STM32 Smart Medicine Box Design Document

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***Abstract*—This design document for the STM32 Smart Medicine Box aims to clearly define the challenges, costs, specifications and objectives of the project in question. This document includes a needs assessment, design analysis, implementation and manufacturing costs, risk assessment, and a final testing and prototyping plan.**

I. Needs Assessment

A. Customer Definition

The STM32 Smart Medicine Box is tailored for seniors residing independently in Ontario who are grappling with mild to moderate memory impairments. As per Statistics Canada, this demographic encompasses around 2,520,200 individuals, and notably, a significant 21.7 of them live without any external support [1]. According to research conducted in 2022 by Health Canada, an estimated 7.1% of these seniors experience mild to moderate memory loss, some from diseases such as early-onset dementia or Alzheimer's [2]. By combining these statistics, we find that there are approximately 38,280 seniors in Ontario facing memory challenges, living independently and in need of specialized assistance [3]. Furthermore, the senior group with memory loss might demonstrate psychographic attributes of increased reliance on routines and familiarity, as new or unfamiliar situations can cause confusion or discomfort[6]. Moreover, the economic attributes of the seniors experiencing mild to moderate memory loss are that they often require frequent medical consultations, specialized care, and medications, leading to higher healthcare costs.[6] Memory loss can also strain the finances of family members who might need to reduce work hours or hire additional help to provide care and support. Where a medicine box can be utilized to solve the problem.

The American Food and Drug Administration estimates that "non-adherence to prescriptions causes 30 to 50 percent of chronic disease treatment failures and 125,000 deaths per year" [4] We may assume that due to the similar socioeconomic climate, this data is applicable to Canada as well. A significant portion may result from sustained deterioration of memory, and as such our product will support seniors who wish to live outside assisted living in maintaining a high quality of life and good health. Taking prescribed medication regularly is essential to keeping oneself in good health and preventing adverse side effects of irregular medication such as drowsiness, mood swings, overdosing and more.

B. Competitive Landscape

Naturally, there are preexisting solutions to our defined customer problem already on the open market. It is evident that most of these solutions were not innovated for use in our defined scenario, and there exists some shortcomings in which our product may better accomplish the challenge.

Technological System: One solution to remind oneself to take medications would be to set an alarm, either on a phone or a watch. Many seniors choose to do this, but studies have shown that there appears to be only a moderate increase in adherence to medication schedules [9]. It is clear that improvements are possible, and with the medicine box, forcing the user to come to the storage unit to deactivate the alarm will yield better results than a regular alarm.

Economic System: It is also common to have a caregiver ensure that medication is taken regularly. For seniors living alone, however, this is not an efficient solution as oftentimes family members will not be living nearby and will not be available to remind virtually via phone call or text messaging. It is rather expensive to hire a professional part-time caregiver as well at approximately $16/hr [9], and many of our customers may not be in a financial position to do so.

Social System: Another rather antiquated solution is to put up a plethora of reminder notes around the living space to ensure that it is always in the back of the mind. Unfortunately, habits are very difficult to break. If a user forms a habit of ignoring these reminders since they are not visible or forceful enough, it may be detrimental as they will form a habit of ignoring reminders to medicate. On the other hand, as our smart medicine box forces the user to address it with a loud audio signal, it would likely be more effective at forming a habit of taking medication a prescribed [7].

II. Requirements Specification

A. Functional Requirements

- In the case that heavy objects may be placed on top of the medicine box by accident; the box should be able to support masses up to 1 kg. [10]
- The box should be able to withstand an applied force up to 10N in order to ensure durability in daily use. [10]
- The box's button should be able to withstand an applied force up to 1.8N in order to safeguard the button's integrity. [10]

- The storage compartment should be large enough to accommodate at least 30 pills of varying sizes. There will be 2 storage compartments for 2 different kinds of pills, each of dimensions 5cm x 5cm x 7cm.
- The alarm will operate for a maximum duration of 5 minutes to conserve power and protect electronic components. [8]

