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B. ENG. (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

JANUARY 2015

Simulation of Brain-Computer Interface Based Wheelchair Controls Using Microcontroller

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UNIVERSITI TEKNOLOGI PETRONAS
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14657

A Project Dissertation Submitted to the

Department of Electrical & Electronics Engineering

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in Partial Fulfillment of the Requirement for the

Bachelor of Engineering (Hons)

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CERTIFICATION OF APPROVAL

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Approved by:

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DR. MOHD ZUKI B YUSSOF
PROJECT SUPERVISOR

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2015

CERTIFICATE OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and the acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MAZEN ABDULRAHMAN SALEM BA ABBAD

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ABSTRACT

Humans always have the desire to control each single process in their life and looking for the simplicity to live in a comfort and peace. Many technologies have been invented because of the instinct of humans. In our daily life we need to control our body or certain parts of it. For example to walk we need to control our legs and to eat we have to control our hands and mouths, and for the whole body movements we need to have the control all over the spinal cord. But any injuries or problems happen to the spinal cord may lead to obstruction or disability. The handicapped people how lost the control over their body parts. But there are people who are totally paralyzed and can't move in their own, and need some help from others to move them around. With the advancement of science and technology, humans came up with a new technology called Brain Computer Interface (BCI), this technique can acquire the human's brainwave signals and determine the person's thoughts and intentions and convert them in to commands. This has led to invent the so called Brain Controlled Wheelchair (BCW) which gives the human the ability to be a mobile without the physical movements of their body. This technology is definitely useful especially for those who are paralysed or have a physical disability which ban them from moving the joystick and control the wheelchair. Using BCW makes the person become independent and no need of having an attendant to drive the wheelchair so they can move around and having their needs.

ACKNOWLEDGEMENT

First and foremost, all praise is to Allah, the Most Gracious and the Most Merciful, Who through His mercy and grace, I was able to complete my final year project. Next I would like to express my appreciation to Dr. Mohd Zuki B Yussof, for his endless support. My ultimate gratitude to him for his guidance, monitoring throughout my project. My deepest heart gratitude to my parents who strived to get me where I'm now, especially my father, Abdulrahman Salem who helped me in all possible ways to ease my way through this project. His spirit has guided me through my difficult times. Deep appreciation goes to my brothers, sisters and my friends. I dedicate this project to them and I highly appreciate their motivation and encouragement and their valuable advices that they provided me through all this period. Not to forget, I would like to thank Universiti Teknologi PETRONAS (UTP) for their support and for providing me with the necessary equipment and software that were required to run the project smoothly.

CHAPTER 1

PROJECT BACKGROUND

1.1 BACKGROUND STUDY

Brain Computer Interface (BCI) is a technique to get and analyse the signals produced by human's brain with the aim of making a direct way of communication between the human's brain and the outside environment[1-3]. BCI is also known as a Direct Neural Interface and some call it as a Brain-Machine Interface. The BCI machine acquires the signals from the subjected brain and analyse them in order to determine the intentions and thoughts of the subjected brain[4]. this function of the BCI could assist the disabled people to communicate with others and help them to deliver their daily duties in a better manner [1]. So BCI technology has considered as a blessing tool for those who suffer from neuromuscular disorders[4]. But it needs a strong concentration of the user [5].

Most of the BCI systems consist of three units which are: signal acquisition unit; where the electrodes are spread out on the scalp of the user. Signal analysis unit; where the signals can be processed and the data can be interpreted by amplifying the acquired signals and remove the noises from them, in this unit, features are extracted from the input signals and classified accordingly into different classes. Action unit; where the classified signals obtain from the signal processing units are converted into digital control signals which could be used to communicate with the outside surrounding and give a feedback to the user [2, 5]. the successful operation of the interface between the device and the user's brain depends on the amount of the training required for the designing a BCI [3]. Figure 1 is the architecture of general BCI system.

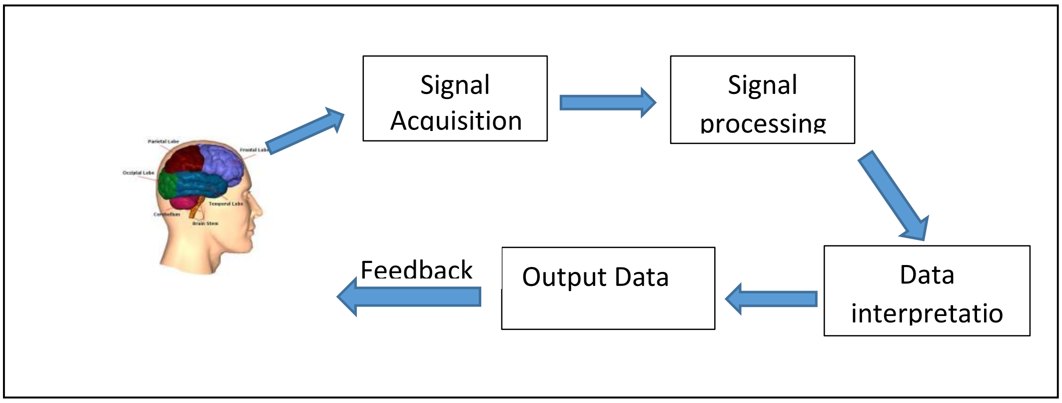

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Figure 1: The architecture of general BCI

BCI system works without any physical movement, or in anther hand BCI system is a non-muscular communication provider which in return it acquires the input signals directly from the brain and analyse them into orders to determine the thoughts of the user. BCI systems has proven its efficiency and accuracy of the operation and it holds the advantage of the ease of use and can be controlled by anyone [4, 6, 7].

For the proposed system, there will be no feedback from the use. The frequencies will be transferred to the microcontroller and will be processed then the action will be taken by moving the wheelchair to the recognized direction. And if there is any problem in the process of the microcontroller the system should stop and start the process again. Figure 2 is the architecture of the proposed BCI system.

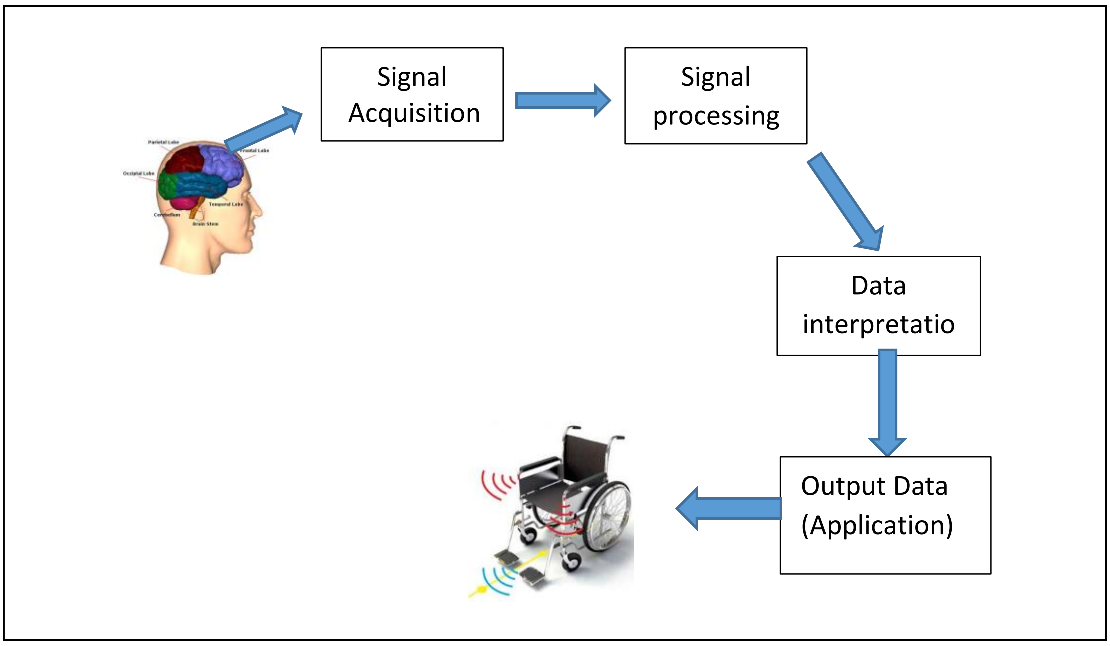


Figure 2: The architecture of the proposed BCI system

1.2 PROBLEM STATEMENT

Individuals with paralysis and disabilities are unable to walk or move around. And most are wheelchair bound. Moreover, decreased or absence of physical activities associated with a long time of wheelchair use has led to a wide range of comorbidities[8]. However the advancement in BCI present great opportunities for development of a wheelchair interface for disabled people based on their thoughts and intentions[4].This will definitely enhance the quality of the disabled people's life in this population, and reduce the happening and the cost of the comorbidities and the care giver burden[8]. In fact BCI system is indeed a useful and powerful application which can be used in different fields such as instrumentation, education, entertainment as well as medical applications [6]. It is worth for the disabled people to have such application that changes their life to better and make them feel more blessed. BCI system makes the physical challenged people to control and manage their own life without the need of any bulky devices and instruments.

