Self-Adjusting Jacket

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Design Document
Group 76

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I. Introduction

1.1 Objectives

During the winter, the outdoor temperature varies a lot throughout the day. During autumn and spring, it may be cold like 20 Fahrenheit in the morning, but rise to 50s-60s during the day. This makes choosing a suitable jacket very hard. Wear a thinner jacket, you will be fine during the day but feel cold in the morning and at night. Wear a thicker jacket will make you sweat during the day but feel just right in the morning and at night. We also noticed that indoors are usually heated, so after you walk into buildings you would need to take off coat/jacket to avoid sweating. The goal of this project is to make a jacket that can sense the temperature outside and adjust the "thickness" of itself automatically.

1.2 Background

To adjust its thickness, we will make use of the insulating property of air. As opposed to a normal jacket, this jacket will have pockets which fill air inside (think of bubble wraps except the cells are all interconnected to each other through bridges). This is then connected to a valve and a air pump which can pump air in/let air out. When the outside temperature is cold, the pump will activate to fill the bubbles with more air to increase insulation, When the outside temperature gets warmer, a hole/fan will be used to let out air, thus making the jacket not as warm. There will also be a sensor that determines how "thick" the jacket is currently. In the case that the air pockets are not entirely air tight, and that the jacket becomes too "thin", the sensor can sense this and tell the pump to pump more air.

1.3 High Level Requirement lists

- Battery Life - In order to satisfy the usage, the battery can sustain and provide the electricity of the system for at least a day on a single charge.

- Temperature Range - The system will automatically adjust the thickness of the jacket (start to pump the air or leak the air) when a temperature change greater than 1 degrees Celsius occurs.

- Thermal Insulation - When the air pockets are filled with air to an appropriate level, the user will stay warm in an environment with a temperature of 0 degrees Celsius.

