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Bilateral Amputation Assistant System Based on Wireless Hand Nerve Signal Communication

A Thesis
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Master of Science in Computer Engineering

By

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Supervised by

Assist. Prof. Dr. Muayad Sadik Croock

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بسم الله الرحمن الرحيم

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Dedication

I dedicate this work to those I love (The inhabitants of my heart), and they love me . . .

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First of all, I thank **God** for all the blessings he has given me throughout my life and until this advanced moment of my scientific career by completing my research project.

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Abstract

Recently, researchers have been remarkably interested in recruiting their studies to help amputees in many sides. Modern studies in the assistant applications based on hand nerve signals are able to meet the needs of those people who suffer from restrictions in upper limb movement. In current work, an electric wheelchair prototype model, represented by a robotic car, based assistant system is proposed and assigned for bilateral amputation people based on hand nerve signals. These signals are represented as Electromyography (EMG) signals, which are collected by using EMG sensor of (Myoware) and transmitted wirelessly via adapting two HC-12 wireless communication modules. This is for performing the required wireless communication between two microcontrollers at the transmitter and receiver sides of the overall system.

It is important to note that the use of one EMG sensor and one channel electrodes is the challenge of this research in order to obtain a low cost and efficient system. Besides, Arduino Nano microcontroller is employed at the transmitter side as analog to digital converter for these hand nerve signals. In addition, the receiver side uses Arduino UNO microcontroller for controlling the state of a robotic car (STOP/MOVE). This system has become more robust by employing HC-SC04 ultrasonic sensors, for the purposes of reducing the risks of collisions, to offer more safety for the patients in the presence of obstacles. At the other hand, the EMG signals are acquired from the surface of the skin of the forearm and biceps muscles to be used in generating different control commands. This research adopts two case studies of amputees that simulate different hand amputation cases, each case study with five upper limb muscles movements. The adopted ten movements of considered muscles in two case studies have been obtained in two types of scenarios. The first one considers the single muscle movement to single control command with (83%) classification accuracy, while the second one adopts the single and double movements with limited recording time for signal generation with (92.335%) classification

accuracy of ten hand motions in two case studies which make the performance of the proposed system excellent. Thus, the system has finally adopts the double action of signals generation operation.

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List of Abbreviations

Abbreviation	**Meaning**
AC	Alternating Current
ADC	Analog to Digital Converter
Ag/AgCl	Silver / Silver chloride
BCI	Brain-Computer Interface
CMRR	Common Mode Rejection Ratio
DC	Direct Current
ECG	Electrocardiogram
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
EPS	Electro-physiological signals
FHSS	Frequency Hoping Spread Spectrum
HCI	Human Computer Interaction
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
KNN	k Nearest Neighbor
Li-Po	Lithium Polymer
MUAP	Motor Unit Action Potential
nEMG	needle Electromyography
NN	Neural Network
PCB	Printed Circuit Board
PLI	Power Line Interface
PLN	Power Line Noise
RAM	Random Access Memory

RF	Radio Frequency
RTOS	Real Time Operating System
sEMG	surface Electromyography
SNR	Signal to Noise Ratio
SRELM	Spectral Regression Extreme Learning Machine
SVM	Support Vector Machine
TTL	Transistor-Transistor Logic
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
WIFI	wireless fidelity
WSN	Wireless Sensor Network
2WD	Two-Wheel Motor Driver

Chapter One

Introduction

1.1 Overview

Disability is a term that states a person inability to perform a personal activity as a result of a problem in his body, accompanied him from birth, or it may occur as a result of an accident. This disability prevents him from performing a function or a set of basic jobs and thus cannot maintain a normal social life. In general, a ratio of (1:50) persons are influenced with some form of disabilities whether they are temporary or permanent according to a recent registering statistics [1]. Therefore, the only concern for those people is the struggle for mobility and communication [2]. Those people live their life with hard suffering from mobility limitation due to the lack or defects in their limbs leading to a restriction in their communication abilities [3].

Human Computer Interaction (HCI) systems have become an increasingly important part of daily life. HCI computed the effective utilization of the available information flow of the computing technologies to be employed in many sides such as control applications. In last years, there has been a huge interest in introducing intuitive and effective interfaces that can recognize the user body motions and translate them into machine commands to be utilized in many assistive applications for disabled people [4].

1.2 Disability with Amputation

From medical viewpoint, the amputation is defined as the removal of an injured limb surgically by cutting it together with the bone so that it cannot be cured. In general, there exist many reasons which lead to amputation including cardiovascular disease, traumatic accidents, infection, tumors, nerve injury, and congenital anomalies. Moreover, amputation also leads to depression along with other psychological risks. Most frequent causes of upper limb amputation are trauma and cancer, followed by vascular complications of disease right arm more frequently involved in work [5], [6].

In order to give rehabilitation to limb amputees, many innovations have been offered to make the life of those people easier as well as to alleviate the psychological burden on them, there is no doubt that such inventions have a positive effect on their lives. Therefore, one of the most important examples of such innovations is the electrical wheelchair [7].

There are many kinds of control methods for managing electric wheelchairs. Traditional methods usually depend on the controlling of electric wheelchairs by joystick which has some limitations as they cannot be affordable by elderly and disabled users as their limb movements are constrained or disabled. Some common observations and also experiments show that a joystick requires a relatively large force from the hand for controlling such devices which reduce the flexibility of using these wheelchairs [2], [8]. Moreover, as a result of these restrictions of wheelchair joystick controlling, several recent studies have been undertaken in this area to give more flexible use to these wheelchairs. Researchers have explored a variety of new control methods based on a variety of electro-physiological signals (EPSs) as control signals.

EPSs signals are electric manifestation of neuromuscular activity during the activation of a desired muscle. The three main types of EPSs signals used in control systems are electromyography (EMG), electrooculography (EOG) and electroencephalography (EEG). These signals have been utilized as one of the specialized interfaces to allow the disabled people to control the assistive devices without the need for joystick [9].

1.3 Hand Nerves

The signals gained from the surface of the skin of the body are called "myosignals". These signals are mainly acquired according to body muscles movements. Moreover, skeletal muscles are composed of individual muscle fibers that contract when being catalyzed by a motor neuron [10]. Motor neuron is a neuron whose cell body is located in the motor cortex, brainstem or the spinal cord, and whose axon (neuron fiber) which transmits the electrical impulses that are called an action potentials away from the nerve cell body. The axon trajectories to muscles where it branches, and forming synapses with muscles fibers. Impulses from the spinal cord arrive to the motor neuron and trigger a group of several muscles fibers, are called motor units. These motor units consist of the motor neuron as axon and all the muscle fibers that are innervated by their branches. When motor units are stimulating, the corresponding muscle fibers are contracting.

The electrical response of a motor unit is called the motor unit action potential (MUAP). A chain of MUAP form an EMG signal and this is caused according to all changes that occur when the nervous system responds to the flow of ions in the membrane of a muscle cell induce an electrochemical impulse and thus a current flow. Such an electrochemical activity travels along muscles at contraction or extension and can be measured and recorded by using electromyography technique to be employed in various biomedical applications [11]. Figure (1.1) shows the motor unit action potential environment [12].

