Chapter 14
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MORSE CODE TO TELEPHONE CONVERTER

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INTRODUCTION

In today's world of advanced communications, the telephone provides the ability to connect with unlimited sources of information. For many persons with physical disabilities, the restrictive design of the telephone prohibits access for emergency assistance, business opportunities, and contact with family and friends. New telephone designs are needed to offer custom interfacing for control of basic phone functions.

A prototype telephone was designed for a student at a local educational institution for the blind. The unit is dialed via a customized hand operated Morse code device. Other external features include customized headset, pick-up, hang-up and error handling.

SUMMARY OF IMPACT

A high school student who is blind and has severe motor control disabilities desired to use the telephone without assistance. He has excellent verbal skills and is highly intelligent, so is an excellent candidate for employment. He wanted to take an available position as a receptionist but his motor skills were not sufficient for him to dial a standard telephone or pick up the handset without assistance.

Morse code was chosen as the input language because of its simplicity and because the student is already familiar with it. Morse coding devices are flexible and easily adaptable to accept various inputs, including motion from a hand, knee, toe, head, or finger.

Using a series of five dots and/or dashes, all digits and keypad symbols are available to the user. The prototype unit accepts a series of Morse code sequences as input while all other interactive telephone functions, such as the receiver component and hang-up/answer capabilities, are external and customized to individual needs.

TECHNICAL DESCRIPTION

The telephone unit is comprised of two individual subsystems communicating between one another. The first is a micro-controller circuit that accepts Morse code as input. The second is a telephone circuit that communicates with the micro-controller and performs all standard phone functions.

A program drives the micro-controller to regulate the timing and feel of the customized hand operated actions. The algorithm polls the input device and waits for an event to occur. When one of the Morse code controls is pressed, the program delays processing the dot or the dash until the user releases. This allows for fast or slow user input.

The series of dots and dashes are stored until five events are recorded, at which time the algorithm converts the Morse code number to its respective dialing code. The special dialing code is sent to the telephone circuit.

The telephone circuit generates a tone corresponding to the dialing code received. This tone is sent via the telephone lines to the local phone company, from which that number is dialed. The telephone circuit also handles incoming calls and handset functions and allows keypad dialing.

Many people with disabilities already have the skills, if not the mechanisms, to operate the switches needed to use Morse code but lack the tools to convert their talents. The custom interface telephone with Morse code dialing is constructed for use with several input devices. The client operates a two-stick customized hand-operated Morse code unit appropriate for his limitations. Any device using standard male phone jack connectors and toggling between short and open would be operational.

The pick-up/hang-up feature involves a nine-pin connection. The client uses a double-throw double-pole switch embedded in a harness made especially for him. However, any device connecting the appropriate wires of the ninepin port is suitable.

The receiver outlet is a standard handset connection, allowing devices such as an everyday headset or a speakerphone extension to be used.

Not including accessories such as speakerphone extensions and the custom Morse code input device, the cost of this system is under $50.00.

KEYPAD PROGRAMMABLE ELECTRONIC DOOR STRIKE

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INTRODUCTION

A device was designed to enable a woman with multiple sclerosis to control the front door of her house from her bed. She wanted to allow a visiting nurse or friend into her home, but also desired the security of a locked front door. A coded keypad, similar to those found on touch-tone telephones, allows specific individuals to have access to her home without disturbing her.

SUMMARY OF IMPACT

The client is able to positively identify visitors over an intercom and let them enter her home. When she is sleeping, care providers can let themselves in using the keypad.

The system entails a wireless intercom and house wiring for communication with a battery back up in case of power failure. The keypad, with a changeable code, is a critical component, obviating the need to distribute keys to potential visitors.

TECHNICAL DESCRIPTION

The Keypad Programmable Electronic Door Strike device consists of four main components: a wireless intercom, a keypad and decoder, an electric door strike, and a battery back up

The wireless intercom unit is a Nutone Comtek Chime Talk Door Answering Intercom with Outdoor Speaker and Push Button. The inside unit "master speaker " was modified to add a switch to control a X 10 switch-closure sending unit and a piezo buzzer horn as an entry alert. This unit has a “press to talk” lever, which was changed to a pull cord switch such as those found in hospitals and nursing homes. The front door unit was not altered, but was connected to the keypad switch assembly. The wiring cable of both was combined to pass through the doorframe.

The Keypad is a Storm series 2000, 12-key pad from Keymat Technology. It is a weatherproof unit connected to a digital lock circuit that uses only nine of the keys (three are not connected), and adds to the security of the entry code. The digital lock uses an LSIKSI LS7222 IC for the decoder, memory and control circuitry. This IC has stand-alone lock logic, momentary lock contro1 outputs, internal keyboard debounce circuit, and high noise immunity. A 555 timer was used to provide a 9-millisecond delay on the door strike power-on command signal to make the door open after the correct code was selected. Upon entry of an incorrect code, the latch is energized.

The Electric Door Strike unit is a Home Automation HAS-5 190 12 - 16 V-DC, 800 mA unit. Either the front door keypad or the modified Xl0 lamp module can activate this door strike. The X10 modification ensures that the module will not latch but pulse on only when its command code is detected from the household wiring.

