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Heat Reducing Using Peltier Effect on Smart Phones

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ABSTRACT

This is the paper presents how the peltier effect can reduce the smart phone's heat using a trigger circuit. A smart phone case is constructed with a peltier tile, a heat-sensing sensor, and a heat sink. That case will be get connected with a trigger circuit, which consist of some hardware like transistor, IC555processor, relay, switch, biaser, buzzer, heat sink and a variable resistor. Using these components how would be the smart phone's heat will get reduced is a concept that this paper has been discussed

Keywords: Peltier Tile, Heat Sensing Sensor, IC555 Processor, LM35,Relay, Variable Resistor, Heat Sink

I. INTRODUCTION

Heating is the major problem that faced by all the fields now-a-days, there are many methods were implemented to resolve the heating problem like peltier effect to reduce heating occurred in the thermal management, an high performance compact optical transceivers were used with the peltier technology. A silicon heat switch or a thermal switch were been used to transfer the heat and cool down the system. Paraffin components were also been used. Hot spots on super hydrophobic surface has been used to cool the electronic device due to jumping droplets, a GaN transistor were used. An AC coils were used in another condition, a high-temperature super conducting bending magnet with a cry cooler. To cool the super computers which can get over heating was done with a chiller-cooling mechanism that was with the help of cold water the heat recovery and the adsorption of heating were been accomplished. Cool- manager and re-cooling mechanism were implemented. Another method, IC self-cooling was implemented to the thermal propagation mechanism. It analyzes the heat and turns of by self-detecting integrated chips. It was constructed as a device chip package. Then the thermal sidewalls, 3-dimention integrated chips, bottom plate architectures were constructed to reduce the overheating issue, here an air cooling and a heat sink played a vital role. Finally a battery powered heating and cooling suit were designed with the help of peltier tile, a transistor, a heat sink, LM35 microcontroller. It was designed as a human wearable suit which can be adjust with heating and cooling its depend up on the temperature. There is a H- bridge circuit that is enable and controlled by hot and cold pushbuttons. Temperature sensor senses the temperature and displayed through LED. So in this paper proposed the same peltier effect with a heat sink connected with them mobile phone case to reduce the heating problem. That case to be connected with a trigger circuit constructed with transistor, IC555processor, relay, switch, biaser, buzzer, heat sink and a variable resistor like semiconductors. A heat-sensing sensor will pass an electric pulse to the processor, the processor read the electric pulse and supply a12v current to the peltier to activate the peltier tile to cool down the heat of the smart phone and the heat sink helps to absorb the heat. Finally, the decrement of heat can be viewed through any smart phone's temperature application.

II. RELATED WORK

Yahya Sheikhnejad et al. [1] has proposed in "Laser Thermal Tuning by Transient Analytical Analysis of Peltier Device" that the design of the high performance transceivers working on the thermal management to reduce the heating problem. A three dimension thermocouple by considering peltier effect to regulate the temperature through the electric pulse and transfer the heat, do cools the equipment from that getting hot and increasing heat by continuous performance. In this study complete characteristics of Peltier device as an exact closed-form expression comprised of one dimensional transient Peltier considering Joule heating, heat conduction, heat flux of laser diode and thermoelectric effect is presented. It says when an electric current flows on same direction then it is a positive current else that is a negative current. In positive current the heating operation might be done likewise in negative current the cooling operation might be done. Forward bias works on PNP configuration do heating through positive current, whereas reverse bias works on NPN configuration. In thermal conductivity, voltage is highly sensitive to variation of electrical conductivity, such that for a same level of current, higher conductivity leads to a lower differential potential. By the peltier effect the system can be made cooler.