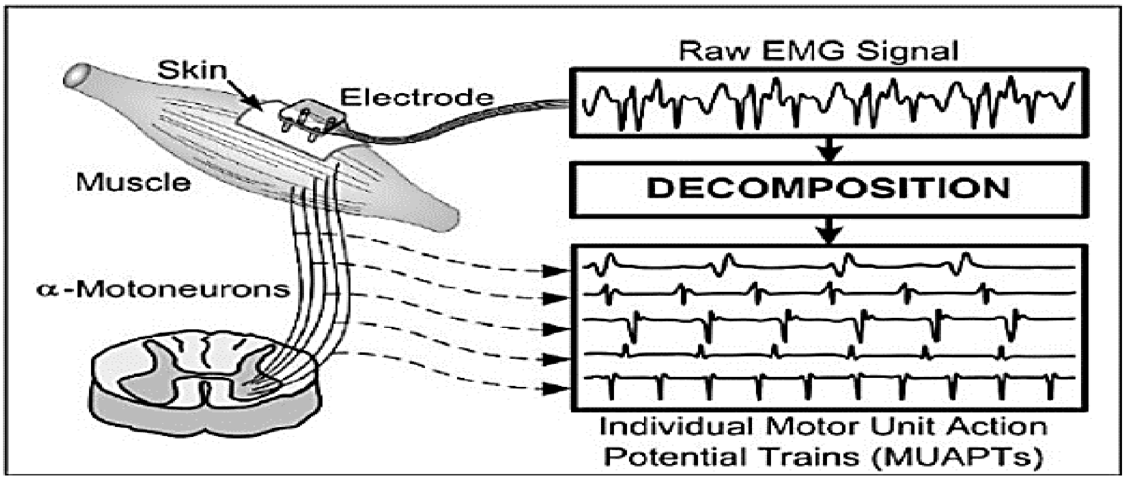


Fig. (1.1): Motor unit action potential environment [12].

1.4 Literature Survey

As mentioned earlier, many researchers had addressed the problems related to using HCI systems in covering the needs of disabled people. Therefore, the control applications of hand nerve signals are becoming a crucial part of researches in recent years, especially under the recent enormous increase of the elderly and disabled people. The researchers adopted many studies based on hand nerve signals for helping disabled people in different sides. This section can be divided into two sub-sections for facilitating the reading flow.

1.4.1 Hand Nerve Signal Readings

In order to include hand nerve signals in the modern control applications, it is necessary to pass through previous researches related to this field in order to achieve high levels of efficiency. Some of these researches can be summarized as follows:

In 2010, Kyung-Jin You, et al. [13] suggested a novel method to estimate the finger motions by using surface EMG signals. The proposed system employed four EMG channels placed around the forearm for classifying eight fingers motions only. The result had been recorded as a positive, but the system was costly and restricted the movement of the amputees, which in turn can decrease the overall flexibility of this system.

In 2013, Khairul Anam, et al. [14] classified ten individual and combined finger movements successfully with more than 90% accuracy by using two sEMG channels. There were some challenges in recognizing some of these classes especially in the combined finger movements, such as the thumb-little finger action which degraded the system efficiency.

In 2014, Sungtae Shin, et al. [15] published a paper to evalute the gestures of the hand based on the classification of EMG signals. The acquisition system employed two channels for classifying seven motion classes which made the system simple and low in cost. However , all gestures require three seconds to be performed with another three seconds for rest action were placed between gestures which reduced the response time. This project employed seven classifiers but support vector machine (SVM) classifier that required more time than the others and therefore the system was slow.

In 2018, Phukpattaranont, et al. [16] evaluated the different approches of feature extraction and classifiers for fingers actions based on EMG signals. This system classified fourteen finger movements that were acquired by six channels with the employment of six methods of feature extraction and seven classifiers. This system had accomplished 99% classification accuracy according to spectral regression extreme learning machine (SRELM) and neural network (NN) classifier in combination which made this system efficient. This system was too expensive and restricted the movement of the paralyzed people in terms of hardware complexity and classification techniques used.

In 2019, Nicola Secciani, et al. [17] suggested efficient control strategy for hand exoskeleton relying on EMG signals. This system involved the use of two sEMG sensors that were located near the wrist joint for classifying only three actions. This system satisfied high performance during testing but suffer from hardware complexity. This was because it had been designed with many hardware equipements such as HS-5495BH High-Torque Servo motor of hand, MagEnc V3.0 Low Rev for measuring fingers response velocity , and arduino Nano.

1.4.2 Hand Nerve Based Assistant Systems

With the progression of technology, appreciable amount of scientific studies volunteered to track the problems of disabled people and providing assistive control systems to those physically handicapped people. This can be achieved based on hand nerve signals from their upper limb by developing HCI systems to the disabled. Different research works had been presented in this field including:

In 2015, T. Puttasakul, et al. [18] designed a robust real time robotic arm based on sEMG signals. The proposed system used four sEMG channels for recognizing six kinds of hand and arm gestures. This system obtained reasonable results but the weak points were the average percentage of classification rate to be 81.6% and high cost of system in terms of many EMG channels used with few number of generated arm gestures.

In 2016, Rudi Hardiansyah, et al. [19] designed an electric wheelchair controlled by electromyography (EMG) sensors which were placed on the arm muscles of the disabled people i.e. biceps, teres, wrist flexor and wrist extensor. In addition to this, the proposed system used four EMG muscle sensors as four channels for recording only four muscles movements. The result was positive but the cost and complexity of the system was high compared with other systems.

In 2017, Jinlong Shi, et al. [20] proposed a control system for disabled people based on sEMG signals of the hand. This system had successfully predefined only five hand motions. In the control experiments of this system, the average accuracy was up to 88%. It also explained the control method for the classification of these limited hand motions was feasible and practical. In general, this system employed multiple types of sensors for analyzing hand motions which made the proposed system costly when compared with other systems.

In 2018, Sidharth Pancholi and Amit M. Joshi [21] developed multi-channel EMG system based on EMG signals for upper limb prosthesis. This system adopted five EMG channels placed on five different arm muscles for classifying only seven hand activities with six different types of classifiers and many features that were extracted by Matlab in time and frequency domains. This system was efficient with the Random Forest, k-NN and Random tree classifiers. But the accuracy of classification was varied from 57.69 % to 99.92 % for all subjects.

In 2019, Widodo Budiharto [22] proposed and developed a prosthesis hand for helping disabled people. This system gave only three actions performed on prosthesis hand based on EMG signal from Myoware muscle sensor for activating the wrist with 90% success tests. EEG signals were collected from additional one channel Mind Wave Mobile Brain-Computer Interface (BCI) device for activating grasp an object and releasing an object from the hand with 80% accuracy. This system was limited by three actions but was efficient by sending signals wirelessly to hand.

In 2019, L A Bautista and D F Villegas [23] developed a myoelectric prosthesis that were specifically represented for people who suffer from transracial amputation at below elbow. This system was designed to satisfy geometric design, instrumentation, control design, drive and validation algorithms as well as adopt 3D printing for manufacturing the prosthesis of forearm and fingers. All activities were managed by Myoware muscle sensor and rotation angle sensor of each finger. This system was efficient but suffer from slow time response.

1.5 Problem Statement

Recently, many systems varied in degree of efficiency and usefulness for those disabled people and most researchers try to add improvements to increase the systems efficiency, the majority of existing systems offered share some limitations, especially with respect to their accuracy, ease of use and total cost which can be explained as follows [5]-[23]:

1- The main issue in these systems is the poor quality of muscle sensor used including muscle sensor version three (v3) and super simple EMG muscle sensor. Thus, it can restrict disabled people movement. In addition, it is not comfortable in use and hence the flexibility of these systems is decreasing in terms of hardness in use.

2- There is another important factor limiting the efficiency of these systems and must be taken into the consideration is the appropriate and precise location of the muscle sensor on the muscles of the upper limb. As the random and unlearned selection of the muscle sensor location can lead the system to a number of risks including lack of accuracy of the classification between the upper limb movements. This can increase the conflict between these movements to cause a defect in the accuracy of the overall system. Therefore, there was a need for additional number of muscle sensors at many places on the upper end which can increase the cost of systems designed and also reduce the response time to amputees. This is because of requiring different classification techniques for nerve signals for the purpose of increasing accuracy.

3- Many of the presented assistant systems suffer from the hardware complexity because they require many hardware equipments, indeed efficient systems must be designed without extra hardware as much as possible to facilitate the use from all levels of amputees and to reduce the cost of building these effective systems. Therefore, high cost, usage difficulty, hardware complexity, low level hand motions classifications accuracy and the extra complex classification algorithms can slow down the system efficiency as they are not friendly with all levels of people.

As a result, all studies try as much as possible to make every effort to obtain high efficiency assistant systems based on nerve signals.

