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April 16, 2009

Mr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 440/305 Project Post Mortem for Smart Stove

Dear Mr. Leung,

The attached document, *Smart Stove Post Mortem*, outlines the first phase of our prototype. Smart Stove is an innovative pixilated induction cooktop that allows the users to put the cookware anywhere on the surface. Our project phase has finished its first developmental phase, but will continue on to implement additional features that will ultimately take our project into a marketable product.

Our post mortem describes the current state of Smart Stove, as well as the design challenges that we had encountered and the future works that we will be taking on. Budget and schedule analysis will also be discussed in the post mortem, which determines the accuracy of our initial estimates and if future adjustment need to be made.

Thermopix Inc. is comprised of four creative, motivated and experienced engineering students: Phoebe Liu, Claire Wu, Hao Su and Andrew Lin. If you have any questions or concerns regarding our proposal, please feel free to contact me by phone at (604) 436-5755 or by e-mail at pliu1@sfu.ca.

Sincerely,

Phoebe Liu
Chief Executive officer
Thermopix Inc.

Enclosure: Post Mortem for Smart Stove

Smart Stove Post Mortem

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2. Abstract

The heating technology of the Smart Stove is based on the method of induction cooking. Induction cooking has already long been widely accepted around the world, both in a professional and personal realm. In recent years, induction technology has improved exponentially, while development and production cost has reduced dramatically. Smart Stove makes many new and exciting high-tech improvements to the traditional induction cooker, adding the ability for the user to place the pot anywhere on the smooth cooktop with our arrays of pixilated heating elements.

The development of the Smart Stove will occur in several iterations. Thermopix Inc. has made the decision to outsource the control circuit for our system, due to the power constraints imposed by the electronic components and the power supplies. This will minimize the design decisions, thus minimizing the susceptibilities from external factors. This does not imply that the development of the Smart Stove will be limited to the control circuit, rather design decisions will be made to improve Smart Stove.

The second iteration of the development will focus on the software algorithms that will automatic categorize each pots as an individual component, as well as controlling the specified pot. Design decisions will also be made to ensure that Smart Stove fulfill the safety and environment standards. Other design considerations will focus on the casing and mechanical calibration of the cooktop to ensure that the system is capable of withstanding the specified weight and pressure.

The post mortem will evaluate the developmental process that Thermopix has undertaken to reach the current phase of the project. The post mortem document the current phase of the project and the design challenges encountered, to reach the completion of this proof of concepts by April, 2009. The post mortem will also state the direction Thermopix will take to reach our ultimate goal of commercializing of the Smart Stove. Throughout the process, each team member will documented their experiences of the project, which will be discussed in this post mortem as well.

2. Current System State

2.1 System Overview

The overall Smart Stove system is shown in Figure 2.1, and the subsystems can be categorized into input conversion module, control and processing module, power generation module, and output conversion module.

