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INFORMATION ENGINEERING DESIGN II

Design of a Thermally Controlled System for Medications

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Abstract

This paper presents the research, design and simulation of a compact, portable, insulated container that can store any vaccination or injectable substance. The design was simulated using a multiphysics software, *Energy2D*, and multiple test cases are completed, in order to test the thermal properties of the designed container. An electronic system is designed based off a temperature controller, that uses a MPU and two Peltier devices to process and control the temperature within the container as well as battery pack that is designed that can last up to 4 days without requiring a recharge. The materials used for designing the container can be made from recyclable materials, and can maintain the temperature of the system at an average of 30 min without the use of the Peltier devices. The Peltier devices take $40\ min$ to cool the medication down to $3°C$ in a constant heat environment. The designed electronic component consumes $1.86255W$, and costs $R1500$ to produce. The system is critically analysed and recommendations of a better heat conductor or different insulating container are given.

Index Terms

Temperature controller, thermal insulation, Peltier, vaccine cold chain, insulin container

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I INTRODUCTION

The history of medicine has led to multiple discoveries such as vaccines, insulin and penicillin allowing humans to have a greater lifespan, treat diseases and ultimately prevent them [1]. According to the World Health Organization (WHO), majority of children receive their vaccines in a timely manner, however those who do not have access to certain medical facilities are unable to get their immunisations. This includes approximately 20 million people worldwide that are susceptible to diseases and illnesses that can be easily prevented with the use of vaccines [2]. Vaccines must be kept in temperature controlled containers, within a temperature range between $2°C$ and $8°C$ when kept in a refrigerator [3].

This paper presents the design of a wearable system that can contain an injectable substance such as a vaccine, epipen or insulin and maintain a settable temperature, with the use of a thermoelectric cooler, within the container. The structure of the paper is as follows: Section II discusses the background of the project including a literature review and existing solutions to the proposal. Section III looks at the requirements and specifications of the project. Subsequently, Section IV looks into the design of the proposed solution, whereas Section V provides various simulations thereof. Section VI discusses the critical analysis of the design, providing possible recommendations for future improvements, and lastly with Section VII presenting the concluding arguments.

II BACKGROUND

The foundational idea for the system is that of a temperature controller, which is tasked with maintaining the temperature of the system or device at a constant value. The temperature in these systems are maintained by the use of one of two actuators: a thermoelectric (Peltier) device or a resistive heater [4]. In this paper, the designed system utilizes a Peltier device in order to maintain the temperature of the container. A Peltier device is a simple device, driven by current in order to generate heat on one of the two ceramic plates. The direction of the current determines which one of the plates generates the heat and the which plate absorbs it [4].

A. Literature Review

Containers that use Peltier devices exist today and are used in various ways. Hassan-Younis and Ur-Rashid [5] designed and created a cabinet that utilizes a Peltier device for the transport of the polio vaccine for people in remote areas of Pakistan. The cabinet designed was supplied with a $12V$ DC power supply and made use of the aforementioned Peltier device in conjunction with two fans to improve heat diffusion in the container. An Arduino Mega 2560 controlled the system and sampled and logged the data within the container. The construction of the container did not focus on the thermal properties of the container, but rather used simple plywood to construct it. Overall the designed and built container was proven to be a success, being economical and efficient in creating a controlled temperature environment for the vaccine cold chain [5].

Ahmad et al., created a portable container made of polystyrene to test whether a Peltier device is able to maintain the temperature of the water in it [6]. The main focus of the project was to cool and heat the water in the container with the use of the Peltier device. The control unit in the project included a thermal loop controller, that drove a voltage controller which affects the temperature output of the Peltier. The device was regarded as a success being portable and powered by a battery [6].

Peltier devices are not the only types that are used for cooling in medical applications. Prosthetic limbs, especially lower limb prosthesis cause the users unnecessary excessive heat within the respective socket. This excessive heat can lead to dermatological complications, due to the socket and its lining having poor thermal conductivity [7]. Han et al., designed a new socket that utilizes a heat pipe array and a flow channel array connected to an ice pack. This type of thermal design combined with an automatic temperature control scheme will allow users to maintain a desired skin temperature with regards to their prosthetic limbs [7].

B. Existing Solutions

There are many products that exist that allow users to carry their insulin or vaccines on their person for short periods of time, without worrying about the temperature of the medication exceeding the recommended limits. One of the most popular cases that exist is known as the *FRIO® Insulin Cooling Case*. The case must be submerged in cold water, and the crystals contained in the panels of the case expand into a gel. The gel relies on evaporation for the cooling effect of the gel to stop working and can keep insulin safe at the required temperature for a minimum of 45 hours [8].

A vaccine cold chain solution is provided by the *Fresh Vaccine - Cool Cube^{TM}*, where these compact units will maintain the required temperature between $2°C$ and $8°C$ for more than two and a half days [9]. These containers are a viable solution for vaccine storage which reduce the need for any ice or electrical components in order to maintain the temperature of the medication.

III REQUIREMENTS AND SPECIFICATIONS

The objective of the project is to design a compact, portable, insulated container that can store any vaccination or injection. The container must maintain a settable temperature range between $3°C$ and $11°C$. A thermoelectric cooler is not required for this design, but the emphasis of the design must be on portability. There are three main components to the design:

- The container design, which must be thermally insulated
- The electronics design which is focused around a temperature controller
- Power supply that can power the entire system and last for a month without recharging.

Each of these components must be designed and simulated in some fashion, be it mathematical or utilizing some sort of software. Assumptions are made throughout the design of the project and are mentioned in each of the respective subsections in Section IV.

The project must be completed within a six week time-frame and the simulations must be simulated on software with usable licenses. All project management information, including Gantt chart and meeting minutes can be found in Appendix D.

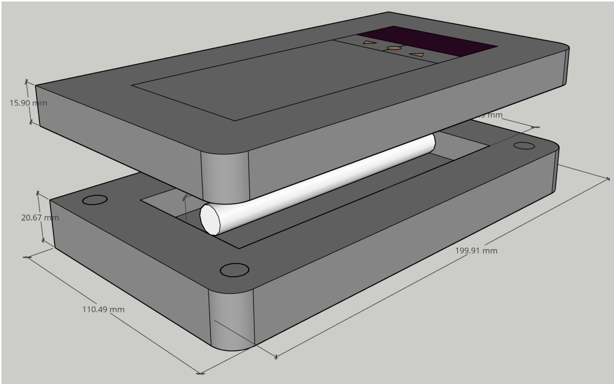
IV DESIGN

The main components of the design are done individually with consideration to one another. The initial design began with the container, deciding on the materials to use for the container. Following this, the electronics of the system is designed looking at specific elements for the purpose of the system. In conjunction to this, the programming of the microprocessing unit (MPU) is designed with a potential algorithm and pseudocode provided. Lastly, the power supply is investigated, deciding on the battery used and the total power that will be consumed by the electrical components.

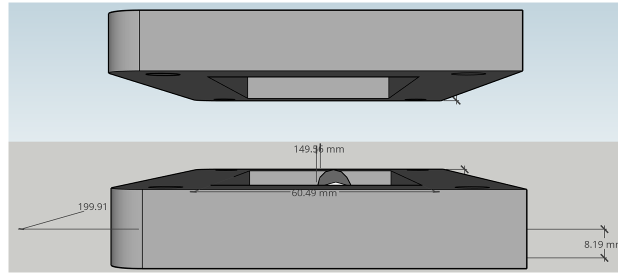
A. Container

The design of the container was a simple idea based on that of a wallet. Since the emphasis of the project was the portability of the container, this prerequisite was taken into consideration in the design. The renderings of the container design was done on *Google SketchUp*. Figure 1a shows a three dimensional rendering of the container, whereas Figure 1b shows the back view of the container, revealing the gaps on the inside of the container for the electronics and medication placement. All other angles of the container renderings can be seen in Figures 11a to 12c in Appendix C-A. The total dimensions of the container is approximately $200mm \times 111mm \times 37mm$, which is larger than most conventional smartphones today.

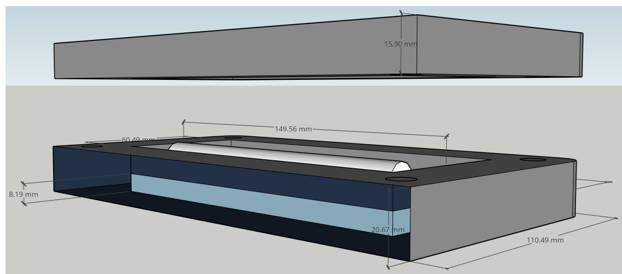
The container is constructed from thin aluminium sheets on the outside, preferably in silver to reflect some light from heating the container. Aired polystyrene is then found underneath the outer aluminium sheet providing the primary insulation for the container. Heat is lost in one of three ways: conduction; convection; and radiation [10]. Polystyrene is regarded as a good insulator as the air bubbles found within it slow down and potentially prevent heat energy from flowing through them. Figure 1c shows the cross section of the container as to where the aired polystyrene will be present. The inner layer of the container will be a thin aluminium sheet again, as this metal forms a decent conductor. The reason this was done was that when the Peltier device is turned on to cool the medication, the aluminium sheet on the inside will conduct the energy provided by the Peltier device to cool the medication quicker [10]. The top half of the container will be joined to the bottom of the container with the use of four magnets, as the use of a hinge may leave an air gap between the top and bottom parts of the container causing an undesirable leakage of heat. The assumption made is that the use of these magnets to join the top and bottom



(a) 3D view



(b) Back view



(c) Cross-section

Fig. 1: Container Design rendered in *Google SketchUp*

parts of the container, will leave a negligible air gap between the two parts, and create an insulated container which prevents the leakage of heat energy.

The top part of the container will house the electronics, including the outer cover where the LCD screen and buttons will be present. The top half will also have a space for the insertion of the SD card and the battery pack, which will being housed near the bottom of the cover. The bottom part of the container will house the medication, and is given an volume of approximately $150mm \times 61mm \times 13mm$. The dimensions for this medication space is based around multiple medication bottles and the respective dimensions that were provided by a local doctor from a hospital. Figures 13a to 13g in Appendix C-B shows the images of the different medications provided by Dr. K Ramparsad [11]. Table I shows the approximate dimensions of the various medications\vaccines, and with the requirement being to carry a single injectable substance, certain vials such as the Tetanus and Diptheria vaccine can be drawn into the syringes and stored in the container.

TABLE I: Various medications and their dimensions

Medication	Height (cm)	Width (cm)
Actrapid (Insulin)	5	1.5
Conjugated Pneumococcal Vaccine	4	1
Hexavalent Combo Vaccine	2.5	1.2
Measles Diluent	6	1
Measles Vaccine	3.5	2
Oral Rotavirus Vaccine	2	1
Tetanus and Diptheria Vaccine	2	3

B. Electronics

The design of the electronic component of the container is carefully chosen to utilize electrical elements that are low-power, yet high precision. Figure 2 gives a high-level diagram of the electronic component of the design, with everything in the red box requiring a voltage from the power supply.