Yunda Wang et al.[2] on Silicon Heat Switches for Electrocaloric Cooling proposed heat switches are devices with actively or passive switchable conductance. They may either to be a thermal switch or thermal conduction switch. Thermal energy says to be heat and mass energy. In chip-scale atomic clocks, cryogenic coolers, thermal management of spacecraft, electrocaloric, thermal cooling systems etc, The switch is capable to transfer heat devices on the mode off and on. The electro caloric effect is a phenomenon characterized by change in the temperature. There is an alternated opened and closed synchronization thermal connection between capacitor and heat source sink in the heat switch based system. In cryogenic application, passive heat switch is used to minimize heat loads on cooling system. Paraffin components are used as one type of passive heat switch enable on thermal expansion. There are two paths were created, through one path the heat readily flows, through other path heat switch utilize the thermal expansion materials. This is the one of the method of cooling the system.

Thomas Foulkes et al.[3] on Active Hot Spot Cooling of GaN Transistors With Electric Field Enhanced Jumping Droplet Condensation proposed about the ability to remove heat using active cooling techniques from the internal hotspot contain this techniques as required to mitigate hotspots. As an advanced techniques wide band gap semiconductors and cooling technique are used and for this proposed work hotspot cooling method were used to cool the device. In this technique water droplets merge on the super hydrophobic surface, they jump independent and the droplet has a positive charge. These techniques are most efficient at heat and mass transfers for an active cooling method, heat sink were used with metal forms.

Daisuke Miyagi et al.[4] on Study on Thermal Measurement Method of AC Loss in a Conduction-Cooled HTS Coil proposed this by using high-temperature superconducting (HTS) bending magnet with the cry coder. This study reports thermal measurement method of AC loss in a conduction cooled HTS coil using a heater and a cryogenic temperature controller. The cooler using the accelerator can be realized and apply a conduction- cooled high temperature super conducting blending magnet. And this high temperature super conducting coil is especially designed for the cooling system to maintain a proper temperature using coils. There are two methods were handled, one is electromagnetic method another one is thermal measurement method, using this HTS method they were proposed a new cooling technology.

Torsten Wilde et al.[5] on A Supercomputing Cluster with Heat Recovery for Adsorption Cooling have proposed a new technology HPC that is high-performance computing chiller- less cooling, HPC system used for heat-recovery scheme to drive an adsorption refrigeration process, the mechanical chiller adsorption technique is efficient than the mechanical chiller at least two times more. In this technique air cooling with 18°C-27°C temperature, due to Due to the superior thermal properties of water over air, direct liquid cooling allows for higher compute densities. Here also two different methods were used, one is promoting to run as cold as possible without chiller. Other one is avoiding higher water temperature. The first method would reduce the current leakage and improve the performance of the computer. Super

computer excess heat in summer a challenge, so a solution of this HPC technique has been supported the computer were 70°C, 60°C heat and by this technique the temperature level of cooling water on super computer were get cooled, adsorption refrigeration process been used. Chiller-less high temperature direct liquid cooling (HTDLC) is a very energy efficient cooling method which reduced the need for mechanical chillers in data centers. This paper proposed The "Cool Manager", which consists of a pump and a heat exchanger to separate the computer cooling loop. Heat is removed through the existing Cool-Manager and room air-conditioning infrastructure. Re-cooling is provided by a cooling tower that has an integrated control unit to adapt fan speeds and the spray-on functionality for evaporative cooling to achieve a configurable outlet temperature. The cooling tower operates solely for the re-cooling of the adsorption chillers.

T. Nishimura et al.[6] on Measurement and Modeling of IC Self-Heating Including Cooling System Properties, An efficient IC- cooling system, it is inventible were investigate the thermal propagation mechanism were designed. in their investigation heat propagation have been analyzed within the real-chip and model it to predict the most efficient cooling system. It determines the temperature increase through the infrared form the chip surface. Different bias conditions were applied to obtain different temperature under different power dissipation. The cooling system properties were varied by changing the length of cooling package. So through IC also the cooling has been done.