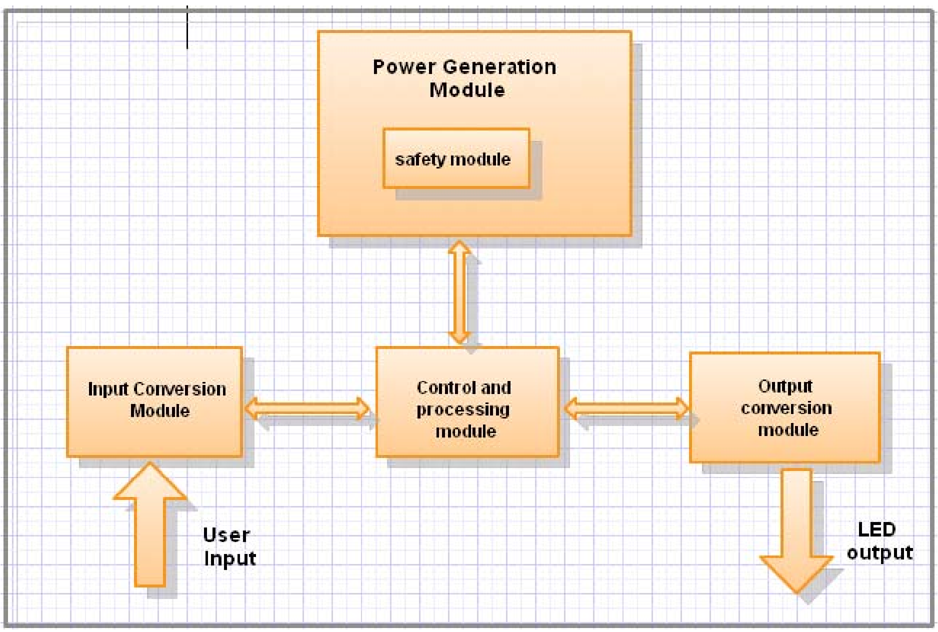

Figure 2.1 Smart Stove system overview

The Input Conversion Module includes the temperature adjustment buttons, temperature sensors, and the cookware detection hardware and algorithms. The Power Generation Module includes the power circuits that generate a resonance waveform for the induction coils, and the DC circuit that powers the input, control and output modules of the system. The safety module is contained within the power generation module because high voltage and current need to be shielded from the user. The safety module includes the insulating case that covers the power circuitry, as well as heat sinks to prevent overheating, and fuses and regulators to prevent abnormally large currents and voltages. The output conversion module displays information about system status to the user. This includes the induction coil LED display and the temperature control LED display. Finally, the control and processing module includes microcontroller and other logic circuits that controls and regulates the operation of the Smart-Stove.

2.2 Power Module

The power generation module provides induction heating to the system. In layman term, the power source used in our system is from the AC power supply, which is then converted to DC using a rectifier. The DC current goes through a high frequency switching circuit to provide high frequency current to the heating coil, which then creates a high frequency magnetic field around the heated induction coil. Generally speaking, induction cook-top employs two types of topology used in the power system: a half-bridge series resonant converter and a quasi-resonant converter. Since Smart Stove requires high voltage and high frequency with the least components, we adapted the quasi-resonant converter.

The power module of Smart Stove prototype is composed of two step-up transformers which are 1KW and 2KW in power rating. Due to the power constrains of step-up transformers, Smart Stove prototype can only trigger a maximum of 6 induction coils at the same time. With our power distribution design, each coil is powered by its assigned transformer in the way shown in Figure 2.2. The control main algorithm is distribute the power evenly to the coil between the two transformers.

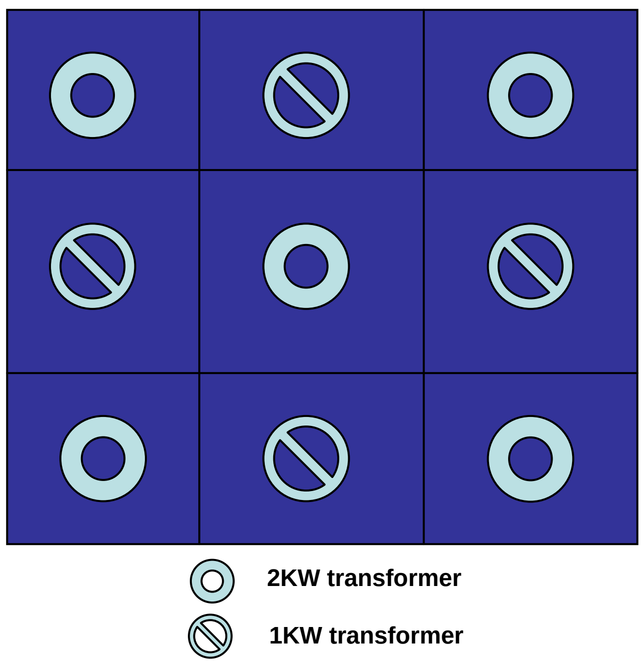

Figure 2.2 power distribution design

2.3 Input Conversion Module

The input conversion module consists of temperature sensing, pot sensing, and temperature adjustment sub-modules.

Temperature sensing

The temperature input signals are generated by temperature sensors whose outputs are fed to comparators with a reference voltage. With a supplied reference voltage, temperature input signals are applied to positive terminal for comparison. We note that the temperature input signal is normally lower than the reference voltage. Therefore, the output of comparator is high as long as the reference voltage is greater than the applied voltage in this specific design. On the other hand, ground potential output will be generated if the input voltage is higher than the supplied reference level. Temperature interrupt sequence will be triggered once a low output signal is applied from a comparator.

Pot sensing

In current pan sensing technology, the two most popular sensing methods are current pan detection and pulse pan detection. The pulse pan detection method is selected in Smart Stove design due to the following advantages: low power consumption, stable detection distance, and high resolution. Pulse sensing method can be achieved by determining the status of IGBT and pulse counts. In such design, the IGBT will be off if there's no load on the surface of the stove. A high signal will allow the IGBT to operate at a fixed period of time, at which time the system will start counting pulses. By comparing the total counting pulses and the setup standard pulses, the system will be able to conclude if the pan allocates on the surface for detection purposes.

Temperature/pot adjustment

In the Smart Stove's temperature adjustment module, users are able to select from four different temperature levels, 350, 300, 250, and 0 degrees Fahrenheit, for each heating cookware. The user adjustment interface is shown in Figure 2.3.

