# SCRIM LIGHT

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ECE 445 Design Document

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# Contents

# 1. Introduction

Photography lighting is a complicated and many-faceted issue, often requiring thousands of dollars in equipment to achieve the desired lighting effect. Rick Kessinger, a local photographer in Bloomington, approached the 445 students with a problem; he was attempting to photograph automobiles in a particular fashion, and therefore needed a particular lighting setup in order to achieve that.

## 1.1 Objective

Our proposed solution would be a light that gives much more control to the user, allowing them to produce different gradients, such as fading from one end to the other, or from the center out and vice versa. The user has the ability to vary the brightness and intensity of the light, adjust the starting position and profile of the gradient, and individually group LEDs together and adjust their brightness to produce a well-defined custom profile. The user is also able to store their current profile for non-volatile retention and later use as a preset mode. Finally, as a last potential feature, we will allow the user to alter the temperature of the light, but this is a secondary feature as temperature of light can be altered through other sources. One of the more important parts of this solution is that the device is cordless and battery powered, which would allow for increased mobility when using the device in the studio. The design is also modular, allowing the user to easily replace any malfunctioning LED and add more if the extra space is properly accommodated.

## 1.2 Background

When photographing cars, light would typically need to be reflected off surfaces known as scrims in order to deliver a professional look and finish to the final product. Complicated setups often arise when the desired result looks to highlight the contours and shapes that make the vehicle unique, and small studios typically cannot afford the cost.

Rick proposed a prototype solution: The same effects can be achieved via long-exposure shots, but would require an appropriate lighting mechanism that can produce the specified gradient directly. His initial design consisted of a wall-powered LED strip which he could coat in a particular way to produce the gradient. This, however, was not an appropriate solution, as this would only produce a single non-adjustable gradient and made transportation around the studio very difficult.

## 1.3 High Level Requirements

- The device should, at a minimum, emit a single color temperature of approximately 4500 K at a brightness level of 250 lumens per foot. Additional functionality would include production of multiple color temperatures, ranging from ~3000 K or ~6000 K.

- The device must be cordless and battery powered, and be able to be run for an entire photography session. This would require it to work over a period of 30-45 minutes, while only being on for increments of 10-20 seconds. There should also be different power modes, wherein the LEDs are off, but the internal circuitry is still operational, and a mode where the entire device is shut off. According to our power estimates, this would require a supply with a 3.6V nominal voltage and about ~6000 mAh of charge.
- The device should be a 4 foot strip, which would require about 40 LEDs. Depending on the implementation of different color temperature functionality, this may require twice the amount (80) LEDs. These LEDs would require a nominal total current draw of about 3 A without color temperature functionality, and 6 A with, using a supply voltage ranging below 2.8 V.

# 2 Design

## 2.1 Block Diagram

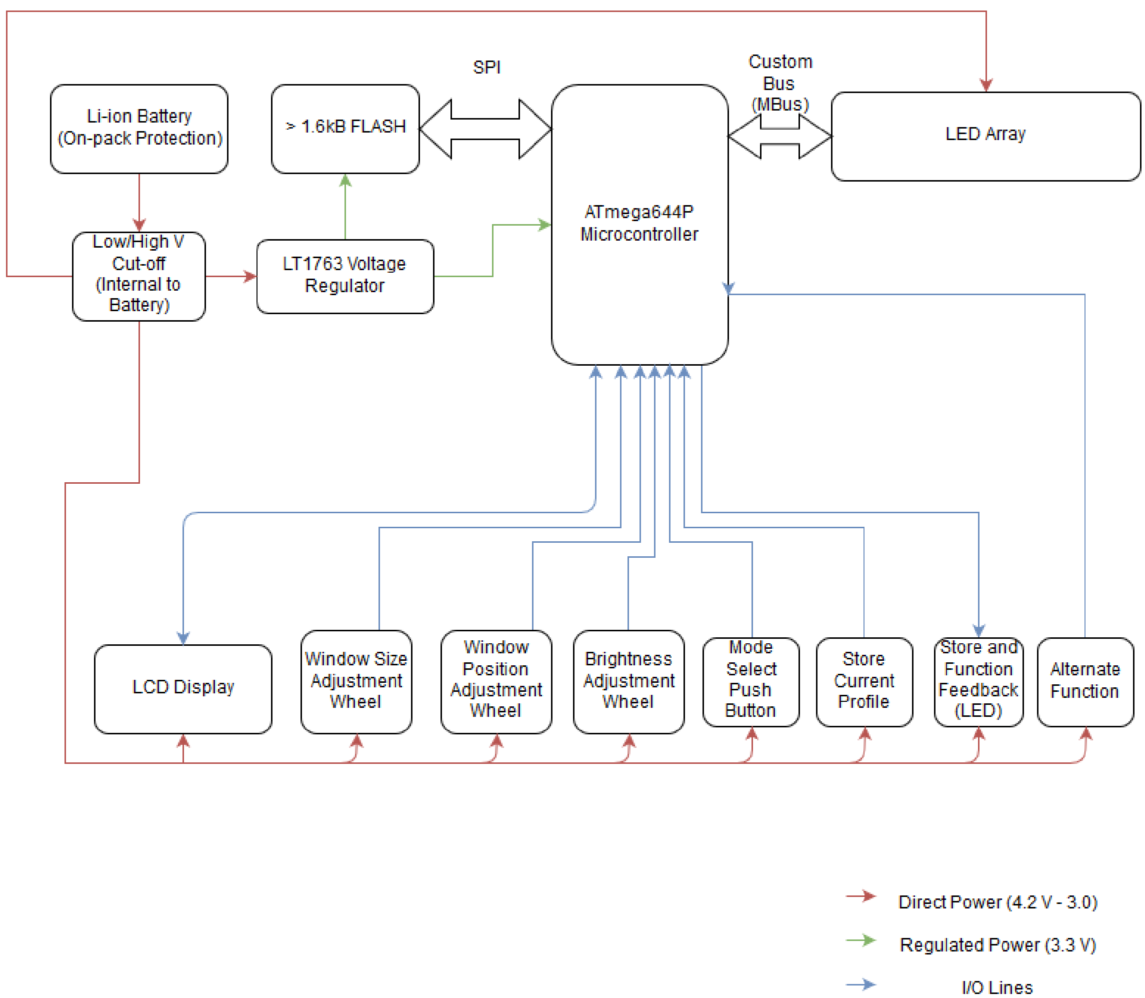


Figure 2.0 – Block Diagram of General Design

## 2.2 Physical Design

The device consists of a rectangular housing of dimensions 48x3x1 inches (LxWxH), two handles attached (primary at the top and another below the central point), with the primary handle housing the user interface described in the block diagram. We estimate the handle to have minimum length and width of 3 in and 1.5 inches, respectively. The main housing will contain the LED array and will sit on two rubber wheels to allow the device to rest and be transported on the ground.

