least one room away with a door closed.
2. The subsystem must include a snooze button allowing user to silence the alarm for a period of time.
3. The alarm must be able to operate continuously for at least 1 minute without failing and without causing a significant voltage drop that could affect other subsystems.
4. Testing: Audibility tests for the CMS-251472-24SP buzzer confirm its sound level falls within the 80-90dB range at specified distances, ensuring it can be heard from another room. The snooze functionality is tested for correct operation, including silence periods and reactivation. Continuous operation and voltage stability are also assessed, ensuring the alarm can function for at least a minute without significant voltage drops, maintaining system integrity.

Confirmation Subsystem:

1. The Thin Film Pressure Sensor (SEN-09376) must detect a minimum weight of 50 grams, which corresponds to the weight of a key and keychain, with a sensitivity tolerance of +/- 10 grams.
2. The subsystem must send a confirmation signal to the control subsystem within 50 milliseconds of the keys' placement.
3. The pressure sensor must have a lifecycle that is long enough.
4. Testing: This involves testing the Thin Film Pressure Sensor (SEN-09376) for sensitivity and response time by applying precise weights and measuring the system's reaction, ensuring it detects a minimum of 50 grams within a +/- 10 grams tolerance and confirms placement within 50 milliseconds. The sensor's lifecycle is also evaluated through repeated use cycles to verify durability and consistent performance.

Power Subsystem:

1. The system must be designed to operate with a electrical outlet, ensuring a continuous power supply without the need of battery replacement.
2. The subsystem must include proper voltage regulation to adapt the outlet voltage to the voltage levels required by the system components, including the ATTINY85V-10SU and the CMS-251472-24SP buzzer.
3. Testing: The power subsystem is rigorously tested by connecting the system to an electrical outlet and measuring voltage output under various loads to ensure stable power supply and regulation. This confirms the system's ability to adapt outlet voltage to the required levels for all components, ensuring reliable operation without the need for battery replacement, and validating the design's power efficiency and safety.

Tolerance Allowance

The following table includes the current draw of every component in our circuits under 3.3V.

Components	Current Draw (mA)	Comments
ATtiny84A	200	DC Current VCC and GND Pin At 125°C
DWM1000	13.4	Total Current Draw from all supplies IDLE Mode
Total	213.4	Sum

The regulator we will use is LM1117 TO-220, which has the following ratings.

Variable	Value	Comments
Max Temperature	150°C	Mas Temperature LM1117 can operate
I_{out}	213.4mA	Calculated Above
V_{in}	12V	Input voltage from the AC-DC Converter
V_{out}	3.3V	Output voltage
T_A	40°C	Ambient Temperature
$R_{\theta JA}$	23.8°C/W	Junction to Ambient Thermal Resistance

Using these values, the maximum junction temperature the voltage regulator will reach is calculated as

$$T_J = T_A + PR_{\theta JA} = 40°\text{C} + (12\text{V} - 3.3\text{V})\,(213.4\text{mA})\,(23.8°\text{C/W}) = 84.18°\text{C}$$

This is well below the maximum junction temperature (150°C) of the voltage regulator. Therefore, the LM1117 TO-220 regulator will output the required power without overheating.

Ethics and Safety Requirements

The design prioritizes privacy and fairness, adhering to ACM's Section 1.6 [9] and IEEE's ethics, ensuring the key tracking feature enhances functionality without compromising user data. It complies with safety standards in voltage and current management, reflecting ACM's Section 1.2 and IEEE's focus on safety and risk [9][10]. The alarm's sound level is based on acoustic research, aligning with ACM's Section 3.1 [9], to be effective yet safe for hearing, and includes a snooze button for user autonomy and safety. Safety features like voltage regulators, a comprehensive lab safety manual for electrical components, and a choice of a 12V power supply address overcurrent, overvoltage, and high voltage risks. Software incorporates redundant safety checks as per ACM's Section 2.5 [9], proactively ensuring public safety and health, in line with IEEE's standards. This design approach upholds leading professional organizations' codes, emphasizing responsible development and stakeholder well-being.