February 5, 2012

Dr. Andrew Rawicz
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Burnaby, British Columbia
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Re: ENSC 440 Functional Specifications for a Smart Dimmer

Dear Dr. Rawicz,

The following functional specification describes the functionality of our Smart Dimmer device. The Smart Dimmer will transparently replace traditional dimming switches while automatically maintaining a desired brightness and saving power by maximally utilizing exterior sources of light.

The Smart Dimmer will work by measuring changes in the overall brightness in a room and using this to adjust the lighting fixtures up or down to maintain a desired, user set, level of brightness. As the brightness from exterior sources increases the Smart Dimmer will decrease the brightness of the lighting fixture; maintaining the desired levels and saving energy.

The functional specification will describe the overall system functionality as well as the functionality of its three main subsystems: Dimmer Subsystem, Control Subsystem and Sensing Subsystem. These specifications will be utilized by our team of engineers as they design and implement the Smart Dimmer. With their experience on embedded digital systems Jonathan Kehler and Aram Grigorian will focus on the digital Control Subsystem. Thomas Plywaczewski's and Larry Zhan's knowledge of hardware and circuits will be used to spearhead the analog Dimming Subsystem. Finally, Waris Boonyasiriwat's expertise in light sensing apparatus will move forward the development of the Sensing Subsystem.

Questions or concerns regarding the functional specifications may be addressed to me by email at jka37@sfu.ca or by phone at 604-291-1721.

Sincerely,

Jonathan Kehler
Project Director
Smart Light Solutions

Enclosure: *Proposal for a Smart Dimmer*

Smart Light Solutions

Functional Specification

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1 EXECUTIVE SUMMARY

The Smart Dimmer by Smart Light Solutions will allow users to avoid the annoyance of fluctuating light levels and save power all without any complications to the current user models of a standard dimming switch. Homes and offices suffer from "over-illumination", meaning they are periodically brighter than the occupants require. This causes annoyance and a significant waste of energy. The Smart Dimmer will solve this problem maintaining a constant interior brightness in the face of fluctuating exterior conditions.

The Smart Dimmer will look and function, like a conventional dimming switch. An adjustable knob will increase or decrease the brightness of the associated lighting fixture between its maximum and minimum dimmable levels. When the exterior lighting situation changes the Smart Dimmer will recognize this and adjust the dimming level of the lighting fixtures in opposition to the exterior changes to maintain a constant interior illumination. With these features the Smart Dimmer will not add any complications to the traditional models of usage. The Smart Dimmer will not limit the capability of any lighting fixtures it controls, in all respects it will appear to function just like a traditional dimming switch.

2 GLOSSARY TERMS

LED Light Emitting Diode

Illuminance Measure of the intensity of the incident light [1].

Lux [*lx*] The SI unit of illuminance and luminous emittance, measuring luminous flux per unit area [2].

Neutral Density Filter (NDF)
Filter that, ideally, reduces and/or modifies intensity of all wavelengths or colors of light equally, giving no changes in hue of color rendition [3].

3 INTRODUCTION

The Smart Dimmer is a smart dimming switch to work with both incandescent and fluorescent lighting fixtures. The requirements of the design of the Smart Dimmer are described in the following specification.

3.1 Scope

The functional specifications detailed in this document will be used to design and implement the Smart Dimmer. The System Requirements will detail general system level behavior while the subsystem requirements will cover details of the individual subsystem in more detail. The final design and implementation will meet all the requirements laid out in the final version of this document.

3.2 Intended Audience

These specifications will be employed by each member of our engineering team as they design and implement the Smart Dimmer's subsystems. The System Specifications will be particularly relied on by the Project Director as he monitors and coordinates integration. This document also serves as a submission requirement for our 305W course.

3.3 Classification

All requirements/specifications throughout this document will be labelled with a tag of the following format.