II. Design

2.1 Block Diagram

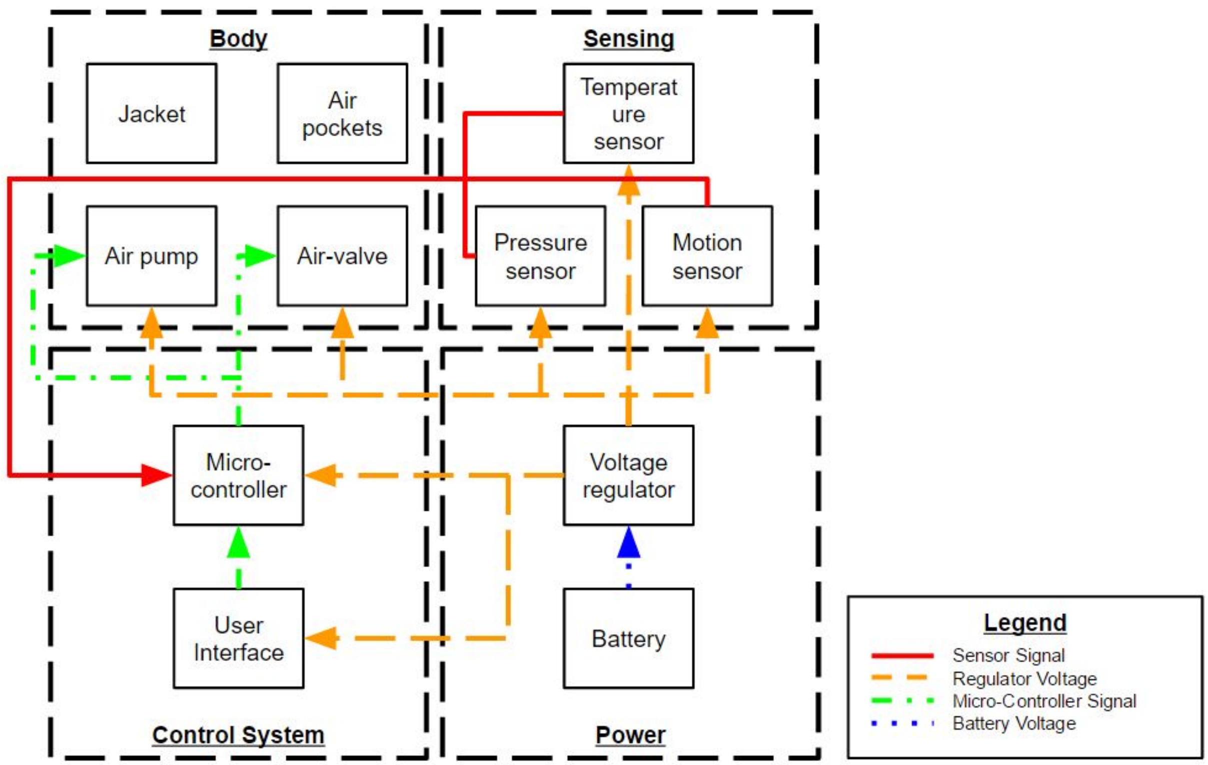

Figure 1. Block Diagram

2.2 Physical Design

The Self-Adjusting Jacket, on the outside, will look like similar to a normal jacket. On the inside layer, in addition to the traditional thermal insulating material like down/cotton, there is an additional layer of inter-connected air pockets. Each air pocket is 10cm by 10cm, and they are connected to neighboring air pockets via bridges 2cm wide. At the bottom of the jacket, the air pockets are connected to the air valve, and then connected to the air pump. The air pump will be exposed to outside air via a small hole in the jacket. The electronic components of the jacket will be located near the air pump, with the temperature sensor exposed to outside air via the air pump hole.

2.3 Block Design

2.3.1 functional overview

Body

The body module of the Self-Adjusting Jacket consists of the outer jacket, air pockets, an air valve, and an air pump. The air pockets, the air valve, and the air pump is made air-tight and serves as the adjustable thermal insulating layer. It’s important that there’s next to no air leaks so that cold air doesn’t need to be pumped into the jacket constantly, which would jeopardize the thermal insulating property of the jacket.

Sensing

Temperature sensor:

The temperature sensor senses the current temperature outside and sends this information to the microcontroller of the jacket. The microcontroller then compares the temperature to the amount of currently in the jacket. It then opens the air valve or turns on the air pump to adjust the amount of air inside the air pockets, effectively adjusting the “thickness” of the jacket to an appropriate level.

Pressure sensor:

The pressure sensor measures the air pressure inside the air pockets and sends this information to the microcontroller. Using this information, the microcontroller determines the amount of air that’s currently in the air pockets. This information is compared to the temperature outside to help the microcontroller determine if the air pockets are inflated to an appropriate level.

Motion sensor:

The motion sensor measures whether the jacket is currently being worn. It sends this information to the microcontroller.

Control system

Microcontroller:

The microcontroller receives data from the sensors, interprets the user setting from the user interface, and controls the air pump and the air-valve. The microcontroller takes in the outside temperature data from the temperature sensor and determines the appropriate air pressure that should be in the air pockets for the optimal “thickness” of the jacket according to the user setting. It will then compare the optimal air pressure to the current air pressure in the air pockets according to the pressure sensor. If the difference between the two is high enough, It will either open the air valve to release air or pump more air into the air pockets to adjust thickness of the jacket. The microcontroller also takes in data from the motion sensor. When the motion sensor senses no movement for a certain amount of time (the jacket is not being worn), and the temperature sensor senses the outside temperature is above 18 degrees Celsius (room temperature), the microcontroller determines that the user has entered indoors and taken off the jacket, and enters indoors mode. In this mode, the microcontroller pumps the jacket up to full capacity using warm air indoors and maintains it that way. Once the user puts on the jacket again, and goes outside (signified by temperature drop from the temperature sensor and movement from the motion sensor), the microcontroller returns to the default mode and adjusts the thickness of the by opening the air valve and letting air out.

