CHAPTER 6
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WHEELCHAIR DESK

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INTRODUCTION

A high school student with Duchenne Muscular Dystrophy needed a wheelchair-mounted desktop surface for schoolwork, computer work, and eating. He previously used a commercial work surface that rested on his lap. This surface was cumbersome and would move undesirably when he moved. A removable desk was constructed to mount to the client's powered wheelchair. The desk slides on to two custom fixtures attached to the sides of the wheelchair frame, and can be removed for storage behind the chair. The desktop is edged with soft rubber tubing to prevent items on the desk from slipping off, and the desk shape allows for normal wheelchair function.

SUMMARY OF IMPACT

The client's mother had this to say about the desk: "He really likes it. It makes his schoolwork more accessible. He doesn't have to adjust to the existing tables, which are often not the right height. We put it on in the mornings, and he leaves it on all day. He can keep all of his work on top, so everything is handy. It has brought his work up to him, and has helped him a lot. It's been neat to see how he really wants it, and asks for it."

TECHNICAL DESCRIPTION

The desktop is made of ¼" thick clear polycarbonate and is lined around all edges with ½" diameter black rubber tubing for protection, slippage prevention, and comfort. The desktop attaches by four screws to a frame welded from ½" square steel tubing. Foam rubber padding lines both the top and bottom of the rear portion of the desk top, which rests on the wheelchair armrests. The padding on the bottom protects the armrests from damage caused by contact with the desk, while the padding on the top increases comfort during use. A cutout in the desktop allows the client to reach the power switch and joystick for his chair.

Two ¾" I.D. square steel tubes, both 10" long, are attached to the desktop frame by hinges, which are welded to these support tubes and the frame. The hinges allow the support rods to fold parallel to the desktop, so that the desk can be stored in the rear of the wheelchair. In the storage position, the desk rests between the back of the wheelchair seat and the client's backpack, on top of the wheelchair's battery housing. A single Velcro strap secures the desk in the storage position.

The support tubes slide over support rods, which extend from custom brackets mounted to horizontal members on each side of the wheelchair frame, below the seat. The brackets are made of ¼" plate steel, and mount to the frame members with two ¼-20 bolts. The support rods consist of ¾" square solid steel rod, 2" long, welded vertically onto the end of each bracket. The support rods are tapered to accommodate the support tubes for easy mounting and removal of the desk. To mount the desk, the support tubes are slid onto the support rods, which is a simple operation for one person. The brackets do not inhibit normal wheelchair use and remain on the wheelchair at all times. Because the horizontal members of the frame do not provide a vertical surface for mounting the brackets, custom aluminum wedges between the members, brackets, and mounting bolts ensure that the support pins are vertical.

All steel portions of the desk, except for the support rods, are painted black to blend in with the rest of the wheelchair. The support rods are unfinished to maintain the fit with the support bars.

Materials for the desk cost approximately $150; machining costs were approximately $400.

Figure 6.1. Wheelchair Desk.

FREESTANDING MOTORIZED CHILD SWING

Designers: Amy Congdon and Jessica Foley
Client Coordinator: Linn Wakeford, Frank Porter Graham Childhood Development Center
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INTRODUCTION

A four-year-old boy with cerebral palsy has limited vision and mobility and is dependent on adults. He enjoys motion, especially swinging. The goal of this project was to provide a powered swing he can control himself. A motorized swing controlled with a switch was designed and constructed. This freestanding swing safely swings a child up to 50 pounds in weight, and provides appropriate support for the client as he swings.

SUMMARY OF IMPACT

Most of our client's day-to-day activities require that he depend on adults. His limitations in play behavior make it difficult for his parents and therapists to create play opportunities for him that are both enjoyable and allow him to develop independence. His occupational therapist believes that "the swing will offer him the opportunity not only to do something he really likes, but also to control that activity to some extent. He can rely more on his own desire to engage, rather than on an adult's desire that he play with something." She added that the swing "really will enhance his quality of life." After five months of use, the client's parents commented: "As you know (he) is immobile and nonverbal. While he can't express himself directly, his pleasure (or displeasure) is quite apparent. The swing has brought great joy. He uses his swing every day and enjoys it most in the evenings after dinner. He laughs and kicks while in the swing and always comes out of the swing with a smile on his face."