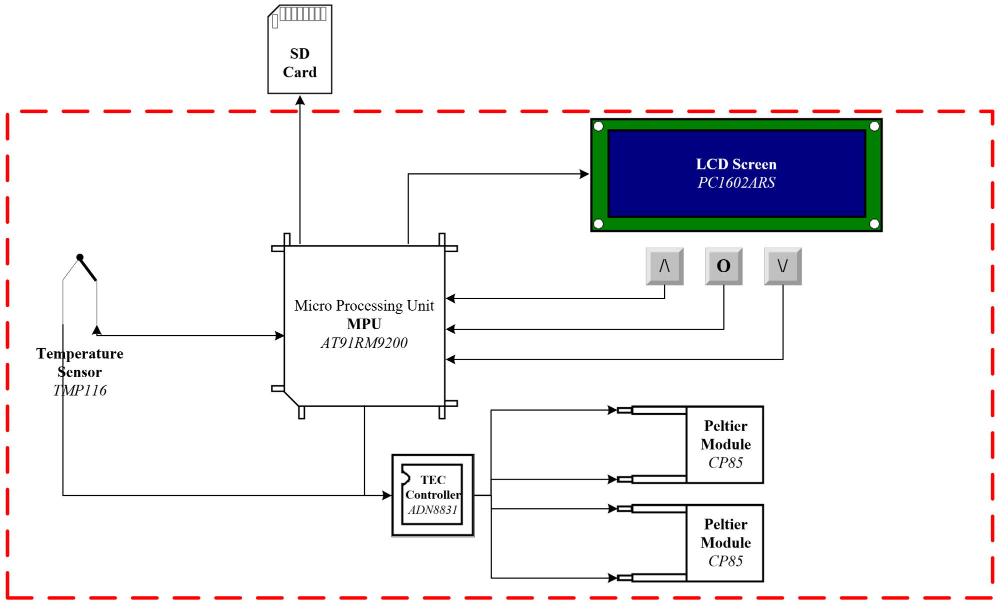


Fig. 2: High level diagram of the electronic system design

The temperature sensor that is chosen for the design is a *TMP116 Digital Temperature Sensor*, as it is a low-powered and high-accuracy sensor. The sensor can operate in a variety of temperatures, providing high temperature reading accuracy of $0.25°C$. It requires a voltage between $1.9V$ and $5.5V$ consuming a typical $3.5\mu A$ up to a maximum of $9\mu A$. In order to achieve a temperature reading with minimal error a supply voltage of $3.3V$ is required [12]. The sensor will be set into the respective *Therm Mode* where either a `HIGH` or a `LOW` signal will be sent if the temperature exceeds its respective boundaries. Since the sensor has its own analog-to-digital converter (ADC) and I^2C interface, the output of the sensor will be read into the microprocessing unit (MPU) with ease [12].

The MPU that was chosen is the *ATMEL SMART AT91RM9200* microprocessing unit, for its low-power usage, large embedded memories, fast processing and its extensive system peripherals [13]. The MPU is the key element in the electronic component of the design. The MPU will control the entire system, dictating when the LCD display will turn on and what it will display, as well as logging the data to the SD card. Most importantly, the MPU will trigger the controller that will control the Peltier devices. The core processor can operate in the range of $1.65V$ to $1.95V$ and the input/output lines requiring $3.0V$ to $3.6V$. The MPU will communicate with the temperature sensor depending on the type of input commands it will receive from any of the push buttons, as well as the LCD screen where all internal clocks will be synchronized to one another.

The LCD screen chosen is a *PC1602ARS Alphanumeric LCD*, which allows 16 characters across 2 rows [14]. The screen is a low-power, simple one and serves the purpose of presenting the user with the commands to set the boundary temperatures and displaying the current temperature of the container. The up and down buttons used will be simple push buttons that require no power to be on, and will allow the user to change the temperature boundary of the container. The center button will be a simple push button that will trigger the MPU to display the current temperature on the LCD screen.

The most important element of the electronic system is the Peltier device. In the design, a thermoelectric cooler controller, *ADN8831*, is used to act as the PID controller for the Peltier device [15]. The controller will take an input from the temperature sensor in order to get the current temperature of the system, and take the required temperature of the container and output the relevant amount of current to the Peltier devices. Since two Peltier devices are used to improve the eate of cooling that will occur, these devices will be connected in series so that the same current is passed through. The Peltier devices chosen are *CP85138 Peltier Modules*, with aluminium oxide ceramic plates. These are solid state devices with precise temperature control and quiet operation [16].

All Peltier devices require a heat sink in order to dissipate the generated heat accordingly. There are various types of heat sinks that can be used, including natural and forced convection and liquid cooling heat sinks. Since the system operates at low temperatures and at a low power, the natural convection heat sink should be utilized [17]. For this system, the natural convection heat sink is assumed to be used, ultimately optimizing the Peltier devices.

C. Programming

The MPU will need to be programmed in order to perform the necessary functions required for the designed system. Figure 3 presents a flow diagram of the proposed algorithm that will be embedded onto the MPU. A timer of 30 minutes is used and assuming that the internal clock and timer continue to run in *sleep* mode, will be used to log the temperature data and save it to SD card. The standard SD card has 9 pins, with only pins 1 to 7 being used. The respective pins will be connected to the MPU, and powered from the output voltage of it [18]. The SD card clock will be synchronized to the MPU clock and since the SD card is powered by the MPU, it is assumed that it does not require any power from the battery.

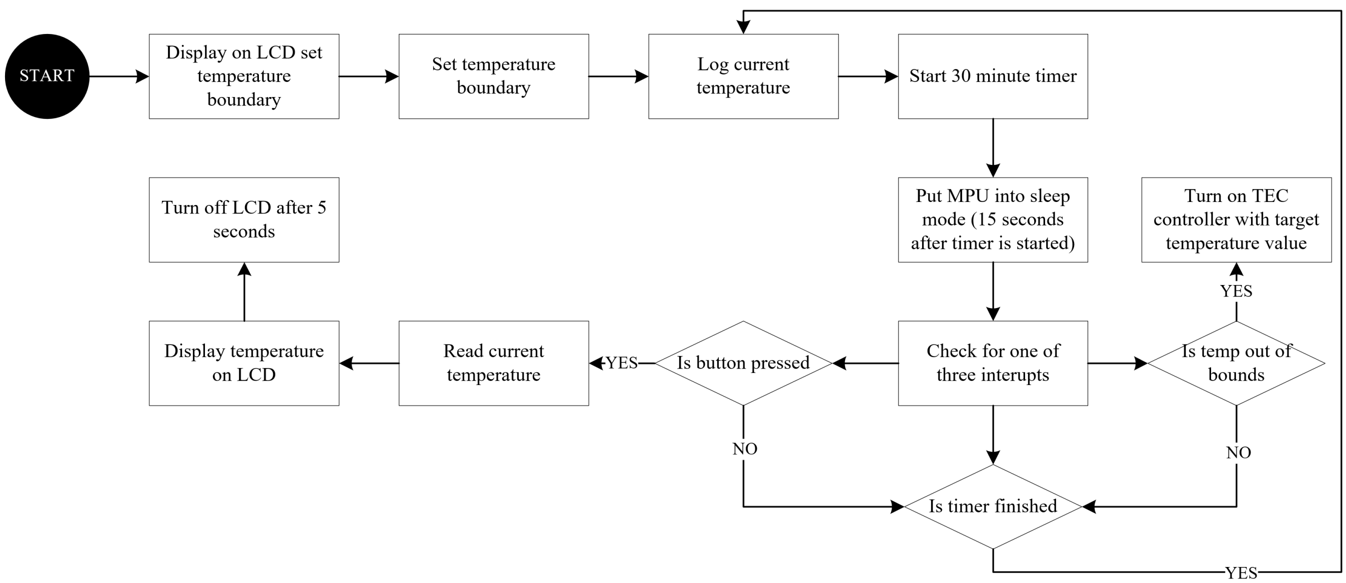


Fig. 3: Flow diagram of the MPU programming

D. Power Supply

The battery chosen is a lithium-ion battery as it is a common battery that is used for rechargeable products. The specific battery chosen for the design is the *Samsung INR21700-40T* battery, that will be placed in parallel with two others to form a battery pack. Although this battery is mainly used for e-cigarettes or vaporizer devices, it is a suitable battery for this container as each battery has a capacity of $4000mAh$ providing voltages up to $4.2V$ [19]. The calculations done on whether the designed system is able to last a month without recharge is determined in Section V-B.

The *LM3914 Dot/Bar Display Driver* is chosen to be combined with the battery pack as an indicator, in order to determine how much charge is left. This element was chosen as it is a simple 10 LED indicator that can be adjusted for this battery pack and its relevant power specifications [20]. Along with this, it is assumed that the element to charge the battery is included with it for a simple plug and charge ability.

V Simulations and Results

The simulations done on the design of the system was done in a variety of ways. The thermal simulations were done using a free-to-use multiphysics simulator, *Energy2D*, that models all three types of heat transfer: convection, conduction and radiation [21]. Although the models are two dimensions, the heat transfer considers all three dimensions. A three dimensional program is available to use, *Energy3D*, however it cannot be scaled to a millimetre level.

The electrical simulations are done by calculating the amount of power each element uses and calculating the total power the designed system uses. Subsequently, the battery pack power is analysed and calculations are done to determine if it can last the required amount of time without recharging.

Lastly, the MPU's programming is given in a high level pseudocode that conforms to the flow diagram presented in Figure 3. Since there is no way to simulate this component of the project, the pseudocode is given as a high-level simulation.

A. Thermal Simulations

The thermal simulations were done using *Energy2D* multiphysics software, and Figure 9 in Appendix B shows the model created in the software that was used to simulate results for the test cases that tested the container and its thermal properties. Figure 10 in Appendix B gives the model that was created to simulate the rate of cooling the Peltier devices will have in the container.

Although the models are in two dimensions, the heat equation used to simulate the flow of heat energy is the partial differential equation, seen in Equation 1 [21].

$$\rho c \left[\frac{\partial T}{\partial t} + \nabla \cdot (vT) \right] = \nabla \cdot [k \nabla T] + q \tag{1}$$

where:

- ρ is the density
- c is the specific heat capacity
- $\frac{\partial T}{\partial t}$ is the rate of change of temperature over time
- ∇ is the function that takes in functions as an argument
- v is the velocity field
- T is the temperature as a function of space (x, y, z) and time
- q is the internal heat generation.

There are two parts to Equation 1: the first part is the conductivity field function which represents the diffusion part; and the second part is the loss of heat through the atmosphere characterized by the velocity field function. The internal heat generation is regarded as the external force [21].

Table II shows the thermal properties of the materials involved with the container's design [22], [23]. The weather data that was used was sourced for Johannesburg, South Africa and gave the monthly weather averages over the past 21 years [24]. In addition to the weather data sourced, the global horizontal irradiation was estimated at $5800Wh/m^2$, and the software default value of 25 sun rays was used for the simulation [25].

