Thermopix Inc.

School of Engineering Science
Burnaby, BC • V5A 1S6
sfu.ca/~pliu1 • pliu1@sfu.ca

February 16, 2009

Mr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440/305 Project Functional Specification for Smart Stove

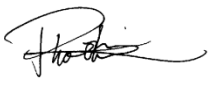
Dear Mr. Leung,

The attached document, *Smart Stove Functional Specifications*, outlines the functional specification for our project for ENSC 305/440. Smart Stove is an innovative pixilated induction cooktop that allows the users to put the cookware anywhere on the surface. The functional specification will outline the requirement that Smart Stove prototype and the final version will need to meet.

Our functional specification describes the design parameters in which our system will be able to operate. The functional specifications will also document the list of specification to be met by the end of April, as well as continuing development of further iteration of the prototype.

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: Functional Specifications for Smart Stove.

Thermopix Inc.

Smart Stove Functional Specification

Project Team: Phoebe Liu
Hao Su
Claire Wu
Andrew Lin

Contact Person: Phoebe Liu
theromopix-ensc@sfu.ca

Submitted to: Steve Whitmore, ENSC 305
Patrick Leung, PEng, ENSC 440
School of Engineering Science
Simon Fraser University

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1. Executive Summary

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, and cook with as many pots and pans that will fit simultaneously. The induction sensors on the Smart Stove also sense how many pots are being used and the location and size of each pot on the stove. The user-friendly GUI then graphically maps these pots and allows the user to adjust the temperature and timer of each pot individually, thus completely automating your cooking experience.

The development of the Smart Stove will occur in several iterations. Based on the schedule outlined in the proposal, the first stage of the prototype will involve in designing the hardware components of the induction cooktop. Thermopix Inc. is currently in the process of building its own heating individualized heating elements, where high voltage and amperage are taking into account as uncertainty. Following the first stage of development, subsequent features of the prototype will be added, such as:

- Resistance to high voltage and current susceptibility
- Automatic detection of cookware placed on the surface
- Integration of individual heating elements to achieve the pixilated structure of the cooktop
- Temperature controls of the detected cooktop
- Fulfillment of safety and environmental standards
- Casing and mechanical calibration of the cooktop

The completion of this proof of concept will be completed by April, 2009. While developing these features as outlined above, rigorous testing will occur in parallel. Analyzing and interpreting the significance of the data results will prove to be a key component to the success of the first iteration of the prototype.

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2. Introduction

Smart Stove is an innovative home appliance that provides users convenience while being energy efficient, safe, and easy to clean and maintain at the same time. With the large surface area of available heating elements, it is easy to achieve the desired efficiency in time and energy by allowing more cookware to be heated at the same time, as compared to that of conventional cooktop. Since induction heating mechanism can only work with magnetized cookware, the system results in dramatic energy savings than traditional electric or gas cook-tops. Without constraints of fixed heating area, users will be able to heat up any size of cookware anywhere within the surface area. After the sensors detected a pot is placed on the surface, LEDs will flash to indicate where temperature adjustments are applicable.

The project is divided into two increments. Increment 1 will be completed during ENSC 440. Increment 1 will mainly focus on electrical prototype of 3 by 3 heating elements. Increment 2 will add further features and improvements, mostly focusing on LCD touch screen control.

2.1 Background

In present days, most households are still using traditional gas or electrical stoves, which concerns for energy waste and safety need to be taken into account [1]. Conventional induction cooktop will achieve energy conservation and safety. However, all the current commercial stoves encounter numerous constraints due to its fixed heating area and limited heating elements per unit cooktop. With Thermopix's Smart Stove, many problems discussed above can be solved.

2.2 Scope

This document contains a list of functional requirements that Thermopix's Smart Stove prototype and the final product are required to meet. The following functional specification ranges from the constraints of electronic components to the power supply standard. This document will not only provide a list of requirements that Smart Stove strives to meet, but also a benchmark of the minimum standards that the prototype must achieve.

2.3 Intended Audience

The primary intended audience for this document is the project managers, research and development engineers, and quality assurance personnel. These functional specifications will act as a guideline for which all the prototype modules must comply. The managers are obligated to use this document to monitor project progress and to determine the project direction. By the end of the product cycle, this document will also provide business groups for further references.

