LEaD Design:
Team Portfolio

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CS 480/481: Fall 2017 - Spring 2018
Senior Capstone Design Project
UI CS - Wireless Tower of Lights
Sponsor - Dr. Robert Rinker

University of Idaho
College of Engineering

Contents

1 Introduction

1.1 Project Summary

The University of Idaho has, for several years, done various projects involving the Tower of Lights Show and equipping the marching band with light-up glasses. The current "TowerLights" product involves LED-based light bars that are placed in front of front-facing widows of a large buildling (Theophilus Tower) and are then illuminated to play animations alongside/synchronously with music. The goal is to enhance the current "TowerLights" product. The current implementation of this product uses the ethernet wiring system in the building to control the LEDs. The goal of the project described in this document is to convert this part of the system to a wireless operation. This in turn requires the development of a wireless module that would be attached to each of the light bars. Thus this module has to sleep and wake up, as well as respond to wireless signals from a computer, and since it's wireless, these modules will need to be battery powered. Battery power must also be conserved by staying in the sleep state until needed. The purpose of this enhancement is to provide a certain level of portability to have "TowerLights" at other locations.
The product will give the user the ability to run a program that reads in .tan files and .wav files, have this program communicate with a XBee Wireless module on an Arduino that is attached to a computer via USB, then communicate wirelessly with each Arduino receiver, that is battery powered. Each of these Arduino receivers are attached to an LED board, that will then communicate with each LED on that board through wired communication from the Arduino (same one that holds the receiver) to the LEDs. The program that broadcasts the shows will be available for OSX, Windows, and Linux based operating systems.
This documentation lives at https://github.com/YupHio/LEaD_Design/tree/master/Doc/TeamPortfolio_LEaD_Design.tex
The code for the project can be found at https://github.com/YupHio/LEaD_Design/tree/master/Code

1.2 Document Purpose

This document is a team portfolio for the Fall 2017-Spring 2018 CS 480/481: Senior Capstone Design project at the University of Idaho. The purpose of this document is to outline the methodology, design, and keep a record of this project. It defines terms used, outlines the scope of the project, details specific design choices, meeting minutes, project learning, design goals, specification and constraints, system diagrams, analysis of alternatives, engineering modeling, manufacturing/assembly plan, experimental design, data analysis, balance sheet, and other items.

1.3 Definition of Terms

- **Arduino** - open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world
(https://en.wikipedia.org/wiki/Arduino)
- **Arduino Shield** - Shields are boards that can be plugged on top of the Arduino PCB extending its capabilities. The different shields follow the same philosophy as the original toolkit: they are easy to mount, and cheap to produce.
(https://www.arduino.cc/en/Main/ArduinoShields)
- **Xbee** - The Arduino Xbee shield allows multiple Arduino boards to communicate wirelessly over distances up to 100 feet (indoors) or 300 feet (outdoors) using the Maxstream Xbee Zigbee module.
(https://www.arduino.cc/en/Main/ArduinoShields)

1.3.1 Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them. https://www.arduino.cc/en/Main/Software

1.3.2 Pulse

PulseAudio is a sound system for POSIX OSes, meaning that it is a proxy for your sound applications. It allows you to do advanced operations on your sound data as it passes between your application and your hardware. Things like transferring the audio to a different machine, changing the sample format or channel count and mixing several sounds into one are easily achieved using a sound server. https://www.freedesktop.org/wiki/Software/PulseAudio/l

2 Team Meetings and Minutes

Weekly action items and summaries of progress made are detailed below. Furthermore, subsections discuss what was helpful and what was not during these meetings. Discussion of attendance and participation, as well as contribution and discussion topics are discussed below.

2.1 9/14/2017 Team Meeting 1 Notes

Meeting started at 3:30 in room 133 of the library. Adrian's having Internet issues and is unable to attend.

Project priorities: essentially, everything GUI related should be left until the end. Figuring out, prototyping, and testing hardware is the most important thing this semester.

We need to schedule another meeting with Rinker to go over more hardware details. We should create some rough drafts of high level UML diagrams before then, and make sure that we have the big picture correct.

What resources (old code, parts, lab space, etc) do we have available right now?

See timeline below

Meeting adjourned at 4:16, summary and schedule sent to Adrian afterwards

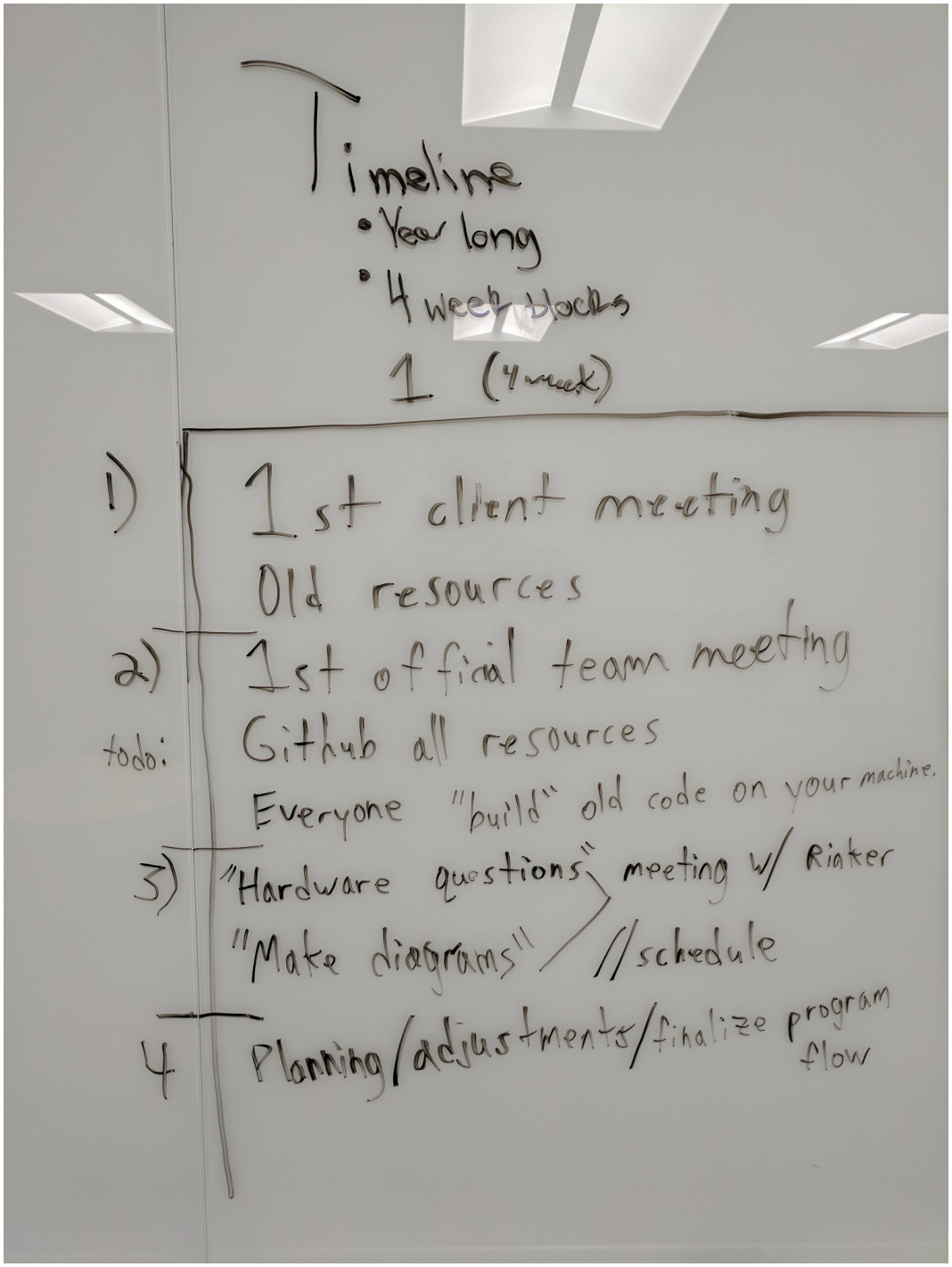


Figure 1: 9/14 Meeting Project Schedule

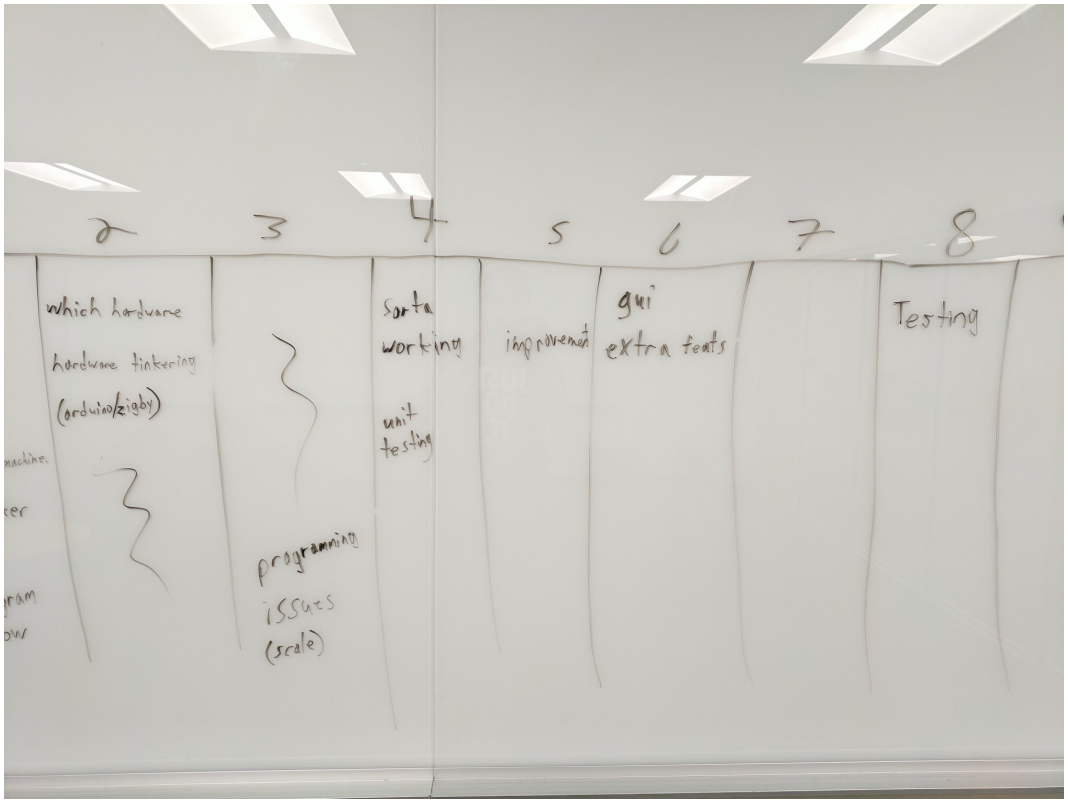


Figure 2: 9/14 Meeting Project Schedule

2.2 10/05/2017 Team Meeting 2 Notes

Meeting started at 3:30, all members except Adrian preset. Adrians running a few minutes late due to construction.

Diagram status and breakdown (Kevin, started 3:31):

- Need to breakdown exactly how the wireless protocol/transmitting will work. Might not be an actual diagram.
  - What frequency?
  - How many bits/s?
  - How many bits/packet?
  - Order/encoding of packets
- Breakdown the LEDs
  - How many?
  - Series or parallel?
  - Total/individual amperage? (270 mili-amps per currently)
  - Voltage drop per diode for each color
- Battery specifications
  - Chemistry/options/alternatives
  - Voltage
  - Amp hours/capacity
- Receiver/Arduino board
  - What code runs on the Atmega328p chips?
  - LED driver circuit

Action items (directly off of the diagram status, 3:48)

- Wireless description (Paul)
- LEDs description (Andrew
- Battery specification (Adrian)
- Receiver/Arduino board specification (Kevin)

Meeting adjourned at 4:10

2.3 11/02/2017 Team Meeting 3 Notes

Meeting started at 3:29 with all members present, Adrian via Zoom meeting

Wiki page: Pauls gotten it started, pages are created and have some content.

