Battery Powered Heating and Cooling Suit

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Abstract— **Temperature related inconveniences such as heat stroke, heat rash, frostbite, hypothermia and others, have been a persistent problem for people throughout history. Some of these conditions, when left unchecked, have led to unfortunate deaths. What is even more common is the un-satisfaction that people have with the weather at various points of the year. People often complain that it is either too hot or too cold. The current technological solutions made to keep people thermally comfortable such as air conditioning and heating units have come a long way and have been successful in helping people obtain comfort in their dwellings (e.g. home or car), but are not personal mobility solutions. What if one has to be out in the weather? The addition or subtraction of layers with coats and jackets or beach wear, are popular solutions to that problem, but do not always yield upmost satisfaction, for layers become cold over time and sunburn is a serious problem. This is why a heating/cooling suit is a very beneficial product for the masses. Such a suit allows the user to control and monitor the internal temperature of the suit from high temperatures to low temperatures, depending on the season. Creating the most comfortable thermal environment for the user within an enclosed space of small proximity while providing comfort, practicality and mobility is the objective of this suit. With the use of the thermoelectric effect, microcontroller technology and a bit of ingenuity, this suit can be realized.**

Keywords- Heating/Cooling suit; Garment temperature control.

I. GOALS AND IMPACT

The proposed solution is a battery powered heating/cooling suit, in which the user can control the temperature through controls and thermo-electric devices that are embedded in the suit. The usefulness and practicality of such a suit is the motivating factor of embarking on this project. Ultimately, we set out to achieve a body suit that is easy to wear, comfortable, and provides simple and adequate controls that allow for any user to utilize it to their needs. We hope that such a suit can be marketable to the general public and its functionalities can be used to prevent the unfortunate conditions that are caused by heat strokes, hypothermia, and other thermally induced maladies.

The functionality of the suit is as follows: The user wears the suit like any other garment, but has the ability to turn on the temperature control device within the suit. Once turned on, the device displays the temperature of the inside of the suit in an LCD display. Initiating the hot or cold functions are as simple as pushing a button, and a rotary knob allows the user to control the internal temperature of the suit.

The heating or cooling suits that are on the market are high in cost because they use pumps with moving parts or nano-fiber technology. None of them provide dual functionality. Therefore, a big goal and selling point for our product is its design for low cost and dual functionality.

II. BACKGROUND

This application requires the development of a system that ensures both warming and cooling. There is a very interesting device that does both heating and cooling simultaneously on a small scale. The thermoelectric cooler (TEC) is a solid state heat pump made of thermocouples of high-efficiency semiconductor material that creates a difference in temperature of its two sides when a voltage is applied and current runs through it. A P-type and N-type semiconductor alignment is enclosed between two ceramic plates [8].

This phenomenon is called the Peltier effect. 17th Century French Physicist Jean Peltier concluded that when a current flows through a junction between two different conductors (from a battery or other voltage source), heating and cooling occur because charge carriers diffuse to opposite sides. This is the reverse of the Seebeck effect (Thomas Seebeck, Germany, 17th Century), which states that a difference in temperature of adjacent conductors generates a voltage. This effect is very strong when used in systems with many semiconductors, as is the case with the thermoelectric cooler [7]. These effects, collectively known as the thermoelectric effect, note a correlation between voltage and temperature of conductors [4].

When the polarity of the current is changed, and current is flowing in the opposite direction, the hot side of the TEC becomes cold and the cold side becomes hot. Therefore the ability to change the polarity of the flow of charge in the thermoelectric cooler allows one side to have dual function. One of the important advantages of the TEC is that it has no moving parts. Unlike traditional heat pumps, it is

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lightweight, and relatively small. This is crucial for a practical design.

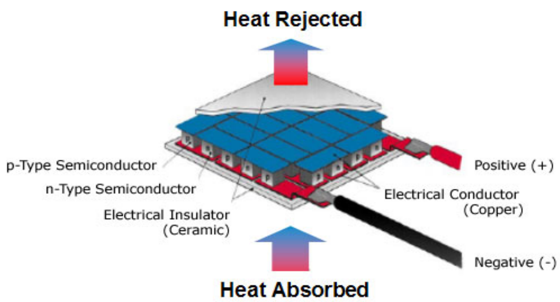

Figure 1: Comprehensive diagram of TEC. Courtesy of Alibaba.com

III. DESIGN

A) Design Constraints

To undertake this project and conduct useful research that would yield a successful design, several design challenges had to be taken into account. A primary obstacle was coming up with a delivery method to spread the heat/anti-heat to as much of the garment as possible. The safety of the potential user is also important. The design cannot be hazardous, and the product shouldn't burn or shock the user. Therefore parameter limitations and proper wiring and encasement procedures ought to be implemented. There is also a cost limitation on the project so our design could not exceed that cost. The design considers size limitations of garments worn by people and avoids excess bulk, weight, waste, and user uneasiness, all at a low cost.

