**LED SLACK LINE**

<table>
<thead>
<tr>
<th>Kristina Forystek</th>
<th>Bridget Benson</th>
<th>I agree to supervise this senior project.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 462</td>
<td></td>
<td>2. The specifications are [1]-[2];</td>
</tr>
</tbody>
</table>

- Implementation Free—Describes what project should do, not how.
- Bounded—Identify project boundaries, scope, and context
- Complete—Include all the requirements identified by the customer, as well as those needed to define the project.
- Unambiguous—Concisely state one clear meaning.
- Verifiable—A test can prove if system meets specification.
- Traceable—Each engineering specification serves at least one marketing requirement.

**ADVISORS:** Please initial above, if you agree to supervise this senior project. Also, please check applicable boxes above. Comment below, if requirements or specifications require revision.
LED SLACKLINE

By

Kristina Forystek

Senior Project

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

June, 2016
Abstract

A Slackline is a nylon rope that uses tension to suspend itself above ground. Slacklines are usually tied between two trees while the user walks across the line. Slacklining provides a daytime activity as user vision weakens after the sun goes down.

A LED slackline allows users to practice tight roping at night. The lights let the user know when they perform well. The slackline uses a three axis system to determine how much the user moves. The slackline senses how much the user shakes in three dimensions and then relays it back to the LEDs. If the user shakes or bounces, the LEDs light up and flash accordingly. Overall, the LED slackline helps the user to perfect their tricks and tight roping capabilities in the dark!
Acknowledgments

Advisor:
Bridget Benson

Moral and Financial Support:
Roger and Susan Forystek

Technical Support:
Joe Fitzpatrick and Maci Miri
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CHAPTER I: Introduction

Slacklining provides an excellent hobby, and has become increasingly popular in the past few years. The first and only patent for a slack line apparatus dates back to 2011 [5]. This activity, widely held among young adults, shows popular at many college campuses and young towns alike. Slacklining consists of a relaxing past time and improves the art of balancing. This hobby shows difficult to many and requires a lot of practice in order to maintain balance and perform more advanced maneuvers. [7].

The LED Slackline provides a fun and enjoyable addition for those who enjoy such a hobby. The line aims to allow users to practice after sundown, providing feedback based on performance criteria [4]. The project consists of a dual axis system for measuring user input, and then signal processes the information to the output or LEDs on the line.

Motivation for this project comes from a love for slacklining as well as embedded systems. Slacklining relaxes the performer, and calls for a tranquil state of mind. These qualities prove optimal for an ideal hobby. Additionally, allowing one to combine a profession with a hobby explains a dream of many young professionals. Overall, this project consists of fun design and testing environments.
CHAPTER II: Customer Needs Assessment

The target market for this product includes children six years and older, young adults whom enjoy outdoor activities, and professional slackliners. A customer needs assessment consists of putting myself in the customer’s shoes and researching the benefits of slacklining [7]. Research, conducted by carrying a slackline to various locations, determines the best places to enjoy the hobby. Putting oneself in the customer’s shoes proves a great way to identify customer needs. In this case, enjoying the hobby on the beach, in parks, and in various other locations provides great insight to the needs of the customers. Over the course of three months, customer needs narrowed down to: a resilient and sturdy slackline that proves useful at night, easy to travel with, easy to set up, and constructed from weather proof and waterproof materials [4]. The fact that the slackline helps the customer to improve their slacklining skills by showing them how well they perform in real time, provides an additional, necessary, benefit.

Requirements and Specifications

Table I lists the marketing requirements and engineering specifications for the LED Slackline. Customer needs, outlined in the previous section, drive the marketing requirements. In addition, the engineering specifications represent design choices meant to address the marketing requirements. The limiting factors associated with this project include power, accuracy and durability of the design. The microcontroller only supplies 5V while the LEDs need a 12V supply [3][8]. In addition, the circuitry and slackline consists of weatherproof material. The purpose of the product design includes the lights reacting in accordance to how well the user performs, therefore accuracy proves necessary. The line allows little to no delay time from user input to the LED output. The design aims to meet all specifications with the most efficiency. Table II sets a timeline for delivery dates over the course of a year.
<table>
<thead>
<tr>
<th>Marketing Requirements</th>
<th>Engineering Specifications</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The LEDs must respond in real time to the ranking of the user’s performance on the line [9].</td>
<td>The delay proves faster than the human eye can see.</td>
</tr>
<tr>
<td>1</td>
<td>Accelerometer 5% tolerance [2][6].</td>
<td>5% accuracy allows customers to know how well they perform.</td>
</tr>
</tbody>
</table>
| 1                      | The LEDs flash according to the accelerometers X, Y and Z values. The absolute value of each one is added together and set as variable A. The LEDs are then controlled by this variable as follows: A < 800 – White  
A < 900 – Yellow  
A < 950 – Blue  
A < 1000- Violet  
A > 1000 - Red | The LEDs flash red, yellow, and green. They transition through a large spectrum depending on which one illuminates. |
<p>| 2                      | Should sustain entire system for 3 hours. [3]. | 18650 batteries sustain 3000mAhours and LEDs pull 1A max current. |
| 3                      | For an untrained consumer, installation should take at most 10 minutes. | Installation only requires threading the slack line through a ratchet. |
| 4                      | LEDs contain waterproof materials and adhere to the line. Circuit Design should meet IP67 specification. | LEDs consist of waterproof material, circuit design allows light rain for small periods of time or humidity/ sea weather. |</p>
<table>
<thead>
<tr>
<th>5</th>
<th>Board design consists of material under ~5”x5”, the entire product weighs less than 8 pounds.</th>
<th>Total package proves aesthetically pleasing. Slack liners need less bulk. Slack lines by themselves weigh 7 pounds, therefore 1 pound for the board design.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>50 ft slack line can support up to 800 lbs.</td>
<td>A typical slack line can support up to 800lbs at 50 feet.</td>
</tr>
</tbody>
</table>