Meeting tomorrow with Prof. Rinker: allocate a couple hours. The plan is to discuss circuit details, assemble hardware to start testing basic functionality.

Hardware list(Adrian): List has been created, can hopefully be finalized and whatever new parts are needed to create a prototype can be ordered.

Arduino low power mode: 2 interrupt pins, potentially have to be woken up on low level trigger? Look more at datasheet and test Arduino this weekend or early next week.

Update portfolio: include everything from snapshot day, update timeline, part list/price per unit if we can get details from Rinker on time.

- Wireless design spec and wiki page information in portfolio (Paul)
- Arduino/Receiver design spec and client meeting section in portfolio (Kevin)
- Budget decisions, part list, battery specification in portfolio (Adrian)
- LED design specification, timeline, and team meeting section in portfolio (Andrew)
- Finish wiki page (Paul)

Meeting adjourned at 4:10

2.4 11/16/2017 Team Meeting 4 Notes

The Team meeting started 3:30 with all members present, Adrian via Zoom meeting.

The team reviews the slide deck created for the design review one presentation. After all team members agree the design review one presentation slides look good we begin to practice our presentation for design review one.

Adrian (on zoom meeting) agrees to be the mock audience for the practice presentations.

The team practices the presentation three full times from start to finish, and after some small discussion, all team members decide we are ready for the design review one presentation.

Meeting ajourned at 4:21

2.5 01/18/2018 Team Meeting 5 Notes

The team meeting started at 3:30 with all team members present, Adrian via Zoom meeting.

The main points of this team meeting are as follows:

- Finalize Hardware Decisions
  - Select Battery Type
  - Calculate Expected Battery Life
  - Determine Resistor Values
  - Finalize Circuit Layout
- Begin Initial Prototyping
  - Prepare for Production of Circuits
  - Gather all required materials
  - Prepare for a single wireless light bar prototype

The team decides to use a 9v Li Battery, the team also decides to use the existing "Goofy Glasses" circuit as our bast design. Our team also decides to use Series connection for our LED's.

The team contacts Dr. Rinker to begin requesting parts to begin the construction of an initial prototype.

2.6 02/15/2018 Team Meeting 6 Notes

The meeting began at 3:30 with all team members except Adrian present.

As Adrian is a remote student, and this team meeting was solely for practicing the design review two presentation, Adrian did not attend this team meeting, as agreed on by the team.

As stated above, the purpose of this team meeting was to practice going over our updated design review two slides, as well as practicing our teams design review two presentation.

After the team's review of the design review two slides, and a few minor alterations to the slide deck, our team begins practice runs of the design review two presentation.

After three full practice runs, from start to finish, the team agrees that we are well prepared for deign review two.

2.7 03/01/2018 Team Meeting 7 Notes

The meeting began at 3:30 with all team members present, Adrian via Zoom meeting.

The purpose of this team meeting is to discuss, and delegate items that need to be updated for the upcoming Snapshot Day 3 presentation. Our team also used this meeting time to look into team portfolio additions, and assign team members to all items that need to be added into the team portfolio.

The Snapshot Day 3 items to be updated are as follows:

- Update Team Info. (Adrian)
- Update Problem Statement (Kevin)
- Update General Specifications (Kevin)
- Update Project Learning (Andrew)
- Update Proof of Design (Adrian)
- Update Visualization of Final Product (Paul)
- Update Project Completion (Andrew)
- Issues and Plans (Paul)

The Team Portfolio Additions are as follows:

- Update Battery Specifications (Adrian)
- Update LED specifications (Andrew)
- Update Team Meetings (Kevin)
- Update Client Meetings (Kevin)
- Update Prototype Progress (Paul)
- Add Design review 1 section (Kevin)
- Add Design Review 2 section (Kevin)
- Update Wiki Page info. (Paul)
- Update Budget and parts list (Adrian)

The team agrees to have all items above completed by Monday 03/05/2018 before Snapshot Day 3.

3 Client Meetings and Minutes

3.1 9/08/2017 Client Meeting 1 Notes - With Dr.Rinker

Meeting started at 3:31, all members present, Adrian on Zoom meeting

Question and Answer with Rinker:

General schedule: Rinker's in CDA start of the week, always in Moscow on Friday, in between depends on events.

Current system in the tower: 3 high powered LEDs (in series) in each room facing the proper direction, controlled over CAT cable from the basement. LEDs prefer constant current over constant voltage, using constant current power source. Each color takes 270 mili-amps. Constant current circuit used here.

Future objectives: Convert system to be wireless. Nodes will need to sleep for a couple days before the show begins, using low power, and should then be remotely wake-able. Power and LED configurations are up to us.

Current goofy lights: broadcast from laptop to Arduino like board, transmits out to the glasses. Wireless protocol related to Zigby. Not wifi, but 802.15.4 (ad-hoc sensor network). Devices can sleep, wakeup, reconnect to network, etc. Zigby handles errors when reconnecting, etc. We avoid using Zigby as were broadcasting in real time, and do not want the error handling. Broadcasts on 2.4ghz, regular wifi frequency. 9v lith-ion batteries are being used in the glasses. LEDs in the glasses are in series. Uses a resistor to deliver the correct voltage. Uses the chip from an Arduino, straight up programmed from the Arduino IDE. Atmega328p. Broadcasts to all glasses i.e. DMX. Uses 16 different channels for groups of lights.

802.15.4 only goes at 250kbps. Might want to reduce each channel to 2 bytes instead of 3?

DMX protocol: Used in theater lights, wired protocol, goes through each light sequentially.

Current code is all available for use, we're going to get that from Rinker and put on GitHub(?)

Mouser.com parts. Superbrightleds.com

Meeting adjourned at 4:39

3.2 9/22/2017 Client Meeting 2 Notes - With Dr.Rinker

All members present, Adrian via Zoom, meeting started at 3:32

We only need to deal with .tan file to hardware, theres another group redesigning the .tan file creator. Theyre finishing up in December. Also may be redesigning the interface for the player?

Current implementation uses xbee to transmit to receiver, then transmits to the light controller serially.

We can probably use old CSAC space to store hardware, work. This has a soldering station too, along with some goofy glasses and the old tower hardware being stored.

328p chips are super cheap, could definitely use one of those for each light bar.

Arduino IDE supports turning off bootloader now, etc, which should make development even easier.

Current player is Linux specific, supposedly has Mac and Windows equivalent libraries though. Pulseaudio and FTDI. Look into making this cross platform compatible.

Main thread of player sends wav bytes to the audio thread, updates lights once the program reaches the proper time.

Parts needed: transmitter, shield, USB to serial, receiver chips, light bars themselves, batteries.

Meeting adjourned at 4:33

3.3 11/03/2017 Client Meeting 3 Notes - With Dr.Rinker

Meeting started at 3:39, all members present, Adrian via Zoom meeting.

Constant current circuit: start with the Goofy glasses circuit, figure out what will work for us, modify what we need to. Diagrams using PCBArtist(4pcb.com): Each part has a schematic symbol and a footprint describing what the actual part looks like.

Receiver (MRF chip) can send signals on the 328Ps interrupt pin! Regulator chips should function no matter what battery we choose, within reasonable limits, so we should be able to keep using those.

Rinkers going to send us the current circuit diagram so well have access to parts list, details, etc.

PCBArtist lets you create the traces for the circuit board, then order the custom board based on your output. Print as many per sheet as possible, $33 for each sheet, for students (60 square inches max).

Rinker has some breadboard type shields for Arduino that we could use for prototyping if those would be helpful. Could basically just add transistors between the Arduino 3.3v supply and the LEDs to create a prototype.

Xbee transmitter is same between Tower Lights and Goofy Glasses.

3.4 01/26/2018 Client Meeting 4 Notes - With Dr.Rinker

Meeting started at 3:30, with all team members present, Adrian via Zoom meeting.

Client Meeting 4 discussion topics:

- Goofy Glasses Circuit design
- Goofy Glasses Parts List
- Obtaining parts to create a prototype
- System Design changes brought to Dr. Rinker
  - Use of 2 9v Li Batteries Run in Parallel
  - LED configuration changed to 2 sets of 2 LED's run in series, connected in parallel
- Project completion schedule and planning

Dr. Rinker liked all of our teams purposed design changes except for the idea of running 2 9v Li batteries in parallel.

Dr. Rinker informs our team that running two batteries in parallel can be problematic. Dr. Rinker notes that running two batteries in parallel can be safely done with connecting the batteries with a resistor to limit cross charging.

Meeting adjourned at 4:49.

3.5 03/23/2018 Client Meeting 5 Notes - With Dr. Rinker

Meeting started at 3:30, with all team members present, Adrian via Zoom meeting.

Client Meeting 5 Discussion topics:

- ZIF Socket
- Total number of final prototypes (to be delivered)
- Goofy Glasses Code

During client meeting 5, our team received a ZIF socket (Zero Insertion Force). The ZIF socket is the last hardware item our team needs to finish the construction of multiple prototype circuit boards, and light bars.

Our team asks Dr. Rinker how many circuit boards and light bars he is expecting for out final project delivery.

Dr. Rinker informs our team that four light bars, and prototype circuits is plenty to prove we have a working design for the final product delivery.

Meeting adjourned at 4:49.

4 Project Learning

Technologies used to solve problems are described below. Further discussion of these technologies are left in each section's subsections.

4.1 Team Info

A discussion of the various pieces of info that relates to team information is provided below.

Team Name

- LEaD Design

Team Members

- Adrian Beehner
- Andrew Butler
- Kevin Dorscher
- Paul Martin

Sponsor

- Dr. Robert Rinker

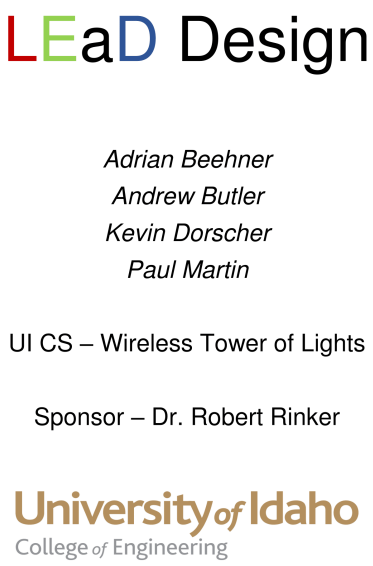


Figure 3: Team Info

4.2 Proof of Design

A discussion of the various components is shown below, providing evidence of components working together.

LightBar

- LightBar designed similar to original "Tower of Lights" one
- 1 in x 2 in
- Size supports common sizes that are used for PCBs and LEDs

LED Driver Circuit

- Similar to "Goofy Glasses" Circuit
- Schematic will be very similar, besides the fact that higher voltage and some other additional items will be added

Towerplayer Program

- Modified from various files from original "Tower Player" programs:
  - towerarduino.ino
  - towerplayer.cpp
  - yswavfile.cpp
  - yswavfile.h

LED

- LEDs already function on "Goofy Glasses"
- Similar design, with battery and circuit providing the power and data to correctly display specific color for LED
- Layout of LEDs will actually follow similar design as the original "Tower of Lights" LightBar.

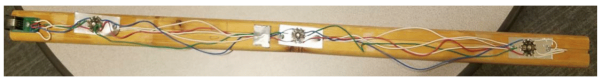
Battery

- 9V Lithium Ion Battery already working on Goofy Glasses
- Currently provides 30 minutes of run time
- Current Battery choices are between 9V Lithium Ion and 18650 (which would last longer)

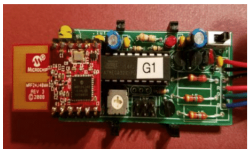
A diagram that correlates to the information that is provided above discussing the proof of design id shown below. Images are provided in the diagram to help provide a visual for certain aspects.