Kaoru Furumi et al.[7] on Cooling Architectures using Thermal Sidewalls, Interchip Plates, and Bottom Plate for 3D ICs proposed the three dimensional integrated circuit, they were proposed thermal- SIB architecture can be secure heat conduction path to a heat sink that removes most of the heat generator in the device. SIB is sidewalls, interchip plates, button plate. The basic structure has reduced up to 40% temperature raised with conventional structure that uses only a heat sink. 3-d ICs enable the integration of both homogeneous and heterogeneous device. Homogeneous in sense of CPUs/ DRAMs and heterogeneous devices are digital logics and analog circuits, RF circuits, bio-devices, power devices, sensors etc,. 3D IC offer high bandwidth, low power and overall system miniaturization. And 2D IC which are system on-chip and system-in-package ICs. This paper proposed air cooling heat sink plays a vital role for cooling process and such a high power density ICs used for determining temperature range. 3D ICs made as cheaply as possible. It is most useful to detect the temperature raise. Embedded ICs are also made for kind of implementation now-a-days.

These were the various technologies have been used for reducing the heat but a peltier tile, a suit was proposed by Gregory Paul et al.[8] on Battery Powered Heating and Cooling Suit. On this paper they proposed battery powered heating/cooling suit, which the user can control the devices that are embedded in this suit. The thermocouple semiconductor create a difference in temperature of its two sides that is cooling and heating and this were used on thermoelectric cooler (TEC). By this two ceramic plates were enclosed which contains P-type and N-type semiconductor. This phenomenon is called peltier effect (on one side heat and other side cool temperature). Which is when a current flows through a junction between battery and voltage source, heating and cooling occurs because charge carries diffuse the opposite side. When the polarity of the current is changed, current floes in opposite direction. It is like cold becomes hot and hot becomes cold. The ability is to change the polarity if the flow of charge in the thermoelectric cooler allows one side to have a dual function.

This paper is about microprocessor based system that heat and cold one side of several TEC by using bridge circuit that is capable of controlling hot and cold push buttons and rotary variable register. The system also uses a temperature sensor, and an LCD module to continuously sense and display temperature in Fahrenheit or Celsius. This design was chosen because it is effective, lightweight, impressive and within our budget. Hereby for the temperature sensing LM34 is used as temperature sensor connected to the microcontroller LM34 is an easy-to-use sensor to detect the Fahrenheit temperature. Thermoelectric peltier cooler were selected with maximum operating voltage. The circuit was designed to be able to spin either direction by reversing the polarity of current going through them by using this technique one side getting heat and another side getting cools down. Reverse polarity also possible using switches to turn off and turn on. The diagonal transistors, a digital signal have

been sent form the microprocessor. Thermal glue was used to connect the sides that used for heating or cooling parts. These layer suits conduct heat and cool in a timely manner.

Using the peltier effect heat sink thermocouple have proposed system have been implemented in mobile phones to reduce the heat of the mobile phone by their care using peltier effect and trigger circuit with IC555 processor.

III. PROBLEM STATEMENT

Smart phones getting heat when they are in continuous usage, because of it could be that smart phone is overheating it could be that your smart phone is overheating due to the way in which Wi-Fi is being overused. Android users in particular are susceptible to apps running in the background, such as CPU, Wi-Fi or mobile Internet, mobile games. If apps are allowed to run in this way, things can heat up. And humans can feel the overheating by using the phone. Of course the recent massive offer reliance jio, when using that network the mobile internet should be always turn on. So normally he phone gets heat and people suffer to adjust the heat when they use to talk by near of their ear. So an alternative method is proposed to cool the smart phone using peltier technology with the phone case.

IV. BACKGROUND WORK AND PROPOSED WORK

The peltier technology was used in a suit that cools or heats the temperature and the humans can wear it when they need warm or coolness. It consists of the peltier tile, heat sink, transistor, etc. A microprocessor based system that heat and cold one side of several TEC by using bridge circuit that is capable of controlling hot and cold push buttons and rotary variable register. The system also uses a temperature sensor, and an LCD module to continuously sense and display temperature in Fahrenheit or Celsius. This design was chosen because it is effective, lightweight, impressive and within our budget. Hereby for the temperature sensing LM35 is used as temperature sensor connected to the microcontroller LM35 is an easy-to-use sensor to detect the Fahrenheit temperature. Thermoelectric peltier cooler were selected with maximum operating voltage. Reverse polarity also possible using switches to turn off and turn on. The diagonal transistors, a digital signal have been sent form the microprocessor. Thermal glue was used to connect the sides that used for heating or cooling parts. These layer suits conduct heat and cool in a timely manner.