TECHNICAL DESCRIPTION

The overall swing is pictured in Figure 6.2. It includes the swing frame, seat, drive mechanism, motor speed control and power supply. A drive plate is attached to the motor. A drive pin, surrounded by a cylindrical bearing and mounted on the drive plate, rides in a channel of the swing drive arm. As the motor spins the drive plate, the drive pin causes the drive arm to move in an oscillatory manner about a crossbar. The drive arm is rigidly attached to the swing arms, which freely rotate about the crossbar. The swing seat attaches to the swing arms with four ropes, which decouple the drive mechanism from the swing pendulum sufficiently to allow the swing to start from rest without a push. Horizontal cross-supports are added to the base of the swing frame, which was purchased commercially (Sammons Preston), for added stability. The frame is further stabilized by filling the lower legs and these cross-supports with sand. The motor mechanism is mounted with a custom plate and six ¼" bolts to the crossbar at the top of the frame. The motor is a 12V DC, 37 RPM, 1/5 HP gearmotor. A pulse-width modulated speed controller is mounted in a control box, and adjusted to match the motor speed to the natural frequency of the swing pendulum. 12V DC is provided with a computer power supply, mounted next to the control box on the swing frame. A relay in the control box allows an external switch with a 1/8" plug to actuate the swing. A bypass plug allows the swing to be used without the external switch.

Materials for the swing cost approximately $950; machining costs were approximately $600.

Figure 6.2. Freestanding Motorized Swing.

TILTING DESK FOR POWER WHEELCHAIR

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INTRODUCTION

The client is a man with quadriplegia who uses a power wheelchair. Most commercially available wheelchair desks attach to the armrests, often interfering with the control joystick on power wheelchairs. The goals of this project were to construct a desk that easily attaches to the client's wheelchair, and that provides access to the wheelchair's joystick and a tilt feature that he can control himself. The project consists of a wooden desktop, supported by a steel frame. The frame inserts into clamps mounted to the footrests of the power wheelchair, avoiding the joystick. A ratchet mechanism allows the client to tilt the desk without assistance.

SUMMARY OF IMPACT

The client could not find a commercial desk that was suitable for his needs, and therefore had difficulty finding surfaces on which he could read, write, and eat. The wheelchair desk fastens to his power wheelchair without interfering with the joystick control. Its non-slip surface allows him to read, write, and eat without finding a non-slip table or transporting certain dishes and bowls. The client can tilt the desk without the help, thereby extending his independence.

TECHNICAL DESCRIPTION

The desktop is constructed of ¾″ maple for durability and to accommodate the client's aesthetic preference. It is comprised of three boards jointed together, 26″ wide, the width of the wheelchair's armrests. The corners are rounded, and the surface sanded and finished with polyurethane to make it waterproof. The center area is routed to accommodate a 12″x12″ sheet of hard rubber, which provides a non-slip surface for writing and eating. A wooden ledge, attached below the rubber insert, holds reading material in place when the desk is tilted.

Facilitating independent desk tilting for the client was an important structural consideration. Three pieces of ¾″ square metal tubing are welded together with a solid steel rod to form a rectangle. Two vertical supports of ¾″ square tubing are welded to this frame. The solid rod rotates within holes in wooden tie braces, attached to the bottom of the desktop. One end of the solid rod attaches to the drive point of a ½″ socket wrench. The arm of the wrench is bolted to the bottom of the desktop. An extension bar is attached to the ratchet mechanism of the wrench, extending 6″ above the desktop surface.

When the extension bar is pushed forward, the desk can be lifted to a desired tilt angle; it will stay at the highest angle achieved until the extension bar is pulled backward, which allows the desk to return to horizontal. The extension bar attaches to the ratchet mechanism using a screw and a milled groove, which allow the bar and ratchet mechanism to remain in contact under considerable force.

The desk is attached to the power wheelchair using two custom support brackets, which clamp to the foot rests of the chair. Screw-and-hinge clamps attach each bracket to two sites along the curved rods of each of the footrests. These clamps attach to a metal plate with an adjustable mounting, so that the exact fit of the brackets can be adjusted on the chair. The clamps are lined with foam rubber to prevent slipping. Also attached to each metal plate is a piece of square steel tubing, slightly larger than the vertical support poles of the desktop frame. The support poles are tapered slightly to make attachment and removal of the desk easier.

Two safety features of the desk help prevent damage to fingers that might be under the surface when it is lowered into the resting horizontal position. First, a strip of foam weather-stripping is attached to the underside of the desktop to cushion the area between the desktop and the metal frame. Second, an anti-slam lid support, as used for toy boxes, is attached between the desktop and frame. The device consists of a sliding track with a rubber disk that glides with adjustable friction. This lid support is adjusted using a single screw to create the desired damping effect.

Materials for the desk cost approximately $210; machining costs were approximately $300.