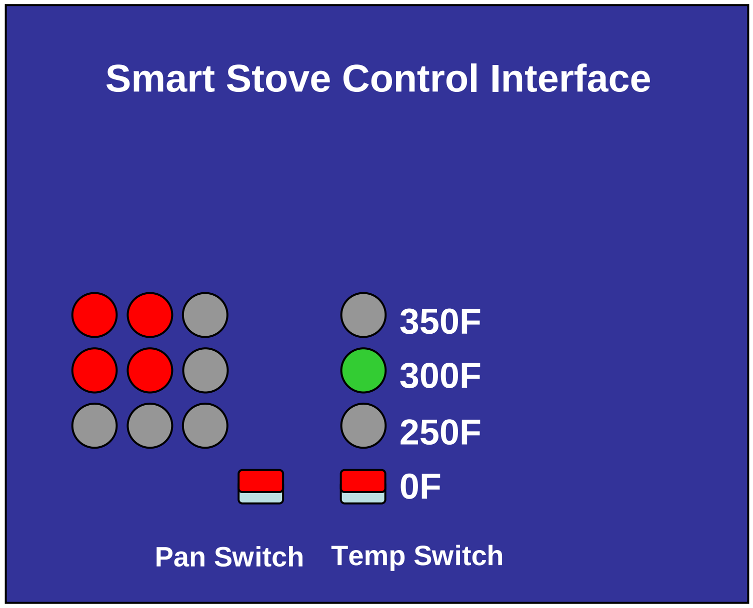

Figure 2.3 control interface

The square 3 by 3 LED lights represent each heating element on the cook-top surface for indicating if there is a pan on. Due to our pan detection design constraint, each time the user place a new cookware, he needs to press a reset button to store the current information as which coils are being used. Pan switch button switches between different pot and the corresponding LED(s) associated with that pot. User can adjust heating level with temperature switch button.

2.4 Control and Processing Module

General processing algorithm

Figure 2.4 shows the control algorithm of Smart Stove. After the user places a cookware on the stovetop, the inductive heating elements below will sense the change in inductance and get powered on, thus the induction heating begins. Initially, after the cookware has been detected, the system sets the goal temperature to a default value to ensure that the heating begins immediately. The user is then prompted to enter a new desired temperature as the goal temperature using one of the temperatures setting button. Each inductive coil heating element is fitted with a temperature sensor, and the detected temperature of the cookware is the average of all temperatures sensed by the coils below the cookware. Once goal temperature is exceeded by 5 degrees, the induction coils under the cookware will be powered off, while the temperature sensors keep detecting the temperature of the cookware. When the temperature of the cookware dips below the goal temperature again, the elements below the cookware will turn on again to resume heating. Heating will stop permanently when the user removes the cookware or power off the system.

