ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Smart Pill Hub

Team #65

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1. Introduction

1.1Problem

With the world's population aging, old age well-being is a huge issue in society today. Illnesses are afflicting more and more elderly people, and probably all of them can't live without taking medication. However, doctor's orders can sometimes be confusing, especially for seniors with degenerative mental illnesses, such as Alzheimer's disease, and taking medication on time and as prescribed can be difficult. However, the cost of smart pill boxes on the market today is generally high, which is another huge expense for seniors who already have to pay high medical bills. On top of that, the features included in the smart pillboxes on the market seem to be less than satisfactory. The smart pillboxes nowadays only have some basic functions such as reminding you to take your medication. Therefore, a relatively inexpensive and feature-rich pillbox is urgently needed by society and the market nowadays.

1.2 Solution

To solve the above problem, we propose a smart pill box that can store, dispense, and manage many different types of pills. Our smart pillbox has separate compartments, a precise dispensing mechanism, and a user-friendly mobile application that will be used as a control center for the pillbox. The mobile app will connect the box to the user's cell phone via Bluetooth or the Internet. Through the app, the user can make settings for the box, such as dosage, schedule, and number of tablets remaining. We have added a reminder system to our design which includes a buzzer and LED, this design reminds the user to take the pills at the set time. We designed a conveyor belt with dividers through which the smart pill box can dispense medication accurately. In addition, we designed a temperature and humidity sensor to monitor the temperature and humidity of the pillbox to prevent the pills from losing their medicinal properties.

1.3 Visual Aid

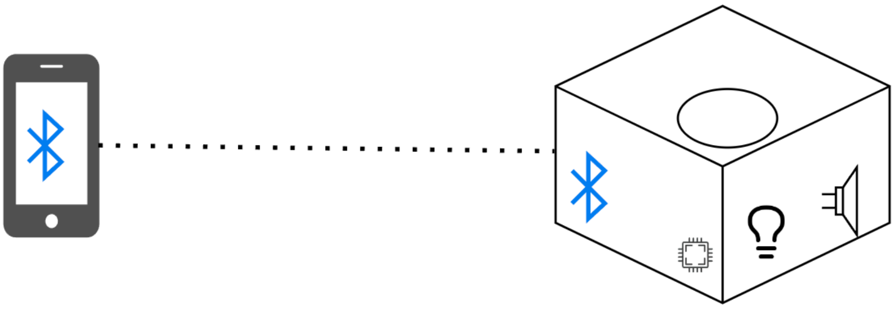

Figure 1: Visual Aid

As shown in the figure above, the pillbox we designed is mainly controlled by an app in the phone for scheduling and dosage adjustment. When users connect to the box via Bluetooth from their cell phones, they can set the date and dosage of their medication according to their needs. When the time set by the user is reached, the pillbox will remind the user to take the medicine through LED and buzzer. At the same time, the microprocessor in the box will control the box to dispense a precise dose of pills.

1.4 High-level requirements list

1. Our design will enable the dispensing of the correct number of pills according to a set schedule, within 5%, by coordinating the software with the hardware.

2.Our design will be realized according to all designed schedules. Users will be alerted when they do not take their medication at the prescribed time.

3. Our design will have a functioning app connected to our hardware device via Bluetooth and allows the user to set and adjust the schedule and dosage of medication on the box. The app should be able to communicate/set parameters for the box in around 10 meters.

