Self-Adjusting Jacket

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Final Report for ECE 445, Senior Design, Spring 2017
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03, May, 2017
Project No. 76

Abstract

This report documents a solution to the problem caused by the rapid temperature rise/drop throughout the day. We designed a jacket with adjustable-thickness airbags, air-pump/valve, microcontroller, and sensors that the jacket can adjust its thickness based on the current environment and/or by user preference. Although this design is only in its prototype, and require more trials and testings to be commercially available and user-friendly, our design does meet the specification of our original proposal. With further improvements and revises, we believe this project can be brought to the society and bring convenience to people's daily life.

At last, we would like to thank those who contributed to this project, especially our TA Kexin and each member of the team. Without those support and hard work, this project may never come out with a successful result.

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I. Introduction

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 50-60 Fahrenheit during the day. This makes choosing a suitable jacket very hard. Wearing a thinner jacket, you will be fine during the day but feel cold in the morning and at night. On the other hand, wearing a thicker jacket will make you sweat a lot during the day but feel just right in the morning and at night. In addition to that, we also noticed that indoors are usually heated, so you would need to take off coat/jacket to avoid sweating inside buildings.

The goal of this project is to make a jacket that can sense the temperature outside and adjust the "thickness" of itself automatically. To adjust its thickness, we 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.

II. Design

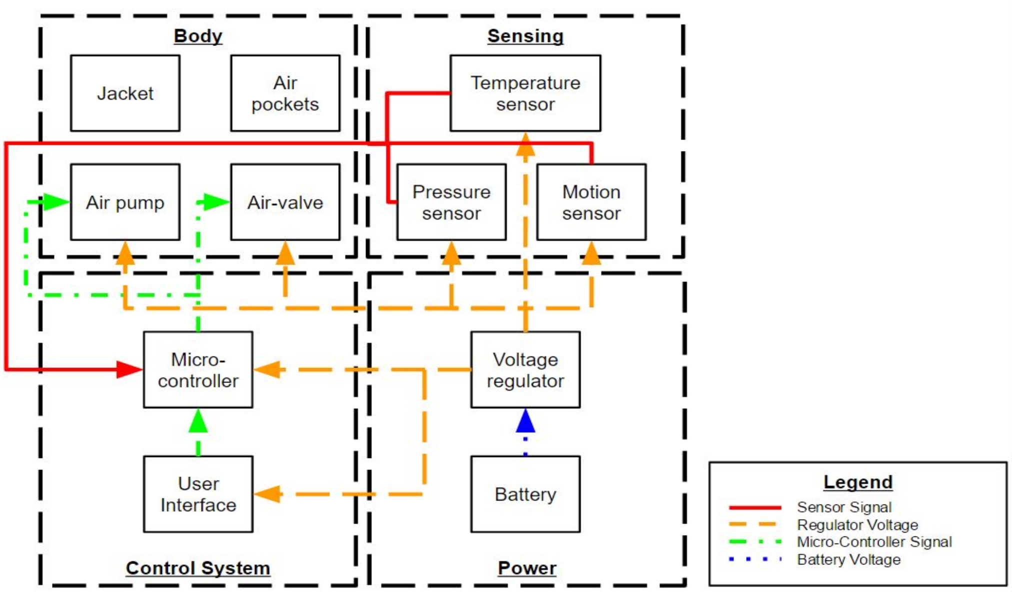

Figure 1. Block Diagram

2.1 Design Procedure

The Self-Adjusting Jacket, on the outside, will look 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. At the bottom of the jacket, the air bags are connected to the air valve and 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 which is placed at the collar of the jacket. Each of the blocks from figure 1 will be described in details in this section below. Any changes we made in the blocks during the semester will also be stated below as well. Overall, our design meets most of our requirements for our solution to the proposal.

2.2 Design Details

2.2.1 Main 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 are made air-tight and serve as the adjustable thermal insulating layer. It is important that there is 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.

