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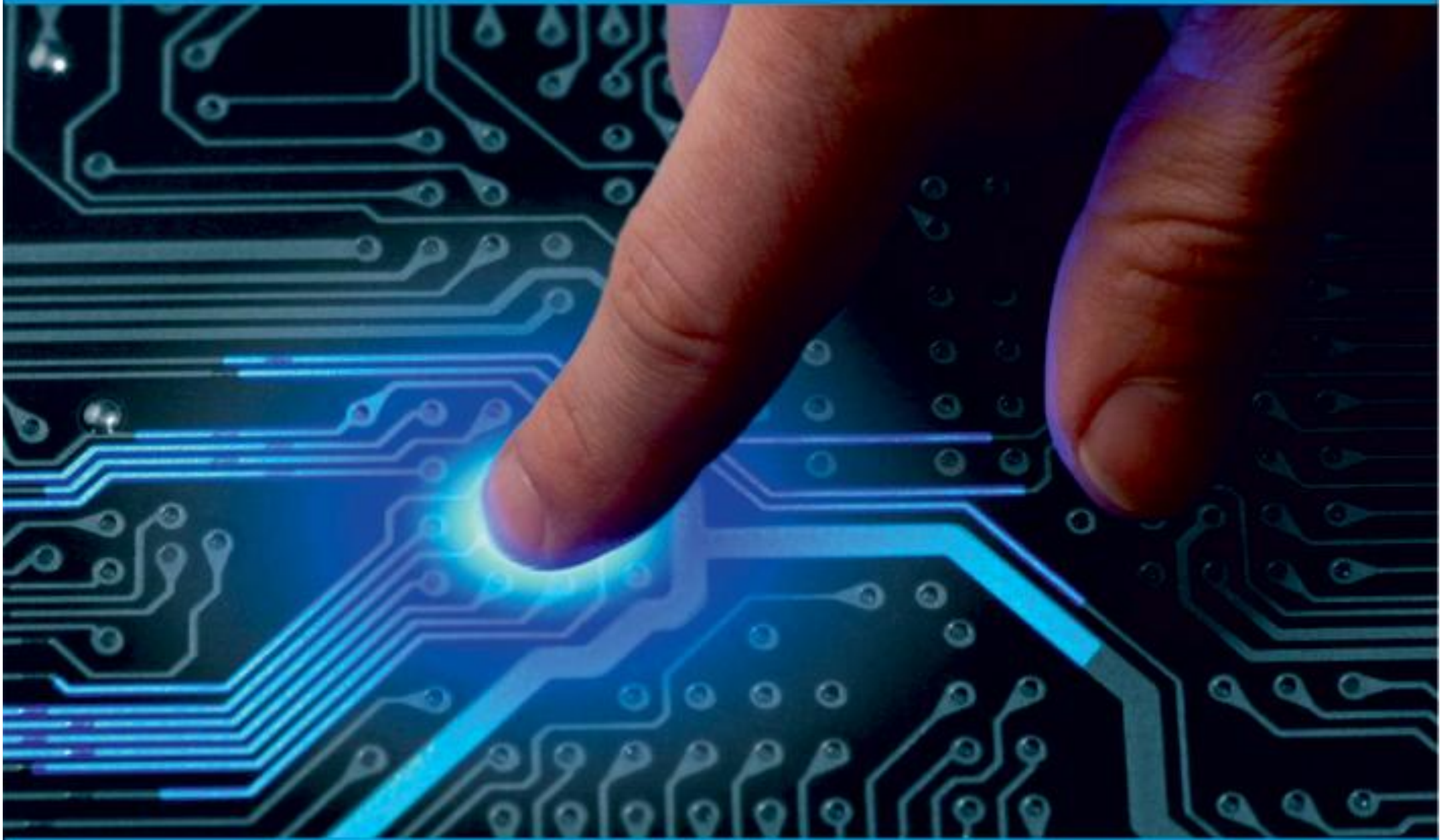

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Automated Heat and Cool Jacket Works on the Principle of Peltier Operation

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ABSTRACT: The Peltier effect is a process whereby heat is generated or absorbed when an electric current is given across a junction between two different materials. Peltier module consists of two external ceramic plates separated by semiconductor p-n junctions. The process of transfer of thermal energy takes place from one ceramic plate to another. This transferred heat has to dissipated and hence one surface of the Peltier module becomes hot and the opposite surface becomes cool. Peltier-effect devices are used for thermoelectric cooling in electronic equipment and computers, where other compact cooling systems might not be available. But this effect can also be expanded to solve various heating or cooling problems. One such solution to this type of problem is to build an Automated Heat and Cool Jacket that can provide coolness or warmth to the user according to the changing climatic conditions. This paper explains how such a jacket can be practically implemented.

