Simultaneous Heating and Cooling functionality for a Lunch Box

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***Abstract*—The paper discusses the concept of creating an insu- lated lunch box that limits the heat transfer with its surrounding. In addition to limiting the heat transfer, the concept also proposes a method with which heat can be added to the system. This, in turn, prolongs the period where edibles can be stored at the desired temperature. A Thermoelectric Cooler is incorporated which makes possible the inception of two separate compartments in the lunchbox which stay at different temperatures to make possible the storage of hot as well as cold food inside a single lunchbox. Due to the increasing importance of healthy and warm food, one can have midst the work, the paper ascertains the need to understand the potential working mechanism of this project. This concept can possibly change the conventional way of carrying food by introducing an additional cold compartment to store the food in addition to a hot one. The design of the prototype is discussed. Various electronic components to be used are discussed and the working of the prototype is explained.**

***Index Terms*—Portable Food Storage, Thermos Tiffin, Electric Tiffin, Heated Lunchbox, Cooled Lunch Box, Fresh Food Storage, Peltier module, TEC or Thermo-electric cooling, Heat Pump.**

I. INTRODUCTION

In our daily life, there are many appliances that we use seamlesslytoderivetheworkfromthembecausetheyarevery convenient. Oneofthemostusedproductsis a Thermos Flask. For people who work away from home, the food or fluids they carry to eat later can easily get to room temperature only within a few hours; rancid in the case of high oil content food. Therefore, Vacuum flasks are utilized to keep beverages fresh and hot or cold for extended periods. Thermos flasks were invented in 1892 by Sir James Dewar as a result of his radical research in the field of cryogenics. By evacuating the air between the two chambers in a flask, a state of partial vacuum can be created; such was his observation. He refused to patent it. It was not until 1904 that two German glassblowers, Reinhold Burger and Albert Aschenbrenner, discovered that it could be used to keep food and beverages hot or cool for a longer amount of time and can be used in daily use. They termed it as *Thermos* [1]. Due to its design, the thermos flask is able to keep hot food hot and, cold food, cold. As the paradigm shifted, it became widely used.

In the age of scientific advancement, there is an energy reduction race. How can one increase efficiency? We are coming to the realization that there is an urgent need to reduce energy usage and deliver suitable outcomes in a very sustainable way. Thermos flasks came in various shapes and sizes given that they ensured the storage of multiplekinds of food and beverages. Later, flasks with double-wall vacuum insulationwereavailablecommercially.Thevacuuminsulated thermos flasks that are used by the masses today still lack in their ability to limit heat transfer through long periods of time. Empirically, it can be witnessed that if a thermos were to be filled with coffee for later consumption, the flask can only keepthetemperatureconstantforasmalltime.Afteran hour or two, the heat inevitably gets out rendering the coffee bland. This problem is inherent because of the construction of the vacuum flask. The space inside the double-wall insulation is definitely evacuated but the outer wall still has to connect at some point with the inner holding compartment. This allows for heat transfer through conduction. A little by little the heat seeps out, the edibles eventually reach room temperature and they do not come out as fresh as was expected. Some might suggest simply to overheat the coffee before pouring it into theflaskbutthatcanonlybedonewiththiscase.Whatabout the other beverages whose taste gets destroyed due to the high temperature? And in the case when a cold beverage needs to be stored, a layman cannot supercool a beverage at home. To combat this, it is necessary to devise a system that can not only keepenergyinsidethesystembut,whennecessary,addenergy to it. This paper explores an idea with such a contraption that can suit this case.

II. PREVIOUS WORK AND ADVANCEMENTS

Upon looking for such products, it can be noted that most of the products which are being used are simple Thermos flasks without any abilities to add energy to the system. Digging in further we find about the efforts that were being put in this field to further expand the capabilities of a Thermos Flask. Ref [2] started off by presenting an elegant solution to minimize the heat loss from the cups or fluid containers. It is a system for retaining or controlling the temperature of the fluid. Suitable for all kinds of environments, it comprises of a heat sink with a thermoelectric device. The thermoelectric device is attached to the bottom surface of the cup. Such a placement maximises the heat transfer by sheer contact.