1.6 Aim of the Thesis

In order to cope the issues mentioned in the literature survey and illustrated in the problem statement section, it was important to gather some of the positive features in the other systems and innovate to provide new features in the proposed system. The aim of this thesis is to design and implement an efficient assistant system based on wireless hand nerve signals for driving a wheelchair prototype model for bilateral amputated people. The main contribution of this work is to generate different control signals by using one channel surface EMG (sEMG) electrodes and one muscle sensor as to guarantee the low cost with high utilization flexibility and excellent efficiency in terms of fast response time with easy detection and acquisition of EMG signals. In the proposed system, five control commands for each of the two suggested case studies of bilateral amputated people are adopted for processing different hand amputation cases according to upper limb muscles movements. Different hardware and software components are used for managing all events that occur with wheelchair from all aspects.

1.7 Methodology and Objectives

In order to satisfy the overall targets of this project, various methodologies have been adopted in this study to avoid the occurrence of some problems and also to organize the project structure. Figure (1.2) shows the phases that the system passes through until reaching the final obtained results.

1. *Requirements*: In this phase, several tools are gathered to fulfill the overall system on both hardware and software sides. In addition, these requirements can be analyzed in order to ensure their validity and compatibility.
2. *Design*: In this phase, all mechanisms that are responsible for designing the software and hardware system can be prepared depending on the specified requirements in the previous phase. However, all peripherals that are attached to the wheelchair can be aggregated and organized in this phase to give perfect prototype of the system which is represented by a robotic car.
3. *Implementation*: In this phase, the overall designed system can be implemented in two main sections; hardware and software. The hardware section can be represented as a robotic car with its accessories, microcontrollers and additional sensors. Besides that, the software section includes all programs operations that are applied on the robotic car and the programming side of microcontrollers to perform the wireless communication between the wheelchair prototype and upper limb muscle sensor.
4. *Testing and Evaluation*: In this phase, the implemented system can be tested under various experiments with different hand actions and conditions in order

to evaluate it in terms of obtained results and hand motions classification accuracy. Additionality, this system is highlighted on the various problems it faces to be solved in future work.

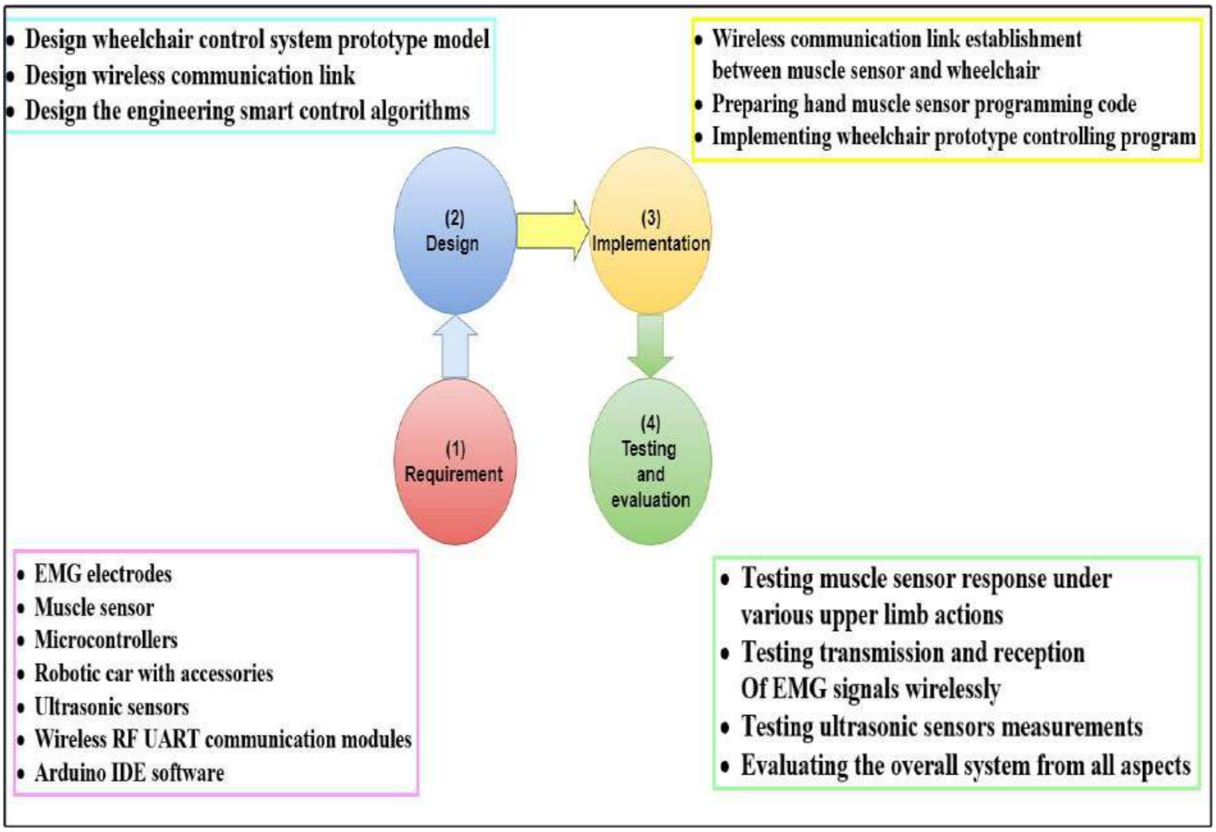


Fig. (1.2): System development life cycle.

1.8 Thesis Layout

This thesis is presented in five chapters; the remaining chapters are structured as listed below:

Chapter Two covers the major techniques for detecting hand nerve signals. It also highlights the fundamentals and processing methods of nerve signals with studying all factors that impact the quality of nerve signals and how to be removed. In addition to that, a variety of control systems have been introduced in this chapter. Besides this, it deals with wireless communication systems.

Chapter Three offers the structured algorithms of the overall proposed system and states the system design and implementation from all aspects.

Chapter Four focuses on the obtained results from the conducted experiments of the system. It also illustrates the overall system accuracy and performance in terms of single action or double action control signals generation mechanisms with their behaviors.

Chapter Five contains conclusions obtained from designing, implementing and testing the system, and also it discusses suggestions for future works.

Chapter Two

Hand Nerve Methodology and Theoretical Concepts

2.1 Introduction

One of the most painful things in social life is observing disabled people who abstained from exercising the movement because of their loss of control over their limbs. Thus, this category of people should return back and practice their daily activities without challenges, therefore all modern techniques aimed at helping them. It has become necessary to recruit hand nerve signals in many assistive systems. Before designing and implementing this system, it is necessary to offer the fundamentals of nerve signals in addition to the fields that exploit these signals in their applications and how to further improve these signals in terms of the best ways to process them and the precise techniques that reveal these signals.

Additionally, this chapter has highlighted EMG processing unit which is explored as a portable innovative device that can be placed on the hand for recording hand nerve signals in real time and how this unit can be utilized to build the aimed assistant system.

2.2 Nerve Signal Fundamentals

One of the ultimate important and most common ways in the world is to control the muscles activities that happen with muscle motions and how to exploit them in many aspects. Therefore, one of today's urgent assignment is how to recruit practical signals of the bioelectrical activity of body muscles in required control applications [24].

In general, some electrical currents are created in body muscle fibers before the muscle force is produced due to the interchange of ions across structural muscle fibers membranes and therefore small potential differences are generated [24]. When muscle activation process is performed, measurable signals can appear. These signals are called myoelectric or electromyography signals which are a type of electric signals [11].

In nature, EMG signals are stochastics and can be described as a function in time domain and hence the maximum usable energy of EMG signal lies in the range 0 to 500 Hz in frequency domain range, with the dominant components range being in the 50-150 Hz range. Moreover, the amplitude of EMG signals ranges from one microvolt to several tens millivolts related to the types of muscle fibers that are activated and the circumstances during the EMG recording process with electrodes placement [25].

At the other hand, the controlling of EMG signals is performed by the nervous system because the motor neurons of this system are ready to receive impulses from the spinal cord to activate the desired muscles in contraction/relaxation states [25].

