INTERACTIVE ACCELEROMETRIC GLOVE FOR HEARING IMPAIRED

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ABSTRACT

In this paper we propose a human interface device that converts the mechanism of hand sign language into alphanumerical characters. This device is in the form of a portable right hand glove. We propose this device in concurrence with assistive engineering to help the underprivileged. Our main goal is to identify 26 alphabets and 10 numbers of American Sign Language and display it on the LCD. Once the text is obtained on the LCD, text to speech conversion operation is carried out and a voice output is obtained. Further, the text obtained can also be viewed on a PC or any portable hand held device. People with hearing disability find it difficult to communicate with others using their Universal Sign Language, as a normal person doesn't understand these sign languages. Our main objective is to set an interface between the Deaf/Dumb and normal person to improve the communication capabilities so that they can communicate easily with others. We mount dual axis accelerometers on the glove and propose and efficient methodology to convert these sign languages.

Index Terms— Dual Axes Accelerometer, PIC Microcontroller, Fingers Orientation, Weight Formula.

1. INTRODUCTION

We propose a sensor glove which converts the mechanism of hand sign language used by hearing impaired into alphanumeric characters and finally gives a voice output, hence bridging the gap between them and the normal people. Communication which involves the exchange of information can only occur effectively if all participants use a common language [1]. Hearing impaired people need an efficient nonauditory means of expressing and interpreting information in order to communicate, and sign language have proven effective in communicating across a broad spectrum of requirements from everyday needs to sophisticated concepts. It is important that intuitive and efficient tools for teaching sign language are available to ensure that hearing impaired people are able to develop extensive social networks with deaf and hearing people. In addition to ensure that deaf people are able to obtain the best possible education and services within the community. We propose a device which will prevent the hearing impaired to be felt left out and can easily communicate with the normal people. The device in the form of a wearable hand glove which recognizes the Universal Sign Language and convert it into text on any hand-held device and finally gives a voice output.

1.1. Sensor Glove Technology in Literature

This research investigates an alternative input device in the form of sensor gloves that can be used to convert the American sign language into Alphanumeric characters and give a voice output. . Each sign consists of a number of parts: hand shape, place of articulation, orientation, path of movement, and nonsign components including facial expression [1]. For this research we are focusing on the hand shape component as one important aspect of a sign.

Sensor gloves are hand worn devices with inbuilt sensors that can capture information about the movements and positioning of the user's hands. Some of the most widely known sensor glove technologies are the (i) DataEntry Glove [2], (ii) Data Glove [3], (iii) CyberGlove [4].

The DataEntry Glove was presented by Gary Grimes from Bell Telephone Laboratories in 1983, and was the first widely published sensor glove [2, 5, 6]. The DataEntry Glove was originally devised as an alternative to the keyboard, and made it possible to generate 96 printable ASCII characters from 80 different finger positions. The glove was made out of cloth and had flex sensors along the fingers, tactile sensors on the fingertips, and inertial sensors positioned on the knuckle side of the hands. The distribution of the sensors was specified with the aim of recognizing the Single Hand Manual Alphabet for the American Deaf [5].

The DataEntry Glove was researched but was never commercially developed. Thomas Zimmermann developed the DataGlove in 1987. This glove was constructed of a lightweight fabric glove equipped with optical sensors on each finger, and magnetic sensors on the back of the gloves [3, 6]. The optical sensors were constructed of optical cables with a small light in one end and a photodiode in the other. When the fingers were bent, the light was reduced in strength before it reached the photodiode. The bending of the fingers could therefore be determined by measuring how much light the photo diode detected. The magnetic sensor measured the rotations of the hand in relation to a fixed reference point [3, 5]. The DataGlove was commercialized by VPL Research and could be purchased at a reasonable price, which lead to widespread use of this glove.

