CHAPTER 20
WRIGHT STATE UNIVERSITY

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**The Raider Talker**

Designers: Brett Keffer and Rebecca Morrisey  
Client Coordinator: Mrs. Troehler  
Gorman Elementary School  
Supervising Professor: Dr. Hangarfer  
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**Introduction**

The Raider Talker, a modification of a device called the Hawk, is designed for Gorman Elementary School. Gorman is currently using the “Hawk” as a teaching aide for their mentally and physically challenged students. The teachers use the Hawk as an accompaniment when reading stories aloud to the children. The sounds of different objects, such as an animal or a train, pictured throughout the book, are programmed into the Hawk. The accompanying picture of the object is placed in the appropriate field on the Hawk. When the object is encountered in the story, the picture on the Hawk is pressed by the student and the sound of the object is produced. This helps the students learn to associate phrases, or names of objects, with their corresponding pictures and sounds. It also helps develop hand-eye coordination. The Hawk is also used as an answering device for those students who cannot speak.

According to Mrs. Troehler, the Hawk has a few limitations. The most serious limitation is the inability to maximize the field size (field size is the number of squares comprising the working area) to incorporate the entire user surface. For example, when the Hawk is programmed as a two choice answering device, one third of the user interface is not used. This results in a small working area that makes it extremely difficult, if not impossible, for students with poor motor skills to press the correct field. The problem escalates further when the child's hands need to be directed to the appropriate field by a teacher or aide. The presence of the teacher's hand along with the child's covers the entire field, thus preventing the child from seeing the picture as the sound is produced and therefore the child does not realize why the entire activity is done. Another limitation of the Hawk occurs when the number of choices, or fields, is to be reduced. To reduce choices, each field must still be programmed whether it is the exact message as another field or complete silence.

The current field configurations available to be used with the Hawk are a one, three, five, and nine choice variety. Mrs. Troehler also wants the Hawk to have two, four, and six field configurations with the ability to maximize the entire interface (field configurations are shown in Figure 20.1). The current design does not allow for this versatility.

![Figure 20.1. Configurations available after the modification of the Hawk.](image-url)
necessary to program silence into one of the fields in order to have no response given when the field is touched. The approach taken in order to modify the existing Hawk into a more user compatible workstation completely rectifies all of the problems that Mrs. Troehler had indicated.

Figure 20.2. The Raider Talker.

Summary of Impact
The Raider Talker is a much more versatile device than the original Hawk. Therefore, Mrs. Troehler has more control as to the level of teaching she can offer her students when using the Raider Talker as a teaching aide. She begins by offering the students a small number of choices, depending on their ability. As they improve, she increases their choices, thus allowing the student to make tremendous progress in the control of their hand motions.

This helps her students develop better motor skills over time since the device helps to motivate the students without overwhelming them.

Technical Description
The Hawk has a rectangular shape with a length of 14.25 inches, a width of 10 inches and a depth of 1.75 inches. This device weighs approximately 2 lbs. 11 ozs. Two thirds of the device’s length is comprised of a grid (a 6x6 matrix) where the user interfaces with the device. Located to the left of the interface is a yellow shield. Located under the shield are a rotary switch, surrounded by small pictures of the different configurations that are available, along with an on/off switch. The plastic overlay, outlining the dimensions desired, is placed upon the laminated overlay, securing it in place. To begin using the device, the on/off button is pressed in the on position. The rotary dial must be turned with the arrow pointing to the configuration corresponding to the plastic overlay previously selected. In order to program the specific fields for a particular message, the blue button located beneath the yellow shield must be pressed. The device is now in record mode. The programmer then touches the field that needs to be programmed and begins speaking the phrase to be recorded. Once this is done, release the field. Continue recording until all fields are programmed. When programming is complete, press the blue button to place the device back into the playback mode. The individual wishing to use the device pushes one of the fields, activating it, and the message that is programmed to that field is played back.

