

# CHAPTER 8

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# MODIFIED ELECTRIC SCOOTER

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## INTRODUCTION

At the age of three, the client had both of his arms severed by a farm machine. Now nine, the client has learned to use his right and left arms, which measure 6" and 8 ½", respectively, for a wide range of tasks. As an active and sociable person, mobility is important to the client. Most traditional modes of transportation available to young people, such as bicycles, scooters, and roller blades, are not appropriate for the client. Various surgeries to improve the functionality of the client's arms have left his legs weakened; this fact further limits the transportation options that are available to the client. Attempts to adapt a traditional bicycle, for example, were unsuccessful.

The modified electric scooter (see Fig. 8.1) provides the client with an effective form of transportation. Each scooter modification was designed using the client's anthropometric data, which resulted in a custom device that accommodates his unique needs. The scooter is rugged and adjustable.

While there are many electric scooters available on the market, most are designed for geriatric clients. Few, if any, would pass as the type of scooter used by today's youth, and none appealed to the client. During the initial design meetings, the client communicated his desire for style as well as functionality. The client did not want an electric tricycle. Following a review of available two-wheeled electric scooters, the client selected an ESR 750 electric scooter manufactured by GoPed to serve as the platform for the project.

## SUMMARY OF IMPACT

The scooter increases the client's independence. As reported by his mother, "the scooter is so good for him and especially in regards to confidence and mobility and keeping up with friends and their bikes. Once again, as spring approaches, I would like to say, 'Thanks'. He goes like a bandit on it."



Fig. 8.1. Modified Electric Scooter.



Fig. 8.2. Initial Scooter Adjustments.

## TECHNICAL DESCRIPTION

The ESR 750 by GoPed is a high-quality, award-winning electric scooter that utilizes a 24-volt brush DC motor powered by 12-volt sealed lead acid batteries. In turbo mode, the scooter is capable of speeds up to 20 miles per hour and a range of approximately five miles. In economy mode, the scooter's top speed is reduced to approximately 12 miles per hour, but the range increases to around

eight miles. Further, the scooter weighs a manageable 50 pounds.

To properly accommodate the client, the scooter required several modifications. First, the handle bars were fitted with foam grips that provide the client better grip and control than the factory default. Second, the post connecting the handle bars with the front wheel was modified to allow height adjustments within 0.5" increments. Such adjustments are necessary to ensure comfortable riding posture as well as handle bars that will safely contact the client's arms as he grows. Proper height adjustment is also critical to ensure the client can manipulate the front caliper brakes. The brake lever was designed and positioned on the left handle to take advantage of the strength and leverage available with the client's left arm.

One of the most substantive modifications to the scooter was the speed control mechanism. The original thumb-actuated throttle was replaced with a right-foot actuated controller located on the front right portion of the scooter's standing platform. The throttle's range of motion, and thus the scooter's top speed, is parent-adjustable; initial settings limited the scooter's speed to less than 10 miles per hour. Lastly, the throttle surface was designed to withstand the forces associated with foot actuation.

The cost for the modified electric scooter, excluding labor and machining costs, was approximately \$700.



Fig. 8.3. Maiden Voyage on Modified Scooter.

# MOTORIZED TRANSPORTER

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## INTRODUCTION

The motorized transporter is designed for individuals who have difficulty with heavy objects, such as carrying full backpacks, around campus (see Fig. 8.4). By moving the objects for them, the motorized transporter eliminates the need for the user to carry the objects themselves. The transporter contains two methods of control: a small joystick that can be controlled by the user's thumb and a leash control that uses a cable connected to the cart. The transporter has a built-in lift allowing objects to be brought up to waist height, giving the user the ability to slide objects from the unit onto a table. The motorized transporter is powered by a 12-volt battery which is recharged in a standard wall outlet by an onboard battery charger. The transporter is surrounded by a Plexiglas enclosure which extends with the lift to protect the user and others from moving parts.

## SUMMARY OF IMPACT

The motorized transporter gives the user the ability to easily transport heavy objects and removes the physical strain associated with lifting. The leash control allows the user to move around campus without the need to consciously steer the cart. The cart simply follows the movement of the user's hand. The joystick allows precise control of the cart in both the forward and reverse directions. The platform area is 26" by 21", which makes it large enough to transport most objects students carry.

## TECHNICAL DESCRIPTION

The motorized transporter consists of five main components: 1) control; 2) control circuitry; 3) motors and gearing; 4) lift; 5) battery charger. Fig. 8.5 shows a side view drawing of the motorized transporter and its components. Transporter speed and direction are controlled through a joystick or leash. The joystick is located inside the control handle and allows for precise 360-degree control. The leash cable extends, retracts, and swings side-to-



Fig. 8.4. Motorized Transporter.

side. These motions are sensed with potentiometers and cause the transporter to increase speed, decrease speed, and turn. Also located inside the control handle are a rocker switch that controls the lift, and a toggle switch that is used to select the operation mode.

The control circuitry consists of: 1) a 5-volt regulator; 2) a PIC16F876A processor; 3) three fully integrated automotive H-bridges. The regulator is used to step down the battery voltage from 12-volts to five-volts and maintains the voltage when the battery level drops. The processor converts the joystick and leash control signals to digital values. Using these values, the processor adjusts the duty cycle of the pulse width modulation (PWM) outputs to the motors, thereby controlling speed and direction. The H-bridges amplify the PWM signals to suitable levels for the motors.

The motorized transporter uses two 12-volt DC motors where each attaches to its own wheel. There is a five to one gear reduction between the motors and the wheels to reduce speed and increase torque.



Platform height is controlled with a scissors lift that extends 14" and can handle 50 pounds. Fig. 8.6 diagrams a top view of the lift components. The lift is driven by a 12-volt motor controlled by an H-bridge with a sprocket connected to the shaft. A gear connected to a threaded rod is driven by a chain connected to the sprocket. Two thresh washers hold the rod in place. The threaded rod passes through a ball screw that is inside of a track support. As the threaded rod rotates, the ball screw and support track move along the rod. There is a roller at each end of the support track for smooth movement.

The battery charger uses a UC3906 IC that monitors and controls the output current and voltage. The charger has three levels: 1) a high current bulk charge; 2) a controlled over-charge; 3) a standby state. The battery charger uses a standard wall

outlet for power.

The total cost to build the motorized transporter was \$731, which included all of the hardware needed to build the enclosure.

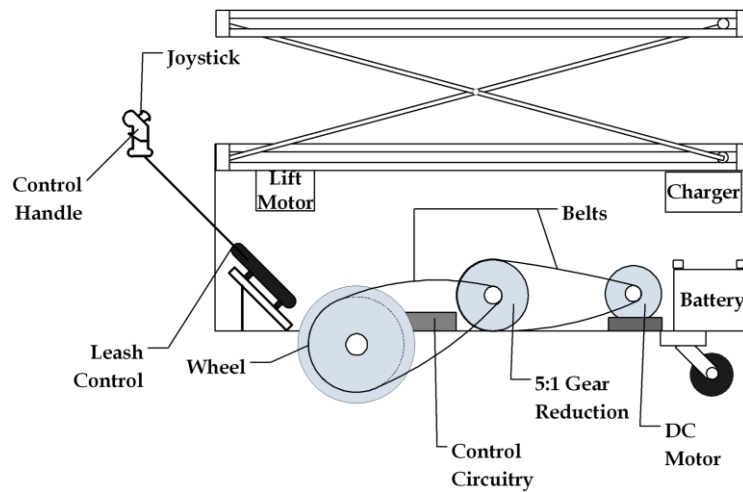


Fig. 8.5. Side View of Motorized Transporter.