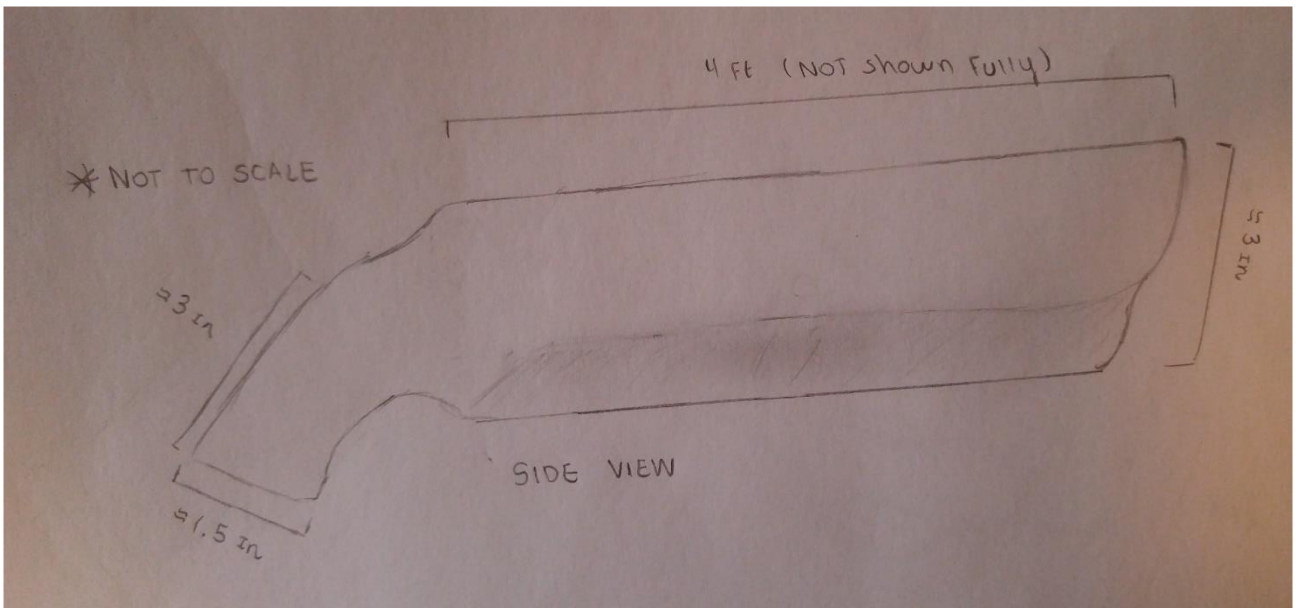


Fig. 2.1 – Side view of the approximate profile of the device

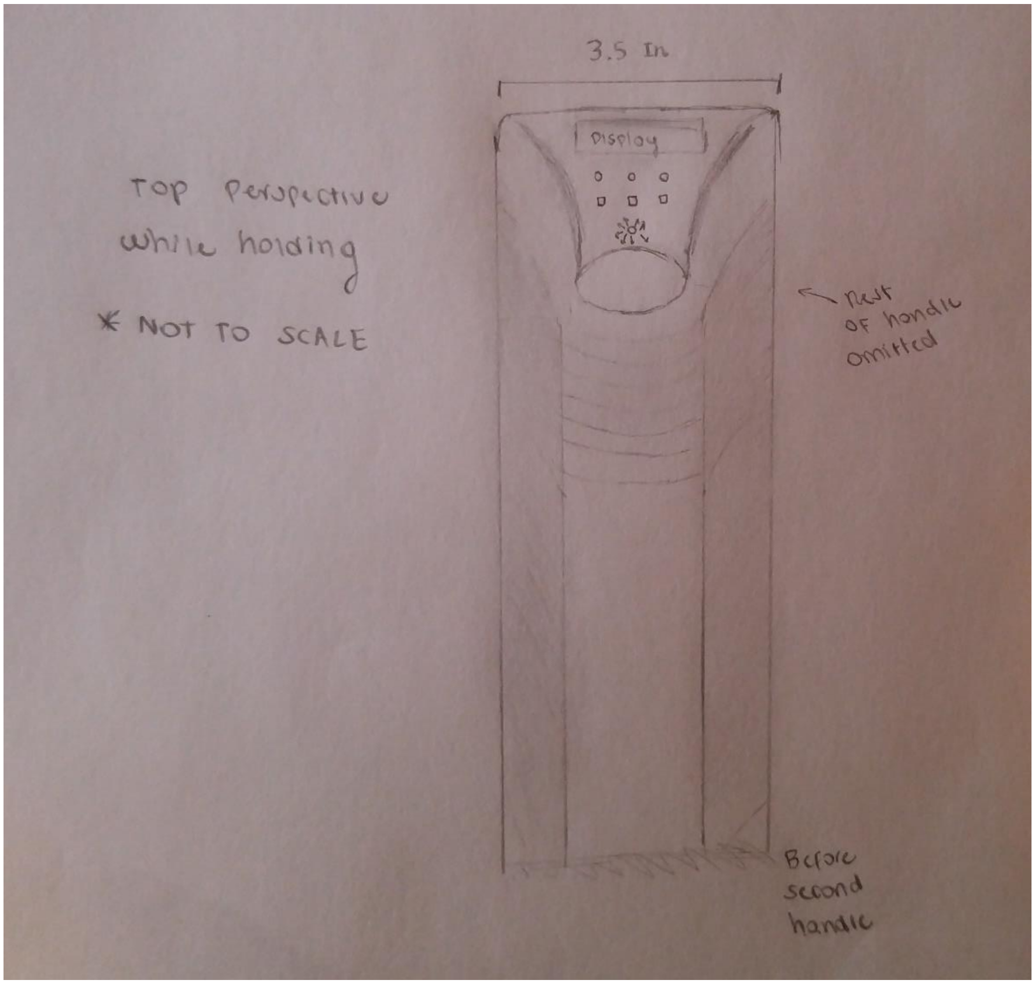


Fig. 2.3 – Top-rear view of the device in how it would be held

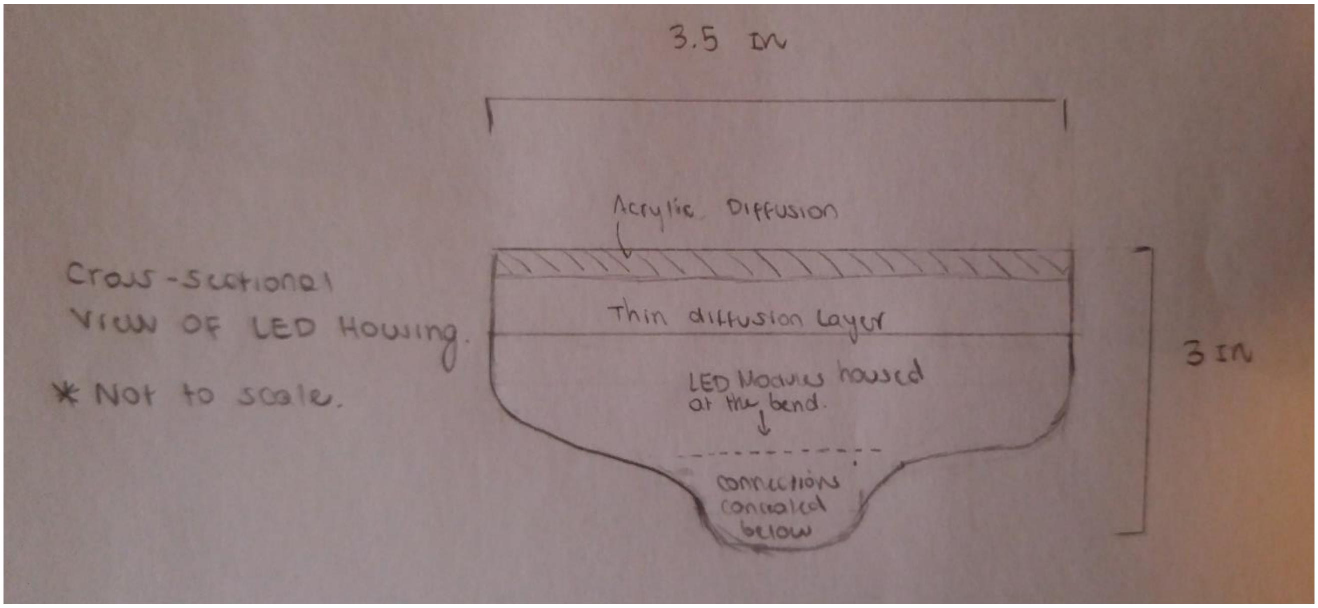


Fig 2.4 – Cross-sectional view of the main housing

## 2.3 Hardware Functional Overview

### 2.3.1 Li-ion Battery

Due to the high-current nature of the application (40/80 LEDs, each driven at a maximum forward current of 60 mA) and the portability requirements set forth by the end-user, Lithium-Ion cells were chosen as the ideal source of on-board power. The life-time of the device must be at least 45 minutes.

| Requirements | Verification |
|---|---|
| - Must be able to provide a minimum of 20 Watt-hours (~5,500 mAh) at a voltage range of 3.6 – 4.2 V with a discharge current of 1C (5 – 6 A). Lower voltages would require a DC-DC step-up module, but these ranges would incur on battery longevity. | 1. Connect the battery to a constant-discharge circuit with appropriate low voltage cut-off and discharge at 6A.<br>2. Use a Voltmeter to measure the battery voltage after 45 minutes and verify that the output is above 3.6 V. |

### 2.3.2 Li-ion charger

Due to the dangers of using Li-ion batteries, we have opted to purchase an industry-standard charger for the battery pack housed in the device. The charger is designed specifically for use with the battery pack, and provides the safest option for charging to the end-user.