Air pump:

In our initial proposal, we planned to use a more powerful air pump. However, the problems comes with it is that the the air pump is heavy and loud. So we replaced it with a much smaller size air pump. Even though the new motor requires more time to pump the airbags to full capacity , but we want to keep our jacket as light as possible. Also, we do not want the noise to bother users.

Air bags:

The airbags need to be foldable, flexible and lightweight so that air bags can wrapped around the Jacket. Users should feel comfortable wearing the jacket even with the air bags pumped.

Air is a very good insulator because the molecules of air are very apart, thus do not transfer heat very well. We use R values (Thermal Resistance) to measure the insulating property of air bags. The R value for air gap 1.95 cm thick is 0.87 and the air bag we use in our design is 2cm thick. The recommended R values skiing is around 1.7, so to achieve this values, we use a light spring jacket, which typically has an R value of 0.9 to fulfill this requirement.

Figure 2. Air Bags

Air-valve:

The purpose of this air-valve is to release the air in the airbags. Our air-valve in this project is a passive air-valve, which means that when the microcontroller sends the signal that indicating the air need to be released from the airbag, the valve will open but do not actively drain the air but will let the air been released as time goes by. Our air-valve will open when it receives a min. 12.8V from the microcontroller.

2.2.2 Sensing Unit

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.

Figure 3. Temperature Sensor

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. We also have a physical size requirement for pressure sensor. Since we connect all the components with pipes, we want the to able to connect the Pressure sensor with pipes so that it can detect the pressure inside the system. The pressure sensor we choose has a 1.8 * 0.8 mm O-ring that can exactly fits into our tubes.

Figure 4. Pressure Sensor

Motion sensor:

The motion sensor measures whether the jacket is currently being worn or not. It sends the information to the microcontroller. Taking into consideration the numerous different locations a user can be in (driving, outside walking, sitting down), we will record how the sensor acts in a moving car vs when it's on someone walking. The motion sensor we use is an infrared motion sensor. We placed the motion sensor inside the jacket, so that when the jacket is being worn by the user, it should not detect any light and therefore indicating the microcontroller that the jacket is been worn and is in motion. However, this will not pump/stop pump the air since this information is not enough to tell the jacket is indoor or outdoor. We will combine with the data from temperature sensor; if the temperature is high and the motion sensor detects user is wearing the jacket, this means the jacket is indoor. Vice versa.

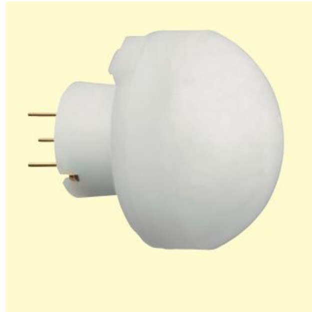

Figure 5. Motion sensor

2.2.3 Control system

Microcontroller:

We bought two types of microcontroller MSP430 and MSP 432. MSP430 has fewer pins and relatively easier to setup. However, we could not get the serial print function work on the computer with this type of controller. The serial print functions is very important for programming and debugging. So we replace it with MSP 432. We were able to use the serial print function to debug the code and analyze sensor data from this type of controller.

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.

AnalogRead and DigitalWrite were the two main functions we used in our control logic. AnalogRead maps voltage 0-3V to integer values 0-1023. That being said, we can use the inter value to interpret output from sensors. DigitalWrite will output a constant 3.3V signal that feeds into transistor to power air pump and air valve.

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 from the user 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 6. Flow chart for the micro controller

User Interface:

We designed the user interface by using a on-off button 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. From our proposal, our original idea is to use a knob. After modulation, we decided to use two on-off buttons for air-pump and air-valve respectively. In this way when user wants to pump/stop the air he/she would only simply need to push the button. Same way to use the button for air-valve to release/stop release the air.

2.2.4. Power

Battery:

The battery powers the entire electrical systems of the Self-Adjusting Jacket. 4 AA batteries provide 6V voltage, which feeds directly into the voltage regulator.