From the side of our university, In UTP CISIR lab, there are several PC-based software tools that can be used to acquire and analyse signals. However, an action unit is still not available in this laboratory, preventing a developed "thoughts-to-command" algorithm from being validated on real equipment (e.g., wheelchair).

1.3 OBJECTIVES

The goal of the research project is to design and implement an advanced microcontroller-based device on intelligent approach acting as an action unit which is able to convert the classified signal into a discrete control signal and accurately moves the wheelchair to forward/backward and turns it to left/right.

The objectives of the research are as follows:-

1- To design microcontroller system that is able to measure different frequencies by utilizing control, embedded systems and programming concepts.
2- To implement the programmed microcontroller in the wheelchair and move it in the four directions (front, back, right and left).

1.4 SCOPE OF STUDY

The scope of this study is to design and implement a microcontroller control system that can drive a smart wheelchair. This system depends on the value of the frequency that the microcontroller measure. And then give a command to the interface circuit to move the wheelchair accordingly in the four directions; forward, backward, right and left. The wheelchair is in a stop motion if no command is given. When the user selects a command, there is no need to concentrate in the external stimuli.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW OF SMART WHEELCHAIR

Electrical wheelchairs which requires less effort have been invented to accommodate the needs of the disabled people and assist them in moving around and communicate with external world as well as to control devices. However some of the disabled users cannot drive their wheelchair professionally and have some difficulties especially driving it in narrow places. And moreover these inventions still have some disadvantages. For instance the language communication response is a bit slow to the command and sometimes it gets stuck when many of commands are given within a short period of time. The head posture interpretation is said to be discomfort and assume that the user is totally paralysed then none of the above systems could assist on the flexibility of the movements. To overcome this problem, a lot of techniques have been proposed to help people in driving their wheelchair [5, 6].

Brain Computer Interfaces (BCIs)considered one of these techniques that help the disabled human to drive and control their wheelchair using brain signals[5]. But these techniques needs the user's focus and concentration all the time while driving the wheelchair [5, 6]. Human's brain contains billions of nerve cells. These cells send signals to the muscles through the spinal cord to give the human the ability to move. But the injuries of the spinal cord or other conditions can prevent these weak electrical signals from reaching the muscles[9]. The researchers designed a special device such as a cap in which can cover the scalp. This device captures the signals from the scalp and send them to a computer. The computer analyse the signals and commands the motorized wheelchair [10].

EEG is a method to record the electrical brainwave signals. This can be obtained by placing the electrodes on the humans scalp with a conductive gel or paste[10]. The voltages of the obtained brainwave signals are very small and got some noise (of the order of few microvolts) so the signals needs to be filtered and amplified and the digitalized before transfer it to the computer for processing where the features extraction is performed then the signals will be classified, followed by converting the classified signals into the digital form and suitable commands will be generating to control the wheelchair[2, 5, 11].

2.2 BRAIN STRUCTURE

Brain is the most complex and biggest structure in human's body. It consists of more than hundred billion of nerve cells connected to each other by trillions of connections named as synapses. In fact the brain is the human command centre the nervous system. The brain receives the input from the sensory organs and give the outputs to the body muscles to control the part all over the body and do the communication. This function enables human beings to successfully interact with their environment[12].

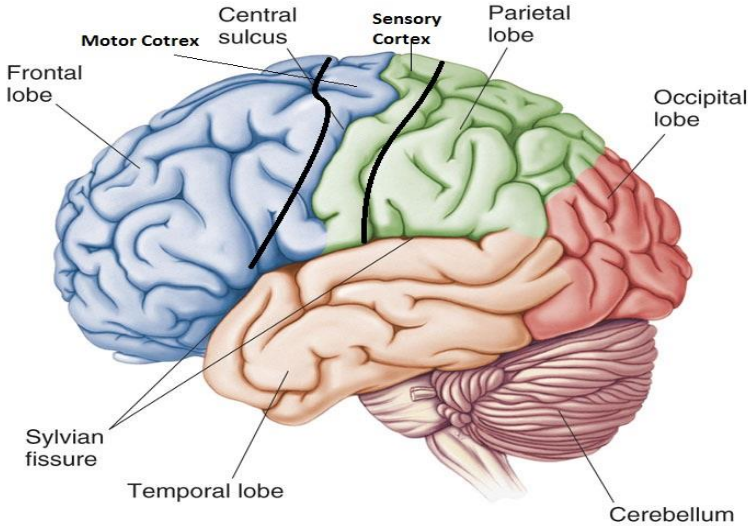


Figure 3: The lobes of Cerebrum

The cerebral cortex of human brain is divided into four main sections called lobes which are: Frontal lobe, Parietal lobe, Occipital lobe and temporal lobe Figure 3.

- <u>Frontal Lobe:</u> is the front part of the brain and it is responsible for several elements such as: creative thought, planning, problem solving, physical reaction and movements [13].
- <u>Parietal Lobe:</u> is located behind the Frontal lobe and it's in the top middle of the skull, it has sensory and motor cortex located at the most front part of this lobe and at the top middle if the brain which assist the brain to monitor and control the movements and orientation of the body. And it also involves in recognition, balance and posture [13].
- <u>Occipital Lobe:</u> this lobe helps to control the vision and it is located at the back side of the head [13].

- Temporal Lobe: positioned at the base of the brain mainly under the Frontal and Parietal lobes and beside the Occipital lobe and above the ears. This area is responsible for visual and auditory memories and hearing and speech capabilities [13].

Cortical areas are very important for the BCIs systems. Because these areas involve in the signal acquisition and data analyses of the behaviour of the EEG [14].

2.3 SIGNAL PROCESS AND ACTION

2.3.1 Data acquisition process

Data acquisition is the process of sampling brainwave signals and converting them into digital signals in which can be manipulated by the computer [6]. Generally converting analogue signals to digital numeric values for processing. Emotiv EPOC headset which is based on Electroencephalography (EEG) this is a way to get and sample the brain signals[5]. These brainwaves can tell the system what the user wants to do in the virtual reality. The Emotive EPOC headset is easy to use and the user can use it without any assistance. The electrodes should be positioned against the user's scalp in order to pick up the brain signals. The area to acquire the human body movement is the sensory motor cortex and these signals is only ranged between alpha band (8 –12) Hz and beta band (13-30) Hz. Figure 4 summaries the data acquisition process[15].

