Final Design Report:
Modified Communication System
Accessory Devices

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Abstract

The project entails a joystick control designed for the use of a 15-year-old boy with Athetoid Quadriplegic Cerebral Palsy. The joystick control is designed to operate the client’s augmentative device, developed by DynaVox Technologies®, by controlling the cursor used to select letters and words. The use of the joystick to control this device enables the client to use a direct-select option, which allows for a faster and more efficient means of communication than the current method of scanning. The structural design of the joystick allows a large gripping surface to accommodate the client’s grasping difficulties and is constructed of materials capable of withstanding high cyclic stresses.

The mechanical design implements the use of Hall effects, which eliminates any contacting or wiping parts that could wear or fatigue. The only parts subjected to stress and friction are the handle, shaft, and shaft support. The joystick is designed to operate efficiently under repeated force applications of up to 250 pounds to accommodate the client’s high tone and extraneous movements. The joystick has also been designed so that a minimum force application of 0.188 pounds is required to move the cursor. The design offers a one-touch selection feature and gives the client the option to use either a hand-grip mounted button or an externally connected head-switch, developed by AbleNet®. The joystick control connects to the augmentative device through a USB connection and can therefore be used universally as a cursor control on any computer, PDA, or other cursor-controlled device with a USB port.

A secondary viewing screen has also been designed to enhance the client’s existing augmentative device, developed by DynaVox Technologies®. The 7 inch liquid crystal display screen, with a rechargeable NiMH battery pack, allows the client to engage in more active and personal conversations by displaying the images that are on the DynaVox to others. With a green LED indicating that the screen is powered, this additional monitor will connect to the DynaVox via a VGA video card and will sustain usage for a minimum of 10 hours before needing to be recharged. Combined, the two devices will meet the client’s needs to interact more effectively with his friends and family.
1 Introduction

1.1 Background (Client and Disability)

The client for whom this product is being developed is a 15 year-old high school student who has had cerebral palsy since birth. His physical condition is specifically classified as the “Athetoid Quadriplegia”. This means that he often experiences involuntary movements and has trouble with grasping, gripping, maintaining posture and anything that involves fine motor control. He has little to no finger dexterity, except in his thumb, and often has trouble controlling head movements as well. Despite his physical limitations, he is otherwise self-sufficient in many aspects of his life. He uses a motorized wheelchair to move around by his own means and is able to actively participate in honors-level courses at school.

The main concern, and frustration of the client is his ability to communicate at the same level of his peers. While the client is able to convey an above-average intelligence for someone his age, he is not physically able to speak to his peers and must communicate with friends and family through other means. One method of communication, which has proved to be very effective in conversation, is the use of a simple template, containing characters of the alphabet and a few key conjunctions and articles, printed on paper and taped to a tray on the wheelchair. The client carries out conversation by pointing to characters on the paper while others look along. While this method is effective in conversation, as it allows people to anticipate words as he spells them out, it does have the disadvantage of peers always needing to read his words rather than listen to them. As a method to get past this inconvenience, the client also communicates through the use of an augmentative device, the DV4® developed by DynaVox Technologies®, which has a touch-screen with access to many pages similar to the printed template the client uses. The selection of options on this device then allows the client to “speak” the phrases and sentences he creates. The use of this device, however, also has several disadvantages. One major problem is that the client lacks the finger dexterity to operate the touch-screen. This is not a huge problem, as there are several cursor control devices, such as a computer mouse, joystick, head-switch, eye-tracker, etc., that can be used to operate the machine as well.

As of yet, a suitable means of cursor control has not been found for the client. One type of joystick has been used and was not durable enough to withstand the constant cyclic stresses.
applied by the client. The buttons used to operate this particular joystick were also troublesome and inconvenient for the client to use. The client’s current method of control for the DynaVox DV4® is the use of a single head-controlled button which is used to scan through and select the screen options. This method is not only tedious, but takes much too long. Due to this dilemma, the client is not able to communicate as fast as he would like in order to keep up a conversation with anyone.

In addition to the problem of slowness due to scanning, the device only has one screen visible to the client while mounted onto his wheelchair. This eliminates any possibility one may have of using word anticipation in conversation, as one would do with the client’s other method of communicating with the template on his tray. While the method of communication through the use of the tray template is effective, it also presents the inconvenience of having to read over the client’s shoulder, as was previously mentioned, and it makes for a cluttered look, thus taking away from any aesthetic features of the client’s wheelchair. However, the lack of an auxiliary LCD screen for others to view the client’s words makes the possibility for word prediction impossible when the client uses the DynaVox® as opposed to the tray template.

1.2 Purpose of the Project

The purpose of this project is to help solve the client’s problem of slow communication and lack of a proper cursor control device to work the DynaVox DV4®. In addition, the development of this project seeks to eliminate any need for a tray-mounted template to spell out conversation. It has been determined that, of all the options for controllers compatible with the DynaVox DV4®, a joystick would best suit the client’s needs and would be the most likely to work within his physical constraints. The problem with the joysticks the client has used in the past is that none have had the durability required for the use by someone with such high tone and extraneous movements. The development of this design project will provide the client with a joystick controller that is ensured to have the required durability to withstand continuous usage for long periods of time without wearing down or breaking. As mentioned before, the client has trouble with gripping objects and limited fine motor control, which makes the use of some control devices overly difficult, sometimes requiring more effort and thus slowing down communication. The design itself allows the client the
capability to communicate at more desirable pace while offering the most ease of operation possible.

### 1.3 Previous Work Done by Others

#### 1.3.1 Products

Several products exist on the market to assist people with disabilities, many of which are similar to those of the client. A product that the client has previously used was produced by the Don Johnston Corporation and was one of the Penny & Giles Joystick series. The client had previously used the Penny & Giles Joystick Plus®, which was a simple potentiometric joystick design meant for the use of cursor control. The joystick implemented several buttons of numerous functions, protected by a plastic shield to prevent accidental activation. Other features of the design include positive spring centering, five speed options, and button-touch requirements of 2.25oz. While this product does have many desirable features, it did not sufficiently meet the needs of the client. It did not have the durability to withstand the client’s constant rigorous use and would wear out and break after approximately 6 months of use. The cost of this particular joystick is approximately $510.00, and the cost of constantly replacing this product so frequently was unacceptable.

Other joystick products available include the SAM Joystick, available through EnableMart™, which offers many alternatives to cursor controls. The SAM Joystick operates like a standard computer mouse, with click, double-click, and drag features. The cursor speed is independent of the force applied or the speed at which the joystick handle is moved, and it can be selected by an external switch on the base of the joystick. It is available for either a Windows or Macintosh computer operating system, however it is not necessarily compatible with a DynaVox® device.

Other joystick products that exist on the market are gaming controls and controls used for industrial purposes. Since durability is of primary concern, the main focus centered around industrial joysticks. Industrial quality joysticks are manufactured by companies such as J.R. Merrit Controls, Inc., whose joysticks mainly use potentiometric design, P3 America, Inc. and P-Q Controls, Inc., whose joysticks range from simple potentiometric to inductive and hall-effect configurations.
1.3.2 Patent Search Results

The following patents were researched:

The inductive joystick apparatus is documented as United States Patent 5598090. The product description is described as follows: "The joystick includes a control shaft and a pivotal mount for the control shaft. A plurality of centering springs bias the control shaft to a neutral position, and extend and contract in response to pivotal movement of the control shaft. An oscillator circuit is coupled to the centering springs and produces an output signal having a frequency responsive to the inductance of the centering springs."

The System and method for converting radio control transmitter and joystick controller signals into universal serial bus signals is documented as United States Patent 7010628. The product description is given as follows: "A device for converting joystick controller generated analog and digital signals into Universal Serial Bus (USB) format, or for converting imported pulse position modulated (PPM) encoded signals from an external radio control (RC) transmitter into USB format data. The device is used, in an embodiment, for controlling simulated RC model aircraft as displayed, for example on a personal computer screen through the use of computer software. In an embodiment, the device includes a pair of two-axis gimbals, an auxiliary channel control potentiometer, and various control key switches to generate analog and digital joystick type signals as a result of direct manipulation by a user. The device also includes microcontroller circuitry for importing PPM signals, such as PPM signals generated by a commercially available model aircraft RC transmitter, to a USB port signal for interface with a computer."

A fixing structure for an LCD panel is documented as United States Patent 7006167. The product description is given as follows: "An LCD panel fixing structure for fixing and holding an LCD panel has a first holding member, which holds the LCD panel and a second holding member, which holds the LCD panel, the LCD panel being housed, fixed, and held between the first and second holding members, thereby increasing the degree of design freedom."

The color LCD panel is documented as United States Patent 5295008. The description is given as follows: "A color LCD panel
includes a lower substrate, an upper substrate and a liquid crystal which is sealed between the lower substrate and the upper substrate. A plurality of pixels are provided on the lower substrate so as to form a matrix of a plurality of rows and columns. Each pixel includes a substantially rectangular pixel electrode. A plurality of scan driver lines are provided on the lower substrate in the rows in the matrix. Each scan driver line extends in parallel to shorter sides of the rectangular pixel electrodes of the pixels. A plurality of data driver lines of a transparent conductor are formed in the columns in the matrix. Each data driver line extends in parallel to the longer sides of the pixel electrodes of the pixels.

The backlighting system for an LCD is documented as United States Patent 6992733. The description is given as follows: “A computer display is disclosed. The computer display includes a LCD housing, a light source coupled to the LCD housing, and a LCD coupled to the LCD housing. The LCD housing conducts light from the light source to the LCD. A method for conducting light is also disclosed. The method includes generating light and conducting the generated light through a LCD housing.”

The VGA controller card is documented as United States Patent 5150109. The product description is given as follows: “A bus mountable Video Graphic Array (VGA), controller card for IBM personal computer family products, including the PC, PC/XT, PC/AT, and PS/2 computers and completely compatible clone computer products to provide VGA standard signals to drive conventional Cathode Ray Tube, (CRT) and flat panel displays is disclosed. The VGA controller card is hardware compatible to the IBM PC family products; functions to provide VGA standard signals capable of driving flat panel displays and converts standard PS/2 VGA signals to simultaneously drive conventional CRT and flat panel displays.”

1.4 Map of Final Report

This report covers many important aspects of this design process, as well as issues relating to the final product. The report will show the process of designing the final product by first outlining, briefly, the first three design alternatives, then covering the optimal design in great detail. Comparisons between the alternate designs and optimal design will be made to show the changes that occur in a designing process, as well as to display the superiority of the optimal design over the alternate designs. Following the design descriptions, a detailed
analysis of the actual prototype and the impact it has on the client's life will be discussed. There will be numerous descriptions and photographs to accurately convey the scope of the devices and their operation. The testing of the devices will also be fully illustrated as to how the client uses them and how they have impacted the client's life. Additionally, the project constraints as they relate to real-world solutions will be discussed. This topic is important, as it relates the practicality of the product’s use in the real world and its compliance with engineering standards, as well as some economical aspects relating to the device itself. Following discussion of the realistic constraints of the project, the more significant topic of the device safety issues will be discussed. This is extremely important in the development and engineering of any device, as one must take great care to develop a device that is safe for use. Following the topic of safety, the impact of this device development will be discussed regarding social and economic aspects both on a personal and societal scale.

Next, it will be discussed how the development of the project itself implements the concept of life-long learning. The budget will then be covered, along with a project timeline, showing the tasks required to complete the project and the time of completion. Following the budget overview, the contributions and responsibilities of each team member will be reviewed and discussed in further detail. A conclusion of the final project will be given, drawing together any other necessary details and completing the overall report. Finally, all sources used to research the project will be documented and any outside parties who aided in the development of the project design will be acknowledged. At the end of the report, there will be an appendix containing the most current project specifications.

2 Project Design

The final design for this project was developed through a long process of researching, designing, revising, and refining of several design alternatives. The development process also relied heavily on the cooperation and input from the client and the client’s family. The different methods and designs are explored in brief detail and the differences between all three alternative designs will be examined. The optimal project design will be explained in great detail and comparison will be made to the three alternative designs. It will be shown how the optimal design is superior to all of the alternative designs in its
capabilities and functionality, as well as in its compliance with the client’s needs and requests.

2.1 Design Alternatives

2.1.1 Design I

The first design is a single joystick will be able to operate under constant hand pressure and be molded to the client’s hand for comfort and more accurate selection options. The joystick is a right-handed joystick that will have two main functions; the joystick will operate the motorized wheelchair and the DynaVox DV4® communication system that the client already uses. The joystick will have one spring-loaded push-button that, when in the released position, the joystick will only control the wheelchair. Additionally, when depressed, the joystick will only operate the DynaVox DV4®. The joystick will receive power from the existing power supply of either the DynaVox DV4® or the wheelchair.

The joystick will control both options by attaching to the existing DynaVox DV4® computer via USB port and to the wheelchair through another separate connection. No other computer or PDA will be used in this system. The design has two buttons strategically placed on the handle of the joystick. One button will be placed on the right side of the cylindrical shaft, and the other will be placed on the left side on the shaft, where the client’s thumb would be positioned if the joystick was in his right hand. The left button will control the alternation between the wheelchair operation and the DynaVox DV4® operation. Depression of this button will switch the function of joystick to the DynaVox DV4® operation. To switch back to wheelchair operation, the user only has to press the button once more, and so on, alternating between the control of either device. The right button will be operated by the user’s index finger. It again will be a one-touch select button and unlike the left side button, this type of button will spring back to its original position. The side button will act as the left finger button on a PC mouse. It will activate the image that the cursor is hovering over on the computer screen of the DynaVox DV4®. The right side button will only be able to function when the left button of the joystick has selected to control the DynaVox DV4®.

The electrical design implements a potentiometric unit, which uses a potentiometer to convert mechanical displacement to electrical output. The curvilinear motion of the joystick is
converted through a process involving shafts, gears, and torsion springs. Figure 1 is a block diagram that represents the flow of information between devices and buttons in this system.

![Block Diagram of Design I]

**Figure 1: Block Diagram of Design I**

The front view of the joystick, as shown in Fig. 2 (all figures that follow, with dimensions included, are labeled in inches), depicts a simple, classic design for the joystick, but contains many variations that cater to the client’s needs. The base casing of the joystick is made of aluminum. This will be a square shaped box that will only have a seam surrounding the top
cover. The box will be a total of 1.5 inches (3.8 cm) in height and will be 3 inches (7.6 cm) square. The aluminum will provide the durability and strength it needs for daily use. As with all seams and holes in this aluminum casing, they will be sealed with a black rubber gasket that is specified to keep out moisture and water from damaging the internal mechanisms of the joystick.

There will be two wires that exit this aluminum base unit and each of the wires will be round and will be able to fit snuggly through the 0.25 inch (0.6 cm) holes drilled in the base

Figure 2: Front View of Design I Joystick
of the box. One wire will go to the DynaVox DV4® communication system and the other will go to the electric wheelchair controls. Each wire will be surrounded by a neoprene gasket at the exit sight of the wire from the box. These gaskets will again provide a water-tight seal for the internal mechanisms of the joystick.

The shaft of the joystick will be made of an aluminum rod. The rod will extend from the potentiometers inside the base unit, almost halfway up the handgrip on the joystick. This rod will be about 3.5 inches (8.9 cm) in length. The neoprene accordion gasket will extend up that exposed shaft, leaving about 0.25 inches (6.4 cm) of the shaft with no rubber protective covering. This will allow the rubber folds of the gasket to expand and be compressed, moving up and down the aluminum shaft, without becoming damaged.

