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Development of an Electronic Glove with Voice Output for Finger Posture Recognition

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Abstract – *This project is to develop an electronic glove which can translate hand posture in Malaysian Sign Language into spoken words. The glove is built to help deaf, blind and non-vocal persons to communicate with normal people like us. Furthermore, this project can be divided into 4 main parts. First is the sensing part which consists of flex sensor and accelerometer, they are sewn on the electronic glove to detect the motion of finger. Second, the 555 timer circuit is used to convert the analog voltage to frequency. Then, part three consists of microcontroller, it is used to analyze the input signal, as a frequency counter and as a controller. Finally, the result would be output as spoken words via a small speaker. Some simulation and lab testing of the flex sensor have been carried out. The flex sensor is reliable to detect finger posture.*

Keywords: Malaysian Sign Language, Electronic Glove, Talking Glove, Finger Posture, Microcontroller

1.0 INTRODUCTION

Sign language is a combination of hand shapes, orientation and movement of hands, arms or body, and facial expression to express a speaker's thoughts [1]. In Malaysia, there many sign language such as Penang Sign Language and Selangor Sign Language. These two sign languages began in 1980 before Malaysia Sign Language. Malaysia Sign Language was introduced when the Malaysian Federation of the Deaf was established in 1998 [2].

Problem occurs when deaf person wants to communicate with normal people like us. The only way they can communicate with us is by using sign language. But, the main problem is most of us do not understand sign language. A translator is needed in order to start a conversation. The same problems would occur to non-vocal people.

Consequently, this project is to develop an electronic glove which can translate hand posture in Malaysian Sign Language into spoken words. Furthermore, the project can be divided into four main parts. First would be the sensing part which consist of flex sensor and accelerometer. These sensors are able to detect the posture of finger. Second part would be the analog voltage to frequency converter. It will convert the analog input to frequency. After that, part three is using microcontroller to analyze and recognize the hand posture. Finally, part four is displaying the glove's output. The output is in the form of spoken words. Figure 1 shows the block diagram of the development of the electronic glove.

Journal of Advanced Research in Applied Mechanics
ISSN (online): 2289-7895 | Vol. 10, No. 1. Pages 36-46, 2015

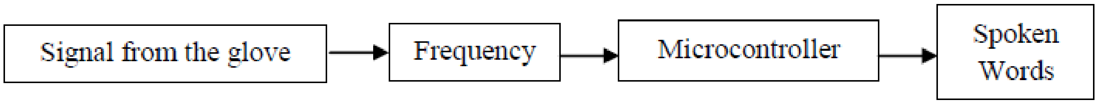

Figure 1: Block diagram of the development of the electronic glove.

2.0 HARDWARE DEVELOPMENT

In this section, it will discuss the hardware used to build the electronic glove. As mentioned before, the hardware used can be categorized into four main parts namely sensors, analog to frequency converter, microcontroller and sound output. The operation and function of each part will be explained in the following sub-sections.

2.1 Sensors

The sensors consist of flex sensor and accelerometer. For flex sensor, it is sewn on each finger on the glove (Figure 2). As finger bend, the resistance will change. For the normal condition which is not bending, the resistance is about 10 kohm. If it is fully bended, the resistance can reach 25 kohm. However, the resistance is not the same for all flex sensor. When it is not bending, different resistance value will be obtained as different piece of flex sensor is used. So, different reading will be produced for different flex sensor.

Apart from that, the ADXL 311 dual-axis accelerometer is used to detect the position of forearm. The accelerometer is small in size, which is only 5 mm x 5 mm x 2 mm. It is placed on the forearm. The accelerometer has two outputs and both are DC outputs. The capacitor used are both set to 10 μF. The large value of capacitor is used to reduce the oscillation of output. With two outputs, one of them is used to detect the rising and falling of forearm, and another output is to detect the turning of forearm.

Figure 2: Electronic glove assemble with flex sensor.

2.2 Analog Voltage to Frequency Converter

555 timer is a device for generating accurate time delays and oscillation. The circuit of 555 timer used is for a stable operation. In this operation, the frequency and duty cycle are accurately controlled with two external resistors and a capacitor.

Penerbit
Akademia Baru
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Referring to Figure 3, by not changing the value of C1, 0.01 uF capacitor, the output period can be changed by varying the resistance R2. Based on experiment (Table 1), the resistance R2 is chosen to be 5 kohm. This is because the percentage of error is small. Moreover, the 5 kohm resistance gives larger output range.