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2.4 Objectives

We will follow the convention to denote functional requirements below throughout this document.

R [I-X]

Where I denotes the incremental number of the listed requirements

Where X is a letter represented by the following values:

P - represents the embodiment design stage of our product prototype, so the selected features from the concept stage will be implemented.

F - represents the additional features of our product prototype, so it will be implemented if time permits.

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3. System Overview

Figure 1 shows the overview of the Smart Stove system. The stove's heating surface will be limited to a 4x4 array of induction heating elements. When the stove is turned on, the user interface will prompt the user to place a piece of cookware on top of the flat heating surface. 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.

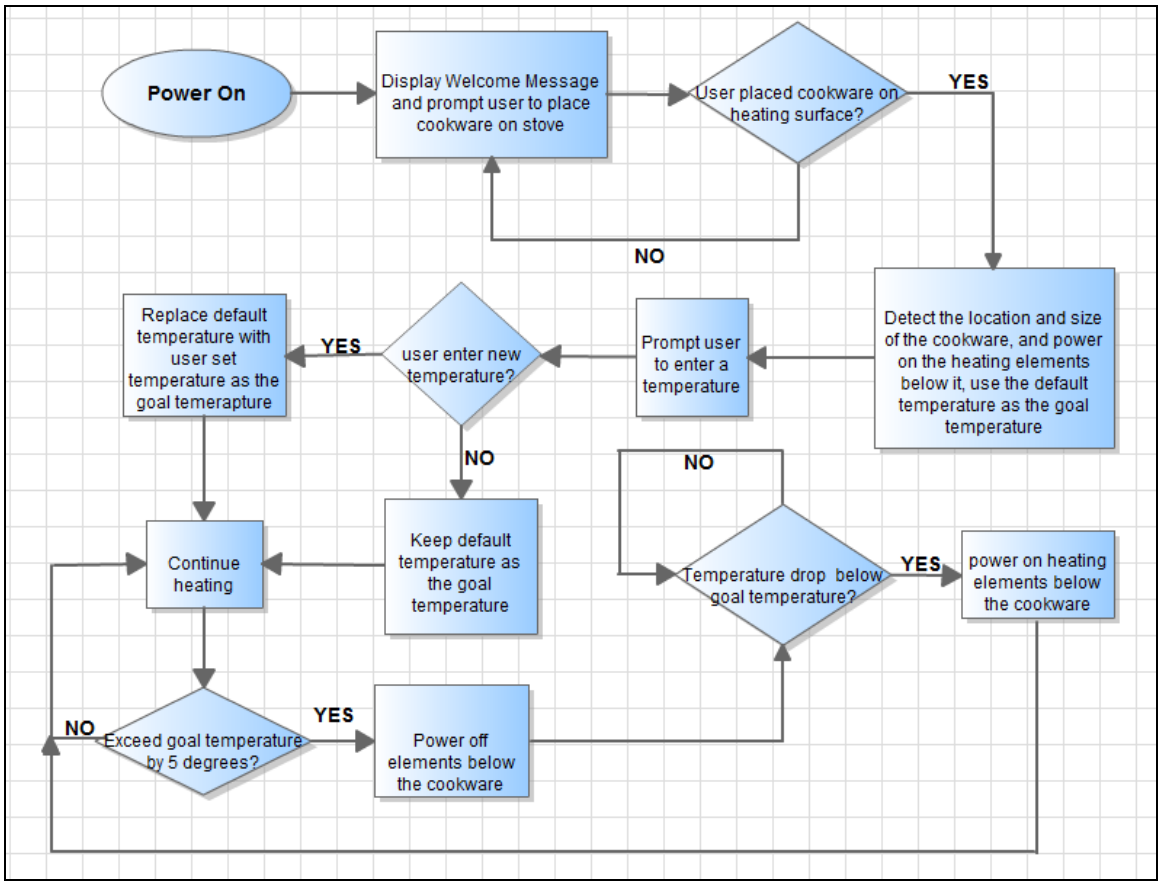

Figure 1. Smart Stove system's flow chart

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. 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

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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 1 will also apply when more than one pieces of cookware are being used at the same time. The system will simply treat each cookware as a separate entity, and apply temperature and heating algorithm to each individually.