The handgrip portion of the joystick will be cylindrically shaped. It will be 1.38 inches (3.5 cm) in diameter and 3.5 inches (8.9 cm) in length. The handgrip will come in two halves and will be screwed together by two hexagonal bolts. The handgrip is made of a thick-walled glass-reinforced nylon. This type of material is used in industrial applications and can withstand constant abuse. The rugged design is rated to work in outdoor application and be weather and corrosion resistant.

The handgrip will have four finger grips on the back side to provide extra comfort to the user. The handgrip will also be hollow, as will be the aluminum shaft, to provide a passageway for the button wires to connect between the base unit and the handgrip. The two buttons located near the top of the handgrip will be on opposite sides and will each be 0.5 inches (1.3 cm) in diameter. The buttons will be adjacent to the finger grips and will be 0.5 inches (1.3 cm) from the top of the handgrip. The client will be able to select options of the DynaVox DV4® with the thumb and index finger of his hand using the buttons on the handgrip of the joystick. The opposite button on the left side of the handgrip will be the button which controls the switching between the DynaVox DV4® communication system and the electric wheelchair functions and will be controlled with his thumb.
This joystick device is positively spring-centered, meaning that the joystick handle will spring back to the central position once the applied force has been released. This function will be implemented through a spring-shaft apparatus which is shown in Fig. 3. This section of the joystick’s handle shaft partially concealed by the rubber gasket. At the top of the apparatus is a circular polymer lip which has been bolted to the shaft. Surrounding the shaft is a helical coiled spring. Below the spring is polymer cylinder with a bottom lip. This cylindrical part is free to slide along the surface of the shaft. This allows for the extension and compression of the spring as the joystick handle is moved in various positions. In addition to the portion of the apparatus shown in Fig. 3, the remaining portion of the entire spring-centering apparatus is shown in Fig. 4. This portion is a circular plate-like part with
four raised ridges spaced equally around the circumference of the plate.

Figure 4: Top View of Shaft Seat

The shaft of the joystick is threaded through the central hole of the plate and is secured at the bottom to additional shafts, controlling the movement of the potentiometers. The plate is then secured inside the joystick base at a fixed position. The bottom lip of the spring-shaft apparatus is free to slide along the ridged surface of the plate. The spring is always meant to be in compression, in order to have a constant resisting force present in the joystick handle. When the handle of the joystick is moved in any direction, rather than allowing for extension of the spring, the bottom lip presses against the raised surface of the plate, causing a greater compression of the spring. When the applied force on the handle is released, the spring releases to its position of least compression, which is located back at the center.

2.1.2 Design II

The joystick of Design II will be similar to that of Design I, but will contain changes that allow for better usability of the client. The two main functions of the joystick will be the operation of the motorized wheelchair and the DynaVox DV4® communication system. The joystick will have a spring-loaded push-button switch that, when in the released position, will
only control the wheelchair; however, when changed to the depressed position, it will only operate the DynaVox DV4®. Additionally, a True Green colored light emitting diode (LED) will be placed in the joystick and illuminate when the joystick is functioning in the wheelchair mode. The joystick will receive power from the existing power supply of either the DynaVox DV4® or the wheelchair. As a safety feature, there will be an emergency stop button placed on the top of the joystick handgrip and will kill all power to the joystick in case of an emergency. The following block diagram, Fig. 5, represents these functions as to the paths of the signals of the joystick system.
The design will have two buttons strategically placed on the handle of the joystick. One button will be placed on the right side of the cylindrical shaft, and the other will be placed on the left side on the shaft. The left button will control the alternation between the wheelchair operation and the

Figure 5: Block Diagram of Design II
DynaVox DV4® operation. The right button will be a one-touch select button and will spring back to its original position until pressed again. The right side button will activate the image that the cursor is hovering over on the computer screen. The right side button will only be able to function when the left button of the joystick has selected to control the DynaVox DV4®.

The electrical design still implements a potentiometric unit, which uses a potentiometer to convert mechanical displacement to electrical output to control the motion of the wheelchair. The curvilinear motion of the joystick is converted through a process involving shafts, gears, and torsion springs.

The joystick will have the same aluminum base unit as in Design I and will be fitted with the same high-grade solid neoprene rubber gasket that prevents any liquids from seeping through the cover of the joystick box, around the screw holes, the circumferencing seam, or top hole where the joystick shaft exits the box. Figure 6 represents the joystick design with the addition of the green LED on the handgrip.
The LED indicator light is made by the Nichia America Corporation and is rated at 525 nm wavelength in the light spectrum for color. This color is called True Green. The LED is 0.20 inches (5 mm) in diameter and has a viewing angle of 15 degrees. The casing of the LED is a water-clear epoxy package. A schematic of an LED is shown in Fig. 7. The current drive that the LED requires is 20 mA. This type of power is easily taken, in addition to the joystick control system, from the wheelchair power supply. The light is illuminated when the wheelchair function is activated. When there is power connecting the electric wheelchair controls, via the depression of the left side button, there will be a low current passing
through the LED, indicating that the wheelchair activated, not the DynaVox DV4®.

The shaft of the joystick will be made of an aluminum rod. The rod will extend from the potentiometers inside the base unit, almost halfway up the handgrip on the joystick. This aluminum rod will be 0.32 inches (0.8 cm) in diameter. This rod will be about 3.5 inches (8.9 cm) in length.

The joystick will have the same two buttons on either side of the handgrip as in Design I. Their type and functions are the same as in Design I. A third button has been added that will have a different function compared to the other two buttons. This button, located on the top of the joystick handgrip will be the emergency stop button. If ever there was a situation that would arise and all operational capabilities of the wheelchair and the DynaVox DV4® needed to end, all the client, or a helper, would have to do is push the emergency stop button. The button is wired so that it creates a short circuit between the wheelchair or DynaVox DV4® and the joystick control system. Then to make the system operational again, push the center button a second time to depress it and all functions are back to normal. This button would be the same type as the right
side button of the joystick handgrip. All three buttons will be of identical dimensions and color.

One major difference between Design I and Design II is the electrical circuitry. The electrical circuitry of this joystick is more involved than in the first design, as it is meant to perform two separate functions, both of which are more effective with different electrical configurations. The wheelchair control function requires a simple set-up involving potentiometers. The variable resistance of a potentiometer is responsible for the movement along each of the x- and y-axis. The motion of the joystick handle causes a simultaneous movement of the potentiometer wipers, causing the variation of resistance. The variation in the resistance is responsible for a change in the voltage in either direction and is translated to mechanical displacement in the wheelchair mechanics. The electrical components for this function can be simply represented by the diagram in Figure 8.

![Diagram of Wheelchair Potentiometer Control]

Figure 8: Wheelchair Potentiometer Control

The required circuitry for the DynaVox DV4® cursor function is much more involved than that of the wheelchair mobility function. The electrical circuit schematic used for this design was based on the schematic for PC mouse implementation presented in National Semiconductor Application Note 681, by Alvin Chan in 1990, which uses the COP800 Microprocessor Series for an opto-mechanical computer mouse. The opto-mechanical mouse implements the use of LED’s and photo-transistors. The LED light shines
through the slits of rotary disc, another pair of slits which are offset at 90° angles, and is then received by the photo-transistors. The rotary discs are rotated due to the movement of the joystick shaft in either the x- or y-direction. As the discs move, the light is transmitted and received in pulses, which can be represented as square wave signals. These pulsed signals are then interpreted by the microprocessor and translated to digital language and can then be transmitted to the computer or DynaVox DV4®. The information sent to the computer system from the microprocessor is represented by the cursor seen on the screen. The two phase slits set at the 90° angles are necessary because they cause a phase difference in the pulses received by the photo-transistors. This creates the possibility for two separate signals in the x-direction and two separate signals in the y-direction, depending on whether the joystick is pushed in the positive or negative directions. This makes it possible for the computer to differentiate between forward and backward or left and right motions. The rotary disc and phase slits are represented in Figure 9. Two LED/Photo-transistor pairs will be placed at each wheel, 180° from each other.

![Figure 9: Rotary Disc and Phase Slits of the Potentiometric Joystick](image)

The circuit schematic for the cursor function of the joystick is represented in Figure 10. Section 1 of Fig. 10 is the portion of the circuit which acts as a variable duty cycle oscillator and is responsible for the baud-rate generation of the joystick. The baud rate is responsible for both the resolution and tracking speed of the cursor. The power supply for the COP822C microprocessor (shown in Fig.10) is also obtained through this portion. When incoming voltage levels are
positive, the supply to the microprocessor is obtained by damping down with the diodes. When the voltage levels are negative, the LM555 timer is used as an oscillator to convert the voltage from positive to negative. Section 2 of Fig. 16 shows the connection between the joystick and the computer or DynaVox DV4®. The voltage is input through the RTS line (G0, pin 17 of COP822C). The TXD line (G1, pin 18 of COP822C) is the source for communication signals between the joystick and DynaVox. Section 3 of Fig. 10 represents the “mouse” selection button, which performs the same function of selecting options as the left-mouse button. Section 4 represents the set-up of the four LEDs used to transmit light through the slits of the rotary wheel, and Section 5 represents the set up for the four photo-transistors receiving the light pulses.
Figure 10: Electrical Schematic for the Cursor Function

The movement of the joystick handle is translated to the movement of both the potentiometer wipers and the rotary discs through the use of two axis shafts, placed along both axes, with cut-outs for the shaft of the handle. As the handle moves, the
shafts move according to the direction of the handle movement. At one end of a shaft is a potentiometer and at the other end is a rotary disc. This set up is shown in Figure 11.

2.1.3 Design III

The third alternative design eliminated many unnecessary components of the joystick for the client and consisted of many longer-lasting components. This design eliminated the left side
button on the joystick, the emergency stop button on the top of
the joystick, the green LED, the potentiometric mechanical
system, and the control of the wheelchair. The client specified
that the joystick need only be of industrial quality, contain
minimal rubbing parts, only control the DynaVox DV4®, and have
more then one option to select images on the DynaVox DV4®
computer screen. The modified joystick now uses an inductively
coupled system to detect field variations, which do not have any
rubbing parts that could wear out over time. There is one
button on the top of the handgrip, one on the right side of the
handgrip, and a connection for the head-switch, which the client
already has. This joystick is now a left-handed joystick and
has a toggle switch to select which button is activated for the
DynaVox DV4® cursor control. Figure 12 is the block diagram for
Design III and shows the signals of the joystick system.
The electrical design implements an inductively coupled unit, which uses a field to convert mechanical displacement to electrical output. The curvilinear motion of the joystick is converted through a process involving a drive coil, ferrous shaft, and a secondary coil. The joystick will be of the same dimensions as Designs I and II, only changing the form and function of some of the components, minus the loss of the left-side button. Figure 13 shows the front view of the joystick.
Exiting the base unit of this joystick is two wires. One wire will go to the DynaVox DV4® communication system and the other will go to the head-switch. The head-switch is a product that the client already has and wants to be worked into the joystick design. The head-switch is manufactured by the Ablenet Corporation and is called the Specs® switch access tool. It is a 1.38 inch (3.49 cm) diameter circular switch that is
mounted to the client’s wheelchair headrest via a 24 inch (60.96 cm) Velcro strap. Figure 14 shows a rough diagram of the top view of the Specs® switch. In addition, each wire that exits the aluminum base unit will be surrounded by a neoprene gasket. These gaskets will again provide a water-tight seal for the internal mechanisms of the joystick.

![Figure 14: Top View of Specs® Switch](image)

There will be two buttons located near the top of the handgrip. One will be in the right side of the handgrip and the other will be on the top of the handgrip. Both buttons will act as the select function on the DynaVox DV4®. In other words, it will be the index finger click button on a right-handed mouse. The client will be able to select options of the DynaVox DV4® using the thumb of his left hand. The joystick is only a left-handed joystick. The button on the top of the handgrip will perform the same function as the side button and the Specs® switch. Each button will be a single select button, meaning that once it is pressed, it will spring back to its original position. Only one button can be used at a time, meaning that the new toggle switch located on the base unit of the joystick will control the selection of any one button.
Figure 15 is a schematic of the new 3-postition toggle switch. This will act as the selection of which button the client prefers to use at that time. When pressed on the left side, the Specs® switch will be activated as the only mode of selection on the DynaVox DV4®. When centered, as shown in Fig. 15, the toggle switch will only activate the button on the top of the joystick, and similarly, when pressed on the right side, only the right side button on the handgrip will be activated to control the DynaVox DV4®.

This joystick is positively spring-centered and uses a more wear-resistant system controlling the cursor positions. The inductively coupled movement of the joystick is responsible for the movement along each of the x- and y-axis. The motion of the joystick handle causes a simultaneous movement of the primary coil, causing the variation of electric field. The variation in the field is responsible for a change in the voltage in either direction. This inductively coupled joystick has no contacting or wiping parts, giving it an advantage over the potentiometric joystick. This is an advantage because there is a higher life expectancy of the joystick mechanical parts and the complexity is much less. The only moving parts of an inductively coupled joystick are the lever, centering cup, and helical compression spring.

2.2 Optimal Design

2.2.1 Objective
The objective of the optimal design is to provide the client with the most efficient and user-friendly device to aid in his communication abilities. The device is meant to provide the client with a fast and simple means of communication, thus enabling him to carry out normal conversation with friends, family, and others. This design was developed based on the client’s physical capabilities, as well as successes and failures with past devices. The client’s specific requests and ideas were also taken into great consideration for the development of the optimal design. This design implements all of the best features from the alternate designs while applying even greater features to maximize the performance and capabilities of this device and to fulfill the necessary functional requirements.

Of the components for this project, the necessity of a more durable joystick and an additional viewing screen were determined to be of top priority, under budget constraints. The joystick will implement a new technology (for joysticks), the Hall effect, recommended to us by P&Q Controls, for its superior durability and frictionless parts, while providing long-lasting usability. The Hall Effect joystick is an industrial-rated joystick and employs conversion of mechanical forces, through magnetic fields, to electrical signals, which move the cursor of the DynaVox DV4. An electrical current, provided by the USB connection to the DynaVox DV4, flows through a conductor in a magnetic field. The magnetic field exerts a transverse force on the moving charge carriers, which push them to one side of the conductor. At the conductor, the degree of charge produced is balanced by a magnetic field where a measurable voltage is produced between the two sides of the conductor. This measurable voltage is called the Hall Effect and is the driving force in the movements of the joystick.

Combined in the design of the joystick is a mono jack port for the optional addition of a Specs switch. This switch is in addition to the two buttons on the top of the joystick and will have the same function as the right button on the joystick. The left-handed joystick uses the right button as the dominant button as designed specifically for our client, who uses the right button as the main button. The Specs switch does not override the joystick button but can act simultaneously with it to allow our client to maintain better posture, per request of our client's mother.

Lastly, the additional viewing screen, will be added to our client's existing DynaVox DV4 communication system. The screen
is a 7 inch color liquid display screen that will have a rechargeable NiMH battery life of 10 hours, a rocker switch to separate the battery voltage from the monitor, the charger and the off functions, and will include adjustment for display color, brightness, and contrast. A green light emitting diode (LED) will work in conjunction with the rocker switch to indicate the status of the LCD screen (on, off, or charge). The LED will be illuminated when the screen is in the "ON" position. The enclosure for the screen is composed of a durable and strong black ABS plastic. Both the joystick and the screen enclosure will be mounted to our client's existing wheelchair in predetermined spots and will be removable or adjusted with ease, to accommodate an ever changing environment.

