Introduction to Engineering: GE Align Lighting Technology

EG 10112 - Section 3

Dr. Brian Smith

Group 7

Catherine Breakfield, Jack Dimpel, Michael Kay, Matthew Lillie, Marcus Schimizzi

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Signatures:

Abstract:

Differing from other pure open-ended projects, the group chose to do a project that was proposed by GE. This does not, however, mean the group had little motivation behind the decision to do the GE LED lighting project. As college students, the group members all have skewed sleep schedules and a project that focused on restoring balanced sleep was more than a little appealing. The idea behind the project was to design a program that could determine the values of resistances necessary in a color tunable LED light consisting of white, blue, green, and red LEDs that would successfully recreate the colors of the GE's marketed Align AM and PM bulbs. The approach to create this program was to create separate functions for each of the mathematical formulas provided by GE and to then implement them all in a single function, "masterFunk," that could calculate what color points to be created tested by applying various currents through the separate LED channel. By utilizing the the color point coordinates that represent both the AM and PM bulbs, currents needed for each LED in the color tunable bulb were able to be calculated. Upon testing these calculated coordinates, the results did not yield a perfect color match due to the difference in the brightness of the lights GE supplied and our own LED. By using the developed computational model, one can reasonably determine a match of color for the GE AM and PM bulbs while also designing colors of their choosing by using the GUI to calculate what color would be present at various currents.

Needs Assessment and Problem Formulation:

The goal of the GE Align Lighting Technology Project was to develop a system that controlled an LED in order to manage a person's circadian rhythm. Certain colors of light affect the body's production of melatonin, the hormone that helps the body sleep. Blue light suppresses the production of melatonin while red light increases it. The AM and PM bulbs use blue and red light respectively to manage a person's circadian rhythm. A possibly more effective system involves a single, color tunable LED. The end product of this project was just that: an LED that produces the energizing effect of the GE Align AM bulb and the soothing effect of the GE Align PM bulb, prototyped using a color-tunable LED light bulb.

The computational aspect of this project was to design the LED functions and features using a mathematical model. This model allowed users to see the necessary amperages to which the individual LED channels needed to be tuned to match the color of the AM and PM bulbs. It also allowed users to see what values could be used to produce customized light colors. Generally, the goal was to develop a mathematical model that controlled the LED's properties in order to manage a person's circadian rhythm and foster healthier sleep.

The physical build consisted a of a basic circuit and white walled, doubled celled box into which the LED and GE Align bulbs were shown. This setup facilitated comparing the two lights, as shown below in Figure 1. The circuit was simply constructed from the power supply and color tunable LED bulb provided by GE and four potentiometers purchased for each LED channel in order to adjust the current flow to each bulb to determine the output color.

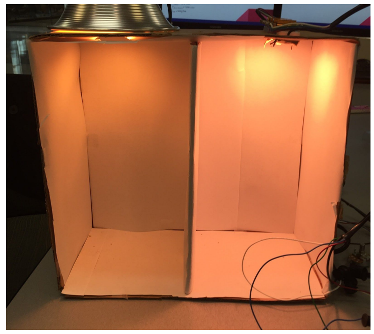

Figure 1: Physical Build

As seen in the figure, the control light (the GE Align PM Bulb in this figure) is shining into the left cell. The right cell houses the tunable LED light connected to the previously described circuit, which is tuned to match the color of the PM bulb in this figure.

There were very few project constraints. The largest constraint faced was the sharing of materials used in the physical build. This provided a small challenge when it came to designing our final build. In order to share certain parts of the build, including the LED channel and the powersource, the build was not as robust as it could have been as those parts needed to be easily removed.

Table 1 below shows the costs of the parts that were purchased for the build. The total cost came to $18.63.

