Exploring the Neurosky Wave (Brainwave) Sensor Application for Wheelchair

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AUTHOR'S DECLARATION

We hereby declare that we are the sole authors of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. It is further declared, that I have fulfilled all the requirements in line with the Quality Assurance guidelines of the HEC/PEC.

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Abstract

Traditional special persons craft machines are mostly made for partially disabled persons, e.g. a person who lost her legs in accident, considered as a partial special person, as he/she can drive the special designed machines which can be controlled via joystick, remote control or can be control manually. But what if a person is paralyzed, or persons without hands and legs. In these circumstances above mention traditional system may not work as per demand or requirement. To tackle these kinds of issues a special designed system is proposed, which tackles individual problems by using EEG & EMG (electromyography) based brain controlled machines, in this system no muscle power or movement of the body is required to control machines. For implementing and verifying our work/ exploring the applications of EMG Sensor via (NeuroSky Mind Wave EEG Headset), a special type Arduino based wheelchair is designed using Brain Computer Interface (BCI). The movement of the wheelchair is controlled by variation of attention level of the patient. The main advantage or requirement of smart wheelchair design is mobility, as patients can train the machine (via iteration) according to brain wave signals. The prototype is designed and tested over different subjective patients in different scenario. The outcomes and results attain were above 95% effective. The movement of wheelchair were as per requirement. The designed machine is basically effective for all kind of patients, so instead of designing different types of wheelchair (on the basis of patient to patient demand), better is to make only proposed design, which can be Commercialized for the betterment of mankind.

Key words: Wheelchair, Arduino, NeuroSky Mind Wave EEG Headset etc.

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List of Acronyms

BCI	Brain Computer Interface
SPECT	Single Photon Emission Computer Tomography
PET	Positron Emissions Tomography
FMRI	Functional Magnetic Resonance Imaging
MEG	Magneto encephalography
EEG	Electro-Encephalon-Graphy (EEG)
SWMC	Smart Wireless Mind-based Controlled
LCD	Liquid Crystal Display
WSHGWC	Wireless Smart Hand Gesture Wheelchair Control

Chapter 1

INTRODUCTION

1.1 Background

The disable people in daily life use wheelchairs. The elders use mostly the wheel chair and partially disabled are the people with highest rates of sing both manual and electric wheel chair [6]. Wheelchairs users faces difficulties while maneuvering of electrical and mechanical wheel chair. The engineers and scientists use different technologies to overcome the difficulty facing by the disables while operating the wheelchair [7]. The main goal of the engineers is to provide facilities for the abnormal people by using technologies and to make their life easier and more flexible. The technologies provide easiness for the problem that are faced by the human kind. The clinical trial which was recently taken, according to them, assistive technologies enable the individuals to maneuver a powered wheelchair via a variety of guided systems like mouse control or by using joystick, tactile screen and voice recognition based can be functioned by a person with upper body mobility [8]. Now a day the technologies helping medical fields which is our main goal to achieve in this project. To minimize the dependency on the others, the engineers made different solutions that helps disables [10]. Some of the elders and quadriplegic disables having paralysis may not be able to use present technologies. The present technologies use accurate control. Our goal is to design a system, which receive a signal from the brain and move accordingly. Here system we mean the accumulator sensor. The sensor work is to convert the raw form of signal in to an electrical signal. Accumulator sensor should be provided by specific activities, which will be converted to the analog signal (encoder and decoders protocols), transmitted by Bluetooth HC-05 transmitter, and then received by other Radio Frequency RF receiver [18]. An ARDUINO using ATMEGA 328P-PU controller is used to analyze and translate the encoded signals to useful commands. Brain Computer Interface (BCI) communicates the brain with computer. BCI establishes the communication between the computer and brain via physical devices, which converts the raw signals of the brain to valuable signal. BCI are invasive or noninvasive

[11]. Non-invasive techniques are nowadays research hot consideration and very famous. Other techniques like Single Photon Emission Computer Tomography (S.P.E.C.T), Positron Emissions Tomography (P.E.T), functional magnetic resonance imaging (F.M.R.I), magneto encephalography (M.E.G), optical brain imaging and single neuron recording using microelectrodes, and electroencephalography (EEG)1 [13]. Electro-Encephalon-Graphy (EEG) is a test which detects abnormalities in brain's wave or more likely in the electrical activity of your brain. The process is used to monitor the brainwaves of a person [11]. The EEG sensor is used to record and monitor the changes occurring in the brain during any activity with time while performing different tasks. Brainwaves are sensed by using external electrodes having physical contact with the skin. EEGs are placed on the forehead of individuals. It is noninvasive based BCI. Mactrotellect EEG device used in this project can be placed on the forehead for measuring the brain signal related to the forehead potential differences for different complex actions. EEGs do not use any instrument that are to be introduced in the body [14]. It just used the skin contact without any harm to the body. It is an external contact device. In this project, we are going to use to the above-mentioned technique and implement a Smart Wireless Mind-based Controlled SWMC wheelchair to overcome the challenges faced by the disabled people.

1.2 Problem statement

The wheel chair is a good invention for the abnormal patients and it made the lives of the patients easier but the wheel chair need some sort of source for movement like moving the wheel by hands. It is easy for younger patient in some scenarios but in most cases like old patients or the patients with arms, disabilities make this invention useless. To overcome these problems and limitations, engineers introduce the mechanics to make it easy to operate like hand rotary system (bicycle peddle). The achievements of the engineers are to achieve comfort in any case and make the environment for the disable friendlier. Numerous patients with abilities like mentioned above and other patients like locked-in syndrome and Polio, due to advancements in artificial respiration, the locked-in population is growing.

1.3 Objectives

The first and most important objective is to facilitate the disable personnel in our society by providing them SWMC wheelchair by improving their quality of life and make them independent on other.

- To design a Brain wave technique for controlling wheelchair.
- To design a generalized algorithm for controlling all kinds of wheelchairs.
- Design a training set based Standard design for all wheelchair users.

It is an efficient and hybrid approach. The traditional techniques use wires, which make the circuit messier and harder to find circuit errors in case of any failures or having error in errors. Our project makes it simpler by having a wireless communication and making the circuit simpler and straightforward.

1.4 Scope of the project

This project helps the disable people to move freely and independently in the society without been extra burden on other. The compact size and easy to access make this project more valuable from the existing methodologies. It can carry 120kg person easily and no gears require to control it. A person can use this technique to movie infant while walking easily or it can be used to move the load from one place to another.

1.5 Thesis Organization

The first part of this chapter is background: basic principles, history, and Application of Brain Control Wheelchair are outlined in order to better define specific Aspects of brain control wheelchair and performance modeling addressed in this thesis. The second part of this chapter provides an overview of Problem statement. The final part outlines Objective of the project. Chapters 2 explain the Literature review, which makes us able to design the wheelchair. Chapter 3 includes first what is smart wireless mind base controlled wheelchair and how it will be giving help to the paralyze people. Chapter 4 indicates all the testing and results given by our system. Chapter 5 define the conclusion and future work in our design system.

Chapter 2

Literature Review

We cannot challenge the nature neither change someone faith. Being fit from the body is a blessing and we should thank ALLAH for having no disabilities. However, some of us having abnormalities like polio, Amyotrophic lateral sclerosis, brain stem stroke, brain or spinal cord injury, cerebral palsy, muscular dystrophy, multiple sclerosis, and numerous other diseases damage the nerve pathways that control muscles or the muscles themselves. For the patient mentioned above, it is difficult to survive and they are dependent on other.

Figure 2.1: Simple Manual Wheelchair Need Person to Operate

To make the life simpler and easier for them, the engineers are working on different technologies over the years. The most effective way of individuals' mobility is making a wheelchair. The wheelchair is a very effective and intelligent approach to overcome such limitation. In the beginning, the wheels have been introduced to the chair to provide the mobility for the patients. However, for movement, some sort of energy is required, which was provided by either a person by himself or someone else provide. The patient like elders and paralyzed were completely dependent on the others and making them burden on society. To overcome such problems, engineer and scientist started working to make their life independent from other and make them an honorable individual like normal ones.

Figure 2.2: Simple Manual Wheelchair Need Person to Operate

Later on, the chain-based wheel chair was introduced and cover up majority of the disable person. It was a helpful tool but everything has their limitations. It operates manually by hands. Still many patients are incapable of controlling and operating the chain-based wheelchair.

Then a motor was introduced, which was a very big achievement and relief for patients and for other people. The motor is control by joystick using wire system. In this wheelchair, the disadvantage is to operate it by hand which still is not compatible for some patients as if having complete paralyzed body.