Figure 2 Smart Stove cooktop

Figure 3 User interface of final product

Figure 2 and Figure 3 gives an idea of the Smart Stove's final interface. Figure 2 shows the top view of a 7x7 induction coil Smart-Stove, although the prototype will only likely to be 4x4.

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Figure 2 shows the LCD touch-screen representation of the stove-top. [2] The user sees the 7x7 matrix of induction heating elements represented on the LCD screen, and when a cookware is placed on top of the stove-top, the induction coil heating elements below the cookware will show up as the red dots on the LCD screen. The user can then use the right side of the LCD screen to adjust the temperature of this group of induction coil heating elements as one entity. When one more cookware is added to the stove-top, the LCD screen will show the second cookware, and the user can adjust the temperature of both pieces of cookware independently. Note that this LCD touch-screen interface will only be implemented if time permits in this project timeframe. We will most likely implement the prototype interface in an embedded PC, or have analog controls, with LED lights representing each coil element.

The system of Figure 1 that we are going to implement is not without limitations. Ideally, we would want as many inductive heating elements as possible in order to maximize resolution and have more precise definition of the cookware shape, size and position. However, having more heating elements would mean that we have to decrease the size of each induction coil, leading to less inductance. From a circuit design perspective, this would mean that we would need very large capacitors in our power circuit. Therefore, we will limit our prototype cook top to have only an array of 4x4 induction coil elements. Furthermore, the on-off temperature control system shown in figure 3 will not give very exact cookware temperatures, as there will be temperature overshoots by 5 degrees.

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4. Overall System Requirements

This section outlines the requirements that the Smart-Stove product must satisfy in order to deliver a safe, affordable and easy-to-use device. Specific requirements relating to specific system modules are described in other sections of the document.

4.1 Functional Requirements

R[1-P] The user interface will be intuitive, easy to understand, and the user should know how to use it correctly without referring to the manual.

R[2-P] The prototype will have at least three temperature levels.

R[3-P] The prototype must heat and maintain a stable temperature according to user's temperature settings with at most 10°C overshoots.

R[4-P] The prototype will have sixteen heating elements in 4 by 4 configuration.

R[5-P] The heating elements will be 2" diameter each.

R[6-P] The prototype will have a light source or LCD display to indicate which heating elements detected a cookware.

R[7-P] The system will not operate when no cookware is placed on top of the elements.

4.2 Physical Requirements

R[8-F] The physical width and length of the cooktop shall not exceed 14" by 14" with nine heating elements.

R[9-F] The physical height of the cooktop shall not exceed 4".

R[10-P] The physical dimension of the control until shall not exceed 5" in length, 5" in width and 2" in height.

R[11-P] The cooktop and the control unit shall not weight more than 4kg with sixteen heating elements.

4.3 Safety, Regulations and Standards Requirements

R[12-P] The system will comply with CSA [8], CE, and FCC [5] standards for domestic and residential use.

R[13-P] The system must conform to the IEC 60335 standards for safety of electrical household appliances. [6]

R[14-P] The system must conform to the applicable IEC 61503 specifications for functional safety of electrical/electronic/programmable electronics safety-related systems.

R[15-P] The product will be RoHS compliant. [7]

R[16-P] All material contained in the final product will be non-flammable

4.4 Power Requirements

R[17-P] The peak power consumption of the device shall not exceed 1800W when every element is active.

R[18-P] The maximum current drawn by the system shall not exceed 15A.

4.5 Environmental

R[19-P] The prototype must be resistant to spills on the surface as well as the underside of the unit.

R[20-P] The induction coils must be able to detect most iron based cookware (this excludes aluminum).

R[21-P] The prototype components must operate at a wide range of ambient temperatures, from -30 to 45°C.

R[22-P] The prototype must operate at a wide range of humidity levels of up to 100%.

R[23-P] The prototype's induction components must not fail or malfunction at normal household radiation and magnetic field strengths.