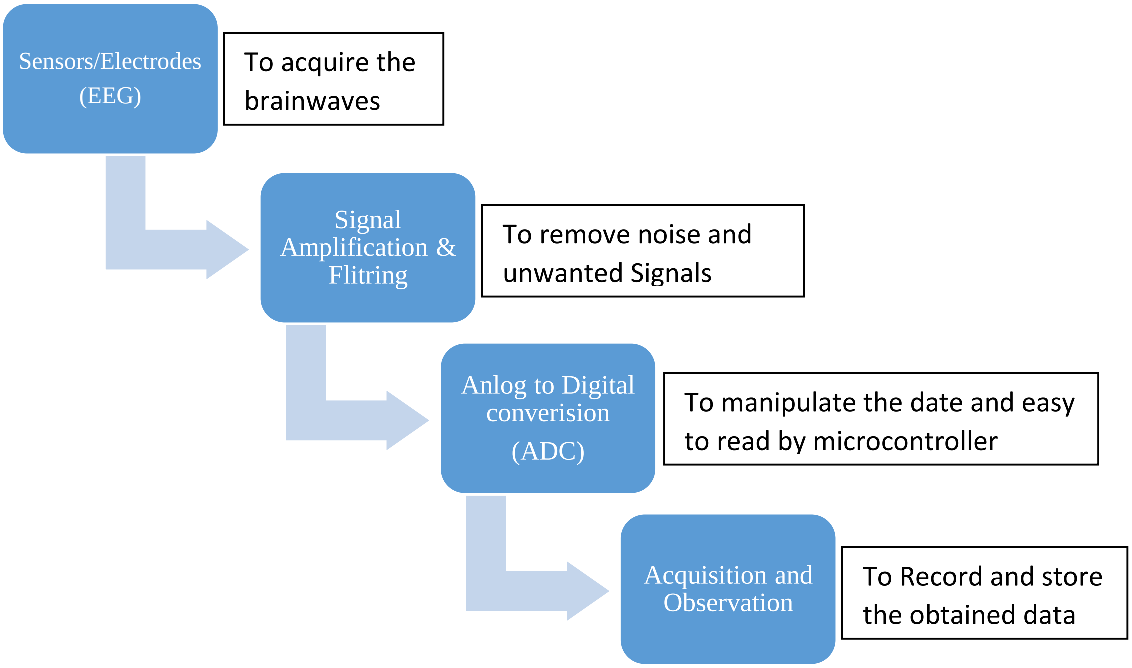


Figure 4: Schematic of the data acquisition system

2.3.2 Signal Processing Unit

Emovit EmoEngine can be used as a signal processing unit. In this unit the signals will be processed and the date will be analysed by removing the noise form the acquired signals and convert them into a numeric values so that the computer can easily understand them and convert them in to states or commands which can operate the wheelchair according to the detected brainwave frequency[16]. Below is a tabulated record of brainwave frequencies for two different persons Table 1.

Table 1: brainwave frequencies record for two persons

Subjected Person	Brainwave signal direction	Frequency in Hz
1	Forward	14 (beta)
	Backward	8 (alpha)
	Left	20 (beta)
	Right	26 (beta)
2	Forward	16 (beta)
	Backward	8 (alpha)
	Left	22 (beta)
	Right	20 (beta)

Most of the human brainwave signals that are responsible of the body movements are ranged in alpha or beta only[17]. The dominant frequencies ranged for the backward movement comes from alpha band (8-12) Hz, whereas the other body movements (forward, right and left) are usually ranged in beta (14-30) Hz, those frequencies are only whole even number, they never be an odd or in decimal number (8,10,12,14,16,18,20,22,24,26,28,30) [18].

2.3.3 Action Unit

In this unit the states produced by the signal processing unit should be taken to generate appropriate control signals. There are two states in this system, let us say: satisfied state and unsatisfied state as shown in Figure 5.At first the user is in the satisfied state and should do a mental activity to choose an action. When the action is selected or recognised then a suitable control signal is produced. This unit needs a full concentration of the user. Then the system will move to the following state.

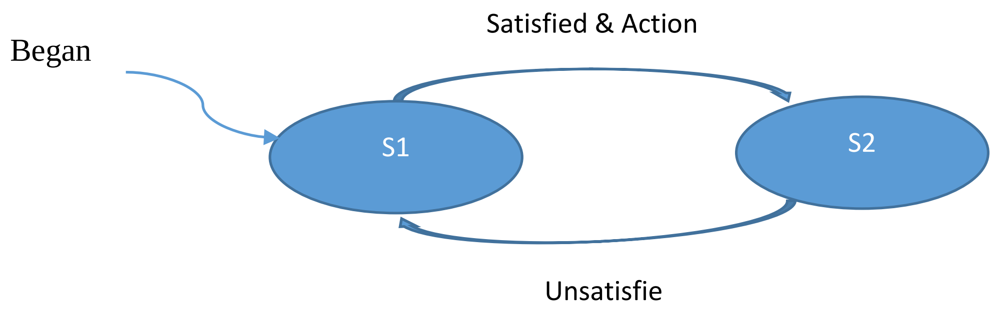
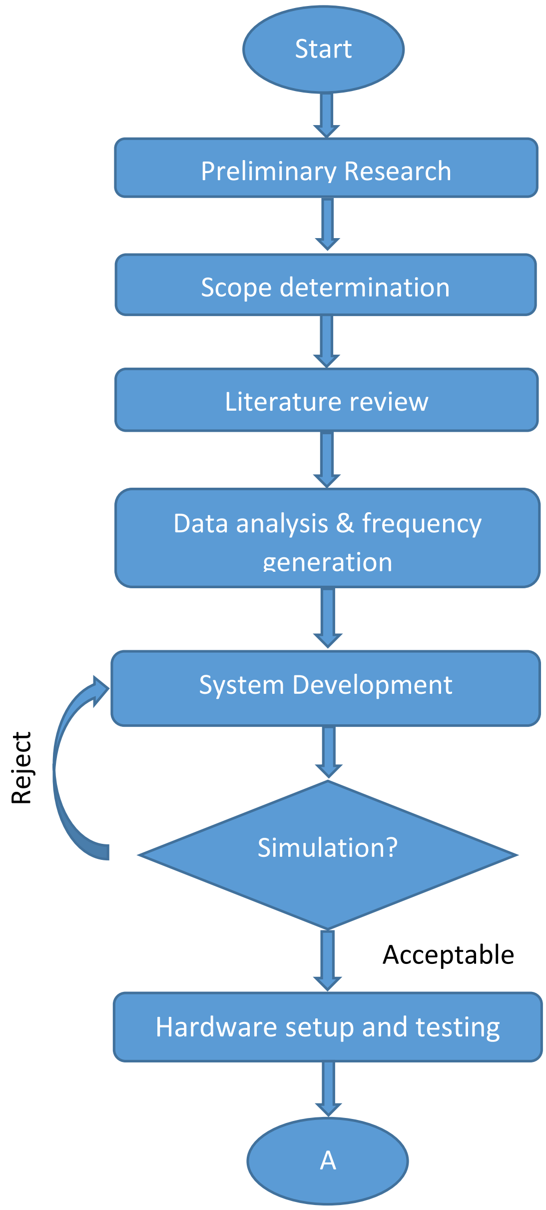


Figure 5: System States

CHAPTER 3

METHODOLGY

3.1 PROJECT FLOW CHART



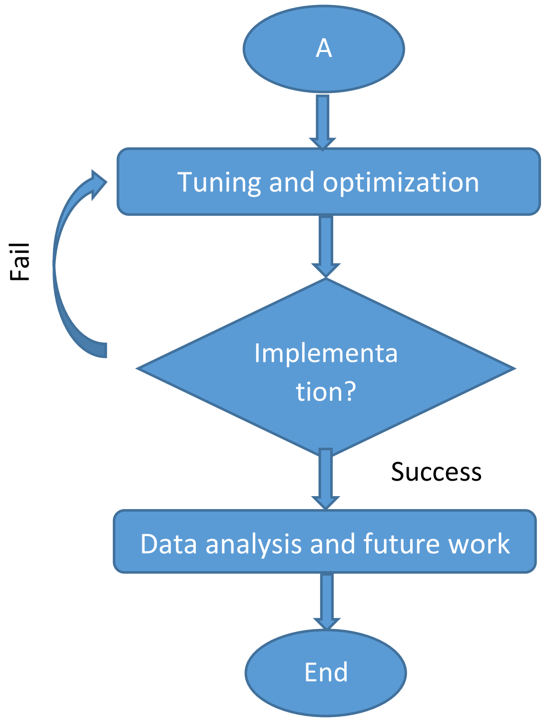


Figure 6: the project flow chart

3.2 PROJECT ACTIVITIES

Table 2:project activities

Activity	Description
Preliminary Research	The information regarding the project is gathered.
Scope determination	Decide the type of the microcontroller to be used and the task to be achieved.
Literature review	Comprehension of the current literature and findings of what researchers have done.
Data analysis & frequency generation	Study on how the frequency can be generated and transfer it into the microcontroller.
System development	Develop the inference system for the controller by adding IR camera to avoid the obstacle.