[Rn-L]

n - Number of requirement (simple consecutive ordering)
L - Level of priority

Levels of priority:
1 - both prototype and production system
2 - prototype system only
3 - production system only

4 SYSTEM REQUIREMENTS

4.1 System Overview

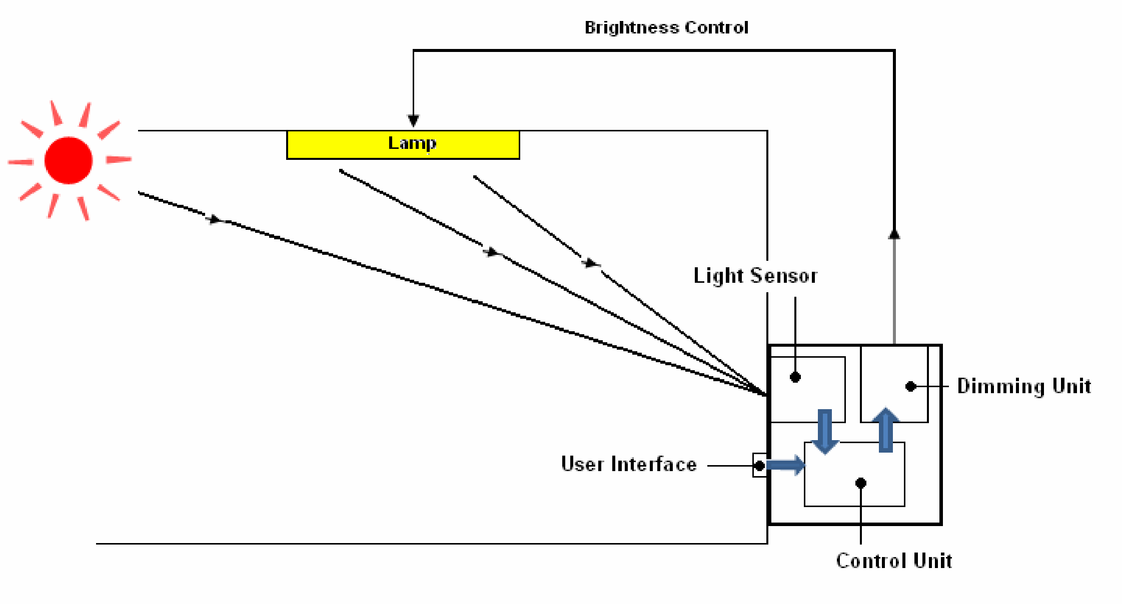

Figure 1: System Overview

Our system is comprised of three subsystems; the light sensor, the control unit and the dimming unit. Room brightness is sensed by the light sensor which feeds this information to the control unit. User interface data indicating the desired brightness is also fed into the control unit. The control unit implements an algorithm which takes the two inputs communicates with the dimming unit. The dimming unit uses the results of the control algorithm to apply the appropriate amount of dimming to the external lamp.

4.2 General Requirements

[R01-3] The system will not exceed a retail price of $30

[R02-1] The system will be able to function with both incandescent and dimmable fluorescent bulbs.

4.3 Physical Requirements

[R03-3] The system will be fully enclosed and none of the internal circuitry directly accessible to user.

[R04-3] The system will continue to function if dropped from 2 meters or less.

[R05-3] The system will fit in conventional light switch housings for simple installation.

4.4 Electrical Requirements

[R06-3] Total power consumption of the system will not exceed 5 Watts.

[R07-3] The system will be fully powered by the AC mains of the building.

4.5 Environmental Requirements

[R08-3] The system will not contain any hazardous materials/elements.

4.6 Standards

[R09-3] The system will be designed to pass necessary certification to be a saleable device.

4.7 Reliability and Durability

[R10-3] The system (and all sub components) will have an expected average functional lifespan of at least 5 years.

4.8 Safety Requirements

[R11-1] The system will not constitute a fire hazard.

