Motorized Track Lighting System

Team 80
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1. Introduction

1.1 Objective

The objective of our project is to create a remotely controllable ceiling-mounted lighting system. Our goal is to build a track-based system upon which multiple carts, each housing a light source, can be controlled through a mobile application. The degrees of freedom in each light cart will allow them to move left and right along a single shared linear track, pan the light source a full 360 degrees, and tilt the light through a range from straight down to horizontal.

This product will make arranging the lighting in a space simpler. It will give artists, gallery owners, and homeowners the ability to change the focus of their lighting on demand. The user will not need to modify the lighting configurations manually, risking burns from hot bulbs, electrical shock, or falls from high ladders. The user will be able to move individual light carts along the track and change the direction the light bulb is shining through a cell phone application communicating with the light system over Bluetooth.

Our remotely controlled system will mitigate the physical hassle of manually adjusting a lighting setup. In addition, this lighting solution allows the user to view the changes they are making to the lighting in a space from the vantage point that viewers or customers will have of the illuminated subject.

1.2 Background

Many current lighting solutions for home, museum, and studio use are static systems. While static systems can be useful in fixed environments, if the environment they are meant for use in is rearranged regularly, manually adjusting the lighting in the space is an awkward, frustrating and potentially dangerous process. There are thousands of stationary track light heads available for purchase [11], but they generally clip into place on tracks powered to 120 V ac. There are some lighting systems that are motorized to move side to side, but in slow periodic motion for greenhouse applications [13]. One company, Formalighting, has a product that is similar to our project in that the light sources can pan and tilt, but their pan and tilt ranges are limited, and their carts are stationary on the tracks [14].

1.3 High-Level Requirements

- The light carts must be able to move independently from one another along the track and accelerate to a speed of 2 ± 0.5 inches per second.
- The directional light source must be able to pan 360 degrees around a vertical axis and tilt from 90 to 180 degrees from vertical upright.
- The control module must be able to turn on and off individual light bulbs when there are multiple carts on a track.

2. Design

The system has three major components as shown in Figure 1: the power system, the traversal system, and the mobile application interface. The power system converts wall power to 12 V dc to supply the electronics it is mounted with on one end of the track. From that end of the track, power and ground spring cables will run between the carts on the track. Each cart needs the 12 V dc for the light source and the servos. The 12 V dc is stepped down to 5 V dc at each cart to power the ATmega328P microprocessor and Bluetooth chip on each cart.

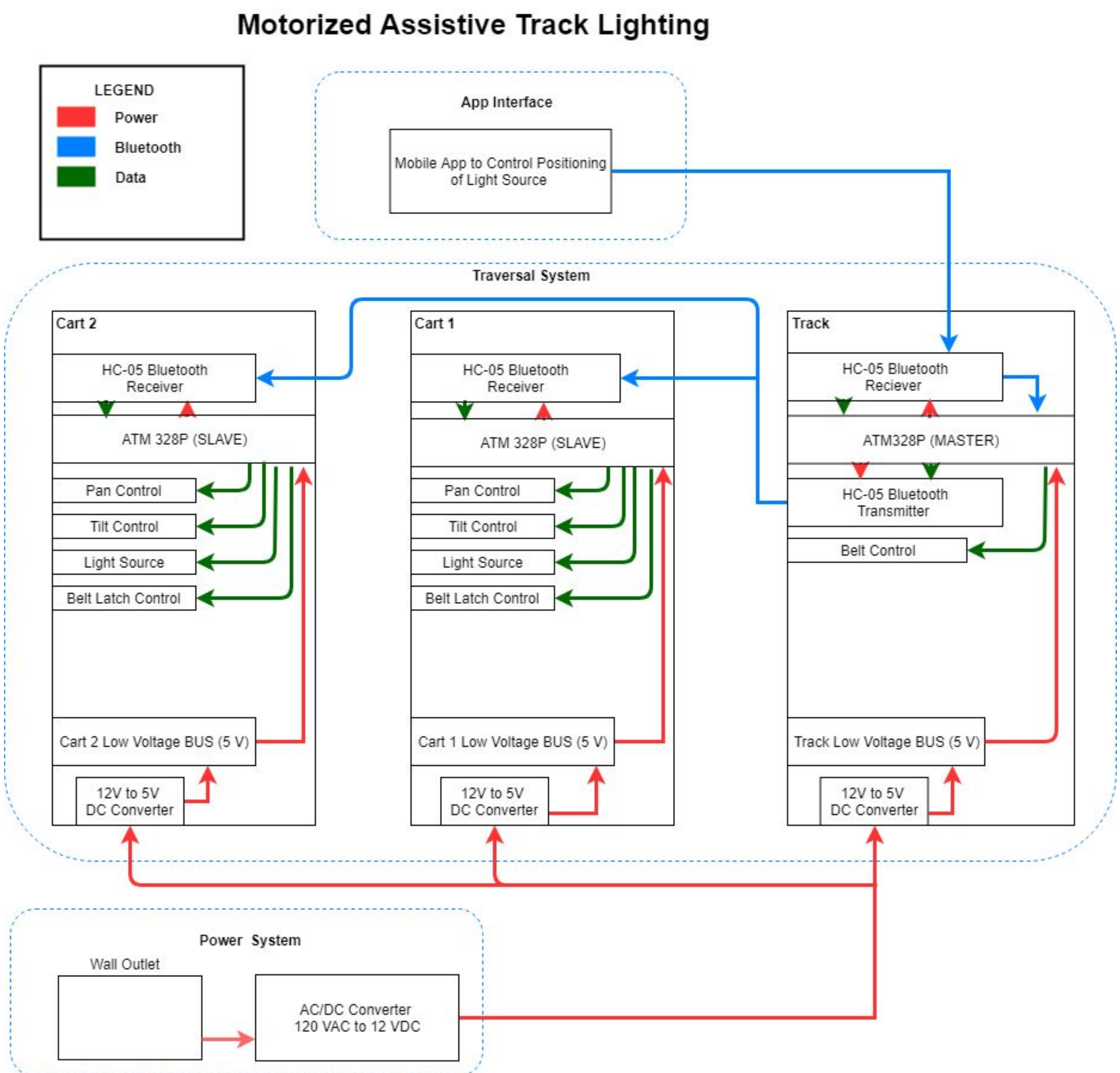

Figure 1. Block Diagram

The traversal system is comprised of the track and carts. Aluminum extrusion track is a cost-effective basis for linear motion systems, and we intend to use 1”x1” or 1.5”x1.5” T-slotted profile with four channels as the basis for ours as shown in Figure 2.

