Automated Retraction Coaster Slide
(ARC Slide)
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Abstract

Joey Toce is a 6 year old boy who suffers from cerebral palsy; a condition which inhibits his ability to fully control his posture and limbs. Joey enjoys playing outdoors, but is in need of custom recreational equipment. The overall purpose of this project is to design and build a modified slide coaster for Joey. This slide, named the Automatic Retracting Coaster (ARC) Slide, will give Joey a safe and enjoyable means to play outdoors.

The ARC slide will have a custom car for Joey to safely sit in; fully equipped with a harness and leg supports. The coaster will have a controllable winch mechanism to connect to the rear of the car to pull Joey back to the top of the slide. Once the cart is hooked to the winch, the motor will be turned on and off using a wireless remote, or by depressing a switch located near the motor. As the car reaches the top of the hill, the motor will turn off automatically once sensing feedback from a photoelectric sensor. From that point, the winch will disengage from the car and Joey will be allowed to safely slide down the coaster. Lastly, the top of the slide will have an automatic rear tilt, also controlled using a wireless remote. This feature will slightly tilt the top rear of the platform to a small angle such that the car can begin its decent without needing to be manually pushed. Currently, there are no slides similar to this design on the market. Thus, this project will give the client, Joey, a fun, unique, and safe recreational slide for him to play on.

1. Introduction

The Automated Retracting Coaster (ARC) Slide is an adaptable recreational slide created for people with motor control disabilities. Specifically, the ARC Slide is designed for a 6 year old male, Joey Toce. Joey Toce suffers from cerebral palsy, a condition which inhibits his capability to fully control his posture or limbs. Because of his condition, Joey has trouble sitting upright, controlling spastic movement of his arms and legs, and making small gestures at will. Like any six year old, Joey enjoys playing outdoors, and is in need of custom recreational equipment to accommodate his activities.
1.1. Background

Joey is a six year old male with Cerebral Palsy. For a reason undetermined, he has a damaged cerebellum- the portion of the brain responsible for motor function. Due to his condition, Joey does not have full control of the muscles in his torso and limbs. Although he has the muscular potential to sit upright, walk, or move his arms and legs for everyday tasks, the damaged neuromuscular path hinders his ability to control those muscles at will. Joey’s torso naturally slouches, and without supports or harnesses, he is unable to sit in an upward position. Furthermore, he cannot walk without an assisting device, and often kicks his legs when expressing emotion. Joey is small for his age and is not expected to grow a significant amount in the near future. Currently, he is 3 feet tall and weighs 35 pounds.

Despite his disability, Joey is an active and healthy 6 year old, and is in need of recreational equipment to allow him to safely play outdoors. In the past, he has played on an outdoor slide called the Extreme Coaster by Step 2. This slide consists of a small car to sit in while traveling down the track. Although Joey enjoyed playing on the Extreme Coaster, it lacked many features that are necessary for Joey's safety. Primarily, the extreme coaster was not equipped with harnesses or supports to maintain his posture while traveling down the slide. For this reason, Katrina, Joey’s mother, had to hold him in place and run next to him every time he descended down the slide. Furthermore, Katrina had to push Joey back to the top of the slide prior to descending – a strenuous activity that will continue to get more difficult as Joey gets bigger.

1.2. Purpose

The purpose of this project is to design an outdoor recreational slide with Joey in mind. This slide, called the ARC slide (Automatic Retracting Coaster) will consist of a small car for Joey to sit in, as well as a custom track for the car to travel down. To maintain Joey’s comfort and posture, the car will have foam cushioned seating, as well as chest harnesses and leg supports. The track will be made from sustainable material to withstand outdoor conditions. To limit the amount of strain that Joey’s guardians exert when pushing him to the top of the slide, the ARC slide will have a remote controlled winch mechanism that will safely pull Joey to the top. Lastly,
the upper platform of the track will have the ability to automatically tilt, causing the car to travel down the track without needing to be pushed. Overall, the ARC slide is designed to be safe, comfortable, and enjoyable for Joey, as well as give him more independence when playing outdoors. Although the ARC slide is designed to contour to Joey’s needs, it is easily adaptable to any child with motor control disorders. Currently, there are no other similar designs on the market. Thus, the ARC slide is a groundbreaking device in the area of modified recreational equipment for people with disabilities.

1.3. Previous work done by others

1.3.1. Products

After extensively researching the NSF, ABLEDATA, and company catalogs, it was discovered that there is very little in the market for modified recreational equipment for disabled persons. Much of the recreational equipment is in the area of bikes and cycles and assisted walking devices. The “Step2” slide coaster on which this design is based is the only related product known at this time (see figure 1.1).

![Step2 Extreme Coaster Model](image)

**Figure 1.3.1.1: Step2 Extreme Coaster Model.**

1.3.2. Patent Search Results

Upon review of the United States Patent database, it was discovered that only two vaguely related devices for recreational purposes for the disabled. The first is US patent # 5,505,663 for a “self operable transfer system for the disabled”. This playground apparatus has
a departure platform connected to a unidirectional conveyer belt to permit only upward movement. The conveyer has handrails extending along the conveyer for pushing or pulling upwardly. A slide is attached adjacent to the conveyer as a means for the participant to go down from the upper platform to the lower platform. This product was designed with the intention to remove the dependence of constant wheelchair transfer for the disabled participant.

A second device, US patent #4,865,312, relies on an extensive wooden access ramp for a wheelchair to reach the top of the slide. There are wheelchair transfer stations at the bottom and top ends of the slide. The access ramp is inclined slowly such that the participant can propel themselves up the ramp to the first transfer station, make the transfer to the slide platform, and subsequently travel down the slide. After descent, the user transfers to a wheelchair again at the landing platform. The participant then repeats the act of travelling up the ramp and down the slide.

Both of these devices have the intention to help develop upper body strength of children having lower body disabilities. Such diseases may include cerebral palsy, spina bifida, and lower body paralysis. However, if the disability affects the core body muscles, then these devices are difficult to effectively utilize. The duration of the actual recreation period is quite short, as well. There is a substantial amount of time and effort to return the user to the top of the slide to repeat the activity.

2. Project Design

The project design consists of three alternative designs as well as a chosen optimal design. The three alternative designs were based upon the budget that would be allotted to the ARC Slide, and proceed in order of cost. All three designs were created with Joey’s safety in mind. The last design was equipped with the most features, and due to the requested budget given, became the optimum design. Each feature of the chosen design, including information on all electrical and mechanical subunits, will be further explained in the Optimal Design section of this report. All figures presented were created in SolidWorks 2009.
2.1. Alternate Designs

2.1.1. Alternate Design 1

Track

In this design the structure of the slide will be made entirely of wood. This will be the most basic of the designs and will keep the costs at a minimum. The platform will be supported by wooden beams and the top sheet will also be made of wood. There will be an on/off push button on the slide and a timer on the winch. The operator will be responsible for engaging and disengaging the hook. Two three inch walls will be installed on the outer edges of the wood track, serving as guides for the car wheels. A depiction of the track can be seen in figure 2.1 below.

![Diagram of Track Design #1](image-url)

*Figure 2.1.1.1: Track design #1.*
Car

In the first design for the slide car, the car will be equipped with handrails, an integrated head support, trunk and hip restraints, and leg restraints. The seat recline angle will be 10 degrees for user comfort. The seat and back rest will be made of foam padding covered with nylon fabric. The hip and trunk supports will be made of nylon and will be fully adjustable to adequately fit to the user’s body. The head support will be an extension of the backrest, and will not be adjustable. The leg supports will be Velco straps on the foot rest and on the lower leg rest portion of the car. These supports will be adjustable to allow for a snug fit for the users safety during descent and retraction. In this design, the winch hook must be manually disengaged from the rear of the car upon retraction to the top platform. The frame will be made out of 1/4” thick rectangular steel tubing. The shaft for the wheels will be made out of stainless steel, 304 grade. The wheels will be 6” diameter with a plastic hub with an outer rubber tread. The width of the tires will be two inches. These wheels are typically found on common outdoor equipment such as lawnmowers and wheelbarrows.