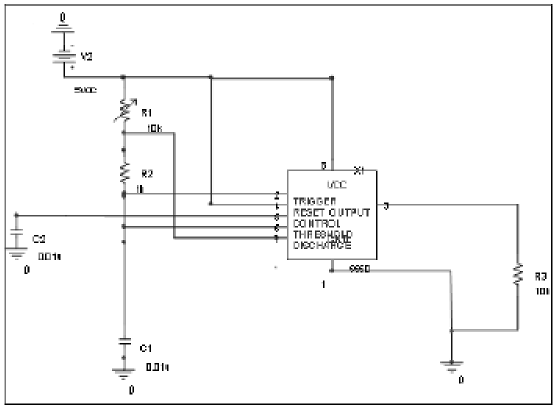

Figure 3: Circuit diagram for 555 timer with R1 represents flex sensor.

Table 1: Summary of experimental result.

Resistance of R2 (kohm)	Percentage of error (%)	Output range (kHz)
1	22.9	**3.47 – 9.28**
5	18.2	**2.97 – 5.92**
10	18.5	**2.37 – 3.90**
15	17.5	**2.01 – 2.96**
20	17.0	**1.70 – 2.40**
25	17.0	**1.50 – 1.99**
30	**16.3**	**1.34 – 1.73**

2.3 Microcontroller

This section would discuss about the PIC circuit. The PIC used is PIC 16F877A. Two PICs have been used for this project, the first PIC (U1) is used to analyze the sensor input and to compare the input with the stored database. Another PIC (U2) is only used to control the ISD 25120 sound recorder. PIC, U2 has to control the length of the sound track. Each segment of the sound is about 1.6 seconds. A timer or delay is programmed into PIC U2 so that after 1.6 seconds, the ISD 25120 sound recorder will stop playback. This is the reason for using two PICs.

2.4 Sound Output

The IC used to record and playback the sound would be ISD 25120 sound recorder. It can play and record for 120 seconds with sampling rate of 4 kHz. The IC is included with on chip oscillator, microphone preamplifier, automatic gain control, antialiasing filter, smoothing filter,

Journal of Advanced Research in Applied Mechanics
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speaker amplifier and high density multi-level storage array. Furthermore, the IC allows complex messaging and addressing. The recorded sounds are stored in a nonvolatile memory cells. With these features, the ISD sound recorder would provide good quality sound effect.
For addressing mode, the sound can be recorded and playback from address 0000000000 to 1111111111 (A0-A9). Based on experiment, pin A2 controls the address for every 0.8 seconds, pin A3 controls for every 1.6 seconds and pin A4 controls for every 3.2 seconds and so on. In other words, when it is needed to play the sound start at 2.4 seconds, set A3 and A2 to "1" and reset other pins. Then the sound will start playing from 2.4 seconds.

Moreover, the CE and PD pins are used to stop the recording or playback process. CE is known as "Chip Enable" which is used to pause and resume the recording. Besides, PD pin is used for start and reset purpose. When PD pin is pushed "High", it will reset the IC. In this project, the entire pin A3 to A9 will be connected to PIC. The PIC will select which segment of sound should be playback.

3.0 SIMULATION

The simulation in this section is done in PSpice to generate the output waveform when different hand posture is made. Here, the output is taken from the 555 timer. In 555 timer, the period of the waveform is changing with different hand postures. When the finger bend, the flex sensor will increase and the period of a cycle becomes longer. As period become longer, the frequency will become smaller.

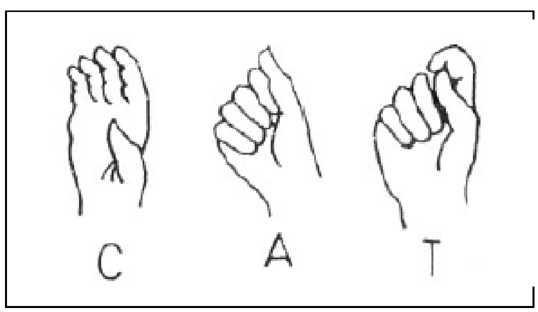

Figure 4: Hand posture of alphabet "C", "A" and "T".

Table 2: Output frequency for each finger.

Finger	Hand Posture (kHz)		
	"C"	"A"	"T"
Thumb	6.74	7.17	6.74
Forefinger	5.41	4.09	5.12
Middle Finger	5.60	4.46	4.49
Ring Finger	5.55	4.38	4.42
Little Finger	6.09	3.75	3.74

Detection of hand posture requires information from each finger. This means 5 set of flex sensor circuits are needed for a hand. Then, the output waveforms or output frequency of each finger are to be analyzed to determine the sign. Table 2 shows the output frequency of hand posture “C”, “A” and “T” (shown in Figure 4).