Voltage regulator:

The voltage regulator takes a voltage input from the battery and outputs a constant 3.3V voltage for the control systems, the body, as well as the sensors. This ensures the correct operation of the systems.

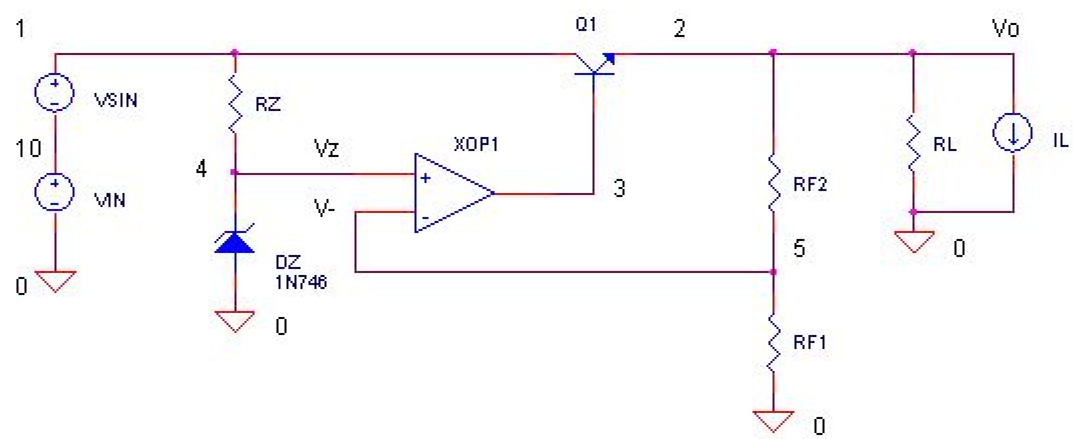

Figure 7. Voltage Regulator Schematic

III. Verification

We had many requirements and verification for our project. These are shown in detail in Appendix A of this report. In this chapter we will discuss only a few of the more important and complicated requirements and verifications.

3.1 Main body

The primary purposes of the jacket we designed is to keep the user warm, thus one of our three high level requirements we listed was that the jacket provides enough thermal insulation for the user to stay warm in an environment with a temperature of 0 degrees Celsius. However, because the project was finished in late April, the weather did not permit us to realistically verify the exact requirement. Instead, using the fact that insulated air gaps of 2 cm, in addition to a spring jacket, provides a R value of around 1.7, which would satisfy the requirement, we verified that the air bag has a thickness of at least 2cm (+/-0.1cm) when it's pumped up, and that an hour after the bag was pumped up, it's thickness has reduced less than 0.3cm.

3.2 Sensing

Another high level requirement for our jacket is the ability to automatically adjust the thickness of the jacket when a temperature change of more than 1 degree Celsius occurs. In other words, the temperature sensor in our jacket, as well as the analog reading ability of the microcontroller, must be able to differentiate a temperature change of more than 1 degree Celsius. To verify this requirement, we first measured using a thermometer that the room temperature is 23.2 degrees Celsius. We then measured the outside temperature of a finger, which is 37 degrees Celsius. With the temperature sensor connected to the microcontroller, and not touching anything else. we read a value of 676 from the microcontroller. Next, a finger is pushed on top of the temperature sensor and the subsequent values read by the microcontroller is observed and collected (table 2) until the the value read by the microcontroller is 480, when it's no longer dropping. We noticed that the microcontroller value drop is very linear. Assuming that the temperature increased relatively linearly, we matched values read from the microcontroller to real temperatures. By doing so, it was observed that for each degree of temperature difference, the microcontroller value changes by around 13. During previous testings on the sensor, it was observed that in an environment without temperature change, the value read by the microcontroller varies up and down by a max of 3, meaning that if the microcontroller value changes by 6 or more, it's very likely that the change is caused by a change in temperature. Referencing back to the linear model, a value change of 6 corresponds to a temperature difference of around half a degree. This verifies that the temperature sensor and the microcontroller can differentiate a temperature change of more than one degree.

