MediEase: Medication Dispensing Machine for Older Individuals and People with Health Impairments

ECE 198
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Introduction

We embark on the engineering journey with a project of utmost importance, the "MediEase: Medication Dispensing Machine." In the words of President Dwight D. Eisenhower, "Plans may falter, but the act of planning remains indispensable."

This design document serves as our strategic guide. We acknowledge that, in the realm of engineering, the definition of the problem often undergoes refinement as our understanding deepens, and collaborative insights emerge.

Our project is dedicated to providing an effective solution for the elderly population in the Peel region, particularly those affected with the challenges of arthritis.

Our collective efforts will adhere to the highest of standards of engineering and medical requirements, ensuring the creation of a robust and dependable medication management system.

Client/Customer Definition

Our targeted customer base consists of individuals aged 65-84 who reside in the Peel region, totalling 66,270 individuals [1]. We are specifically catering to seniors who suffer from arthritis in their hands. According to Arthritis Societies Canada, nearly 1 in 2 adults aged 65+, in Canada, suffer from arthritis [2]. This further reduces our customer base to about 33,135 senior citizens.

The impediment they face in opening medication bottles due to arthritis has inspired our commitment to develop a specialized medication dispensing solution [3]. Also, the older population is much more reliant, so they need easier systems in place for them. Our aim is to alleviate these common struggles by providing a machine that offers convenient and precise medication dispensing, thus enhancing their overall quality of life.

Given Maheen’s volunteering experience at the William Osler Hospital at the Brampton Civic location, she has established a valuable presence in the healthcare industry. Furthermore, her connections have allowed us to get feedback on our machine from healthcare professionals and patients via surveys.

Competitive Landscape

1. Existing System 1: Pill Organizers

How it Addresses the Challenges:
Organization: Pill organizers help patients sort their pills by day and time, reducing confusion [4].
Visual Aid: They provide a visual reminder of whether a dose has been taken, reducing the risk of missed doses.
Accessibility: Larger compartments may be easier to open for arthritis patients compared to traditional bottles.

Shortcomings:
Manual Dispensing: Patients still need to open individual compartments, which can be challenging for those with arthritis. Lack of Precision: Pill organizers may not provide precise dosing for patients with complex medication regimens.
No Smart Features: They lack automated reminders or monitoring for caregivers.

2. Existing System 2: Bottle Opening Aid

How it Addresses the Challenges:
Improved Accessibility: Bottle opening aids like the "Dycem Bottle Opener" assist individuals with arthritis or weak hand strength in opening medication bottles, enhancing their ability to access their medication easily [5].
Non-Slip Design: The non-slip feature ensures a secure grip, reducing the risk of dropping or spilling the medication. It is able to open screw-top bottles with a diametre of up to 1.6-inches [5].

Shortcomings:
Manual Operation: Users still need to manually open and close medication bottles, which can be physically challenging for those with severe arthritis.
Lack of Medication Management: The bottle opening aid focuses solely on accessibility and does not provide features for managing medication schedules, potentially leading to missed doses.

3. Existing System 3: Medication Dispensing Services

Medication dispensing services provide pre-packaged medication doses delivered to patients' homes. These services often cater to the elderly and those with chronic conditions [6].

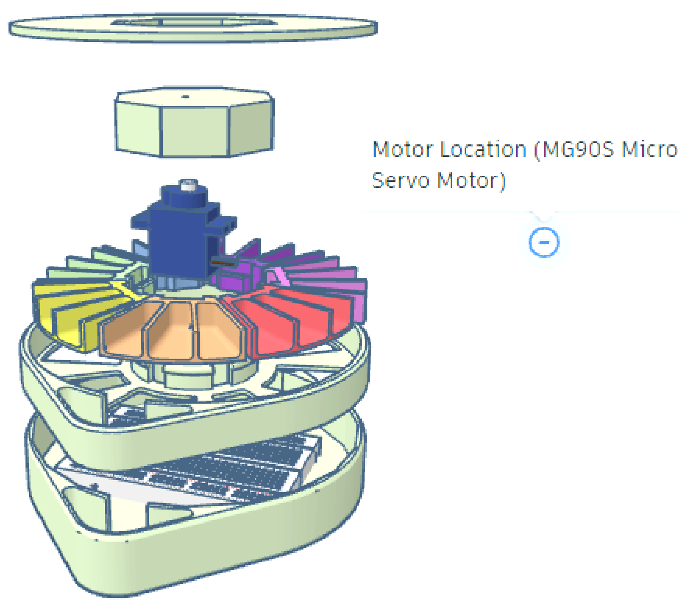
How it Addresses the Challenges:
Convenience: Medications are pre-packaged in easy-to-open pouches, eliminating the need to handle individual bottles or pills.
Medication Management: These services take care of medication scheduling, reducing the risk of missed doses.
Remote Monitoring: Some services offer remote monitoring and alert systems, increasing patient safety.

