CHAPTER 6

THE NEW JERSEY INSTITUTE OF TECHNOLOGY

Department of Electrical and Computer Engineering
323 Martin Luther King Boulevard
Newark, New Jersey 07102

Principal Investigator:

John A. Zelano (201) 596-3534

Ultrasonic Cane For The Blind

Designer: Torr-Odd Hoydal
Disabled Coordinator: Dr. Thomas Findley
Kessler Institute For Rehabilitation, South Orange, NJ
Supervising Professor: John A. Zelano
Department of Electrical Engineering, New Jersey Institute of Technology, Newark, NJ 07102

INTRODUCTION

The motivation for this project was to design an electronic mobility aid for blind people. The most widely used primary mobility aid today is the long cane. The long cane has several limitations such as: a range limited to the length of the cane, typically one pace ahead of the user, difficulties detecting overhanging obstacles, and safe storage in some public places. The goal of this design is to improve upon the limitations of the long cane and to replace it, after a period of training using both a long cane and the Ultrasonic Ranger with the Ultrasonic Ranger as a primary mobility aid. The Ultrasonic Ranger circuitry is divided into separate modules. The first module is the ultrasonic ranging module. It sends out ultrasonic bursts of acoustic energy through an ultrasonic transducer and detects the echo that results from an obstacle in the beam path. The elapsed time between initial transmission and echo detection can be measured, and hence the distance to an obstacle can be calculated from the speed of sound in air. This time difference between transmission and corresponding echo provided by the ultrasonic ranging module is then converted into distance information in the interface module. The output of the interface module, derived from the distance information, is a DC voltage proportional to the distance from an obstacle. Finally this DC output is processed in the output module in order to provide an audible output with the frequency inversely proportional to the distance measured.

The prototype is fitted in a "flashlight-like" enclosure made of a PVC tube with an external battery pack as power supply, an earplug for the audible output, and a range of 0.9 to 35 feet (0.26 to 10.7 meters) shown in Fig. 1A.

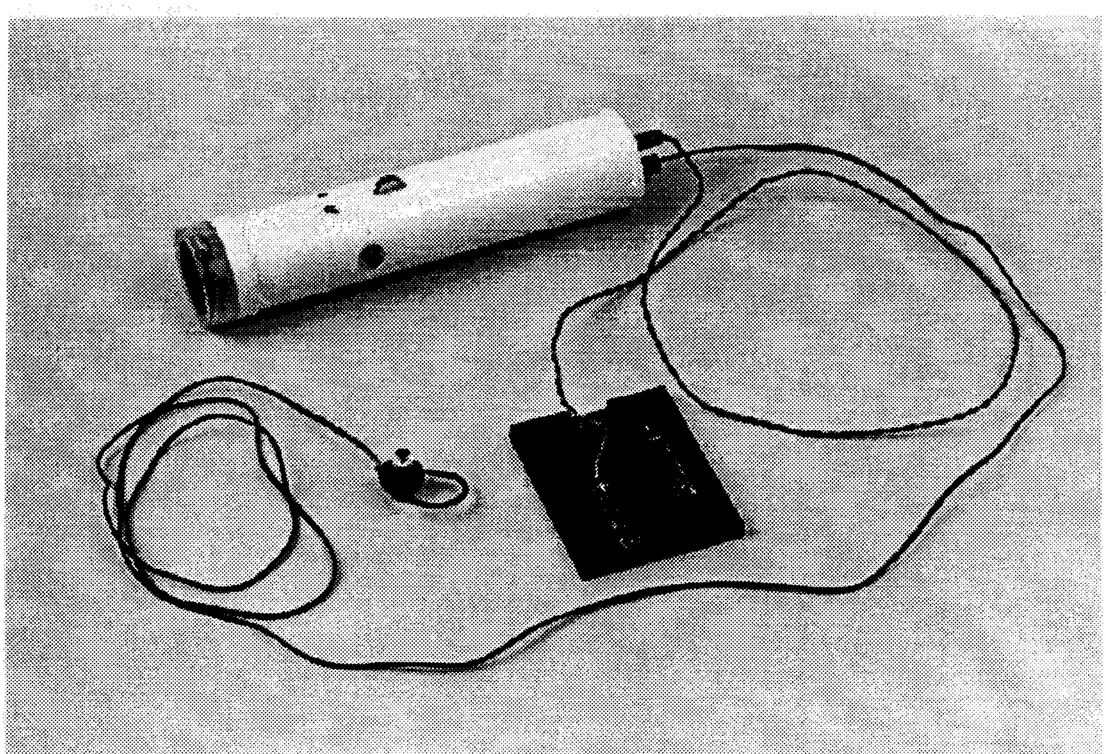


Fig. 1A. Ultrasonic Cane

SUMMARY OF IMPACT

The design of a small portable cane will be useful for the blind individual. It will make it easier for him to find his way on a daily basis without having to use the standard cane available for individuals with this disability. Since the cane is small and light, it is easily portable and can be taken anywhere. A lightweight rechargeable battery provides power. The ultrasonic cane also offers the additional capabilities to sense objects which lie overhead or obstacles that exist at distances farther than the length of a normal cane. As the user adjusts to listening to the tones that the cane emits as a function of distance, he will be able develop an intuitive feel for the distance an object is from him, thereby expanding his overall sensual perception. The device will provide a useful adjunct to the aids that blind individuals use on a daily basis to facilitate their lifestyle.

TECHNICAL DESCRIPTION

The electronic circuitry is divided into four modules (Figure 1B): the ultrasonic ranging module, the interface module, the output module, and the power supply module. The modular design allows for easy adaptation to other applications. A likely extension would be to add a vibrotactile output in order to facilitate deaf people. This could easily be incorporated into the output module. A detailed description of the different modules follows.

Ultrasonic Ranging Module

The detection system chosen was the Polaroid Ultrasonic Ranging Unit originally used as part of the autofocus system in the Polaroid Sonar Auto Focus Camera. It was chosen because of its low cost, adaptability to a lot of applications, and high reliability. It has several advantages over other ranging devices such as, laser, and infrared transmission and detection. The ultrasonic system can detect reflections from a clear plate glass window or door, while a laser system cannot because of the lack of scatter on the glass surface. The ultrasonic system also has a larger range compared to an infrared system and it can even detect reflections from a porous surface such as foam rubber. The Polaroid Ultrasonic Ranging Unit consists of two primary components: they are an ultrasonic acoustic transducer and the ranging circuit board (Figure 2). Together these components can detect the presence of, and distance to any

