Toothbrush Alarm
ECE 445 Project Proposal - Spring 2024

Project #67
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Introduction

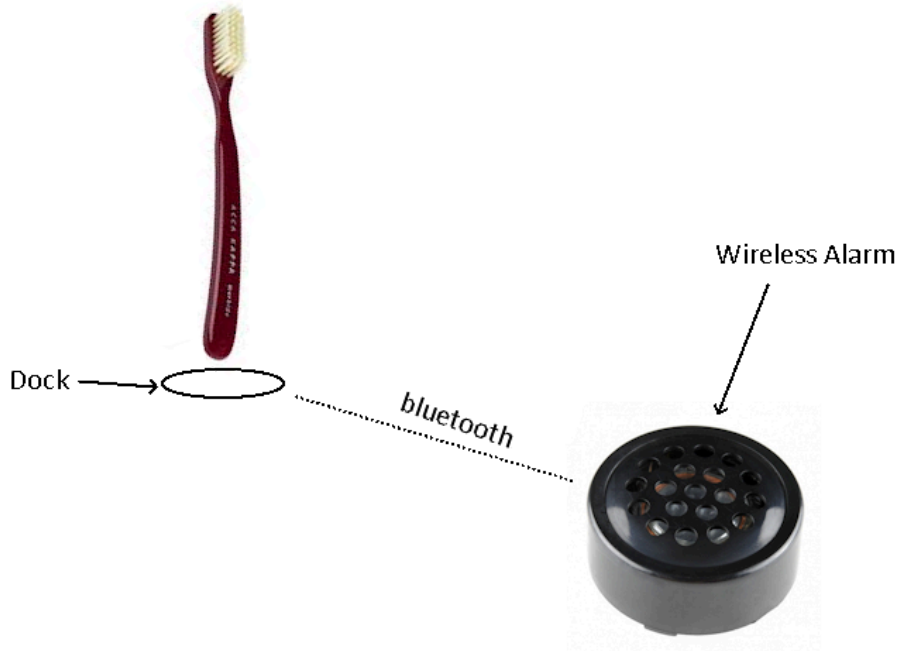
Problem

Waking up early in the morning is a challenge that many people face, and conventional alarms often fail to provide an effective solution. Despite setting multiple alarms, people find themselves constantly oversleeping, waking up significantly later than intended. This issue can lead to a range of negative consequences, including disrupted daily schedules, reduced productivity, and increased stress. Traditional alarms tend to lack the ability to ensure that a person not only wakes up but also gets out of bed and starts their day. This is particularly problematic for those with a heavy sleeping pattern or a habit of snoozing alarms.

Solution

To address this issue, our idea is to create a Toothbrush Alarm. The concept involves an alarm that persists until you get up and spend, for example, 3 minutes brushing your teeth. Once the tooth brushing routine is complete, the alarm automatically stops. This not only ensures a timely wake-up but also promotes a refreshed start to the day after engaging in the morning teeth-cleaning ritual.

