The University of Texas at Tyler
College of Engineering

EENG 4315 - Senior Design II

Intelligent Lighting Control System

a circadian based lighting system for space flight

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Contents

List of Figures

List of Tables

1 Project Description

The goal of this project is to provide a lighting system which can meet the demands and aid the progression of long-term space flight. Although engineers have been able to overcome the immediate dangers of short range space flight we must further develop novel solutions to the issues of long-term confinement in artificial environments. Along with water and food, sleep is among the basic necessities for long term human survival. However, we know that astronauts suffer from sleep deprivation during flights. About half of everyone who flies to space relies on sleep medication and astronauts generally get about 6 hours of sleep in orbit despite being allowed 8.5.[1]

For this reason, NASA developed the "Lighting System to Improve Circadian Rhythm Control" to be used on the International Space Station (ISS). [2] This modular lighting assembly uses a micro controller with power relay to adjust color temperature and perceived intensity. Future spacecrafts will require new and innovative light control methods to improve reliability such as compensating for degrading lighting sources and maintaining the crew's circadian rhythms [3].

Our Intelligent Lighting Control System, centrally controlled with sensor feedback and visual status display, is a complete solution for future astronauts and their needs. Our system features an automatic light compensation algorithm, single communication bus capable of addressing each light fixture, and touchscreen user interface for customized sleep cycles.

2 Final Design Specifications

The Intelligent Lighting Control System is comprised of two interconnected parts, the control system and lighting modules. Our control system includes the Arduino UNO R3 for analog/digital input and ouptut, 4DUINO development board for touchscreen graphical user interface (GUI), AC to DC conversion power supply, RGB light and temperature sensors. Each light module include 3 RGB LED's, aluminum heat shield, Infineon RGB driver, and 3D printed housing for all parts.

Our control system features a light compensation algorithm which accounts for light degradation. The main issue identified by NASA engineers is light degradation due to yellowing of the light covers. Our sensors will measure the amount of red, green, and blue light spectrum generated from our light fixtures. If at any time the light spectrum emitted does not match the light spectrum measured the algorithm will begin adjusting the output of the light driver until the spectrum is back to normal.

The control system also allows the user to input a custom circadian-based cycle on a touchscreen interface. The interface allows central control of all light fixtures so that each light can be set to a different cycle to allow for shift work. The I2C (pronounced "I squared C") communication protocol allows us to control individual devices on a single bus which reduces the amount of cabling needed in the system.

The lighting modules have a two-piece modular design. The top piece can be permanently fixed to a ceiling or wall. The bottom piece which contains the LED's is screwed into the top piece with a threaded pattern on the outside which easily allows crew to replace LED's which have failed during flight. Each light module is equipped with heat shield and temperature sensor. In the event of overheating, the control system will trigger alarms to alert the crew of the issue.