**Marketing Requirements**

1. Accurate light compared to the ranking of the user’s performance on the line.
2. The Slack Line can stay powered for 6+ hours at full LED brightness
3. Easy set up for customers
4. Water Proof
5. Easy to transport and not Bulky
6. Up to four people can perform on the slack line at a time
## Table II
**LED SLACKLINE DELIVERABLES**

<table>
<thead>
<tr>
<th>Delivery Date</th>
<th>Deliverable Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/15/16</td>
<td>Design Review</td>
</tr>
<tr>
<td>3/10/16</td>
<td>EE 461 demo</td>
</tr>
<tr>
<td>3/10/16</td>
<td>EE 461 report</td>
</tr>
<tr>
<td>3/28/16</td>
<td>EE 461 project presentation</td>
</tr>
<tr>
<td>4/22/16</td>
<td>EE 462 beta demo</td>
</tr>
<tr>
<td>5/28/16</td>
<td>EE Senior Project Expo</td>
</tr>
<tr>
<td>6/5/16</td>
<td>ABET Sr. Project Analysis</td>
</tr>
<tr>
<td>6/5/16</td>
<td>EE 462 Report</td>
</tr>
</tbody>
</table>

## Chapter III: Functional Decomposition

### Level Zero Block Diagram

Figure I and Table III describe the level zero block diagram and functionality for the LED slackline. This shows how the inputs affect the outputs of the embedded system.

![FIGURE I
LED Slackline Level Zero Block Diagram](image-url)
TABLE III
LED Slackline Level Zero Inputs, Functionality, and Outputs

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Functionality</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>User’s Motion</td>
<td>The accelerometer measures the user’s movement, this</td>
<td>LED display changes colors and rate of flashing.</td>
</tr>
<tr>
<td></td>
<td>information processes to the microcontroller by the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>input voltage range.</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>Microcontroller, accelerometer and strain guage receive</td>
<td>LED display requires power.</td>
</tr>
<tr>
<td></td>
<td>power in order to start obtaining data.</td>
<td></td>
</tr>
</tbody>
</table>

Level One Block Diagram

Figure II shows the level one block diagram for the LED slackline. The inputs and output described in the level zero diagram stay constant. The blue boxes shown below describe the functionality of the design. The user’s motion feeds into the accelerometer circuitry, this outputs a digital signal that varies depending on the user’s performance. This signal goes through a logic shifter and into the microcontroller. The ATmega328P then sends signals to the Mosfet Switch Circuitry that will power RGB LED color strip without over drawing current from the microcontroller. The Arduino and the LED’s are powered off the 11.1V input.
Table IV  
LED Slackline Level One Functionality Table

<table>
<thead>
<tr>
<th>Inputs</th>
<th>System</th>
<th>Functionality</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>User’s Motion</td>
<td>Accelerometer</td>
<td>Produces a Digital Signal based off the User’s Motion</td>
<td>DC voltage signal between 0 and 3.3V</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.1V Digital Signal</td>
<td>Atmega328P</td>
<td>A microcontroller to control the LEDs based on the digital input</td>
<td>Digital Signal</td>
</tr>
<tr>
<td>SPI communication</td>
<td></td>
<td></td>
<td>SPI communication with accelerometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Power to accelerometer and logic level shifter</td>
</tr>
<tr>
<td>Digital Signal</td>
<td>Logic Level Shifter</td>
<td>During SPI communication between the Accelerometer and the Atmega328P it switches high voltage to low from Atmega328p to accelerometer. It also switches low voltages high from accelerometer to Atmega328P.</td>
<td>SPI Communication and a Digital Signal between 0 and 5V</td>
</tr>
<tr>
<td>SPI communication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>Mosfet Switch Circuitry</td>
<td>Turn on the LEDs and allow them to pull as much current as needed.</td>
<td>LEDs color and rate of flashing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter IV: Project Planning