In order to allow the modifications of the Hawk to be done, a program is written in Assembly code for a Motorola 68HC11 Microprocessor. This code is comprised of three sections. The “MAIN” program contains the code that initializes all of the microprocessor ports that will be used (B, C, D, and E). After initialization is complete, the microprocessor enters a low power state called a “Wait State”. While in this mode, the microprocessor’s clock does not stop, but it consumes less power. The second section is the IRQ interrupt service routine. The entire function of the IRQ routine is to determine which switch is pressed and output a specific pattern to the Hawk’s second microprocessor so that the corresponding memory location in the speech synthesizer is opened for either read or write operation. The third section is the XIRQ non-maskable interrupt routine. This routine is simply used to change the mode of the speech synthesis circuit. When the record/playback button is pressed, the XIRQ routine outputs a “1111” bit pattern to the second microprocessor. This bit pattern signals a change in the record/playback mode of the device.
When the record/playback button is pressed again, the routine outputs the same pattern, this time changing it to the record mode.

A circuit placed between the switch matrix and the microprocessor is used to encode the matrix so that the microprocessor receives the correct input. The circuit (see Figure 20.3) uses several different encoders to reduce the 14 leads of the switch matrix down to 8 so that the microprocessor controls the entire matrix from one port. The mode switch has similar circuitry as well. The total cost of the project is $651.
Figure 20.4. Another Schematic Diagram of the Raider Talker.
**Multi-Adjustable Table**

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Client Coordinator: Ms. Anderson  
Ankeney Junior High School  
Supervising Professor: Dr. Chandler Phillips  
Department: Biomedical and Human Factors Engineering  
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**Introduction**

A multi-adjustable table (see Figure 20.5) was designed for students at Ankeney Junior High School. The students are mainly afflicted with cerebral palsy and spina bifida, and all of the students are confined to wheelchairs. The table fits the students better than a regular desk because it allows room for their wheelchairs to fit underneath it. It also provides a tiltable working surface instead of only a horizontal working surface, is easily moved from room to room, and is small enough to be transported in an elevator. In addition, this table incorporates a storage area for needed utensils and books. Overall, the table's purpose is to provide a customized working area that promotes a sense of individuality for the students.

**Summary of Impact**

The multi-adjustable table is successfully implemented by the children. The table meets all the design specifications in that different sized children are able to fit their wheelchairs easily and comfortably under the table. The table can also be tilted to different angles, which makes it easier for the students to perform their work. Overall, the multi-adjustable table enables them to interact more efficiently with their environment that promotes learning that is more effective.

**Technical Description**

The multi-adjustable table, shown in Figure 20.5, is comprised of a base, frame, storage area, tabletop, tilting mechanism and arm rests. The base used is specially ordered from Preston Company, in South Carolina. This base provides the height adjustibility because of the adjustable inner bar and the portability because of the 4 locking casters. The center post contains a spring unit so that the table height is adjusted by simply loosening the black knob, lifting the frame to a desired height, and then tightening the knob. The height ranges from 23 to 41 inches, which fits all the students. The base itself is 24 inches long by 28 inches wide.

In choosing a base for the table, it is necessary that it be stable, strong and easily handled by the teacher. A steel plate is used as the interface between the base and the frame. The plate is 9 inches wide by 8 inches in length. The plate is designed to support not only the frame and the tabletop, but also the weight of the students’ arms and books.

The frame houses the tilting mechanism and the storage area for books and utensils. Due to the weight factor, the frame is designed so it is lightweight, yet still strong enough to support the tabletop and any extra weight. Therefore the frame is made out of pine wood and assembled with nails and wood glue. The frame is 23 inches long by 35 inches wide and 3 inches deep.

The tilting mechanism is able to tilt the tabletop to five different angles ranging from 15 to 75 degrees. This is made out of pine wood with five slots for the insertion of a hollow metal bar. This hollow bar is attached to the tabletop by four metal clamps. By
simply moving the hollow bar to a different slot in the tilting mechanism, the tilt angle can be changed.

