CHAPTER 7
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WHEELCHAIR DESK

Designers: Mark Palmeri, Brian Pullin and Ethan Fricklas
Client Coordinator: Jodi Petry, Lenox Baker Children's Hospital, DUMC
Supervising Professor: Dr. Laurence N. Bohs
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INTRODUCTION

The client is a 16-year-old male high school student with Duchenne Muscular Dystrophy. This disease is characterized by a progressive weakening and deterioration of muscles, and has limited the mobility of the client's arms and legs. He is therefore restricted to a powered wheelchair during the school day. Desks and tables for writing and eating are not easily accessible from his wheelchair. The designers built a retractable desk that the client can move into position by himself.

SUMMARY OF IMPACT

The client's ability to transport his desk on his chair, and to move it into and out of position, greatly increases his independence. He can use the desk for doing schoolwork and reading, for using his laptop computer, and for entertainment purposes such as playing video games.

TECHNICAL DESCRIPTION

The wheelchair desk (Figure 7.1) is designed to swing into place over his head. This approach was taken because of space constraints and the lack of stationary mounting points on the sides of his powered wheelchair. The storage position for the desk is behind the chair (Figure 7.2). When activated, it swings up and over Ryan's head (Figure 7.3), and down onto the armrests in front of him (Figure 7.1). Retraction of the desk takes place in reverse along the same path.

A 12VDC permanent magnet gearmotor rotates the desk. It produces a maximum continuous torque of 500in-lb, and supports an overhang load of over 200 lb. The motor is powered from one of the two 12V batteries on the client's wheelchair. It mounts to the left seat post of the chair, using a 1/4'' thick stainless steel mounting bracket. A commercial DC motor speed controller kit, Kitrsrus Kit #67, reduces the motor's speed. (Figure 7.4.) The speed controller uses pulse-width modulation to reduce the desk's

Figure 7.1. Ryan's Wheelchair Desk.

rotational speed to approximately 2 rpm.

The motor is connected to the bracket, and the bracket to the seat post, with 1/4'' bolts. Washers on both sides uniformly distribute the clamping force, and a locking washer on the nut side prevents loosening during while the desk is in use. A specially designed coupler made of 1/4'' aluminum connects the motor shaft to the telescoping rails. This coupler is attached to the inside of the end of the telescoping rail using two 1/4'' hex bolts with locking washers. Two setscrews along the keyway and one setscrew on the shaft secure the coupler to the motor shaft.

The extension and retraction of the desk along the telescoping rails is accomplished using a 24VDC linear actuator, capable of a thrust load of 300lb. This actuator runs at half-speed on 12V using the second battery on the client's wheelchair.

The weight of the desk is sufficient to force the rotation of the motor, even after power is removed. A brake is therefore used to prevent further rotation of the desk when the controls are off. The brake is a 24VDC holding brake from Warner Electric (model ERS-57). When it is desired to rotate the desk, a voltage is applied to the brake, which releases internal springs and allows it to turn. When the voltage is removed, the springs activate and the brake locks into position.

The brake mounts to the chair using a 1/2'' thick aluminum bracket and ¼" bolts. An axle mounted on the chair-end of the actuator at a right angle to the actuator axis, connects to the center of the brake. When this axle is locked into position by the brake, the desk is prevented from rotating. The axle is attached to the actuator using a 2-piece bracket that clamps around the base of the actuator shaft. 5/16'' bolts with locking washers join the two halves of the bracket together. Care was taken not to over-tighten this bracket, because the shaft of the actuator is made of sheet metal, and is easily deformed by any non-symmetric radial loading. These pieces are centered underneath the motor of the linear actuator to provide symmetric weight distribution. A second two-piece bracket connects the shaft of the actuator to one of the telescoping rails. The rail attaches to the bracket using low-profile 1/4'' bolts.

The telescoping rails are high-quality commercial file cabinet rails, built to support heavy weights without binding. Ball bearings in the rails reduce resistance to sliding, which is desirable since extension and retraction by the linear actuator is only applied to one rail. Three pieces in each rail slide into one another, with the smallest inner rail guided along a series of ball bearings. The inner rail can also be removed from the rest of the pieces by disengaging a plastic clip. This clip is essential to the quick release mechanism of the desktop. The desktop mounting pieces are attached to these inner pieces, which means that removal of both inner rails allows the entire desktop to be removed as a unit. The inner rail on the actuator side is connected to the actuator using a 1/2'' x 1/4'' aluminum rod and ¼" bolts. The attachment to the rail is made using a wing nut for quick release, and the attachment to the actuator occurs through the hole in the end of the extending shaft.

Figure 7.2. Wheelchair Desk in Stored Position Behind the Chair.

Since separate switches control the motor and the actuator, safety sensors and logic circuitry are

Figure 7.3. Desk Swinging Overhead.

provided to ensure that the desk is fully extended before it passes over the client's head. A reed switch is mounted along the inside of the telescoping rail that is connected to the actuator, and a magnet is placed along the actuator shaft. The mounting positions are set so that the magnet trips the reed switch as the desk reaches the fully extended position. If the desk is fully extended, then it is allowed to rotate freely. If it is not fully extended, the desk may not rotate forward past vertical (directly behind the client's head), or reverse past 45° above horizontal. Three mercury tilt switches are used to determine the angle of the desk. These metal-encased switches are secured with setscrews into a housing situated on the outer actuator mounting piece. A logic circuit (Figure 7.4) connects to these switches and the reed switch to control the operation of the gearmotor and actuator.