Figure 2.3: Joystick-Controlled Wheelchair

In numerous research studies and approaches such as joystick-based control mechanism, gestures-based mechanism, chain-based mechanism was proposed to help the disable person to overcome the dependencies on others. The disadvantage of using joystick-based wheelchair is that it used the wire for communication, which is very difficult for elders to interact with. In another study [4], in real time a translator been used for translation of brain activity to

communicate directly between doctor and patient, which is an easy way for doctor to access the information of patient's brain waves. The main disadvantage of using this technique is, they used sensor having small range for communication while the patients sitting in the wheelchair. Sometimes the patients may be away from the wheel chair, which leads them dependencies on other. [5] Using NEUROSKY brainwave sensor, which reads and combines both brainwaves and eye blinks to control the wheelchair with wired communication. The drawback of this technique is that wheelchair's direction is limited. Recently authors integrated the brainwaves with speech recognition system to control the wheelchair [6]. The purpose of using EEG sensor to read the neuro-electric signal and correlate it with speech quality. The system has low reliability and much costly. EMOTIV developed a device with high accuracy used for measuring the brain signals, which controls the wheelchair by thoughts of the patient. It needed a little bit practice and training for user [7]. The communication between computer and device, which is unique approach from the above-mentioned technique. Moreover, computer was compulsory for monitoring the signal from the patient's brain and communicate it with the microcontroller. In this technique, some sort of liquid use for the sensor of the device and having extra burden of computer over patients leads this technique less attentional. It is more expensive as compare to the other technique. According to reference 8, for controlling the wheelchair, multiple sensors were used. This technique is having high accuracy. It needs wires and computer for the communication of sensors and microcontroller as above-mentioned technique. It is not cost-effective approach and requires maintenance periodically. Having a computer in the system leads it controlling a bit tricky. Many attempts been made to develop a computer-based and brain signals to control the wheelchair [10]. The difference that makes this technique unique from the above-mentioned computer operated techniques is that it requires two signals from the brain, which leads to have limitations on movements for controlling the chair. Therefore, the complete control of the wheelchair is no achievable. The eye traction system was also used for controlling the movement of the wheelchair instead of using brainwaves but the system leads to have low accuracy and thesis also required to get friendly with the chair.

In [11], a robot-based wheel chair was introduced. This technique uses the beta waves from the brain to control the wheelchair by using brainwave sensor and communicate it with ARDUINO. In [12] the wheelchair was controlled by using eye-tracking phenomena. It requires a camera for reading the eye movements and software for changing the unidentified form of signals to make it understandable for the microcontroller. The camera and software lead this development to complexity. The prototype based smart wheelchair was proposed in [14]. It uses hand gesture for controlling for assisting the abnormal people. It requires lot of wires and devices, which leads it inconvenient for users. In [14], the [15] was modified by introducing touch sensors which overall lower the cost of the prototype. This prototype is also based on wire communication, which is hard to be operated for elders, and physically disables personnel is the developed form of the using GPS and GSM modules for location tracking and hand gestures [16]. This prototype is nor accurate in noisy environments [17]. Uses Raspberry pi for controlling wheelchair and image processing techniques. It also requires camera to monitor and recognize the gestures of the patient. The use of camera leads a prototype more complex for the user to control and require a trained person to operate also uses the same technique but changes the voltage supply and cost [18]. It uses AVR microcontroller. GSM and GPS navigation combines with accelerometer -based gesture prototype was proposed for controlling wheelchair [19]. The location of the wheelchair delivered to the control room by using GSM and GPS navigation and mobile-based application was used for monitor. This technique is helpful for those who is having physical illness, presented in [20].

While in the hand gesture technique interfaces with the accelerometer sensor been proposed for controlling the direction of the wheelchair [21]. The transmission system of this technique is wired, which leads to complexity and difficult to handle for the users. Table elaborates the core limitations and drawbacks of the proposed techniques.

Reference #	Aims	Tools used	Drawbacks
(3), (5), (7), (8), (9) & (10)	Control the wheelchair by thought	EMOTIV, NeuroSky wave device headset and computer	Expensive and wired-based control
(4)	Provide direct communication between patients and doctors	Translation different patterns of brain activity into commands in real time	Limited range of area to transfer information in wheelchair.
(6)	Control the wheelchair by brain control	EEG	Not applicable for fully quadriplegic people
(12)	Control the wheelchair using brain wave.	Brain link headset & Arduino circuit.	Expensive and wireless control
(14), (15) & (21)	Control wheelchair through brain	Human Neural network.	Many wired hardware devices are required, which makes it inconvenient for users.
(16) & (19)	Control wheelchair through brain	Bluetooth used.	Not any.

Table 2.1: Main limitations and drawbacks of current solutions [17].

The above-mentioned technique has benefits and limitations and almost satisfies the users. Our approach is unique and more reliable as compare to the mentioned ones. Now in the next chapter, we are going to explain our project in detail.

Chapter 3

Physical Modeling & Hardware Implementation

In this project, our proposed technique Smart Wireless Mind-based Controlled SWMC wheelchair is used to solve the challenges been faced by the elders and disable patients either fully or partially quadriplegic people to ease and comfort their life and perform their daily life activities without been burden on others.

Our approach is to

- The Macro Tellect EEG system used to monitor the brainwaves of the user sitting in the wheel chair.
- The brainwaves are translated into movement's commands and Arduino commands the motors of the wheelchair.
- Brain generates many signals but we are monitoring Focus, meditation.
- The Arduino use 5 commands

  (1) forward

  (2) Backward

  (3) Right turn

  (4) Left turn

  (5) Stop

3.1 Block Diagram

In this project, we are starting from detecting the brain waves and digitize and then magnify or amplify these signals so that the brain sensor can read. Then these signals will be transmitted through Bluetooth device in the headset and collected or received the data on the HC-05 Bluetooth module on the Arduino side. The Arduino then display the condition whether the chair is moving forward, backward, left, right or stop. The personal computer can also be used

to communicate with the Arduino and can monitor the status of the chair with Arduino ide serial monitor. Motor drives are used for driving the motors but with specific signal that are generated by Arduino by reading the data from user brain. There are two motors connected to the wheel chair one is used to move it forward and reverse, the other is used to move it left and right. Finally, the wheel chair is controlled by brain with the help of brainwave control.