| Requirements | Verification |
| --- | --- |
| - The charger must charge the battery from 3.6 V to full *safely* under 5 hours.<br>- Must be supplied directly from an AC wall outlet and be external to the device. | 1. Connect the battery to a constant-discharge circuit with appropriate low voltage cut-off and discharge at 6A to slightly below (by .1 V or less) 3.6 V.<br>2. Use a Voltmeter to measure the battery voltage and verify that the output is below 3.6 V.<br>3. Charge the battery for a period of 5 hours and verify with a Voltmeter that the output has reached the maximum 4.2 ± .02 V. |

### 2.3.3 High/Low Voltage Cut-off and battery protection

We plan to *use a battery pack with a pre-mounted protection circuit.* Our device is designed to operate the LEDs *only* above 3.6 V, and as such the nominal current draw below 3.6 drops *dramatically* long before reaching any critical voltage levels. This indicates to the user that recharging should be imminent (for full functionality of the device), and promotes a higher cycle life (number of discharge cycles) for the Lithium-ion cells by maintaining an approximate 50-65% depth of discharge[2].

| Requirements | Verification |
| --- | --- |
| - The protection circuit must prevent the following:<br>1. Overcharge (>4.2V) protection<br>2. Over-discharge (<3.0V) protection<br>3. Over current (>2C) protection | 4. Connect the battery to a constant-discharge circuit with appropriate low voltage cut-off and discharge at 1A.<br>5. Use a Voltmeter to measure the battery voltage periodically during discharge.<br>6. Verify that the cut-off circuit disconnected the load at 3.0 ± .1V. |

### 2.3.4 Voltage regulator

The Flash memory (Serial NOR Flash) *has a maximum input rating of 3.6 V, and the operating range of the device exceeds this requirement. To keep the cost down (not opting for a bigger memory or different type), the input range will be met by a simple LT1763-3.3 regulator circuit.*

| Requirements | Verification |
|---|---|
| - The output must be a constant 3.3 V (with .3 V tolerance) over the battery output range of 4.2 – 3.6 V.<br>- Regulation must sustain and operate at current draws of at *least* 300 mA. | 1. Supply a voltage within the range of 4.2 – 3.6 with a DC power supply.<br>2. Measure the output of the regulator with a Voltmeter and verify the output is at 3.3 V.<br>3. Load the regulator with an 11 Ω resistor (assuming step 2 was satisfied) and verify the voltage drop across the resistor is constant with an Oscilloscope. |

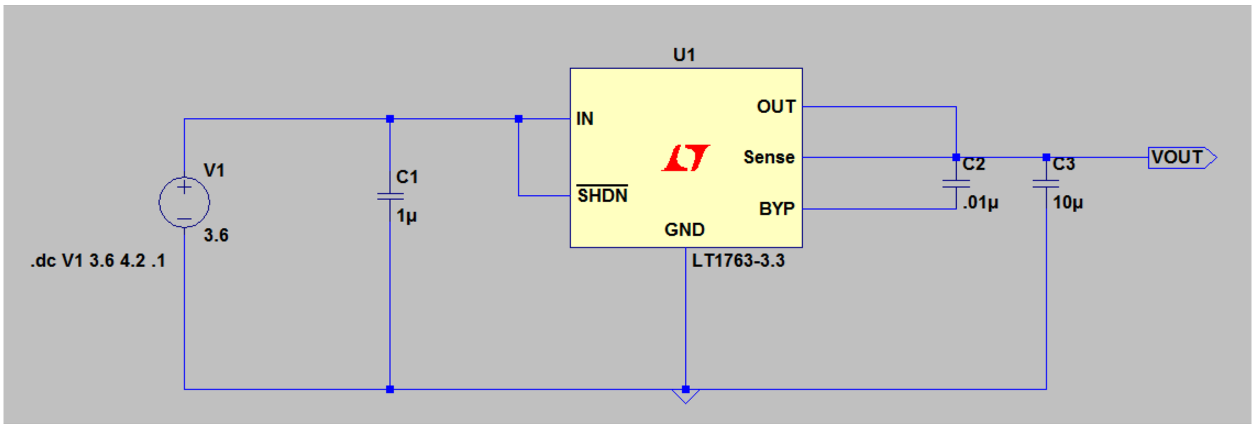


Fig. 2.5 – Schematic of the voltage regulator circuit

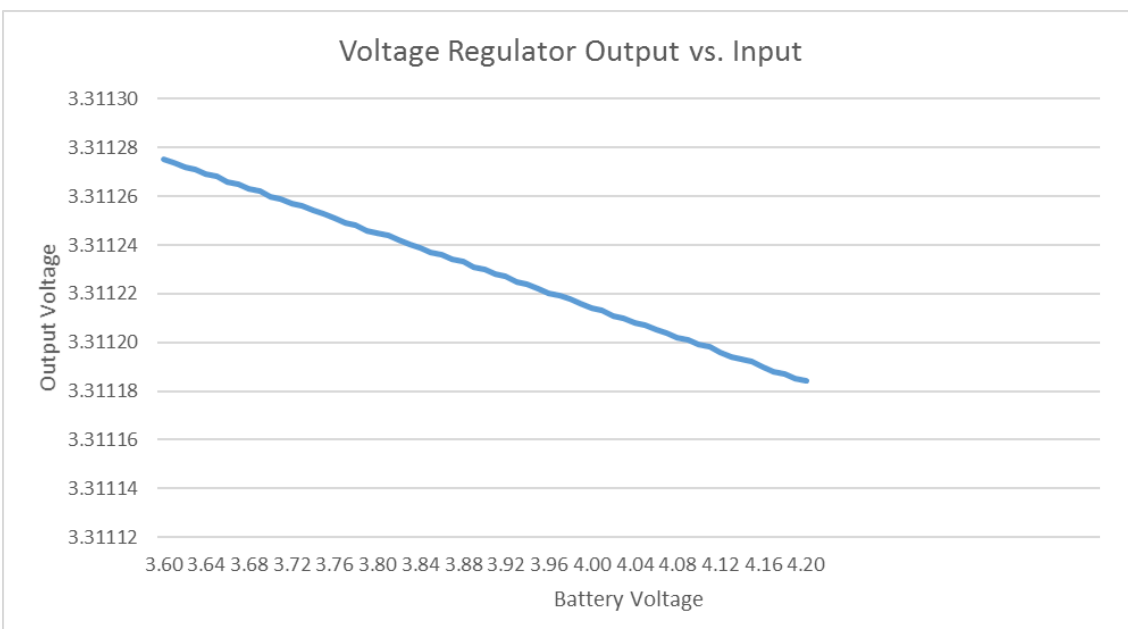


Fig. 2.6 – Simulation of the voltage regulator circuit

### 2.3.5 Flash Memory

A flash memory is the most readily available and low-cost non-volatile, rewriteable storage solution. A large part of the functionality of the device relies on the ability to retain and rewrite user profiles, and it is best to meet these with a low-cost, high data-retention (>10 years) Flash memory.

| Requirements | Verification |
|---|---|
| - The memory must have a capacity of *at least* 1600 bytes (160 bytes per profile over 10 profiles).<br>- Data retention must be >10 years.<br>- Must be SPI ready.<br>- Must provide read and write speeds of *at least* 160 Kbps clocked at 5 MHz (to perform below human visual latency). | 1. Program a looping read/write routine<br>2. Set SCK rate to half the system clock (5 MHz).<br>3. Perform continuous, non-DDR and individual writes and increment a counter for each.<br>4. Verify that the write rate is at least 160 Kbps by obtaining the time it took from the system clock.<br>5. Perform continuous, non-DDR and individual reads of the data written in step 3.<br>6. Verify that the read data is correct, and verify that the read rate is at least 160 Kbps. |

### 2.3.6 User Interface LCD Display

The LCD display will communicate the current settings and mode selected to the user, and must be able to display *at least 20 characters per line with 2 lines with backlighting*. The LCD screen would be facing a different direction from the light, and its brightness is extremely low compared to that of the LED strip, so there will be no light contamination during operation. We understand, however, that some very light sensitive photography may warrant a stronger control on the screen, and as such we leave the time-out options to be set by the user.

| Requirements | Verification |
|---|---|
| - Must be able to display 20 characters per line and have 2 lines of characters.<br>- Must be able to display all alphanumeric characters.<br>- Must be backlit and provide sufficient contrast to be visible in dark environments from arm's length. | 1. In a dark environment, display 40 different characters with the backlight on.<br>2. Hold at arm's length and verify readability. |

### 2.3.7 Buttons

The main handle will house 3 buttons as follows:

- Mode Toggle/Power-On, Hold to Power-Off. Mode toggling will cycle through the modes as they are displayed on the LCD display.
- Save Profile/Hold for Options. The options menu is where all the customization of the operating system can be accessed and altered.
- Alternate-function toggle. This changes the functionality of the rotary encoders/thumb-wheel switches as described in section 2.3.8.

| Requirements | Verification |
|---|---|
| - The buttons must be normally-open momentary contacts with decent "click" tactile-feedback (for user satisfaction). | 1. Push the buttons to verify their tactile-feedback. Ensure that all momentary contacts work as intended.<br>2. Use them to cycle through the various functionalities offered by the device. |

### 2.3.8 Rotary Encoders/ Thumb-wheel switches

The main handle will also house 3 rotary encoders/thumb-wheel switches as follows:

- Window Size Adjustment:

  Function 1 - Used to adjust the size of a selection window targeting a certain range of LEDs for customization.