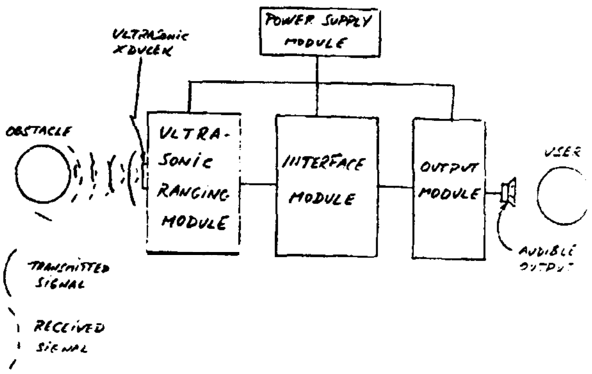


Figure 1B System Block Diagram

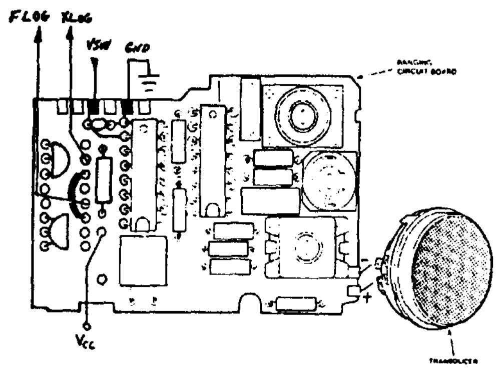


Figure 2 Block Diagram-Ultrasonic Ranging Module

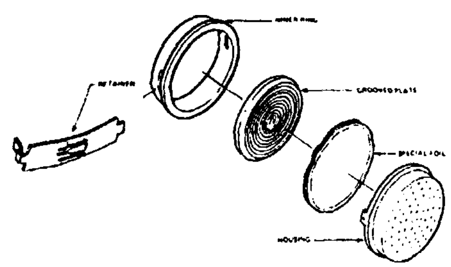


Figure 3 Electrostatic Transducer

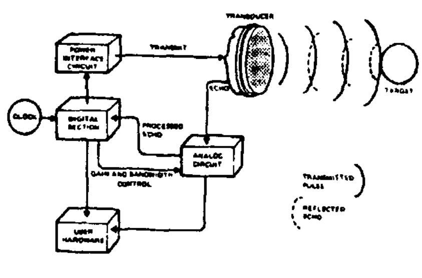


Figure 4 Block Diagram Transmitting/Receiving

obstacle within the specified measurement range of 0.9 to 35 feet (0.26 to 10.7 meters). The principal component in this device is the transducer (Figure 3), which acts as both loudspeaker and microphone. The moving element consists of a special, Polaroid manufactured gold foil stretched over a grooved plate. The grooved, metallic backplate in contact with the insulated side of the foil forms a capacitor which, when charged, exerts an electrostatic force to the foil thus transforming electrical energy into acoustical waves. Similarly the energy flow can be reversed to transform the returning echo into electrical energy. Polaroid Corporation offers three different electrostatic transducers; Instrument Grade, Environmental Grade, and the 7000 Transducer. The one used in this project is the Instrument Grade Transducer.

The ranging circuit board is the second main component of the system. It controls the operating mode (transmit/receive) of the transducer. It consists of three major sections: a digital circuit, an analog circuit and a power section (Figure 4). The following discussion refers to the modified ranging circuit board schematic (single frequency), and the waveforms applied to, and extracted from the ranging circuit board (Figures 5 & 6). The transmit/receive cycle is initiated by supplying the circuit board (Figure 5) with the VSW signal (Figure 6). Bringing VSW high starts transmission approximately 5 msec later. The transmitted signal is controlled by the digital logic drive signal XLG (Figure 6). XLG is a single-frequency signal consisting of fifty-six cycles at 49.41 KHZ lasting approximately 1 msec. All timing relations between transmitted signals and received echoes are determined from the leading edge of XLG. After this 1 msec high-frequency inaudible "chirp" is sent, the operating mode of the transducer changes to the receive mode and the unit then waits to detect the echo indicated by the signal FLG (Figure 6).

The received echo is first amplified and processed in the analog circuit before it is passed on to the digital circuit producing the signal FLG. The energy of the returned signal is greatly reduced over longer distances (return signal power at 35 feet is almost a million times weaker than at 3 feet). In order to compensate for this the gain and Q of the amplifier within the analog section is increased in eight steps, out to 13.3 feet (23.6 msec). Beyond 13.3 feet only the gain of the amplifier is increased while keeping the Q high (Figure 7). This tailored sensitivity

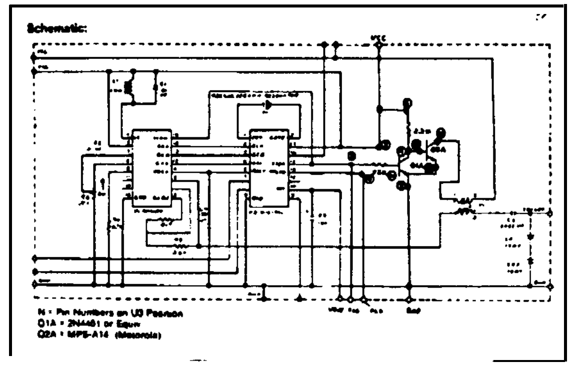


Figure 5 Modified Ranging Circuit Board Schematic

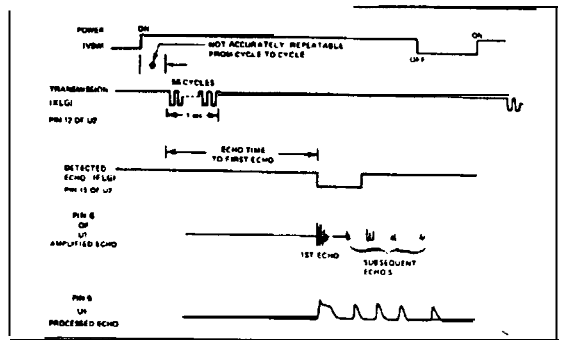


Figure 6 Waveforms on Ranging Circuit Board

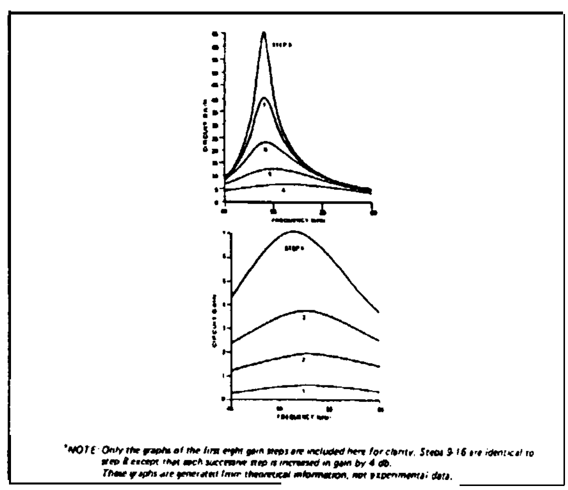


Figure 7 Polaroid Ultrasonic Ranging Unit-Gain vs Frequency

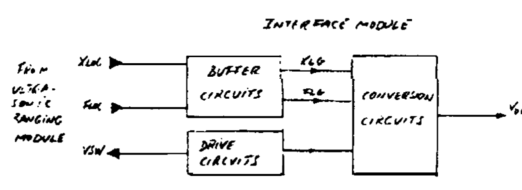


Figure 8 Interface Module Block Diagram

assures optimum performance over the entire operating range. The buffer circuits used to extract the signals XLG and FLG as well as the drive circuit to produce VSW are discussed in the interface module section.

Interface Module

The interface module provides the ultrasonic ranging module with the control-signal VSW, extracts the transmit and receive signals XLG and FLG, and converts the information to a DC voltage proportional to the distance from an obstacle which is fed to the output module (Figure 8).

This time-to-distance conversion is based on the knowledge of the characteristics of acoustical waves in air. The speed of sound in air at 68°F (20°C) is 1125 ft/s (343.2 m/s). It varies only slightly with humidity and is virtually independent of pressure and thus of height above sea level. Only temperature has some influence resulting in a 7% variation for a temperature variation from 32” to 104°F. In an application requiring very accurate distance measurements, this variation due to temperature change would have to be compensated for. But in this application, since highly accurate measurements are not required, the speed of sound can be taken to be approximately constant. With the above knowledge the time required to strike a target two feet away and to return to the transducer would be 3.55 milliseconds. This results in the following time-to-distance conversion factor: 1.777 ms/ft = 177.7 µs/0.1ft (5.826 ms/meter).

The following two alternative designs for the interface module will now be discussed: a Digital Counter & D/A versus an Analog Filter based alternative.

Digital Counter & D/A Alternative

The integrated circuits used are of CMOS type in order to minimize power consumption. This is essential because the system is battery powered. The digital-to-analog converter used is an AD7524. It is a CMOS 8-bit buffered multiplying DAC. This DAC was chosen because it is inexpensive, can be used for single-ended supply applications and has very low power consumption.

The following VSW drive circuit description refers to the waveforms shown in figures nine and ten. The VSW drive circuit consists of a CMOS 555 Timer which produce a 4.16 HZ square wave output with a 50 % duty cycle. This logic level output is buffered through a complimentary transistor drive stage with a power darlington at the output in order to provide enough current to drive the transducer. The output of VSW is then connected to the VSW terminal on the ranging circuit board (Figure 5).