KEYWORDS: Peltier Module, Temperature Control, Heat and Cool Jacket, Embedded system, Temperature sensor, Wi-Fi.

I.INTRODUCTION

In various places especially in hilly regions and cold countries, the weather can become extremely chilly during the winter season. People in such countries often rely on jackets for protection from cold. In such countries, jacket is a part of the day to day clothing. But a simple jacket might not provide the required insulation to a person from the cold. Also, the opposite can be said for warmer regions. During intense summer, the heat can be unbearable and can make a person uncomfortable. It is necessary to protect people from the harshness of climate. When the temperature goes to extremes unexpectedly, the user can feel very uncomfortable and tired. It is necessary for a person to be comfortable as this can affect his/her productivity both in office and home. Exposure to both intense heat and coldness can have both long term and short-term dangerous effect on people which include skin problems, asthma, fever etc. It can also cause an adverse effect on mental health.

There is a restriction for people to put on many clothes, one top of another. It is not plausible for someone to wear 2-3 outfits to protect themselves from coldness. There should also be a way to escape from the intense heat of summer. Also, there are locations on the Earth that have a fixed climate – either very cold or very hot. Thus, there is a need to come up with a solution to protect people from such harsh weather conditions. This is where an automated peltier heat and cool jacket can come in handy.

An Automated Jacket can provide internal heating and cooling mechanism whereby the wearer will feel warm/cool with variation in temperature. As the temperature around a user changes, the user can adjust the temperature inside the jacket to cancel the effect of the external heat and coldness. If the temperature is high, the person can opt for a cooling effect and if the temperature is low the person can choose for a warming effect. The heating and cooling mechanism can be controlled by a smartphone. The mechanism utilized to create this effect is the Peltier effect. It can be defined as, when an electric current is passed through the P-N junction of two different conductors or semiconductors, one junction starts to cool and the other heats up. This jacket will provide more comfort to the wearer. It will warm/cool him according to his requirement or the outside temperature conditions. This project thus aims to build an automated peltier heat and cool jacket and also tries to make it energy efficient and reliable.

II.LITERATURE SURVEY

Air conditioners and cloth irons made with peltier modules consume only about 200W and 50W, and their use in daily life helps us to reduce power consumption [1]. When a refrigerator consists of peltier modules, there is no need of big moving parts such as compressor, absorber, condenser etc. Hence, its design is simple to set-up [2]. Conventional air-conditioner present in automobiles can be replaced with peltier-cooled air conditioners and hence, it helps to reduce the total weight of the vehicle and also increase overall fuel economy [3]. A preponderant, propitious and a simple solution for performing both cooling and heating effects in a more efficient manner by the utilization of solar energy is presented [4]. A thermoelectric cooling system is proposed to remove the heat that is generated by electronic device, where a gravity assistant heat pipe is attached on the hot side of the thermoelectric cooling module, serving as a heat sink [5]. In the field of military and medical science there are refrigerators used to cool samples, preserve specimens and in case of transportation of component from one place to another, there is no refrigeration system. Thermoelectric refrigeration is new alternative because it can convert electricity into useful cooling [6]. A heart rate monitoring prototype was realized using ESP8266 hardware modules, WebSocket library, Node.js and JavaScript which illustrate the communication between ESP8266 modules, server and clients [7]. This paper uses the Cloud and a Web Browser to control the manually operated switches, where the switches are interfaced with NodeMCU, which has an inbuilt Wi-Fi [8]. A battery management system was implemented for Li-ion based battery bank using passive charge balancing method controlled by STM32 microcontroller [9]. Body temperature measurement systems by using STM32 is proposed [10].

III.METHODOLOGY

The automated jacket is fitted with three temperature sensors. Out of which two of them detect the atmospheric temperature and the third one detects the jacket temperature. The first two sensors are placed at the shoulder position in the jacket at opposite sides. The analog values of both the sensors are fed to the ADC input of the STM32 microcontroller. The averaged values from both are calculated to measure the exact atmospheric temperature. The automated jacket can operate in cool or heat mode based on the set temperature and the temperature values read by the sensors. The peltier modules are connected using MOSFET switches and it is controlled by the PWM output of the microcontroller.