  Function 2 – Used to adjust the color temperature *directly* (uniformly overwriting the window).

- Window Position Adjustment:

  Function 1: Used to slide the position of the window along the array.

  Function 2: Used to increase the playback frequency of the recorded animated profile.

- Brightness adjustment:

  Function 1: Used to adjust the brightness of the selected window *directly*.

  Function 2: Used to adjust the brightness of the selected window *passively* (increasing values while maintaining the profile).

| Requirements | Verification |
| --- | --- |
| - The rotary encoders/thumb-wheel switches must be able to distinguish the direction of rotation and be able to communicate it in 2 pins or less.<br>- Their rotation must be *effortless* but robust enough to prevent accidental turning.<br>- The rotation must be position *independent,* and full 360 degrees of motion must be allowed. | 1. Rotate the encoders/switches beyond 360 degrees and verify that their rotation is easy to perform and that their functionality is unaffected.<br>2. Check that minor movements and bumps do not rotate the encoders/switches.<br>3. Verify their functionality as described above. |

### 2.3.9 Microcontroller

| Requirements | Verification |
| --- | --- |
| - Must be able to operate at frequencies > 10 MHz at an input level of 3.3 V.<br>- Must contain at least 20 general-purpose input/output.<br>- Must be able to handle at least 10 interrupt lines.<br>- Must be fully compatible with SPI<br>- Must contain at least 16 Kb of internal SRAM.<br>- Must be self-programmable and allow programming through a JTAG interface. | 1. Load the system program unto the Microcontroller and bootloader.<br>2. Verify system functionality as described herein in this document. |

### 2.3.10 Custom Bus LED array

Due to reasons described in the following subsection, the device will require a custom-made bus in order to provide visually smooth transitions and accurate linear brightness control.

| Requirements | Verification |
| --- | --- |
| - The bus must be open-drain and provide rise-times less than 1000ns.<br>- Must be able to operate at speeds above 140 KHz.<br>- Must support multiple-slave addressing and multiple-slave concurrent data streams of unfixed size. | 1. Probe the SDA and SCL lines of the bus with an Oscilloscope and verify that the rise-time of the signal is less than 1000ns.<br>2. Check that no excessive ringing occurs.<br>3. Clock the SCL line at 180 KHz and send data to *all* modules *concurrently*. Verify that all modules respond accordingly. |

#### 2.3.10.1 Custom Bus: MBus

In order to provide adjustable gradients and fine detail to the illumination provided by the device, the array of LEDs must be able to vary their individual brightness upon user or microcontroller command with unnoticeable latency. We define unnoticeable latency to be a total latency less than the minimum average visual latency of human vision (approximately 8 ms). This would mean that, with color temperature functionality added, the bus must be able to communicate a total of 120 bytes of data (3 bytes per LED module) within 8 ms. This requirement yields a total number of clock cycles (including acknowledgements and data alignment cycles) of

$$120x8 + 160 = 1120\ cycles$$

We can then obtain the *minimum* clock speed the bus needs to operate at as

$$\frac{1120}{.008} = 140\ KHz$$

Note that this clock speed is well above the typical I2C transfer speed (100 KHz), and although Full-Speed Mode can provide a sufficient 400 kbit/s, several devices that could be used to drive the LEDs digitally (such as digitally controlled PWMs) do not support FSM. For this reason, we decided to opt out of using I2C as the bus communication protocol, and instead implement our own protocol and bus controller to seamlessly integrate with the LED Driver.

The protocol is very similar to I2C, with some modifications as follows:

- There is no start condition. A start condition is effectively assumed automatically following a stop condition (note that this means the master cannot sleep the bus).
- The bus is write-only. Data flow modifiers were removed from the communication protocol, and the SCL line is solely controlled by the master (there can be no clock stretching).
- The bus is application specific, and as such does not support multiple masters and is not limited in speed by the masters/slaves it supports. In this implementation, the bus is limited only by the maximum rise-times and propagation times of the SDA line. Note that since the input to the MBus controller is level-triggered, we do not have to worry much about slow rise-times and ringing in the SDA line.
- The bus supports multiple-slave addressing and variable-size data streams. The application benefits greatly from allowing the brightness of multiple LEDs to be changed concurrently rather than in repeated fast succession, and leaving the data stream open for subsequent data removes the need for the bus to re-initiate communication by re-addressing the modules.
- The bus has a third line – Data Enable. This line allows the master to determine when the data stream terminates and closes.

A schematic of the LED module (MBus controller together with the LED Driver) can be seen in Figure 2.8. A simulation waveform of the design in SystemVerilog can be seen in Figure 2.7. The simulation shows the addressing of two modules (addresses 01010101 and 10101010 to show that no aliasing effects occur) and their respective acknowledgements at the stop conditions. Note that the initialization of the bus causes a HIGH on SDA to be clocked at the start of the waveform.

| Requirements | Verification |
|---|---|
| - Must be able to operate at frequencies above 140 KHz.<br>- Must be resistant to slow rise-times (level-triggering).<br>- Must comply with the communication protocol and latch data when appropriate. | 1. Probe the SDA, SCL, Ack, and Comm_Enable lines of the MBus module with separate channels of an Oscilloscope.<br>2. Set the Oscilloscope to edge trigger on the SDA/SCL line. Do not use any averaging.<br>3. Loop through a communication routine infinitely. This allows the oscilloscope to remain triggered and obtain an image.<br>4. Verify the compliance of the waveform with that as shown in Figure 2.3 and with the rest of the protocol specification. |

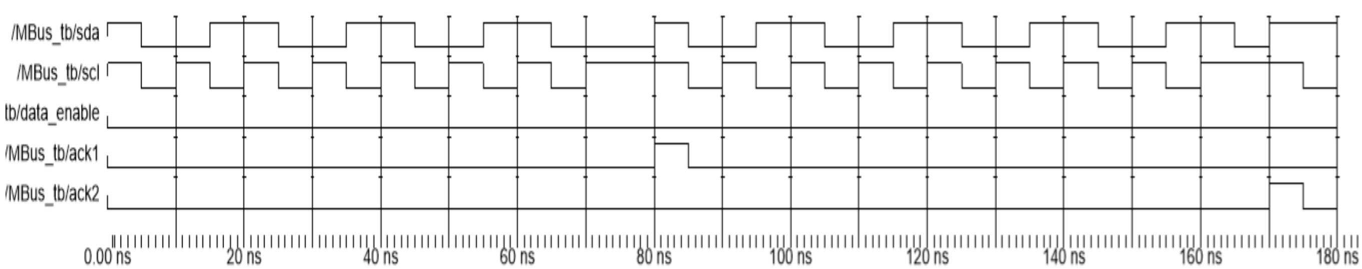


Fig. 2.7 – Waveform with the MBus controller as the DUT

### 2.3.10.2 LED Driver

The LEDs are driven by using an 8-bit register to store their brightness value. This 8-bit value is used as a parallel output to an R-2R Ladder DAC, which inputs into the gate of a PNP BJT in active mode (the setup is an approximate VCCS). Depending on the brightness value stored in the register, a specific current value flows through the LED. *The LED driver must be able to provide a current to the LED of up to 60 mA when the R-2R ladder provides the minimum value of voltage, 0 V (this allows the LEDs to be on during power-on and by default), and regulate the current in linear current steps of fixed size down to 0 A when the R-2R is at the maximum V.*

An 8-bit R-2R ladder can be iteratively reduced by applications of Thevenin's theorem to an equivalent circuit of Thevenin voltage given by

$$V_T = \sum_{i=1}^{8} \frac{V_i}{2^i} \qquad (1)$$

in series with a Thevenin resistance value of R. A diagram of the equivalent circuit can be seen in Figure 2.9. Using the small-signal model of a PNP BJT, we can obtain an expression for the base current $I_B$ given by

$$I_B = \frac{2.9 - V_T}{R_{ladder} + R_B} \qquad (2)$$

from which we can obtain an LED current of

$$I_C = \beta I_B \qquad (3)$$

Solving for the requirement that $I_C = 60\ mA$ with $V_T = 0$ yields

$$R_{ladder} + R_B \approx 14\ K\Omega$$

In other words, *The total input resistance to the base must be 14 kΩ*. Note, however, that these calculations are rough estimates and do not account for the appreciable decrease in the DC current gain as the collector current increases or the battery voltage depletion from 4.2 V. We thus expect the actual values to be somewhat *below* the required range.