3 Design Solution

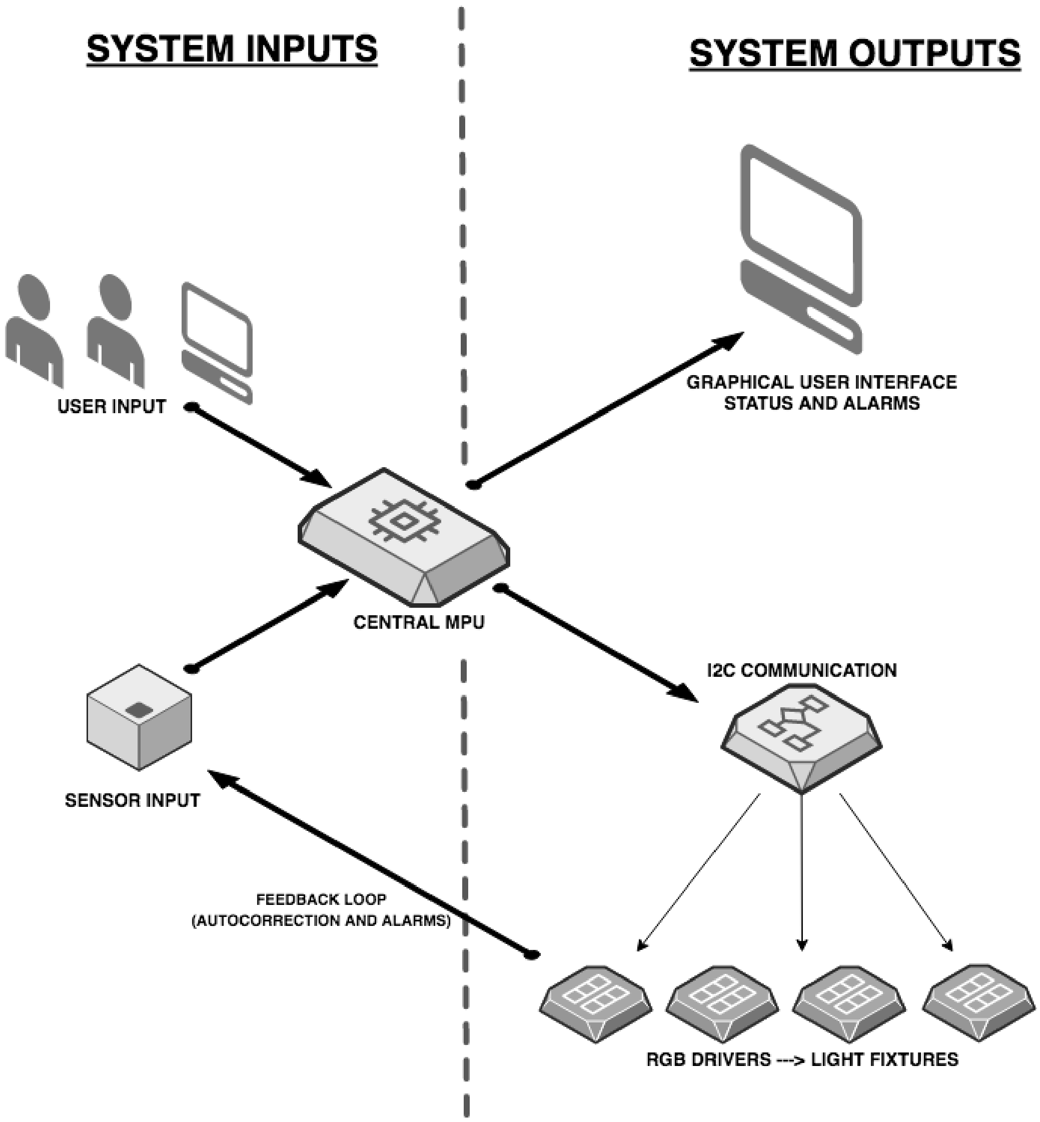

Fig. 1: High Level System Overview

3.1 Lighting Modules

We set out to design a modular light fixture with interchangeable easy to replace parts. The lighting modules use Red-Blue-Green (RGB) light emitting diodes to produce a wide spectrum of light. Each lighting module features an independent current driver board with microprocessor which can communicate with our central microprocessor unit. The light fixture also features an interior aluminum heat shield and temperature sensor to manage excess heat and alert the control system of dangerous temperature levels.

RGB Light Emitting Diodes

Light Emitting Diodes (LED) have many advantages over filament or gas based lights. LEDs are cheaper, lighter, last longer, and dissipate less heat. These advantages make them ideal for space flight. One disadvantage of LEDs is that they are not linear devices and making them behave in a linear fashion in regards to light intensity and color spectrum is not a trivial matter. The goal of a circadian based lighting system is to not only control the intensity of light but also the amount of red and blue light spectrum to simulate daily solar cycle on earth.

To achieve these results we had to choose a solid state driver capable of controlling current in separate individual color channels. To insure rapid development we chose the Infineon RGB Lighting Shield as our LED driver. The heart of this boards functionality is the current controller using buck topology.