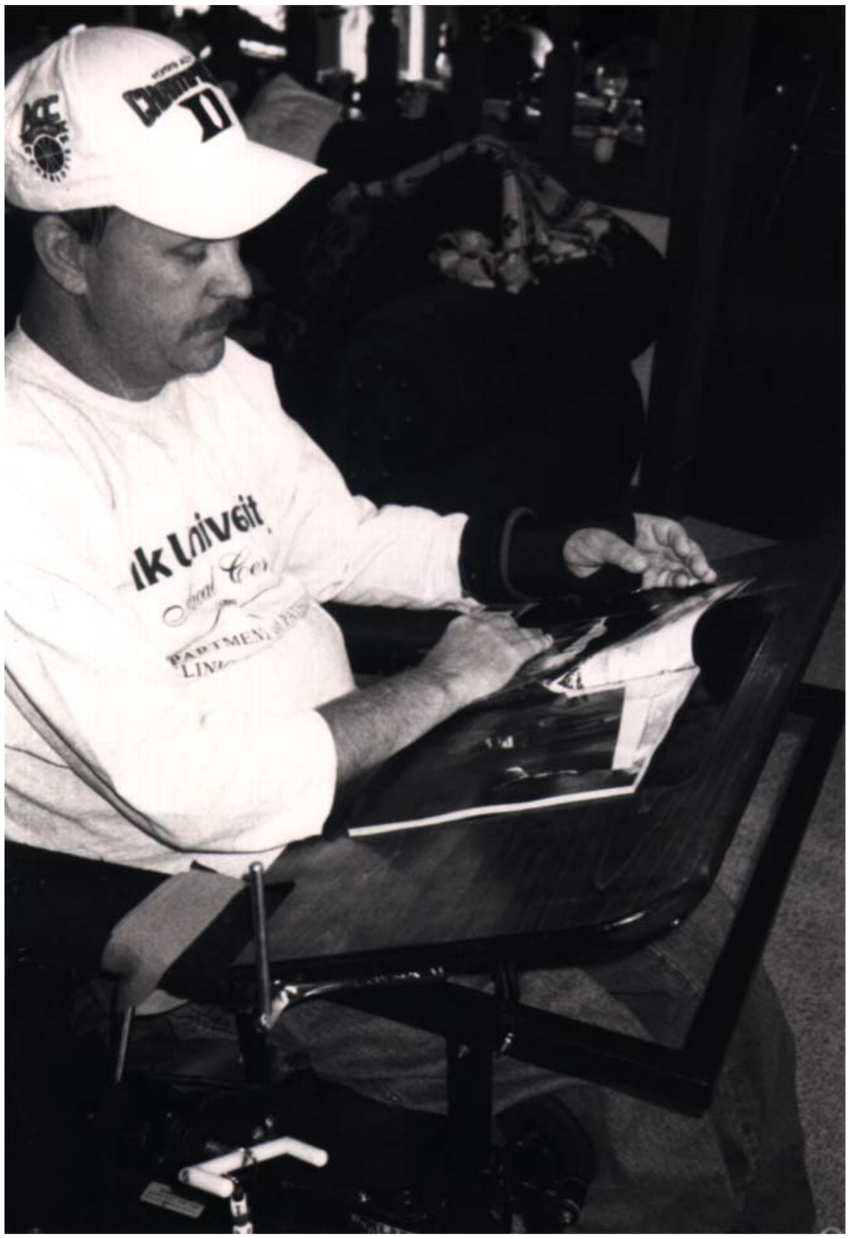

Figure 6.3. Tilting Desk for Power Wheelchair.

RECREATIONAL CHILD JUMPER

Designers: Jennifer Glasgow and Thomas Meese
Client Coordinator: Nancy Curtis, Easter Seals Foundation of NC
Supervising Professor: Dr. Larry N. Bohs
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INTRODUCTION

The goal of this project was to design and construct a recreational jumper for a five-year-old girl with cerebral palsy. The primary objectives were to make the jumper safe, comfortable, quiet, and durable. A commercial swing-quality bungee cord provides for the vertical jumping motion, while a padded seat comfortably supports the child. The device hangs from an eyebolt in the ceiling, and adjustable nylon straps allow the height to be changed. The client will be able to use the jumper for several years, providing her with a safe and enjoyable form of exercise.

SUMMARY OF IMPACT

The client works with her hands and torso at school, but without a jumper, she had no means for safe aerobic activity. She has a walker, but due to her limited vision, the walker does not provide a safe way to exercise without constant supervision. The jumper provides enough support to keep the client upright and balanced, yet provides weight-bearing exercise. Another important benefit is her enjoyment: she loves to jump and spin in the jumper, especially when her parents play her favorite music. Her physical therapist feels that "the jumper will provide her only means of safe and independent combination of play and movement."

TECHNICAL DESCRIPTION

The jumper is described from the top (ceiling connection) down to the seat. A locking caribiner clips into an eyebolt in the ceiling. Two bungee cords are suspended from the caribiner, with a second caribiner attached to the bottom of the bungees. The jumper uses commercial swing-quality bungee cords (Southpaw Enterprises, model 1938), rather than springs, to offer a greater rate of deflection and quieter operation. Currently, a double bungee loop supports a 60 lb working load. As the client grows, an additional single bungee can be attached in parallel to increase the maximum load to 90lbs.

