Smart Toothpaste Dispenser

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1. Introduction

1.1 Objective

The goal for our project is to design a fully automatic electric toothpaste dispenser powered by either a battery or a power outlet. The toothpaste dispenser should dispense a preset amount of toothpaste when a toothbrush presents at the designated location and the user can adjust the preset amount. The settings should be adjustable with the pushbuttons on the device and the user can see the current setting through an interactive screen.

1.2 Background

The majority of the toothpaste dispensers in the market are manual. We purchased one and disassembled it. We discovered that a simple manual pump was used for user to squeeze toothpaste from the tube. The dispensing process was not so smooth since the pump broke easily and there existed a big chance that the toothpaste could not be pumped out.

Figure 1: Existing Manual Toothpaste Dispenser

Those electrical toothpaste dispensers currently on market generally dispense a same amount of toothpaste every time and cannot be easily adjusted. Also, the dispenser does not have any interaction with the users for them to know the time and the current settings. Besides, the existing devices may not be portable since they are powered only with power outlets, but not batteries.

1.3 High-level Requirement

- There must be mechanical design for the toothpaste dispenser.
- The toothpaste dispenser must include some mechanisms to detect the existence of a toothbrush and should automatically dispense a preset amount of toothpaste.

- The toothpaste dispenser must have some mechanism to allow users to adjust the preset amount of toothpaste and reflect the settings and adjustment through an interactive screen.

2. Design

2.1 Block Diagram

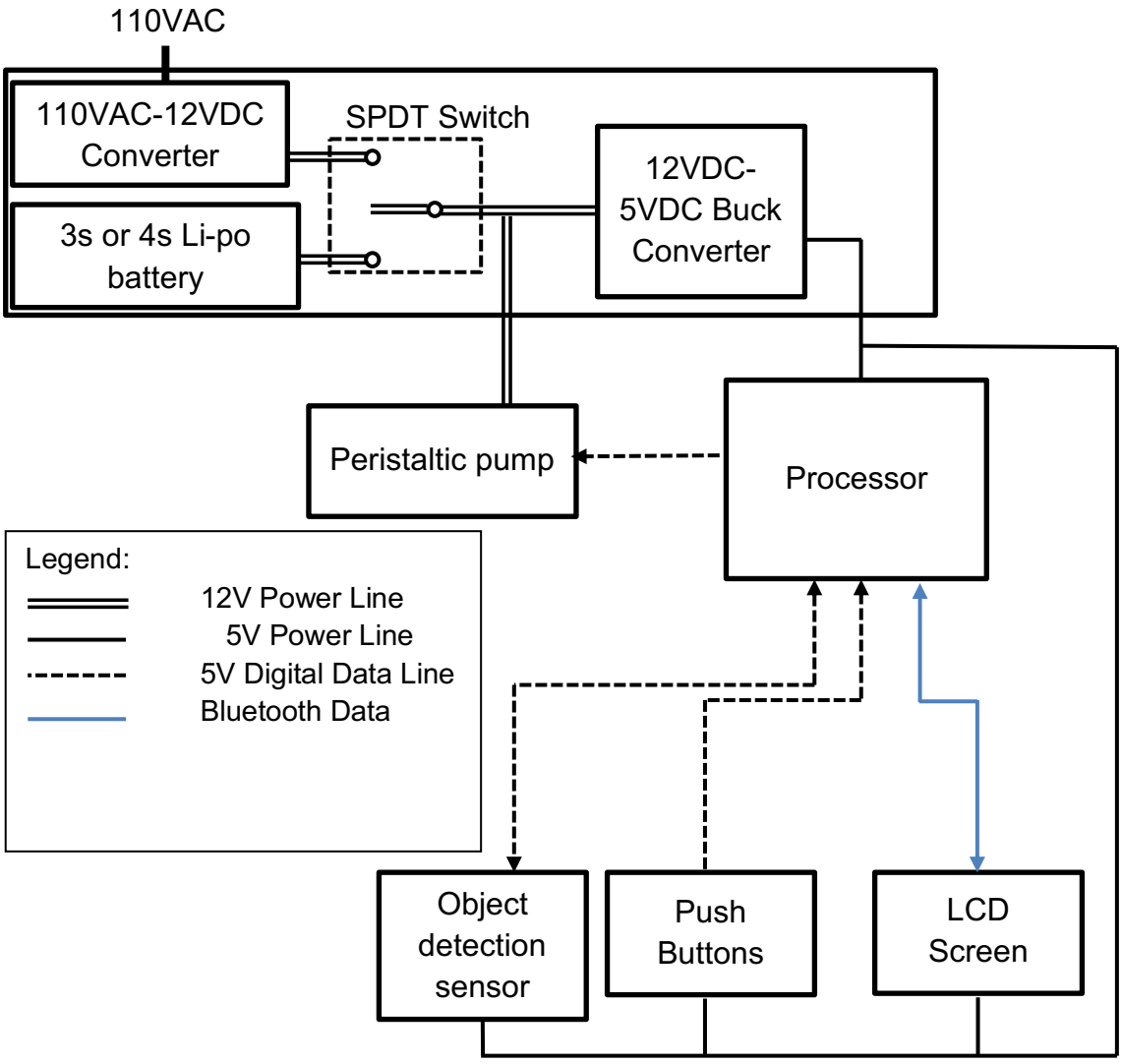

Figure 2: Block Diagram

2.2 Physical Design

Two designs are proposed to achieve the dispensing goal. Our primary design includes using peristaltic pump to pump out toothpaste from the tube as shown in *figure 3*. We have tested our current peristaltic pump and we found it capable of pumping out from the tube with a rate of around 0.08 grams/sec. A back-up plan has also been

designed shown in *figure 4* just in case. This plan uses spring tensioned rollers to roll down a tube in order to squeeze the toothpaste out.