Controls

The controls of this design are very minimal. A 12V DC winch motor will be used to pull the car to the top of the slide. The winch motor will be turned on and off by an RF wireless remote control and by a safety switch on the back of the motor itself. In order to operate the winch, the safety switch will need to be in the on position. The winch cable will extend the length of the slide, and the remote will have two buttons, start and stop, to control the motor retraction. Once the start button is depressed, the motor will retract the cable and remain on for a designated number of counts. These counts will be programmed based on how long it takes for the car to reach the top of the slide. The motor will be turned off by pressing the stop button on the remote, flipping the safety switch on the back of the motor, or automatically at the top of the slide once the system has finished counting. Lastly, when the winch motor is on, a red LED light located on the top of the slide will illuminate, signaling that the winch mechanism is in use. A microcontroller will be used to program all of the controls, including processing signals from the RF wireless remote and the automatic timing on the motor itself.
2.1.2. Alternate Design 2

Track
In this design, the base of the slide will be composed of wooden beams, while polyethylene U-channels (3” x 1”) will be installed on the track surface and serve as guidance for the car’s wheels. For a smooth and polished surface, a polyethylene sheet will be used for the top surface of the platform, roughly ¾” thick. The winch mechanism will automatically disengage through a mechanical mechanism. There will be a winch timer, tower light and sensor combination that will indicate that the car has reached the top platform safely. There will also be an on/off push button on the slide for emergency stopping of the winch. A visualization of track two can be seen in figure 2.1.2.1 below.

![Figure 2.1.2.1: Track Design #2](image)

Car
In the second car design, the head rest/support will be adjustable to desired levels as in an automobile seat headrest. This will accommodate for the user’s trunk growth and development and permit the adaptability for different users, as well. The seat recline angle will be set at 15 degrees, an additional five degrees than design one. In order to account for the shift in the center of gravity towards the rear of the car, the seat position relative to the frame will be set at a distance closer to the front of the vehicle. The headrest will sit on two adjustable notched pins that can be moved up or down to match the user’s head level during use.
Additionally, there will be foot holders in the front of the car to keep the legs from shifting to the left or right in the car during use. In figure three, the restraint straps are not depicted. In this design, the frame will be made of \( \frac{3}{4} \)” thick circular steel tubing 304 grade. The wheels will be 6” in diameter with a steel hub and rubber tread. The width of the tires will be 2”. The attachment site for the winch hook will be spring loaded such that when the car is retracted to the top of the slide, a mechanical trigger on the top platform will release the connection pin from place and allow the winch hook to disengage.

![Figure 2.1.2.2: Depiction of car design #2.](image)

**Controls**

The controls of this design are slightly more advanced than design one. The 12V DC winch motor used to bring car back up the slide will be turned on and off by an RF wireless remote control and by a safety switch on the back of the motor itself. In order to operate the winch, the safety switch will need to be in the on position. The rope of the winch may extend further than the length of the slide, and the remote will have one button, on. When this switch is pressed, the motor will turn on, and when the button is released the motor will turn off again. A photoelectric sensor will be installed at the top of the slide to detect when the car has been fully pulled back to starting position. When this sensor is triggered, the motor will turn off and stay off, regardless of whether the start button on the remote is pressed. When the winch motor is on, a red LED light located on the top of the slide will illuminate, signaling that the
winch mechanism is in use. When the car reaches the top of the hill and the photoelectric sensor is triggered, the red signal light will turn off and a green signal light will illuminate. Once the car travels down the hill and the sensor is no longer triggered, the green light will turn off again. Lastly, if the battery is under 20% charged, a yellow LED light will shine instead of green when car is at the top of the hill. A microcontroller will be used to program all of the controls.

### 2.1.3. Alternative Design 3

**Track**

In the third design, the slide will be made of compressed wood with a polyethylene surface. The compressed wood will provide stability as well as resistance to outdoor conditions. The track will be covered with a polyethylene sheet for a smooth finish, while the middle portion of the steel track will have rubber treads in the event someone needs to walk up the ramp. A lift motor will also be installed on the upper platform to serve as an automatic mechanism that sends the car down the hill. The wooden structure will be painted for aesthetic purposes. A depiction of track design three can be seen in figure 2.1.3 below.

![Figure 2.1.3.1: Track Design 3](image-url)
Car

The third car design will be similar to design two, however, the seat recline angle will be adjustable between zero and fifteen degrees. The operator will be able to adjust the recline angle in 5 degree increments allowing for zero, five, ten, and fifteen degree recline angles. The safety restraints will include a hip strap, a trunk strap, and lower leg Velcro straps to hold the user in place during descent and retraction. The seat bottom, back, and headrest will be made of foam padding covered with nylon fabric.

The footrest towards the front of the car will be adjustable to accommodate for user leg growth and variability. The foot platform will move forward and backward and secured in place with a bolt that will hold the foot platform at the desired length.

The frame will be constructed using 304 grade stainless steel ¼” tubing. The frame will be completely welded together, while the components will be bolted onto the frame using stainless steel parts. The rear hook for the winch connection will also be spring loaded such that the connection pin will release on the car portion of the retraction mechanism and allow the winch hook on the cable to release from the car.

Controls

This design has the most intricate control system. A 12V DC winch motor will be used to bring the car back to the top of the slide. The motor will be turned on and off by an RF wireless remote control and by a safety switch on the back of the motor itself. The winch cable may extend further than the length of the slide, and the remote will have one button for the winch, on. When this switch is pressed, the motor will turn on, and when the button is released the motor will turn off again. A photoelectric sensor will be installed at the top of the slide to detect when the car has been fully pulled back to starting position. When this sensor is triggered, the motor will turn and stay off, regardless of whether the start button on the remote is pressed. When the winch motor is on, a red LED light located on the top of the slide will illuminate, signaling that the winch mechanism is in use. When the car reaches the top of the hill and the photoelectric sensor is triggered, the red signal light will turn off and a green signal light will illuminate. Once the car travels down the hill and the sensor is no longer triggered, the green
light will turn off again. If the battery is under 20% charged, a yellow LED light will shine instead of green when car is at the top of the hill.

Also installed on the slide will be a second lift motor. This motor will be located below the top of the slide, and will be used to lift the top platform to a slight angle so that the car can descend down the hill without needing to be pushed by an operator. The motor will be controlled by an RF wireless signal, and the switch will be located on the same controller as the winch mechanism. There will be one push button, up, that will cause the motor to begin its operation. Using a microcontroller or PLC, the motor will be programmed to raise the platform to a 15 degree angle, remain raised for 5 seconds, and then descend back to zero degree position. This motor will have the ability to turn on only when safety switch is in the on position and photoelectric sensor is triggered. This will indicate that the car has safely reached the top platform of the slide. Lastly, when the lift motor is in use, a blue LED light will illuminate indicating the motor’s status. A microcontroller or PLC will be used to program all of the controls.

2.2. Optimal Design

The optimal design was chosen based on the budget that was allotted to the ARC slide. Ultimately, the third alternative design, with minor modifications to the track, became the model used for the optimal design. This third design is equipped with all features that make the ARC slide safe and easy for Joey and his guardians to use.

2.2.1. Objective

The optimal design for the ARC slide will be equipped with all necessary mechanisms to give Joey more independence. As stated previously, the ARC slide will have two major components, a small car and a wooden track. The modified car will have comfortable seating with side supports to maintain his posture. Because Joey often squirms his way out of seats when he gets excited, the car will also contain a harness and leg supports to keep him safely and comfortably in place. To limit the strenuous task of pushing Joey back to the top of the slide, a winch mechanism will be installed. This mechanism, composed of a winch motor, cable,
and hook, will automatically pull Joey to the top. A releasing mechanism will be installed on the upper platform to automatically disengage the winch hook from the car. Lastly, the slide will have a powered lifting mechanism at the top of the slide to tilt the upper platform downward on command. This optional mechanism will create the necessary slope to send Joey and the car down the slide.