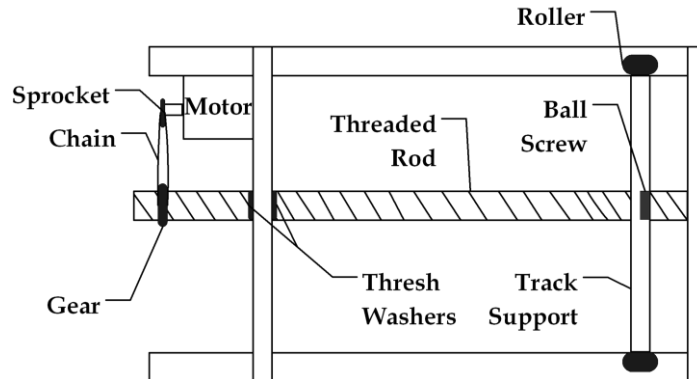


Fig. 8.6. Top View of Lift Components.

# DOOR MONITOR

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## INTRODUCTION

The door monitor was designed for a children's facility that faced the risk of having certain children leave the premises unsupervised. The door monitor consists of a transmitter and a receiver (see Fig. 8.7). The transmitter device attaches to the child and is designed to be: 1) portable; 2) small; 3) durable; 4) inexpensive. The receiver module is unobtrusively located at the doorway and is able to detect multiple transmitters.

## SUMMARY OF IMPACT

The door monitor system allows workers to supervise exits much more effectively. This increases the children's safety. Also, this design is simple enough to allow a facility to easily and inexpensively replicate or replace the transmitters. Upon delivery of the system, an adaptive equipment engineer for the facility remarked, "This is exactly what we needed." The transmitter is durable and easy to use.

## TECHNICAL DESCRIPTION

The transmitter consists of three main components: 1) a 3-volt power supply; 2) a processor; 3) an RF transmitter. The block diagram for the transmitter is shown in Fig. 8.8. This device's dimensions are three inches by two inches by two inches. It has a clip that attaches to a belt loop or wheelchair.

The three volt power supply is composed of two AAA batteries connected in series. The batteries are placed in a battery compartment on the backside of the circuit board and a switch is used to allow power to flow throughout the circuit.

The processor, a PIC16F876A, controls the transmitter. This processor cycles the transmitter on and off to decrease power consumption. The transmitter is a LINX 418 MHz device that uses a 50 ohm whip antenna. To help conserve power, the transmitter's sleep mode is utilized by the processor.



Fig. 8.7. Transmitter and Receiver.

The receiver consists of six main components including: 1) a door switch; 2) an alarm reset; 3) a processor; 4) a receiver; 5) an alarm; 6) a five volt power supply. The block diagram for the receiver is shown in Fig. 8.8. The receiver must be positioned so that the entire doorway is within range of the receiver. The range at which the receiver can detect the transmitter is determined by controlling the power at the level adjust input on the transmitter. Based on facility requirements, the detection range is set to approximately six feet. This requires the receiver to be placed directly adjacent to the doorway.

The five volt power supply is an AC/DC converter that is plugged into a wall outlet. The power to the circuit is controlled by a power switch mounted on top of the receiver. The receiver is connected to a door switch that tells the receiver whether the door is open or closed. A piezoelectric speaker is mounted to the top of the receiver. This speaker is used as the alarm, and a potentiometer is used for volume control.

The receiver processor is a PIC16F876A and is used to control the alarm. When the door is opened, the door switch tells the processor to search for a transmitter. The processor actuates the alarm once the receiver sees the transmitter. The receiver is a LINX 418 MHz device. Once the door is opened and the processor determines that there is a transmitter

in the area, the alarm is sounded and the user must press the reset button to silence the alarm. The processor will then wait ten seconds before it starts searching for the transmitter again.

The cost for the receiver was approximately \$80, and the cost for each tag was approximately \$70.

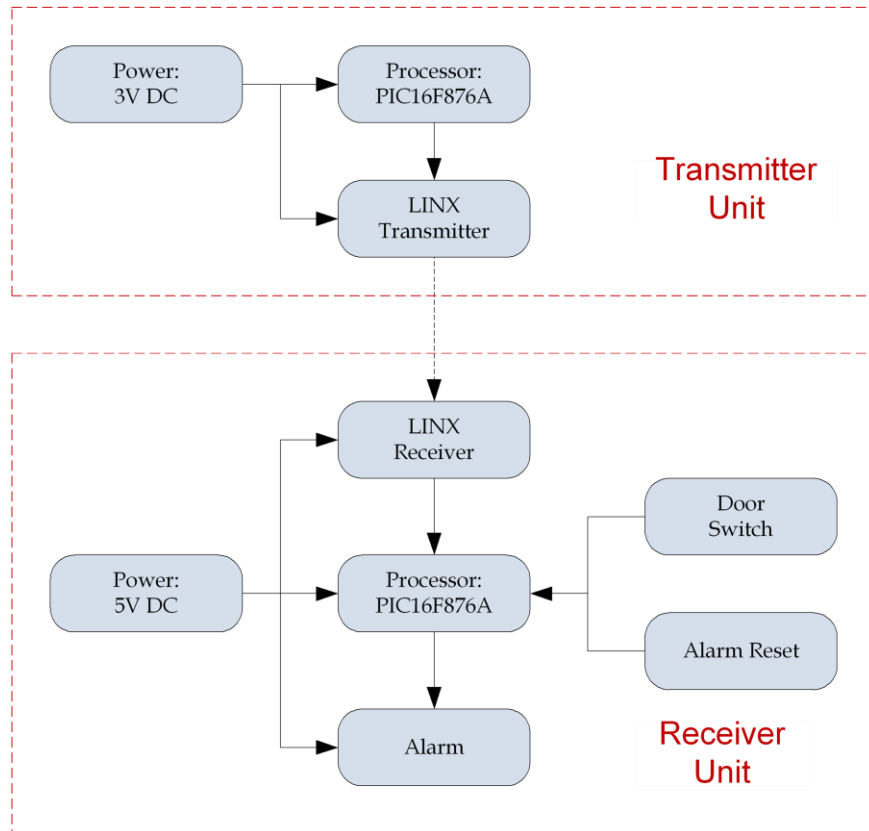


Fig. 8.8. Block Diagram.

# PRIVATE DISTRIBUTION MAILBOX ALERT SYSTEM

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## INTRODUCTION

The private distribution mailbox alert system is a continuation of an earlier senior design project. The previous system was designed for one mailbox. This project expands the design: 1) to provide functionality for multiple mailboxes; 2) to call individual users when mail is received; 3) to provide an interface for a mailbox user to change the phone number that is called. This system eliminates the need to make a trip to their mailbox unless mail is actually present. Whether the user calls into the system or the system calls the user, the user will know the status of his or her mailbox at any time of day.

An insert with infrared light sensors is placed at the base of each mailbox to detect mail. A central device connects to and polls each insert every 15 minutes. The central device consists of four microcontrollers as well as integrated circuits that: 1) keep time; 2) log each user's mailbox status; 3) store audio; 4) place and receive calls from a standard phone line. The device logs the date and time a user receives mail and dials out to the user's stored telephone number to play an audio message indicating that mail is present. Each user may also call into the system and enter his or her unique four-digit user identification number to check mail status or change his or her stored telephone numbers.

