Color Control Toaster

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1 Introduction

1.1 Objective

Although we concede the toaster is a great invention, we feel that it could use a much-needed upgrade. Most toasters use a timer to control the darkness of toast. This approach requires one to envision a desired darkness preference, and estimate the required time needed to toast their bread, necessarily resulting in a relative result not exactly what may have been preferred. In addition, forgetting to change this time setting when switching between lighter varieties like white bread and heavier grains such as bagels results in accidental undercooking and burning perfectly good bread. Furthermore, once the timer is up, the toaster completely turns off, and it is often cold by the time it is picked up, making it hard to evenly spread butter onto it.

What if instead you could select your perfect toasted color right on the toaster and have your bread toasted to perfection and still warm when you pick it up? Our project will use a camera or color sensor to monitor the bread as it toasts, and switch to a low power setting when the toast reaches the input color to keep the toast warm until retrieved.

1.2 Background

Burning starchy foods such as bread creates acrylamide, a chemical known to cause cancer [1]. By creating a toaster that shuts off when the bread turns the correct shade of brown, we seek to decrease the likelihood of people eating unhealthy burned or overly dark toast.

To detect the color of the toast accurately and precisely, we will need to view an area uniformly as it cooks. We may be able to simply use the dim orange light generated by the heating elements for color detection, if it works. Otherwise, we will light the toast with LEDs; we are wary of bleaching out the color due to Metamerism if the light is too bright [2].

In order to keep the toast warm while it awaits retrieval, we suggest switching the toaster into a lower power warming mode. The entire dual slot toaster is one series heating element, run on line voltage. To warm and not cook the toast, we propose transferring the driving of this heating element to a half wave rectifier. This will not simply cut the power in one fourth, since the heating element resistance increases with temperature. The temperature will likely be greater than one fourth of the 309 F full power [3]. The temperature will be some fraction of 309, which we will experimentally determine. If it is hot enough to continue toasting the bread, we will revise our approach to keeping the bread warm.

1.3 High-Level Requirements

- Eject toast that is the same color as selected
- Keeps toast warm enough to melt butter after cooking
- Functions uniformly across different weights and colors of bread

2 Design

2.1 Block Diagram

Our design will encompass a modular design in order to facilitate testing and debugging of individual blocks. Although there are various and numerous parts, this product will consist of four stand-alone systems. These include: a main hub, power/light regulator, digital signal processing (DSP), and a feedback system.