2.3. Subunits

2.3.1. Microcontroller

The microcontroller used in the electrical components of the ARC slide will be the 40 pin, 8 bit Microchip PIC16F877. This microcontroller was chosen because while it is capable of a wide range of tasks, it is also relatively easy to program and use. This software for the PIC is written in embedded C code. For the ARC slide, one PIC will be used per motor.

![Figure 2.3.1.1: I/O pins of 8-bit PIC16F877](image)

2.3.1.1. Control Overview

Truth tables 2.3.1.1.1 and 2.3.1.1.2 describe the basic control mechanism of the system. These tables are divided by motor function, and will similarly divided in the C code using while loops. Truth table 2.3.1.1.1 will be the first unit in the relay of signals. Initially, the system must
be turned by flicking the safety switch on the back of the winch motor. This safety switch will enable the unit to begin receiving and sending signals. Once on, the microcontroller will respond to the two inputs: the RF remote winch control and photo eye at the top of the slide, and three outputs: The red LED light, the signal to the winch motor control unit, and signal to enable the second unit. When the switch to the winch motor is pushed, the motor will turn on. A switch that latches only when pushed will be used, so when the button is released the power supply to the motor will automatically turn off. When the motor is on, the microcontroller will send a signal to illuminate the red LED light on the tower, signaling the winch is in use. As soon as the photoelectric sensor is triggered, the power supply to the motor will turn off, regardless of the input from the controller. At this point, a signal will be sent to enable second unit.

When the second unit is enabled, the system will begin to respond to the RF lift hill remote and battery low signals. Similar to the winch user control, the lift hill remote will have one push button as well. However rather than stopping when released, the lift will continue its operation. Once the switch is pressed, the lift motor will slowly ascend until the platform reaches a downward position set at 20 degrees. From there, a delay of 5 seconds will be programmed before the motor automatically descends back to its starting position. When the lift is in use, the yellow LED stack light will illuminate, and remain on until the motor resumes back to its original position. When the car is at the top of the slide and the lift push button is not in use, the green LED light will illuminate. Once the car descends down the hill, the photoelectric sensors will stop triggering, causing the enable B signal to shut off. Thus, after the car descends down the hill, the lift motor will lose its ability to operate and the yellow, green, or blue lights will turn off.

Truth tables will be used to test the functionality of the microcontroller. All inputs will be tested in the combinations given and the outputs will be noted.
### Winch Motor (A)

<table>
<thead>
<tr>
<th>Safety Switch (enable)</th>
<th>Motor Up</th>
<th>Sensor</th>
<th>Winch</th>
<th>Enable B</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
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<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Description**
- Winch Motor is on- Red light is illuminated
- Winch Motor is off
- Sensor is triggered, second microcontroller is enabled
- Sensor is triggered, winch motor no longer can run. Second microcontroller is enabled
- System disabled

Table 2.3.1.1.1: Truth table of first unit

### Lift Motor (B)

<table>
<thead>
<tr>
<th>Enable (B)</th>
<th>Battery Low</th>
<th>Lift on</th>
<th>Lift</th>
<th>Yellow</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

**Description**
- Green light illuminates signaling lift can begin
- Yellow light illuminates signally battery is low and lift can begin
- Lift is on, blue light is illuminated
- Lift is on, blue light is illuminated
- System disabled

Table 2.3.1.1.2: Truth table of second unit
2.3.2. Winch Motor

A winch motor will be installed behind the safety rails to pull the car back to the top of the slide. The 1/2 horse power winch motor will be powered by a motor control unit with a 12V DC supply voltage. The 40 pin microcontroller will send a signal to the motor control unit when indicated by a wireless remote. The microcontroller will be programmed to turn on the motor when the push button on the remote is pressed, and will turn off the motor when the push button is released. Furthermore, a photoelectric sensor will be installed at the top of the slide. As a safety measure, the motor will be programmed to turn off when this sensor is triggered for more than 3 seconds.

The winch motor to be used is manufactured by TRAC, an outdoor trailing company. This motor was chosen because it fit all criteria necessary, is inexpensive, and as has the convenience of being designed for outdoor use. It maximum pulling capacity is 2000 lb, a value far beyond our scope. Because the motor is built to pull heavy loads, the minimum amount of current drawn by the motor is high. This may cause difficulty in designing a motor control circuit that is capable of withstanding currents higher than 10 amps for long durations of time. Currently, a motor control circuit using transistor switches is the design for the winch motor control unit (see figures 2.3.2.2-2.3.2.3 for multisym circuit and on/off simulation). This circuit supplies 12V to the motor when triggered by a 5V signal from the microcontroller. If this circuit is found to be incapable of handling high currents though experimentation, than further research on using relays as a motor control switch will be done.
Figure 2.3.2.2: Winch Motor control Circuit when 5V signal from microcontroller is off

Figure 2.3.2.3: Winch Motor control Circuit when 5V signal from microcontroller is off
To test the motor control circuit after the microcontroller is programmed, the cord will be pulled out to its maximum length, and the motor will be turned on using the wireless remote. If the motor remains on when push button is pressed and stops when the push button is released, than the microcontroller is programmed correctly. The motor will be signaled to remain on until the cable is fully retracted. If the circuit does not overheat during this operation, than it will be considered electrically sound. Lastly, the photoelectric sensor will be purposely triggered while the motor is running to ensure that the motor stops.

2.3.3. Lift Motor

A lift motor will be used to slightly tilt the top of the slide to a 15 degree angle as a means to push the cart down the slide. This ½ horse power motor will also be operated using 12V DC input. The motor will be turned on by a wireless remote control, operated through the microcontroller. Furthermore, it will be programmed to turn on only when the cart has reached the top of the hill, or when photoelectric sensor is triggered. Once turned on, the motor will remain elevated for 10 seconds before reversing back to its starting position. Figures 2.3.3.1-2.3.3.3 show multisym simulations of the motor control circuit. This transistor H-bridge circuit is responsible for creating forward and reverse motion of the motor when the corresponding input signal is given (4). The direction of the motor will be triggered by 5V signals from Microcontroller B. When on, the supply voltage to the motor is roughly 8V, a magnitude suitable to run the lift motor at an adequate speed.
Figure 2.3.3.1: Motor control circuit design for the 12V DC lift motor when both signals are off.  

\[ V_{12V}, R_{10k}, Q_{2N3904/Q4N3906}, R_{3/10k}, R_{2/10k}, Q_{IRF510}, D_{1N4001GP}, C_{1uF}, S_{DC_MOTOR_ARMATURE} \]
Figure 2.3.3.2: Motor control circuit design for the 12V DC lift motor when forward signal is on \(^3\)
Figure 2.3.3.3: Motor control circuit design for the 12V DC lift motor when reverse signal is on

The signal voltage to the lift motor will be timed internally by the microcontroller. When triggered by the wireless remote, the microcontroller will turn on the port that signals forward motion of the motor, and will remain on for 5 seconds using a series of internal delays in the code. After 5 seconds, the port signaling forward motion will close. Using a second series of delays, 5 seconds will pass before the port signaling reverse motion of the motor turns on. Once the port for the reverse motion of the motor is turned on, a third series of delays will occur for 5 seconds before the reverse port shuts off. At this point, the motor should be in starting position.
To test the motor control circuit, the circuit will be built on a protoboard and attached to the lift motor. If the motor performs forward and reverse motion when triggered by corresponding 5V signals, than the circuit will be found to work correctly. Furthermore, the circuit will be tested repetitively to ensure overheating does not occur. To test the microcontroller code, the motor will be turned on using the wireless remote and its performance will be noted. If the motor lifts for 5 seconds, stops for 5 seconds, and reverses for 5 seconds in a smooth continuum, than the code will be found to work correctly.