4.0 EXPERIMENTAL RESULTS

Some experiment data for difference hand posture have been taken. In the experiment, the circuit as shown in Figure 3 has been assembled. Firstly, the flex sensor of thumb finger is connected to the circuit, R1. Then, the output of the 555 timer, pin 3, is connected to frequency counter. Now, different hand posture is made and the readings on frequency counter are taken. After that, the process is repeated and the readings for forefinger, middle finger as well as little finger are taken. Table 3 shows the results of output frequency when hand posture “C”, “A” as well as “T” are made. The ring finger is not included because the flex sensor attached to ring finger was not working already when the experiment was carried out.

Table 3: Output frequency from experiment results for each finger.

Finger	Hand Posture (kHz)		
	“C”	“A”	“T”
Thumb	5.12	5.50	4.99
Forefinger	4.22	3.33	3.97
Middle Finger	4.35	3.33	3.33
Little Finger	5.38	3.59	3.71

4.1 Testing on Accelerometer

A series of experiments are done. In the experiment, the accelerometer is fixed on a ruler. The accelerometer has two outputs, and based on a few testing, it can be noticed that the X-axis and Y-axis are perpendicular to each other. Figure 5 shows the turning and rising of hand which is able to be detected by accelerometer.

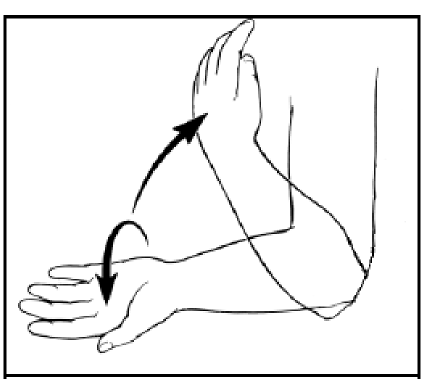

Figure 5: The hand posture which can be detected by accelerometer.

Journal of Advanced Research in Applied Mechanics
ISSN (online): 2289-7895 | Vol. 10, No. 1. Pages 36-46, 2015

After that, the experiment is assembled to examine the relationship between voltage and angle changed. So, the output of X-axis is first connected to voltmeter to read the voltage. Second, the accelerometer is put horizontally (0°) and the voltage is read from voltmeter. Third, the accelerometer is raised up by every 15° until it reach 90° (vertical), and all the readings of voltage are taken down. Forth, the accelerometer is tested from 0° to -90°.

The Y-axis also applies the same concept. However, the experiment is not discussed here. Table 4 shows the experiment results for X-axis. The graphs shown in Figure 6 are plotted to examine the relations between voltage and angle for the X-axis.

Table 4: Experiment of voltage changed due to the change of X-axis in accelerometer.

Angle (°)	Results (Volts)			
	Set 1	Set 2	Set 3	Average
0	2.45	2.45	2.46	2.45
15	2.35	2.36	2.36	2.36
30	2.30	2.3	2.30	2.30
45	2.24	2.24	2.23	2.24
60	2.20	2.20	2.19	2.20
75	2.18	2.18	2.17	2.18
90	2.17	2.18	2.17	2.17
-15	2.55	2.55	2.54	2.55
-30	2.62	2.61	2.62	2.62
-45	2.68	2.69	2.68	2.68
-60	2.73	2.73	2.73	2.73
-75	2.77	2.77	2.76	2.77
-90	2.78	2.79	2.78	2.78

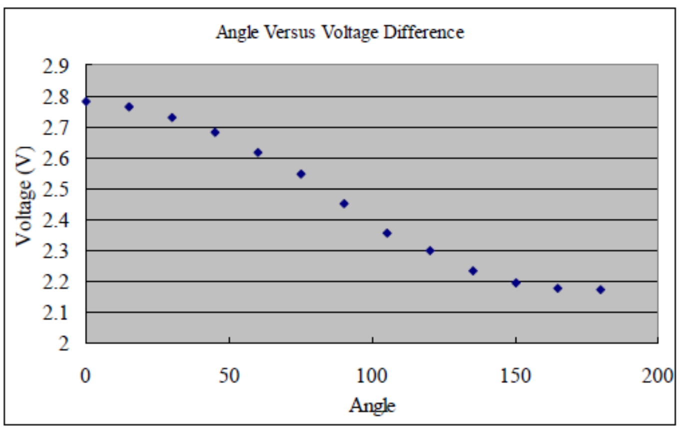

Figure 6: Voltage will change due to different angle for X-axis.