In proposed work the same technology is used, instead of suit here it is used for smart phone case to cool the smart pone form overheating. A transistor, an IC555 processor, a relay, a switch, a biaser, a buzzer, a heat sink, a variable resistor are the hardware components use to manufacture the circuit. Using these components the smart phone should be placed on the smart pone case which is constructed with the peltier tile ad the heat sink. And that smart phone case should be connected with the trigger circuit which is embedded with IC555 processor and other semiconductors, once the transistor sense the heat of 42°C then the electric pulse will pass to the processor and the processor activates the peltier tile, the smart phone gets cool through the case. In the existed work the optimal temperature is 32°C it get exit but by the proposed work up to 21°C the heat can be reducible. The result can be viewed through a smart phone's temperature application.

V. HARDWARE COMPONENTS USED

LM35: It is a temperature sensing sensor. It has three pins. First pin should be connected with Vcc, second pin should be connected with output voltage, and the third pin should be connected with ground. As a temperature of the surrounding environment and relay this temperature to us back in degree Celsius. Whereas the LM34 sensor gives out the temperature in degree Fahrenheit.

Transistor: A transistor is a device that regulates current or voltage flow and acts as a switch or gate for electronic signals. Transistors consist of three layers of a semiconductor material, each capable of carrying a current. Two kinds of transistors are i) NPN transistor, ii) PNP transistor. A transistor has three elements emitter, base and collector.

IC555 processor: The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. Derivatives provide two or four

timing circuits in one package. The IC555 is still in widespread use due to its low price, ease of use, and stability.

Relay: A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal

Switch: electrical relays can be used to allow low power electronic or computer type circuits to switch relatively high currents or voltages both "ON" or "OFF", some form of **relay switch circuit** is required to control it. The design and types of relay switching circuits is huge, but many small electronic projects use transistors as their main switching device as the transistor can provide fast DC switching (ON-OFF) control of the relay coil from a variety of input sources so here is a small collection of some of the more common ways of switching relays.

Bias: Bias is direct current (DC) deliberately made to flow, or DC voltage deliberately applied, between two points for the purpose of controlling a circuit . In a bipolar transistor , the bias is usually specified as the direction in which DC from a battery or power supply flows between the emitter and the base. In a field-effect transistor (FET), the bias is DC voltage from a battery or power supply deliberately applied between the source and the gate. Certain bias conditions are used for specified purposes. In a semiconductor P-N junction, forward bias occurs when the P-type material is positive with respect to the N-type material; in reverse bias, the P-type material is negative with respect to the N-type material. When two electrodes are at the same potential, they are said to be at zero bias.

Buzzer: A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.

Heat sink: A heat sink is an electronic device that incorporates either a fan or a peltier device to keep a hot component such as a processor cool. There are two heat sink types: active and passive. Active *heat* sinks utilize the power supply and are usually a fan type or some other peltier cooling device.

Variable resistor: The resistor whose electrical resistance value can be adjusted as per requirement by adjustable component attached to it is called variable resistor**.** Variable resistors of different sizes from several manufacturers when looking for a variable resistor chip, variable resistor potentiometer, 12 volt variable resistor, digital variable resistor, high power variable resistor or trimmer resistor

Software used: The result can be viewed through any smart phone's temperature application.

VI. METHODOLOGY

Using these components the trigger circuit should be fixed the smart phone case that constructed with the peltier tile and heat sink. And it has the heat sensing sensor to sense the heat. If it sense he heat more than 42°C the electric pulse will collected up and pass to the processor. The processor will read the electric pulse and the board will pass 12V current to the peltier tile to activate the peltier title. The board is consist of IC555 processor, a relay, a biaser, a buzzer, a variable resistor, a switch, a capacitor, a heat sensing transistor, and some other semi-conductors which will support to the main semi-conductors like diodes.