2.2.2 Subunits (As of Spring 2006 Semester)

The overall joystick provides the form and function that the client will be able to use and adapt to very quickly. The front view of the joystick, as shown in Fig. 15 depicts a simple, classic design for the joystick, but contains many variations that cater to the client’s needs. Starting from the bottom and work upwards, the base casing is made of aluminum. This will be a square shaped box that will only have a seam surrounding the top cover. The box will be a total of 2.5 inches (6.35 cm) in height and will be 3 inches (7.6 cm) square. The thickness of the aluminum will be approximately 0.13 inches (0.32 cm), to provide the durability and strength it needs for daily use. As with all seams and holes in this aluminum casing, they will be sealed with a black rubber gasket that is specified to keep out moisture and water from damaging the internal mechanisms of the joystick.

The gasket will be made of a high-grade solid neoprene rubber, with temperature allowances of -30 to 200 deg. F (-34 to 93 deg. C). This gasket will be a single piece that also includes the accordion-like joint cover. In making this rubber one solid piece, it prevents any liquids from seeping through the cover of the joystick box, around the screw holes, the circumferencing seam, or top hole where the joystick shaft exits the box. The aluminum casing will be fabricated at the on-campus machine shop and will be spray painted black to match the rest of the wheelchair accessories.
Figure 15: Front View of Optimal Design for the Joystick
Figure 16 is the top view of the base unit cover. In each corner of the lid, there is a Philip’s head screw that secures the lid to the base unit box and creates a tight seal anywhere the aluminum and the gasket meet. This figure also shows the approximate diameters of the three folds of the continued rubber gasket. The lower-most fold is 2.0 inches (5.1 cm) in diameter while the other two folds decrease in diameter by 0.5 inches (1.3 cm) as they ascend the aluminum shaft of the joystick. The gasket finally ends in a tight 0.32 inch (0.8 cm) diameter opening to seal and fit snugly around the aluminum shaft.

Figure 16: Top View of Base Unit of Joystick
Figure 17 shows the bottom of the base unit. The wire that exit the box will be round and will be able to fit snugly through the 0.25 inch (0.6 cm) holes drilled in the base of the box. The wire will connect to the DynaVox DV4® communication system, and will be surrounded by a neoprene gasket. This gasket will provide a water-tight seal for the internal mechanisms of the joystick. This wire will have a USB connection, which is easily connected and disconnected to the DynaVox DV4®. The USB standard connection allows the device (the joystick) to draw power directly from the DynaVox DV4®. For a device such as a joystick, the USB is a simple connection that draws the needed power supply of up to 500 milliamps at 5 volts. A USB cable contains four wires in its shielded bundle. One of the wires supplies the device with +5 volts and another is the ground. Additionally, there is a twisted pair of wires that carries data back and forth between the joystick and the DynaVox DV4®. The joystick will be hot-swappable, meaning it is possible to plug them into the DynaVox DV4® bus and unplug them any time, without causing damage to the computer system or the joystick electrical components.

The head-switch is a product that the client already has and wants to have worked into the joystick design. The head-
switch is manufactured by the Ablenet Corporation and is called the Specs® switch access tool. It is a 1.38 inch (3.49 cm) diameter circular switch that is mounted to the client’s wheelchair headrest via a 24 inch (60.96 cm) Velcro strap. Figure 14 shows a rough diagram of the top view and Fig. 18 shows the side view of the Specs® switch. Located on the front side of the aluminum base unit will be a 0.125 inch (0.32 cm) female, panel-mount, audio mono jack. This jack will be used to plug in the male end of Specs® switch. This allows the head-switch to connected and disconnected from the joystick whenever used or not needed. This function, rather than being hard-wired into the system, allows for better usability by the client.

![Figure 18: Side View of Specs® Switch](image)

The shaft of the joystick will be made of an aluminum rod. The rod will extend from the induction coils inside the base unit, almost halfway up the handgrip on the joystick. This aluminum rod will be 0.32 inches (0.8 cm) in diameter and will be kept its natural color and finish. This rod will be about 3.5 inches (8.9 cm) in length. It will be 1.0 inch (2.5 cm) in length between the base of the handgrip and the top of the aluminum base box. The neoprene accordion gasket will extend 0.75 inches (1.9 cm) up that exposed shaft, leaving 0.25 inches (6.4 cm) with no covering. This will allow the rubber folds of the gasket to expand and be compressed, moving up and down the aluminum shaft, without becoming damaged. Figures 19 and 20 show the dimensions of the aluminum shaft and rubber gasket as they would be on the actual joystick.

The handgrip portion of the joystick will be cylindrically shaped. It will be 1.5 inches (3.8 cm) in diameter and 3.5 inches (8.9 cm) in length. The handgrip will come in two halves and will be screwed together by two hexagonal bolts. The handgrip is made of a thick-walled glass-reinforced nylon. This type of material is used in industrial applications and can withstand constant abuse. The rugged design is rated to work in
outdoor application and be weather and corrosion resistant. This glass-reinforced material has also been pre-stabilized with a UV resistive material to prevent long-term discoloration due to sunlight and the breakdown of the nylon based material.

Figure 19: Side View of Joystick
The handgrip will be mostly hollow, as will be the aluminum shaft, to provide a passageway for the button wires to connect between the base unit and the handgrip. There will be two buttons located near the top of the handgrip. One will be in the right side of the handgrip and the other will be on the top of the handgrip. Both will each be 0.63 inches (1.6 cm) in
diameter. The side button will be adjacent to the finger grips and will be 0.5 inches (1.3 cm) from the top of the handgrip. Figures 15 and 20 show the front and back views of the joystick and a visual placement of the two buttons. Referring to Figs. 15 and 20, both buttons will act as the select function on the DynaVox DV4®. In other words, it will be the index finger click button on a right-handed mouse. The client will be able to select options of the DynaVox DV4® using the thumb of his left hand. The joystick is only a left-handed joystick. The button on the top of the handgrip will perform the same function as the side button and the Specs® switch. Only one of each button can be used one at a time, so the new selector switch located on the base unit of the joystick will control the selection of any one button. As seen in Fig. 21, there will be the buttons on the right side and the top of the handgrip which control the selection options on the DynaVox DV4® communication system.

![Figure 21: Top View of Joystick](image)

Each button will be a single select button and once it is pressed, it will spring back to its original position.
will provide the similar functions of a standard computer mouse button.

The two buttons on the handgrip will be of identical dimensions and color. The base of the buttons will be black, to match the joystick handgrip and base unit. The buttons themselves will be bright red in color to be easily seen by the user and will have a rounded top so they are easily pressed by a thumb, the side of the hand, or any other part of the hand. Figure 22 shows the dimensional drawings of the two buttons. The total diameter of the buttons are 0.70 inches (1.78 cm) and the total depth the buttons will be set into the handgrip is 0.45 inches (1.1 cm). The leads on the base of the buttons will be approximately 0.19 inches (0.5 cm) in length. The actual diameter of the red button itself is 0.63 inches (1.6 cm). This button type and size will provide the user with ease of operation while not being so large that the buttons can be activated by accident. These will be specified as single pole, single throw push buttons, meaning that there is one incoming power supply and a single throw switch to complete the circuit connection once pushed.
Figure 23 is a schematic of the new 3-postition selector switch. This will act as the selection of which button the client prefers to use at that time. When depressed on the left side, the Specs® switch will be activated as the only mode of selection on the DynaVox DV4®. When centered, as shown in Fig. 23, the selector switch will only activate the button on the top of the joystick, and similarly, when depressed on the right side, only the right side button on the handgrip will be activated to control the DynaVox DV4®.
The dimensions of the selector switch will be 1.0 inches (2.54 cm) long, as shown in Fig. 7, 0.63 inches (1.6 cm) wide, about 0.45 inches (1.14 cm) deep into the base unit, and have four electrical leads that are 0.19 inches (0.48 cm) long. Each lead will connect with one of the buttons and additionally connect with the DynaVox DV4® communication system. There will always be one button activated at all times, depending on the position of the selector switch. This is shown in the following block diagram (Fig. 24).
One of the desired features of this joystick device is that it will be positively spring-centered, in that the joystick handle will spring back to the central position once the applied force has been released. This function will be implemented through a spring-shaft apparatus which is shown in Fig. 25.

Figure 24: Selector Switch Block Diagram
Figure 25: Inner Shaft and Spring of Joystick

This figure shows the bottom portion of the joystick’s handle shaft, part of which is concealed by the rubber gasket. At the top of the apparatus is a circular polymer lip which has been bolted to the shaft. Surrounding the shaft is a helical coiled spring. Below the spring is a polymer cylinder with a bottom lip. This cylindrical part is free to slide along the surface of the shaft. This allows for the extension and compression of the spring as the joystick handle is moved in various positions. In addition to the portion of the apparatus shown in Fig. 25, the remaining portion of the entire spring-centering apparatus is shown in Fig. 26. This portion is a
circular plate-like part with four raised ridges spaced equally around the circumference of the plate.

![Figure 26: Top View of Shaft Seat](image)

![Figure 27: Cross-sectional View of Shaft Seat](image)

The cross section of the plate is shown in Fig. 27. The shaft of the joystick is threaded through the central hole of the plate and is secured at the bottom. The plate is then secured inside the joystick base at a fixed position. The bottom lip of the spring-shaft apparatus is free to slide along the ridged surface of the plate. The spring is always meant to be in compression, in order to have a constant resisting force present in the joystick handle. When the handle of the joystick is moved in any direction, rather than allowing for extension of
the spring, the bottom lip presses against the raised surface of the plate, causing a greater compression of the spring. When the applied force on the handle is released, the spring releases to its position of least compression, which is located back at the center.

The spacing between the ridges is not necessary, but adds to the user-friendly features of this joystick. The spaces are placed at exact 90° angles and are oriented along the x- and y-axes. As the bottom lip of the shaft slides over the raised surface of the plate, a slight disruption occurs in the fluid motion of the handle as the lip catches in the gaps. This catching that occurs indicates to the user that the joystick is positioned exactly on either axis.

Due to involuntary movements the client frequently experiences, a method to prevent the accidental movement of the joystick was devised. This design implementation prevents the joystick from moving if a force less than 3 oz, or 0.188 lbs. is applied to the joystick. This prevents sudden motions of the cursor from occurring if the joystick handle is bumped or jerked slightly unintentionally. This design method is explained by the following calculations and procedure.
Figure 28 represents the possible field of motion of the joystick and the extent to which the spring can be displaced in normal movement. As the motion of the joystick handle is angular, the maximum extension of the spring will take place when the handle is at a 45° angle. The length of the maximum spring expansion was then determined by the following calculations:

\[
\cos (45°) = \frac{1.00\text{in}}{\text{Max Expansion Length}} \quad (\text{eq. 1.0})
\]

\[
\text{Max Expansion Length} = \frac{1.00 \text{ in}}{\cos (45°)} \quad (\text{eq. 1.1})
\]
Max Expansion Length = 1.9 in

The maximum length that the spring will stretch during use is 1.9 inches (4.8 cm). In order for the spring-centering technique to work, the spring must always be compressed. However, the spring does not need to be in a heavy state of compression, therefore a spring with a length of 2.00 inches (5.1 cm) will be compressed to fit the apparatus. The minimum displacement of compression ($x_{min}$) is 0.1 inches (0.3 cm). This value was determined simply by determining the difference between the total length of the spring and the maximum expansion length of the spring once it has been compressed into the apparatus. The maximum displacement of compression ($x_{max}$) is 1.00 inch (2.5 cm). This value was determined by finding the difference between the total spring length and length of the spring at a 90° angle to the base of the joystick, which is the minimum length of spring extension. The minimum amount of force required to move the joystick handle from its rest position will occur at $x_{max}$. Since it is desired that the minimum applied force is 0.188 lb. and the maximum length of compression is known, a spring must be used with the appropriate spring constant to satisfy these conditions. This appropriate spring constant value can be determined by assuming that the compressive force acting on the spring is equal to 0.188 lbs, the desired minimum force of application. The spring constant can then be determined by the following equation:

\[
F_c = \frac{1}{2}k \cdot x_{max} \quad \text{(eq. 2.0)}
\]

\[
k = \frac{2F_c}{x_{max}} \quad \text{(eq. 2.1)}
\]

\[
k = 0.376 \text{ lb./in.}
\]

Once the spring constant value is calculated, the required specifications of the spring are known to fulfill both the spring-centering function and the minimum applied force requirement.
The inductively coupled movement of the joystick is responsible for the movement along each of the x- and y-axes. The motion of the joystick handle causes a simultaneous movement of the primary coil, causing the variation of electric field between the primary coil and the secondary coils. The variation in the field is responsible for a change in the voltage in either direction along the x- and y-axes and is translated to the movement of the cursor on the DynaVox DV4® screen. The electrical components and coil-positioning setup for this function can be simply represented by the diagram in Fig. 29.
Figure 29: Joystick Inductively Coupled Control

In Fig. 29, the inductively coupled system is based on a variable-transformer type relationship. Attached to the base of the inner shaft of the joystick is a primary coil. This coil hovers between four secondary coils, each of which is placed at a positive or negative end of the x- or y-axis. The primary coil creates a field between itself and the secondary coils. Through the movement of the joystick shaft, the induced pick-up from the secondary coils is varied proportionally to the amount of movement. The closer the primary coil is to the secondary coil, the stronger the pick-up signal is. As would be expected, the farther the primary coil is from the secondary coil, the smaller the pick-up signal is. The pick-up signal is then converted to a digital signal through an analog-to-digital conversion circuit. The digital signal can then be read by the
computer, thus allowing the translation of the joystick’s movement to the movement of the cursor.

This inductively coupled joystick has no contacting or wiping parts, giving it an advantage over the potentiometric or opto-mechanical joystick. This is an advantage because there is a higher life expectancy of the joystick’s mechanical parts and the complexity is much less. The only moving parts of an inductively coupled joystick are the shaft, centering cup, and helical compression spring.

A microprocessor will be used to convert the field signal changes from the joystick to digital signals where they can be recognized and used by the DynaVox DV4® via a USB cable. This microprocessor and circuit board will integrate the field changes from the joystick to cursor movements on the DynaVox DV4® screen, and it will detect the button signal which will be used to select objects on the DynaVox DV4®. The voltage supply for the joystick is 5 volts DC. The output of the joystick varies when its position is changed over the induction coils. When the joystick is centered, it has an output voltage of 50 percent of the supply, or 2.5 volts. At the full positive deflection position, the output voltage is 80 percent of the supply voltage, or 4 volts. In the full negative position the output voltage is 20 percent of the supply voltage, or 1 volt.

As requested by the client, for ease in communication, an additional screen will be attached to the opposite side of the existing communication system, so that others can view the same screen that he sees. Following the research into the DynaVox DV4®, it was discovered that the DynaVox DV4® does not have a video output installed in its system. To successfully attach, or install, a video output, a VGA video card, ColorGraphic Voyageur VGA CompFlash card from a company called PC Connection, will be installed. This device will allow the display capabilities of the on-screen image transferred to any VGA compatible LCD monitor. This card that will be installed can even display images on a television screen due to its PAL, NTSC, or S-video output connections (which will be described further in detail). This option allows the user or the people interacting with the user to have a larger, or additional, viewing area. This device can also output MPEG files to a monitor or projector in future applications.