In general, the skeletal muscle of the body contains many fibers but the neural control of these contracted muscles fibers is described by teeny functional units called motor units which are composed of the cell body with motor neuron and muscles fibers it innervates [26].

The muscles fibers gain the motor neuron to be motivated and contracted when receiving an electrical impulse called an action potential which is sent from the motor cortex of the brain to the muscle fibers via the motor neuron, which is activated by motor unit of these muscles fibers. Many action potentials are generated by the muscles fibers of motor unit in the form of electrical transient signals along membranes of muscles fibers. It has been noticed that, these action potentials of all fibers of a single motor unit when integrated are called motor unit action potentials. Therefore, the electromyogram signal is the mathematical integration of motor unit action potentials within the pick-up area of measuring electrodes. The electrode pick-up region involves many motor units because muscle fibers of various motor units are overlapped everywhere in the target muscle [27].

Moreover, these EMG signals are termed raw EMG signals according to Equation (2.1) before entered in the processing techniques as:

$$x(n)= \sum_{r=0}^{N-1} h(r)e\big(n-r\big)+w(n) \qquad \ldots\ldots \quad (2.1)$$

where x(n) is the raw EMG signal, e(n) the point handle firing impulses of the individual motor units (*r* represents the time delay of each impulse), h(r) is the impulse response of the MUAP that is used to combine the individual motor unit impulses, whereas w(n) is the zero mean additive white Gaussian noise, and N is the number of motor unit firings [28]. Figure (2.1) shows a sample raw EMG signal from muscle contraction [29].

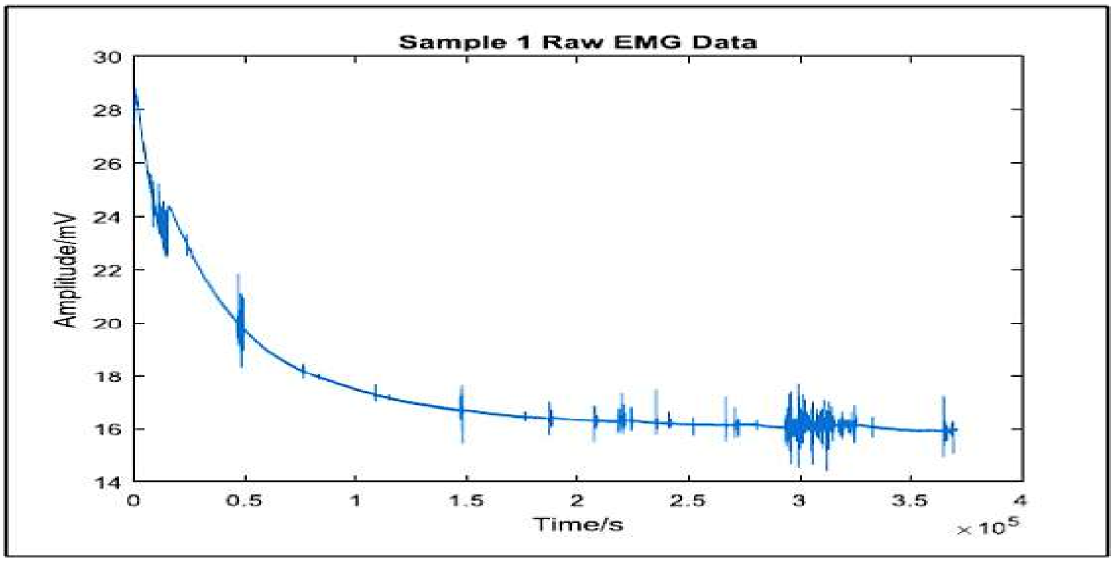


Fig. (2.1): Sample of raw EMG signal [29].

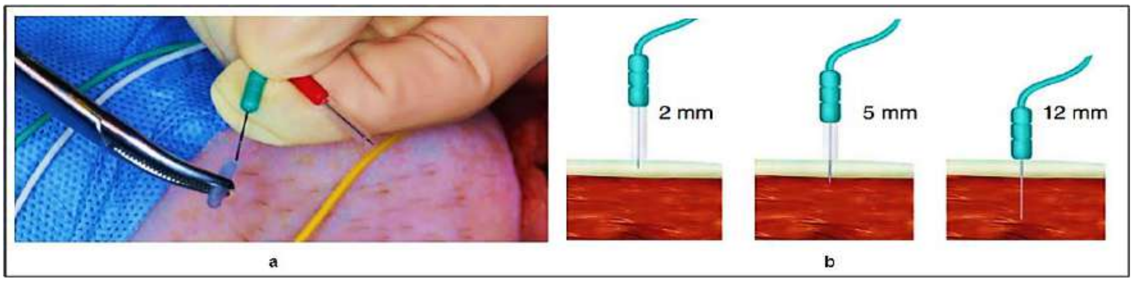
2.3 Hand Nerve Detection Techniques

In general, EMG signals can be expressed as a combination of electrical impulses which are being created in the nervous system and then reached to final destination. Based on that and due to the presence of these impulses, many potential (voltages) differences are generated in muscles which propagate to the surrounding tissues. Hence it is very possible to measure them by adopting specifically designed conductive electrodes placed on the skin surface, or invasively inside the muscle [24]. The selection of the appropriate electrodes is very critical as discovering the better quality EMG signals depends broadly on them [24].

In order to collect EMG signals, there are two general detecting techniques in widespread use: surface electromyography (sEMG,non-invasive) and needle electromyography (nEMG, invasive) [10]. These detection techniques can be summarized in the coming sections.

2.3.1 Needle Electromyography Detection Technique

Indeed, to perform an invasive EMG detecting technique, a needle electrode or fine wire is injected through the body skin into the desired muscle tissue for recording the muscle fibers action potentials [10]. In many cases, this technique is called intra-muscular. Figure (2.2) shows invasive electromyography [30].



(a) Needle electrode **(b) Insertion depths of needle**

Fig. (2.2): Invasive electromyography detection technique [30].

These needles record electrodes signal and their adequate advantages can be summarized as [11], [27]:

1- This method is comparatively accurate and gives better measurements of EMG signals because it produces a heavily measured signal towards motor units in closeness to needle electrodes.
2- Many muscle fibers can be accessed directly by needle electrode as it is capable of gleaning more sensitive and precise data and therefore this technique is preferred in medical applications for diagnosing of muscle diseases.

Despite the advantages of this technique, it contains some serious flaws as [24], [31]:

1- Needle electromyography technique involves many defects when recorded in terms of risks blending and air leak under the skin.
2- In general, for older people who suffer from skin damage, it is not logical to use needle electrodes and hence it is restricted in use.
3- It is not possible to use these electrodes in applications that include many laboratory experiments and examination, so they are recruited only in medical applications and with the help of medical specialists.

2.3.2 Surface Electromyography Detection Technique

By reading the works of researchers and based on their practical data regarding the interactive system between computer and human, it is not practically feasible to utilize needle electromyography detection method with human computer interaction (HCI) applications due to the mentioned above defects and hence surface electromyography became more popular. Practically, surface EMG electrodes are placed above the surface of the skin to derive and measure the voltage difference between two points with two bipolar electrodes connected to the two inputs of an instrumentational amplifier and a reference electrode as a third electrode must be used to set the necessary ground signal [24].