The piezo buzzer is activated when the door strike is energized to let the client know when the door strike is active for door opening. The battery back-up circuitry is in the front door electronic box. The circuitry includes a 12-volt NiCad battery and charging circuitry. This back-up is activated when power is lost to the household. It powers only the front door keypad and door strike coil. There is no control from the bedroom when power is lost, but care providers can still get into the house through the use of the keypad code. The battery can supply back-up power for over 24 hours. This time could be extended with a battery of larger amp-hour capacity.

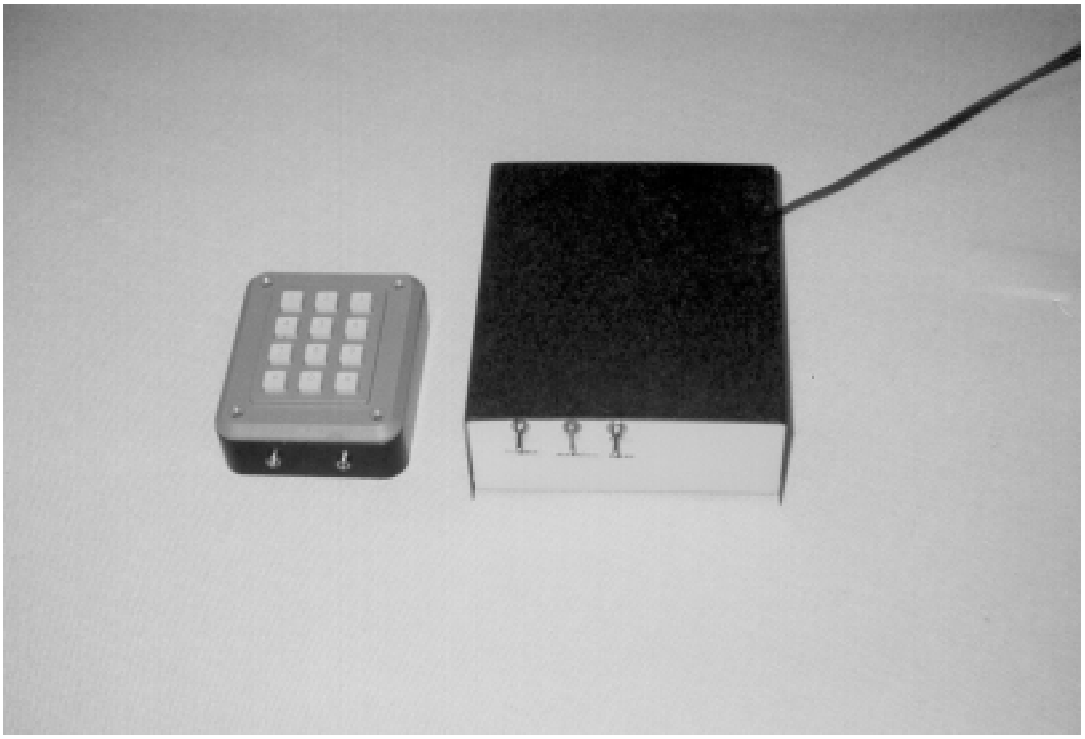

Figure 14.1. Keypad Programmable Electronic Door Strike.

ADAPTATION OF A RADIO REMOTE CONTROLLER

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INTRODUCTION

A remote control device was adapted, with larger buttons and color-coding, for an 18-year-old boy who enjoys listening to a radio but was not able to independently control a standard one. The client has cognitive and motoric limitations as well as poor vision.

SUMMARY OF IMPACT

A commercial portable radio that came with a remote control was selected. Among the many features of the remote control, the most important were keys for power, volume up and down, and tuning. The modification entailed adding buttons for these functions in custom keypads. Four large (approximately 4" by 2"), brightly colored buttons were mounted onto a metal case containing the remote. The new buttons are large enough to operate with a fist. The colors (red, green, blue and yellow) provide cues to help compensate for the client's limited vision.

The client now has enhanced environmental. Additionally, he enjoys entertaining others, playing the role of disc jockey at informal events (The volume up button being his favorite.).

TECHNICAL DESCRIPTION

A production remote packaged with the radio was disassembled. The printed circuit card was installed in a metal box, increasing the controller's size and durability. Two momentary switches were wired in parallel to each selected command and mounted on the new case. To create one large button, the two momentary switches were covered with one piece of colored plastic. Current limiting resistors were mounted in series with the new switches. A lens cap was placed over the LED. The batteries to power the remote are accessible through one end of the case.

The costs were primarily associated with the mechanical aspects of the project. The case to hold the remote circuit card was roughly $12.00. The momentary switches are available for less than a dollar. The plastic for the button covers was obtained for $10.00. Miscellaneous supplies, such as batteries, clips, the lens cap, and hardware, cost less than $8.00.

Figure 14.2. Client with Adapted Remote Control Device.

VOICE CONTROLLED PHONE DIALER

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Client Coordinator: John Otto Schenk
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INTRODUCTION

A voice controlled phone dialer was designed for a client with reduced vision and diminishing sensory acuity in the fingers.

SUMMARY OF IMPACT

The device relieved the client's difficulty in using the telephone.