The PWM duty cycle allows the Peltier modules connected to the MOSFET to attain the required temperature. Duty cycle is the fraction of a period in which the output signal is on the ON condition. Two MOSFETs are used, each connected to the heat bank or cool bank of Peltier modules. Peltier modules work under Peltier effect which says that when an electric current is passed through a circuit of thermocouple, heat is evolved at one junction and absorbed at the other junction. This generated heat is proportional to the product of the difference of Peltier coefficients of conductors at two ends and the current passing through them.

The produced temperature is distributed to the entire body of the jacket using metal strips that pass across all over the jacket's body. The copper strips are attached to the jacket using Velcro straps. Peltier modules for cooling are attached to the heat sink using thermal paste and then attached to the copper strip. The third temperature sensor is used to measure the atmospheric temperature. It also will be sent to the android application and displayed on the user interface screen.

The system operates based on the threshold temperature set by the user. Additional control is also possible by setting the temperature manually by using an Android app from the smart phone. For accomplishing this, the system is connected to an IOT based android application that is installed in the user's smartphone. Connection between the application and NodeMCU is established using Wi-Fi and the NodeMCU connected to STM32 by using USART. The user inputs the required temperature and is sent to the controller which then controls the PWM to obtain the output.

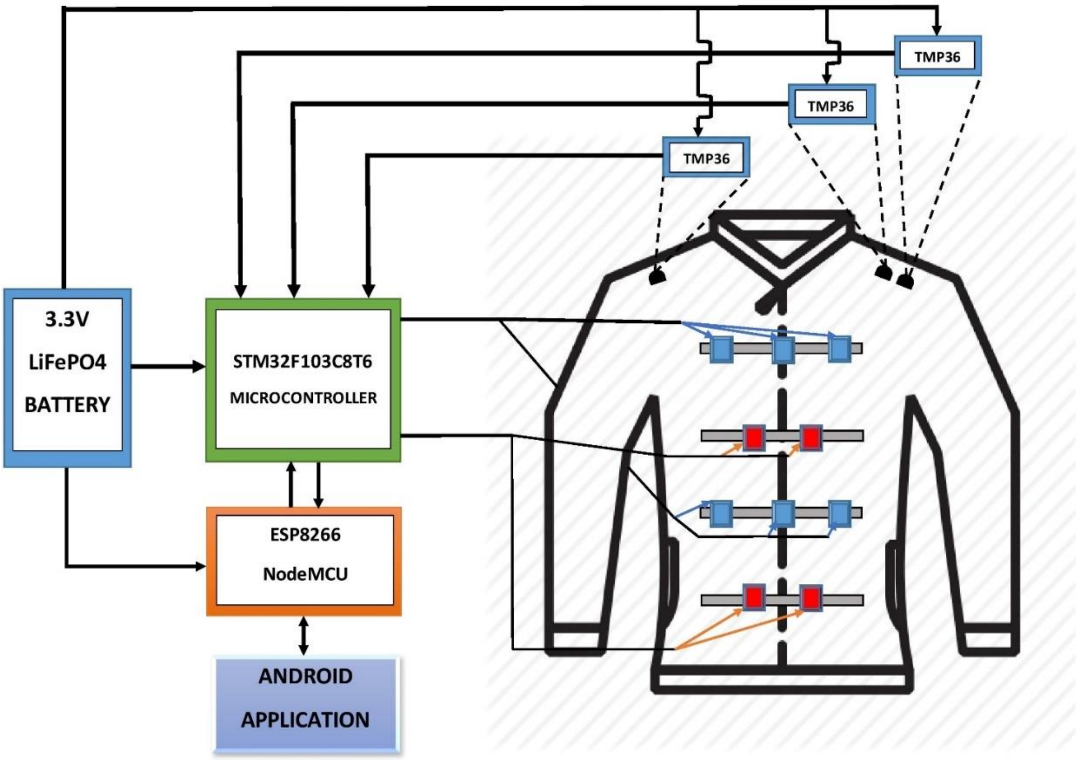
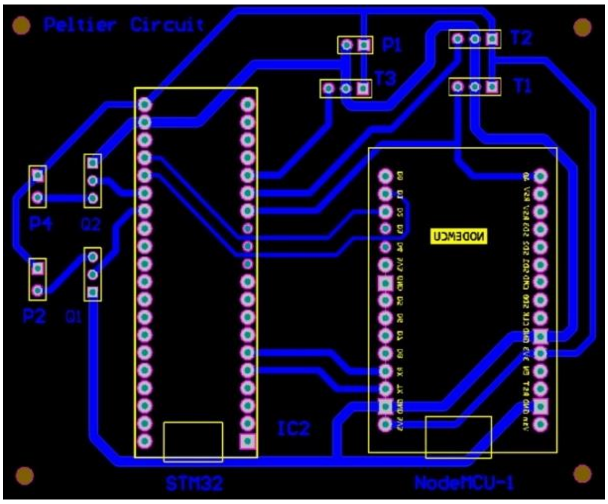


