Lava Lamp 2.0 : The Inductioning

ECE 445 - Senior Design Laboratory

Project Proposal

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Table of Contents

1. Introduction

a. Objective

The standard lava lamp has been in production since the 1960's and has not changed much in design since its inception. The method of heating is slow, inefficient, and dangerous. The lamps take roughly an hour to heat to a level to function properly, and they utilize the inefficiency of an incandescent lightbulb to heat the lamp and make the wax inside flow. When the lamp is removed from the base after operating, a hot surface is exposed that can inadvertently burn the user. In addition to these issues, standard lava lamps offer no user interactivity, are not very bright, and are subject to overheating if left on too long. Our project will correct these issues and make lava lamps great again.

b. Background

Our new lava lamp solves the primary issue that most parents have when buying one for their child - safety. Traditional lava lamps become hot to the touch and are often accidentally detached from the base because their design requires light bulb changes. This increases the chance for breakage and other accidents to occur. Lava Lamp 2.0 will be designed to be durable, non-detachable, and cooler to the touch.

Furthermore, traditional lava lamps take 2 to 6 hours to warm up enough for the lava to flow. The previous senior designed lava lamp (we'll call it Lava Lamp 1.0) heated the lava within an hour. This is still too long. When the Lava Lamp 2.0 is turned on, the user should expect a lava flow within 10 minutes.

c. High-level requirement list

- The heating plate must be redesigned to reduce the risk of burns. Glass and surface temperature less than 110 F.

- The design should be brighter than a traditional lava lamp, more than 210 lumen.
- The operational temperature should be reached within 10 minutes.

2. Design

a. Block Diagram

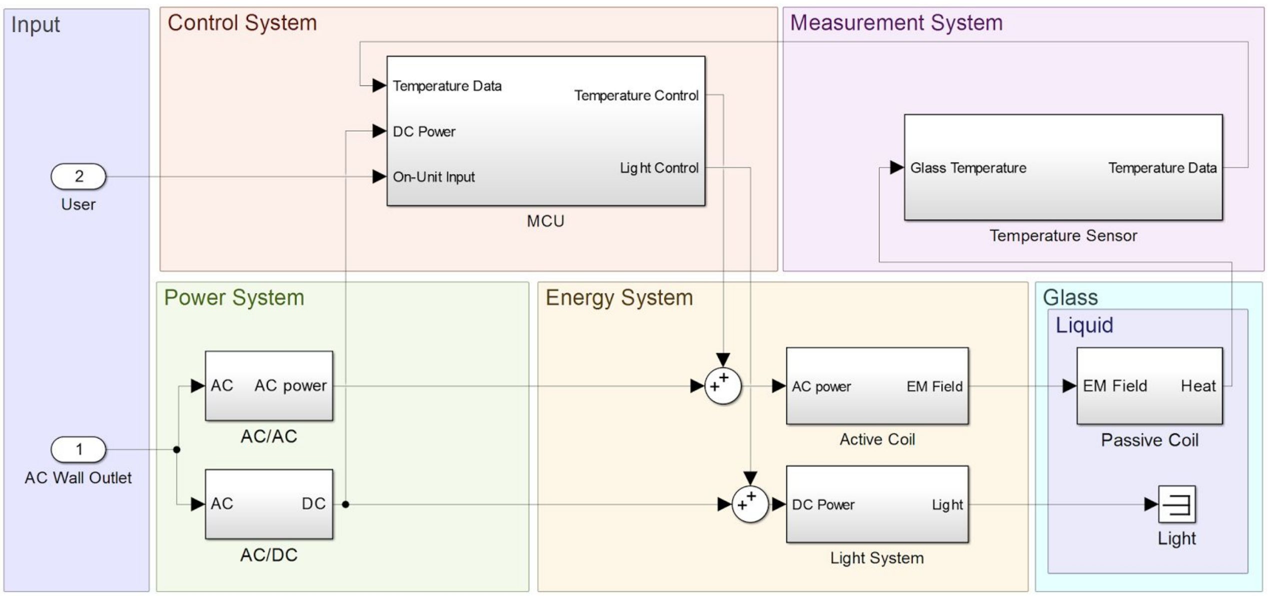

Figure 1: Block Diagram

Our lava lamp consists of 5 well differentiated parts + the input, shown in Figure 1. The power system supplies AC and DC power to the elements that transform energy (energy system) and to the PCB (control system). The PCB is in charge of controlling the amount of power delivered, as it receives feedback from our measurement system. This measurement system will include a temperature sensor to prevent overheating. The energy system is made up of the induction coil, the workpiece and the multicolor LED's.