Table 1: Part Costs

Product	Part Number	Quantity	Cost
Potentiometers	255485	4	$6.20 from Jameco Electronics
Compatible Pot Knobs	264990	4	$3.96 from Jameco Electronics
Portable Fixture	203213	1	$8.47 from Lowe's
Display Box	N/A	1	No cost

Abstraction and Synthesis:

In order to build a prototype light bulb that can represent the correct color points, there are various equations to utilize. The first equation necessary for the project will determine the output of any of the LEDs at any given current:

$$P_\lambda = \frac{I_{actual}}{0.7} \mathrm{P}_{\lambda,REFERNCE} \tag{1}$$

In this equation, $P_{\lambda,REFERENCE}$ is the power given by the Spectral Power Distribution (SPD) at a specific wavelength λ. The SPD is used in determining how each of the four different LED used will look to the human eye. P_λ is the expected power of the LED when driven at I_{actual}.

In the project, a perfect mixing of each of the four LED channels is assumed. Therefore, the total SPD for the color tunable bulb is given by the following equation:

$$P\lambda{,}total = P\lambda{,}red + P\lambda{,}blue + P\lambda{,}green + P\lambda{,}white \tag{2}$$

Using the prior equations, the SPD for the light bulb can be determined. With this SPD, analysis of the color of the light spectra can be done using the color using three coordinates. This description is referred to as the CIE color space, and can be determined utilizing the following three equations:

$$X = \int P_\lambda \bar{x}_\lambda \, d\lambda \approx \sum P_\lambda \bar{x}_\lambda \, \Delta\lambda \tag{3}$$

$$Y = \int P_\lambda \bar{y}_\lambda d\lambda \approx \sum P_\lambda \bar{y}_\lambda \Delta\lambda \tag{4}$$

$$Z = \int P_\lambda \bar{z}_\lambda \, d\lambda \approx \sum P_\lambda \bar{z}_\lambda \, \Delta\lambda \tag{5}$$

In this equation, P_λ is the power given by the total SPD function at a given wavelength, that is the total SPD given by Equation 2. The values $\bar{x}_\lambda$, $\bar{y}_\lambda$, and z_λ are the Color Matching Functions which are constants shown below in Table 1. Finally, $\Delta\lambda$ is the wavelength step size used in the prototype, which will be 5nm in this experiment.

The x, y, and z coordinates given in equations 3-5 can vary based on brightness. Using the following equations, however, it can also determine x and y coordinates of color, shown in Table 2 below, that will not vary based on brightness:

$$x = \frac{X}{X+Y+Z} \tag{6}$$

$$y = \frac{Y}{X+Y+Z} \tag{7}$$

Table 2: AM and PM Color Points

	x-Color Point	y-Color Point	Brightness
Bulb Type	x	y	Y
Align AM	0.313	0.298	1.3177
Align PM	0.521	0.413	0.5124

In order to obtain the proper color from the LEDs, a certain voltage must be applied to each one. These required voltages are given by the following equations:

$$V_{RED} = 13.5 \textit{ volts} \tag{8}$$

$$V_{GREEN} = 19.8 \textit{ volts} \tag{9}$$

$$V_{BLUE,/WHITE} = 18.6 \textit{ volts} \tag{10}$$

In this equation, V_{COLOR}, are the respective voltages of the four LEDs used in this experiment. The following equation is a variation of Ohm's law that can be used in order to determine the current flowing through the LED:

$$I_{LED} = \frac{V_{SUPPLY} - V_{LED}}{R} \tag{11}$$

In this equation, V_{SUPPLY} is the voltage value of the supply source which is 24V in this experiment. V_{LED}, is the respective LED voltage and the I_{LED} value is the value of the current driven through the circuit containing the four LEDs and accompanying resistors.

In order to establish a base for the project, a few assumptions were made. The above equations were provided by GE and it was assumed that these equations are accurate. In addition, GE supplied data for color matching, color points, and LED Spectra which was also assumed to be correct. In respect to the hardware, it was assumed that an ideal diffuser was used to mix the LED channels and that the four channels mixed perfectly. In addition, it was assumed that the output of each LED increases linearly with the increase in current and the total output is equal to the sum of those individual outputs. In general, it was assumed that circadian rhythms are in fact affected by light such as that produced by the color tunable bulbs. This assumption is important because it legitimizes the idea of having a light tunable bulb that allows the user to chose the color of the light based on their needs.