Proof of Design

- **LightBar**
  - Lightbar designed similar to original *Tower of Lights* one



- **LED Driver Circuit**
  - Similar to *Goofy Glasses* circuit, similar schematic



- **Towerplayer program**
  - Modifed *towerarduino.ino*, *towerplayer.cpp*
- **LED**
  - Functioning on *Goody Glasses* with 9V Battery

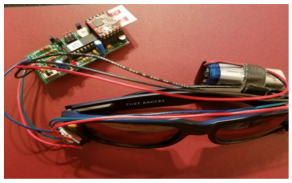


Figure 4: Proof of Design

4.3 Problem Statement

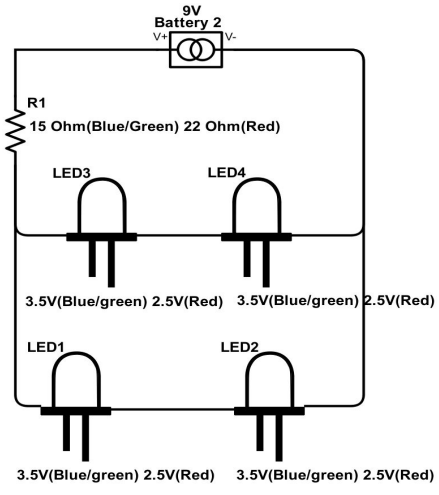
The Wireless Tower Lights problem statement has been updated for Snapshot Day 2.

Figure 5: Problem Statement Update

4.4 General Specifications

The General Specifications have been adjusted to more accurately reflect the design choices and concept.

- LED
  - 10.5 volts for 2 LED's in series. Series LED's run in Parallel



  -
- LED Driver Circuit
  - "Sleep" / "Wake-up" will be delegated to the Receiver chip and LED Driver Circuit

Figure 6: General Specification Adjustments

4.5 Final Product Vision

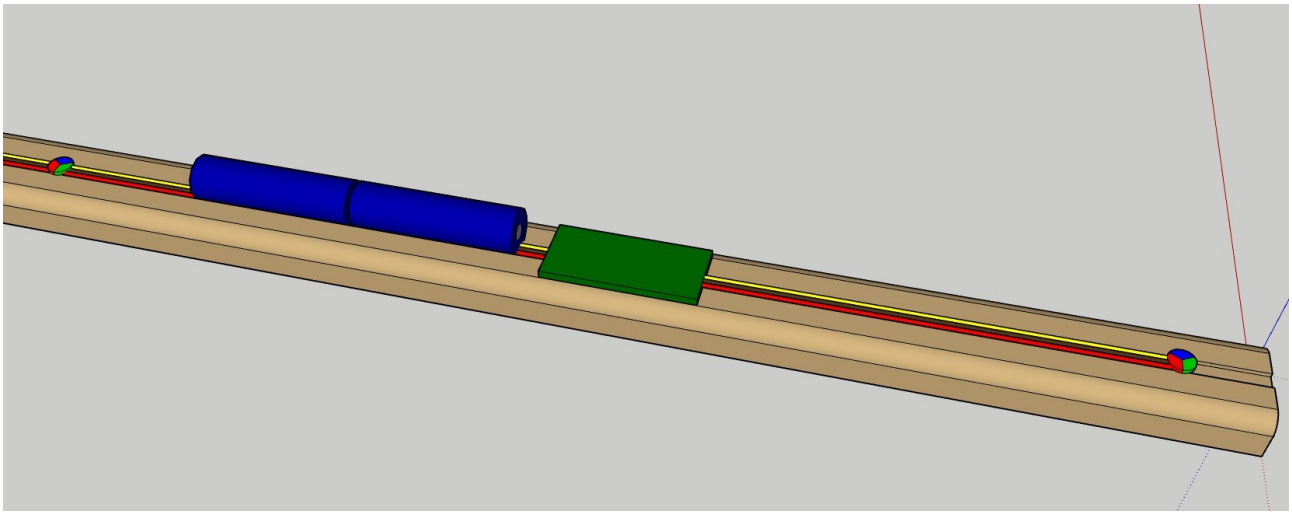


Figure 7: 3D Model of Final Product

4.6 Design Review 1 Presentation

Our teams design review 1 was held on 11/16/2017, in EP 205, at 4:00pm.

The wireless tower lights design review 1 went very well. The team did a few practice runs and the presentation went smoothly as a result.

All design choices purposed by our team were accepted by our client (Dr. Rinker), and our lead instructor (Bruce Bolden). Both our client and lead instructor noted that we understand the problems our team is faced with, and have come up with reasonable efficient solutions to solve the problems that our project has presented.

Some notes mentioned by our client, Dr. Rinker, that our team need to take into consideration include:

Numbering our Design Review Presentation slides

The consideration of an external clock

Refrain from using the term Zigby (use 802.15.4 instead)

Refrain from using the term Ethernet (use Cat-5 instead)

Think sbout how to divide date to support more software channels than 40

4.7 Design Review 2 Presentation

Our teams design review 2 was held on , in EP 205, at 4:30pm.

The wireless tower lights design review 2 presentation went well. Our team did a few practice runs of the presentation, and as a result the design review two presentation went smoothly.

We purposed a few major design changes during the design review two presentation, the items can be found below.

Our team purposed the idea of using two 9v Li batteries in parallel, and a solution to the issue of cross charging (the reason this idea was originally disputed). Our team ides is to run two 9v Li batteries in parallel with a single diode connected to the positive lead of each battery. Using diodes, which only allow current to flow in one direction, both of our batteries would never be able to charge the other, if one battery is producing more voltage then the other.

Out team also purposed a change to the configuration of our LED's. We presented the idea that we plan to run 2 sets of 2 LED's in series, connected in parallel. This would give each light bar 4 high powered LED's instead of three, making each individual much brighter.

Our team also spoke with Dr. Rinker after the presentation and took down some of his suggestions:

> using two hardware channels instead of one.
>
> Using a smaller packet size, with slightly less color resolution to support more software channels.

After speaking to Dr. Rinker about the suggestions above, or team has decided to increase our software channel support by:

> Cut total packet size to 12 bytes (Down from 24 bytes)
>
> Use two hardware channels (Zigby channels 25 and 26)

Using the 2 changed above the team should be able to support more channels then the current 32. Cutting the packet size in half will result in slightly less color resolution (16 million colors, down from 32 million colors), but it will allow us to create 64 software channels over a single Zigby channel. With the use of 2 X-BEE transmitters one transmitter on zigby channel 25, and one transmitter on zigby channel 26, will allow our existing software to support 128 channels (up from 32).

5 Design Goals

Client needs and project goals are discussed below. A Timeline for these is also included. Discussion of revision of goals, and addition of any new goals is also discussed below.

5.1 Client Needs

The needs of the Client (University of Idaho) are as follows:

LED Light Bars

Microprocessor communication (Arduino)

LEDs bright enough to be a coherent display, visible from a distance in the dark

Wireless Protocol SPI

Battery powered

Receiver Module for Arduino (802.15.14 chip)

AdrProcessor for designing chip

Low power mode (sleep mode)

Wake up remotely

1-bit for each color for each window

802.15.4 protocol, channels 3 bytes (1 for each color, RGB)

Avoid wifi (we don't want to have interference)

Design module

Expand channels (for expanding bandwidth)

15-20 stories, need to support enough windows

WAV file support

OSX, Windows, and Linux support (Cross-Platform)

.tan file support -

5.2 Project Goal

The goal of the project is to the extend the versatility of the Tower Of Lights project, which at the moment, gives the user the ability to run a program which reads in a .tan file (animation files for the lights) and .wav files. Then this program communicates with a Arduino via Ethernet. Now, the Arduino communicates to each of the LEDs, and tells them which

color and brightness to be, from the .tan file (thus it basically reads in animation info). The enhancement of the project involves providing cross-platform support, which means having to rework some of the TowerPlayer code so it doesn't use the Pulse library (which is Linux-specific). Also, the enhancement requires making the wired connection to the Arduinos on the LED bar to wireless, this is accomplished by having an Arduino Receiver on each LED Board that receives info sent out from the Arduino connected to the main computer running the program, that Arduino has a XBee Shield attached, which is a wireless module to transmit the info to each Arduino on a board. The Arduino now requires a portable power supply, which needs to be a 9V battery for each Arduino on an LED Board. The final enhancement is that since the LED Boards are running off battery, they require some kind of sleep mode, where they will still be able to receive info (so they can wake up).

The product will give the user the ability to run a program that reads in .tan files and .wav files, have this program communicate with a XBee Wireless module on an Arduino that is attached to a Computer via USB, then communicate wirelessly with each battery powered Arduino receiver, on each LED board, that will then communicate with each LED on that board through wired communication from the Arduino (same one that holds the receiver)to the LEDs. The program that runs through this procedure will be available for the OSX, Windows, and Linux based operating systems.

5.3 Timeline

This is the most recent timeline for the Wireless Tower of Lights project

- September • Planning/Adjustments/Finalize Program Flow
- October • Hardware Decision/Hardware Tinkering (Arduino/Xbee)
- November • Hardware Implementation and Initial Prototyping
- December • Prototype Product/Unit Testing
- January • Product Improvement, Evaluation, and Final Product Hardware Decisions
- February • Implementing and Producing Final Hardware
- March • Hardware Scale Testing, Software Improvements
- April • Testing
- May • Ship/Manufacture (Deliver product)

6 Specifications and Constraints

Discussion of client interviews, pictures, measurements, etc. are provided below. Design specifications and constraints are also presented. Reasoning for any constraints is also mentioned.

6.1 Arduino / Receiver Design Specification

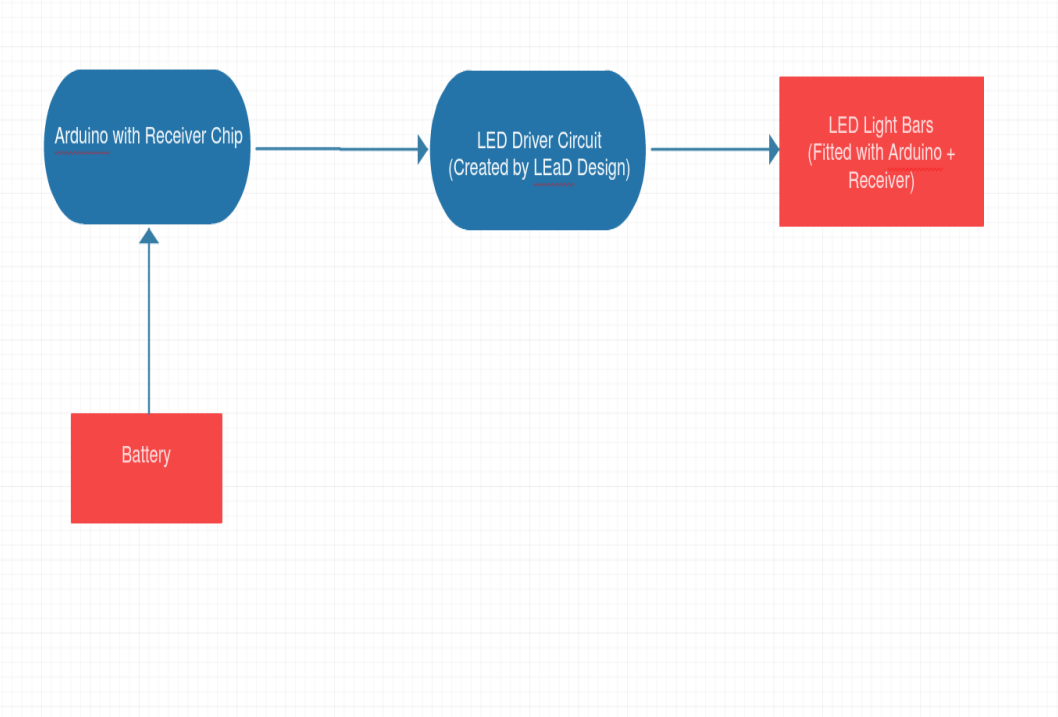


Figure 8: Arduino / Receiver Design Specification

Arduino / Receiver Design Specifications

Multiple Arduino Atmega 328P boards fitted with a shield and attached receiver chip

Programming of the individual Arduino Atmega 328P boards using the Arduino IDE (C++)

Receiver chip will delegate the sleep or wake-up modes for each individual light bar

Receiver will also handle input from the transmitting X-Bee, and output data to the LED driver circuit

Creation of the LED Driver circuit which will modify voltage as requested by each set of LEDs to provide a constant current power flow

After modifying voltage accordingly, the LED driver circuit will output the data stream from the receiver to the network that each Arduino Atmega 328P is connected to

6.2 Battery Design Specification

The list below discusses the attributes for the battery specification, including the requirements, battery chemistry, voltage/capacity, and options/alternatives. Figures "9V Battery Design Specification" and "18650 Lithium Ion Battery Design Specification" corresponding to this information is also shown below.