The desktop is constructed of clear polycarbonate for durability, and also to allow the client to see what is below and in front of him. The desktop is equipped with a cutout for his motion joystick (allowing him to move his chair while the desk is in place), a groove along the perimeter of the surface to prevent items such as pencils from rolling off. Also, rubberized elbow rests cushion his elbows and keep them from slipping off of the desktop. A protruding lip can also be attached to the inner edge of the desktop so that books and papers will not slide off.

Since the gearmotor that rotates the desk only attaches to one of the arms, the desk itself provides the link for rotation of the actuator-side arm. The polycarbonate desk itself is not strong enough to bear this twisting load, so a desk-reinforcing bracket is implemented. This bracket also helps prevent any buckling of the desk as heavier books are placed on its surface. In addition, the elbow areas are further reinforced since they bear the greater load under the client's weight. The reinforcing bracket is made of 1/2" square steel tubing, silver-soldered at all joints. The desktop surface is attached over this bracket using #4-40 machine screws that extend through the tubing to nuts on the bottom side. The inner section of each telescoping rail is attached to the bracket using #10-24 machine screws and cap nuts. 1/2" nylon spacers are included in this connection to align the rails with the width of the desk. To ensure that the desk stops if it encounters an obstacle while rotating, 24" ribbon switches are mounted parallel to each rail on top and bottom sides, using aluminum sleeves mounted to the rails. If any of these four switches is contacted, a logic circuit stops the motor from rotating.

The cost of the project is approximately $1000.00.

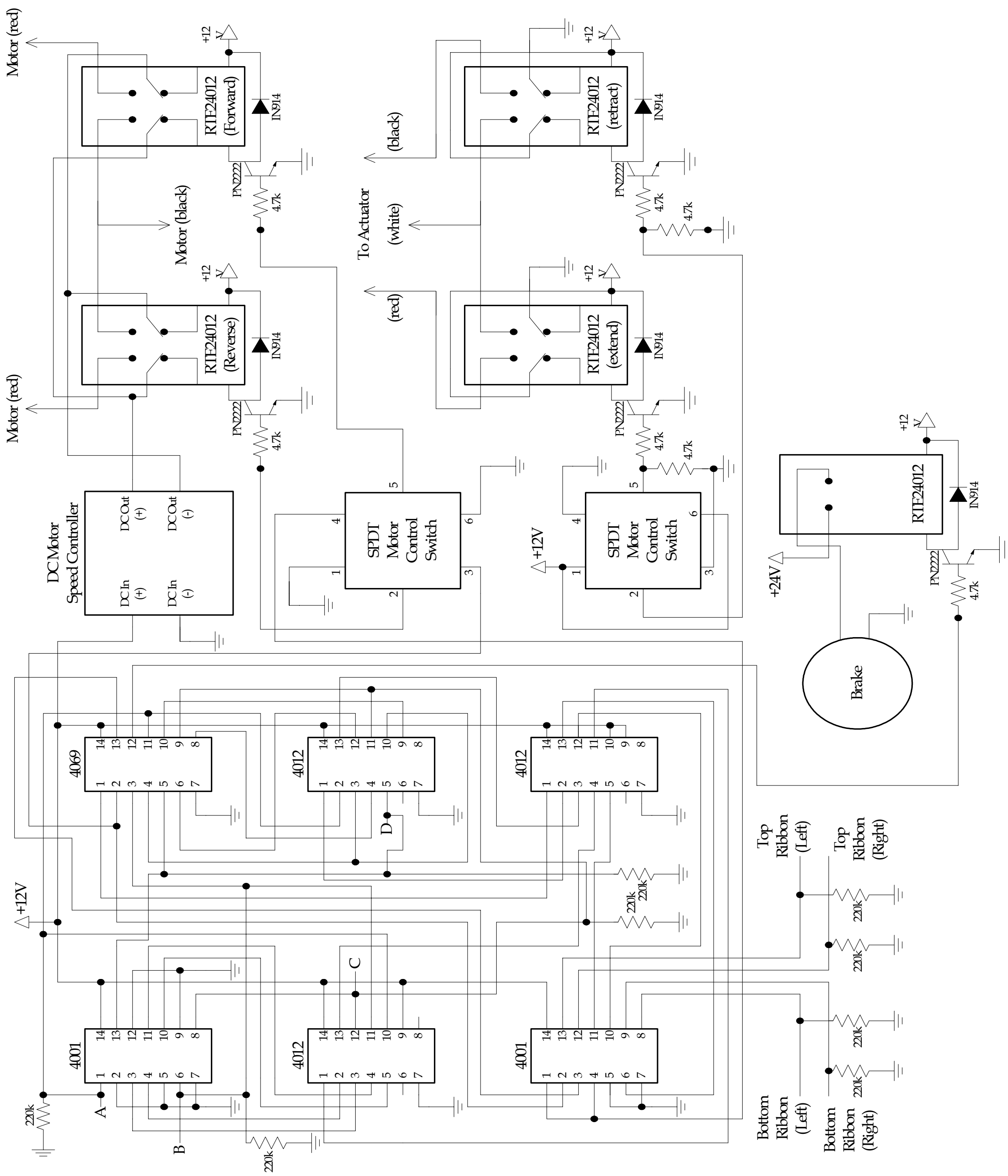

Figure 7.4. Control Circuitry for the Wheelchair Desk.