Shortcomings:
Cost: Medication dispensing services can be expensive, especially for those without insurance coverage.
Limited Medication Range: These services may not accommodate specialized medications or unusual dosage forms.
Dependency: Patients may become overly reliant on these services, potentially reducing their independence.

Requirement Specifications

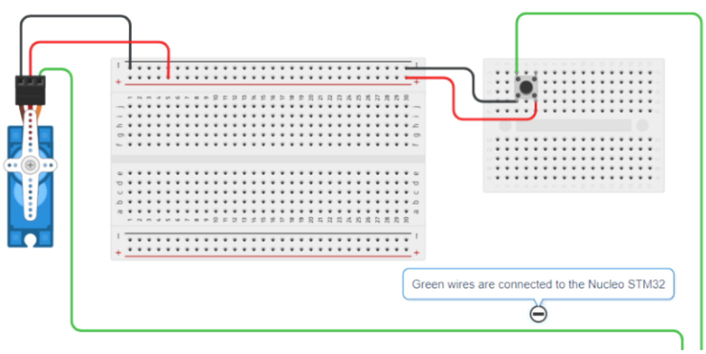
- **Audible Reminders:** Users should receive both audible and visual reminders for medication intake. Audible reminders will generate a sound between 70 to 90 dB, which is known to be effective for waking individuals, supported by sleep research standards [7].
- **Visual Reminders:** Visual reminders shall include a bright LED indicator that can be seen from a distance of at least 2 meters.
- **Response Time:** The machine should dispense medications within a maximum response time of 20 seconds from the user's input.
- **Signal Recognition Time:** A user or caregiver should be able to send a signal to the machine by inputting the value "1" into the program. The machine shall recognize this signal and, in turn, trigger the audible and visual reminders. The machine shall recognize the "1" input within a maximum of 2 seconds from the moment it is entered into the program.
- **Pill Storage:** Each compartment of the machine should be able to store at least 5 pills.

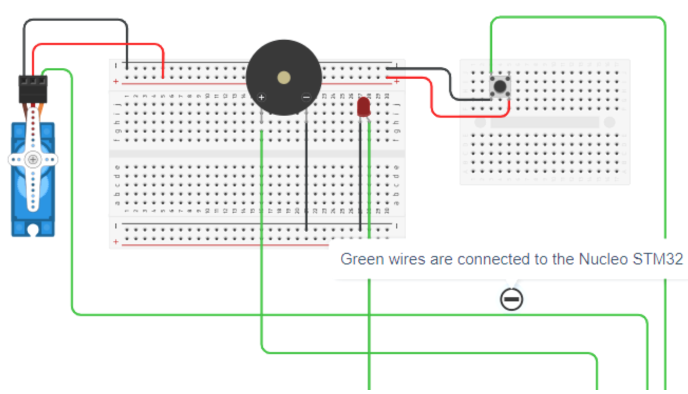
<u>Design</u>



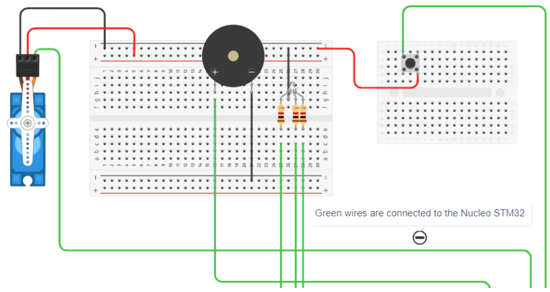
The servo motor, integrated within the machine alongside the main breadboard, allows the rotation of the pill compartments in response to a signal from the pushbutton. The machine is 53 mm in height, and the base has a diameter of 120 mm, with 20 mm extensions to account for pill retrieval. For further measurements, refer to the CAD file.