4.6 Performance

Based on time and resource constraints, and also due to the complex integration of the electronic components and the induction coils, the performance specifications for the prototype unit will not be as high in standards and requirements as the final marketed product. Performance sacrifices include, but are not limited to: fewer induction elements (most likely a 4x4 array), longer boiling time, and lower sensitivity in detecting of cookware placed on top. The course instructor has confirmed these issues. Thus the scope of this document is to only provide the functional requirements of the Smart Stove prototype unit, and not to explanation how to improve on the efficiency and performance of the prototype. With these things in mind, the performance requirements are as follows:

R[24-P] The prototype's induction coils must detect cookware as small as 5cm in diameter.

R[25-P] The prototype must be able to boil 5cm water within 3 min, and do so for any cookware containing at least 40% of ferrous material.

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R[26-P] The prototype must detect cookware and power the induction elements below the cookware within 2 seconds of cookware being placed on top of the stove.

R[27-P] The temperature of the cookware shall not receive overshoots of more than 10°C from the induction elements.

R[28-P] The induction coil detection system and GUI system must accommodate at least 4 pieces of cookware. This means allowing users to adjust temperatures independently for at least 4 pieces of cookware.

R[29-P] The coils must detect the cookware when it is placed at 1cm higher than the stovetop surface.

R[30-P] The prototype should still be able to boil water when half of the cookware is not on the stovetop.

4.7 Reliability

R[31-P] All components should be resistant to power surges.

R[32-P] All components should be serviceable by induction cooktop experts and technicians.

R[33-P] All components should withstand the dissipated heat from the cookware.

R[34-P] All electronics components should withstand current and voltages for prolonged use of more than 4000 hours.

R[35-P] The prototype should be able to withstand the mechanical vibration resulted by dropping from a height of 40cm.

R[36-P] The prototype should be able to withstand a mass of 20kg/10cm^2

4.8 Cost requirements

R[37-P] The cooktop system should not cost more than $400 each to produce when 500,000 units are produced.

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5. Output Conversion module Requirement

The following section will list all the output conversion requirements of the Smart- Stove prototype. By converting electrical signal from control module into an appropriate indicator or physical output, all the output conversion module requirements should be fulfilled in the design stage. Output conversion of Smart Stove can be categorized into temperature adjustment output and sensing cookware output.

R[38-P] The temperature adjustment output conversion module should covert the electrical signal from the control knob or LCD touch-screen input(if time permits) and process into a threshold cutoff heating mechanism with a delay of less than 1ms.

R[39-P] The cookware sensing output conversion module should covert the electrical signal from the cook-top surface and process into a flashing LED indicator or LCD screen representation(if time permits)for heating adjustment, with a delay of less than 1ms.

R[40-P] The cookware sensing indication should be refreshed less than 1ms interval.

R[41-P] All electrical components should not be directly exposed to water or outside of the stove.

R[42-P] Users should not have any means to access the output conversion module.

R[43-P] The module must be able to operate on an 110V power source with 10% fluctuation.

R[44-P] The maximum power consumption of the output conversion module should not exceed 1.6K Watts.

R[45-P] The maximum power consumption of each heating element should not exceed 1.6 K Watts which means power is distributed evenly with numbers of heating units.

5.1 Commercial product output conversion module requirements

R[46-P] The maximum power consumption of the output conversion module should not exceed 20K Watts.

R[47-P] The maximum power consumption of each heating element should not exceed 2.5 K Watts.

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6. Power Generation Module

The following section will list all the power generation module requirements of the Smart Stove system. Details of power generation module include specific energy required for the device. In order to avoid high power testing problem, Smart Stove prototype is applicable with standard power source, 110V. The commercial product will be able to support 220 V, in which each heating element will contain higher energy distribution.

R[48-P] The power generation module should be able to support 110V power source with ±10% fluctuation in amplitude.

R[49-P] The power generation module should be able to activate with a delay less than 1ms.

R[50-P] The power consumption of each control knob should not exceed 1W.

R[51-P] If the development time frame allows the implementation of the LCD touch-screen interface, the LCD touch-screen and its controls should not exceed 20w in power consumption.

R[52-P] The maximum current drain at non-active mode should not exceed 20mA.

R[53-F] The power generation module should include protection circuit for avoiding power surge.

R[54-F] All electrical components should not be directly exposed to water or outside of the stove.