The key requirement for this design is the use of light sensors to detect mail. This is the patent-pending idea of the project's client and distinguishes the product from other products on the market. The use of infrared light sensors eliminates the potential for false readings because the light is only reflected back when mail is in the mailbox. Other systems, which use motion to detect mail, might cause false readings when the mailbox door is opened or closed.



Fig. 8.9. Private Distribution Mailbox Alert System.

## SUMMARY OF IMPACT

The private distribution mailbox alert system is intended to be used where clusters of USPS-approved private distribution mailboxes are present, such as in an assisted living apartment complex. The system benefits users with limited physical mobility by eliminating unnecessary trips to their mailboxes. It allows users to know whether or not mail is present in their mailboxes with little effort.

## TECHNICAL DESCRIPTION

The previous mailbox alert project developed a structure of four PIC 16F876 microcontrollers, one to interface with the phone chip, the voice chip, the real time clock chip, and the infrared mail detection sensors, respectively. This project builds on the previous project to create a fully functional prototype using custom printed circuit boards, and it provides added functionality. This includes developing a communication scheme and commands between each microcontroller, adding outgoing call functionality, supporting multiple mailboxes, and adding the ability for users to change



telephone numbers. The system block diagram is shown in Fig. 8.10.

A standard wall outlet is utilized to transform 120-volt AC power into five volt DC. The microcontrollers are arranged so that each receives data from one microcontroller and transmits data to another. In this manner, data originating from one microcontroller is addressed to be received by another microcontroller and will propagate loop-wise through the system until received by the desired microcontroller.

A Dallas Semiconductor DS1305 real time clock chip provides an alarm every 15 minutes for the sensors to check for mail in each of the mailboxes. Each mailbox uses three bytes of RAM on the real time clock chip to store the hour, minute, day, and month that mail is received (these bytes are cleared when mail is not present). For each mailbox with mail, the device calls the owner using a Xecom XE0068DT Data Access Arrangement chip through a standard telephone line. As soon as a user answers the phone, or the call is forwarded to voicemail, a Winbond ISD4003 voice chip plays audio communicating over the phone line that mail has been received. Once the message has finished playing, the phone chip hangs up the phone line.

A user may also choose to call into the system for mailbox status. The phone chip detects and answers the incoming call, and the voice chip plays an initial audio message (“For mail status please enter your four-digit user identification number, for options please press pound”). The phone chip decodes what the user presses on his or her telephone keypad. If a valid user identification number is entered, the corresponding mailbox status is retrieved from the real time clock chip RAM. The voice chip plays a message back to the user indicating when mail was received or that no mail is present, and the phone chip hangs up the phone line.

Stored telephone numbers can be changed in the event that users are traveling away from home or if any of the mailboxes change individual users. Changing a phone number is accomplished by calling into the mailbox alert system. The user must press the pound key after hearing the initial system message. The system prompts the user to enter his or her user identification number and validates what the user has entered. The user may then enter a new ten digit telephone number and then the initial system audio message is played again.

The private distribution mailbox alert system cost \$814 to develop.

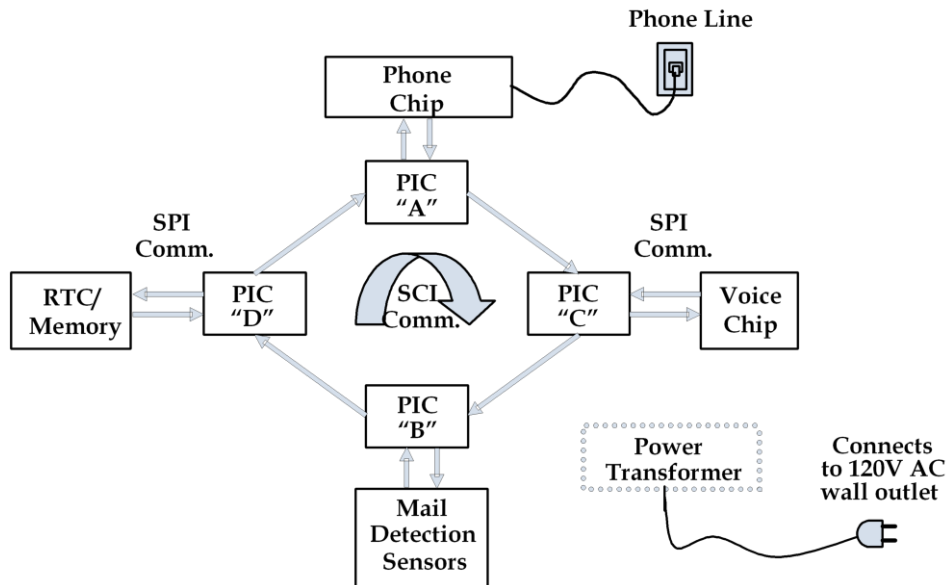


Fig. 8.10. System Block Diagram.

# AUTOMATIC TOILET PAPER DISPENSER

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## INTRODUCTION

The client, a local center for individuals with developmental disabilities, supports approximately 50 adults. The center has problems with clogging toilets resulting from excessive toilet paper use. The automatic toilet paper dispenser solves this problem by limiting the amount of toilet paper used per stall visit (see Fig. 8.11). A person waves his or her hand in front of the sensor, and the device unrolls a set amount of toilet paper. After a preset number of dispenses, no additional toilet paper is given. An automated unit is needed because privacy concerns prevent staff from directly monitoring toilet paper use. While automatic paper towel dispensers are now prevalent, no known automatic toilet paper dispensers are commercially available.

## SUMMARY OF IMPACT

The automatic toilet paper dispenser increases the independence of the clients by allowing them to use restrooms without supervision. Greater privacy is also achieved by requiring the user to close the stall door before toilet paper is dispensed. Although the device can be "fooled" into thinking that there is a new visitor to the stall by opening and closing the door, the act of getting up and opening the door is likely enough to discourage additional use. Through modification, the device could be outfitted for home use, which would help decrease the clients' reliance on others.

## TECHNICAL DESCRIPTION

The system has ten main components (see Fig. 8.12). The device is battery powered to provide safer operation and allow installation in areas that do not have access to standard wall outlets. To prevent unnecessary power consumption, the device is powered only when the stall is in use. To accomplish this, a magnetic reed switch and bar magnet are mounted to the stall door. When the door opens, the switch is open, which breaks the circuit and cuts off power to all of the electronics. When the door is



Fig. 8.11. Assembled Device.

closed, the proximity of the bar magnet to the reed switch closes the circuit and powers the electronics. Since the electronic components and the motor require five volts to operate correctly, a voltage regulator is used to drop the input voltage from the batteries down to five volts. A low dropout voltage regulator increases battery life by allowing the batteries to be used further into their charge cycle than a typical voltage regulator would allow. The estimated battery life is over 300 days for six D cell batteries.

The dispenser uses a capacitive transducer to detect when the user wants more toilet paper. A capacitive transducer allows non-contact detection, which

provides a more sanitary method of activation. To increase the sensing range, a metal sheet mounted to the side of the enclosure is used as a sensing electrode. The size of the electrode can be adjusted to increase or decrease the sensing range. A hand within three to four inches of the electrode will trigger a sense. Starting the motor could cause momentary changes in the output voltage of the voltage regulator that could cause false touches to be recorded by the sensor. To prevent this, the capacitive transducer runs off its own voltage regulator.