Fig. 1. Block Diagram

The temperature can only be varied from 18°C to 30°C to ensure user safety. Previously detected atmospheric temperature is also displayed for user's information. Hence the system works ensuring both optimum temperature and user comfort with low power consumption. The schematic and PCB layout shown below are designed using Altium 10 software.



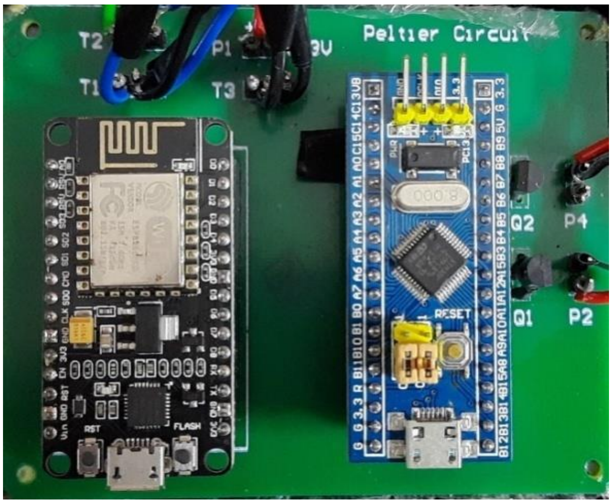


Fig. 2.1 PCB Layout

Fig. 2.2 Final PCB

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IV.DESIGN OF THE SYSTEM

1.Power Calculation:

Peltier modules consume the most current when compared to other components, as it consumes 3A when 5V is applied. But the power source is rated at 3.3V. So, we cannot use the peltier modules to its full capacity. When the peltier module is powered with 3.3V, the amount of heat and cool effect generated is sufficient to attain the required temperature in the jacket.

The TES1-4903 20x20mm 5V 3A peltier module is used for the jacket as it suits our requirements. Ten peltier modules are placed inside the jacket where only five of them work at a time. These five modules are connected parallelly and we need to find the total current consumed by the five peltier modules when 3.3V is applied:

$$\left(\frac{Given\ input\ voltage}{Specified\ input\ voltage}\right) * Specified\ current$$

$$\left(\frac{3.3V}{5V}\right) * 3A = 1.98A$$

As shown above, one Peltier module will consume around 1.98A and in total for 5 Peltier modules, it will be 9.9A. The other components used in the jacket requires current in the range of milliamperes. The below table shows the current consumed for components other than peltier module.

Component	Quantity	Total current consumed
TMP36	3	150mA
STM32F103C8	1	50mA
NodeMCU	1	170mA
2N7000	2	200mA

Now, we can calculate the total current required for powering the whole circuit:

$$150mA + 50mA + 170mA + 200mA + 9.9A = 10.32015A$$

The above shown current is required from the power source for the circuit to work properly.

2.Analog to Digital Conversion (ADC):

The ADC pin used in STM32F103C8 development board is PA0. It is used to convert the incoming analog voltage from TMP36 to the corresponding temperature value. The temperature sensor is powered using 3.3V, but the output analog voltage is independent of it. TMP36 produces an output in the range 0V->2V. The ADC present in the microcontroller is 12-bit. So, the value received at the ADC pin has a range of 0 to 4095 i.e.

$$2^{12} = 4096$$

In order to convert this value to a voltage value, we can do the below calculations:

$$\text{Voltage at pin(mV)} = (\text{reading from ADC}) * (3300/4096)$$

where 3300 is the source voltage = 3.3V. This formula converts the number 0-4096 from the ADC into 0-3300mV (= 3.3V). Then, to convert millivolts into temperature, we can use this formula:

Temperature (in°C) = [(analog voltage (mV)) - 500]/10

where the value 500mV represents the offset voltage, which has to be subtracted to obtain an accurate temperature. This temperature value is then used for comparison and then controlling the heating and cooling effect inside the jacket.