TECHNICAL DESCRIPTION

A voice controlled phone dialer incorporates voice recognition DSP chips, flash memory devices, and existing phone dialers. The design was based on digital control logic, digital signal processing (DSP) and analog. Existing dialer chips, application notes, and basic electrical engineering concepts were applied. Use of existing integrated circuits simplified the design process.

A voice recognition unit controls a switch matrix, which, in turn, controls the phone dialer. Three functions are available: direct number dialing, storage numbers of associated with a name, and recall of stored names. These functions are controlled through familiar words defined and spoken by the user.

Solid-state relays and logic gates were used to replace the matrix of switches that controlled the tone generator or dialer circuit in a regular telephone. Digital logic was implemented to control these switches. An algorithmic state flow chart was first drawn to describe the intended operation of these switches. Two types of memory, programmable and read only, were implemented. With the addition of minor supporting circuitry, including a buffer amplifier and a reference oscillator, a binary controlled switch matrix was developed.

DSP provided a compact solution for a seemingly complex problem. The task of producing a reliable electrical response to specific spoken words is challenging. There are few chips under $100 that operate flawlessly. A hm2007 DSP chip was used in a prototype circuit. A voice recognition unit was built and then connected to a static memory unit (for storage of voice recognition output), and to the switch matrix. The unit allows control through single words. Storage of several binary word patterns can be recalled sequentially. Timing logic, implemented with a simple astable oscillator and a counter, ensures that more than one function can be initiated when a single word is spoken.

A buffer amplifier inserted between the output of the voice recognition unit and the switch matrix allows for a binary decimal display of the word spoken. This provides feedback to the user regarding which word was coded.

The dialer is 7" long, 5 inches wide wide, and four inches deep. It weighs less than one pound. It may be easily replicated. The dialer has other applications, such as security locks and general voice controlled switching systems.

The total cost was below $130.00.

COMPUTER CONTROLLED SPEAKER TELEPHONE

Designer: Rick Bouley
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INTRODUCTION

Computerized speech recognition was used to help a person with spinal cord injury control his telephone.

SUMMARY OF IMPACT

The client is now able to answer and receive calls, as well as to dial out to make calls.

TECHNICAL DESCRIPTION

This project used a commercially available Panasonic speakerphone with a computer digital interface. Twenty switches make up the keyboard in a 4 x 5 matrix on the speakerphone, allowing for control of answering and dialing of selected numbers in memory storage. This matrix of rows and columns was paralleled with nine small Switchcraft IC-type DIP relays, and buffered using two hex driver digital ICs. The computer has an I/O Digital Interface Card. Nine digital lines were used. Power for the relays and ICs was taken from the I/O Card. Power for the speakerphone came via its own wall plug power supply. The relays provided the electrical isolation between the two systems. The software for control is written in Visual Basic from Microsoft.

The cost of this project was $ 263.50

Figure 14.3. Computer Controlled Speaker Telephone.

VOICE ACTIVATED ENVIRONMENTAL CONTROL UNIT

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INTRODUCTION

A voice activated environmental control unit was developed for a man who is paralyzed from the neck down due to an automobile accident. Though he does have enough mobility in his arms to operate a motorized wheelchair, his quadriplegia has reduced his fine motor skills.

SUMMARY OF IMPACT

This voice-enabled system can be used by anyone capable of coherent speech. Blind individuals, those with motoric limitations, and able-bodied persons may employ a similar system.

TECHNICAL DESCRIPTION

The system has three components: the voice recognition (VR) engine, a controlling platform, and hardware. The system receives its voice input from a head-worn wireless microphone. This allows the client freedom to move about in his apartment while maintaining control of the system. A RF link connects the microphone to the base unit, which is then channeled into a standard PC sound card.

The VR engine, IBM's Voice Type Application Factory, interprets the speech and returns the associated text to the Visual Basic (VB) program through a third party Custom Control or OCX. The VB program, essentially a state machine, then either changes state or writes a sequence of bits out to a digital l/O card. Each external device has a pattern of bits, or ID, associated with it. For the remote, each bit pattern specifies a single button. The client’s ventilation system is controlled by a series of logic gates and relays, while his lights and television are controlled through the interfaced universal remote control. Using "Plug 'n Power" or X-10 technology, lights and outlets can be toggled while the remote communicates directly with the TV once the correct manufacturer's code has been entered.

In keeping with the modularity of the overall design, the VR portion uses content files, listings of acceptable words, for each program state. Restricting the number of possible matches resulted in simultaneously improving its accuracy and speed.

The VB program is modular in its series of drop-down menus. To promote usability, the menus reflect the layout of the client’s apartment. Each room has a corresponding drop-down menu containing a list of the devices in that room. Personalizing the menus and program flow facilitates the user's learning.

The universal remote was attached to the digital I/O card via an RS-232 cable. After determining the pinout from the remote's controlling IC for each button, the sequences were hard-coded into the VB program.

Switching relays were used to simulate pressing of the buttons. The "Plug 'n Power" button accessed the X-10 control center, which toggled the individual X-10s directly.

Highlights of the design include power, versatility, user-friendliness, and cost-effectiveness. The power of the system lies in the use of voice recognition. Any individual without a severe speech impairment can use it. It gives the user's voice the ability to accomplish what his body cannot.