2. Design

2.1 Block Diagram

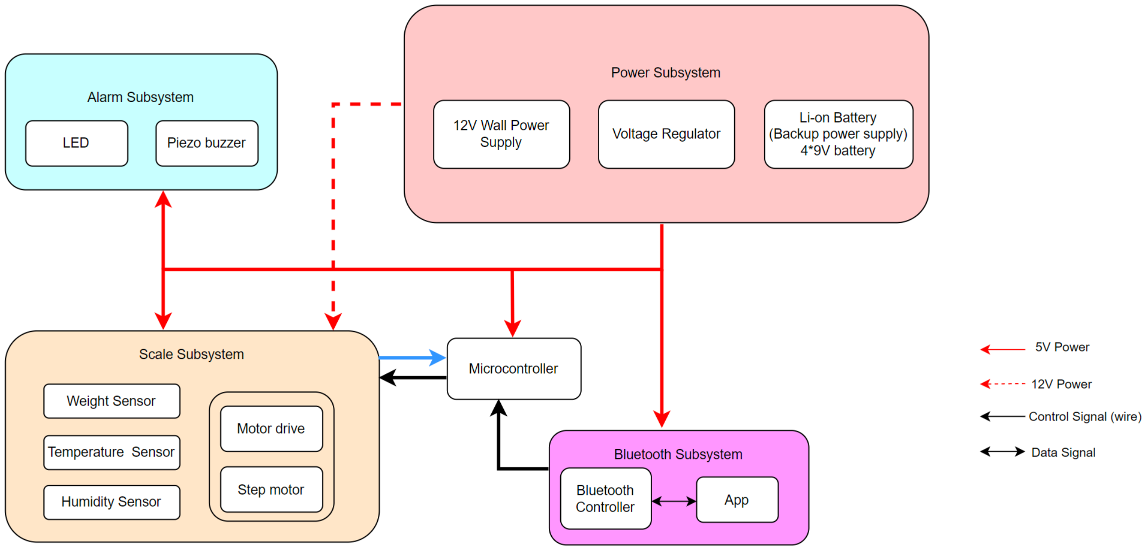

Figure 2: Block Diagram

2.2 Physical Design

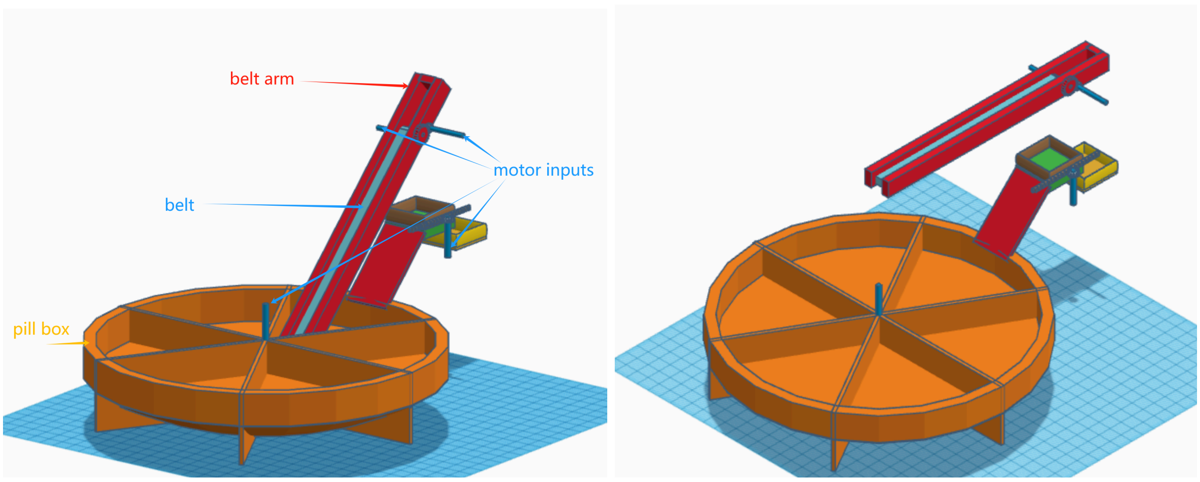

Figure 3: Physical Design (Side View)

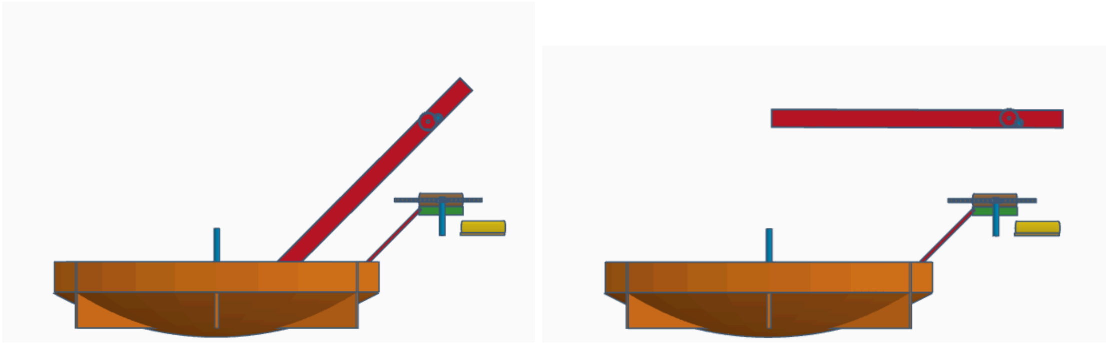

Figure 4: Physical Design (Front View)