B. Technical Requirements

- Servo Motor Requirements: The power input should be within the range of 4.8V - 6V [11], and it must generate an output torque of at least 2 Nm to ensure proper lid operation and prevent jamming. The lid should also be able to be opened manually in the unlikely event of a motor failure. [12]
- The refresh rate of the STM32 board must be maintained between 1ms to 1/10ms to prevent errors. [14]
- The electronic components for this device should be able to withstand temperatures between 10 °C to 30 °C [14]
- The smart medicine box's alarm should be able to alert the senior at a volume between 80-90 dB, since most alarms are around 80 dB in volume. It may need to be louder since many seniors suffer from partial hearing loss. [30]

C. Safety Requirements

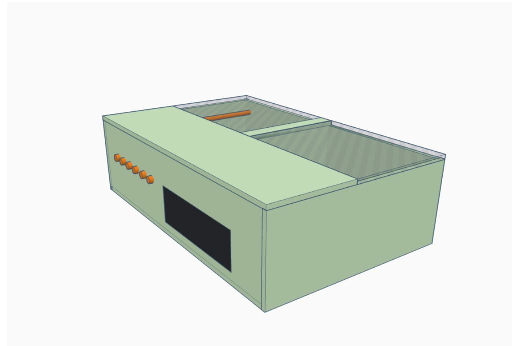
- Power consumption, transfer, discharge, or expenditure during the design's operation shall not exceed 30W at any point. [14]
- The design shall not directly connect to a building outlet with 110V AC.[15]
- The material of the box should be harmless plastic to protect seniors and medicines.
- Ensure that the smart medicine box complies with relevant medical and safety regulations, including those governing medical devices and electronics.

III. Design

The design of this smart medicine box mainly includes two parts: one is the microcontroller side and another is the medicines storage unit.

The microcontroller segment is equipped with essential components to facilitate various functions with the STM32 Boards [16]. These components include a buzzer to alert the user when the allotted time has elapsed, servo motors responsible for opening and closing the pill box, buttons for patient family members to input reminder times, and screens enabling users to confirm their desired time settings.

As depicted in Figure 1, the left section showcases the microcontroller segment featuring all these vital components. It's important to note that Graph 1 represents a basic version of the construction; further intricate details will be elucidated in the implementation phase. For a comprehensive understanding of the device's circuit design, please refer to Figure 3.

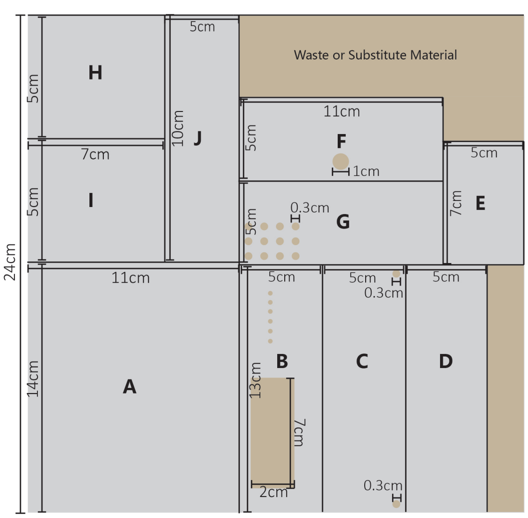


(1)

In the final implementation of this design, a rechargeable battery will be utilized, aligning with environmentally friendly practices. However, for the purposes of design analysis, the device will be connected to a computer, ensuring that the voltage does not exceed 5.0V.

Moving on to the medicine storage unit, this constitutes the device's second component, featuring two compartments for different types of medication. A dedicated pushbutton facilitates the switch between these drugs and enables the setting of distinct schedules for each. The opening and closing of the storage compartments are managed by servo motors. A designated button allows users to open the appropriate pill box effortlessly; the program will automatically adjust to the correct box, simplifying the user experience. Furthermore, the covers will automatically close after 2 minutes, alleviating concerns for elderly users. The servo motors should be able to lift the board, which requires a force that is bigger than 20N.