TABLE II: Various materials and the respective thermal properties

Material	**Thermal Conductivity** ($W/m°C$)	**Specific Heat** ($J/kg°C$)	**Density** (kg/m^3)
Aluminium	250	921.0960083	2700
Air	0.0262	1005	1.2041
Aired Polystyrene	0.03	1300-1500	50
Glass	1.0499	670	2500
Ceramic (Aluminium Oxide)	30	718	3950

1) Test Case 1: Room temperature in convection heat

The objective of this test case is to test the thermal properties of the designed container. Setting the background temperature to be room temperature of $20°C$, with no sunlight present, the aim of this test was to determine how long it would take for the medicine in the container to reach a temperature of $8°C$. Figure 4 presents a graph of the simulated time taken for the temperature of the medicine to reach a value of $8°C$ and it can be seen that the medicine takes 2090 sec or 34.83 min to reach that temperature. This value is the minimum time that the medicine can remain within the temperature range, given that the model created is a simple one, and the surrounding heat is convection.

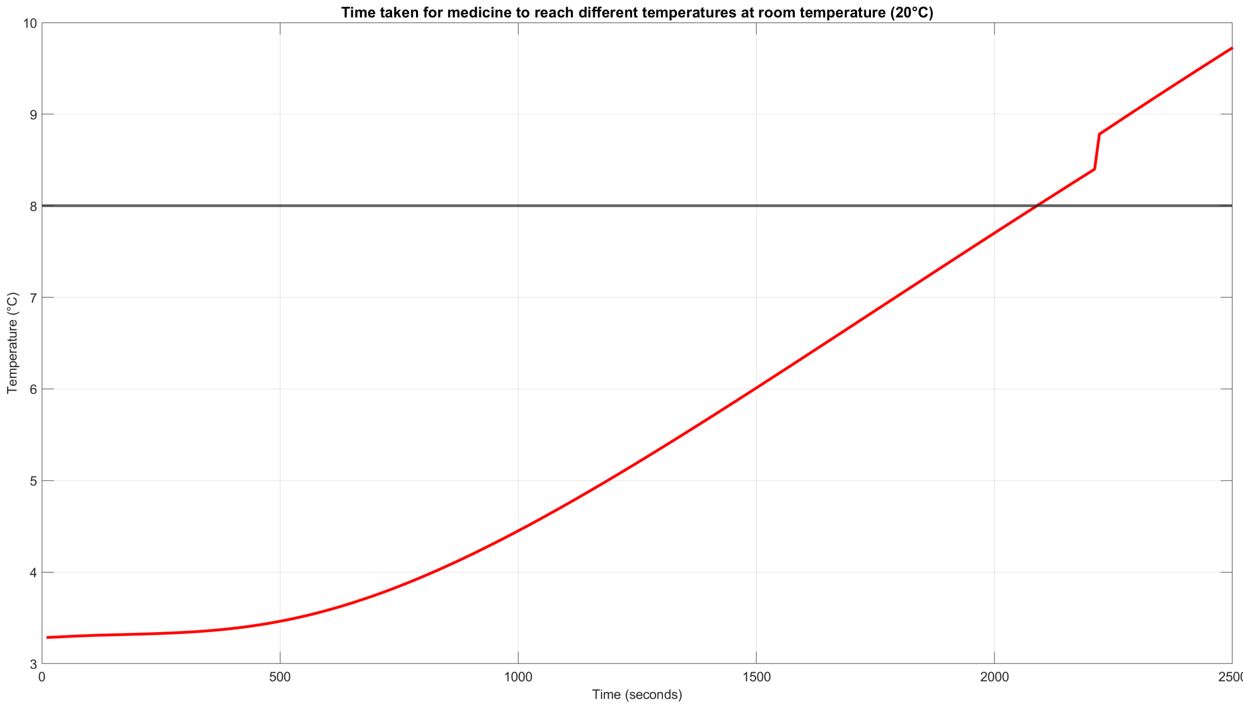


Fig. 4: Graph showing the time taken for the medicine to reach a temperature of $8°C$

2) Test Case 2: Monthly temperatures

The objective of this test case was to test the thermal properties of the container in different weather temperature. This entailed taking the monthly weather averages, over the past 21 years, and setting the background heat to that of radiation (sunshine), with no clouds being simulated.

Once again, the time taken for the medicine to reach a temperature of $8°C$ is recorded. Table III and Figure 5 show the results of the simulation. As seen from these results, the container is able to insulate the medicine almost twice as long in the winter months than it does during the summer months. The annual average temperature of $16°C$ saw that in a cloudless, sunshine environment, the container is able to maintain the medicine within the temperature range for 2420 sec or 40.33 min.

TABLE III: Monthly average temperature and time taken for the medicine to reach $8°C$

Month	**Average Weather** ($°C$)	**Time Taken to reach** $8°C$ (sec)
Janurary	20	2000
February	20	2000
March	18	2180
April	16	2420
May	13	3030
June	10	4580
July	11	3840
August	13	3030
September	16	2420
October	17	2290
November	18	2180
December	19	2090
Annual	***16***	***2420***

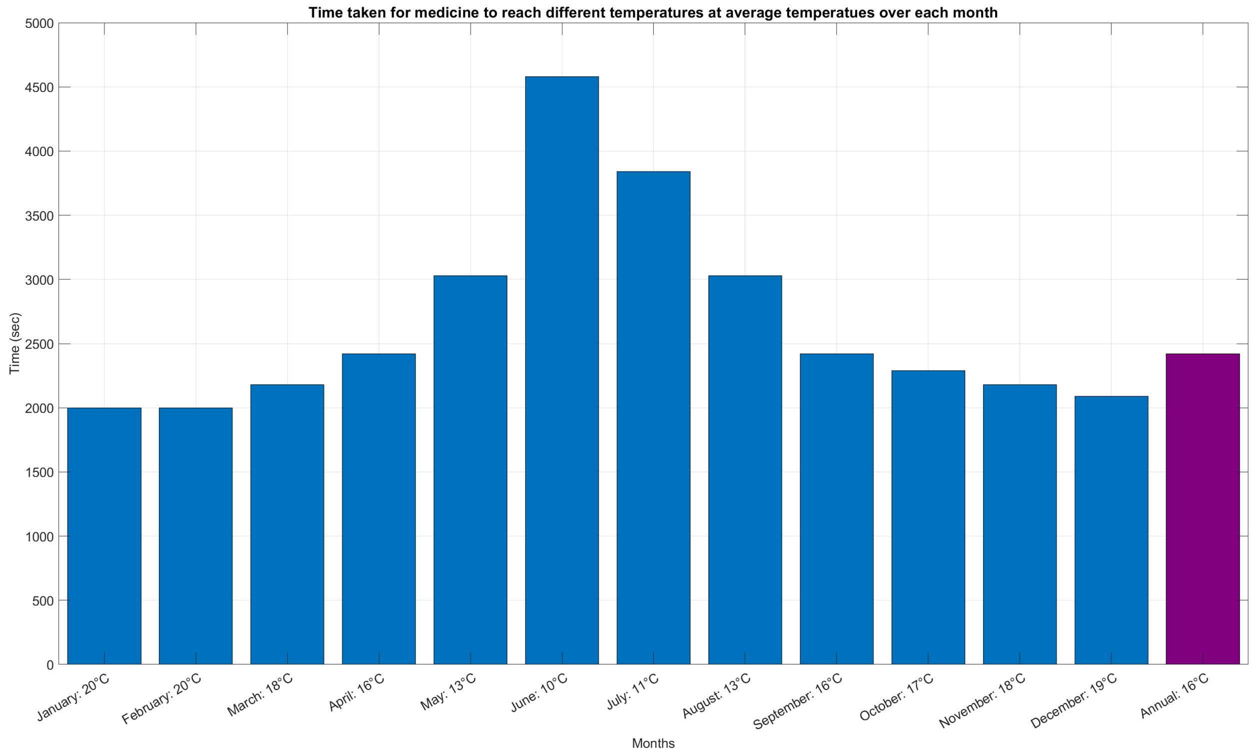


Fig. 5: Graph showing the time taken for the medicine to reach a temperature of $8°C$ for the average temperature per month

3) Test Case 3: High and Low Temperatures

The objective of this test case is to look at the worse-case scenarios, i.e. the average high and the average low temperatures. Once again, to test the thermal properties of the designed container, the time taken for the medicine in the container to reach a temperature of $8°C$ is recorded. The background temperature is a constant radiation heat source from the simulated sun on a cloudless day. Table IV and Figure 6 present the results of the simulation. As seen from the results, at the high temperatures the container performs less efficiently as the it is only able to maintain the temperature for approximately 30 min. However, the lowest average of $5°C$, will never exceed this temperature according to the law of thermal equilibrium.

Overall the designed container is able to maintain the temperature of the medicine for a minimum of 30 min before requiring the Peltier devices to be turned on.

TABLE IV: Average high and low temperatures and time taken for the medicine to reach $8°C$

	Temperature ($°C$)	**Time Take to reach** $8°C$ (sec)
Highest Average High	25	1710
Annual High	21	1930
Lowest Average Low	5	∞
Annual Low	11	3840

4) Test Case 4: Peltier devices

The objective of the final test case was to test how long the Peltier devices would take to cool the medicine inside the container. The environmental temperature was set to be at room temperature, $20°C$, with a radiation heat source of the sun on a cloudless day. The medicine is given a temperature of $8°C$ and the air inside the container is given a temperature of $11°C$. Given the approximate distance between the Peltier devices and the medicine, the time taken to cool the medicine to a temperature of $3°C$ is approximately 2500 sec or 40 min. Figure 7 shows the graph of the time taken to cool the medicine.

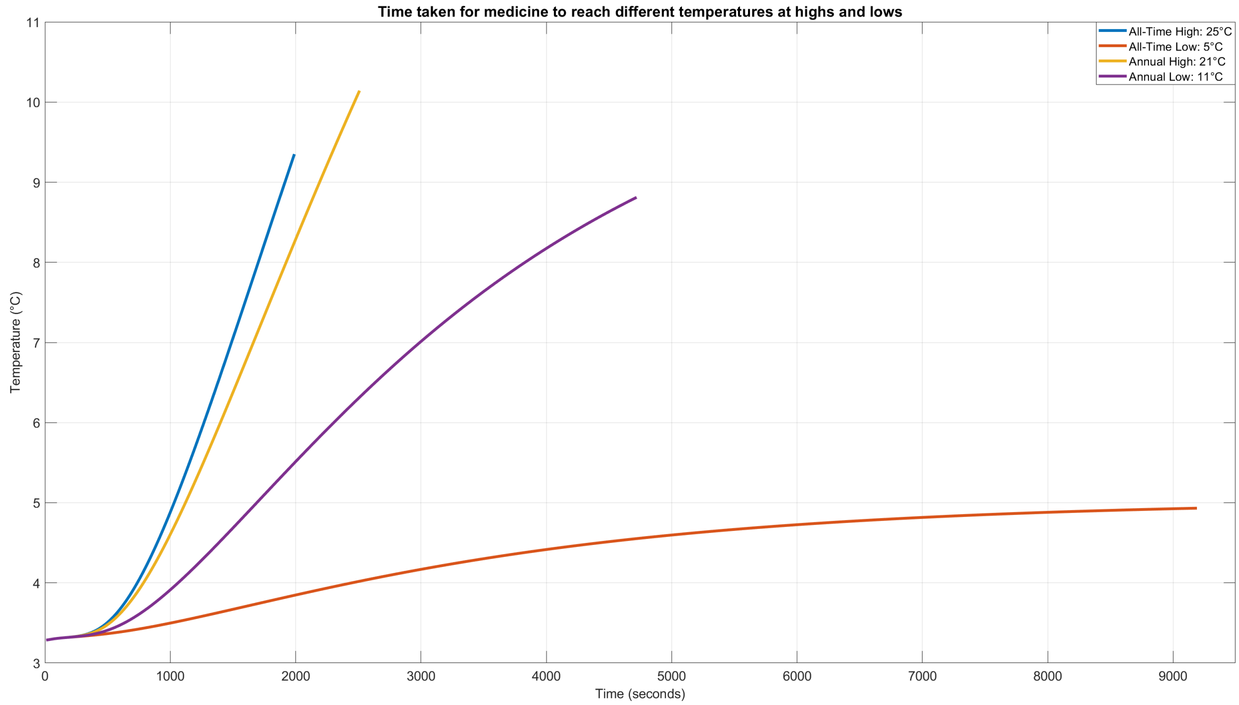


Fig. 6: Graph showing the time taken for the medicine to reach a temperature of $8°C$ for the average high and low temperatures

