Anti-Hypothermia Jacket for Pro Climbers

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1 Introduction

1.1 Objective and Background

ARACHI, Pakistan — Some climbers call it "the savage mountain." K2 stands as the world's second-tallest summit, after Mount Everest, and some climbers consider it even more perilous. Only last month did one group become the first to successfully scale it during winter, braving dangerously thin air and temperatures that can plunge past minus 70 degrees Fahrenheit.

Many who have tried to climb it have lost their lives. In 2008, 11 lives were lost, while 13 climbers died over a two-week span in 1986, one of the worst disasters in mountaineering history. Mountaineering experts say climbers face a lack of oxygen, snow blindness and frostbite.

Highland climbing is always dangerous because of extreme environments such as oxygen deficit and extreme low temperature. Many great explorers died because they are under Anoxia above 5000m and then lose their body heat unconsciously under Coma and Hypothermia. Therefore, a fully automatic system needs to be designed to monitor hazardous body temp loss and adjust the jacket temp to stop climbers' further health problems.

With that, we decided to integrate a traditional climbing jacket with a dynamic temperature adjustment & monitor package powered by detachable battery packages.

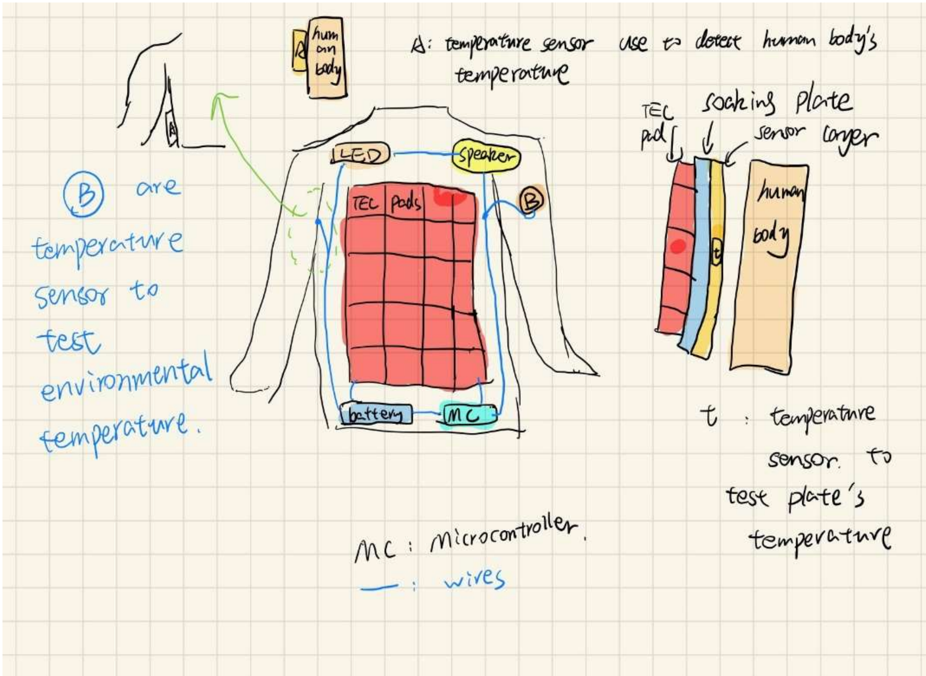

figure1. physical diagram

Our idea is to design a jacket integrated with TEC grids controlled by microprocessors and powered by detachable battery packages. The package has two modes. When body temp loss is not detected, users can use the package to deal with sudden temp drop and the temp adjustment is controlled by a microprocessor and each heating period is 15 minutes. Another mode is first-aiding mode. During this mode, the system will heat the inner temperature of jacket constant at about 37 C and give warning to climbers so that they can return to base within the battery limit or ask their teammates for help. For design overview, two TEC grids (about 20 pads) will be arranged in an efficient way to cover both fore-breast and back-breast and are controlled by a microprocessor and powered by detachable battery packages.

Currently, there is no outdoor company selling such first aiding products for professional climbers to protect their life. So, our product can provide future climbers a safer and more comfortable climbing experience.

1.2 High-Level Requirements

- The jacket with the whole system is designed compactly, incorporating the power supply, control unit, and TEC module systems with total weight lighter than 2kg.
- The whole system can heat the human body to designated temperature in 30 seconds after demands are made by body temperature or manual control.
- The whole system should be fully functional for 1 hour without running out of power.