The tabletop is 24 inches long by 36 inches wide and is made of 3/4-inch pinewood. One side of the tabletop is covered with Formica. A book rest is designed to keep books from sliding off the tabletop when it is tilted. The book rest is located 5 inches from the bottom of the tabletop and is made out of stripped pine wood 36 inches long with a L-shaped aluminum attachment along the strip to increase its strength. At both ends of the strip are two metal hooks screwed in with two thick wires attached to them in order for the book rest to be hooked on at the top of the tabletop. This book rest can be folded and easily placed inside the storage area of the frame.

The armrests are made out of pinewood and are directly attached to the frame by the use of four bolts that can be easily removed with butterflies. The armrests are set apart at a specific width of 17 inches, which is the average distance between the elbows of the students. The armrests are also padded with foam surrounded by red vinyl, which are removable by the use of Velcro. The armrests can be moved out of the way of the student by taking one bolt out from each armrest and rotating the armrests inward toward the frame, one at a time.

An engineering analysis was completed on the adjustable table and it is found that the tabletop can withstand a total force up to 221.5 lb. (using a minimum factor of safety of 1.5), and the support rod can withstand a maximum load of 678 lb. The final cost of the adjustable table is $676.

![Figure 20.6. Multi-Adjustable Table.](image-url)
Touch Plate Activated Toys

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Client Coordinators: Kathy Troehler
Gorman Elementary School
Supervising Professor: Dr. Ping He
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Introduction

A touch plate activated toy, as seen in Figure 20.7, is designed for the students at Gorman Elementary School. Most of the students at Gorman have cerebral palsy with some associated limb deformities. All the students are confined to wheelchairs and have a limited range of motion. A desire to provide the disabled children with a viable switch setup that interfaces with the children's toys via remote control has been expressed by Kathy Troehler, Special Education Teacher at Gorman Elementary School. The goal of the switch setup is to provide the students with a device, using a toy, that teaches them a cause-and-effect relationship by having them turn the switch on and off. This allows the students more independence and more awareness of their environment.

Summary of Impact

This project proved to be an excellent learning experience in electronics design and fabrications for the students involved.

Technical Description

The touch plate activated toy design employs similar principles to those of switching lights and/or appliances on or off with the touch of a finger. The device uses the human body as an antenna to pick up a 60 Hz hum, which is applied to a metal plate by a finger. The signal is fed to the input of an audio amplifier and greatly amplified. When the plate is touched, a signal approximately 2 mV is applied. The amplifier is configured for a gain in the range of 20-200.

The first portion of the design consists of the touch plate, which is a plate switch, and the transmitter. The touch plate consists of an aluminum plate that is 6.5 x 4.25 x 0.125 inches. On top of this plate is a plastic experimenter's box that contains the transmitter and the transmitter's control circuitry (see Figure 20.8a). The dimensions of this box are 2.25 x 4.25 x 1.25 inches. The second portion of the design consists of the receiver and the toy. The toy is mounted on top of another plastic experimenter's box using machine screws and hex nuts through the top of the box. The box has the dimensions of 7.25 x 4.25 x 2.25 inches. The bottom of this box is easily removed to look at the receiver circuitry (see Figure 20.8b). The receiver, the receiver control circuitry and the battery power supplies are fastened to this bottom, and these components are completely hidden once the top of the box is placed over these components. The overall design consists of the touch plate/transmitter mounted together as one unit, with the receiver/toy mounted as a separate unit. The touch plate/transmitter is mounted on top of a rubber mouse pad, and it is designed to lie flat on the student's lap tray. The mouse pad prevents slippage, and keeps the unit in place while the child touches it.