Ref [3] [4] deal with a similar problem of heat addition. The solution provided was rather traditional. Begin et al. 2008 had proposed an idea that included a food chilling device that had a cylindrical body with an outer wall, a closed-end, and an open-end. This device can dip in any container, filled with ice, which will cool down the food for later reheating and serving. Meanwhile, Palena et al. 2011 patented a similar design, a container that can fill up, except the container now had a rechargeable, self-heating supersaturated salt solution. A potential trigger meant a process of crystallization, which essentially is an exothermic process [4]. These reviews concluded that they had a tremendous drawback. They compromise volume, either where they are to be installed or fitted in. However, they addressed the problem statement accurately by providing a solution for heating and cooling a beverage in the flask. Ref

[5] was proposed in 2013 and, it is by far the most relevant patent here in regard to our concept of unifying both heating and cooling processes simultaneously. However, it elaborately explains the heat addition process, but there is no mention of cooling the fluid down. It only balances the temperature of the fluid. It is an actively heated mug. The mug can include many heating elements that heat a surface. The mug also uses the functionality of wireless power charging as a method to deliver power to the respective module. The overall circuitry can be turned off or on based on the usage.

III. COMPONENTS

A. TEC Module/Peltier Module

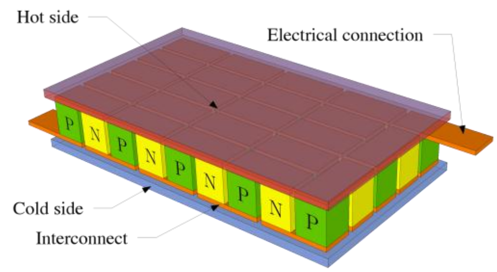

Fig. 1. Peltier Element Schematic [6].

"The Peltier circuit, the basic element of the cooling thermoelectric cell, consists of semiconductors p-type and n-type connected in series with copper plates. The copper plates, on both sides, are thermally bonded to each other through ceramic plates, but are electrically insulated. In terms of electricity, semiconductors are connected in series with each other, however with respect to thermal in parallel." [7].

Thermoelectric Coolers (TEC) work on the principle of Peltier Effect which states that when two different metals are subjected to a voltage potential, a temperature gradient is induced at their junction. Peltier modules, in essence, act like a heat pump which can create temperature differences within the range of 70°C across both sides with no moving parts which prove to be essential in manufacturing small systems with limited space [8].

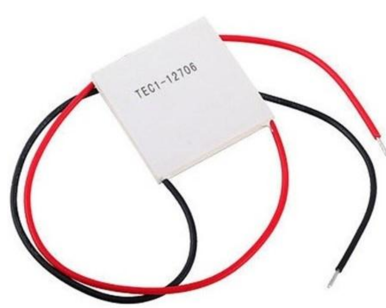

Fig. 2. TEC1-12706 Module.

TEC1-12706 is a 4 cm 4 cm module. It is rated for 60W and works at 12 volts till 6A [9]. 127 in TEC1-12706 stands for the 127 thermocouples it consists of while the 06 signifies its 6 Ampere current rating.

B. Arduino Uno

Fig. 3. Arduino Uno.

Arduino Uno is a prototyping board developed in order to simply developing prototyping circuits for all users. Arduino is an open-source platform which provides MCU boards for making prototyping circuits. Arduino Uno has a circuit base and a software compatibility of C# and C++ [10] [11]. Arduino has a huge scope of application. It is often used in all domains from defence, healthcare to smart homes [12].

C. KY-001 Temperature Sensor

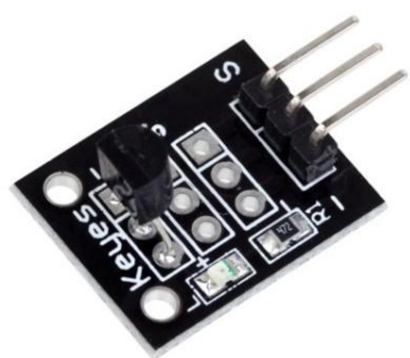

Fig. 4. KY-001 Temperature Sensor

Using a digital bus, the KY-001 allows the measurement of a range of temperatures. It consists of a DS18B20 single-bus temperature sensor, a LED and a resistor. DS18B20 is a widely used digital temperature sensor. It is cheap to manufacture and has high precision. It is compatible completely with Arduino Uno [13].

Operating Voltage: 3 - 5.5V.

Temperature Measurement Range: -55 to 125°C Accuracy: ±0.5°C[5].

D. TIP120 Darlington Transistor

Fig. 5. TIP120 Transistor

The TIP120 is a NPN Transistor. It switches up load to 60V, a peak current rating of 8A and continuous current of 5A. It is very suitable for our project as it can be used for medium to high power demanding electronics like DC motors and high-power LEDs [14].