Chapter four illustrates the project’s plan over the course of nine months. Figure three shows a Gantt chart of the tasks and milestones over the course of three quarters. Table five shows the tasks in table form for clarity as well. The Project plan shows the projects timeline ranging from September 15th to June 10th. The planning of the project finishes in December so the design stage may start in January. The design stage, titled EE461, allows for two separate build and test attempts and finishes in March. EE462 outlines the build stages of the project and allows time for two separate build cycles. The Build of the project estimates finishing two weeks prior the demonstration. This timeline leaves three weeks total between the project finish date and the project due date. Directly following, table five shows the time estimate of each task along with the cost of labor. The labor costs around $5,178, while materials and other costs around $200. This can be seen clearly in Table six as well. Cost for components, board fabrication and assembly, labor and necessary materials makes up the total estimated price for the project. Each time component and part cost derives from the PERT method of estimation, represented by the following equations:

\[
\begin{align*}
    t_{\text{estimate}} &= \frac{t_{\text{optimistic}} + 4t_{\text{realistic}} + t_{\text{pessimistic}}}{6} \\
    C_{\text{estimate}} &= \frac{C_{\text{optimistic}} + 4C_{\text{realistic}} + C_{\text{pessimistic}}}{6}
\end{align*}
\]
Figure III: LED SLACKLINE GANTT CHART
<table>
<thead>
<tr>
<th>Task</th>
<th>Duration</th>
<th>Start Date</th>
<th>End Date</th>
<th>Labor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED SLACKLINE</td>
<td>195 days?</td>
<td>Mon 9/14/16</td>
<td>Fri 6/10/16</td>
<td>$5,178.00</td>
</tr>
<tr>
<td><strong>Project Plan- EE460</strong></td>
<td>61 days</td>
<td>Mon 9/14/15</td>
<td>Mon 12/7/15</td>
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</tr>
<tr>
<td>Abstract(Proposal)V1</td>
<td>6 days</td>
<td>Mon 9/14/15</td>
<td>Mon 9/21/15</td>
<td>$28.00</td>
</tr>
<tr>
<td>Requirements and Specifications</td>
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<td>Mon 10/5/15</td>
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</tr>
<tr>
<td>Block Diagram</td>
<td>4 days</td>
<td>Wed 10/7/15</td>
<td>Mon 10/12/15</td>
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</tr>
<tr>
<td>Literature Search</td>
<td>19 days</td>
<td>Wed 9/23/15</td>
<td>Mon 10/19/15</td>
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</tr>
<tr>
<td>Gantt Chart</td>
<td>4 days</td>
<td>Wed 10/21/15</td>
<td>Mon 10/26/15</td>
<td>$56.00</td>
</tr>
<tr>
<td>Cost Estimates</td>
<td>4 days</td>
<td>Wed 10/21/15</td>
<td>Mon 10/26/15</td>
<td>$28.00</td>
</tr>
<tr>
<td>ABET Sr. Project Analysis</td>
<td>7 days</td>
<td>Fri 10/23/15</td>
<td>Mon 11/2/15</td>
<td>$140.00</td>
</tr>
<tr>
<td>Requirements and Specifications V2 + Intro</td>
<td>4 days</td>
<td>Wed 11/4/15</td>
<td>Mon 11/9/15</td>
<td>$56.00</td>
</tr>
<tr>
<td>Report V1</td>
<td>40 days</td>
<td>Mon 9/21/15</td>
<td>Fri 11/13/15</td>
<td>$112.00</td>
</tr>
<tr>
<td>Report V2</td>
<td>16 days</td>
<td>Mon 11/16/15</td>
<td>Mon 12/7/15</td>
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<tr>
<td>EE461</td>
<td>60 days</td>
<td>Mon 1/4/16</td>
<td>Fri 3/25/16</td>
<td>$1,792.00</td>
</tr>
<tr>
<td><strong>EE461 Report Revision</strong></td>
<td>60 days</td>
<td>Mon 1/4/16</td>
<td>Fri 3/25/16</td>
<td>$1,792.00</td>
</tr>
<tr>
<td>Literature Search</td>
<td>60 days</td>
<td>Mon 1/4/16</td>
<td>Fri 3/25/16</td>
<td>$1,792.00</td>
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<td><strong>Design #1</strong></td>
<td>7 days</td>
<td>Mon 1/4/16</td>
<td>Tue 1/12/16</td>
<td>$1,792.00</td>
</tr>
<tr>
<td>Design/ Simulate Accelerometer Circuit</td>
<td>6 days</td>
<td>Mon 1/4/16</td>
<td>Mon 1/11/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Design/ Simulate Strain Guage Circuitry</td>
<td>6 days</td>
<td>Mon 1/11/16</td>
<td>Mon 1/18/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Design/ Simulate LED Power Circuit</td>
<td>4 days</td>
<td>Mon 1/11/16</td>