The versatility of the system is due primarily to the modularity built into the VB program and VR engine, which ensures that any modifications can be made quickly and without affecting current system operation.

User-friendliness was an important criterion in this design project from its initiation. The wireless microphone gives the user freedom of movement within his home. Visual and audible prompts are relayed back during operation to enhance user awareness. The VR engine has up to a 95% successful recognition rate. If the engine makes mistakes, they can be undone by a spoken RESET command available in all contexts.

Although the system requires a PC for operation, the 486 based machine used in the initial system had recognition times of nearly one second and an overall response time of just over two seconds.

Commercially available systems with comparable functions may cost $5000 and up, whereas the total component cost for this design was slightly under $1200.

Figure 14.4. Voice Activated Environmental Control Unit.

COMPUTER INTERFACE FOR HOSPITAL BED CONTROL

Designer: Bob Hughes
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INTRODUCTION

The purpose of this project was to design a simple interface between a voice activated computer and a hospital style bed for a 49-year-old man with a spinal cord injury. The bed has a hand-held control to raise and lower the feet, torso or head, depending on the buttons pushed. It also has an elevator function that raises and lowers the entire bed.

The interface must be parallel to the hand-held control to allow functionality in case of computer breakdown and to allow control by healthcare providers and family members. A Dallas Watchdog timer chip was added for safety. If control and hand shaking with the computer are lost, the output control is put into high-impedance mode, and the device is electronically removed from the bed controller.

SUMMARY OF IMPACT

A client with a spinal cord injury uses this voice control system to control his hospital bed. Previously, he had to rely on healthcare workers or his son to make adjustments. Now, if the client wants to sit up and watch television, or simply reposition the bed for comfort, he speaks a command and the computer system, through the bed controller interface, obeys. This device helps make the client more independent.

TECHNICAL DESCRIPTION

The system uses the IBM Voice-type Factory speech recognition software and interface drivers written in Visual Basic 4.0. The digital interface from the computer to the bed controller unit is a Computer Boards, Inc. interface card, CIO-111024. This card provides 24 I0 lines through a 37-pin connector mounted on a PC Card, which plugs into the computer bus slot. The heart of the card is a single 82C55 chip operating in mode 0; the signals are TTL with capability of 15 mA Sourcing, and 64mA Sinking. An extension cable connects the interface card and computer and can be unplugged at both ends. The interface uses Port A on the Multiport Board. A0 to A.5 are used to control the bed and A6 is used to strobe the Dallas chip. As long as the Dallas chip is getting strobed the data will pass through the 74LS244 buffer and to the relays that are in parallel with the hand control switches. The Dallas DS1233 chip requires a transistor buffer to drive the 74LS7244 chip G1 and G2 pins.

The Dallas chip operation serves as a safety feature as well as a check in the operational mode. If the computer gets hung up, it would have to put data on the address lines and toggle A6 in order for the bed to operate. For added safety, the relays also have a double normally-open contacts configuration. All control lines have pull-up or pull-down resistors to keep the circuit stable in power-up and power-down conditions. The I/0 card supplies five-volt DC power and ground. All components are socket mounted to facilitate field repair.

To install this control unit, the original hand control unit is removed by unplugging it from the bed controller and replacing it with the cable from the new unit, which has an identical hand unit. The control box and the new hand control switch units have Velcro strips for securing both to the bed.

The cost of the project was $634. The most expensive item is the replacement hand-held switch unit.

Figure 14.5. Computer Interface for Hospital Bed Control.

VOICE OPERATED WHEELCHAIR USING DIGITAL SIGNAL PROCESSING TECHNOLOGY

Designer: Walter R. McGuire Jr.
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INTRODUCTION

A Voice Operated Wheelchair was developed using commercially available digital signal processing (DSP). The device does not require a personal computer or any other costly component. It provides a safe, economical, and compact solution for persons with quadriplegia. The device is small enough to hide under the seat of the wheelchair, consumes low battery power, and can be converted to fit most existing motorized wheelchairs at minimal cost.

SUMMARY OF IMPACT

The development of the Voice Operated Wheelchair using DSP provides a person with even minimal speech capabilities freedom while traveling in a wheelchair.

TECHNICAL DESCRIPTION

The heart of the voice-operated system is the digital signal processing circuit. Supporting the DSP is the programmable logic circuit, the converter circuit and the mechanical safety switch circuit. The signal processing circuitry consists of a commercially available DSP chip, which receives verbal commands from the user with the aid of a simple microphone (Figure 14.6).

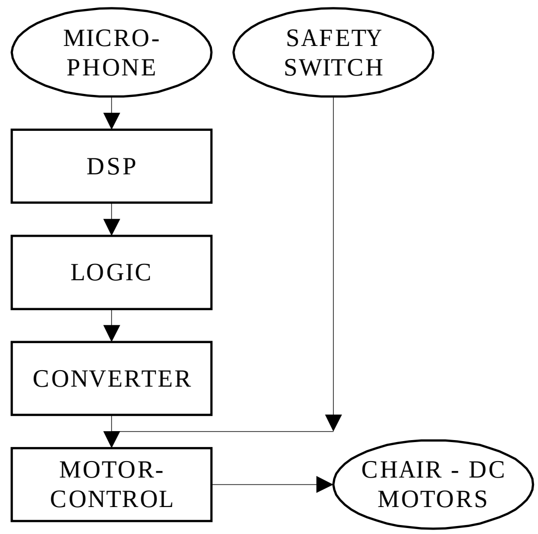

Figure 14.6. DSP Driven Voice Operated System.