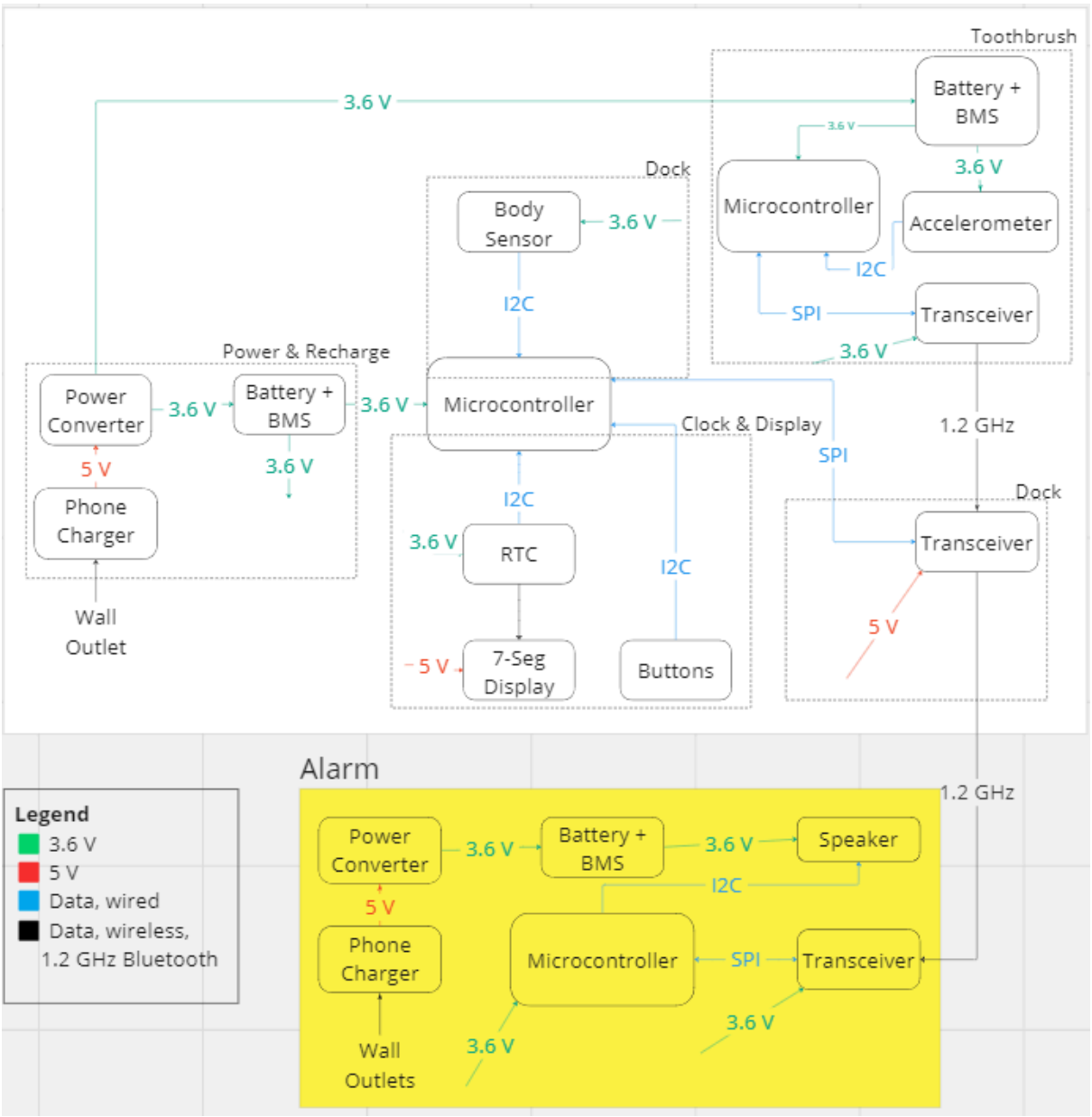
Visual Aid



High-level Requirements

- Alarm will turn off only after the user brushes their teeth for 2 minutes, if the user holds two specific buttons on the dock for 10 seconds, or if the toothbrush is left unattended for 30 minutes
- Toothbrush can detect if it has been used with ± 2.2 mN (the estimated minimum force the sensor can detect), regardless of direction and orientation
- Able to detect the presence of human body within 3 m, in a 180° angle in front of the dock

Design



Subsystem Overview

Subsystem 1 – Dock

The dock will sense the presence of the toothbrush, and how long the user's been brushing their teeth. Once the user picks the toothbrush up and puts it down after brushing their teeth for more than 2 minutes, or whatever time the user sets, it will tell the alarm to turn off. The dock also contains a body motion sensor. It would detect the appearance of an individual in the bathroom to further ensure the system works as intended.

Subsystem 2 – Toothbrush

To ensure the user brushes their teeth after picking up the toothbrush, the accelerometer will be used to detect whether the user is making appropriate teeth brushing movements. While it is possible to simply wave the toothbrush without actually brushing your teeth, the main purpose of the device is to wake up the user, and sufficient physical movement will help, regardless of if it is used to brush teeth or not.

Subsystem 3 - Alarm Speaker

The alarm is wirelessly connected to the toothbrush dock, and it will stop ringing once the user approaches the toothbrush dock. And if the user fails to complete brushing their teeth, it will restart the ringing.

Subsystem 4 - Clock and Display

Source of time for the rest of the subsystems, and a seven segment display of the time. Will also display the desired alarm time, brush time, and current time as needed. Has buttons to adjust them.

Subsystem 5 - Power and Recharge

A charger block to replenish power to the rechargeable battery that powers all the rest of the components

Subsystem Requirements

Subsystem 1 – Dock

The dock will contain our PCB board to control the whole system. Multiple pressure sensors are contained in a shape that perfectly matches the bottom of the toothbrush to detect if the toothbrush is docked. The sensors will be at the bottom and side to ensure the object docked is the toothbrush, and the user is not fooling the dock with another object.

The motion sensor will be installed around the dock, facing the user to detect if they have entered the bathroom and continued present in the bathroom, ensuring they are not fooling the system. The motion detector senses the passive body infrared to make sure the moving object is a human.

- Microcontroller
- Bluetooth transceiver
- IR distance sensor

Subsystem 2 – Toothbrush

The accelerometer will determine the force applied on the brush and how often it switches directions, so it can tell when the user is brushing their teeth

- Accelerometer
- Rechargeable battery
- Battery management IC
- Microcontroller
- Bluetooth transceiver

Subsystem 3 - Alarm Speaker

The alarm will be a speaker integrated into the dock, or can be wired into the user's room to more effectively wake them up.