<td>Thu 1/14/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Finalize Parts List</td>
<td>2 days</td>
<td>Mon 1/18/16</td>
<td>Tue 1/19/16</td>
<td>$56.00</td>
</tr>
<tr>
<td>Order Parts</td>
<td>1 day</td>
<td>Tue 1/19/16</td>
<td>Tue 1/19/16</td>
<td>$56.00</td>
</tr>
<tr>
<td>Parts Arrive</td>
<td></td>
<td>Mon 1/25/16</td>
<td></td>
<td>$0.00</td>
</tr>
<tr>
<td>Solder Boards/Assemble</td>
<td>7 days</td>
<td>Mon 1/25/16</td>
<td>Tue 2/2/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Program Atmega328P</td>
<td>3 days</td>
<td>Tue 2/2/16</td>
<td>Thu 2/4/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Finalize Circuitry</td>
<td>3 days</td>
<td>Fri 2/5/16</td>
<td>Tue 2/9/16</td>
<td>$56.00</td>
</tr>
<tr>
<td>TEST</td>
<td>7 days</td>
<td>Mon 2/8/16</td>
<td>Tue 2/16/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Design Revision</td>
<td>7 days</td>
<td>Tue 2/16/16</td>
<td>Wed 2/24/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Design #2</td>
<td>7 days</td>
<td>Wed 2/24/16</td>
<td>Thu 3/3/16</td>
<td>$112.00</td>
</tr>
<tr>
<td>Finalize Parts List</td>
<td>2 days</td>
<td>Fri 3/4/16</td>
<td>Mon 3/7/16</td>
<td>$56.00</td>
</tr>
<tr>
<td>Order Parts</td>
<td>1 day</td>
<td>Fri 3/4/16</td>
<td>Fri 3/4/16</td>
<td>$56.00</td>
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<td>Parts Arrive</td>
<td></td>
<td>Mon 3/14/16</td>
<td></td>
<td>$0.00</td>
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<tr>
<td>Solder Boards/Assemble</td>
<td>5 days</td>
<td>Mon 3/14/16</td>
<td>Fri 3/18/16</td>
<td>$112.00</td>
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<tr>
<td>TEST</td>
<td>3 days</td>
<td>Mon 3/21/16</td>
<td>Wed 3/23/16</td>
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<td>** EE462</td>
<td>50 days</td>
<td>Mon 4/4/16</td>
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<td>Fri 4/8/16</td>
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</tr>
<tr>
<td>Test Attempt #1</td>
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<td>Fri 4/8/16</td>
<td>Wed 4/13/16</td>
<td>$336.00</td>
</tr>
<tr>
<td>Design Revision</td>
<td>5 days</td>
<td>Wed 4/13/16</td>
<td>Tue 4/19/16</td>
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</tr>
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<td>Reorder Any Parts Necessary</td>
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</tr>
<tr>
<td>Parts Arrive</td>
<td></td>
<td>Mon 4/25/16</td>
<td></td>
<td>$0.00</td>
</tr>
<tr>
<td>Build Attempt #2</td>
<td>5 days</td>
<td>Mon 4/25/16</td>
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</tr>
<tr>
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<td>Fri 4/29/16</td>
<td>Thu 5/5/16</td>
<td>$336.00</td>
</tr>
<tr>
<td>EE462 Report Revision</td>
<td>2 days</td>
<td>Thu 5/5/16</td>
<td>Fri 5/6/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Sr. Project Expo Poster</td>
<td>1 day</td>
<td>Fri 5/6/16</td>
<td>Fri 5/6/16</td>
<td>$112.00</td>
</tr>
<tr>
<td>EE462 Demo</td>
<td>1 day</td>
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<td>$364.00</td>
</tr>
<tr>
<td>Sr. Prj. Analysis Revision</td>
<td>3 days</td>
<td>Sat 5/7/16</td>
<td>Tue 5/10/16</td>
<td>$140.00</td>
</tr>
<tr>
<td>ABET Sr. Project Analysis</td>
<td>2 days</td>
<td>Tue 5/10/16</td>
<td>Wed 5/11/16</td>
<td>$168.00</td>
</tr>
<tr>
<td>Final EE462 Report Due</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Justification</td>
<td></td>
<td></td>
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<tr>
<td>------------------</td>
<td>-------</td>
<td>---------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slackline</td>
<td>$50</td>
<td>Actual Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED RGB Strip</td>
<td>$50</td>
<td>$15/16ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fabrication of Boards</td>
<td>$40</td>
<td>Estimated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Components</td>
<td>$50</td>
<td>Estimated</td>
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<td></td>
</tr>
<tr>
<td>Labor</td>
<td>$5,178</td>
<td>$28/hr</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>$5,368</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter V: Design