4.9 Performance Requirements

[R12-3] There will be no visible time lag between user input and system control of the lights.

[R13-1] The overall illuminance in the room will not vary noticeably as the system is working so long as the light fixture is not at its maximum or minimum operating range.

4.10 Usability Requirements

[R14-1] The system will allow the user to control the light fully within its natural operating range without restriction.

4.11 Luxury Functions

[R15-3] LED lights will inform the user of the current light-bulb illumination level.

5 USER INTERFACE

The user interface will consist of either a knob or a rocker for the user to indicate if they desire more or less light.

Figure 2: Potential user interface designs [4, 5].

5.1 Usability Requirements

[R16-1] The interface will function identically to traditional dimming interfaces.

5.2 Mechanical Requirements

[R17-3] Both the knob and the rocker will be spring loaded to allow adjustments, not absolute settings.

[R18-3] The knob will not be able to rotate 360 degrees.

6 LIGHT SENSOR

The light sensor converts illuminance to voltage. This signal is then passed into the control unit as a representation of the current brightness in the room.

6.1 General Requirements

[R19-3] The light sensor will be masked by a neutral density filter, which will uniformly attenuate the incoming brightness to within the acceptable range of the light sensor.

[R20-3] The light sensor will register a minimum illumination range of 1 to 10,000 lx.

6.2 Physical Requirements

[R21-3] The light sensor will not exceed 2cm in diameter.

[R22-1] The light sensor cannot be blocked or situated in a region where external light sources cannot reach it.

6.3 Electrical Requirements

[R23-1] The output voltage of the light sensor will be between 0 and 5V.

7 CONTROL UNIT

The control unit will implement a control algorithm to translate the user input and sensor input into a means of controlling the level of dimming of the light fixture.

7.1 General Requirements

[R24-1] The control unit will be capable of interfacing with the light sensor and user interface.

[R25-1] The control unit will be capable of outputting a pulse of at least 1 volt at 60Hz.

7.2 Safety Requirements

[R26-1] The control unit will not constitute a fire hazard.

8 DIMMER UNIT

The dimmer unit will be responsible for controlling the amount of necessary dimming. It will be working behind the user interface controls.

8.1 General Requirements

[R27-1] The dimmer unit will be capable of switching the AC main signal at a rate up to 60Hz.

8.2 Electrical Requirements

[R28-1] The dimmer unit will accept an input pulse in the range of 0-5V.

[R29-3] The dimmer unit will contain damping components to eliminate RF pulses generated from the electrical switching.

9 SYSTEM TEST PLAN

9.1 Subsystem (Unit) Test Plan

This will detail how the subsystems will meet the above specifications.
A large portion of these should be dedicated to ensuring it correctly uses the expected input and produces the desired output - in preparation for system integration.

9.1.1 Dimmer Subsystem Test Plan

- Simulate operation using PSpice.
- Simulate operation using function generator as input and oscilloscope to confirm the output is the desired and expected waveform.

9.1.2 Control Subsystem Test Plan

- Observe the characteristics of the control algorithms and ensure it meets requirements in terms of stability and response.
- Ensure the user interface control range is aligned with the dimmer circuit control range to ensure full control of the light fixtures dimmable operating range.
- Ensure the user interface input is scaled correctly with the sensor's input values.
- Use an oscilloscope to ensure the pulses created by the control sub system align with the required pulse for the dimmer circuit.

9.1.3 Sensing Subsystem Test Plan

- Use the light meter to confirm the sensor's readings are accurate and capable of detection within the range 1-10,000 lx.
- Observer the sensor's output to ensure only 0-5V range is outputted.

9.2 System Test Plan

This will detail how the overall system will meet the above specifications. This section will detail several test cases which will test all the important functionality of the system and all major corner cases of operation which may potentially lead to failure of operation.

9.2.1 Ensure constant level of brightness

The exterior lighting will be manually varied and a light meter will be used to measure the overall illuminance in the room.