The CyberGlove was developed at Stanford University in 1988 and was specifically designed for the Talking Glove Project, which focused on translating American sign language into spoken English [4, 5, 6]. This glove was made up of a cloth glove with the fingertips and the palm areas removed. This made it possible for users to easily grasp objects and made it possible for deaf-blind users to conduct manual finger spelling while wearing the gloves [4]. The gloves were equipped with a total of 22 flex sensors, which was made out of thin foil mounted onto plastic modules. These sensors were sewn into pockets running over each joint, and could measure flexing of fingers and wrists. The maximum flex that could be detected by a sensor was regulated by adjusting the thickness and elasticity of the plastic modules. The plastic modules were selected in such a way that they of maximized the output signal, and at the same time minimized fatigue of the sensors [4]. Informal experiments have shown that this glove performs in a smooth and stable way, and that it is accurate enough to capture complex and detailed finger and hand gestures [5]. However, according to Sturman, one must calibrate the sensors to each user in order to accurately capture gestures from different hand sizes and hand shapes. The CyberGlove is commercially available from VR logic [7].

We propose a sensor glove which consists of five dual axis accelerometers to provide orientation and acceleration information. This convert the signs into alphanumeric characters which are displayed on a hand held device which finally gives a speech output. We describe an efficient algorithm used to recognize and interpreted the signs. This makes our glove efficient and free from all other limitations caused by using other sensors as describes above.

This paper is organized as follows. In Section 2, we describe the complete framework of the Sensor Glove and the methodology used, followed by results in Section 3. In the final section of the paper we conclude by outlining the potential for further research in this area.

2. PROPOSED METHOD

In this section we propose the complete framework of the Sensor Glove. Our main objective is to convert the mechanism of Hand Sign language used by hearing impaired into alphanumeric characters and give a voice output.

The Deaf and the Dumb use only their right hand to communicate using the sign language. So, we come up with a right handed glove which is made of fabric, and five sensor boards are mounted on the back nail sections of each finger secured by cotton thread as shown in fig1. This glove consists of 5 dual axis accelerometers ADXL203[8] manufactured by Analog Devices Pvt Ltd. Each sensor board is powered by 5.0 volts. Two outputs from X and Y axis of accelerometer are connected to, two of the ten Analog to Digital ports of the microcontroller (PIC18F-4550). They are labeled AD8-AD9 for thumb and AD0 through AD7 for index through small fingers (2 AD inputs per thumb/finger).

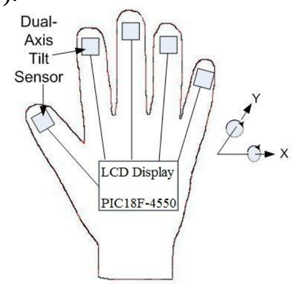


Fig. 1. Sensor Glove showing position of accelerometer and the processor.

The complete block diagram of the glove is as shown in fig 2. The circuit consists of PIC18F4550 microcontroller IC [9], with 5 connectors for 10 Analog to Digital inputs, labeled X0-Y0 for sensor from thumb, X1 through X4 and Y1 through Y4 are for fingers index through small. It clocks by 11.0592MHz crystal. The outputs include a LCD display and RS-232 interface for viewing on PC or any hand held device.

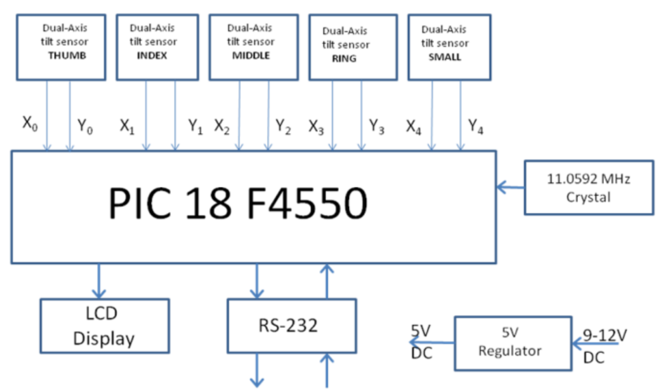


Fig. 2. Block Diagram of the Sensor Glove.

2.1. Sensor Operation

The ADXL203 are high precision, low power, dual-axis accelerometers with signal conditioned voltage outputs, all on a single, monolithic IC. The ADXL203 measure acceleration with a full-scale range of ±1.7 g, ±5 g, or ±18 g. TheADXL203 can measure both dynamic acceleration (for example, vibration) and static acceleration (for example, gravity).