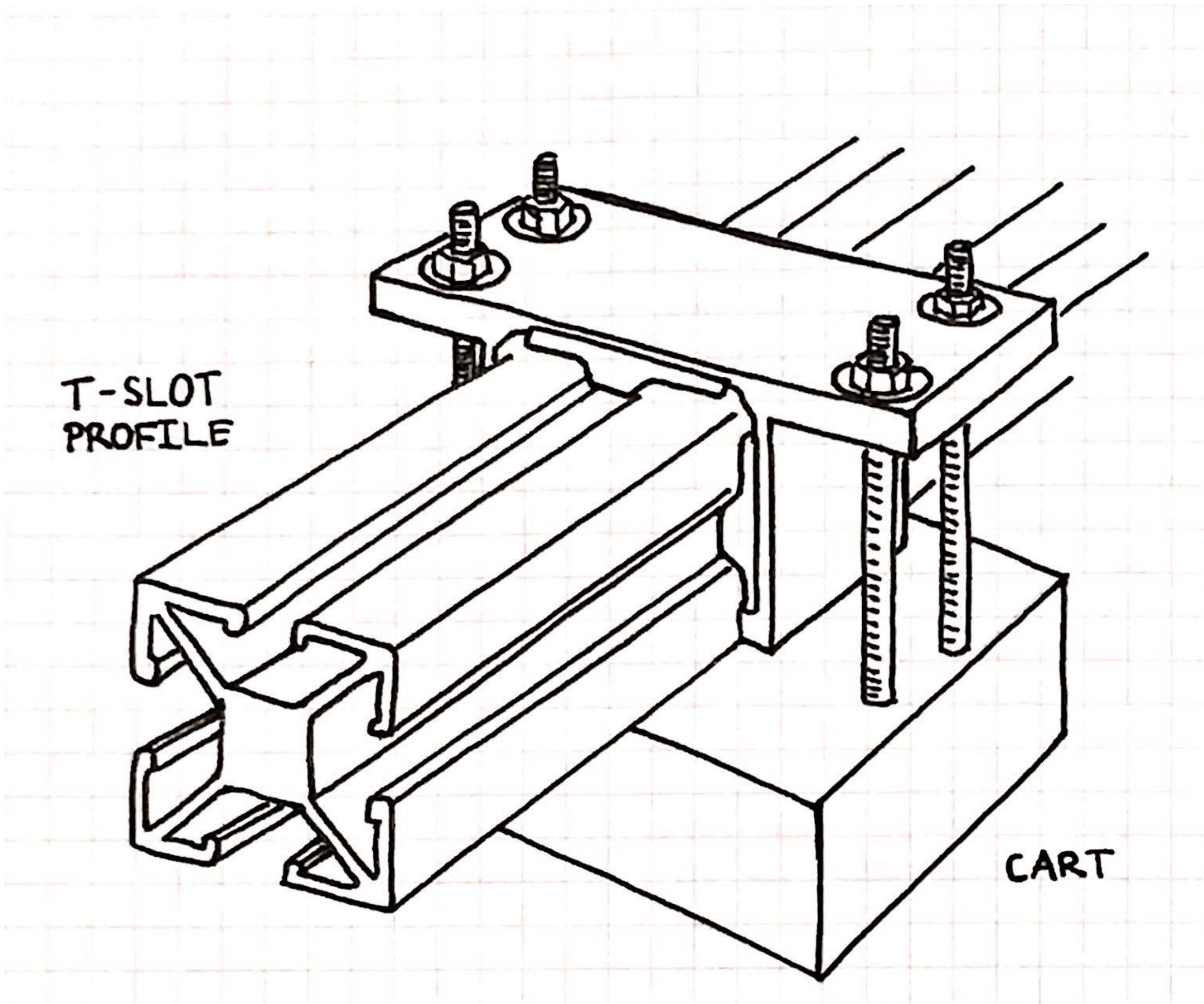

Figure 2. Cart-Track Interaction Design Sketch

At one end of the track will be the master node with an ATmega328P, Bluetooth transmitter and receiver, a stepper motor to drive a GT2 timing belt across the length of the track, and the 120 V ac to 12 V dc converter. The Bluetooth receiver pairs with a mobile device running the application interface, and the transmitters pair with the cart receivers to relay instructions to the correct cart.

The carts (side profile shown in Figure 3) each have a a PCB housing which contains an ATmega328P, Bluetooth receivers, DC-DC power converters to step 12 V down to 5 V, circuitry to control three servos (to pan, tilt, and latch), and a circuit to switch the cart's light source on and off. The PCB housing and pan/tilt kit are hung below a flanged linear bearing to allow driven sliding motion along the track. There is a servo latch mechanism, shown in Figure 4 (purposefully omitted from Figures 2 and 3 for clarity), mounted above each cart's linear bearing that is aligned with the GT2 timing belt. The latch allows carts to optionally traverse with the belt as it is driven by the stepper motor at the master node. Below the PCB housing on the cart is be an off-the-shelf kit designed to actuate panning and tilting of the light source with two standard size servos. The cart's light source will be attached to the end of the pan and tilt kit.