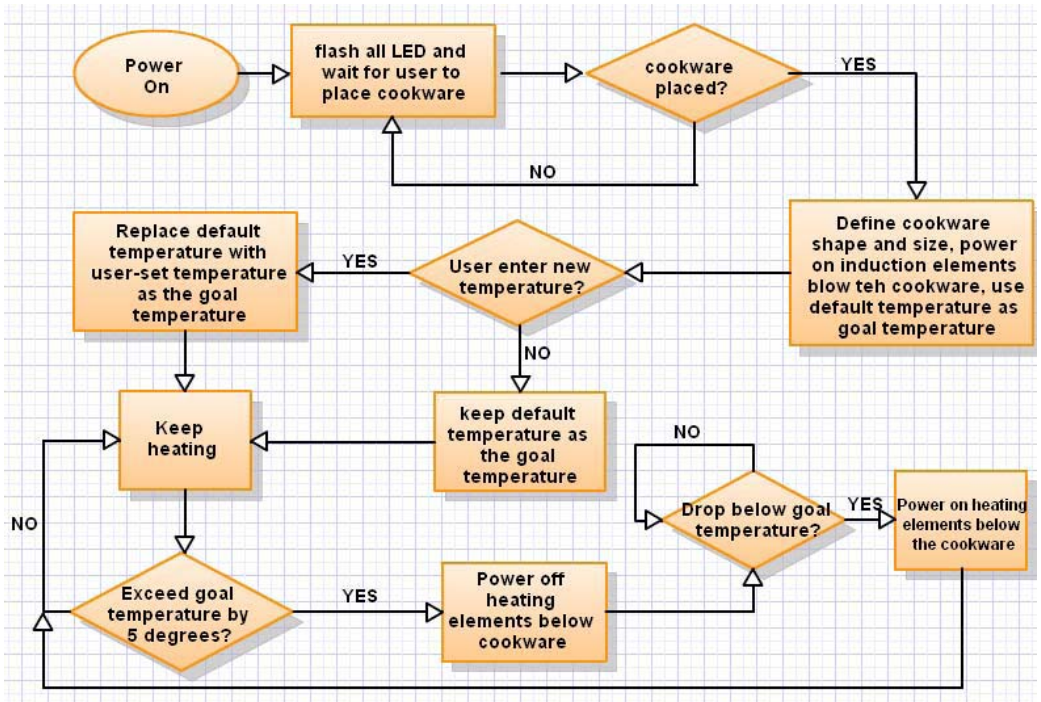

Figure 2.4 Control algorithm of Smart-Stove

2.5 Output Conversion Module

Pot detection and temperature visual Indicators

As shown in Figure 2.3, the control interface panel is the major output conversion module in Smart Stove system. A 3 by 3 LEDs array is the indicator for pan detection. Once a pot is placed on the surface of the Smart Stove, LEDs will light up corresponding to detected heating elements. With pan switching mechanism, the position of different pans will light up one by one on the LED indication panel.

Three LEDs are used for temperature visual indicator, and four levels of temperature control levels are listed as: 350F, 300F, 250F, and 0F degrees Fahrenheit. Switching between temperature levels, the corresponding temperature LED will light up as an indicator.

3. Design Challenges and Results

3.1 System Overview

Ever since our first proposed design, we have undergone and changed several design parameters to reach our current state. Most of the design revision occurred with our hardware limitation, thus leading to the revision of the software. We had modified our original design to stay within our budget, and also making our system more robust, and versatile. The current system state is described in the section of the current state overview, as shown in Figure ? in the previous section.

3.2 Power Module

During initial developmental phase, we decided to use the half-bridge series resonant converter configuration as our power generation module. When 220V AC voltage is applied to the circuit, it goes through a diode bridge and then is leveled by a capacitor, which also the filters out high frequency current from entering the input circuitry. After DC voltage is applied to the load through the IGBT half bridge at high switching frequency, the circuitry creates a magnetic field around the resonant inductor, affecting the load (pot on the plate). Because operating frequency is set at 27kHz, the MOSFETs were not fast enough to keep up with the switching current, and therefore got hot. For that reason, we adapted the quasi-resonant converter topology, which only employ one MOSFET, and prevent the problem of the MOSFET heating up.

As stated in our proposal, the induction surface array is composed of 4 x 4 heating elements. Because of the number of pins available to use in PIC18F4520, we can only implement a maximum of 9 heating elements, limiting our induction surface to a 3 x 3 pixilated array. Power issue was also constrained by the maximum amount of currents that can be drawn from the transformers. A maximum of 30 amperage of currents can be drawn from the two transformers, resulting in a maximum of six induction coils being powered on at any given time. This resulted in initial specification being sacrificed.

3.3 Input Conversion Module

The development of the input conversion module was completed within the proposed specification that was stated out in the proposal.

Temperature sensing

Temperatures sensing are limited by the resolution of the analog and digital converter. The ADC has 10 bit resolution. This limits the temperature range. A calibration of variable resistors and real ambient temperatures was carried out, then plotted in excel to determine the relationship of the ADC output as a function of the variable resistor values. A linear function was extrapolated. However, this function is merely an estimate, thus impeding the temperature sensors' accuracy. As a result, temperature sensors will not achieve 100% accuracy, and will have an error margin of ±5°C.

Pot sensing

As discussed in our current state section, Smart Stove will adapt pulse sensing method. When a load is presented, the IGBT will output a PWM signal of approximately 27 KHz. When a load is absent, the output signal is a DC 5V. The output signal then goes through a high pass filter, which brings the voltage down to a range of -2.5V to 2.5V. A diode acting as a rectifier cuts off the negative voltage, and a capacitor filters out the remaining AC voltage. Finally, a BJT transistor amplifies the voltage to either a 5V (no load) or a 0V (with load). However, the output signal before the high pass filter will periodically jumps to about 3V, resulting in the amplified BJT voltage not reaching threshold voltage. This results in the microprocessor unable to read the correct high and low signal, when input voltage does not reach threshold voltage. The algorithm had to be calibrated correctly to achieve correct pot sensing. This design challenge also lead to a 2 second interval between placing a new pot on the cooktop surface. The 2 second interval will ensure that data are stored properly and there is enough time to sense the 5V DC voltage properly, after voltage fluctuation is taken into account.