The first phase of redundancy helps avoid undesirable responses from the system and the surrounding environment. The verbal commands are outputted from the DSP chip in the form of an eight-bit word, which are then taken by the logic circuit and analyzed. Part of the logic circuitry is a commercially available PIC chip that processes the eight-bit input and makes a decision based on that information. Once again, redundancy is featured. The decision is then further processed in the next circuit, which takes the digital input and converts it into the necessary analog output that is needed to produce the desired response from the motor controller (for example, moving the wheelchair in the forward direction). The final section of circuitry is the mechanical switch that overrides all of the aforementioned circuitry. This circuit acts as a failsafe against erroneously entered commands.

Figure 14.7. Voice Operated Wheelchair.

VOICE ACTIVATED WHEELCHAIR LIFT SWITCH

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INTRODUCTION

The Voice Activated Wheelchair Lift Switch was designed to assist a man with quadriplegia. The design incorporates technology already in use in the client's home, namely, his environmental control system (ECS).

SUMMARY OF IMPACT

The device is used by the client, who, until now, has been dependent on his family to exit his home. This device gives him the ability to raise and lower his wheelchair lift, and to open his garage door, allowing him access to the outdoors.

TECHNICAL DESCRIPTION

This design consists of three main circuits making up the switch: the X-10 circuit, the timer circuit and the relay circuit (Figure 14.8). The switch component is the interface between the voice system and the wheelchair lift.

The home that the switch was designed for has an existing voice operated ECS that operates with X-10 technology. The X-10 appliance modules were modified to pass a 5-volt DC pulse when accessed through the addressing of the X-10 via the ECS. The 5-volt pulse triggers the timer, which is a 555-device, set up to act in the monostable mode. The 555 timer has an RC time constant set to the length of the lift's travel duration, approximately 23 seconds. As the one-shot is charging, the 555's output of 5 volts activates a solid state relay, which, in turn, activates the lift and / or garage door. The device was susceptible to external noise that would trip the timer when the client's wife would use the garage door opener or the wheelchair lift manually. Inserting filter capacitors from all of the V_{cc} to Ground terminals rectified this problem.

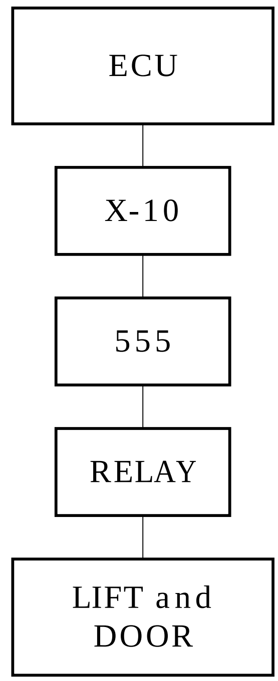

Figure 14.8. Custom Switch Block Diagram.

This device can be expanded for many applications simply by customizing the RC timing circuitry. It can also be made to stand alone, omitting the need for the environmental control system and X-10 technology by replacing it with an inexpensive DSP voice recognition system. The reduced cost would make the device more accessible to those in need of this technology.

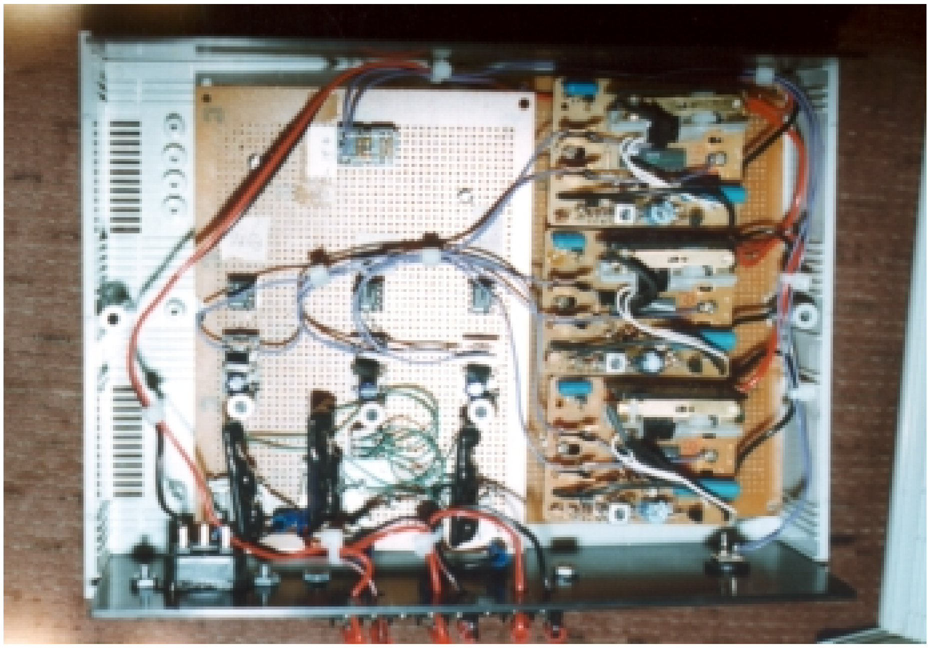

Figure 14.9. Circuit Boards in the Voice Activated Wheelchair Lift Switch.