Time (seconds)	Value	Temperature (°C)
0	676	23.2
45	636	25.8
90	593	28.6
135	551	31.4
180	513	34.2
225	480	37

Table 2. Relation between sensor's value and temperature

IV. Costs

Part costs:

Item	Part #	Unit Price (USD)	Quantity	Total (USD)
Microcontroller	MSP432 Launchpad	13	1	13
Air-valve	N/A	3	1	3
Air-pump	N/A	20	1	20
Air-Pockets	Square Cushion	16	1	16
Temperature Sensor	LM35DZ/NOPB	1.56	1	1.56
Pressure Sensor	MS583702BA0150	16.66	1	16.66
Motion Sensor	EKMC1693111	10.57	1	10.57

Voltage Regulator	LM1086CT	6.45	1	6.45
Battery Placeholder	N/A	1.2	6	7.2
Battery	AA	1	4	4
PCB	N/A	35	1	35
			Total parts cost	133.44

Table 3: Components Cost

Labor cost:

Assume UIUC ECE student average hourly rate is 30USD/hour, we spent approximately 200 hours on this project, and we have 3 members in this team, so total labor cost is: 30 * 200 * 3 = 18000 (USD).

Total cost of this project is: Part cost + labor cost = 133.44 + 18000 = 18133.44 (USD).

V. Conclusions

5.1 Accomplishments

Our implementation achieved most of the the functionalities that we proposed. When temperature rises, the temperature sensor detects the change of temperature and will indicate the microcontroller to send signal to the air pump to pump the air bag. Prior a week before the final demo, when we were soldering the pressure sensor with wires, we accidentally burned the pressure sensor. So instead of using pressure sensor to determine the air pressure inside the airbag, we set a timer to indicate the air pump to stop pumping the air. With the infrared motion sensor, we can detect the motion and start/stop pumping the air. Overall, our design does meet most of the specification of our proposal.

5.2 Uncertainties

As we try to put our whole circuit together, we accidentally burned our pressure sensor. The pressure sensor that we use in our project is very small (3.3 * 3.3 * 2.75 mm) , so it is very hard to solder wires onto the pin. In addition to that, the unit cost is very high (16 USD unit cost), so we didn't have any backups. The purpose of using pressure sensor in our project is to detect the pressure inside air bags so that we will not over-pump the packets. Our remedy is to use a timer in our control logic.

We took forty trials in total and calculated the average time to pump the air bag to full capacity is around two and half minutes. We use the internal clock inside the microcontroller to count the time. Each clock cycle is half seconds, thus we use a counter that counts up to 300. This will definitely bring uncertainty to our project since the actual desired time to pump the air bags may vary.

5.3 Ethical Considerations

Our project follows the IEEE Code of Ethics with the following [4]:

1. To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.

2. Our design will be carefully checked that it is safe to used in public. And all dangerous elements will be isolated or disclosed to the public in the safety statement.

3. All the data above will be calculated and estimated accurately by team members. Estimation made by team members will be realistic and be proved by simulation.

4. To improve the understanding of technology; its appropriate application, and potential consequences.

The goal of this project is to provide user a self-adjusting jacket that can adapt itself of temperature variation to make user feels comfortable wearing it.

5. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations.

The process of designing this project has been under caution, and only done after completely understand the concept of the project.

6. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.

This project has been reviewed by Professors, Teaching Assistants, and other classmates in Senior Design class (ECE 445). All resources that we use for this project are cited and can be found in the end of this document.

5.4 Future Work

Our design at this moment is just a simple demo of what we proposed. In the future, we would like to improve our design so that it may be commercially available to the public.

First of all, we would want to redesign the shape of the airbags so that they can be fitted inside the jacket. Right now we only used a piece of airbag. In the future, we would want to add more airbags in the front and the sleeves of the jacket to improve the thermal insulation. There are several solutions we can come out right now. First, we can connect several different shape of airbags with air pipes. The advantages of this solution are that we only need one set of system, which reduces the cost of the project. And it is easy to connect two or more different airbags. The disadvantages, on the other hand, are the low efficiency of pumping/releasing the air in the airbags and not enough thermal insulation provided by the jacket since there are gaps between each of the airbags. Another solution is that we can find an airbag that can be fitted and covered the entire jacket. This solution we can use only one set of system while also maintain efficiency of pumping/releasing air. But it is hard to find an airbag that can be fitted in the jacket.