### 2.3.4. Tower Light

A tower light will be installed on the top of the slide. The 24V powered tower light will have three color indicators: Red, yellow, and green. The red indicator will illuminate when the motor is in use. If the motor is turned off before the photoelectric sensor is triggered, the light will remain red. The green light will turn on when the cart reaches the top of the hill and the motor is turned off. Lastly, the yellow light will illuminate when the lifting device is in motion. If the motor is turned off for more than 10 seconds and no other signals are sent to the controller, the tower light will turn off.

*Figure 2.3.4.1: LED Stack tower light. Left figure is the 4 color stacked light to be used for the ARC system*
Each LED wire will be attached to an operational amplifier. The operational amplifier will amplify 5V signals to the necessary 24V needed to illuminate the lights. See figure below for the LED circuit design. The 5V signals will be sent from the microcontroller when indicated by the corresponding inputs listed in truth tables 1 and 2. To test the LED circuit, each light will be connected to operational amplifiers built on a protoboard. The circuit will be proven to work correctly if the 3 lights illuminate with high intensity when supplied with 5V. The timing of illumination will be tried when microcontrollers A and B are tested.

Figure 2.3.4.2: Signal amplification circuit for powering of LED lights when 5V signals from microcontroller are off
2.3.5. Photoelectric Sensor

Photoelectric sensors consist of electric eyes mounted in a parallel configuration. When the path of the electric eye is blocked, an output signal is sent. In this application, a retro-reflective photoelectric sensor will be installed at the top of the hill where the car sits before descending. The sensor will be powered using a 12V DC power supply, and will send a signal when the infrared light beam is blocked by the car. Using microcontroller technology, the signal sent by the photoelectric sensor will trigger the motor to stop.

Figure 2.3.5.1: Photoelectric Sensor and infrared reflector
The photoelectric sensor will be directly connected to the microcontroller. Thus, to test the sensor, it will first be connected to a protoboard so that the magnitude of the output signal can be observed. When doing so, the sensor will be purposely blocked, and a digital voltmeter will be used to detect magnitude of voltage. After testing and assembly, the performance of the photoelectric sensor will further be tried when Microcontroller A is tested against truth table 2.3.1.1.1.

2.3.6. Safety Rails

The hand rails used will have to be ADA (Americans with Disability Act) compliant. Due to this compliance, the rails are required to have a smooth finish. The metal of choice is aluminum for its strength, durability and corrosion resistance. The safety rails will be anchored horizontally into the wood beams rising above the platform from the corners (see fig. 2.3.6.1). The rails will be slip-on fittings enabling them to be easily installed or removed.

Figure 2.3.6.1: safety rails.

The safety rails are a fixed to the platform beams at the ends and cannot be pushed out. Therefore if the car bangs against the rails they will hold the car back. The rear of the platform
is open however. The deck as walls in the back to prevent the wheels from rolling too far back and the linear actuator is also in the way therefore the car cannot roll backwards.

2.3.7. Track

The track will be made of wolmanized wood; a pressure treated wood with a copper azole for resistance to rain and other harsh conditions. Because of its strength and durability outdoors, this wood is a perfect choice for the ARC slide. The track will be approximately 26” wide and 141” long. The top of the track will be 35” high, and the bottom will be 136” from the platform.

To keep the car from steering off the track, two 2” barriers will be installed on the side of the slide. The walls will be bolted on to the edge of the ramp and will follow the track from the platform to the bottom of the hill. There will be a 26” clearance between the walls, which will leave a comfortable yet secure spacing for the 24” wide car.

In order for the car to be brought back to the top of the hill, it must first be pushed to the foot of the slide. Because the car width of the car is very close to the width of the track, there is risk that the winch may pull the car sideways off of the track if misalignment occurs. To alleviate this possibility, the end of the slide will be flaired outward. This will limit the amount of precision needed in the alignment of the car before being pulled to the top of the hill. For a smooth transition from the platform to the slide, and from the slide to the ground, the track will be tempered and curved at both ends.

4”x4” wooden posts will be used to stabilize the base of the slide. The top platform of the slide will consist of an upper and lower component. The lower component will made of 2” thick wood, and secured by bolts and 2”x4” brackets. The lower platform will have a hole drilled in the back center to accommodate a space for the piston lift. An upper platform will be installed over this lower base. The upper platform will be approximately 1” thick, and sit on a hinge secured at the front of the hill. Upon movement of the piston motor, the upper component will move radially up and down. This component will be positioned 35” off of the ground. See figures 2.3.7.1 and 2.3.7.2 below.
The winch motor will be installed behind the central platform. It will sit on the bottom component of the top platform, and will be secured using bolted connections. Below the upper
platform will be a lower platform. Here the electrical components and lift motor will be stored. Figure 10 illustrates both platforms on the slide base. Lastly, safety rails will be placed on the top of the slide. These rails will be approximately 12” tall, and will prevent the car from traveling any other direction other than forward.

2.3.8. Car Frame

The car frame will be constructed of one inch square tubing at ¾” thickness. The steel used for the frame will be 304 grade. The dimensions of the base are 20” x 30”. The mounting beams for the foot support and seat will also be made of the same square tubing and are welded to the car frame as seen below in fig. 10. The underside of the frame will be covered with 1/8” thick stainless steel sheeting to provide the mounting area for the release mechanism for the winch hook. The wheel mounts provides 1.15” clearance between the wheel shafts and the underside of the frame. The wheels will have a 6” hub diameter made of polypropylene plastic. The tires are 1.00” inch thick with a diamond tread. The tire width is 1.50”. With a 3/8” steel shaft at 23.5” long, the clearance between the wheel hub and car frame is 0.25”. The wheels are held in place using cotter pins and 3/8” stainless steel washers. Figure below depicts the car frame with wheels mounted.

![Figure 2.3.8.1: ARC Slide car frame with wheel assembly.](image-url)
The underside of the car is depicted below in fig.2.3.8.2.

Fig. 2.3.8.2: Underside of car (release mechanism not shown).

Fig. 2.3.8.3: Top View of ARC Slide Car
2.3.9. Car Restraints

The car must have a high level safety measures to ensure the user’s optimum safety during operation. Due to Joey Toce’s inability to hold his trunk upright, hip and trunk restraints will be incorporated to hold him safely in position. The trunk harness will be made of seatbelt grade nylon and steel seat buckles. The trunk restraint will form an “X” pattern on the front of the trunk and will buckle at mid-chest level. The lengths of the restraints are adjustable to meet the growth of the user and user variability.

A hip restraint and buckle similar to those found in airplane seats will hold the anterior portion of the pelvis in place and does not permit the hips to move forward in the seat. This will deter an unsafe and uncomfortable position. The restraint will buckle and the mid-sagittal region of the hips.

The headrest incorporated into the seat back also provides another safety measure. The headrest is comprised of high density foam and a nylon fabric cover that will absorb impact of the head in the case of whiplash from sudden movements. In order to account for the growth of the user, the headrest level is adaptable. The headrest pins are notched every one inch to gain up to four inches in headrest elevation.

2.3.10. Car Seating

While the seat of the ARC Slide is designed based on the limb and trunk dimensions of Joey Toce, the car seat is large enough to accommodate children approximately five to ten years old. The top back of seat is equipped with foam padding with raised edges to keep the user from drifting from side to side during movement. The seat bottom also possesses this characteristic. In addition to the restraints, the seat is also designed to hold the user in place.

The leg rests are also made of foam padding with a nylon fabric cover. The limb area of the seat is rounded inward to keep the legs in place. Velcro leg straps are sewn into the distal portion of the leg cover to secure the user’s lower limbs during the use of the ARC Slide. Figure 13 depicts the seating complete with padding and headrest (seating restraints not depicted).
The chair also has arm rests for user comfort. They also serve has an extra mechanism to keep the user from sliding out of the chair and into an unsafe position. Maintaining the user’s position is necessary to stop a shift in the center of gravity from tipping the car over. The dimensions in inches of the car are depicted in fig. 2.3.10.1 below. The armrests have a length of 10.812”, seat back padding, 10.750”, seat bottom padding, 7.150”, and leg rest padding, 10.124”.

