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# Design of a portable device to store and disinfect masks of SARS-CoV-2 virus using Peltier modules

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## ABSTRACT

The current pandemic has disrupted our routines and masks which were nowhere to be seen have become an essential part of our day-to-day life. The means to carry a mask without contaminating it and also disinfecting them is a challenge in the current scenario and should be so for some time to come. The portable device proposed through this study for storing and disinfecting masks embeds mechanical and electronic design. The device consists of a box that can house six masks, is compact, easy to carry and can disinfect masks. The main purpose is to heat the mask placed inside the box above the temperature of 65 °C for a duration greater than three minutes, so that bacteria and viruses such as SARS-CoV-2 can be eliminated and the mask can be kept safe, disinfected and reused. This in turn helps to reduce the waste caused by disposing masks and enables portability of masks in a safe and hygienic manner. The box comprises of two Peltier modules controlled by the ATtiny85 microcontroller, a metal plate that is in contact with the Peltier modules, two Li-Po batteries as power supply and a switch to turn on the device. The box can be recharged easily using the micro-USB port.

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## 1. Introduction

Mask has become an everyday commodity; hence its storage should be in a hygienic and user-friendly manner. It is one among the precautions that can be taken by human beings against the rampant Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) virus. Disposable and reusable masks are used by human beings around the world, and as a consequence, these masks end up as waste after one time use and it is a huge ask on the environment to degrade it. In other words, if masks are not correctly disposed, they can pollute the water as well as harm the wildlife according to the reports by [7]. Furthermore, it will lead to the virus spreading at a faster pace affecting millions of people. In order to tackle this issue, a device is designed through this study which would enable safe and hygienic reuse of masks thus reducing wastage and littering. Certain factors are to be considered when such a box is to be designed. Firstly, it should protect masks by preventing contact with the atmosphere and secondly, used masks should be disinfected of any SARS-CoV-2 virus.

Hygiene is crucial in order to reuse it and thus, an efficient way to store and disinfect masks is essential.

The device is designed with dimensions 140 mm × 90 mm × 43.25 mm, making it compact and providing sufficient space to accommodate six masks. The main purpose of the device is to house the mask and heat it up to a certain temperature using the Peltier modules. Considering various studies in the area of effect of temperature on elimination of SARS-CoV-2 virus, it is generally accepted that at a temperature above 65 °C, SARS-CoV-2 is eliminated, when exposed for more than 3 min (refer, [1]). The components of the device are two Peltier modules connected to a metal plate to provide the necessary heat, two Li-Po batteries, a circuit board that consists of ATtiny85 microcontroller, a TMP36 temperature sensor and two IRF520 Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). Through this paper, the design of a portable device capable of housing and disinfecting masks of SARS-CoV-2 virus is proposed.

## 2. Literature survey

Masks made of synthetic materials provide protection and permits the user to breathe-in and breathe-out properly according to Roger (1980) [8]. Research done by Chamteut [4] conveys that N95

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respirator masks can be decontaminated using dry heat from electric cookers for about 50 min. According to studies conducted by Abraham et al. (2020), SARS-CoV-2 virus is completely inactive when exposed to temperatures above 65 °C for duration greater than 3 min. As the temperature value is decreased, more amount of time is required to deactivate the virus.

Research by [9] reveals the consumption of 50 Watts while cloth-iron manufactured using Peltier modules are put to use. A suit integrated with Peltier modules that help in cooling and heating according to the external conditions is discussed by [6]. The idea of replacing air-conditioning system used in vehicles with Peltier-cooled air conditioners is considered in the paper by [2], resulting in reduction of total weight of the vehicle and also increase in overall fuel economy. The use of TMP36 temperature sensor to measure the body temperature of human beings is discussed by [5]. The ATtiny85 microcontroller used to gather data and control the RF receiver module for kinematic analysis of a toy car along the three axes is proposed by [3]. Review of the literature did not reveal a device similar to the one proposed through this study for the purpose of storing and disinfecting masks for SARS-CoV-2 virus.