A microcontroller detects touches from the capacitive transducer and controls the stepping pattern used to drive the motor. An internal counter is maintained to track the number of dispenses left. Once this counter reaches zero, the controller will no longer respond to touches signaled from the sensor. The microcontroller interfaces with an array of light emitting diodes (LEDs) indicating the number of dispenses left. The array also features an LED controlled by the voltage regulator that indicates when the batteries need to be replaced.

A stepper motor is used to drive the roller because it allows precise control of the amount of toilet paper to be dispensed and is easily controlled through a microcontroller. The toilet paper is unrolled by a pinch roller (see Fig. 8.13). The toilet paper is squeezed between two rubber rollers: the capstan and the idler. The capstan is driven by a motor, and the idler is allowed to turn freely. As the capstan is turned, the roll of toilet paper turns and gravity feeds the sheets through a chute and out of the enclosure. The pinch roller is superior to turning the entire roll, where the amount dispensed per revolution stays constant as the roll is used and the diameter of the roll decreases.

The overall cost of a single unit is about \$154.

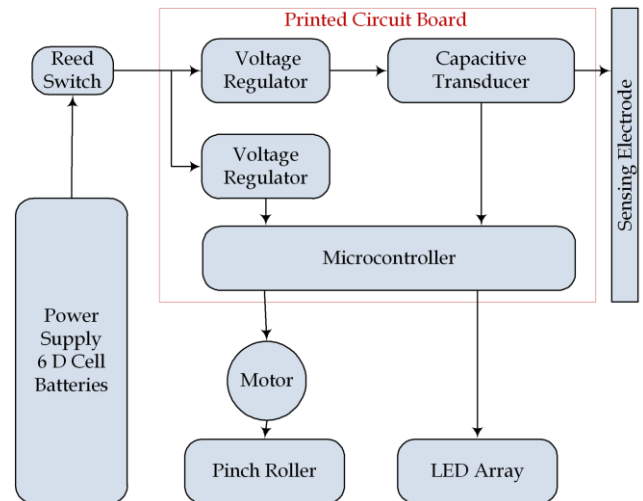


Fig. 8.12. Block Diagram.

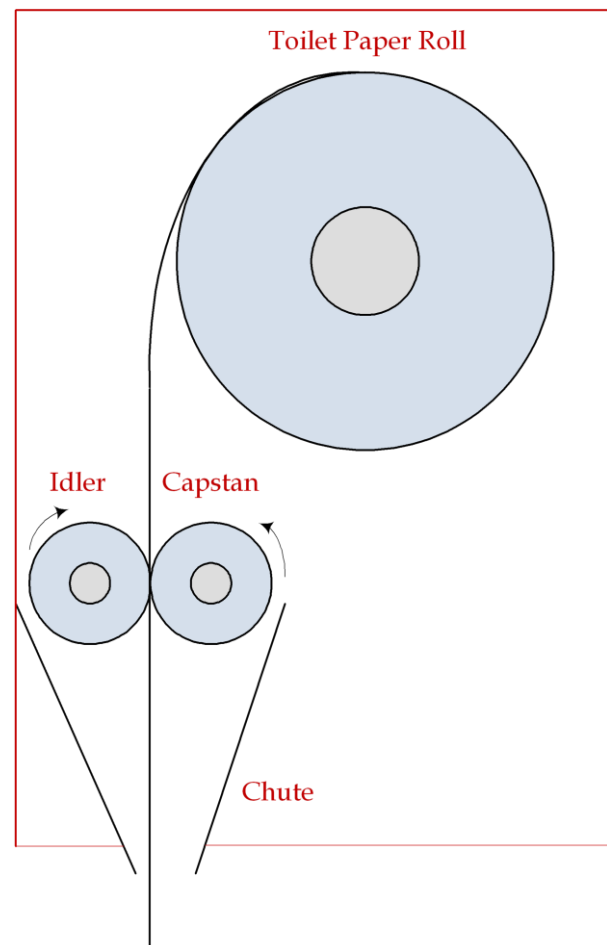


Fig. 8.13. Pinch Roller.

# POWER LINE INSTANT MESSENGER

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## INTRODUCTION

An assisted living home in North Dakota provides care for individuals with developmental disabilities. Given the limited staff of the home, automation is desired to improve services and quality of care. A major concern of the home is the proper use of appliances such as refrigerators and climate control systems. The power line instant messenger (PLIM) is a system that facilitates the communication necessary to efficiently control and monitor devices and appliances.

The basic idea of PLIM is to utilize the existing power lines of the home as communication channels. These communication channels serve as paths of automation. Messages and commands are sent over power lines to control and monitor devices and appliances. The PL 3150 smart transceiver from Echelon Corporation is integrated into the PLIM network to execute power line communication.

PLIM is a three unit prototype built to demonstrate the functionality of power line communication and appliance automation to the home. Two units demonstrate point-to-point communication over the power line network. The third unit functions as a PC interface and data logger. The completed prototype units are shown in Fig. 8.14.

## SUMMARY OF IMPACT

There have been several attempts to improve automation and services at the assisted living home. These include: 1) radio frequency (RF) devices that monitor access to pantries; 2) an automated medication dispenser that distributes medication at specific times; 3) a system that controls access to the refrigerator at each home. Each of the individually designed devices operates independently and requires separate training and maintenance. Such characteristics are not convenient for the assisted living staff.



Fig. 8.14. Complete Assembled System.

The PLIM system forms an integrated and unified network for the home automation tasks. Instead of several appliances and devices acting on their own, they share a centralized communication network. Consequently, less time is required for training and maintenance. Although the PLIM prototype currently does not control any appliances, existing ones such as the refrigerator door control as well as future applications can be integrated into the system with some effort. The PLIM network requires the availability of wall outlet power and is susceptible to power disruptions and excessive power line noise.

The clients at the assisted living home were excited about this system and planned new additions for the network. The assisted home services director stated, "They plan to have one or more in each house".

## TECHNICAL DESCRIPTION

The block diagrams of the three prototype PLIM units and their interconnections are illustrated in Fig. 8.15. The two point-to-point communication PLIM units, or instant messengers, are made up of three hardware parts: 1) a PL 3150; 2) an LCD; 3) a keypad. The PC interface and data logger simply consist of a PL 3150 and a serial cable.

At the core of each PLIM unit is a PL 3150 smart transceiver. The PL 3150 uses an Echelon protocol called LonTalk to transmit data over the power line. Custom code, programmed in the Neuron C language, establishes the communication network and implements point-to-point communication. The code also drives the LCD and keypad. Future applications only require minor code adjustments to add appliances or new PLIM units to the network. A wall transformer provides the 12-volts required to

power the PL 3150. In turn, the PL 3150 provides five-volts of power to the LCD and keypad.

The LCD uses a serial cable to transmit and receive data from the PL 3150. The LCD is programmed with a character map. This character map enables the PL 3150 to identify which character to print on the LCD according to which button is pressed on the keypad. The keypad uses an eight-bit parallel connector to communicate button presses to the LCD. The LCD then relays the information to the PL 3150, which prints the appropriate character on the LCD. The LCD and keypad interface allows messages to be generated and viewed without a computer at any target location.

The third PLIM unit provides a PC interface, which is accessed through an RS-232 serial cable. The PC logs and displays messages via software that reads data from the serial port. Data logging allows home supervisors to track network activities, such as refrigerator or pantry accesses.