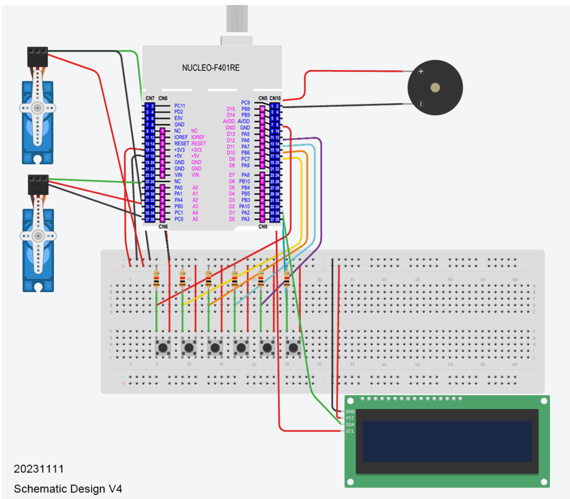
The PVC board must be cut precisely according to the specifications outlined in Figure 2 to form the outer casing of the medicine device. Please note that a specific allowance of 0.5cm has been accounted for to accommodate the board's thickness and ensure a perfect fit of the box components. The cropping dimensions are clearly indicated in Figure 2. (More details in installation manual)



(2)

Additionally, it is imperative to create openings on each section of the board to guarantee the proper functionality of the box. Specifically, the holes on board C facilitate the functioning of the servo motors, those on B enable user interaction with the buttons, the hole on F permits wires to cross the board and connect to the STM32, and the holes on D allow the buzzer's sound to reach the users.

When designing the circuitry, refer to Figure 3 for guidance.



(3)

Upon ensuring that the STM32 Board is appropriately connected to all components and the breadboard, proceed to assemble this section with the outer box previously constructed. Utilize wooden sticks and plastic supports to connect the movable boards (H and I) in a manner that allows them to open when the predetermined time is reached. Refer to Installation Manual/UserGuide for detailed construction instructions.

It is important to mention that the PVC board intended for this project should ideally be transparent. However, for demonstration purposes, all components except the movable boards have been coloured(As shown in Figure 1). You may use non-harmful dyes of different colours to tint these boards.

IV. Application of Scientific and Mathematical Principles

A. Analog Circuits

Kirchhoff's Current Law: $\sum_{n=1}^{N} i_n = 0$ (Where N is the number of branches connected to a node) The sum of all currents flowing into a node equals the sum of currents flowing out of the node. [17] [18] We can utilize this law in circuit design to ensure that the currents at different junctions within the circuit balance out. This helps prevent excessive current flow that could damage components or pose a safety risk. Also, in case of an emergency or electrical fault, Kirchhoff's Current law can be part of safety systems that disconnect power or trigger alarms to protect users, especially seniors who may be using the device.

Kirchhoff's Voltage Law: $\sum_{m=1}^{M} I_m = 0$, where M is the number of voltages in a closed circuit loop. The voltage around a loop equals the sum of every voltage drop in the same loop for any closed network and equals zero. [19] With this law, we can monitor the battery's voltage. When the battery voltage drops below a certain threshold, it can trigger alerts or notifications to indicate that it's time for a battery replacement or recharge.

Ohm's law:

$$V = IR \tag{4}$$

states that the voltage across a conductor is directly proportional to the current flowing through it, and that the current is inversely proportional to resistance. [20] We can use this law in button and LED manipulations by determining the appropriate resistor values to achieve the desired current status. Additionally, we can also use Ohm's Law to calculate the power dissipation (P = IV) [20] across resistors or other components.

Given that we are aware of the input voltage's maximum limit of 5.0V, which ensures that no component receives a voltage exceeding 5.0V, it's crucial to recognize that certain components within this device are connected in series, leading to varying voltages across different components. Additionally, other components operate in parallel, necessitating further voltage calculations.

To ensure the safe operation of all components within an acceptable range, we employ Ohm's law for precise calculations of current and voltage. By using the formula V = IR, we can accurately assess the current passing through each component. For instance, when evaluating the current passing through the push buttons to prevent any potential damage, it's essential to consider the specifications provided by Components 101. For the specific push buttons (Switch ECE 4926112), the maximum Power Rating is 50mA at a voltage of 5.0V.