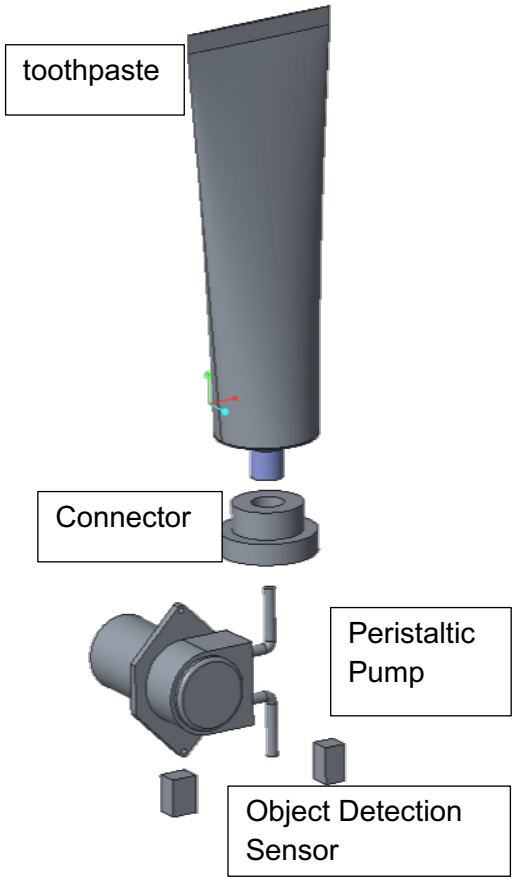

Figure 3: Primary Design Configuration

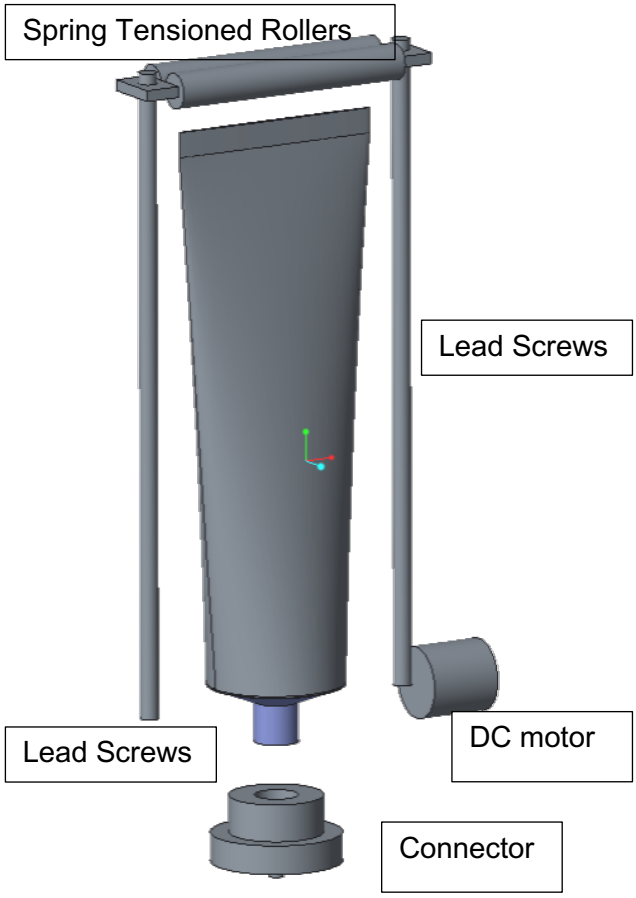

Figure 4: Backup Design Configuration

2.3 Functional Overview and Requirements

2.3.1 Mechanical Design

a. Dispenser Shell

The dispenser case or supporting structure will be mostly plastic and 3D printed. It holds the components, including the pumping system, the sensors, the processors and the screen in place.

- Requirement: the shell must have a reasonable size comparable to those currently in market and be able to fix all the necessary components.

b. Dispense Mechanism

A peristaltic pump is used to get the toothpaste out of the tube and dispense it onto the toothbrush. The peristaltic pump is powered by a DC motor and dispense toothpaste at a rate about 0.1grams/sec. The amount dispensed will be controlled by controlling the activation time of the pump.

- Requirement1: the dispensing mechanism is able to dispense a designated amount of toothpaste within 0.02 grams precision.
- Requirement2: the dispensing mechanism should be able to dispense most of the toothpaste in the tube with minor assistance from the user.
- Requirement3: the dispensing mechanism should be able to be taken apart by the user, cleaned, and reassembled without removing or adding any glue.

