Appliance Proximity Sensing and Standby Power Consumption

ECE 480 Design Team 5
For Whirlpool Corporation

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Proposal
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Executive Summary

The drive to lower energy consumption and protect the environment has become a growing priority in consumers’ minds. The Environmental Protection Agency & U.S. Department of Energy’s ENERGY STAR compliance has also developed a new requirement that appliances must enter a standby mode and consume one watt of power or less. In light of the energy demands, Whirlpool Corporation is determined to design and manufacture the most customer friendly and energy efficient products. This has created a need for appliances that include proximity detection both in the same room and directly in front of the product. Near negligible cost is also necessary with respect to Whirlpool’s lower-end products. ECE 480 Design Team 5 will develop an end design that includes a proof of concept for appliances to detect user proximity and minimize power consumption using standby mode.
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1. Introduction

1.1. Whirlpool Project
The drive to lower energy consumption and protect the environment has become a growing priority in consumers’ minds. ENERGY STAR compliance is also expected to enact a requirement that appliances must enter a standby mode and consume one watt of power or less. In light of these energy demands and expectations, Whirlpool Corporation continues in its determination to design and manufacture the most customer friendly products. This has created a need for appliances that can smoothly enter and exit an energy ethical standby mode. Whirlpool’s novel approach is to use proximity detection in the same room and directly in front of the product. Near negligible cost is also necessary with respect to Whirlpool’s lower-end products.

1.2. ENERGY STAR
In 1992, ENERGY STAR was introduced as a voluntary labeling program to promote energy efficient products. It was a joint venture created by the U.S. Environmental Protection Agency and the U.S. Department of Energy. Corporations must follow strict energy efficiency guidelines in order to market their products as ENERGY STAR approved. By using products that adhere to these guidelines, last year Americans saved enough energy to avoid using as much greenhouse gas emissions as 29 million cars and saved $19 billion on utility bills.

1.3. Whirlpool Corporation
Whirlpool Corporation was founded in 1911 with the goal of creating the best home appliances for the American consumer through utilizing then-novel electrical technologies. Whirlpool, the world’s pioneer appliance manufacturer and marketer, grossed approximately $19 billion in annual sales in 2008. This performance continues to improve through their innovative and international business strategies in combination with a customer-oriented philosophy. Hence, Whirlpool Corporation took action for their eco-friendly production as early as the 1970’s with the creation of their Sustainability Office. This environmentalist attitude has piloted Whirlpool towards today’s energy and water-efficient appliance production. Along with the Whirlpool brand, they also own and market many other major brands such as
Maytag, KitchenAid, and Jenn-Air. Since 1956, Whirlpool has been headquartered in Benton Harbor, MI. At present, Whirlpool employs more than 70,000 employees. Whirlpool employs a large workforce in Michigan and is a premier partner with ENERGY STAR. Whirlpool is also a leading supporter of Habitat for Humanity. They are committed to providing energy efficient households for the Habitat for Humanity families and were recently the lead sponsor of a Habitat for Humanity build, at which 270 employees helped build more than 230 houses in Michigan. Other charitable and commendable actions include the donation of over 1 million dollars worth of money, products, and services after Hurricane Katrina in 2005, as well as over 175 washer-dryer units for use at the Houston Astrodome shelter. At the global headquarters in Benton Harbor, MI Whirlpool Corporation promotes high quality products and conducts green-living sustainable research projects.

1.3.1. Whirlpool in Association with ENERGY STAR
Whirlpool has been an active ENERGY STAR partner since August 1998. During that time, they have won ten ENERGY STAR awards, including the Partner of the Year Award seven times, as well as the 2006 through 2009 ENERGY STAR Sustained Excellence Award. They continue to create innovative products that not only match, but surpass, ENERGY STAR guidelines in order to save consumers money and help the environment. Whirlpool presently designs, manufactures, and markets over 590 ENERGY STAR appliances.
2. Research Project

2.1. Project Overview
ECE 480 Design Team 5 will develop an end design, including an experimental proof of concept that enables an appliance to detect human presence utilizing sensing technologies, then boot out of standby mode when a presence is detected in within a specific range, and if time allows relevant share information from a single sensing point across a wireless interface.

2.2. Types of Sensors
In this section, the suitable sensing technology options that have been researched are discussed along with their features, limitations and applications in order to present background information on the sensor selections for proximity detection to be used in the appliances.

2.2.1. Infrared Sensing
Infrared (IR) refers to the classification of the wavelength range 1mm – 750nm that is radiated from all objects and is invisible to the human eye. It is helpful to think of IR in terms of radiated heat. Infrared sensors are common in many standard household applications such as remote controls and motion detectors. There are two main types of infrared sensors; those that emit an infrared beam and those that do not. The former is simply referred to as an IR sensor and the latter is known as a Passive Infrared (PIR) sensor. An IR sensor will emit a pulse of infrared light that will be reflected back to the device only when an object crosses its path. Some IR sensors, such Sharp IR, use a method of triangulation to estimate the distance to the object crossing the beam path. A PIR device, on the other hand, only accepts incoming infrared radiation.