The device proposed through this study comprises of a metal plate for distributing the heat throughout the length and breadth of the box, two TES1-4903 20 mm × 20 mm, 5 V, 3A Peltier modules that are connected to the metal plate using thermal paste and a TMP36 temperature sensor to measure and hence maintain the temperature at 65 °C which is placed on one of the corners of the box. The power source consists of two 3.7 V, 2600 mAh Li-Po batteries that are connected in parallel and placed at the bottom to power the whole circuit. The brain of the circuit is the ATtiny85 microcontroller, which is used to maintain the temperature in the box. Two IRF520 MOSFETs are used as a switch with the Peltier modules as the load. A charging port is provided to charge the batteries and a switch is given to turn on the device.

### 3. Design

Tangible objectives of this study is to design a portable device capable of housing and disinfecting masks, and the solution to these questions are addressed in the subsequent sections namely, the mechanical and electronic design of the device.

#### 3.1. Mechanical design

##### 3.1.1. Design

The design of the box is accomplished using the Creo Parametric tool by considering the dimensions of a standard N95 grade mask. The device is light in weight and compact in size (Figs. 1 and 2). The box is divided into two compartments, the top compartment holds the masks and it can accommodate around six N95 masks that are folded. The bottom compartment incorporates the control circuit,

battery, switch and USB port integrated onto one side and Peltier modules along with the metal plate between the compartments. The switch is designed to stay recessed from the outer wall to prevent accidental operation. The design features are selected with utmost attention to protect the masks from the outside environment. The top of the box can be opened up to 180° for the ease of use. The walls of the box are 3 mm thick, adding to its strength and thermal insulation. The box has an integrated self-locking closing mechanism to guarantee trouble-free operation. The figures shown below represent the various views of the device along with the respective dimensions.

The position of various components inside the box is shown in below (Fig. 3) and are arranged to facilitate smooth operation of the device.

##### 3.1.2. Calculation of wall thickness

The total heat load generated by the two Peltier modules is:

$$q = 20W$$

If we assume that the entire heat passes through the side of the box with least area, the maximum temperature on the outer surface can be determined and the side of the box with least area is:

$$A = 0.00207m^2$$

Heat Flux  $q''$  is:

$$q'' = \frac{q}{A} = 9661.83 \frac{W}{m^2}$$

Assuming that pure conduction takes place, and from Fourier's law, we have:

$$q'' = K \frac{dT}{dx}, \text{ where Thermal Conductivity } K = 0.58$$

For Acrylonitrile butadiene styrene (ABS) plastics, the value of  $K$  is around 0.25, but for other type of plastics the range of thermal conductivity varies from 0.2 to 0.58, and hence 0.58 is chosen for further calculations as it is the upper limit. By substituting the values of  $q''$ ,  $K$  and  $dT$ , the thickness of walls of the box required to maintain the temperature can be calculated. Assuming the outer surface temperature to be 303 K the thickness is calculated as below:

$$9661.83 = \frac{0.58 * 25}{dx}$$

$$\text{Hence, } dx = 1.5 * 10^{-3}m$$

Thus, the wall thickness required to insulate 338 K (65 °C) temperature inside the box is 1.5 mm. Sheets of thickness 3 mm is selected to ensure proper insulation of the box.

##### 3.1.3. Analysis

The analysis of the model is done using the tool ANSYS. As the model is designed for everyday use, it should be structurally strong. The main point of concern in the analysis is the structural

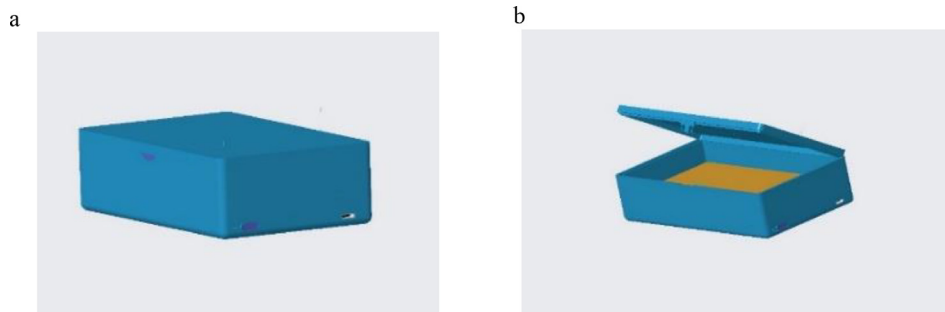


Fig. 1. (a) Closed View; (b) Open View.