2.3.2 Power Supply

The device can be powered by either an 110VAC power outlet or a battery pack between 10V and 12V. The two power sources cannot be connected simultaneously, since such connection may cause a short circuit and damage the battery. The simultaneous connection will be prevented mechanically.

There will be a converter used to step down the voltage further to meet the requirement of the processor.

- Requirement1: The power unit can be powered by either a standard wall plug or a battery around 12V ($\pm 2V$).
- Requirement2: The power unit should be able to prevent fire or electric shock hazard even if user uses the wrong battery rating.
- Requirement3: The power unit should be able to stay safe(grounded) even if water drops on its shell.

2.3.3 Control Unit

All the components in control unit are designed collectively to detect the existence of a toothbrush and allow users to see and modify the preset amount of toothpaste, which is intuitively represented by integers.

a. Microcontroller

A microcontroller, chosen to be PSOC4 BLE (Bluetooth Low Energy) [1] processor, controls the sensors, buttons and LCD screen by receiving, analyzing and sending signals across the above three components.

- Requirement 1: The microcontroller should have an Analog to Digital Converter(ADC) responsible for the communication between the other three components in the control unit.
- Requirement 2: The microcontroller should have an LCD drive compatible for the model of LCD screen we choose to use.
- Requirement 3: The microcontroller should set up a mapping between the integers on the LCD screen, representing the preset toothpaste level that users can modify, and the real amount of toothpaste to be dispensed.

b. LCD Screen [2]

The LCD screen displays the preset amount of toothpaste to be dispensed, which is represented as a sequence of integers from 1 to 10. The amount of toothpaste to be dispensed will increase with the increase of number displayed.

- Requirement 1: the LCD screen should be compatible with the LCD driver on the microcontroller and with the voltage of microcontroller.
- Requirement 2: the LCD screen should be able to display digits or alphanumeric characters, which in this case can be satisfied by a segment LCD.
- Requirement 3: the LCD screen should be able to communicate with the microcontroller via certain Bluetooth protocols.

c. Push Buttons

Users can adjust the amount of toothpaste by pushing the increase button (+) and decrease button (-) several times to achieve the desired amount of toothpaste.

d. Object Detection Sensors

The sensors will be able to detect when users insert toothbrushes into the dispense slot. We are currently testing out 3 types of sensors: Infrared Proximity Sensor, Infrared Break Beam Sensor, and Ultrasonic Distance Sensor.

- Requirement 1: the sensor should be able to sense when an object is inserted into the toothpaste dispense slot and under dispense mechanism.
- Requirement 2: the sensor should be able to function in high humidity environment such as bathrooms.
- Requirement 3: the sensor should be able to communicate with the microcontroller by either analog or digital signals.

2.4 Risk Analysis

There are many aspects of the project need to cooperate with each other to achieve a successful product. For example, if we choose to use Infrared Proximity Sensor for toothbrush detection, the color of the toothbrush could vary the output voltage of the sensor. If we were to choose to use Ultrasonic Distance Sensor, its response time is subject to the variants in the environment such as humidity. Humidity could also post a great threat to our Control Unit and Power Supply Unit, therefore, we need to be very careful with the details of our implementations of the units by taking measures such as widening the gap between the electrical pathways of our PCB board design.

For the control unit, the greatest risks reside in the communication between the processor (PSOC 4 BLE) and the LCD screen. First, there is certain risk that the voltage of processor and LCD doesn't match as most LCD uses 3.3V not 5V as processor. Second, it is not certain that the LCD drive provided by the processor is compatible with the LCD screen we will use. Third, it is probable the Bluetooth connection between LCD and processor is not reliable and stable enough.

3. Ethics and Safety

Although we are not working with high voltage with our implementation, there are still several safety concerns with our project. First of all, since this dispenser is designed to be used in bathrooms, sealing up the casing for the power supply unit, sensors and peristaltic pump is necessary to prevent shorting the circuits and electric shocks to the users. Secondly, considering we are expecting children to use the device, it must not contain small easily disassembled small components or sharp edges that may hurt children. In addition, because toothpaste goes into people’s mouth, we must carefully choose those components that contact the toothpaste directly so that the user will not accidentally consume any toxic substance. According to IEEE Code of Ethics [1], it is important to be aware of and to inform the potential damage to people or the environment caused by our design. We will be constantly aware of our effect to the surroundings and the user at every step to obey the Code of Ethics.

Bibliography

[1] Cypress, "PSoC® 4 BLE (Bluetooth Smart)," Cypress, 2019. [Online]. Available: https://www.cypress.com/products/psoc-4-ble-bluetooth-smart.

[2] Cypress, "AN87391 - PSoC® 4 Segment LCD Direct Drive," Cypress, [Online]. Available: https://www.cypress.com/documentation/application-notes/an87391-psoc-4-segment-lcd-direct-drive.

[3] Institute of Electrical and Electronics Engineers, "IEEE Code of Ethics," 2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html.