Through meticulous application of Ohm's law, these calculations enable us to determine the exact current values, ensuring that the components function optimally without risk of damage. If necessary, additional protective measures such as resistors can be incorporated to safeguard the integrity of the device.

$$V = IR$$

$$R = V/I$$

$$R = 5.0V/50mA$$

$$R = 100\Omega$$

Certainly, considering the specifications outlined in Components 101, it becomes evident that the push buttons have a maximum resistance of 100 mOhm, equivalent to 0.1 Ohm. This resistance value is notably smaller than what is necessary for safe operation within our setup. Connecting the push buttons directly to the STM32 Board under these circumstances would pose a significant risk of damage to both the buttons and the board.

To mitigate this risk and ensure the proper functioning and longevity of the push buttons, the introduction of an external resistor becomes imperative. A resistor with a value of at least 100 Ohm is required in this context. Incorporating a resistor of this magnitude into the circuit, acts as a protective barrier, controlling the flow of current and preventing any excess voltage from reaching the push buttons. Its presence not only safeguards the integrity of the buttons but also prevents any potential damage to the STM32 Board, ensuring the reliability and durability of the entire system. Consequently, the careful selection and integration of this resistor serve as an essential aspect of the circuit design, guaranteeing the optimal performance and longevity of the push buttons and the overall device.

B. Newton's Second Law

Newton's Second Law, which is:

$$F = ma \tag{5}$$

states that an object's acceleration (a) is directly proportional to the net force (F) acting on it and inversely proportional to its mass (m). [22] In the context of the smart medicine box, we will apply this principle to compute the force exerted on the buttons and the force needed for a senior to close the box's cover. Furthermore, employing this law will enable us to determine the maximum force that can be safely applied to the box.

Another formula we will utilize is the Torque Formula, which is:

$$\tau = Fr \tag{6}$$

Determining the maximum weight a servo motor can lift necessitates a grasp of the servo motor's torque specifications and the mechanical leverage within the system. In the context of this device, it is crucial to calculate the optimal weight for the opening board, ensuring the motor isn't damaged or rendered incapable of lifting the load.

As shown in Components 101, the MG90 servo motor boasts a stall torque of 1.8 kgcm and a maximum stall torque of 2.2 kgcm [24]. According to the Conversion Kilogram centimetre to Newton meter[23]:

$$1kgcm = 0.0980665Nm$$

$$2.2kgcm = 0.2157463Nm$$

The opening boards have dimensions of 7cm in length and 5cm in width. Therefore, according to equation (3): The force a servo motor can bring for a 10cm cover is calculated by:

$$F = \tau / r$$

$$F = 0.2157463Nm/0.07m$$

$$F \approx 3.081N$$

Utilizing the maximum torque force, the maximum weight the servo motor can lift can be determined as follows:

$$F = ma = mg$$

$$m = F/g$$

$$3.081N/9.81kgm/s^2 = 0.31411kg = 314g$$

yielding an area of 50 cm^2, calculated using the formula A = LW and we will get 50 cm^2. This results in a weight distribution of:

$$314g/35cm^2 = 8.97g/cm^2$$

Comparing this weight to the PVC board's weight, which is approximately

$$1.8g/cm^2$$

[35] for 1 cm thickness according to Edcorusa, confirms that the board can be lifted by a single servo motor safely. Delving deeper into this calculation, understanding the maximum lift force of the servo motor at the edge is crucial for the safety and reliability of the smart medicine box, especially in the context of its primary users—elderly individuals.

The calculated maximum lift force according to our previous calculation, which in this case is determined to be 3.081 N (Newtons), signifies the force the servo motor can exert at its full capacity. In the delicate ecosystem of the smart medicine box, precision is paramount. This modest force, while seemingly small in the realm of physical strength, is meticulously engineered to be perfectly suited for its intended purpose.