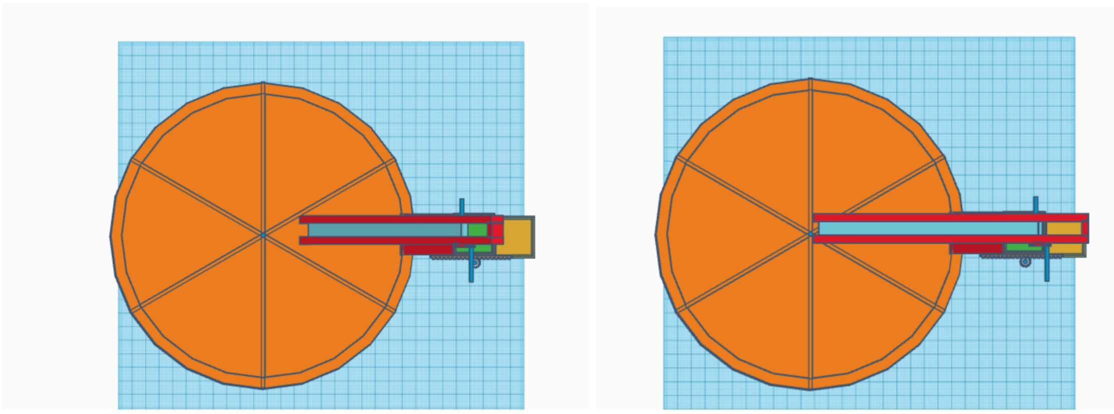

Figure 5: Physical Design (Top View)

The picture above shows the mechanical part of our design, and we will be utilizing 3D printing technology to complete our design. We will be modeling more accurately as well as having a more logical layout. Also to increase the overall portability of the pillbox, we will be using a method that uses battery power.

2.3 Subsystem Overview:

Subsystem 1: Pill Storage and Dispensing Mechanism

Each of the 6 containers can hold a different type of pill. 2 step motors, controlled by an MCU, will activate a mechanism to dispense the correct number of pills from each compartment. The mechanism we will use is similar to a conveyor belt with a blocking board to ensure at most one pill is brought up. Throughout our design process, we found the typical medication sizes[2], and we believe we can use a couple of different belts to implement the design. We can use the design like the visual aid above, the red/brown/blue line will be made to be suited according to the dimension size of the pill. The 6 containers will each have its belt, and a step motor will spin the other step motor in place to drive a different belt corresponding to which box of pills we want to dispense. Our design will be very strict and not allow any pill not in a certain direction, which we might bring up no pill at all. We will use an ultrasonic sensor on the other side to detect if any pills fall to help determine the amount of pills dispensed. All those will be controlled by an MCU

https://www.amazon.com/STEPPERONLINE-Bipolar-Stepper-22-6oz-Extruder/dp/B00PNEQ79Q/ref=asc_df_B00PNEQ79Q/?tag=hyprod-20&linkCode=df0&hvadid=312066954908&hvpos=&hvnetw=g&hvrand=17351285031048341922&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9022196&hvtargid=pla-571445301101&psc=1&mcid=405497855edc3b6cb918264fad8b7ffe&gclid=CjwKCAiAlJKuBhAdEiwAnZb7lYwjdzFbX1fog6HtIc8zQg7SaG7tL5BI1zkSkLm6J2yIJ4XmN-NDlBoC7OoQAvD_BwE

Subsystem 2: Control and Mobile Application with Bluetooth Connectivity

An intuitive mobile app will interface with the MCU via Bluetooth. Users can set the name of the pills, the number of pills added, the dosing schedule, and the dose amount, and view the estimated number of pills remaining. The app will also allow users to confirm the count of newly added pills as measured by the scale. The app will also allow the hub purely used as a dispenser, which allows the user to dispense a certain amount of each pill to the compartment at once, or allow the user to dispense a mix of pills(e.g. daily mix) x(e.g.days) amount of times for traveling purposes and such. The app will also notify the user at the scheduled time as well.