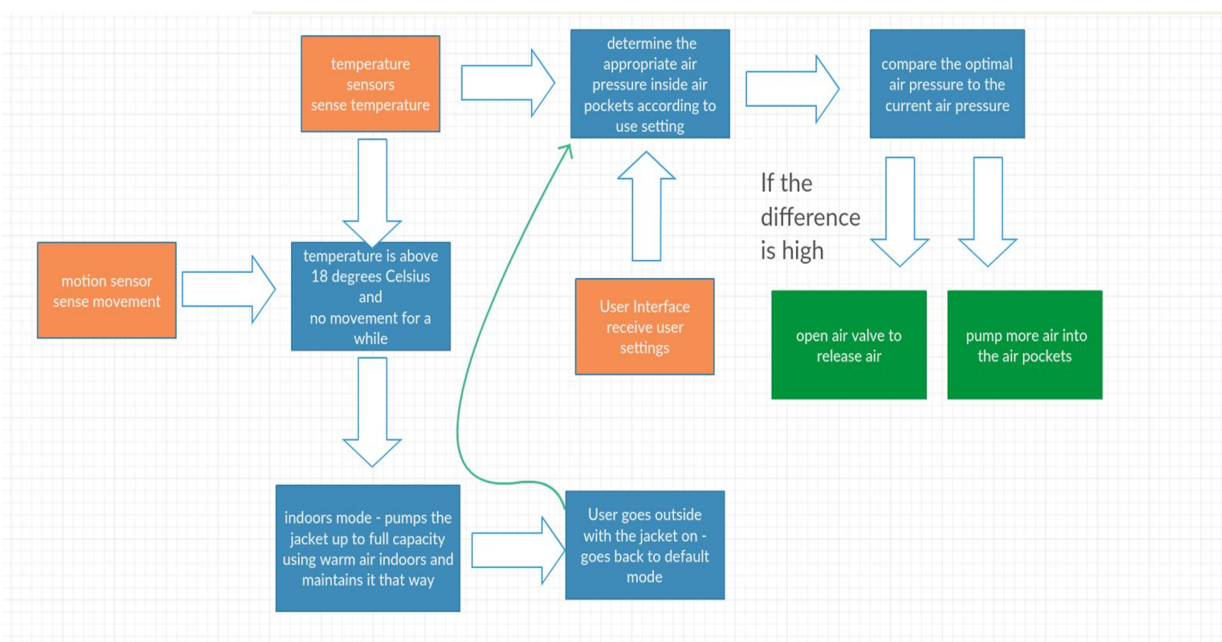

Figure 2. Flow chart for the micro controller

User Interface:

The user interface is a knob that lets the user set how warm he/she wants the jacket to be. For example, someone that get's hot relatively easily can set it the knob to low temperature, compared to someone that get's cold easily and sets the knob to high temperature. In this case, the jacket with the low temperature setting will be thinner than the jacket with high temperature setting for any arbitrary outside temperature.

<u>Power</u>

Battery:

The battery powers the electrical systems of the Self-Adjusting Jacket. The battery provides a 12V voltage. It feeds directly into the voltage regulator.

Voltage regulator:

The voltage regulator takes a voltage input from the battery and outputs a constant 5V voltage for the control systems, the body, as well as the sensors. This ensures the correct operation of the systems.