The signals XLOG (transmission) and FLOG (echo detected) are tapped from the ranging circuit board (Figure 5) and buffered through the IC darlington drivers to give the buffered signals XLG and FLG respectively. XLG and FLG are connected to set their respective R-S latches. The XLG latch is reset by the leading edge of the logic level VSW signal, and the FLG latch is reset by the output of the XLG latch. The outputs of the two latches are the signals LC (latched transmission) and LE (latched echo) respectively (Figure 9).

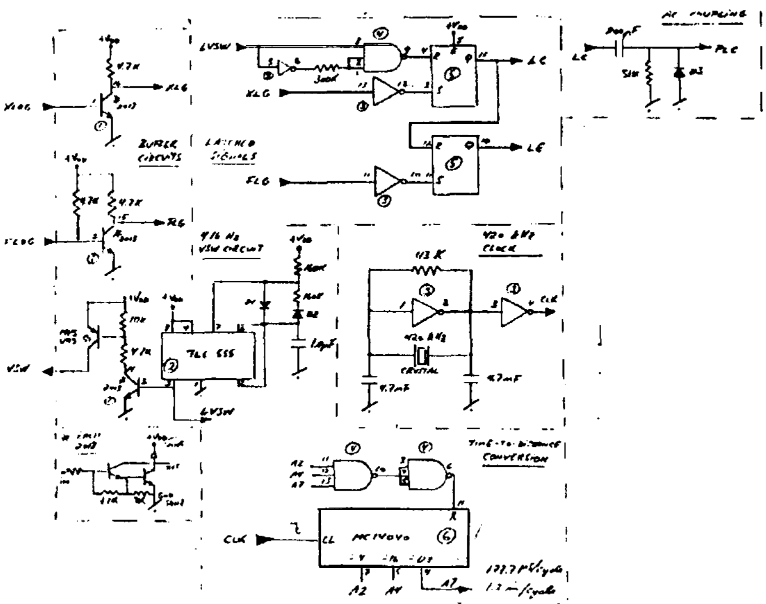
The 420 KHZ clock circuit is made of a buffered inverting Schmitt trigger oscillator with a 420 KHZ ceramic resonator in the feedback path. This reference is used to clock the 12-stage binary ripple counter which is wired to produce the time-to distance conversion signal, A7, of 177.7 µs per cycle or 1.2 inch per cycle.

The counter used to measure the time slot between transmission and echo detection is a dual synchronous up counter. It is reset through a coupling capacitor when transmission starts by the LC signal, and is clocked by the conversion signal A7. The condition that, either LE goes high or that the counter has reached its maximum count produces a STOP signal that halts the counter.

The STOP signal after stopping the counter triggers two cascaded monostables which after a delay of 1 msec allow the counter to settle and produce a 1 msec wide negative pulse, WR, that latches the count into the DAC. The DAC then converts the count into a DC voltage which is amplified through an op-amp producing a DC voltage output proportional to the distance from an obstacle. Finally this output is connected to the input of the output module.

Analog Filter Alternative

The circuits here are also of CMOS type in order to reduce the power consumption from the battery. The signals VSW, XLG, FLG, LC, and LE are obtained using the same circuitry as in the previous alternative. The 420 KHZ clock, the counter, and



IC #	V_{DD}	GND
1	9	8
2	8	1
3	14	7
4	14	7
5	[illegible]	8,7,6
6	16	8

IC #	V_{DD}	GND
7	16	8
8	14	7
9	14	7
10	16	8
11	17	3
12	8	4

IC #	DESCRIPTION
1	[illegible] 2003, 7 CH DARLINGTON DRIVER
2	TLC 555, CMOS TIMER
3	MM74HC14, HEX INVERTING SCHMITT TRIGGER
4	MC14023, TRIPLE 3-INPUT NAND
5	MC14044, QUAD TRI-STATE NAND RS LATCH
6	MC14040, 12 BIT BINARY COUNTER

IC #	DESCRIPTION
7	MC14520, DUAL SYNC. UP COUNTERS
8	MM74HC30, 8 INP NAND
9	MM74HC32, QUAD 2-INP OR GATES
10	CD4098, DUAL RETRIG. MONOSTABLES
11	AD7524, 8-BIT BUFFERED MULTIPLYING DAC
12	LM358, DUAL OP-AMP

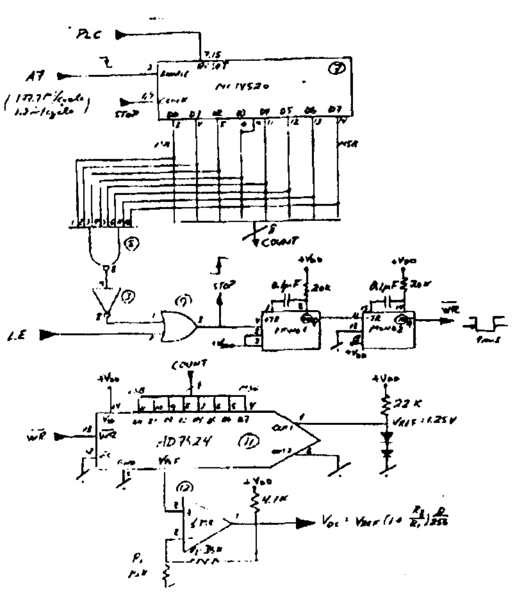


Figure 10 Digital Counter and D/A Alternative Circuit Diagram

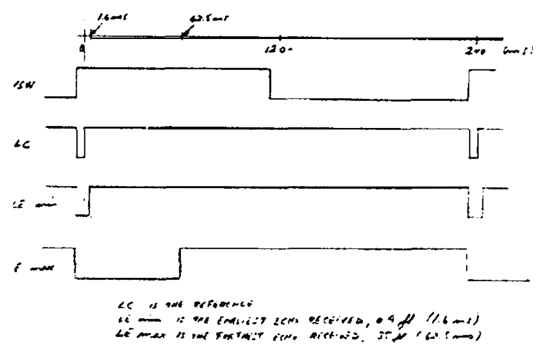


Figure 9 'liming Waveforms for D/A Altemativc

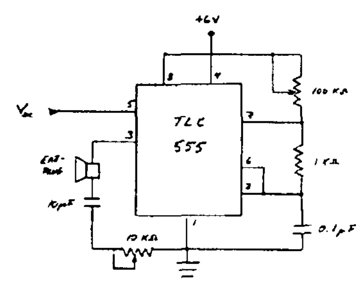


Figure 13 VCO Circuit Diagram

the DAC are all replaced by an averaging filter. Frequency and transient response graphs for the filter obtained using Microcap 5.0 are shown in figures 15 through 17. The entire circuit description and diagram are shown in figures eleven and twelve.

The latched transmission signal, LC, sets a R-S latch while the latched echo signal, LE, resets the same latch. The resulting output, PWM, is a pulse with pulse width proportional to the distance from an obstacle. The minimum pulse width is 1.6 msec, corresponding to the minimum range, 0.9 ft, of the ranging module. The maximum pulse width is 62.5 msec, corresponding to the maximum range of 35 ft for the ranging module. The pulse repetition rate is equal to the frequency of the VSW signal, hence it is 4.16 HZ (period=240 msec).