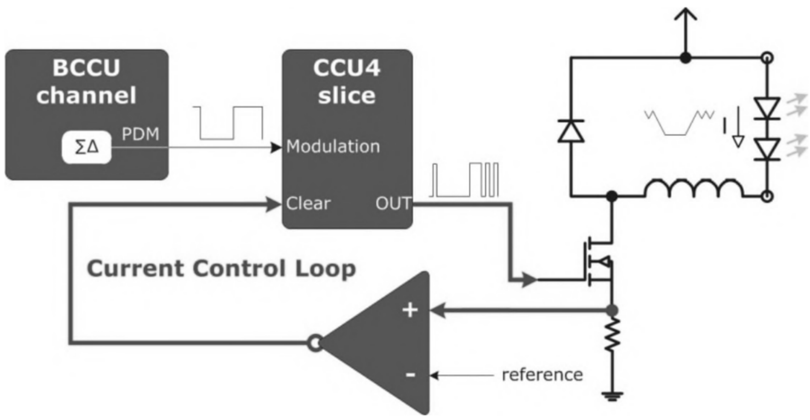

Fig. 2: Buck Converter Current Controller

In this configuration, see Fig. 2, the inductor is constantly charging and discharging inside the circuit. After proper configuration the result is a constant current which can be changed to give us various intensities on a linear scale. We configured an acceptable ripple current (see I in figure 3.) which will result in constant light intensity. The higher the ratio between input voltage and forward voltage, the more difficult it will be to configure a small ripple [4]. We can lower the input/forward voltage ratio by using a voltage divider to lower the input voltage.

RGB LED Driver

Discuss the parts of the development board, the buck converter, the current limiter

Light Fixture Housing

Show drawings and discuss modular design of the pieces

3.2 Control System

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Central Microprocessor Unit

Discuss Arduino, code, I2C protocol, Light Degradation Algorithm

Graphical User Interface

The graphical user interface we used for the Intelligent Lighting Control System is the 4Duino, an Arduino compatible display with built in 240x320 resolution TFT LCD Display with Resistive Touche and Wi-Fi capabilities. The display requires a uSD card to load required images for the program. When connected to our power supply, the display resets its communications and intiializes its setup routine by connecting to wireless communications. In the scenario any errors occur, the Callback Error Handler function raises flags for errors associated with setup. The 4Duino then mounts the uSD Card images and loads the program file, and connects to the Arduino slave on the I2C bus. The desired touch-screen interface objects are displayed after setup and can be interacted with after short delay. The GMT is generated with a modified NTP_Clock routine that sends signals to the Arduino Slave indicating the time of day. The User Profile setting button allows the user to customize the GMT standard time with offsets. Warnings that are received from I2C communications with the Arduino slave are displayed to a webpage.

Sensors

Here we will discuss the temperature and light sensors

Power Supply

Due to NASA specifications, we chose an AC/DC power supply. The DC power will supply to the RGB LEDs, GUI, and Programmable Logic Controller. After performing our calculations on our simulated RGB circuit, we realized that necessary current and not voltage would be the greatest design concern. Our new choice for a power supply is a 24-volt DC, we changed the power supply again so that we have a slight change in current and voltage. The power supply that he had before had no case and just came with the printed circuit board, we felt that when powering the power supply there would be no protection for our teammates and the system. We also made a small circuit to step down the voltage from 24 volts to 5 volts, that voltage will be used to power the GUI and Programmable Logic Controller.