The circuitry of PIR sensors allow the device to store, or remember, the ambient amount of infrared energy in a room and then trigger once a significant change in infrared energy is detected. In many cases the amount of IR energy needed to trigger the PIR can be adjusted so that small animals will not affect its use. A PIR sensor has a much greater detection range than a standard IR sensor; however,
both are known for low power consumption. PIR sensors are the most common form of motion detector used in household security systems and are quickly finding use in many other applications. Due to their popularity and versatility, IR and PIR sensors are relatively inexpensive and come in a variety of configurations which makes them an ideal sensing solution for this project.

2.2.2. Ultrasonic Sensing

Ultrasonic sensors work in ways that are similar to radar and sonar. The sensor generates a high frequency sound wave and the distance of an object is evaluated once the echo is received back. This allows the distance to be calculated by multiplying half the elapsed wave time delay by the speed of sound. However, along with this simplicity, there are also certain limitations. It is not possible to discern between small and large objects. This may causes issues on our appliances when we only want to detect people in the area and not small pets. Another major concern is that ultrasonic technology lacks the ability to detect objects over a wide area without the use of multiple sensors. This would drive the price of Whirlpool’s products up with each additional sensor. Prices of sensors vary with the power and sensitivity of the transducer. Inexpensive sensors typically have a range up to 3 meters, whereas high quality sensors can sense upward of 10 meters. However, the price of high quality sensors is not feasible for this project. Due to the need for multiple sensors and the high price of long range sensors, ultrasonic technology is not best suited for the use of detecting consumers in the same room as an appliance. However, on certain high-end Whirlpool products, it could be beneficial to use an ultrasonic sensor to detect a consumer walking up to use an appliance. As the distance between the user and the appliance decreases, more and more information can be displayed for the user.

2.2.3. Capacitive Sensing

Capacitive proximity sensing is implemented by creating an electrostatic field that will change in accordance to interference created by objects entering the field. Traditionally, capacitive sensors are built using two circular, flat electrodes, one in the center and the other, ring-shaped, concentrically surrounding the first.
When an object enters the field, this alters the capacitance of an oscillator circuit. This can then be processed to determine the presence and, for a known object, the distance to the object. This type of capacitive sensor has a maximum range of approximately 50 mm. Capacitive sensors can sense both conductive and non-conductive materials, unlike inductive sensors that are limited to detecting conductive materials.

For the purposes of this project, capacitive sensing is not a good option. The maximum range is approximately 50mm, far too short for any practical application to this project. The cost is also much higher than other sensor types, such as PIR. Capacitive sensing cannot distinguish between a human, pet, or counter island in front of it. Low-end capacitive sensing is meant for industrial measurement, such as multiple sensors on a tank indicating the approximate level of a liquid inside. Capacitive sensing is optimal for this because it has the ability to “see” through other objects. High-end capacitive sensors are used for extremely precise measurements of distance and thickness of known materials, however.

Another, newer, implementation of capacitive sensing uses one large, planar electrode than measures the capacitance between the electrode and ground. Changes in the capacitance are processed into a useable output. Since the layout of every kitchen is different, the floating capacitance, the capacitance when there is not a human in front of the electrode, will be different because of counters, cabinets, and walls. This type of capacitive sensing has a longer maximum range, 300mm, but due to its lack of accuracy, it is not a usable option for this application.

2.2.4. Video Image Sensing
Current applications of Video Image Sensing or Video Image Detection (VID) are employed mainly by transportation services that manage traffic flow through video images. The idea behind VID is straightforward, an image, or more appropriately, a constant stream of images are captured by a video camera which are then sent to unique microprocessor board where this information is put through an algorithm to determine motion characteristics. Most high end digital
streaming systems usually require 6-7 W, which is power consumption above the requirement of this particular project. Another option in video detecting can be found in microcameras. Microcameras usually run on 9-12V, produce AVI video, and are no larger than a quarter. The range of microcameras needs not be precisely defined in the application of this project, for if the microcamera is positioned properly it has the ability to view an entire room, making it ideal for an accurate motion detector. The detection of motion algorithm can be encoded onto a microprocessor for a relatively low price.

The potential for the use of a microcamera as a motion detection device for current products in the Whirlpool line is unlikely as most cameras are out of the current price range, with wireless embedded cameras costing even more. Another drawback includes the complexity of the microcamera implementation. The complex algorithms and processing consumption are a serious drawback. The microcamera device option on high end products may be feasible, especially if its price comes down, as it has the ability to accurately detect any movement and can be programmed to calculate distances between objects in the kitchen.