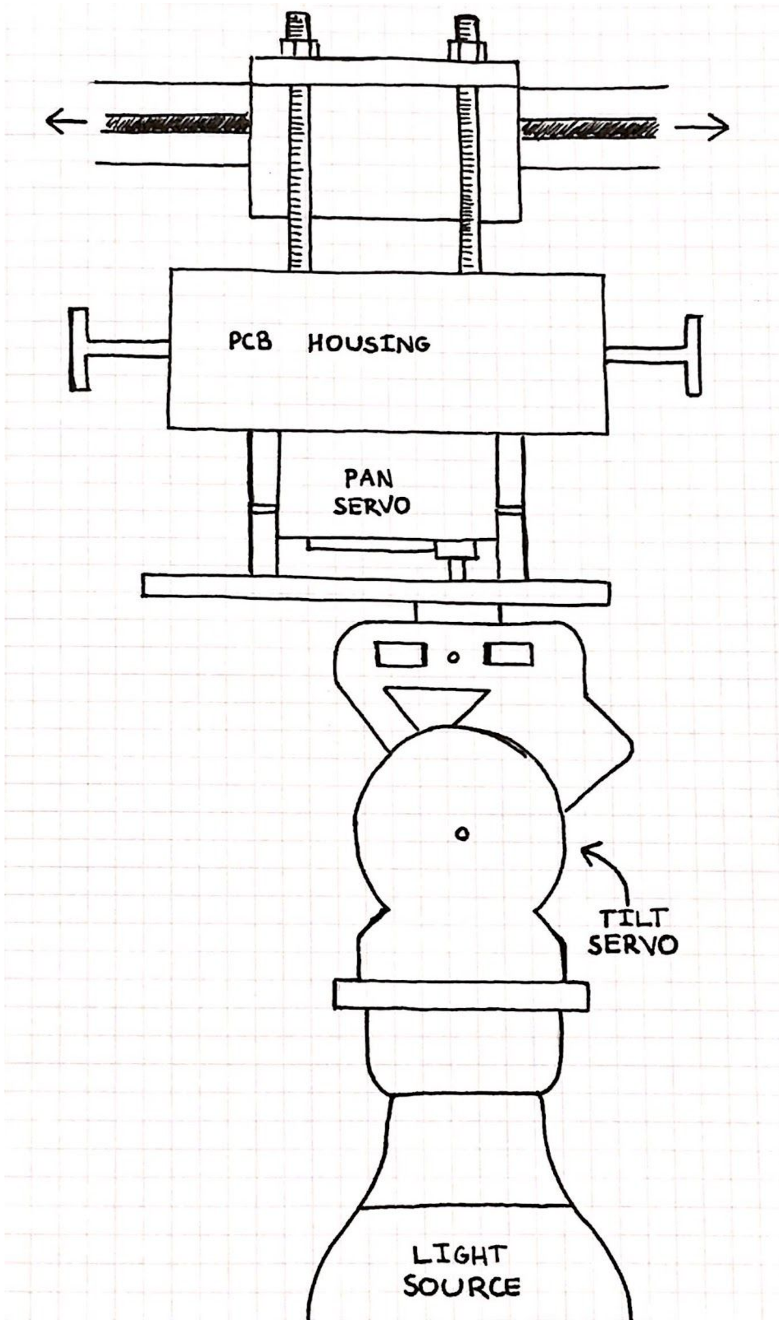

Figure 3. Cart Design Sketch

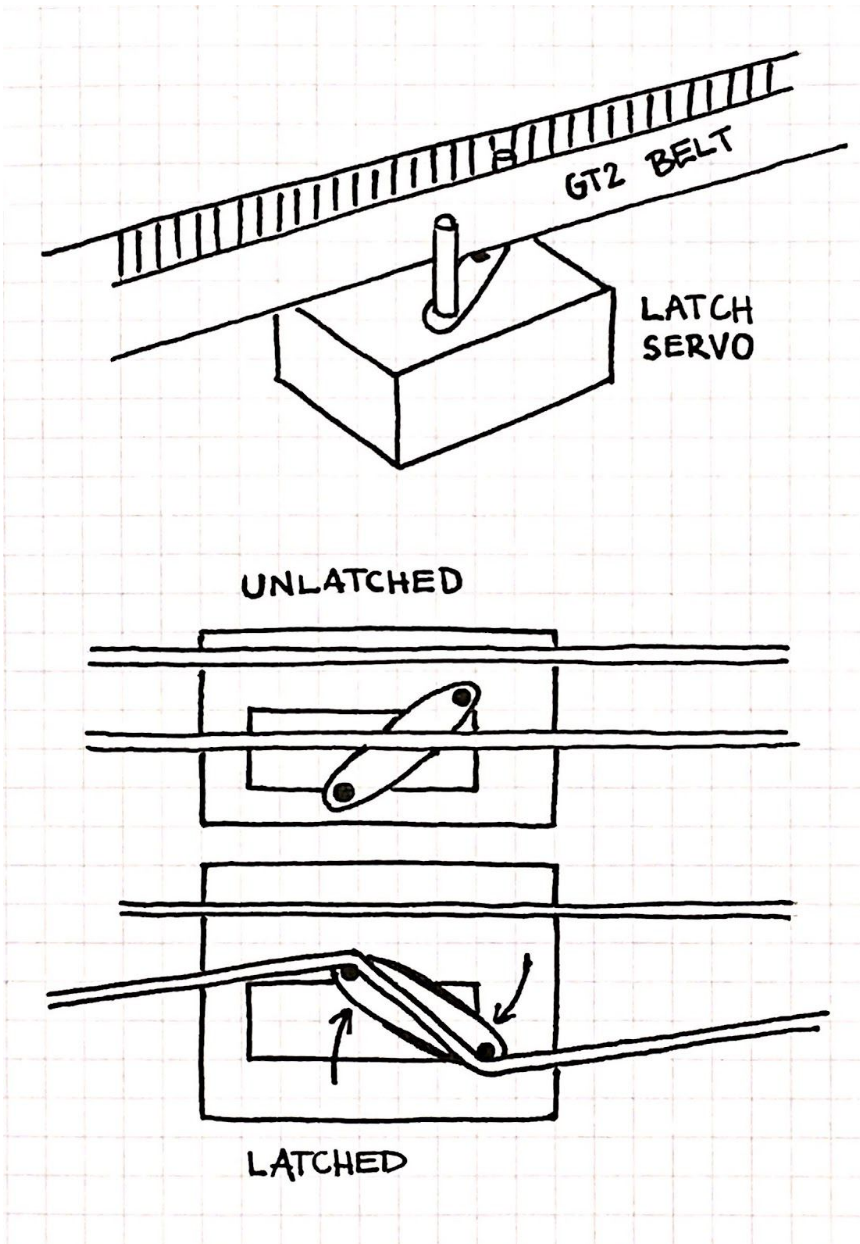

Figure 4. Servo Latching Mechanism

The application interface to our system will be a lightweight mobile application which we develop that provides an interface to select a cart and control it independently of the others. The app will implement a small communication protocol we devise that the master node will parse and relay to the correct cart.

2.1 Power System

The power system is responsible for providing power to all the other subsystems. It draws power from a wall outlet and distributes it to all the other components. This module is fixed to the end of the track with the system's master node. Additionally, this system distributes the 12 V dc output in serial to the carts.

2.1.1 Wall Outlet

The entry point for power to the system is the wall power supplying 120 V ac. This power will be converted to 12 V dc to power the voltage bus in our system.

2.1.2 AC-DC Converter

An off-the-shelf component to convert 120 V ac to 12 V dc.

Requirement	Verification
1. Convert 120 V ac power from the wall outlet to 12 V dc (±5%) needed to power the motorized track system	1. a. Plug the AC-DC converter into a standard 60 Hz 120 V dc grounded outlet b. Using a multimeter, verify that the voltage at the converter output is 12 V dc (±5%)

2.2 Traversal System

The traversal system consists of three ATmega328P processors: one master and two slaves. The app communicates with the master processor via Bluetooth, which relays the relevant information to the specified slave processor utilizing a bluetooth transmitter. The user sends commands through the application interface.

This design is expandable to accommodate up to six total light carts for additional configuration flexibility. As a result of the modularity of the design, a light cart can simply be mounted onto the track, and once power is supplied the device will be able to begin pairing operations with the track's master node.

2.2.1 Motorized Track

The motorized track operates by running a vertically mounted stepper motor to drive a GT2 timing belt across the top of the track. The motor must be able to run both forwards and backwards so we can drive the carts both directions using one latch. When a drive instruction is received by the master bluetooth node, the master node sends a latch instruction to the light cart selected by the user before beginning to run the timing belt motor. We aim to latch the cart to the belt within 1.5 seconds of the user sending a move request. After some small delay beyond the window reserved for the cart to latch, the stepper motor begins driving the belt in to actuate the user's instruction.

The operational circuitry is seen below for the track's master processor in Figure 5. The stepper motor driver that controls the belt motor and its corresponding wiring configuration can be seen in Figure 6. The digital inputs D1, D2, and D3 set the stepping modes of the stepper motor.