The filter averages the input pulse PWM and outputs a DC voltage which is equal to the average DC voltage of the input signal. The lowpass filter is used with buffered input and an op-amp gain stage at the output functioning as an integrator (averager). The filter itself is a third order tapered

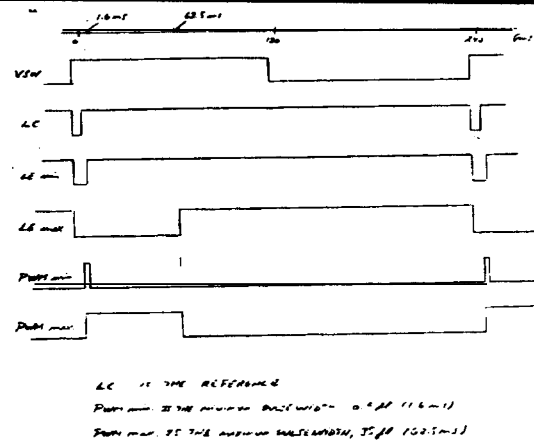


Figure 11 Timing Waveforms

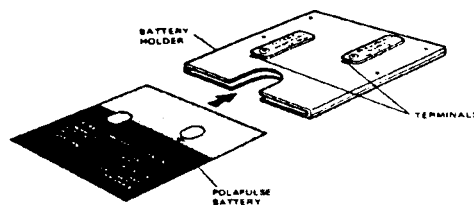
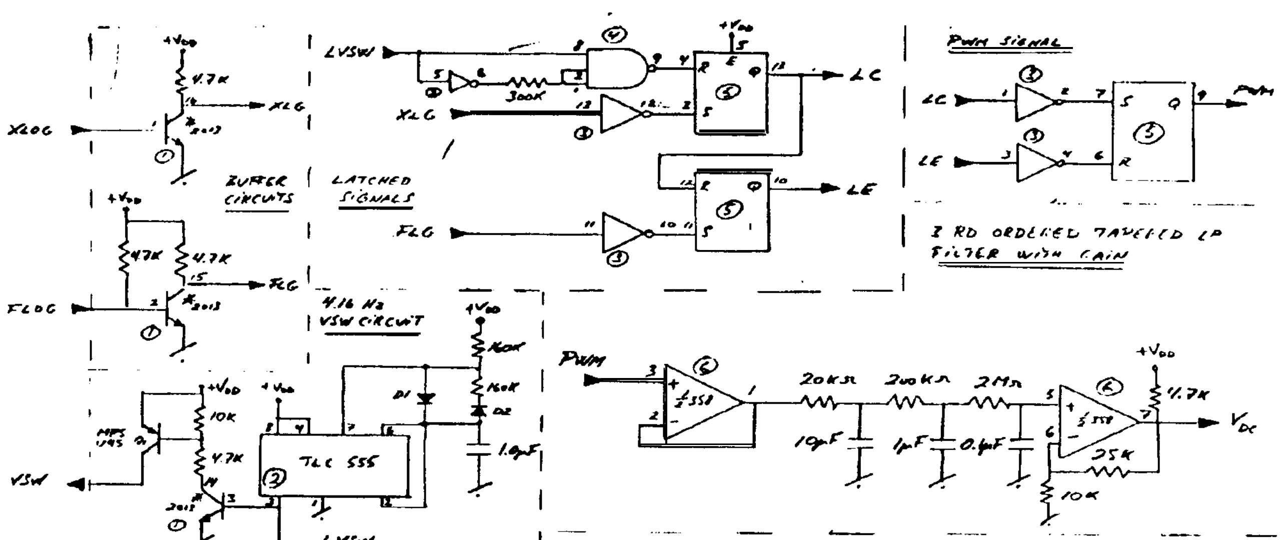


Figure 14 Polapulse Battery and Holder



IC #	V_{DD}	GND
1	9	8
2	8	1
3	14	7
4	14	7
5	16,15,14	8
6	8	4

IC #	DESCRIPTION
1	NTE 2013, 7 CH DARLINGTON DRIVER
2	TLC 555, CMOS TIMER
3	MM74HC14, HEX INVERTING SCHMITT TRIGGER
4	MC14023, TRIPLE 3-INPUT NAND
5	MC14044, QUAD TRI-STATE NAND R/S LATCH
6	LM 358, DUAL OP-AMP

Figure 12 Analog Filter Alternative Circuit Diagram

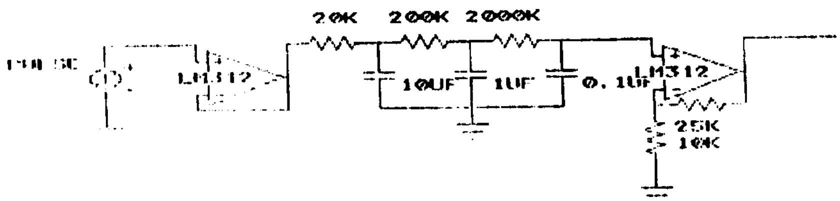


Figure 15 Third Order Tapered Network(F3DB = 0.8 HZ)

