April 11, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specifications for a Smart Dimmer

Dear Dr. Rawicz,

The enclosed Post Mortem summarises the status 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.

Questions or concerns regarding the post mortem 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: *Post Mortem for a Smart Dimmer*

Smart Light Solutions

Post Mortem

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Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
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Issued Date: April 11, 2012

Revision: 1.0

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1 INTRODUCITON

With an increasingly green mindset the design of buildings are focusing on the maximal utilization of natural light through the use of glass and open design styles. We at Smart Light Solutions are aligning ourselves with this philosophy as we design a smart dimming switch which will take full advantage of the naturally available light in a space. While new building designs will allow more light into structures, parts of the construction world are still stuck in the old ways. While installed lighting is needed for the evenings, it is used in excess to provide a constant "over-illumination" during the brightest parts of the day. This waste of energy is what we at Smart Light Solutions intend to solve. With our smart dimming switch we will reduce energy expenditures at times when external light can contribute to the overall desired illumination of a space, and most importantly we do this without adding any complications to the user.

Over the 2012 spring semester Smart Light solutions has successfully completed a breadboard proof of concept prototype, as well as constructed a larger secondary prototype for demonstration purposes in small sized rooms. This document reflects on the current state of the project. It compares our initial budget and scheduling estimates to what we actually spent. In addition, members of the team provide a page of personal reflection on the Capstone Project experience.

2 SYSTEM STATUS

Figure 1 shows a system diagram of the Smart Dimmer. The blocks illustrate the interconnections between the various components, and how input light levels lead to the adjustment of light fixtures. Overall the project adheres closely to the design specifications.

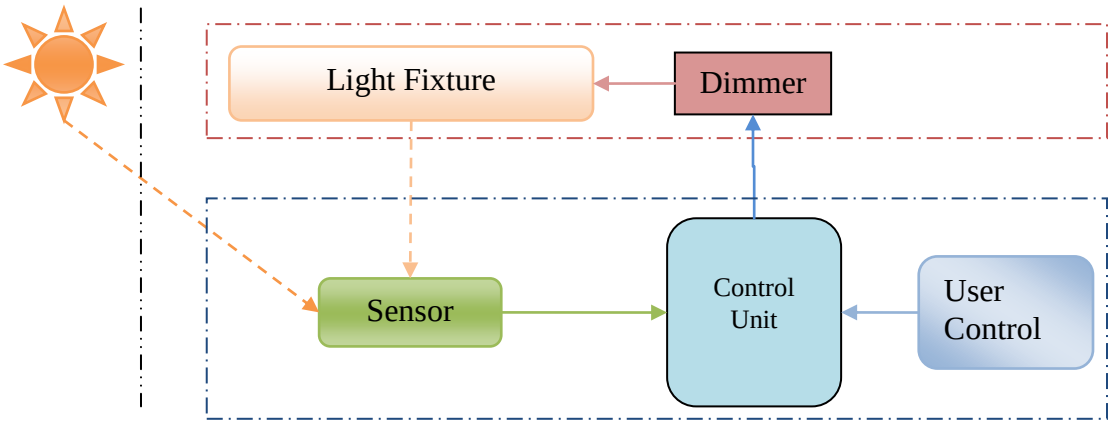

Figure 1: System Overview

The demo system prototype consists of two parts: A fully functioning dimmer circuit with three standard light fixtures powered via wall outlets or an extension cord; and a separate unit, powered by a step down transformer, contains a voltage rectifier, the light sensor, two push buttons, and a micro-controller along with a small circuit board where everything is fitted. The output of the control circuit is a single signal used to trigger the dimming of the light bulbs. The small, 8-pin, PIC micro-controller has met our needs and serves as the main control unit of the whole system, consuming very small amounts of power.

Aside from incandescent lamps, a dimmable compact fluorescent bulb demonstrates the possibility of using more energy efficient light fixtures.