THE SPINNER

Designers: Ashlan Reid and Peter Hultman
Client Coordinators: Susan Parker and Edie Kahn, Durham County Schools
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INTRODUCTION

The client is a four-year-old boy with thiamine-responsive megaloblastic anemia (TRMA), also known as Rogers Syndrome. His disease is characterized by severe physical disabilities and limited cognition. The client's disabilities hinder movement to the extent that he rests lying on the floor on his side. He cannot independently rise from this resting position into a seated position. Once assisted into a seated position, he has limited movement. The objective of this project was to improve the client's quality of life by aiding him in independently maintaining a seated position while allowing him to freely rotate to change his visual field. Secondary objectives include strengthening his abdominal, oblique, and arm muscles, improving his balance, and providing him with greater independence in the classroom.

SUMMARY OF IMPACT

The Spinner impacts the client's life in three ways. First, it strengthens his trunk muscles, and improves balance to aid him in attaining a seated position independently. Second, it increases his independence; the specially designed seat allows him to remain in a seated position without assistance from classroom workers or tight straps. Third, the detachable seat designed for this device may be used by itself as a stationary sitting aid. This further grants the client more inclusion in normal group activities.

TECHNICAL DESCRIPTION

The Spinner (Figure 7.5) includes a specially designed seat and backrest with optional chest and lap straps. The seat is a wooden frame padded with relatively firm supportive foam blocks. The seat is attached with Velcro to a disk that rotates with respect to a base. An adjustable and removable table provides a play surface and houses a tilting surface for other activities. The rotation of the disk is limited to approximately 180^{o} to keep the client within the reaches of the table. The rotation of the disk is also damped so that motion is controlled. Evenly spaced notches around the inside circumference allow the client to propel himself to different areas of the table.

Figure 7.5. Spinner.

A 6” by 8” bread-shaped area in the center of the table contains a tilting surface that can be used for artwork, pictures, or toys. This surface normally lies flush with the table, but can be raised to various angles by placing the upper edge of a supporting panel between any two of the rubber stoppers on the back of the primary panel.

An attachment to the tilting surface provides 12”x15” of workspace. This attachment also has a ledge that resembles the chalk holder of a chalkboard.

The device includes two detachable side panels of special felt-like material that works well with Velcro used to secure toys to the table. The Musical Gears toy sits on the tilting surface extension and plays music when the client rotates the colorful gears. The Box and Blocks toy can be placed anywhere on the Velcro pads and requires the client to recognize which blocks fit in each hole. The blocks in this toy are modified so that the client can play with shapes and sizes that he could not normally manipulate.

Each leg of the table is made from a pair of hollow telescoping square poles. The height of the table is determined by aligning a pair of the inner leg holes with a pair of the outer leg holes. Self-locking pushbutton pins hold the legs in position. This arrangement allows approximately 3.5” of vertical adjustment.

The client’s bucket seat is composed of a trapezoidal wooden shell, five foam cushions, and an adjustable belt strap. The design encourages the client to sit straight instead of leaning to one side. A pommel fits between his legs to ensure that he cannot slide out of the front of the seat. The belt strap is placed over his lap, angling backwards, so that he cannot fall out of the seat by rotating forward. The seat is attached to the spinning disk using strong Velcro so that it can be removed. The backrest is comprised of two telescoping poles, a wooden frame, a cushion, and an adjustable chest strap. The height of the backrest is altered to match the table height.

The disk (Figure 7.6) is attached with epoxy to a spacer made of Plexiglas. The Plexiglas is screwed to one plate of a Lazy Susan ball bearing. The other plate of the bearing is screwed to the main section of the base. Removing the disk reveals the “pick system”, which slows the client’s motion with a variable resistance. A semicircle of 0.25” diameter dowels protrude down from the bottom of the disk but do not contact any part of the ball bearing or stationary part of the base. A small, flexible plastic pick sticks out horizontally into the disk area from the side of the primary base. As the disk turns, the pick is pulled across each dowel in turn, thus slowing the disk. The range of rotation is limited to just over 180° using three additional dowels.

The cost of the project was $335.