B) Final Design

The final design is a microprocessor based system that heats and cools one side of several TECs by using an H bridge circuit that is enabled and controlled by "hot and cold" pushbuttons and a rotary variable resistor. The voltage across this variable resistor is used to pulse width modulate the signal to the H bridge through software, allowing the user to adjust the gradient temperature that the TECs generate. The TECs will ultimately come out of the circuit via their wires and be attached (on the side that we are using) to heating/cooling pads that are placed in strategic places within the suit. 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.

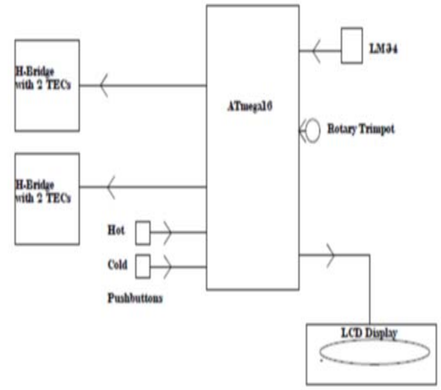

Figure 2: Block Diagram of the Final Design

At the heart of the circuit is the ATMega16 microcontroller. This Atmel microcontroller is an 8-bit device with 16KB of programmable flash it also has 32 programmable I/O lines of the 40 pins with 4 ports, 3 interrupt pins and 4 PWM channels. It provides the control for the periphery of the circuit [2].

The circuit is powered by a 12V alkaline battery. To turn on and off the circuit, a toggle pushbutton switch is between the power supply and the rest of the circuit and acts as an on/off switch. The voltage of the microcontroller is regulated by a voltage regulator that limits the 12V from the battery to 5V, which is in the range of operation for the ATmega16. This voltage regulator is the KA7805, it is capable of regulating high voltage sources to approximately 5 V (5.2V max, the ATmega16 can handle 5.5V max) [1].

For temperature sensing, the LM34 Precision Fahrenheit Temperature Sensor was selected and would be connected to the microcontroller. The LM34 is an easy-to-use sensor that does require external calibration, but is able to output a voltage that is linearly proportional to the Fahrenheit temperature, and can provide typical accuracies of +/- 0.5 F at room temperatures over a -50 to +300 F temperature range.

The temperature sensed by the LM34, is converted from binary to decimal via programming of the microcontroller, and through further coding will be displayed on a LCD module that would display real time internal temperature of the suit in decimal numbers. The LM34, like the TECs will come out of the circuit via its wires and be attached to the mid-section of the inner layers of the suit to measure temperature. In addition to the display, a push button has been added to allow the user to alternate between Fahrenheit and Celsius on the display. This is achieved through assembly language code loaded into the microcontroller.

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The most pivotal part of this heat/anti-heat generating circuit is the heat/anti-heat generating component, which in this case are the four TEC units. For the TEC units, the TEC1-12706 Thermoelectric Peltier Cooler were selected with a maximum operating voltage of 16.4 V and amperage of 6.4 A. The dimensions are 40mm x 40mm x 3.6mm [11]. But it is not connected directly to the microcontroller. Since the use of one side of the TEC units is desirable, we need to use them within H bridges circuits. The H bridge functions to allow a voltage to be applied across the load (i.e. TECs) in either direction. This circuit is very frequently used with motors to enable them to spin in either direction by reversing the polarity of the current going through them.

An H bridge has four switches, two on the same side (in series), and the other two on another side, these two sides are connected by the nodes between the two switches on each of the sides. This forms an “H”, hence the name. When a battery is connected across the top of the H and the lower “H” is grounded the circuit is complete. Now when the power is on and two diagonal switches are closed (while the others are opened), a current flows one way through the middle of the “H”, and if a motor is connected in that middle, the motor spins one way. If a TEC is connected, the one side heats up while the other cools down. Reverse the polarity and the motor spins the other direction, while in the TEC’s case, the hot and cold sides switch [5].