Figure 2.3.10.1: Car seat with supports.
The car will be covered with covered polypropylene sheets to give a playground and recreational toy appearance. The sheets will be 1/8” thick and will be securely screwed into the frame and the car seat for the finished design. A depiction of the car will is depicted below in fig. 2.3.10.3.

Fig. 2.3.10.2: Car seat dimensions.

Fig. 2.3.10.3: Depiction of the ARC Slide Car without harnesses and polypropylene coverings.
2.3.11. Car Retraction and Release

For the safety of the user, it is necessary that the cable hook disengages only when the car is on top of the platform. To cut costs, the release mechanism is designed as simple as possible and without using complex electrical equipment. This mechanism is completely mechanical with moveable parts that will allow the release of the hook without any input from the parents.

The first component of this mechanism is a 1 x 1 inch square, ‘block’, protruding upwards from the platform. Then a series of moveable parts, labeled A through E in the figure below, will be installed on the undercarriage of the car. The parts are solid one piece parts that have holes drilled in them where the hinges will be placed.

As the car reaches the top of the hill, it will move over a ‘block’ centered in the middle of the platform. Part A is positioned such that the block will apply a force on its upper side, causing it to rotate about a fixed hinge. This rotation will cause the lower end of part A to hit the rear end of part B which will then cause part B to rotate counter-clockwise about the fixed hinge. As part B rotates counter-clockwise, it will apply force on the rear end of part C, causing it to rotate clockwise about its hinge. Finally part C will apply force from the bottom on the rear end of part D, the end component of the mechanism, causing it to move away and separate from part E in a downward counter-clockwise rotation. This domino effect will allow the hook to be disengaged.
The figure 2.3.11.1 below shows a view from the top of the car with the base being “invisible”.

![Diagram of the mechanism](image)

**Figure 2.3.11.1: Release Mechanism for the winch hook**

The hinges are planned to be spring loaded to enable the parts to move back to their original. As the car goes down the incline and proceeds ahead, the gate will close automatically. Once the ride is over, the car will be pushed back to the bottom edge of the ramp and the winch cable, which will unspool freely, will then be attached on to the gate. The winch will then be turned ON for the retraction to begin. This is where the ‘stopper’ comes in. The stopper acts as a barrier or as a cancelling force applied by part D due to the retraction. As the hook is pulling the car backwards, there is horizontal force applied on part D in the left direction, which will cause it to spin counter clockwise unless stopped. The stopper will prevent part D from rotating and opening the gate. The only time the gate can be opened allowing the hook to disengage is when the block applies force on the top portion of the stopper, pushing it backwards and rotating it about its hinge. So the stopper out of the way, the rest of the parts will move as described above and thus completing the mechanism and releasing the hook.

The movement of the parts and the block is represented by the arrows in figure 2.3.11.1.
Each part will be tested to make sure it moves according to the predictions as depicted in the schematic. After a prototype of the release mechanism is built, the whole system will be tested repeatedly to make sure that it will not fail. Since the first component is the block on the platform, it needs to be sturdy enough to withstand any amount of force exerted by the stopper when the cart is being pulled back onto the platform. A failure would result if the block is pushed backwards and out of its position. This will cause the cart to keep retracting as the winch hook would be still engaged to the car and an emergency stop of the winch will be required to kill the power and stop the retraction and any injuries. The stopper will need to be strong enough to resist the backward motion caused by the retraction force from part D. Part B needs to touch part C away from the hinge of part C in order to avoid damaging the hinge. Any perpendicular force on the hinge will break it. This is consistent for every part that will be moving on hinges. All parts will have to rotate enough to touch the next part in series and there needs to be enough contact area for the part to move the required distance. The next task is to make sure the parts are strong enough to not fracture over repeated use around the hinges. The hinges will need to be lubricated well enough and must have a low friction coefficient to the parts move freely or else any hindrance might cause the part to come out of its position.

All these parts will first be assembled onto a surface exactly like the base of the car and will be tested there onwards. This will resemble the conditions closest to that of the final product and will give information about failures and how to improve the design if necessary.

2.3.12. RF Controls

The winch motor and platform lift motor will be controlled remotely using radio frequency (RF) controlling. A Colpitts circuit will be used for the high frequency oscillation portion of the circuit. Figure 2.3.12.1 below depicts the Colpitts circuit.
The oscillation of the circuit will be approximately 83 MHz which will not overlap with the frequencies of FM broadcasting. The transmitter emits an electric wave from the antenna (ANT). The control code used with the PIC16F877 turns the electric wave on or off. For the ports, +5 V will equal a high or on level and 0V will be equivalent to a low or off level. The operation of the transmitter circuit only occurs with the constant push of the control switches (SW1 and SW2, fig 2.3.12.2). When the switch is not pushed, the circuit is not powered, suppressing the consumption of the supply battery. In the case of control code malfunctions, the diode will be used to prevent voltages and currents that would damage the rest of the transmitter circuit. A final printed control board (PCB) layout is depicted below in fig. 2.3.12.3.

Fig. 2.3.12.1: Colpitts circuit for high frequency oscillation

Fig. 2.3.12.2: Circuit Design for Transmitter (7)
The receiver is comprised of a high frequency amplification circuit, a detection circuit, a voltage comparator, a clock oscillation circuit for the microcontroller, a relay drive circuit, and a power circuit for the microcontroller. A total circuit diagram for the receiver portion of the RF controls is depicted below in fig. 2.3.12.4.
The high frequency amplification circuit is a two stage FET amplification circuit. It will only amplify the received voltage signal and apply it at the gate (G, fig. 2.3.12.3). The resonance portion of the circuit will be constructed to pick up the resonant frequency of the transmitter, approximately 83 MHz. The detection circuit rectifies the output of the high-frequency amplifier with a diode to make a DC voltage from the high frequency voltage. The DC voltage then reaches the voltage comparator; an LM358N op amp. The output of the voltage comparator is either at a high level if the circuit is receiving a signal or is at a low level if the circuit is not receiving. By using a Zener diode connected to the output (D3/RD5A fig2.3.12.3), the voltage at the output level will not exceed the permissible level that could damage the microcontroller. The clock oscillation circuit provides a 4 MHz oscillation frequency for the microcontroller. The relay drive circuit makes an LED light up to signal when the relays are in operation. A resistor in series with the LED limits the current to 10 mA. The relays are then connected to start the on/off operation of the winch and lift motors on the track platform. The PCB layout for the receiver can be seen below in fig. 2.3.12.5. Example source code that will be used to program the microcontrollers is listed in appendices A and B.

![Printed Circuit Board for Receiver](7)

**Figure 2.3.12.5: Printed Circuit Board for Receiver (7)**
2.3.13. Electrical Housing Unit

The electrical housing unit (EHU) will be constructed to house all of the circuit components, shield them from noise, and protect the circuitry from the outdoor weather. The unit will be made of aluminum sheeting and attached to the base of the track platform. In order to shield the circuits from interference, the aluminum EHU will be covered in electromagnetic interference shielding resin. The receiver will also be stored here, with the antenna extending out of the unit to receive the signals from the remote transmitter. A depiction of the front control panel of the remote control is depicted below in fig. 2.3.13.1. The transmitter circuit will be housed inside the remote control. This remote control will be made of impact resistant plastic in the case that the unit is dropped. The transmitter circuit will be powered by an on-board 9V battery.

![Remote Control for ARC Slide](image)

**Fig. 2.3.13.1: Remote Control for ARC Slide**

In a separate compartment of the electrical housing unit, a 12V DC battery will be installed. The housing unit will supply a grounding connection for the battery and will have an easily removable cover to allow the battery to be removed, replaced and/or recharged. The EHU circuit portion will be completely sealed from the weather and elements, however, the
battery portion will allow for the drainage of moisture through the bottom face of the unit. The dimensions of the battery compartment will be 8x12x8 (HxWxD) inches.