The typical noise floor is 110 µg/√Hz, allowing signals below 1 mg (0.06° of inclination) to be resolved in tilt sensing applications using narrow bandwidths (<60 Hz). The user selects the bandwidth of the accelerometer using Capacitor CX and Capacitor CY at the XOUT and YOUT pins. Bandwidths of 0.5 Hz to 2.5 kHz can be selected to suit the application. The ADXL203 are available in a 5 mm × 5 mm × 2 mm, 8-terminal ceramic LCC package.

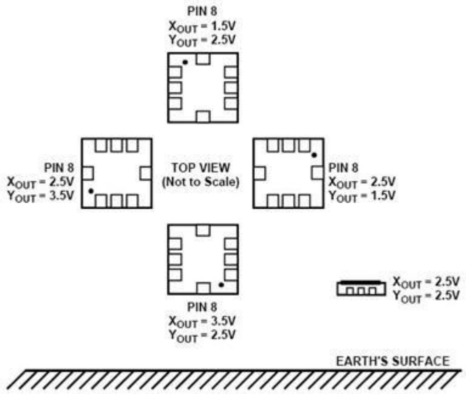


Fig. 3. Accelerometer Orientation. [8]

The output of each sensor provides X and Y orientations of finger relative to earth's surface, and their output DC voltage levels are ranging from 1.5 Volts to 3.5 Volts whereas the sensor leveled (paralleled) to earth surface would produce 2.5 Volts for both X and Y axis.

The equation below represents the relation between tilt angle (in degree) and voltage output of two axes is:

$$X_{OUT} = 2.5V + \sin(\alpha_x)$$
$$Y_{OUT} = 2.5V + \sin(\alpha_y) \quad (1)$$

Or

$$\alpha_x = \operatorname{asin}(X_{OUT} - 2.5V)$$
$$\alpha_y = \operatorname{asin}(Y_{OUT} - 2.5V) \quad (2)$$

Where,
X_{OUT} and X_{OUT} are voltage output response when sensors rotate about X and Y axes. α_x and α_y are tilt angles about the x-axis and y-axis
For instance: All fingers - hand – are pointing upward (straight up or orthogonal to earth's surface) would result all X_{OUT} =1.5V and Y_{OUT} =2.5V or
All 4 fingers except the thumb point downward will indicate X_{OUT} =3.5V and Y_{OUT} =2.5V.

The ADXL203 as shown in fig 4 has provisions for band limiting the XOUT and YOUT pins. Capacitors must be added at these pins to implement low-pass filtering for antialiasing and noise reduction. A minimum capacitance of 2000 pF for CX and CY is required in all cases. We chose CX and CY to be 0.1µF.

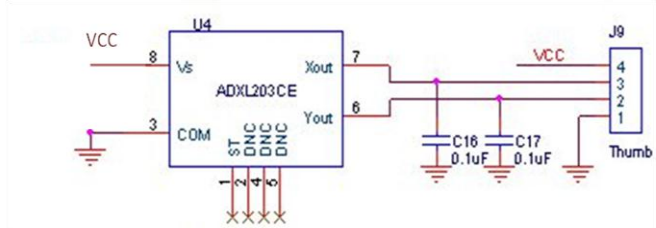


Fig. 4. Schematic of Sensor Board (ADXL203) [8]

2.2. Methodology

We divided each thumb/finger motions into 2 planes, X and Y axes. Each of X or Y axis has 3 distinctive sections, labeled 1, 2 and 3. X axis sections cover the ranges of angle 0°, 90° and 180°. Y axis sections cover -22.5°, 0° and +22.5° where 0° is being upward. To create distinctiveness among weight numbers, natural numbers were used.

Referring to fig 5.1, the index finger at straight-up position is in section 1. Similarly, the index finger leveling to earth's surface or angle 90° is in section 2, and its pointing downward or 180° is in section 3. We also Notice that, the horizontal motion index finger is only in sections 1 and 2 (fig 5.2), The middle finger is in sections 2 and 3, (Fig 5.3) and the ring and small fingers are only in section 2 (fig 5.4).