We simulated our design in LTSpice with the calculated value in order to obtain a more accurate representation of the physical implementation. The collector current as a function of the R-2R digital input shows an approximately linear relationship that is ideal for our requirements and application, but falls short of the required maximum draw of 60 mA at only 45 mA. The simulation plot can be seen in Figure 2.10.

We instead chose an input resistance of 1kΩ in order to improve the range provided by the BJT (a lower base resistance would allow for a higher base current that offsets the decrease in the DC current gain). Figure 2.11 shows the simulation results for this circuit, demonstrating that the requirement of 60 mA is met for an input voltage of 0 V. Note that as the current range increases, the linear behavior of the relationship starts to fade. For our application, the linearity in the 0-60 mA range is sufficient. Current ratings for the LED are also satisfied at the maximum voltage of 4.2 V, as shown in Figure 2.12.

| Requirements | Verification |
|---|---|
| - Must be able to provide a linear voltage-controlled range of currents from which to drive the LED.<br>- Must not exceed a maximum continuous forward current of 65 mA.<br>- Must not drop the linear range beyond 5 mA (~ 2 lumen drop) as the voltage drops from 4.2 to 3.6 V. | 1. Provide a constant DC source at 3.6 V to the Driver.<br>2. Vary the ladder output from 0 to max in *at least* 1 step, and verify the endpoints (and linearity if more steps are used) of the current through the LED using an Ammeter.<br>3. Vary the DC source to 4.2 V and guarantee that the range increases by *no more* than 5 mA ± 1 mA.<br>4. If a light meter is available, verify that the lumen output of the LED varies by *no more* than 3 lumens as the DC source changes from 3.6 to 4.2. |

