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Efficient Home Lighting Project Plan

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Client: Gary Tuttle

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Project Statement

Advances in Light Emitting Diode (LED) technology have made residential and commercial lighting more cost effective and energy efficient than any other period in history. Two major criteria for evaluating LED lighting are the efficiency of the bulb, and the lifespan of the bulb. While the LED portion of the bulb is extremely efficient, circuitry exists inside the bulb to convert the house electricity (AC) to a smaller DC voltage that the LED can run off of. These converters, known as Switched Mode Power Supplies (SMPS), produce relatively large amounts of heat that becomes the limiting factor in bulb life.

The client (Dr. Tuttle), has proposed a project that will address both the energy efficiency of the bulb and SMPS, while further extending the lifespan of the bulb. Dr. Tuttle also proposed to make the project "smart" by adding the capability to control lighting in a room through a smartphone app.

System Requirements

Project Requirements

Several possible solutions exist that would satisfy Dr. Tuttle's proposal. In general, reducing the heat produced near the LED's in the bulb would both increase the lifespan of the bulb, and would be more energy efficient as a result of decreasing the power consumed in the circuitry. One option to satisfy this would be to create new circuitry that further decreases power consumption of the SMPS to a level that does not affect the life of the bulb, or to change the way the bulb is made to be more resistant to heat.

However, a more feasible idea was to move the SMPS away from the LED's in the bulb. This would remove the LEDs from the heat completely, and greatly extend the lifespan. It was suggested that the SMPS could be placed in the light switch, and then the DC voltage would be wired to be broken by the switch instead of AC.The SMPS could be made with multiple outputs to be wired to multiple bulbs. By moving the SMPS to the light switch, room would be made for a bluetooth module and microcontroller to give users more control over their environment.

To reach these goals, several requirements were established.

- The LED bulb should at least match the efficiency of current LED bulbs
- The LED bulb should be the equivalent of an 60W (700-900 Lumens) white incandescent bulb
- The SMPS should have an efficiency of 90% or greater
- The output of the SMPS should be below 24V to adhere to NEC standards for exposed DC lines
- The system should adhere to applicable NEC standards
- The smartphone app will communicate with the SMPS within a range of 10 meters
- The smartphone app will be able to control dimming of the lights and other functionality

Proposal Assessment

Overall, the proposed solution appears to be a valid way to advance both LED lighting and home automation. The proposed solution has several strengths:

- Increased LED bulb lifespan
- Decreased LED bulb energy consumption
- Reduced circuitry will result in cheaper lighting systems
- Using a microcontroller gives the possibility to implement additional “smart home” features in the future
- Exposure to low DC voltage is much safer than exposure to 120 AC when rewiring fixtures

However, the proposal does have some challenges:

- Meeting all NEC standards for residential wiring
- SMPS may be difficult to repair in the event it breaks
- The circuitry for the microcontroller/bluetooth/SMPS must fit in a standard light switch cases

Validation Tests

Many of these requirements will require only simple measurements and calculations to be performed to prove they are met.

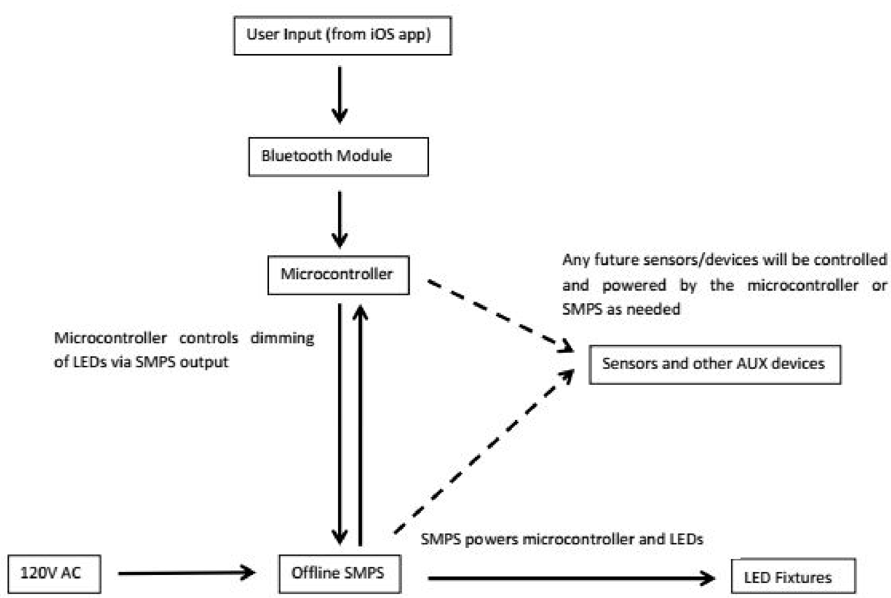
To measure the output of the LED an integrating sphere will be used to measure the the light intensity in Lumens. From that, LED efficiency can be calculated by taking the ratio of the light emitted to the power dissipated, and should at least match that of current LED bulbs. Efficiency of the SMPS can be measured and calculated by taking the ratio of the power consumed by the circuit and the power it supplied, while cross checking our design with the NEC standards available to the public will satisfy that requirement. Wireless communication and the dimming function can be tested simultaneously by physically dimming the lights from a distance of 10 meters using the completed app and communication circuit.