2.1 STRUCTURAL

We originally anticipated having a single block that included sensing, dimming, and user interface capabilities. We could then replace the actual light switch in a single room with our prototype to demonstrate its auto-dimming capabilities with the existing light fixtures. However, due to the dangers of working with wall power the team opted to construct a small, custom, light fixture that could be powered with and extension cord and include fuses and breakers to ensure safety. The current prototype is purely for demonstration purposes. It's also portable, enabling us to demonstrate our system in a variety of rooms and lighting conditions. Our production system would consist of a single block, very similar to standard light switches.

2.2 ELECTRICAL

Our prototype includes a lot of electrical components. It was important to avoid dealing with wall power as this can be very dangerous. We purchased metallic enclosures for the light fixtures that are grounded and conceal all bare wiring. A step-down transformer was fitted into one of the enclosures to power the control circuitry however it proved to be broken as two PIC chips stopped functioning shortly after being powered by the transformer. We had already purchased a separate plug-in step down transformer that was known to function correctly, so as a result the prototype requires two power sockets to function. A limitation that is of no concern since all tests are done using an extension cord for safety reasons.

2.3 SOFTWARE

As mentioned already, the PIC micro-chip fully met our specifications and needs. The current control algorithm meets all design and functional specifications while only occupying about 30% of the PICs memory capacity. This means we can potentially add a lot of advanced additions to the control algorithm, such as brightness trend tracking, motion detection, or even simple learning capabilities. It should also be noted that upgrading to a bigger PIC would be very easy giving us even bigger processing and memory capabilities at fractional power consumption and cost increase.

3 BUDGET

The table below shows a list of what we spent our $600 of ESSEF funding on.

Description	**Expenditure ($)**
RP Purchase, 3 TRIAC	2.81
Digi Key Order 32130862	27.52
RP Purchase. Lux Meter/Transformer	140.48
RP Purchase. PIC programmer.	85.06
Digi Key Order 32387999 (10 x PIC12F675)	21.09
Canadian Tire Purchase. Demo materials.	53.21
Home Depot Electrical Boxes	19.20
Lee's Electronics Purchase Demo props	15.23
Digi Key Order 32539158 (extra light sensors + upg. PICs)	31.16
Home Depot Electrical Box Extention	10
Lee's Electronics Fuse + Opto-Couplers	10.64
Lamp Shades	15.10
Total Spending	**431.50**

Table 1: Expenses

As you can see, the amount received from ESSEF was sufficient for purchasing all the foreseen and unforeseen equipment, parts, and tools. Before purchasing anything, we consulted with each other as a group whether the part was crucial or if we could do without it. We believe this intelligent system of budgeting is what allowed us to build and demo the Smart Dimming System under $600.

It was very useful to have this funding so that when we needed a part on short notice, we were able to purchase it without worrying too much on price. For example, we were programming the microcontroller with the PIC programmer in lab 1 until it failed for some unknown reason. As a result, we had to buy our own programmer right away otherwise we would have to face down time.

4 TIMELINE

We used a project management tool called “Zoho Projects” which allowed us to keep a timeline of important dates. Below is a gantt chart of when we anticipated completion of important tasks and when we *actually* completed the tasks.