Requirements

- Battery required to power the LightBar for TowerOfLights
- 3 LEDS on LightBar requires 800 mA
- Voltage must be within the range of 8.6 9.3 V (Charge)
- 10.5 V to run 3 LEDs in a series
- 7V for 2 LEDs in a series
- Microprocessor based wireless Module distributes the power supply to LEDs on each board

Chemistry

- **Lithium Ion:** rechargeable battery type, due to high energy density, tiny memory effect, and low self-discharged, lithium ions move from negative electrode during discharge, and back when charging
- **Alkaline:** Popular primary battery (non-rechargeable), dependent on reaction between zinc and manganese dioxide

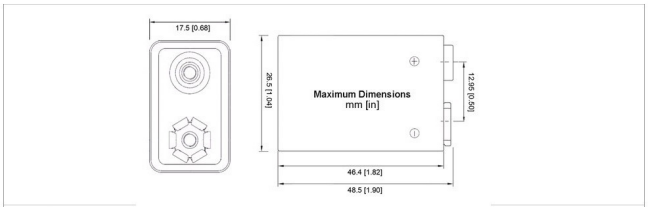
Voltage/Capacity

- Each LED requires around 3.5 V and each color takes 270 mA
- A 9 V battery could support two LEDs in a series, 9V batteries support a wide range of mAh, generally from 400-700 mAh
- A 18650 Battery, which has 3.7 V, can be placed in a 18650 holder for 3 batteries, providing 11.1 V, enough to power 3 LEDs in a series (current LightBar setup), with 18650 supporting a range of 1600-3600 mAh

Options/Alternatives

- **18650 Battery:** large capacity (mAh), allowing LEDs to run longer and can be configured to run LEDs in a series, if making battery pack from these, but requires long charging
- **9V Battery:** Provides smaller capacity, but faster recharge rate. Can only run 2 LEDs for a single 9 V

9V Battery



Voltage	8.6 - 9.3 V
Capacity	400 - 700 mAh
Power	> 3.44 Wh
Charge Current	< 250 mAh
Approximate Charge Time	> 1 hr
Weight	34 - 45 g
Battery Chemistry/Type	Lithium Ion
Operating & Storage Temp	Around 21 °C (70 °F)

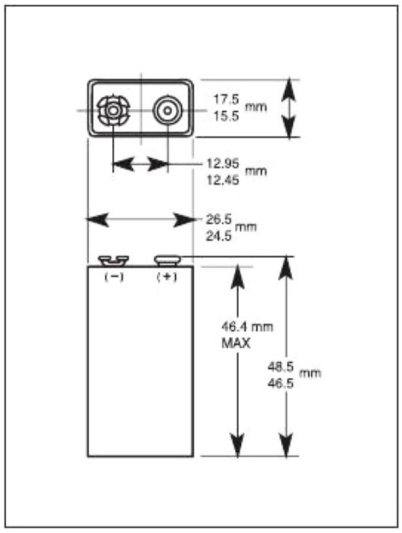
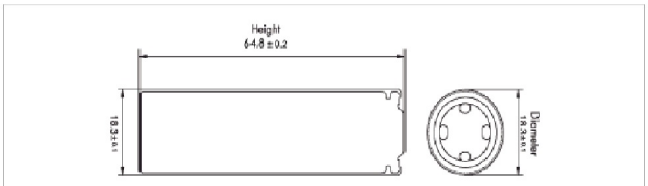


Figure 9: 9V Battery Design Specification

18650 Battery



Voltage	3.7 V
Capacity	1600 - 3600 mAh
Power	> 5.92 Wh
Charge Current	< 500 mAh
Approximate Charge Time	> 4 hr
Weight	45 - 48.5 g
Battery Chemistry/Type	Lithium Ion
Operating & Storage Temp	Around 21 °C (70 °F)

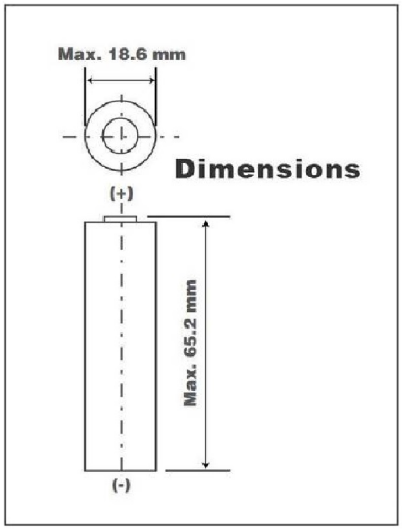


Figure 10: 18650 Lithium Ion Battery Design Specification

6.3 LED Design Specification

LED specifications and 2 potential solutions detailed below.

Specifications

- 3 LEDs of each color (red, green, blue) per room
- Uses constant current (270-300 mA)
- Red LEDs drop 2.5V per diode
- Blue and green LEDs drop 3.5V per diode
- Colors are displayed with pulse-frequency modulation, as each diode can only be fully on or fully off at any moment

Circuit Options

- **Series:**

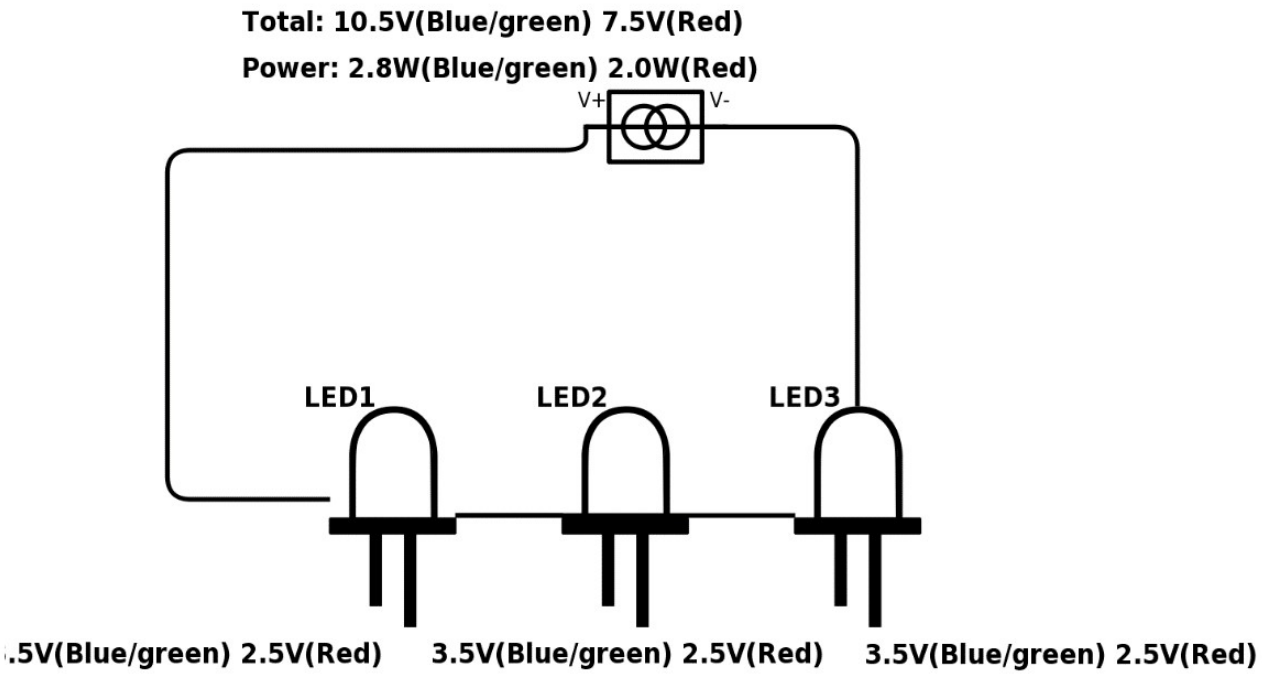


Figure 11: Circuit diagram with LEDs in series

- **Parallel:**

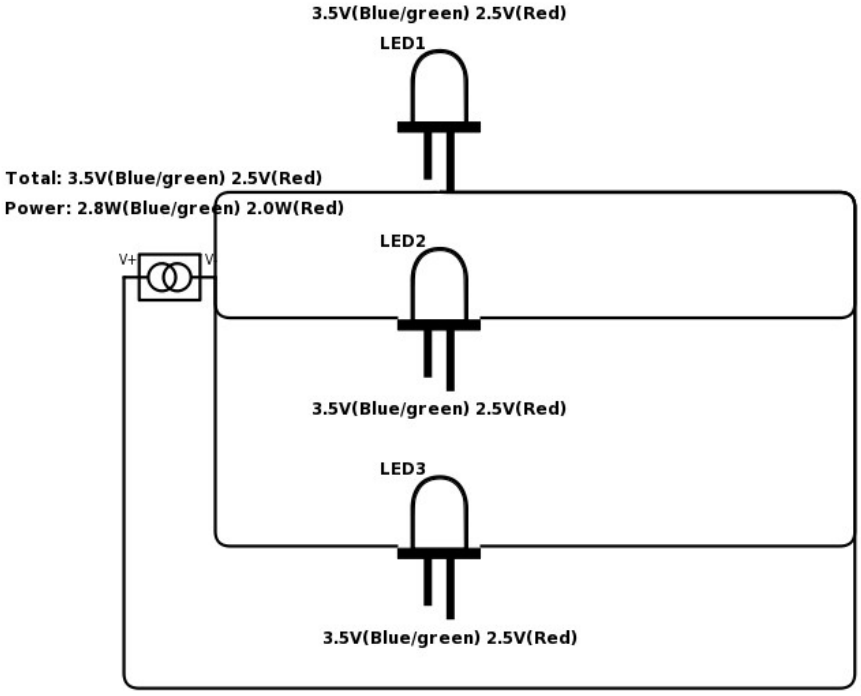


Figure 12: Circuit diagram with LEDs in parallel

6.4 Wireless Design Specification

Frequency Requirements

– The wireless protocol needs to have an effective range of potentially up to 100 meters. Additionally, the frequency must be one that will work even in crowded venues, with lots of different cellphones, and Wi-Fi signals present.

Speed Requirements

– The wireless protocol needs to have the ability to send enough data fast enough to keep up with the Tower Lights show. Depending on the total number of light-bars, this number can change. The speed requirement will also depend on how many possible colors we implement and how many frames per second we will display.

Packet Requirements

– The information packets sent over the wireless protocol must contain all the information needed to set the individual light bars to the appropriate color. There can be only one packet that will be sent to all the light bars, and each light bar will be encoded with which part of the packet to read.