The 60 Hz hum from the body, caused by touching the plate, causes a low voltage input signal. This sig-
nal is then amplified by the transmitter circuitry, which causes the transmitter to send out a signal pulse from Channel One. This pulse is brief to conserve on the battery usage, and triggers the toy. The signal from Channel One is received by the receiver, and the receiver control circuitry causes the toy to turn ON by closing a relay. As long as the relay is closed, the toy remains ON. The toy turns OFF whenever the student removes his/her hand from the touch plate. This action causes the transmitter to send out another brief signal, this time via Channel Two. The receiver circuitry automatically causes the relay to open, turning the toy OFF. In order to prevent unnecessary bouncing, the receiver logic circuitry has a built-in refractory period that is initiated as soon as the toy is turned OFF. The refractory period is approximately three seconds, and during this time, the toy is prevented from turning ON again. The receiver channels are fed directly into the R-S flip-flop. Channel One is used to “set” the flip-flop, thus turning the toy ON. Channel Two is fed directly into the “reset” of the flip-flop and it always turns the toy OFF. The refractory period is accomplished by a feedback loop, which disables an “AND” gate. The gate is disabled for three seconds, and during this time Channel One is usable to trigger the flip-flop. Whenever this refractory period times out, the entire system returns to its resetting state and is ready for another pulse from Channel One.

The transmitter/receiver unit operates at a distance of up to 100 feet. The transmitter and circuitry operate on one battery power source of 6 volts. The touch plate is reliable for up to 90% of this supply, or 5.4 volts. The receiver/toy unit has two power supplies. The toy is powered from two C-size batteries, or 3 volts. The receiver requires at least 8 volts, while the rest of the circuitry requires 5 volts. The receiver and the receiver control circuitry is powered by a 9 volt power supply, which uses a 5 volt voltage regulator to power the rest of the integrated chips. The receiver will not work once the power has dropped from 9 volts to 8.3 volts. The total cost for the design is $223.

Figure 20.8. Left: Touch Pad and Transmitter Circuitry. Right: Receiver and Toy Circuitry.
Environmental Control System

Designers: Patrick McHale and Nakul Arora
Client Coordinators: Dan and Terry Larkin
Parents of Nathan
Supervising Professor: Dr. Rowley
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Introduction
An environmental control system was designed for a child named Nathan Larkin. Nathan suffers from cerebral palsy, which impairs his movements and thus his ability to perform the most basic day to day functions. The project developed is an environmental control unit (ECU), as seen in Figure 20.9. This ECU, which is an attached unit on his wheelchair, gives Nathan control over lights in five areas of the house and helps Nathan change channels on the TV and gives him the ability to adjust the volume to his preferred level. He is also able to fast forward, rewind, play and stop the tape on the VCR. This project enables Nathan to gain control over all of these functions by way of easily accessible switches, thereby giving Nathan independence and a higher quality of life. This higher quality of life requires less supervision of Nathan by others and at the same time gives Nathan a greater feeling of freedom that will have a positive effect on his intellectual development.

Summary of Impact
This project proved to be an excellent learning experience in integrated system design for the students involved.

Technical Description
Nathan is left hand dominant and has reasonable manual dexterity. But due to fact that he has curvature of the trunk, lack of tone in his back muscles and has had multiple hip operations, proper seating is made very difficult and painful. The keyboard is therefore placed on the left side of Nathan’s wheelchair. Several tests were performed to assess Nathan’s abilities and the results concluded that the keyboard should have square, horizontal, color coded keys with an image on top of them. The ECU and keyboard layout is made of the plastic polymer called Centra. The ECU acts as a remote control that sends signals to the X-10 devices in order to control the lights and acts as a universal remote that transmits signals to the TV and VCR.

Input from Nathan is fed to the driving circuitry, via the momentary switches that are connected to the driving circuitry with ribbon connectors. The output of the driving circuitry controls the TV, VCR and the house lights. An X-10 device (see Figure 20.10a), with a radio frequency controller, enables the power to be turned on or off on any line fed appliance, in this case the lights, from a remote location. To control the VCR and TV, input from Nathan is fed to the universal remote, via the driving circuit.
Plug ‘n Power controllers, such as the Wireless Remote Controller (the X-10 device) sense high frequency signals through household wiring. The plug ‘n power Modules receive the controller’s signals and turn the connected lights on and off. Two different types of codes—house codes and unit codes—let the user control many different Modules or groups of Modules. The house code is the master code. The Wireless Remote Control transmitter and receiver, as well as all the Modules it controls, must be set to the same house code. Each Wireless Remote Control center operates up to 8 different Modules or groups of Modules. The controller is set to control any Module or group of Modules set to the same unit code.