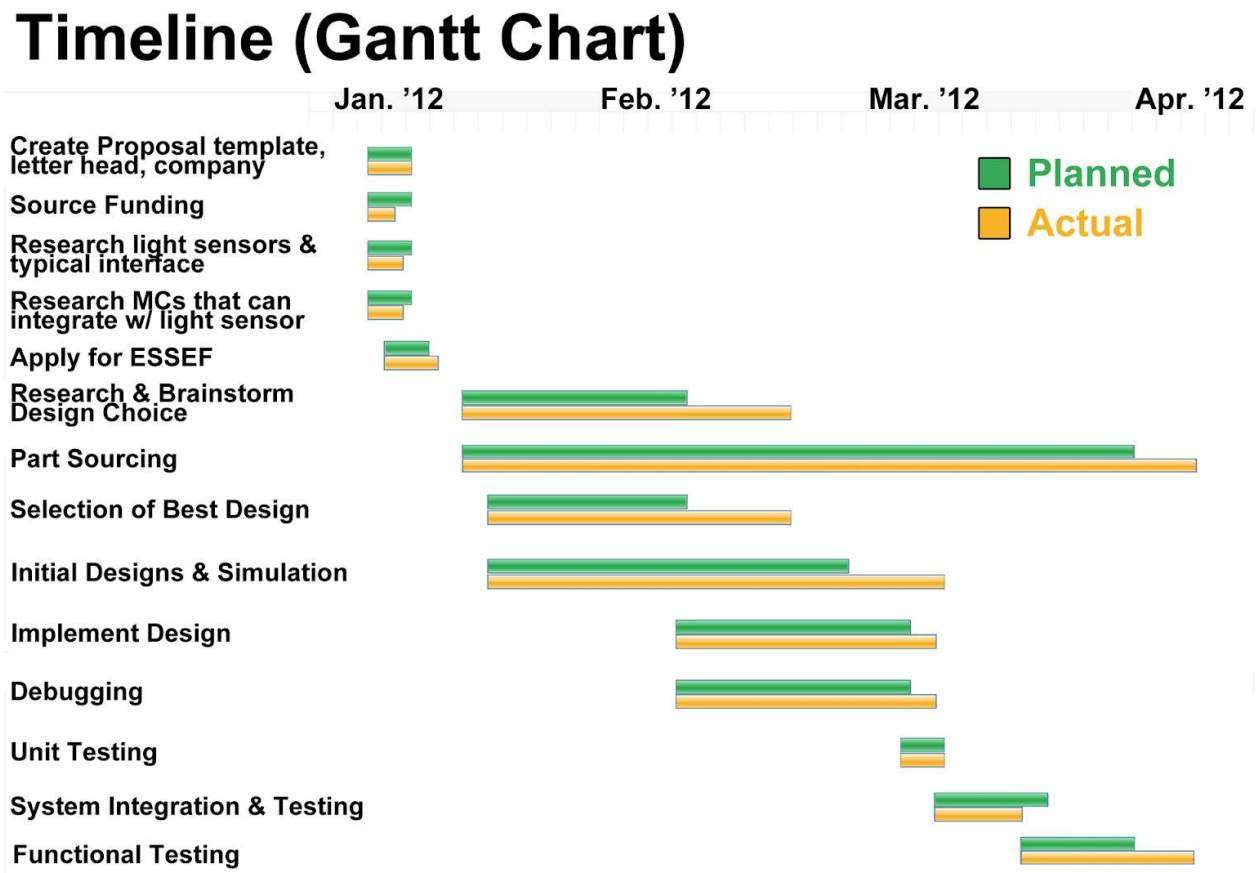

Figure 2: Timeline (Gantt Chart)

For the most part, we were on schedule with our initial predictions. Some completed tasks were not updated right away in Zoho Projects, thus resulting in an average appearance of completing tasks slightly later than they actually were.

5 PERSONAL THOUGHTS

5.1 Aram

The semester passed right by. I remember very well meeting in December for preliminary planning and initial project brainstorming. It seems like yesterday we settled on the idea and began experimenting. And here we are at the end of it all.

I feel that this project suited my abilities very well; I was able to apply a lot of what I had learned as well as learn a lot and gain valuable experience. There were plenty of problems for us to overcome, which we did. Together with John, I was responsible for interfacing and programming the microcontroller, then implementing the control algorithm. I provided assistance in a lot of other areas as well, from design decisions to helping with the build. Looking at our prototype now, it seems simple, but I think that's because I'm now fully familiar with every detail of it. It's safe to say the amount of work has been plentiful. Some of my contributions were in designing the initial breadboard prototype, understanding and correctly interfacing PIC capabilities (without any debuggers), implementing experimental control algorithms, helping with the construction of the demo prototype and resolving several major bugs.

I'm now much more comfortable with electronic circuits and have a much better understanding of common practices. I also become proficient with MicroChip's PIC chips and associated software. The experience was, of course, very valuable. I am proud to be graduating having completed this and other projects throughout my degree progress.

5.2 John

Let me start off by saying I think we made a good decision in terms of the size and scope of our project - even if we didn't reach a level of completion that we desired.