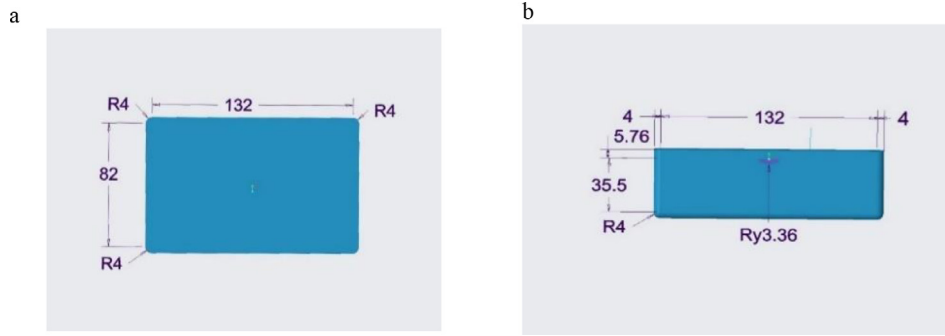


Fig. 2. (a) Top View; (b) Front View (all dimensions in mm).

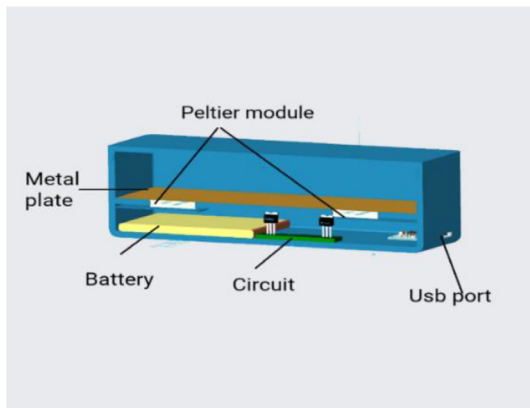


Fig. 3. Sectioned view of the box.

rigidity and strength of the box. The model should survive day to day handling, accidental forces that may act on it and the hinge should not fail in any circumstances. In the analysis the model is subjected to a force of 100 N that act all over the geometry. The values of equivalent stress and strain and total deformation is obtained from the examination and the below figures (Figs. 4, 5 and 6) display their maximum respective values. It easily withstands 100 N thereby showing its structural rigidity. The size of the mesh is  $4 \times 10^{-3}$ . The design of rounded corners, neatly executed hinges, precise closing mechanism and symmetrical wall

thickness helps the model in tackling forces acting on it. The material of the box is assumed to be ABS. To improve thermal properties, other plastic materials like Polyphenylene sulfide, Polyetherimide, Polyether ketone and TORELINA with better thermal properties can also be used.

### 3.2. Electronic design

#### 3.2.1. Calculation of power required

Compared to other components of the device, the two Peltier modules consume the most current. When the Peltier module is powered with 3.7 V Li-Po battery, the amount of heat generated is sufficient to attain the required temperature of 65 °C in the box.

The TES1-4903 20x20mm, 5 V, 3A Peltier module is used as it is small and compact in size. The two batteries rated at 3.7 V, 2600 mAh are connected parallel to form a power source rated at 3.7 V, 5200 mAh. The current consumed by a Peltier module is as below:

$$\frac{\text{Given input voltage}}{\text{Specified input voltage}} * \text{Specified Current}$$

$$\therefore \frac{3.7V}{5V} * 3A = 2.22A$$

One Peltier module will consume around 2.22A and in total for two Peltier modules, it will be 4.44A. The other components used in the device requires current in the range of mill amperes. The below table (Table 1) shows the current consumed for components other than Peltier module.