Simulation	Simulation of the developed system to check its performance.
Hardware setup and testing	Setting up hardware and test the performance of the microcontroller.
Tuning and optimization	Tuning the system of the developed controllers based on the testing.
Implementation	Implementing the controller and testing it under several disturbances then optimizing it further.
Data analysis and future work	Analysis of the results and comparison with conventional electrical wheelchair then suggestions for future work.

3.3 ARDUINO FREQUENCY INPUT MEASUREMENT

FreqMeasure needs a specific pin for the input frequency to measure as a digital level signal. In Arduino Uno, the frequency Input Pin is 8, and keep in mind that pins 9 & 10 are Unusable with analogWrite() and Most pins of Arduino boards gives a frequency of the PWM signal of 490 Hz, While pins 5 & 6 in Arduino Uno have a frequency of about 980 Hz.

There are cases where the input frequency signal could got a noise or may be a high level frequency, to solve this problem we should add a low pass filter Figure 7 to reduce the noise and give a clear reading of the frequencies.

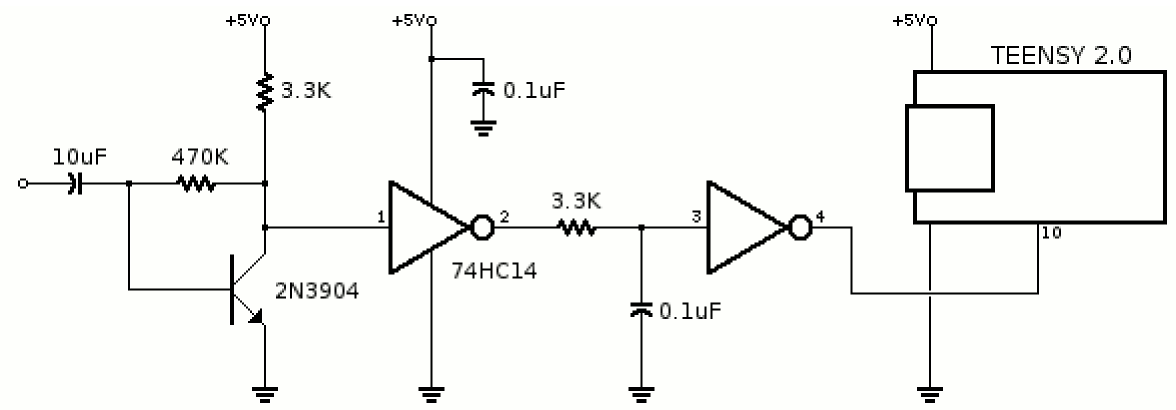


Figure 7: Low pass filter Design

In case if the input frequency is in a form of a sine wave or small alternating current (AC) signal, an amplifier circuit is needed to adjust the wave as these type of signals cannot directly drive a TTL logic level input.

3.3.1 Arduino Functions Basic Usage:

FreqMeasure.begin();

This function is to start measuring the frequency.

FreqMeasure.available();

This function returns the available readings of measurements or zero (0) if none are un-read and gives the average of these readings to ensure the accuracy of the measurements.

FreqMeasure.read();

This function will read the readings of the measurements based on the elapsed time of one cycle of the waveform. Every measurements starts directly after the prior waveform without any delay. For a better accuracy, several measurements should be averaged.

FreqMeasure.countToFrequency(count);

This function converts the unsigned long numbers (32 bit) from read () to actual frequency.

FreqMeasure.end();

This function will terminate the process of frequency measurement. And the PWM (analogWrite) functionality could be used again.

Figure 8: Function generator

3.4 DEVICES SET UP

Function Generator: is an electronic device used to produce an electrical waveforms of different types such as: sine, square, triangular and sawtooth shapes, Figure 9 shows the shapes of the function generator waves.

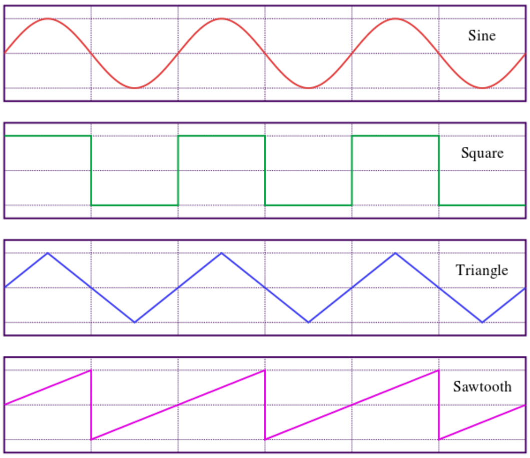


Figure 9: shapes of waveforms

Since the human brain frequencies that we obtained are in square waveform then the functions generator should be set to produce the square waveform. This generated frequency should has a 5 volt digital signal levels (amplitude should be 5 V).

Oscilloscope: is used to observe the change of the electrical signal over the time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analysed for such properties as amplitude, frequency, rise time, time interval, distortion and others.

In our project, the Oscilloscope should be calibrated for a positive square wave form of a 5 volt amplitude while the time is clearly indicated to calculate the coming signal frequency from the function generator.

Motor configuration: the used wheelchair is bought from Karma Mobility Ltd. And it comes with two 24 DC motors Figure 10 and Table 3 shows the details of the motor:

Table 3: motor specification

MOTION TECH MOTOR DC motor (EC Series)		
TYPE: EC82M243820GLGBL		
24 VDC	2.5 Amax	3800 (32:1)
200 Watt	C.C.W	H class


Figure 10: 24 VDC Motor

This motor attached with an electromechanical break, this break can only be released when a minimum of 22 DV volt is applied across its terminals, and full release will be obtained when 24 DC volt is applied. The motor starts rotating when a minimum of 12 DC volt is applied to it. And can move for a full speed when 24 DC volt is applied. The motor will stop if the break voltage drops below 22 DC volt. For the current, 2.2 Amp should be applied across both the motor and the break. And the minimum current that should operate them is 1 Amp.

3.5 INTERFACE CIRCUIT

An interface circuit is required in this project to receive the commands from the microcontroller and do the task accordingly. Figure 11 shows the interface circuit diagram.

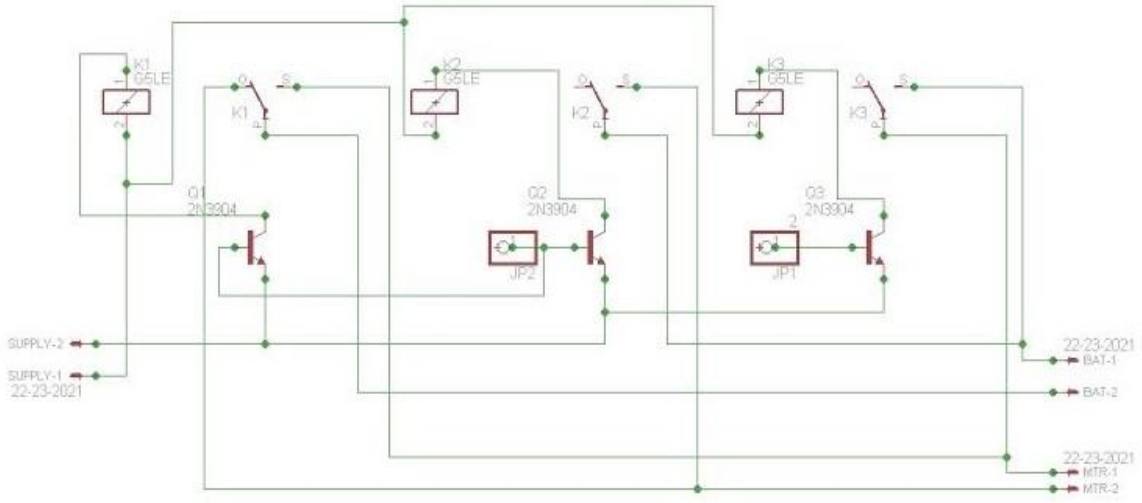


Figure 11: interface circuit diagram

This interface circuit this basically a switching circuit. It controls the direction of the rotation of the wheels, either clockwise or counter clockwise. As the motor operates according to the supplied voltage across its terminals, when the positive terminal of the battery connects to the positive cable to the motor and the negative terminal of the battery connected to the negative cable of the motor then the rotation of the wheel should be clockwise whereas when the connection of the battery terminals goes opposite sides of the cables of the motor then the rotation of the wheel should be counter clockwise. This connection is based the commands coming from the microcontroller.