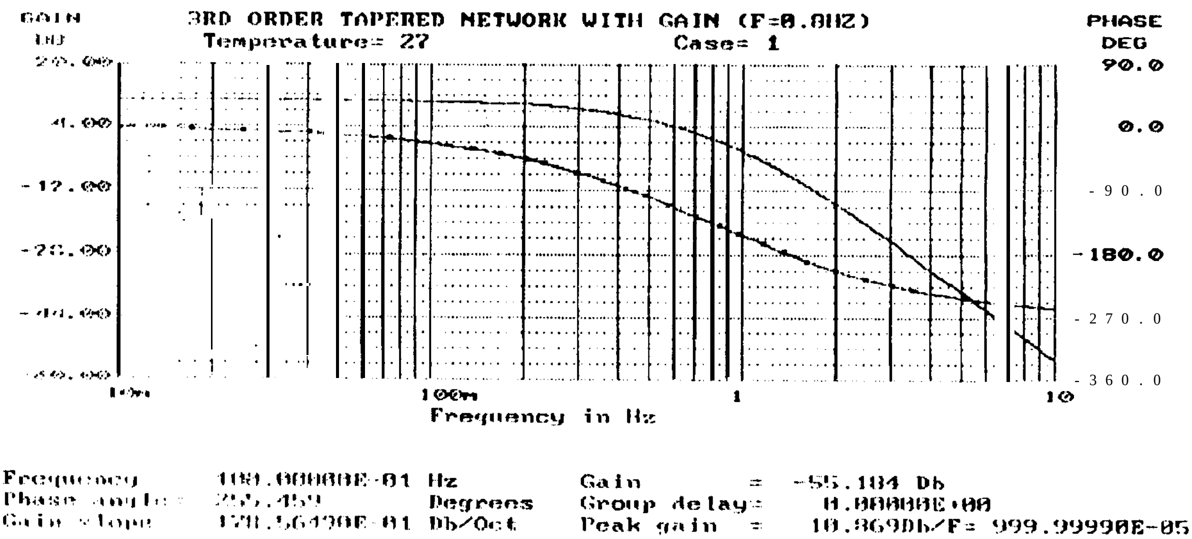


Figure 16 Third Order Tapered Network Gain and Phase Response

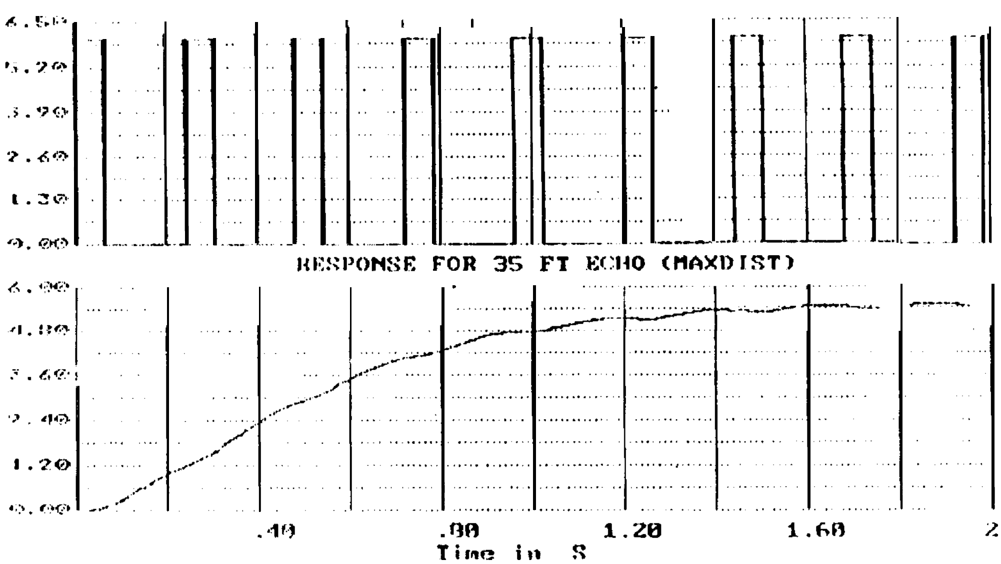


Figure 17 Third Order Tapered Network, 35 Foot Echo Time Response

lowpass network giving an attenuation of -60 dB/decade above the break frequency. The choice of break frequency ($f=1/2\pi RC$) is a- compromise between the circuit transient response (settling time) and the ripple on the DC output. A very small ripple on the DC output makes the settling time too long, while a short settling time results in increased ripple on the output. A suitable choice for the 3 DB break frequency is 0.8 HZ. This choice results in a ripple of less than 3%, a settling time of approximately 1.3 seconds, and an attenuation of -40 DB at 4.16 HZ. This attenuation is needed in order to filter out the noise produced by the high energy VSW signal. The amplified output of the filter is then fed to the output module.

Output Module

The output module takes the DC voltage VDC, which is proportional to the distance from an obstacle and transforms it into an audible signal with frequency inversely proportional to the distance. This conversion is done by a CMOS 555 timer wired as a voltage controlled oscillator (VCO). The VCO has two potentiometers, one for adjusting the frequency of oscillation and one for adjusting the volume in the earplug driven by the VCO (Figure 13). An increase of distance to an obstacle results in a decrease in frequency of the audible tone, while a decrease of distance will result in an increase in the frequency of the audible output.

Power Supply Module

The power supply is very simple and consists of an external battery pack connected to the rest of the hardware through a DC power jack. The choice of making the battery pack external enables different battery technologies to be tested. The manufacturer of the ultrasonic ranging unit (Polaroid) specifies that the power supply has to be 6 volts nominally and that it must be able to deliver current surges of up to 2.5 amps during the 1 msec transmission of the ultrasonic "chirp".

In order to comply with these requirements Polaroid developed the Polapulse P100 battery (Figure 14). This battery is not rechargeable, but it is very compact and flat and therefore suited to be an external battery pack. A rechargeable alternative to the P100 with even greater capacity, 450mAH compared to P100's 230mAH for a constant drain of 20mA, is a series connection of five regular 1.2 Volts AA Nickel-Cadium cells. Still another rechargeable alternative could be the state-of-the-art rechargeable lithium batteries with very high charge density and low weight.

Mechanical Design

The mechanical design consists of a PVC tube enclosing the electronic circuitry with a Plexiglass plug fitted in each end. The front end plug is machined to fit the ultrasonic transducer, and the rear end plug supports the DC power plug and the earphone plug (Figure 18). In this picture, it is also easy to see the layout of the entire device since the cane is pictured with its cover off. The front part clearly shows the Polaroid transducer mounted in the Plexiglass housing. The ranging board is directly placed behind the transducer and fits in machined slotted groove in the PVC. The interface circuit board then sits behind this module and provides the signal processing and outputs described above. An on/off button is provided along with a potentiometer to vary the volume of the audio output. The whole unit is light, compact and easily concealable.

Results and Conclusion

The cost of the ultrasonic ranging module, consisting of the modified ranging circuit board and the instrument grade transducer, for a minimum purchase of 10 units would amount to $44 a piece. The cost of the additional electronic circuitry would be approximately $30 if choosing the Digital Counter & D/A alternative, and $20 if choosing the Analog Filter alternative. The cost of the mechanical enclosure was $5 giving a total component price between $70 and $80. The use of an *8751* microcontroller was considered for this design but was not chosen because of cost considerations and due to the fact that most of the complex signal processing is performed by the Polaroid ranging board. It therefore did not seem to be a viable alternative.

The simplicity of the analog filter alternative, reducing the total number of IC's from fourteen to seven, together with the cheaper price favors this alternative. The digital counter & D/A alternative is a somewhat complex design and the accurate timing and actual distance measurement is not necessary in this application. It also proved to be too sensitive resulting in an unacceptable "jumping" in frequency not found in the Analog Filter alternative. The entire Ultrasonic Ranger system using the Analog Filter alternative was therefore chosen as the final design.

Preliminary testing with two blind individuals shows that some minor circuit adjustments for filter response time had to be made. Other than that, after a brief training period, blind people could get around easily using the device. Some problems still occur when people encounter staircases, which can be circumvented if a long cane is used in conjunction with the ultrasonic cane or if a more extensive training period is administered. In general, the initial results seemed to indicate that the users found that their perception of their environment was enhanced using the ultrasonic cane. Obviously, more extensive testing will be required to completely evaluate the device.

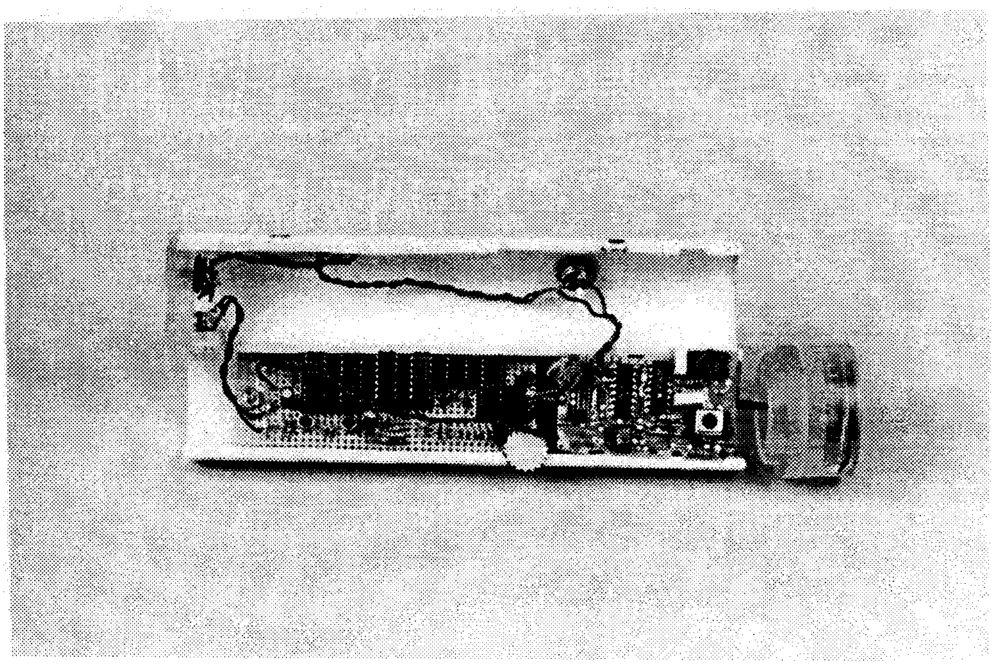


Fig. 18. Ultrasonic Cane Mechanical Layout

Radio Frequency Message Receiver for the Disabled

Designer: Riccardo Lacaille
Disabled Coordinator: Dr. Thomas Findley
Kessler Znstitu te For Rehabilitation, South Orange, NJ
Supervising Professor: John A. Zelano
Department of Electrical Engineering, New Jersey Institute of Technology, Newark, NJ 07102

INTRODUCTION

The radio frequency message receiver was primarily designed for communication with a hearing impaired person but can be used for any disabled individual. It utilizes a low power FM transmitter and a matching dual conversion FM receiver. A message is sent from a computer terminal or a personal computer(K) at the transmitter and the message appears on a liquid crystal display at the receiver, where it can be easily read by the individual. The receive circuit utilizes an 8751 microcontroller for handshaking and hardware control because of the relative complexity of the display unit. The display used at the receiver end is a large, forty character display that can be programmed for up to eighty characters in length. In this implementation, the display is programmed for up to seventy characters in length. When the message exceeds this length, separate responses occur on the receiver and transmitter end. At the transmitter, a clear screen prompt is issued at the terminal. The user sending the message at the computer hits the ESC key three times to initiate this operation at the receiver end. After ESC is struck, the display at the receiver end does not clear immediately but waits for a fixed delay of ten seconds to insure that the individual at the receiver has read the last of the message. The microcontroller at the receiver is intelligent enough to partition the message into words so that no parts of any word will appear on the screen.