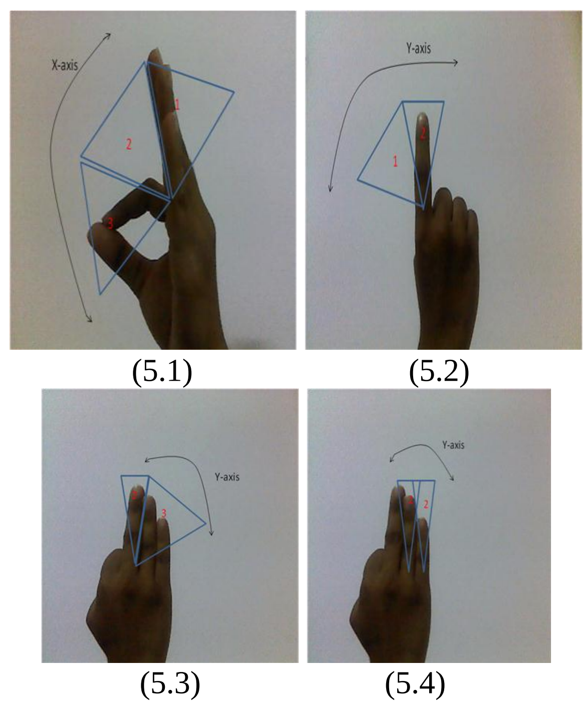


Fig. 5. Sectional representation for thumb/fingers in X and Y axis motion.

Table 1 shows the translation of thumb/fingers orientations into predefined sections. To identify a thumb/finger position, the two voltage outputs from each sensor, represent its orientation in X and Y planes. A lookup Table 1 shows voltage measurement on 3rd column and 10 bit value in its 4th column. Then, they are divided into sections, as shown in columns 5th through 14th, for each corresponding thumb/finger.

Table 1. Voltages, 10 bit value and corresponding Sections for each thumb/finger.