An adjustable nylon strap is suspended from the lower caribiner. The strap has one metal adjuster clip and ranges in length from a minimum of 4 inches to a maximum of 4 feet. A swivel bearing is suspended from this strap, and a caribiner connects it to the center of a 1.75" diameter metal support bar. The support bar is padded for safety and includes a sewn-on warning label describing the weight limits of the device.

An eyebolt is attached to each end of the support bar, and an adjustable nylon strap is suspended from each of the eyebolts. Both ends of the nylon straps are sewn into the seat, which is padded and constructed from parachute fabric. The seat reaches a height that will allow it to support the child's chest and back. The front two nylon straps are surrounded at the bottom by plastic tubing for cushioning. Three horizontal pieces of 1" nylon webbing are sewn approximately 2.25" apart on the front and back of the seat. The ends of these straps are connected to clips on the left side and adjusters on the right side, allowing for over ten inches of adjustability in the horizontal direction.

The upper and lower adjuster straps can accommodate substantial variations in the ceiling's height, and provide an easy means for inserting and removing the client from the swing. The jumper was thoroughly tested by analyzing its components separately. According to load testing and manufacturer specification sheets, the jumper was to provide a minimum safety factor of 1.9.

Materials for the jumper cost approximately $300.

Figure 6.4. Recreational Child Jumper.

BATTERY TESTER FOR PEOPLE WITH PHYSICAL AND COGNITIVE DISABILITIES

Designers: Brandon Stroy and Ravi Baji
Client Coordinator: Lisa Williams, Generations Tadpole Assistive Technology Lending Library
Supervising Professor: Dr. Larry N. Bohs
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INTRODUCTION

A lending library that provides low-tech assistive technology devices and toys to people with disabilities has many products that use batteries, which must be tested regularly. Because the library employs people with various disabilities, an easily manipulated battery tester with obvious, multi-sensory indicators is needed. A device was built to make testing batteries simpler and more interactive. It features simple operation, as well as visual, auditory, and vibratory indications of a good or a bad battery. The device allows more employees to test batteries, improving their rate of pay and independence.

SUMMARY OF IMPACT

Employees earn income based upon the type and number of jobs they can accomplish. If employees learn to do a new task, they increase their pay. The director of the library had this to say about the Battery Tester: "The employees… have been using it daily. The employees are responding well to the variety of feedback that the battery tester offers. We have been able to allow five more employees to expand their job responsibilities to include testing batteries! This has increased their participation in the program as well as their salary. We have a young lady with a visual impairment and a hearing impairment who is now able to test batteries independently."

TECHNICAL DESCRIPTION

The battery tester (Figure 6.5) consists of a mechanical testing unit, a circuitry unit, and three peripheral response units. The testing unit allows all standard types of cylindrical batteries to be tested between two copper plates in the front of the device. The top plate is angled downwards, and held in position with a spring and hinges. Batteries are held vertically and inserted by sliding them to the back of the tapered testing unit. When the battery is pushed in completely, a rear pushbutton switch is contacted, signaling the circuitry to test. Two parallel copper strips on the top of the box test 9V batteries. One of the strips is spring loaded, with a contact pushbutton to signal battery insertion.

The circuitry unit includes four input optoisolators, which allow batteries to be inserted in either polarity orientation. When the battery voltage is above a threshold and the battery insertion switch is activated, a "good battery" signal is generated. If the voltage is below the threshold, a "bad battery" signal is created.

Three sensory outputs are available: LEDs (visual), vibration (tactile), and digital voice (auditory). Any combination of outputs may be selected to tailor the device for specific users. Two of the peripheral response units contain LEDs and digital voice circuitry. A good battery creates constant-on LEDs and a message such as "good battery" on one of the response units. A bad battery creates flashing LEDs and a "bad battery" message. The third response unit contains a motor with an offset weight to create vibration. A good battery creates constant vibration, while a bad battery creates pulsating vibration. The visual/auditory response units can be positioned in proximity to battery bins to facilitate sorting of good and bad batteries.

Materials for the battery tester cost approximately $500.