Version 1: (October 24th, 2023)

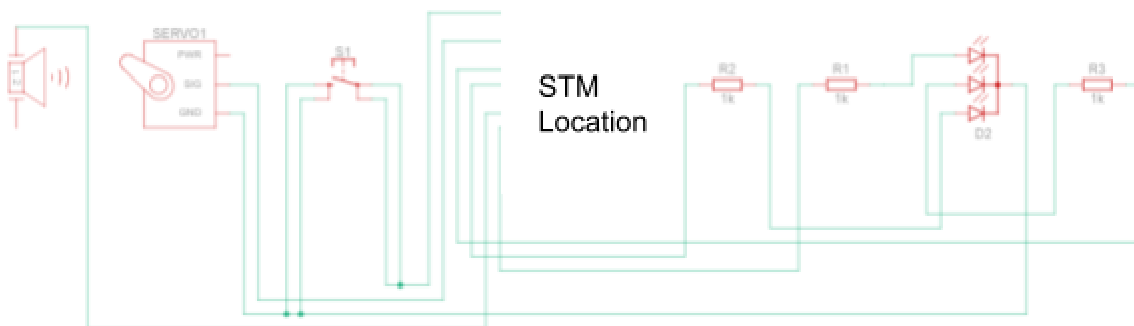




Version 2: (October 30th, 2023)



Version 3 (November 15, 2023):



<u>Scientific or Mathematical Principles</u>

- **Power:** To assess the energy efficiency of our Medication Dispensing Machine, we will calculate its power consumption using the formula **Power(P) = Voltage(I) × Current (I)** [8]. This calculation helps us understand the machine's energy usage, contributing to both cost-effectiveness and environmental sustainability.
- **Ohm's Law:** Since our design relies on a rotary motor to operate, it is necessary to calculate its maximum load. This is to ensure that our design is able to operate safely and efficiently under the given circumstances. We will apply Ohm's Law, which states **V = I * R**, to calculate the voltage and current requirements of the rotary motor [9].
- **Pythagorean Theorem:** We will apply this theorem, namely $c^2 = a^2 + b^2$, to maximize the strength, internal space, height and uniformity of the tray that will hold the pills once they are dispensed [10]. This is to ensure that the users are able to store as many pills as they can without causing any detrimental stress issues.
- **Circumference of a Circle:** Using the formula **Circumference (C) = 2πr,** we will calculate the maximum dimensions of the daily pill containers that will enable us to fit at most eight within the holder [11]. This way the containers fit perfectly in place with no issues for the user.

By meticulously addressing these principles and requirements, we aspire to create a robust, user-friendly, and effective medication management solution that significantly enhances the lives of seniors with arthritis in the Peel region.

Technical Analysis

1. Calculating the dimensions of daily pill compartments

Outer circle: diametre = 120 mm → radius = 60 mm

$C = 2\pi r$
$C = 2\pi(60)$
$C = 120\pi$

Since the pill containers are a trapezoidal shape, we are first calculating the length of the longer side.

Length = $120\pi / 8$
Length = 47.1 mm (approximately)

Next we are calculating the length of the shorter side.

Inner circle: diametre = 40 mm → radius = 20 mm

$C = 2\pi r$
$C = 2\pi(20)$
$C = 40\pi$

Length of shorter side = $40\pi / 8$
Length = 15.7 mm

The remaining side lengths will be equal in length and will be the difference between the inner and outer circle's diameter:

Remaining length = 120 mm - 40 mm
Length = 80 mm

Thus the pill containers will have two slanted lengths of 40 mm each, an approximately 15.7 mm side and an approximately 47.1 mm side.

2. Calculating power usage of the motor:

Each servo motor requires 2A to run. Since we have 5 volts available from the microcontroller,

using one iteration of the power formula being **P = V * I**

We can calculate the power utilized:

P = 5 volts * 2 Amps
P = 10 watts

Therefore, we know that our design will absorb 10 watts of energy.