Angle in Degree	Sine (Angle)	Output Response in VDC	Value in 10 bit Decimal	Finger Normalization in Sections									
				Thumb X0	Thumb Y0	Index X1	Index Y1	Middle X2	Middle Y2	Ring X3	Ring Y3	Small X4	Small Y4
130	0.77	3.27	669	3	2	3	2	3	3	3	2	3	2
125	0.82	3.32	680	3	2	3	2	3	3	3	2	3	2
120	0.87	3.37	689	3	2	3	2	3	3	3	2	3	2
115	0.91	3.41	698	3	2	3	2	3	3	3	2	3	2
110	0.94	3.44	704	3	2	3	2	3	3	3	2	3	2
105	0.97	3.47	710	3	2	3	2	3	3	3	2	3	2
100	0.98	3.48	714	3	2	3	2	3	3	3	2	3	2
95	1.00	3.50	716	3	2	3	2	3	3	3	2	3	2
90	1.00	3.50	717	3	2	3	2	3	3	3	2	3	2
85	1.00	3.50	716	3	2	3	2	3	3	3	2	3	2
80	0.98	3.48	714	3	2	3	2	3	3	3	2	3	2
75	0.97	3.47	710	3	2	3	2	3	3	3	2	3	2
70	0.94	3.44	704	3	2	3	2	3	3	3	2	3	2
65	0.91	3.41	698	3	2	3	2	3	3	3	2	3	2
60	0.87	3.37	689	3	2	3	2	3	3	3	2	3	2
55	0.82	3.32	680	3	2	3	2	3	3	3	2	3	2
50	0.77	3.27	669	3	2	3	2	3	3	3	2	3	2
45	0.71	3.21	657	3	2	3	2	3	3	3	2	3	2
40	0.64	3.14	644	2	2	2	2	2	3	2	2	2	2
35	0.57	3.07	629	2	2	2	2	2	3	2	2	2	2
30	0.50	3.00	614	2	2	2	2	2	3	2	2	2	2
25	0.42	2.92	599	2	2	2	2	2	2	2	2	2	2
20	0.34	2.84	582	2	2	2	2	2	2	2	2	2	2
15	0.26	2.76	565	2	2	2	2	2	2	2	2	2	2
10	0.17	2.67	548	2	2	2	2	2	2	2	2	2	2
5	0.09	2.59	530	2	2	2	2	2	2	2	2	2	2
0	0.00	2.50	512	2	2	2	2	2	2	2	2	2	2
-5	-0.09	2.41	494	2	2	2	2	2	2	2	2	2	2
-10	-0.17	2.33	476	2	2	2	2	2	2	2	2	2	2
-15	-0.26	2.24	459	2	2	2	2	2	2	2	2	2	2
-20	-0.34	2.16	442	2	2	2	2	2	2	2	2	2	2
-25	-0.42	2.08	425	2	2	2	1	2	1	2	2	2	2
-30	-0.50	2.00	410	2	2	2	1	2	1	2	2	2	2
-35	-0.57	1.93	395	2	2	2	1	2	1	2	2	2	2
-40	-0.64	1.86	380	2	2	2	1	2	1	2	2	2	2
-45	-0.71	1.79	367	2	2	2	1	2	1	2	2	2	2
-50	-0.77	1.73	355	1	1	1	1	1	1	1	2	1	2
-55	-0.82	1.68	344	1	1	1	1	1	1	1	2	1	2
-60	-0.87	1.63	335	1	1	1	1	1	1	1	2	1	2
-65	-0.91	1.59	326	1	1	1	1	1	1	1	2	1	2
-70	-0.94	1.56	320	1	1	1	1	1	1	1	2	1	2
-75	-0.97	1.53	314	1	1	1	1	1	1	1	2	1	2
-80	-0.98	1.52	310	1	1	1	1	1	1	1	2	1	2
-85	-1.00	1.50	308	1	1	1	1	1	1	1	2	1	2
-90	-1.00	1.50	307	1	1	1	1	1	1	1	2	1	2
-95	-1.00	1.50	308	1	1	1	1	1	1	1	2	1	2
-100	-0.98	1.52	310	1	1	1	1	1	1	1	2	1	2
-105	-0.97	1.53	314	1	1	1	1	1	1	1	2	1	2
-110	-0.94	1.56	320	1	1	1	1	1	1	1	2	1	2
-115	-0.91	1.59	326	1	1	1	1	1	1	1	2	1	2
-120	-0.87	1.63	335	1	1	1	1	1	1	1	2	1	2
-125	-0.82	1.68	344	1	1	1	1	1	1	1	2	1	2
-130	-0.77	1.73	355	1	1	1	1	1	1	1	2	1	2

To calculate a weight for each position of hand, a below formula is used:

$$\text{Weight} = X0\ 3^0 + Y0\ 3^1 + X1\ 3^3 + Y1\ 3^4 + X2\ 3^4 + Y2\ 3^5 + X3\ 3^6 + Y3\ 3^7 + X4\ 3^8 + Y4\ 3^9 \quad (3)$$

Where X0 through X4 and Y0 through Y4 are natural numbers (1, 2 and 3):

- X0 and Y0 are assigned to the thumb. X0 varies in sections 1 through 3 and Y0 is in sections 1 and 2
- X1 and Y1 are assigned to the index finger. X1 varies in sections 1 through 3 and Y1 is in sections 1 and 2
- X2 and Y2 are for the middle finger. X2 varies in sections 1 through 3 and Y2 is in sections 2 and 3
- X3 and Y3 are for the ring finger. X3 varies in sections 1 through 3 and Y3 is in section 2.
- X4 and Y4 are for the small finger. X4 varies in sections 1 through 3 and Y4 is in section 2.

The weight for each ASCII character is calculated and shown in Table 2.

The American Sign Language used by hearing impaired is as shown in fig 7.