3.4 Control and Processing Module

General processing algorithm

While developing the general control algorithm, we took into consideration of all possible cases, while ensuring that only a maximum of 4 coils will heat up at any given moment. One of the design challenges is to allocate the number of pins on the PIC18F4520 efficiently so there is enough number of pins for our control algorithm. To reduce the number of pins used, shift register, analog and digital multiplexers are used. The design challenge is to incorporate the components so that they function within the specification. The oscillation speed of the microchip also limits the speeds for pan detection and LED output. A delay was added to turn the pot on and off, reducing performance speed.

Another design challenge was the memory available in PIC18F4520. Variable definition in the algorithm was changed to free up memory space. Main algorithm was structured to have long repeating loop, one within another, reducing the performance speed once again. The algorithm was optimized so that the maximum performing speed was achieved. As mentioned above, in order to overcome these design challenges, initial specification was deviated and sacrificed. Another design challenge was the integration of software and hardware, which resulted in long, tedious debugging sessions.

3.5 Output Conversion Module

Pot detection and Temperature Visual Indicators

According to our proposal, initial speciation of the output conversion module consisted of a touch screen with a GUI to indicate which coils are being powered on. After careful examination, this option was not feasible given the amount of time we had. Instead, a 3 by 3 LED was adapted as the indicator for pan detection. Since LEDs was fed by shift registers, the LEDs needed to be grouped such that they corresponded with the temperature sensing circuits. A design challenge was to make sure the LEDs are arranged in the most efficient manner.

Coil Inductance

Another design challenge that we encountered is when the coils are placed close to each together, the inductor on the power board will make a strange noise. This is due to the fact that the magnetic fields emitted by the coils interfere with each other. We had to look for ways to shield the magnetic fields produced by each coil, thus the mutual inductance will not interfere.

4. Budget and Timeline Evaluation

4.1 Budget

The table below compares our estimated cost at the beginning of the semester with the actual cost incurred for our project.

Part Description	Estimated Prototype Cost	Actual Prototype Cost
Induction heating Elements x 9	$500	$215
LCD screen with touch panel	$150	$0
Glass Ceramic Counter Top	$100	$31.92
Microcontroller with EEPROM and Flash	$35	$199.27
Motors and Sensors	$20	$0
Power Supply Regulator high wattage	$220	$0
Case and Buttons	$50	
PCB Manufacturing	$80	$123
Other Electronic Part	$50	$803
Total	**$1,205**	$1,372

Table 4.1. Estimated Costs and Actual Cost

Thermopix had gone over our proposed budget because of the shipping cost incurred by getting parts from China. Although the actual component purchasing cost were cheaper, but shipping cost were higher. We managed to borrow two transformers, one from the Science department and one from Dr. Ash Parameswaran, cutting our cost drastically. We also decided to use wood coated with high heat resistance protective paint as a substitution for ceramic glass cover, cutting our cost even more. Power board testing cost us the most, since probing with an oscilloscope often cost an accidental short circuit or wiring incorrect transformer blew up the fuse or the entire board. Thermopix applied to the Engineering Science Student Endowment Fund, and successfully received approximately $700, but this funding was not enough to cover the whole developmental cost. Each of the team members had agreed to contribute an equal share of money to the remaining cost.

4.2 Timeline

Figure 4.1 shows our proposed schedule. We have deviated from the original schedule.