Without a Bluetooth connection, the hub should still be able to dispense correctly and store the data(e.g. amount of pill dispensed), which the app can be updated once the Bluetooth is connected again. A light to the corresponding box on the hub will be lit if there is less than 3 days' dosage of a certain pill as well.

https://www.amazon.com/HiLetgo-ESP-WROOM-32-Development-Microcontroller-Integrated/dp/B0718T232Z/ref=asc_df_B0718T232Z/?tag=hyprod-20&linkCode=df0&hvadid=647148730756&hvpos=&hvnetw=g&hvrand=8450100406722233004&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9022196&hvtargid=pla-437464910793&psc=1&mcid=39e993471cc236d386eb2101d62bb68e

Subsystem 3: Integrated Digital Scales

A small scale will be integrated into our hub as well. When the user did not add an entirely new bottle or the user wanted to add an unknown amount of pills into the containers, the user can put a single pill on the scale, and our device will record the weight of the single pill. Users can then add one kind of unknown amount of pills into one container, which we will use to scale to weigh the weight difference to estimate how many of the kinds of pills have been added. This procedure of user adding pills will work together with our mobile app

https://www.amazon.com/Bolsen-Tech-Portable-Electronic-Weighing/dp/B07HQGQ3YR/ref=asc_df_B07N5KTQ2L/?tag=hyprod-20&linkCode=df0&hvadid=312172042767&hvpos=&hvnetw=g&hvrand=11013582059401301827&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvd

vcmdl=&hvlocint=&hvlocphy=9022196&hvtargid=pla-647045072379&mcid=c6c43dfa4338 3ab69f3a16a8adba03fc&gclid=CjwKCAiAlJKuBhAdEiwAnZb7lUayFPcNJ-BHWoo-DBlkG 8l-9Ygv92hECjcQSvtca-q_Ah5Pkr_4LBoCz2QQAvD_BwE&th=1

Subsystem 4: Alert System

The device will feature a dual alert system - a dim light that turns on at the time of dosing and a beeping sound that activates every minute if the compartment is not opened post-alert, ensuring the user takes their medication at the scheduled time.

https://www.amazon.com/outstanding-Connector-Sounder-Speaker-Electronic/dp/B08ZS19SHL/ref=asc_df_B08ZS19SHL/?tag=hyprod-20&linkCode=df0&hvadid=658824471335&hvpos=&hvnetw=g&hvrand=16447128557375967698&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9022196&hvtargid=pla-2087070526749&psc=1&mcid=023bf04fbe853cf29c2a9b5c223f2c47

Subsystem 5: backup battery

We will use a couple of 9v batteries as the backup power plan. The backup power should work and be able to supply the hub for a couple of days. the hub should indicate it is on backup power and potentially show the backup power level as well.
https://www.amazon.com/Excelity-AC-DC-Charger-Power-Adapter/dp/B07PGGLRYR/ref=sr_1_4?keywords=dc+5v+power+cord&qid=1707456487&sr=8-4

https://www.digikey.com/en/products/detail/keystone-electronics/232/303804?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=PMax%20Shopping_Product_Low%20ROAS%20Categories&utm_term=&utm_content=&utm_id=go_cmp-20243063506_adg-_ad-__dev-c_ext-_prd-303804_sig-CjwKCAiAlJKuBhAdEiwAnZb7lRtbHAaHoWYBQugkQBMHXX2-TibofItP3kXX5soU2CtpfxzcJ0IkcxoCr2MQAvD_BwE&gad_source=1&gclid=CjwKCAiAlJKuBhAdEiwAnZb7lRtbHAaHoWYBQugkQBMHXX2-TibofItP3kXX5soU2CtpfxzcJ0IkcxoCr2MQAvD_BwE

2.3 Subsystem Requirements:

Subsystem 1: Pill Storage and Dispensing Mechanism Verification

Requirement	Verification
The mechanisms should be available that can accommodate different types of pills without causing contamination or damage.	Evaluate storage compartments for compatibility with different pill sizes and shapes to ensure no damage or contamination occurs. Test the mechanism's ability to prevent moisture or other environmental factors from affecting the pills.
The designed mechanism can dispense the pills associated with the command request received by the paired device.	Conduct tests using pills of various sizes to ensure the design can accommodate multiple sizes of pills. Perform multiple tests to eliminate randomness.