The PLIM devices offer secure, sound, and efficient communication and control. Each PLIM uses a common wall outlet for power, so no batteries are required. The prototype system can be extended to incorporate a wide range of appliances and devices. Some appliances may require more effort than others to integrate into the network. The cost for one PL 3150 is \$99.95. The prototype system uses three PL 3150s, two LCDs (\$69.95 each), two keypads (\$13.13 each), and three enclosures (\$160.00), which brings the cost to \$626.01.

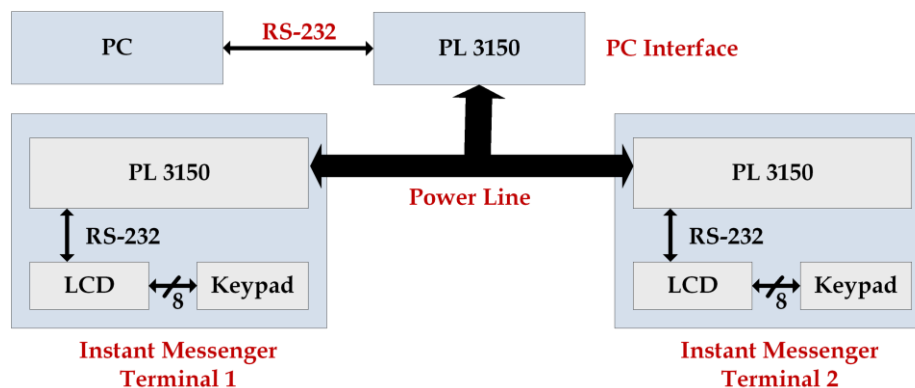


Fig. 8.15. Block Diagram of Prototype PLIM Units.



# HANDS-FREE MOUSE

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## INTRODUCTION

The hands-free mouse (HFM) was designed for a client who had a double-arm amputation following a farming accident (see Fig. 8.16). The device consists of a shoulder mounted package that communicates with a foot-pedal base via a three-wire bundle. The base controls the left, center, and right clicks. The arm package monitors all the movement functions normally associated with a mouse. The HFM pairs an arm-mount with a foot-pedal and offers advantages to the client over other products.

The HFM is not a perfect replacement of a mouse; response is somewhat sluggish by comparison. The cursor movement is not like that of a regular mouse. Instead, the cursor moves one of three set speeds selected by the amount of arm tilt (much like a joystick). Precision control is difficult at first but can be achieved with moderate use. During initial testing, most users were able to play online games with only a few minutes of practice.

## SUMMARY OF IMPACT

The HFM is flexible and offers advantages to people with a range of disabilities. It can be used by anyone that has full use of one leg and at least a four inch appendage with a good range of motion. The arm unit can be programmed to work with an arm or leg from either the left or right side of the body.

The HFM is a more financially feasible when compared to other available products. It also takes advantage of the client's ability to move his shoulders and legs, encourages movement, and promotes flexibility in the client's shoulder.

## TECHNICAL DESCRIPTION

There are two components to the HFM: an arm unit that is worn on the shoulder and a foot-pedal unit that controls the mouse clicks. The arm unit detects and transmits tilt data to the foot-pedal unit. The foot-pedal unit detects any clicks and communicates



Fig. 8.16. Arm Unit and Foot-Pedal Unit.

with the PC via USB 2.0. A block diagram is illustrated in Fig. 8.17. The three wires between the two units are: 1) five-volt power; 2) data; 3) ground. The wires meet at a connector between the two units. This allows them to be easily detached.

The arm unit (see Fig. 8.16) consists of an ergonomic enclosure manufactured by OKW that is specially designed to fit an arm or leg. This unit has a top-mounted on/off switch that is easily activated by the user's head. The enclosure contains a three-axis accelerometer that sends three analog signals to a PIC16F876A microcontroller. The PIC uses an onboard analog-to-digital converter along with programmed logic to determine the direction and magnitude of the tilt detected by the accelerometer. The PIC sends a seven bit data packet through the data wire to the foot-pedal. This transmission occurs every 20 ms at 9600 baud.

The foot-pedal (see Fig. 8.16) receives the signal from the arm unit. The data packet sent by the arm unit is received by a USB 2.0-compatible PIC18F4550. This data packet is then translated into change-of-position data for the x- and y-axes of cursor movement.

Given the capabilities of the client, clicking functions were built into the foot-pedal rather than the arm unit. There are six push buttons on the base's face that are seen as logic high or low by the PIC. These data are decoded into left, middle, and right click, plus killswitch and two programmable buttons. The PIC then combines the position and button data and writes them to a buffer that the PC reads via USB when it is ready. If the killswitch is active, the PIC writes all zeros to the buffer, indicating that there has been no activity from the mouse. This killswitch

allows the user to effectively turn the unit off without unplugging cables or removing anything.

The foot-pedal is powered entirely through the USB port, which supplies +5 volts and more than enough current. No drivers are required to operate this product as it emulates a standard mouse. The user only needs to plug in the foot-pedal with a USB cable and then turn on the arm unit. This product only works with a USB 2.0 port.

The entire product cost approximately \$230.

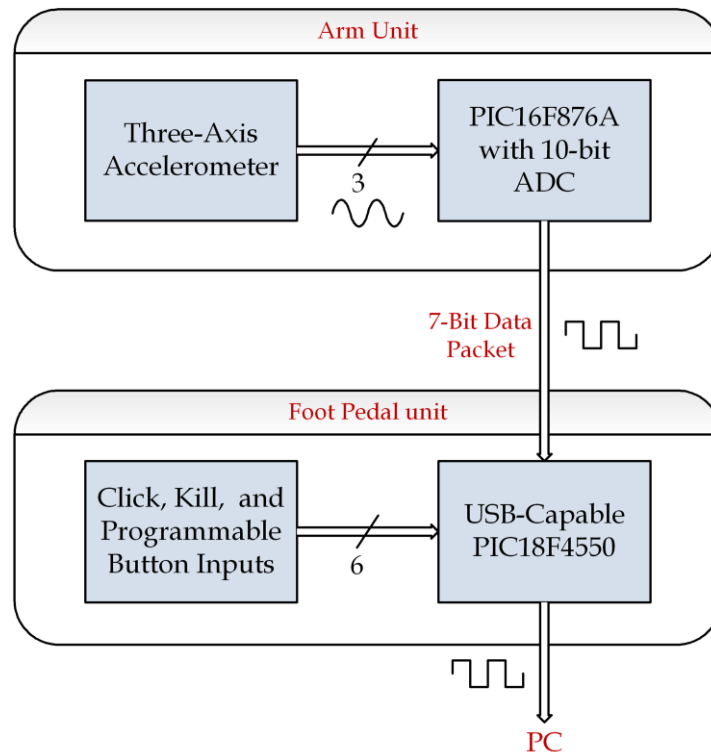


Fig. 8.17. System Block Diagram.

# CONTROLLED ACCESS REFRIGERATOR

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*Fargo, ND 58105*

## INTRODUCTION

Caregivers in an assisted living facility desired a way to control refrigerator access that is easy to use for residents with refrigerator privileges but also ensures that residents without refrigerator privileges are not given access. The controlled access refrigerator accomplishes these goals by securing the refrigerator door with an electromagnetic lock until an access key is inserted. The controlled access refrigerator: 1) ensures only authorized residents have access to the refrigerator; 2) provides a system interface that is robust, simple, and easy to use; 3) installs without modification to the refrigerator; and 4) is packaged in a professional manner.