2 Design

The whole package for the jacket requires three sections to work properly: the power supply module, the control unit, and the TEC heating module. The power supply module can handle the whole system's power consumption for at least 1h at 12V and 18A peak. The control unit is composed by a microcontroller to handle both analog input from sensors and digital PWM signal output. The TEC heating module contains both front and back breast TEC grids which can quickly compensate for body temp loss.

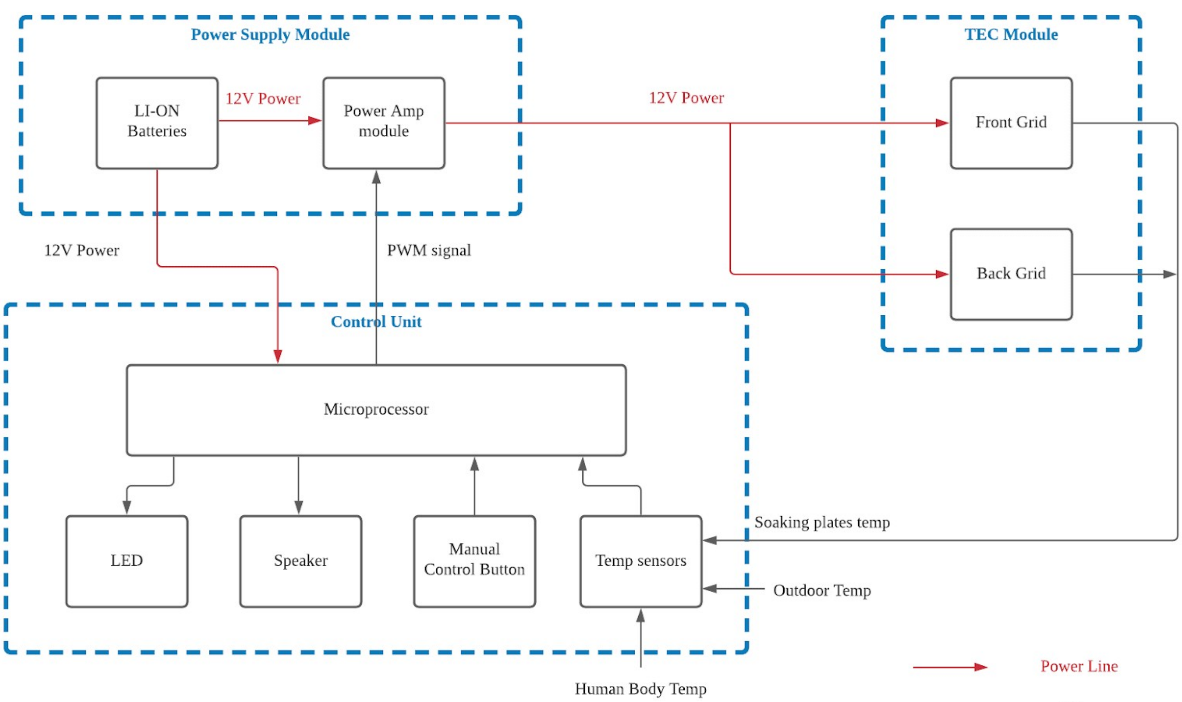

figure 2. Block diagram

2.1 Power Supply Module

A power supply is applied to keep the power consuming system working for at least one hour. The Li-ON batteries will provide 12V voltage directly for the control unit and will also provide large current for the TEC module through a power amp module.

2.1.1 Li-ON Batteries

The lithium-ion batteries must be able to keep all the TEC pads working at a certain temperature for at least 15min under manual model and at least 1H under first aiding mode. Besides, the battery also needs to provide 12V power for the Control Unit.

Requirement: The batteries must be able to handle at least 9A and at most 18A current at 12V voltage. The operation period is dynamically controlled by a 5V PWM signal.

2.1.2 Power Amplifier Module

The Power Amp Module takes 5V PWM inputs from Control Unit and then acts as switches to deliver at least 9A and at most 18A for TEC Module and is worked under 12V.

Requirements1: The BJT switch doesn't need active cooling during operation and the heat can be absorbed by TEC Module's soaking plates.

Requirements 2: The BJT switches can individually pass at least 3A current and at most 6A during operation.

2.2 Control Unit

The Control Unit is powered by a 12V power supply and can handle analog inputs from temperature sensors and dynamically output PWM signal to the power amp module to control TEC grids. The micro-controller provides a user interface with LED, Speaker, buttons. The LED and Speaker are for first aiding purpose and the manual control button is for operation mode change.