Subsystem 2: Control and Mobile Application with Bluetooth Connectivity Verification

Requirement	Verification
Must be able to pair seamlessly with a designated app on a smartphone or tablet to allow wireless transmission of distribution commands.	Verify the ability of the device to pair with apps on different devices (phones and tablets) and operating systems. Test the range and stability of Bluetooth connections to ensure commands are received without loss.
The device should provide operational status feedback through the application interface, including successful dispensing, errors, or warnings of insufficient pill stock as well as the schedule and does of dispensing.	Tests the ability of the system to provide feedback to the application about its status, including successful operations, errors (e.g., lag, empty storage), and warnings (e.g., low inventory). Tests the ability of the system to provide feedback to the application about its status, including successful operations, errors (e.g., lag, empty storage), and warnings (e.g., low inventory).

Subsystem 3: Integrated Digital Scales Verification

Requirement	Verification
The weight sensor detects the weight of the pills remaining in the pill box, as well as detecting the weight of the dispensed pills to evaluate the exact number of pills.	Ensure through testing that the weight sensor can detect the required weight changes. Conduct multiple tests to avoid randomness in the results. Ensure that the correct signals are received from the control subsystem and the correct commands are accomplished based on those signals.
Temperature, humidity and pressure sensors test the temperature, humidity and pressure in the pill box and display the data to the application.	Tested to ensure that the temperature humidity and pressure sensors can accurately detect the temperature humidity and pressure in the pill box.

	Ensure that this data can be transferred to the application via Bluetooth signal.
The motor can be rotated by a corresponding angle according to the received signal.	Test to make sure the motor can turn at the desired angle. Test to ensure that the motor is receiving signals and can fulfill the correct commands.

Subsystem 4: Alert System Verification

This subsystem consists of LEDs and buzzers that are responsible for providing visual and auditory feedback to the user.The LEDs and buzzers will be used to alert the user that the time for taking the medication or the ambient conditions inside the box (e.g., temperature and humidity) do not meet the preset criteria. The use of LEDs and buzzers has been chosen because they are effective in getting the user's attention while avoiding over-stimulating the user. Each alarm device will be controlled via the digital pins of the control unit, utilizing switching transistors to regulate the input voltage, allowing full control over the intensity of the alarm. The brightness of the LEDs and the volume of the buzzer will be adjusted by varying the power supplied to the motors.

Requirement	Verification
Alarm device exist	Perform a physical check to confirm that the LEDs and buzzers are properly installed in the system, and verify their operating status with a simple circuit test (e.g., activation with a test power supply).
Adjustable alarm strength	Using a PWM signal generator, provide "high" and "low" PWM signals to the switching transistors controlling the LED and buzzer, respectively. Observe and record the change in brightness of the LED and the change in volume of the buzzer to verify the ability to adjust the intensity of the alarm.
Ability to work independently	Verify that the LEDs and buzzers can operate independently based on the input signal by controlling the alarm subsystem directly (not through the main control system). This can be tested by manually supplying a voltage or by sending a PWM signal using a simple controller.
Ability to integrate work	Integrate the alarm subsystem with the main control unit to simulate an actual use scenario (e.g., setting specific warning conditions) and verify the response of the alarm subsystem in the integrated environment. This can be accomplished by controlling the main control unit with software that triggers the alarm subsystem under predetermined conditions.

Subsystem 5: Backup Battery

This subsystem consists of a battery backup designed to ensure that the Smart Pill Hub program seamlessly continues to operate and provide continuous service in the event of a mains power failure. The backup battery is introduced to automatically switch to the backup power supply in the event of power failure or instability, safeguarding the normal operation of the system and the continuous user experience. The backup battery is designed with sufficient capacity to support system operation for a certain period of time without external power supply, ensuring that users' medication management tasks are not affected until power is restored.