2.4. Prototype

2.4.1. How to use the ARC Slide.

In order to safely operate the ARC Slide check the car and wheels to make sure they are intact. Check the winch motor for any debris that may have blown into the opening. Check the lift motor and make sure the battery is charged. Make sure there are no obstructions in the path of the car on the track. Before seating the rider in the car, a test run is recommended to ensure all systems are working properly.

Figure 2.4.1.1: The ARC Slide
2.4.1.1. The Car

Properly secure all harnesses after placing rider in the seat before proceeding to retract the car up the track. The foot rests can be adjusted to the rider’s desired comfortable position.

To take rider out of the car, first make sure the car is on the ground and remains stationary throughout the exiting process. Second, press the red eject button to release the harnesses.

Figure 2.4.1.1.1: Car shown with seat and harnesses.
2.4.1.2. The Wireless Remote

Please note that the wireless remote does not control the car. The wireless remote only allows the user to control the retraction of the winch and the up and down motion of the lift motor. It will not, however, disengage the winch hook from the car. The release mechanism is designed to do that. The picture below shows a picture of the remote and the picture of the components inside once the back cover is removed.

Figure 2.4.1.2.1: The wireless remote.
2.4.1.3. The Winch Motor

To use the winch motor (see figure 4), make sure the hook is engaged and the car is in line with the track. Push the retract button on the winch to start retracting the car back to the top of the platform. Once at the top press the release button to stop the winch. By this time the release mechanism would have disengaged the hook. The car will be then ready for a second run down the track.

Figure 2.4.1.3.1: The winch motor.
2.4.1.4. The Lift Motor

In order to use the lift motor (see figure 2.4.1.4.1) make sure the winch has been disengaged from the car and the car is in positioned in the divets. Push the up button under the sign “LIFT”. The upward motion of the lift motor will begin and the platform will rise about 6 inches. This will be enough height for the car to start the journey down the track. After the car has left the platform, press the down button to start the downward motion of the lift motor to bring the platform back to starting point. A kill switch (see figure 2.4.1.4.2) is placed under the platform which when pressed will signal the micro-controller to stop the downward motion. This is a safety measure which will prevent any damage that may occur to the platform or to an individual. The down button on the remote will reset and function once the car is back on top of the platform and the lift is initiated. The linear actuator (see figure 2.4.1.4.3) is responsible to raise the platform.

NOTE: It is important to keep hands clear of the linear actuator at all times regardless of it being in use or not.
Figure 2.4.1.4.1: The lift motor.

Figure 2.4.1.4.2: The lift motor kill switch.
2.4.1.5. The Kill Switch

An emergency kill switch is installed on the electrical unit box. In the event of a malfunction of a motor or remote occurs simply push the button to cut off all the power supply to the motors hence reducing chances of injury or damage to the slide. Figure 2.4.1.5.1 shows the switch in OFF position. Figure 2.4.1.5.2 shows the switch in the ON position.
Figure 2.4.1.5.1: Switch in OFF position.

Figure 2.4.1.5.2: Switch in ON position.
2.4.1.6. The Photo-Electric Sensor

The photo-electric sensor is pre-installed on the platform. They are powered by 12V DC power supply. It sends signal to winch motor to stop when the infrared light beam is blocked by car wheel. This prevents the car from being pulled back too far.

Figure 2.4.1.6.1: Depiction of the infrared beam and positions of the sensor.

Figure 2.4.1.6.2: Close up view of the transmitter/receiver and reflector.
2.4.1.7. The Release Mechanism

The release mechanism is mounted on a plate under the car. This is the mechanism through which the winch hook disengages once the car is retracted to the top. In the picture below all of the parts of the release mechanism are shown. The schematic 1 in figure 2.4.1.7.1 shows the movement of the parts. It shows the location of the parts and how they will move once the car is backed up on the platform and the block, which is mounted on the platform, will push PART A at the black rectangle side. This will make the part rotate about its fixed hinge, secured by a ¼ inch hex bolt, and push PART B which will rotate and push PART C at the rear and cause it to rotate and open the latch to release the winch hook. Schematic 2 in figure 2.4.1.7.2 shows the positions of the parts post release of the hook.

Figure 2.4.1.7.1: Release mechanism schematic 1
Figure 2.4.1.7.2: Release mechanism schematic 2

Figure 2.4.1.7.3: Release mechanism prototype
2.5. Technical Description

2.5.1. Circuitry

2.5.1.1. Microcontroller

The microcontroller used in the electrical components of the ARC slide will be the 40 pin, 8 bit Microchip PIC16F877. This microcontroller was chosen because while it is capable of a wide range of tasks, it is also relatively easy to program and use. This software for the PIC is written in embedded C code. For the ARC slide, one PIC was used to control all electronics.

Figure 2.5.1.1.1: I/O pins of 8-bit PIC16F877
2.5.1.2. **Winch Motor**

A winch motor was installed on the back of the platform to pull the car back to the top of the slide. The motor was interfaced with a motor driver manufactured by robot marketplace for power and control. The microcontroller sent two signals from pins 21 and 22 to the motor driver to cause the winch to release or retract. All signals relied on the input from a wireless control unit. The microcontroller was programmed to turn on the motor when the push button on the remote was pressed, and to turn off the motor when the push button was released. Furthermore, a photoelectric sensor was installed at the top of the slide. As a safety measure, the motor was programmed to turn off when this sensor is triggered for more than 3 seconds.

The winch motor used is an anchor winch manufactured by TRAC, an outdoor trailing company. Its maximum pulling capacity is 100 lb, a value that was ideal for pulling a small car up a 20 degree incline hill. The motor draws a maximum of 10 A, powered by a 12V battery.
2.5.1.3. Lift Motor

A lift motor was used to slightly tilt the top of the slide to a 15 degree angle as a means to push the cart down the slide. This 9 A gear motor attached to a linear actuator was also operated using the 12V DC car battery and robot market place motor driver. The signals to put the motor in forward or reverse motion were sent from pins 19 and 20 on the microcontroller. The motor was programmed to turn on by a wireless remote control, operated through the microcontroller. Furthermore, it was programmed to turn on only when the cart reaches the top of the hill, or when photoelectric sensor is triggered. When the push button for the lift up mechanism is pressed, the motor remains on until the car slides off the platform. At that point, the photoelectric sensor stops sending a signal to the microcontroller, and the motor is unable to lift any further. From there, the lift motor can only travel in a downwards direction until it is stopped by a position switch located at the base of the platform.
2.5.1.4. Tower light

A tower light was installed on the top of the slide. The 24V powered tower light has three color indicators: Red, yellow, and green. The red indicator was programmed to illuminate when the winch motor is in use. The green light illuminates when the car at the bottom of the hill, or when it reaches the top of the hill and the motor is turned off. Lastly, the yellow light illuminate when the lifting device is in motion.

Three transistor switch circuits were used to turn on and off the tower lights using the signal sent from pins 28, 29, and 30 on the microcontroller. To power the LEDs up to 24V, a 12-24V DC-DC boost converter was used. To test the LED light, a plug-in power supply was used.
Figure 2.5.1.4.1: LED Stack tower light. Left figure is the 4 color stacked light to be used for the ARC system.

2.5.1.5. Photoelectric Sensor

Photoelectric sensors consist of electric eyes mounted in a parallel configuration. When the path of the electric eye is blocked, an output signal is sent. In this application, a retro-reflective photoelectric sensor was installed at the top of the hill where the car sits before descending. The sensor was powered using a 12V DC power supply, and sends a 5V signal when the infrared light beam is blocked by the car. Using microcontroller technology, the signal sent by the photoelectric sensor will trigger the motor to stop.
The photoelectric sensor has four useful wires: blue, white, brown, and black. The blue wire was directly connected to a 12V power supply, the brown wire was directly connected to ground, and the black wire was directly connected to a 5V source. Lastly, the white wire was connected to a grounded resistor, as well as pin 9 on the microcontroller. To test the photoelectric sensor, a protoboard and plug in power supply was used to make all initial connections. After the sensor turned on, the reflector was positioned, and the changes in the white wire’s signal were recorded when the sensor was triggered.

