LAB 4: PROSTHETIC DEVICES

Introduction:

In this laboratory, we will explore basic sensors and their use in the development of biomedical devices and other instrumentation systems. Primary objective of this lab is to introduce the concept of an integrated project comprising sensors, signal processing and an output. Three of these instrumentation systems and three experiments will be demonstrated. At the end of each, a series of questions will be asked to provoke your thoughts regarding the use of these systems in other medical devices. NOTE: ALL ANSWERS MUST BE LIMITED TO 150 WORDS OR LESS UNLESS SPECIFIED.

Demo 1: Virtual Keyboard for Quadriplegics

By: Abhishek Rege and Kartik Murari

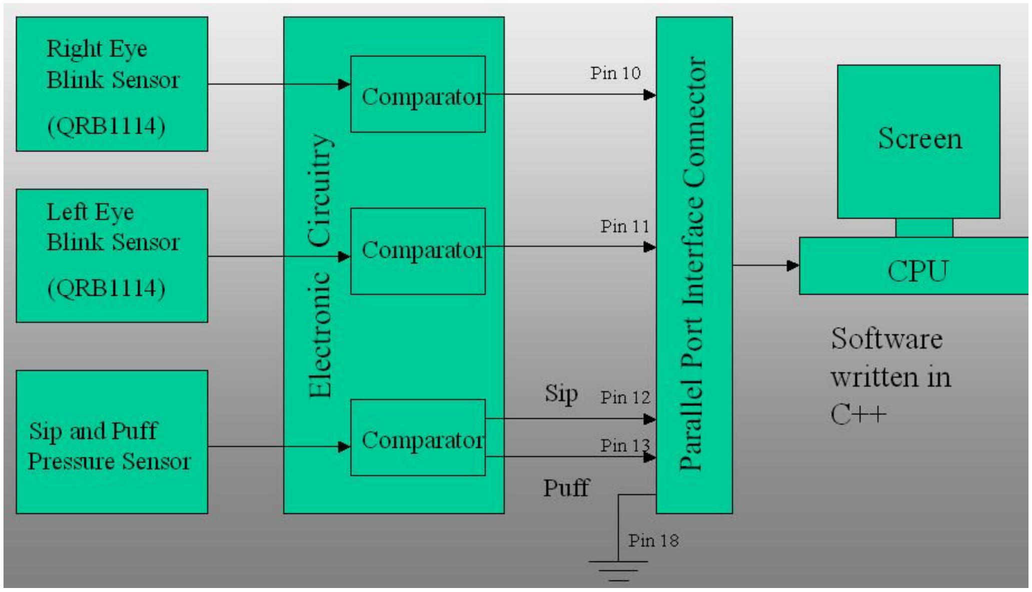
The Objective

It is a common concern that quadriplegics find it difficult to communicate with the world on account of their disability. The term quadriplegic is used to describe a wide variety of impaired people with restricted motion of body parts. This could probably be the reason why no commercial communication device is available for them. Most devices need to be customized to suit particular requirements of the quadriplegic. The designed interface prototype caters to those people who cannot move their body from and including the neck downwards. They cannot even speak or move their head about the neck. However breathing activity and ocular control is retained. The device takes inputs from the restricted activities of such a quadriplegic and converts them into text which can be displayed on a computer screen, thus enabling them to communicate.

Design Schematic

The circuit consists of two distinct sensors. One is the sip and puff detector which is realized using a differential pressure transducer. The output of this is fed into a differential amplifier and then using two comparators, one with a positive threshold and the other with a negative, the sip or puff signal is detected. This is then inverted using a digital inverter due to the logic levels of the parallel port. The other sensor which detects the open or closed state of the eye is made using a reflective object sensor, which consists of an IR photodiode and a phototransistor in once compact package. Depending on whether the eye is open (reflection) or closed (no reflection) the output goes low or high. However, this is not a true digital output so it is again fed into comparators and an inverter.

To interface into a computer we use the control pins of the parallel port. These are normally used by the printer to give in signals like PAPER OUT, etc. Pins 10, 11, 12 and 13 are used for taking in the signals. The port is read using C++. These pins are active low, so to change state a 0 is needed which is why the inverters are used. Once the four signals are in the computer, the SELECT is generated by AND-ing the left eye closed and right eye closed signals. Now the five signals are used to navigate around a virtual keyboard also created in C++.



Discussion Questions:

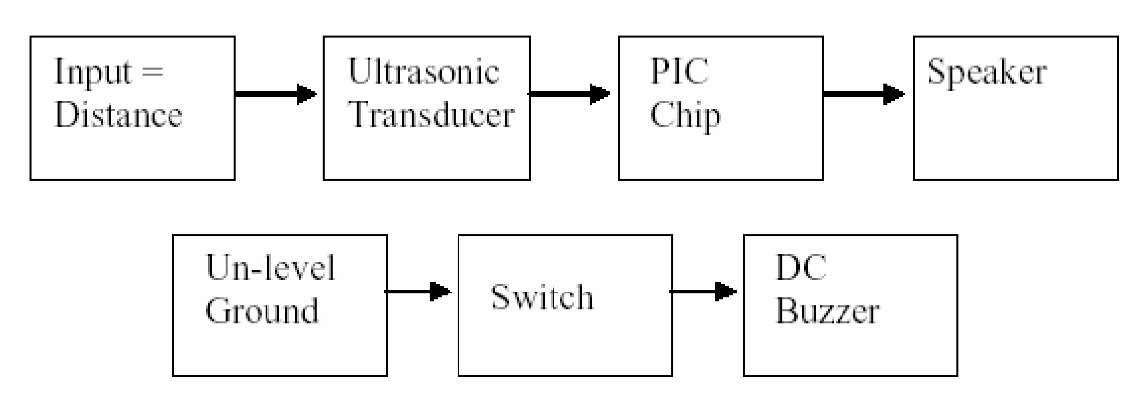
1) What alternate sensors could be used for this system (recall this system is for quadriplegics paralyzed from the neck downwards)?
2) Suggest alternate methods of quadriplegic communication techniques.