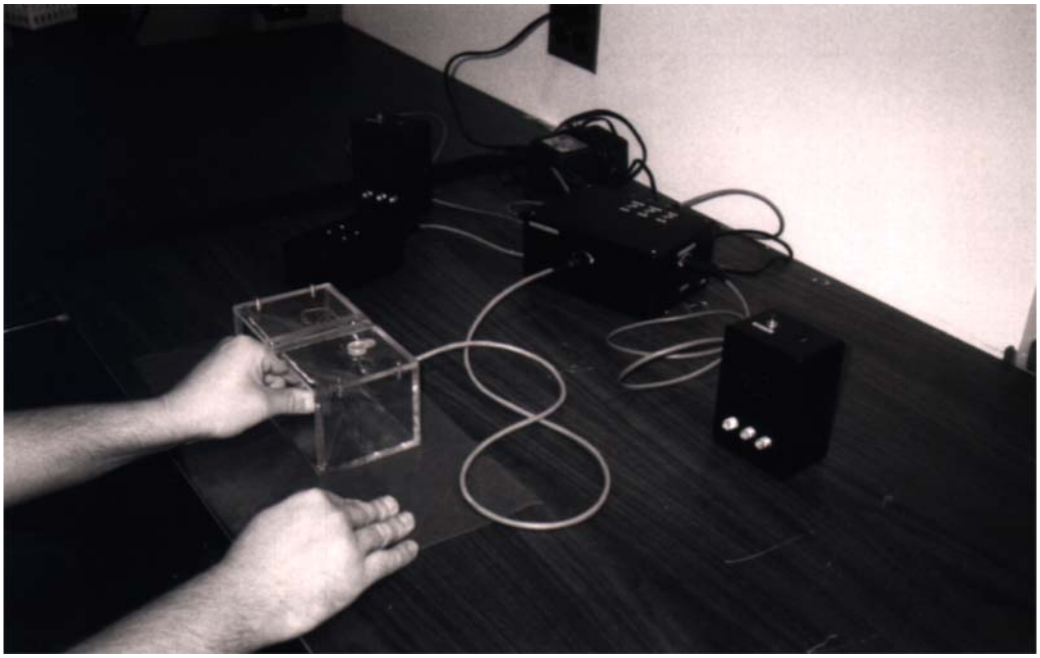

Figure 6.5. Battery Tester.

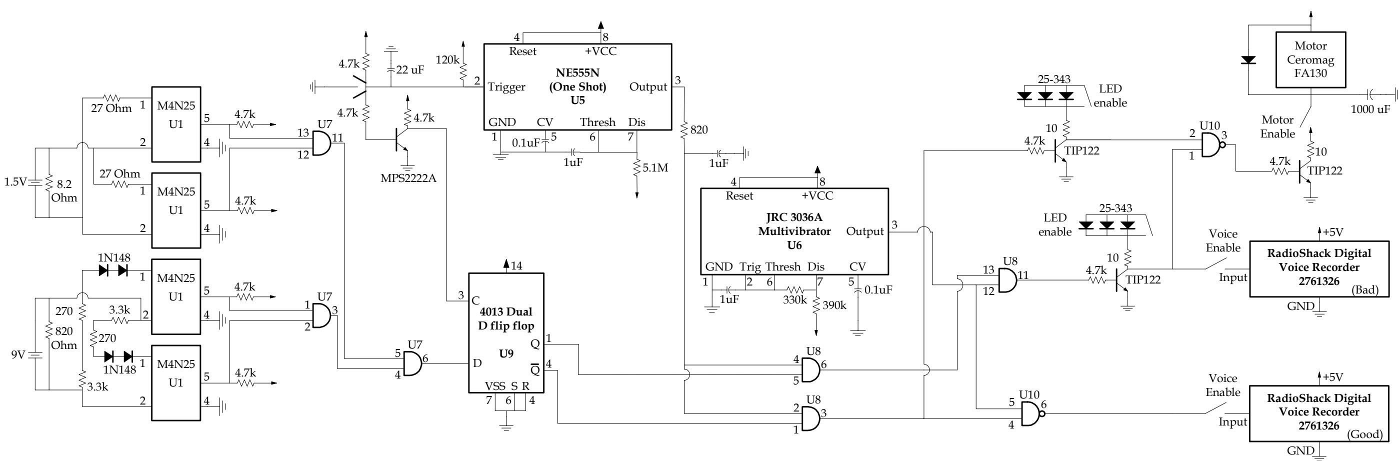

Figure 6.6. Battery Tester Schematic.

MOTORIZED SWING SUSPENDED FROM RINGS

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INTRODUCTION

The client is an eight-year old girl with cerebral palsy, spastic quadriplegia, blindness and hearing loss. Due to her limitations, swinging is one of the few stimuli she can enjoy. Her family desired a motorized swing because she often desires to swing for hours at a time. She is now 56 pounds, 42 inches tall, and has long outgrown her commercial motorized infant swing. The goal of this project was to design and construct a device to swing the client from rest for extended periods of time. It is to support her through adulthood. The swing is suspended from two rings, which support the swing's driving mechanism as well as the child. An offset crank converts rotational motion to oscillatory action. Two speeds are available to change the degree of swinging.