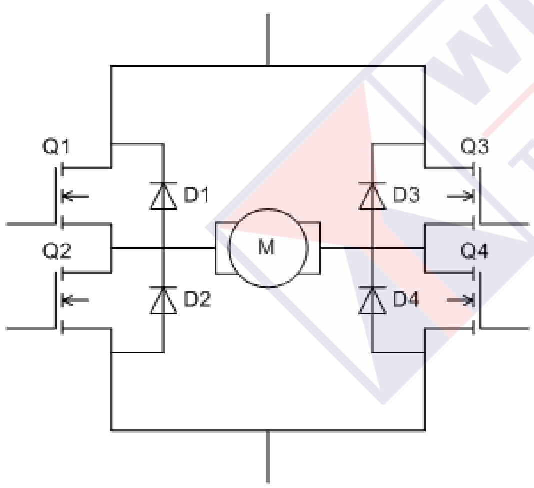

Figure 3: Example of a MOSFET based H bridge Circuit. Courtesy of electro-tech-online.com

These switches can be replaced by transistors to allow for digital system control. In the system, instead of closing and opening switches, we send a digital signal from the microprocessor to turn on or off diagonal transistors. MOSFETS transistors are used in the design to act as the switches. A logical high signal to the gate of a PMOS transistor to turn it on. That transistor is connected to its diagonal NMOS counterpart to push the current one way or the other. And with additional components, this H bridge can be designed to be functional and durable. Inverters can be added between the microcontroller and the transistors to allow for better digital communication, and diodes across the transistors can prevent high voltage spikes when switching signals or there is an abrupt shut down. In the design, two H-bridges are used, and four TECs (two to each H bridge) are connected in parallel to evenly distribute the voltage across them. The H bridges are enabled by one of two pushbuttons (hot and cold), which are connected to the microcontroller, which is set up to be interrupted if one of the buttons is pressed. If the interrupt occurs, the microcontroller sends a signal to the H bridges triggering activation of the TECs.

In order to give the user the ability to change the temperature of the suit, pulse width modulation is used to send a signal going to the H-bridge circuit. This is done through software, but a piece of hardware is used to allow the user to control the temperature precisely and by small increments. The rotary variable resistor connected between 5 volts (Port A power supply) and ground will have a voltage across it depending on its resistance at a particular time. Changing the value of the variable resistor will change the voltage. The microprocessor can perform the task of a potentiometer and read the voltage coming from an input device, with that information, we can equate different voltage levels with different duty cycles of the signal going to the H bridge circuit [9]. This is called pulse width modulation (PWM) and is used to control the inner temperature of the suit.

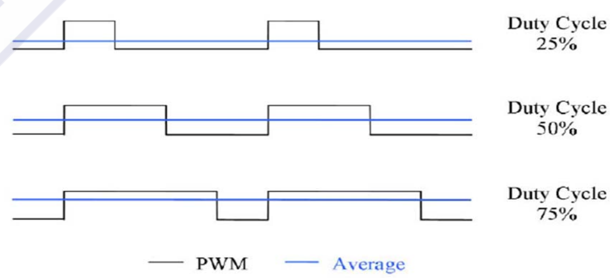

Figure 4: Representation of PWM

As for the distribution of the heat/anti-heat. The TECs will come out of the circuit and will connect on the side that we are using to heating/cooling pads via thermal glue. These heating/cooling pads are between the layers of the suit and conduct heat and cold in a timely manner. With the contact of the TEC with the pad, the temperature will be retained and distributed evenly throughout most of the suit.

Software Documentation:

The code for the microcontroller is programed in the following manner. First the code starts with the initialization of the interrupt vector table (in order for the interrupts to be properly handled), the configuration of the ports (in order to see which pins are inputs and outputs), and initialization of

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the stack pointer, interrupt controls, and LCD module. Next the main loop (and continuous background task) of the code checks the input pin for the LM34 sensor for temperature information. The suit's current temperature is converted from binary to decimal and parsed and stored for display. Next, the Celsius/ Fahrenheit pushbutton pins are checked to see whether the temperature should be displayed in the default Fahrenheit scale or converted into the Celsius temperature scale. If the Celsius scale is selected, the main loop of the code calls the conversion routine where the parsed data from the temperature sensor is converted and then returned back to the loop. The stored temperature is then sent to the LCD module for display. This continues to take place until an interrupt occurs. The main loop checks if the hot and cold push buttons are pushed in (interrupt has taken place), so it can read in the input from a manual dial (variable resistor), which acts as the temperature control for the suit. The input is then set to modify the pulse width modulated signal that is being sent to the H bridge circuit. The code will make the voltage linearly proportional to the duty cycle of the pulses sent to the H bridges. This allows for change in output voltage for the TECs, thus a change in temperature. If the hot or cold push buttons are not pressed, however, the system continuously reads and displays the internal temperature of the suit.