IC555 processor is a timer processor used in clocks; the data can be read through the processor. The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. A relay is an electrically operated switch. It used to pass the current to the peltier are controlled by the switch. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The switch is used to turn on and turn off the circuit. Some form of **relay switch circuit** is required to control it.

Many small electronic projects use transistors as their main switching device as the transistor can provide fast DC switching (ON-OFF) control. The variable resistor, it is based on the temperature the trigger circuit should be turn on and the current suppose to be passed to the peltier tile are determined. The resistor whose electrical resistance value can be adjusted as per requirement by

adjustable component attached to it is called variable resistor. 12 volt variable resistor is been used here.

The buzzer is an indicator; it indicates the limit of the heat rose on the smart phone and has to get cooled as an alert sound. A buzzer or beeper is an audio signalling device. It may be mechanical, electromechanical. It used in beepers include alarm devices, timers, and confirmation of user. The biaser, is used to biasing function. There are two kinds of bias i) forward bias ii) backward bias. Forward bias works on PNP configuration do heating through positive current, whereas reverse bias works on NPN configuration. In thermal conductivity, voltage is highly sensitive to variation of electrical conductivity, such that for a same level of current, higher conductivity leads to a lower differential potential. The capacitor, it is used as a stabilizer; it prevents the circuit form sudden shutdown of the current flow. It stabilizes the current and makes a smooth current disconnection. Because basically Capacitor is an electronic component that stores electric charge. The capacitor is made of 2 close conductors that are separated by a dielectric material. The plates accumulate electric charge when connected to power source.

The heat sensing transistor, here it is the master transistor of the transistor which is connected with the smart phone case to sense the temperature. A transistor is a device that regulates current or voltage flow and acts as a switch or gate for electronic signals.

Two kinds of transistors are i) NPN transistor, ii) PNP transistor. A transistor has three elements emitter, base and collector. Block diagram and symbol of transistor is shown in figure for NPN and PNP transistor.

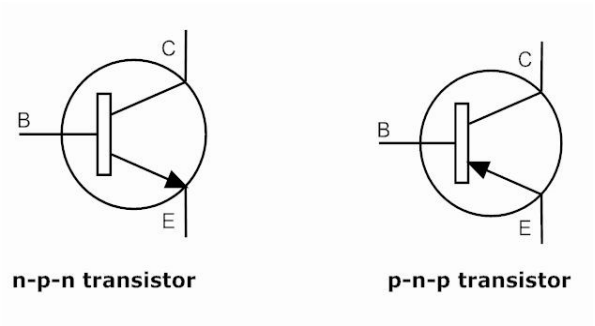


Figure 1. NPN and PNP transistors

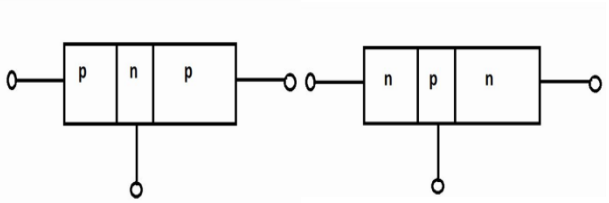


Figure 2. NPN and PNP transistor block diagram

n-type semiconductor sandwiched between two layers of p-type semiconductor in a p-n-p transistor. In n-p-n transistor p-type semiconductor sandwiched between two layers of n-type semiconductor. A transistor have two junctions made are emitter-base junction and the other one is base-collector junction. One junction is made forward biased and another is reverse biased. In upper figure an n-p-n transistor is shown. In the left side the emitter base junction is forward biased. P-region is more positive than n-region. So electrons from n-region can move easily towards the p-region. It is meant that electrons come to the base from the emitter. On the right side collector-base junction is reverse biased so the collector region is more positive.