Hardware

Figure IV Shows the Schematic of the LED Slackline Control Unit. The schematic was built first with a bread board and through-hole components. After validating the design, the Schematic was drawn using the program Eagle. The microprocessor used for the design is the Arduino Uno, therefore the board built acts an Arduino Shield. The PCB board is the same shape as the Arduino with male connector pins on all sides that fit directly into the Arduino I/O pins. The schematic shows the Arduino footprint with all the necessary connections to the rest of the circuit. U1 is the ADXL362 accelerometer that sends data through SPI to the Arduino. The signals from the ADXL362 to the Arduino are sent through a level shifter to change the 3.3V logic to 5V logic for easy communications. Additionally, any signals going from the Arduino to the accelerometer are down level shifted from 5V to 3.3V. The Arduino then controls N-channel mosfets that act like switches to turn the RGB LED strip on and off and different colors and frequencies.

Figure V, Figure VI, and Figure VII show the layout of the board. Figure V shows the entirety of the layout with the dimensions, top and bottom layer, and silkscreen. Figure VI shows the copper routing of the bottom layer, while Figure VII shows the copper tracing of the top layer. The layout is meant to be an “Arduino Shield,” or a board that perfectly sets on top of the Arduino Uno with male connector pins. This is easily seen by looking at any of the PCB boards shown below. The Copper traces are at a minimum of 10mils, while the larger power lines are at 56mils to overcompensate for the current that will be sent through the traces.
Figure IV

LED SLACKLINE CONTROL UNIT SCHEMATIC
Figure V
LED SLACKLINE CONTROL UNIT LAYOUT

Figure VI
LED SLACKLINE CU BOTTOM LAYER

Figure VII
LED SLACKLINE CU TOP LAYER
The board was manufactured from Bay Area Circuits and can be seen in Figure VIII and IX below. It is a two layer board, with all components on the top side, and only traces going through the bottom layer when necessary. The Bill of Materials is shown in table seven, and are the components that were soldered on during assembly.

![Figure VIII: MANUFACTURED BOARD TOP](image1.png)  ![Figure IX: MANUFACTURED BOARD BOTTOM](image2.png)

**TABLE VII**

**LED SLACKLINE CONTROL UNIT BILL OF MATERIALS**

<table>
<thead>
<tr>
<th>RefDes</th>
<th>Description</th>
<th>Package</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>BSS138</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>Q2</td>
<td>BSS138</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>Q3</td>
<td>BSS138</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>Q4</td>
<td>BSS138</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>R1</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R2</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R3</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R4</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R5</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R6</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R7</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>R8</td>
<td>10k</td>
<td>805</td>
<td>Resistor SM</td>
</tr>
<tr>
<td>U$1</td>
<td>IRFL024Z</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>U$2</td>
<td>IRFL024Z</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>U$3</td>
<td>IRFL024Z</td>
<td>SOT23-3</td>
<td>MOSFET-NCHANNEL</td>
</tr>
<tr>
<td>U1</td>
<td>ADXL362</td>
<td>ADXL362</td>
<td>Micropower 3-axis accelerometer</td>
</tr>
</tbody>
</table>
The Board after manufacturing was assembled using surface mount soldering and through hole techniques.

Unfortunately, the board was found to have some errors. After trouble shooting the board, another breakout board was soldered over the accelerometer portion of the layout. This skipped over the problem area to allow for the board to work at its full functionality. This problem solving technique can be seen in Figure ten. The board was then placed in a project box and hooked up to two 18650 batteries with a switch to easily turn the board on or off. This manufacturing can be seen in Figure X and XI.

Figure X: PCB BOARD ASSEMBLY

Figure XI: PROJECT BOX
The LEDs were than assembled to the slackline by hand sewing. Figure XII and XIII shows the stitching used for the project. The Project box was adhered to the line using Velcro and attached to the LED RGB strip on the line. The industrial strength Velcro is strong enough to keep the box on the line during use shown in Figure XIV.