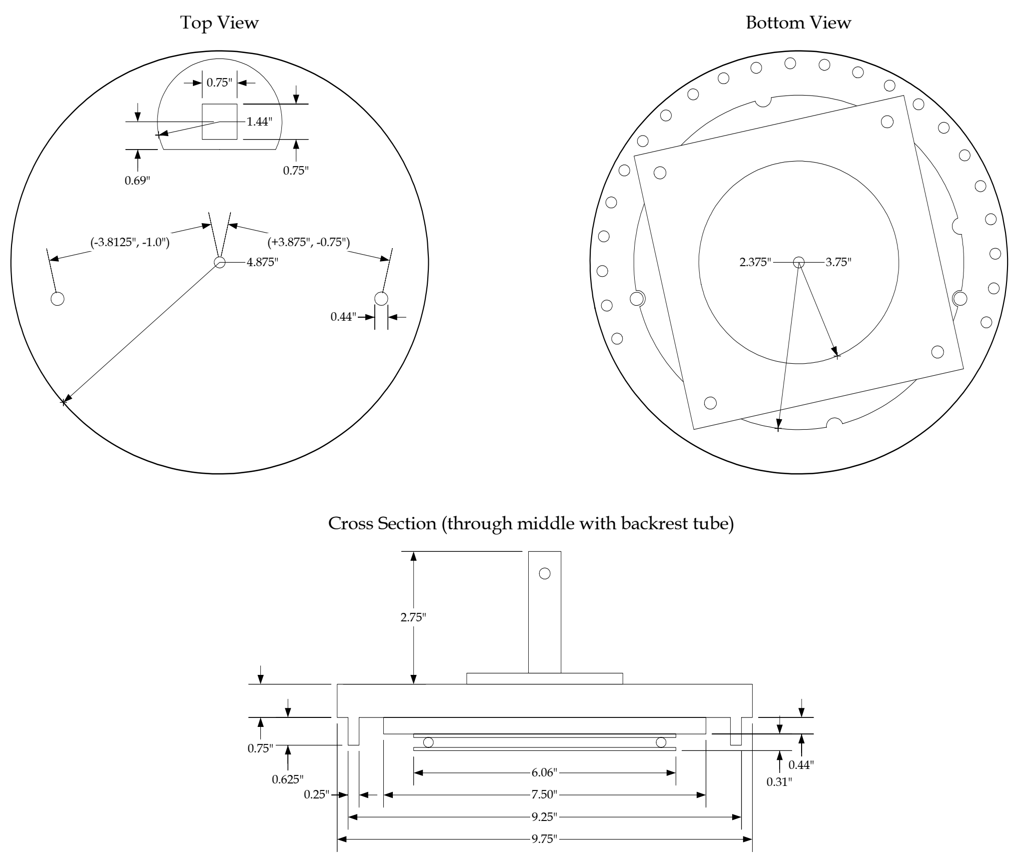

Figure 7.6. Disc and Pick System for the Spinner.

GUITAR STRUMMER

Designers: Jason Bennett and George LaVerde
Client Coordinators: Jane Stavely, Kaaren Jewell
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INTRODUCTION

The client, now eleven, had a left hemisphere stroke when he was three. Consequently, he does not have the physical coordination in his right arm and hand to strum a guitar. The Guitar Strummer gives the client the opportunity to learn how to play the guitar, despite physical restrictions. The design is simple, lightweight, and portable, and the client can assemble and use it without assistance. He uses his left leg to control the rhythm of strumming.

A foot pedal actuates a pivoted striking rod that hits all of the strings at once. When the pedal is tapped, a cable pulls up on the short end of the rod, causing the long end of the rod to swing down and strike all the guitar strings simultaneously, creating a sound similar to strumming. The striking rod housing unit is removable for easy transportation and storage.

SUMMARY OF IMPACT

Because the client has minimal control over his right arm and leg, he does not have the capability to play the guitar. This device improves the client's life by providing him with that capability. The project supervisor and client's mother hopes that "having music as an outlet for his creative energies will boost his self-esteem, (and) provide him with a means to entertain himself as well as others."

TECHNICAL DESCRIPTION

The Guitar Strummer (Figure 7.7) uses a foot pedal to pull a bike cable attached to a polycarbonate-striking rod. The rod's starting position is slightly above the strings. When the client taps the foot pedal, the mechanism on the pedal pulls the bike cable, which thereby pulls the short end of the rod so that the opposite end swings down and strikes the strings. A rubber band, which attaches to a hook on the striking rod, holds the striking rod in the resting position. The rubber band rests in a groove on the back of the striking rod housing unit. The striking rod is slightly loose on the cable so that

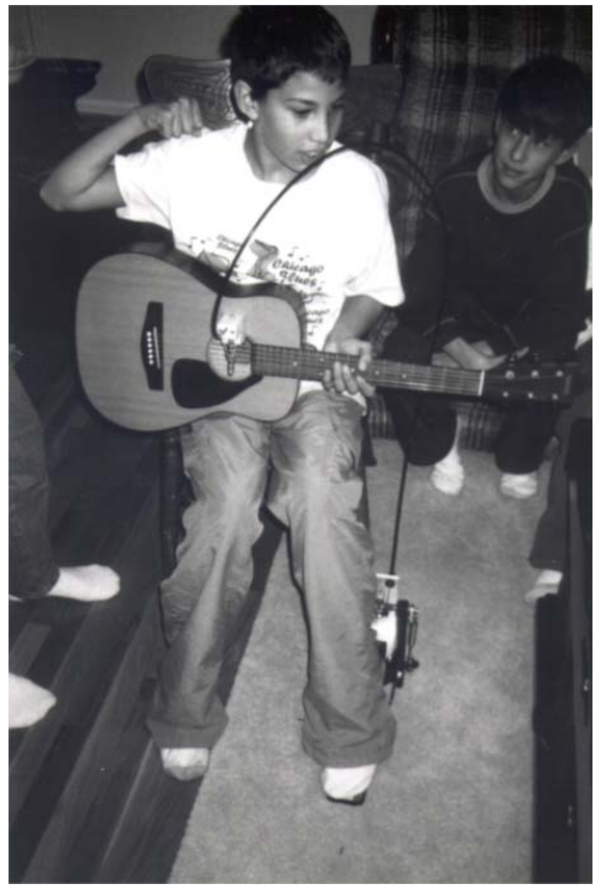

Figure 7.7 Client Using the Guitar Strummer.

when it hits the strings, the rod has some mechanical freedom from the cable mechanism and can thereby bounce to prevent damping. Additionally, when the rod strikes the strings, the rubber band pulls the rod back up and allows the strings to resonate.

The foot pedal mechanism is modified from a bass drum foot pedal. The bike cable housing is attached to an aluminum L-shaped plate. The cable passes through a hole in the plate. A rotating disk that is fastened to the original mallet rod holds the end of the cable. When the pedal is pressed, the end of this mallet rod is rotated along a circular arc away from the aluminum plate, thereby pulling the cable. The cable and cable housing extend up to the guitar where they attach to the striking rod housing unit.

The striking rod housing unit holds and stabilizes the end of the cable housing, and is shown in Figures 7.8. The cable, which has a stop at the end to pull the striking rod, extends past the end of the cable housing and through a slightly loose hole in the rod. The striking rod pivots on a horizontal pin that runs through the center of the striking rod. The height of the striking rod pivot pin is adjusted using the four Allen screws.