The X-10 remotes’ circuitry allows the input signal to be filtered to a usable input to the D flip-flop. The D flip-flop supplies a basic high and low output based upon the input. This simple toggling function is accomplished by feeding the Q bar output back to the input D. The input from the debouncing circuit is then fed into the clock pulse of the D flip-flop. The D flip-flop is used to toggle the ON/OFF states of each device. The X-10 is supplied by four 1.5V batteries.

The steering logic for the user with the TV/VCR remote (see Figure 20.10(b)) is less complicated due to the usage of single switches for each input instead of one switch for activating two inputs. The input to this device does not need to be debounced, eliminating two chips.

The transmitter, which incorporates the steering logic and is located within the ECU, converts the audio/visual remote’s signals that come from the ECU’s driving circuitry, into wireless transmissions. The receiver senses the transmissions, converts them back into identical infrared signals, and then relays them to the audio/visual equipment. The transmitter and receiver must be within 100 feet of each other, but does not need to be in each other’s line of sight. However, the receiver must be within 20 feet of the TV/VCR and in its line of sight. The wireless remote extender is supplied by the Maxim 762 power supply. The total cost is $537.

Figure 20.10. Left: Output Circuitry for the X-10 Device. Right: Steering Logic for the TV/VCR remote.
Actively Controlled Prosthetic Ankle

Designers: Dave Brown, Keith Clark, Chris Coning, Dale Kennard and Jim Webb
Client Coordinators: Fidelity Orthopedic, Inc. and Ohio Willow Wood Company
Supervising Professors: Dr. David Reynolds and Dr. Kuldip Rattan
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Introduction

The intent of this project is to produce an actively controlled, electro-mechanical prosthetic ankle-foot substitute. The prosthetic ankle is designed to have a self-contained power supply with a mechanical brake and be electrically controlled. Also, the ankle is interchangeable with both the right and left legs, which reduces cost for both the manufacturer and consumer. Such a device, as discussed above, has not been available. However, many other artificial ankle-foot devices are already available, but none feature the natural adaptation to uneven terrain that amputees highly desire.

Currently, most all of the available ankle-foot substitutes are passive mechanical devices. State of the art provides some degree of flexibility in prosthetic feet. However, no device has successfully proven itself an adequate replacement for the lost limb. For efficient use, these models require a compromise of an individual’s normal gait style and an adaptation to the prosthetic device. This requires an increased expenditure of energy from, and an increased risk to the patient. Furthermore, although successful when used on level ground, most of these devices do not provide the confidence needed to traverse uneven terrain, including inclines, declines and stairs. The amputee must continuously consider the upcoming terrain to ensure a successful stride. Therefore, the need exists for an actively controlled prosthetic ankle. The proposed artificial ankle, as seen in Figure 20.11, closely simulates the biomechanical properties of support and mobility of the natural ankle with the use of a mechanical brake and active electric control. In terms of innovation, this would be the first such device to incorporate electrical control as a control method for a prosthetic ankle.

Summary of Impact

Although the prosthetic ankle does not function as well as anticipated, this project has many possibilities forthcoming. To date, the electrical control device functions properly. However, the mechanical braking and locking of the ankle does not meet design specifications. Therefore, the ankle could not be tested on humans. An alternative solution to the mechanical objective of this project, now being developed and tested, uses hydraulics instead of a cam device.