SUMMARY OF IMPACT

Few toys provide positive stimulus for the client due to her cognitive and physical limitations. Since swinging is known to be an enjoyable stimulus, a motorized swing allows her parents to more easily accommodate this need. Additionally, the swing gives her a new seating option. After five months of use, the client's mother said, "She has so few options for enjoyment, the swing gives her another choice for stimulation that she didn't have before. She uses it all the time. Other children with disabilities, including those with Down's syndrome, have visited and enjoyed the swing as well."

TECHNICAL DESCRIPTION

The swing suspends from two rings for compatibility with both the client's porch and her school. This design eliminates the need for a frame and increases the swing's portability. The swing's driving mechanism consists of a variable speed motor with an offset crank, and a drive channel attached to a drive shaft. The offset crank moves in the channel and oscillates the drive shaft, which is mounted with pillow block bearings to the swing suspension system. The motor and offset crank are mounted rigidly to the swing suspension system, which uses eyebolts (rings) screwed into overhead attachment points such as ceiling beams. A solid square steel rod slides through both eyebolts, and custom brackets clamp onto these to prevent the rod from rotating. The swing driving and suspension systems are mounted rigidly to this stationary square rod.

The suspension system includes two swing arms, which act as lever arms to push the swing. These arms are connected together with a round steel drive shaft, which is attached to the solid square rod by three pillow block bearings. These bearings suspend from the square rod and permit smooth rotation of swing's drive shaft. Adjustable-length chains connect the swing seat to the swing arms, allowing the swing to gradually obtain the speed of the driving motor. This design is compatible with any seat that can be attached to two chains, providing customization for a given user. Switching seats involves detaching two caribiners.

The swing is powered using standard 110V AC power, with a GFCI (ground fault circuit interrupter) attached for electrical safety. A variable speed control (Dayton 4Z827) converts the AC input to 90V DC for the 1/8 HP, 24 RPM DC gearmotor (Dayton 4Z130), and allows adjustment of the motor speed to match the natural frequency of the swing. Two variable settings in the offset crank allow for two different swing angles.

Safety of the client played a large role in the design. The attachment to two suspended rings prevents the possibility of tip-over. The final swing design was tested using no weight, 25 lbs., 50 lbs., and 170 lbs. For each trial, the swing started properly from rest, and swung to the predicted arc. Human trials were conducted to confirm the weight limit, and to observe the smoothness of the swinging motion. Additionally, a finite element analysis using Pro/MECHANICA was performed on the offset crank, which was considered the most crucial component of the design, to predict its maximum von mises stress and insure it was within the limits of the materials used.

While this device was made for a specific individual, it can be used in any location with two suspended eyebolts, used with any seat, and can swing individuals up to 150 pounds. Materials for the swing cost approximately $435; machining costs were approximately $500.

Figure 6.7. Motorized Swing.

AUTOMATED DESK MOUNTED ON WHEELCHAIR

Designers: Ethan Fricklas and Brian Alonso
Supervising Professor: Dr. Laurence N. Bohs
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INTRODUCTION

The client is a 17-year-old male with Duchenne Muscular Dystrophy who uses a power wheelchair. A senior in high school, the client currently uses a small lap tray that must be placed in front of him for reading and writing. To be more independent, the client desires a desk that he can move into place automatically without assistance. This project involved modifications to a 2000 senior design project. Chiefly, the previous design did not provide sufficient torque to lift the desk reliably. In addition, numerous safety features were incorporated. The Automated Desk mounts to the power wheelchair and is actuated with two switches. One switch rotates the desk from its storage position behind the chair, over the client's head, and into working position in front of him. The other switch controls a linear actuator that extends and retracts the desk to provide head clearance and suitable storage and working positions. Several sensors provide for safe operation and help automate desk motion. An electronic brake prevents the desk from moving when the rotational motors are not active.

SUMMARY OF IMPACT

Evaluation of the completed design on the client's wheelchair indicated that all functions of the deskwork as intended. Using two switches, the client can independently move the desk into a workable position, and retract it to a storage position. Nevertheless, further work is necessary to improve the overall appearance, to provide further clearance in two positions, and to build a printed circuit board for the electronics. The nature of this project is such that the client will rely on it heavily. For this reason, future development is required to address remaining issues such as product reliability and comprehensive safety testing.