The heat sink, it is used to cool down the smart phone's heat used with the peltier and attached on the back side of the peltier tile on the smart phone case. There are two heat sink types: active and passive. Active heat sinks utilize the power supply and are usually a fan type or some other peltier cooling device. These are the mainly semiconductors that are used in the trigger circuit. Apart from these semiconductors, some other semiconductors also were used for example diodes etc, are used as a supporting semiconductors with the trigger circuit. Then the main component is peltier, It create a difference in temperature of its two sides that is cooling and heating

By this two ceramic plates were enclosed which contains P-type and N-type semiconductor. This phenomenon is called peltier effect (on one side heat and other side cool temperature). Which is when a current flows through a junction between battery and voltage source, heating and cooling occurs because charge carries diffuse the opposite side. When the polarity of the current is changed the current flows in opposite direction. It is like cold becomes hot and hot becomes cold. The ability to change the polarity if the flow of charge in the thermoelectric cooler allows one side to have a dual function.

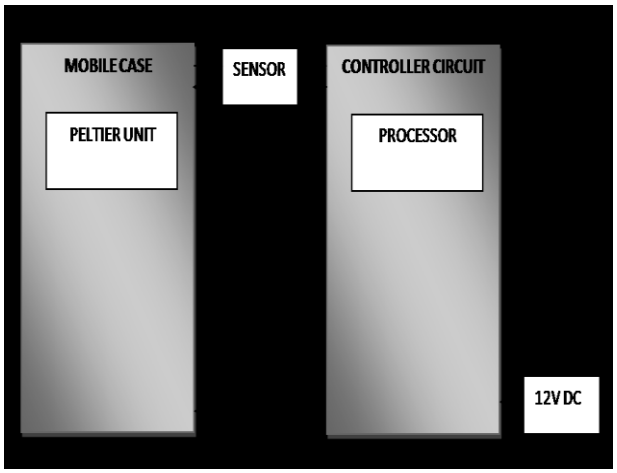


Figure 3. Block diagram of peltier unit and controller circuit

VII. PROCEDURE

Place the phone on the smart phone case which that case manufactured with the peltier technology and connected with the trigger circuit board. Plug in with switch board to get that activate through the current source. Once the heat sensing sensor sensed the temperature above than 42°C, the electric pulse will pass to the processor with the step-up send a 12v current to the peltier tile to get the peltier activated. Meanwhile the buzzer alerts with a sound and the mater transistor on the trigger board also get the electric pulse. The peltier absorbs the heat transform it into a cooler one. Peltier component is constructed with two sides, one side can absorb heat and other side will release the cooling. Current flows through a junction between battery and voltage source. In P-N junction there will be a positive current and it will be in heating mode. Likewise in reverse junction there will be a negative current and it will be in cooling mode. Within 5 seconds the temperature will get cool down until it get the optimal temperature that is 32°C it will works and until 21°C the temperature can be reduceable if the trigger circuit is continuously connected with the case. The result can be viewed through any smart phone's temperature application.

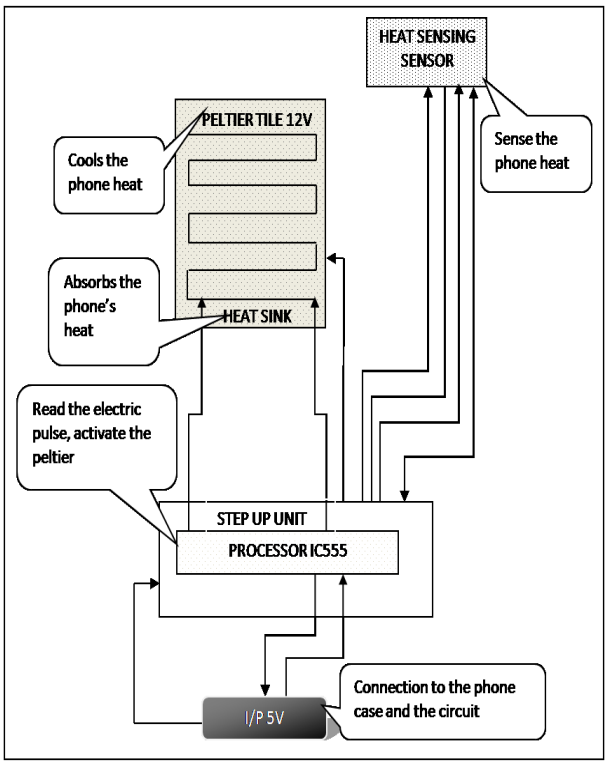


Figure 4. Circuit connection of mobile case and trigger circuit

Algorithm:

Step 1: PT + ST = TtH

Step 2: If T> 42°C then it is TH

Step 3: Processor ⟶ Start

Step 4: 12V ⟶ Pa ON

Step 5: Pc ⟶ TL

Step 6: If T< 32°C

Step 7: Processor ⟶ Stop

Else

Step 8: Pa OFF

Nomenclature

Roman letters

PT - Phone temperature
ST - Sensing temperature
T - Actual temperature
TH - Temperature high
TL - Temperature low
Pa - Peltier activation
Pc - Peltier cooling

Flow Chart

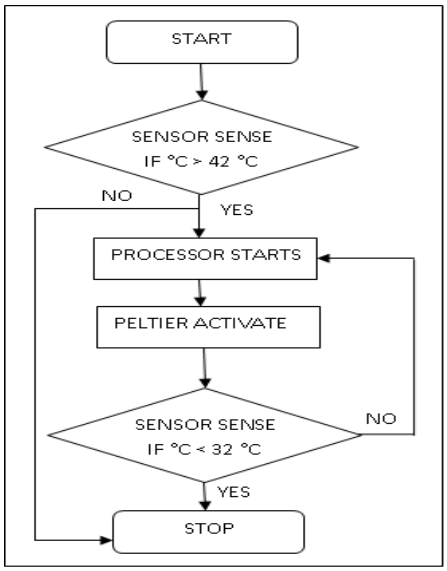
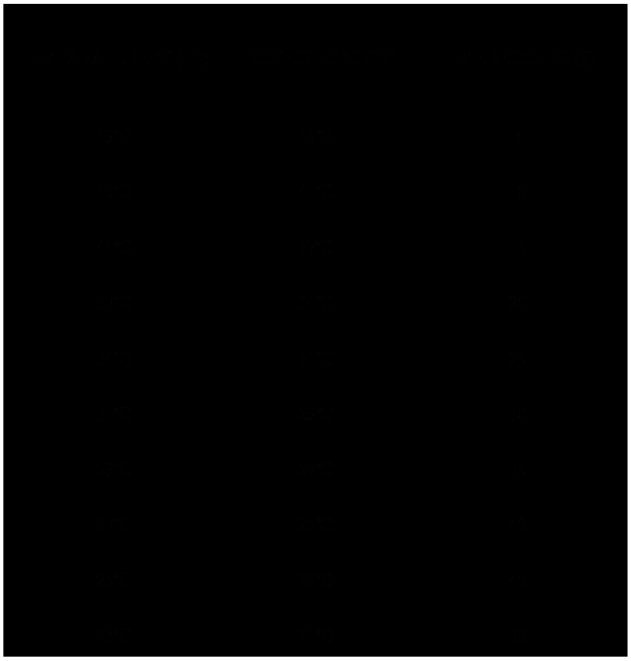


Figure 5. Flow chart of the experiment.