Manufacturing Costs

- The STM32F401RE microcontroller is manufactured by STMicroelectronics with manufacturing sites in France, Italy, Singapore, Malaysia, China, and other countries. The specific vendor the microcontroller was purchased from is DigiKey, whose central distribution centre is in Michigan.
- The MG90S Micro Servo Motor we utilized was manufactured by Adafruit Industries LLC. They are headquartered in and manufacture their products in New York City. We purchased the motor from DigiKey, whose central distribution centre is in Michigan.
- The active buzzer we used for our product is manufactured by TDK Corporation, its product number is PS1240P02BT. Although they are a multinational company, they are primarily based in Japan. Once again we purchased the buzzer through DigiKey, which is centralized in Michigan.
- The red LED bulb we used was manufactured by the company onsemi, which has multiple manufacturing and assembly facilities globally, with the closest one being in Waterloo, Ontario. The vendor we obtained the LED bulb from was DigiKey.
- The Mini Breadboard and Breadboard we used are from the same manufacturing company, Bud Industries, which has its main office in Ohio, United States. Both products were purchased through DigiKey, which is centralized in Michigan.
- The pushbutton was manufactured by Omron Electronic Components LLC., whose parent company is Omron, which is headquartered in Tokyo but has manufacturing facilities in Japan, China, the United States and many other countries. The button was sourced through DigiKey which has its central distribution centre in Michigan.

Implementation Costs

Installation Manual and User Guide for MediEase

Welcome to the Installation Manual and User Guide for the "MediEase: Medication Dispensing Machine." This guide is divided into sections for both caregivers and users, providing detailed instructions on setting up the machine and its daily usage.

Section 1: Initial Setup (Recommended for the Caregiver)

Before the Medication Dispensing Machine can be used by the intended user, caregivers must complete the initial setup. Here are the steps to follow:

1.1 Machine Cleansing and Disinfection

- Thoroughly cleanse and disinfect the machine using a mild, non-abrasive cleaning agent.
- Ensure that components are free from contaminants to maintain a hygienic environment.

1.2 Medication Loading

- For user convenience, it is recommended that the caregiver places all medications into the designated compartments. This ensures that the machine is ready for daily use.
- Important: Do not overload the pill compartments. If necessary, place any extra pills into the eight-compartment pill holder.
- Before proceeding, insert a fresh 9-volt battery into the machine's battery compartment to ensure proper functioning.

1.3 Storage and Accessibility

- Store the machine in an area easily accessible to the intended user.
- Keep it in a dry area to protect the electrical components from moisture and potential damage.

1.4 Triggering Reminders

- As the caregiver, you are responsible for triggering the machine's audible and visual reminders when it's time for the user to take their medication.
- Input '1' into the program to trigger these reminders and prompt the user to take their medication.

Section 2: Daily Usage (For the User)

This section is intended for the user who will interact with the MediEase machine on a daily basis.

2.1 On Command Medication Dispensing

- When it's time to take your medication, press the "Dispense" button on the machine. Wait for the machine to dispense the necessary pills into the accessible compartment.

2.2 Audible and Visual Reminders

- Pay close attention to the audible and visual reminders provided by the machine. These reminders will help you remember when to take your medication, ensuring timely and accurate dosage.
- **Warning:** Do not forcefully stop the machine while it is in motion. Wait for the machine to complete the dispensing process to avoid any potential damage or injury.

Section 3: Maintenance

Proper maintenance of the Medication Dispensing Machine is essential to ensure its longevity and functionality. Here are the maintenance guidelines:

3.1 Regular Cleaning

- Regularly clean the machine's exterior using a mild, non-abrasive cleaning agent.
- Ensure that the machine remains free from dust, debris, and any contaminants that could affect its operation.

3.2 Component Replacement (Caregiver Responsibility)

- If any components or parts of the machine need replacement, contact the manufacturer or authorized service provider for assistance.
- Do not attempt to replace components without proper guidance.

Additional Information:

- The caregiver must ensure that they can access a computer to send the necessary signal ('1') to the device when it is time to dispense the medications. This ensures that the machine functions as intended for timely medication dispensing.

We hope that this Installation Manual and User Guide will assist both caregivers and users in effectively using the "MediEase: Medication Dispensing Machine." By following these guidelines and heeding the warning, you can ensure a safe and efficient medication management system for improved health and quality of life.