For the system to be built, we need to prepare the eight tools of the system listed below:

Shows the system component.

1- Electric wheelchair.
2- Function generator.
3- Power supply.
4- Oscilloscope.
5- Laptop computer.
6- Microcontroller (Arduino).
7- Custom software (Arduino Program).

8- Interface circuit.

Shows the system component.

The Electric wheelchair is acquired from the CISIR lab as it is available there for experimental purposes. For the signals acquisition and analyse we can use the function generator to produce a square wave frequency signals with. And we can analyse and measure the frequency values using the oscilloscope. The output of the function generator will be connected to the Arduino as input for it and will give the command of going "forward, backward, left or right" resulting in the movement of the wheelchair Figure 12 [11]. The Arduino should use the Freqmeasure library to enable it to measure the values of the square frequencies produced by the function generator. Then commands should be given based of the values of the frequencies as programmed Figure 12. Any laptop computer can do the job. It only requires to have a USB inlets. To be used for the Arduino connection. The Uno Arduino which is a microcontroller board based on the ATmega328, it has a USB serial for interface with the computer. A connection should be made between the function generator and the interface board by the Arduino. The interface circuit connects the Arduino's outputs with the wheelchair’s motors. The Arduino will send a commend to the interface circuit then the wheelchair will move based on the received commands thinking that the user have moved the joystick. Figure 14 shows the block diagram modal of the wheelchair control modal.

```
if (freq = 24)                    //  move forward (FW)
 {
  digitalWrite(7, HIGH);          // right motor FW
  delay(1000);                     // wait for a second
  digitalWrite(8, HIGH);          //  left motor FW
  delay(1000);                    // wait for a second
 }
 else if (freq = 8)               // move backward
 {
  digitalWrite(9, HIGH);          // right motor BW
  delay(1000);                    // wait for a second
  digitalWrite(10, HIGH);         //  left motor BW
  delay(1000);                    // wait for a second
 }
 else if (freq = 14)              // turn left
 {
   digitalWrite(7, HIGH);         // right motor FW
  delay(1000);                    // wait for a second
  digitalWrite(10, HIGH);         //  left motor BW
  delay(1000);                    // wait for a second
 }
 else if (freq = 18)              // turn Right
 {
   digitalWrite(9, HIGH);         // right motor BW
  delay(1000);                    // wait for a second
  digitalWrite(8, HIGH);          // left motor FW
  delay(1000);                    // wait for a second
 }
```

this is an example of the values of the frequencies that is responsible for the four directions of the human movement.

Forwared Frequency = 24 Hz
backward Frequency = 8 Hz
Turn left Frequency = 14 Hz
Turn Right Frequency = 18 Hz

note:
the subjected person should undergo for a training to measure his/ her brain frequencies, these frequencies should be recorded and the program should be amended accordingly so that the sbjected person will be able to use this wheelchiar.

Figure 12: part of the Arduino program to input the user Frequencies

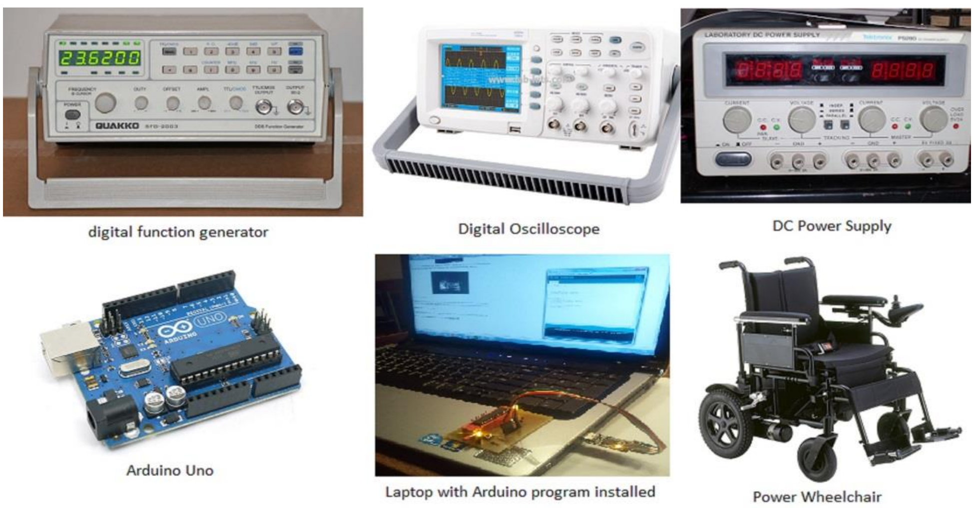


Figure 13: system component

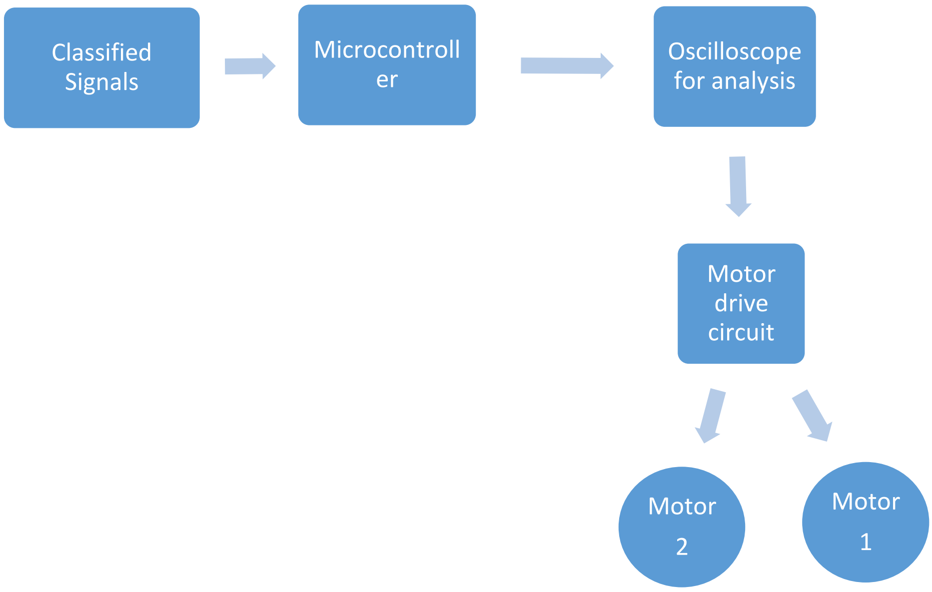


Figure 14: Schematic block diagram modal of the wheelchair control modal

This wheelchair uses two single batteries of a 12 volts connected in series to go a total of 24 volt. The battery is not functioning anymore, since the chair has been unused for a long period of time, and the condition of battery now is totally ruined and needs to be replaced. In this case, we supply the wheelchair with an external power supply.