![Figure XII: TOP SIDE STITCHING](image1)

![Figure XIII: BOTTOM SIDE STITCHING](image2)

![Figure XIV: LED CONTROL UNIT ATTACHED TO LINE](image3)

**Software**
The Arduino Uno is written in Arduino code which is similar to C. The Codes purpose is to take in the X Y and Z locations from the accelerometer, and then output signals to the RGB LEDs to light them up accordingly. The code imports the ADXL362 library in order to communicate with the accelerometer. In addition, the accelerometer communicated with the Arduino through SPI communication. The code uses if statements to analyze the values received from the accelerometer and then output certain colors to the LED strip. The values from the accelerometer that relate to a certain color can be seen in Table VIII below. The code is found in Appendix A.
Chapter VI: Testing and Conclusion

Testing
Testing was done in three stages. The first stage was to build the entirety of the circuit using through-hole components and a bread board. The board was testing in lab to ensure functionality requirements. After the circuit proved to meet all the engineering requirements, the schematic was build.

Within the program Eagle, there is an Electric Rules check or ERC that is run once the schematic is complete. This ensures all connections are made were needed and no mistakes were made in the design. The board was then sent to layout and completed. Here, a DRC or Design Rules Check was ran in order to ensure there were no issues with the layout. Issues could include traces overlapping, copper traces being too close to one another or the side of the board. In addition, drill sizes being too small or in inappropriate areas. After the DRC checks out the board was ordered.

After assembling the board, appropriate power was feed to the input pads of the PCB and the functionality of the board was tested. The RGB LEDs were plugged into the male connectors on the side of the shield, and the shield was attached to the Arduino Uno.

The PCB Board was found to have some errors, they were trouble-shoted and fixed as mentioned in the hardware section of this report. Once the functionality of the PCB was proven to meet the engineering requirements, the entire unit was placed onto the slackline.

There were no issues testing the Slackline with the entire unit assembled, and the LED Slackline successfully meets the requirements listed in the requirements and specification section of this report. It was tested at night to see if the user could produce a green light while standing still on the line, produce a yellow light while shaking slightly and walking across the line normally, and produce red when the user was falling. These different lights can be seen in Figure XV, XVI, and XVII below.
Figure XV: LED SLACKLINE SET UP WITH USER STANDING STILL

Figure XVI: LED SLACKLINE SET UP WITH USER WALKING SUCCESSFULLY ACROSS LINE

Figure XVII: LED SLACKLINE SET UP WITH USER FALLING OFF LINE
Conclusion

The LED Slackline was a successful project from start to finish. The project's life cycle was approximately nine months with project planning, designing, and testing. The design and test phases followed the project planning fairly well and made for a smooth project from start to finish. The project meets all the requirements and specifications that are listed in this report and therefore is complete. The project could be improved in the future by using programmable address accessible RGB LEDs. Then, the slackline could light up not just as a unit, but could light up different colors at the same time. The LED Slackline built is a great product that many consumers would be interested in.

Figure XVI II: LED SLACKLINE FINAL PRODUCT AT SENIOR PROJECT DEMO
#include <SPI.h>
#include <ADXL362.h>
#define REDPIN 5
#define GREENPIN 3
#define BLUEPIN 6
#define FADESPEED 100

ADXL362 xl;

int16_t temp;
int16_t XValue, YValue, ZValue, Temperature;

void setup() {
    pinMode(REDPIN, OUTPUT);
    pinMode(BLUEPIN, OUTPUT);
    pinMode(GREENPIN, OUTPUT);
    Serial.begin(9600);
    xl.begin(10);                   // Setup SPI protocol, issue device soft reset
    xl.beginMeasure();              // Switch ADXL362 to measure mode
}

void loop() {
    int r = 0;
    xl.readXYZTData(XValue, YValue, ZValue, Temperature);
    int myalg = abs(YValue) + abs(ZValue);
    // put your main code here, to run repeatedly:

    if(myalg <800 ) //WHITE
    {
        analogWrite(BLUEPIN, 255);
        analogWrite(GREENPIN, 255);
        analogWrite(REDPIN, 255);
        delay(200);
    }
    else if(myalg < 900 ) //TEAL
    {
        analogWrite(BLUEPIN, 0);
        analogWrite(GREENPIN, 255);
        analogWrite(REDPIN, 0);
        delay(200);
    }
    else if(myalg < 950) // BLUE
{    
analogWrite(BLUEPIN, 255);
analogWrite(GREENPIN, 0);
analogWrite(REDPIN, 0);
delay(200);
}

else if (myalg < 1000) // VIOLET
{
analogWrite(BLUEPIN, 0);
analogWrite(GREENPIN, 255);
analogWrite(REDPIN, 100);
delay(200);
}

else // RED
{
analogWrite(BLUEPIN, 0);
analogWrite(GREENPIN, 0);
analogWrite(REDPIN, 255);
delay(100);
}
Project Title: LED SLACKLINE

Student’s Name: Kristina Forystek

Student’s Signature:

Advisor’s Name: Bridget Benson   Advisor’s Initials:   Date: 11/1/15

• 1. Summary of Functional Requirements

The LED Slackline lights up according to the user’s performance during practice. The slackline lights up in real time compared to the user’s performance on the line. The product takes the user’s input data and process it such that the information displays on the LED’s adhered to the line.