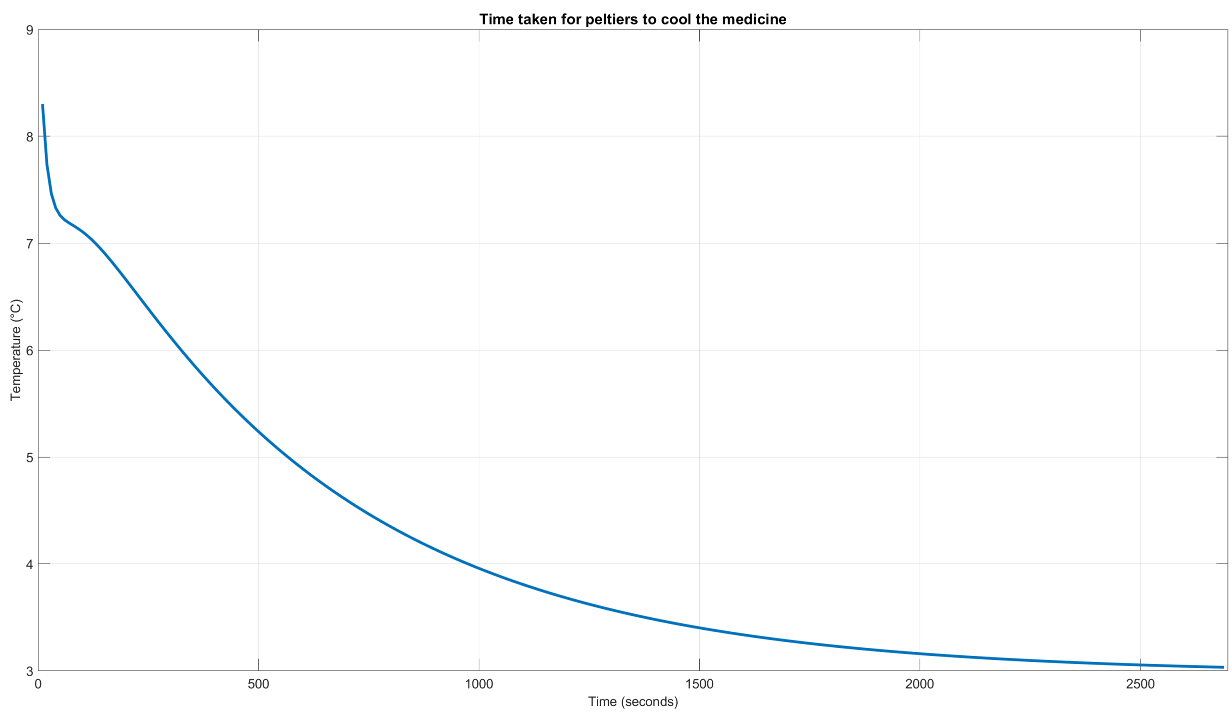


Fig. 7: Graph showing the time taken for the Peltiers to reduce the temperature of the medication to $3°C$

B. Electrical Simulations

The electrical simulations are focused on the power the respective component of the design takes, and determining how long the battery pack can last without recharging. These simulations are done mathematically looking at the maximum ratings for each of the elements used in the design of the electrical component, as a way of looking at the worse-case scenario. The assumption made is that any voltage regulators, resistors and other electrical elements will draw negligible power and can be equated to 0.

Equation 2 was used to calculate the total power each electrical element requires. All relevant voltage and current values are taken from each respective datasheet and Table V gives the calculated power of the electronic component of the design.

$$P = VI \tag{2}$$

where:
- P is the power
- V is the voltage
- I is the current.

TABLE V: Power required for electronics component

Electrical Element	**Voltage** (V)	**Current** (A)	**Power** (W)
Temperature sensor TMP116	5.5	220×10^{-6}	1.21×10^{-3}
MPU AT91RM9200	3.6	24.4×10^{-3}	87.84×10^{-3}
LCD Screen PC1602ARS	5.0	1.5×10^{-3}	7.5×10^{-3}
TEC Controller ADN8831	5.5	12×10^{-3}	66×10^{-3}
Peltier Device CP85138	1	1.7	1.7
TOTAL			1.86255

Now that the total power required for the circuit is known to be $1.86255W$, the charge of the battery pack must be calculated to determine how long the chosen batteries will last without recharging. Using Equation 3, and the fact that the battery pack has a nominal voltage of $3.6V$ and a capacity of $12000mAh$, the energy stored in the battery is $43.2Wh$. This means that if the electronics are running continuously, the battery can last for 23.194 $hours$ or 1391.64 min.

$$E = VQ \tag{3}$$

where:
- E is the energy stored in battery
- V is the voltage
- I is the battery capacity.

The container is designed to be a portable one, when the user is away from conventional medication storage appliances. Given that in Section V-A3, the high and low temperatures for the year was simulated, and that the time between sunrise to sunset in Johannesburg, South Africa is approximately 12 $hours$ [24], the expected lifespan of one single charge in the battery pack can be calculated.

The assumptions made for these calculations are:
- The annual low temperature ($11°C$) will occur for 6 hours a day (06:00 and 12:00)
- The annual high temperature ($21°C$) will occur for 6 hours a day (between 12:00 and 18:00)
- The container is able to maintain the temperature inside for 60 min at the low temperature
- The container is able to maintain the temperature inside for 30 min at the high temperature
- The Peltier's take 40 min to cool the medication back down to $3°C$.

This means that the electronic component will need to be turned on 8 times in one day, which totals 320 min. Given the capacity of the battery pack, this means that the battery is able to last approximately 4.348875 $days$, given the assumptions made. Figure 8 presents a typical timeline of when the Peltier devices will turn on and turn off during the sunrise and sunset.

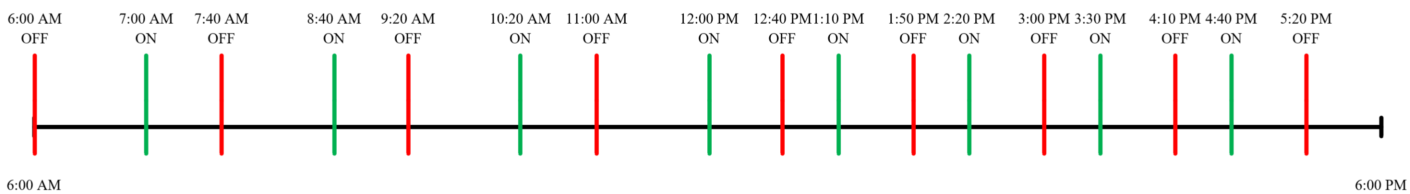


Fig. 8: Timeline of when the Peltiers will turn on and off during the day

C. MPU Proposed Pseudocode

The pseudocode that will be programmed onto the MPU is based on the flow diagram in Figure 3. Algorithm 1, presents a high-level algorithm on setting up the MPU, whereas Algorithm 2 presents a high-level algorithm of the `main` function that will control how the MPU will work.

VI CRITICAL ANALYSIS AND RECOMMENDATIONS

The designed system is able to store and maintain the temperature of any medication that needs to be stored into it. The container is marginally larger than most conventional smartphones today, and is approximately $4cm$ thick. This poses an issue as it may be deemed too large to fit into a conventional pocket, however the container is still small enough to fit into a bag without being intrusive on space, meeting the requirement of the container being portable. The container is able to store multiple injectable substances, or multiple syringes and a specific vial of a medicine or vaccine.

The simulations carried out on the container determined that it is able to maintain the temperature for an average of 35 min throughout the year's temperatures. The container being constructed from aluminium sheets and polystyrene indicates that it could theoretically be constructed from recycled materials. This minimises the cost of the container to a negligible value leaving the cost of the entire design on the electronics. According to various retailers, the total cost of the electronics component is approximately $R1500$. The cost of the designed container against a popular case such as the *FRIO® Insulin Cooling Case* is five times more expensive, however the *FRIO®* case is only made for insulin, whereas the designed container can store any type of temperature dependent medication or immunisation. The *Fresh Vaccine - Cool Cube™*, although able to maintain the temperature of a vaccine for multiple days at a time, is five times more expensive than the designed container, and much larger in size.

The weight of the designed container will come from the heat sink and the battery pack. The batteries in the battery pack each have an individual weight of $66.8g$. The total weight of the battery pack is therefore $200.4g$, and assuming that the heat sink will have a weight of $50g$, the total weight of the container without the medication is approximately $250g$, which is $150g$ heavier than the conventional smartphone today [26].

The one constraint of the design was to ensure that the power supply is able to last for at least a month without recharging, however, the designed container can only last for 4 days without recharging. This is a trade off of the design, as the designed system would require a battery that can supply $25747891.2Wh$ in order to last 30 days without recharging. This type of battery pack would reduce the portability of the designed container. The overall designed system can be said to have achieved all of the objectives set out for it.

For future development, a simpler MPU could potentially be utilized to perform the same functions as the chosen MPU. This will allow for a cheaper alternative to be used to perform the same functions, ultimately reducing the cost of the container. The container design can be reduced in size to accommodate only a single injectable substance. This would allow the container to cool faster with the Peltier devices.

The materials used in the container design can be made from recycled materials, however the utilization of a different type of container, such as a vacuum flask may keep the medication at the required temperature for a longer period of time. In addition to this, the designed container can be simulated in a better multiphysics program to fully analyse the design.

A final recommendation would see a better heat conductor used for the Peltier devices. Within the polystyrene, a pipe array can be used to ensure that the electronic component has a better efficiency [7]. Alternatively, the electronic component could utilize liquid cooling, as the water has a higher thermal conductivity than air [27].

