Lava Lamp 2.0 : The Inductioning

ECE 445 - Senior Design Laboratory

Mock Design Review

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1. Block diagram

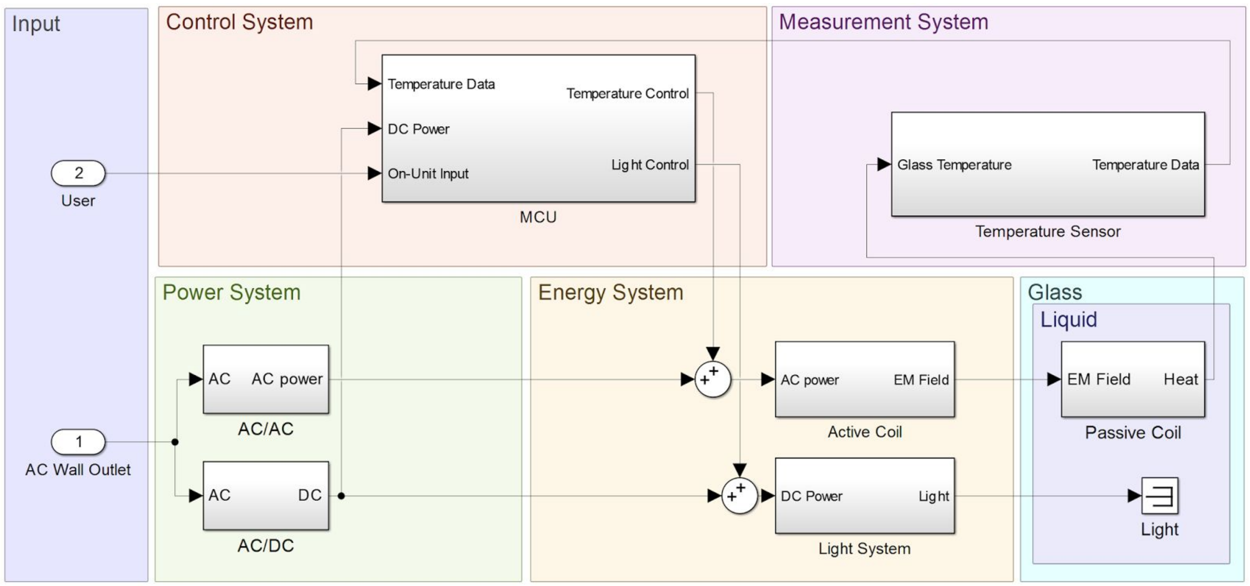

Figure 1: Block Diagram

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.

2. Power System Circuit schematic

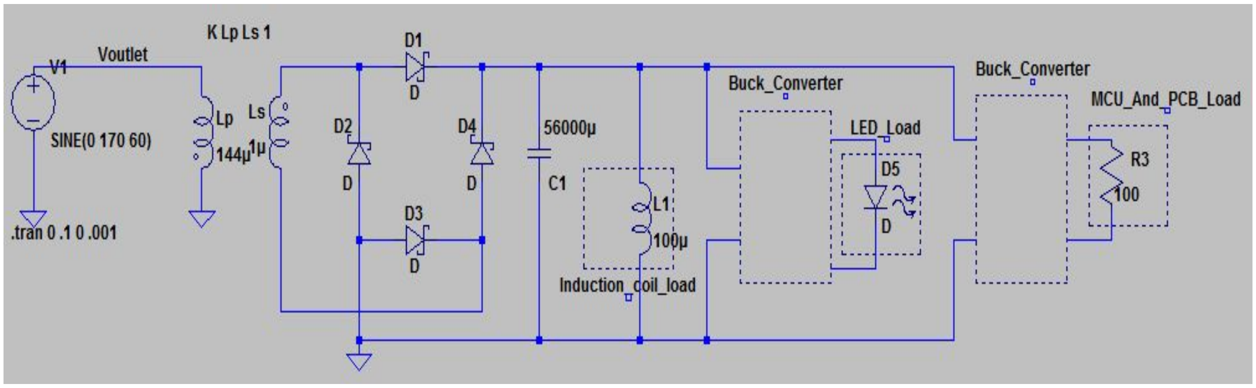

Figure 2: Circuit Schematic

The above circuit depicts the power system for the lava lamp. V1 is input voltage from a standard wall outlet. This input voltage is stepped down to 10VAC using a 12:1, 100VA transformer. This 10VAC voltage is converted to DC by means of a full-wave rectifier and filter capacitor. Rectified DC is what will power the induction coil directly. The LEDs and MCU will each need their own buck converters to further step down the DC voltage. The MCU will likely require 3.3V while the LEDs will likely require 5V.

3. Calculation

We performed a series of calculations in order to determine the correct filter capacitor value for our AC/DC converter. It is known that capacitor charge is related to capacitor current and half-cycle time by

$$Q=I*t$$

It is also known that capacitor charge is related to capacitance and voltage drop by

$$Q=C*\Delta V$$

Combining these two equations yields the following equation. Assuming a 7A current draw, a half cycle time of 8.3ms, and a voltage drop allowance of 1V, we calculated the value of the filter cap to be