Potential Solution

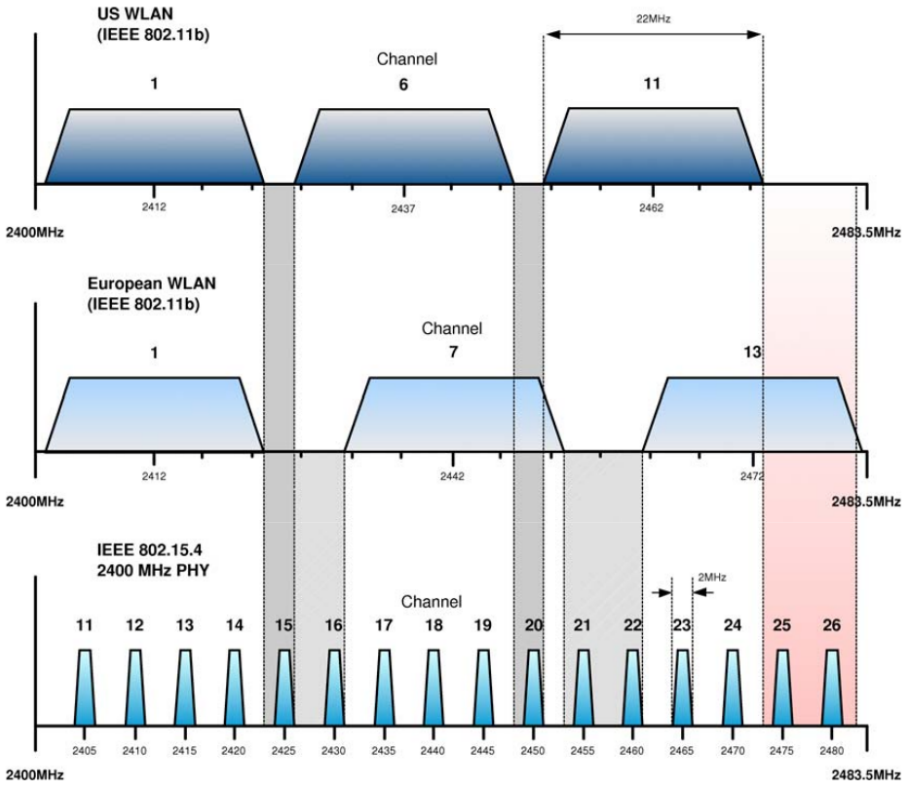


Figure 4: LR-WPAN vs Non-Overlapping WLAN Channel Allocations

Figure 13: **Zigbee Wireless Protocol** Uses Channels Above Wi-Fi

7 System Diagrams

Discussion of symbols used, the diagrams themselves, and the software used for the diagrams is discussed below.

7.1 Current Product

The current product flow in regards to the final product is shown below in Figure below. The current setup does not have any battery setup, and requires a wired connection. Changing this is the core of this project, which will improve the versatility of the TowerOfLights product.

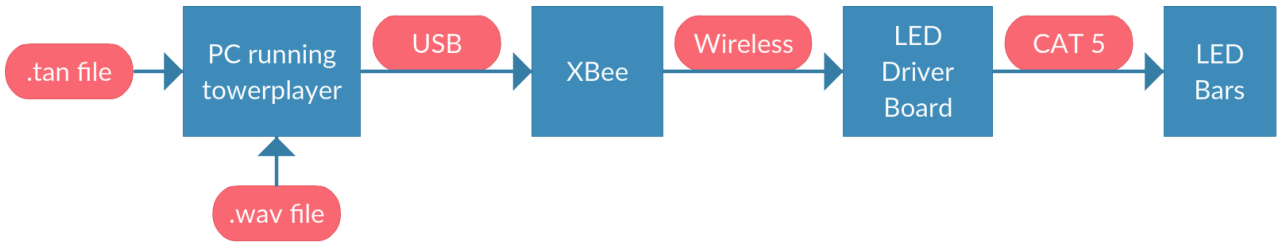


Figure 14: Current Product Flow

7.2 Desired Product

The desired product flow is shown in the figure below. The main focus is on the battery that should power each Arduino reciever, as well as the SPI protocol from XBee to the Receiver. This is to make the process wireless instead of wired, which is the main goal of this endeavor.

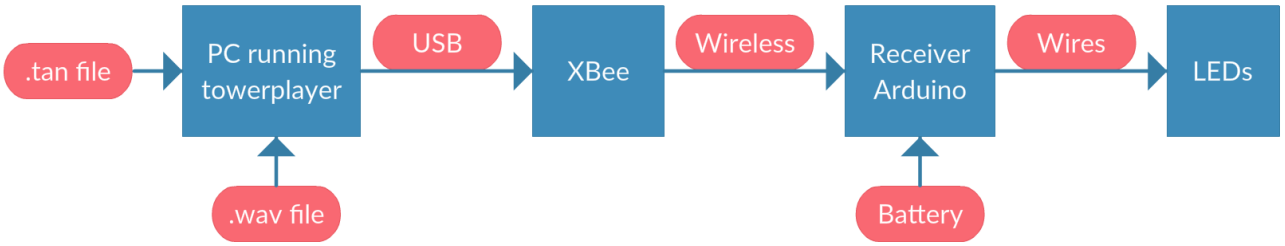


Figure 15: Desired Product Flow

7.3 PC Running TowerPlayer

The diagram for a flow chart depicting the sequence of actions for running the TowerPlayer program on a computer is shown in the figure below. This diagram helps with understanding

the underlying software that needs to be setup and used before the hardware can successfully work together.

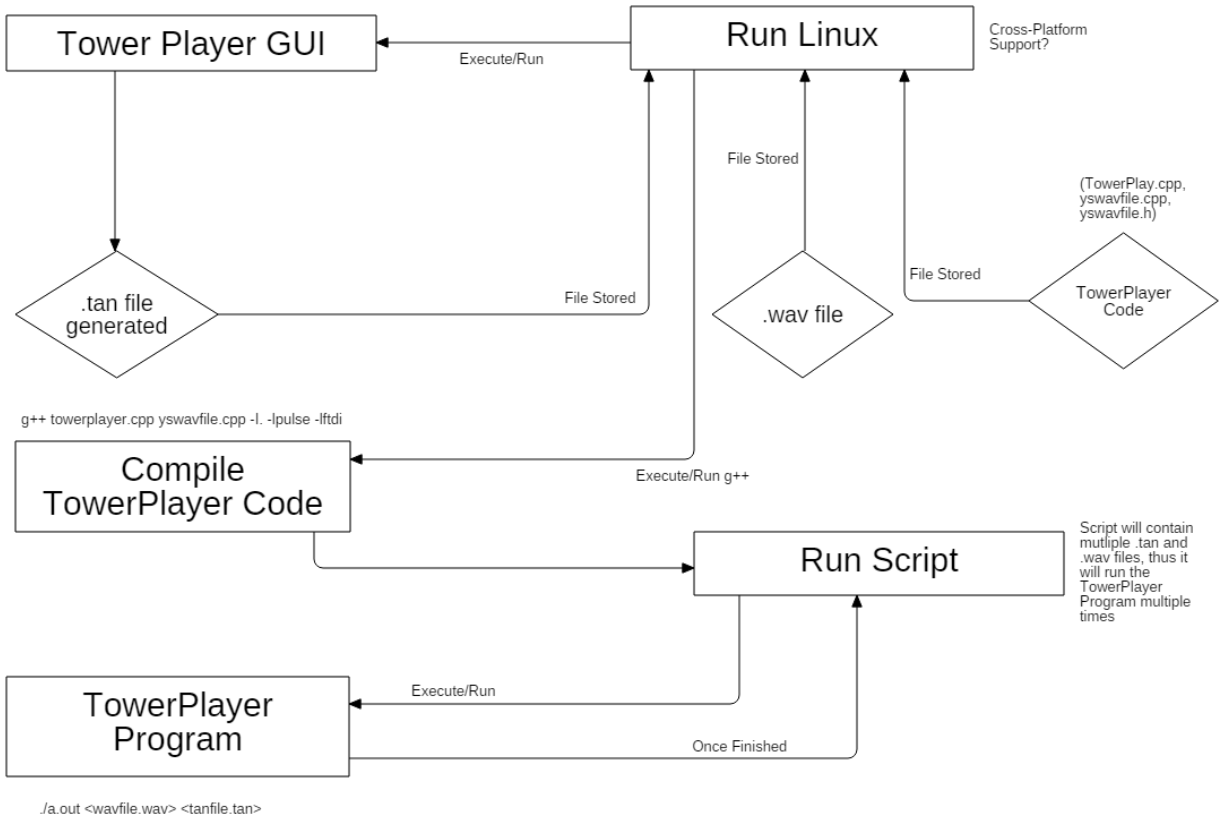


Figure 16: Flow Chart Diagram for PC Running TowerPlayer

8 Analysis of Alternatives

Discussion of possible alternatives and why some alternatives are better is described below. These topics include: safety, moving parts, cost, durability, compatibility, and reliability.

8.1 9V Battery vs 18650 Battery

One of main decisions in this project was deciding whether to use a 9V battery or a 18650 litium ion battery, as they each have advantages and disadvantages. Before desrcibing the choice that was decided upon, its important to examine both batteries, to lay out the benefits and costs of using each in regards to topics such as safety, moving parts, cost, durability, compatibility, and reliability.

9V Battery

Safety

- A 9V battery is considered generally safe, as long as handled fairly carefully, but in the wrong hands they can be somewhat dangerous, not to mention the chemical make up of them is harmful to the environment.

Moving Parts

- For the 9V Battery the circuit required a volotage of 11V, but that was if the LEDs were in a series, if they were designed in paralled, the voltage would be reduced to 3.3V. Thus this in its own way was a decision that needed to be made use two 9V batteries with higher voltage and more mAh, but at a higher cost and more moving parts, but that is not the exact topic at hand.

Cost

- The cost of a 9V battery can range drastically, espeically depending on the chemistry of the battery, however the customer specified that they wanted specifically lithium ion batteries, which narrowed down the focus. However, due to the range of mAh, the prices still factors in consideribly, but once again the customer had a specific range around 600 mAh, thus the cost a 9V Lithium Ion battery is around seven dollars.

Durability

- The reason that 9V batteries are among the most popular batteries is due to their high durability and remarkable lifespan. Most 9V lithium ion batteries have a guarantee of at least 10 years of rechargeable battery life, makign the battery a fairly competetive choice.

Compatiability

- 9V Batteries are known for their wide range of compatability and work easily with a variety of configurations. 9V batteries can easily be utilized within most circuits boards (if they are designed with them in mind)

Reliability

- 9V Batteries are among the most reliable batteries known. It is not difficult to aquire these batteries from almost any store and know that they will provide good quality power (however brands do make a difference). Overall, they are one of the most well-known and used batteries for a reason.

18650 Battery

Safety

- A 18650 battery is considered highly safe as well, perhaps even above the 9V battery counterpart, due to the packaging of the batteries, whihc is usually in builk and with the positve and negatives not easily accessibile.

Moving Parts

- For the 18650, each one is 3.3V, while the circuit requires at most 11V, so once again if the LEDs were in a series, it would requires three whole 18650 batteries, which are considerably large. This factored into the decision, as more batteries can produce more issues, however even running the LEDs in parallale the voltage would be considered too close to only use one 18650 battery.