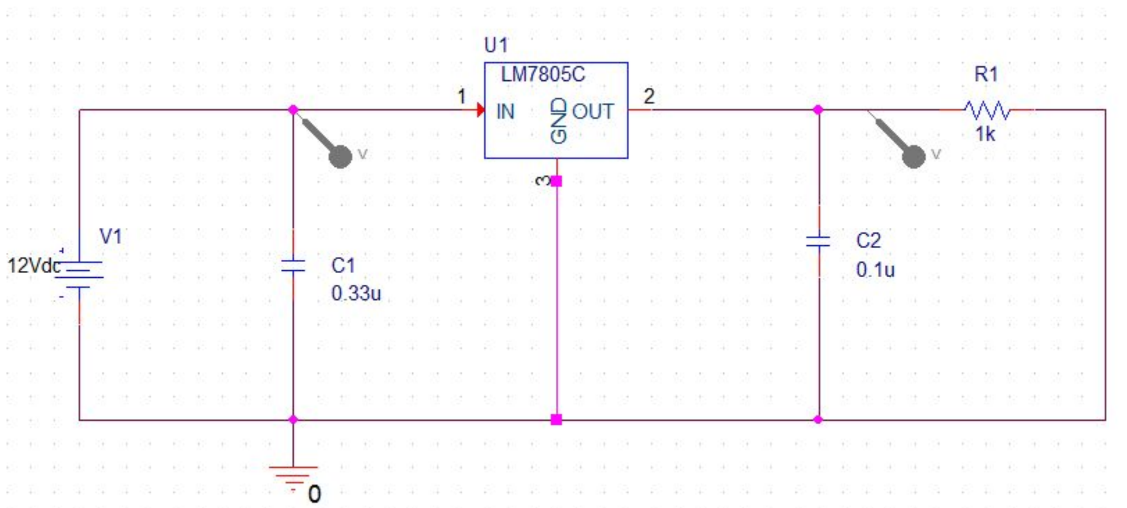

Figure 3. Voltage Regulator schematic

2.3.2 Requirements and Verification

Requirement	Verification
Body: ● The inner air pockets must be airtight enough that when it's pumped up with an air pressure of 1.2Atm inside, the air pressure will stay within 0.1Atm after an hour. And it will be able to stand a maximum air pressure of 2Atm. ● The air pump can pump air into the air pockets with an air pressure of more than 1.5Atm. ● The air valve can open and close within 5s 99% of the time.	● Attach a pressure gauge to the air pockets. Using the air pump, pump air into the air pockets until the pressure inside the air pockets reaches 1.2Atm and close the air valve. After an hour, the air pressure gauge should show a value within 0.1 Atm of 1.2 Atm in at least 9 tries out of 10 ● With an air pressure of 2.0 Atm (we assume this is the maximum air pressure that the air pocket can hold), the air pump can pump the air into the air pockets within 5 minutes. ● Using the electronic control of the air valve, open and close the air valves 10 times. The air valve should complete opening/closing within 5s at least 9 times.
Sensing ● The temperature sensor can sense the correct temperature within 0.2 degrees Celsius 90% of the time ● The pressure sensor can sense the correct air pressure to within 0.05Atm 90% of the time. ● The motion sensor can correctly detect motion 90% of the time.	● Get the current room temperature using an electronic thermometer, compare this to the reading from the sensor. The difference is less than 0.2 degrees C at least 9 times over 10 tries ● Get the current room pressure using an electronic air pressure gauge, compare this to the reading from the sensor. The difference is less than 0.05Atm at least 9 times over 10 tries ● Connect the motion sensor to power and the output. Take the motion sensor in one hand and wave it for 5 seconds, then stay still for 5 seconds. This will count as one trial. The motion sensor should correctly detect motion at least 9 times over 10 tries

Control System • Microcontroller will receive and interpret signals from the sensors correctly 95% of the time. • Microcontroller will send appropriate signals based on sensor input and User Interface input to the air pump and the air-valve 95% of the time.	• Have output signal from motion sensor, pressure sensor, and temperature sensor communicate with microcontroller. See if it is the correct signal and record if pass or fail. Repeat this 20 times, the microcontroller should receive the correct signal at least 19 times. • Measure the output of the microcontroller using a multimeter. Let the jacket sit still for 5 min in room temperature (higher than 18 degrees). The air valve and air pump output should be turned on. Move the jacket into a fridge at 0 degrees. The air valve output should turn on then turn off. Repeat this 20 times and the output should be correct at least 19 times.
Power • The battery will supply a voltage of 12(+/-2)V and power all the functions of the jacket for 12 hours. • The voltage regulator will output a constant voltage of 5(+/-0.1)V	• Hook the battery up to the system. Using a multimeter, measure the voltage across the battery. The voltage should be within 2V of 12Volts • Connect the battery to the jacket, the jacket operates properly for 12 hours. • Using a multimeter, the measurements of the voltage output of the voltage regulator is within the requirement level

2.4 Calculations

Jacket Length (US Medium sized) = 0.6m, Jacket width=0.5m, sleeve width = 0.2m, Sleeve length = 0.6m.

Surface Area:

$$\begin{aligned} Surface\ Area \ &= \ Length_{body} * Width_{body} * 2 + Length_{sleeves} * Width_{sleeves} * 4 \\ &= \ 0.6m * 0.5m * 2 + 0.2m * 0.6m * 4 = 1.08m^2 \end{aligned}$$

The amount of insulation that allows a person to maintain thermal equilibrium in an environment at 21 degrees C is 0.88R. While it's recommended that a R value of 1.76R is used for skiing. We will use this as the value we wish to achieve when the jacket is fully inflated. From the R-values of materials: Table of insulation r-values and properties for various insulation materials & building materials [1], we know that an air gap of 1.95cm will provide insulation equal to 0.87R. Since we will also use a normal jacket in addition to the air pockets for insulation, we will assume that the jacket we use will have a insulation of 0.88R. When the two values are combined together, we get the combined insulation to be 1.75R, which reaches our desired level of insulation.