Interface/System Description

System Diagram and Process Flow

This project really has two "sub-projects" that will run parallel to each other for most of the development process. An overall view of the system diagram and flow of information can be seen in **Figure A.**

Figure A. System Diagram for Efficient Home Lighting Project



One track will be more hardware based. This track will take 120V AC available in most residential wiring and step it down to roughly 24V DC using an Offline SMPS. The output of the SMPS will drive an LED bulb made by the group.

The other track is mostly software based. An iOS app will be developed that will communicate with a bluetooth module, which will communicate with a microcontroller.

The microcontroller will then tie everything together, and control the hardware based off of a user input from the iOS. The microcontroller will be used to implement future sensors that may be implemented in the future.

Process Details

Meeting the current requirements will signal that the 1.0 Version of the project is completed and ready to be demonstrated. However, future versions of the project may need revised or additional requirements. The current setup is only for ceiling mounted LEDs, but may be extended to other means of lighting or to control other appliances within the means of the microcontroller.

Test Plan

Once the design requirements are met, testing the functionality of the project will be simple. It will require a small wooden structure to simulate a wall, a light switch, the hardware created by the group, and a user with the iOS app. After the equipment is mounted to simulate a basic room with one light and one single switch. The user will turn on the light, turn off the light, and then dim the light. Once these tasks are complete, the project will be deemed a success. Expanding to multiple lights or two-way switches will require a minimal amount of work.

Work Breakdown Structure

Project Schedule

The Gantt chart is given at the end of the document as **Table A** in **Appendix A.**

Risks/Feasibility Assessment

The proposed solution is realistic, and should have no catastrophic setbacks. From a non-technical standpoint, one of the major risks to the project is violating a standard set by the NEC. If that occurs and there are no workarounds, it would pose a significant challenge to the project.

From a technical point of view, the risks are safety related. Anytime 120V AC is being worked with, the proper safety precautions should be taken.

Tentative Bill of Materials and Cost

For demonstration purposes, this should be a relatively cheap to make. It is estimated that the overall cost of this project will be less than $1000 for demonstration purposes, and will be relatively cheap on a full scale level, because only one SMPS is needed to power several LEDs. It will also be possible to use only 1 microcontroller/bluetooth per room. The largest costs will most likely be purchasing the materials to simulate a simple room. While specific components are not known yet, a generic BOM was generated to estimate the total cost. **Table B** shows the tentative BOM. It should be noted that one major factor driving the price down is that many parts were already on hand, and open source software was used when available. This will keep the cost to a minimum without compromising the quality of the project.

Table B. Tentative BOM

Efficient Home Lighting		Revision: 1			
Bill Of Materials					
Item	Qty.	Ref.	Cost	Part Desc.	Supplier
1	1	U1	$ 5.00	Atmega328	Atmel
2	1	B1	$ 5.00	Bluetooth Module	
3	1	U2	$ 2.00	AC-DC PWM controller	
4	8	D1-8	$ 10.00	White LEDs	
5	1	D9	$ 3.50	Full Wave Bridge IC	
6	1	D10	$ 0.50	SMPS Diode	
7	Assortment	Rx	$ 10.00	Various Resistors	
8	Assortment	Cx	$ 20.00	Various Capacitors	
9	1	Power FET	$ 2.50	Power FET for SMPS	
10	1	2x4x10	$ 15.00	Lumber for demo	Lowe's
11	1	Single Pole Double Throw Switch	$ 15.00	Light Switch for demo	Lowe's
12	1	Bulb/Fixture for LEDs	$ 20.00	To hold LEDs for Demo	
13	2	Printed Circuit Board	$ 15.00	To fabricate	
14		Solder	$ 5.00	To fabricate	
Total			$ 128.50		

Market/Literature Survey

Currently, there is nothing that exactly matches what is being done in this project. While high efficiency LED's and Switched Mode Power Supplies are common, no work has been done to separate the two to change the way LED lighting is done. Much work is being done with "smart homes" currently, with ideas similar to ours in the aspect of controlling home lighting from your phone. A company, called Zuli[1], uses wall outlets to communicate wirelessly between a phone and the light fixture. However, it is inconvenient use up an outlet. Implementing the communication circuitry with the power supply inside of the switch junction box will make it more convenient and more aesthetically pleasing.

Overall, the goal of this project is to implement a new system of wiring LED bulbs and fixtures to increase bulb life span and decrease the energy consumption of each bulb while making LED lighting "smart home" friendly. Doing so should decrease the cost of LED lighting and make it a more attractive option to consumers.