Cost

- A single 18650 Battery doesn't range as drastically, as they have only one chemsitry makeup of the battery: lithium ion. Thus instead of having a broad range of selection, the 18650s are quite narrow in the range. The average cost of a single 18650 battery of around 2500 mAh is seven dollars (similar to the 9V), however since it would require 3 batteries, this cost goes up quickly, and the mAh is very far outside the range of the customers needs of 600 mAh, but 18650 batteries all have a mAh range that is generally high

Durability

- The 18650 Batteries are not as durable as their 9V battery counterparts, especially if you buy them in bulk, as they are wrapped with filmsy plastic coverings to hold mutliple batteries together. The bigger issue is, the limited awareness of how durable they are, with such a high mAh generally, its safe to assume they die out at a fairly quick rate (300 recharge cycles and usually replaces within 12-24 months)

Compatiability

- 18650 Batteries are not widely known for being compatible with items (thats not to say they aren't used, as laptop batteries actually use them sometimes and many other items, but they are designed in a particular way for those uses), they are

not as widely used as 9V batteries are when it comes to circuit board integration. This can easily be shown by the previous project our product is based off of, Goofy Glasses, which used 9V batteries, not 18650.

Reliability

- 18650 batteries are not exatly known for being reliable. Due to their high mAh rate, they quickly become obselete and need to be replaced. That is not to say they don't provide a great amount of power, as they beat out a lot of similar battieres when it comes to mAh, but these batteries are not easily accesible, as they are not commonly sold in major stores.

Conclusion

The decision that correlates the best with the current design of the project is the 9V Battery, as with the various costs and benefits mentioned previously about the two, the 9V battery satisfies the client's needs better. THe 18650 would have easily been the better alternative if the product required a much longer operation time, as 9V batteries just don't offer nearly the same amount of mAh as the 18650 batteries do, in the end, the decision is about what is best in meeting the client's needs and making sense in the overall design of the system.

8.2 9V Battery - 1 vs 2 Quantity

The decision betwen utilizing one or two 9V batteries is a difficult one, as the pros and cons of each are heavily important in the decision decision moving froward. it is important to discuss each and determine which one provides the best solution to the problem at hand, while evaluating the other one as a possible alternative.

1 9V Battery

One 9V Battery woudld follow the decision to have 2-LEDs in a series with one 9V battery, following very closely to the idea of the orignal Goofy Glasses Circuit. This would allow almost no configuraiton, but fails to meet the needs of the client when it comes to having at least three LEDs. But it also avoids the difficult challenge of heavily modifying the Goofy Circuit to work with 18v (as 3 LEDs would requires two 9Vs). This also for a very cheap LightBar that only requires one 9V Battery

The issue with the one 9V Battery is simply that the runtime might just be too short and having only two LEDs in ery limiting. Also, since with very littles configuraitons being made to the circuit this just appears as Goofy Glasses 2.0 (which is in some regards the idea, an evolution of TowerOfLights and Goofy Glasses). However, two LEDs is not enough to provide brightness needed, unless some clever workaround were made.

2 9V Batteries

Two 9V Batteries would follow with the decision to have 2 sets of LEDs-in-series. Thus this would have two sets of LEDs that are in parallel then, and two 9V battries in parallel. So instead of the design of three LEDs per LightBar, there would be four, allowing each

LightBar to be slighlty brighter. This also allows for less modification of the circuit, as dealing with a 9V in a circuit that is currently designed for 9V means not much needs to be tampered with. This also provides a better duration time to run the LEDs, as the drain from running both the Arduino and Reciever will be reduced by half (between the batteries), also this allows for easily modularity, if one needs more capacity, simply add another battery.

Now the issue that two 9V Batteries present is for one, and the big one, the cost, if each LightBar requires now two 9V lithium Ion Batteries, the cost per LightBar has risen dramatatically. Also, there is the issue of meeting the clients needs (however the client has now agreed that this concept is fine as well). Finally, this means having to adjust the LightBar confifuration that had been already predetermined, since there would now be four LEDs instead of three.

Conclusion

The decision to use two 9V Batteries in the system is the best and most logical decision, as it provides the best benefits with reduced costs. The main advantage is having even more brightness and ease of modularity. While the one 9V Battery otpion would easily win if this product was more concerned with mobility (like the Goofy Glasses), as having 2 9V Batteries is going to weight somedown quite a bit. Also, if costs needed to be cut more as well, but the issues that come alongside using just one 9V battery are too great in this product to utulize it, but perhaps in a similar porject, it would be a good alternative, or it could be used here for extensive and relatively cheap testing.

9 Engineering Model

Discussion of the physical, chemical, and biological system modeling. Also discusses modeling criteria, expected accuracy, and pitfalls. Section of modeling software used is present, as well as data needed and how the data was obtained. Lastly a validation scheme for the model is shown.

9.1 Design Failure Mode Effects Analysis (DFMEA)

The DFMEA is shown below

Description of component, subsystem, or function	Symptom (what?)	Effect (so what)	Failure mode (why?)	Probability of failure	Severity of effect	Risk priority	Remedial action
Wireless LightBar System	System Fails to Operate	User cannot use the desired system	1) User's Computer is not set up correctly 2) User failed to set up parts as directed	1	1	1	Make simple and clear directions for user
LightBar	LightBar fails tot Operate	User sees no effect from lightbar during operation	1) Wireless Protocol Error 2) Computer Error	2	1	1	Warn Users of Wireless Protol and Computer Errors
TowerPlayer Program	Audio/Frames for Display is Unsynced	User experience is frusterating/ruined and fails to meet design intent	1) User's Computer permissions/libaries not correct 2) Missing permissions/libraries 3) Wireless Protocol Error	2	1	1	Inform user of required libraries/software, warn of Wireless Protocol Errors
TowerArduino Program	Arduino does nothing	Cannot send or receive data (LightBar will show nothing)	1) Incorrect use of "Arduino" Software 2) Wireless Protocol Error	1	1	1	Inform user of required libraries/software, warn of Wireless Protocol Errors
LED Driver Circuit	Data is sent, but LightBar displays nothing	No feedback/display for User	1) Circuit became damaged	1	4	4	Warn User to handle LightBar carefully or create more protective case for circuit
Logic Diode	Temperature Increase	Major Damage to LED Driver Circuit Will Eventually Occur	1) Component Failure	1	4	4	Add "Warning" to Product

Figure 17: DFMEA

2-Pin to 9V Adapter	No Power Supply	The LightBar Will not Operate	1) Component Failure	1	2	2	Add "Warning" to Product
4-Pin Header	No Connection to LEDs	LEDs will not operate, thus no display	1) Component Failure	1	3	3	Add "Warning" to Product
6-Pin Header	NA	NA	NA	NA	NA	NA	NA
Atmeaga48-10p	Circuit Cannot Evaluate Data Received	Rest of circtuit useless, depends on microcontroleler for control	1) Component Failure	1	2	2	Add "Warning" to Product
BoardPadSmall	NA	NA	NA	NA	NA	NA	NA
CAP5mm (Ceramic Capacitor)	Short Circuit or High (Voltage) Leakage for Circuit	Prolonged use will bring about permanent damage (or system may fail to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product
Disscacap	Short Circuit or High (Voltage) Leakage for Circuit	Prolonged use will bring about permanent damage (or system may failt to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product

Figure 18: DFMEA

FET Nchan - TN0604	Thermal Runnaway, Short Circuit, Excessive Gate Leakage	Prolonged use will result in perminant damage and failure of system, short term, reduce reliability of system	1) Component Failure	1	3	3	Add "Warning" to Product
LED-T1 (Through Hold Red Diffuse)	No Red LED shining when Circuit is on	User doesn't know if circuit is on or off (dangerous) (on/off switch doesn't say "on" or "off")	1) Component Failure	1	4	4	Add "Warning" to Product. Add label for "On" and "Off" to switch
LM78L05	Short Circuit, or Open Circuit Burnout	Prolonged may bring about permanent damage (or system may fail to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product
MCP1700 3.3V 250 mA	Fluctuating Voltage (usually too high), or high temperature near microcontroller	Prolonged use will bring about permanent damage. Short term system will be unstable (LEDs flicker/unbirght)	1) Component Failure	1	3	3	Add "Warning" to Product
MRF24J40MA	No data received (from Xbee Transmitter)	Nothing will happen, circuit will act as though the towerplayer is not running	1) Component Failure 2) Wireless Protocol Error	1	2	2	Add "Warning" to Product & Discuss Wireless Protocols Errors
R0.25W (Carbon Film Ressitor)	Open Circuit Faults	Prolonged may bring about permanent damage (or system may fail to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product
R1W (Metal Film Resistors - 15 ohm)	Fail-Open Fault	Prolonged may bring about permanent damage (or system may fail to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product

Figure 19: DFMEA

R1W (Metal Film Resistors - 22 ohm)	Fail-Open Fault	Prolonged may bring about permanent damage (or system may fail to start entriely)	1) Component Failure	1	3	3	Add "Warning" to Product
Rotary Dip (Coded Rotary Switch)	NA	NA	NA	NA	NA	NA	NA
Switch - Mini Slide PCB	Circuit cannot connect/disconnect	User cannot turn the circuit on/off (dangerous)	1) Component Failure	1	4	4	Add "Warning" to Product
XTAL/Resonator (Ceramic)	Timing of circuity is incorrect, LightBars are not displaying , high failure rate	Whole System appears to be unreliable, may be harmful to overall functionality	1) Component Failure	1	2	2	Add "Warning" to Product
9V Li Ion Battery	LED Circuit Fails to turn on, or doesn't respond	LightBar won't display anything, no feedback to running towerplayer	1) Component Failure	1	1	1	Add "Warning" to Product. Remind user what battery type is required
1 in. x 2 in. x 8 in. Furring Strip Board	LightBar Doesn't stay in desired location or Components are loose on it	Odd-looking displays or components becomign damaged over time	1) Component Failure 2) Misuse of Component	1	1	3	Add "Warning" to Product. Adivse user to handle LightBar carefully
Atmega 328P Chip	Cannot run towerplayer.cpp and send data	LED circuit relies on this data, thus circuit/LightBar will do nothing	1) Component Failure 2) Computer Software Failure	1	2	2	Add "Warning" to Product. Inform user to check their "Arduino" software was installed correclty on computer

Figure 20: DFMEA

Xbee Shield	Cannot tansmit data from towerplayer.cpp	LED circuit relies on this data, thus circuit/LightBar will do nothing	1) Component Failure	1	2	2	Add "Warning" to Product
Xbee Transmitter Chip	Cannot tansmit data from towerplayer.cpp	LED circuit relies on this data, thus circuit/LightBar will do nothing	1) Component Failure 2) Wireless Protocol Error 3) Permission Errors	1	2	2	Add "Warning" to Product. Provide User with Instruction on how to set correct permission for use of product
towerarduino .ino	LED Circuits are unresponsive and do nothing during execution of towerplayer.cpp	LightBar does nothing during execution of towerplayer.cpp, so nothing happens in eyes of the user	1) Wireless Protocol Error 2) Atmega error	1	2	2	Inform user of required libraries/software, warn of Wireless Protocol Errors
towerplayer.cpp	User's computer gives error when trying to run towerplayer or data is not sent	Towerplayer and LightBars both do nothing, system completely fails	1) User's Computer permissions/libaries not correct 2) Missing permissions/libraries 3) Wireless Protocol Error	1	2	2	Inform user of required libraries/software, warn of Wireless Protocol Errors
yswavfile.cpp (& .h)	During execution of product, audio either doesn't sync or doesn't play at all	Ruins user experience of product and fails to meet design intent	1) User's Computer permissions/libaries not correct 2) Missing permissions/libraries 3) Wireless Protocol Error	1`	2	2	Inform user of required libraries/software, warn of Wireless Protocol Errors

		Very Probable	**Probable**	**Occasional**	**Remote**	**Improbable**
		5	**4**	**3**	**2**	**1**
Catastrophic	**4**	20	16	12	8	4
Critical	**3**	15	12	9	6	3
Marginal	**2**	10	8	6	4	2
Negligible	**1**	5	4	3	2	1

Severity of Effect

Catastrophic The failure causes substantial damage to the product itself or related items (including people), requiring repair.

Critical The failure causes significant damage to the product itself or related items, requiring repair.