3.PWM Generation:

Pulse Width Modulation (PWM) is a technique of modulating the width of a digital pulse, which has a logic-1 and a logic-0. Duty cycle can be defined as the proportion of 'ON' time to the regular interval or 'period' of time. A low duty cycle means that the signal will be OFF for most of the time. A 50% duty cycle signal means that the square wave will be ON for half of the time and OFF for the other half period.

Here, the function of PWM is available on the microcontroller and it can be configured using the software Cube MX. The HAL libraries are helpful as they provide all the initializations required. The PWM output wave is given as input to the gate of the MOSFET. The Peltier modules are connected to the drain terminal of the MOSFET. Hence, if more cooling effect is required, then, a pulse (Fig. 3.1) will be produced, so that the MOSFET is ON for a longer time and thereby the Peltier modules.

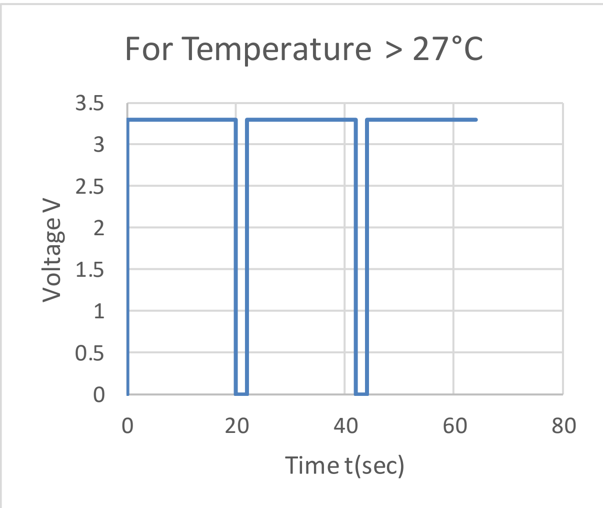

Fig. 3.1 PWM wave for Cooling Peltier Modules

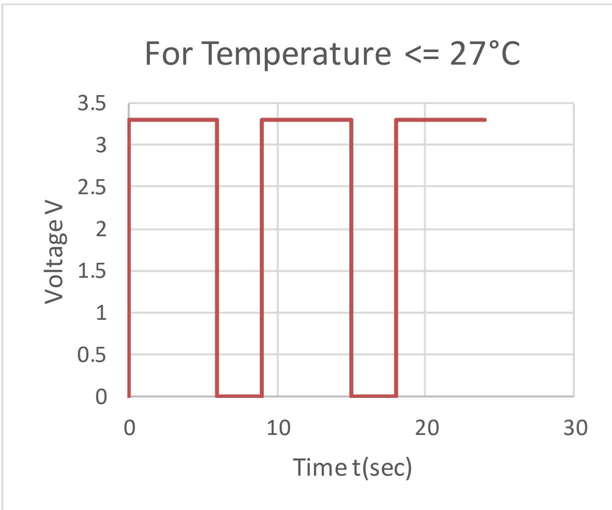

Fig. 3.2 PWM wave for Heating Peltier Modules

4.Jacket Design:

Mainly, we have focussed on the placement of the PCB and the placement of Peltier modules. The board has to placed in such a way that it does not cause any obstruction to the user. We have decided that the board should be placed where the pockets are originally stitched. The Temperature sensors TMP36 are connected to the PCB through wires. We have two sensors for measuring the atmospheric temperature. These sensors are placed on the shoulders with contact to the open environment, in order to accurately measure the temperature. The placement of Peltier modules is a crucial task. We have tried to design the jacket in an ergonomic way, so that the user doesn't feel uncomfortable at all. If the cooling Peltier modules are placed near the chest, it can cause wet cough or chesty cough, which can lead to chest infection. Also, considering the placement of heating Peltier modules, it cannot be placed at some sensitive parts. The below figure shows the places where heating can be effectful.

The Peltier modules will be mounted over the adhesive copper strip, which will be stitched onto the inside of the jacket. The copper strips are placed parallelly to each other to accommodate more Peltier modules. The copper strips also have a width of 2cm so that it perfectly sticks onto the Peltier module. In order for the cooling process to work properly, small heatsinks are also used and they are made in contact with the Peltier module with the help of thermal paste.