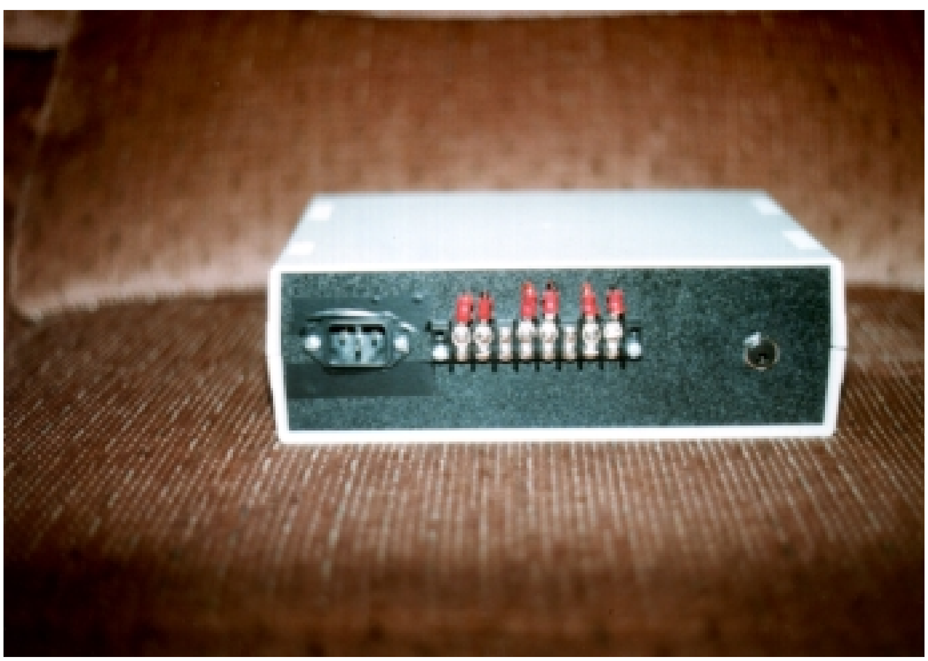

Figure 14.10. Voice Activated Wheelchair Lift Switch.

MOTORIZED EXERCISE BICYCLE

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INTRODUCTION

An exercise bicycle was modified by adding an electric motor, for a woman who has limited use of her legs due to a progressive neuromuscular disease. In the past, the client used an exercise bike, but her disease took away her ability to move the pedals. Using this device, she has an opportunity to get the exercise she needs.

SIIMMARY OF IMPACT

An electric motor and modified motor controller were added to an exercise bicycle. The client comments that she uses the bicycle daily, and that it provides needed range-of-motion exercise to her arms and legs, slows muscle atrophy, helps with weight control, and increases her sense of well being. Such an adaptive device could assist others with neuromuscular deficits and perhaps stroke and cardiac patients as well.

TECHNICAL DESCRIPTION

The rider sits on the seat of the DP Air Gometer Exercise Bicycle, placing her feet on the pedals and her hands on the handlebars. When used in its original state, the crank turns as the handlebars move toward and away from the rider. A large plastic fan wheel turns and provides more resistance the faster it turns. The fan was removed. A steel mounting plate was welded on the frame of the bike. To measure the torque required to push the pedals, an able-bodied rider rested his foot on one pedal while a spring scale was hung from the opposite pedal. As he pulled downward on the spring scale, the required force was 19.5 in-lbs. The minimum rate of rotation for the pedals was determined to be 2.5 RPM, while the maximum was found to be 45 RPM.

The DC brush motor selected was a Bison Gear and Engineering series 746 DC Gearmotor #507-02-128 with right angle drive. A matching controller, Minarik Corp. model XPO5-115AC, was purchased. It is equipped with the following features: current limit, voltage (IR) compensation, acceleration adjuster, deceleration adjuster, and maximum speed setting. The motor and controller were an excellent match for this design, as well as the cheapest and simplest solution.

Figure 14.11. Motorized Exercise Bicycle.

The motor, the motor controller, fuse holder, and ground fault interrupter were all mounted to the underside of the frame. A main power switch and power indicator were mounted to the topside of the frame, where the rider can easily reach them. In addition, a start / stop switch and speed control were mounted inside the control box that sits between the two handlebars, in front of the rider. Wiring to the start / stop switch and speed control is fed from the motor controller, up through the frame, and through a hole in the bottom of the control box. Finally, the power cord is strung from the back of the bike, where it can be conveniently plugged into a typical wall outlet. A plastic shroud along with a plastic fan cage was remounted on the front of the bike. The shroud and cage enclose the motor, sprockets, chain, controller, GFI, fuse, and all associated wiring. The only modifications accessible to the rider are the main power switch power indicator, start / stop switch, speed control, and power cord.