For the elderly users who rely on this technology, this force translates into a gentle, controlled movement of the opening boards. The servo motor, with its calculated lift force, ensures that the lids of the medicine compartments are lifted and closed smoothly[30], eliminating any sudden jerks or jolts that could potentially startle or harm the users. This smooth operation is especially crucial for individuals with limited dexterity or frail health, where abrupt movements could lead to accidents or spills.

C. Logic Gates

The logic gate is a device that acts as a building block for digital circuits [25]. They perform basic logical functions that are fundamental to digital circuits. Logical gates can be used to authorize the dispensing of medication. For example, a medication can be dispensed only if the user's prescription data matches the scheduled dosage time (using an AND gate). Additionally, logical gates can also be used to trigger alerts and reminders. For instance, an OR gate can be used to trigger a reminder if it's time to take medication OR if the medication box has been left open for too long.

Logic gates play a fundamental role in the operation of a smart medicine box project. These digital circuits are essential components that manipulate and process electronic signals, making decisions based on specific conditions. In a smart medicine box, logic gates are used for various purposes, enhancing the functionality and intelligence of the device. Here's how they are useful in such a project:

Control and Decision Making: Logic gates are used to make decisions based on the input signals they receive. For instance, they can be configured to determine whether a particular compartment of the medicine box should be opened based on the user's input or a pre-set schedule. This decision-making ability is crucial in ensuring that the right medication is dispensed at the right time. To be specific, the local gates within the smart medicine box system serve specific functions, ensuring precise control and user safety. For instance, these gates are instrumental in detecting whether the box is currently open or closed, enabling seamless transitions between various pre-set programs. If the box is opened, the alarm is promptly silenced, initiating a countdown timer of two minutes. After this period, the system automatically closes the medicine box, promoting user convenience and security.

In the event of the box being closed, the program intelligently assesses its status. If it confirms that the box has indeed been opened, the countdown resumes until the next scheduled reminder, allowing for continuity in the medication routine. Conversely, if the box has not been opened, the alarm persists, ensuring the patient is continuously alerted until the medication is taken successfully. This dynamic response mechanism ensures the user's adherence to the prescribed medication regimen.

Moreover, the logical gates also play a pivotal role in managing the multiple medicine boxes in the system. Given that there are two distinct boxes, each storing different types of pills, logical gates come into play. They determine the appropriate box to manipulate, guaranteeing that the patient receives the correct medication. By effectively analyzing the input data, these gates prevent any possibility of the patient taking the wrong treatment, enhancing the overall safety and effectiveness of the smart medicine box.

Logic gates are designed to operate with minimal power, making them ideal for battery-powered smart devices like medicine boxes. Their low power consumption ensures energy efficiency and prolonged battery life for the device.

V. Project Costs

A. Manufacturing Costs

Materials and technologies required to manufacture the Smart Medicine Box include:

- STM32F401RE Microcontrollers
- Rigid plastic
- Plastic hinges
- Lithium batteries(Optional)
- Automated saws to machine the rigid plastic
- Permanent industrial strength plastic bonding adhesives
- Programming jigs for mass programming and testing of microcontrollers
- Servo motors
- LCD 1602
- Plastic push buttons
- Wiring
- Buzzer
- Breadboard
- Resistors

These materials will be sourced via:

- ST Microcontroller fabrication centres located in Italy, France and Singapore. Assembly, testing, and distribution facilities are located in China, Malaysia, Malta, Morocco, the Philippines, and Singapore. In this case, the manufacturer is also the vendor. [26]
- Buttons, servo motors, LCD displays and speakers distributed by Mouser Electronics with headquarters in Mansfield, Texas and operating 21 distribution centres worldwide.
- TS24-62-14-BL-200-SMT-TR-68 tactile button switch, manufactured by CUIDevices [27]. Headquartered in Lake Oswego, Oregon. Manufacturing plants operated in various locations within Canada and China.
- Servo motor MG90S WARMCA manufactured by TowerPro in Shanghai, China.
- LCD 1602 display, manufactured by TCC LCD[28]. Fabrication centers in Shenzhen, China.
- Rigid plastic sheets manufactured and distributed by Interstate Plastics. Offered: cut-to-size bulk orders. Fabrication and distribution facilities across the United States, including centers in Austin, TX, Seattle, WA, and Portland, OR[36].
- Batteries not included.
- Plastic hinges manufactured and distributed by Sierra Pacific Engineering Products. Headquarters located in Anderson, CA, USA[36].
- 2PCS Active Buzzer Alarm Module Sensor Beep Buzzer manufactured by CUIDevices. Headquartered in Lake Oswego, Oregon. Manufacturing plants operated in various locations within Canada and China[26].