For seamless switchover, the system will be equipped with a power management module that monitors the status of both the primary and backup power supplies and immediately activates the backup power supply when an interruption in the primary power supply is detected. This process is designed with the goal of minimizing switchover delays and avoiding any kind of operational disruption. The power management module will also be responsible for automatically switching back to the main power supply once it has been restored and simultaneously charging the backup battery in case of emergency.

Requirement	Verification
Non-disruptive switching capability	Test the system's ability to immediately and seamlessly switch to the backup power supply by simulating a mains power failure. This can be achieved by disconnecting the mains power supply and immediately monitoring whether the system continues to operate without any functional interruption. Focus on how quickly the system switches to the alternate power supply and whether there are any operational interruptions.
Long-term backup power supply capacity	Test the durability and reliability of the backup power supply by running the system continuously for a certain period of time (e.g., a few hours to a day) while it is powered by the backup power supply. This will verify that the system can maintain normal operation and its endurance in the absence of primary power.
Power supply fluctuation adaptability	Simulate power fluctuations, such as short-term voltage drops or instability, and test whether the system can continue to operate stably or automatically switch to a backup power source when the main power source is unstable. Observe the system's response to power fluctuations to ensure that system operation is not affected during fluctuations.

Subsystem 6: Control

Requirement	Verification
Receive the signals from the application program and complete the correct operations according to the instructions. Signals can be communicated with motors and weight sensors.	Ensure that the control sensor can dispense the correct tablets based on the date and measurement set by the application. Ensure that signals can be exchanged with weight sensors, temperature humidity and pressure sensors and motors. To accurately control the angle of rotation of the motor and the weight of the pills as well as the temperature, humidity and pressure in the pill box.

2.4 Tolerance Analysis

We recognize that there will be some errors in our system. According to the FDA, pill sizes in the US are very close to each other. Then, because of a series of irresistible forces such as different manufacturers. Tablets from each manufacturer leave the factory with slight variations in size. In addition, during transportation, the tablets may also be bumped, which can lead to a change in size. Therefore, we will allow some margin of error in our designed dispensing mechanism. More specifically, we will allow for one more or one less tablet per twenty deliveries. On the software side, according to the datasheet of our chosen Bluetooth module. This module will have a 1 in 1,000 chance of losing the connection. This means that the connection between our designs is not perfect and stable, and in addition to this, there will be a delay in the signal transmitted via Bluetooth. Therefore, we will allow the connection between our software and hardware to fail once every twenty data transfers. Depending on the datasheet of the microprocessor we have chosen, we will also allow for delays in the processing of data from the software by our hardware, as well as system crashes due to the design of the chip itself. We set the threshold for this to no more than once every fifty times.

3. Ethics and Safety

In terms of ethics, our group is primarily guided by the IEEE Code of Ethics adopted by the IEEE Board of Directors[1]. We recognize that technology can change a person's life, so our team will professionally conduct our work. We will hold ourselves to the highest ethical standards. We will seek and provide honest evaluations and feedback on our technical work. We will continue to learn and master our skills through training and design, and all members of our team have completed CAD training and PCB soldering training and have passed lab safety tests. We will continue to complete the training required by the program. We will treat everyone with respect and kindness, understanding and helping each other. We know the power of technology and we are always learning with a humble heart. We believe that technology is in the service of people, so we will design our project with the user as the primary focus. Our team in the lab will follow the strict rules of the lab for our safety. When it comes to network connections and sensor data, we will ensure that the user's network or Bluetooth connection is private and secure. We will ensure that the user's connection to our system is private and secure including, but not limited to, the data in the IP packets. We will adhere to the rule of not using the user's data for any purpose other than the project. We will comply with any relevant license terms in all software used.

Reference

[1] IEEE. " "IEEE Code of Ethics"." (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/08/2020).

[2] FDA "Size, Shape, and Other Physical Attributes of Generic Tablets and Capsules Guidance for Industry," (2015), [Online]. Available: https://www.fda.gov/files/drugs/published/Size--Shape--and-Other-Physical-Attributes-of-Generic-Tablets-and-Capsules.pdf