The physical testing required attempts to match the color points of the GE Align AM and PM bulbs with each channel of the color tunable bulb being set to a specific resistance in the physical circuit based on the currents calculated by the mathematical model. This physical testing could have been approached by two routes. The first, physical guessing and checking of resistances through turning the potentiometers to specific settings until the colors matched. Once this was achieved, checking with the computation model's settings would then confirm its accuracy. The second method, which was the chosen method, was to determine a certain set of desired currents to match the colors of both the AM and PM bulbs through the mathematical model and then test this set with the corresponding resistances set in the potentiometers. This method yielded precise and accurate results shown in Table 3 and Table 4 below displaying the calculated and tested current and resistance measurements as well as the color points they determine.

Table 3: AM Bulb

	Red	Green	Blue	White	Color Point
Current (mA)	17	57	46	250	x: 0.31295
Resistance (ohms)	618	74	117	22	y: 0.29778

Table 4: PM Bulb

	Red	Green	Blue	White	Color Point
Current (mA)	142	105	0	26	x: 0.52107
Resistance (ohms)	74	40	N/A	208	y: 0.41318

These calculated values are the final data points used in the display. The data represents one physical output that successfully matches the colors of the Am and PM bulbs. These data points could be a number of variations of the input currents to yield the color points necessary. The correlation between the physical output and the model developed displayed this functionality and along with the accuracy of the computational model developed itself.

Analysis:

The final GUI design reflected the engineering design process. The initial design displayed a much more congested user interface with functionality deemed unnecessary when growing from initial needs to the final synthesis of needs. The final GUI design (Figure 2) reflects a more simplistic layout with more easily operated interactive features which are the core necessities in executing and visualizing the end result of matching the color points of the Align AM and PM light bulbs.

