ECEB Artwork Illumination

ECE445 Project Proposal – Fall 2018

TA: Evan Widloski

Ansel Higgs
ahiggs@illinois.edu

Lance Pan
lhpan2@illinois.edu

Fadi Al Zuabi
alzubai2@illinois.edu

I. Introduction

A. Objective

An important aspect of all artwork is visibility. Many modern art pieces are displayed prominently in areas of high visibility that instantly draw attention, but this is not true of all pieces. There is a delicate balance between highlighting the art piece and detracting from the piece itself. While lighting is often used to attract focal attention on art pieces, traditional methods of lighting such as large spotlight installations are not always practical and may instead detract from the art piece. An appropriate system would ideally attract attention to the art piece and not itself, which presents a unique problem that often requires highly specialized solutions.

Our goal is to create a modular, programmable lighting system that is adaptable for various applications. We will start with a basic starting setup of compact, addressable LEDs, after which we will explore various options for artwork-specific lighting applications. We aim to create a modular system that will be both easy to maintain, replace, and expand upon. Our approach should allow for low cost highly expandable discrete control of a large amount of lighting fixtures. We will also explore different fiber optic cables and connections to effectively transfer light into the glass artwork and draw attention..

B. Background

While many lighting solutions exist on the market, they are expensive and often obtrusive. There is a lack of high power easily customizable modular products that offer easy expansion and programmability options, with many market options only allowing control over approximately 8 lighting fixtures. We intend for our system to comfortably work with independent control of 200 or more lighting fixtures. Our lighting system should be as compact and discreet as possible, allowing for non-obtrusive integration into art pieces. It must be bright enough to accent the piece under various background lighting conditions, as well as focused enough as to not instead highlight the backing wall or other parts of the surrounding background.

Current solutions do not have the limits needed to keep the lightning within the proper brightness that won't affect the beauty of the artwork. We intend to work very closely with the end product user in order to ensure that the final result will closely match their criteria, especially with regard to finer aesthetic details. As a highly specialized design for a very specific application, we plan to explore a great deal of many diffusion options in order to provide the option for the end product user to fine tune the design as they please. As the appearance of our project matters the most, modular design and fiber optics bring the flexibility to our solution and allow variety of moods to meet the user's preferences.

DMX512 is an asynchronous differential level serial information transfer protocol with a standard of 3 pin balanced connection. We decided to use DMX512 as it is the standard protocol used in order to control lights, which means that integration into existing control systems will be trivial. DMX512 is also a very robust protocol which allows for convenient, fast control of up to 512 addresses. The robustness of the protocol also means higher reliability for wireless transmission and the asynchronous nature eliminates the need to sync clock rates between wirelessly connected systems.

C. High-Level Requirements List

I. Lighting fixtures must be modular and have the ability to connect to a link to a single DMX wireless receiver.

II. Lighting fixtures must provide sufficient light output across the entire piece regardless of external lighting conditions.

III. Lighting fixtures must be compact enough to integrate into the existing art piece without extensive modification to its supports..

II. Design

A. Block Diagram

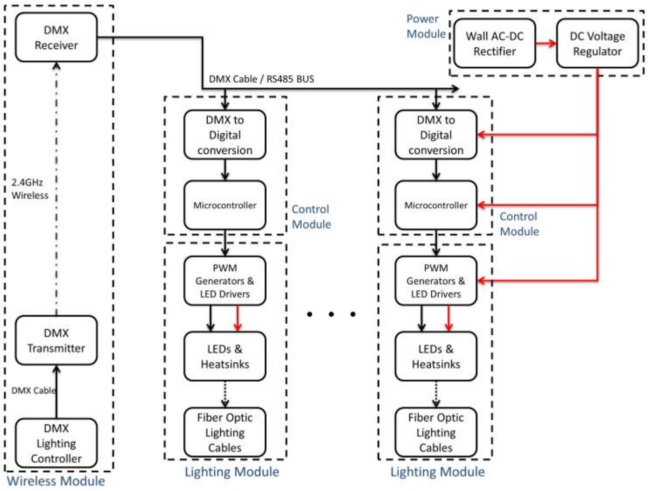

Figure 1: Block Diagram

In our block diagram shown in Figure 1, a generic off the shelf DMX lighting controller will be used to program the lighting sequence for the artwork. The DMX output of the controller will connect to a generic wireless DMX transmitter. A receiver connected to the first module will pick up this input. The first module will pass the signal along to the others and each will read the section of addresses corresponding to the lights they control. Each part of the artwork will use its own DMX to digital convertor, microcontroller, PWM generator, and LED driver to light up the fiber optic cables connected to its tubes. The power supply will also be located near the modules above the artwork and supply power for the DMX receiver, microcontroller, ICs, and LEDs.