VII CONCLUSION

The research, design and simulation of a compact, portable, insulated container that can store any vaccination or injectable substance has been presented. The container design was simulated using the multiphysics software, *Energy2D*, and although modelled in two dimensions, simulated all three dimensions by using the partial differential equation. The container was simulated in cloudless, sunny conditions with monthly average temperatures used as the background temperature. The highest average high and lowest average low temperatures were simulated against the container to analyse both ends of the spectrum. It was seen that the container maintains the temperature of the medication in the acceptable range for $30\ min$ before requiring the Peltier devices to be turned on. The multiphysics software was also used to simulate how long the Peltier devices would take to reduce the temperature of the medicine to $3°C$. It was observed that it takes approximately $40\ min$ to cool the medication down before being turned off. The container can be constructed from recycled materials, and the cost is incurred from the electronics component of the design, which totals $R1500$. The electronics consume a total of $1.86255W$ and the battery pack chosen can last 4 days before requiring a recharge. A battery that could last at least a month would be too large and remove the portability trait of the container. The designed system is critically analysed and future recommendations are given including a better heat conduction system or a different, more expensive container type.

ACKNOWLEDGEMENTS

The author would like to thank Professor D. Rubin for his guidance, support and general advice throughout the project. The author would also like to thank Doctor K. Rampersad, an interning doctor in Pietermaritzburg, South Africa, for her assistance for all medical information required, images and information validation.

REFERENCES

[1] Thomson et al.; *History of Medicine*; https://www.britannica.com/science/history-of-medicine; Encyclopaedia Britannica, Inc.; 25 October 2017; Last Accessed: 18 October 2019

[2] World Health Organization; *WHO — Vaccines*; https://www.who.int/topics/vaccines/en/; Last Accessed: 18 October 2019

[3] U.S. Department of Health & Human Services; *Pinkbook — Vaccine Storage and Handling — Epidemiology of VPDs — CDC*; https://www.cdc.gov/vaccines/pubs/pinkbook/vac-storage.html; Last Accessed: 19 October 2019

[4] Wavelength Electronics; *TEMPERATURE CONTROLLER BASICS Wavelength Electronics*; https://www.teamwavelength.com/temperature-controller-basics/; Last Accessed: 19 October 2019

[5] Hassan-Younis, Ur-Rashid; *Energy efficient, peltier based portable cabinet cooling system for vaccine cold chain*; Processions of the 4th International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET); 10-12 September 2018; Islamabad, Pakistan

[6] Ahmad, Abdullah, Yaakub, Jidin, Johari, Zahari; *Analysis of portable temperature-controlled device by using peltier effect*; Proceedings of Mechanical Engineering Research Day; pp 176-177; May 2017

[7] Han, Liu, Zhao, Zhe; *An Automatic and Portable Prosthetic Cooling Device with High Cooling Capacity Based on Phase Change*; Journal of Applied Thermal Engineering; Vol. 104; pp 243-248; July 2016

[8] FRIO Insulin Cooling Case; *How It Works*; https://www.frioinsulincoolingcase.com/how-the-frio-insulin-cooling-case-works.html; Last Accessed: 19 October 2019

[9] VeriCor, LLC; *Fresh Vaccine - Cool Cube at Fridge Temperatures Transport Coolers Archives - VeriCor, LLC*; https://www.vericormed.com/product-category/cool-cube-transport-coolers/fresh-vaccine-cool-cube-at-fridge-temperatures-transport-coolers/; Last Accessed: 19 October 2019

[10] Science Learning Hub; *Insulation Science Learning Hub*; https://www.sciencelearn.org.nz/resources/1006-insulation; Last Accessed: 21 October 2019

[11] Dr. K. Ramparsad; Personal Communication
[12] Texas Instruments; *TMP116 High-Accuracy, Low-Power, Digital Temperature Sensor With SMBus- and I2C-Compatible Interface*; Texas Instruments Incorporated; Dallas, Texas; USA; May 2019
[13] Atmel; *AT91RM9200 [DATASHEET]*; Atmel Corporation; San Jose, CA; USA; 03 March 2016
[14] POWERTIP; *PC1602ARS-CWA-A-Q*; Powertip Corporation; Taichung; Taiwan; 2005
[15] Analog Devices; *Thermoelectric Cooler (TEC) Controller Data Sheet ADN8831*; Analog Devices, Incorporated; Norwood, MA; USA; 2019
[16] CUI; *CP85 Peltier Module Datasheet*; CUI Incorporated; Tualatin, OR; 12 March 2018
[17] FerroTec; *Thermoelectric Reference Guide - Thermoelectric*; https://thermal.ferrotec.com/technology/thermoelectric-reference-guide/; Last Accessed: 21 October 2019
[18] Bindu; *How to use SD Card With PIC Microcontroller using mikroC FAT16 — StudentCompanion*; https://www.studentcompanion.co.za/interfacing-sd-card-with-pic-microcontroller-mikroc/; Last accessed: 21 October 2019
[19] Samsung; *INR21700-40T Datasheet*; Samsung SDI Co., Ltd; San Jose, CA; USA; December 2017
[20] Texas Instruments; *LM3914 Dot/Bar Display Driver*; Texas Instruments Incorporated; Dallas, Texas; USA; March 2013
[21] Charles Xie; *Interactive Heat Transfer Simulations for Everyone, The Physics Teacher*; Volume 50; Issue 4; pp. 237-240, 2012
[22] Engineering Toolbox; *Thermal Conductivity of common Materials and Gases*; https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html; Last Accessed: 22 October 2019
[23] Engineering Toolbox; *Specific Heat of some common Substances*; https://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html; Last Accessed: 22 October 2019
[24] Weatherbase; *Johannesburg, South Africa Travel Weather Averages (Weatherbase)*; https://www.weatherbase.com/weather/weather.php3?s=86386&cityname=Johannesburg-Gauteng-South-Africa; Last Accessed: 22 October 2019
[25] Solargis; *Solar resource maps and GIS data for 180+ countries — Solargis*; https://solargis.com/maps-and-gis-data/download/south-africa; Last Accessed: 22 October 2019
[26] Peter; *Weekly poll results: the ideal weight for a phone is between 140g and 170g - GSMArena.com news*; https://www.gsmarena.com/weekly_poll_results_the_ideal_weight_for_a_phone_is_between_140g_and_170g-news-29934.php; Last Accessed: 21 October 2019
[27] Wilson; *Heat Sinks vs. Liquid Cooling — HowStuffWorks*; https://computer.howstuffworks.com/liquid-cooled-pc1.htm; Last Accessed: 21 October 2019

Algorithm 1 High-level algorithm of the `setup` function

```
Set relevant pins for inputs (temperature sensor, three push buttons)
Set relevant pins for outputs (temperature sensor, SD card, LCD, TEC controller)
Set internal clock and synchronize to all output pins

Start the LCD screen

Set cursor on LCD ← (0,0)
Display on LCD ← "Set upper temp."
Set cursor on LCD ← (0,1)
Display on LCD ← "8 C"
TempRegister ← 8

if UP button pressed then
  TempRegister ← TempRegister + 1
  Set cursor on LCD ← (0,1)
  Display on LCD ← TempRegister
else if DOWN button pressed then
  TempRegister ← TempRegister - 1
  Set cursor on LCD ← (0,1)
  Display on LCD ← TempRegister
else if SELECT button pressed then
  Save current temperature ← UpperTempRegister
  Send saved temperature to temperature sensor
end if

Set cursor on LCD screen (0,0)
Display on LCD ← "Set lower temp."
Set cursor on LCD screen (0,1)
Display on LCD ← "2 C"
Set default temp in register to 2

if UP button pressed then
  TempRegister ← TempRegister + 1
  Set cursor on LCD ← (0,1)
  Display on LCD ← TempRegister
else if DOWN button pressed then
  TempRegister ← TempRegister - 1
  Set cursor on LCD ← (0,1)
  Display on LCD ← TempRegister
else if SELECT button pressed then
  Save current temperature ← LowerTempRegister
  Send saved temperature to temperature sensor
end if
Turn off LCD
```

Algorithm 2 High-level algorithm of the `main` function

```
Log current temperature to SD card
repeat
   Start timer for 30 minutes
   Wait 15 seconds
   Put into sleep mode

   while timer is running do
      if SELECT button pressed then
         Read current temperature from temperature sensor
         Start LCD screen
         Set cursor on LCD ← (0,0)
         Display on LCD ← "Current temp."
         Set cursor on LCD ← (0,1)
         Display on LCD ← CurrentTempRegister
         Wait 5 seconds
         Turn off LCD
      else if HIGH or LOW received from temperature sensor then
         Trigger TEC controller
         Send to TEC controller, value of 3 for comparison
      end if
   end while
   Log current temperature to SD card
until Timer is up
```

APPENDIX A
NON-TECHNICAL REPORT

The history of medicine has led to multiple discoveries in the world, such as vaccines, insulin and penicillin allowing humans to have a greater lifespan, treat diseases and ultimately prevent them. According to the World Health Organization (WHO), majority of children receive their vaccines in a timely manner, however those who do not have access to certain medical facilities are unable to get their immunisations. This includes approximately 20 million people worldwide that are susceptible to diseases and illnesses that can be easily prevented with the use of vaccines. Vaccines and insulin must be kept in temperature controlled containers, within a temperature range between $2°C$ and $8°C$.

Currently, there are a variety of solutions that a person can purchase to keep their medication on them at all times. One of the most popular cases is the *FRIO® Insulin Cooling Case*, that offer a variety of options from keeping two insulin pens or two insulin vials and syringes, to a larger case that can store ten insulin pens or ten vials and syringes. The case is activated by submerging the case in cold water for 5-15 minutes. The gel inside the case expands and forms crystals, and this relies on the process of evaporation for cooling. The *FRIO®* case is able to keep the insulin safe for a minimum of 45 hours, making it the ideal companion for travel.

The *Fresh Vaccine - Cool Cube™* is another available product that can maintain the temperature of the vaccines without the use of ice or any electrical components. This case, although expensive, is able to maintain vaccines within the temperature range of $2°C$ and $8°C$ for more than 65 hours. This product is perfect for remote located vaccinations, long-term transport and as a backup for hospitals with a power outage.

A new container has been recently designed that is portable and insulated and can maintain any type of injectable substance within it at any settable temperature. The container is constructed with an aluminium sheet on the outside, followed by aired polystyrene and lastly the inside of the container is another aluminium sheet. All of these materials are recyclable, and as a result is a step towards an environmentally-friendly solution. The outer aluminium sheet, being silver reflects some of the sunlight that shines on it. The aired polystyrene is the insulator of the container, providing excellent insulation, as the air bubbles in it slow down the heat energy from flowing through them. The aluminium sheet on the inside acts as a good conductor, reducing the time take for the medicine to cool, when the cooling element is turned on. The container's top and bottom parts are joined to one another with the use of magnets, creating a minimal air gap inside the container, ultimately isolating and insulating the medication inside from the environment outside.

The top half of the container houses the electronics, where all elements are low-power, high precision ones. With a temperature sensor directly conversing with a microprocessing unit, the internal temperature of the container is constantly maintained within any desired temperature range. The element that is responsible for cooling the medication on the inside of the container is known as a thermoelectric cooler or a Peltier device.

A thermoelectric cooler is given the alternative name of a Peltier device as it utilizes the Peltier effect in its function. Two conducting plates on either side of the device, generally ceramic plates, are connected to one another by the use of semiconductors. The Peltier effect occurs by passing a current through the semiconductors, which causes heat to be generated on one of the plates and absorbed on the other. The absorbed heat is passed through to the other plate, resulting in a cooler environment. This is how the medication in the designed container will be kept cool if the temperature reaches the boundaries. Since heat is generated on one of the plates, this heat needs to be dissipated into the atmosphere, and is done so with the use of natural convection heat sinks.