Based on the graph plotted, Figure 6, it can be observed that, the graph is similar to a Sinus curve. A linear line is not able to fit all the points. Especially when the voltage converges at two ending, the linear equation is totally cannot fit to the graph. Therefore, a Sinus equation has been developed as shown in (1):

$$V=2.45 + K \sin(A) \quad (1)$$

Journal of Advanced Research in Applied Mechanics
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where K is a constant and A is the angle.

Based on the experiments data, the constant K can be obtained by substituting A=-45° and V=2.68 V into (1). Then, the value of K is -0.31. Now, the equation for the accelerometer is as shown in (2):

$$V=2.45 -0.31 \sin (A) \quad (2)$$

In order to verify that (2) can correctly explain the characteristic of the accelerometer, A is substitute with angle +60° and -60°, and the answers are 2.18 V and 2.72 V. Comparing this with the value in Table 4, it is noticed that the calculated values and experimental results do not show much difference.

4.2 Testing for Finger Spelling

By referring to the database, it has been noticed that a few sign language are not able to be detected by the electronic glove. The main reason is the electronic glove do not have sensor to detect the bending of wrist. The sign language which is not able to be differentiated is shown in figure below (Figures 7 to 9). Furthermore, for alphabet R and V, the flex sensor is not able to detect the closing and separate of fingers.

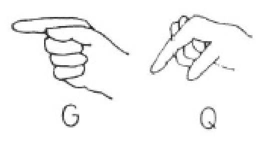


Figure 7: The sign language G and Q have same values for all the fingers.

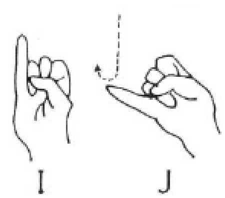


Figure 8: The sign language I and J have same values for all the fingers.

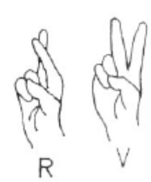


Figure 9: The sign language R and V have same values for all the fingers.

Beside the failure case, a few testing on finger spelling have been done. Based on the testing, those hand posture such as M and N, one of them has been eliminated. The database is only containing the distinct hand posture. The alphabets which have been eliminated are H, J, L, N,

Journal of Advanced Research in Applied Mechanics
ISSN (online): 2289-7895 | Vol. 10, No. 1. Pages 36-46, 2015

O, P, Q, R, V, W and X. Therefore, only about 15 alphabets can be detected by this electronic glove.

By using the limited database, the hand spelling for words SUM (Figure 10) and CAT (Figure 4) have been done. The results for the hand posture are shown in Tables 5 and 6. In the Tables, the Thum is thumb, Index is index finger, Mid is middle finger, Little is little finger and Acce is accelerometer (X-axis).

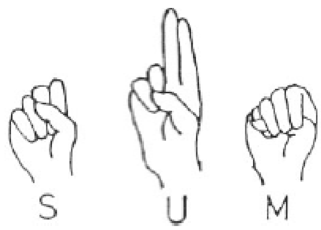


Figure 10: Hand posture for alphabet "S", "U" and "M".

Table 5: Result for hand spelling of word "CAT".

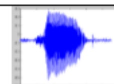
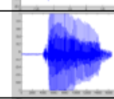
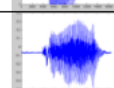
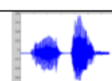
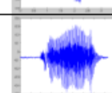
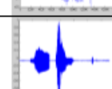
	Input					Output
	Thum	Index	Mid	Little	Acce	
C	5.12 kHz	4.22 kHz	4.35 kHz	5.38 kHz	2.68 V	
A	5.50 kHz	3.33 kHz	3.33 kHz	3.59 kHz	2.68 V	
T	4.99 kHz	3.97 kHz	3.33 kHz	3.71 kHz	2.68 V	

Table 6: Result for hand spelling of word "SUM".

	Input					Output
	Thum	Index	Mid	Little	Acce	
S	4.74 kHz	3.07 kHz	3.33 kHz	3.58 kHz	2.68 V	
U	4.86 kHz	4.86 kHz	5.38 kHz	3.84 kHz	2.68 V	
M	4.48 kHz	3.58 kHz	4.4 kHz	3.71 kHz	2. 68 V	

4.3 Testing for Gesture

The main objective of this system is to detect the gesture of Malaysian Sign Language. Therefore, a few testing on Malaysian Sign Language have been carried out to verify the reliability of the system.