Color television transmission has two main types of standard signals today. PAL, or Phase Alteration Line, and NTSC, or National Television System Committee, each support
separate transmission of brightness and color signals and
interlacing in television signals. NTSC was first introduced in
1953 in the United States for color television use. It was the
standard being used and allowed the compatibility with the
black-and-white television sets. NTSC uses 525 lines of visible
color and a 59.94 Hz frame rate. PAL was introduced in 1961 and
was an improved version of the NTSC system of connections.
Telecasting in PAL started in Europe in 1967 and had the main
advantage over the American NTSC system of having a higher color
stability. The color coding in PAL has 576 visible lines out of
625 at the frame rate of 50 Hz. In our situation, the VGA video
card that will be installed into the client’s DynaVox DV4® will
have a wide range of capabilities and uses once put into place.

The VGA card can be seen in Fig. 30. The opposite end of
the card has all three, VGA, PAL, and NTSC connections on one
plug. Only one connection can be used at any single time, but
the connections are available to use. To install the VGA card
into the DynaVox DV4®, first, the card cover needs to be removed
from the device. The card cover is on the top of the device and
is held down by two flat head screws. Next, the new VGA card
can be inserted into the secondary slot of the device. The VGA
wire can be connected to the provided 7 inch LCD screen, which
can be then turned on. In the DynaVox DV4® go into the pull-down
menu and select Setup, followed by System Settings, and select
the VGA Output option. After selecting the VGA Output option
you can select OK to close the menu and then select OK if the
message “Please Insert Voyager PMCIA Card” comes up on the
screen. If theses steps do not install the VGA card correctly,
pull the card out of the device and reinsert it. Replace the
protective cover on the device and select OK to any additional
prompts that come upon the screen. If all steps are correctly
followed, the VGA card should be installed and should be
projecting the same image on the DynaVox DV4® to the LCD screen.
The Liquid Crystal Display or LCD screen that will be used is a Phylon 7 inch wide screen with a VGA TFT display. The new VGA card installed into the DynaVox DV4® will have the VGA, PAL and NTSC connections allowing the capabilities to connect to this LCD or any other additional display devise, like a projector, television or an additional monitor. This screen has a display size of 7 inches and a 16:9 widescreen with a resolution of 800 by 480 native which supports input scaling up to 1280 by 1024. The brightness of the screen is rated at 300 cd/m² with a contrast ratio of 150:1. Again, the screen has video inputs for one VGA connection and two composite RCA connections.

This LCD screen does not have the touch-screen technology or any audio capabilities, because neither are needed based on the design that it will be used for viewing purposes only. This LCD monitor uses a power consumption of 10 watts maximum and needs an input voltage of DC 12 volts, which will be provided via a lithium ion rechargeable battery. The monitor being purchased also comes with the VGA and audio/video cables, a headrest shroud, an infrared remote control and a dashboard stand. The monitor will be easily mounted to the existing
DynaVox DV4®. Either by using the dashboard stand provided with the LCD monitor or the mounting device will be fabricated in the on-campus machine shop. Figure 31 shows the front view of the Phylon 7 inch LCD screen being used in this project, while Fig. 32 shows the side view with two of the possible connections, which are the VGA and S-video connection. Lastly, fig. 33 shows all of the accessories that come standard with the LCD screen.
Figure 32: Side View of LCD Screen

Figure 33: Included Accessories in the LCD Screen Package
2.2.3 Additional Subunits (As of Fall 2006 Semester)

Many changes have been made between the optimal design of Spring 2006 and the final design of Fall 2006. These major changes to the design will be outlined and described as to the purpose for the changes and their significance. Many changes were a result of budgeting issues and client needs, but all were necessary and enhanced the overall outcome of the project.

The new design for the joystick came about when the Hall Effect joystick was recommenced to us by the P&Q Controls representative. The Hall Effect has fewer contacting parts than the inductively coupled joystick and gives our client the newest and best technology available in joysticks. This fully electrical joystick will convert mechanical movements to variations in electrical fields, made possible by the variations in magnetic fields between the three conductors in the base of the joystick. The new joystick will have the same dimensions as the old joystick, but will take advantage of the two built-in buttons (rocker switch) on the top of the joystick. Figure 34 shows a schematic of the new joystick and its top rocker switch. As this joystick is a left-handed joystick, the right button will be the main selector used by the client’s thumb, and the left button is available to be used as an optional “right-click” selector for the cursor on the client’s DynaVox DV4®.
Figure 34: New Joystick Design with Some Dimensions

The base of the joystick has also been modified, but only because the type of the joystick was altered. The Hall Effect joystick is now considerably larger in the base than the previous design. The new base unit is a rated as a NEMA 4X sealed die-cast aluminum enclosure. The aluminum is specified
as aluminum alloy #A380. There are four screws, one in each corner made of M-4 stainless steel, which is non-magnetic. These screws hold the cover onto the bottom unit. The top screws are also recessed for a finished look. There is an EPDM recessed gasket around the lid to prevent any dust or moisture from entering the casing. The enclosure is ideal for housing electrical equipment and sensitive electronic assemblies. The aluminum enclosure has a baked-on gray paint and has the outer dimensions 4.75 inches in width, 4.75 inches in length, and 4.0 inches in depth.

On the right side of the enclosure, the mounting bracket is attached to allow easy attaching and removable options by the client. Figure 35 shows the front of the enclosure with the inset 1/8 inch mono-jack to accommodate the Specs® switch and act as an additional main selector option for the client. This 1/8 inch mono-jack is the size of the male end that plugs into the jack opening. The hole that must be drilled in the aluminum enclosure is 0.229 inched in diameter to allow for the threads of the jack to pass through, but is small enough where the nut that screws on the threads will not slide through the hole.

Figure 35: Front of New Joystick Enclosure with 1/8 Inch Mono-Jack
The USB cord is sealed in its opening with a black vinyl grommet to make for a water tight seal and a more aesthetically pleasing appearance. Figure 36 shows a picture of the vinyl grommets used for the USB cord in a 0.296 inch outer diameter. Figure 37 shows the opposite side of the enclosure, with the USB cable exiting closer to the bottom of the enclosure then the mono-jack.

![Figure 36: Vinyl Grommet to Seal the USB Cord Exiting the Joystick Base Enclosure](image)

The joystick is connected to the DynaVox DV4® communication system via a USB connection. The USB connection provided the 5 volt power supply to the joystick and all additional signals that will detect which button is being selected and which directions that joystick is positioned.
Figure 37: Back of New Joystick Enclosure with 3/16 Inch USB Wire and Grommet Exiting Hole

The 80/20 Inc. mounting bracket is Double Flange Linear Bearing and provides the easy-on easy-off accessibility for the client. This feature will be incorporated with a ratcheting L-handle to secure the enclosure to the 1 inch by 1 inch 1050 80/20 extrusion rod. The mounting bracket is connected to the enclosure with raised flat-head screws and nuts. These screws are 0.25 inch in diameter. Figure 38 shows the mounting bracket attached to the right side of the aluminum enclosure. Figures 35 and 37 do not have the double flange linear bearing in them.
With the Hall Effect joystick came a new wiring scheme where a USB connection and a rewiring of the existing buttons was needed. Figure 38 shows the new schematic for the wires that power and connect the joystick to the DynaVox DV4®. The schematic also shows where the wires connect to the two buttons on top of the joystick handle and where they will connect to the mono-jack. The same wires also connect the different components and conductors of the Hall Effect.

On the left side of Fig. 39 there is HUB#1 which has all of the leads that connect the joystick to the DynaVox DV4® via a USB cord. All labels on the hubs indicate the labeled ports that already existed on the joystick. Below the labeled ports is the color and purpose of the wire exiting it. From the left to the right, the Shield label for a USB connection would connect with a shield wire in the USB bundle, but in our situation, there was no shield wire, so it is left blank. The GND label is connected
to the black wire in the USB bundle and grounds the joystick to the DynaVox DV4®. The D+ labeled port connects to the green wire in the USB bundle and provides the joystick with a positive signaling, while the D- labeled port connected to the white wire in the USB bundle provides the negative signaling in for the joystick. The VCC port provides the joystick with its power. This red wire carries a 5 volt power supply provided by the DynaVox DV4® to power the joystick and its Hall Effect functions.

On Hub#2 there are many more connections, most of which connect to the magnetic field conductors to control the Hall Effect function of the joystick. The ports labeled DIG 1, DIG 2, DIG 3 and DIG 4 control and relay the button functions of the joystick. DIG 1 was modified to accommodate our client’s head switch. To do this we split green wire exiting the DIG 1 port and also the red wire exiting the COM port. An additional green wire was spliced into the positive lead from the main control button and an additional yellow wire was spliced into the red wire from the common port labeled COM. In splicing the wires, this gives the head switch an optional function if plugged into the mono-jack port. Both the head switch and button (DIG 1) will function as the same entity if either button is pressed, or both are pressed at the same time. DIG 2 port was kept intact, providing a “left-click” option. The COM port also connects to the opposite side of the button controlling DIG 2, completing the circuit for the button. DIG 2 and DIG 3 remain blank, with no additional buttons added and the opportunity, if ever arose, to install an additional two buttons for the client.

All additional ports control the Hall Effect for the joystick. The labels are self-explanatory, meaning that the GND port is the common ground for the joystick functions, the Y OUT port provided the voltage variations and detects the differences the joystick moves in the Y-direction. Y in the positive direction means that the joystick is moving forward, or away from the user, while Y in the negative direction means that the joystick is moving backwards, or towards the user. Similarly the X OUT port provides the voltage variations and detects the differences the joystick moves in the X-direction. X in the positive direction means that the joystick is moving to the right, while X in the negative direction means that the joystick is moving to the left.
Figure 39: Inner Joystick Electrical Port Connections

As more considerations were taken into account about the design of the screen, there were modifications and changes made to better accommodate the client’s needs. The new design will implement different modular pieces, all combined into one custom enclosure. The enclosure will be composed of a black Acrylic-Butadiene Styrene or ABS plastic material. ABS has high-impact strength and can be machined, sawed, routed and heat formed. This plastic will be smooth on one side while the other side will have a textured hair-cell finish, to hide scratches. The textured side will be facing outward to provide a more finished look. The enclosure will be 8.0 inches in length, 5.25 inches in height and 2.50 inches in width. Each ABS panel will have mitered corners so that each edge will meet the other edge at a 45 degree angle. The ABS plastic is 0.25 inches in thickness. There are two panels that are 8 by 5.25 inches, two panels that are 5.25 by 2.50 inches, and two panels that are 8.0 by 2.50 inches.

The recommended bonding agent for the ABS plastic was Cyanoacrilate. This adhesive is rated especially for ABS. It dries clear and is thin bodied, meaning that it is a very viscous liquid and needs minimal thickness to serve its purpose in bonding two surfaces. The bonding agent is a fast-setting cement for purposes such as construction projects involving various plastics. To apply the adhesive, the two surfaces that need to be bonded should be clean, smooth and free of any dust or debris. A thin layer of bonding agent should be applied to
both surfaces that will connected. Once both surfaces have a thin, smooth layer of the Cyanoacrilate on them, place the two pieces in the exact position that is desired and hold for 10 seconds while the adhesive sets up. This will result in a secure structure, but allow the adhesive to dry for 24 hours to be sure it is fully cured.

The 7 inch liquid crystal display screen that will be used is a TFT-LCD open frame widescreen color monitor. The screen comes equipped with different controls that perform different functions to the image on the screen. There are three main jacks on the attached PCB of the screen and they are the on/off switch, a power input jack that comes with a connection cable that has a black and red wire which can be connected to any power source, and lastly, there is an RCA or PAL connection for video input. The PCB also has switches to flip the image on the screen from left to right and a switch to create a mirror image of the image on the screen. Three knobs are also present on the LCD. These knobs are able to adjust the color, the contrast, and the brightness of the image on the screen. Figure 40 shows the reverse side of the LCD screen and the attached PCB with the assorted controls on it.
This screen has a dot format rated at 1440 x 234 and a CCFT backlight. The screen is rated for 15,000 hours of service and has a brightness rating of 350 NITS. With a contrast ratio of 150:1, the screen will show a clear and detailed image for the client. The viewing angle of 15°/55°/15°/35° from left/right/top/bottom, also provides many positions that the client can properly view the screen image from. The screen needs a 12 volt DC supply at 700 milliamps and a video input level of 1.0 volt p-p (positive) 75 Ohm. The full dimensions of the driver board are 2.6875 inches by 4.0 inches by 0.5 inches. The total dimensions of the control board are 1.75 inches by 2.0 inches by 0.5 inches. There is an operating temperature range of 0°C ~ 60°C and a storage temperature of -20°C ~ 80°C that should be observed to ideally run the screen. The total weight of the screen and its components is 12.0 oz.
To power the screen, a NiMH rechargeable battery pack will be used. The battery pack is composed of 10 AA NiMH batteries. The total output voltage of the pack is 12 volts DC at 2200 milliamp hours. The 10 piece NiMH AA cells are connected with 14 Ga Silicon wires and have a max discharge of 2 amps. The battery pack is rated for rapid charge, no memory effect, and a long cycle life of charging, using, and recharging. The battery pack measures 54 mm. by 29 mm. by 72 mm. in height, width, and length respectively. Figure 41 shows the battery pack that is used in this project. The total weight of the battery pack is 10 oz.

![Figure 41: Rechargeable NiMH Battery Pack at 12 Volts DC and 2200 mAh](image)

Used in conjunction with the rechargeable battery pack will be a universal battery pack charger rated for this type of application. The charger is called a Multi-Current Universal Smart Charger for RC 7.2 V-12 V NiMH/NiCd Battery Packs. The charger is rated for 6-10 cell battery packs and can have an input range of 120-240 V. The charger uses a pulse plus negative pulse technology (10 percent negative pulse) to avoid overheating and polarization during fast charging. This pulse varying technology provides a safe guard for the battery pack and dramatically extends the battery pack’s life span. This charger automatically detects the battery pack’s voltage and is equipped with a red LED to indicate that the battery pack is being charged. There is an automatic cut-off by negative delta V when the battery pack is fully charged.

The charger comes with a selectable amperage range setting, used when charging battery packs of varying voltages, but will
only by used in the 1.8 A setting to avoid any complications with the charging process. This 1.8 A setting is used because the battery pack that is being used is over 2100 mAh, specifically 2200 mAh. The charger will be connected to the battery pack via a female Tamiya connector that is already attached to the charger. A male Tamiya connector will be attached to the reverse side of the ABS enclosure, where the charger can be connected, making a full circuit with the NiMH battery pack. The charger is 1.5 inches by 2.5 inches by 5.75 inches in height, width, and length respectively. The total weight of the Universal Smart Charger is 0.6 lbs. Figure 42 shows the Universal Smart Charger that will be used in this project.

Figure 42: Multi-Current Universal Smart Charger for RC 7.2 V-12 V NiMH/NiCd Battery Packs

As the main connector switch between the monitor power, the battery pack, and the charger will be an appliance rocker switch. The rocker switch is rated as an ON-OFF-ON switch, meaning that there are two “ON” positions and one “OFF” position, where the connections never are crossed with each other. This type of switch is a double pole, double throw that is maintained in the thrown position without springing back to
its original position. Figure 43 depicts a classic double pole, double throw schematic.

When describing a double pole, double throw switch, a pole refers to the number of switch contact sets and a throw refers to the number of conducting positions. The rocker switch that is used in this situation has two sets of poles, or four contacts, with two more throws or two more contacting positions. When the switch is called maintained, it again means that it will not return to its normal position when released. The switch will stay in the on, off, or charge position until it is changed to a different function.