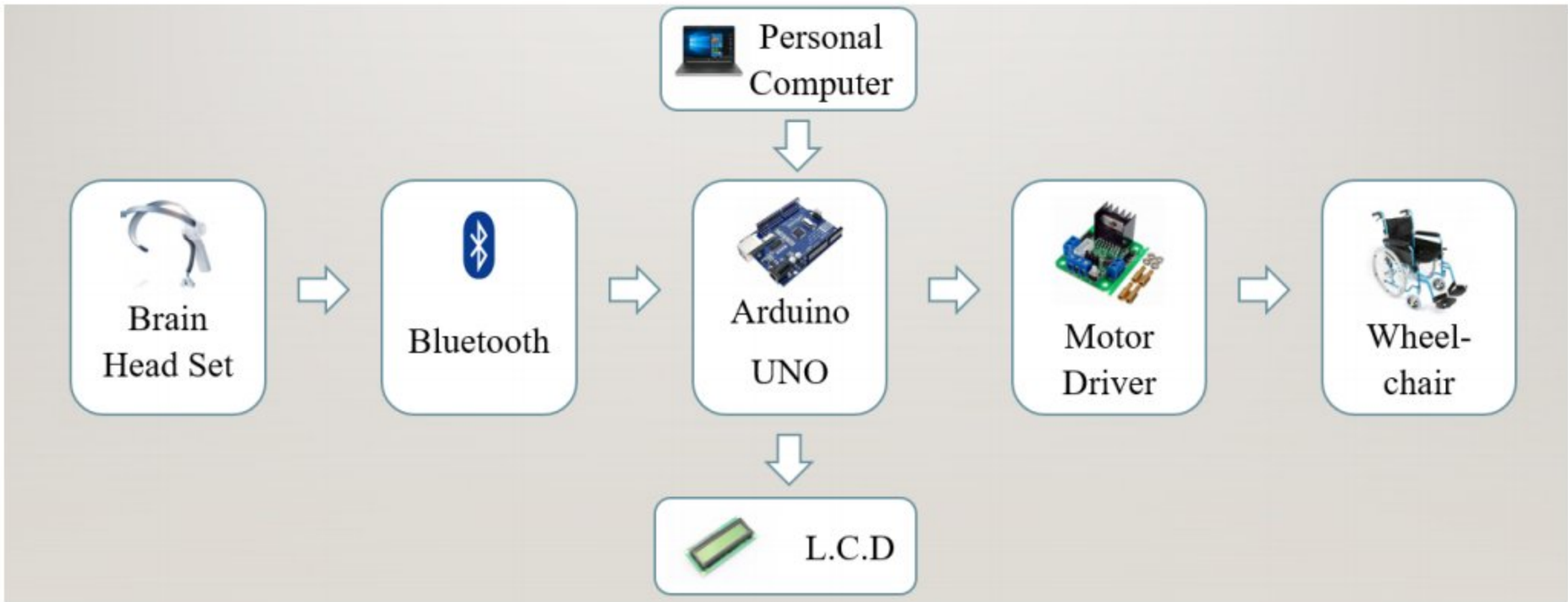


Figure 3. 1: Block Diagram

3.2 Synchronization and data reading algorithm

In this project, we develop an algorithm for the protocol used by measurement device. The meditation, concentration and some weak signals data are read by the sensor and fed it to the microcontroller. The flowchart of the given technique is shown in figure 3.3. We establish communication between Arduino ATMEGA328P-PU microcontroller and the Macrotellect headset for reading the brain waves and control wheelchair according to the thoughts of the user.

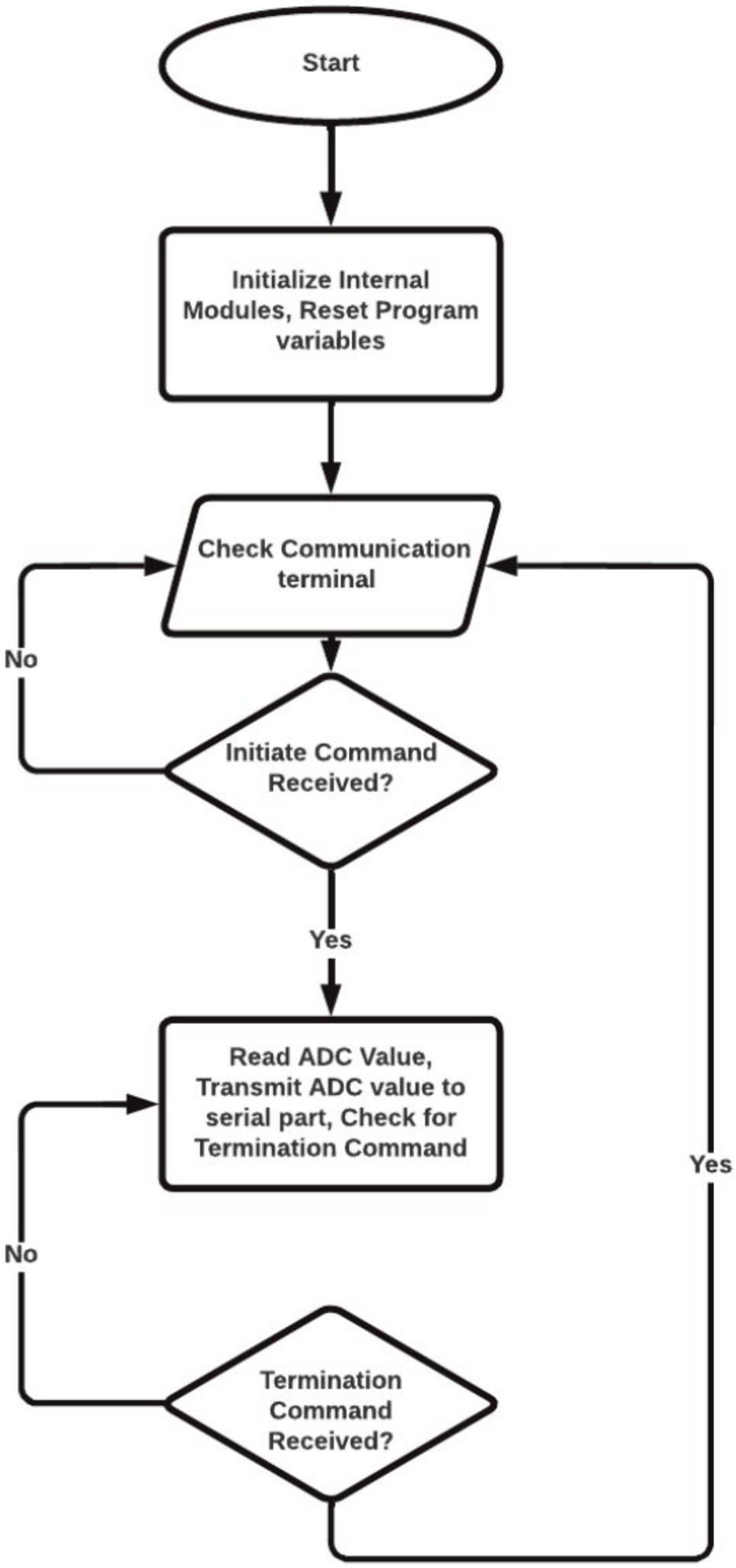
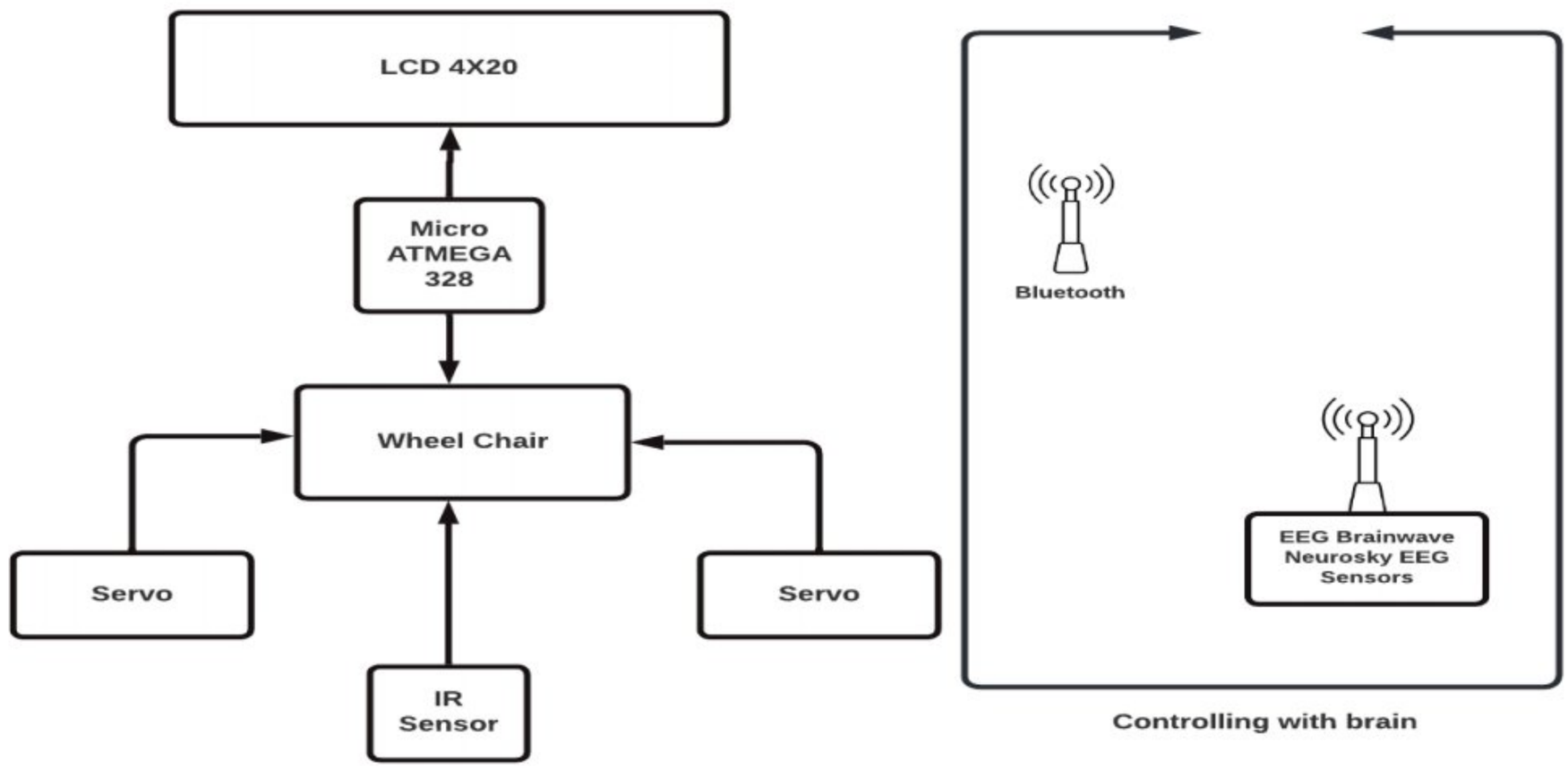


Figure 3.2: Complete Flowchart Macro Tellect and Microcontroller's Communication

3.3 Core Components

In SWMC approach, the wheelchair is controlled by EEG signals received from the brain. The signals are then translated (ATMEGA328P-PU) using the AVR microcontroller which has Arduino programmed to move the servo motors and control their speed. A microcontroller is attached to a sensor to measure the distance at which the wheelchair should be parked at the edges and other boundaries. Brain signals and data processing data are displayed on the LCD connected to the microcontroller. Figure 3.2 shows the basic components and working methods of SWMC.