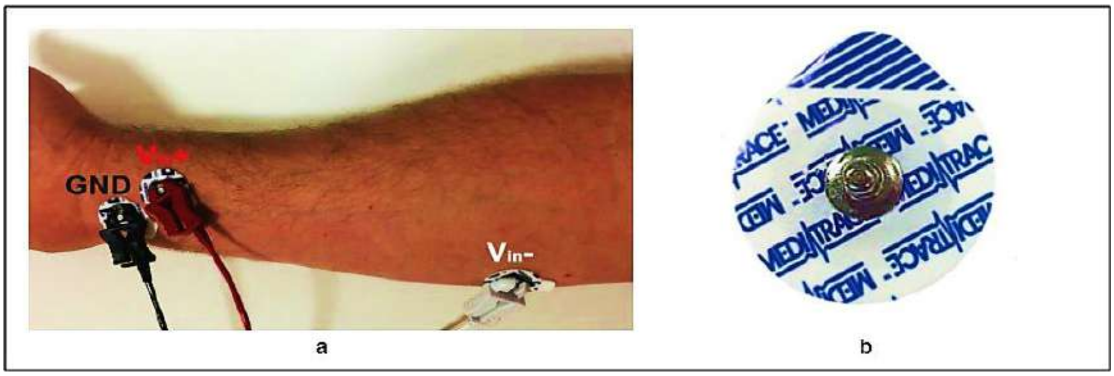
Besides, the basic principle of surface EMG signals is to acquire useful features displaying neuromuscular activities which anticipate usable in myoelectric control systems for robot and wheelchair. In addition to that, the positive features of surface electromyography electrodes can be estimated as follows [31]:

1- Surface electromyography guarantees the detection of biomedical signals without any surgical intervention of the patient and hence it is more comfortable when compared with needle electromyography.
2- According to non-invasive nature, huge information content, and better performance in classification techniques provide a clearly perfect picture about essential motor units’ behavior. For this surface electromyography is important tool in many controlling fields such as bio-medical and engineering applications.

All these features have given a positive characteristic to these electrodes and made the disabled people tend to prefer them on the needle electromyography. Thus, this thesis adopts this type in the proposed system in order to ensure the desired results and high flexibility.

In fact, the accuracy of surface EMG signals measurement is varied and depends on some factors that influence the overall reading such as thickness level of the skin, wrong location of electrode and excess fat on the skin. Moreover, it is necessary to take precautionary precautions to ensure the reception of more correct signals by adapting the procedures of the preparation of the skin surface by removing the skin hair from the target areas and cleanse the skin [31].

Practically, surface electrodes are made up of plastic foam materiality with a silver plated disk and demand a conducting gel to be stable on the surface of the skin. This assists in the conduction of the signal from the muscles to the electrodes which are silver / silver chloride electrodes (Ag/AgCl). In addition, it contains an adhesive surface to attach it to the skin [10]. Figure (2.3) shows noninvasive electromyography [32], [33].



(a) Placement of surface electrodes on forearm muscles, (b) Surface electrode

Fig. (2.3): Noninvasive electromyography detection technique [32], [33].

2.4 Hand Nerve Processing Techniques

Actually, the amplitude of EMG signal is random and fairly weak. Therefore, the presence of noise is normal which leads to loss of information gained from muscle activity. It is most important to evaluate and understand the sources of this noise which restricts EMG signal diagnoses.

2.4.1 Sources of Noise

There are various types of noise sources that influence the behavior and characteristics of EMG signals in the analyzing stage that can be listed as follows:

A. Ambient Noise

All surface bodies are continuously flooding with electromagnetic radiation and became impossible to prevent these bodies from exposure to this radiation as long as they lie on the surface of the earth. Furthermore, the most common source of this type of noise is electromagnetic radiation from the environment. In addition to this, there are other factors that are widely dominant and occupy considerable space in causing this noise such as radio waves, power supply, electrocardiogram (ECG) intervention, Nuclear Radiation, etc. The dominant concern of the ambient noise is reaching to this frequency range (50 Hz - 60Hz) from power sources. Ambient noise has magnitude may be three times greater than that of raw EMG signals and hence its removal is necessary [11], [31].

B. Transducer Noise

This external noise appears in the electrode - skin intersection area. Actually, the basic principle of electrodes is to transform the ionic current generated in muscles fibers into electrical current that can be easily processed in electronic circuits and stored as a voltage potential in either analog or digital format, two noise sources are presented due to this conversion are:

1- Direct Current (DC) voltage potential: occurs according to the differences in impedance between the electrode and the skin and from oxidative and reductive chemical reactions taking place in the connecting region between the electrode and the conductive gel.

2- Alternating Current (AC) voltage potential: which is caused by impedance variations effects between the conductive transducer and the skin.

Moreover, all the previously mentioned impedance effects can be reduced by staffing Ag-AgCl electrodes in human computer interaction (HCI) applications [31], [34].

C. Crosstalk Noise

Crosstalk phenomenon occurs when an EMG signal that is undesirable, interferes at a specific point of time period with the target original EMG signal. This can contaminate the signal and lead to misinterpretation of the information measurements of the required muscle. Furthermore, by careful and perfect selection of the proper electrode size and shorter inter-electrode spacing, it will make the crosstalk effect ultimately smaller [10], [35].

D. Power Line Noise (PLN)

In fact, all the electrical and electronic circuits need an electric current to be running and this is done by the power supply. Specifically, the power supply in Iraq is about 220V with frequency of about 50 Hz. So there is a 50Hz frequency component that will appear in the signal and act as noise. So, it is preferred to adopt batteries when recording biomedical signals as the noise level will be reduced considerably [10].

E. Noise in Electrode Connecting Wires

Indeed, after detecting raw EMG signals by the specified electrodes they are transferred from body surface to signal acquisition circuit by connecting wires. During this transmission, raw EMG signals are the most oversensitive to noise. Therefore, measures should be taken to reduce the impact of this noise through the use of good quality and noise-resistant connection cables such as coaxial cable [10].

In addition to the all mentioned essential noise sources with the stated mechanisms to reduce their effectiveness or remove them. There exists a variety of stochastic factors which have a direct influence on the quality of the biomedical signals, and can be divided into two groups as:

1- **Intrinsic factors:** the status of raw EMG signals in the recording stage depends on the internal features of body and affected by different kinds of noise according to the different chemical behavior of body cell membranes and also the various actions that take place inside the body such as active motor units number, muscle blood flow, amount of tissue between the surface of the muscle, and firing rate of motor unit [35].

2- **Extrinsic factors:** these factors are related to the correct positioning of electrodes on the target muscles and skin preparation methods in terms of removing the hair and cleansing the skin. All these procedures must be satisfied before placing the electrodes on the desired muscle [35].

2.4.2 EMG Signal Processing Stages

According to the previously mentioned various noise sources and the discussed side factors which distort the shape of signals and reduce the efficiency of their employment in many systems which causes degradation in the performance of these systems. Therefore, EMG signal processing strategies have become essential task by adopting filters, operational amplifiers and some additional electronic circuits. This is to reduce the influence of all unwanted signals and to produce a noiseless signal [29]. Generally, EMG processing unit contains the following circuits:

A. Instrumentation amplifier

The basic job of EMG signal acquisition unit is to diagnose the EMG detected signals from the surface electrodes that are placed on muscles surface.

Actually, the amplitude of these signals is between the range from microvolts (μV) to 10 millivolts (mV) and their frequency band lies between 20 Hz and 500 Hz and hence it is necessary to be amplified. For a better amplification, this unit employs an instrumentation amplifier instead of differential amplifier to measure and slightly amplify the very small voltage differences between the two electrodes. The reasons of preferring this kind of amplifier are listed as:

1- The problems of the input impedance that happens in the differential amplifier which is recompensed in the instrumentation amplifier by eliminating the use of input impedance matching and providing low DC offset, low noise, low drift and high open loop gain.
2- The number of operational amplifiers which exists in the instrumentation amplifier is two more than the single differential amplifier such INA118.

Recently, most systems focus on selecting AD620 instrumentation amplifier in EMG acquisition stage. This is because they possess intrinsic characteristics such as low cost, low power consumption making it a good fit for battery powered and a high common mode rejection ratio (CMRR) which makes it very positive in EMG purpose [15].

B. High Pass Filter and Low Pass Filter

Actually, after performing the amplification stage in EMG acquisition unit, EMG signals must be filtered to eliminate different noise such as crosstalk, ambient noise and so on from the amplified detected signal. This is because noises are amplified with the detected EMG signals simultaneously in acquisition stage [10], [36].