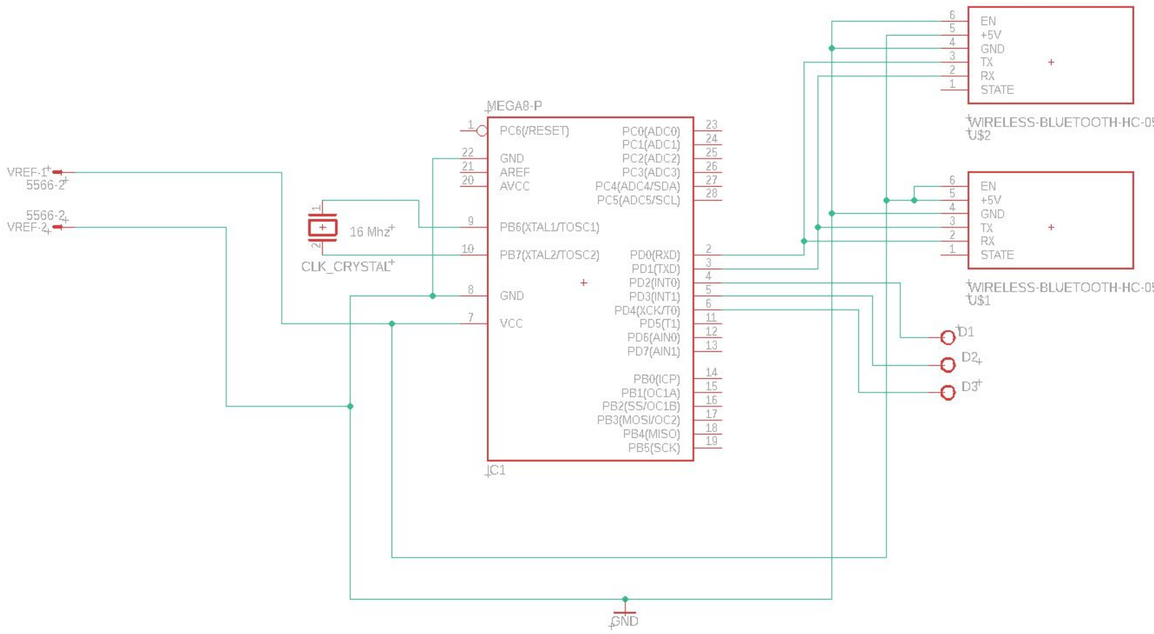

Figure 5. Track Module Communication Circuit Schematic

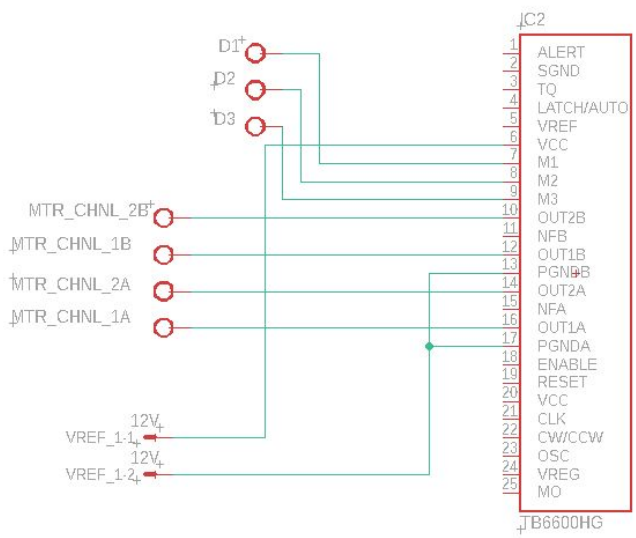

Figure 6. TB660 Stepper Motor Driver Schematic

Requirement	Verification
1. The track stepper motor driver must be able to receive forwards and reverse	**1. With an oscilloscope:** a. Validate the signal produced by

<table>
<tr><td>signals from the master ATmega328P

2. The track motor must be able to move forwards and backwards on command from signals sent from the master ATmega328P</td><td>the ATmega328P being sent to the motor drivers against datasheet for the driver [10]
b. Validate the signals produced by the motor drivers to accelerate the stepper motor to cart cruising speed of 2±0.5 in/s
2.
a. The torque must overcome the coefficient of friction of UHMW against aluminum, (μ=0.1-0.2) times the weight of the light cart
b. The forward drive signal must make the motor rotate the correct direction (without loss of generality) to move a latched cart away from the motorized end
c. The reverse drive signal must make the motor rotate the opposite direction as the forward drive signal to move a latched cart towards the motorized end</td></tr>
</table>

2.2.1.1 HC-05 Bluetooth Receiver/Transmitter

For all our Bluetooth communication in this system, we are using the HC-05 chip [3], a Bluetooth Serial Port Protocol (SPP) module capable of wireless serial communication. This Bluetooth receiver is responsible for receiving the user's instructions sent from the app and will be located on our master node's PCB.

The instructions we need to encode will command the light carts to perform these functions:

- Toggle power to light source
- Pan the light source
- Tilt the light source
- Latch on to the traversal belt
- Move the cart forwards and backwards

<table>
<tr><th>Requirement</th><th>Verification</th></tr>
<tr><td>1. Receive an instruction that will be in the form of a sequence of bits</td><td>1.
a. Using a power supply set to 5.0V and 50 mA, power the HC-05 chip
b. Connect to the HC-05 through Bluetooth using a laptop
c. Create the test circuit shown in</td></tr>
</table>

	[3] d. Follow the rest of the step outlines in [3] e. Ensure that the information f. Connect an oscilloscope to the Rx pin of the HC-05 chip g. Ensure that the sequence displayed on the oscilloscope matches the sequence sent
2. Transmit an instruction that will be in the form of a sequence of bits	2. a. Using a power supply set to 5.0V and 50 mA, power the HC-05 chip b. Connect an oscilloscope to the Tx pin of the HC-05 chip c. Send the ascii value "a" through the serial communication software d. Ensure that the sequence displayed on the oscilloscope matches the sequence sent

2.2.1.2 Master ATmega328P Processor

The master ATmega328P Processor will be located on the Track PCB. It will be responsible for relaying the instructions it receives from the app to the specified slave ATmega328P Processors.

Requirement	Verification
1. Processor must be capable of utilizing serial port to write data	1. Write Process a. Mount ATM 328 processor to a base arduino launchpad. b. Power the device via usb connection to a computer c. Connect the Tx output line of the processor to an oscilloscope channel and ground the other lead. d. Utilizing the Arduino IDE, upload the tutorial serial test sample sketch[] to the board. e. Run the application f. Open the Arduino serial interface inside the IDE g. Send the ascii char "a" through

	the interface. h. Verify that the output on the oscilloscope side displays 0100 0001 by observing the rising and falling edges of the data stream passed in.
2. Processor must be capable of utilizing serial port to read data	2. Read Process a. Mount ATM 328 processor to a base arduino launchpad. b. Power the device via usb connection to a computer c. Configure a function generator to output a 3.3V, 1.65v offset, 1kHz, 50% duty cycle square wave. Connect the positive lead to the Tx line of the processor. d. Utilizing the Arduino IDE, upload the tutorial serial test sample sketch [] to the board. e. Run the application f. Open the Arduino serial interface inside the IDE g. Check to see that a sequence of 1's is received on the serial port followed by a sequence of zeros, representing the square waveform.

2.2.1.2 HC-05 Bluetooth Transmitter

The HC-05 transmitter is dedicated to sending instructions from the master node to the carts. We're using a Bluetooth piconet to communicate between the master node and the carts (slaves) to avoid the signal loss over distance we would experience through long jumper wires which would otherwise be required to allow the carts to drive away from the master node.

Requirement	Verification
1. Receive an instruction that will be in the form of a sequence of bits	1. a. Using a power supply set to 5.0V and 50 mA, power the HC-05 chip b. Connect to the HC-05 through Bluetooth using a laptop c. Create the test circuit shown in [3] d. Follow the rest of the step outlines in [3]

2. Transmit an instruction as a sequence of bits defined in Table	e. Ensure that the information f. Connect an oscilloscope to the Rx pin of the HC-05 chip g. Ensure that the sequence displayed on the oscilloscope matches the sequence sent 2. a. Using a power supply set to 5.0V and 50 mA, power the HC-05 chip b. Connect an oscilloscope to the Tx pin of the HC-05 chip c. Send the ascii value “a” through the serial communication software d. Ensure that the sequence displayed on the oscilloscope matches the sequence sent

2.2.1.3 Belt Control

The belt control consists of a stepper motor used to move the GT2 timing belt that individual carts can latch onto to be pulled along the track. This stepper motor is driven by a Toshiba TB6600HG bipolar stepping motor driver. This belt control module can drive the motor in both directions, as the carts will need to be able to move both forwards and backwards along the track.