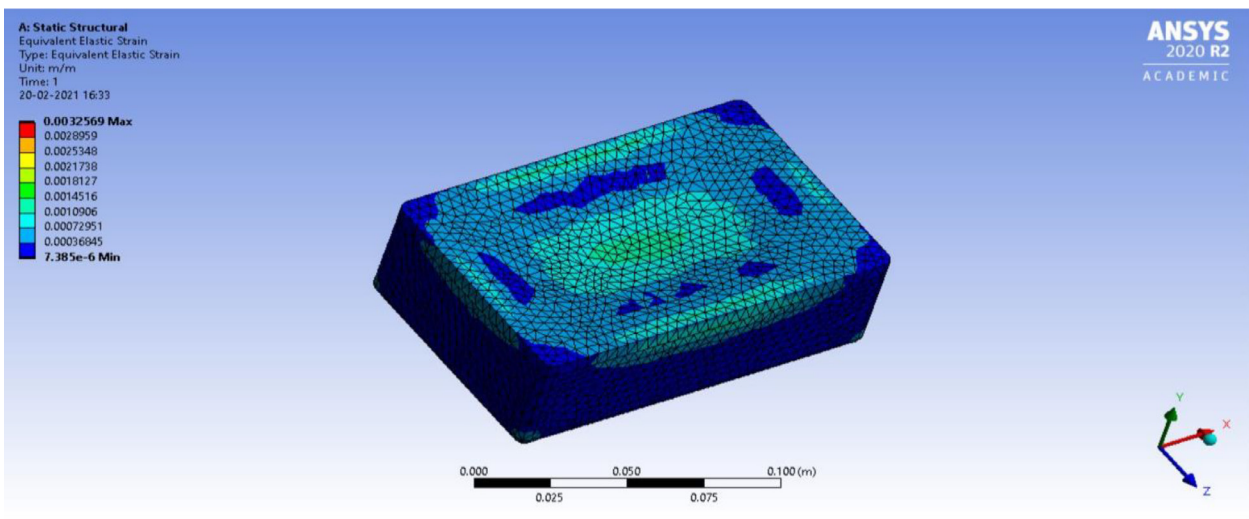


Fig. 4. Equivalent Elastic Strain.

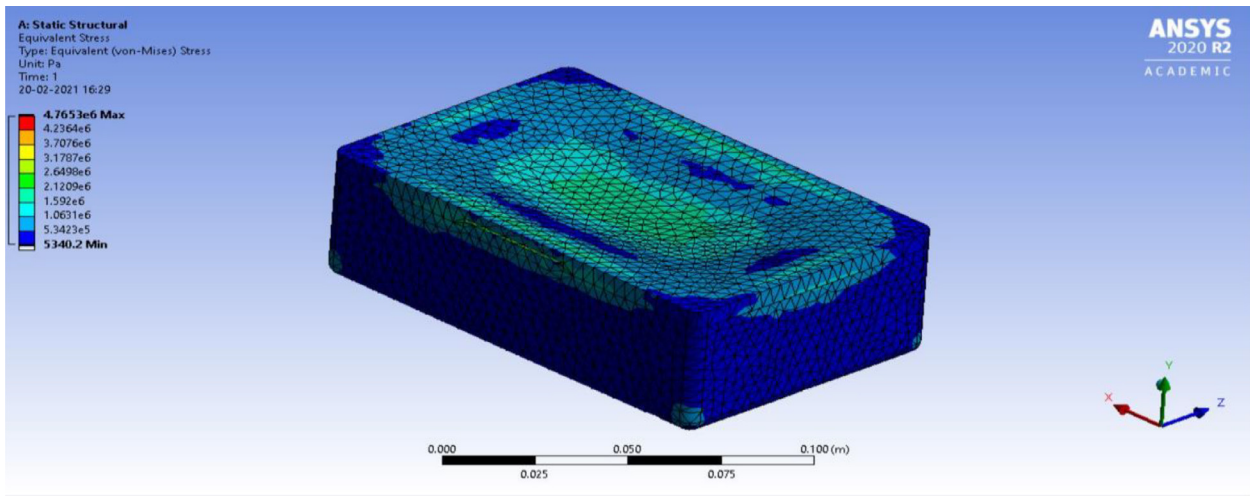


Fig. 5. Equivalent Stress.