The rocker switch is black and has six 0.25 inch quick-connect terminals. Figure 44 shows the terminal connections for the rocker switch. The Rocker switch will be mounted in a hole on the right side of the screen enclosure that measures 1.450 inches in length and 0.83 inches in width. Figure 45 shows the position of the rocker switch in the right side panel of the screen enclosure.
Also in Fig. 44 there is the green LED indicator light that signals when the rocker switch is positioned in the monitor “ON” position. The LED is depicted as the circle directly below the “ON” label of the rocker switch. This LED is implemented as a safeguard to ensure that the users do not leave the screen with continuous power unknowingly. If there is no input signal to the screen from the existing communication system, then the 7 inch screen will appear to be black, but will be drawing power continuously, slowly draining the battery. If the rocker switch was left in the “CHARGE” position and the charger was not attached to the Tamiya port, there would be no drain on the battery, eliminating the need for a “CHARGE” position LED indicator light. When the rocker switch is in the central “OFF” position the battery is connected to nothing, making an open circuit. When in the “ON” position, the green LED is illuminated and a complete circuit is made between the battery pack and the monitor. When in the “CHARGE” position, the green LED is not illuminated and a complete circuit is made between the battery pack and the charger, if plugged into the Tamiya connector.
When wired into the circuit, the green LED will have a 500 Ohm resistor in series, to prevent over heating and limit the amount of current to the LED. When soldering an LED, one must be sure not to overheat the leads on the LED, because if the temperature gets too high, the LED can be damaged. LEDs are polarized and have an anode and a cathode. The anode is the positive end which is indicated by having the longer lead coming out of the plastic body. The cathode is the shorter lead.
exiting the plastic body of the LED. The resistor is placed before the long lead, the anode, on the LED. This circuit is integrated into the monitor positive and negative leads. Using Equations 3.0 through 3.3, one can determine the correct resistance needed for a LED or series of LEDs. In Equation 3.0 the \( V \) represents the voltage, the \( I \) represents the current and the \( R \) represents the resistance. With a little modification of eq. 3.0, substituting in for the voltage, the voltage across the resistor or \( V_S - V_L \) (eq. 3.1). In equations 3.1 and 3.2, \( V_S \) represents the supply voltage, \( V_L \) represents the LED voltage (usually 2 volts for a red or green LED, 4 volts for a blue or white LED). The \( I \) in equation 3.2 represents the LED current. Substituting in all relative values for each situation, specifically the situation for a green LED, all values are listed below with the final calculation and result of a resistance of 500 Ohms.

\[
V = I \times R \quad \text{(eq. 3.0)}
\]

\[
V = (V_S - V_L) \quad \text{(eq. 3.1)}
\]

\[
R = \frac{(V_S - V_L)}{I} \quad \text{(eq. 3.2)}
\]

\[
V_S = 12.0 \text{ volts}
\]

\[
V_L = 2.0 \text{ volts}
\]

\[
I = 20.0 \text{ mA}
\]

\[
R = \frac{(12.0 \text{ V} - 2.0 \text{ V})}{20.0 \text{ mA}} \quad \text{(eq. 3.3)}
\]

\[
R = 500 \text{ Ohms}
\]

Figure 46 shows the appliance rocker switch that will be used in the project. The picture also shows the 0.25 inch pink plastic quick-clamp terminal connectors. These connectors
permanently connect to the wire that is clamped in them, but allows for the clip to be removed, because the larger 0.25 inch end is held in place on the male terminal of the rocker switch via an indent in the metal connections and friction. If ever needed, the terminals can be removed and easily replaced without needing to be resoldered or spliced.

Figure 46: Appliance Rocker Switch and Pink Quick-Connect Terminal Connectors

The overall block diagram of the general electrical connections of the monitor can be seen in Fig. 47. This block diagram shows the different electrical paths through the arrow directions and when the rocker of flipped in that position, which path is turned on. The battery pack is always connected to and depending on which position the rocker switch is located, the battery pack will power the monitor or it will be charged by the Universal Smart Charger.
Once all of the different sections of the ABS enclosure are fabricated at the machine shop, they can be bonded together to form the diagram that is shown in Fig. 48. The overall enclosure is in the shape of a box that is 8.0 inches by 5.25 inches by 2.50 inches. The cut-out for the 7 inch LCD screen is not centered on the face of the enclosure, vertically, but it is centered horizontally. There is 0.938 inches of ABS on either side of the screen, 0.50 inches on the top of the screen and 1.25 inches in the bottom of the screen. This makes the opening for the screen 3.50 inches high by 6.00 inches long. When
measuring the screen itself, the 7 inch figure is reached by measuring from opposite corners of the screen to each other.

Figure 48: Complete Screen Enclosure, Front View

Figure 49 shows the reverse side of the front panel of the screen enclosure. This side is dramatically different from the front, because the border around the screen varies from side to side. Since the screen will be inset into the plastic, a 1/8 inch deep pocket will be machined out on the inside of the opening to hold the screen tight in place, but allowing the front viewing area to be centered in the opening. Looking at the back side of the front panel, there will be a 0.25 inch slot cut out from the left of the opening, a 0.1875 inch slot cut out from the right of the opening, a 0.1875 inch slot cut out from the top of the opening, and a 0.375 inch slot cut out from the bottom of the opening. Again, all slots will be 1/8 inch deep,
leaving 1/8 inch of ABS to hold the screen in place, because the total thickness of the ABS is 0.25 inches thick.

Figure 49: Inside View of the Front Panel

Following the research into the DynaVox DV4®, it was discovered that the DynaVox DV4® does not have a video output installed in its system. To successfully attach, or install, a video output, a VGA video card, ColorGraphic Voyageur VGA CompFlash card from a company called PC Connection, will be installed. This device will allow the display capabilities of the on-screen image transferred to any VGA compatible LCD monitor. This card that will be installed can even display images on a television screen due to its PAL, NTSC, or S-video output connections.

The VGA card can be seen in Fig. 50. The opposite end of the card has all three, VGA, PAL, and NTSC connections on one plug. Only one connection can be used at any single time, but the connections are available to use. To install the VGA card into the DynaVox DV4®, first, the card cover needs to be removed from the device. The card cover is on the top of the device and is held down by two flat head screws. Next, the new VGA card can be inserted into the secondary slot of the device. The VGA wire can be connected to the provided 7 inch LCD screen, which
can be then turned on. In the DynaVox DV4® go into the pull-down menu and select Setup, followed by System Settings, and select the VGA Output option. After selecting the VGA Output option you can select OK to close the menu and then select OK if the message “Please Insert Voyager PMCIA Card” comes up on the screen. If these steps do not install the VGA card correctly, pull the card out of the device and reinsert it. Replace the protective cover on the device and select OK to any additional prompts that come upon the screen. If all steps are correctly followed, the VGA card should be installed and should be projecting the same image on the DynaVox DV4® to the LCD screen.

Figure 50: VGA Card and Opposite Connections

There will be two methods for mounting the joystick and one method for mounting the monitor. The monitor will use a Single Horizontal Base with a 1.0 inch diameter opening that will be bolted to the reverse side of the screen enclosure and will be clamped to a 7/8 inch pipe that exists on the client’s wheelchair. To account for the difference in diameters, a 16” self adhesive neoprene hard close cell strip will be wrapped around the 7/8 inch pipe and the Single Horizontal Base will clamp around that neoprene sheet, providing a tight seal and secure mounting. All tightening of the brackets are done using
Allen wrenches in U.S. or metric units, depending on the clamp being used.

The first option to mount the joystick is to attach the base unit of the joystick to the existing tray table on the wheelchair with a Velcro-type product. The product is manufactured by the 3M™ Company and is marketed under the name Dual Lock™. This product is self-mating and simply reattaches to itself over and over again. When pressed together, thousands of mushroom heads interlock with one another creating an audible snap that indicates that the fastener is locked. One side of the Dual Lock™ will be attached to the tray table and the other side of the Dual Lock™ will be attached to the bottom side of the joystick enclosure, so that when placed on top of each other they will securely hold the joystick in a place that is comfortable for the client.

Figure 51 shows option two for the joystick mounting. It is basically two pieces of 1050 80/20 attached to each other. The shorter piece of 1050 is 6.0 inches long and the longer piece of 1050 is 10.50 inches long. There will be three 0.25 inch holes drilled through the 6.0 inch piece of 1050 at 1.0 inch on center increments. These holes will provide the attachment screws to first go through the armrest bar already mounted on the wheelchair, then through the smaller 1050 piece, then into the three drop-in T nuts with set screws, already placed in corresponding positions in the longer piece of 1050. The female ends of drop-in T nuts will exactly correspond to where the screws will be once through the smaller piece of 1050. The joystick will be able to slide on and off of the free end of the longer piece of 1050 via the attached linear bearing already on the joystick base unit. This linear bearing will have a ratcheting L-handle to be able to secure the joystick in place and be removed easily if not needed for the time being.
Figure 51: Joystick Mounting Option Number Two: Two Pieces of 1050 Secured Together for the Joystick to Slide Onto and Off of with Ease
2.3 Prototype

The finished prototype consists of the modified joystick and the LCD viewing monitor. The joystick’s main function will be to operate the cursor of the client’s current DynaVox DV4® device. It has a large durable grip that makes it easy for the client to handle, and it incorporates the use of the head switch as an additional option for selection. Figure 52 below shows the finished joystick prototype with the connected head switch.

Figure 52: Finished Joystick Prototype with Head Switch Attached

The joystick was tested for its functionality on multiple occasions using a personal computer to monitor cursor movements and button selections. The computer display showed that the
joystick did, in fact function properly, as was anticipated prior to the testing phases, based on the connections made. Figure 53 shows the screen of the computer that the joystick was tested on.

![Figure 53: Picture of Computer Screen with Evidence of a Functioning Joystick](image)

Before any permanent connections were made to implement the head switch as an additional selection button, temporary connections were made, linking the head switch to the digital ports on the USB board. Figure 54 shows a general view of the digital ports on the USB board for the selection button connections.
Digital ports 1 and 2 are occupied by connections to the two buttons at the top of the handle. Ports 3 and 4 are not used. The PC test verified that both of these buttons worked correctly. To test the addition of the head switch, we made test connections from the head switch to digital port 1, as shown in the following figure:
This setup worked in the testing. Once the tests were completed, the connections were made permanent. Since the ports were already occupied by the wires, which are permanently
clamped into place and cannot be removed once installed, the connections between the joystick and the head switch were made by splicing the wires of the joystick buttons and the wires connecting the head switch mono-jack. Figure 57 shows where the wires were spliced to include the mono-jack connection permanently.

Figure 57: Splicing the Mono-Jack Connections Permanently

The mounting for the joystick was specially designed to be convenient and simple for the client and his family members, who are mainly responsible for attaching all components to his wheelchair. A double-flange linear bearing is permanently secured to the right side of the joystick case. This is meant to slide over an aluminum bar with T-slot extrusions on all four sides. The extrusion pieces are to be permanently mounted to the inside of the bar under the left armrest of the client’s wheelchair. Figure 58 shows underneath the left armrest of the client’s wheelchair and also clearly shows the four 0.25 inch in diameter, 1.00 inch on center holes that the mounting will be attached to.
The piece will protrude forward from under the armrest. The joystick can be mounted into position by sliding the linear bearing over the T-slot extrusion protruding from underneath the armrest. This setup was first tested in the laboratory, as shown in the figure below, with the original plan to place the extrusions on the outside of the armrest. This test showed thus far that the mount was secure and stable and should be sufficient to mount the joystick to the client’s wheelchair and withstand daily use. Figure 59 shows how the joystick and its attached double flange linear bearing will slide onto the 1050 t-slot and secure with a ratcheting L-handle.
This setup was then tested on the client’s actual wheelchair. Mounting the extrusion to the outside of the armrest was not appealing to the client, as the addition of the joystick would add an extra 4in. to the width of his chair, possibly making it more difficult for him to navigate the chair through doorways. The design was altered to accommodate this by placing the extrusion on the inside and adding an extrusion of a length extending past the length of the armrest. Figure 60 shows the mounting bracket for the joystick under the armrest of the wheelchair.
This new setup was tested on the client’s wheelchair. The client tested out the position of the joystick and the movement of the joystick and found to be both comfortable and accommodating. It will rest at a comfortable position, at a desirable distance for the client’s reach, as shown in Figure 61.
The LCD Viewing Monitor prototype took a great amount of effort for testing and assembly. The first important task was locating a battery pack that would supply the monitor with sufficient voltage without causing damage to the monitor or its circuit components. The appropriate battery pack was found, judging from the electrical theory that a battery pack meeting the requirements of 12V supply with 2200mAh would be the correct power source for the monitor. Once the battery was obtained, the monitor needed to be tested with the voltage supplied to it. The monitor was tested with the battery pack connected, but without a video input. This test verified that the battery pack would supply the monitor sufficiently without causing any damage to the electrical components. Next, the monitor was tested with a video input, an older version of the client’s DynaVox™ that they were kind enough to lend to us for testing purposes, and the battery pack connected. The setup for this test is shown in Figure 62.
This test gave the desired results, giving a display of the DynaVox® screen on the LCD monitor. Figure 63 shows a close up of what the client sees on the DynaVox® but which is projected to the auxiliary LCD screen in our preliminary testing trials.
Once the monitor was proven to work in the manner that it is meant to work for the purposes of this project, the next important task to be completed was the design of the appropriate case to place the monitor in. A basic case design was devised and drawn, as shown in Figure 64.
This design was then made into a model, to test for sufficient space for all of the necessary internal components. Figure 65 shows the front of the cardboard cut-outs used to test the design of the LCD screen enclosure. Figure 66 shows the reverse side of the cardboard cut-outs used to test the design of the LCD screen enclosure.
Once the model was made, measurements and dimensions were readjusted. Next came the task of determining the best and safest way to set up the power circuit so that the battery could be recharged. The circuit design would be simple, but it needed to ensure that there would be no possible way to damage the
monitor during the charging process. The best design to suit these needs involved a switch circuit, which placed the monitor and charger on separate paths so that they would never both be connected to the battery pack at the same time. The diagram for this circuit is shown in the following figure:

![Diagram of the Rocker Switch Set-Up](image)

**Figure 67: Circuit of the Rocker Switch Set-Up**

This circuit was tested, using LED indicators to indicate that only one component of the circuit would be activated at a time. Figure 68 shows the rocker switch illuminating a red LED when depressed on the opposite side of the electrical connections. Figure 69 shows the rocker switch illuminating a green LED when depressed on the opposite side of the electrical connections. When wiring the final circuit, the electrical connections will be labeled on opposite sides so that the depressed side of the rocker switch will activate what it is labeled as.
This test resulted in a successful circuit design that would allow a safe charging of the battery without causing damage to the monitor. Once this test had been completed, it was safe to test the components with this same circuit design. The LED indicators were replaced with the monitor and the charger, and this setup was tested as well. The test was successful and the circuit works as was theoretically planned.