The following sub-sections describe the process of reading brain signals using MACROTELLECT. Translate them into commands to control the unit and wheelchair. Integrating Macro Tellect with Arduino ATMEGA328P-PU microcontroller First, to measure the intensities of concentration and meditation the protocol with electric sensor is used. The microcontroller uses 8-bit high-speed protocol to read and analyze the measured value. These



packets include

Figure 3.3: Main Components of SWMC Wheelchair [11]

- Packet header: it consists of 3-bit synchronization in which one of them is used to measure the length of the main part and other two is for synchronization.
- Packet payload: this part is the most important one consist of meditation and concentration data. The length should be between 0 and 169 bytes.

  Packet checksum: it uses checksum algorithm to validate the sent data consist of only one byte.

The values of the configured bytes for each part and the packets that are in addition to the definition of the bytes are been showed in table 2

Sent bytes are used to represent code that performs a specific function. These bytes can be expressed in decimal or hexadecimal values. Table 3 shows the key byte values and their functions.

The monitored signals of the brain are shown in figure 1.7, 1.8 and 1.9.

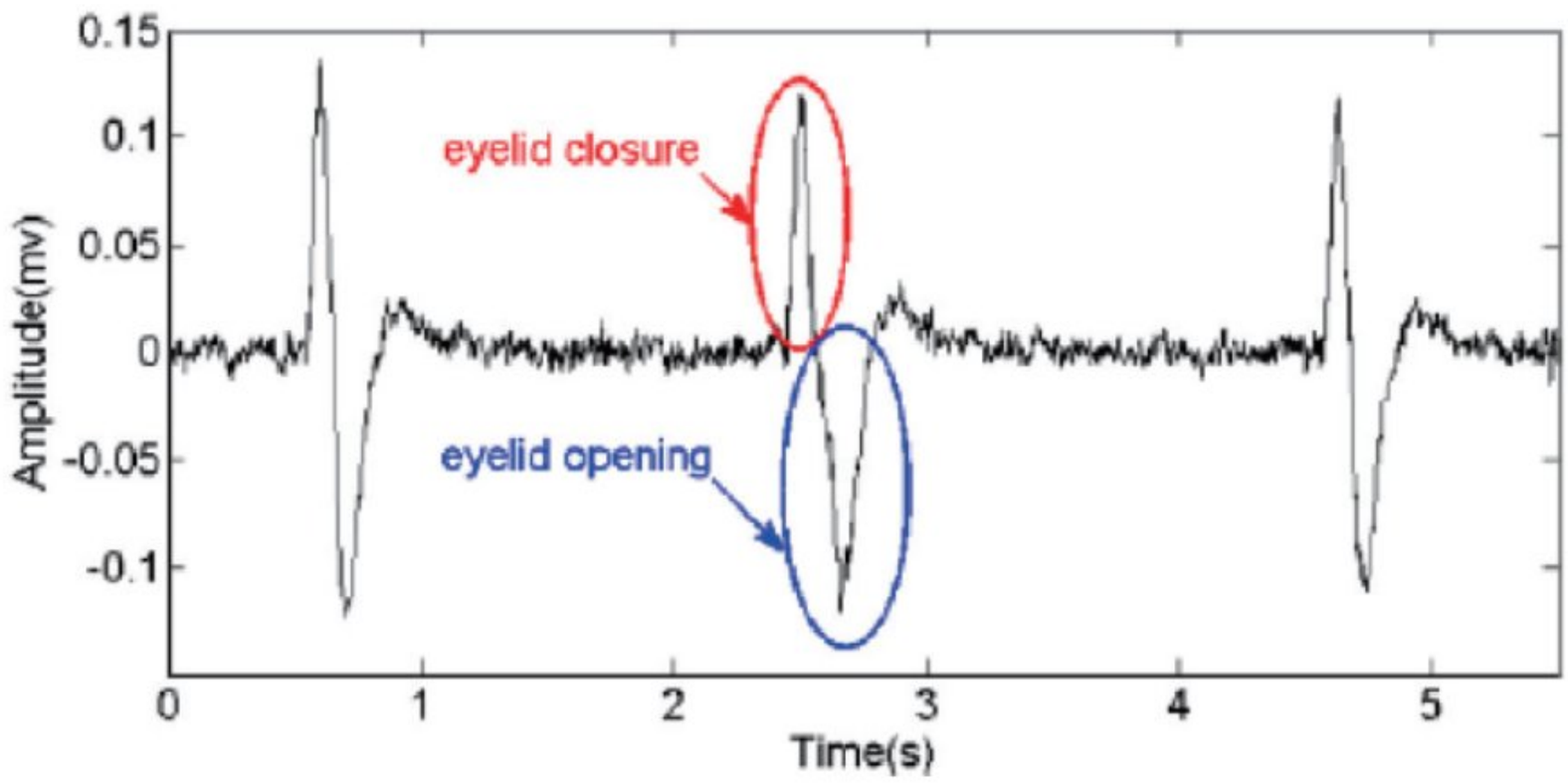


Figure 3. 4: EEG Brainwaves [22]