2.2.5. Pressure Sensing
Pressure sensor chips are devices that sense changes in pressure (deflection) over an area. They contain an embedded microcontroller in their system, and can operate as a stand alone transducer or can be integrated on a surface then export a signal for processing. Some generate analog current or analog voltage that is proportional to the input. Others function with a digital parallel output (pulse width modulated voltage. Pressure sensors are mainly used in automotive, industrial, or medical fields.

Some of the pressure sensor’s performance specifications are pressure range, supply voltage, impedance, and accuracy. Usually, the pressure range is expressed in pounds per square inch (psi). Impedance is recognized as the opposition to current flow, and it is measured at the input of the sensor. Accuracy is specified by the frequency range of the sensor. When pressure sensors were used in home appliances they responded to low pressures that were 15 pounds or less. Pressure sensors can be found in clothes washers to monitor the water
level. They can also operate in dishwashers and clothes washers, built in near the cleansing liquid chamber. However, over time the accuracy of the sensor may be reduced due to chemical cleansing substances.

3. Design Specifications and Objectives

- Initial research was conducted and showed that a passive infrared (PIR) sensor is the most viable solution for detection in the room. The extensive range and low cost of PIR sensor were the leading factors in this decision. A PIR sensor solution is one that will fit the entire range of Whirlpool products without adding significant cost and will meet the energy consumption benefits.

- An active infrared sensor has been confirmed as a possibility for the low cost solution for near appliance user detection due to the simplicity of the technology.

- The concept of using an ultrasonic sensor in order to detect the distance a consumer is away from an appliance was also confirmed as a possibility. This technology would be used on Whirlpool’s higher-end products such as an appliance with an LCD screen that will display more and more information as the consumer moves closer to it.

In designing the Proximity Detector for Appliances, the following design specifications must be met:

- Power: A standard of consumption of 1 Watt or less as expected future by ENERGY STAR requirements. The 1 Watt power consumption is the total power consumption of the appliance in a standby state.

- Size: The ability to fit aesthetically on or behind the appliance, box limitations are ideally limited to the predefined Whirlpool circuit module; however, if this cannot be met the most important aspect is to demonstrate the functionality of the sensors, not the aesthetics.

- Cost: Reasonable cost within the limitations of the product range

- Flexibility: Ability to adapt intelligently to different environments

- Accuracy: Accurate distance measurement concerning the consumer’s position relative to the appliance

- Safety: Short circuit avoidance to protect the appliance is important. All sensors will meet EPA guidelines.
4. FAST Diagram

Function Analysis System Technique (FAST) Diagram is a powerful design tactic for analyzing the functional strategy structure of a technical system. Below is the FAST Diagram that is developed for the proximity sensing project.

5. Conceptual Design Descriptions

5.1. Introduction

Over the years technology has been advancing at an exponential rate. As technology evolves, so too do the priorities of both manufacturers and consumers. Recently there has been an ever increasing focus on the development of more energy efficient products. The project set forth for ECE 480 Design Team 5 originated from Whirlpool Corporation’s consumer-oriented philosophy and the increasing restrictions for ENERGY STAR compliance. However, the implications of this project are not limited to energy efficiency. A growing trend in technology is the concept of “smart” houses, or home automation. This is the idea that houses will be able to detect human presence, or absence, and adjust lighting, temperature, etc. accordingly without the need of human interaction. Whirlpool has also recognized
the place that home appliances will have in this growing trend. Thus, ECE 480 Design Team 5, working with Whirlpool, has developed two initial conceptual designs. One concept will apply to the low to mid-range cost appliances that will focus on energy efficiency and functionality. The second concept will apply to high-end appliances that, while not neglecting energy efficiency, will focus on the user experience.

5.2. Low to Mid Range Solution
Many of the appliances currently manufactured by Whirlpool Corporation do not fully utilize the standby modes of their microprocessors. The aim for the low-end solution will be to properly utilize this standby mode while not adding significant cost or affecting the functionality and current user experience of the product. The current user experience includes ability to read the clock display while in the room but not using the appliance and the appliance’s ability to respond immediately to user input.

In order to accomplish this, it is proposed that the team will be using a passive infrared sensor (PIR) mounted in a central location in order to detect human presence within a room. The PIR was chosen due to its low cost, low power consumption, and high detection range. The PIR would then communicate via wireless signal to the appliances within the room that a presence has been detected. In order to detect user presence in close proximity to an appliance active infrared sensor would be used within each appliance. Finally, a low-power consumption controller within the appliance would send a signal using Whirlpool’s existing bus network to return the controllers in standby mode to the active state. In the event that the use of wireless technology is scaled-back or eliminated, the appliances will be fitted with individual lower range PIR sensors.