Penerbit Akademia Baru
Journal of Advanced Research in Applied Mechanics
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The gestures for "Why" and "Bread" have been done (refer to Figure 11). The results are shown in Table 7. For Table 7, "B1" is the first movement of bread and "B2" is the second movement of bread. Furthermore, "W1" is the first movement of why and "W2" is the second movement of why. With fulfillment of first and second motion, the system will able to recognize the sign language and play out the sound of the sign language.

For gesture "Bread", it can be used to check the reliability of accelerometer. The right hand has to move from upward to downward. However, the inputs from flex sensors do no change. So, by moving upward and downward, it can be noticed that the voltage at upward location is about 2.6 V. When the hand is putting horizontally (downward), the output voltage of accelerometer will be drop to 2.4 V.

Again, from Table 7, it is noticed that the accelerometer for gesture "Why", the "W1" and "W2" did not changed. This is due to the gesture has no movement on arm. Thus, the recognition of gesture "Why" is based on the bending of fingers. At first, the system detects the all the fingers are no bend (W1). Then, the system will check whether the index finger and middle finger are bending ("W2").

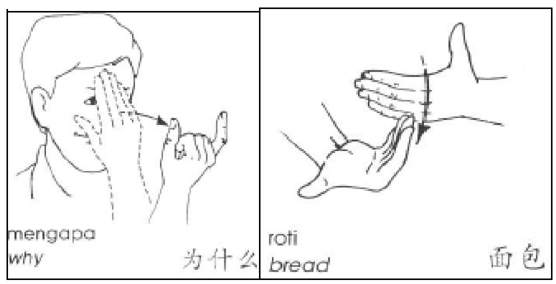
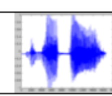
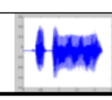


Figure 11: The hand gesture for "Why" and "Bread".

Table 7: Result for hand gesture "Why" and "Bread".

	Input					Output
	Thum	Index	Mid	Little	Acce	
W1	5.0 KHz	4.9 KHz	5.4 KHz	6.1 KHz	2.6 V	-
W2	5.0 KHz	3.6 KHz	3.7 KHz	6.0 KHz	2.6 V	
B1	5.5 KHz	3.8 KHz	4.1 KHz	4.1 KHz	2.6 V	-
B2	5.5 KHz	3.8 KHz	4.1 KHz	4.1 KHz	2.4 V	

5.0 DISCUSSIONS

Based on the simulation and result from experiment, the 555 timer can be used to convert the information from flex sensor into frequency. When the finger bent, the output waveform will be changed, the period will become larger or frequency becomes lower. By getting this information, the movement of the finger can be detected and determined.

Journal of Advanced Research in Applied Mechanics
ISSN (online): 2289-7895 | Vol. 10, No. 1. Pages 36-46, 2015

However, by comparing the result of experiment and the simulation, it is slightly different. The difference is about 20%. This error may be due to the simulations and experiments are done separately. So, the posture made will be slightly different. Moreover, the 555 timer is assembled in breadboard. The breadboard may contribute extra resistance to the circuit. The error may also due to the probe which is used to detect the output frequency. However, it is common for error to occur in 555 timer, because the capacitor value and the resistor values have a tolerance range of 10%. This may cause a lot of difference in output frequency.

So, the 555 timer circuit has to be calibrated one by one and only the physical values are considered. The simulation is only for reference and by knowing the characteristic of the output waveform. Based on the simulation output, it gives a clear idea on how to use microcontroller to calculate the output frequency.

For the sign language, there are 5 pairs of sign language which cannot be differentiated. This problem can be solved by adding another flex sensor to detect the bending on wrist. Apart from that, the problem can be solved by editing the sign language so that the flex sensors can read the difference.

For gesture, the testing is very little. Furthermore, most of the gestures need two hands.

6.0 CONCLUSIONS

The flex sensors had been sewn on the electronic glove and the circuit used to convert the analog input to frequency output has been assembled. The flex sensor had been tested with 555 timer. Some experimental results of the flex sensors have been recorded. Some simulations based on Malaysian Sign Language have also been done. For the accelerometer, some experiments have been carried out to investigate the characteristic of the accelerometer.

Besides, the PIC has been programmed to analyze the signal sent from the sensors. The PIC is able to perform as frequency counter and analog to digital converter. The sound system has been tested. Now, the PIC is able to control and playback the sound track store in the ISD sound recorder.

Apart from that, the system is able to interpret the Malaysian Sign Language. However, not all the sign language can be interpreted. Thus, further calibration on the system is needed in order to increase the possibility to recognize Malaysian Sign Language.

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