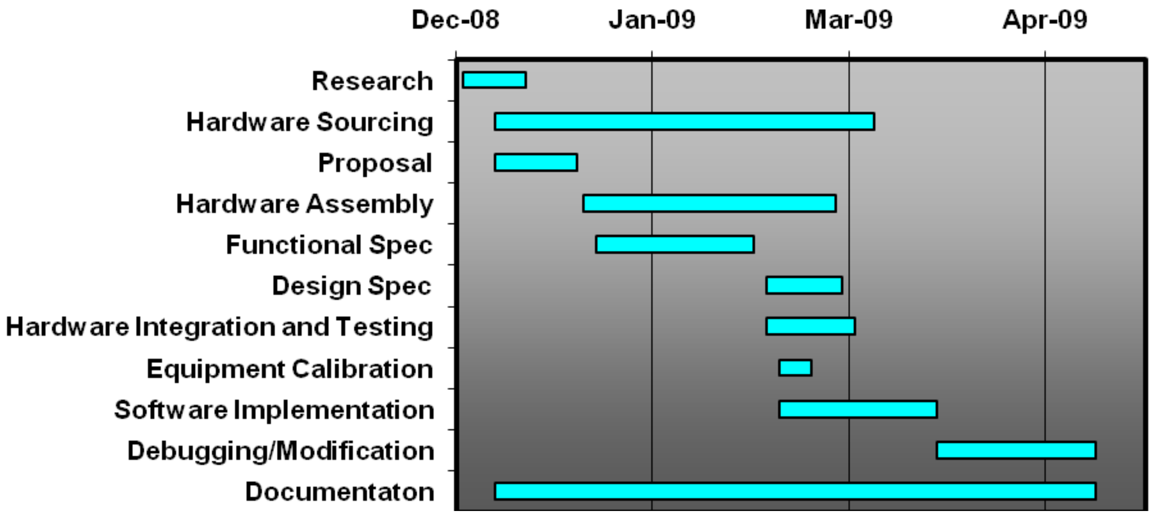

Figure 4.1 Proposed Timeline

The following Gantt chart below is the actual time distribution that our project team followed during the developmental phase. Our plan does not really match the reality; our plan does not really match the reality; we often faced problems and new issues that we were not expected as the project goes. We spent about a month developing the power board, and found that it is just simply too expensive, and often the hardware run into problem. These affected our schedule a lot. We believe if we need to do another schedule in the future, we will have more experience and be able to come up with a more reliable schedule.

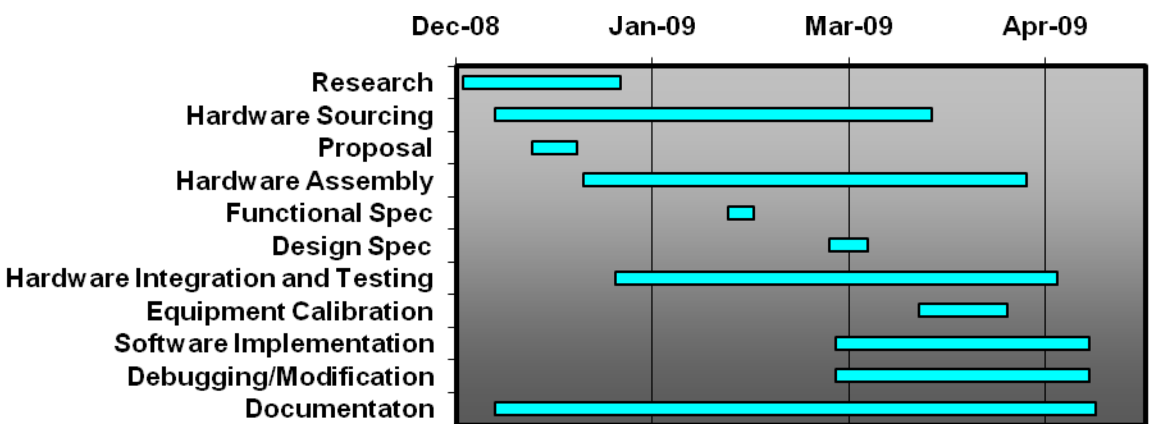

Figure 4.2 Actual Timeline

5. Future Design Plan

Thermopix has a great potential for further research and improvement. There are five major directions to develop Smart Stove to a more success product:

5.1 Power Distribution Efficiency

Due to the time constrain of the project, we didn't manage to design the whole induction stove system by ourselves. The outsourced power board is designed to draw 3A-4A of current from wall. Each coil has a power rating of 880W. Connecting the coils in parallel will add the coil current together; this is not practical since a normal household power outlet can only support a maximum of 20A with 220V. In the current design, we can only power up to four coils at the same time, so we have to implement software algorithm in order to select between heating elements. For example, if the pot is placed on 4 heating elements, we can trigger two diagonal ones to maximize the use of heating area. However, this constraint can be overcome with a more power efficient design on the power board. Power distribution efficiency can be either accomplished by lowering the power consumption on each coil. Lowering the power consumption of each coil will significantly decrease the overall current drawing from power outlet. This way, more coils can be controlled and powered with a standard power source. Also, we can reach high power distribution efficiency with an advanced power circuit design to control power distribution by calculating the percentage of heating elements used. For instance, with existing pan detection mechanism, we would be able to determine the numbers of heating elements used overall. By dividing the number of coils with power source maximum rating, power is distributed evenly within the supporting power range. In this design, we can ensure that power consumption will not exceed the limit at each standard power outlet/source.

5.2 LCD Touch Screen Control Panel

The first stage of Smart Stove prototype uses LEDs display as pan detection/ temperature adjustment user interface panel. In future design, Thermopix is planning to implement an LCD touch screen control panel for selecting pans and adjusting temperature levels with visual display on LCD screen. Also, with touch panel design, users can select and change temperature by touching the pot displayed and then selecting desired temperature level. This user interface will improve the usability. Thermopix will aim to implement LCD touch screen control panel as our 2nd stage of prototype version.