Energy Analysis

Reference Standard Appropriateness:

The reference standard for the design is the "Nucleo-F410RE" microcontroller. This microcontroller has been carefully selected based on its specifications, ensuring its compatibility with the project's power requirements. The following evidence and images support its appropriateness for the design:

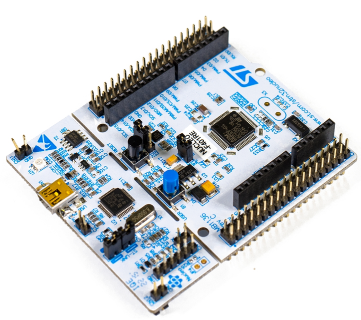
Microcontroller Specifications:

The Nucleo-F410RE microcontroller has been chosen for its power-efficient operation. Its technical specifications, including power consumption characteristics, align with the project's power limits, ensuring that it does not exceed 30 Watts of power consumption. STM32 microcontrollers are typically used to control various functions within electronic systems, process data, and interface with external sensors and devices. They can manage power modes to minimize power consumption when needed, but they do not have the capacity to store significant amounts of energy. The STM32 microcontrollers can be used in combination with energy storage solutions, such as batteries and capacitors to control and monitor their operation, but since we are not utilizing these features, it does not pose any violations to the reference standards. To be more specific, the microcontroller draws 300 mA of current using the USB and 160 mA without it, while needing approximately 3.3 V, which complies with the project's requirements.

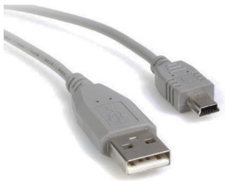
Power Supply Source: The design primarily relies on power supplied by a laptop. The laptop's power output has been assessed to ensure it complies with the power requirements of the "Nucleo-F410RE" microcontroller. This ensures that the chosen power source is suitable for the design's operation.

Cable Specifications: The "Startech 1ft USB A male to USB Mini B male cable" is employed for power connection. This cable has been selected for its compatibility with the microcontroller and its ability to meet the power transmission needs of the design.

Visual Evidence: Included below are photographs that highlight the relevant components and their suitability for the design:



Microcontroller: Nucleo-F410RE Microcontroller This image showcases the microcontroller, emphasizing its labeling and specifications that confirm its power requirements and efficiency.



This image displays the USB cable connectors, demonstrating its appropriateness for power transmission.

Analysis of Energy Storage:
The design does not incorporate energy storage components such as batteries, capacitors, or resistors. Without these components, it is less likely to store significant energy. Microcontrollers, like the "Nucleo-F410RE," typically do not possess substantial energy storage capacity.

Quantification of Maximum Total Energy Stored: Due to the absence of energy storage components, the maximum total energy stored in the system during operation is likely negligible in terms of electrical energy.

Ensuring Compliance with Project Limits: Given the design's reliance on a laptop for power and the specified power limit of 30 Watts, it is unlikely to exceed this limit. Additionally, without energy storage elements, the energy consumption is generally well below 500mJ, ensuring compliance with the project's energy and power constraints.

Risk Analysis

Possible Negative Consequences from Using the Design as Intended:
Risk: Inaccurate medication dispensing due to a technical malfunction.
Consequence: Users may receive incorrect doses, leading to health issues or inadequate medication. This could pose a safety risk to patients.

Risk: Audible or visual reminders not functioning as intended.
Consequence: Users may miss their medication doses, affecting their treatment plan and overall health. Safety is compromised as users may forget to take important medication.

Risk: Battery failure or depletion.
Consequence: The machine may stop working, leading to missed doses if the user relies solely on the machine for medication management. Battery disposal could also pose an environmental risk.

Possible Negative Consequences from Using the Design Incorrectly:
Risk: Forcefully stopping the machine while it is in motion.
Consequence: This can damage the machine's mechanical components, causing malfunctions and rendering it unusable. This could pose a safety risk and lead to the need for component disposal.

Risk: Overloading the pill compartments with medications.
Consequence: Overloading may jam the mechanism, leading to incorrect medication dispensing or damage to the compartments. This poses a safety risk and may require component replacement.

Risk: Inserting the battery incorrectly or using a non-standard battery.
Consequence: Incorrect battery insertion can damage the machine or cause it to malfunction. The use of a non-standard battery can lead to power-related issues, affecting safety and the environment due to battery disposal concerns.