My Contribution:

I was Project Director and as such I tried to strike an appropriate balance between this responsibility and my technical and written contributions to the project. I approached this role as more of an aggressive facilitator as opposed to a Project Manager with real authority due to the obviously equal authority of all participants; I think it was a successful approach. I believe I succeeded in directing the project for the most part, though just over half way through, my diligence in maintaining the projects momentum waned somewhat - I think we all experienced a lull in motivation during this period due to some over confidence in our progress.

Before the project began I learned how to setup a home webserver and hosted a wiki-page for project collaboration. The functionality grew to incorporate a forum for discussions as well. Later as our needs grew I moved us to an account at "Zoho Projects" (a free online

project management host). Zoho Projects has great project management features (gantt charts, document repository, updates, task scheduling, meetings, etc..) as well as it's own inbuilt forum, wiki and chatroom. We used it extensively. After the project began I organized meetings, took minutes (those definitely could have been better), initiated collaboration and collusion, pushed for strict and aggressive deadlines and implemented procedures and guidelines for productive and efficient interaction (such as a maximum of 2-3 authors/owners per document). I also actively coordinated assigning project roles and responsibilities and the planning of the project. Throughout the implementation stage I tried to facilitate communication between sub groups to minimize conflicts at system integration time.

In the planning stages I always tried to keep in mind the questions "Where are we going? How are we going to get there? What needs to be done and who needs to do it?". As the project shifted to implementation my questions shifted to "Why are we doing what we are currently doing? Is it furthering our overall goals? Is it a useful activity wrt to our high level goals and objectives?". Constantly being conscious of these questions I believe I was able to keep on top of the project and helped avoid letting it get too far off course.

My technical contributions included:
- Bringing up and developing the control portion of the project
- Configuring the PIC microcontroller to act as the control
- Interfacing the PIC with the photodiode sensor, the triac (via the opto-coupler) and the control switches
- Working to create the control code and algorithm
- Working with the others to construct the final demo prototype and test environment

My written contributions included:
- Writing the Project Proposal with Waris
- Writing the Functional Spec with Aram and Thomas
- Proofing and Editing all other documents

As far as group dynamics went I think we were all lucky to have a pretty good group. We were all aquaintences before the project and are better friends after it - with no major conflicts arising. Everyone put in work, the amount varied depending on person and time due to differing course loads and timing of exams but overall I think we were all satisfied with each others efforts.

Mistakes we made:

One major mistake was the fact that Dr.Rawicz mentioned the trickiness of dealing with the directionality and shadowing problems of sensing the current lighting conditions accurately. His advice fell by the wayside because we didn't appreciate it well enough until the prototype was mostly finished and we could see it's effect. At that point it worked well in a small area with artificial external light. However testing in a larger, more realistic environment quickly showed the problems Andrew had mentioned.

Aside from this rather large mistake of underestimating the consequences of this aspect of the project I believe we didn't' have any other crucial mistakes.

What I learned:

In the initial planning stages of the project I focused a lot on implementing efficient and structured communication. I tried using Wikis, Forums, Collaborative Note-taking programs (Evernote), the list goes on. I discovered the benefits and drawbacks of each of these and that Frequent face to face meetings mitigates the need for a lot of them.

Evernote (collaborative media sharing) - useful in planning stages when frequently sharing information (in various media formats) and meetings are less often.
Forums - great for discussion and debate during planning stages when many points must be decided.
Wikis - great for storing static information
Project Management Software - very versatile and useful
Email - the most useful communication tool

Nothing beats face to face meetings with good minute taking and task setting followed by a summary email listing all the agreed upon duties for each member with strict deadlines.

I also learned that even though groups informally meet to work on project tasks, semi-frequent structured meetings are still very important to keep on track of higher level objectives (obviously during informal meeting periods the focus is on lower-level implementation problems).

Feasibility studies are of the utmost importance. I learned that even though it's difficult to appreciate some factors (like the difficulty of accurately measuring the light) until they are directly observable it is imperative to fully consider them in the planning stages. Even if this means creating test platforms to adequately investigate the effects and consequences of the factors. This should be obvious as this really falls to the heart of the feasibility of the project.