Moreover, a high pass filter and a low pass filter electronic circuits are designed to remove this unwanted information from the sEMG signal. Both the high and low frequency noise corrupt the raw EMG signal. Sensor drift on skin and temperature inconstancy causes the low frequency noise which will be removed by using high pass filter. While nerve conduction and high frequency interference from pc, phones, etc. Which causes high frequency noise and can be removed by utilizing a low pass filter. In addition to that, signal aliasing effects are avoided by low pass filter [10], [36].

C. Rectifier Circuit

In order to overcome the problem of averaging both positive and negative amplitudes of signal to zero. Rectification process is widely used for this aim and plays a significant role to gain the envelope of EMG signal. Moreover, two types of rectifier are used: full-wave and half-wave but many systems encourage the use of full-wave rectifier because it gives more accurate results.

The target of full-wave is to reflect all negative amplitudes of the signal to positive amplitudes by passing only positive portion of entered signal over the diode. On the other hand, the negative portion passed from the operation amplifier as inverting input so the final output EMG signal lies in the positive level as to overcome the problem of averaging both portions to zero [25].

D. Inverting amplifier

After passing the EMG signals in amplification and filtering stages, it passes later in the amplification with inverting amplifier because the latter have low input impedance according to the feedback resistors.

2.5 Embedded Systems

An embedded system is a dedicated computer system which is designed to perform a specific job under a set of rules. Minutely, embedded system can act as a special purpose system hardware with designed purpose software embedded inside it which makes the embedded system adapt itself for any dedicated application. Moreover, large embedded systems must contain real time operating system (RTOS) for management purposes and to represents the system works [38].

Nowadays, these systems occupy considerable space in various diversified applications and exist in a variety of electronic circuits in many forms as Arduino, Teensy, and Raspberry Pi [38].

2.5.1 Arduino UNO Microcontroller

Arduino Uno as depicted in Figure (2.4) is an open source programmable board that can be used in a wide variety of electronic projects and is considered one of the most quite popular Arduino boards for all levels of users. Arduino Uno platform is based on the ATmega328P and consisted of a programmable circuit named microcontroller which is possible to program it for controlling physical objects. In addition to that, it can be programmed by uploading the code to it from the computer via universal serial bus (USB) , this programming code is written by Integrated Development Environment (IDE) with C/C++ programming language [39], [40].

In general, Arduino Uno is 5 volt board that can be powered with USB link, AC-to-DC connector or battery. Moreover, this board has RX and TX LEDs to indicate the success of information transmission by means of USB to serial chip or PC association with USB port [41].

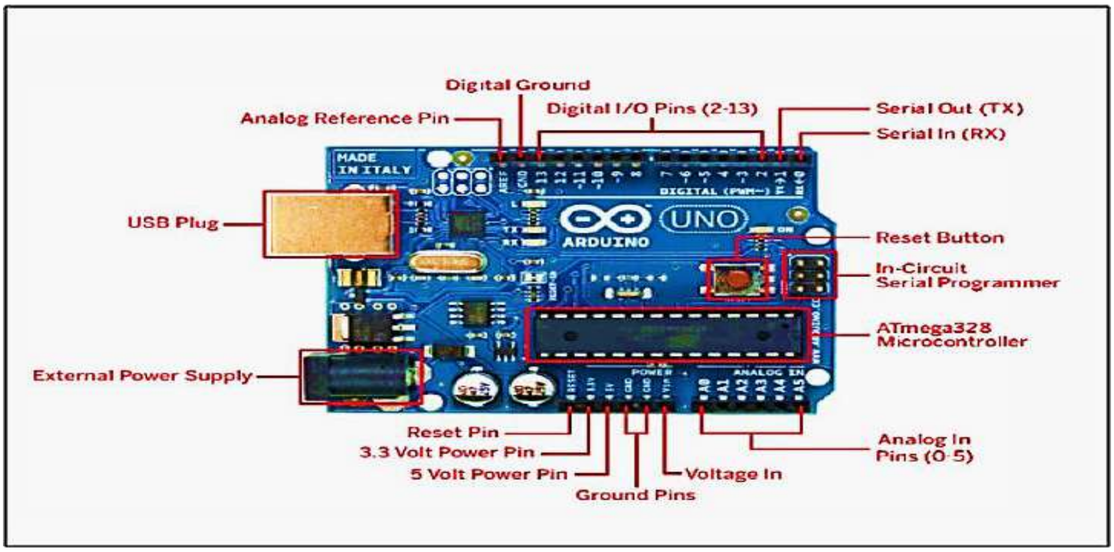
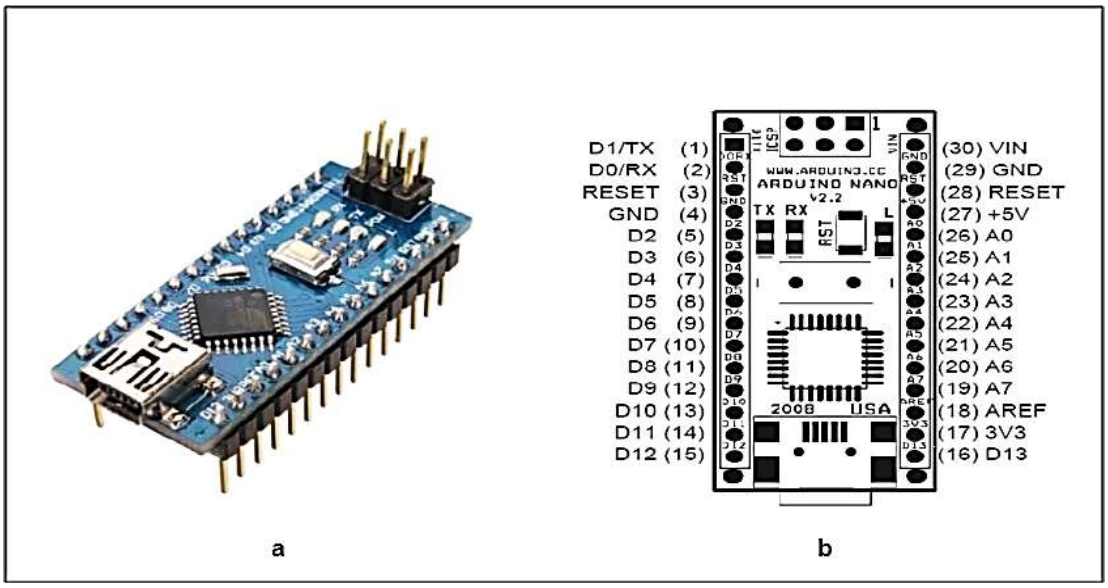


Fig. (2.4): Arduino Uno microcontroller board [40].

2.5.2 Arduino Nano Microcontroller

Arduino Nano is a microcontroller board which is designed for a wide range of control projects. Nano board is a small, complete, and breadboard-friendly board so it can be plugged with other electronic elements in only one breadboard which increase its flexibility. In fact, Arduino Nano 3.0 is based on the ATmega328 microcontroller but Arduino Nano 2.x based on ATmega168 microcontroller. This board is seem to be similar to the versions of other Arduino but it lacks to a DC power jack and works with a Mini-B USB cable standard to connect to the computer [42].

Arduino Nano has the ability to provide digital communication for the sensors via USB cable and hence the real time readings of sensors can be viewed easily during the serial monitor of Arduino Nano [43]. Arduino Nano contains 14 digital input/output (I/O) pins, 8 Analog reference pins and has a clock frequency of 16 megahertz (MHz) [46]. Figure (2.5) shows Arduino Nano microcontroller [44].



(a) Arduino Nano board, (b) Pin diagram of Arduino Nano

Fig. (2.5): Arduino Nano microcontroller [42], [44].

2.5.3 Raspberry Pi Microcomputer

Raspberry pi is a single board computer which is equipped with many computing capabilities in a tiny board to be easily interfaced with any dedicated system or project. Therefore, it is exploited currently in widespread applications and works with Linux operating system efficiently. To give an illustration, Raspberry Pi runs on ARM11 microcontroller that has clock frequency of 700MHz and comes with 512 megabytes (MB) of Random Access Memory (RAM). In practical, raspberry pi is an open source platform produced in 2012 by the Raspberry Pi Foundation.