Requirement	Verification
1. Move the belt away from the stepper motor 2. Move the belt towards the stepper motor	1. a. Use a power source set to 12 V dc to power the stepper motor b. Using a function generator, send a forward command to the stepper motor driver c. Ensure that the stepper motor moves in a CW motion d. Using an multimeter, probe the input channel A+ and A- with positive and negative leads respectively e. Repeat same instruction for channel B+ and B-. Voltage should be high in the CW direction 2. a. Use a power source set to 12 V dc to power the stepper motor

	b. Using a function generator, send a forward command to the stepper motor driver c. Ensure that the stepper motor rotates CCW

2.2.1.4 Track Low Voltage Bus

This bus is responsible for powering the master ATM 328 processor with 5 V dc as well as provide the source for other low voltage peripherals on the PCB.

Requirement	Verification
1. Provide uninterrupted power of 5 V dc (±5%) to the master ATmega328P Processor	1. a. Connect the low voltage bus to a power source set to 5 V dc. b. Using a voltmeter, verify that the bus is supplying a steady voltage of 5 V dc (±5%)

2.2.1.5 12V to 5V DC-DC Converter

An off-the-shelf DC-DC component to convert 12 V dc to 5 V dc to power the ATmega328P Processors.

Requirement	Verification
1. Convert 12 V dc (±5%) to 5 V dc (±5%)	1. a. Connect power supply set to 12 V dc to the input of the converter b. Using a voltmeter, verify that the output voltage is within 5% of 5 V dc

Note: In requirement 1, there is a tolerance of 5% on the input voltage of 12 V because in the system, the input comes from the 120VAC-12VDC converter (section 2.1.2)

2.2.2 Cart 1

Each cart houses a light source and the motors on this cart should be able to do these things on command from its on system processor:

- Toggle power to the light source
- Pan the light source
- Tilt the light source
- Latch on to the timing belt

The cart module circuitry is designed as seen in figures 7–9 below:

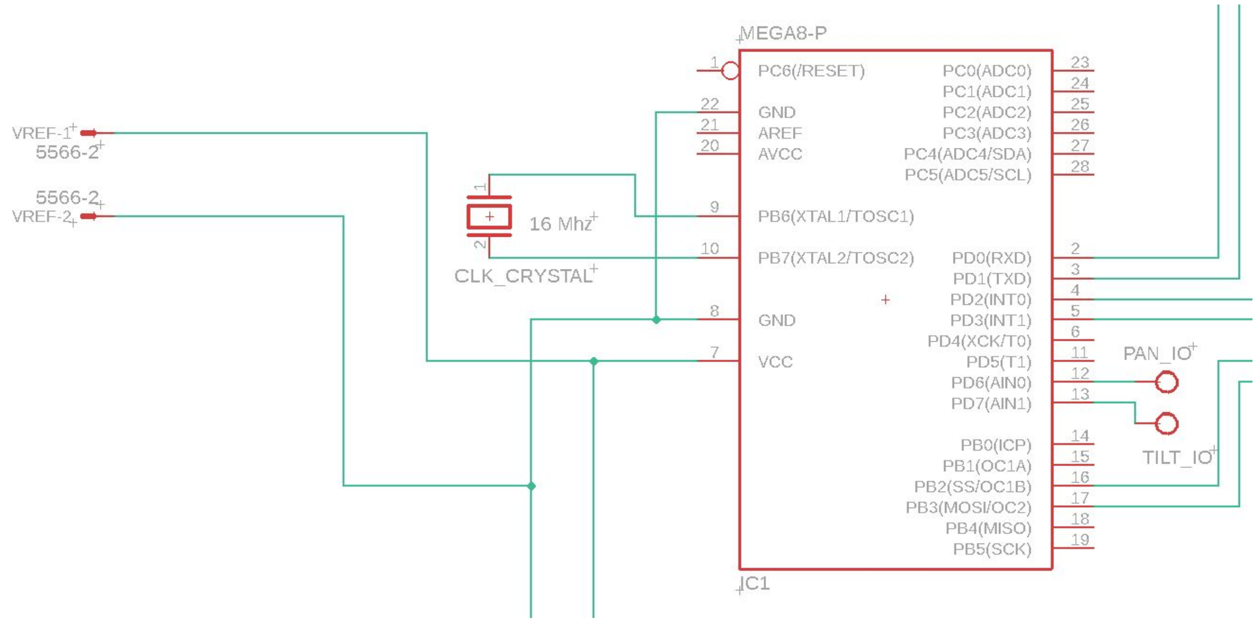

Figure 7. ATmega328P Setup for each Slave processor

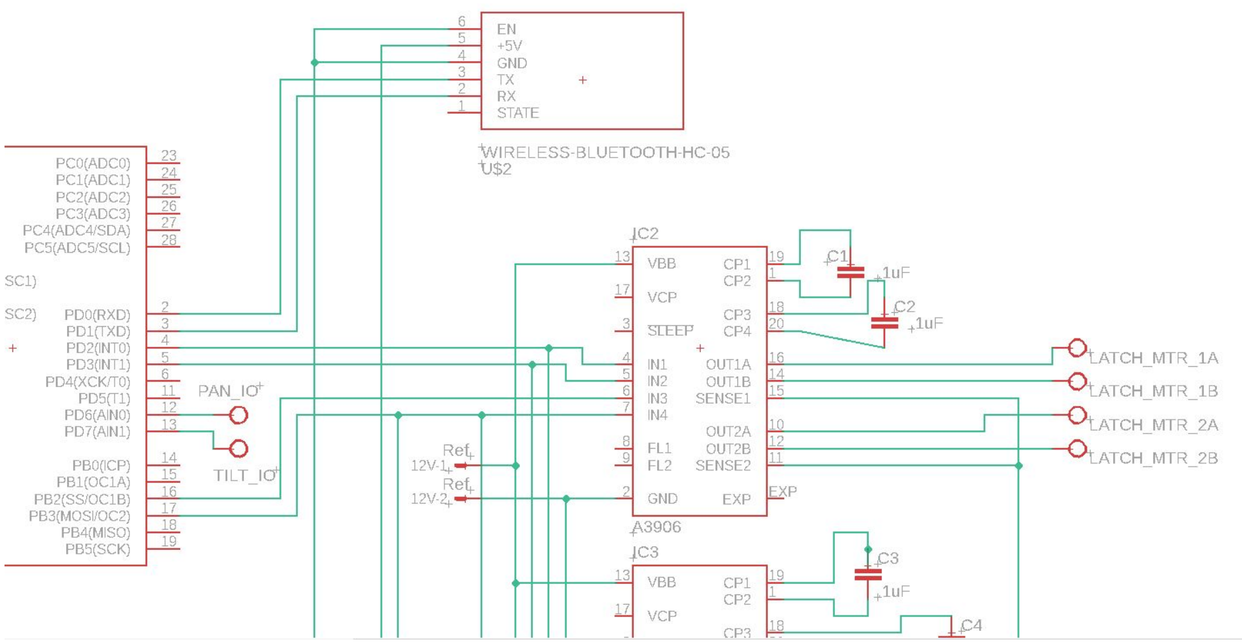

Figure 8. I/O Layout for HC-05 Module and Motor Driver for Latch Control.