Every 30 minutes, the temperature of the medication is read and saved to an external SD memory card that will be able to be read and the data analysed. With a system being able to perform the responsibilities of a temperature controller, power must be supplied by some sort of battery. A battery pack consists of three e-cigarette or vaporizer lithium-ion batteries. This pack has its own charge level indicator and can be charged via a normal USB cable. Having taken into consideration the portability of the design, the batteries are able to last 4 days before requiring a recharge, making it a bi-weekly charging chore.

The designed container is able to keep the medication within the set temperature range, for 28-32 minutes on a cloudless, sunny day, when temperatures are between $21°C$ and $25°C$. In cooler temperatures of $11°C$, the designed container can maintain the temperature of the medicine for 64 minutes. Should the temperature of the medication reach the upper bounds, the Peltier devices will turn on, cooling the inside of the container, bringing the temperature to the lower bound within 40 minutes.

Overall, the container itself can be made from recycled aluminium and polystyrene, and as a result the cost of the entire designed system lays in the electronics. A total cost of $R1500$ is required to build the electronics, which includes the battery pack, microprocessing unit and Peltier devices. This price is five times more expensive than the popular *FRIO*®case, however the designed container is able to store any type of temperature dependant medication, whereas the *FRIO*® case can only store insulin. The designed container is however, five times less expensive than the *Cool Cube*™ vaccine storage, and much more portable.

The designed container has the dimensions $200mm \times 111mm \times 37mm$, making it marginally larger than most conventional smartphones today. The thickness of $37mm$, does make the designed container harder to fit into conventional pockets, but can be stored in bags without being too intrusive on space. The total weight of the overall container is approximately $250g$ which is $150g$ heavier than what consumers prefer as the ideal weight of a cellphone.

This newly designed container is constructed from recyclable materials, costing an average of $R1500$ and provides a viable, economical and environmentally-friendly solution to a portable container that can house temperature-dependent medication.

APPENDIX B
SIMULATION MODELS

This appendix provides the two models that were created in *Energy2D*. Figure 9 shows the model that was used to simulate the container's thermal conductivity, looking from the top view. Figure 10 gives the model that was used to simulate the cooling of the Peltier devices from the side perspective.

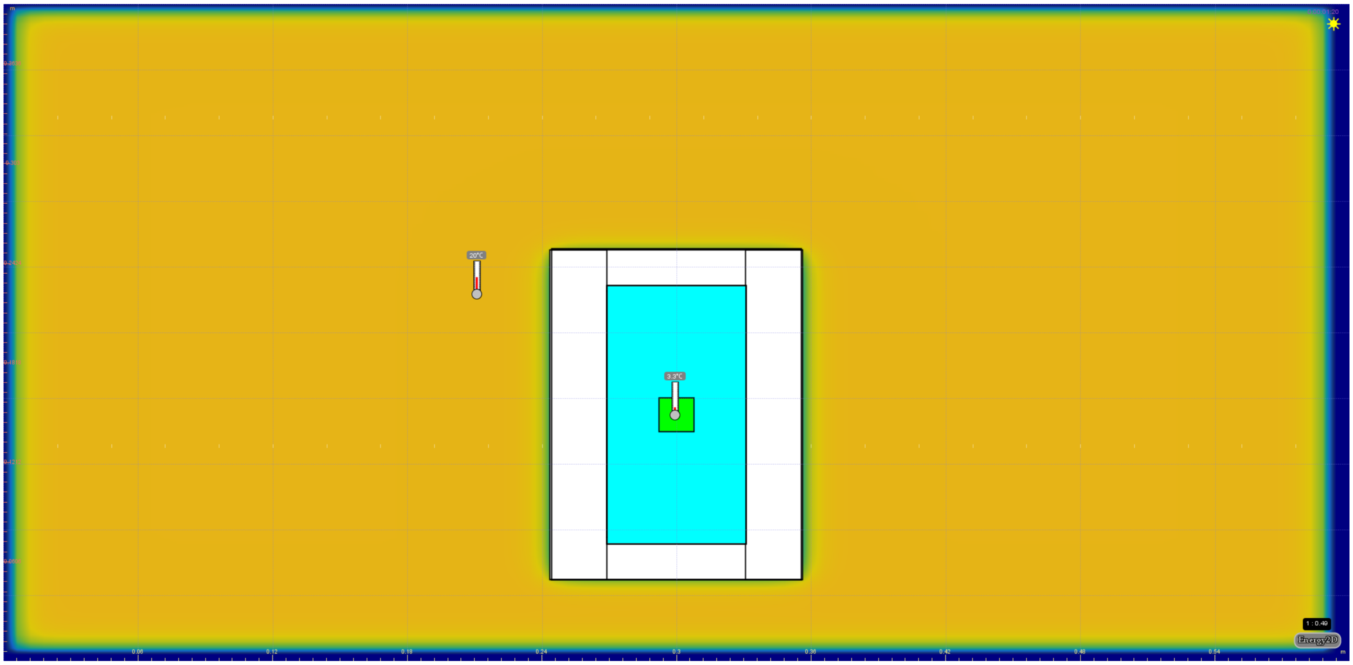


Fig. 9: Model created in *Energy2D* for the container

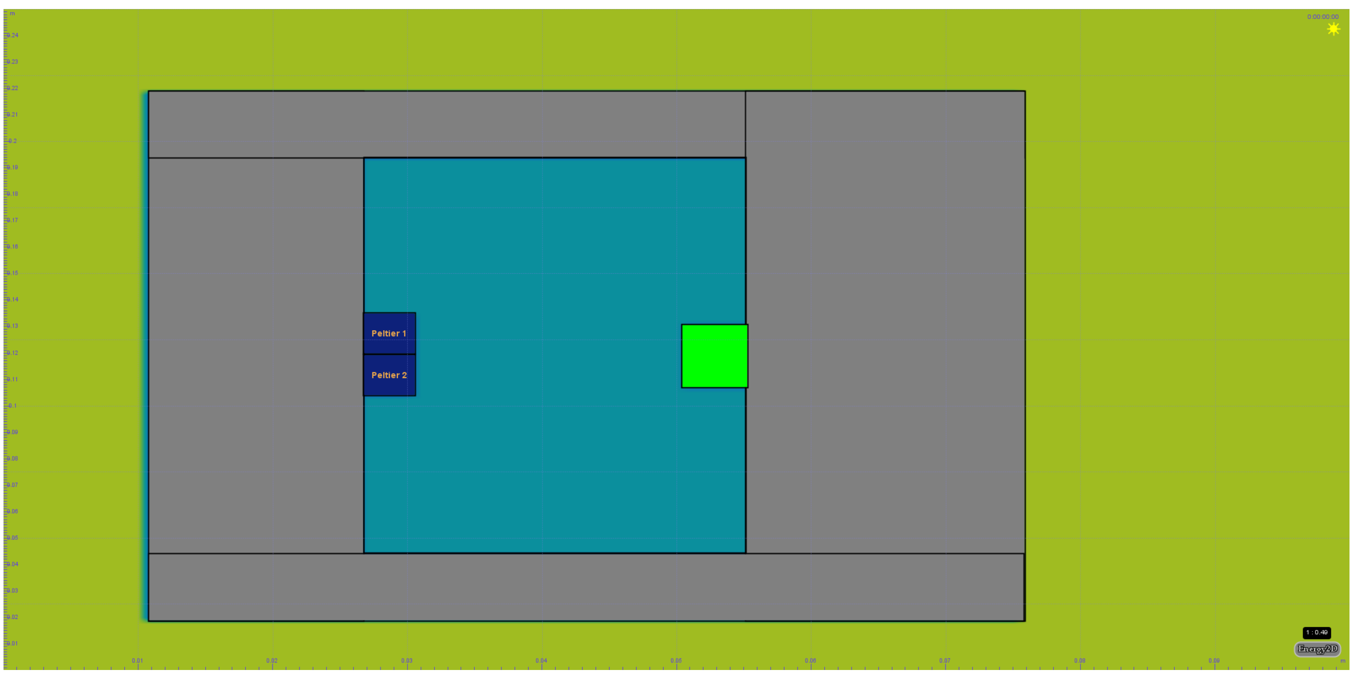
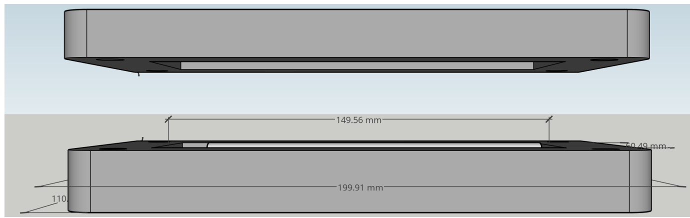


Fig. 10: Model created in *Energy2D* for the Peltier device

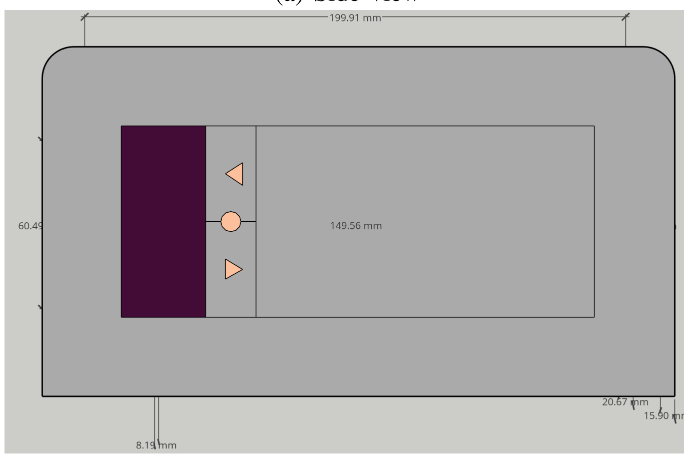
APPENDIX C
SUPPORTING IMAGES

This appendix provides all supporting images for the project design. Section C-A displays the other rendered images of the container design, whereas Section C-B displays all of the images taken of the various medication vials provided by Dr. K. Ramparsad [11].