We can fulfill our 3 high level requirements because the heat flow will only occur inside the glass, the LEDs can be as bright as a traditional lava bulb, and the induction will lead to faster heating.

b. Physical Design

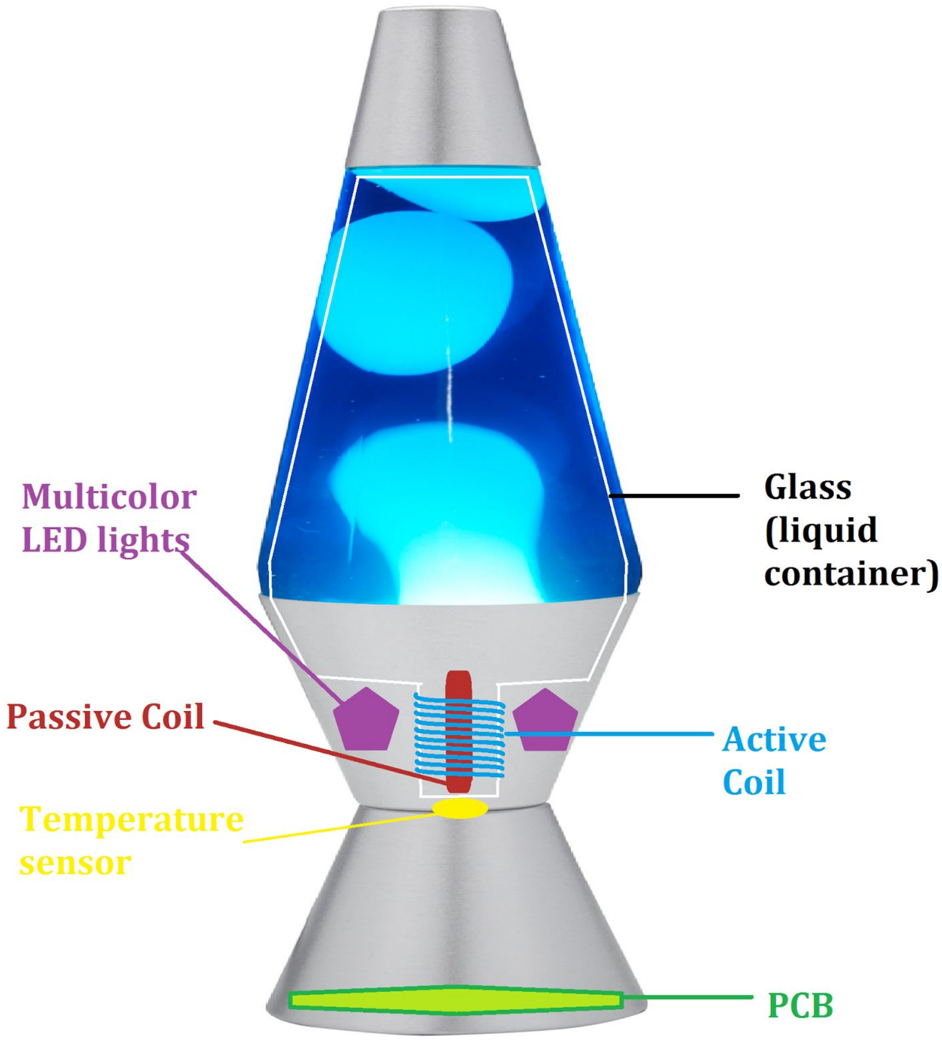

Figure 2: Physical Design

Above is a first sketch of what our design will look like. The innovation in the glass's shape allows us to achieve a faster and more energy efficient induction, as the induction coil and workpiece are held close to each other. This also leaves space around them to place our LED lights, and in the bottom of the glass we can measure the temperature, which will be correlated to the current flowing through our coil, and thereby controlled by the MCU.

c. Functional Overview and Block Requirements

1) Input

1.1) Input power:

120V, 60Hz AC power from a wall outlet will provide power to both the AC/DC and AC/AC converters.

Requirement: *input power must be sourced from a standard 120V, 60Hz wall outlet.*

1.2) User input:

There will be a set of pressure-sensitive buttons and an ON/OFF switch mounted to the base metal part of the lamp. There will be a button to cycle through 3 LED colors, and a button to cycle through 5 LED brightness settings.

Requirement: *ON/OFF must properly provide and cut power to all components.*

Requirement: *Buttons must be labeled and easily pressable.*

2) Control System

2.1) Microcontroller:

The microcontroller will receive and respond to user input, via push buttons, and it will also respond to sensor signals. The user can decide to alter the brightness or color of the LEDs by pressing a button. The microcontroller will then have to adjust the output of the AC/DC power supply to control brightness, or it will have to send a signal to the LED to change color output. The microcontroller also receives a signal from the temperature sensor and adjusts the AC/AC power converter to alter the heat output of the induction coil. This is done to regulate lamp temperature.