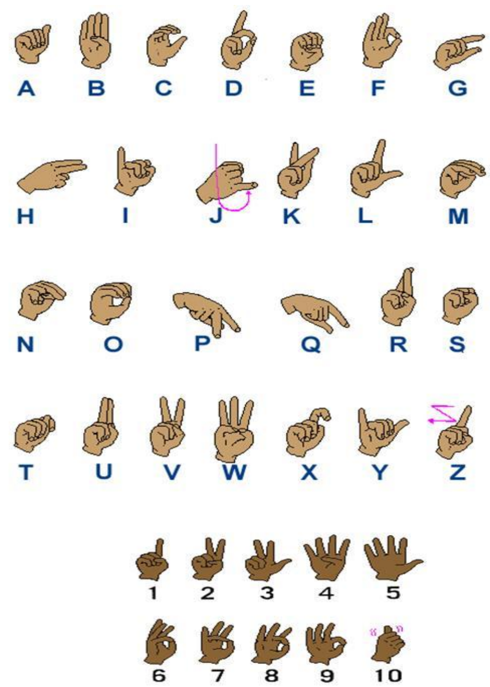


Fig. 6. American Sign Language used by Hearing Impaired.

Table 2 is combination of fig 6 and Table 1. Let us consider one of possible cases of for character "A". It occurs when:

X0 = 1, Y0 = 2
X1 = 3, Y1 = 2
X2 = 3, Y2 = 2
X3 = 3, Y3 = 2
X4 = 3, Y4 = 2

Substitute these values in the weight formula (eqn 3), the total weight is 66427, and the corresponding character for this character is 'A', referring Table 2. This character is display on LCD and also sent through RS-232 interface to PC.

Due to the fact of the gloves being made of fabric, the sensor boards often do not orient themselves in perfect directions, so, many calibrations and simplifications during the debugging process were done to obtain the calculated values which are shown in Table 2.

Table 2. Look-up Table for the combination Thumb/Finger Sections and Weight.

Character	Thumb sensor # 1		Index sensor # 2		Middle sensor # 3		Ring sensor # 4		Small sensor # 5		Weight
	X0	Y0	X1	Y1	X2	Y2	X3	Y3	X4	Y4	
A	1	2	3	2	3	2	3	2	3	2	66427
B	2	2	1	2	1	2	1	2	1	2	51668
C	2	1	2	2	2	2	2	2	2	2	59045
D	2	1	1	2	2	2	2	2	2	2	59036
E	2	1	3	2	3	2	3	2	3	2	66425
F	2	2	2	2	1	2	1	2	1	2	51677
G	2	1	2	2	3	2	3	2	3	2	66416
H	2	1	2	2	2	3	2	2	2	2	59288
I	2	1	3	2	3	2	3	2	1	2	53303
J	2	1	3	2	3	2	3	2	2	2	59864
K	1	2	1	2	2	2	3	2	3	2	66328
L	2	2	1	2	3	2	3	2	3	2	66410
M	2	1	2	2	2	2	2	2	3	2	65606
N	2	1	2	2	2	2	3	2	3	2	66335
O	2	1	2	2	3	2	2	2	2	2	59126
P	3	2	3	2	3	2	2	2	2	2	59139
Q	3	2	3	2	2	2	2	2	2	2	59058
R	2	1	2	2	2	3	3	2	2	2	60017
S	2	2	2	2	2	2	2	2	2	2	59048
T	2	2	2	2	3	2	3	2	3	2	66419
U	2	1	1	2	1	2	3	2	3	2	66245
V	2	1	1	2	1	3	3	2	3	2	66488
W	2	1	1	2	1	2	1	2	3	2	64787
X	2	2	3	2	3	3	3	2	3	2	66671
Y	1	2	3	2	3	2	3	2	1	2	53305
Z	3	2	3	2	2	3	2	2	2	2	59301
1	2	1	1	2	3	2	3	2	3	2	66407
2	2	1	1	2	2	2	3	2	3	2	66326
3	2	2	1	2	1	2	3	2	3	2	66248
4	2	1	1	2	1	2	1	2	1	2	51665
5	1	2	1	2	1	2	1	2	1	2	51667
6	2	1	1	2	1	2	1	2	2	2	58226
7	2	1	1	2	1	2	2	2	1	2	52394
8	2	1	1	2	2	2	1	2	1	2	51746
9	2	1	2	2	1	2	1	2	1	2	51674
10	2	2	3	2	3	2	3	2	3	2	66428