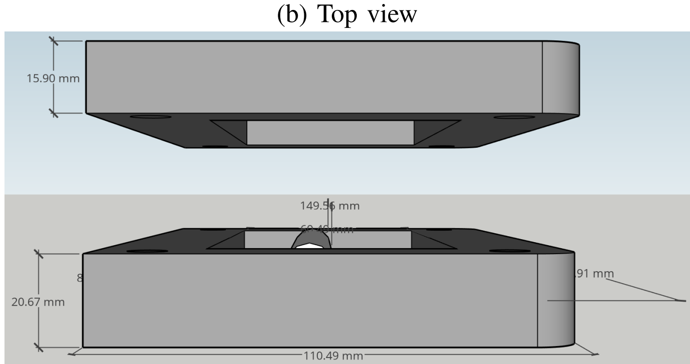
A. Container Design



(a) Side view

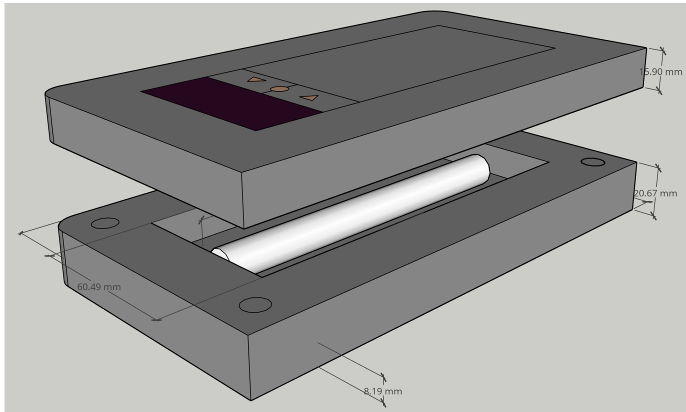


(b) Top view

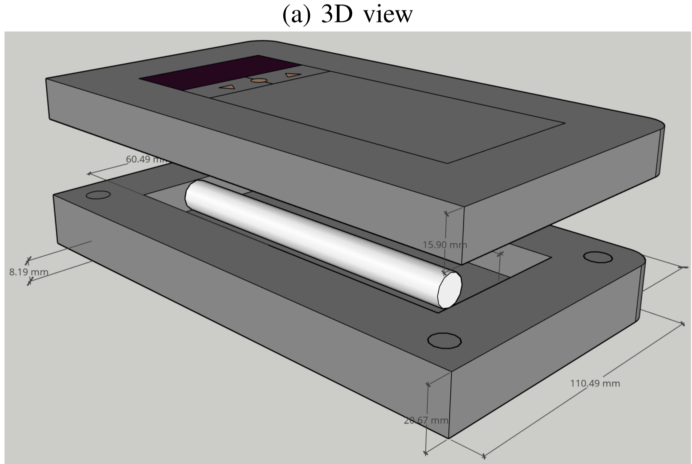


(c) Front view

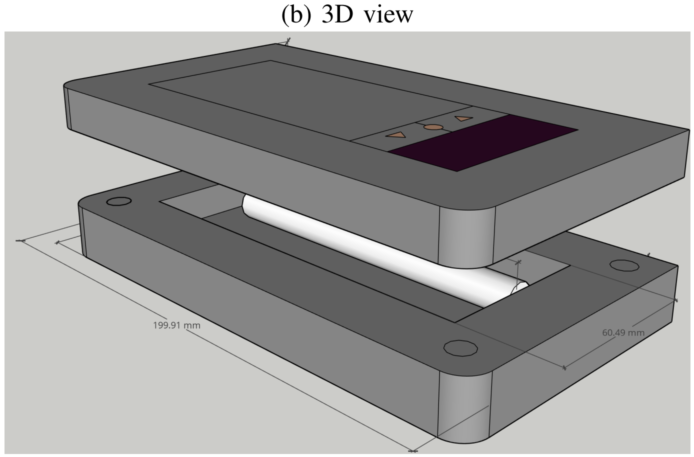
Fig. 11: Side, Top and Front view of Container Design rendered in *Google SketchUp*



(a) 3D view



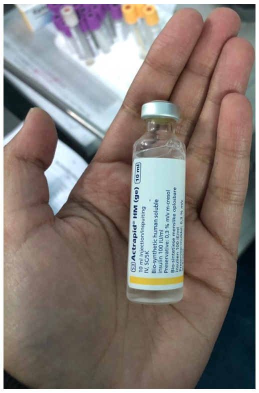
(b) 3D view



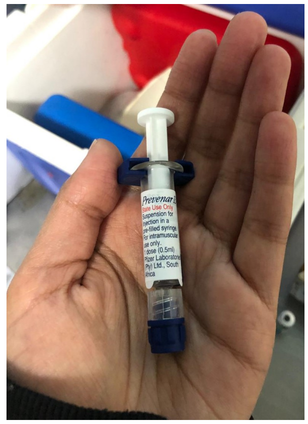
(c) 3D view

Fig. 12: 3D views of Container Design rendered in *Google SketchUp*

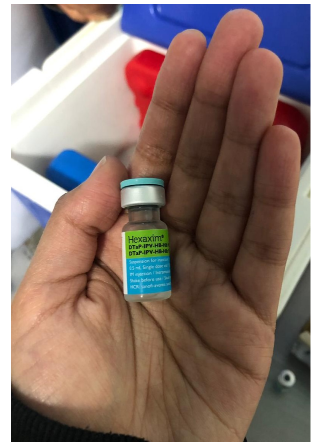
B. Medication Images



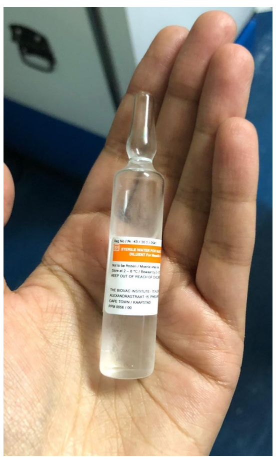
(a) Actrapid (Insulin)



(b) Conjugated Pneumococcal Vaccine

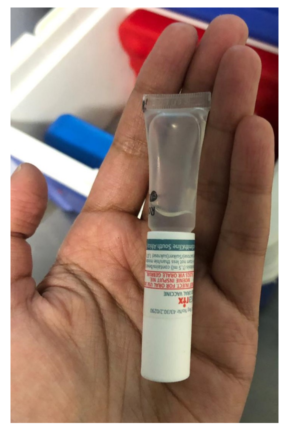


(c) Hexavalent Combo Vaccine (Hepatitis B, Haemophilis Influenza)

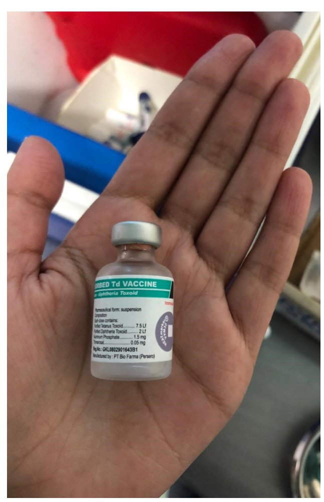


(d) Measles Diluent

(e) Measles Vaccine



(f) Oral rotavirus



(g) Tetanus and Diptheria Vaccine

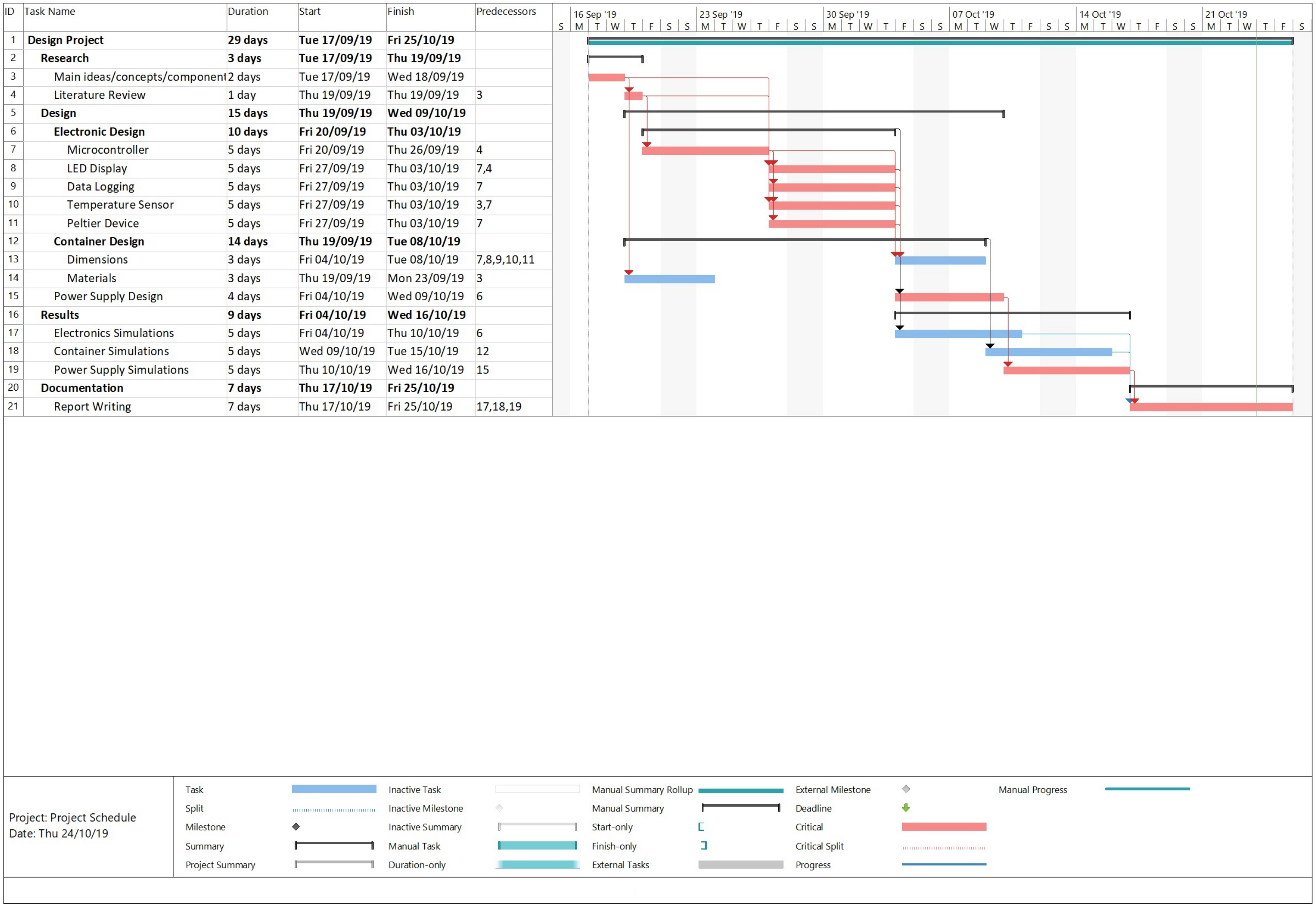
Fig. 13: Various medications that could be stored in the container

APPENDIX D
PROJECT MANAGEMENT

This appendix presents all information related to project management. Section D-A presents the created tasks and the Gantt chart that is used for the project completion. Section D-B presents all meeting minutes for the five weeks of the project, with various members in the group keeping minutes.

A. Gantt Chart

The subsequent page presents the figure of the Gantt chart created.