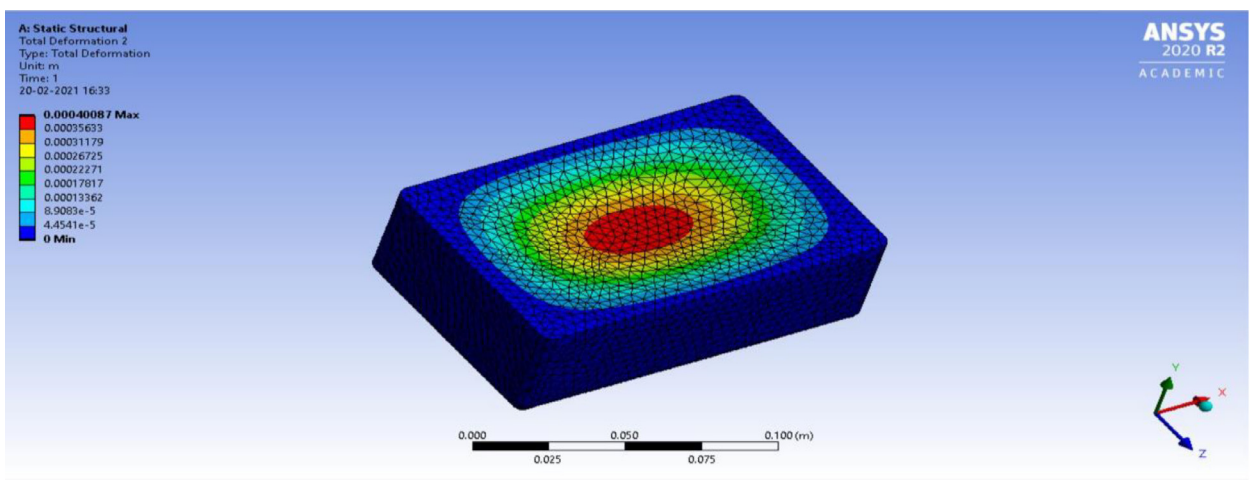


Fig. 6. Total Deformation.

So, the total current is:

$$50\mu A + 40mA + 500\mu A + 4.44A = 4.48055A \cong 4.48A$$

The above current is required for the circuit to operate properly.

### 3.2.2. Analog to digital conversion

The Analog to Digital Converter (ADC) pin used in the ATtiny85 microcontroller is PB2 which converts incoming analog voltages to its corresponding digital values. Even though the TMP36 sensor is powered with 3.7 V battery, its output ranges from 0 V to 2 V. This output is given to the microcontroller, which has 8-bit and 10-bit resolution. Here, we will use the 8-bit resolution to compare the input voltage to the threshold voltage, i.e.  $2^8 = 256$ . The values vary from 0 to 255. To find the ADC 8-bit value for the corresponding input voltage, the below formula can be used:

$$ADC = \frac{V_{in}}{V_{ref}} * 255$$

The reference voltage ( $V_{ref}$ ) is set as voltage common collector voltage ( $V_{cc}$ ), which is 3.7 V. In order to calculate the temperature from the input voltage, the below formula can be utilized.

$$Centigrade\ Temperature = \frac{(analog\ voltage\ in\ mV) - 500}{10}$$

Using the above expression, the analog voltage for 65 °C is 1150 mV or 1.15 V. Hence the ADC value for 1.15 V is:

$$ADC = \frac{1.15 * 255}{3.7} = 79$$

Thus, 79 is the threshold value with which the input voltage from TMP36 sensor should be compared with.