Technical Description

The electrical system used consists of foot sensors, an accelerometer (see Figure 20.12a), a micro-controller and a power source. Three tape switches are used at the heel, ball and toe to detect the position of the foot.
with respect to the ground. An accelerometer chip, the ADXL50 from Analog Devices, is mounted upon the upright extension, and senses when the leg is vertical with respect to the ground. The first amplifier zeroes the output and provides low pass filtering above 4 Hertz. The second amplifier scales the output so that 1 g equals 5 volts and -1 g equals 0 volts. The microprocessor used is the Motorola 68HC11. The device reads the information from the foot sensors and accelerometer and activates the solenoid to engage the brake (see Figure 20.12b). The microprocessor program only checks for heel strikes; however, it can be changed to incorporate any combination of foot sensors. The power source consists of seven nickel-cadmium batteries, which provide 9 volts to drive the solenoid. A voltage regulator circuit derives 5 volts from this source to operate the microprocessor.

A cam prototype comprises the braking and locking systems of the prosthetic ankle. A solenoid actuator is used to activate this brake because it is not temperature dependent. The prototype functions as follows: when the foot sensors are depressed, meaning the foot is flat, and the lower leg is in the vertical position with respect to gravity (not necessarily the ground), the microprocessor activates the solenoid to engage the cam, causing the cam to bind to the base block. (The solenoid just provides the initial push and does not stay engaged.) Once the cam binds with the base block, as long as pressure is applied, i.e., weight is applied to the ankle, the cam stays locked. Once the pressure is released, meaning the foot has been lifted from the ground, the rear spring returns the cam to the forward position, thus releasing the brake.

The design criteria followed that the ankle has a 20° dorsiflexion and plantarflexion, weighs 1.7 lbs. (manufactured from 7075 aluminum), and measures 17.5 cubic inches. Another design criterion is that the ankle needed to be able to withstand a worst case scenario torque of 1500 in-lbs. (This is an estimate of a 300-lb person with their center of gravity displaced 5 inches from the ankle.) However, experimentally, it is found that the prototype could only withstand 464 in-lb. This is the reason why further testing and experimentation are being conducted. However, keep in mind that the electrical control device is a great success. The final cost of the project to date is $1069.

Figure 20.12. Left: Accelerometer Circuit. Right: Brake Amplifier Module (Voltage Regulator).
Adjustable Mat Table

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Client Coordinator: Mrs. Donna Galardi
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Introduction
The Gorman School is a facility that educates children with disabilities. Many times these children are incontinent and must wear diapers. The teachers at Gorman change the children’s diapers on a table that is one foot above the ground and cannot be adjusted to different heights. This means that the teacher must either kneel on the floor or bend over the child to change the diaper. Obviously, this places great strain on the teacher’s back and knees. Therefore, the existing mat table is modified so that it raises and lowers using a crank system. With the adjustable mat table (as seen in Figure 20.13), the strain placed on the teacher’s knees and back will be greatly decreased, making it easier to change the children’s diapers without compromising their safety.

Summary of Impact
This project is a very good educational experience in mechanical design for both students.

Technical Description
The adjustable mat table’s dimensions are 6' 7" long, 30" wide, and 1.75" thick. The table itself is made out of wood, all other parts are made out of steel or aluminum. The operation range of the table is 3 feet above its lowest position. The existing mat table was modified to be used with a raising mechanism. A crank/gear system is implemented in the design of the adjustable table. This design requires no motor, and is relatively easy for the teacher to operate. It will raise 2 ft. in 30 seconds, due to a 4:1 gear ratio, if the operator applies 18 in-lb. of torque. With the crank hand being 4 inches, the teacher only has to exert 4.5 pounds to the crank. All parts, excluding the steel plate, are standard parts and can be easily obtained. Plastic caps are placed on the top of the threaded rods to prevent the user from cranking the table up past the end of the rod.

To use the table, the teacher adjusts the table to the height of the child’s wheelchair. The teacher then slides the child off the wheelchair and onto the table. The safety bar is then put in place. The teacher turns the crank to raise the table to the desired height. When the teacher is done, she turns the crank in the opposite direction to lower the table. The safety bar is then released, and the child can be taken from the table and placed back in her wheelchair. The safety bar should be placed in the up position when the table is not in use. The total cost of the adjustable mat table is $535.
Figure 20.13. Adjustable Mat Table.