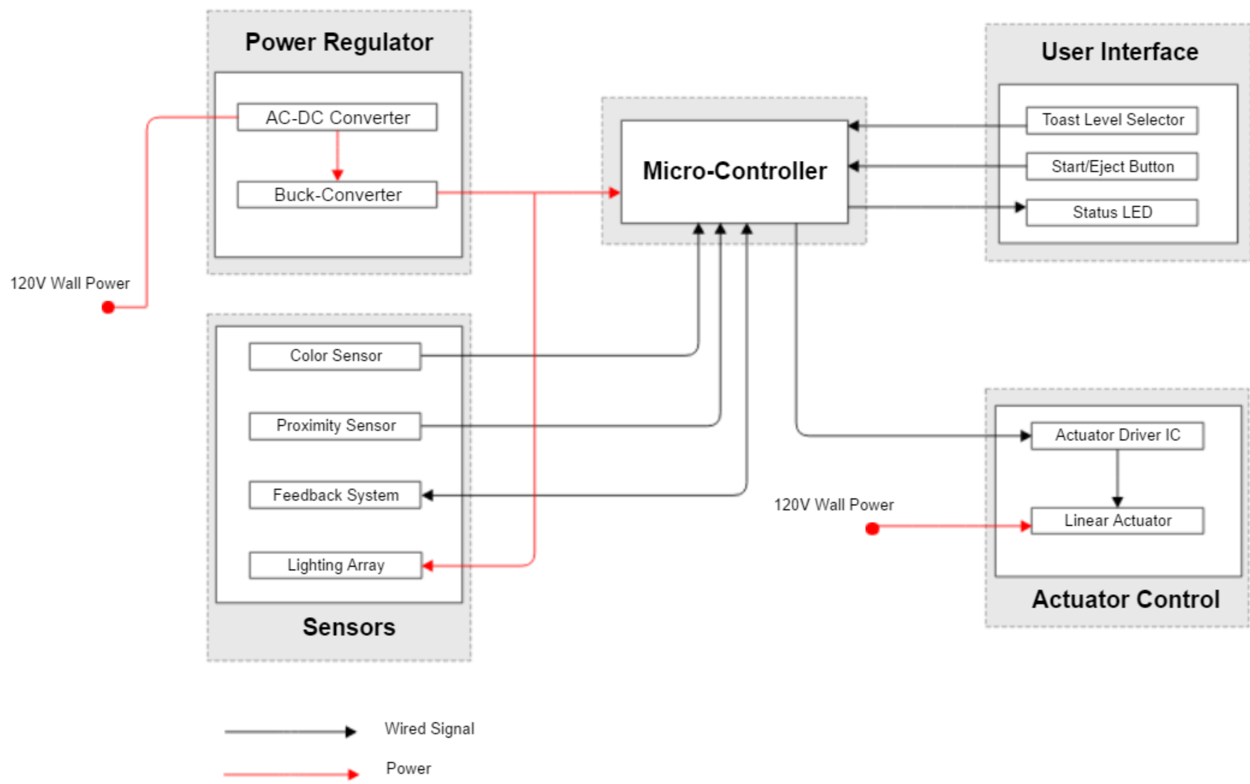

Figure 1: Block Diagram of Color Toaster

2.3 Block Descriptions

2.3.1 Power Supply

As a means of supplying power to all components of the electro-mechanical system for the toaster, specifically the heating elements, we will use the 120 VAC supplied by a GFCI (Ground Fault Circuit Interrupt) receptacle electrical outlet.

Requirement: Will deliver 120V, with 15 amps of current to the load (1800W max).

2.3.2 Power Adapter (AC-DC Converter) for electronics

In order to control and monitor the toasting, we will use a microcontroller such as the AT tiny. Also, we will need to supply direct current to the electromagnet. We will use laptop power supply fly-back converters to supply 5V to our micro-processor and 30VDC actuator systems.

Requirement: Must provide 0-16mA and maintain 5V (the input power range for the small micro-controller) with a 120V AC input source.

2.3.3 Microcontroller

The ATmega328P low-power microcontroller will be tasked with maintaining and using the data received from the RGB color sensors and relaying voltages to the linear actuator and LED's, but also handling the different modes/states using a finite state machine (FSM) library. The microcontroller will have attached the necessary elements (e.g. a clock)

Requirement 1: Turn on all LEDs with a supply voltage of 2.7-5.5V

Requirement 2: Efficiently operate the linear actuator with a supply voltage of 5V

Requirement 3: Consistently shift between states given particular inputs, without reaching a deadlock state.

2.3.4 Feedback System

Consistent monitoring of the color of the bread will be necessary to drive the error signal (bread color – desired color) to 0, so sampling at a rate of 1 sample/sec will be sufficient and achievable for the 16MHz sampling rate of the ATmega328P.

Requirement: Must maintain constant communication between the sensors and the micro-controller to accurately shut down heating elements once bread is toasted to a desired shade. Status should be checked no less than 1Hz.

2.3.5 Linear Actuator

Lifting and pushing of the bread from the toaster is accomplished by a small 5N, 40mm (1.5 inches) stroke, linear actuator situated at the handle or if time permits at the bottom of the toaster beneath a flat surface.

Requirement: The linear actuator should lift the toast up to 1.5-2.0 inches (38mm – 50 mm) +/- 15mm, the distance required to lift the top edge of the bread out of the toaster.

2.3.6 LED Network

This array of white LED's is vital for providing consistent lighting to the inner walls of toaster so that the color sensors can collect data that is invariant to their location or proximity to the bread.

Requirement: The LED network will supply a luminosity value of about 1500 Lux +/- 500, over the course of the toasting process. It must allow the color sensor to differentiate across toasted colors, and not wash out the color.