Once the electrical portion of the monitor was taken care of, it was then necessary to assemble the case for the monitor. The design was simplified to a rectangular shape to allow more space for wires and components. The material used for the case was acrylonitrile butadiene styrene (ABS) of 0.25 in. thickness. The ABS was cut into pieces to make according to the design.
layout. A hole was cut into the front panel for the monitor screen to show through and a 1/16 in. inset was milled into the edge of this hole so the screen could rest inside. This is shown in the following figures:

![Figure 70: LCD Screen placed in the Recessed ABS Front Panel](image-url)
The edge of the inset was filed down for a better fit and to eliminate some of the rough edges left over from the machining. The top panel was reserved as the removable access panel, so that the client is able to access the interior controls to the monitor if necessary. The Monitor was mechanically secured to the inside of the front panel by screwing small, flat metal bars into place behind the monitor. The provided a tight and secure hold, ensuring that the monitor would not slip or fall out of place. An LED indicator was added to the general power circuit to indicate that the monitor was on and drawing power from the battery, even if the monitor was connected to another device and displaying no image. The power/charge switch and the LED indicator were fixed into the right side panel. Finally, two screw holes were drilled into the back panel to attach the mounting bracket, in addition to the hole through which the female Tamayia clip extends to attach the battery charger. All of the separate panels were bonded together using a cyanoacrylate bonding agent. The small PCB containing all manual adjustment controls for the monitor was attached to the top panel, and the top panel is screwed on to the top.
portion of the monitor case. The following figure shows the top access that is allowed by the removable panel:

![Figure showing top panel of monitor enclosure](image)

**Figure 72: Inside of Top Panel of Screen Enclosure Showing The Power (Black) and Video (Yellow) Connections**

Finally, when the case was completely assembled, the monitor was tested once more, to ensure that the assembly had been a complete success. When the screen was activated, it gives off a slightly distinguishable glow. Unfortunately, the monitor could not be tested with the DynaVox™ because the version we had did not have the proper connection ports for the video card and since it was such an old model, the battery had died and would not recharge. The following figure shows the working monitor inside the finished case:
Figure 73: Working LCD Screen with Illuminated Green LED Showing that Power is Being Supplied to the Screen

The indicator LED that is below the rocker switch illuminates when the monitor is in the “ON” position. These labels show the positions that the rocker switch can be placed in. The top position is the “CHARGE” position, the central position is the “OFF” position, and the bottom position is the “ON” position. Figure 74 shows the labels on the rocker switch and when depressed, the rocker switch activates the function that is labeled.
Figure 74: Rocker Switch Labels, Monitor is in the “ON” Position

Figure 75 shows the working screen with no image feed into the video input. The screen has a wide viewing angle and a long battery life of about 10 hours before needing to be recharged. The screen has a dot format rated at 1440 x 234 and a CCFT backlight. The screen is rated for 15,000 hours of service. With the color screen there needs to be controls for the various brightness, contrast and color controls. The contrast ratio of the screen is 150:1 and has an optimal viewing angle of 15°/55°/15°/35° from left/right/top/bottom.
The mounting components could then be attached, once the monitor case had been completed. The following figures show the individual components that make up the mounting system of the LCD viewing monitor:
Figure 76: The Single Horizontal Base Bracket for the Monitor Mounting on the 7/8 Inch Bar
Figure 77: A Demonstration of the Position Where the 7/8 Inch Bar will be Placed in the Single Horizontal Base
Figure 78: Additional Mounting Capabilities Provided by the Double Quick Cross Clamp in the Event That the DynaVox DV4® is More Obtrusive Then Known
3 Realistic Constraints

The joystick design incorporates many engineering standards into its design while functioning at environmentally and economically safe standards. This joystick uses the latest materials which provide a life-long sustainability and operational functionality. The high-grade aluminums, glass-reinforcednylons, and plastics being used are rated to withstand extreme cold and warm conditions without failing or becoming damaged over time. These materials provide the user with the reliability that is desired with any product on the market today. As with any product that is purchased by a consumer, this joystick will last through many cycles of usage and withstand the constant motions and forces applied to it. This type of reliability is environmentally conscious due to its minimally replaced parts that require earthen mining and depletion of the earth’s natural resources.

Economically, the price of the parts and manufacturing of the joystick are minimal and within any reasonable budget. If manufactured, purchased, and shipped in bulk, the prices would be reduced due to their availability. This project is mostly focused on the customization of a functional joystick for
specific needs and abilities of a client. As most joysticks are
generalized and multifunctional, this joystick will provide the
client with a more compact and longer-lasting device that will
control a DynaVox DV4® communication system. While other
joysticks are not customized, this one will be specific to the
client’s hand motions, forces placed on the joystick,
operational capabilities, and size constraints.

Previous joysticks supplied to the customer were of
residential grade and did not provide the client with the proper
sustainability or functions which he desired. This joystick
will be manufactured with constraints and usage specifications
based on an industrial joystick. Following the analysis of the
clients needs, the lighter weight and cheaper joysticks did not
provide the client with the proper functionality needed under
the daily stresses he inflicted on the joystick. With a more
reliable joystick, like the ones used in industrial
applications, the client will be able to use and abuse the
joystick as is done in most industrial applications, without it
failing or breaking under the stress and pressure. Compared to
purchasing a new joystick every six months, because it broke due
to the client’s high tone and forceful motions in his hand, this
single joystick will outlast the previous ones twenty-fold,
preventing the client from the indirect costs of time, stress,
and pain, not to mention the direct cost of having to purchase a
$510.00 (USD) joystick biyearly.

This device only consists of a single joystick that will be
powered via DynaVox DV4® communication system. It needs no other
power source or rechargeable battery to power its functions. It
will act similar to a personal computer mouse and give the
client the assurance and reliability he desires so as not to
worry about the joystick ever failing while at an inopportune
time.

The Hall Effect joystick is safeguarded against stray
electrical fields, which could interfere with the signals of
nearby electronic devices or possibly cause harm to the user.
This will be made possible because the system will include a
synchronous detection system. The system in sealed in an
aluminum enclosure and has the proper connections for a ground
and power supply, while allowing for an additional connection of
a separately operated head switch. This secondary switch
provides the client with the most amount of flexibility possible
in the joystick system.
The joystick does not have any major ethical issues associated with it because it does not attach to the human body in any way and does not harm any living creatures in its manufacture process or testing process. The joystick will only be operating one existing device and will have to be incorporated into this function seamlessly through USB ports and standard electrical connections. These electrical connections will be at a safe distance from the body where they will not ever come in contact or harm the user. All components of the joystick are composed of insulating materials where they will not transmit or conduct electricity and harm the client. The metal portions of the joystick will not contain any currents or be a possible risk to the client for conducting electricity or stray current, because they will all be either be surrounded by a rubber, nylon, or insulating material.

Designing the joystick to have a low profile and be unobtrusive was a main concern because as there are many other obtrusive devices already attached to the wheelchair and another was not needed. Socially, the joystick will be of neutral colors and will not make the user feel ostracized because of its looks. However, it will provide the user with a greater ease and functionality of the DynaVox DV4® communication system. The client will be able to scroll, select, and put together sentences with greater efficiency and with much less effort than previously possible with his head switch functioning as a scroll device. The client will be able to make normal conversation, and communicate at the same rate as any other normally speaking peer.

When considering the design of the monitor system, there are different issues that are taken into account. The monitor casing is custom made and sealed at each joint. This type of encasement would not be economical in any manufacturing setting due to its labor intensive construction. For this enclosure to be properly manufactured it should be die-cast and made of two pieces that could be snapped or screwed together. With some simple engineering skills by redesigning the enclosure, the wiring schematic and the battery pack design, the enclosure can be dramatically reduced in size and efficiency. The design that was built for this project had to make do with many pre-manufactured parts that were not specifically made for this application. Money and budgeting constraints were to blame for the lack of customized parts in the monitor enclosure.

By an environmental standpoint, the only part of the monitor system that can be toxic of dispose of improperly is the
10 AA pack of NiMH batteries. Although this type of battery pack provides the client with the highest amount of voltage with the smallest battery and on of the longest charges of any battery pack available, it serves its purpose in sustainability for the client. A long lasting battery with few recharges is a very important aspect of the design for the client.

As with most parts in this project, if properly recycled, the metal scraps and non-renewable resources of the earth will not be depletes as quickly if recycling plants were not available. If ever manufactured in bulk, many of the products that this screen and its components were made of could be changed to largely recycled products, to protect the environment and its resources. All parts included in this monitor enclosure were of reasonable price for their purpose, but when considering being purchased in bulk, many of the prices will dramatically decrease, making the economic implications more considerable to manufacture this product and less of a burden on the manufacturer.

This monitor fits unobtrusively on a pole that is attached to the client’s wheelchair and is hidden behind the existing communication system. This makes the safety considerations much less due to it not being in any major path of action or a place where it could get damaged or broken. This system is electrical, so it does have the safety issue of getting wet and shorting out. This enclosure is not water proof so, if kept dry and cared for properly, it should be as safe as is it was when delivered. Socially, this monitor can only enhance the client’s ability to communicate with others. It will give the client the feeling of a real conversation, looking face to face with whoever is conversing.

4 Safety Issues

Safety is a major issue in the project design. The optimal design of the joystick is a simple, but effective, mechanical device that is operated through the force and movements of the hand. The hand and hand movements are very sensitive and in the case of our client, a young boy with cerebral palsy, are limited. Just as a person who uses a keyboard typing all day long, a person who used a joystick might get wear spots on areas of their hand where they rub against an unpadded surface all day, or even acquire carpal tunnel syndrome from pressed nerves on hard surfaces.
All materials, from the aluminum base, to the glass-reinforced nylon joystick handle are safe to the client and are non-allergenic to the client. All corners on the device will be rounded off to prevent damage or the puncturing of the skin. All materials that are used are UV resistant and can withstand extreme weather conditions from intense heat to cold winters. The plastics, rubbers, aluminums, and circuitry are rated to be fail-safe from -40 to 185 deg. F (-40 to 85 deg. C). Moisture is one of the leading causes of corrosion and mechanical and electrical failure in electronic devices, especially for our client who resides by the ocean, where the humidity and salty air can easily condense in a closed casing and corrode the electronics of the joystick, so keeping the joystick and the monitor system free of any water or moisture is essential to the electrical components longevity and sustainability.

All wires containing electrical signals going into the joystick and leaving the joystick will be insulated and covered in a plastic or polymer coating to again, prevent corrosion, and protect them from getting frayed or splitting at inopportune times. The seam where the lid of the base unit meets the vase will be sealed with a rubber membrane and the holes where the USB for the DynaVox DV4® control exit will be sealed with a rubber gasket to prevent air and moisture penetration into the electrical components of the joystick.

The NiMH battery pack is extremely corrosive if moisture penetrated the protective plastic coating on the battery pack. The chemical of nickel, magnesium, and hydrogen are not too dangerous alone, but when combined they can start fires, if short circuited, they can pollute the environment if not disposed of properly and can corrode any metal surface if the contents of the battery were to leak out. The battery contents is extremely corrosive and toxic to humans and the skin. If the contents of the battery pack were to leak and touch the skin, call the local Poison Control Center immediately. Additionally, if ever disposed of, remove the battery pack properly and contact the local Environmental Protection Agency to find the proper place to recycle the NiMH battery pack and other electrical components. Do not throw any electrical components in a landfill, the copper and other precious metals are non-renewable and can be reused in other applications.

5 Impact of Engineering Solutions
This product, as one might imagine, will have an enormous impact in many socio-economic aspects. A device such as this has potential to become an aid for not only the client specifically, but for many others who may share similar conditions to the client. This device will greatly simplify the operation of computers and other electronic devices for the client and will enable him to communicate and interact with others more effectively.

One of the main concerns of the client is his ability to communicate at a normal pace and interact with his peers. Alternative options that the client has used have allowed for faster communication but have been unreliable and expensive. Other alternatives have been durable and inexpensive but only allowed for slow communication. The design of this device presents a reliable and durable product and will enable the client to communicate at a normal pace. In making such things possible, this joystick device will greatly enhance the client’s communication experience both socially and academically. If this device can prove to be this beneficial to one person, one can only imagine the benefit it can have to others with similar disabilities.

Those with such disabilities will find that several of the limitations that they may face, such as limited communication abilities or large financial expenses from expensive communication tools or devices, can be eliminated through the benefits this device offers. By decreasing or eliminating such communication limitations, this device offers the client, and others who may share similarities to the client, a much greater opportunity to interact as members of society on the same level of those without any communication disabilities. Such a device can greatly enhance the market for accessible devices.

The device is also designed to use durable, yet low-cost materials, therefore promising to be a relatively inexpensive product. Another major concern of the client is the product cost and durability. The client has had past experience with joystick products which were in the price range of $490 - 510 (USD). These joysticks, however, did not hold up to the desired function under the client’s rigorous movements and would not last very long (approximately six months) before wearing out or breaking. The durability of this design offers a much more reliable product which will withstand the high impact forces of the client’s extraneous movements and the high strength of his regular movements. This will therefore benefit the client economically, as well as other prospective users, as it will be...
reliable for a long usage life and cost effective. All materials used to construct the device are also safe for all users, as well as environmentally safe if disposed of properly.

Most of the products used in this project will have little impact on the global environment as a whole. When metal parts and non-renewable resources are used, they have been used as minimally as possible. By reducing the amount of non-renewable resources, the project is helping reduce the amount of waste and is aiding in global clean-up efforts. Also, with proper recycling efforts of the components of this project, like the battery pack and the LCD screen, the client will help preserve and minimize the need to mine other metals, helping protect the environment.

On the global scale of manufacturing of this project, there does seem to be a need for it and its joystick and monitor components. If ever mass produced, these two components would solve a lot of social and economical problems for persons with disabilities. If one person has the problem, other people have the same problem. Socially, the additional screen will aid in the client’s ability to properly have a face-to-face conversation with others. This will eliminate any segregation that a person has when conversing with others, because the person using the communication system can now look whoever they are talking to, in the eye. This eliminates awkwardness and struggle in daily conversation.

The only changes that could be made the project would be a more streamline and compact design for both the joystick enclosure and the screen enclosure. The joystick base is not custom manufactured to fit snuggly around the electrical components of the Hall Effect of the joystick, leaving precious empty space on the interior of the encasement. But, the long-lasting and heavy cyclic load rated joystick will dramatically reduce the need for additional joysticks and components that wear and do not last.

Ideally, the monitor should be built into the existing communication system. The manufacturer of the DynaVox DV4® should spend more time with the persons that it manufactures its products for, because they should have an option for the DynaVox DV4® to include an additional LCD screen on the reverse side of the computer system, which displays the text bar of the DynaVox DV4®. Simple engineering modifications to the DynaVox DV4® would solve this problem and provide a more realistic conversation environment for its clients. Our solution is a temporary fix,
because the manufacturer should put what this project designed and their communication system into one entity, reducing the numerous different components on the client’s wheelchair.

6 Life-Long Learning

In the process of learning how a joystick works, new knowledge and techniques were acquired. Researching the mechanisms and designs of joysticks revealed that there were many types, shapes, and functions to how a joystick works. Our type of joystick is one that is based on the Hall Effect and its movements, converting displacement through magnetic fields to electrical signals. This type of joystick has its advantages and disadvantages in our client’s situation. The conductors and the joystick shaft have no physically touching parts that can wear out over time. They provide a simple and effective mechanism for a joystick, while keeping cost low and productivity high. There are magnetic field changes that induce signals that move desired objects.

Joysticks come in different shapes and sizes, depending on the application it is used for. A large joystick with a large spring constant can be used in an industrial application. But, a smaller joystick with a smaller spring constant can be used for a more residential application like video games and light-use wheelchair controls. When a residential-use joystick becomes worn out more quickly than it is designed for, a mix between the two designs is desired to cater to the perfect long-life and high use application as in our client’s situation.