The striking rod housing unit attaches to the guitar via the aluminum housing brace. The brace acts as a clamp that attaches to the face of the guitar. Two Allen screws hold the brace in place by clamping the free aluminum piece tightly against the inside face of the guitar. The strings of the guitar can be removed to access the two Allen screws. The striking rod housing unit slides onto the brace and locks into position using ball detents located on the brace. Therefore, the brace is fixed to the guitar, but the striking rod housing unit is easily removable.

The final cost of the project was about $275.

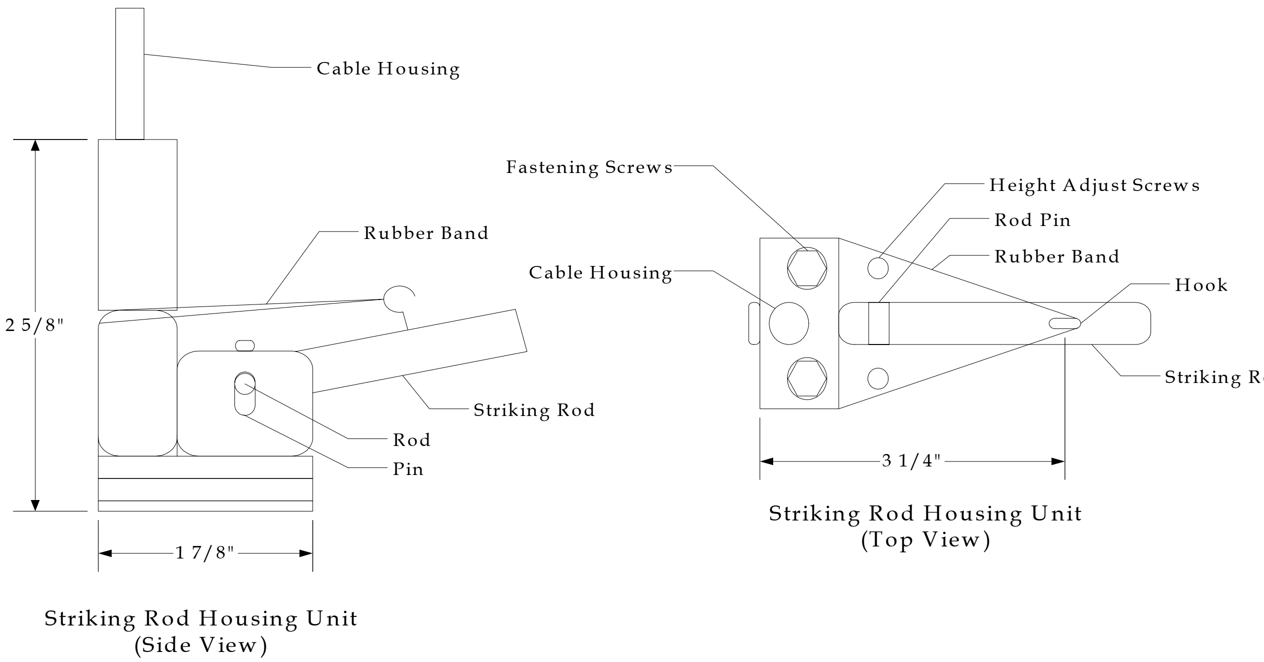

Figure 7.8. Striking Rod Housing Unit.

SHOPPING AID FOR PERSONS WITH VISUAL IMPAIRMENT

Designers: Nupur K. Modi and J. Brent Ratz
Client Coordinators: Dr. Henry A. Greene, Assoc. Prof. of Ophthalmology, UNC
Supervising Professor: Dr. Laurence N. Bohs
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INTRODUCTION

Many people with severe visual impairments can only read newspaper headline-sized print or larger. Many of these people have medical conditions that make it essential for them to be aware of nutritional facts and ingredients. For these people, grocery shopping is not only inconvenient, but also potentially dangerous since they have trouble reading labels on food packages.

The Shopping Aid for Individuals with Visual Impairment (SAIVI) provides this information in a large, easy-to-read manner. The components of SAIVI include a laptop computer and barcode scanner secured to a typical shopping cart. After the user scans a product's barcode, the laptop uses the UPC number to access a corresponding data file. The item name, price, promotional information, ingredients, and nutritional facts are displayed in a standard format. Large buttons on the keyboard allow the user to scroll through all of the information or to jump directly to a desired heading. Keys for variable magnification, color reversal, and audio feedback of the product name and price are also provided. An additional feature lists the items in the cart and displays the running price total, while allowing products to be added to or deleted from the list.

Figure 7.9. The Shopping Aid for Individuals with Visual Impairment (SAIVI).

SUMMARY OF IMPACT

For many people, a product's ingredients, nutritional content and price are the major influences in a purchasing decision. As a result, individuals with visual impairments may be limited to purchasing only the items they already know about or may need assistance shopping. In addition, knowing the amounts of certain nutrients and ingredients can be crucial for shoppers with medical conditions or special dietary needs. In addition to the direct health implications of the device, greater independence is achieved. As Dr. Henry A. Greene, Associate Professor of Ophthalmology at the University of North Carolina points out, "Their vision loss makes it hard for them to derive the information required for them to make their own decisions, including what they eat. This device will afford them an ability to retain or regain at least some level of independence."

TECHNICAL DESCRIPTION

SAIVI consists of a barcode scanner, computer programming and the mounting system (Figure 7.10). Computer programming includes all of the code used to enter, access, and display the product information. The programming can be separated into the Customer Interface, which is used by the person with visual impairment to access product information, and the Data Entry Page, which is what the store employee entering the information uses. Because both facets of the programming require substantial user interaction and graphical display, the Java programming language is used.