However, pi boards are appropriate for advanced engineering applications as it guarantees terrific processing speed. This board does not contain a solid-state drive or a built-in hard disk and hence it uses an SD card for booting and storage. Specifically, Raspberry Pi III model B has embedded built-in Wi-Fi that has the ability to enhance the communication capabilities remotely which make it powerful in various wireless communication applications [44], [45].

2.6 Wheelchairs Models for Assistant Systems

Generally, one of the top priorities of helping the disabled is to restore their motor abilities through developing the extreme important primary assistive techniques which are wheelchairs. In fact, the most commonly used wheelchairs are manual, electric and smart wheelchairs. All these wheelchairs can be controlled either manually by using joysticks or automatically (using head movements, eye tracking or biomedical signals as ECG, EMG, EEG and EOG) [46], [47].

Based on that, there exist a variety of wheelchairs models as assistive systems, some of these can be illustrated as follows [47]:

1- The manual wheelchairs are suitable for elderly people who have difficulty in mobility and also used by disabled people who have minor physical disabilities who have the ability to adjust the movements of their hands or fingers. These chairs are not appropriate for people with dangerous disabilities.

2- The electrical wheelchairs are made to solve the problems experienced by the disabled in terms of their inability to pay the manual chair as a result of light injuries in the limbs. Some of these chairs are controlled by joysticks.

3- There exist a modern assistive technique to overcome all limitations that are caused by electric wheelchairs and are classified as the perfect manner for helping people with severe motor disabilities. To put it another way, this technique is called smart wheelchairs. Actually, smart wheelchairs are electrically controlled devices that are enjoyed with self-mobility and based on the control command from patients and therefore the user effort and force to drive the wheelchair are minimized.

Moreover, smart wheelchairs cannot be compensated by other technology in order to help disabled people because they provide autonomously locomotion between locations and assuring collision-free driving based on obstacle detector sensors that are attached to these chairs. All these advantages have made the disabled tend to use these chairs despite their complexity [47].

2.7 Wireless Communication Systems

Wireless communication has proved to be the fastest growing and important when compared to other fields of communication and has attracted the attention of researchers due to its continuous development. Generally, its role is to transmit data wirelessly by using wireless signals via wireless communication technologies and devices through incorporating all procedures and wireless protocols that are responsible for communicating between two or more devices or systems [48]. There are many wireless techniques and protocols, some of these can be explained as:

2.7.1 Bluetooth

Bluetooth is also known as IEEE 802.15.1 standard. It works with master-slave principle designed with low cost, low power consumption, user friendly and it has less interference in comparison with the other technologies due to the use of Frequency Hoping Spread Spectrum (FHSS) technique. However, bluetooth can be operated with three different classes: class1, class2 and class3 where the coverage area is about 100,10,1 meter respectively with 2.4 gigahertz (GHz) frequency band [31], [49].

Indeed, the radio frequency of bluetooth make it face big drawbacks through its security threat and hence can penetrate through walls. For this reason, it is not advisable to adapt bluetooth for critical signal transferring such as biomedical signals and so on [31].

2.7.2 WIFI

Wi-Fi is a wireless replacement of high speed cables which carry huge data and refers to IEEE802.11 standards which commonly adapts itself for connecting nodes in wireless mode and deliver data at high frequency which is especially designed for indoor communication with high data rate. This technique is based on radio frequencies to exchange data for short distances between nodes [50].

Generally, 802.11 operates on either 2.4GHz or 5GHz depending on its type. Basically, four types exist, these are 802.11a, 802.11b, 802.11g, and 802.11n each of which has different modulation techniques. Despite the desirable features it offers, the quality of performance is reduced by many factors limiting its wireless efficiency such as high power consumption. Additionality, wifi signals are susceptible to interference from many devices that are operated at the same frequency [50], [51].

2.7.3 HC-12 Wireless Serial Port Communication Module

The HC-12 remote wireless serial port communication module is a new-generation of multichannel that installed remote information wireless data transmission module [41]. That is very useful, extremely powerful, guarantee long communication distance and easy to use. Therefore, all these features encourage to employ them in control applications that involves embedded systems and sensors. Practically, the STM8S003F3 microcontroller and the Si4463 transceiver are integrated to form the HC-12 transceiver circuit board which gives it a great many advanced features. Usually these transceivers are capable of communicating up to and possibly slightly beyond 1 kilometer (km) in the open and are more than adequate for providing coverage throughout a typical house because it paired with external antenna [41].

There is a PCB antenna pedestal ANT1 on the module, and customer can use external antenna of 433MHz frequency band through coaxial cable. There is also an antenna solder eye ANT2 in the module, and it is convenient for user to weld spring antenna. In addition, the developer could select one of these antennas according to the used requirements of the project. There is MCU inside the module, and the costumer does not need to program the module separately but just sends and receives UART data and all four transparent transmission modes of HC-12 are only responsible for receiving and sending serial port data and permits the programmer to make a choice through AT commands according to the operating requirements, so it is convenient to use them [41].

In this project two HC-12 modules can be utilized as a part of the place of physical wiring because the required communication range should be more to convey hand nerve signals in order to perform the communication between hand nerves of amputees and wheelchair to achieve the project objective.

2.8 Sensors

Sensors are sophisticated devices that are frequently used to detect or sense the changes and events in the environment. A sensor converts the physical parameter into a signal which can be measured electrically because the output is generally a signal. So, it is necessary to convert it to human-readable display at the sensor location or transmit it electronically over a network for reading [52].

In this project two essential types of sensors devices are employed. The first is Myoware muscle sensor which is considered the core of the overall system, while the other is utilized for the obstacles detection purposes in order to give safety for amputees while driving wheelchair.

2.8.1 Muscle sensor

In order to have a more flexible and transparent system in use it is necessary to reduce system electronics to the lowest possible level in order to ensure the activation of low cost guidelines [53]. Therefore, it is worth mentioning that most of the systems responsible for the acquisition of EMG signals are traditional and composed of analog filters and gain stages for each channel as well as the other embedded electronic circuits. All this goes against the objective to be achieved by using less components than the traditional EMG signal acquisition system [22].

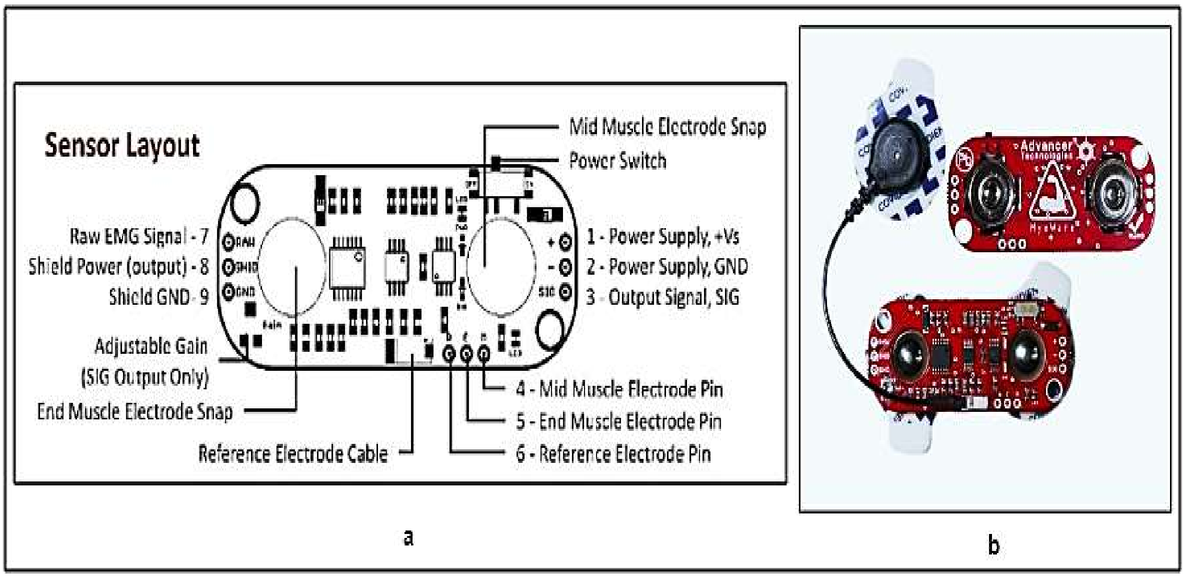
Hence, technical devices have emerged to reduce these limitations, which are muscle sensors. Nevertheless, these sensors are limited by standards when designed and developed, including small size, light weight, longevity, wearability, ergonomics and power consumption to comply with the parameter of reliability [54].