The motor controller was set for a maximum speed of 45RPM, the acceleration / deceleration setting was adjusted for a usable ramp rate, and the current limit was set so that if a person's feet fall off the pedals the resistance caused by the pedal against a leg easily stops the motor from rotating.

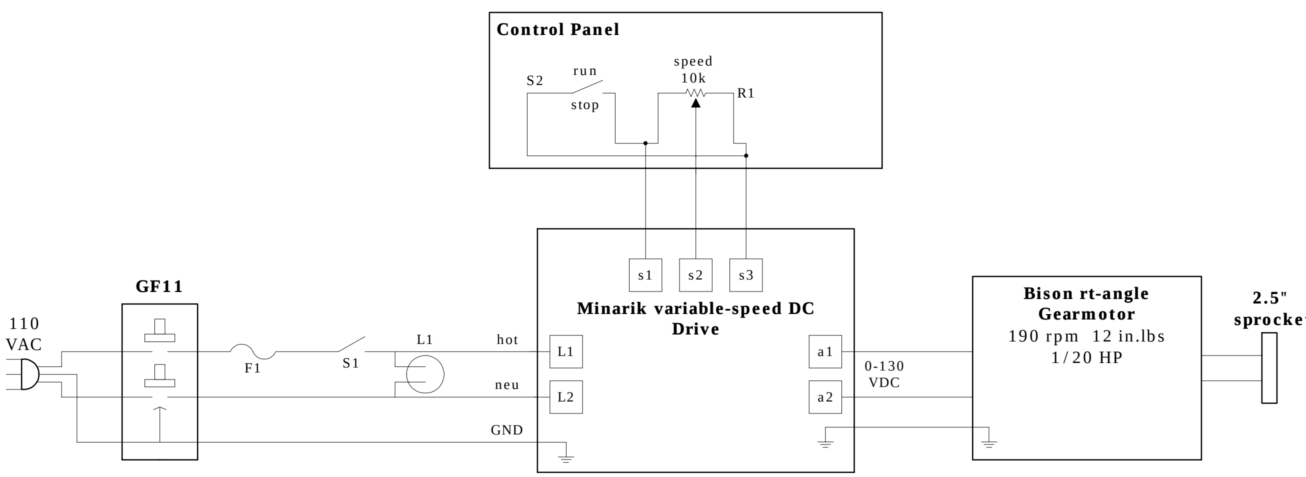

Figure 14.12. Circuit Diagram Used for the Motorized Exercise Bicycle.

WIRELESS REMOTE CONTROLLER

Designer: Nancy Donahue
Client Coordinator: Margaret Mahoney, Anne Sullivan Center, Early Intervention Program, Tewksbury, MA
And Donn Clark, Assistive Technology Program
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INTRODUCTION

A four-year-old girl can push buttons, but has little strength in her fingers, hands and arms. She can point her forefinger and move her hand slowly but she has neither the accuracy to touch a specific button nor the strength to depress one. A switch box was developed to allow her to control devices such as lights and a television.

SUMMARY OF IMPACT

A Radio Shack Remote Control X10 unit was modified and remounted in a large project box with three large diameter jellybean switches, one pink, one purple, and one yellow (the client's favorite colors). Each appliance module was painted the same color as the switch that controls it. The device allows the client to have some control of her environment.

TECHNICAL DESCRIPTION

There arc three parts to the Plug 'N Power ™ system. The first part, the wireless controller, sends RF signals to the wireless control center, which is plugged into the wall power outlet. The control center then sends signals on a high frequency carrier through the house wiring. These signals are received by appliance modules. They turn the appliances connected to them on and off. The wireless controller makes the Radio Shack's Plug 'N Power ™ system easier to operate for users with physical challenges.

The wireless controller was removed from the plastic box it was purchased in and remounted on a vector prototype board to allow for additional circuitry. The board was, in turn, mounted in a large box, with the three jellybean switches mounted on its top (Figure 14.13).

The house code select switch contacts were removed. Code A to H was then hardwired to switch position A with a jumper wire. The switch contacts for the individual appliance units were also removed and their contact closures were replaced with a CD4066 analog switch IC.

The transmitter required two switches for each device, one to turn the device on and one to turn the device off. The system was modified so that one switch turns the device on and off. A J-K flip/flop, 74HC76 wired in the toggle mode was used to control the analog switches (See switch schematic in Figure 14.15). The switch, when depressed, toggles to the alternate position and also limits the closure and transmit time of the control command signal. A 555 timer IC provides the ground to the analog switch. When the timer releases the ground after 100 milliseconds, the controller sends the proper control codes to the receiver for the appliance modules and then waits for the next jelly-