Total volume of desired air: $1.08m^2 * 0.02m = 0.0216m^3$

2.5 Tolerance Analysis

The block that posts the greatest risk is the power supply. Since we are supplying power to sensors and microcontroller, it is crucial to maintain a steady voltage. We have established the output voltage to be 5V +- 0.1V. If the power supply cannot provide the desired voltage to the sensors and microcontroller, the jacket cannot perform the tasks correctly. Another thing to be considered is that we are attaching battery and voltage regulator on fiber, it is crucial that we maintain their temperature. If they are overheated, the fiber may burn and cause damage to the jacket and may even lead to bigger casualties.

III. Cost and Schedule

1. Cost

Labor - Assume an ECE graduate can earn 30 USD per hour. 30 USD * 600 hours = 18000 USD. We have three partners in the team, so 18000 USD * 3 = 54000 USD.

Parts

Item	Part #	Unit Price (USD)	Quantity	Total (USD)
Microcontroller	MSP432P401RIPZR	7.89	1	7.89
Air-valve	N/A	~5	1	5
Air-pump	N/A	~20	1	20
Air-Pockets	N/A	~20	10	10
Jacket	N/A	50	1	80
Temperature Sensor	LM35DZ/NOPB	1.56	1	1.56
Pressure Sensor	MS583702BA01-50	16.66	1	16.66
Motion Sensor	EKMC1693111	10.57	1	10.57
Voltage Regulator	LM7805CT	0.61	1	0.61
Knob	NA	~3	1	3
Battery	A23BPZ	3.2	2	6.4

Grand Total = labor cost + parts cost = 54161.69 USD.

2. Schedule

Week	Task	Responsibility
2/27	1. Figure out the relationships between PV = nRT and how do we apply on our design	Haoyu Wu Chuan Xie
	2. Determine which material we should use for the air pockets	Michael Hou
3/6	1. Start designing the the user interface	Haoyu Wu
	2. Design the position and layout of the air pockets, sensors, air-valve, air-pump, and batteries	Michael Hou Chuan Xie
3/13	1. Start programming the microcontroller	Haoyu Wu Chuan Xie
	2. Finish the power supply system	Michael Hou
3/20	Spring Break	
3/27	1. Continue to work on microcontroller	Haoyu Wu
	2. Start work on sensors design components	Chuan Xie
	2. Start work on body design components	Michael Hou
4/3	1. Finish the first draft of microcontroller	Haoyu Wu
	2. work on sensors design components	Chuan Xie
	3. work on air pockets design components	Michael Hou
4/10	1. Connect and construct the system components 2. Debugging and revision	Michael Hou Chuan Xie Haoyu Wu
4/17	1. Further Debugging and revision	Michael Hou Chuan Xie Haoyu Wu
4/24	1. Final round of testing and verification 2. Demo	Michael Hou Chuan Xie Haoyu Wu
5/1	Final Presentation and final report	Michael Hou Chuan Xie Haoyu Wu

IV. Ethics and safety

Safety is one of the most important concerns in our project. Although the jacket itself may not be dangerous, we must also put the safety hazards during the design process into consideration.
First, we need to make sure that the material we use for this jacket fulfill the safety requirements. we will use a stable, durable, and inflammable substance as our air pockets. One of our options is to use the material from the airbags in a blood pressure meter.
Second, we must consider the conditions and environment during the operation. Although the temperature indoor or outdoor is unlikely to pass the limit, precaution must be made. In case of overheated power supply that may burn the fabric, we may add a buffer material to our power supply to avoid direct contact of the power supply and the jacket.
Last but not least, to avoid the air pockets getting over pumped and explode, we may add a switch in the jacket that the user can manually leak the air in the air-pockets.

Cited Sources

[1] InspectApedia. *R-values of materials: Table of insulation r-values and properties for various insulation materials & building materials (brick, block, wood, soil, air gaps, etc)*. 2017. Web. 24 Feb. 2017. (http://inspectapedia.com/insulation/Insulation_Values_Table.php#Air)

[2] Geofrey. "Insulation: What you need to know to stay warm this winter." *SYNC News*. Performance First, 29 Sept. 2015. Web. 24 Feb. 2017 (http://www.syncperformance.com/blog/insulation-what-you-need-to-know-stay-warm-this-wint e r/)

[3] N.D. Web. 24 Feb. 2017. (https://en.wikipedia.org/wiki/Clothing_i)