$$C=I*t/\Delta V= 7*0.008/1 = 0.056F = 56000uF$$

4. Simulation of Power System

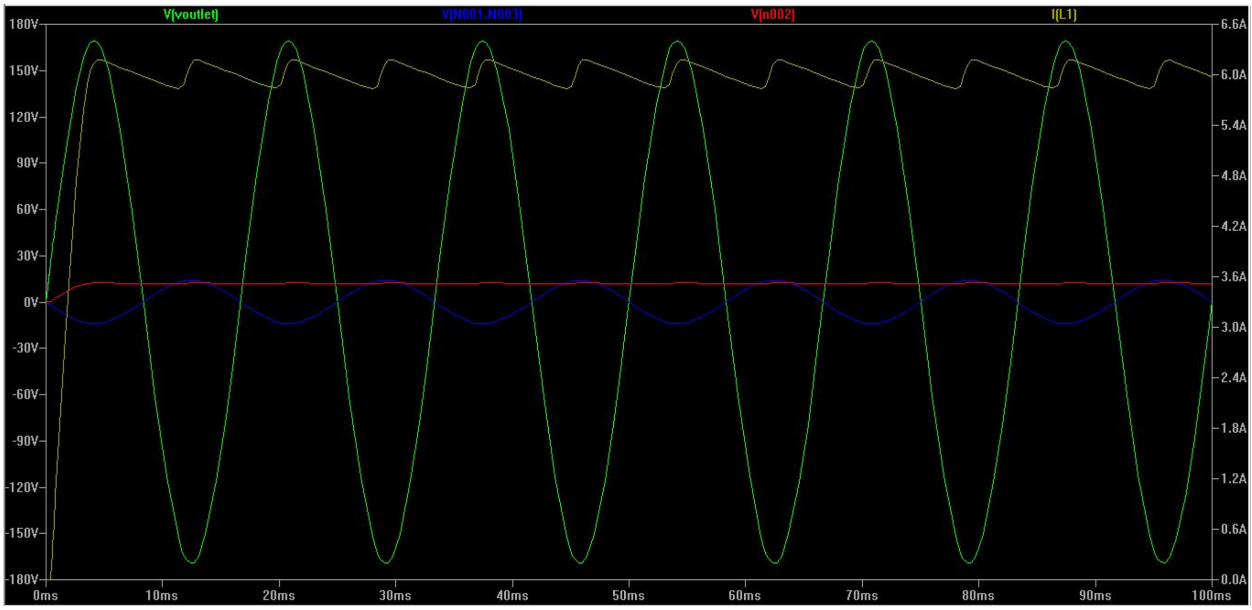

Figure 3: Power System simulation

Green: 120 rms A/C input voltage from the outlet
Red: 12V D/C output voltage from full wave rectifier
Blue: 10V A/C output of transformer secondary
Yellow: Output current to induction coil with ~0.4A ripple

5. Block description of Power Supply System

AC/AC power supply:

The AC/AC power supply will take 120V, 60Hz input power from a wall outlet and reduce the voltage via a 100VA 12:1 transformer. The converter must provide suitable AC power to the induction heating coil, which will, in turn, heat the lamp. (some induction coils require DC power. If one of those is chosen, we will power it with the rectified signal described below).

AC/DC power supply

The AC/DC power supply will take 10V, 60Hz input power from a the transformer secondary and convert it to DC by means of a full wave rectifier and filter capacitor. 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.

6. Requirements and verifications for the temperature sensor

Requirements	Verifications
Accuracy of ± 2 °C	a) Attach temperature sensor to a heatable object (for example cooking plate) b) Heat object c) Use independent temperature measurement device (accurate thermometer) to track temperature variations d) Compare measurements, verify requirement
Track temperature at least 1 time every minute	a) Verify requirement in temperature sensor datasheet
Transfer temperature data as analog voltage to MCU	a) Analog temperature sensor gives us a voltage drop, measured with voltmeter. b) With temperature equation in temperature sensor datasheet, find relationship voltage-temperature. c) Track temperature with measurement device and verify if equation fulfilled.

Table 1: Requirements and Verifications for Temperature Sensor

7. Safety statement

Safety is a big concern for us and is at the forefront of our project requirements. When designing a lava lamp with a new inductive heating circuit we must be mindful of electrical, chemical, and thermal hazards.

When developing our system we must follow certain safety procedures to avoid danger of electric shock. We will work at a lab bench when testing our circuit at all times. Before adjusting any circuit we will make sure to unplug all power sources and test any electrical leads for current with a multimeter. We will make sure our circuits are properly grounded at all times. We will avoid using frayed or damaged wires and cables. Finally, we will test our power system with an oscilloscope before connecting to our control and energy systems.

The composition of the wax inside of our lava globe presents a chemical hazard. While the chemical formula of the LAVALITE® MOTION LAMP is a trade secret, the official US Patent for lava lamps states that the wax contains a chemical called carbon tetrachloride[1]. Carbon tetrachloride causes eye, skin, ingestion, and respiratory irritation so we must wear gloves when handling the wax at all times and avoid ingestion[2]. Furthermore, if we replace the wax inside with our own formula we must adhere to proper safety procedures for any chemicals involved according to the OSHA guidelines.

When running our power system we will run thermal tests to make sure any components do not overheat. Our induction system and heated glass also presents a thermal hazard. Temperatures of greater than 110°F on the external surface of the lamp will cause burns when touched [3], and excessively high temperatures on the bottom surface the glass may cause it to break therefore we will disconnect power from the induction system if our temperature feedback fails or rises above the desired temperature.

8. Citations

[1] Google, “Patent US 3570156 A”, 1971. [Online]. Available:
https://www.google.com/patents/US3570156
[2] Fisher Scientific, “Carbon tetrachloride Material Safety Data Sheet”, 2008. [Online].
Available: http://fscimage.fishersci.com/msds/90116.htm
[3] Reference, “At what temperature does human skin burn?”, 2017. [Online]. Available:
https://www.reference.com/health/temperature-human-skin-burn-82a1af6b1322b289