**Table 1**  
Current consumed by other components.

Component	Quantity	Total current consumed
TMP36	1	50 $\mu$ A
ATtiny85 microcontroller	1	40 mA
IRF520	2	250 $\mu$ A*2 = 500 $\mu$ A

### 3.2.3. Printed circuit board (PCB) design

The circuit board was designed using the Altium software and has dimensions 3.5 cm x3.5 cm and is shown in Fig. 7.

U1 represents ATtiny85 microcontroller, T1 is the TMP36 temperature sensor, Q1 and Q2 are the IRF520 MOSFETs, P1 is the power supply header pin and P2 and P3 represents the header pin to connect the two Peltier modules.

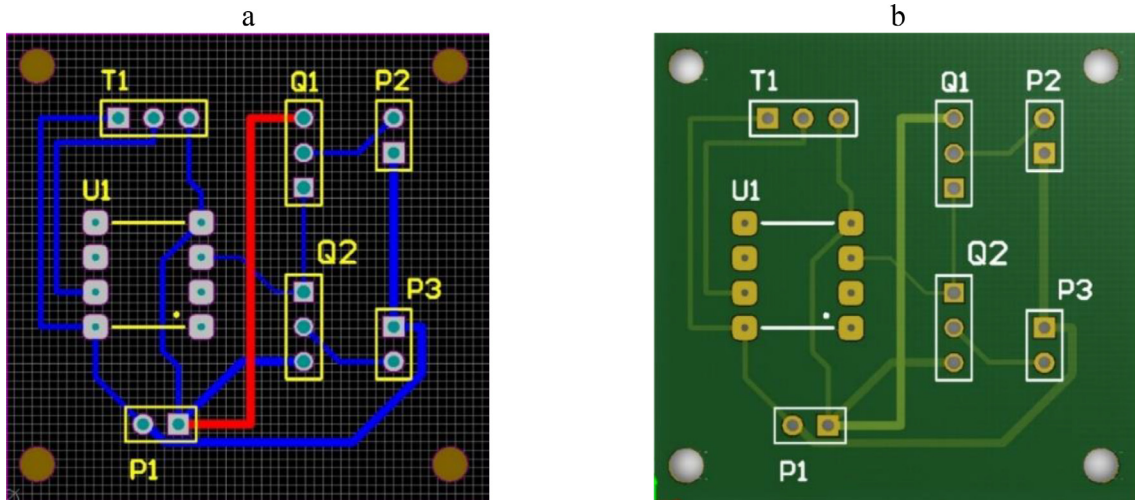


Fig. 7. (a) PCB Layout; (b) Final preview.

**4. Working of the device**

Referring to Fig. 8, when the circuit is switched on, the temperature sensor is activated and produces an output to the PB2 pin of the microcontroller. It is the ADC pin which converts the analog value to digital value. This converted value is compared against a threshold temperature, which in this case is 65 °C and this comparison can be achieved by programming the microcontroller. Correspondingly, a logic 0 or logic 1 pulse is given as output from the microcontroller to the gate of the two MOSFETs, which acts as a switching mechanism for the Peltier modules.

Peltier modules work on the basis of the Peltier effect. They contain junctions formed between two dissimilar conductors and contain a copper sheet on both surfaces. When a direct current source is connected to a Peltier module, the electrons in the first conductor will have to gather energy by absorbing heat to flow into the second dissimilar conductor. These electrons after crossing reaches another junction where they fall back to the first conductor (considering that the second conductor has a higher lattice energy), thus releasing energy as heat. This phenomenon is observed in a

Peltier module, where one surface absorbs heat, the surface becomes cooler, and the opposite surface releases heat, thus becoming hotter. The hot side of the two Peltier modules are in contact with the metal plate through the use of thermal paste and therefore distributes the heat across the box.

The circuit diagram shown in Fig. 8 depicts the working of the model. P1 is the power source, T1 is the temperature sensor TMP 36, U1 is the AT Tiny 85 microcontroller with pins PB0, PB1, PB3, PB4, Vcc and GND, Q1 and Q2 are the two IRF520 MOSFETS and P2 and P3 are the two Peltier modules. Voltage common collector (Vcc) and ground (GND) are the power source connections of the respective components.