Possible Negative Consequences from Misusing the Design:
Risk: Attempting to disassemble or repair the machine without proper guidance.
Consequence: Misuse during disassembly or repair can lead to injuries, component damage, and further malfunctions. Safety is compromised, and component disposal may be required.

Risk: Unauthorized tampering with the machine's programming.
Consequence: Unauthorized changes to the machine's programming may result in incorrect reminders or dispensing medication at the wrong times, affecting safety and user compliance.

Possible Ways the Design Could Malfunction:
Risk: Mechanical failure of the pill dispensing mechanism.
Consequence: Medication may not be dispensed accurately, potentially leading to incorrect doses or missed medication. This poses a safety risk.

Risk: Electronic component failure, such as the microcontroller or motor.
Consequence: Electronic component failure can lead to a complete system breakdown, rendering the machine non-functional. Safety is compromised, and proper disposal of electronic components may be required.

Risk: Battery-related malfunctions, like leakage or sudden depletion.
Consequence: Battery issues may result in a loss of power and a failure to dispense medication or provide reminders, impacting safety and the environment due to battery disposal concerns.

Consequences on Safety or the Environment for each of the Failure Mechanisms Specified:
Mechanical failure of the pill dispensing mechanism:
Safety Consequence: Inaccurate medication dispensing poses a safety risk to patients, potentially leading to incorrect doses or missed medication.
Environmental Consequence: Mechanical failure may require the disposal of damaged components, contributing to electronic waste.

Electronic component failure, such as the microcontroller or motor:
Safety Consequence: Electronic component failure can lead to a complete system breakdown, compromising patient safety if they rely on the machine for medication management.
Environmental Consequence: The disposal of electronic components can pose environmental risks, contributing to electronic waste if not properly handled and recycled.

Battery-related malfunctions, like leakage or sudden depletion:
Safety Consequence: Battery issues may result in a loss of power, leading to missed medication doses. This poses a safety risk for patients who rely on the machine for their medication schedule.
Environmental Consequence: Battery disposal issues, such as leakage, can lead to environmental contamination and pollution. Proper battery disposal and recycling are necessary to mitigate these environmental risks.

Test Plan

Test Plan 1: Audible Reminders

Test Objective: To verify that the machine's audible reminders meet the specified standards.
Test Setup: Place the MediEase machine in a quiet room. Ensure the machine's audio output is unobstructed. Use a sound level meter to measure sound levels.
Environmental Parameters: Room temperature: 20°C ± 2°C
Relative humidity: 50% ± 5%
Test Inputs: Configure the machine to generate an audible reminder.
Quantifiable Measurement Standard: Measure the sound level using a sound level meter.
Pass Criteria: The machine should produce an audible reminder with a sound level between 70 to 90 dB.
Result: The audible reminder is within the decibel range. This was tested via physical tests and the decibel-reading app.
(November 15, 2023) - Version 3

Test Plan 2: Visual Reminders

Test Objective: To ensure that the machine's visual reminders are visible from a specified distance.
Test Setup: Set up the MediEase machine in a well-lit room. Place a measuring tape at a distance of 2 meters from the machine.
Environmental Parameters: Room lighting: 200 lux ± 50 lux
Test Inputs: Configure the machine to display a visual reminder.
Quantifiable Measurement Standard: Measure the visibility of the LED indicator from the 2-meter distance using a lux meter.
Pass Criteria: The LED indicator should be clearly visible from a distance of 2 meters under the specified lighting conditions.
Result: The visibility of the LED is within the lux range. This was tested via physical tests and the lux-meter app.
(November 15, 2023) - Version 3

Test Plan 3: Response Time Test

Objective: To test the machine's response time for dispensing medication.
Test Setup: Set up the machine on a stable surface. Prepare a stopwatch for timing.
Environmental Parameters: Room temperature: 25°C ± 3°C
Test Inputs: Activate the machine by pressing the dispense button.
Quantifiable Measurement Standard: Use a stopwatch to measure the time it takes for the machine to dispense medication from the moment the button is pressed.
Pass Criteria: The machine should dispense medication within a maximum of 20 seconds from the user's input.