Maintaining momentum on a project is of the utmost importance.

What I would do differently:

- Maintain diligence on keeping the momentum of the project
- Assign work more rigorously so everyone always has something to do with a strict and timely deadline
- Invest more in the planning stages (specifically in looking at performance and functionality in terms of feasibility)

5.3 Larry

ENSC440 Capstone offers such a unique opportunity for senior students to experience what it feels like to be a real engineer. Team collaboration is essential to the success in this field. Although through the last five years, I've been involved in team projects in many engineering courses, there has never been any course like this one that requires such large group of people working together in a full semester long, going through a full cycle of product development, facing problems as well as sharing the success together.

When the project first started, we divided the project into several pieces, including dimmer unit, control unit, sensor, power, and user interface. This modular methodology helped make our work organized and efficient. Knowing our team is well rounded with software and hardware students, I was so confident that we would finish everything way ahead of the schedule. After all, how long does it take for an electronics major student to wire some electronics components together, or for a software student to write a couple of hundred lines of code for a microcontroller, right? Well, after two weeks of struggling with my partner on running simulation for TRIAC to prove the design concept, all my ambition and expectation vanished into thin air. It took my partner and I half the term to develop the dimmer unit, longer than I would ever expect at the beginning of the term. But the knowledge I gained was way beyond the circuit itself.

I worked with Waris on the dimmer unit. We went through the process from doing research on the dimmer circuit, selecting and optimizing the design, to running the design on the simulation and assembling and testing it on the breadboard. We got help from Ash and Fred. Also, I wrote part of the design spec, progress report, and demo presentation. Together with the rest of the team, I reviewed other documents as well as ran test on the integrated system.

I wished that we left more time for the prototype testing and that we should've had selected some specific locations and scenarios to test our product. It would be really nice if we could present our product to our audience with a fully integrated and installed switch in a lecture room, and maybe even implement our product in a office environment for a couple of days to test the consistency and energy efficiency. However, it has been, with no doubt, a great experience for me.

5.4 Thomas

Coming into this project I thought I knew much more than I actually did. It was a humbling experience to say the least. The areas/skills that I developed most in the past 13 weeks were: analogy circuitry, fluorescent and incandescent dimming systems, group document writing, light sensors, and microcontrollers.

I remember at a group meeting before the semester started, we all stated that analog circuitry was not our strong suit. Looking back, I am glad we still chose to go such an "analog circuit dense" route. Analyzing circuits in analog circuit courses (like ENSC 320)

compared to analyzing real world circuits that is specific to your design is very different. I learned that not having a solution manual really meant I could only depend on myself, my team mates, or ENSC staff recommendation to form solutions to the many design problems we faced.

We must have changed the design of our dimming system ~20 times. I never realized being versatile and adaptive would come into play so much. Also, trust was a big part too. Everybody was assigned a subcomponent to research on their own, so when the design of a certain subcomponent needed to be modified, we had to trust that the person assigned to that subcomponent knew what they were talking about.

My understanding of incandescent and fluorescent bulbs and dimming systems has grown exponentially. I never look at light bulbs the same anymore. I've learned the differences between old dimming circuits and modern dimming circuits. I've also learned about the differences between modern dimming circuits and our dimming circuit which incorporates a microcontroller and light sensor. Aside from the differences of these circuits, I've also learned about their similarities: the TRIAC.

Getting to play around with these electronic parts gave me a feel as to how non-ideal they work. Determining resistor values and useful voltages is so much different on a breadboard than it is on a piece of paper.

I chose to accept the role of document manager. Seeing as how I just completed a work term at BC Hydro where the majority of my responsibilities consisted of document management, I thought it would be appropriate for me to take on this role. I learned the best way to write documents as a team: assign 2-3 people to work on each document to maintain a cohesive, readable flow throughout the document. Everybody writes with their own style, and while there is nothing wrong with that, when you try to piece together paragraphs written by 5 different people, it gets messy and time consuming.