ID	Task Name	Duration	Start	Finish	Predecessors
1	**Design Project**	**29 days**	**Tue 17/09/19**	**Fri 25/10/19**	
2	**Research**	**3 days**	**Tue 17/09/19**	**Thu 19/09/19**	
3	Main ideas/concepts/component	2 days	Tue 17/09/19	Wed 18/09/19	
4	Literature Review	1 day	Thu 19/09/19	Thu 19/09/19	3
5	**Design**	**15 days**	**Thu 19/09/19**	**Wed 09/10/19**	
6	**Electronic Design**	**10 days**	**Fri 20/09/19**	**Thu 03/10/19**	
7	Microcontroller	5 days	Fri 20/09/19	Thu 26/09/19	4
8	LED Display	5 days	Fri 27/09/19	Thu 03/10/19	7,4
9	Data Logging	5 days	Fri 27/09/19	Thu 03/10/19	7
10	Temperature Sensor	5 days	Fri 27/09/19	Thu 03/10/19	3,7
11	Peltier Device	5 days	Fri 27/09/19	Thu 03/10/19	7
12	**Container Design**	**14 days**	**Thu 19/09/19**	**Tue 08/10/19**	
13	Dimensions	3 days	Fri 04/10/19	Tue 08/10/19	7,8,9,10,11
14	Materials	3 days	Thu 19/09/19	Mon 23/09/19	3
15	Power Supply Design	4 days	Fri 04/10/19	Wed 09/10/19	6
16	**Results**	**9 days**	**Fri 04/10/19**	**Wed 16/10/19**	
17	Electronics Simulations	5 days	Fri 04/10/19	Thu 10/10/19	6
18	Container Simulations	5 days	Wed 09/10/19	Tue 15/10/19	12
19	Power Supply Simulations	5 days	Thu 10/10/19	Wed 16/10/19	15
20	**Documentation**	**7 days**	**Thu 17/10/19**	**Fri 25/10/19**	
21	Report Writing	7 days	Thu 17/10/19	Fri 25/10/19	17,18,19

Fig. 14: Gantt Chart for the project with the critical path highlighted

B. Meeting Minutes

The following pages present the meeting minutes recorded for the weekly meetings.

Week 1 Meeting 17 September

12:00 PM / EIE Seminar Room

ATTENDEES

Chair: Professor David Rubin

Jason Smit (secretary), Muhammed Rashaad Cassim, Anita de Mello Koch, Alexandra de Nooy, Joshua Isserow, Nicholas Kastanos, Daniel Katz, Kishan Narotam, James Phillips, Sixolele Toko, Wavhudi Tshithivhe, Graeme Young

ABSENTEES/EXCUSED

Robert Bradfield

MINUTES

Reduced restrictions:

- Any vaccination/injection not specifically epipen.
- Design may be designed for first world countries to allow for a less restrictive budget.
- Peltier is not a fixed requirement, however portability is the emphasis.
- Any shape container is acceptable provided the syringe fits within.

Required components:

- Portable compact container
- Heat exchange system
- Logging
- In depth power audit

General comments:

- Design may require heating in cold environments.
- Use the time constant to determine the minimum required logging time.
- High level design with circuit diagrams is the goal.
- The two page write-up should be read like a magazine and should be understood by a lay person.

- Wind chill should be considered.
- Protection of contents not a requirement of the design.

ACCEPTED PROPOSALS

- A single meeting will be held every week, Tuesday at 12PM.
- The meeting for week 2 is moved to 11AM Wednesday (25/09), since Tuesday is a public holiday.

WEEK 2 AGENDA

Please send any matter to be addressed to Kishan prior to Wednesday to allow for a concise agenda and meeting.

NOTES:

Daniel Katz will serve as the liaison between Professor Rubin and the group.

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Week 2 Meeting 25 September

11:00 AM / EIE Seminar Room

ATTENDEES

Chair: Professor David Rubin

Kishan Narotam (secretary), Muhammed Rashaad Cassim, Anita de Mello Koch, Alexandra de Nooy, Joshua Isserow, Nicholas Kastanos, Daniel Katz, James Phillips, Jason Smit, Sixolele Toko, Wavhudi Tshithivhe, Graeme Young

ABSENTEES/EXCUSED

Robert Bradfield

MINUTES

How far do we have to take it:

- Prof will see a lot of circuit diagrams
- He will not build or test it
- Run it on a simulator:
    - For analogue circuits - Spice
    - For digital simulation - Multisim
    - For thermal simulations - OpenFoam
- When doing thermal simulations, look at Newton's or Fourier's law of cooling - heat transfer
- A rough idea is required for the dimensions of the container.
- The main focus should be on thermal design NOT on the power supply, but limitations must be given.
- Energy optimisation is important.

ACCEPTED PROPOSALS

- When simulating, worst case simulations can be looked at.
- Simple calculations can be used to calculate basic heat transfer, and a physics simulator can be used to check against worst-case and best-case scenario

- Should the interface for data want to be changed, an email must be sent to Prof.
- Pseudocode is acceptable for coding on the microcontroller.
- Current implementations can be used, as long as referencing is given.

WEEK 3 AGENDA

Please send any matter to be addressed to Nicholas prior to Wednesday to allow for a concise agenda and meeting.

NOTES:

Daniel Katz will continue to serve as the liaison between Professor Rubin and the group.

Week 3 Meeting 2 October

12:00 PM / Jackson Room

ATTENDEES

Chair: Professor David Rubin

Nicholas Kastanos (secretary), Muhammed Rashaad Cassim, Anita de Mello Koch, Alexandra de Nooy, Joshua Isserow, Daniel Katz, Jason Smit, Wavhudi Tshithivhe, Graeme Young

ABSENTEES/EXCUSED

Robert Bradfield, Kishan Narotam, James Phillips, Sixolele Toko

MINUTES

- Prof. Rubin suggests approaching the problem from a high level design before developing an in-depth solution.
- Concerns were raised about the 30-day per-charge battery life specification. Through preliminary results and market research, the concerned party believes the result is unattainable.
    - If the specification cannot be reached, proper substantiation must be given. This includes design trade-offs and analyses.
- If the proposed application requires a temperature range which is different to the specification (3-15 degrees C), the application and new temperature range must be specified.
- Temperature logging can occur through any applicable communication channel (serial, bluetooth, wireless).
- The device must have a real-time temperature display. Can be in the form of an LCD display or even a red and green light to indicate whether the internal temperature is acceptable.
- Concerns were raised about the ability of multiphysics packages to provide electrical (power) analysis alongside heat analysis.
    - Code solutions (Fortran, MatLab, etc) can be used to create models which incorporate both aspects.

- For “one-time use” applications such as EpiPen, design the device for indefinite storage. Assume that the container must always be within the specified temperature range.
- For applications which have temperature tolerances (eg must be within a range for 80% of the time), specify a range between which the device temperature must always remain.

ACCEPTED PROPOSALS

- The weather conditions for Johannesburg, Gauteng are sufficient for external conditions. Extreme temperatures do not need to be considered as they are not livable.

WEEK 4 AGENDA

Please send any matter to be addressed to Alexandra prior to the next meeting to allow for a concise agenda and meeting.

The date for the next meeting will be decided at a later date.

NOTES:

Daniel Katz will continue to serve as the liaison between Professor Rubin and the group.

Week 4 Meeting 7 October

12:30 PM / Jackson Room

ATTENDEES

Chair: Professor David Rubin

Alexandra de Nooy (secretary), Muhammed Rashaad Cassim, Anita de Mello Koch, Nicholas Kastanos, Joshua Isserow, Daniel Katz, Jason Smit, Wavhudi Tshithivhe, Graeme Young, Robert Bradfield, Kishan Narotam, James Phillips, Sixolele Toko.

ABSENTEES/EXCUSED

None

MINUTES

- Prof. Rubin suggests that simplifying assumptions should be used if challenges are being faced with respect to the thermal modelling aspect of the project.
- It is noted that multi-physics simulations are not a requirement, but that electrical simulations must be performed.
- It is noted that at the time of the meeting the focus of most individuals had been on the thermal modelling and not yet a full design for the electrical design.
- Queries were made with respect to the use of microcontrollers and the following points were made:
    - The system can be designed as an embedded system (as long as it is justified) and as such the microchip can be presented as a black box. In this case the microchip pin out and likely algorithm to be coded should be presented.
    - If time permits, use of the microchip should be reported at a register level (e.g when describing an SPI interface). There is a noted trade-off between detail that can be presented and the remaining time until the project deadline.

- It was confirmed certain assumptions with respect to thermal modelling could be made. A main assumption discussed was that of the air inside the flask being well-mixed. It is noted that while this may not be a realistic assumption it is a valid one to make in terms of project modelling.
- It is noted that a review of the power consumption for the design is a requirement. It is suggested that a possible table of comparison with respect to components and their power consumption could be used to justify design choices.
- It is noted that the used of existing battery chargers is acceptable and that these can be treated as black boxes.
- For this project it is noted that it could be reviewed as a systems design and that all reasonable assumptions should be stated.
- The group is reminded that the design is for a practical model which would show feasibility that an implementation of the design could be constructed and would function correctly.

ACCEPTED PROPOSALS

- The thermal modelling may be completed in pairs (though this is not a requirement), as long as it is stated and each member is acknowledged.

WEEK 4 AGENDA

Please send any matter to be addressed to James prior to the next meeting to allow for a concise agenda and meeting.

The date for the next meeting will be confirmed at a later date.

NOTES:

Daniel Katz will continue to serve as the liaison between Professor Rubin and the group.

Week 5 Meeting 15 October

12:30 PM / Seminar Room

ATTENDEES

Chair: Professor David Rubin

Alexandra de Nooy (secretary), Muhammed Rashaad Cassim, Anita de Mello Koch, Nicholas Kastanos, Joshua Isserow, Daniel Katz, Jason Smit, Graeme Young, Robert Bradfield, Kishan Narotam, James Phillips, Sixolele Toko, Wavhudi Tshithivhe.

ABSENTEES/EXCUSED

MINUTES

- Set the temperature, concerned party asks about the user input to the temperature range. Prof says this should not be difficult to implement. This device should be applicable to various medications. The temperature should be settable, but is up to the student to specify.
- A range of temperature settings is allowed, based on the range specified in the brief.
- Additional design of external elements are allowed, but have to be related to flask.
- Student is not restricted to how the areas of the flask are designed for storage.
- Prof mentions that the project outcome is to have a design for the interpretation of specifications, but the amount of interpretation and real-world effects are considered and discussed. *A logical discussion of why you chose what you chose.*
- Formatting of the report:

  - Prof Nixon's template should be suitable for report, but single column.
  - It is possible to find a Overleaf/LATEX Template which should match to the IEEE template.
  - Prof will not be strict on the finer formatting details, but the main requirements on formatting should be adhered to.
  - 2 page report:
    - More as a *proposal to an investor.*
    - Trying to show off what you can do/have done, but not to an engineer. (Prof's interpretation)
- Battery: Just a level detector, capacity and battery specifications, but high level.
- Thermal model:
  - Prof wants to see a very basic thermal simulation
  - We want to see what sort of range the device will operate in
  - Be careful of 2D approximations to the 3D model. Be sure that the correct dimensional factors are taken into account. Must not be a 2D plate.
  - Free ones suggested:
    - SimScape
    - Energy 2D
- Change of Temperature:
  - Changing PID constants for varying temperatures. You can have a few ranges and have a lookup table. Prof thinks that PID is an overkill model to this. Prof thinks that Proportional control will suffice, due to the rate at which the temperature changes.
- Quosent ICs:
  - Supply current vs quosent - Having to use assumptions for currents for IC components will suffice for the power analysis.

ACCEPTED PROPOSALS

WEEK 5 AGENDA

Next meeting 22 Oct 12h30

NOTES:

Next minutes Robert Bradfield