3.3 Display Model

Here we will talk about the wooden display model we built and make it clear that it is not part of the system, only for display

3.4 System Schematics

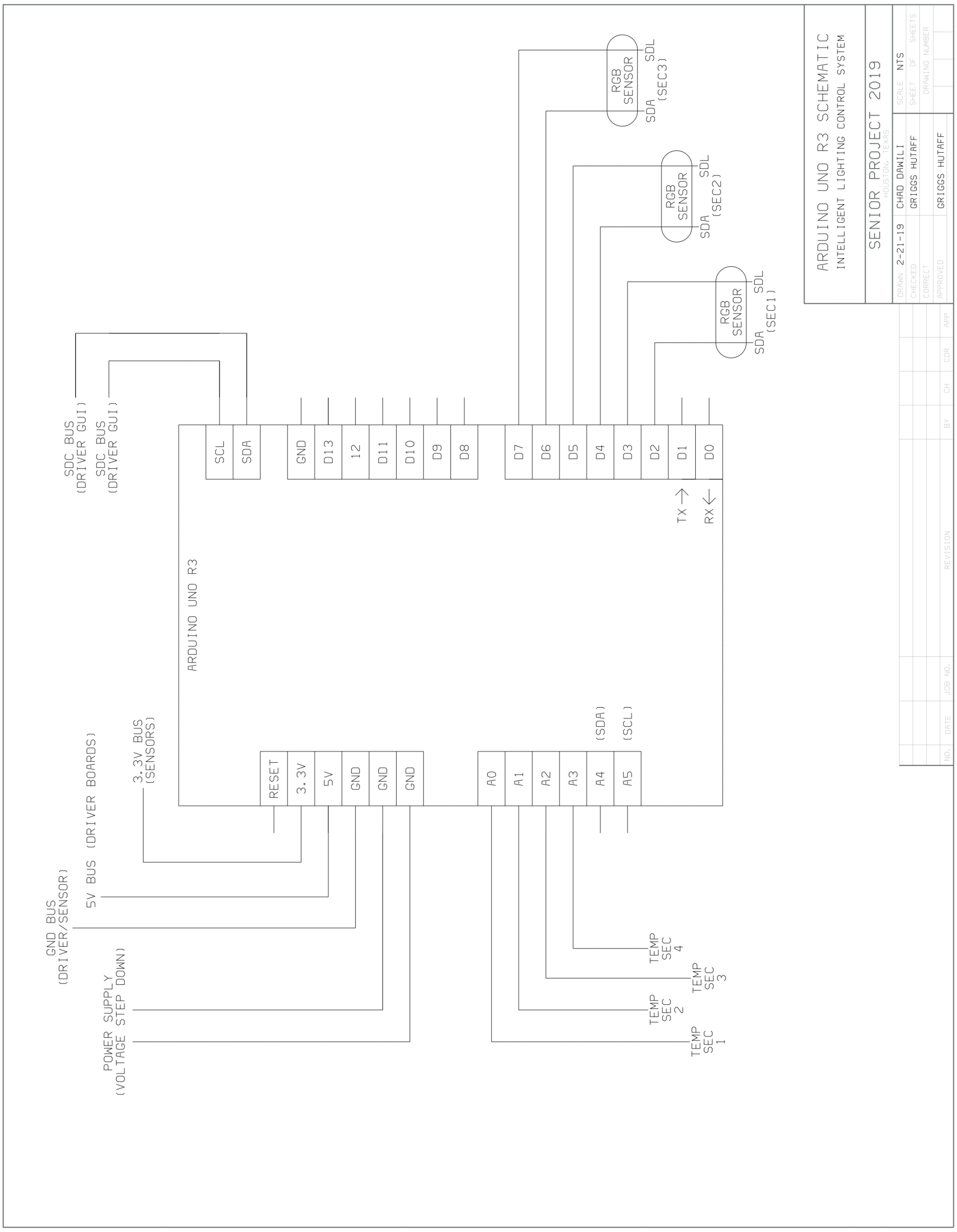

Fig. 3: Central Microprocessor Unit

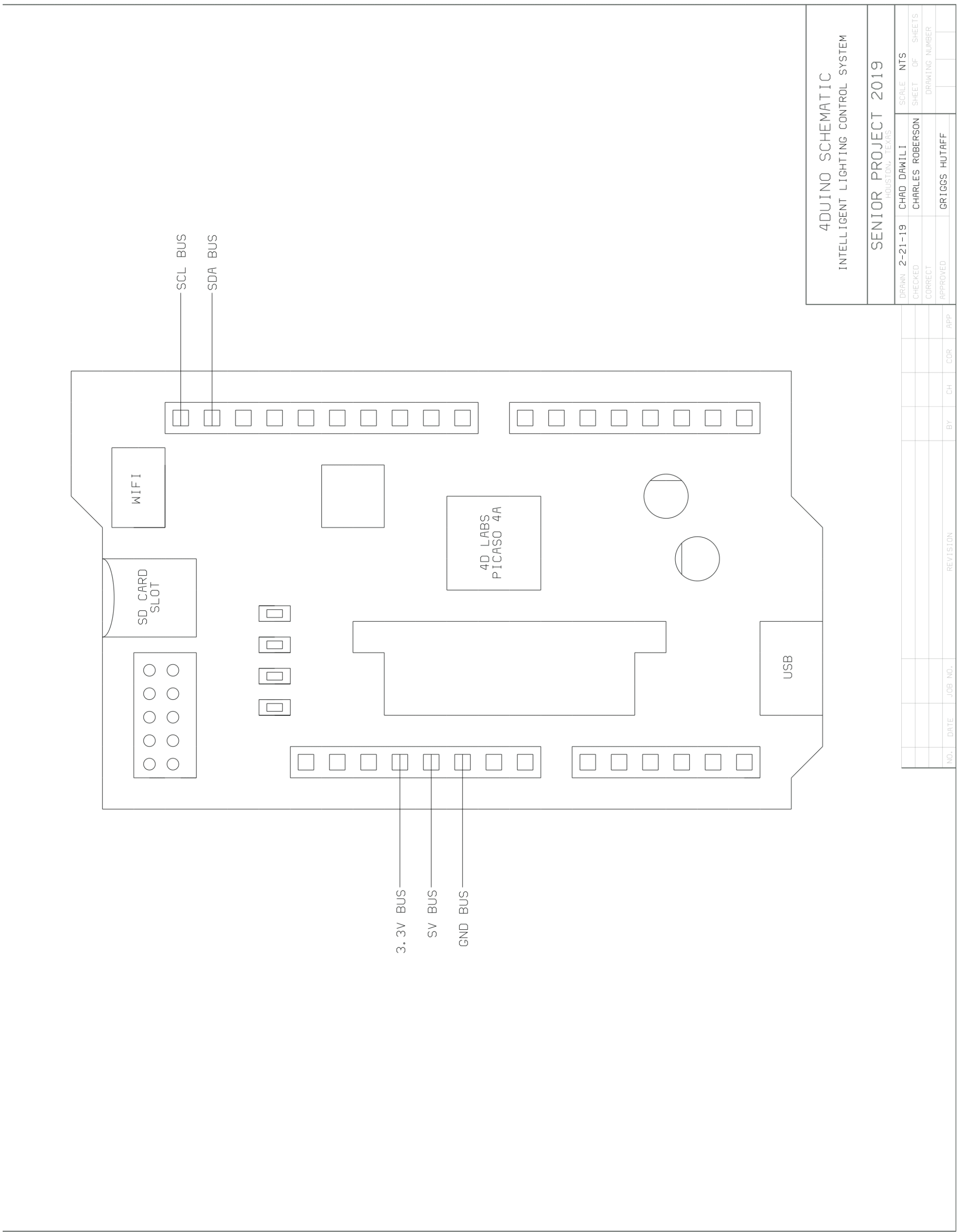

Fig. 4: Graphical User Interface (Input)