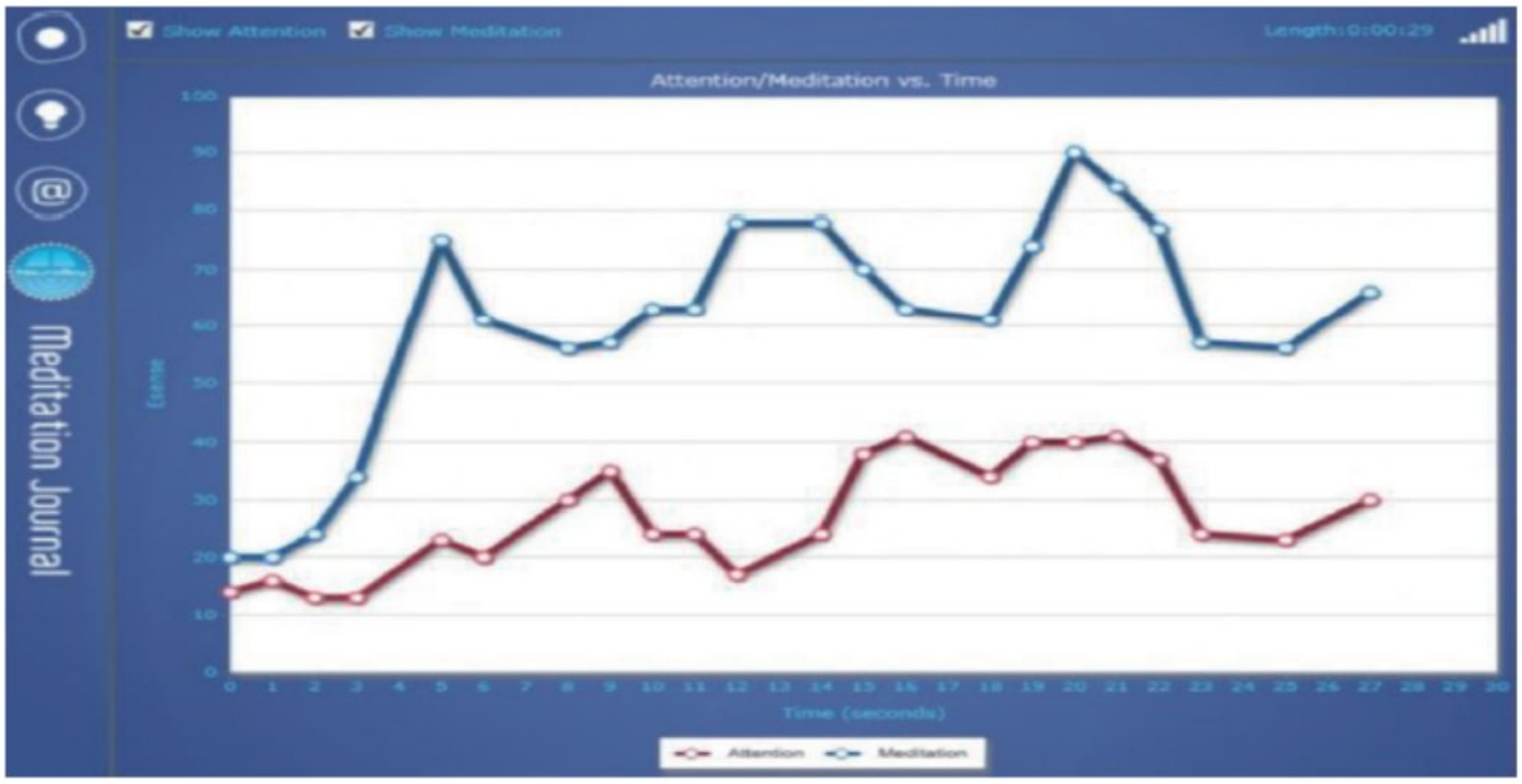


Figure 3. 5: EEG Attention and Meditation Signals [23]

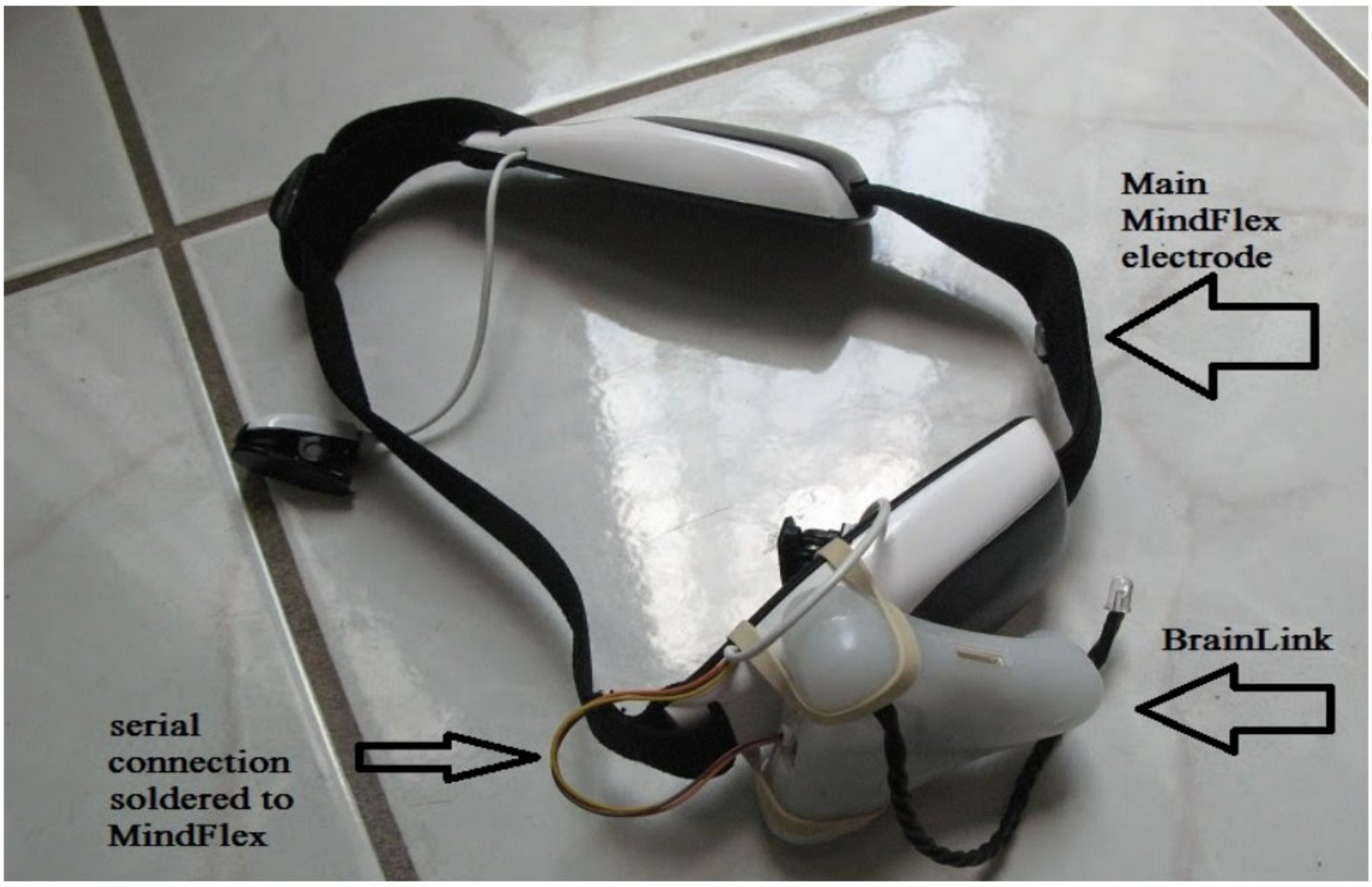


Figure 3. 6: Components Shown In EEG Sensor [24]

Now we are having brainwaves which to be measured and analyzed is 2 namely

- Focus signal
- Indication of meditation signals.

Therefore, we are going to modify these two signals for controlling brain-controlled wheelchair using microcontroller. The commands are:

- Forward command
- Backward command
- Directions (right turn, left turn)
- Stop command

So, let us start discussing everyone in detail

3.2.1 Forward command

By having two signals from the brain that is meditation and focus, the best one for this command is focus. The concentration intensities range from 1-100. We are going to divide these intensities by 100 for facilitating calculations. Therefore, the initial value of concentration is determined. If the measured concentration value surpasses the given initial intensity, the forward command will be operated and send it to the motors. The initial concentration value is taken 0.45. It may vary for user to user. Therefore, we are going to place variable resistor to change the value according to the person.

Equation (1) is used for finding the initial intensity and to find lower and higher intensities.

$$\textbf{Initial focus intensity} = \frac{measured\ intensity - low\ intensity}{high\ intensity} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