The locking mechanism (see Fig. 8.18) mounts with a card reader on the side of the refrigerator. A key card is carried by the user and is inserted into the card socket to gain access. The control unit (see Fig. 8.19) mounts behind the refrigerator. There are currently no aftermarket devices of this type available.

## SUMMARY OF IMPACT

The assisted living home serves a range of clients, and each client requires a different balance between independence and direct supervision. The controlled access refrigerator allows the home staff to better meet the unique needs of each client. Lock simplicity enables residents of all skill levels to use the key card with ease.

## TECHNICAL DESCRIPTION

The controlled access refrigerator (see Fig. 8.20) is composed of three main parts: 1) the lock housing; 2) the key card; 3) the control unit. When a user inserts a key card into the card socket, a digital signal processor (DSP) validates the key card's code. Once validated, the control unit triggers the actuator circuit and opens the lock for 15 seconds.

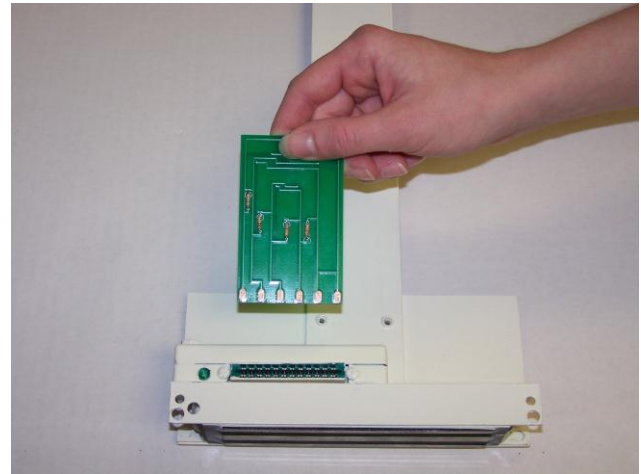


Fig. 8.18. Lock Housing.



Fig. 8.19. Control Unit.

The lock housing contains: 1) an electromagnetic lock; 2) a card reader; and 3) two LED indicators. With a pulling force of over 300 pounds, the electromagnetic lock secures the door with sufficient force to control refrigerator access. LED indicators provide a quick and easy way for the assisted living home caregivers to determine whether or not the

lock is active. The lock mechanism is easy to install without modifying the refrigerator; installation relies only on existing bolt holes.

Key cards are distributed by the home staff and allow card owners to access the refrigerator. To gain access, a resident simply inserts his or her card into the card reader on the lock housing. When the key is inserted, it receives power over the +3.3-volt channel (see Fig. 8.21) and returns outputs INT and D1-D3 to the DSP. Data lines D1-D3 provide the lock combination of the card. The simplicity and rigidity of the printed circuit board design give the key card higher durability than most other key card options; the card will still operate if washed.

The control unit houses: 1) the DSP controller; 2) the actuator circuit; 3) the power supply. The DSP controls system operations and has sufficient processing power for alternate authentication schemes, such as biometric authentication. The key card's INT output triggers an interrupt on the DSP to signify the presence of the card. The DSP then performs an analog-to-digital (A/D) conversion on the three channels D1-D3. An average of 16 conversions is compared to pre-assigned ranges for each output. If the combination is valid, the DSP outputs 3.3 volts to the actuator circuit. The actuator circuit buffers the DSP output and then uses a transistor to switch a three-volt relay, which releases

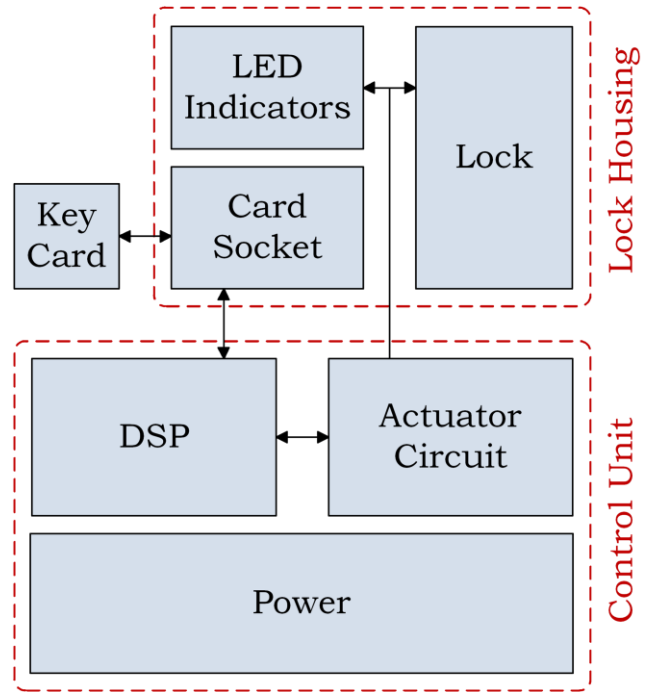


Fig. 8.20. Device Block Diagram.

the electromagnetic lock by cutting its 12-volt power supply.

The cost of the assisted living home unit was about \$650.

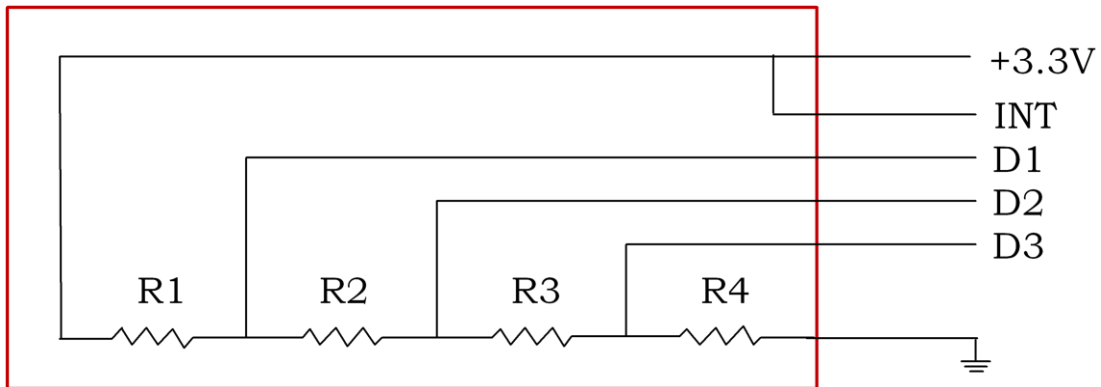


Fig. 8.21. Key Card Schematic.

# AUTOMATIC LOCKER DOOR OPENER

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## INTRODUCTION

An activity center employs individuals with various disabilities. One employee with cerebral palsy lacks sufficient finger control and strength to open the door to his work locker. The automatic locker door opener is a device that opens a locker door with the push of a button.

The automatic locker door opener operates by lifting the door latch with a solenoid and then propelling the door open with energy stored in a spring. The door can be opened by pressing a button on the exterior of the door or by using a remote control (see Fig. 8.22). The solenoid for lifting the door latch and its corresponding control circuitry are enclosed on the inside surface of the door. A power supply and transceiver for communicating with the remote are located in an enclosure mounted on top of the locker (see Fig. 8.23).

## SUMMARY OF IMPACT

The automatic locker door opener provides employees greater independence and freedom while at work. The door opener enables individuals to open their lockers at any time without needing to wait for staff assistance. This saves time for both the individual and the staff. The individual is also empowered to use his or her locker more frequently throughout the day. The design is robust and reliable.