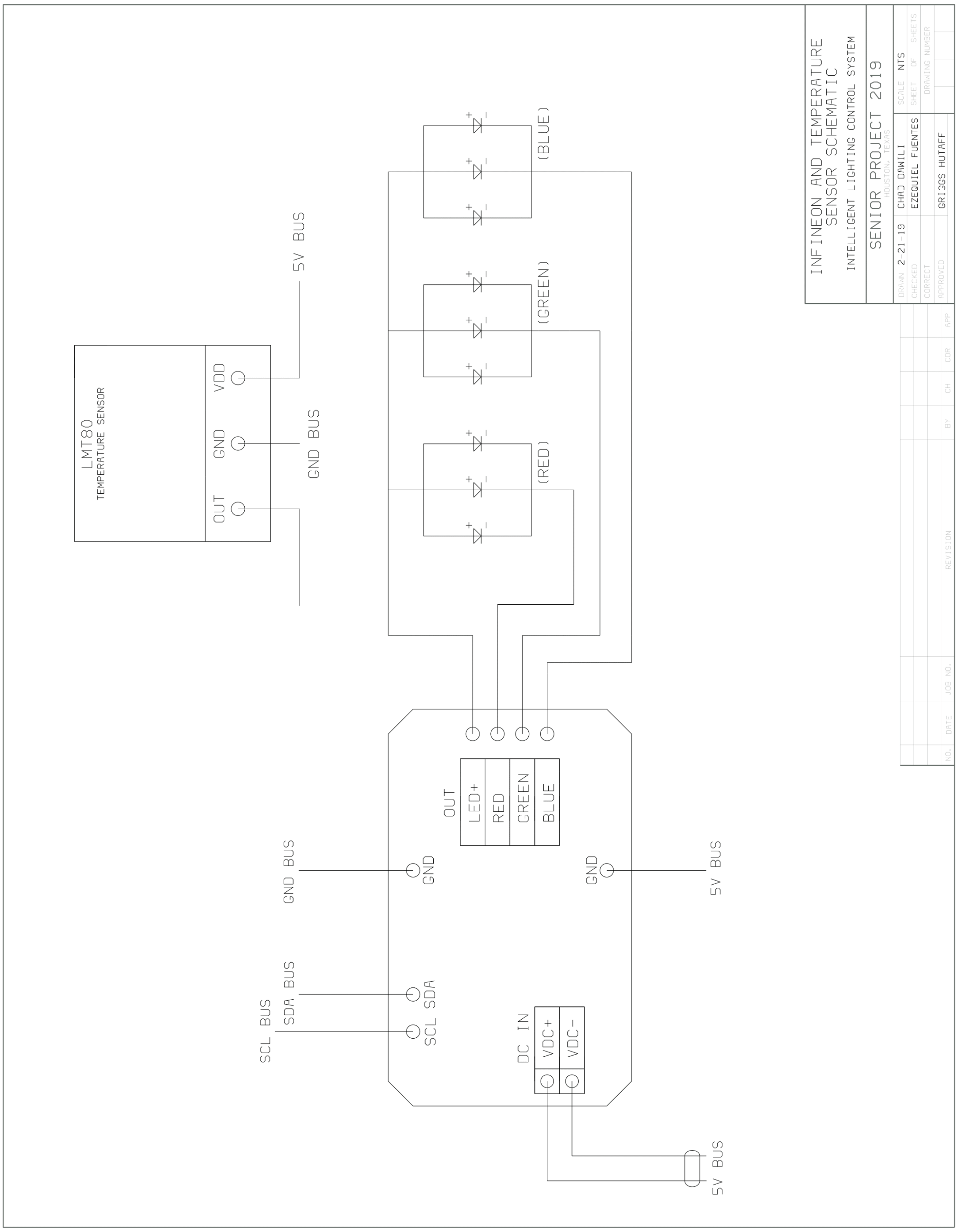

Fig. 5: Light Module (Single Unit)