To control the wheelchair the two motors of the wheelchair should be connected to the interface circuit output. The function of this interface circuit it to change the polarity of the battery to the motor terminals. However the power supply should also be connected to the interface circuit power up the motors. There are four control wires going out form the Arduino to the interface board, which make the wheelchair thinks that the joystick is moved. The interface circuit we will use consist of NPN transistors (2N4401) and 5DVC relays. The emitter of the npn transistor should be supplied with 5 volt and the base should receive the command from the Arduino and the collector should be connected to the relay coil and the other relay coil terminal should be grounded. When the Arduino give command then the current will flow in to the coil giving the common of the relay to switch from the normally closed terminal to the normally open terminal. This function will help to change the polarity of the battery. In this way we can let the four pins of the Arduino (0/5V digital) control the direction of the 24V wheelchair motors, Figure 15 shows the interface circuit.

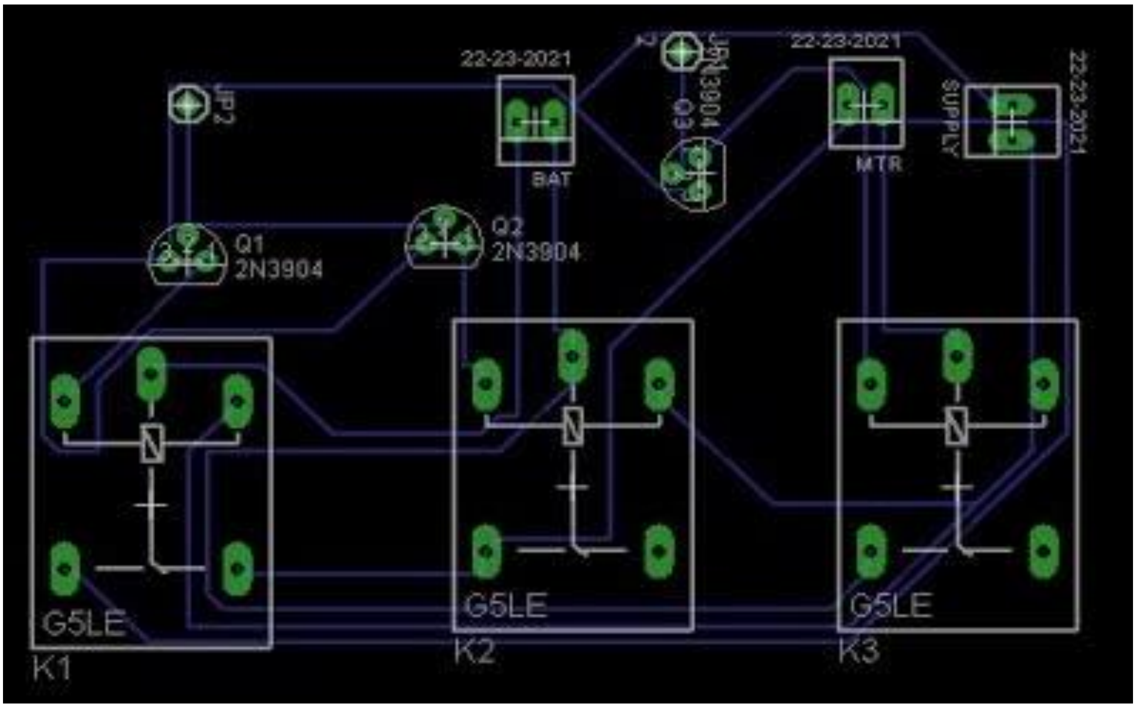


Figure 15: the Schematic of interface circuit of the system

After building the system and integrate all its components then start operating the system make sure you follow the safe operation of the system and the wheels of the wheelchair should be elevated to prevent the chair form moving. In case if the wheelchair does not move, we should try to move the knob clockwise until we obtain the slowest speed. This is because of the electromechanical breaks. Table 4 shows the output of the Microcontroller which results in the wheelchair's direction.

Table 4: Behaviour of the wheelchair directions for various Microcontroller outputs.

Microcontroller O/P				Motor Direction		Wheelchair Direction
A	B	C	D	Right motor	Left motor	
1	0	1	0	Clockwise	Clockwise	Forward
0	1	0	1	Counter Clockwise	Counter Clockwise	Backward
1	0	0	1	Clockwise	Counter Clockwise	Left
0	1	1	0	Counter Clockwise	Clockwise	Right
0	0	0	0	Stop	Stop	Break/Stop

3.6 SAFETY MEASURES

Safety here is coming first especially since it transports a particularly vulnerable person. Safety measures should be taken for the user and the device to protect them from the electrical hazards as well as from the Collision that may occur while driving the wheelchair. In addition to good grounding, insulation of the device and the wires, incorporating fuses or circuit breakers, shock preventers the devices like EEG that are directly connected with the patient's body require certain other safety features to be incorporated. To achieve the safety measures for the device and the patient, power and signal isolation are required[15].

CHAPTER 4

RESULTS & DISCUSSION

This project depends on two main parts, the first part is the coding part which should receive the frequencies and read them so that the microcontroller can move the wheelchair accordingly, the second part is the integration of the microcontroller with the wheelchair so that the wheelchair can receive the suitable frequencies and respond to them correctly.

Using the library (FreqMeasure) enables Arduino Uno microcontroller to generate frequency of approximately 980 Hz on pin 5 & 6 -This is a fixed frequency-, and this library also can read any other frequencies in case if we input frequencies using the frequency generator or any other source. In this project the frequencies have been generated using analogue Pulse Generator, this generator is connected to the oscilloscope Figure 17 to measure the period of the wave to complete one full cycle. Then we use the relationship between the frequency and the time, as the frequency of a wave is the number of times per seconds that waves repeats its shape. The Arduino Serial port Figure 18 can be used to check the value of the frequency and make sure it is the same as set up in the pulse generator.