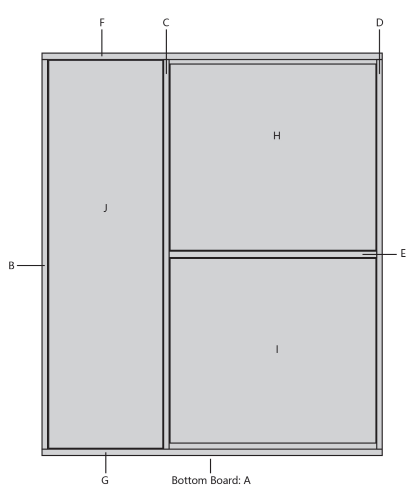
- Resistor in different values including 50, 100, 200ohm's resistor. They will be factored from Aniann in Shenzhen, China. They will be distributed and stored in Amazon storage in Canada[27].

B. Installation Manual

As previously mentioned, it is crucial to accurately cut the PVC board based on the specifications provided in Figure 7(Same as Figure 2). This precise cutting is necessary to create the outer casing for the medical device. It's important to consider a 0.5cm allowance to accommodate the board's thickness and guarantee a seamless fit for the box components. The specific cropping dimensions can be found in Figure 7 for reference.

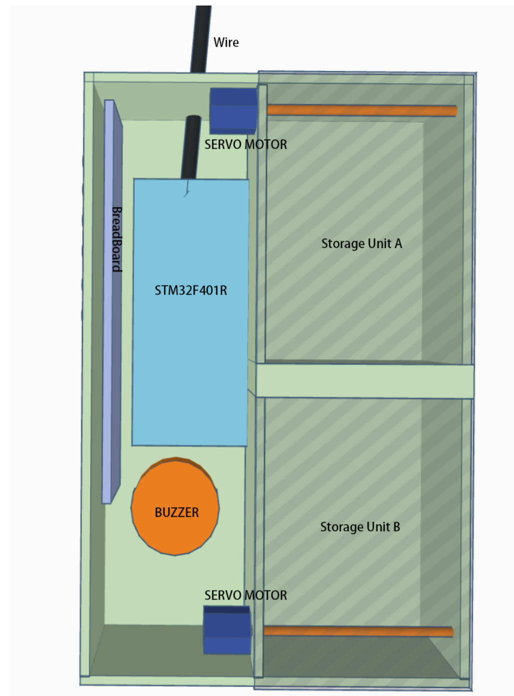
(7)

The modified board, as illustrated in Figure 8, should be assembled using a hot melt glue gun to construct and consolidate the box. Notably, please refrain from melting sections H, I, and J during this phase.



(8)

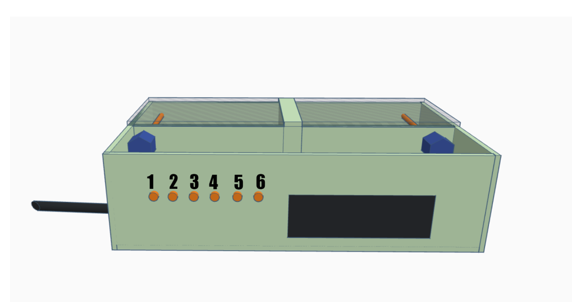
Once the board has been accurately cut and assembled, carefully position the electronic components inside, ensuring they are placed correctly as illustrated in Figure 9.