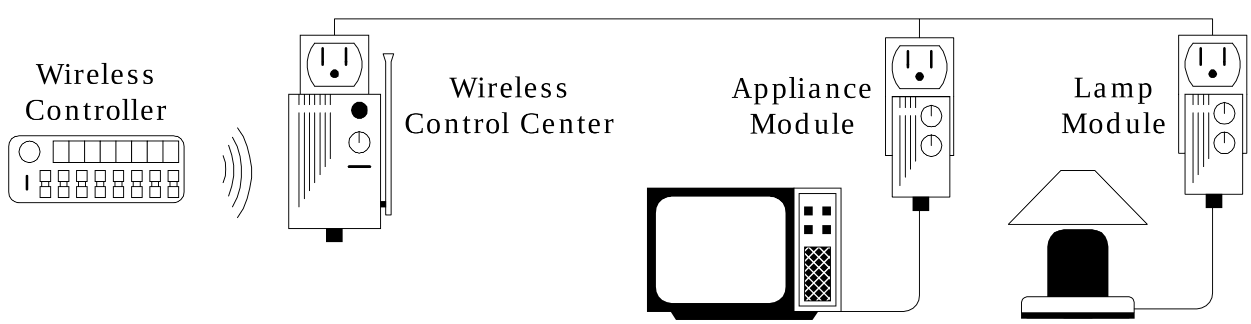

Figure 14.13. Drawing of the Wireless Remote Controller.

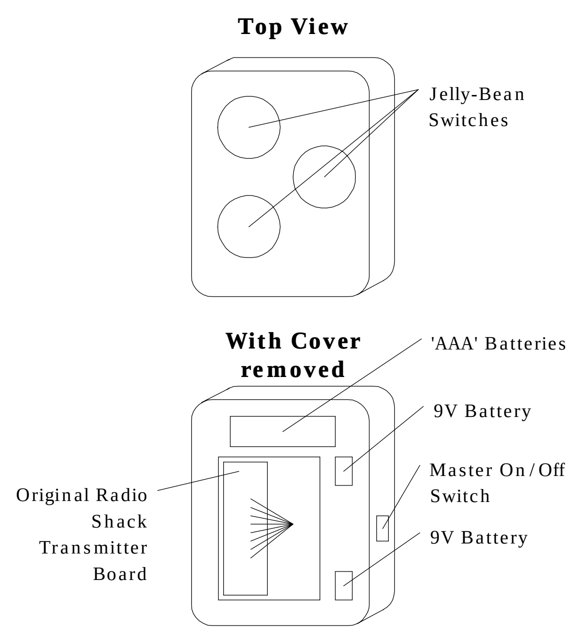

Figure 14.14. Diagram of Switches for the Wireless Remote Controller.

jellybean switch closure. Four AAA batteries provide power to the timer's digital circuit (JK flip/flops and analog switches) via a Master Power Switch. The Radio Shack controller is powered by a nine-volt battery and has its own power-down circuits to limit power drain.

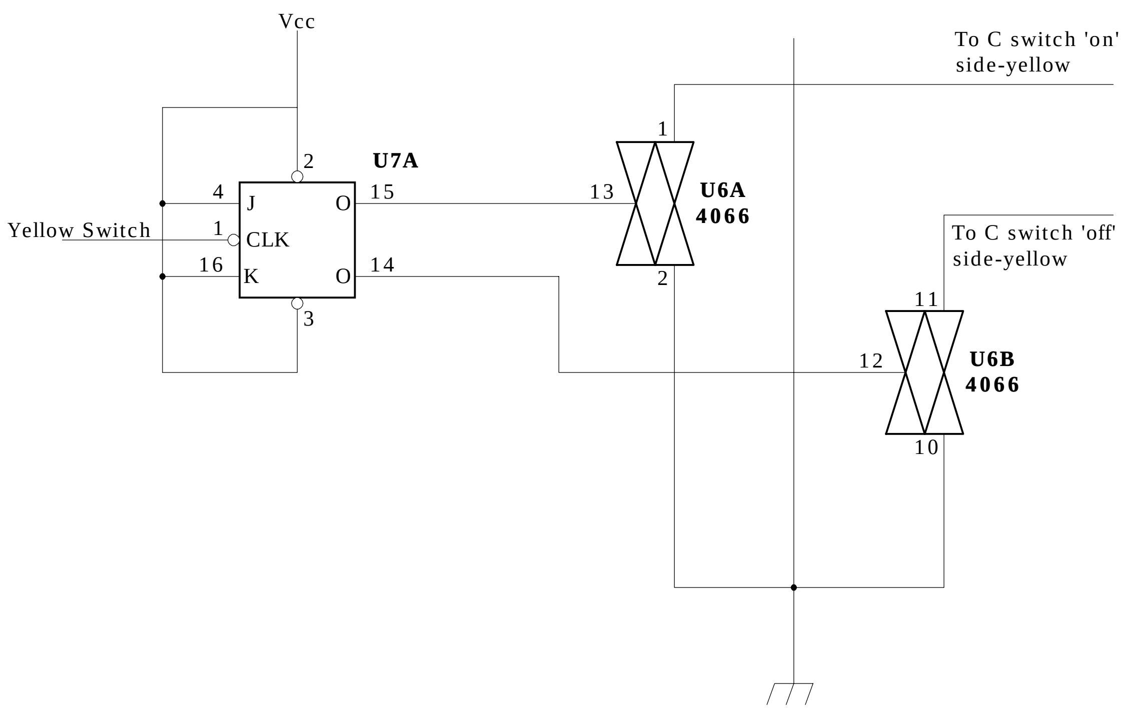

Figure 14.15. Circuit Diagram for Wireless Remote Controller.