- Speaker
- Rechargeable battery
- Battery management IC
- Microcontroller
- Bluetooth transceiver

Subsystem 4 - Clock and Display

The Clock Display and Settings system will take the Clk signal from the microcontroller in order to keep track of time. This signal will be inputted into a counter to increment and be translated into something readable for the 7-segment display. There will also be 5 buttons: up, down, left, right, and toggle. Toggle will switch between the current time and the time of the alarm. The direction buttons change the time on both modes. Left and right switches between hours and minutes, up and down increment or decrement the number respectively.

- 7-segment display
- Real time clock
- Buttons

Subsystem 5 - Power and Recharge

Power converter to draw power from wall outlets to charge the various batteries. Then further voltage converters to change battery voltage to appropriate voltages for components.

- Rechargeable battery
- Battery management IC
- Phone charger block

Subsystem Interaction

Subsystem 1 – Dock

The dock will send out signals to the alarm speaker to activate or deactivate, and receive wireless signals from the toothbrush on whether it is used properly or not. It will also be wired connected to the clock display.

Subsystem 2 – Toothbrush

The toothbrush will send signals on if the user is properly brushing their teeth or not to the dock wirelessly.

Subsystem 3 - Alarm Speaker

The alarm speaker will receive wireless signals from the dock to activate or deactivate.

Subsystem 4 - Clock Display and Settings

The clock display and settings subsystem will be wired to the dock and provide the timing for all the systems.

Subsystem 5 - Power and Recharge

The power and recharge subsystem will supply power to the dock and the alarm speaker.

Tolerance Analysis

In-Use Sensor

From the datasheet, the user may exert 2.2 mN of force at minimum (F_{min}) to brush their teeth

$$(minimum\ acceleration\ resolution)\ *\ (mass\ of\ toothbrush) = minimum\ detectable\ force\ \rightarrow$$
$$((2\ *\ 9.8\ m/s)\ /\ 16384\ LSB)\ *\ (18\ g)\ =\ 2.197265625\ mN/LSB\ (1)$$

This means there will be no trouble detecting the user use the toothbrush since

$$(mass\ of\ toothbrush)\ *\ (gravity\ acceleration)\ =\ (weight\ of\ toothbrush)\ \rightarrow$$
$$18g\ *\ 9.8\ m/s\ =\ 176.58\ mN$$

Meaning the user will have to use more force to move around the toothbrush than the minimum the accelerometer can detect.

Our testing indicates the average user brushes their teeth at a frequency averaging 5 Hz and not exceeding 10 Hz (f_{brush_max}).

Given our microcontroller, PIC16F886-I/SO, will be running at 20 MHz (f_{clock}) , and the accelerometer can output data at 1 MHz (f_{accel}), there will be no issue detecting the change in direction.

Proximity Sensor

From the datasheet, the IR distance sensors have a sensor range of a 100° cone (θ_{range}) centered from itself. In order to ensure a reasonable range of detection, two of these sensors will be used, with a 100° difference to minimize overlap. This is sufficient because

$$2\ *\ \theta_{range} = \theta_{range\_total} \rightarrow 2\ *\ 100° = \theta_{range\_total} \rightarrow \theta_{range\_total} = 200°\ (2)$$

Since the total range is now greater than 180°, it is reasonable to assume any approach from the front will be detected, so the toothbrush alarm may function properly.

Ethics and Safety

Our project is committed to the highest safety standards, placing safety as our foremost priority. Given that the toothbrush will be used inside the user's mouth, it is crucial that it remains safe under rigorous scrutiny. Designing a device for personal hygiene, we prioritize the safety and health of the users above all, aligning with IEEE's Code of Ethics Section I.1, to “hold paramount the safety, health, and welfare of the public.” [1]

Understanding the potential hazards associated with electrical devices, particularly those in close contact with water, we have designed the components on the toothbrush to be enclosed within the handle and water-tight to prevent potential harm to the user. This design choice minimizes any risk of electric shock, making the device safe for everyday use in a bathroom environment.

Moreover, batteries catching on fire has long been a public safety concern, and we take good notes of that. Our BMS will constantly monitor the condition of our batteries, and regulate the charging and discharging cycles to prevent accidents caused by overcharging.

During the execution of the project, we will maintain our work environment according to Section II, to “treat all persons fairly and with respect, to avoid harassment or discrimination, and to avoid injuring others.” Additionally, as stated in Section III, we will support and assist each other as needed. [1]

References

[1] “IEEE Code of Ethics.” Available: https://www.ieee.org/content/dam/ieee-org/ieee/web/org/about/corporate/ieee-code-of-ethics.pdf