Prior to scanning, a separate data file is created for each product using the Data Entry Page. The filename for each data file is the UPC code for the product itself. The data file contains all nutritional, promotional, ingredient, and price information for a particular product. At this time, the Data Entry Page must be completed by hand. In the future, the information for each product will be downloaded from the store's database.

Once the customer obtains the device from customer service, they are greeted with the "Welcome" page. The device then waits for the user to press a key or scan an item. If the user is not familiar with the device, brief instructions and key descriptions are available when the "Down" arrow is pressed at the start-up screen.

When a shopper holds a product up the scanner, the UPC code is loaded into the program. Because the scanner automatically concatenates the ASCII code for the "Enter" button at the end of the UPC number, the program can read a barcode of any length. Once the program recognizes the "Enter" code, it reads the data file that corresponds to the UPC variable points, making all the information about that product available to the shopper. The program automatically displays the product name and price in the first screen, which appears immediately upon scanning the product.

Before making a decision, the user may view the item's nutrition facts, ingredients, or a list of the items currently in the cart by pressing the "N," "I," or "LIST" button, respectively. The magnification feature allows the user to choose between 75pt, 100pt, or 120pt font sizes. The REVERSE COLORS button toggles back and forth between white-on-black and black-on-white. In addition to these features, audio output is also available for the product name and the price by pressing the HEAR PRODUCT/PRICE button (yellow speaker). Pressing this button plays a .wav file (constructed using the Windows Sound Recorder) that contains the product name and the price.

The mounting system consists of a cover, designed to replace the standard laptop keyboard with 11 large buttons and a base plate, which is permanently mounted to the cart and serves as a platform for the laptop computer and the laser scanner. The cover is constructed from 1/16" sheet metal. Two side brackets mounted to the cover secure the laptop to the base, using small pad-locks. The cover contains cut-outs for the scanner plug and the buttons from a large button telephone, to which custom labels are attached to designate the user functions (see Figure 7.10). These buttons provide a mechanical link to selected buttons on the laptop keyboard.

The total cost of this project was approximately $400.00, excluding the laptop computer.

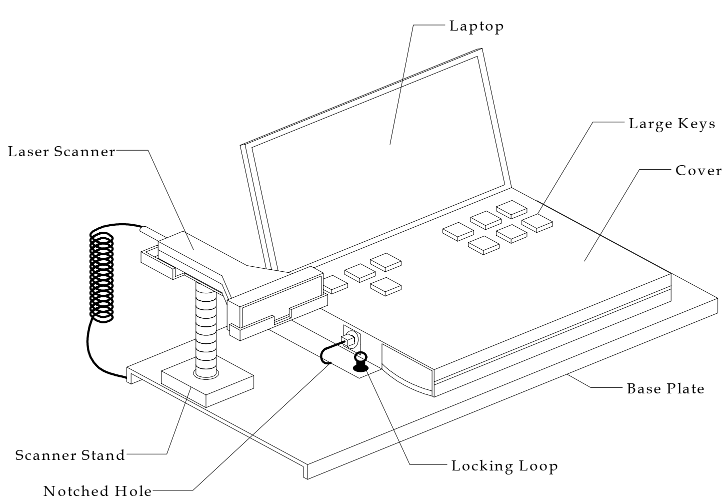

Figure 7.10. Shopping Aid Components.

THE POINTER TRAINER

Designers: Samuel Kuo and Peter Wang
Client Coordinator: Mary Caldwell, Duke Hospital Pediatric Rehabilitation Unit
Supervising Professor: Dr. Laurence N. Bohs
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INTRODUCTION

The goals of the Pointer Trainer are to improve head coordination in children with brain injuries, and to help them learn to communicate using a laser pointer. Hospital rehabilitation therapists will use the device.

The Pointer Trainer consists of a target box and a laser diode. To improve head coordination, the laser diode is mounted to a headband so that children with traumatic brain injuries (TBI) can use their head to point the laser diode at the target box. Upon hitting the target for a specific period of time (1 or 3 seconds, selectable by the therapist), an audio response is activated. This response is recorded prior to the therapy session, and can be associated with a picture or word near the target box. The design allows children to communicate by pointing to a target box with the desired audio response.

SUMMARY OF IMPACT

The physical aspect of training and strengthening neck muscles through maintaining the laser position in order to activate the target box helps children improve their muscular control. During their recovery, children without the ability to speak will have a simple form of communication through the audio response of the target box. The ability to interact with other people despite their limited physical and communication abilities gives children with TBI greater independence.

TECHNICAL DESCRIPTION

A positive focal length Fresnel lens (2" diameter, 1.3" focal length) is positioned as a collector in the target box. Light hitting the Fresnel lens is directed towards a photoresistor placed at the focal length of the lens. A trigger circuit determines the amount of time that light needs to strikes the photoresistor.

The main components of the trigger include the photoresistor and an LM311voltage comparator (see

Figure 7.11. The Pointer Trainer.

Figure 7.12). The resistance of the photoresistor decreases with increasing light intensity. The trigger circuit automatically adjusts to the ambient light level as follows. The voltage at the negative input of the LM311 drops instantly as light hits the photoresistor. However, a capacitor/resistor pair delays the voltage drop at the positive input. The voltage at the positive input eventually drops below the voltage at the negative input as the circuit approaches steady state. Voltages at both inputs vary with ambient light intensity, thereby eliminating the need for a fixed reference voltage. The output of the voltage comparator is low during a steady state and becomes high when the laser illuminates the photoresistor.

The comparator circuit uses hysteresis to eliminate output oscillations. These oscillations result from noise on the comparator inputs. By setting the hysteresis voltage greater than the noise, oscillations are eliminated.