**5. Results**

In the structural analysis of the model, a load of 100 Newton is applied on the body. From Figs. 4, 5 and 6, the maximum equivalent strain and stress obtained is 0.0030557 m/m and 4.793e6 Pa and total deformation obtained is 0.00039477 m and is found to be within safe limits. The ampere calculation helps us to decide

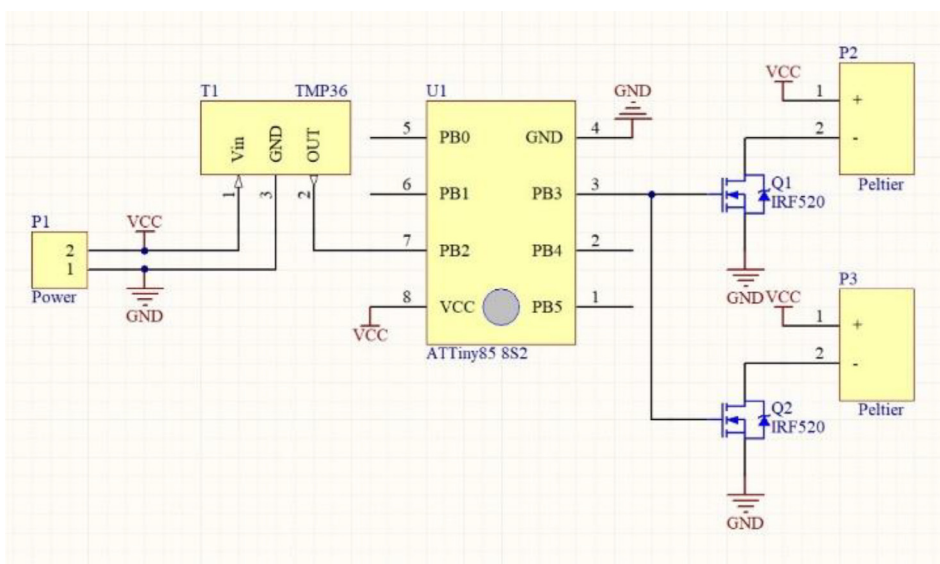


Fig. 8. Schematic of the circuit diagram.

the specifications required for a battery to power the circuit. Since the total capacity of the battery is 5200mAh, and the total current is 4.53A, the amount of time that the battery can be used is:

$$\frac{5200mAh}{4530mA} = 1.147 \text{ hour}$$

$$1.147 * 60 = 68 \text{ minutes or 1 hour and 8 minutes}$$

The time obtained is enough to use the box for a day, as the time required for the mask to be free of pathogens is around 10–15 min.

## 6. Conclusion and future scope

The design and analysis of the device was performed. Designing was materialised using Parametric Technology Corporation Creo 6.0 and, the structural analysis was performed using ANSYS. The design of printed circuit board was done using the Altium software. According to theoretical studies, exposure to temperature of 65 °C for a duration of three minutes can eliminate SARS-CoV-2 viruses. Hence this device is capable of eliminating SARS-CoV-2 viruses present in the surface of the mask by exposing it to the required temperature over the required period. The device can be used multiple times to disinfect multiple masks as the battery on full charge enables it to work for over an hour. This device can be recharged, hence facilitates multiple usage with ease. The masks that are used can be reused safely, and this device being compact and portable, is very helpful for long journeys and for employees who work on long shifts. This device would enable safe re-use of masks, and hence reduce its wastage. A device capable of housing more number of masks and disinfecting it at the same time is a thought for the future. With the advent of battery technology, compact and powerful batteries than the existing would enable slicker design for the device and can be explored in the future.

## CRediT authorship contribution statement

**Baslin Abraham James:** Conceptualization, Methodology, Software, Writing – original draft. **Alias Sonnet T. Eldho:** Conceptualization, Methodology, Software, Writing – original draft. **Kurian**

**John:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision, Project administration.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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