List of References

1. https://zuli.io/smartplug/

Appendix A

Category	Role	Start Week	End Week	Owner	Details	Weeks Till End Date	1	2	3	4	5	6	7	8	9	10
Overview																
		9/28/2015	12/7/2015	Team	Final Presentation	10										
		9/28/2015	11/23/2015	Team	Refined product for final presentation	8										
		9/28/2015	11/9/2015	Team	Demonstrate basic functionality of design	6										
Hardware																
	SMPS	9/28/2015	10/5/2015	David West	Draw systems level design of switching mode power supply and general circuit layout.	1										
	LED	9/28/2015	10/5/2015	John Stabenow	Specify light requirements and order LEDs to test.	1										
	Microcontroller	9/28/2015	10/12/2015	Ryan Marion	Specify microcontroller to be used and hardware connections needed.	2										
	Bluetooth	9/28/2015	10/12/2015	Mitchell Wheaton	Specify Bluetooth module to be used and hardware connections needed.	2										
	LED	10/5/2015	10/19/2015	John Stabenow	Build integrating sphere or other testing method to measure Lumens.	3										
	SMPS	10/5/2015	10/19/2015	David West	Specify circuit components and experiment with circuit layout on breadboard.	3										
	Bluetooth	10/12/2015	10/19/2015	Mitchell Wheaton, Ryan Marion	Determine hardware connections to microcontroller.	3										
	SMPS	10/12/2015	10/19/2015	David West	Verify circuit meets efficency specifications and output ratings per NEC.	3										
	LED	10/12/2015	10/19/2015	John Stabenow	Verify LEDs meet specifications.	3										
	Microcontroller	10/12/2015	10/19/2015	Ryan Marion, Mitchell Wheaton	Design related hardware to be used on PCB and connect to Bluetooth.	3										
	SMPS	10/19/2015	10/26/2015	David West, Ryan Marion	Design PCB layout and integrate with microcontroller.	4										
	LED	10/19/2015	10/26/2015	John Stabenow, David West	Verify Operation of LEDs with SMPS and dimming.	4										
	Microcontroller	10/19/2015	10/26/2015	Ryan Marion, David West	Design PCB with SMPS and microcontroller.	4										
	SMPS	10/26/2015	11/2/2015	David West, Ryan Marion	Prototype light switch mounting enclosure for SMPS and microcontroller.	5										
	LED	10/26/2015	11/2/2015	John Stabenow	Design PCB layout and verify NEC specifications are meet	5										
	LED	10/26/2015	11/2/2015	John Stabenow	Prototype light bulb with LEDs and PCB.	5										
	Microcontroller	10/26/2015	11/9/2015	Team	Verify operation of system.	6										
	SMPS	11/2/2015	11/9/2015	Team	Final testing of SMPS and microcontroller.	6										
	LED	11/2/2015	11/9/2015	Team	Final Testing of LED with SMPS and microcontroller	6										
Software																
	IOS APP	9/28/2015	10/12/2015	Flavia Cavalcant, Alex Rhinehart	Specifications of all of the features of the app.	2										
	IOS APP	9/28/2015	10/12/2015	Flavia Cavalcant, Alex Rhinehart	Design user interface layout.	2										
	Firmware	9/28/2015	10/12/2015	Ryan Marion and David West	Make specifications needed for IO pins and expected output.	2										
	Bluetooth	9/28/2015	10/12/2015	Mitchell Wheaton	Specify Bluetooth commands.	2										
	IOS APP	10/12/2015	10/26/2015	Flavia Cavalcant, Alex Rhinehart	Enable the user to turn lights on and off.	4										
	Bluetooth	10/12/2015	10/19/2015	Mitchell Wheaton, Ryan Marion	Specify Bluetooth commands function correctly with microcontroller.	3										
	Firmware	10/12/2015	10/26/2015	Ryan Marion	Develop firmware to control SMPS and dim LEDs.	4										
	IOS APP	10/26/2015	11/2/2015	Flavia Cavalcant, Alex Rhinehart	Enable dimming function.	5										
	Firmware	10/26/2015	11/2/2015	Mitchell Wheaton, Ryan Marion	Develop function to communicate with Bluetooth module	5										
	IOS APP	11/2/2015	11/9/2015	Flavia Cavalcant, Alex Rhinehart	Add smart features that allow the user to specify what happens when they enter a room etc.	6										
	IOS APP	11/2/2015	11/9/2015	Flavia Cavalcant, Alex Rhinehart, Mitchell Wheaton	Verify App communicates with Bluetooth module.	6										
	IOS APP	11/2/2015	11/9/2015	Team	Verify correct output from microcontroller to SMPS on PCB board.	6										
	Firmware	11/2/2015	11/9/2015	Mitchell Wheaton, Ryan Marion	Verify microcontroller performs given operation based on different Bluetooth commands.	6										