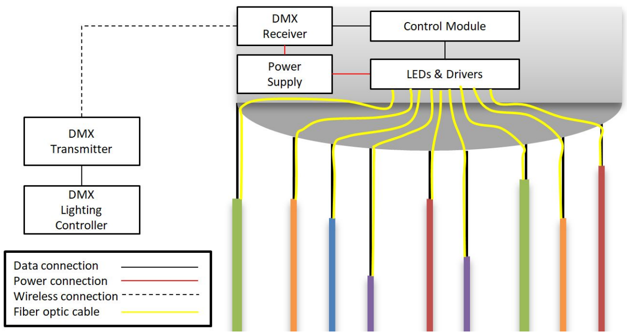

Figure 2: Physical Layout

Figure 2 shows the physical layout for one module of our project. Complete implementation for this art installation would consist of seven modules, as the piece has seven sections. The lighting controller and DMX transmitter will be positioned in a suitable location to control the project, such as in an adjacent 2nd floor office. The DMX receiver and power supply will be located at one end of the artwork on top of the existing metal support. The control modules, of which one section is pictured, will be connected in series to the output of the receiver. The LEDs and drivers will be located in a second module connected directly to their sections control module. Fiber optic cables will be attached to each LED and route down into the tubes along the existing support cables. We must verify that the weight of the project can be supported by the existing structure and explore options to reinforce the existing structure if required.

B. Functional Overview

1) *Wireless Module*

This module will consist of the commercially available Chauvet Obey 10 DMX512 controller, which has full control of all 512 channels in the DMX512 protocol. The Obey 10 also has the capability to program and run lighting routines at variable speed. The output will be sent using a wireless DMX512/XLR transmitter. This is intended for immediate control for rapid prototyping and diagnostics. For potential expansions and in actual use, a USB to DMX512 cable can be used to send commands from a computer program.

Requirement: Must provide 512 channels of DMX protocol signal wirelessly up to 100m.

2) *Control Module*

2.1 DMX to Digital Conversion

A RS-485 transceiver chip will be used in order to convert the differential level DMX512 input signal from the bus into digital logic to be sent to the microcontroller. One chip, placed near its microcontroller target, will be used per section of the artwork to reduce the potential for noise.

Requirement: Must operate up to +6 VDC per input, 250mA max current, and at least 250kbit/s data transfer rate.

2.2 Microcontroller

The microcontroller will receive and interpret the digital output from the RS-485 transceiver.. It will parse which command goes to which specific LED, as well as passing along the desired data to control brightness. This will need to strictly keep up with the data input, as the entire DMX512 data packet is sent approximately 25ms long with an idle period of 70-90ms [1].

Requirement: Minimum memory of 16KB and clock rate of 30kHz.

3) *Lighting Module*

3.1 PWM Generators & LED Drivers

The PWM generator will receive the data from the microcontroller in order to determine the rate at which to drive the LEDs allowing for fine control over brightness. A dedicated chip will be used for the generator as most low cost microcontrollers do not supply enough different PWM channels. The LED Drivers will provide the appropriate power level to the individual LEDs.

Requirement: PWM frequency of >300Hz. At least 15 serially addressable PWM channels per chip.. LED driver must match LEDs at 2.5-3.5V.

3.2 LEDs & Heatsinks

The LEDs will be white and need to be energy efficient as well as have good thermal characteristics in order to ensure longevity and efficiency. Passive heatsinks will be added in order to ensure good temperatures.

Requirements: LEDs must have a minimum efficiency of 100 Lumens/Watt running at 2.5-3.5 V. Heatsinks must keep LED temperature below 100°C.

3.3 Fiber Optic Lighting Cables

Fiber optic cables will be used to distribute light amongst the various components of the art installation. Different varieties of cable may be used for light transmission and light emission in the artwork.

Requirement: Cables must support lighting up to 4m and a minimum bend radius of >50mm.

4) Power Module

4.1 Wall AC-DC Rectifier

The input source will be a standard 120 VAC outlet located behind the artwork. A power cable of discreet appearance will run up the wall to the power module located on top of the mount for the artwork. The input AC source will be rectified to the appropriate DC voltage for the LEDs. Since the LEDs will draw a large load, active or passive thermal management may be implemented.