VIII. RESULTS DISCUSSION

Table 1. Temperature Management



Graph

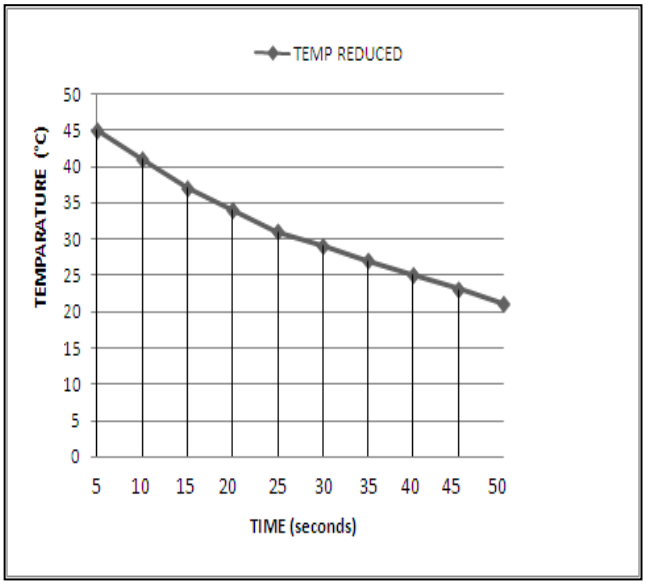


Figure 7. Temperature decreased through peltier effect**.** The sensor if sense 49°C then the circuit get activated and do cooling until it reaches the optimal temperature 32°C. And it is also capable of reducing up to 21°C if the trigger circuit is continuously connected with the smart phone case which is having the peltier technology. The result can be viewed through any smart phone's temperature application.

IX. CONCLUSION AND FUTURE ENHANCEMENT

By this work the smart phone's temperature can be reduced using peltier effect with low cost. And the case can be applicable for all the types of smart phones with a peripheral hardware, the temperature should get reduced and the phone gets cool although it can be over used. It prevents the smart phones form bursting due to overheat. This technology can be constructible with low budget components. The result of the temperature reducing can be viewable in any temperature diagnosing application through the smart phones. As a future enhancement this peripheral work may become as an inbuilt with every mobiles in the market or it can be an idea of all the devices which can be getting over heat due to over processing and necessary of all times.

X. REFERENCES

[1]. Yahya Sheikhnejad, Ricardo Bastos, Zoran Vujicic, Ali Shahpari, Antonio Teixeira," Laser Thermal Tuning by Transient Analytical Analysis of Peltier Device",p.p1-5",IEEE,2016.

[2]. Yunda Wang, David E. Schwartz, Member, IEEE, Sylvia J. Smullin, Qian Wang, and Martin J. Sheridan," Silicon Heat Switches for Electrocaloric Cooling", JOURNAL OF MICROELECTROMECHANICAL SYSTEMS, P.P1, IEEE,2017.

[3]. Thomas Foulkes, Junho Oh, Patrick Birbarah, Jason Neely, Nenad Miljkovicy, Robert C.N. Pilawa Podgurski, "Active Hot Spot Cooling of GaN Transistors With ElectricField Enhanced Jumping Droplet Condensation",P.P 912-913, IEEE,2017.

[4]. Daisuke Miyagi, Noriyuki Fukushima, Shuhei Sakurai, Makoto Tsuda, and Shoichi Yokoyama," Study on Thermal Measurement Method of AC Loss in a Conduction-Cooled HTS Coil", IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY,VOL.27,NO.4,P.P 1, JUNE 2017.

[5]. Torsten Wilde, Michael Ott, Axel Auweter, Ingmar Meijer, Patrick Ruch, Markus Hilger, Steffen K¨uhnert, Herbert Huber," CooLMUC-2: A Supercomputing Cluster with Heat Recovery for Adsorption Cooling", 33rd SEMI-THERM Symposium, P.P 115-117,IEEE, 2017.

[6]. T. Nishimura, H. Tanoue, Y. Oodate, H. 1. Mattausch, M. Miura-Mattausch," Measurement and Modeling of IC Self-Heating Including Cooling System Properties",P.P 90,IEEE,2015.

[7]. Kaoru Furumi, Masashi Imai, Atsushi Kurokawa," Cooling Architectures using Thermal Sidewalls, Interchip Plates, and Bottom Plate for 3D ICs", 18th Int'l Symposium on Quality Electronic Design, p.p 283, IEEE, 2017.

[8]. Gregory Paul and Edward Gim, David Westerfeld," Battery Powered Heating and Cooling Suit",P.P1-3,IEEE,2014.