Two interrupt service routines (ISR) are added for each heating and cooling functionalities. In each of these ISRs, the registers are pushed onto the stack and the routine proceeds to ensure that the push button that triggered the ISR is pushed down and checks whether or not the other push button is pressed. If it has been pushed down then it proceeds to exit the ISR, because we do not want to simultaneously send current both ways, this would create a short circuit and may damage the component. If the other push button is not pressed then control remains in the ISR and the microprocessor send a signal to the H bridge circuit in order to enable them and apply the appropriate current through the TECs to be in accordance to the push button that was pressed (hot or cold). Once it's done, the routine pops the registers from stack and returns to the main loop.

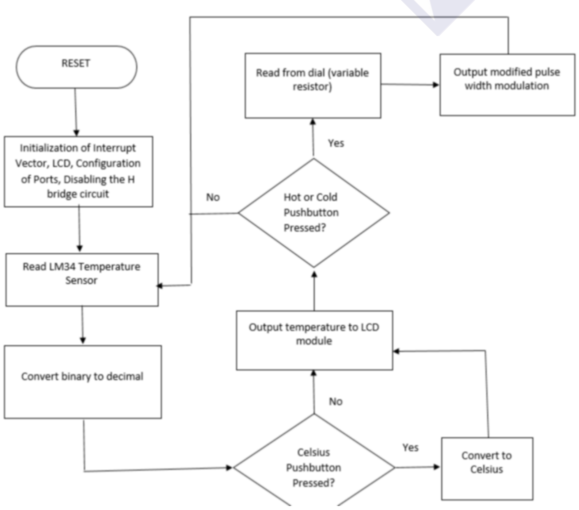

Figure 5a: Flowchart of the programming methodology

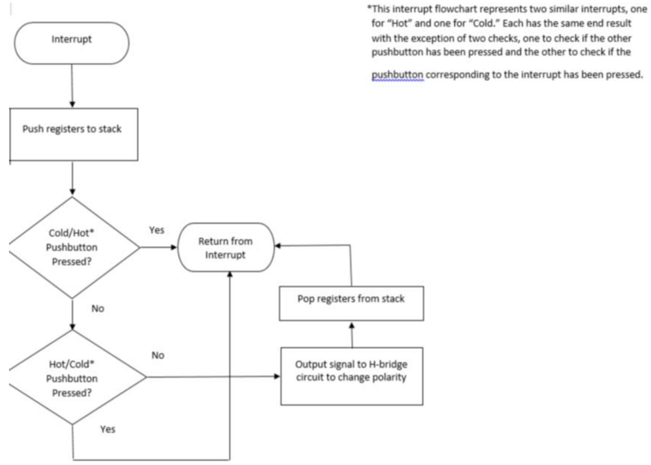

Figure 5b: Interrupt Flowchart

IV. Implementation Stage

The implementation process of this project is ongoing. The electronics has been prototyped and is mostly working as expected. The H bridge circuit allows the TECs to become hot or cold, but we are experimenting with different variations to maximize gradient temperature. The PWM does control the temperature of the TECs. The programming aspect is in progress. Communication with the periphery indicators, the LCD module and the Temperature sensor is soon to be completed. The final challenge is to find the right material for the suit, and observing the effects of the TEC's on the pads.

Results and Discussions

A. Multi-Disciplinary Issues

The project touched upon a vast range of disciplines from embedded system design to a brush-up on ancient history. This required the collective educational experience between the members of the group, and the ability to use this knowledge and apply it to the project. However, it also touched upon topics that the authors were unfamiliar with, such as commercial heating and cooling garments already on the market and the market for such products. On the engineering front, the authors also had to understand and combine many disciplines to approach this task. MOSFET electronics, as it pertains to the H-Bridge, was one topic that was thoroughly researched to gain a better understanding for implementation in the design. The software aspect involved using assembly language to program the chip to control the system. Heat transfer and thermodynamics were also concepts that the authors wrestled with in doing this project. Despite the issues the authors had along the way, the collaborative efforts of the group allowed them to design a project that did not stray too far from the original vision they had for the suit.

B. Professional/Ethical Issues

There were a few professional and ethical issues that were considered during the designing and planning of the project. During the planning phase of our design, we had to disapprove alternate design aspects because of the hazards that would have presented themselves in the construction of the suit. Additionally, cautionary measures were taken in the realization of the circuitry of temperature control device with the addition of capacitors and diodes in order to prevent electrical dangers from occurring. We also thought of ways to protect the component from damage. For example, we would encourage the consumer not to wash the suit, in order to protect the electronics in the temperature control device. Or we could realize a method to detach device from the suit to allow washing.

SUMMARY AND CONCLUSION

The final design of the project was an arduous journey that required repeated brainstorming and research. However, the design process provided a learning experience that augmented the authors' knowledge of Computer and Electrical Engineering. In this project, the complexity and practicality behind the embedded system design was learned and understood to create a system that would maximize the functionality of the TECs through the thermoelectric effect.

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