2.3. Software Details

The finite loop controls the following steps:

- Configure and acquire 10 AD inputs from 5 fingers 5 then assign them to X1, Y1… X4, Y4, X0, Y0 for index, middle, ring, small and thumb, respectively.
- For each thumb/finger X0, Y0, X1, Y1… X4, Y4, determine the section where each thumb/finger is in by calling filter routines. These filters are derived from pre-defined sections, shown in Table 2.
- Compute the total weight for the current hand orientation based on each thumb/finger section weight.
- With the total weight, use look-up table (header.c file) and SWITCH/CASE to determine whether the character is valid or invalid.
- Store a new valid character if it's different from a previous valid character, then later this stored character is used to compare for the next coming character.
- Send a valid character to LCD display and RS-232 interface.

We use the following software's for coding and writing programme into the microcontroller.
1) mikroC Pro (for PIC) for Embedded C programming[11]
2)MPLAB IDE for burning the hex file on to PIC microcontroller chip using PIC KIT 3.

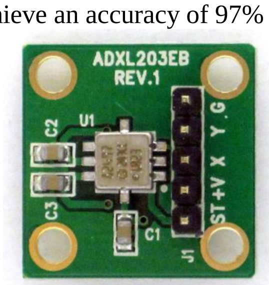
3. RESULTS

We initially used normal cotton clothed glove and sensors directly mounted on the glove for out prototype. We connected the accelerometer ADXL203CE [8] as per the circuit shown in fig 4. PIC18F Development Environment Board [9] was chosen and the code was burnt in it based on the look-up table as shown in Table 2. Initially it was tested for single alphabets and numbers and then extended for words. Fig 7 show the results of the glove.

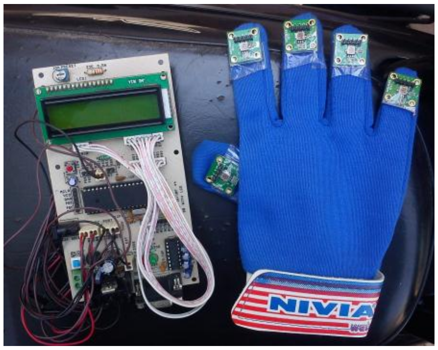
(a) (b)

Fig. 7. (a) Shows the sign for "Y" and corresponding letter displayed on the LCD. (b) shows the prototype of the glove.

Once the prototype was ready we tried to productize the glove. We used a fabric glove on which accelerometer board ADXL203EB [10] were mounted as shown in fig 8. By using this board we remove external connecting wires and capacitor bank. The complete product of the glove is as shown in fig 8(b). We tested the glove for speed and accuracy on various hearing impaired people. We observed that we could achieve an accuracy of 97% using our glove.



(a)



(b)

Fig. 8. (a) Shows the accelerometer with capacitors mounted on single board [10]. (b) Shows the final product of the glove.

4. CONCLUSION

Our paper describes the design and working of a system which is useful for dumb, deaf and blind people to communicate with one another and with the normal people. The dumb people use their standard sign language which is not easily understandable by common people and blind people cannot see their gestures. This system converts the sign language into voice which is easily understandable by blind and normal people. The sign language is translated into some text form, to facilitate the deaf people as well. This text is display on LCD or any hand held device. The glove has been tested very efficient and accurate which eradicates the limitations of other sensor glove described in the literature.

There can be a lot of future enhancements associated to this research work, which includes:

1- Designing of wireless transceiver system for “Microcontroller and Sensors Based Gesture Vocalizer”.
2- Perfection in monitoring and sensing of the dynamic movements involved in “Microcontroller and Sensors Based Gesture Vocalizer”.
3- Designing of a whole jacket, which would be capable of vocalizing the gestures and movements of animals.
4- Virtual reality application e.g., replacing the conventional input devices like joy sticks in videogames with the data glove.
5- The Robot control system to regulate machine activity at remote sensitive sites.

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