Where the inner mechanical workings of the joystick can be specified to a certain application, the handgrip can also be customized for certain applications. Joystick handgrips can be molded to fit a person’s hand exactly, or they can be made like a simple rod. There are designs that are fixed at angles when in their standard resting position, used for industrial cranes and forklifts. There are also designs that do not self-center after being released and need the physical pull-back of the joystick to re-center. Joysticks that are self-centering are ones that are used in applications where, for example, the joystick is pushed forward, machine moves forward, then when the joystick is released, it re-centers and stops its movement all together. Joysticks that do not self-center keep moving until they are physically put in the position to stop.
Other joystick-like devices are ones that use a roller ball, similar to an opto-mechanical mouse and there are devices that could be modified that use the client’s head or eye movements and control a cursor via pupil movement or a dot that is placed on the client’s forehead movement. After talking with our client, the best design was to use a more reliable, customized joystick that performs many functions, due to the client’s body movement limitations. As learned though this process, a new design is not always better for the client, but one that is not on the market today, or one that has been customized to fit his own needs may work best.

The best techniques taken from this project include time management skills and the ability to affectively communicate with a client, or in a real-life situation, a sponsor or supervisor. It is crucial to get work done early, leaving time for any unforeseen problems that may arise. These problems may range from a simple mechanical adjustment to a total project overhaul. When corresponding with other people it is extremely necessary that all measurements and information is as accurate as possible to be able to manufacture parts that fit and accomplish their purpose. The best method of obtaining information is to do it first hand, otherwise problems begin with compatibility issues and could lead to project malfunctions.

7 Budget and Timeline

7.1 Budget

The budget of this project is supplied by the National Science Foundation. They provide Senior Design students with a budget of $750.00. This is an amount of money given to supply us students with all of the needed components and supplies that the project may require. This budget is allowed to exceed the $750.00 limit, but only in emergency situations and only when deemed necessary for the project.

The ColorGraphic Voyageur VGA CompFlash card by the Colorgraphic Communication Corporation is being purchased through the PC Connection website at a price of $158.64 with $13.50 for shipping and handling. The total cost of this part to connect the LCD screen to the DynaVox DV4® is $172.14. The Liquid Crystal Display 7 inch Wide Screen (non-touch) is being ordered from the AEI Components website at a cost of $181.00. There is an additional charge of $9.30 for shipping and handling.
that brings the total cost to $190.30. The Specs® switch, in black, will be ordered from the Ablenet Corporation for a price of $49.00, with an additional $7.00 for shipping and handling. The total price for the Spec Switch is $56.00. Ordering from batteriespace.com, will be a 12 volt, 2200 milliamp hour NiMH battery pack for $15.95, a multi-current Smart Charger for $23.95, and a pair of Tamiya connectors for $2.95, with a total shipping and handling price of $8.39. The order form batteriespace.com will cost $51.24. The NEMA Sealed Die-Cast Aluminum Enclosure for the joystick will have a baked-on gray gloss finish and will cost $37.24, with a $10.94 shipping and handling cost. The aluminum enclosure from the Allied Electric Incorporated Company will cost $48.18 in total. The Appliance Rocker switch from MSC Incorporated is $6.31 with $8.79 shipping and handling, totaling $15.07. The 2 foot by 2 foot black ABS plastic sheet will cost $25.25 and $13.97 shipping and handling from TAP Plastics of California. Lastly, the total joystick mounting from 80/20 Incorporated will cost $51.55 and the total monitor mounting from 80/20 Incorporated will cost $107.97. The shipping and handling for 80/20 Incorporated is $13.14, giving a total 80/20 Incorporated order price of $175.66.

The Hall Effect joystick price has been estimated a $439.00 by the P&Q Corporation. But, after speaking with them directly, they have agreed to construct the joystick, without the modifications, for free, based on the type and nature of the project. They only require two weeks of notice before they start to manufacture it. Other dollar amounts will be set aside for other expenses that may arise in the design process, and other materials that may be needed later in the Fall 2006 semester. Table 1, below, depicts the various costs that were budgeted for this semester (Fall 2006).

### Table 1: Budget Spreadsheet

<table>
<thead>
<tr>
<th>Part</th>
<th>Price</th>
<th>Shipping and Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) ColorGraphic Voyager VGA CompFlash</td>
<td>$158.64</td>
<td>$13.50</td>
</tr>
<tr>
<td>(1) Specs® switch</td>
<td>$49.00</td>
<td>$7.00</td>
</tr>
<tr>
<td>(1) NiMH Battery Pack:12 Volts, 2200 mAhhr</td>
<td>$15.95</td>
<td>$8.39</td>
</tr>
<tr>
<td>(1) Multi-Current Smart Charger</td>
<td>$23.95</td>
<td>N/A</td>
</tr>
<tr>
<td>(1) Pair of Tamiya</td>
<td>$2.95</td>
<td>N/A</td>
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</table>
### Connectors

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount 1</th>
<th>Amount 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 7 Inch LCD Monitor</td>
<td>$181.00</td>
<td>$9.30</td>
</tr>
<tr>
<td>(1) Die-Cast Aluminum Enclosure</td>
<td>$37.24</td>
<td>$10.94</td>
</tr>
<tr>
<td>(1) Appliance Rocker Switch</td>
<td>$6.31</td>
<td>$8.79</td>
</tr>
<tr>
<td>(1) ABS Plastic Sheet, 1/4 Inch Thick, 2'x2'</td>
<td>$25.25</td>
<td>$13.97</td>
</tr>
<tr>
<td>Complete 80/20 Joystick Mounting Order</td>
<td>$51.55</td>
<td>$4.38</td>
</tr>
<tr>
<td>Complete 80/20 Monitor Mounting Order</td>
<td>$107.97</td>
<td>$8.76</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>$659.81</strong></td>
<td><strong>$85.03</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Budget Supplied By NSF</th>
<th>Amount Used</th>
<th>Amount Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>$750.00</td>
<td>$744.84</td>
<td>$5.16</td>
</tr>
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</table>

This budget plan contains a total of $659.81 for parts and $85.03 for shipping and handling for this project. The total dollar amount spent for this semester is $744.84, leaving $5.16 for additional expenses, out of $750.00 total supplied by the National Science Foundation.

### 7.2 Timeline

The timeline that was laid out for this Fall 2006 semester was kept on track and updated throughout the semester when unforeseen problems arose. The timeline was laid out with 109 separate tasks, detailed enough to provide links between projects and preference between what projects have preference over others (Table 2). The required man-hours are listed next to each task, including their beginning and ending dated. The timeline consists of the task names, durations, start and finish dates, and the precedence of each task. As the project is now completed, there is no need to provide anything other than the shortened timeline for this past semester.
<table>
<thead>
<tr>
<th></th>
<th>Project Description</th>
<th>Duration</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Research Parts 2</td>
<td>2.81 days</td>
<td>Mon 9/1/06</td>
<td>Fri 9/15/06</td>
</tr>
<tr>
<td>2</td>
<td>Parts Order 2</td>
<td>0.5 days</td>
<td>Fri 9/15/06</td>
<td>Fri 9/15/06</td>
</tr>
<tr>
<td>3</td>
<td>Research Parts 3</td>
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<td>Mon 9/25/06</td>
<td>Fri 9/29/06</td>
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<tr>
<td>4</td>
<td>Parts Order 3</td>
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<td>Fri 9/29/06</td>
<td>Fri 9/29/06</td>
</tr>
<tr>
<td>5</td>
<td>Parts Order 4</td>
<td>0.5 days</td>
<td>Fri 10/13/06</td>
<td>Fri 10/13/06</td>
</tr>
<tr>
<td>6</td>
<td>Configure DynaVox</td>
<td>7.63 days</td>
<td>Fri 9/1/06</td>
<td>Fri 9/22/06</td>
</tr>
<tr>
<td>7</td>
<td>Research P&amp;O</td>
<td>5.63 days</td>
<td>Fri 9/8/06</td>
<td>Fri 9/22/06</td>
</tr>
<tr>
<td>8</td>
<td>Compile DynaVox: Program</td>
<td>16.44 days</td>
<td>Tue 10/3/06</td>
<td>Fri 11/10/06</td>
</tr>
<tr>
<td>9</td>
<td>Determine Wiring Scheme</td>
<td>5.63 days</td>
<td>Fri 9/15/06</td>
<td>Fri 9/29/06</td>
</tr>
<tr>
<td>10</td>
<td>Communicate with Client</td>
<td>33.56 days</td>
<td>Wed 8/30/06</td>
<td>Wed 11/29/06</td>
</tr>
<tr>
<td>11</td>
<td>Take Machine Shop Class</td>
<td>2.81 days</td>
<td>Mon 8/7/06</td>
<td>Fri 8/11/06</td>
</tr>
<tr>
<td>12</td>
<td>Determine Machine Shop Tasks</td>
<td>3.56 days</td>
<td>Wed 9/20/06</td>
<td>Wed 9/27/06</td>
</tr>
<tr>
<td>13</td>
<td>Order Machine Shop Parts</td>
<td>1 day</td>
<td>Fri 9/29/06</td>
<td>Mon 10/2/06</td>
</tr>
<tr>
<td>14</td>
<td>Construct Base Unit in Machine Shop</td>
<td>10.81 days</td>
<td>Mon 10/23/06</td>
<td>Fri 11/17/06</td>
</tr>
<tr>
<td>15</td>
<td>Review Joystick Mechanics</td>
<td>7.31 days</td>
<td>Mon 10/9/06</td>
<td>Tue 10/24/06</td>
</tr>
<tr>
<td>16</td>
<td>Disassemble Joystick</td>
<td>2.81 days</td>
<td>Mon 10/16/06</td>
<td>Fri 10/20/06</td>
</tr>
<tr>
<td>17</td>
<td>Determine Placement of Buttons on Joystick</td>
<td>2.38 days</td>
<td>Fri 10/27/06</td>
<td>Fri 11/3/06</td>
</tr>
<tr>
<td>18</td>
<td>Confirm Placement of Buttons with Client</td>
<td>2 days</td>
<td>Mon 11/6/06</td>
<td>Wed 11/8/06</td>
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<tr>
<td>19</td>
<td>Prepare Joystick for Drilling</td>
<td>0.88 days</td>
<td>Tue 11/7/06</td>
<td>Thu 11/9/06</td>
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<tr>
<td>20</td>
<td>Drill Holes in Joystick</td>
<td>1 day</td>
<td>Thu 11/9/06</td>
<td>Mon 11/13/06</td>
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<tr>
<td>21</td>
<td>Determine Hole Placement for Wires</td>
<td>1 day</td>
<td>Thu 11/9/06</td>
<td>Mon 11/13/06</td>
</tr>
<tr>
<td>22</td>
<td>Drill Holes in Base Unit</td>
<td>1 day</td>
<td>Thu 11/14/06</td>
<td>Wed 11/15/06</td>
</tr>
<tr>
<td>23</td>
<td>Trouble Shoot VGA Installation</td>
<td>15.63 days</td>
<td>Tue 10/17/06</td>
<td>Fri 12/1/06</td>
</tr>
<tr>
<td>24</td>
<td>Trouble Shoot Joystick</td>
<td>8.5 days</td>
<td>Fri 10/27/06</td>
<td>Fri 11/17/06</td>
</tr>
<tr>
<td>25</td>
<td>Cut and Compile Needed Wires</td>
<td>2.81 days</td>
<td>Mon 9/18/06</td>
<td>Fri 9/22/06</td>
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<tr>
<td>26</td>
<td>Wire Joystick</td>
<td>2.81 days</td>
<td>Mon 10/23/06</td>
<td>Fri 10/27/06</td>
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<tr>
<td>27</td>
<td>Solder Joystick</td>
<td>1 day</td>
<td>Mon 10/30/06</td>
<td>Wed 11/1/06</td>
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<td>28</td>
<td>Download VGA onto DynaVox</td>
<td>2.81 days</td>
<td>Mon 9/25/06</td>
<td>Fri 9/29/06</td>
</tr>
<tr>
<td>29</td>
<td>Configure Screen with DynaVox</td>
<td>5.63 days</td>
<td>Fri 10/6/06</td>
<td>Fri 10/20/06</td>
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<tr>
<td>30</td>
<td>Trouble Shoot Screen</td>
<td>6.31 days</td>
<td>Sat 10/21/06</td>
<td>Mon 11/6/06</td>
</tr>
<tr>
<td>31</td>
<td>Determine Battery Life</td>
<td>10.94 days</td>
<td>Thu 8/21/06</td>
<td>Fri 9/29/06</td>
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<tr>
<td>32</td>
<td>Parts Order 5</td>
<td>1 day</td>
<td>Tue 11/28/06</td>
<td>Wed 11/29/06</td>
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<tr>
<td>33</td>
<td>Travel To New Jersey 2</td>
<td>1 day</td>
<td>Sat 10/21/06</td>
<td>Sat 10/21/06</td>
</tr>
<tr>
<td>34</td>
<td>Travel To New Jersey 3</td>
<td>1 day</td>
<td>Sat 12/2/06</td>
<td>Sat 12/2/06</td>
</tr>
<tr>
<td>35</td>
<td>Test Joystick and Screen Together</td>
<td>5.81 days</td>
<td>Tue 11/28/06</td>
<td>Fri 12/8/06</td>
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<tr>
<td>36</td>
<td>Compile Weekly Report 1</td>
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<td>37</td>
<td>Compile Weekly Report 2</td>
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<td>Fri 9/8/06</td>
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<tr>
<td>38</td>
<td>Compile Weekly Report 3</td>
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<td>Fri 9/15/06</td>
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<td>39</td>
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<td>Fri 9/22/06</td>
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<td>40</td>
<td>Compile Weekly Report 5</td>
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<td>Fri 9/29/06</td>
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<td>41</td>
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<td>Task Description</td>
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<td>End Date</td>
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<td>Compile Weekly Report 8</td>
<td>0.5 days</td>
<td>Fri 10/20/06</td>
<td>Fri 10/20/06</td>
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<td>Compile Weekly Report 9</td>
<td>0.5 days</td>
<td>Fri 10/27/06</td>
<td>Fri 10/27/06</td>
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<td>Compile Weekly Report 10</td>
<td>0.5 days</td>
<td>Fri 11/3/06</td>
<td>Fri 11/3/06</td>
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<td>Update Website 1</td>
<td>0.5 days</td>
<td>Fri 9/22/06</td>
<td>Fri 9/22/06</td>
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<td>Update Website 2</td>
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<td>Fri 9/29/06</td>
<td></td>
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<td>Update Website 3</td>
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<td>0.5 days</td>
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<td>Update Website 6</td>
<td>0.5 days</td>
<td>Fri 10/27/06</td>
<td>Fri 10/27/06</td>
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<td>Update Website 7</td>
<td>0.5 days</td>
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<td>Update Website 8</td>
<td>0.5 days</td>
<td>Fri 11/10/06</td>
<td>Fri 11/10/06</td>
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<td>Update Website 9</td>
<td>0.5 days</td>
<td>Fri 11/17/06</td>
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<td>Update Website 10</td>
<td>0.5 days</td>
<td>Fri 12/1/06</td>
<td>Fri 12/1/06</td>
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</tr>
<tr>
<td>Start Final Report</td>
<td>26.06 days</td>
<td>Mon 10/2/06</td>
<td>Fri 12/8/06</td>
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<td>Finish Final Report</td>
<td>0.5 days</td>
<td>Fri 12/8/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Finish Website</td>
<td>0.5 days</td>
<td>Sat 12/9/06</td>
<td>Sat 12/9/06</td>
<td></td>
</tr>
<tr>
<td>Start Operator’s Manual</td>
<td>11.44 days</td>
<td>Fri 11/3/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Finish Operator’s Manual</td>
<td>0.5 days</td>
<td>Sat 12/9/06</td>
<td>Sat 12/9/06</td>
<td></td>
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<tr>
<td>Start Final PowerPoint Presentation</td>
<td>5.81 days</td>
<td>Sat 12/9/06</td>
<td>Mon 1/1/07</td>
<td></td>
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<td>Finish Final PowerPoint Presentation</td>
<td>0.5 days</td>
<td>Fri 12/8/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Deliver Finished Project to Client</td>
<td>4.31 days</td>
<td>Sat 12/9/06</td>
<td>Tue 1/19/06</td>
<td></td>
</tr>
<tr>
<td>Prepare for Senior Design Day</td>
<td>8.63 days</td>
<td>Fri 11/10/06</td>
<td>Fri 12/8/06</td>
<td></td>
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<tr>
<td>Senior Design Day</td>
<td>0.5 days</td>
<td>Sat 12/9/06</td>
<td>Sat 12/9/06</td>
<td></td>
</tr>
<tr>
<td>Review NSF Guidelines</td>
<td>24.25 days</td>
<td>Wed 8/30/06</td>
<td>Fri 10/27/06</td>
<td></td>
</tr>
<tr>
<td>Be Sure All Papers Meet NSF Guidelines</td>
<td>20.44 days</td>
<td>Fri 10/13/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Fine Tune Base Unit</td>
<td>15.31 days</td>
<td>Sat 12/2/06</td>
<td>Mon 1/15/07</td>
<td></td>
</tr>
<tr>
<td>Be Sure Base Unit is Water-Tight</td>
<td>2 days</td>
<td>Tue 11/28/06</td>
<td>Fri 12/1/06</td>
<td></td>
</tr>
<tr>
<td>Make All Electrical Connections</td>
<td>8.5 days</td>
<td>Sat 12/2/06</td>
<td>Tue 12/19/06</td>
<td></td>
</tr>
<tr>
<td>Trouble Shoot Connections Before Connecti</td>
<td>19.44 days</td>
<td>Sat 12/2/06</td>
<td>Thu 1/25/07</td>
<td></td>
</tr>
<tr>
<td>Determine Signal Output From DynaVox</td>
<td>3.56 days</td>
<td>Wed 8/30/06</td>
<td>Fri 9/8/06</td>
<td></td>
</tr>
<tr>
<td>Seal All Gaps in Casing</td>
<td>2 days</td>
<td>Tue 11/28/06</td>
<td>Fri 12/1/06</td>
<td></td>
</tr>
<tr>
<td>Re-Test Joystick</td>
<td>4.31 days</td>
<td>Fri 12/1/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Re-Test Screen</td>
<td>5.38 days</td>
<td>Sat 12/9/06</td>
<td>Mon 1/1/07</td>
<td></td>
</tr>
<tr>
<td>Document (Pictorially) All Components</td>
<td>38.06 days</td>
<td>Wed 8/30/06</td>
<td>Fri 12/8/06</td>
<td></td>
</tr>
<tr>
<td>Determine Budget</td>
<td>38.06 days</td>
<td>Wed 8/30/06</td>
<td>Fri 12/8/06</td>
<td></td>
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<tr>
<td>Evaluate Design</td>
<td>12 days</td>
<td>Wed 8/30/06</td>
<td>Fri 9/29/06</td>
<td></td>
</tr>
<tr>
<td>Work on DynaVox and Screen Connections</td>
<td>21 days</td>
<td>Wed 9/27/06</td>
<td>Wed 11/15/06</td>
<td></td>
</tr>
<tr>
<td>Test Joystick</td>
<td>6.63 days</td>
<td>Fri 10/13/06</td>
<td>Fri 10/27/06</td>
<td></td>
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<tr>
<td>Test Screen</td>
<td>9.44 days</td>
<td>Mon 10/30/06</td>
<td>Thu 11/30/06</td>
<td></td>
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<tr>
<td>Re-Test Joystick</td>
<td>6.69 days</td>
<td>Thu 10/19/06</td>
<td>Fri 11/3/06</td>
<td></td>
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</tbody>
</table>
8 Team Member Contributions