## TECHNICAL DESCRIPTION

The automatic locker door opener has three major components: 1) the locker unit; 2) a power supply and transceiver unit; 3) a remote control. The system is expandable to multiple lockers. In this case, only the locker unit must be duplicated and installed on each desired locker. All lockers share the same power supply and transceiver unit. A block diagram of the interconnection of these units is shown in Fig. 8.24.



Fig. 8.22. Locker Button and Remote Control.

The locker unit mounts to the locker door (see Fig. 8.23). The solenoid that lifts the locker door latch has greater lifting capacity than is typically needed. This provides reserve capacity for a sticky or jammed latch. To reduce mechanical wear on the solenoid and latch, the solenoid is driven with a PWM signal that is gradually increased until motion of the latch is detected. The PWM signal is maintained at the lowest level that provides upward motion of the latch. In this way, the solenoid applies the minimum amount of force needed to lift the latch each time it is opened. If the solenoid is unable to lift the latch in a time period of one second, the microcontroller shuts off the solenoid. At this point the cause of the jam must be determined. Each locker microcontroller saves statistical data regarding the PWM control signal as well as overall locker use. When needed, this data is displayed on the remote control's LCD.

The power supply mounts above the locker (see Fig. 8.23). The solenoid used to lift the locker door latch requires a 12-volt DC source capable of providing 30 amperes. This high current is needed for only a few



hundred milliseconds each time the door is opened. A rechargeable 12-volt DC sealed lead acid battery provides this low duty-cycle high current. The transformer and circuitry output a regulated 13-volt DC to charge the battery. A regulated five-volt DC is required for the microcontroller and transceiver.

The remote control is capable of opening any locker on the system as well as recovering stored data from each locker. During use, the remote transmits an eight-bit number comprised of a seven-bit locker ID number and a single command bit. The command bit tells the locker with the matching ID whether to open the door or transmit its stored data. The power supply can only provide current to open one locker at a time. When a locker is commanded to open from a remote all other lockers deactivate their door buttons and wait for the remote to verify that the other locker is no longer in use.

The solenoid has adequate force to lift the locker latch, even under load. The enclosures and packaging of the power supply and locker unit are designed to withstand much physical abuse. The range of the remote is approximately 125 feet indoors. The use of a higher voltage solenoid would lower the current requirement of the power supply and make for a simpler and more efficient design.

The design cost about \$550, with additional locker units costing \$210 each.



Fig. 8.23. Locker Unit and Power Supply.

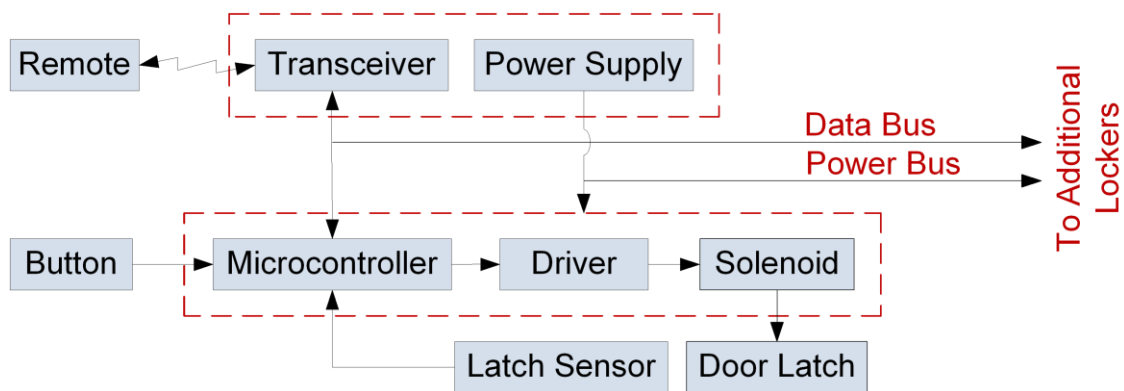


Fig. 8.24. Automatic Locker Door Opener Block Diagram.

# COMBINATION HAND AND ELECTRIC TRICYCLE

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## INTRODUCTION

The combination tricycle was designed for a client who is paralyzed from the waist down but retains the full use of her upper body. The tricycle provides the client with a new mode of transportation (see Fig. 8.25). The tricycle is driven by an electric motor or a hand crank. Mounted on the tricycle is a display unit that includes: 1) a speedometer; 2) an odometer; 3) a battery level indicator.

While there are several similar options on the market today, this tricycle uniquely combines a hand crank and an electric motor into one solution.

The tricycle combines both functions into one cost-effective product.

## SUMMARY OF IMPACT

Since the tricycle is powered by either a hand crank or an electric motor, the tricycle accommodates the client well. The tricycle's hand crank provides excellent upper body and aerobic exercise. The motor allows for casual recreation and assists in the transport of small items. The tricycle gives her the opportunity to get out and enjoy the world. The client was particularly excited about this tricycle because it brings back memories from her childhood



Fig. 8.25. Combination Hand and Electric Tricycle.

when she had a hand-driven tricycle.

## TECHNICAL DESCRIPTION

The tricycle has two modes of operation: hand-driven and motor-driven. Both modes operate independently, so the rider can select which mode to use at any given time. A hand crank attaches to the front wheel and replaces the original foot pedals. A motor is attached to the rear wheels. The main modifications of the tricycle include: 1) a motor; 2) a hand crank; 3) batteries; 4) a PIC microcontroller; 5) an LCD display. Fig. 8.26 shows how these components integrate with one another.

The motor is a 24-volt 300-watt brushless DC motor. It can easily drive the tricycle with up to a 250-lb load. It is connected to the rear drive axle with a gear ratio of three and a half to one to permit speeds in a range of zero to 25 MPH. The motor speed is controlled by a thumb throttle, which is simply a 5k potentiometer that is connected to the motor controller unit. The thumb throttle has a spring resistance so that when the user releases the throttle, the motor disengages and the tricycle coasts. If a more urgent stop is necessary, a hand brake is available. For safety reasons, a 30-amp circuit breaker provides current protection for the motor. Should the circuit breaker trip, it can be reset through the manual switch next to the batteries.

The hand crank drives the front wheel and operates independently from the motor. A footrest replaces

the tricycle's original foot pedals which are not needed by our client. The crank is attached to a newly fabricated handlebar assembly. The new handlebar assembly is designed to withstand the additional stress that results during hand crank use. The hand crank attaches to the front wheel through a chain and a set of sprockets. A spring tensioner keeps the chain taut.

Two 12-volt, 18-amp rechargeable batteries are attached in series to provide the necessary 24-volts to power the motor. At half throttle, the batteries can power the motor for approximately one hour. One of the batteries also provides the power for all of the electronics on the tricycle. The batteries are recharged using an included wall charger.

Using pulses from an optical sensor that is attached to the drive axle, the PIC microcontroller computes and displays speedometer, odometer, and battery level information. The sensor sends 24 pulses for every rotation of the axle, which ensures speedometer accuracy to within one MPH. The PIC also uses its analog-to-digital converter to read the current voltage on the batteries. This measurement is then converted into a ten-bar battery level indicator. The PIC updates the LCD panel with current speed, distance, and battery level values eight times per second.

The project cost approximately \$2500.