2.3.7 Color Sensor/Camera

By far the most important block of the project, our RGB color sensors will measure and transmit the data which will determine the toast's color as it heats to the microcontroller. This will be powered by the microcontroller and will receive 5V. They will be positioned in three different locations so as not to depend on a single point of measurement: top corner, center, and bottom corner.

Requirement: The sensors should be able to detect darkness of brown using shades of Red, Green, Blue to within +/-30 RGB values.

2.3.8 Proximity Sensor

Proximity sensors can detect the presence of a nearby objects, which we will use to signal to the microcontroller when there is a piece of bread inside the toaster. Or in our case, when a piece of bread is present, keep warm, and when it has been picked up, turn off.

Requirement: Detect a piece of toast from ¼ inches away for both slots.

2.3.9 Dial and Push Button

The user will select the shade of brown desired through a dial potentiometer input and initiate the toasting process by a push button that will transmit the user input to the microcontroller. This differs from traditional toasters since it eliminates the need to mechanically push the bread down.

Requirement 1: The potentiometer consistently and accurately sets the browness of toast.

Requirement 2: The dial must be easily-turnable and intuitive.

2.3.10 Status LED and Sound

Will notify the user that the toast has been toasted by signaling an LED and sounding a ready sound.

Requirement 1: Visible up to ten feet to notify the user when inside the kitchen.

Requirement 2: Audible from other rooms in the household, using a high-pitched beep

3 Safety and Ethics

3.1 Ethics

As stated in the IEEE Code of Ethics, we have an obligation to our profession, “to accept responsibility in making decisions consistent with safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment” [4]. This directly applies to the design of our toaster, since it is imperative that we provide appropriate warning signs which let the user know that the surface is hot and to disallow the insertion of objects which could lead to a short-circuit and initiate a fire. Not only that, but equally important is “to be honest and realistic in stating claims or estimates based on available data” [4]. Since our software component will contain an algorithm which will monitor the change of color of a respective bread, whether wheat or rye, we should make it apparent that this is not like the standard toaster which uses time-based method, but actually has some signal processing aspect and a functional algorithm for handling varying scenarios/cases. Since the toaster is not a novel idea and we are redesigning its anterior designs we should, “improve [our] understanding of [the] technology; its appropriate application, and potential consequences” [4]. We see it as a necessary act to take apart a toaster and observe the basic functionality and design of old toasters, so that we could continue or improve its safety measures upon use. Due to this course’s excellent structure we will find it easy “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others” [4]. Unless we decide to skip weekly meetings with our TA’s and/or disregard the design review, then this ethical task will be trivial. Considering all that was expressed in the preceding paragraph we should be set to comply with the IEEE Code of Ethics.

3.2 Safety

Given the nature of our project, and the fact that toasters are heat-generating electrical devices, there are numerous safety precautions that should be taken into careful consideration. Looking at the power consumption of common, household appliances, the toaster is in the high-wattage category at 1800W. So it should come as no surprise that there are dangers and hazards associated with this device, these include: electrocution, 1st degree and 2nd degree burns, and fires.

The toaster itself involves two obvious dangerous elements that involve risk: electricity and heat. It can produce an electric shock of 120VAC to the user if the toaster electronics are not wired and the chassis grounded properly. Also, the toaster can get too hot and burn a person’s hand when they try to use it for a second batch of toast. Furthermore, since we are meddling with the shut off time control of the heating elements, if the toaster doesn't stop toasting after a long time, the bread might catch on fire. By using a plastic chassis thermally isolated from the heating elements, we hope to eliminate the possibility of burning hands or electric shock. As far as starting a fire, we anticipate having a maximum time for toasting, and also may include a temperature sensor to shut down when the device becomes too hot.

4 References

[1] https://www.food.gov.uk/news-updates/news/2017/15890/families-urged-to-go-for-gold-to-reduce-acrylamide-consumption

[2] https://en.wikipedia.org/wiki/Metamerism_(color)

[3] http://www.allaboutcircuits.com/textbook/direct-current/chpt-2/nonlinear-conduction/

[4] http://www.ieee.org/about/corporate/governance/p7-8.html