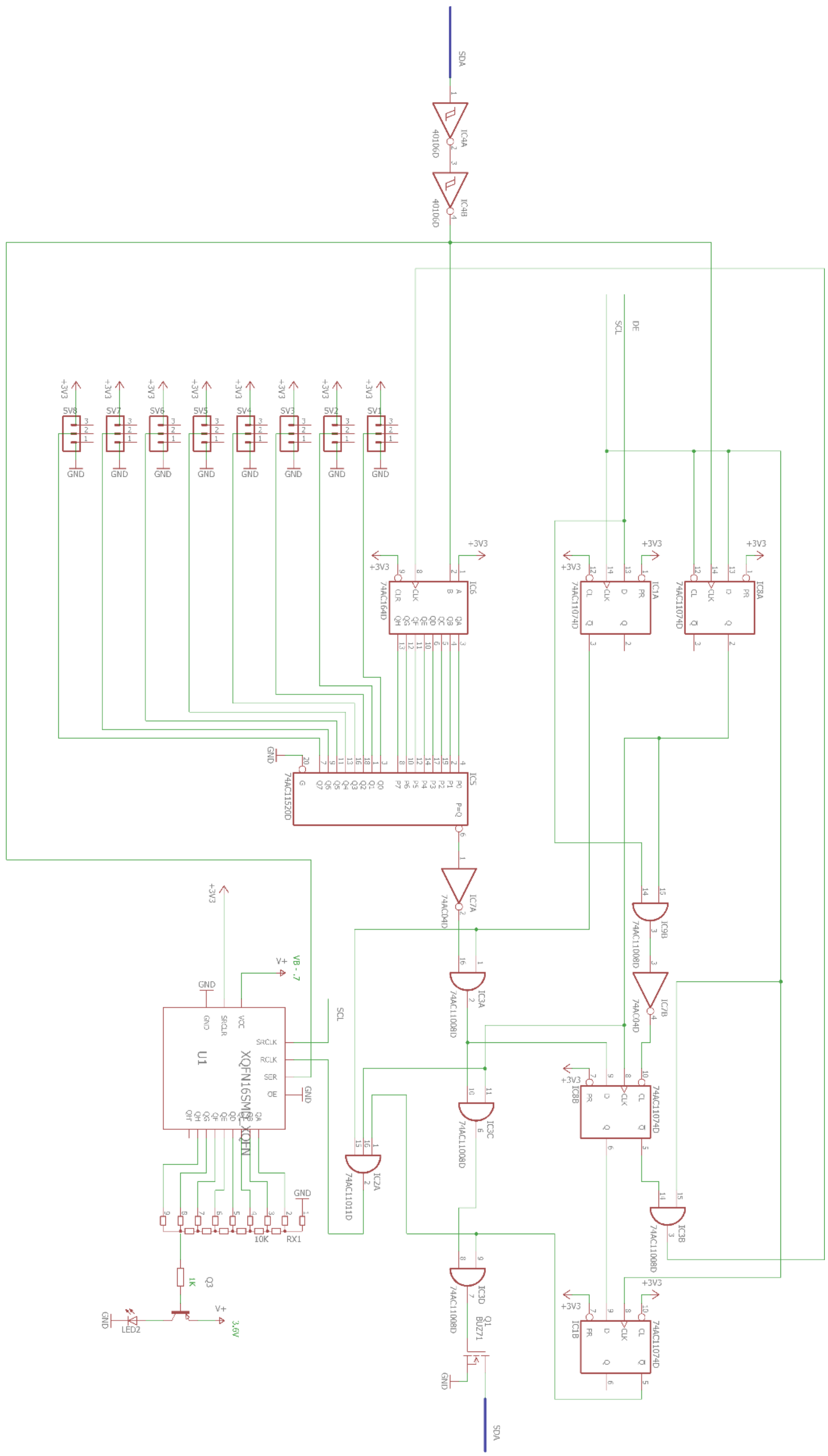

Fig. 2.8 – Schematic of the full LED Module

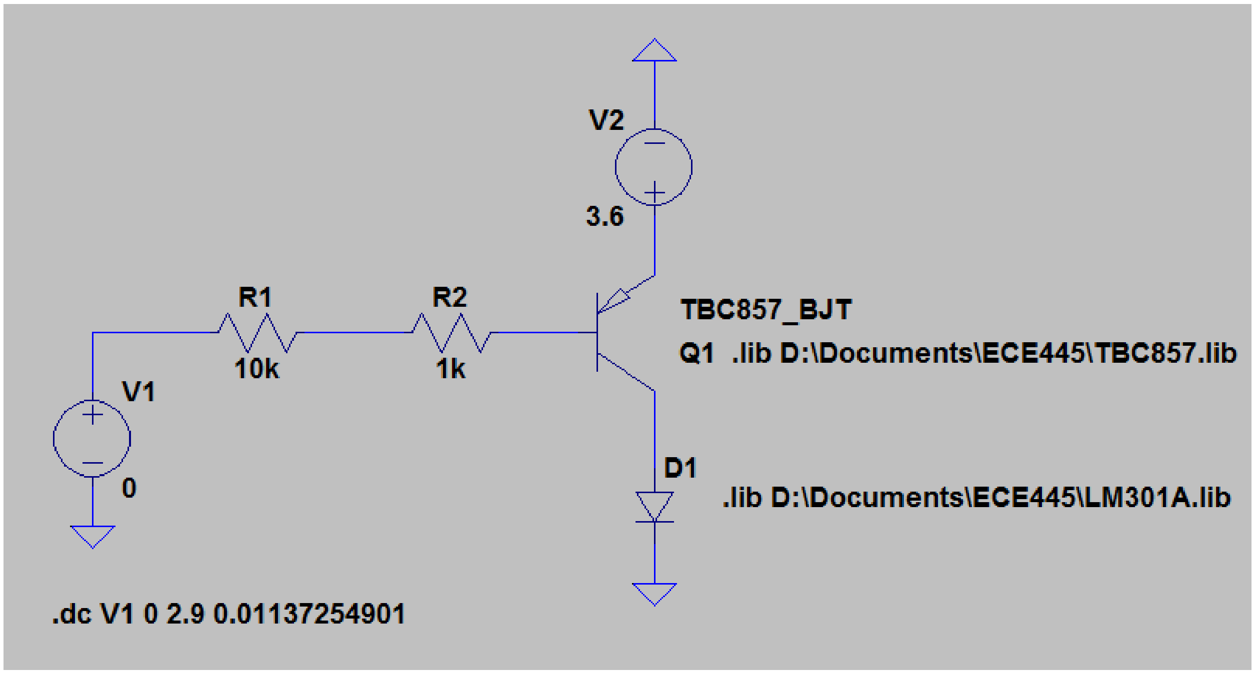


Figure 2.9 – LED Driver Schematic

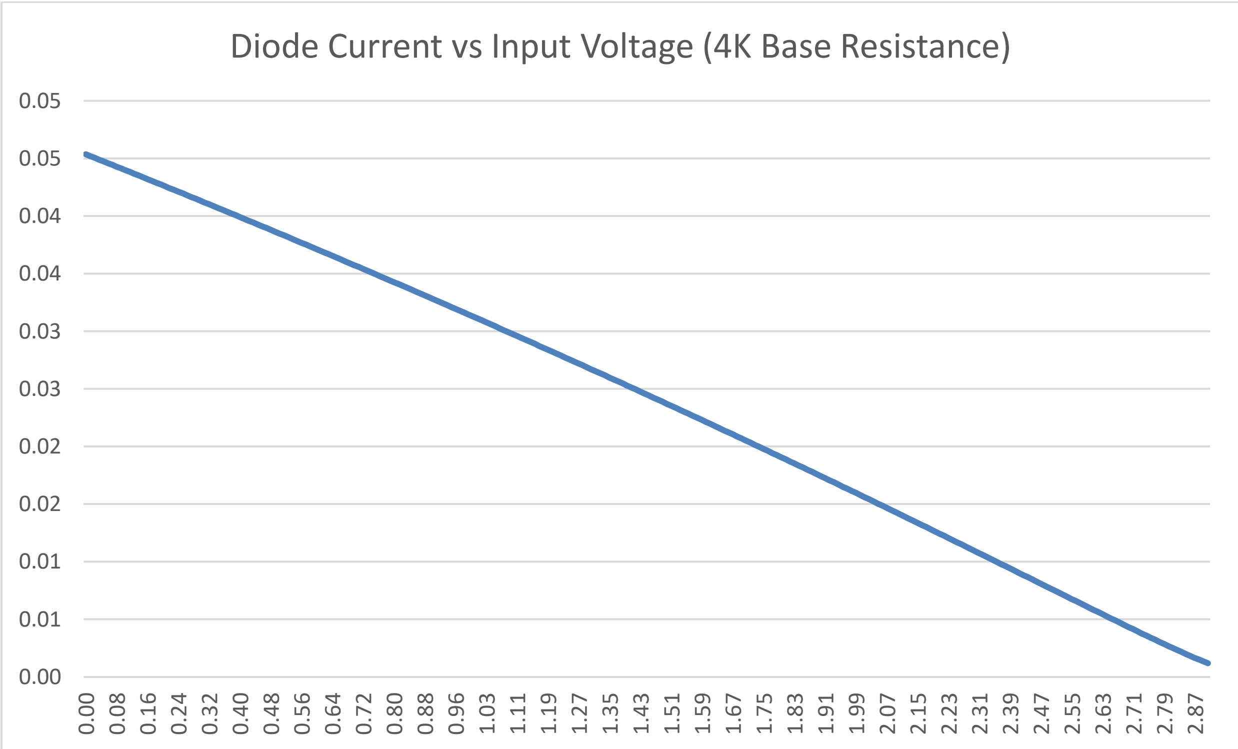


Figure 2.10 – Diode Current vs Input Voltage for $R_B = 4\ K\Omega$

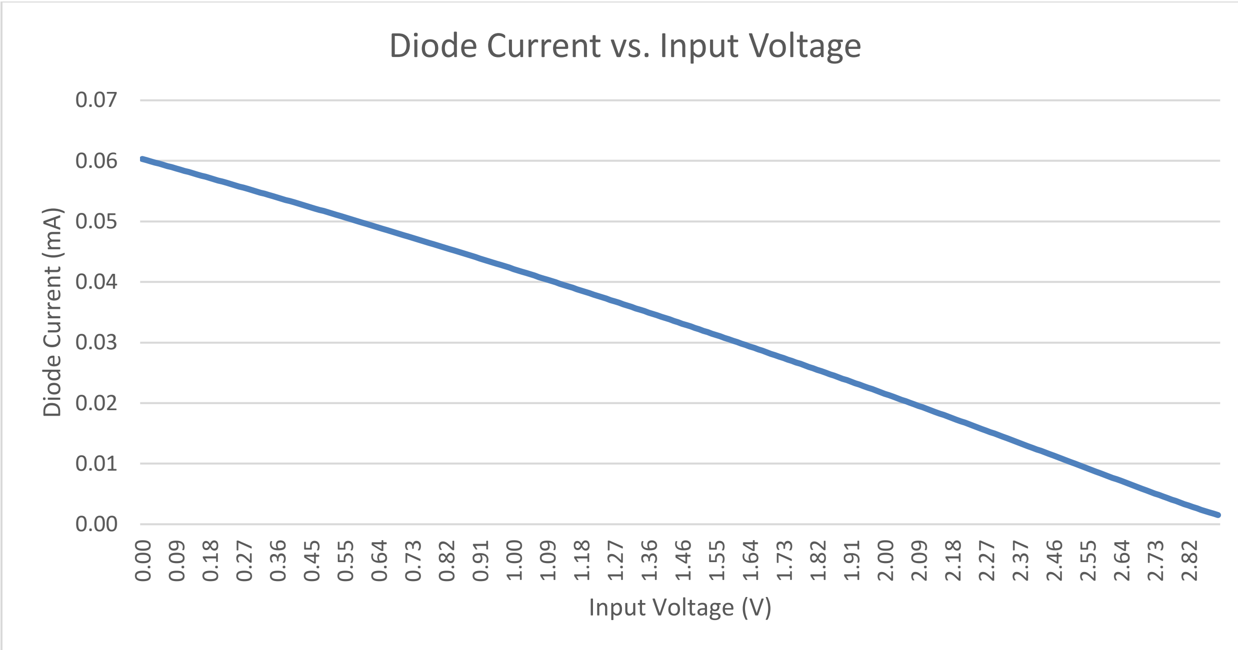


Figure 2.11 – Diode Current vs. Input Voltage for $R_B = 1\ K\Omega$

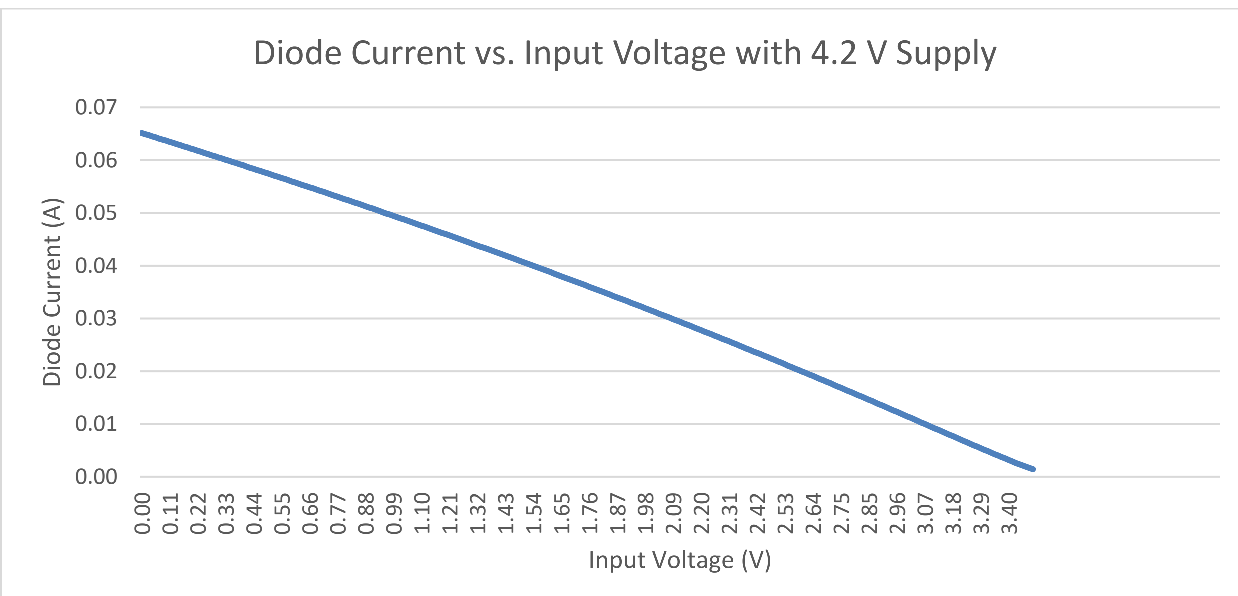


Figure 2.12 – Diode Current vs. Input Voltage for 4.2 V Supply

## 2.4 Software Functional Overview

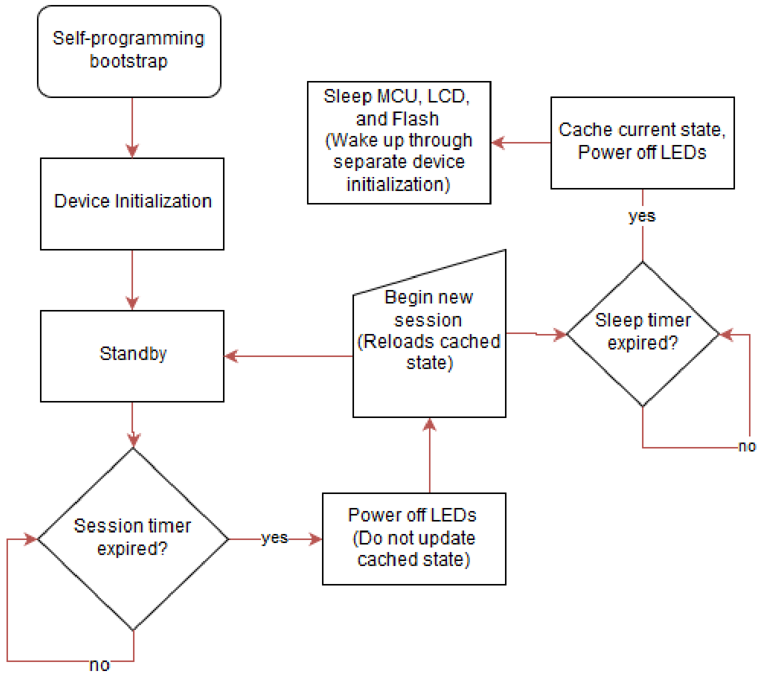


Figure 2.13 - High level flowchart of the operating system

### 2.4.1 Device Initialization from powered-off state

Upon entering the power-on state, the device must carry the following procedures in order:

1. Disable interrupts.
2. Assign pinout functionality.
3. Initialize the LCD Display.
4. Initialize an open SPI interface with the Flash memory.
5. Initialize the Flash Chip (Clocking to clear, setting SPI mode, etc..).
6. Initialize an open MBus interface with the LED Array (consists of clearing out buffers).
7. Diagnose all LED Modules (address all modules and verify their responses). Note that device discovery is not supported by MBus.
8. Load the previously-left system state (stored upon shutdown and periodically every few minutes to recover from unexpected loss of power).
9. Cache current state.
10. Re-enable interrupts
11. Initialize the internal Watchdog timer (for robust system operation).

The initialization bootstrap must report any and all errors encountered during execution.

### 2.4.2 Device initialization from sleep mode

Upon waking up from sleep mode, the device must carry the following procedures in order:

1. Disable interrupts.
2. Wake up Flash Chip and re-establish SPI interface.
3. Reset MBus communication by performing a reset sequence on the bus.
4. Load current state.