Secondly, we can also implement a rechargeable battery like Lion battery and an USB charger. This not only avoids waste of batteries but also provide more power than normal AA batteries. And by adding a power indicator we can find out how much power left is in the battery.

Last but not least, we would also want to add a LED panel which attaches to the jacket and can show the information such as temperature, percent of air is filled inside the airbags, and how much power left in the battery. I think this feature is the most important factor since it provides so much more functionality and is more user-friendly. We can also add bluetooth feature to the jacket so that we can control the jacket to pump/release the air remotely.

VI. Citation

[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-win te r/)

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

[4] IEEE Code of Ethics. March 9, 2017. http://www.ieee.org/about/corporate/governance/p7-8.html

Appendix A. Requirement and Verification Table

Team 76 RV Table

Requirement	Verification	Points
Body: ● The air pump will start pumping the airbag when temperature sensor detects temperature rise and motion sensor detect no motion ● The air valve will release the air in the air bag when temperature is high and there is motion detected by the sensor ● The inner air pockets, when pumped full with air, is at least 2cm (+/-0.1cm) thick and is airtight enough that 1 hour after it's pumped up, its thickness is within 0.3cm of what it was when it was first pumped up. ● The air pump and can pump air into the air pockets to a thickness of 1.95cm within three minutes.	● When we hold the temperature sensor with our hand, while keeping the motion sensor still,the air pump will start pumping the air bag ● When we hold the temperature sensor with our hand, while keep the system moving ,the air valve will start releasing the air in the air bag ● Attach the air pump to power. Turn on the air pump for 3 minute. Measure the average thickness of the airbag. ● Within the trial of 10, the air pump can fill the air in the airbag within 3 minutes	● 6 ● 6 ● 4 ● 4
Sensing ● We want to know the current environment temperature when is temperature is above 18 degree celsius, so that it can help us decide if the user is indoor or outdoor. ● We want to detect the different activity of users . For example, we want to know if the user is walking, driving or just being static.	● We can use a temperature sensor to help us decide the current temperature. To make the reading accurate, we should pretest the sensor before installing to our circuit. We can compare its reading with an electric thermometer so that we know if it works properly. ● The motion sensor detects motion by measuring the difference of infrared light. We will first block the light from motion sensor, motion sensor will assumed this is a static environment. The microcontroller will receive low signal. Then we will remove the block from	● 5 ● 5

	light and let the motion sensor detect motion. The microcontroller should receive high signal indicating the system is in motion	
Control System ● Microcontroller will receive signals from the sensors correctly 95% of the time. ● Microcontroller will send correct signals based on sensor input and User Interface input to the air pump and the air-valve 99% of the time ● Sampling rate is 14 bits per second	● Have output signal from motion sensor, and temperature sensor sending signals to the microcontroller. Check the output of the microcontroller matches to our desired response by printing out the value inside IDE.. 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. The air valve and air pump output should be turned on if the output signal is correct. Repeat this 20 times and the output should be correct at least 19 times.	● 6 ● 6
Power ● The battery will supply a voltage of 6 (+-1)V and power all the components of the circuit for at least 2 hours. ● The voltage regulator will output a constant and stable voltage of 3.3(+/-0.1)V ● The maximum current draw should be no more than 1 amp	● Connect the battery to the system. Using a multimeter, measure the voltage across the battery. The voltage should be within 1V of 6 Volts for 2 hours ● Connect the battery to the voltage regulator, the system should operates at least for 2 hours. ● Using a multimeter and resistors, the measurements of the current is under 1 amp until the battery is fully discharged	● 4 ● 2 ● 2

Table 4. R&V table