Figure 2.5.1.5.1: Photoelectric sensor and infrared reflector.

2.5.1.6. Limit Switch

A limit switch was used to detect when the platform has reached its initial position. The limit switch used was purchased by neat marketplace, and had two connecting wires, white and black. The black wire was connected to 5V signal, and the white wire was connected to a grounded resistor as well as pin 26 on the microcontroller. The limit switch was first tested on a protoboard using a plug-in power supply to observe functionality before being attached to printed circuit board.
2.5.1.7. Motor Drivers

The motor control units used for the winch and lift motors were SyRen motor drivers manufactured by robot marketplace. These DC motor drivers are rated for 25A, and are suitable for medium powered electronics. The drivers can handle short currents which peak up to 45A. Located on the motor driver were eight terminals. On one side, two terminals were for the battery supply and ground, and the other two terminals were for the wires to the motor. On the other side of the motor driver was a terminal for ground, a 5V signal, an input signal S1 and another input signal S2. S1 and S2 were attached to pins on the microcontroller, and controlled the motor’s motion and direction.

To set the motor drivers so that they can control both forward and reverse motion, six switches located on the driver itself were set. Switches 1, 2, 3, and 6 were positioned to face up, and switches 4 and 5 were positioned to face down. A signal on S1 of 0v corresponds to the motor being fully stopped, while a 5v corresponds to full power. A second signal is fed to S2. If the signal on S2 is greater than 2.5 volts, the SyRen will drive the motor forward. If the signal on S2 is less than 2.5 volts, the SyRen will drive the motor backwards. Both S1 and S2 signals were regulated to be either 5V or 0. The motor drivers were both first attached to a protoboard to observe functionality. Once PCB was assembled, the 12V, ground, 5V, 0V, S1, and S2 inputs were attached, and a digital voltmeter was used to observe whether or not the drivers turned on and off correctly given certain inputs from the wireless control units. Once they were determined to work properly, the designated motors were attached to each driver.
2.5.1.8. DC-DC Converter

A DC-DC boost converter was used to convert the 12V signal from a car battery to a 24V signal needed to power the LED tower lights. This converter had four terminals: two for inputs, and two for outputs. The value of the output voltage could be adjusted using a potentiometer, but was set to 24V for the arc slide application. The two input terminals were connected directly to the car battery power supply, while the two output terminals were connected directly to pins 1 and 2 on J4 of the PCB. The boost converted was first tested and adjusted on a protoboard before attachment to control system.
Figure 2.5.1.8.1: DC-DC boost converter.

2.5.1.9. Wireless Control Unit

A 4 channel RF transmitter and receiver were purchased online from hobbyengineering.com. This wireless control unit was powered using a 12V DC power supply, and turned on and off specific ports using four relays. The relays were each wired to a common 5V signal, and when a button on the transmitter is pressed, the relay switched the designated common signal to its output port. The four output ports of the wireless receiver were each attached to a grounded resistor and sent to pins 10, 15, 18, and 23 on the microcontroller. To test the wireless control unit, it was first attached to a plug in power supply. The voltage of each output terminal was measured using a digital voltmeter, and the changes in voltage were observed and recorded when triggered by the wireless transmitter.
2.5.1.10. Printed Circuit Board

A Printed circuit board was designed and manufactured to collect all inputs and outputs from the electronics and microcontroller. On the circuit board are 7 different terminals which the electronics attached to. The PCB contained the microcontroller, 7 transistor switch circuits, and grounded resistors for all inputs. See figure 2.5.1.10 for drawing.
The design for the side rails had been changed and instead only one bar going all the way across was used.

3. **Realistic Constraints**

   The electrical components, such as the photoelectric sensors, motors, and tower light, compromise the most expensive portion of the ARC slide. Although these units are a great percentage of our budget, they are necessary for the functionality and safety of the system, and are thus required expenses. To counter these costs, the material of the slide itself will be durable but less expensive. The wolmanized support beams and coverings are robust and
provide longevity, while at the same time are less expensive than aluminum or stainless steel. Overall, the ARC slide will maintain affordability without compromising safety and performance.

Environmental durability is another constraint. The ARC slide will be assembled and used outdoors. The terrain of the yard is flat, which eliminates the concern of the car traveling far distances. However, the material must maintain its strength in rainy conditions, extreme heat (~105 degrees F in summer) and extreme cold (~5 degrees F in winter). Furthermore, the electrical components must be encased and sealed in housings that will shield the circuits from precipitation. In order to address these constraints, the material chosen for the arc slide, wolmanized wood, is known to be strong and durable in extreme weather. Furthermore, an outdoor winch motor will be purchased, and all circuits will be covered and shielded using resin.

Comfort is another constraint that needs to be addressed. The cart must have an equal balance of strength, comfort, and safety. To maintain comfort, the seat will be purchased from NeatMarket, a second hand store located in Hartford. This Market sells used seats and harnesses designed for people with disabilities. Joey will attend the trip to Neat Market and will try out multiple options for seating units. After assessing multiple seats, the one that gives him the most comfort and support will be purchased.

Furthermore, after the base of the car is built, the positions of harness and leg supports will be tried out on Joey to ensure that all components are placed in a way that will provide maximum comfort and support.

4. Safety Issues

The ARC slide has both electrical and mechanical systems that must be periodically inspected to ensure the proper operation of the slide. As with any outdoor equipment, mechanisms are prone to rust and failure if not properly maintained. The car wheels should be lubricated regularly. Also, the seat restraints should be visually inspected to ensure that the nylon has not ripped and that the user has maximum safety during use.

As with any device using electricity, the proper ground connections must be made to reduce the chance of hazardous shock. The electrical housing unit must have a ground
connection. The chance of shock is quite low as materials for the ARC Slide are mostly wood, plastic, and rubber. This significantly lowers the chance of harm to the user.

While the ARC Slide car can be stored away while not in use, the track will remain outdoors and exposed to sunlight, rain, snow, and other elements. With wood and changes in temperature, cracks can begin to form along the components and weaken the structure's strength and stability. The slide will be covered with a weather-proofing coating however, the slide should be periodically checked for cracks in the support beams and platform to ensure user safety.

Commercial winch motors are design to have a high lifting capacity. While the car and the user are way below the weight limit, the speed of the motor will be under constant control such that the car retraction is at a safe speed and will not harm the user. The winch cable is also prone to corrosion when exposed to the outdoor elements. Rubbing and abrasions that may occur will also weaken the cable. The cable must not have any cuts or nicks or it may break and result in dangerous situations.

The winch motor disengage system ensures that the car is not pulled beyond the top platform retraction point. The photoelectric sensors will signal that the car is back in place and ready for descent; it will not be pulled further than necessary. The cable disengage system between the car and the top platform ensures that the cable is still not attached to the car when the lift motor is activated to begin descent. The logic table as seen earlier ascertains that the retraction and release mechanisms do not malfunction even if one of the components fail. The fail safe circuitry keeps the user from harm when using the ARC Slide.

The materials used are biocompatible with the user in mind. Joey Toce is not allergic to nylon material, so it will be a safe for him to come in contact with. Nylon allergy occurrences are very low. With a hypo-allergenic coating material, there will be a lower chance of a harmful reaction for any multiple of users that will utilize this device.

The user safety is the main priority of the design such that the car is equipped with the necessary restraints to keep the user in place and keep the car’s center of gravity from moving and possibly tipping the car over. The user not only has a safe place to sit but is in a comfortable position as well. The ergonomic design for the device produces a fun piece of
recreational equipment that can be safely utilized by a disabled child with motor control problems.