The RF message receiver has an operating range equivalent to a cordless telephone. This enables adequate communication with the hearing impaired person around the house or in the backyard. Once a message is sent to the receiver, the receiver has a “message sent” indicator to indicate arrival of a new message. To attract the attention of the people with normal hearing, an audible tone is also output at the receiver for ten seconds. The transmitter is powered from the serial port on the PC while the receiver is battery operated so that it may operate remotely. Except for the liquid crystal display, all components are standard and can obtained from commercial *electronics* suppliers. Figure one shows both units.

SUMMARY OF IMPACT

It is difficult for disabled individuals, particularly deaf people to communicate with people if they are in a remote location. This device is designed to make life easier for disabled individuals if they are located remotely, but in proximity to their attendants. It enables the disabled person to maintain a greater level of independence and individuality while helping him to maintain contact with his surroundings. If the person is deaf, he may particularly find it useful in a work environment. The device can be used in conjunction with an FM transceiver so that he may speak to his attendant and receive a written response on the message transmitter.

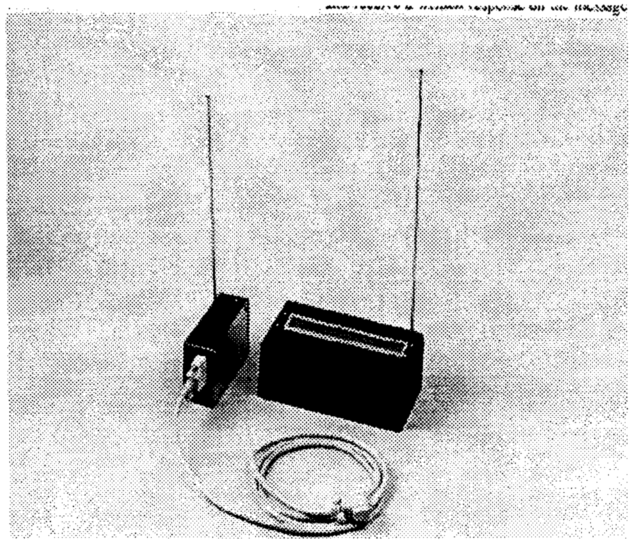


Fig. 1

TECHNICAL DESCRIPTION

The total transmitter-receiver system consists of two individual modules. Each module operates independently and has its own hardware for FM communication. The transmitter is a low power Motorola MC2833 FM transmitter system normally used for cordless telephones. It has a built-in voltage controlled oscillator and two auxiliary transistors which are used for frequency multiplication and output gain adjustment. It therefore is ideally suited for this application. The transmitter interfaces with the computer through a 741 operational amplifier. This is used to convert the +10/-10 RS-232 voltage levels to the modulation input voltage levels of the transmitter(0.8-->1.2V). This is done by using two 25K potentiometers to adjust the gain and offset of the 741 amplifier to yield the proper output swings upon RS-232 signal input. Hence a low RS-232 input(0.8V) yields an FSK output signal of 49.7 MHZ - 10 KHZ and a high RS-232 input(1.2V) yields an FSK output of 49.7 + 10KHZ. The center frequency of 49.7 MHZ was chosen so as not to interfere with the 49 MHZ carrier frequency allocated for cordless telephone usage. All power for the transmitter is derived from the RS-232 port of the host PC. The antennas used in this application are standard units obtained from Radio Shack. The transmitter schematic is shown in Figure two. The receiver is a Motorola MC3362 low power dual conversion FM receiver. The receiver has dual FM conversion capabilities but is configured for single frequency operation at 49.7 MHZ under quartz crystal control. The receiver has oscillators, mixers, a quadrature discriminator, and meter drive/carrier detect circuitry. The MC3362 also has buffered first and second local oscillator outputs and a comparator circuit and therefore can perform complete FM demodulation and FSK detection. The first mixer of the MC3362 amplifies the 49.7 MHZ input from the transmitter and converts the RF to 10.7 MHZ. This IF signal is filtered externally and fed into the second mixer, which further amplifies the signal and converts it to a 455 KHZ signal. After external bandpass filtering, the low IF is fed into the limiting amplifier and detection circuitry. The audio is then recovered using a conventional quadrature detector. Twice-IF filtering is provided internally. The audio signal is then fed into the open collector comparator and the RS-232 output that was generated by the host PC at the transmitter is recovered at the receiver. The schematic is shown in Figure two. Due to the relative complexity of display control and character decoding, it was decided to use an Intel 8751 microcontroller to read the digital output of the receiver and control the display. This integrated circuit has a built-in serial port, clock, baud rate generator, RAM, EPROM, and three additional I/O ports. The serial input of the 8751 is connected to the data output of the receiver. Both serial ports at the transmitter and receiver are configured for 300 baud. An assembly language program reads the serial port, and converts each character appropriately. Each character is then loaded into an I/O port for output to the display. Additional lines on another I/O port are used to activate hardware control lines on the display. As stated previously, the lengths of input messages and word sizes are monitored so that a message exceeding forty characters will be read without fragmentation at the receiver end. An AND601 one line forty character display is used for the application. It is a compact LCD module having a dot matrix LCD panel, a controller and driver circuit. The module can display 160 kinds of alphabets, numerals, symbols and "Kana" letters, as well as eight custom characters. It is configured for a character shift-left mode which means that when forty or more characters are sent, the entire display shifts left to tell the reader that another line is coming. Edit functions in the form of a screen clear and backspace for correction are also featured. The display acknowledges ASCII code and therefore the transmitter code is fully compatible with this unit after proper decoding of the RS-232 stop and start bits has been performed and the character is sent to the parallel I/O port of the 8751. When a message is received, the 8751 activates one of its real-time clocks and sends out a 1 KHZ square wave on one of its I/O lines. This line is buffered and drives a small speaker for ten seconds. A second I/O line is also activated for this period which drives a FET transistor which turns on an LED mounted in the chassis which houses the unit. The entire unit is powered by rechargeable Nicad batteries. Since both transmitter and receiver process RF signals and require RF components, all the circuitry had to be mounted on printed circuit boards. Components lie on a single large ground plane so that noise contaminants were kept to a minimum. The entire project costs $181.00 to build.