5. Re-enable interrupts

### 2.4.3 Standby

The main state of the system is in stand-by mode, which comprises of low-level thread bookkeeping and empty execution awaiting both hard (user or flash originated) and soft interrupts.

SPI interrupts will take priority over all other interrupts. Buttons and rotary encoders do not need a particular hierarchy and are free to be ordered as it Is most convenient. MBus communication should be second highest priority and can be safely interrupted in the middle of a transaction. Timer interrupts for session, sleep, and watchdog servicing must take priority over the user interface, but must not interrupt the SPI or MBus communication.

## 3 Tolerance Analysis

The most critical overall feature of this is the ability to accurately control the brightness of individual LEDs. Consequently, this means our LED driver is a crucial part of the project.

The component most involved with the LED driver is the R-2R Ladder DAC that we use to convert the 8 bit brightness value to an analog voltage to drive the LED, combined with the base input resistance used to control the base current. Our particular 10 kΩ R-2R is listed as having a tolerance of 2%, and the 1 kΩ base resistor we chose is listed as having a 0.1% tolerance. Since there is a linear relationship between the voltage driving the transistor and the current from the diode, we can expect that the tolerance values for each resistance will produce a variation from this linear expectation.  The LED driver circuit was simulated again, except this time sweeping each resistance value between its minimum and maximum tolerance range. These simulations assume the worst case by having each resistor in the R-2R ladder experience the same tolerance change (and therefore the change translates fully to the Thevenin equivalent). The results of these simulations are shown below:

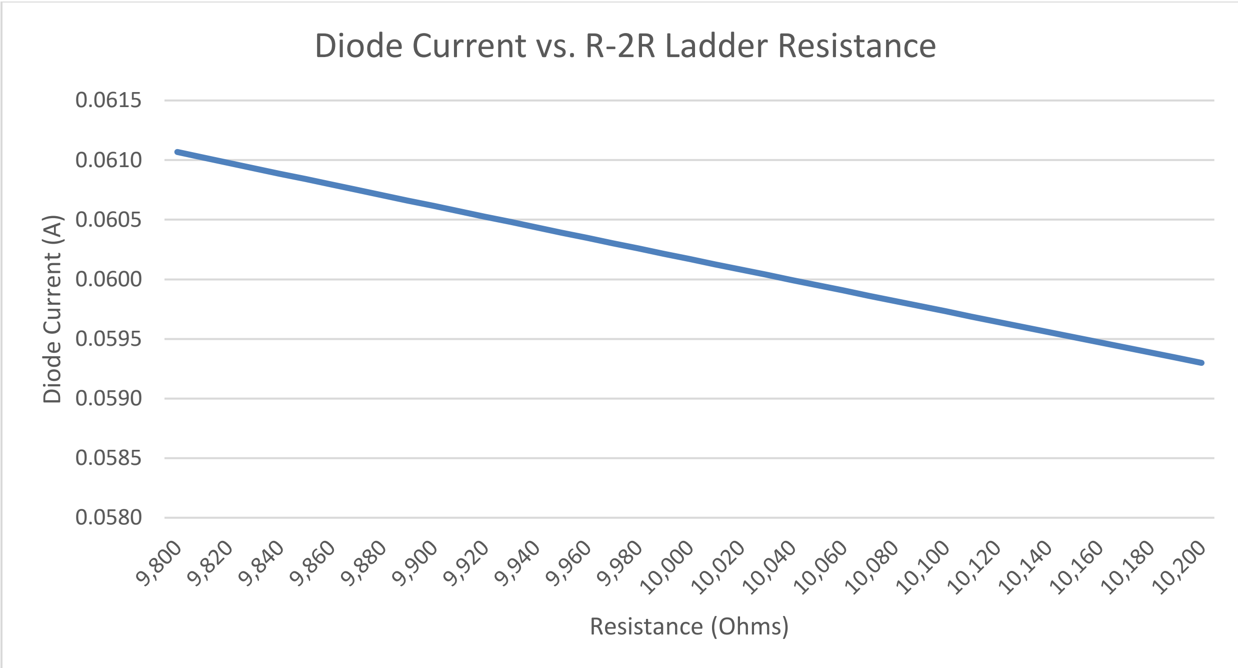


Figure 3.1 - Diode Current vs R-2R Equivalent Resistance

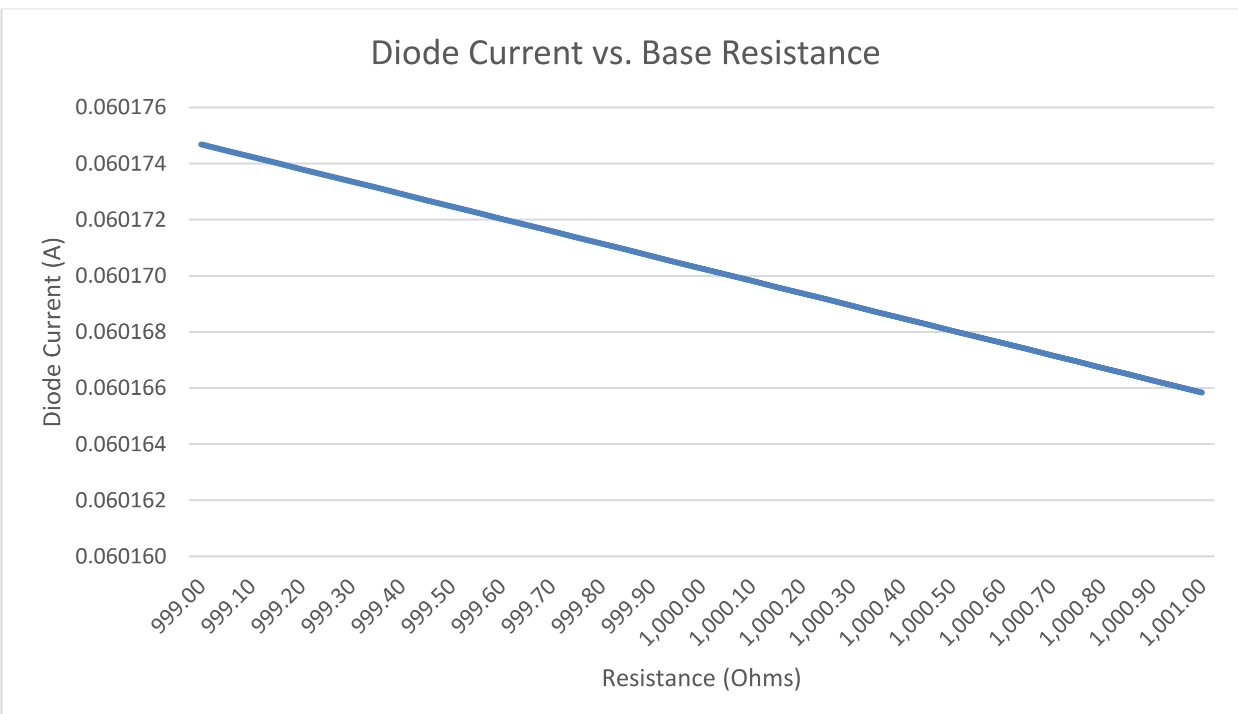


Figure 3.2 – Diode Current vs. Base Input Resistance

As is shown in the plots, the output diode current varies very little over the tolerance changes of the resistors, the maximum change being a new output current of 61 mA for an R-2R ladder resistance of 9.8 kΩ, which is still within the nominal current draw that our LEDs are rated for. For the base resistance, the change is on the order of µA, which again, is still well within our requirements for our LED.

# 4 Cost and Schedule

## 4.1 Cost Analysis

### 4.1.1 Labor Costs

For our project, we are estimating a salary of around $20 an hour. Assuming that we spend 20 hours a week, the same as a part time job, working on the project, with about 10 weeks remaining at the time of submission of this document, our total labor cost would equate to:

$20/hour x 2.5 x 200 hours to complete x 2 partners = $20,000

### 4.1.2 Parts Cost

| Part | Manufacturer | Quantity | Unit Cost ($) |
|---|---|---|---|
| 74LVC1G17 Schmitt Trigger | Nexperia | 40 | $0.50 |
| SN74HC595B 8 bit Shift Register – 8 bit D type Storage Register | Texas Instruments | 40 | $0.50 |
| 4816P-R2R-103LF R-2R Ladder | Bourns | 40 | $1.85 |
| PSMN022-30BL,118 N-MOSFET | Nexperia | 40 | $0.84 |
| 74AC164D 8 bit SIPO Shift Register | Texas Instruments | 40 | $0.65 |
| S25FL128S 128 Mbit SPI Flash Memory | Cypress | 1 | $2.42 |
| ATMEGA644P 8 bit Microcontroller | Microchip/Atmel | 1 | $5.56 |
| 74AC11074 Dual D type Flip Flop | Texas Instruments | 40 | $2.20 |
| SN74AC11DR Triple 3 Input AND Gates | Texas Instruments | 40 | $0.52 |
| CD74HC08M96Quad 2 Input AND Gates | Texas Instruments | 80 | $0.52 |
| SN54HC688 8 Bit Identity Comparator | Texas Instruments | 40 | $0.88 |
| CD74AC04M Hex Inverters | Texas Instruments | 40 | $0.57 |

| | | | |
|---|---|---|---|
| SPMWHT541ML5XAVMS0 WHITE SMD LED, 3000 K LM561C | Samsung | 40 | $0.50 |
| SPMWHT541ML5XAPKS0 WHITE SMD LED, 6500 K LM561C | Samsung | 40 | $0.50 |
| TBC857 PNP BJT | Toshiba | 80 | $0.16 |
| CRT0603-BY-1001EAS 1K SMD Thick Film Resistor | Bourns | 80 | $0.55 |
| CRCW04022K00FKED 2K SMD Thick Film Resistor | Vishay | 40 | $0.10 |
| Li-Ion 3.7V 1.5A Battery Pack Charger | Tenergy | 1 | $34.99 |
| LT17663-3.3 Voltage Regulator IC | Linear Technology | 1 | $12.19 |
| 04026C105KAT2A 1uF SMD Ceramic Capacitor | AVX | 1 | $0.25 |
| C1206C103JARACTU .01uF SMD Ceramic Capacitor | Kemet | 1 | $0.12 |
| TCM0J106M8R 10uF SMD Tantalum Capacitor | ROHM | 1 | $0.40 |
| TOTAL COST | | | $538.73 |

Table 4.1 – Parts Listing and Cost

GRAND TOTAL = $20,538.73

## 4.2 Schedule

| Week | Task (Mario) | Task (Gary) |
|---|---|---|
| 2/27-3/3 | Layout PCB for custom parts and for prototype boards | Create EAGLE schematics |
| 3/6-3/10 | Start working on microcontroller programming | Layout prototype PCB for LED control |
| 3/13-3/17 | Receive prototype PCBs and build, test prototype modules | Verify and test PCB prototype modules as well |
| 3/20-3/24 | Program microcontroller for user interface | Work on interfacing with microcontroller |
| 3/27-3/31 | Integrate user interface parts into microcontroller | Start building and testing user interface |
| 4/3-4/7 | Finish programming microcontroller | Test and verify user interface |
| 4/10-4/14 | Prepare for mock demo | Prepare for mock demo |
| 4/17-4/21 | Perform mock demo, begin working on strip housing | Work with Rick to obtain specifications and evaluation on device |
| 4/24-4/28 | Perform real demo, work on final paper | Perform demo, work on final paper |
| 5/1-5/5 | Finish final paper! | Finish final paper! |

Table 4.2 - Scheduling

# 5 Ethics and Safety

Every component and part that we design or use should be RoHS compliant. This falls under the ACM Code of Ethics Section 1.2[1], which means that our product should avoid harming the end user. By making the product RoHS compliant, we would avoid using dangerous chemicals and substances in our design.

In terms of safety concerns, our greatest involves the usage of Li-ion batteries. These batteries could pose a threat if not charged and used properly. We have turned to industry to provide the necessary guidelines and equipment to safely house, use, and charge the batteries in the device. This includes protection from both thermal and voltage-induced runaway events, preventing potentially harmful explosions and fires. Also, we will work to make sure that there is no potential for sudden shorts and opens by designing our circuit and carefully verifying each portion, across all ranges of potential usage. By doing this, we ensure that no matter what the user does with the device, within reason, they would not be injured.

The user should also be mindful of how the batteries are handled, taking care to properly add and remove the batteries from the device when charging. Ensuring the terminals are connected in the correct polarity, and one at a time, will guarantee proper usage of the device. Also, the user should make sure to not leave the device in temperatures above 40 degrees Celsius. Finally, when charging the battery pack, only the specified charger for the pack should be used, and the user should make sure to remove the charger when the peak voltage is reached, and use a correct wall input voltage.

# 6 Citations

[1] ACM Council, "ACM code of ethics and professional conduct," in Association for Computing Machinery, 1992. [Online]. Available: https://www.acm.org/about-acm/acm-code-of-ethics-and-professional-conduct. Accessed: Feb. 25, 2017.

[2] I. Buchmann, "How to prolong lithium-based batteries," in Battery University, 2017. [Online]. Available: http://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries. Accessed: Feb. 25, 2017.