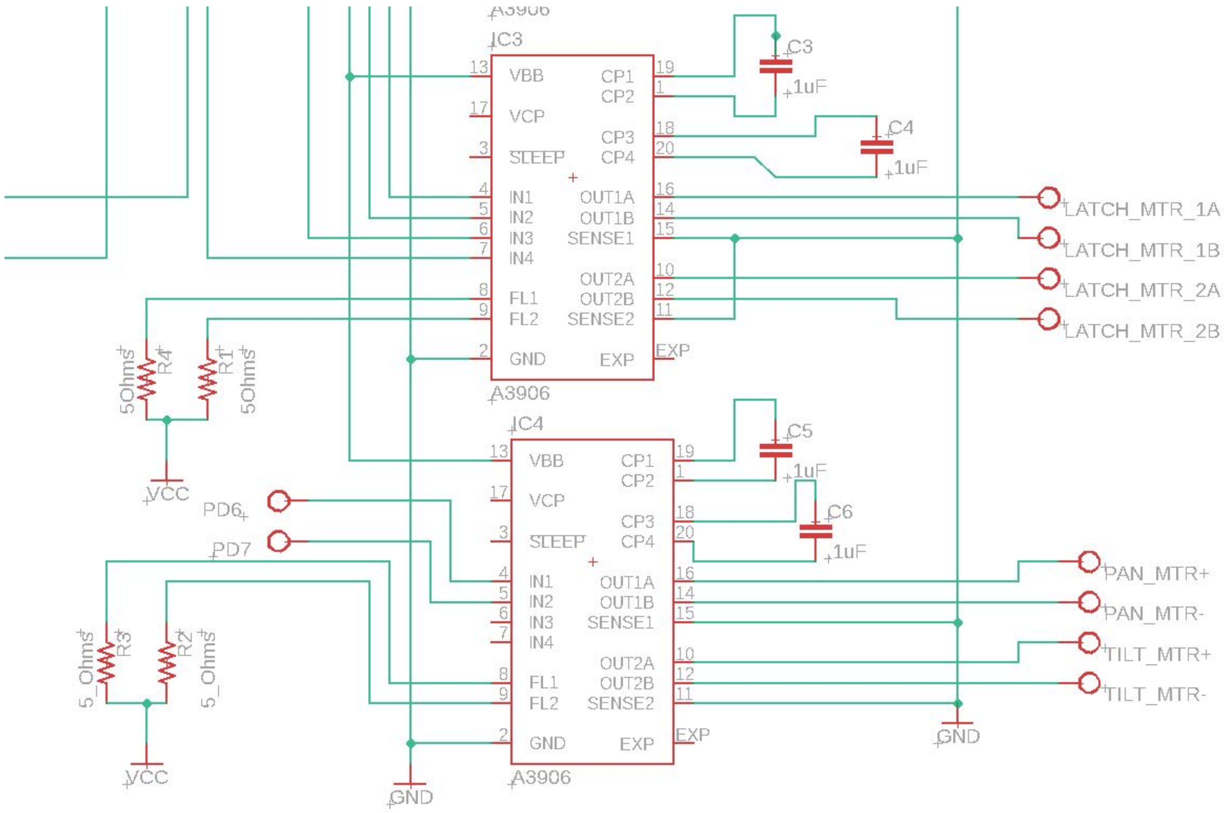

Figure 9. Motor Driver that corresponds to latch 2 as well as the

NOTE: Both latch drivers require the same output direction/load to ensure successful operation

Requirement	Verification
1. The latching servo motor(s) must be able to latch on command from its respective slave ATmega328P 2. The pan servo must be able to pan on command from its respective ATmega328P 3. The tilt servo must be able to tilt on command from its respective slave ATmega328P	1. a. Servos should actuate arms to pinch the belt within 1.5 seconds to maintain the responsiveness of the system b. Effective latching means the pinching force overcomes the force required to overcome the static coefficient of friction of the linear bearing on the track 2. a. Full 360 degrees or +/-180 3. a. Tilt +/-90 or tilt 90 to 180 from +z

2.2.2.1 HC-05 Bluetooth Receiver

This HC-05 Bluetooth receiver is located on the cart PCB and is responsible for receiving instructions from the HC-05 Bluetooth Transmitter located on the master node's PCB (section 2.2.1.1). The instructions that this chip will receive include:

- Toggle power to light source
- Pan the light source
- Tilt the light source
- Latch on to the traversal belt

Requirement	Verification
1. Receive an instruction that will be in the form of a sequence of bits	1. a. Using a power supply set to 5.0V and 50 mA, power the HC-05 chip b. Use a barebones test application on an ATmega328P to send data from one Bluetooth transmitter to the Bluetooth receiver in question c. Connect an oscilloscope to the Rx pin of the HC-05 chip d. Ensure that the sequence displayed on the oscilloscope matches the sequence sent

2.2.2.2 ATM 328 Processor (Slave)

This slave processor will be located on the track PCB. It will receive instructions from the HC-05 Bluetooth Receiver (section 2.2.2.1) and then control the respective subsystem.

Requirement	Verification
1. Processor must be capable of utilizing serial port to write data	1. Write Process a. Mount ATM 328 processor to a base arduino launchpad. b. Power the device via usb connection to a computer c. Connect the Tx output line of the processor to an oscilloscope channel and ground the other lead. d. Utilizing the Arduino IDE, upload the tutorial serial test sample sketch[] to the board. e. Run the application

	f. Open the Arduino serial interface inside the IDE g. Send the ascii char “a” through the interface. h. Verify that the output on the oscilloscope side displays 0100 0001 by observing the rising and falling edges of the data stream passed in.
2. Processor must be capable of utilizing serial port to read data	2. Read Process h. Mount ATM 328 processor to a base arduino launchpad. i. Power the device via usb connection to a computer j. Configure a function generator to output a 3.3V, 1.65v offset, 1kHz, 50% duty cycle square wave. Connect the positive lead to the Tx line of the processor. k. Utilizing the Arduino IDE, upload the tutorial serial test sample sketch [] to the board. l. Run the application m. Open the Arduino serial interface inside the IDE n. Check to see that a sequence of 1’s is received on the serial port followed by a sequence of zeros, representing the square waveform.

2.2.2.3 Pan Control

The pan control gives the light source a degree of freedom in φ of canonical spherical coordinates. This subsystem makes use of a pan and tilt kit with two servos [4] in order to effect this range of motion.

Requirement	Verification
1. Rotate the pan servo from [4] through the full range of motion [-180, 180] degrees (or [0,360]) (±5%)	1. a. Using a power source set to 5 V dc and 150 mA, power the pan servo b. Using a function generator, send a high signal to the servo control pin. c. Use a protractor to ensure that the servo rotates through its full range

	of motion: 360 degrees (±5%).

2.2.2.4 Tilt Control

The tilt control gives the light source a degree of freedom in θ of canonical spherical coordinates. This subsystem makes use of a pan and tilt kit with two servos [4] in order to effect this range of motion.

Requirement	Verification
1. Rotate the tilt servo from [4] through its full range of motion [180, 90] (±5%) from vertical	1. a. Using a power source set to 5 V dc and 150 mA, power the pan servo b. Using a function generator, send a high signal to the servo control pin c. Use a protractor to ensure that the servo rotates through its full range of motion: 90 degrees (±5%)

2.2.2.5 Light Source

The light source consists of an LED light bulb with roughly 800 lumens. The light bulb will be connected to a small circuit involving a FET and a resistor which will allow us to turn the light on and off.

Requirement	Verification
1. Turn the LED light bulb on	1. a. Connect the LED light bulb to the test circuit b. Using a function generator, connect the gate pin of the FET to a constant voltage of 2.0 V dc c. Ensure that the light bulb turns on
2. Turn the LED light bulb off	2. a. Connect the LED light bulb to the test circuit b. Using a function generator, connect the gate pin of the FET to a constant voltage of 0.0 V DC c. Ensure that the light bulb turns off

2.2.2.6 Belt Latch Control

The belt latch control consists of a servo that has two standoffs attached to its arms as shown above in Figure 4. It rotates to deflect the GT2 belt around the two standoffs so that the cart is effectively connected to the belt.