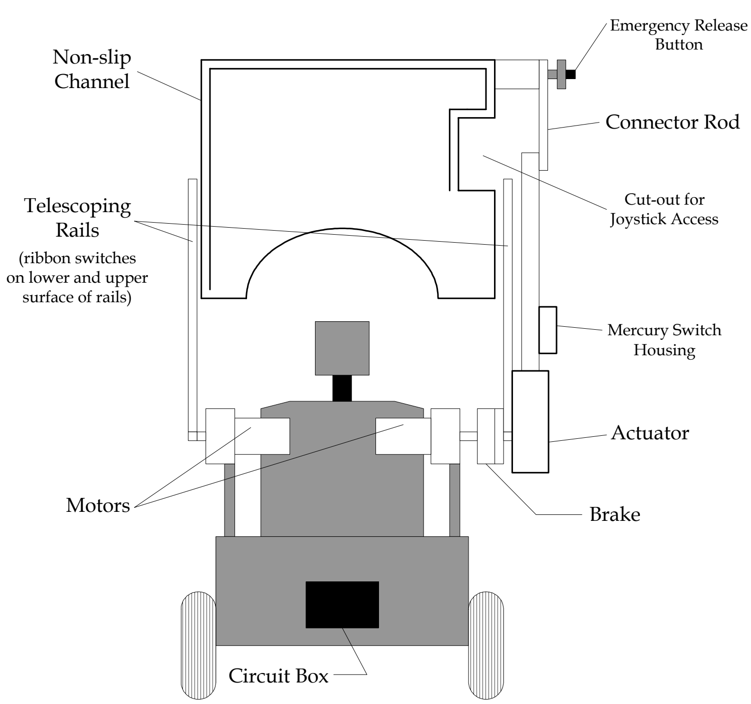

Figure 6.8. Rear View of Automated Desk.

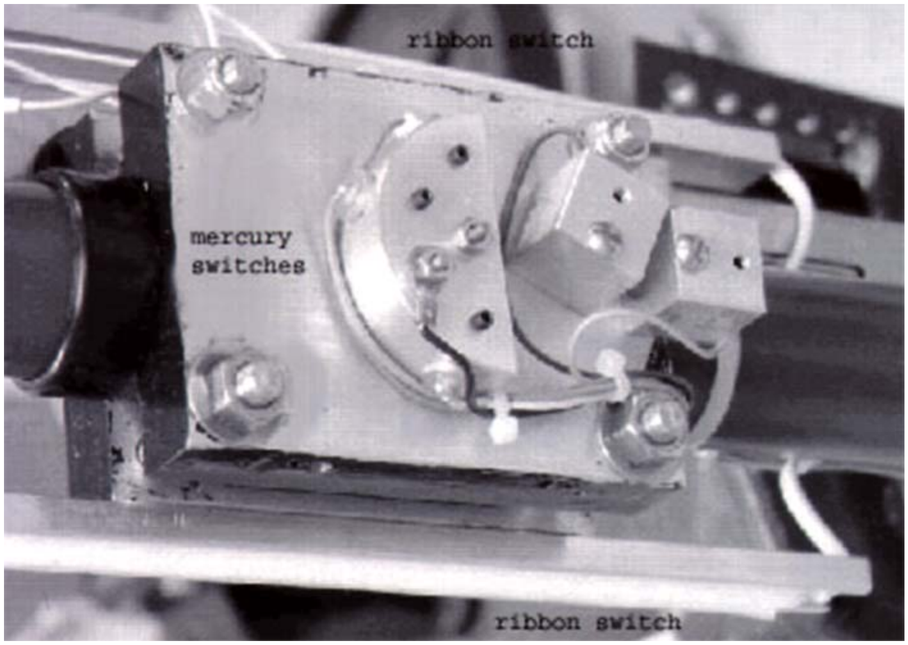

Figure 6.9. Mercury Tilt Switches with Housing.

TECHNICAL DESCRIPTION

The desktop is constructed from clear ¼″ polycarbonate, with a steel reinforced under-frame. This assembly attaches to telescoping rails for extension and retraction using a 24VDC linear actuator (Dayton® 2506). In the initial design, the desk and actuator were to be rotated from the storage position to the armrests by a single 12VDC, 6 RPM gearmotor (Dayton® 1L474). This motor, located on the left-hand side of the wheelchair, can produce 500 lb-in of torque, which is insufficient to reliably rotate the desk. In addition, the motor speed was deemed too fast. To solve these problems, a second motor was added to the right side of the wheelchair, and a pulse-width-modulated speed controller integrated into the electronics to adjust the motors to the desired speed.

A custom mounting plate was machined out of ¼″ steel and welded together so that the brake, extra motor, and actuator (Figure 6.7) all mount together to the right side of the wheelchair frame. On the left side, a ¼′ steel mounting bracket was fabricated for the single motor. All fasteners are Grade 5 bolts and nylon insert locknuts, to prevent loosening due to vibration.