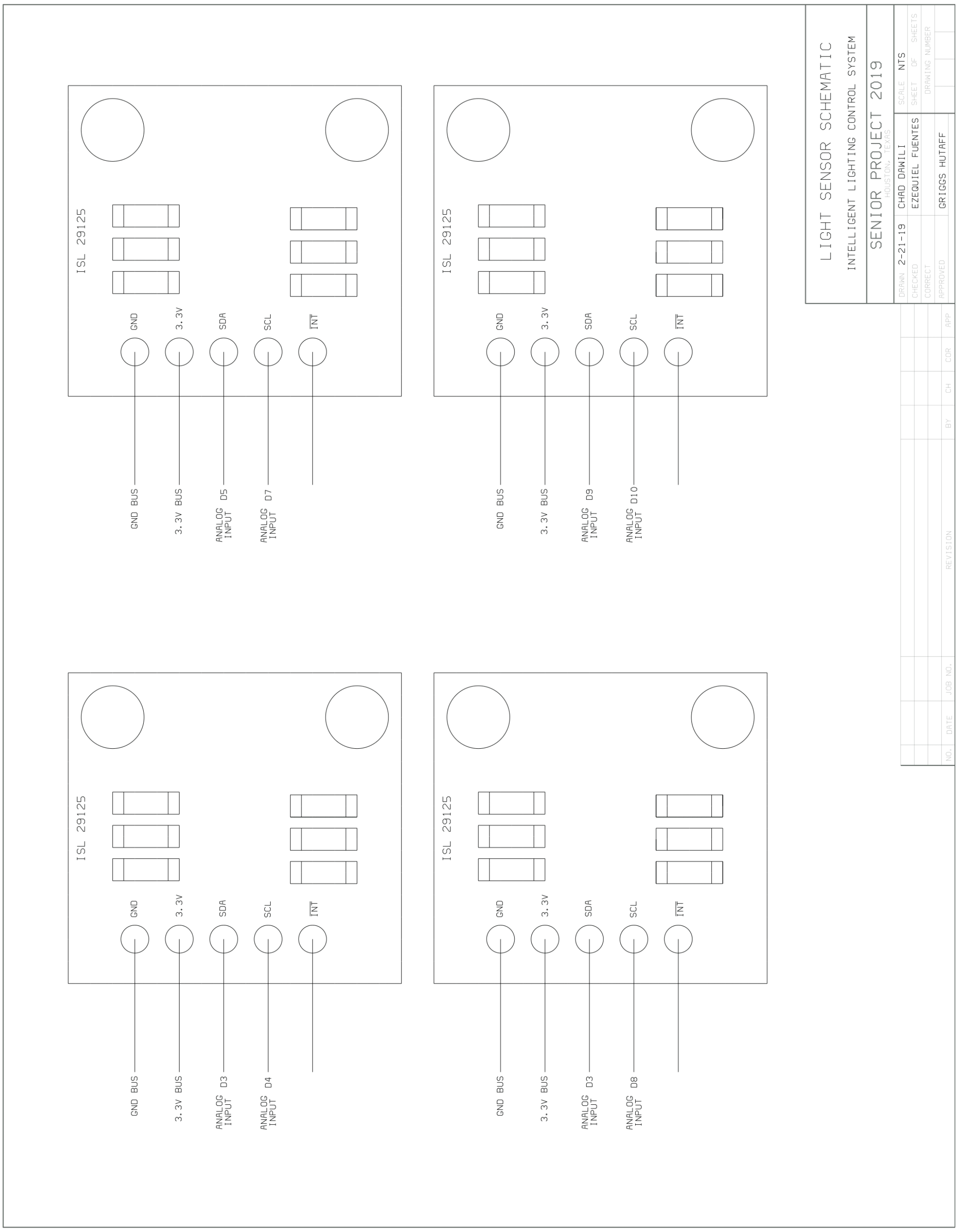

Fig. 6: Light Sensor Network

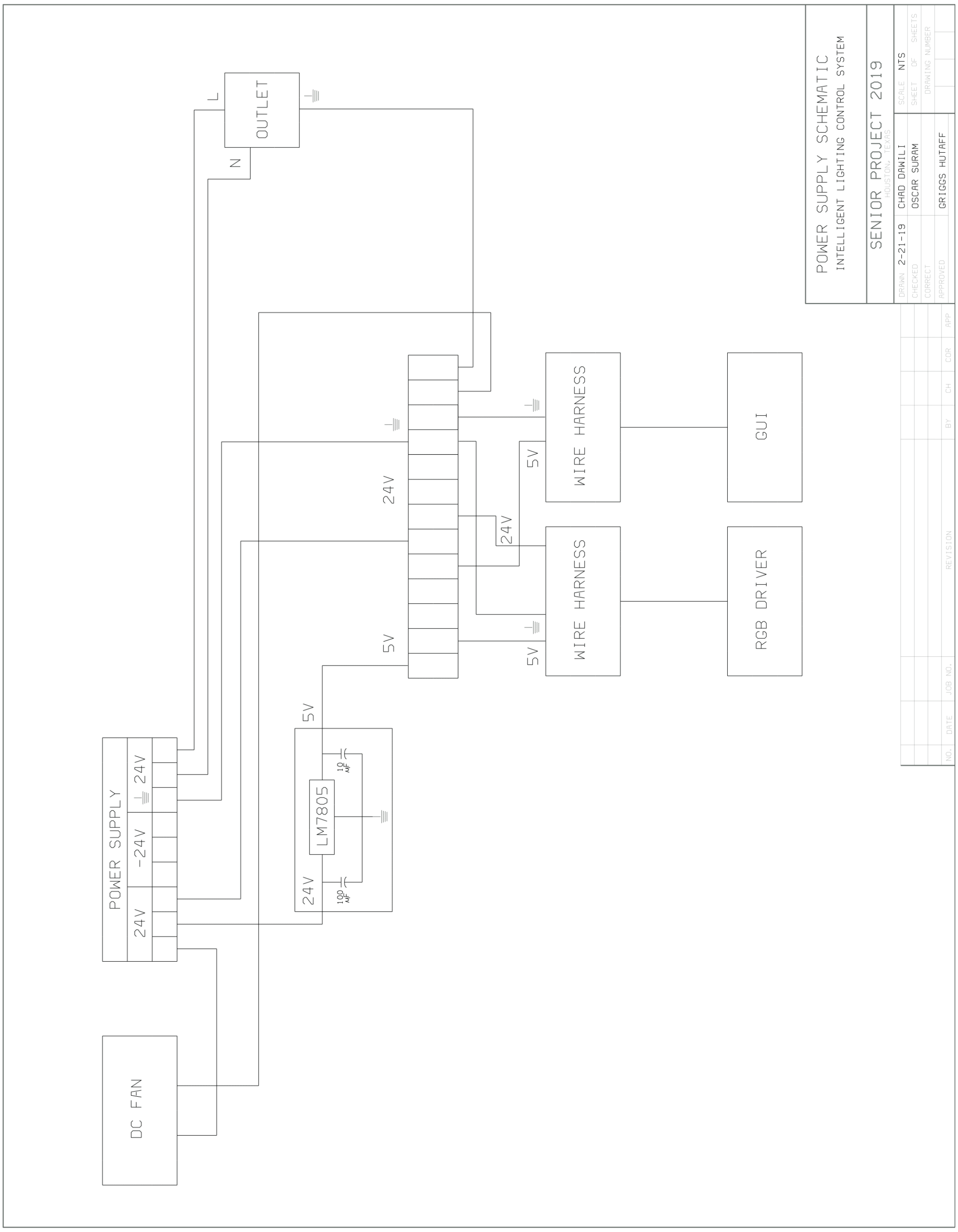

Fig. 7: Power Supply and DC Power Circuit

9 References

[1] Elizabeth Howell. Space station to get new insomnia-fighting light bulbs. *https://www.space.com/18917-astronauts-insomnia-light-bulbs.html*, 2012.

[2] Kurt R. Kessel. Lighting system to improve circadian rhythm control. *https://technology.nasa.gov/patent/KSC-TOPS-52*, 2016.

[3] EV/Human Interface Branch. Intelligent lighting control system — topic - tdc-25-s19. *http://www.tsgc.utexas.edu/challenge/PDF/topics/Topic_TDC_25_S19.pdf*, 2016.