5.3 Multi-Pan Detection

The current design of Smart Stove is unable to detect pan if they are placed within 2 seconds of each other. Smart Stove is limited by the 2 seconds interval before placing another cookware. However, this limitation can be discarded if we can shorten the pan detection mechanism to few milliseconds. Thermopix is currently scheduling this implementation in 3rd stage of design prototype.

5.4 Movable Sensing Detection

People sometimes move cookware around during cooking process, so it will be a good to detect moving cookware. In current prototype, once the pan is detected, the position is stored in the microprocessor memory. Temperature adjustment can only be controlled according to the stored positions. The current design is unable to detect a pan moving or change the temperature of the pot at the new position. In future implementation, Thermopix is planning to add the feature of movable sensing detection.

5.5 More Pixels of Heating Elements

In the current design stage, we only constructed 3 by 3 heating elements.In the future, Thermopix will further investigate on the relationship between energy efficiency and number of coils triggered. We speculated energy distribution is proportional to the number of coils turned on. Thus, smaller coils should result in a more accurate shape defining feature; hence, power consumption will be minimized as the shape of a cookware is precisely detected. Furthermore, increasing in the number of heating elements will also allow more cookware to be heated within the limited surface area. Thermopix will include this advanced module in the 2nd stage of design prototype.

6. Interpersonal and Technical experiences

Phoebe Liu

This project has given me the opportunity to learn what it is really like to be involved in the whole cycle of project development. During the first month, our team tried to develop our own power board. When a tiny screw was heating up, we were all excited and driven to take the project to the next step. However, progress seemed to hit a stall as frustration increases. At one point, we thought about changing to a different project. We also encountered power problems with our project, and could not find the expertise in SFU to guide us. When boards blew up one after another, we tried to figure out alternatives to solve this situation. Although there were many barriers and obstacles throughout the whole project, our group as a whole overcame them and beat out the odds. In my opinion, this project readily simulates the "real" workplace where adapting to tight deadlines and modifying plans constantly on the fly is a crucial part to the overall success of a project.

The development of our project had exposed me to various technical knowledge in different fields, such as physics, power electronics, and mechanical engineering. I also learnt how to debug a black box circuit, and knowing which signals were significant to our project. On the software side, I learnt how to utilize the full features of PIC, such as its ADC and PWM function. The greatest challenge is still the integration of the control board and the power board, which blew up the first part when we tried to integrate. After investigation, we decided to eliminate the autotransformer, and integration proved smoother than anticipated.

Our team dynamics is somewhat unique. Although Steve Whitmore had advised against working with your close friends in the beginning of the semester, I find that it also gave the team a fun and positive atmosphere, where each team member had something to contribute and something to complement one another. One of the downside to the team dynamics were working with friends often make the team procrastinate. This often resulted in documents being submitted at the very last second before the deadline, literally. As the team leader, I also learnt how to assign roles to each team members that allow each person to use his/her skills most effectively.

Overall, this project was probably one of the most dangerous projects in ENSC 440 history, simply because we were dealing with 220V and 30A. The project had also gone over budget, resulting in each team members contributing equal amount to fund our project. However, we are still grateful that none of our team members had been seriously injured, or end up in the hospital, yet.

Hao Su

ENSC 440 is a course to be remembered. This was my last course in SFU, and I have to say, that this course has been full of surprises, with lots of ups and downs. When I first started the project, I had lots of doubts about the feasibilities of this project, mostly due to resources and time. Since SFU does not offer electrical engineering, I was not able to get much supports from faculty members. On top of that, balancing other course load and a part time job really tested my limited. To me, the high point of the project was seeing the little step of my design working. The low time of this project also tested my patience and endurance, since boards were one by one blown up. Aside from that, I have to say that it was nice to work in such a forgiving group environment. There were times when I could not stand some of the team members, and resulted in pacifying others or battle egos. At the end, we were able to overcome our differences in opinions and personalities, and concentrate on the project. Overall, while this project was ambitious, I was really content with myself that we were able to get it to a working stage, and was the project was large enough in scope to be interesting. It also allowed me to understand how the microcontroller work, and able to integrate other digital components into the PIC. Overall, it was a great learning experience. It was very exciting and fulfilling to see the project grow from an idea to a prototype.