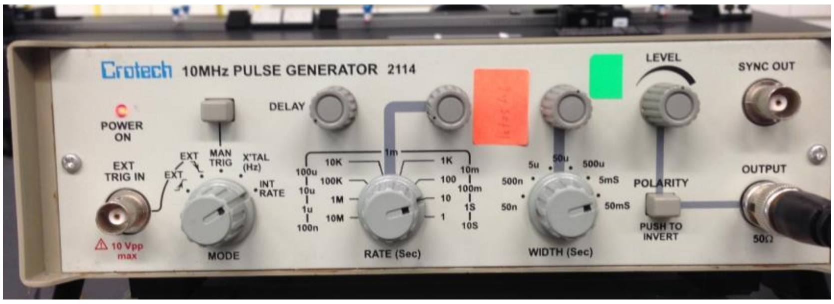


Figure 16: Pulse Generator

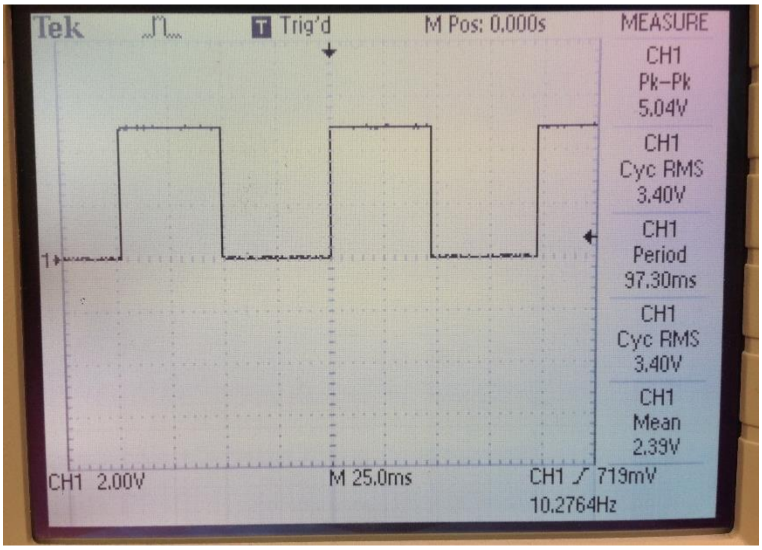


Figure 17: Oscilloscope

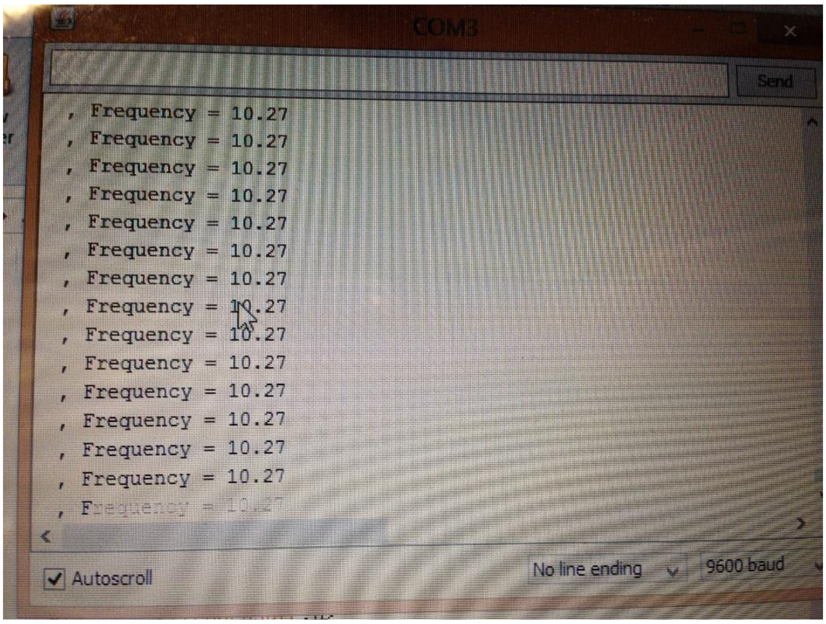


Figure 18: Arduino Serial Port

From Figure 17 we see that the generated pulse has a time of 97.30 ms, which is (1/97.30ms) = 10.27 Hz same as it's in the serial port of Figure 18, this indicates a 100% accuracy.

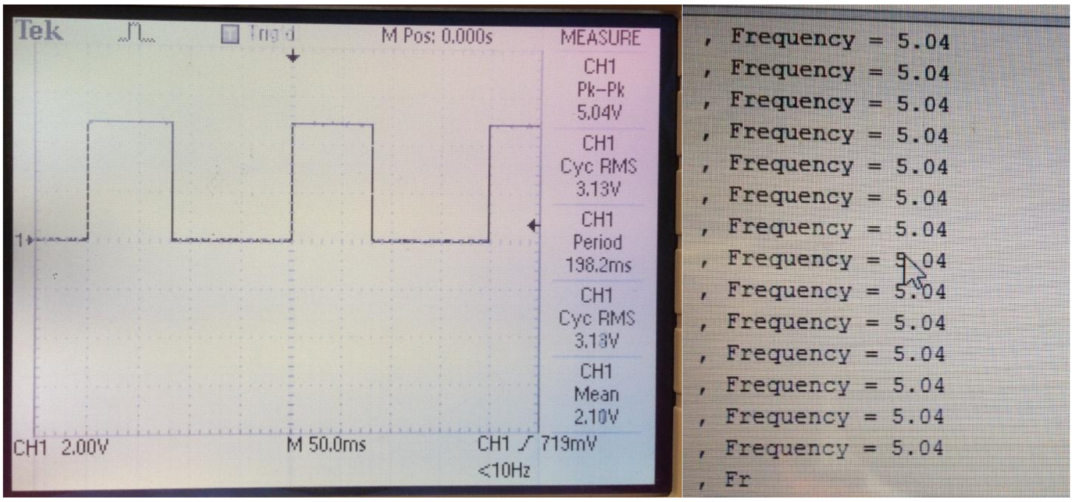


Figure 19: reading for 5.04 hz

From Figure 19, the signal has a period of 198.20 ms (1/198.20 ms) = 5.04 Hz. This also indicates a 100% accuracy.

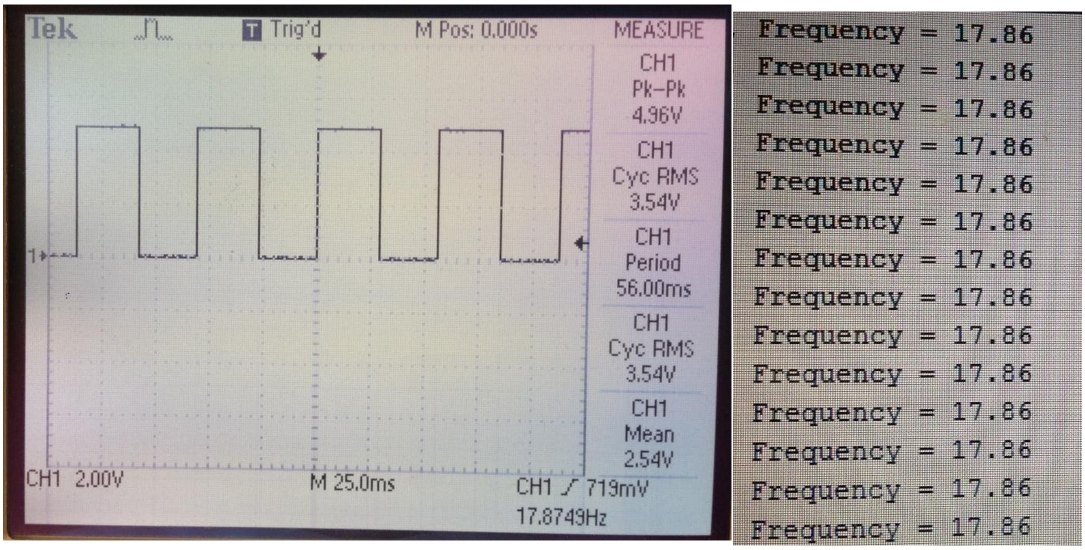


Figure 20: reading of 17.86 hz

From Figure 20, the signal has a period of 56.00 ms (1/56.00 ms) = 17.86 Hz. This also indicates a 100% accuracy.

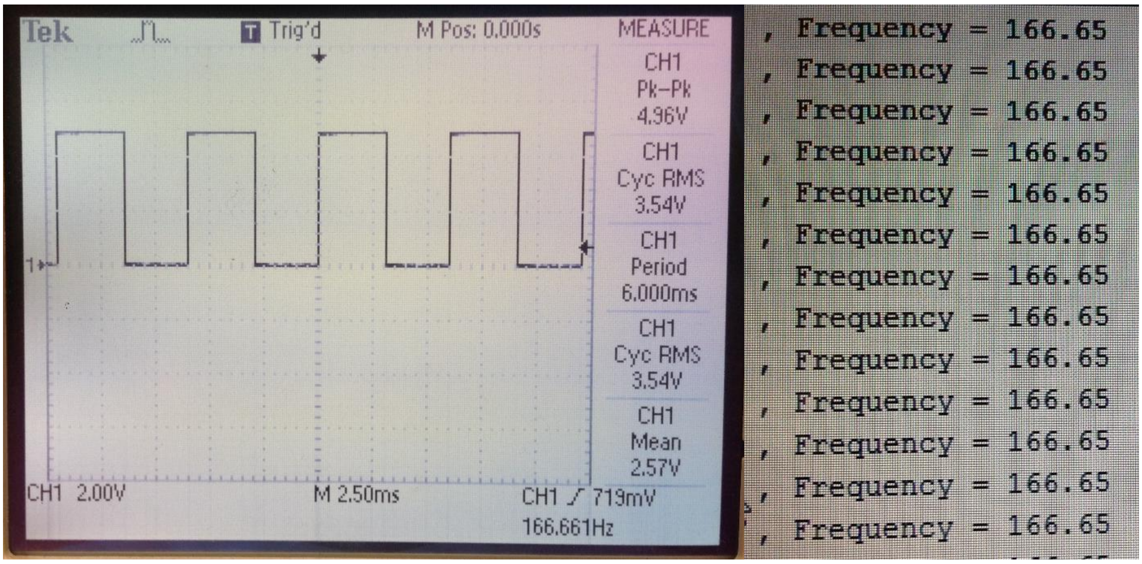


Figure 21: reading for 166.65 hz

From Figure 21, the signal has a period of 6.00 ms (1/6.00 ms) = 166.67 Hz. The accuracy of this reading is slightly different, $he\ accuracy = 100 - \frac{166.67-166.65}{166.65} x\ 100\% = 99.98\%$.