When the laser hits the photoresistor, the CD4017 counter is enabled. The counter is a decade counter with a separate output pin for each count. The clock input is from a 555 timer with a 415 ms clock cycle. At approximately 1 and 3 seconds, the counter counts to "3" and "7", respectively. The two pins corresponding to these outputs are connected to a switch that selects the desired activation time. The position of the switch determines which output triggers the record/playback circuit.

The record/playback circuit uses an ISD1520 chip, which allows the therapist to record a message up to 20 seconds long. An LED illuminates to indicate recording. A condenser microphone is used to record the audio message. The ISD1520 drives a LM386 audio amplifier to provide output to the speaker. The entire circuit draws 21mA at resting state and 50mA during an audio feedback response.

On the rear of the target box are momentary switches to operate the record and playback functions, a 10kΩ potentiometer for volume control, and sliding switches for power and to select the desired activation time.

The cost of the project was about $200.

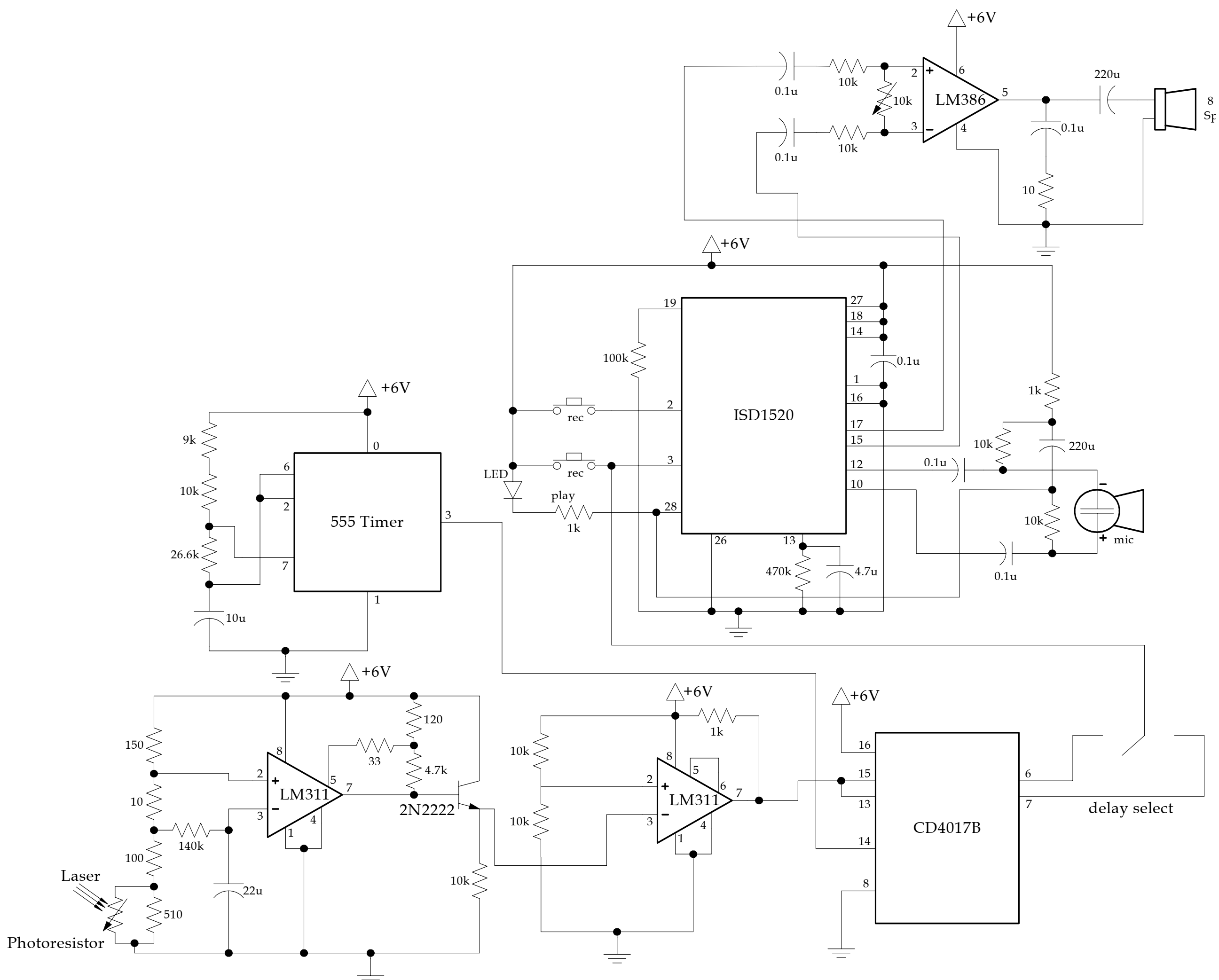

Figure 7.12. Pointer Trainer.

CHILD FRIENDLY TIMER

Designers: Mike McCarthy and Justin Wool
Client Coordinator: Lenore Champion , Duke University Medical Center
Supervising Professor: Dr. Laurence N. Bohs
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INTRODUCTION

The objective of this project was to build a timer that is visually and aurally enticing to children with brain injuries. The child friendly timer shows the passage of a specified period of time and helps children learn that they must complete tasks, such as eating, at specific times. The timer is portable and aesthetically consistent with the toys of young children. The timer countdown time can be set in increments from one to 30 minutes. At the end of the countdown, the timer creates visual and auditory stimulation to signal that time has expired.