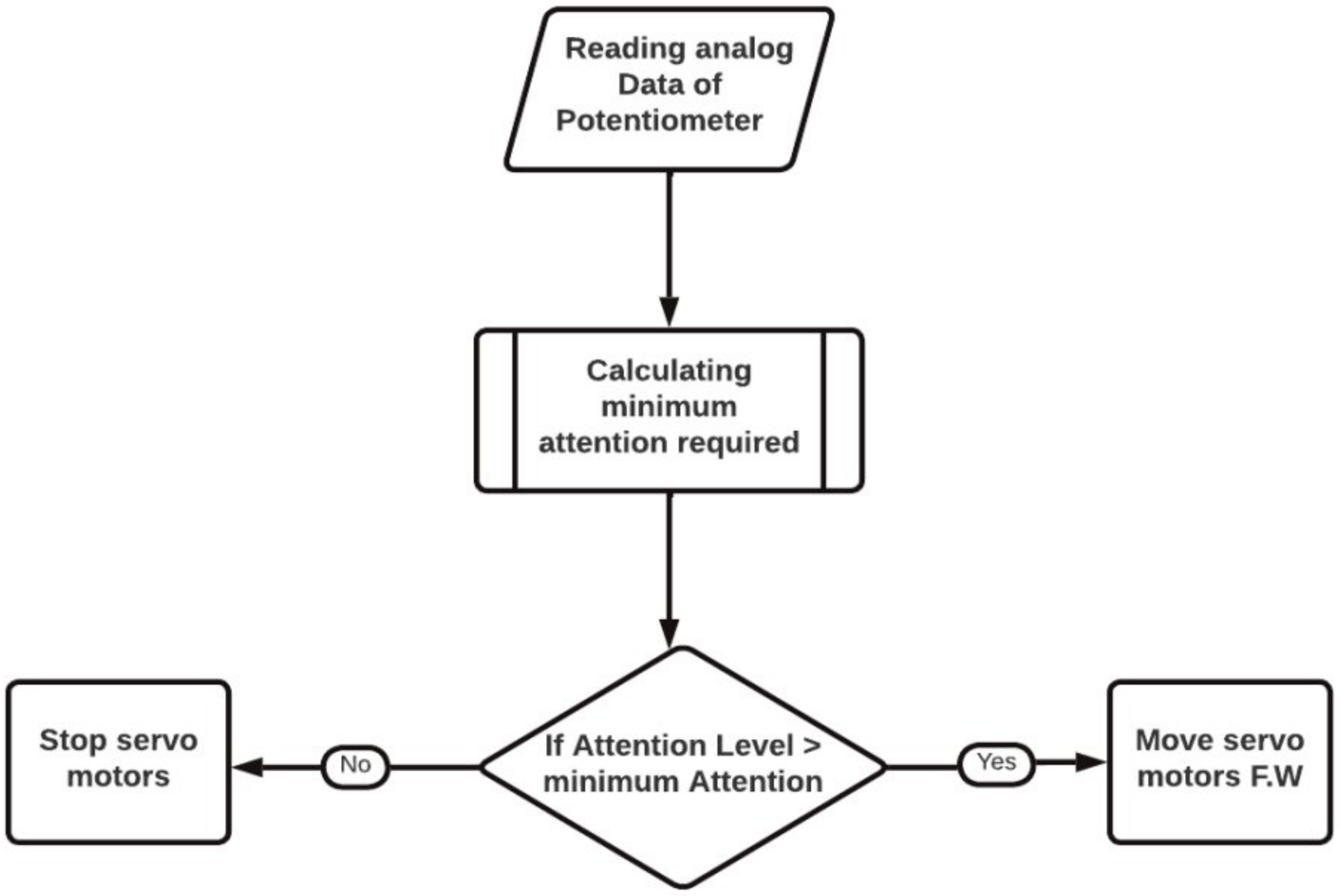


Figure 3.7: Forward Command Flowchart.

3.2.2 Backward command

The best matching signal for this command is meditation, which contains the same properties as of the focus. Because of having all analogue control, we used fixed initial intensity. Therefore, we used constant initial value for backward command set for post experiment reflection. The intensity is 0.85; less meditation requires the motors to move backward.

A problem raised by having two signals focus and reflection signals depended command so we programmed a strategy to separate the signals.

- By storing the concentration's intensity and reflection's intensity in separate variables.
- By comparing intensity of concentration with meditation, if the concentration's value is greater than meditation, which means that the person is being focused and the forward command will operate. However, if the value of mediation is greater than that of

concentrations, backward command will be applied.

- While for backward command the intensity of meditation and initial intensity of meditation is compared, if the initial intensity of meditation (0.85) is less than that of intensity of meditation, the motors operate in backward direction otherwise the motor should be stopped.

The comparison of reflection signals and focus are shown in figure 3.8.

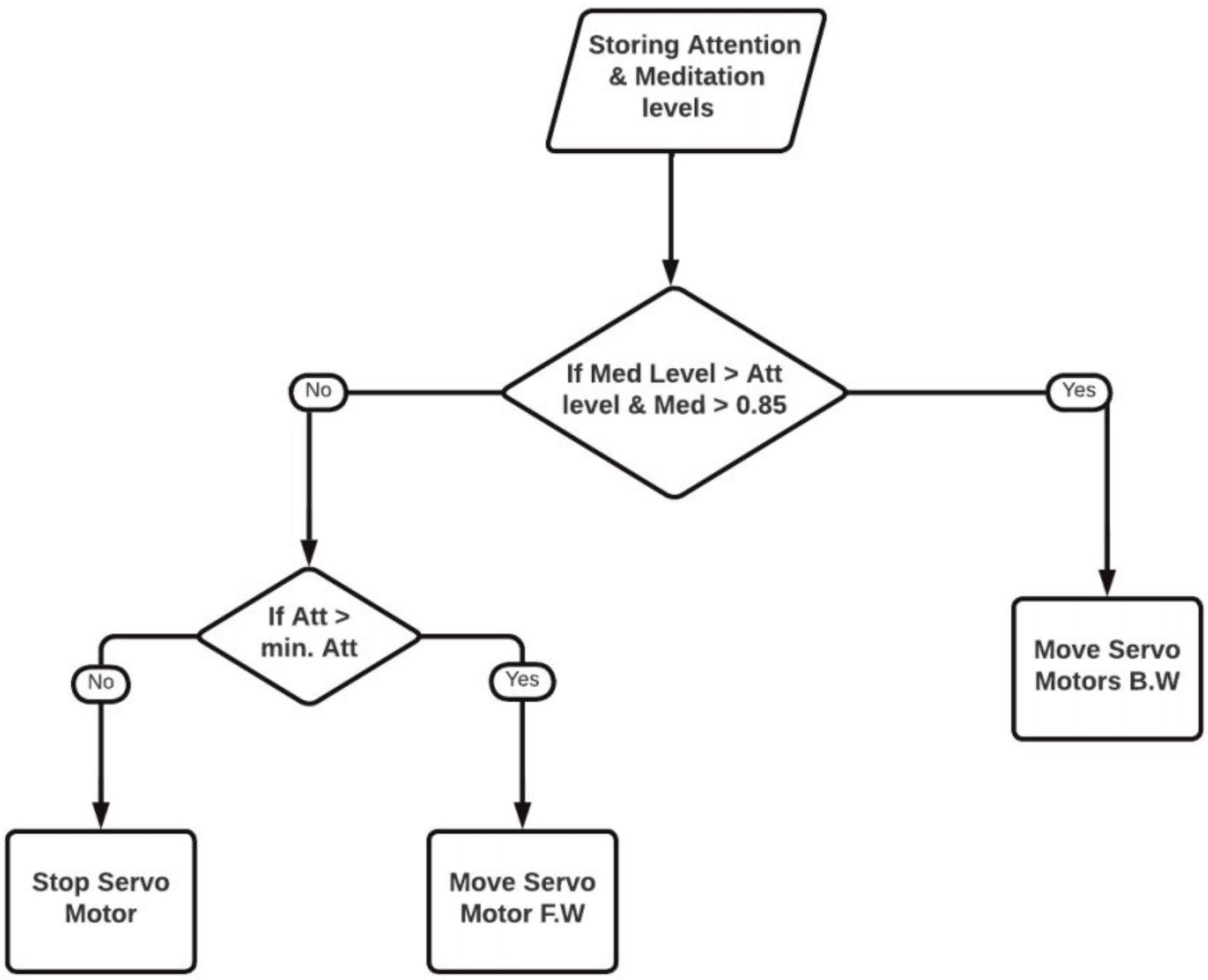


Figure 3.8: Flowchart Showing Motor Is Direction

3.2.3 Directions

The microcontroller cannot sense the brain signals, the two commands to move left and right were removed. Some commands were added to replace the movements and then forward this command to operate the motors.

3.3 Brain signals to commands conversion

The Macro Tellect is having metallic electrodes through which the headset senses the brainwaves using TGAM1 protocol. The sensor translates the measured signals (concentration, meditation) to the analog voltage and then sent it to the microcontroller by using Bluetooth RN -42 as shown in below figure. There are five controls required by the user to control wheelchair namely, forward, backward, left turn, right turn and stop.

Figure 3.9: Brain Link Macro Tellect Device Used For Sensing Brainwaves [25]

3.4 Hardware Implementation

There are different components of the hardware implementation such as Arduino UNO, motor drive circuit, HC-05 modules; D.C gears motors brain link head set etc.

Which we discuss one by one here.

3.4.1 Arduino UNO

Arduino's hardware and software specifications are both open source, allowing amateurs to manufacture even the most basic Arduino modules by themselves. It is possible to get more advanced pre-assembled Arduino modules for a reasonable price. Wearable devices and bigger surface-mounted modules are only two examples of the hardware options available. USB is the

most common way to connect a computer, although other options include Bluetooth, serial, and Ethernet.