5. Impact of Engineering Solutions

This device has never been seen before in the world of modified recreational equipment for the disabled. While most of the equipment is for walking or biking, there is very little in the realm of playground equipment. With this device, disabled persons can have another alternative way to safely be involved in outdoor recreation. The wireless control given to the operator removes the constant contact a guardian has to give when supervising a disabled child. This device can give a perceived sense of individuality because the operator will not be in much contact during the ARC Slide use.

This device is built from medium strength, yet less expensive materials. The manufacturing of the ARC Slide would not be as expensive as recreational equipment that relies on many motorized and metal components for operation. By using the materials selected in this optimal design, the device can be built at and sold at a moderate price, yet will still be affordable for many families that have to find means of providing mobility to their disabled children. If this optimal design be produced and marketed on a global scale, it would provide thousands of children with the ability to experience the same recreation that non-disabled children can. The ARC Slide provides many new opportunities and experiences to the disabled that may have seemed unlikely before this device.

The ARC Slide is environmentally friendly in that it does not have any toxic emissions and uses a 12 V car battery for the motors and a 9 V battery for the remote control. The slide does not consume a large amount of power and the batteries can be recharged until they reach their recharge limit. The ARC Slide does not need to be near a 120 V outlet so it has a greater degree of freedom when placing the track in a yard or playground.

6. Life-Long Learning

The ARC Slide design requires strong skills in electric circuits, mechanics, biomaterials, and computer programming. Through the design process, this team has acquired new
knowledge of radio frequency transmission and wireless control. To control these components, we have developed an in-depth knowledge of microcontrollers and PIC programming in order to control the winch motor, lift motor, photoelectric sensor, and tower light in order to create a safe and reliable recreational device for disabled persons.

To depict and dimension our design, this team has learned multiple CAD software programs including AutoDesk, Microsoft Visio, and SolidWorks. The CAD designs in SolidWorks allowed for a complete assembly of the components to provide a working design that will successfully meet the needs of the client. We have also learned to effectively use MPLab and Multisim to create and test circuit theory and apply it to the ARC Slide design.

Working as a team in a design project has given us insight into developing effective communication skills with each other and also the client. Without these skills, it is nearly impossible to effectively create a device, such as the ARC Slide. The design would fail to meet the objectives set in the early design phase of the project.

7. **Budget**

   Budget Initially: $1,385.00
   Second Budget: $1,685.00
   - New motor controller, PCB, wireless module.

   Total Expenditures: $1760.00
   Remaining: -$74.32
Figure 7.1 below shows a pie chart of the distribution of the budget. Most of it was spent on electrical components as it is seen.
Table 7.2 shows the itemized expenditure

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Total: $1,735.32

Remaining: ($134.89)
8. Team Member Contributions to the Project

Hillary Doucette

Hillary was responsible for the electrical components of the ARC slide. This task included interfacing both the lift motor and the winch motor with a wireless control unit, and determining electrical safety measures for the client, Joey Toce. With a background in bioinstrumentation and equipment engineering, Hillary was able to design a system which incorporated electrical feedback devices intergraded with a 40 pin microcontroller. The electrical components included in the arc slide are the winch motor, lift motor, tower light, motor control units, boost converter, kill switch, wireless control unit, position switch, photoelectric sensor, printed circuit board, and programming the microcontroller in C code.

The first task Hillary took on was creating a truth table which summarized the electrical feedback system of the microcontroller. This truth table included the inputs of the wireless control unit and photoelectric sensor, as well as the outputs of the 3 color tower LED lights and the motion of the lift and winch motors. Once an outline of the electrical components was created, purchases were made for the motors and tower lights which contoured to a 12V DC battery power supply. Because the tower lights found required 24V, a 12-24V DC boost converter was also researched and purchased so that all devices could be powered using one small 12V 30A-hour car battery.

After the initial electrical components were delivered and tested, two motor drivers were purchased by Hillary which controlled the forward and reverse motion of both the lift and winch motors, given inputs from the microcontroller. Both of these units analyzed two inputs, S1 and S2, to determine the motor’s operation, and were tested using a plug-in power supply. Also, a photoelectric sensor and position switch were purchased to detect the final position of the car and lift platform. A 4 channel, RF wireless transmitter and receiver was purchased, assembled, and tested, to integrate the commands from the user to the controlling unit. Lastly, a microcontroller was programmed in C code and tested to analyze the six inputs of the positions switch, photoelectric sensor, wireless control unit, all inputs and outputs.
Hillary’s final task included designing a printed circuit board which incorporated all input and output ports, as well as creating and testing transistor switches to turn on and off output signals. After the PCB was assembled and tested, each electrical component was soldered and tested individually using a plug in power supply and digital volt meter. A voltage bus was created to distribute the power supply from the 12V DC car battery to all electrical components, and a kill switch was attached to the electrical housing unit to cut the power supply to all electronics. The last main task Hillary took on was to waterproof all components using an apoxy resin so that the ARC slide was suitable for outdoor use.

**Stephen Kustra**

Stephen’s role in the ARC Slide project included designing and constructing the car, selecting materials and building the platform and track. He also fabricated and machined components needed to complete the optimal design of the device.

Stephen determined that the structure should be made of pressure treated lumber and composite decking in order for the slide to endure the outdoor elements in all seasons. With this design modification, the ARC Slide will last longer than as if built with regular lumber. It will also be able to remain in place year round.

The car was built by Stephen, also. He located a used metal frame from a gait trainer when visiting the NEAT Marketplace in Hartford, CT. He modified and increased the length of the car frame such that the Carrie seat also purchased at NEAT Marketplace could be mounted to the car frame in an ergonomic and stylish fashion. With the use of nylon fabric, Stephen fabricated a custom fit seat cover for the Carrie seat. He also constructed the leg rests and modified the foot rest mounting system to the Carrie seat.

While some hardware could not be purchased at the local hardware store in Storrs, CT, Stephen made numerous trips to Home Depot to purchase lumber and hardware for the car and the slide.
Sarmad Ahmad

Sarmad was given the tasks of working on the platform, track, the release mechanism and the flares. Firstly Sarmad designed the slide and the release mechanism was drawn using Microsoft Visio. In it the locations of the supports for the slide and the locations for the winch and lift motor were declared. The design changed a little bit when it was finally assembled in Solid Works and it was decided that wolmanized wood will be the best choice. In the schematics for the release mechanism the location and movements of the parts was shown.

He started with the fabrication of the release mechanism first as the lumbar needed for the track and platform had not arrived yet. Aluminum was machined and the pieces started to come together. The design of the release mechanism changed a little and became a little simpler. All the parts were put together on an aluminum base which was then mounted under the car.

The track was built by both Stephen and Sarmad. It was a combined effort between the two. The wood for the track was cut out and ready to be put together using wood screws. The flares for the track were also made out of the same wood used for the track, pressure treated wood. The wood pieces were carved out and then attached on to an aluminum plate as well. The plates were then screwed into the track for added support.

Sarmad also helped Stephen by painting the car however the frame had to be repainted due to chips and peeling.

9. Conclusion

The objective of this project was to design a safe, easy to use, and fun slide for Joey Toce, a 6 year old boy with Cerebral Palsy. Since the car was custom built with a Carrie seat that was approved for Joey’s size, this slide will be a safe and enjoyable. Safety was also the number one concern when designing the track for the ARC slide, and a lot of measures have been taken to ensure that all electrical and mechanical components work properly before delivery. Once
delivered, the ARC slide is expected to be an excellent means for Joey to have fun while gaining more independence when playing outdoors

10. References


11. Acknowledgements

We would like to thank Dr. John Enderle, James Paolino, Katrina Toce, Jennifer Desrosiers, Kerrie Wenzler, Lisa Ephriam, Serge Doyon, Pete Glaude, Rich Bonazza from the Uconn machine shop, the National Science Foundation, Eric Leknes, Faruk Dirisaglik, Ray Kustra, and Mike Doucette, for their insight and support for the completion of this project.

12. Appendix