5.3. High-End Solution
The ultimate goal of the high-end product solution is to effectively utilize microprocessor standby modes while enhancing the user’s experience with the appliance. For this solution, cost is of lower concern so there is more flexibility for the Design Team to utilize different forms of technology. It is proposed that the team will be using an ultrasonic sensing device. The ability of these devices to not only detect a person’s presence but also detect the location of the person makes it an
attractive solution. Many high-end appliances currently manufactured by Whirlpool offer LCD modules that display more information than a simple clock or timer. The exploratory concept is to use the ultrasonic sensor to communicate with the appliance and gradually increase/decrease the amount of information displayed on the LCD as the user approaches/departs the appliance, also known as information density. The proximity sensing controllers would be able to communicate wirelessly to each other whether a presence has been identified within their detection range. This would eliminate the need of a separate sensing unit like the PIR and allow for a more seamless design.

6. Consideration of Conceptual Designs

After considering all of the proposed design solutions for every appliance at the high- and low-end, ECE 480 Design Team 5 will choose two appliances to pursue further. This focus has been established due to the time frame of the project. ECE 480 Design Team 5 feels that a better solution can be delivered to Whirlpool by focusing our attention on two of the appliances, one low-end and one high-end. The best low-end and high-end choices are currently under consideration. Input from Mr. Jeffery, Engineer in Advanced Electronic Applications from Whirlpool, will also be carefully considered in the best choices to pursue.

7. Risk Analysis

The main points of concern in implementing the proposed design solution for the proximity sensor will be to genuinely achieve energy savings and ease of use. These challenges present cost issues for the low-end appliances. The heart of this project will be to cut cost and energy consumption simultaneously, while enriching the consumer’s interactions with Whirlpool appliances.

There will be minimal safety hazards for this project. While precautions must be taken when dealing with the 120V – 125V system inside the appliance circuits, there will be no contact with higher voltage components for the entire project.
8. Budget

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The budget is subject to change as project progresses.

9. Project Management Plan

9.1. Team Member Roles

Each member of ECE 480 Design Team 5 will have a technical role per decision as a team, as well as the administrative position assigned by Dr. Goodman. While one team member may be in charge of a particular technical aspect of the project, ECE 480 Design Team 5 will work together to accomplish our mutual goals by working with each other on our individual assignments as required.

9.1.1. Kevin Harrison

**Wireless Technology, Documentation Preparation**

Mr. Harrison is responsible for the proposed wireless communication between appliances. Any network routing programming that is necessary will be performed by him. Due to cost and project scope this aspect of the project will be considered exploratory. Per Mr. Jeffery’s decision, if the wireless communication is scaled back or eliminated, Kevin will transition to partner in the design and building of the board containing the sensor processor and microcontroller. He is also responsible for all deliverable document preparation, editing, coordination, and final polishing.
9.1.2. Eric Hosey  
**PC Interfacing, Website Information Management**

Mr. Hosey is responsible for any coding practices that are required in order to interface the PC and the sensors. Any programming that is necessary will be performed by him. He is also responsible for designing, deploying, and updating the project website with relevant information that can be viewed by any interested parties.

9.1.3. Berna Saracoglu  
**Modular Enclosure Designer, General Management**

Ms. Saracoglu is responsible for the enclosure design of the sensor and on board microcontroller as a single modular unit. She will evaluate various approaches to determine the optimum system configuration with specific design requirements such as power efficient product with tight space constraints, minimum cost, target weight, and aesthetic look. The layout will allow flexibility for later customizations.

As the team’s general manager, she also is in charge of the Gantt chart, progress updates, budgeting process management, and ensuring the device configuration meets the design specifications. She also facilitates communication between the team, faculty advisors, and sponsors.

9.1.4. Leslie Hodges  
**Sensor Design, Presentation Preparation**

Ms. Hodges is responsible for the selection and design of the proximity sensing devices to be used with the appliances. She will be in charge of making sure the devices are able to detect a human presence within a certain degree of accuracy. Leslie is also responsible for all presentations made by the group. She will coordinate the preparation and evaluation of oral reports and is to make sure that all presentations are uniform in style and consistent in content.
9.1.5. Nathan Kelly  
Power Management, Laboratory Coordination

Mr. Kelly is responsible for identifying and providing conditioned power supply to the team’s microprocessor circuits and IR sensors, as well as maintaining suitable power consumption for appliances in stand-by mode. He is also responsible for the oversight of project development in the Lab. He is further in charge of ordering laboratory supplies through either the Whirlpool Corporation or specific manufacturers.

9.2. Proposed Schedule

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10. References


<http://classes.engr.oregonstate.edu/eecs/spring2003/ece44x/groups/g14/white%20papers/whitepaper_matt.htm>.