Requirement	Verification
1. The latch stepper motor is able to deflect the belt 20 degrees (±5) to transmit the belt's motion to the cart	1. a. Using a power source set to 5 V and 100 mA, power the latching servo b. Using a function generator, connect the signal pin to 5 V dc c. Measure belt deflection with a protractor d. Iterate on the value in this requirement experimentally with a range of weights (0-8 lbs) hanging below the bearing to simulate carts of different weight

2.2.2.7 Cart Low Voltage Bus

The processor and Bluetooth module require 5 V dc.

Requirement	Verification
1. Provide uninterrupted power of 5 V dc (±5%) to the carts respective slave ATmega328P Processor	1. a. Connect the low voltage bus to a power source set to 5 V dc. b. Using a multimeter, verify that the bus is supplying a steady voltage of 5 V dc (±5%)

2.2.2.8 12V-5V DC Converter

The light source and motors require 12 V dc, but as stated in 2.2.2

Requirement	Verification
1. Convert 12 V dc (±5%) to 5 V dc (±5%)	1. a. Connect power supply set to 12 V dc to the input of the converter b. Using a multimeter, verify that the output voltage is within 5% of 5 V dc

2.2.3 Cart 2

The requirements and respective verification procedures are identical for each light cart on the motorized track. Refer to section 2.2.2.

2.3 App Interface

The application interface portion of the block diagram in figure 1 is the high level interface between the motorized track system and the user. It is a react native application with Bluetooth connectivity. The user will be able to communicate instructions to the master node's ATmega328P processor over Bluetooth. A possible structure for the app's UI layout with buttons to designate the different lateral directions can be seen in figure 10.

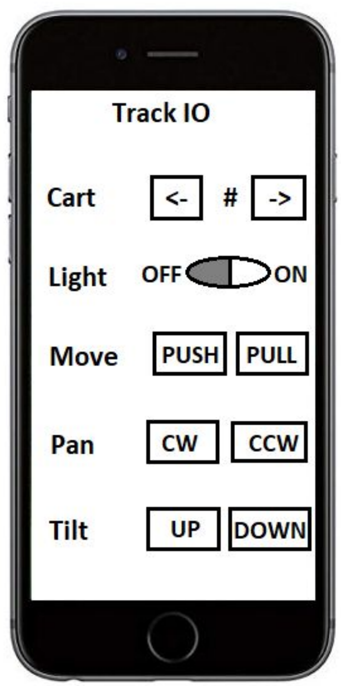

Figure 10. App UI Layout for Functionality Testing

There are five commands can be sent by the user as shown in the application UI mockup in Figure 10. The application will allow the user to change the cart to control based on toggling the '<–' and '–>' buttons for decrease and increase along the track. The light for that specific cart can also be set to the on and off state utilizing the Light switch button. The Movement, Pan, and Tilt operations all utilize two buttons (for the opposite actuation) that when pressed tell the program to relay the appropriate movement instruction to the selected cart. These Instructions are sent in 8 bit instructions over bluetooth. Utilizing a 9600 baud rate, the ATMega processors will receive and parse the byte of data utilizing the addressing table seen in Figure 11 below.

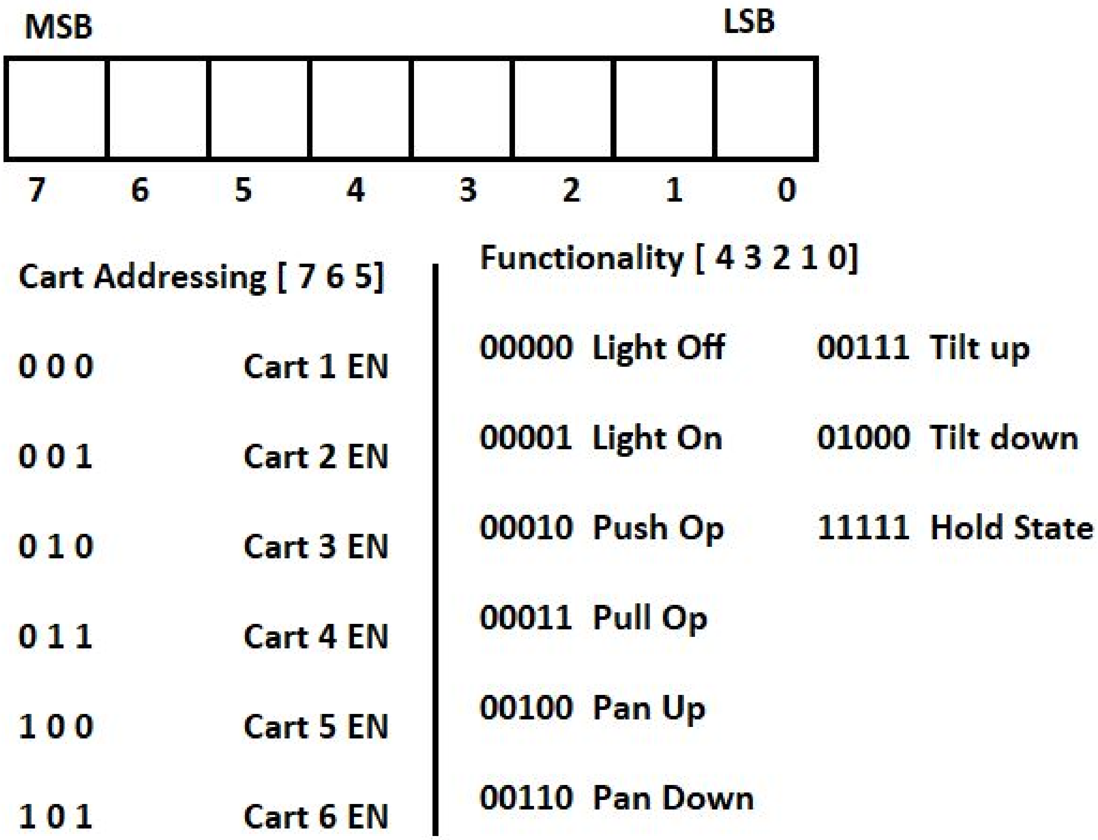

Figure 11. Instruction table for how data is partitioned in each sent instruction.

From the perspective of data transmission and flow, the full byte is received by the master ATmega328P processor from the master node's Bluetooth receiver. To transmit the appropriate instructions to the relevant cart, the master processor reads at the three most significant bits to determine which slave processor needs to be transmitted the configuration data. The master processor then sends the byte to the slave processor of the address set by the user's cart selection.

To decode the relevant instructions for each operation, the remaining 5 bits are split into the configurations above. Each one affects only a single action in the system while holding all other current settings in place.

Requirement	Verification
1. An instruction should be carried out on the selected cart within 1.5 seconds of being sent from the app	1. a. Using a power source set to 5 V and 50 mA, power the test HC-05 chip

  2. Connect to the test HC-05 Bluetooth Module within 10(±2) seconds	b. 2. a. Using a power source set to 5 V and 50 mA, power the test HC-05 chip b. Check that the app is not connected to the test HC-05 chip c. Start stopwatch d. Initiate connection sequence from the app e. Stop stopwatch once connection confirmation is received f. Ensure that the connection process took less than 10 (±2) seconds

2.9 Tolerance Analysis

One of the major points of emphasis in our design of this system is scalability to more than two carts and to longer runs of track. When scaling size up, we don't want the utility of the system to diminish for the user. One trait of the system which we need to characterize better through both simulation and later experimentation is the speed and acceleration of a cart as it's being moved along the track.