Fig. 6. TIP120 Transistor

E. XY-016 2A DC-DC Step Up Power Module

The XY-016 power module can act as a multipurpose voltage booster. It is often used in various prototypes and DIY projects. It has been observed to have a voltage range from 5.5VDC to 28VDC, up to peak 2A [15]

F. Container

Container (the body) of the lunchbox can be made from Stainless steel or Aluminium having two compartments divided by a wall which is used to mount the Peltier module as shown in Fig. 2.

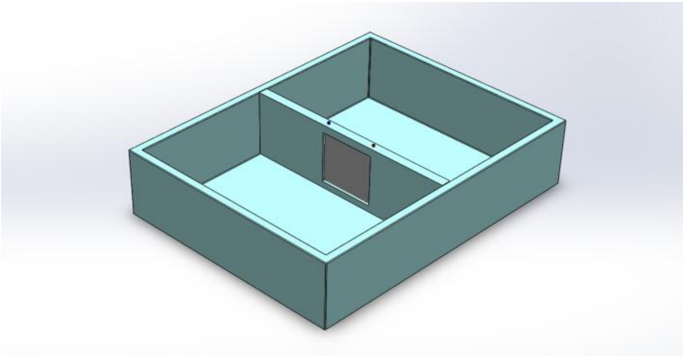

Fig. 7. Illustrative model of the Lunch Box.

The body of the tiffin can be double walled introducing a vacuum between the walls to provide further insulation which can increase the efficiency and prevent heat diffusion to the surroundings by nearly a factor of ten. The insulation of the divider wall is critical since ignoring it will nullify the temperature gradient introduced by the TEC module rendering the setupuseless.

The lid of the box is to be made such that it isolates the compartments from ambient atmosphere and each other when closedtominimizeheattransferfromthesystem.

IV. WORKING OFPROTOTYPE

TEC1-12706 works in the range of 5-12V. However, to attain a suitable temperature and have the independence of varying it based on the feedback, it becomes necessary to supply 12V initially. For the sake of portability and easy access to the end user who would make the most use of this product

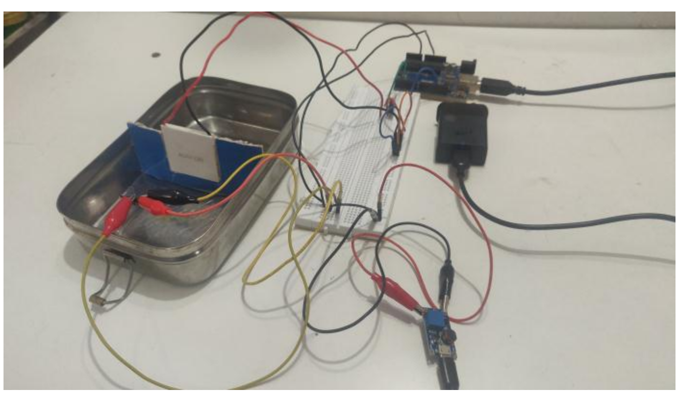

Fig. 8. Developed prototype so far.

When outdoors, feeding 12V directly would not be feasible. The ubiquity of the Smartphones has given this world an easy access of 5V from an AC adapter everywhere. Making use of this, this prototype makes use of a DC-DC Step Up converter which takes an input from a 5V USB charger and steps it up to 12Vforthisapplication.

To control the temperature inside the lunchbox, the power to the TEC module needs to be controlled actively. This is done with the help of the prototype friendly MCU, Arduino Uno. Arduino acts as a brain for this prototype, it takes an analog input from the temperature sensor KY-001 mounted inside the compartment and determines whether to supply voltage to the Peltier module or not. The temperature ranges are specified while programming. If the threshold temperature is surpassed and the temperature sensor demands cooling, Arduino sends a Pulse-Width modulation signal to the TIP120 Darlington Transistor. TIP120, based on the input voltage provided by the Arduino varies the 12V supply it receives from the DC-DC Step Up module and supplies it to the Peltier for the pumping of heat. This process continues until the desired cooling/heating is reached. When the temperature sensor measures more heat than desired, Arduino stops the supply of voltage to TIP120 thereby limiting the temperature. After this, the system enters maintenance mode where a supply of low voltage to the TEC module is conducted to maintain the temperaturerequiredbythesystem.