Fig. 4.1 Internal parts of the jacket

Fig. 4.2

Fig. 4.3 Outer side of jacket

V. EXPERIMENTAL RESULTS

The first step is to get atmospheric temperature from the TMP36 temperature sensors, which are utilized for setting the temperature in the jacket. The NodeMCU module is used for two aspects: one, to display the atmospheric temperature in the android application and two, to set the jacket temperature suitable for the user, using the application. This is done by establishing communication between the Wi-Fi module and our smart phone. USART communication is used to communicate between STM32 and NodeMCU.

Achieving temperature control inside the jacket by utilizing the atmospheric temperature input is the main highlight of this project. This is fulfilled with the help of STM32F103C8 microcontroller. The ADC, USART and PWM features are used in the microcontroller. A PWM wave is generated as output of microcontroller and is given to two MOSEFTs, which acts as switches. The heat bank or cool bank of peltier modules are connected to the drain of the MOSFET and turned ON and OFF to attain the required temperature in the jacket. The conductive and adhesive copper strips are used to distribute the heating or cooling effect throughout the jacket. The proper placement of copper strip helps to make the temperature distribution process more accurate and effortless.

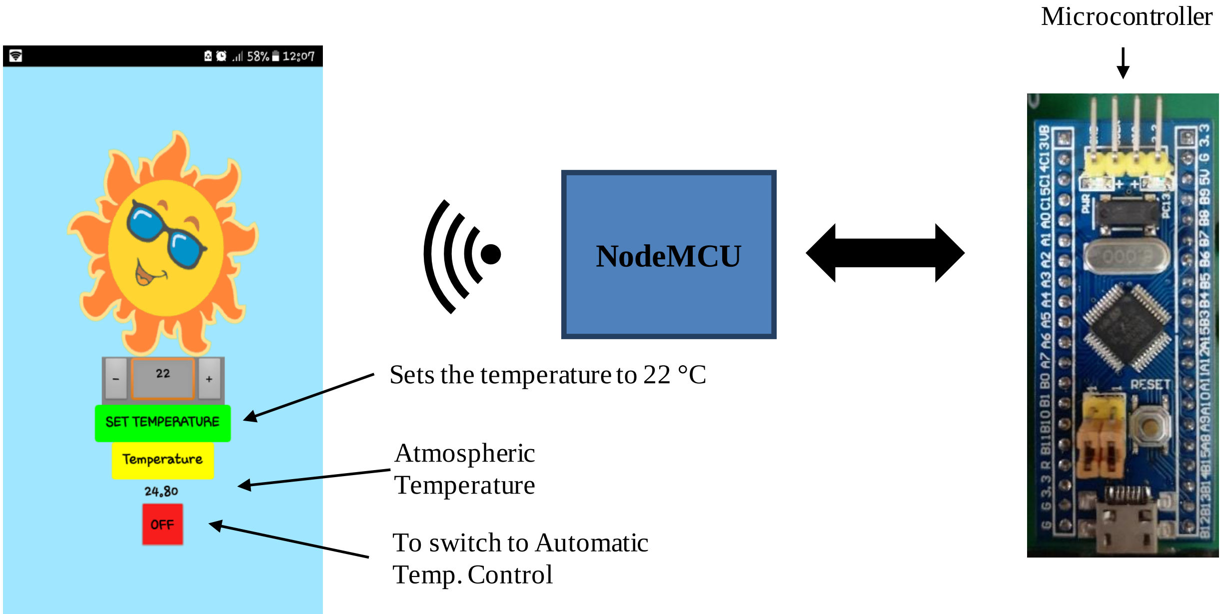

Fig. 5. Sending temperature value from application to STM32

VI.CONCLUSION

This project was mainly concentrated on how to implement a low power, portable and user-friendly heat and cool jacket that works either automatically or according to the user decisions. The jacket is usable depending on the atmospheric conditions. One of main attractive feature is the Automatic control of temperature. Also, there is manual control where we can control the jacket temperature using our smartphone. Peltier modules are used for heating and cooling purposes and has the feature of low power consumption. The peltier module has a good range of temperature difference which makes it a best fit for our product. Its small size helps to stick the module to the copper strips which made the design part compact. Another important part of this project is the user-friendly behaviour of the product. If the user is not happy with the automatic control, then he/she can switch it to manual control. An Android application is developed to set a suitable temperature and then send that value to the jacket. The user can make a decision according to the atmospheric temperature value displayed in the application. In future, a battery management system can be included to protect the battery from operating outside the safe region. We can add flexible solar panels as power supply for the system. As we conclude, we can guarantee that this product will definitely improve the lives of people.

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