When the track is six feet long, it's acceptable for a single cart to drive perhaps an inch or half an inch per second. In the six foot case, it would already take one to two minutes to move a cart across the length of track! If, however, the track were twenty feet long, the time to move each of the carts balloons to unreasonable lengths. If the user has to spend five to ten minutes waiting for one of six carts to drive across the track, the utility of our product decreases greatly.

Because we're using stepper motors and 2mm GT2 timing belts, we can efficiently quantify the distance that the cart travels per step of the motor. Our NEMA-17 stepper motor makes one revolution per 200 steps. The neoprene GT2 belt has a pitch of 2mm, where pitch is the separation between teeth on the inside surface of the belt. Then we need to select a drive pulley for the stepper motor with a number of teeth that translates the number of steps per rotation into a movement speed that upholds the utility of our project even when scaled beyond our implementation this semester.

At 200 steps/rotation * 2000 steps/second we get 10 rpm
10 rpm * 36 teeth/pulley = 360 teeth per second
360 teeth/second * 2mm/tooth ~= 29 inches per second, much faster than what we need, and perhaps unsafe!

Unfortunately we needed to pause here in our analysis. Graphs/viz/sim to come

3. Cost Analysis

3.1 Material Costs:

Material/Part	Length	Quantity	Unit Cost($)	Total Cost($)
HC-05 Bluetooth Receiver/Transmitter	N/A	4	$7.41	$29.64
ATmega328P	N/A	3	$3.78	$11.34
5 V regulator	N/A	3	$7.00	$21.00
120 V ac to 12 V dc Converter	N/A	1	$ 28.22	$ 28.22
SPT200 Pan & Tilt Kit	N/A	2	$45.99	$91.98
16 MHz crystal	N/A	2	$0.30	$0.60
Nema 23 Stepper Motor	N/A	1	$26.00	$26.00
Toshiba TB6600 Driver	N/A	1	$29.00	$29.00
GT2 Timing Belt (inventables 26053-03)	4 m	1	$20.00	$20.00
80/20 T-Slot Channel (1515-ULS)	72 in	1	$30.03	$30.03
A3091 MTR driver	N/A	6	$1.32	$7.92
D645-MW Servo	N/A	2	$39.99	$79.98
D645-MW Servo (continuous rotation)	N/A	2	$59.99	$119.98
A19 LED Bulb 12 V dc 820 lumens	N/A	2	$9.95	$19.90
			Estimated Total Cost	$507.59

Figure 12. Table of Projected Materials Costs

3.2 Design Labor Costs:

For the purposes of estimating labor cost, the national average for an Electrical Engineer was slightly more than $71,000/year [6]. For the sake of simplicity 71,000 will be used for the annual salary and the hourly rate can be determined from the computation below:

$71,000 / 40 hours / 52 weeks = $34.13/hr.

Hourly Rate :

Name	Rate ($/hr)	Hours/Week (10 weeks)	Sum($)
Pratik Ainapure	$34.13/hr	20	6,826
Adithya Bellary	$34.13/hr	20	6,826
Ethan Hickman	$34.13/hr	20	6,826
Total Labor Cost			$20,478
Adjusted Labor Cost (Total Labor Cost x 2.5)			$51,195

Figure 13.

After taking into consideration of both material and labor cost, the total estimated cost to implement to develop this motorized track lighting system is: $51,702.59

4. Schedule

Week	Adithya	Ethan	Pratik
2/17- 2/23/2019	Research Bluetooth communication	Discuss track design options with the ECE metal shop	Purchase test components for cart bluetooth configuration
2/24 - 3/02/2019	Create version 1 of app	Begin sourcing mechanical components	Begin developing PCB version 1
3/03 - 3/09/2019	Test version 1 app with small-scale circuit	Begin build of light cart module #1	Revise circuit designs and begin version 2 pcb design
3/10 - 3/16/2019	Create version 2 of app	Complete build of light cart module #1 and begin unit testing.	Complete Final PCB design and submit order

3/17 - 3/23/2019	Test version 2 of app with small-scale circuit	Wait for track system to be finished being machined and begin prototyping necessary revisions to light carts	Purchase remaining circuit components for cart 2
3/24 - 3/30/2019	Integrate app with existing prototype	Implement revisions to light cart and Integrate light cart 1 with track system	Solder board and unit test PCB's
3/31 - 4/06/2019	Fix bugs	Begin build and testing of light cart 2	Continue work from previous week
4/07 - 4/13/2019	Continue work from last week	Continue work from last week	Integrate control into final design
4/14 - 4/20/2019	Finalize app specifications and UI	Integrate cart 2 with track	Continue work from last week
4/21 - 4/27/2019	Run final tests on system control		
4/28 - 5/02/2019	Prepare Final Presentation and Complete Final Report		

5. Ethics and Safety

Ethics

Throughout the development of this product design, we will regularly consult the IEEE Code of Ethics [1] to ensure that the final product that we create aligns with this Code established by IEEE. We understand that there are safety hazards regarding this product and therefore will abide by the statement #1 "hold paramount the safety...of the public". Appropriate safety circuitry and mounting practices will be implemented. Individual components will be verified to reduce the chance of malfunction and injury. The safety considerations that were made are expanded in greater detail in the following safety section.

Safety

There are several safety considerations to be made regarding this product. One potential hazard would be the manner in which we are powering the system as whole. We are designing the product to draw power from a standard wall outlet, which is 120VAC. The individual components on our track take in DC voltage, so we will need to use a AC-DC transformer. This could be potentially dangerous, so appropriate safety circuits will be put in place. Light bulbs could also pose a fire hazard in the case that they overheat. The Led bulbs will be regulated to ensure that they operate under their 60 watt maximum rating.

An additional consideration to be made is in the event of current overdraw or power loss from the source. Depending on whichever part of the world this product is being installed, there is a possibility of random power fluctuations due to less stable power infrastructure that would significantly hamper the functionality of this system.

To minimize the impact of power spikes and loss, this system was designed with the intentional selection of parts with higher power ratings to minimize damage from overdrawing current. In the event of a power failure. The system will likely need to be reconfigured to determine it's zero positions. Currently, the only portion of the system that does get saved is the addressing between the master and slave processors on the track system and the software that will be flashed onto each processor.

To allow the user more flexibility in their lighting configuration, the system must allow the user to add and remove carts. To ensure safety when making modifications to the system, removing the outlet plug to the power source to ensure electrical hazards can be minimized is crucial in ensuring safety. In addition, the base track must be sturdy enough given the specified length to hold up a 1 light cart module per 5 ft. The materials chosen for the track were picked to minimize deflection of adding additional modules.

This track system will be mounted from the ceiling and therefore could possibly come in contact with water from a ceiling sprinkler or any residual moisture, so the casing that will contain the power and control modules will need to adhere to at least IP65 guidelines [2].

Another safety consideration to be made is security. The user connects to the track system through Bluetooth communication, theoretically anyone in the vicinity could connect to it. In order to prevent any unauthorized users from controlling the track system, we will be implementing the bluetooth password pairing functionality at a minimum with the possibility of integrating additional security functionality if time permits. This will keep anyone with malicious intentions from connecting to the device and potentially misusing and/or damaging it.

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