Marginal The failure causes some damage to the product itself or related items, potentially requiring repair.

Figure 21: DFMEA

Negligible	The failure causes no significant damage.

Probability of Failure

Very	Every time
Probable	Most times
Occasional	Observed multiple times during the project.
Remote	Might be possible during the project.
Improbable	Maybe observed once during the project or predicted to happen after hand off.

Figure 22: DFMEA

10 Manufacturing/Assembly Plan

Discussion of the fabrication need, a flowchart of process oriented projects, a bill of materials, and the estimated manufacturer and delivery time is discussed below.

10.1 Bill of Materials

The bill of materials (BOM) is shown below.

For Each LightBar

Component	Package	Value	Unit Cost	Manuf
1N4148 Logic Diode	USER		$0.06	Parts Express
2-pin to 9V Adapter	DIL	Battery	$1.19	Philmore
4-pin header	USER	LEDs		TE Connectivity
6-pin header	USER	ISP	$0.60	Gravitech
atmega48-10p	DIL	ATMega	$1.87	Microchip
BoardPadSmall	USER			Rx
	USER			Tx
CAP5mm (Cermaic Capacitor)	USER	1uf	$0.28	TDK
disccap	USER	.1uf	$0.30	KEMET
FET NChan - TN0604	USER	BLU	$0.98	Microchip
	USER	GRN		
	USER	RED		
LED-T1 (Through Hole Red Diffuse)	USER		$0.37	Broadcom Limited
LM78L05	USER	5v	$0.67	Texas Instruments
MCP1700 3.3V 250mA	DSC	3.3v	$0.45	Microchip
MRF24J40MA	DIL		$9.12	Microchip
R0.25W (Carbon Film Resistor)	R035	390K	$0.05	Multicomp
R0.125W (Carbon Film Resistor)	R035	10K	$0.10	RadioShack
R1W (Metal Film Resistors)	USER	15 ohms	$0.70	Vishay
R1W (Metal Film Resistors)	USER	22 ohms	$0.36	Vishay
Rotary Dip (Coded Rotary Switch)	DIL	7.4mm	$2.17	CTS
Switch - mini slide PCB	USER		$0.58	E-Switch
XTAL/Resonator (Ceramic)	DSC	16MHz	$0.95	adafruit
9V Li Ion Battery		600 mAh	$6.99	EBL
1 in. x 2 in. x 8 ft. Furring Strip Board			$1.05	Home Depo
Total			**$28.84**	

For Xbee Shield Communicating With All LightBars

Component	Package	Value	Unit Cost	Manuf
Atmega 328P Chip			$0.00	Microchip
Xbee Shield		2.4Ghz	$0.00	SparkFun
Xbee Transmitter Chip		250k bps	$0.00	Digi International
Total			**$0.00**	

Figure 23: Bill of Matierals

For Each LightBar

Manuf Part No	Distrib	Distrib Part No	Ref Name	Qty
1N4148	Parts Express	1N4148	D2	1
48-9000	intertex Electronics	PH-48-9000	J1	1
640456-4	Mouser Electronics	571-6404564	J3	1
6fx1L-254mm	Mouser Electronics	992-6FX1L-254MM	J5	1
ATMEGA48V-10PU	Microchip Direct	ATMEGA48V-10PU	U3	1
			J2	1
			J4	1
FA28C0G2A101JNU00	Mouser Electronics	810-FA28C0G2A10100	C3 C5	2
C320C104M5U5TA	Digi-Key	399-4266-ND	C1 C2 C4 C19	4
TN0604N3-G	Microchip Direct	TN0604N3-G	Q1	1
			Q2	1
			Q3	1
HLMP-1301	Mouser Electronics	630-HLMP-1301	D1	1
LM78L05ACZ/NOPB	Mouser Electronics	926-LM78L05ACZ/NOPB	U2	1
MCP1700-3302E/TO	Mouser Electronics	579-MCP1700-3302E/TO	U4	1
MRF24J40MA-I/RM	Microchip Direct	MRF24J40MA-I/RM	U1	1
MCF 0.25W 390K	Newark	38K0372	R1	1
2710006	RadioShack	2710006	R3 R4 R5 R8	4
CPF115R000FKB14	Mouser Electronics	71-CPF1-15R0FT1	R2 R7	2
MBE04140C2209FC100	Mouser Electronics	594-MBE04140C2209FC1	R6	1
220AMC04R	Mouser Electronics	774-220AMC04R	SW2	1
EG1201A	Mouser Electronics	612-EG1201A	SW1	1
1873	adafruit	1873	XTAL1	1
LN-8161	newegg	9SIABFB5250166		2
100009348	Home Depo	100009348		1
				34

For Xbee Shield Communicating With All LightBars

Manuf Part No	Distrib	Distrib Part No	Ref Name	Qty
ATMEGA328P-AU	Microchip Direct	ATMEGA328P-AU		1
WRL-12847	Mouser Electronics	474-WRL-12847		1
XB24-API-001	Mouser Electronics	888-XB24-API-001		1
				2

Figure 24: Bill of Matierals

Importance

The bill of matierals provides a list of all the products components, details about said component, distributor numbers, manufacturer number, name of company, price, and if pertaining to the PCB schematic, its corresponding symbol in it. This bill of materials is very essential as it provides the basic idea of the manufacturing/assembly plan listing out all of the components needed, where to order, them, at what cost, and what their importance is in manufacturing.

11 Experimental Design

The characterization of the purpose of the experiment, model validation, data gaps, and performance measurement are discussed below. Also the details on documentation, instrumentation, and measurements are also described.

11.1 Prototype Progress

We have completed our first Wireless Lightbar prototype, utilizing 4 LEDs. The prototype can be viewed below:

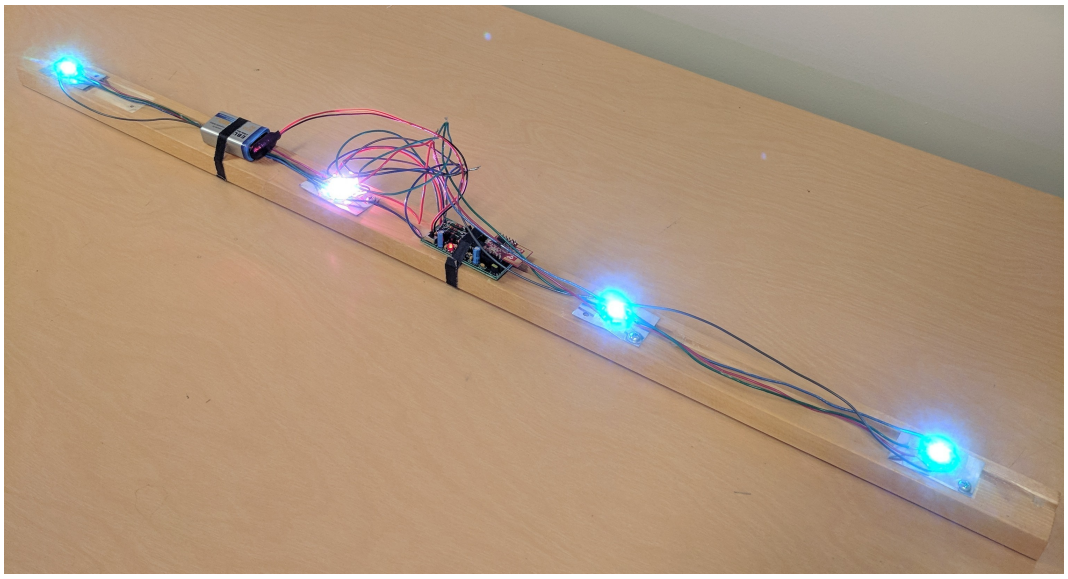


Figure 25: Prototype One

12 Data Analysis

Documentation on statistical tools used, accuracy of data, and experiments shown below. Discussion on confidence is results also discussed below.

13 Balance Sheet

Discussion on initial budget, estimated cost for materials, components, labor, and spending plan are all described below.

13.1 Budget

The initial budget of the project itself has yet to be decided. However, the current plan should be to not go over $500, as the budget/spending of the project should be kept to a minimum. However, as our client's needs are still somewhat 'to be decided' when it comes to how much production of products will be required. In the following subsections, everything will be with the goal in mind to try to keep costs down when ever possible, while still fulfilling client's needs, safety, environmental concerns, and so on. Budgeting is an important factor in this project, since the product is largely hardware-based (while still having some software involved). Evaluating and surveying alternatives and solutions to purchasing and building components is an essential aspect to proper Budgeting for the project.

13.2 Hardware Decisions

Decisions for hardware budget are discussed in the list of topics below, each item discusses the reasons, costs, and possible alternatives that could have been taken when deciding how to properly use the budget.

Arduino Atmega 328P Chip One of best microcontrollers available, affordable, and works with Arduino boards. Other microcontrollers are the LPXCpresso Boards and ARM Cortex-M4 Microcontroller, these are also affordable micrcontrollers, but they lack the simplicity and versatility that the 328P chips have.

"MuRF" Chip The MRF24J40MA chip is one of the best priced radio transceiver modules, with support for Zigbee protocol, which is the desired protocol for the project, it was the optimal choice. There not really any specific alternatives out there that cater to the needs of the project. Zigbee protocol was the client's desired wireless personal network protocol, and also as benefit to the project, as Zigbee is considered simpler and less expensive than other wireless personal networks such as Bluetooth and Wi-Fi.

Xbee Sheild Required Shield/Board to interface with the Program that will transmit the data to the LightBoards. The price of this hardware is somewhat high, due to XBee brand, but since this unit is only required once, for whole product, client will be providing the unit free of charge, this not affecting the budget. Unless the product changed the whole wireless personal network to something other than Zigbee, then this was the only available hardware.

9V Lithium Ion Battery The choice for the 9V Battery was due to the 3 LEDs in a series requiring 10.5V in a series. The only other practical alternative was the 18650

lithium battery. However when it comes down to size, mAh, and Voltage, the 18650 battery is the better option, however price is also a large factor, and the 9V wins there.

18650 Lithium Ion Battery The choice for the 18650 Battery was due to the 3 LEDs in a series requiring 10.5V in a series. The only other practical alternative was the 9V lithium battery. However when it comes down to size, mAh, and Voltage, the 18650 battery is the better option, however price is also a large factor, and the 9V wins there.

Common Anode RGB LED This was a fairly simple choice, as there really is only one type of LED that will work properly for the project, as the product requires the standard LEDs with three dinodes for each color, 3.5V for Red and Green, and 2.5V for Red.

LightBar Board This was requested by the client, needed a board to house the product, this is fairly cheap, as it it just na board to house the hardware for the product. The materials/quality of materials to build the board at least at the moment are TBD, while a simple wood board will probably suffice. The size of the board is required to be 1 in x 2 in, thus with this estimate the board would be a fair price for housing the hardware, and providing easy assembly (since with wood the parts can be screwed in).

LED Driver Circuit The actual LED Driver Circuit will be designed by the team, thus there won't be an additional cost in designing, as once the design is done, there are companies that allow the consumer to design PCBs (Printed Circuit Boards) and then order as many PCBs as needed. The company that LEaD Design will be working with to order the circuits is 4PCB, a company that "Specializes in printed circuit board manufacturing and PCB assembly, including prototype and production circuit boards" (www.4pcb.com). They offer special discounts to students, where a 60 in^2 board can be created for $33, and the consumer can put any amount of PCBs, as long as they fit within the 60 in^2 size (the 60 in^2 is not limited to 6 in x 10 in either, it can be any dimension that fits 60 in^2). Thus until the design of the LED Driver Circuit is done, the actual cost per unit of it cannot be determined. The goal in the design process will be to try to make the circuit as small as possible while fulfilling the requirements and keeping in mind the manufacturing process of the circuit (if it is too small, it will be difficult to attach the circuit to rest of the product).