• 2. Primary Constraints

The limiting factors associated with this project include power, accuracy and durability of the design as seen in Table I LED slackline requirements and specifications. The microcontroller only supplies 5V while the LEDs need a 12V supply [3][8]. In addition, the circuitry and slackline consists of weatherproof material. The purpose of the product design includes the lights reacting in accordance to how well the user performs, therefore accuracy proves necessary. The line allows little to no delay time from user input to the LED output.

• 3. Economic

Major economic impacts from developing and selling this product include, human capital, financial capital, manufactured or real capital, as well as natural capital.

The project uses human capital and real capital for the design and manufacturing stages. Labor costs include the design of the product as well as the actual building of the product. People develop all the materials and designs necessary to implement the project, therefore the project can impact human capital. Additionally, the machines that the workers use prove necessary to design and build chips, boards, and other materials make an impact. Soldering irons, pick and place machines, and other large machines permits product development. Real capital includes the different technologies necessary for the project to succeed [10].

Additionally, the project uses financial capital. As the demand for slacklines increases, the slackline industry benefits from the sales. Loans prove necessary to start a small company, providing banks with economic benefits. The Project requires many materials that circulate
money throughout the economy as well. The cost to rent office and lab space continues as an additional economic benefit [7].

Natural capital used by this project includes the world’s natural resources. The transportation of supplies persists as one bad economic impact, as it decreases natural gas. Additionally, the supplies needed to make the product include silicon, copper, metals, etc.

Major Costs of the LED slackline occur in the beginning of the projects life. Labor cost of the design and planning stages provides the largest expense. The actual materials for the slackline stay almost negligible in comparison. The benefits accrue at the end of the projects life, as it sells for profit.

The cost of this device consists of the assembly of the boards needed and the components, as well as the LEDs and slackline. The boards and components contain about $120 of the budget, while the slackline and LEDs contain about $100. Overall without unexpected costs, it costs about $220 to build the project. This money comes from the project designer and builder.

The project expects to sell for $250 a slackline. This gives a $30 profit per slackline sold. The profits go directly to labor costs.

The product plans for the development and build timeline ending in 9 months. After the design plan subsides, reproducing the product takes a few days as the development stages subside. The products should work properly until the 12V battery dies. Maintenance requires the user to change the battery when this happens. There contains no operational costs for the user once the products purchased.

4. If manufactured on a commercial basis:

The estimated manufacturing price for each device calculates to $220 without unexpected costs. In order to breakeven, the unit should sell at $250 to include labor costs without design. The price per unit calculates to $250 and stays fixed throughout the products life cycle. The estimated number of devices sold per year stays at 73,000 of approximately 200 devices sold a day. While the estimated purchase price per device calculates to $270 in order to make profit. This leaves a net profit per year of $1,460,000.

5. Environmental

The product consumes natural oil and gas for transportation and production. Machining the product gives off greenhouse emissions that may damage the environment. Also, other natural resources for the products materials include: silicon, copper, precious metals, and other materials that make up the slackline webbing. These materials steal from the environment and deplete the limited amount of resources available.
Furthermore, this could disturb native species that inhabit the environment where the natural resources grow. The species need the same resources the product requires, limiting the amount of use for the species.

Additionally, the project uses trees while in practice to tie the lineup. Necessary precautions prevent harm to the trees. If such precautions stay ignored, trees may become damaged.

• 6. Manufacturability

Manufacturing production proves simple for the LED slacklines. Issues include testing all the boards before installing them onto the line as well as integration of the product. The LED’s could adhere wrong, the boards may assemble incorrectly, and the connection between electronics can have incorrect wiring. This could increase labor costs if each board has to go through intense procedures for testing. In addition, labor costs increase with each wasted material do to mistakes.

• 7. Sustainability

The product’s durability for many conditions proves necessary for use. The product travels with the user and needs weatherproofing. The product runs off a single 12V battery, therefore, the maintenance of the device includes changing the battery when it dies[3][8]. The change to our sustainable use of resources includes the natural gas needed to transport supplies.

In order to sustain the environment successfully, users must take precautions. Set up of the device permits the user to treat the trees with care, or to disturb them. In order to sustain the environment, the user must make sure to pick durable trees with appropriate bark. A strong enough tree, thick in width, with heavy and durable bark proves as the best tree to use. If palm trees or other feeble trees provide for the activity, the user must set towels under the rope to protect the trees from damage.