(9)

C. User Manual

- Carefully remove the smart medicine box from the packaging. Ensure that no components have been damaged and everything appears to be in good working order(As shown in Figure 10).
- Press the rightmost button (6) to power on the box. The LCD display should light up.
- The button functions are:
  (1) Changes the selected box, 1 (left) or 2 (right).
  (2) Add 10 minutes to the timer
  (3) Add 1 hour to the timer
  (4) Reset all timer counts
  (5) Open/close the lid of the selected box
  (6) Power on/off



(10)

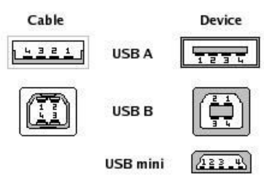
- Once you have verified that all the buttons are functioning properly, set the timer to when you would like the alarm to go off again using buttons 2 and 3. Once the time runs out, the alarm will sound. By default, it will proceed to repeat the alarm at every timer interval past when you

set it. If you do not wish for this to occur, you may reset the timer or turn off the box.
- Enjoy the full functionality of the smart medicine box and don't worry about missing your medication interval again!

VI. Risk Assessment

A. Energy Analysis

For illustrative purposes, our device will be directly linked to our laptop. As per the NUCLEO-F401RE Guide[14], we'll utilize a USB 2.0 cable to establish the connection between the computer and the board. The USB 2.0 A male to Mini B male cable specification enables hosts to supply 5.0V to the STM32 board, meeting our power requirement for the board. However, the NUCLEO-F401RE board only has an input voltage of 3.7V[32], it can lower the input voltage to 5.0V with the built-in component[32]. Additionally, if we opt for battery usage, the specification also ensures a 3.7V voltage delivery to the STM32 board.



Pin	Signal	Color	Description
1	VCC		+5V
2	D-		Data -
3	D+		Data +
4	GND		Ground

(11)

Furthermore, the servo motors, with a maximum operational voltage of 6.0V, will be linked in parallel. The NUCLEO-F401RE board's pins provide a stable 5.0V[32], ensuring both motors receive a consistent 5.0V, surpassing the minimum requirement of 4.8V. Consequently, the servo motors are guaranteed to operate efficiently within this setup.

The buzzer, having matching minimum and maximum operating voltages, will also be connected in parallel to the board, meeting our specified project criteria effortlessly.

As for the buttons, following previous calculations, we will incorporate 100-ohm resistors to safeguard them. These buttons will be wired in parallel, and one of them will be connected to an LED in series, serving as an indicator to signify the medicine box's operational status.

In the following calculation, we will calculate the maximum Power of this device in Watts[33]: (Note: STM32 consumes 12.7 mA of current during ideal conditions in run mode[32])

$$P = IV = I^2R = \tau w \tag{12}$$

$$Buttons 5V^2/100\omega * 6 = 1.5W$$

$$Buzzer : 5V * 0.03A = 0.15W$$

$$Motors : 0.022kgm * 10.471976rad/s * 2 = 4.6W$$

$$STM32 : 0.0126A * 3.7V = 0.0466W$$

$$Total : 1.5W + 0.15W + 4.6W + 0.0466W = 6.29W$$

The Power we calculated is below the maximum power that the project guide indicated[14].

In terms of mechanical energy, it is essential to account for the energy required to open and close the box covering. However, this energy expenditure is encompassed within the electric energy utilized by the servo motor. Essentially, we convert electric energy into mechanical energy to raise the covering, acknowledging that there will be some energy loss in the process, resulting in the electric energy not equating precisely to the mechanical energy produced.[34]

Thus, we can calculate the mechanical energy storage using the following formula:

$$W = Fd \tag{13}$$

$$Buttons : 2.55N * 0.2mm * 6 = 3.06mJ$$

The total electric energy consumption for 5 min of operation is approximately 117J. Therefore we can calculate the average energy storage at any time:

$$117000mJ/(5 * 60)s = 390mJ$$

Therefore, the total energy storage will be 390mJ + 3.06mJ = 393.06mJ, which will not exceed 400mJ at any point in time. This value is smaller than 500mJ (0.5J)[14].

In summary, our device fulfills all the specified requirements, operating within safe parameters without exceeding any project limits.