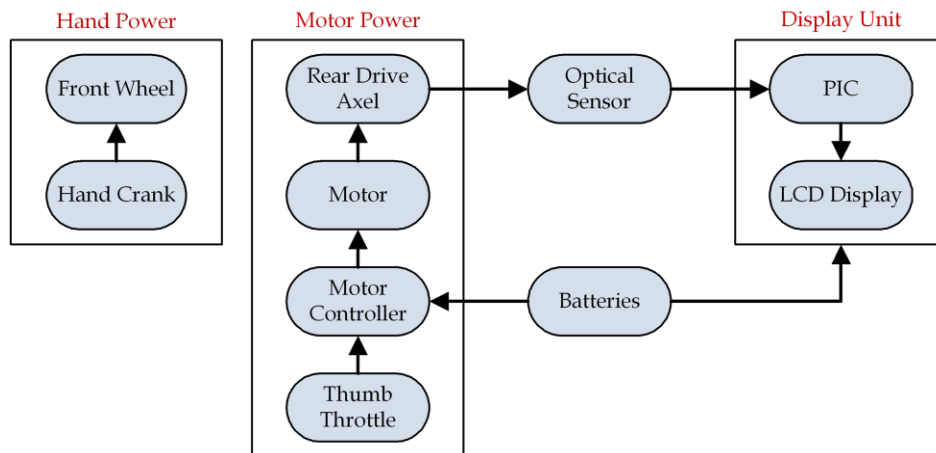


Fig. 8.26. System Block Diagram.

# THE GIZMO

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## INTRODUCTION

The Gizmo is a device that entertains and educates children at a local center for children (see Fig. 8.27). This center nurtures individuals with physical and mental health impairments through creative combinations of special education and training. The gizmo focuses on helping individuals understand the phenomenon of cause and effect through an interactive and entertaining interface. The device is: 1) easy to use; 2) durable; 3) wheelchair accessible; 4) safe; and 5) adjustable to three levels of difficulty.

The Gizmo includes: 1) a five-button interface; 2) a 16-by-16 colored LED display; 3) two speakers; and 4) three fans. Using a switch, the instructor selects the appropriate level of difficulty for the user. When the student pushes a sequence of one or more buttons, he or she is rewarded by hearing music, seeing blinking lights, feeling blowing air, or a combination of the above. Different sequences produce different combinations of sound, light, and air. A sequence length of one, two, or three corresponds to the easy, medium, and hard levels, respectively. These short sequences match the needs of the center and its clients. The Gizmo is different from other products on the market due to its number of sensory outputs, flexibility, and educational component.

## SUMMARY OF IMPACT

The children's center is continuously looking for novel devices to teach and engage children. The center serves many children with pervasive developmental disorders (PDD). Children with PDD often respond positively to lights, sound, and air pressure. The Gizmo provides these features in an effective and creative way. As children progress through the three levels of difficulty, they learn cause and effect relationships. Knowing cause and effect, children are equipped to independently operate many everyday devices such as light switches.



Fig. 8.27. Completed Gizmo Device.

The Gizmo is entertaining and helps prevent children from getting bored or frustrated. The gizmo's outputs are well suited for young users due to the use of bright colors and fun sounds. Each button has a different texture, which helps children with visual impairments identify them. As a table-top device, the gizmo is wheelchair accessible. Such features make gizmo a unique device that can be used by most students at the center.

## TECHNICAL DESCRIPTION

The gizmo (see Fig. 8.28) is composed of twelve primary components: 1) a 5-button interface; 2) a main microcontroller; 3) a slave microcontroller; 4) an instructor accessible switch; 5) flash memory; 6) two digital-to-analog converters; 7) two low-pass filters; 8) two amplifiers; 9) two speakers; 10) LED drivers; 11) a 16-by-16 LED display; 12) several fans.

The backbone of the device is a PIC16F876 microcontroller. The PIC is responsible for coordinating and managing system components and tasks. As the device powers up, the main microcontroller scans the instructor-accessible switch in order to set the level of difficulty, then it waits for user input. The PIC compares the user



input sequence to predefined sequences stored in its memory. If a sequence matches, then the chip activates the appropriate combinations of outputs.

If the output requires music or sound to be played, then the main microcontroller uses a universal asynchronous receiver/transmitter (UART) bus to send the desired file number to the slave microcontroller. The flash memory and slave microcontroller communicate across a serial peripheral interface (SPI) bus. The PIC receives data from the flash memory at 128-kbps. The flash memory sends serial data in 512-bit packets to the slave microcontroller, which converts it into 8-bit parallel data and writes each word to a digital-to-analog converter (DAC) at the appropriate time. The signals are then filtered using low-pass filter (LPF) chips. These filters are linear phase to ensure constant group delay and minimal waveform

distortion. After filtering, the signals are sent through audio amplifiers and output to the speakers. The result is an eight-bit stereo quality sound with an eight-kHz sample rate.

To create a flashing pattern on the LED display, the main microcontroller sends control data via SPI bus to the two MAX6960 matrix graphic LED drivers. These chips provide individual intensity and pattern control of the LEDs using a minimal number of data and control lines.

When fans are needed, the main controller activates the fan circuitry. The fan circuitry is composed of transistors and diodes that are required to properly drive the fans.

The device cost about \$520.

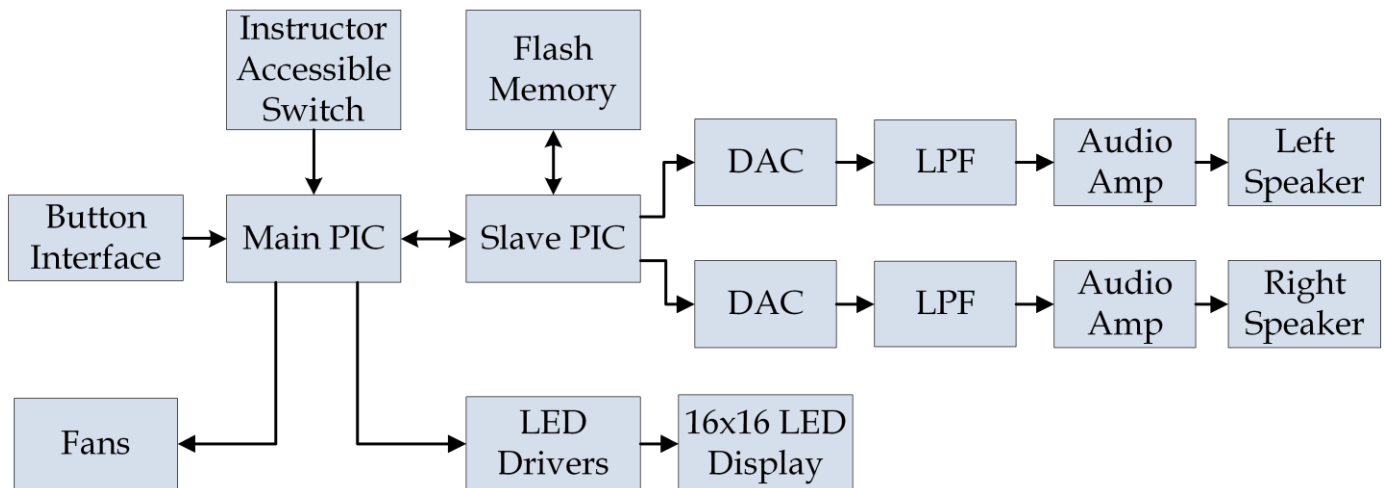


Fig. 8.28. Gizmo Block Diagram.