13.3 Hardware List/Cost of Materials

The figure below is the current Hardware list, describing the physical components of the product, their required quantity, and cost per unit. These specifications are still subject to change and evaluation.

Hardware List			
Hardware	Quantity	Cost of Unit	Description
Atmega 328P Chip	1	$2.00 ~ $6.00	Low-powered CMOS 8-bit microcontroller based on the AVR® enhanced RISC architecture.
MRF Receiver Chip	1 (For Every LED Driver Circuit)	~$9.00 (1-25 Units Ordered) ~$7.00 (26-99) ~$6.00 (100+)	Certified 2.4 GHz IEEE 802.15.4 radio transceiver module. It has an integrated PCB antenna, matching circuitry, and supports the ZigBee, MiW and MiWi P2P protocols. The MRF module connects to hundreds of PIC microcontrollers via a 4-wire SPI interface
XBee Shield	1	$0.00 (Provided by Dr. Rinker)	The Xbee shield translates data between your computer and the XBee. There's also a reset button, and a voltage regulator to supply the XBee with plenty of power. Works with XBee modules.
XBee Transmitter Chip	1	$0.00 (Provided by Dr. Rinker)	2.4GHz XBee module, takes the 802.15.4 stack (the basis for Zigbee) and wrap it into a simple to use serial command set. These modules allow very reliable and simple communication between microcontrollers, computers, systems, and so on.
9V Lithium Ion Battery	1 (For every LightBar Board)	$7.00 ~ $12.00	9V Battery has a rectangular prism shape with rounded edges and a polarized snap connector at the top
18650 Lithium Ion Battery	3 (for every LightBar Board)	$2.00 ~ $5.00	The 18650 (18mm by 65mm) battery is a size classification of lithium-ion batteries, complete voltage range for most 18650s is between 2.5 volts and 4.2 volts.
Common Anode RGB LED	3 (For every LightBar Board)	~$2.00	Units generally have four pins: one for each color (dinode) and a common anode. Use this one LED for three status indicators or pulse width modulate all three and get mixed colors
Arduino Wires	?	~$2.00	TBA
LightBar Board	?	$1.00 ~ $10.00 (Quality of board)	The Board that will hold the components of the Light Bar. 1 in x 2in. size.
LED Driver Circuit (From Circuit Board Sheet)	1 (For every LightBar Board)	? (the Company 4PCB charges $33.00 to make 60 in ² board that can hold as many circuits as the size allows, thus cost of unit depends on size of circuits, which is TBD)	Circuit that will modify the voltage as needed by each set of LEDs to provide constant current power flow and also output the data stream from the receiver to the network that each of the Arduinos are connected

Figure 26: Hardware List

14 Other Items

File management, archiving, documenting any issues, reports of accidents/incidents/near misses/precautions are described below.

14.1 Team Wiki Page

Our team has done a lot of work during this project. Some of the highlights of the projects design elements as well as more team information has been added to our Wiki page.

The team Wiki Page for LEaD Design can be viewed at the following URL:
http://mindworks.shoutwiki.com/wiki/Wireless_Tower_of_Lights

14.2 LEaD Design Team Contract

The team contract for the *LEaD Design* is shown below. The contract discusses the various professional approaches the team will be held accountable to act towards during the time spent on the project. The contract is an important document, as it dicusses the various inner workings of how the team will work on assignments, resolve conflicts, manage work, make decisions and so on. The contract is four pages total.

LEaD Design Team Contract

Section 1: Team Name and Mission
Team Name: LEaD_Design
Mission of Team: To provide a quality product of portability and functionality that meets and/or exceeds the expectations of the client. Also to provide a professional level of conduct and documentation for swift and successful communication between all parties involved.

Section 2: Membership
Team Members: Adrian Beehner, Andrew Butler, Kevin Dorscher, Paul Martin
Consultants/Mentors/Instructional Staff: Dr. Robert Rinker

Section 3: Roles and Responsibilities
Budget: Adrian Beehner
Primary Client Contact: Kevin Dorscher
Organize Team Meetings: Paul Martin
Team Documentation: Andrew Butler

Additional Roles: Scheduling, Project Management, Online Repository Management, Communication Management, Designing (Goals, Specification, Experimental), Prototyping, Testing, Researching, Diagraming, Analyzing (Data, Alternatives), Modeling, Manufacturing/Assembly

Roles Will Be Selected/Assigned By: Team consensus, with evaluating the strengths and weaknesses of teammates and accordingly assigning roles based on these. Discussion/volunteering for responsibilities will be the primary method, if this proves inefficient, a variation of team voting will be required. Some roles will not be individual responsibilities however, but instead a collaborative effort that requires the professional coordination and responsibility of the entire team.

What are the key responsibilities associated with each role?

Budget: Initial Budget, estimating cost for materials/components/labor/etc., and create Spending Plan

Primary Contact Client: Professional Communication with Client, Schedule Times to meet with Client, Discuss/Report Progress

Organize Team Meetings: Communication with Team Members about meeting times, Meeting Agenda, Primary Figure in Meeting

Team Documentation: Record and Document Essential Meetings, Events, etc., Organize Documentation, Monitor teammate documentation

Scheduling: Create weekly and monthly schedules, plan goals, due dates, meetings, etc., factor in all teammates when scheduling

Project Management: Evaluate and monitor team progress, tasks, etc., rectify any project issues or roadblocks

Online Repository Management: Set up/monitor online repository, keep backups, correct any mistakes in repository

Communication Management: Set up/monitor team communications (email, Discord, etc.), promote professional team communication

Designing: Design with Client's needs goals, specifications, and constraints in mind, promote and

justify experimental design, set new goals

Prototyping: Simulate beginning aspects of design, provide only basic client needs and specifications, evaluate what aspects to disregard

Testing: Run tests to generate quantitative data about product, provide objective view of product in current state, create extensive tests for possible bugs in product

Researching: Find current technologies to use, determine how the technologies work, correct implementation of them, evaluating design, determine needed changes

Diagraming: Use standard symbols, properly labeling and referencing, documenting which member drew what and software used to draw the diagram

Analyzing: Determine possible alternatives in design, conceptualize testing data, document statistical tools used, document accuracy of data, determine confidence in results

Modeling: System Modeling, document modeling criteria, expected accuracy, and pitfalls, document modeling software used, document required data and where it was acquired, provided validation scheme

Manufacturing/Assembly: Provide fabrication, create flowcharts for process oriented items, Provide bill of materials, drawing, manufacturer and estimated delivery time

Section 4: Team Relationships
Relationships among team members must support full and respectful engagement of all members for the benefit of the entire team.

Members Will: Promote professional and respectful relationships among each other. Each member will have a positive and respectful attitude towards one another. Every member will have a voice and respected opinion in the team, and other teammates will listen in a respectful manner. Members will openly listen to any concerns a teammate has in regards to the project and promote solutions.

Members Will NOT: Create unprofessional and disrespectful relationships among each other. Each member will not have a negative and confrontational attitude towards one another. Members will not be isolated and have their opinion ignored, and teammates will not ignore opinions. Members will not shutdown any concerns a teammate has in regards to the project and forsake the concern.

Section 5: Joint Work
5a. **Purposes of Joint Work**
Team members will work together to establish collective goals and to produce decisions and work products that advance teamwork and project success.

Members Will: Work together in a professional collaborative environment, to help promote team decisions and products, while creating positive teamwork and successful progress in the project. Members will communicate and complete joint work in a timely and professional fashion. Team members will include all members in decisions and actions regarding the project, such as deciding goals, schedules, events and so on. Each team member will ensure that their collaborative work is up to the standards of the team.

Members Will NOT: Work individually in an unprofessional environment with no collaboration, to dismiss team decisions and products, while ignoring teamwork and progress in the project. Members will not withhold and ignore joint work in a tardy and unprofessional manner. Team members will not exclude members in decisions and actions regarding the project, such as deciding goals schedules, events, and so on. Each team member will not neglect to check that their collaborative work is up to standards of the team.

5b. **Team Meetings**
Team meetings are an important example of working together.

* *Where and When for Team Meetings:* Large Study Room, in Library at 3:30pm, on Thursdays

* *Components Required in Team Meeting Agenda:* Current progress in project, current due dates, weekly schedule, topics to be discussed, upcoming due dates, progress to be made by next meeting

* *How Meeting Minutes Be Taken/Circulated:* Documented by teammate in charge of team documentation, when meeting transcript is written minutes will be calculated as well.

Section 6: Individual Work
Team members are expected to work alone in many cases to complete work important to the team.

* *How Will Work Assignments Be Made:* Decided in team meeting when planning the schedule for the week/month, team will discuss/decide/designate what assignments will be suitable for each member.

* *How Will Quality Expectations Be Established and Verified:* Everything a team member does will be pushed onto the team's GitHub repository, where all other members will have access to view and evaluate work. Also, during meetings, team will go over last week's progress, which will involve evaluating each member's individual work and determining its quality.

* *How Will Due Dates Be Established and Verified:* During team meetings, the weekly schedule will verify due dates. Since each team meeting discusses progress made previously, due dates for weekly work assignments will be every Thursday before 3:30 pm.

* *How Will Status of Work in Progress Be Communicated:* Team members will communicate status of work in progress through the current pushed work on the GitHub repository, as well as communicating any updates about individual work through the Discord server chat. Team members will be sure to provide meaningful commit messages.

Section 7: Documentation and Communication
The team must maintain timely and accurate documentation of its individual and collective achievements, while also communicating needed information to one another and key project stakeholders.

* *Individual Documentation to Be Kept:* Diagrams, research, reports, analyses, sketches, ideas, design processes, math calculations, data and results

* *Team Documentation to Be Kept:* Transcripts for meetings, schedules, team portfolio, client meetings transcript, events documentation

* *Process for Communicating with Other Team Members:* Using team members' email or utilizing the Discord "LEaD Designers" server for communication between one or more members. Each team member must make sure that their means of communication and effective and that their message is clear and concise, for quick and simple understanding

* *Process of Communicating with Your Client/Outside Stakeholders:* The designated Primary Contact Client will be responsible for contacting and communicating with the client/outside stakeholders. Thus is a team member needs to contact the client, they must notify and discuss it with the teammate responsible for being the Primary Contact Client

Section 8: Conflict Resolution
The team will strive to resolve conflicts quickly and to the satisfaction and benefit of everyone involved.

* *Process Will Be Used to Address Conflicts:* Each team member is responsible for bring up conflicts in

weekly team meetings, or on the Discord Server, if needing to be resolved quickly. All team members will discuss the conflict, and decide upon a reasonable conclusion, based on everyone's opinions. If team members cannot resolve the conflict, the instructor/mentor should be notified to help progress towards conflict resolution.

* *Team Dynamics Be Communicated to Instructors/Mentors:* All team members are responsible for coordinating information together to be presented to the instructor/mentor, on a monthly basis. Include information such as progress of project, current deadlines, team performance, behavior, and so on. Communicating to the instructor/mentor any shortcomings and issues on the project will also be an essential asset.

Section 9: Amendments

* *This Team Contract Will Be Kept: Online in the team's GitHub Repository:*
  https://github.com/YupHio/LEaD_Design
* *Contract Will Be Reviewed:* On a Monthly Basis.

* *Contract Will Be Amended:* If teammate or team as a whole desire to amend the contract, the whole team must be notified, such as a group message, and then the teammate or will be amending the contact will pull the current contract from the online repository, make the needed changes, and push the change to the repository with an appropriate commit message.

Section 10: Affirmation of Compliance

We, the members of this team, affirm that we have established this contract with input and consensus of all members. By our signatures, we commit to compliance with the contract for the benefit of all members and the team as a whole.

Name	Signature	Date
Adrian Beehner	AB	9/21/17
Kevin Dorscher	KD	9/21/17
Paul Martin	PM	9/21/17
Andrew Butler	AB	9/21/17