2.2.1 Microcontroller

The microcontroller, chosen to be an ATmega328p Arduino, deals with analog signals from temperature sensors/ buttons, conducts logic evaluation based on the quantized signal and outputs the PWM control signal to the TEC module.

Requirement: Must be able to output 5V PWM signal and work at 12V.

2.2.2 LED

The LED light is used to warn climbers when the system detects any abnormal body temp drop.

Requirement1: The LED light has to be visible from 5m away during fog day.

Requirement2: The LED must use less than 20mA current.

2.2.3 Speaker

The Speaker will make a series of loud sounds to give both climber and teammates low body temp warning.

Requirement1: The sound made by the speaker has to be clearly heard from 5m away during a windy day.

Requirement2: The Speaker must use less than 20mA current.

2.2.4 Manual Control Button

The button is used to start manual mode of the system. During manual mode, the system will work for 15min/cycle to help users get rid of sudden weather change.

Requirement: The button must be durable and is not made of metal because of the low temp environment.

2.2.5 Temperature Sensors

The Sensors are located on the outer jacket, human body, and grids' soaking plates. They are used to give the microcontroller real time analog signal for evaluation.

Requirement: The accuracy of the human body temp sensor should be within +/-0.25 C and can be power at 3.3V/5.0V.

2.3 TEC Module

The TEC module contains 20 TEC pads and 2 soaking plates. The pads are designed to be attached on soaking plates to evenly distribute heat.

Requirement1: Each TEC pad must be able to achieve 20-40C in 1min

Requirement2: Temperature differences between pads should be within 5C.

Requirement3: Each pad should achieve a certain temp in the range of 20-40C at 4V and less than 3A.

Requirement4: Soaking plate should be able to evenly distribute the heat to achieve Requirement2 and the material must be flexible.

2.4 Risk Analysis

The power supply module is the most significant risk we need to deal with to succeed in this project. First, the battery must be light enough so that it won't make the jacket too heavy. However, the pads are very power consuming. In detail, each pad will use 4V and 3A and we have 18-20 pads. Therefore, the static power is above 200W. Therefore, we must design an efficient PWM system to reduce the dynamic power usage to make the system work for at least 1H when using 100Wh battery.

Besides, the large current drain is also a risk. Normal Li-ON batteries can only supply 6-7Ah power at 12V. Therefore, we plan to test several structures to properly handle the peak 18A total current drain. For example, by carefully designing the grids' structure, we can attach 3x3 pads on each soaking plate so that the 9A/ grid current can be divided into 3A per column which can be handled by one 25Wh battery. Then we can use four 25Wh batteries instead of one 100Wh battery to supply the large current. However, it is difficult to simultaneously control 4 batteries at the same time and that may cause uneven pad temperature and it's harder to design the Control Unit to control each part's operation.

Also, the power amp module has some risk. We plan to use BJT as switches. However, we only have Arduino's 5V PWM signal as input and the max current input is 20mA. Therefore, to achieve saturation without using voltage regulators, we plan to design a multi-stage amp circuit instead of a single stage to properly bias the BJT.

3 Safety and Ethics

There are potential safety hazards in our project. Lithium-ion batteries can be damaged or even explode due to physical impacts such as crushing and dropping and extreme cold temperatures [1]. If the TEC grid cells keep heating, it may cause burning of the circuit system and the jacket. To prevent those safety hazards, we will design a negative feedback loop to avoid excess heat. We would take all aspects of potential safety problems into consideration in our design and try our best to obey the IEEE Code of Ethics, #9: “to avoid injuring others…” [2].

In our design of the anti-hypothermia jacket, we aimed to save climber’s lives and protect their safety during climbing experiences. This purpose is coherent with the IEEE Code of Ethics, #1: “to hold paramount the safety…” [2].

In the process of designing and testing our project, we will consult teaching assistants and professors when we encounter troubles and we are open to criticism which would help to improve our project. Our attitudes align with the IEEE Code of Ethics, #5: “to seek, accept, and offer honest criticism…” [2].

4 References

[1] “UNITED STATES DEPARTMENT OF LABOR,” Safety and Health Information Bulletins | Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices | Occupational Safety and Health Administration. [Online]. Available: https://www.osha.gov/dts/shib/shib011819.html. [Accessed: 19-Feb-2021].

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[3] “Hopes Dim for Three Climbers Missing in Winter K2 Attempt,” Zia ur-Rehman and Sameer Yasir, the New York times. [Online]. Available:

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