Team Member 1: Philip Licitra

Philip was the main client contact and corresponded with the client on a sometimes daily basis. Keeping close contact with the client helped us in making the correct decisions on what to design and construct for the client. Philip also did extensive research on the various different options that we could present to the client. These options were of great importance because they allowed the client to see the progress that we were making and see what different systems were available to him and could then decide which one would facilitate the ease in communication.
Philip kept an extensively detailed budget Excel spreadsheet so as to make sure that all items including shipping and handling costs were kept within the $750.00 budget provided. Included with the budgeting of the project, Philip also filled out every purchase order form and submitted them with the proper documentations to provide reason for the orders and the company contacts for the orders. Philip spent a week in the summer taking the School of Engineering Machine Shop Certification Class, which allowed him to access the machine shop numerous times to machine various parts needed for the project. Philip machined the ABS enclosure for the LCD screen, the various holes in the joystick enclosure and the clips to hold the LCD screen in the ABS enclosure.

Philip was also in charge of the soldering of the joystick components, and the LCD screen components. By taking great care in the soldering work, all electrical connections no only function properly, but aesthetically look nice. All exposed connections were covered with shrink wrap to protect them from touching other connections or just being exposed.

All reports for the semester, including the weekly reports, the team reports, the final report, the operator’s manual, and all PowerPoint presentations were converted to PDF files by Philip. He posted all the reports and maintained the Team 1 website throughout the semester.

In addition to researching current and past projects and options available to the client, Philip also conducted a patent search to inform himself and his group member what has already been invented and what could be possible patent infringements when designed. Philip drew numerous pictures, diagrams, and schematics for the various designs in Microsoft Visio. Both Philip and Stephanie were able to divide up a majority of the writing into equal parts, because there are only two group members in this group. If ever one person was not to carry his or her own weight, they would let the other know.

**Team Member 2: Stephanie Santos**

Stephanie conducted a considerable amount of research on the methods and mechanics of various types of joysticks, which was crucial knowledge, necessary to the development of this project. Intensive research on the different workings of joysticks made possible the development of several alternate
designs. Stephanie also heavily researched the electrical workings of cursor controls in order to develop a design by which one joystick could alternate between the function of a wheelchair operation device and cursor control. Such researching is essential to the development of such a project, as thorough knowledge of any and all devices involved in a project is vital to the development process.

In conjunction to research on joystick mechanics, Stephanie also did further research on the client’s condition to gain knowledge on the client’s physical limitations and abilities. In doing so, some project guidelines regarding the client’s physical capabilities were able to be determined by the group members when information was not always readily available by the client or his family. When developing a device for a person with physical disabilities, it extremely important to have a clear idea of their exact capabilities and limitations so as not to design a product for a client that they may not be able to use.

In addition to conducting project research on joysticks and cursor devices, Stephanie also contributed greatly to the specific design development. Stephanie was responsible for the theoretical calculation and design for the spring centering feature of the joystick control, as well as the electrical and mechanical layout of the opto-mechanical joystick in the second alternate design. Stephanie also contributed by performing a secondary patent search to research any patents on newly implemented devices in the optimal design. Stephanie also had correspondence with John Hayner from P-Q Controls, Inc. and consulted him on matters relating to the development of the joystick and the most effective mechanical design.

Stephanie was the main correspondent to the representatives of P-Q Controls. This company was generous enough to donate a joystick to the cause of this design project. Stephanie kept in contact with John Hayner, and consulted him on the details and requirements of the joystick needed for the project. She also consulted him and other representatives of P-Q Controls on connections issues troubleshooting issues once the joystick was received and integrated into the testing phases of the project. She also consulted other sources for assistance with problems encountered with the initial operation of the joystick in the early testing phases. Stephanie also made the initial tests of the joystick and found the correct computer settings under which it was possible to demonstrate that the joystick was functional and worked correctly.
In addition to the work with the joystick, Stephanie also spent a considerable amount of time working through the electrical theory behind the LCD monitor connections and wiring setup. She worked with Philip in developing a general design for the power and charge circuit, then did more of the revising and testing of the circuit. She also made contact with representatives of other companies for the best input on case materials and where to find some that would be cost effective. She also took responsibility for some of the interior set up of the monitor case and assembly of some of the case parts. Once the case was completed, she spent several hours working on finishing the edges and corners of the case to seal off the seams and make it more aesthetically pleasing.

9 Conclusion

To best suit any client with cerebral palsy, a modified joystick to fit his own personal needs is a superior choice to any pre-made option. When designing the joystick and other speaking aids, the best path to follow is the one where the products are molded to the client’s hand, are the best size and tension spring, include and incorporate all other accessible options, so the client knows that they are receiving something made with care and personalization. This joystick is best suited for this client specifically, who has to use his left hand to select options with the joystick, needs his existing head-switch integrated into the design, and who wants others to view his same screen so be sure they read his sentences as fast as he forms them. An joystick which implements the use of the Hall effect is one that has minimal to no touching or rubbing parts that may wear out over time and leave the family with the burden of having to purchase new, costly and poorly constructed joysticks on a six-month basis. A durable, tough, and almost frictionless joystick is the solution to most of the communication problems that our client faces.

The joystick will be powered by a USB cable connected to the existing DynaVox DV4® and will be rated to run off the minimal power of a 5V current, provided by the communication system. In addition to the ease in selection provided by the new, more sturdy, and more graspable, joystick, there will be a 7 inch LCD screen placed opposite the existing screen and will allow other to see what he is typing out before the DynaVox DV4® reads out the sentence. This option eliminates the excess time of waiting around to hear what he has to say, making the communication time and the conversation time much quicker for
the client and his family and friends. After considering all of the options, concerns and suggestions that our client and his family and friends gave to us, this system incorporates everything into one entity, pleasing everybody’s needs. By designing a system that is more durable, reliable, and speeds up communication time in any way, will make daily life for the client more enjoyable.

10 References


11 Acknowledgements

Frankie Kineavy, Client
Madeleine Kineavy, Client’s Mother
Frank Kineavy, Client’s Father
Dr. John Enderle
Bill Pruehsuer
Jonathan Sapienza
Christopher Leibler
John Hayner, P&Q Controls, Incorporated
P&Q Controls, Inc., Supplied the joystick for the project
Michael Santos
DynaVox Technologies
National Science Foundation Project to Aid the Disabled Project
National Science Foundation, Supplied the funding for the project
Dave Mareiro and Team 2
12 Appendix

12.1 Updated Specifications

Technical Specifications for Joystick and its Components:

<table>
<thead>
<tr>
<th>Electrical Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Life from DynaVox</td>
</tr>
<tr>
<td>Voltage Supply</td>
</tr>
<tr>
<td>Forward Displacement</td>
</tr>
<tr>
<td>Backward Displacement</td>
</tr>
<tr>
<td>Output Connections</td>
</tr>
<tr>
<td>Input Connections</td>
</tr>
<tr>
<td>Magnetic Fields</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size:</td>
</tr>
<tr>
<td>Handle:</td>
</tr>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Height</td>
</tr>
<tr>
<td>Finger Grip Diameter</td>
</tr>
<tr>
<td>Base:</td>
</tr>
<tr>
<td>Outer Dimensions (L/W/H)</td>
</tr>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>Button</td>
</tr>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Spring:</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Coil Diameter</td>
</tr>
<tr>
<td>Spring Constant</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Durability</td>
</tr>
<tr>
<td>Withstands every day practical usage, high impact or sudden movements, continuous cyclic forces applied by user with high</td>
</tr>
<tr>
<td><strong>Mountability</strong></td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td><strong>Number of Axes</strong></td>
</tr>
<tr>
<td><strong>Spring Return</strong></td>
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**Environmental**

<table>
<thead>
<tr>
<th><strong>Location</strong></th>
<th>Mobile</th>
</tr>
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<tr>
<td><strong>Dust</strong></td>
<td>Routine cleaning is necessary</td>
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<tr>
<td><strong>Rain</strong></td>
<td>Waterproof</td>
</tr>
<tr>
<td><strong>Sunlight/Ambient Light</strong></td>
<td>UV Resistant</td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td>-30 to 200 deg. F (-34 to 93 deg. C)</td>
</tr>
<tr>
<td><strong>Storage Temp</strong></td>
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**Technical Specifications for LCD Monitor and its Components:**

**Electrical Parameters**

<table>
<thead>
<tr>
<th><strong>Battery Specs:</strong></th>
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<tbody>
<tr>
<td><strong>Lifetime</strong></td>
<td>10 Hrs.</td>
</tr>
<tr>
<td><strong>Amperage</strong></td>
<td>2200 mAh</td>
</tr>
<tr>
<td><strong>Composure</strong></td>
<td>10 Piece NiMH AA cells</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>10 oz.</td>
</tr>
<tr>
<td><strong>Size (H/W/L)</strong></td>
<td>51 mm./29 mm./72 mm.</td>
</tr>
</tbody>
</table>
| **Monitor Specs:** | |}

| **Input Voltage** | 12 V (DC) at 700 mA |
| **Display**       | Color TFT-LCD Active Matrix Monitor |
| **Weight**        | 12 oz.                  |
| **Video Input Level** | 1.0 V p-p (positive) 75 Ohm |
| **Lamp Life**     | 15,000 Hrs.             |
| **Device Connections** | PAL/NTSC/Auto Switching |

**Monitor Mechanical Parameters**

<table>
<thead>
<tr>
<th><strong>Screen Size:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>6.5 in.</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>3.94 in.</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>0.25 in.</td>
</tr>
</tbody>
</table>
| **Screen:**      | |}

<p>| <strong>Dot Format</strong>  | 1440x234                  |
| <strong>Back Light</strong>  | CCFT                      |</p>
<table>
<thead>
<tr>
<th>Viewing Angle</th>
<th>55°/55°/15°/35°</th>
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</thead>
<tbody>
<tr>
<td>Brightness</td>
<td>350 NITS</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>150:1</td>
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<tr>
<td>Enclosure:</td>
<td></td>
</tr>
<tr>
<td>Size (L/W/H)</td>
<td>8.0 in./2.5 in./5.25 in.</td>
</tr>
<tr>
<td>Material</td>
<td>Acrylic-Butadiene Styrene</td>
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<tr>
<td>Bonding Agent</td>
<td>Cyanoacrilate</td>
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**Monitor Environmental**

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<tr>
<th>Location</th>
<th>Wheelchair Mounted</th>
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<tbody>
<tr>
<td>Dust</td>
<td>Routine Cleaning Necessary</td>
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<tr>
<td>Rain</td>
<td>Water Resistant</td>
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<tr>
<td>Sunlight/Ambient Light</td>
<td>Screen is should be visible in all lighting conditions</td>
</tr>
<tr>
<td>Operating Temp.</td>
<td>0°C ~ 60°C</td>
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<tr>
<td>Storage Temp.</td>
<td>-20°C ~ 80°C</td>
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**Battery Charger Parameters**

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<tr>
<th>Connection Type</th>
<th>Male/Female Tamiya Clips</th>
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<tbody>
<tr>
<td>Compatibility:</td>
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</tr>
<tr>
<td>Battery Type</td>
<td>NiMH or NiCd</td>
</tr>
<tr>
<td>Battery Voltages</td>
<td>7.2 V – 12 V</td>
</tr>
<tr>
<td>Amperage</td>
<td>0.9 A – 1.8 A</td>
</tr>
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<td>Size (H/W/L)</td>
<td>1.5 in./2.5 in./5.75 in.</td>
</tr>
<tr>
<td>Weight</td>
<td>0.6 lb.</td>
</tr>
<tr>
<td>Charging</td>
<td>Automatic cut-off indicated by LED</td>
</tr>
<tr>
<td>Technology</td>
<td>Pulse and Negative Pulse to avoid overheating</td>
</tr>
</tbody>
</table>