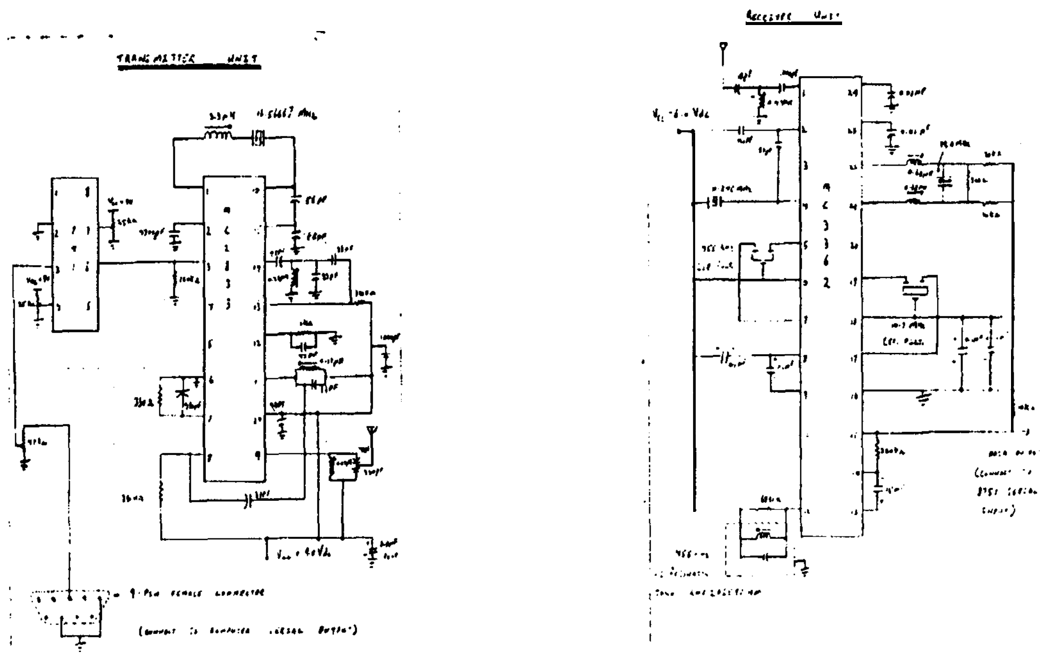


Fig. 2. Transmitter {left) and Receiver (right).

Force Feedback System

Designer: James *W. Cowell*
Disabled Coordinator: Dr. Thomas Findley
Kessler Institute For Rehabilitation, South Orange, NJ
Supervising Professor: John A. Zelano
Department of Electrical Engineering, New Jersey Institute of Technology, Newark, NJ 07102

INTRODUCTION

The Force Feedback system is a device designed to give audio and video feedback proportional to the force applied to an object by a prosthetic hand or gripper. The system has a straightforward modular design which allows for easy conversion to a variety of maximum load ranges from two to twenty five hundred pounds and a choice of audio, video or vibrotactile sensory output. The systems output can also be interfaced digitally with no modifications of the circuit necessary. The system uses a commercially available miniature piezoresistive transducer and standard operational amplifiers and components to implement the design. It is therefore quite small and inexpensive and can therefore be made readily available to disabled individuals. Since the transducer is miniature load cell, it can be easily accommodated by most commercial or experimental mechanical arms. The current version of the system outputs an audio **tone** whose frequency is proportional to input force. A LED bar readout is also provided to give a visual indication of the force applied to the transducer input. The entire system is battery operated and completely portable.

SUMMARY OF IMPACT

Mechanical arms are frequently used in robotic applications as well as for prosthetic devices for the disabled. Artificial limbs are typical applications where it is necessary for the individual to know the amount of force he is applying to an object. This is particularly crucial if the individual is performing fine ordetailed work and it may be possible to deform or break the object that he is handling. This portable, battery operated force sensor will enable disabled people with Artificial limbs to easily incorporate a force sensing device into their routine so that they may perform fine mechanical manipulations. In the long term, this may help them develop better skills and improve their chances for obtaining jobs that require increased manual dexterity.

TECHNICAL DESCRIPTION

Figure One shows the transducer mounted in an aluminum pedestal alongside of the two batteries used for power and a belt mountable box of dimensions 2 X 5 inches. The box has an LED bar display which gives a visual estimation of the applied force. This is an optional feature and will increase the size of the component box. In the absence of the LED display, the box can be made even smaller. A speaker yields a tone whose frequency is proportional to input force and an earphone jack is also provided for use in noisy environments. The unit is light, compact and easily adaptable for used with any type of mechanical arm or manipulating device.

The force feedback system is divided into five separate modules: the transducer sensing unit, the amplifier section the audio output section, video display section, and power supply. Each unit was chosen to minimize both circuit size and power consumption while yielding a cost effective design. The schematic of the circuit board is shown in Fig. 2.

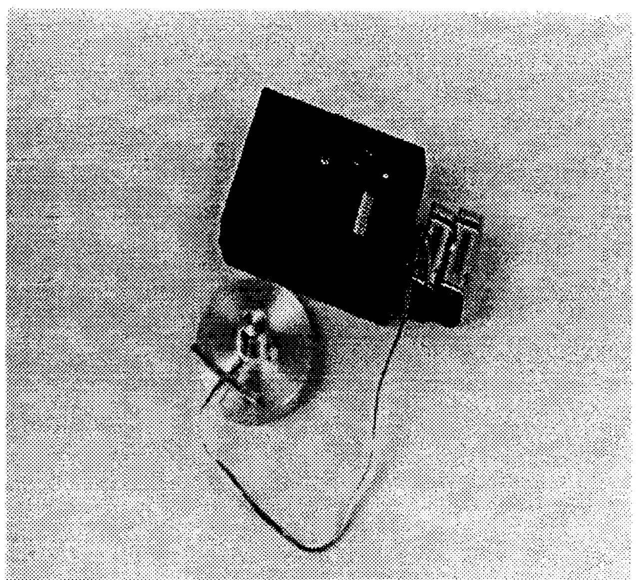


Fig. 1

The transducer sensing unit is an Entran ultra-miniature load cell, series ELF-500. It is made up of a single piezoresistive element configured as a bender element and three matched resistors connected in a Wheatstone bridge. The major axis of strain is in the (1,1,1) crystal axis direction which provides a sensitivity of 42.3 mv/lb. The bridge excitation voltage is 15 volts. A load cell rated for five pounds of pressure was chosen for this application. Other load cells of higher rating may be used for other applications. In order to insure good linearity, it is important not to load the bridge Two LF-442 low power JFET operational amplifiers(IC-1) are used as unity gain input buffers. A third operational amplifier&-2) is configured as a difference amplifier with a gain of 10 to boost the voltage from the bridge to usable levels. Since the bridge produces a relatively high signal level in contrast to the ambient noise, high common mode rejection is not necessary and the matching of the resistors of the differential amplifier was performed with one percent components. The signal output is then fed into an inverting summing amplifier to condition the signal level for input to the audio section. A 100k potentiometer in conjunction with -15 volt power is used to adjust the DC level bias of the input signal. The audio section consists of a 555 timer configured as a voltage controlled oscillator. The oscillator has two potentiometers: one is used for adjusting the frequency sweep range over the dynamic range of the input signal and the second is used to adjust the speaker volume. A vibrotactile transducer may also be coupled to the audio output to provide a stimulus for people who are deaf. The video display section is made up of an ADC0804 analog to digital converter. The converter receives its signal input from differential amplifier output and outputs an eight bit byte proportional to the input signal level. This output is then used to drive an LED bar display so that the user may visually estimate the input force to the transducer. These eight digital lines along with the ready line of the ADC0804 are also available for a digital interface if desired. The power supply is a simple circuit consisting of two nine volt batteries. The batteries can drive the operational amplifiers directly as a bipolar +/- volt power supply. The bridge voltage of eighteen volts is also directly supplied by these batteries. A 7805 voltage regulator is used to provide a five volt supply to the analog to digital converter. The overall design gives a linear audio output over the entire range of the transducer. Suitable adjustment of potentiometers allows portions of the input force range to be expanded in the audio output range if certain levels of force are expected.

Another possible design alternative to the approach outlined above is to use a 8751 microcontroller to perform the analog to digital conversion and digital output. The audio frequency tone could also be generated by one of the real-time clocks outputs and an appropriate passive filter. This approach would be desirable if more complicated processing and applications were to be performed with the device. It would cost a little more in components since the 8751 is more expensive than the discrete design but would provide a much greater flexibility in design. The cost of the present system is approximately 80 dollars.