9.2.2 Ensure full operating range of lamp

The lamp brightness will be increased to its maximum via the user interface. This brightness will be compared to the normal maximum operating brightness of the lamp. The lamp brightness will be decreased until the lamp appears off.

9.2.3 Measuring Power Savings/Consumption

A power meter will measure the power consumption of the lamp under various operating conditions. The system's power consumption will be measured using the power meter to ensure it does not exceed specification.

9.2.4 Functional with Incandescent and Dimmable Fluorescent

The system will be tested with both incandescent and dimmable fluorescent bulbs to ensure it operates within specification with both.

9.2.5 Operational Corner Cases

These cases are to deal with the difference between the reference level set by the user and the actual conditions. These corner cases exist because the user may set a desired level of brightness which, because of changing conditions and limitations of the lamp, becomes impossible to maintain. The system should remember the user's desired reference level even though the external conditions do not currently represent it. The reference level should be remembered until the user adjusts the user interface – at which time it should then adjust from the currently existing conditions and not the previous reference level.

Case1
The user sets the lamp to its maximum setting; we will call the current level of overall brightness the 'reference level'. The exterior light decreases. The lamp cannot increase because it is already at its maximum level, therefore the overall brightness decreases. Later, if the exterior light were to increase, we would not want the system to respond immediately by decreasing the brightness of the lamps. Rather we would want it to wait until the reference level was reached and then attempt to maintain that level – because that is what the user originally desired.

Case2
The user sets the lamp to its minimum setting; we will call the current level of overall brightness the 'reference level'. The exterior light increases. The lamp cannot decrease because it is already at its minimum level, therefore the overall brightness increases. Later, if the exterior light were to decrease, we would not want the system to respond immediately by increasing the brightness of the lamps. Rather we would want it to wait until the reference level was reached and then attempt to maintain that level – because that is what the user originally desired.

Case3
The user sets the lamp to its maximum setting; we will call the current level of overall brightness the 'reference level'. The exterior light decreases. The lamp cannot increase because it is already at its maximum level, therefore the overall brightness decreases. Later, if the user were to adjust the user interface the old reference level should immediately be replaced by the new reference level being defined by the user as they turn the knob.

Case4
The user sets the lamp to its minimum setting; we will call the current level of overall brightness the ‘reference level’. The exterior light increases. The lamp cannot decrease because it is already at its minimum level, therefore the overall brightness increases. Later, if the user were to adjust the user interface the old reference level should immediately be replaced by the new reference level being defined by the user as they turn the knob.

10 CONCLUSION

This functional specification has defined the requirements and capabilities that will be provided by the Smart Dimmer. A production device meeting these specifications can be expected to operate effectively and integrate with existing fluorescent and incandescent lighting fixtures. A prototype meeting the specifications of the final version of this document is currently scheduled for completion by April 16th 2012.

11 REFERENCES

[1] “Illuminance.” Internet: http://en.wikipedia.org/wiki/Illuminance, Dec. 3, 2011 [Jan. 30, 2012].

[2] “Lux.” Internet: http://en.wikipedia.org/wiki/Lux, Feb. 4, 2012 [Jan. 30, 2012].

[3] “Neutral Density Filter.” Internet: http://en.wikipedia.org/wiki/Neutral_density_filter, Jan. 28, 2012 [Jan. 30, 2012].

[4] “Decora to Toggle Switch Plate Filler Insert.” Internet: http://www.kyledesigns.com/product/327-DECORA-INSERTS/Decora-to-Toggle-Switch-Plate-Filler-Insert.html, [Feb. 4, 2012].

[5] “X10 Switches, Dimmers & Controllers.” Internet: http://www.stereoexperience.com/Leviton-DHC-Rocker-Dimmer-Switch-600-Watt-Scene-Capable-LVHCM061SW_p_20706.html, 2012 [Jan. 28, 2012].