SUMMARY OF IMPACT

Children with brain injuries are often unable to focus on a specific task, which can make them unable to perform essential daily activities. The Child Friendly Timer teaches how to focus on daily tasks for an appropriate amount of time by assigning significance to time. The climbing fireman is interesting to children, but not so interesting that it distracts them from the task at hand. The timer is large enough to facilitate the visualization of passing time.

TECHNICAL DESCRIPTION

The child friendly timer is developed from a commercial toy in which a fireman climbs a 4-ft. ladder. The fireman climbs up a ladder as the timer counts down from the initial starting point. As the clock runs out, the climber reaches the top of the ladder, and then returns to the base of the toy. When the fireman reaches the top, a music and light show clearly signals that the allotted time has expired and that the child will have to finish the activity. The timer is controlled by an electronic system including a BASIC stamp microprocessor and several other components (see Figure 7.13).

Figure 7.13. Child Friendly Timer.

Five interface buttons provide inputs to the timer. Each has a specific function:

- To reset the timer value,
- To reset the time increments,
- To start the timer,
- To pause or stop the timer, and
- To trigger an emergency finale and reset the timer to zero.

An LCD display, which is mounted to the surface of the device, shows the time remaining in the countdown process once the timer has been started.

The microprocessor controls the operation of the Child Friendly Timer. Initially, the user sets the clock to the desired duration for the therapy session. Based on this assigned time, the microprocessor calculates the number and duration of steps that the fireman will use to climb the ladder so that the top is reached just as time runs out. With each step, the microprocessor controls a reed relay switch that connects power to the motor inside the fireman climber for a specific duration. Once the climber reaches the top, the microprocessor switches another reed relay to trigger a melodic generator circuit that plays "Old MacDonald." The melodic generator circuit is connected to a speaker and audio amplifier housed within the toy case. A third relay is actuated at the end of the therapy session to control a light show consisting of forty LEDs, of which 20 flash in a random sequence. Two AA batteries power the climber, while the microprocessor and associated circuitry use four C batteries.

The final cost of the project was approximately $400.

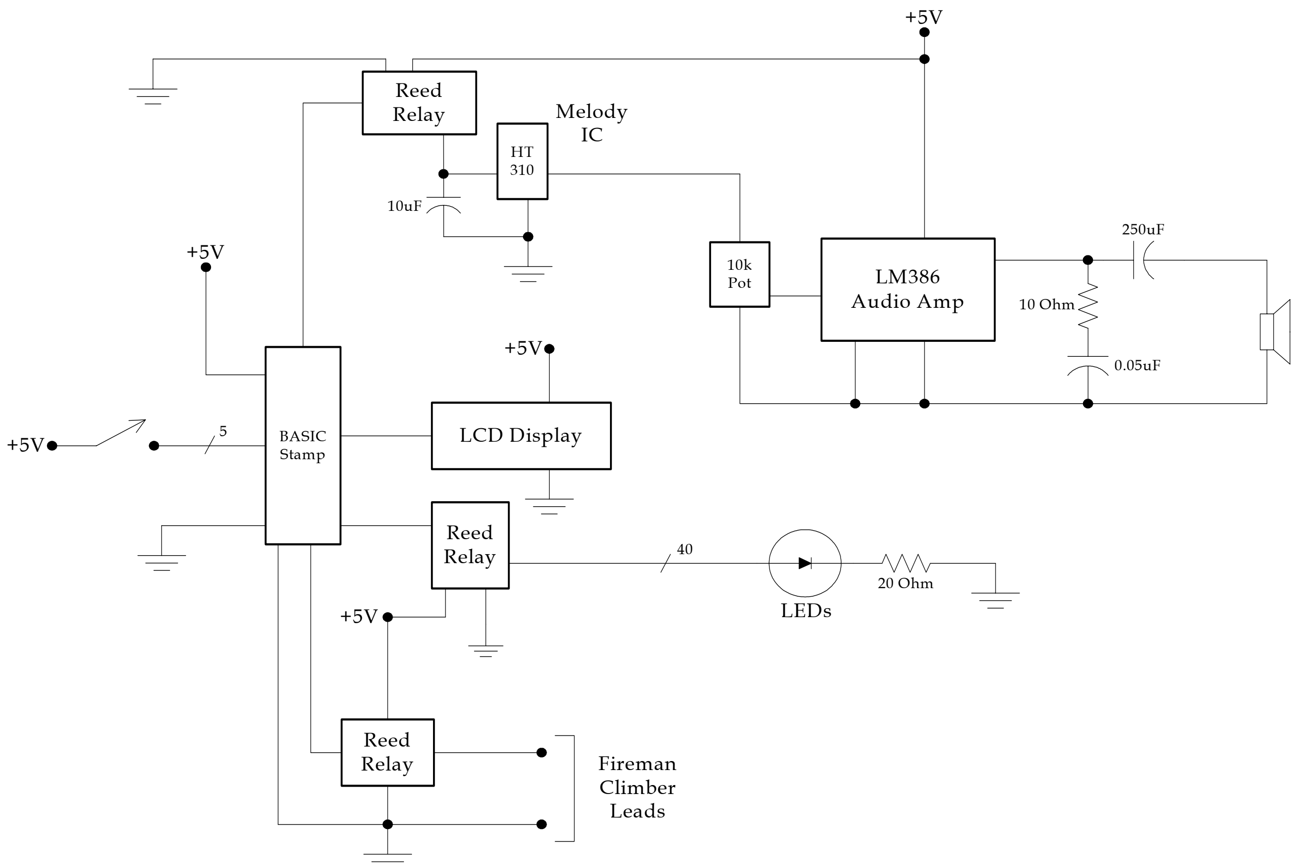

Figure 7.14. Electronic System.