A. Pulse-Width Modulation

Pulse-width modulation is a method to extract analog output from a digital signal. Unlike digital signals which are binary in their nature, analog signals have a range of values between their On and Off expressions. Pulse-width modulation does this by chopping up the signal into discrete parts [16]. The square waved signal is broken into many parts by rapidly switching the voltage supply on and off. This on and off motion results inasquarewavethatisonforaspecificamount oftime, and off for a specific amount of time. The result of this process is an average voltage which acts as the analog output of the digital signalthatismodulated.

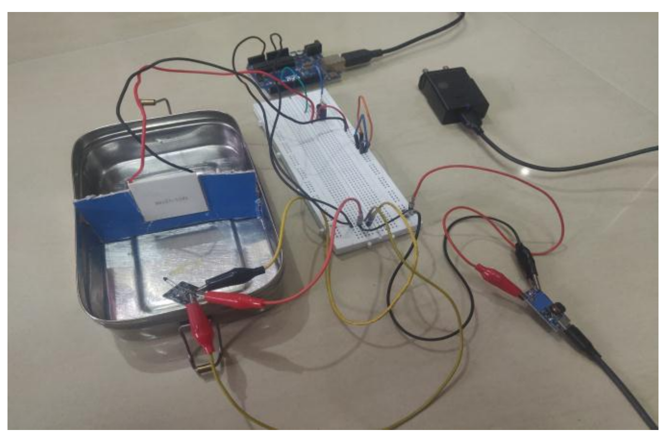

Fig. 9. Developed prototype so far.

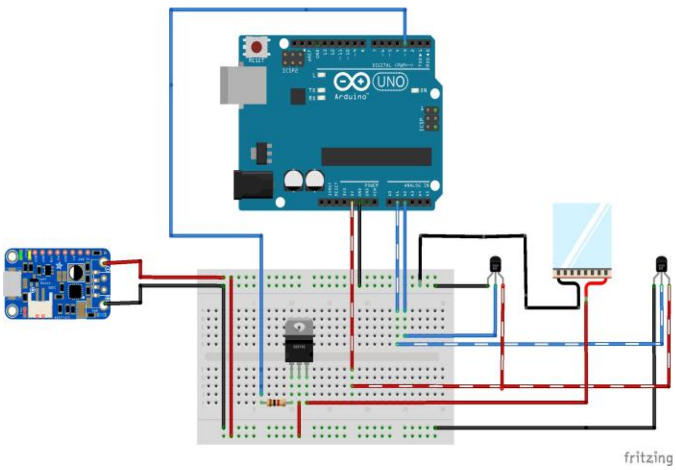

Fig. 10. Simplified Circuit Schematic.

ADVANTAGES

1) Provision of a cold compartment in addition to a hot one.

2) Increased energy efficiency since the emergence of cold compartment is a by-product of pumping heat to the other compartment.

3) Fresh food for prolonged time unlike traditional Thermos where there is no addition of energy into the system.

4) Can act as a portable food storage while keeping the quality of food essentially the same.

5) Quick response to the heat demanded.

DISADVANTAGES

1) Introduction of an electrical system makes it difficult to manufacture.
2) Larger than conventional lunchboxes since heavy insulation is required.
3) Manufacturing is difficult since vacuum insulation is difficult to achieve.
4) Difficult to isolate both compartments since heat transfer is encouraged due to the temperature gradient across the sides.
5) Addition of electronics and vacuum leaves less space for actual food storage.
6) Bulkier and Heavier than traditional food storage solutions.
7) Food in the hot compartment may get very dry if the box is not sealed well and the water content manages to evaporate out.

POSSIBLE WORKAROUND FOR THE DISADVANTAGES

- The weight can be trimmed down by using lightweight composites.
- Materials with lower thermal conductivity can help to better isolate the two compartments.
- Usage of embedded electronics with small PCBs will help in reducing the size and cost of the product.
- Proper rubber sealing with air-tight locks can be used to avoid the problem of evaporation.

CONCLUSION

The simultaneous heating and cooling in a single unit is unlike any other commercially available product and seems more efficient than just utilizing the heat or just the cold and rejecting the counterpart. It shows great potential and can change the way people look at packed food. However, manufacturing seems to be a major challenge and more research is needed regarding its efficiency and feasibility. Preventing energy loss from the system proves to be a major challenge in the prototype. Electric components can be substituted for minute circuits that can fit on the bottom of the lunchbox. More research regarding its thermal efficiency is required to be carried out.

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