• 8. Ethical

This project follows the Egoistic Approach, or ethics of self-interest. This approach often uses utilitarian calculation in order to produce the greatest amount of good for him or herself. Slacklining, practiced to benefit an individual’s state of mind and balance capabilities, resides as an individual activity. The project improves this activity by allowing the user to practice at night and obtain performance criteria on themselves. The product benefits only the user, and includes many qualities that only help the customer or user of the line. The projects intent does not include helping the greater good, or society as a whole.

The project also needs to adhere to the IEEE Code of Ethics. The third aspect of the code states, “to be honest and realistic in stating claims or estimates based on available data.” This means the project designer remains honest during cost estimates, reliability data of materials needed,
timeline estimates, and technical knowledge necessary to complete the project. Adhering to the
code means honesty at every point of the design, testing, and manufacturing phases.

The seventh IEEE code of ethics point says, “to seek, accept, and offer honest criticism of
technical work, to acknowledge and correct errors, and to credit properly the contributions of
others.” This directly applies, as each project holds a learning environment for those involved.
The product designer must seek to build the best product possible and accept constructive
criticism along the way. This project asks for criticism from peers, advisors, and technical
professionals alike.

Additionally, the IEEE Code of Ethics states the ninth point, “to avoid injuring others, their
property, reputation, or employment by false or malicious action.” Slacklining entitles a
dangerous sport, as users stay susceptible to falling off the line. The safety of the user may stay
jeopardized in this situation. Though legal, the ethical issues of this remain arguable. This code
may depict as jeopardized because the product may astray from the morality stated.

The Last IEEE Code of Ethics that applies directly to this project states, “to assist colleagues and
coworkers in their professional development and to support them in following this code of
ethics.” This project design implements the use of peers or colleagues during the development
stages. It proves necessary to support one another throughout the planning and design of the
project and hold other engineers accountable for the IEEE code of ethics.

9. Health and Safety
The user stays susceptible to falling when using this product. The concerns include the safety
factor, as injury stays an issue when practicing slacklining. The LEDs on the slackline prevent
users from harming themselves if practicing at night. The danger of the user falling off the line,
or harming oneself during tricks continues as valid danger. The product itself proves safe and
reliable.

In addition, the health and safety of all workers needs consideration during every step of the
project. Following the IEEE code of ethics, designers hold themselves responsible for a safe
work environment, safe design, and promise honesty during the entirety of the project.

10. Social and Political
Social issues include some parks and businesses banning slacklining. For example California
Polytechnic State University San Luis Obispo has banned slacklining on campus. Although
students developed a petition to change the rule, the political issues among leadership at Cal Poly
and students offers an issue.

This project impacts those who invest in the product, because it contains a successful plan and
design. Slacklining has become extremely popular in the past few years and the production of the
lines has therefore increased drastically. The LED slackline provides an even more popular
product. Stakeholders stay limited to employees only, eliminating unfair benefits and insuring
that all holders have equal rewards. Each holder lives in the same community, works for the
same company, and has equal knowledge on the product. Employees endure the opportunity for
stock options that insure the simplicity of who owns the company’s shares.
• 11. Development

New skills prove necessary to develop the project. Board Design shows necessary to this products plan. Cal Poly’s IME156 shows students how to route traces with DipTrace, but this class does not show the entire complexity of designing a circuit, sending it to layout, and routing the board. This project allows the designer to learn OrCAD Schematic and Layout in order to develop the boards as necessary and package them with an esthetic design. Additionally, project management consists of many skills necessary to the production of this project. Management includes creating timelines or Gantt charts, laying out requirements and specifications, and estimating costs correctly.

Literature Search


[1] LED slackline uses this microcontroller and proves necessary in order to program the product. ATMEL proves itself as a prestigious company.

[2] An accelerometer adheres to the slackline in order to measure body movement. This IEEE conference paper talks about how they used an accelerometer for body angles and movements. IEEE proves itself as a known reliable source.

[3] Power management proves one of the most challenging problems for my project. This article sites creditable references.

[4] The slackline uses happen strictly at night. I need to know which color LEDs can harm human site and which ones advance night vision etc. The author has a PHD in the subject.


[6] This book tells about strain gauges and how they work. The product uses a strain gauge to measure the human body weight on the slackline. This proves as an accredited publisher.

[7] This talks about the benefits of slacklining on the human body and how one can improve. This proves helpful during the testing phase. It proves accredited by the US National Library of Medicine.
[8] This article contains information about power management on embedded systems. This can help my challenge of power for the LEDs. In addition Texas instruments proves known as an accredited institution.

[9] This speaks of the benefits of LEDs and the back story of why they hold popularity right now. The journal article proves as an accredited by IEEE spectrum

[10] This speaks of how transistors contain flexibility! This starts the research of flexible materials so that the slackline proves able to torque appropriately. In addition, this is accredited by the UC San Diego and there EE research department.