Results: It took 4-6 seconds each time the machine was tested.
(November 15, 2023) - Version 3

Test Plan 4: Signal Recognition Time
Test Objective: To verify the machine's ability to recognize a signal input within a specified time.
Test Setup: Connect the machine to a computer interface. Prepare a script to send the signal input.
Environmental Parameters: Room temperature: 22°C ± 2°C
Test Inputs: Send a signal input of "1" to the machine's program.
Quantifiable Measurement Standard: Measure the time it takes for the machine to recognize the "1" input and trigger audible and visual reminders.
Pass Criteria: The machine should recognize the "1" input within a maximum of 2 seconds from the moment it is entered into the program.
Results: The response was instantaneous.
(November 15, 2023) - Version 3

Test Plan 5: Pill Storage Capacity
Test Objective: To verify that each compartment of the machine can store at least 5 pills.
Test Setup: Prepare a set of pills with a known size (in our case, we are using skittles). Open the compartments of the machine.
Environmental Parameters: Room temperature: 23°C ± 2°C
Test Inputs: Insert a set of 5 pills into each compartment.
Quantifiable Measurement Standard: Count the number of pills that each compartment can hold without overloading.
Pass Criteria: Each compartment should be able to store at least 5 pills without issues.
Results: The machine is able to store at least 5 pills in each compartment (however, this is based on uniform sizes, not taking into account different pill shapes).
(November 15, 2023) - Version 3

These test plans cover each of the five Requirement Specifications and include test setup, environmental parameters, test inputs, quantifiable measurement standards, and pass criteria without involving human test subjects. Each test plan should help ensure the quality and functionality of the MediEase machine.

References

[1] S. C. Government of Canada, “Census profile, 2016 census Brampton, city [census subdivision], Ontario and Ontario [province],” Census Profile, 2016 Census - Brampton, City [Census subdivision], Ontario and Ontario [Province], https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/Page.cfm?Lang=E&Geo1=CSD&Code1=3521010&Geo2=PR&Code2=35&Data=Count&SearchText=Toronto&SearchType=Begins&SearchPR=01&B1=All (accessed Oct. 30, 2023).

[2] “Arthritis facts, figures and statistics,” Arthritis Facts, Figures and Statistics | Arthritis Society Canada, https://arthritis.ca/about-arthritis/what-is-arthritis/arthritis-facts-and-figures (accessed Oct. 30, 2023).

[3] A. Beckman, C. Bernsten, M. G. Parker, M. Thorslund, and J. Fastbom, “The difficulty of opening medicine containers in old age: A population-based study,” *Pharmacy World & Science*, vol. 27, no. 5, pp. 393–398, 2005. doi:10.1007/s11096-005-7903-z

[4] A. Dowden, “Do pill organisers improve medication adherence?,” *Prescriber*, vol. 31, no. 9, pp. 24–27, 2020. doi:10.1002/psb.1865

[5] R. Charlton, J. Wakamatsu, M. J. Spomer, and Milo, “Dycem bottle opener :: Arthritis Bottle Opener,” The Wright Stuff, Inc. | ArthritisSupplies.com, https://www.arthritissupplies.com/dycem-bottle-opener.html (accessed Oct. 31, 2023).

[6] “Live well with our home care services,” Home Instead, https://www.homeinstead.ca/home-care-services (accessed Oct. 31, 2023).

[7] S. J. McFarlane, J. E. Garcia, D. S. Verhagen, and A. G. Dyer, “Alarm tones, music and their elements: Analysis of reported waking sounds to counteract sleep inertia,” *PLOS ONE*, vol. 15, no. 1, 2020. doi:10.1371/journal.pone.0215788

[8] “What is power? (article) | work and energy,” Khan Academy, https://www.khanacademy.org/science/physics/work-and-energy/work-and-energy-tutorial/a/what-is-power (accessed Oct. 31, 2023).

[9] “Basic electrical quantities: Current, voltage, power (article),” Khan Academy, https://www.khanacademy.org/science/physics/circuits-topic/circuits-resistance/a/ee-voltage-and-current (accessed Oct. 31, 2023).

[10] “Pythagorean Theorem,” Pythagorean theorem, https://pi.math.cornell.edu/~mec/Summer2008/Jones/pythagoras.htm (accessed Oct. 31, 2023).

[11] “Geometry of a Circle,” Numeracy, Maths and statistics - academic skills kit, https://www.ncl.ac.uk/webtemplate/ask-assets/external/maths-resources/core-mathematics/geometry/geometry-of-a-circle.html (accessed Oct. 31, 2023).