Requirement: Minimum 80% thermal efficiency. Maximum operating temperature of at least 45℃. Must have UL and/or CE certification.

4.2 DC Voltage Regulator

Due to the non standard input voltage required by the microcontrollers, PWM generators, DMX Receiver, as well as any active cooling elements, additional DC-DC conversion will be required with a voltage regulator protecting any sensitive components.

Requirement: Regulated output voltage at 5 VDC ± 10%.

C. Risk Analysis

The most complicated part of our system will be the microcontroller. It must be programmed in order to interpret and route large amounts of data very quickly in order to avoid any potential latency issues. This means that not only will it be required to accurately parse DMX512 signals, it must do so efficiently. DMX512 has many aspects to make it extremely robust, but this design necessitates many very fast checks and error detection on the microcontrollers part. For example, the asynchronous design of DMX512 paired with the relatively large total data stream size (compared to other protocols such as MIDI) means that very little clock drift will be allowed.

Each microcontroller also controls a large number of LEDs, approximately 30 per section, meaning a serial output method (such as shift registers) will introduce a fair amount of complexity into the design and ensuring that it is fast enough to ensure as little latency from controls to lights as possible. A parallel method would involve a great deal of wiring, which could be a significant source of error and unsightly clutter. We anticipate the programming of this chip to take a significant portion of this project, and expect many adjustments to be required in order to ensure reliability and compatibility with any existing DMX512 systems.

In order to address this, we intend to also implement a backup via the microcontroller in order to facilitate static lighting. This can also be used in the event that there is an interruption in the signal from the wireless control module.

III. Ethics and Safety

One possibility safety concern is the lighting itself. LEDs are known to have signature peaks around the 450 nm wavelength region (the generally blue region), which is known to be a wavelength range that human retinas are more susceptible to damage from [2]. This has come in conversations about very bright, glaring lighting installations such as street lights. However, studies have shown that LEDs are no more damaging than other light sources with equivalent correlated color temperature [3]. We do not expect to constantly oversaturate the surrounding area, but we will ensure that no single on the art piece is too bright or concentrating light onto other areas. There have also been concerns raised in the past about how white LEDs in particular can disrupt the body's circadian rhythm. Despite what impression finals week may impart, the ECEB lobby is not an area meant for sleeping so we do not expect this to be an issue.We will keep this issues in mind to ensure that our approach does not affect the health of those around it, aligning with Article 1 of the IEEE code of ethics [4].

Another significant safety issue is power. As we are working with voltage supplied from a wall socket that has significant potential for damage. To ensure that power is regulated at all times the power module will be well overrated for our intended maximum use situations. We also must keep the weight of our design in mind, as too much weight put onto the existing mounting bracket for the art installation will cause structural failure, which violates

Article 1 of the IEEE code of ethics by risking the “safety, health, and welfare of the public”[4]. To ensure this does not happen, we will strictly adhere to the engineering design of the current predecessor and reinforce the mounting solution if required.

Article 1 of the IEEE code of ethics dictates that we “strive to comply with ethical design and sustainable development practices”[4]. We intend to adhere to this by ensuring that our design is as efficient as possible, taking advantage of the energy efficiency of LEDs compared to more traditional lighting elements. We will vigorously stress test our design in order to adhere to Article 9 of the IEEE code of ethics: “to avoid injuring others…”[4]. We also will establish clear communication with the end product user in order to be clear and ethical in our presentation of results as Article 3 of the IEEE code of ethics states [4].

References

[1] Element 14. (2018). *DMX Explained; DMX512 and RS-485 Protocol Detail For Lighting Applications*. [online] Available at: https://www.element14.com/community/groups/open-source-hardware/blog/2017/08/24/dmx-explained-dmx512-and-rs-485-protocol-detail-for-lighting-applications [Accessed 18 Sep. 2018].

[2] Stevens, R. (2018). *American Medical Association warns of health and safety problems from 'white' LED streetlights*. [online] The Conversation. Available at: http://theconversation.com/american-medical-association-warns-of-health-and-safety-problems-from-white-led-streetlights-61191 [Accessed 18 Sep. 2018].

[3] Brodrick, J. (2015). *LED Watch*. [online] Energy.gov. https://www.energy.gov/sites/prod/files/2015/02/f20/feb2015_ledwatch.pdf [Accessed 18 Sep. 2018].

[4] Ieee.org, "IEEE IEEE Code of Ethics", 2018. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 18 Sep. 2016].