Andrew Lin

I came into this course not knowing just how much workload is ahead of us. One of our first main tasks in this course was dividing up the tasks. However, the first stage of our project only involved in hardware, so having four members to all work on hardware was redundant. This resulted in that I wasn't able to do a lot of work at the beginning. When we actually started testing the power board, the group was clearly divided into 2 sections, and I was responsible for testing the power board. Working on the hardware was uncertain everyday, as some days I was able to test the signals, while other days the board completely blew up, Working on this project was an exceptionally worthwhile experience from which I learned a great deal. Also, working with the hardware components of this task gave me a chance to improve my skills and to apply the many things I learned in the various classes I have taken. Although certain classes had project where I can apply what I learned, this project was by far the most challenging, and required me to use knowledge from ENSC 325, ENSC 387, and ENSC 489.

I also had the chance to work on the software aspects of the project. My responsibilities were the main algorithm used for controlling the pots, as well as implementing algorithm to trigger the interrupts. My C++ coding was rusty at the beginning of the project, so I started with debugging the code. After I was able to familiar myself with C++ again, I was able to program the microcontroller, so that It was able to detect multiple pots at once. Debugging the code was troublesome, because the codes are nested within the loops. Fixing one bug often resulted in another bug appearing.

Time management was a skill that was needed to be enhanced with the project, since some of the team members, including myself, has a part time job. As a result of this, time management grew from managing various course projects and personal activities to managing very important personal goals. As difficult as this is individually, we now had to manage our own time with each's time. We were all willing to meet and work during late nights and weekends in order to accommodate everyone's needs and to complete the project as best as possible. I learned that it is important to motivate each team member. Having even one group member not in sync with the rest of the group can cause great damage with the respect to the end product. Overall, it strengths our friendship, and further bonded my relationship with each team member. All in all, it was like a roller coaster ride, and I learnt how to manage my emotions effectively.

Claire Wu

The successful Smart Stove project is fueled by our great team dynamics and 5 years solid trained engineering practice. Most of our group members have been devoted majority of time in this project for the past four months since we all committed to take a light graduating semester in order to push this project through major milestones.

Throughout the entire project, we encountered numerous difficulties that forced our project progress delayed and even reconsider the feasibility of Smart Stove. Due to the lack of high power knowledge and resources, we spent tremendous time on evaluating high power IC chips and designing high power control circuits. Also, since the project requires a 220V power source, we experienced a wide variety of transformer problems regarding to different configurations and polarity issues. With high power transformer problems, we blew up many power boards and designed control circuits, in which we also faced some serious safety issues and concerns. However, everyone was highly motivated to acquire high power knowledge and to look for alternative solutions, and we decided to employ only one fully isolated transformer for the project in the end. As part of Thermopix development team, I am truly proud of what we have encountered and accomplished even though we didn't have enough of high power engineering background.

In this project, I have gained valuable experience on hardware design, testing procedures, and project overview. During the project developing stage, I was be able to apply my engineering knowledge from Ensc225, Ensc325, and Ensc387, as well as the hands on electric design from previous direct study experience with Dr. Menon. Moreover, I had broadened my engineering knowledge by seeking assistance from high power industry professions and some professors. All these valuable experiences not only allow me to contribute to the Smart Stove project but also to enhance my engineering skills.

In addition to engineering experiences, I have also built up a better understanding on project overview and time management. Throughout the project, our team was well organized on documentations and meeting scheduling which allowed us to keep our project progress on schedule. Although grouping with close friends sometimes led to procrastination, a fun working atmosphere also helped us to work longer period of time without too much stress. In summary, Smart Stove is not only the last project during our academic years but also a good memory for our friendship.

7. Conclusion

This document has defined the post mortem for Smart Stove cook top prototype. Thermopix strive to exceed the standards in developing Smart Stove Cooktop which promises a safe, affordable and easy to use cooktop. The Smart Stove Cooktop will also improve the energy efficiency, safety, reliability of the existing technology. The post mortem outlined in this document reflects our development process for our first stage prototype. Thermopix will continue to improve overall performance of our final product. Thermopix Inc. is confident that our proof-of-concept prototype has achieved most, if not all, of the functional requirements.

Table of Glossary

EEPROM – Electrically Erasable Programmable Read-Only Memory, is a type of non-volatile memory to store small amount of data.

Flash – A specific type of EEPROM that can program in large blocks.

Induction Cooktop – A type of cooker that heats forremagnetic pots from magnetic field hysteresis loss. This type of cooker is faster and more energy efficient than traditional cooktops.

Ferromagnetic – A material that form permanent magnets and exhibit strong interactions with magnets such as iron.

CSA – Canadian Standards Association

CE – CE mark is a mandatory conformity mark in the European Economic Area

FCC – Federal Communication Commission

RoHS – Restriction of Hazardous Substances Directive

IEC – International Electrotechnical commission

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