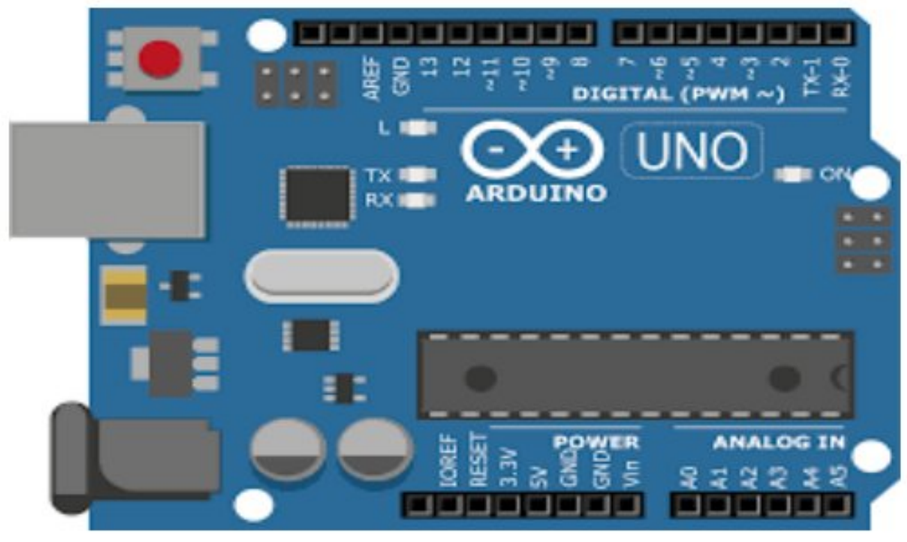


Figure 3.10: Arduino Uno

3.4.2 Motor drive circuit

The fundamental purpose of the motor control gear is to lower the speed of a gear series, resulting in an increase in torque.

The motor rotor and main shaft are linked to the gearbox (or integrated gear series) via a second reduction shaft in order to achieve this goal. This is known as a reduction gear series, or a reduction gear train. It is theoretically possible to prolong this reduction gears train, but the longer it is, the lower the ultimate output.

Figure 3.11: Motor Drive Module

3.4.3 HC-05 Bluetooth module

It is an easy-to-use Bluetooth SPP (Serial Port Protocol) module developed for transparent wireless serial connection setup. It communicates with the controller or PC through serial communication, making it simple to use. For this reason, it is not possible to receive or send data using the HC-05 Bluetooth module in either master or slave mode.

Figure 3.12: HC-05 Bluetooth Module

3.4.4 D.C Gear motor

A gear motor combines a motor with a gearbox in a single unit. Additives like an external gear limit the speed of a motor while boosting torque. Speed (rpm), torque (lb.-in), and efficiency are the most critical factors for gear motors (percent). You must first determine the load, speed, and torque requirements of your application in order to pick the best gear motor for your needs. ISL Products has a wide selection of Spur Gear Motors, Planetary Gear Motors, and Worm Gear Motors to fulfil the needs of any application.

Figure 3.13: D.C Gear Motor

Chapter 4

Testing and Result Discussion

For control circuit, we used Arduino with ATMETGA328P-PU and to program the microcontroller we used C programming based Integrating Development environment IDE called Arduino. Proteus is used for implementation purpose. The Arduino IDE and Proteus has many built in functions which make them strong tools for projects, and it gives a good environment for engineer to play with circuits. Below we have discuss the block diagram of proposed system in figure 4.1.

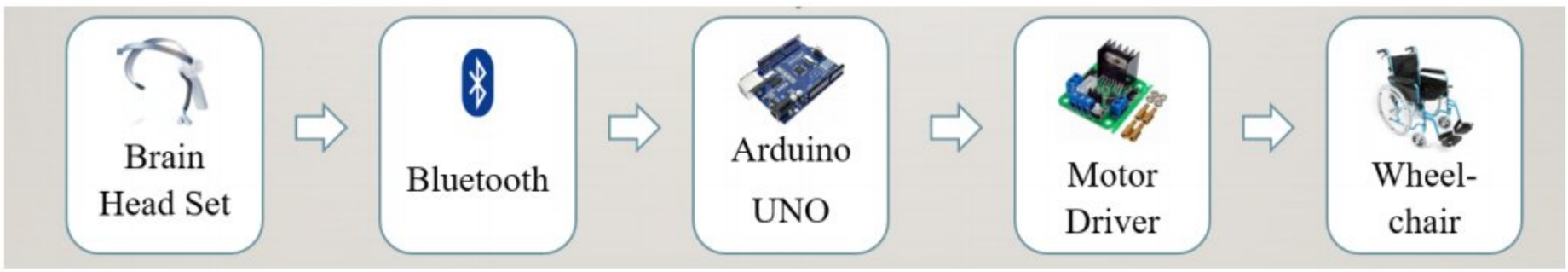


Figure 4.1: Block Diagram

First, we have put on headset and enabled Bluetooth, which directly connect us to Arduino. Which in turn Arduino Connects with Motor Driver (which enables the wheelchair to navigate in the right direction).

4.4.1 CIRCUIT GIAGRAM

The below circuit diagram is consist of aurdino, Bluetooth, motor drive module. When the input signal is start through the Bluetooth the head set sensor and aurdino booths are paired. When we start the iteration the aurdino progressed the signal and and control the direction's (forward, backward, vice versa) of the brain control wheelchair.

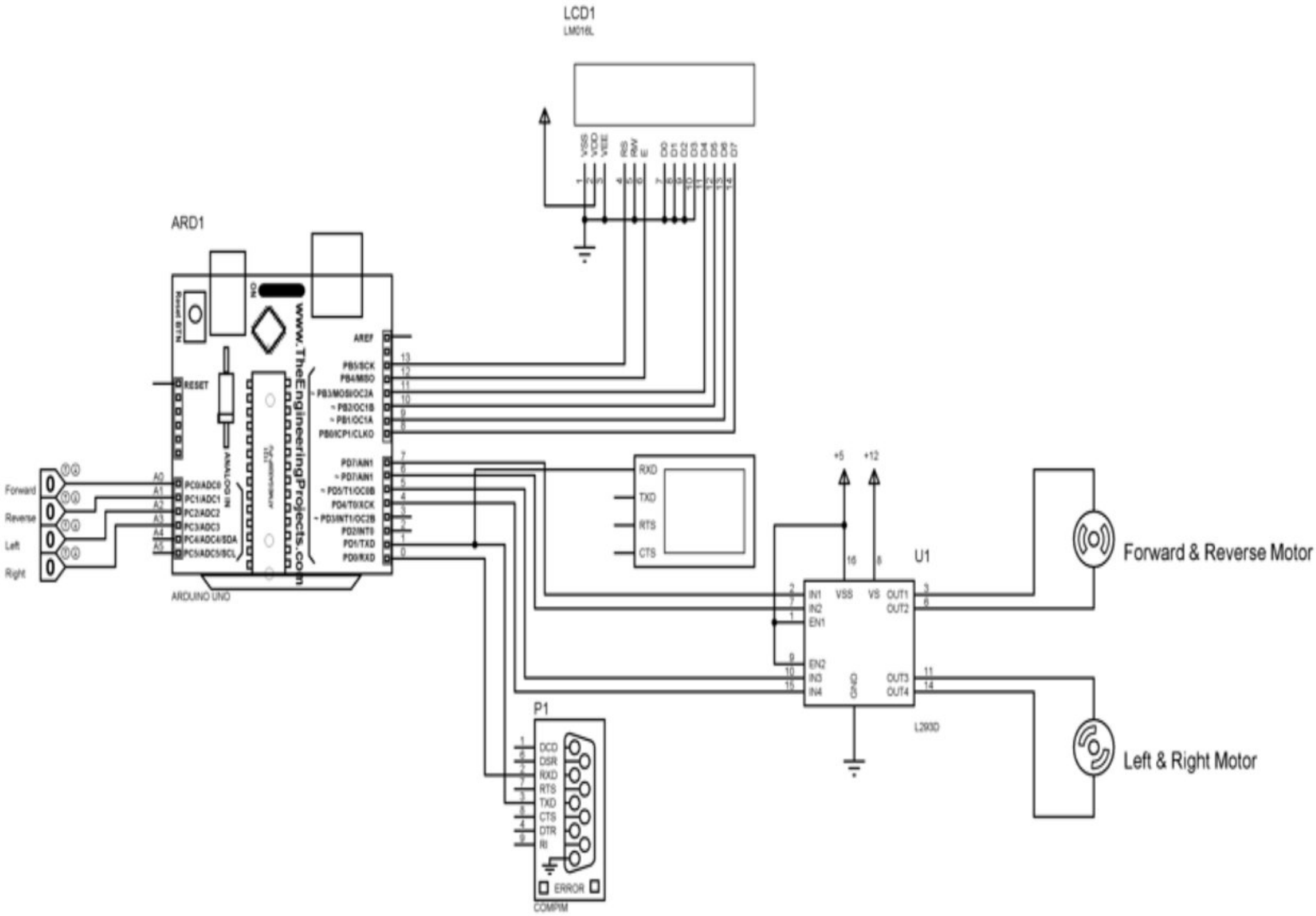


Figure 4.2: Circuit Diagram

4.5 Flow connection connections

The sensor sense the command of the human brain give to the processor unit ,to process the command then send the command to the decision and decide the direction of the brain control wheelchair.