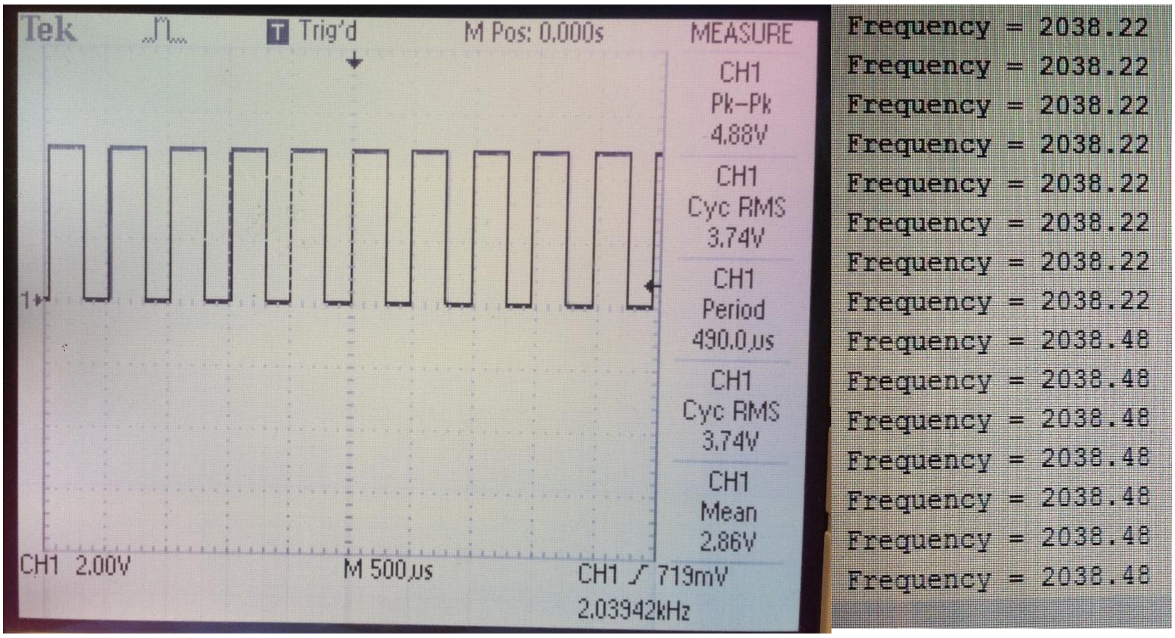


Figure 22: reading of 2038.48 hz

From Figure 22, the signal has a period of 490.00 ms (1/490.00 ms) = 2040.82 Hz. The accuracy of this reading is slightly different. $the\ accuracy = 100 - \frac{2040.82-2038.48}{2040.82} x\ 100\% = 99.88\%$.

From the above readings, it is noticeable that when the signal time is small the accuracy is 100% and when the signal time is high the accuracy decease slightly of less than 2%. The used library can read frequencies from 0.01 Hz up to 100 kHz. This project needs frequencies between 8 Hz to 30 Hz which is only alpha and beta bands, so the accuracy of these frequencies is 100%.

The second part of the project is to control the wheelchair using these frequencies so the output of the frequency generator is connected to the interface circuit through Arduino and the wheelchair responded to the those frequencies perfectly. Figure 23 shows an LED circuit to represent the directions of the wheelchair movements. The LED circuit showed a full correct response to the commands.

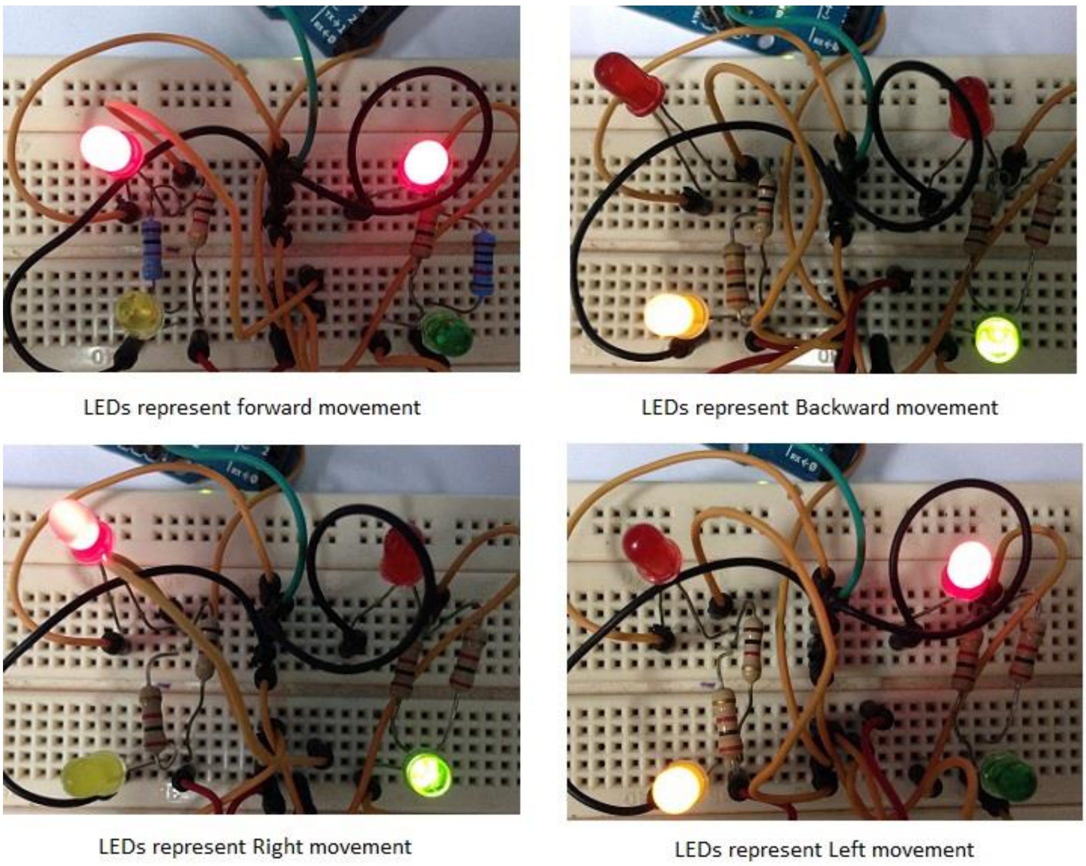


Figure 23: LEDs represent the four wheelchair directions

CHAPTER 5

CONCLUSION & RECOMENDATION

As a conclusion, this project have met the required objectives of making a microcontroller that is able to read and measure different frequencies by using Arduino Freqmeasure library and the accuracy of this library is almost 100% since the targeted frequencies are only from alpha and Beta bands (8-30) Hz . These frequencies are applied to an LED circuit to try the performance of the system. The LED circuit showed a good response of the system then we integrated to the wheelchair through the interface circuit and the wheels of the wheelchair showed a perfect response to the commands of the microcontroller. However, this project will help those people how are handicapped or paralysed. Because the wheelchair only needs commands which are generated by the brainwave signals without any physical movements and take a break from needing an exterior assistance. This will make their life easier and will help them to move around by themselves.

For future recommendation, the wheelchair should be designed in such a way to give it the ability of climbing the stairs safely. And further step should be taken in which the frequencies should be inputted directly from the user brain using the EEG Cap. This will require a quite long time of training to ensure a good response of the wheelchair system.

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