It's hard to say what I would do differently if I were to take on a similar project in the future, but one thing I would do is (if it involved analog circuitry) create a master circuit design drawing and whenever the team makes a change, update the master design drawing while saving the previous version. Since we had to modify our design sometimes several times a day, doing this felt too time consuming, but now I realize how beneficial it can be.

5.5 Waris

I feel strongly that this project has been one of the most amazing experiences I have had in this program. Regardless of the success or failure to come during and after the demo day, I am proud of what we have done. Of course, there have been some shortcomings, but given our humble level of expertise, I can't help but think positively of what we did.

I'd say one of the things I am really glad we did was the fact that we looked really early for the best method of project management. Our project director, John, searched for the best tools to manage our information. As a result, we ended up with Zoho Projects, an online project management software. Zoho allows us to keep all our documents in one place, manage tasks, and even maintain a wiki page. It also offers a Gantt view in order to have an overview of how we are doing. This is very similar to industrial experiences I have had during my co-op, and I'd say John has put the appropriate amount of attention into it.

I am also glad we stuck to the "2 authors per document" rule. I remember the composition of my first ever engineering lab report: one of us writes each section, and the integration of those sections end up a disaster. We also tend to have copies of the same document lying around. Our earlier documents fell for that trap, but we learned to do better along the way.

The composition of the Design Spec was very illustrative of this. The document was composed by two authors and the review process was done via Google Docs by comments only. Changes were addressed in the original document. This ensures that only one person has access to the deliverable and avoids having multiple copies of the same document It has occurred to me that this practice is also very similar to the industrial code review process. I feel like management and documentation were our strong points, but of course, there were also many shortcomings.

Repeated power circuit mess-ups and mini-lectures from Fred Heep were very common occurrences. In fact, one of our semiconductor components literally exploded during testing. The design of our dimmer was changed many times. We went from digital to analog and back again to digital after discussion with many professors. Being mostly computer engineering and engineering physics students, we know very little about the wall power. And this project, for some reason, was all about the wall power. This led to many dramatic "power on" moments, where we would duck and cover before switching on the system. This is the point where Fred helped us immensely. Fred's suggestions, which allowed isolation between control and the power units as well as making sure no 120V ever touches the control unit during demo, gave us a great sense of comfort.

This project has taught me a lot. I went from knowing nothing about dimmers to knowing enough to rival the average home-hacker. I also gained valuable circuit prototyping and microcontroller interfacing experience. My awareness in safety concerns

regarding high power has also increased immensely. Most importantly, I learned a lot about project management and teamwork skills. This project was one of the best things I could have asked for in terms of gaining practical experience. Now, I feel like if I were to make a small home automation project in my basement, I know exactly what to do.

As the team's technical director, my main task was parts sourcing. I was responsible for making sure other team members have electronic parts and tools to work with. This includes making purchases and keeping a financial account. Aside from this, I also was responsible for initiating idea of the sunlight-responsive dimmer. I built and tested the thyristor subsystem, turning it from a knob-actuated dimmer to a logically controlled one. I also designed and built the power unit for the microcontroller which turns 12 VAC to 5 VDC (with Fred's help). I also was responsible for building and soldering the majority of the circuit on the stripboard as well as determining the layout of the components. I co-authored the project proposal, the design spec, and the demo presentation, and reviewed the rest of the documents.

In terms of what we could have done better, I wish we paid more attention to the physics side of things as warned by Dr. Rawicz. I also wish we made better plans about purchases so we can order everything we need at once (although that is very difficult given we're learning as we go). I also wish we completed the prototype earlier to allow time to discover and fix the more subtle issues.

All in all, it was a great experience. I feel like we got along very well as a team and that made our capstone project very enjoyable and educational.

6 CONCLUSION

During the Spring 2012 semester Smart Light solutions developed two working prototypes of our Smart Dimmer. There are still things to be done; our production system would consist of a single block, very similar to standard light switches. The electrical systems would have be compactly and professionally created, all sensor issues need to be addressed to avoid any sort of fluctuations in light intensity due to shadows, and more tests need to be conducted to determine what the optimal sensor configuration is.

But overall we've achieved what we set out to do at the beginning of the semester. Everyone has gained much technical and non-technical experience.