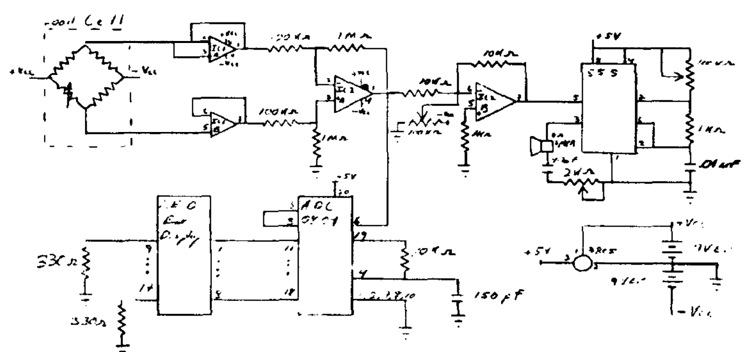


Fig. 2. Circuit diagram.

Home Environmental Control Through The Use Of A Personal Computer

Designers: Michael McKernan, Juan Padilla, John Valatkavage
Disabled Coordinator: Dr. Thomas Findley
Kessler Institute For Rehabilitation, South Orange, NJ
Supervising Professor: John A. Zelano
Department of Electrical Engineering, New Jersey Institute of Technology, Newark, NJ 07102

INTRODUCTION

The purpose of this project is to provide the disabled individual with complete control of his environment through the use of the many automation devices that are currently available on the market. Figure one shows the main menu that lists the support provided by the program. The program provides complete telephone support for either pulse or tone dialing. The user can answer or hang-up the phone depending on the state of the telephone. Support for X-10 controllers is provided. The X-10 controller plugs into a standard AC power outlet and has a series of modules which also plug into outlets anywhere in the home. The controller sends a digital pulse code to each assigned unit making it possible to turn appliances or lamps on or off by a simple command. Lamp dimming levels are selectable through program commands. Core controller support provides complete support for up to one hundred infrared controllable devices. This includes television, radio, stereo systems as well as novel devices such as thermostats, windows and lighting fixtures. Relay control is the final type of support provided for custom devices or devices which need some type of digital or voltage on/off type control. Both conventional on/off as well as pulsed relay control is provided. The entire program is configured through a separate program which asks specific questions regarding the types of devices present in the household. A configuration file is written which the standard application program reads so that it knows what devices are available for control. The input characters to the program have been kept simple so that conventional interfacing with voice boards which input characters into the keyboard buffer is easily facilitated. Figure one does not show the highlighted first characters well but simply 'R' triggers the relay control menu, 'D' will trigger the dial number directory and so on. The program does not take very much memory space and can easily be run in a multiple window environment such as Software Carousel. This program can be run in a separate window and can then be quickly switched to another DOS window where either another application is running, for example a word processor or perhaps a multiple choice menu program which can direct the user to a variety of other tasks. The user has a variety of capabilities at his fingertips or at the sound of a single word.

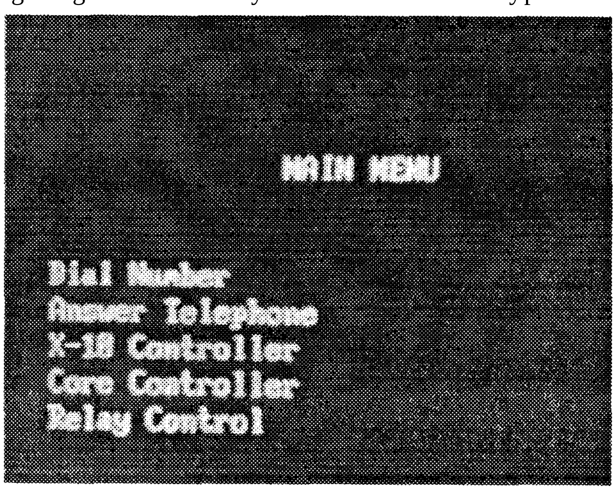


Fig. 1. Main Menu of Control Program

SUMMARY OF IMPACT

The impact of this type of software is obvious since it enables any disabled individual to completely control his environment. There are packages available like this commercially, but they are not easy to customize or modify as needed for specific applications. This package was written to provide extensibility for future applications. This package will facilitate the lifestyle of a large number of disabled individuals, particularly paraplegic and quadriplegics. A future application for stroke victims is planned which will use eye movement to control the screen cursor and select menu items.

TECHNICAL DESCRIPTION

Figure one shows the main menu that appears when the program is initiated. Although it is not clearly shown here, the first character of each line is highlighted to indicate which keystroke the user should input in order to initiate the command. The program is not case sensitive. This also makes voice to keystroke translation simple for a voice editor/compiler system. To dial a number, the user inputs "D" and the directory shown in Figure two appears on the screen. The menu shows the several options that exist: The user may add, delete, or edit any of entries in the list. The total number of entries in the list is also shown. If more than one page of entries exists, the user may scroll through these entries with the page up and page down functions. To place a phone call, the user then enters "P" and the user is prompted for either a phone number or an entry number. Upon receiving the information, the program takes the phone off hook, dials the number and returns to the main menu. Either pulse or tone dialing is supported. A conventional speaker phone(Radio Shack) or FM cordless phone may be used. The Answer Telephone command takes the phone off hook and allows the user to talk. After the phone is taken off hook, the Answer Telephone command is then changed to a Hangup Telephone command. The user continues to speak until he is finished and then inputs an "H" to hangup the phone. The X-10 command(specified by entering "X") brings up a menu that asks for the type of X-10 module to be addressed. There are two primary types of modules: lights and appliances. The user inputs either an "L" or "A" and a small list of available lights or appliances is displayed which shows all of the modules available with a short description of what is attached to them. He then inputs a number corresponding to the position in the list that the module of interest occupies. He then enters a "T" to turn on the module, an "O" of turn off the module or a "D" for a dim intensity level for lamp modules. If "D" is entered, a number from 1 to 9 is entered to specify the light intensity. The operation is performed and the main menu reappears on the screen. The core controller is a general purpose infrared control unit that can be programmed to output any number of pulse codes to any device. It is interfaced via a serial port. Upon entering "C", the user is prompted with a menu of choices, the most common being television, VCR, compact disk, stereo, or radio. After choosing a device, a function control menu is displayed and the user may choose an appropriate function. For instance, a television has "channel up", "channel down", "turn on" and "off" in its list of commands. The user may perform any number of commands in sequence and then exit back to choose another device or return to the main menu. The configuration program that accompanies the control program allows the user to enter any customized device and then setup a function control menu for that device.

The final type of control available is through conventional relay control. This is performed using a standard digital I/O board(Data Translation) in combination with OPTO 22 digital relays. This offers isolation and provides the capability to switch a variety of different voltages to initiate 5 volt digital or 24 volt reed relay control. Upon entering "R", a list showing relay number and description is displayed. The user selects the number and the relay will be toggled to its complement state. Pulsed relays are also supported and may be specified with the configuration program. The duration of the pulse may also be specified from one to ten seconds. After the relay function has been performed, the main menu reappears back on the screen. The end result of this project is that it provides our group with a general interface that will be useful for the basic quadriplegic individual and which will also be extensible for more complicated disability cases. One current extension of this interface is for stroke victims which can only move their eyes. The input to the computer will be the users eye movements obtained from a device mounted on his head. It is expected that this program will provide a basic kernel for many of the software applications that deal with the different disabilities that are encountered in the NJIT program.

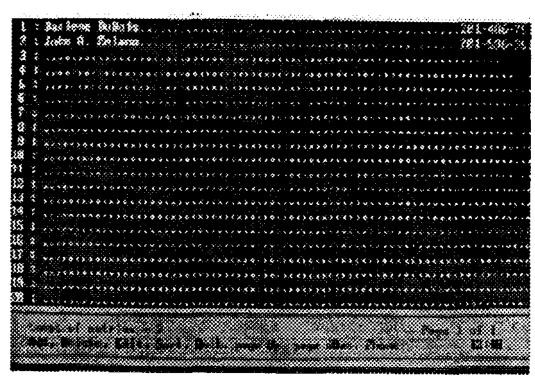


Fig. 2. Telephone Dialing Directory and Edit Functions