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7. Control & Processing Module Requirements

The control and processing module consist of temperature adjustment and cookware sensing mechanisms. With input conversion module, system will output with appropriate indicators such as flashing LED or LCD touch-screen representation of heating elements.

R[55-P] The control and processing module must compare input temperate with cutoff threshold temperature and well controlled over its thermal system.

R[56-P] The control and processing module must refresh sensing mechanism less than 1ms interval.

R[57-P] The control and processing module must convert electrical sensing signal into flashing LED indicators or LCD touch-screen representation of heating elements(if time permits).

R[58-P] The control and processing module conversion time should not exceed 1ms.

R[59-P] The control and processing module should be applicable with 12V amplitude with of ±10% fluctuation.

R[60-F] All electrical components should not be directly exposed to water or outside of the stove.

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8. Casing and Mechanical Module Requirements

Smart Stove will be building a plastic enclosure for the electronic components of the system. The ceramic glass cover will show the overall area where the cookware can be placed on. The cover will also show the arrays of induction heating elements as well as controls that adjust the temperature. This section lists all the specific requirements that the module shall fulfill.

R[61-P] The casing module should be assembled and disassembled easily by the user.

R[62-P] The enclosure will be able to hold all the components, including the electronic components and the heating elements itself as a standalone device.

R[63-P] The enclosure must have two ventilations to allow proper flow of air.

R[64-P] The cover of the casing must have a smooth surface and allow spacing to where the controls or LCD touch-screen can be placed.

R[65-P] The enclosure should provide adequate spaces that allow communication port to be placed.

R[66-P] Water and other liquids leaked from the pot should not affect the day-to-day operation of the device. However, enclosure will not be susceptible to corrosive chemicals or vapors, as it is not designed for industrial or laboratory use.

R[67-P] The surfaces of the galley surrounding the cooktop, which would be exposed to a fire on the cooktop surface or in cookware on the cooktop, must be constructed of materials that comply with the flammability requirements.

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9. Documentation & user Training Requirements

User training manual should be provided such that it will bridge the space between the designer's conceptual module and the user's interpretation of the system. The user's manual should have the following features:

R[68-P] A general website will be offered along with user manual. Another section on the website will include general support, where the users can send inquiries via email to Thermopix Inc. In the general support section, a subsection of FAQs will also be posted to answer users' technical questions. Contact personnel will be listed on the website, in the event of needing technical support.

R[69-P] A hardcopy of the user's manual will be included with the final version of the prototype. The user's manual should be easy to comprehend, with clear figures and diagrams of the general system. A step-by-step guide of initializing the cooktop will also be included. The user's manual will include description of device characteristics and troubleshooting guidelines.

R[70-P] The user's manual is targeted to the mass market, where minimum electronic experiences are expected. The user's manual will include description of all general functions in layman's terms.

R[71-P] The user's manual will be written in English and Chinese, which are the two main languages used by the market Thermopix intend to penetrate.

R[72-P] The user's manual must provide clear instructions on specific type of material that is compatible with the induction cooktop.

R[73-P] Users should be informed of cleaning instructions of the cooktop, in order to minimize damages and maximize life expectancy of the cooktop.

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10. Device Limitation

The intention of the Smart Stove Cooktop is to provide the user a new and intuitive way of cooking, whereby the surface will automatically sense the cookware placed on the surface and allow temperature adjustment accordingly. This section lists some of the major design limitations that Smart Stove system may impose.

1. The Smart Stove Cooktop will not have any explicit shock protection.
2. The Smart Stove Cooktop does not provide any indication of the stove temperature for colorblind individuals.
3. The Smart Stove Cooktop is unable to prevent the user from intentionally burning themselves on the Cooktop.
4. The Smart Stove Cooktop requires induction cookware. Ceramic, aluminum or other non-ferrous materials will not work.
5. The Smart Stove Cooktop does not prevent overcooking or undercooking.

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11. Conclusion

This document has defined the functional requirements 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 functional requirements outlined in this document are not a strict specification that Thermopix must adhere to, but rather a guideline that enable Thermopix to facilitate the flow of the project. Appropriate changes are expected during our prototype development to improve the overall performance of our final product. However, Thermopix Inc. is confident that most, if not all, of the functional requirements detailed in this document will be met by April 2009.

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12. 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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13. Reference

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