Requirement: *PCB with microcontroller must be able to fit within the base of the lamp.*

Requirement: *Microcontroller must respond to user input in under 2 seconds.*

3) Energy System

3.1) Induction Coil:

An electronic oscillator supplied by an alternating current generates an alternating magnetic field which will induce the Eddy Currents and produce heat in the workpiece.

Requirement: *Remains cool enough to not damage the system, we will set a maximum of 110 F.*

Requirement: *Handles a strong enough alternating load current to heat the workpiece to 140 F[1].*

3.2) Workpiece (passive coil):

The workpiece is the electromagnetic metal cylinder attached to the bottom of the lamp that is heated by the active induction coil. This, in turn, heats the liquid at the bottom of the lamp and causes the lava to flow.

Requirement: *Is chemically inert with the liquid.*

Requirement: *Heats up to 140 F[2] but no more than 190F (to not exceed the temperature at which water boils, 212 F).*

3.3) Light System:

A system of 6 multi-colored RGB LED's will be mounted into the top of the metal base, adjacent to the induction coil. The LEDs receive control signals from the microcontroller to determine color, and receive DC power from the PCB, which in turn comes from the AC/DC converter.

[1] Lava Lamp Temperature. URL: http://kitsch.wikia.com/wiki/Lava_lamp
[2] Lava Lamp Temperature. URL: http://kitsch.wikia.com/wiki/Lava_lamp

Requirement: *Must have variable brightness, with one or more settings brighter than 210 lumens.*

Requirement: *Must be able to change colors dynamically (ROYGBV).*

4) Measurement System

4.1) Temperature sensor:

This will be mounted to the outside of the glass just below the induction chamber. This is the hottest part of the lava lamp besides the conductor itself, however this area is not accessible to touch. The sensor will take a continuous temperature reading from this area and provide continuous feedback to the control system. This information will be used to regulate the output of the induction circuit and make sure that the lamp doesn't get too hot.

Requirement: *External glass and metal surface of the lava lamp must not exceed 110 degrees Fahrenheit.*[3]

5) Power System

5.1) AC/AC power supply:

The AC/AC power supply will take 120V, 60Hz input power from a wall outlet and reduce the voltage. The converter must provide suitable AC power to the induction heating coil, which will, in turn, heat the lamp.

Requirement: *Be able to receive power from standard wall outlet at standard tolerance (60Hz, 120V +/- 5%)*

Requirement*: must have protection in place from current surge or Voltage spike.*

Requirement: *Must provide enough wattage and a high enough frequency to the coil in order to heat the workpiece.*

5.2) AC/DC power supply

[3] Human Skin Pain Temperature. URL: https://www.reference.com/health/temperature-human-skin-burn-82a1af6b1322b289

The AC/DC power supply will take 120V, 60Hz input power from a wall outlet and convert it to DC. Supplied DC power will be at the correct voltage to operate the control circuit board, the microcontroller, and the LEDs that brighten the lamp. successive DC/DC converters may be necessary on the PCB to provide various voltage levels.
Requirement: *must have protection in place from current surge or Voltage spike.*

d. Risk Analysis

The block or interface that possesses the greatest risk to successful completion of the project is the heating element. The heating element is crucial to the successful operation of our project and there are many requirements that must be met for a successful design. Not only does the inductive circuit have to be functional and fit into our physical lamp, it must be able to heat the above liquid evenly and consistently. If the heating element does not operate properly, the high-level requirements of reducing risk of the lamp overheating, reducing risk of burns, and reaching operating temperature in specified time will not be met. Additionally, it may prove difficult to provide the wattage and frequency necessary to sufficiently heat the workpiece.

3. Ethics and Safety

Ethical issues from the IEEE Code of Ethics[4]:

- "To be honest and realistic in stating claims or estimates based on available data." We won't falsify data and be sure the data we use is credible and real.
- "To improve the understanding of technology; its appropriate application, and potential consequences." We will always work having

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

in mind the safety risks involved in our project and will not use our lamp outside of its intended purpose.

- "To avoid injuring others, their property, reputation, or employment by false or malicious action." We will give credit to all sources, and make sure our source information is accurately represented. Furthermore, we will not use others work without their permission.

Safety considerations:

- External magnetic field induced by the coil should be non-disruptive.
- Because the bulb heating a standard lava lamp can reach very high temperatures and cause burns, we will try to reduce this risk by implementing an induction heater. With this, the only thing that would get hot would be metal inside the heating coil, and the coil itself would not heat up.

  In order to reduce the risk of metal objects being inadvertently placed inside the heating coil, the glass will be inseparable from the base. This will realistically prevent foreign objects of any kind from interacting with our heating element.