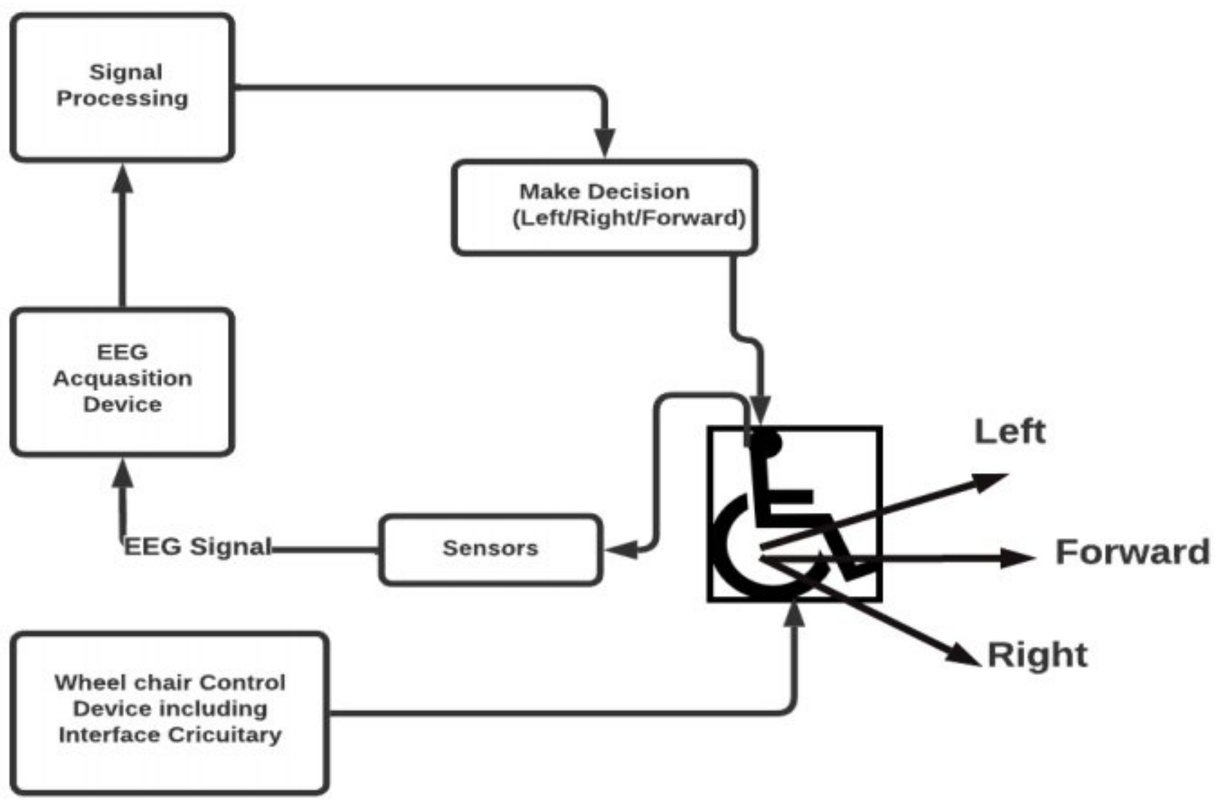


Figure 4.3: Flow Block Diagram

4.6 Interfacing and connection of Bluetooth dongle with ATMEGA328P-PU

The whole project communication is taken on Bluetooth to minimize the number of wire connection. The microcontroller and brain sensor EEG are communicating through Bluetooth device HC-05, the data are transmitted and by serial communication without using the computer.

The voltage for either transmitting, receiving and wireless communication device, voltages must be considering as follows.

- The main voltage in circuit is 12 volts because the motor operates on 12V for moving wheelchair.
- The Bluetooth dongle requires 3.3 volts, so used 7805 to convert 12 volts to 5 volts, the capacitor 15v 100uF is used on 12volts's side for filtering purpose and 10uF on the 5v side. The 3.3 is taken from Adriano on Adriano's side while for sensor side we are using voltage divider to provide 3.3 volts to operate dongle properly.

- The receiving pin RX of the Adriano is connected to the TX transmitting pin of the transmitter (brainwave sensor). The transmitting voltage is 3.3 volts, so we not need acquire to change the voltage for transferring the data. Therefore, no effect will be on wireless communication.

Proteus simulation is shown in figure 4.2. In this figure, USB dongle is connected with the microcontroller.

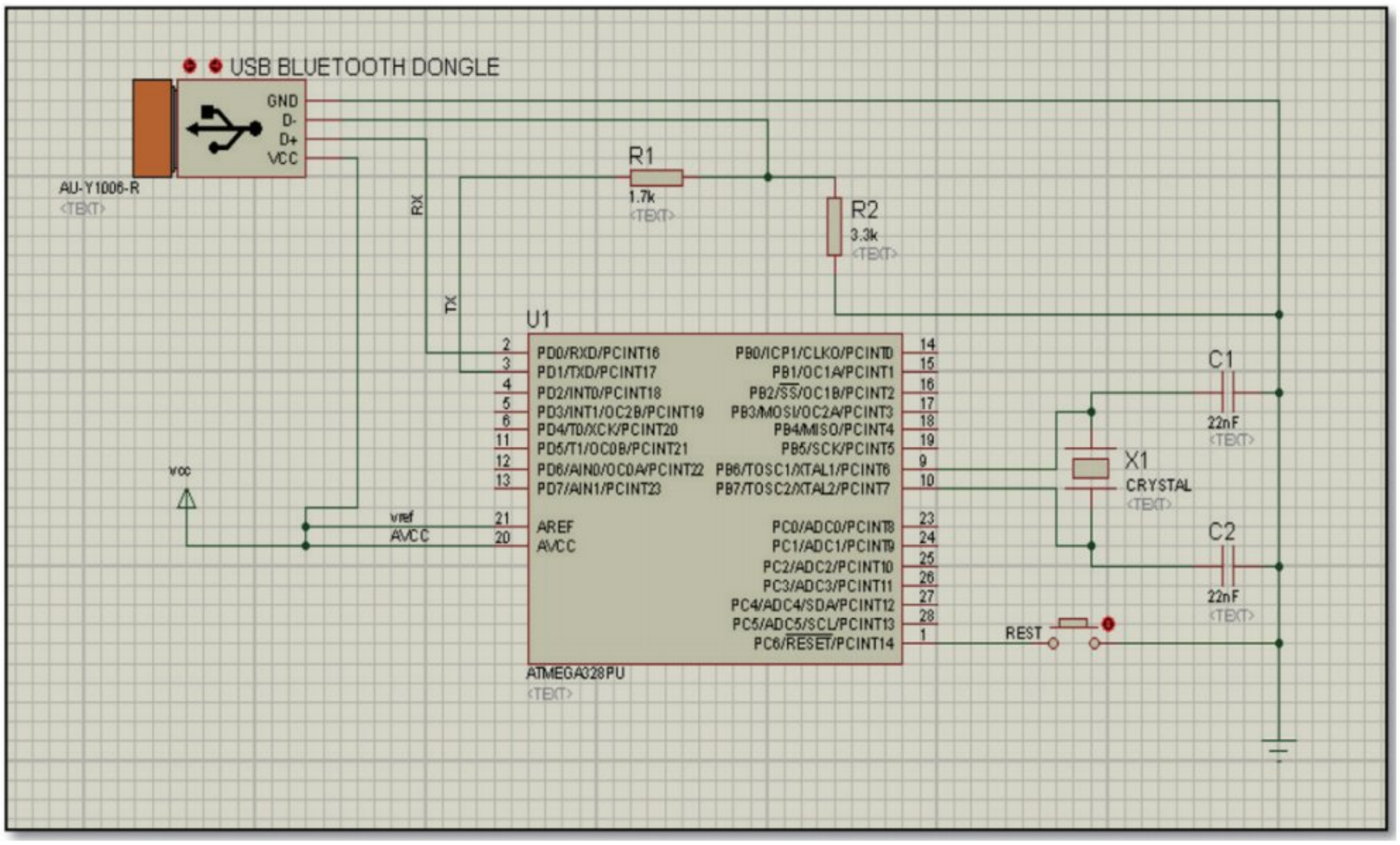


Figure 4.4: USB Dongle Simulation and Connection with Microcontroller.

4.7 Simulating servo motors with microcontroller