A number of sensors and electronic logic circuits ensure safe operation of the desk. Along the linear actuator, upper and lower limit magnetic reed switches sense full extension and retraction of the desk. These switches are closed when contacted by a magnet mounted to the actuator shaft. Five mercury tilt switches are orientated at various positions on the actuator side of the desk (Figure 6.8). The combinations of signals from these switches at any given time are processed by the electronic logic circuit and dictate the position of the desk. The logic is designed to prevent the desk from ever touching the client or his wheelchair. For example, if the desk is rotated back from the working position, the actuator must be fully extended or the desk will not move beyond a certain limit. Additionally, ribbon switches placed along the upper and lower edges of the desk (Figure 6.7) will stop all motion if the desk comes into contact with an object.

The device is controlled with two remote single-pole double-throw switches, one for motor forward and back, and one for actuator extend and retract. The electronics are housed in a resilient plastic enclosure. The circuitry also contains a power conservation relay to minimize current draw when not in use, which significantly increases the time required between charging of the wheelchair's batteries. The cost of materials added to the project this year was approximately $375.

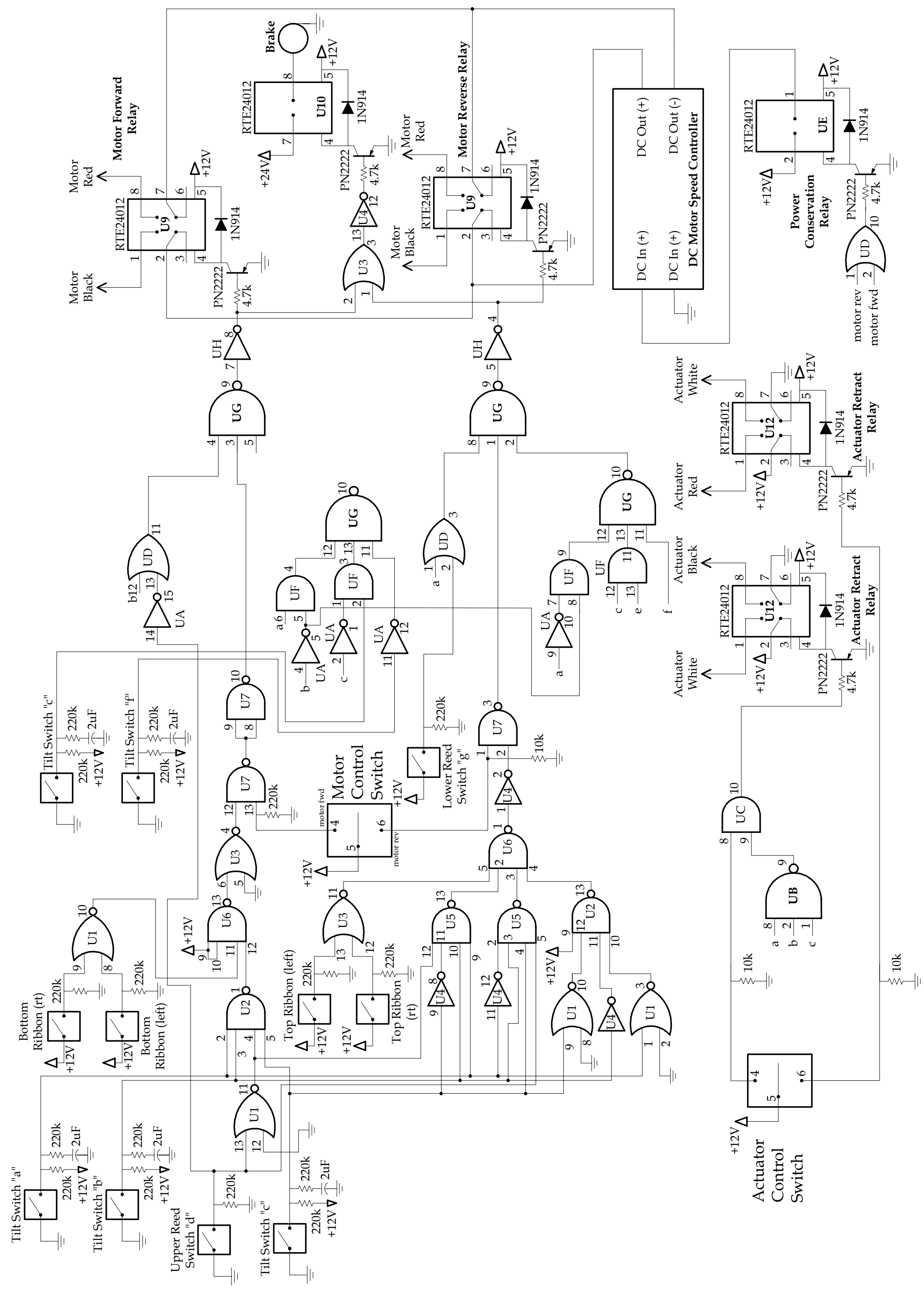

Figure 6.10. Schematic of Control Circuitry.