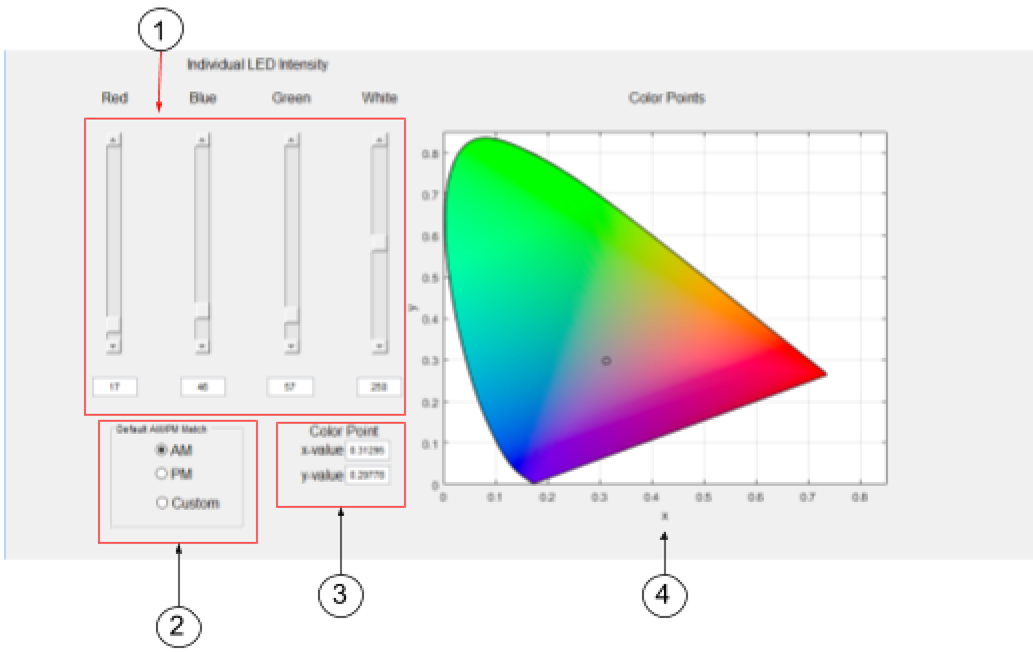

Figure 2: Final GUI Design

The final GUI design compacted the user interfacing needs to four key features. (1) This feature includes four sliders linked to four text boxes. Each slider represents the current sent to the individual LEDs in the color tunable GE bulb. The use can interact with this feature by sliding the sliders to any current between 0 mA and 500 mA or inputting any value in the same range in the individual text boxes. The modification of these sliders and text boxes is the basis of the outputs pertaining to the other features. That is, the inputs to this feature act as components in calculating the Color Points which output to the black circle shown on the graph. (2) The second feature is a button group of three buttons linked to the sliders and text boxes. The first two buttons, “AM” and “PM,” can be pressed to output specific settings for the sliders based on the calculation of the specific currents needed to output the specific AM and PM color points the group was attempting to match as the end result of the project. The Custom button, when pressed, allows the user to play with the sliders and text boxes, setting any value and seeing the output of the Color POints and specific color on the plot. (3) This feature takes the inputs of current from the sliders and outputs the color points of those specific settings. These points are then the coordinates of the black circle plotted on the graph. (4) The final main feature of the GUI is a plot displaying the CIE color spectrum where specific coordinates, deemed color points, correspond to specific x-values and y-values in the plane. This feature always has the CIE color space plotted and regenerates the black circle at the specific Color Point coordinates inputted from Feature 3.

Implementation:

The implementation of the determined color points proved to be quite open-ended. Given the nature of the color tuning of LEDs to match another color, many options were possibilities. However, our computational model eventually led to one color point to match each of the GE lightbulbs. In testing the resistances given by the determined color point, the colors generated matched the GE colors relatively well. The determined AM color ended up being more blue in color than the one that GE supplied. The determined resistances for the PM color point matched more closely to the bulb from GE, however, it was slightly more yellow than the GE light bulb. Overall, the testing did match the expectations relatively well. This project did not require repeated physical testing, because once a color point was found computationally, it only needed to be replicated through resistances physically once.

The variations between the predictions (the GE bulbs) and the results (the color-tuned bulb) can be explained by a few major factors. Perhaps most notably, the color tunable bulb had physical limitations as far as power and brightness capabilities that prevented it from being able to exactly match the bulbs GE provided. Even if the resistances perfectly matched the color point of the GE bulbs, the resulting color of the color-tunable bulb would still differ from the Align bulbs. GE engineered the AM and PM bulbs exactly so that they would be able to produce the exact colors they do. The color-tunable light bulb is instead engineered to be able to change colors, not replicate the exact appearance and brightness of other bulbs.Additionally, the initial assumption of perfect color mixing likely caused some inconsistencies between the predictions via the color points and the actual appearance of the resulting bulb.

A few ways exist in which the project could have been improved. One way to have vastly improved our project would have been to constantly read in the resistances from each channel into a computer using Arduino. In fact, this addition was a stretch goal for the project, but was not achieved due to time constraints. This addition would have granted the project more accuracy in tuning the potentiometers and would have also allowed the GUI to update in real-time with the current color point of the light bulb. This would be one improvement that has the potential to vastly improve the project. Additionally, another potential improvement would be to have a method to scale and adjust brightness on our bulbs. Therefore, the project would have been able to match the GE light bulbs perfectly.

Supporting Documentation:

Sources used in the background of this project were provided by GE. Below are the documents and uploaded to webfile are the data samples in the Excel spreadsheet file.

Shilling, David. G.E. Lighting. *GE ALign Lighting Project Proposal.* Web. 2016.

Shilling, David. G.E. Lighting. *GE Lighting: Lighting and Sleep.* Web. 2016.