Demo 2: The Smart Cane

By: So-Ching Chen and David Man

General Design and Construction

Design of the smart cane focused on detection of objects in the pathway and detection of staircases. A modular design was used for the ultrasonic detector giving the user a fixed or handheld solution. The bottom of the cane consisted of a fixed staircase detector. PVC pipe was used due to minimal cost and weight. All electronics were built in closed enclosures for safety and aesthetics. Below is the Smart Cane block diagram.



Handheld Ultrasonic Obstacle Detector

The obstacle detector was designed using the following criteria: detection of objects above and below the knees, detection of doors, detection of physical persons, and detection descending stairs. With those design objectives in mind, the detector was built using one Devantech Ultrasonic Range Finger as the primary method of detection of obstructions. The range finder was programmed using a PIC microchip. The range finder operates off of a 5 volt power supply and detects objects ranging from approximately 3 cm to 3 meters in distance with a detection cone of approximately 30 degrees. Using the PIC, a trigger pulse is sent to range finder and the return pulse is measured. The width of the return pulse is proportional to the distance between the object and the detector. The detector alerts the user of impending obstructions via a series of low decibel, beeping noises firing at a rate that is proportional to the user's distance away from the impending obstruction.

Descending Staircase Detector

A mechanical solution was used to detect staircases. Upon reaching un-level ground (i.e. staircase drop), the detection pin falls, causing depression of the switch. The switch completes the circuit housed within the detector enclosure. Completion of the circuit causes a piezoelectric buzzer sound to notify the user of un-level ground. An electromechanical solution was used for its fast response time.

Demo 2: The Smarter Cane

By: Jason Brooke and Joseph LaRosa

General Concept

The Smarter Cane is composed of an object detection system and range finder for the visually handicapped that provides speech response to the user. Utilization of an ultrasonic transducer array, IR sensors, and a tilt sensor, the device detects an object that blocks the path of the user, including ascending and descending stairs, and low to high objects. The ultrasonic transducer array provides necessary information to navigate these objects and maintain the originally-desired path. Two modes of operation are provided: *planned* and *evasive*. Both modes direct the user around objects; however, the *planned* mode will allow the user to maintain a straight direction. The infrared and tilt sensors determine the presence of stairs and distance traveled in a given direction.

Design Schematic

The main compartment contains the electronics necessary to perform signal processing and feedback control. The ultrasonic transducers transmit a burst of ultrasonic pulses and produce an output signal with varying pulse-width dependent upon the distance of the object from which the pulses are reflected. The input from the infrared sensors on the lower-leg unit enters the main compartment via a 9-pine serial cable. The main compartment is worn around the waist and held in place by the use of a belt.
The microprocessor sends the initiation signal to and receives the pulse-width modulated signal from each of the sonar transducer modules for detection of mid- and high-height objects. The analog signals produced by the knee and ankle infrared sensors are

converted to digital signals via the analog-to-digital converter. These digital signals are received by the microprocessor for detection of low objects and stairs. The voice response chip is controlled by the microprocessor and transmits the response commands via headphones or a speaker. For determining direction travel and additional signal processing, a digital compass outputs to the microprocessor the degree toward which the visually-impaired person is facing.

The signal processing necessary to determine object-detection and to control feedback response is contained within a program stored in the microprocessor. The normal path-impeding object-detection and evasion is performed in both the *evasive mode* and the *planned mode*. The object-detection begins by the initiation of the ultrasonic pulses sent from the three sonar transducer modules and the conversion of returned pulse-width modulated signal to an object-distance measurement. The digital signals from the infrared sensors are also converted into distance measurements. These measurements are then compared to defined threshold values to determine whether an object has been detected. If an object is detected from the middle sonar transducer module, the values of the left and right sonar transducer modules are compared to determine the least-impeded path. The voice response chip is triggered to play the appropriate command message for the desired action to evade the object. The detection of a low object or descending or ascending stairs by the infrared sensors will result in the appropriate output to the speaker from the voice chip. Once the output message is played to the visually-impaired person the program returns to the beginning to detect objects again.

With this device, the user has the option to operate in the *evasive mode* or the *planned mode*. As stated, the *planned mode* performs the same operations as the *evasive mode*, with the added ability to maintain a desired path direction. If no object is detected by either the middle sonar module or the infrared sensors, then the program determines the distance the user has deviated from the path. If the distance is sufficient to trigger a response, the appropriate response is determined and fed back to the user via the voice response chip and the speaker. The once the appropriate message is played to the user, the program begins again in the *planned mode* unless the user switches back to the *evasive mode*.

In all modes of operation, the middle sonar transducer module is angled upward at approximately 45 degrees above horizontal in order that the spatial object-detection field, represented by the horizontal and vertical fields, is capable of detecting mid to high obstacles. The knee infrared sensor is angled at approximately 30 degrees below horizontal in order that the object-detection field produced is capable of detecting ascending and descending stairs. A tilt sensor is used to determine when steps have been taken.

Discussion Questions:

1) What is ultrasound and what is its typical range finding range? Why is ultrasound advantageous for some biomedical devices (i.e. fetal monitoring)?
2) What is a Doppler Effect Sensor? Can a Doppler Sensor be used in this device?

3) Analyze, critically, the merits and demerits of the two “SmartCane” designs. What suggestions can you give to improve the designs?