B. Risk Analysis

We are reasonably certain that there is negligible environmental impact from using the design as intended. There is a minor safety concern that the user may close the box while holding it in a manner where the finger lies between the lid and the box. In this scenario, the user may experience mild discomfort and the servo motor will suffer some damage. The motor is not powerful enough to cause serious or lasting bodily harm.

Should the design be used in a way that was not intended, there may be adverse chemical reactions with the plastic or adhesive, or that liquid may short-circuit the electronics and cause a sudden release of heat. There would be a moderate environmental impact as the design would have to be disposed of permanently and could not have parts recycled or reused.

There is a small but non-zero chance that the design may malfunction. It is possible that the alarm will not turn off, the door will not open, or the design will spontaneously combust. In the unlikely event that the design malfunctions, it should be a mild nuisance to the user in the majority of cases. In the worst-case scenario that an electronic component combusts, the limited scale should allow for easy extinguishing of the fire with a method of choice. In all cases, the negative environmental impact would range from mild to moderate, depending on if the malfunction may be easily resolved.

VII. Testing

A. Functional Test 1

- This test will be conducted at RTP (room temperature and pressure).
- No special environmental conditions are necessary.
- The purpose of this test is to determine whether the box meets the functional requirements for durability, namely supporting masses up to 1kg or 10N of applied force.
- The box will be placed on a flat surface, such as a desk. An evenly distributed kilogram mass will be placed on the box for 60 seconds. This is roughly equivalent to an applied force of 10 N to the top of the box.
- Should the box suffer any damage or functional loss, the test will be considered failed.
- If the box is fully operational and has not suffered any physical damage after the test has concluded, this test will be considered passed.

B. Functional Test 2

- This test will be conducted at RTP (room temperature and pressure).
- No special environmental conditions are necessary.
- The purpose of this test is to determine whether the box meets the functional requirements for size, which consists of being able to store at least 30 pills of varying sizes.
- The box will be placed on a flat surface, such as a desk. 30 plastic beads of various sizes approximating pills will be poured into each compartment. It will be observed whether or not the box is large enough to store all the beads securely.
- To pass this test, both compartments of the box must be able to be fully closed without any usage of excessive force.

C. Technical Test 1

- This test will be conducted at RTP (room temperature and pressure).
- This test will be conducted in a quiet room to eliminate background noise as a potential source of error.
- The purpose of this test is to determine whether the alarm fulfills the requirement for volume, producing at least 70 decibels of sound.
- The box will be placed on a flat surface. The alarm will be manually activated. The noise level will be measured with an electronic sound meter on a nearby computer.
- To pass, the noise measured must be above 70 dB, after accounting for a +/- 2 dB margin of error due to potential sources of error such as poor microphone quality.

D. Technical Test 2

- This test will be conducted at RTP (room temperature and pressure). .
- No special environmental conditions are necessary.
- The purpose of this test is to determine whether the torque is sufficient for smooth operation of the device.
- The box will be placed on a flat surface. A Newton spring scale will be attached to the underside of the lid and held in place. The motor will be activated and the measurement will be recorded with an appropriate standard error. The torque will be calculated in Newton * meters by multiplying the force applied and the distance between the motor and the spring scale.
- To pass, the calculated torque must be greater or equal to 2 N*m and the box must have suffered no physical damage or loss of functionality.

E. Safety Test 1

- This test will be conducted at RTP (room temperature and pressure). .
- No special environmental conditions are necessary.
- The purpose of this test is to determine whether the device exceeds safety requirements relating to power present in the system.
- The box will be placed on a flat surface. The current and voltage in multiple closed circuit loops will be measured using a digital multimeter. These measurements will be recorded in a table. The power present in each loop will then be calculated using a corollary of Ohm's law, $P = IV$.
- To pass, the calculated power must not exceed 30W at any point.

References

[1] StatCan, "Canada: Number of seniors by province and age group," Statista, https://www.statista.com/statistics/485562/number-of-seniors-in-canada-by-age-group-and-province/ Accessed Sep. 26, 2023.

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