EMG muscle sensor is an intuitive and common device to measure the electrical response of muscles activities and has effective behavior to enhance all biomedical signals. Notably, it has entered into many industrial fields and control systems and the best example of this that is widely used in the control and biomedical applications is Myoware muscle sensor. Myoware muscle sensor (AT-04-001) is electromyography sensor especially designed for controlling applications [55] developed by Advancer Technologies in United States to be adopted for acquiring EMG signals by measuring the activity of muscles fibers via electric potential that is recorded by surface electrodes and transformed this into variable electrical voltage. The previously mentioned voltage can be read by any analog input pin of any microcontroller and therefore this sensor is designed to be compatible directly with any ADC microcontrollers such as Arduino microcontroller [22].

Myoware muscle sensor is low power device, small size (20.8 x 52.3 mm^2), and has the ability to be powered directly from 5v microcontroller. Moreover, it has two outputs either raw EMG signal or pre-processed EMG signal (amplified, rectified, filtered and smoothed EMG signal) [53]. In addition, this sensor can be powered by a voltage source between 2.9 - 5.7 v with a maximum current of 14 mA [55].

Myoware muscle sensor contains embedded electrode connectors for two electrodes with interelectrode distance of 3.0 cm and third electrode to be placed out of the desired muscle region near the bone as reference electrode [57]. It is worth noting, the basic feature that made this sensor a favorable in many microcontroller applications as this sensor has been designed as a wearable device to be placed on body parts directly instead of using biomedical pads separately and connecting them via cables. Therefore, all the previously mentioned noise sources and the factors limiting the signal quality which are caused according to the movement of these wires will fade when using this sensor. Figure (2.6) shows the Myoware muscle sensor and pin layout of this sensor [55], [56].

Moreover, one of the possibilities of Myoware muscle sensor is its ability to produce the raw EMG signal before processing it through pin 7 and also allows to connect external electrodes cables via pins 4, pin 5 and pin 6. But this project tends to use the envelope EMG signal that is resulting from the pin 3 (SIG) as it guarantees enhanced and noiseless signal as control signals to be recruited in providing assistance to people with disabilities, particularly for bilateral amputees. This project also preferred to employ electrode pads that are attached straight to Mid and End muscle electrode snaps on the Myoware Muscle Sensors' PCB board [56].



(a) Pin Layout of sensor, (b) Myoware Muscle Sensor external view

Fig. (2.6): Myoware muscle sensor [55], [56].

2.8.2 Ultrasonic Sensor

Given the developments of modern technologies, ultrasonic sensor technology has become a vital factor because it occupies a large space in many fields including applied science, engineering and medical applications. The most proper advantage of ultrasonic sensing is enormous ability to explore floating objects in all types of media including steel, liquid and gas without destroying these objects. So, the overall goal of these techniques is recognizing the closest object in its path [58]. In fact, the principles and foundations of the work of ultrasonic technology and their sensing are carried out through a device called ultrasonic sensor [59]. Figure (2.7) illustrates the pin diagram of ultrasonic sensor.

Ultrasonic sensor is essentially sound sensor. To put it another way, it is an emitter and absorbent of ultrasound waves which is one type of mechanical waves that operates at a frequency beyond the human hearing (20 kHz) [60]. The maximum geographical area can be covered by this sensor is four meters (13.1234 foot) [61].

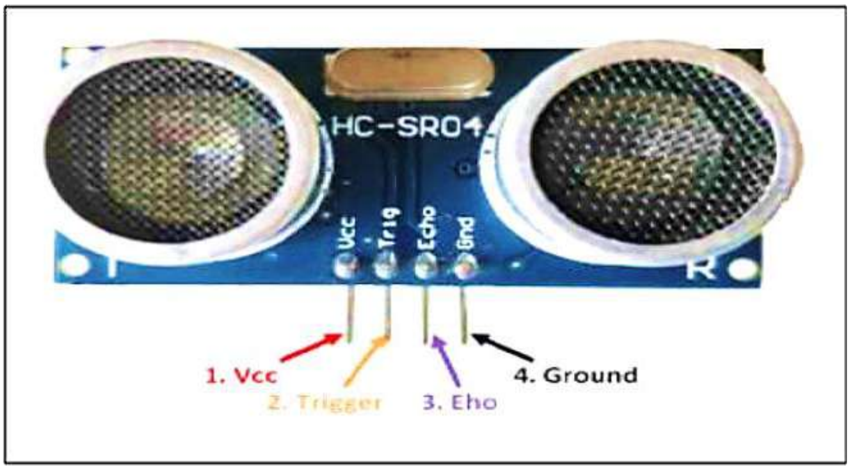


Fig. (2.7): Pin Diagram Ultrasonic Sensor [52].

In order to measure the actual distance to an object, 8 burst of a 40 kHz ultrasonic waves are emitted by ultrasonic sensor through the transmitter side of this sensor and the timer is started. Then, these pulses are travelling outside until they come across an obstacle. If there is a barrier, the reflected waves are received by the receiving side of the sensor and the timer stops immediately then ultrasonic sensor records the elapsed time between the generated sound wave and the returned-back sound wave and hence the distance is calculated according to the propagation time of ultrasonic waves as illustrated in Equation (2.2) [52].

$$d = \frac{ET * 34300}{2} \qquad \ldots\ldots \quad (2.2)$$

Where, ET is the elapsed time, d is the measured distance and the 34300 is the speed of sound in air measured in cm/s.

Chapter Three

The Proposed System Design Based on Hand Nerve Signals

3.1 Introduction

Several studies and surveys have been conducted in recent years to diagnose chronic limb injuries that lead to motor injuries to people with bilateral amputation. Therefore, the only concern of these studies is how to meet these challenges through the establishment of interactive systems that translate the intentions of the injured. This can be done through hand nerve signals and used to control the means of assistance to them and the most common ones are wheelchairs that give high degree of the independence of the amputees.

Actually, this chapter briefly describes the mechanisms that are responsible for the design and implementation of these wheelchairs, which is represented as robotic car. In addition, this chapter includes hardware components and software algorithms that all constitute the proposed system.

3.2 Hand Nerve Signal Analysis

As mentioned earlier that the proposed system is based on the signals collected from the hand nerve for bilateral amputation people. This section considers the hand nerve signals and can be divided into different sub-sections to facilitate the reading flow.

3.2.1 Hand Nerve Signal Preprocessing

Factually, it is substantial to preprocess hand nerve signals for wheelchair control since many factors and noise sources determine the complexity and influences the validation of these signals and due to the tiny amplitude of hand nerve signals as measured in microvolts. This can reduce its accuracy as affected by unwanted signals which caused associate incorrect interpretation of the signals [29].

Preprocessing can be considered as a mandatory because many controlling hand nerve systems based on EMG amplitude evaluation in time domain as the extracted information must be correct to specify the actual job of assistive systems [62]. Figure (3.1) illustrates the basic steps of EMG preprocessing unit that considers the deep analysis of the components of this unit as it is assumed to be the center of this system and can be summarized as follows:

A. EMG Surface Electrodes (Data Acquisition Unit):

Due to muscle activity, many brain neuromuscular signals are triggered in the form of electrical signals which are picked by surface electrodes and have varied frequencies depending on the strength of flexing of the muscle. These electrodes are located on the Biceps Brachii and forearm muscles in two suggested case studies of the mentioned amputating muscles [63].

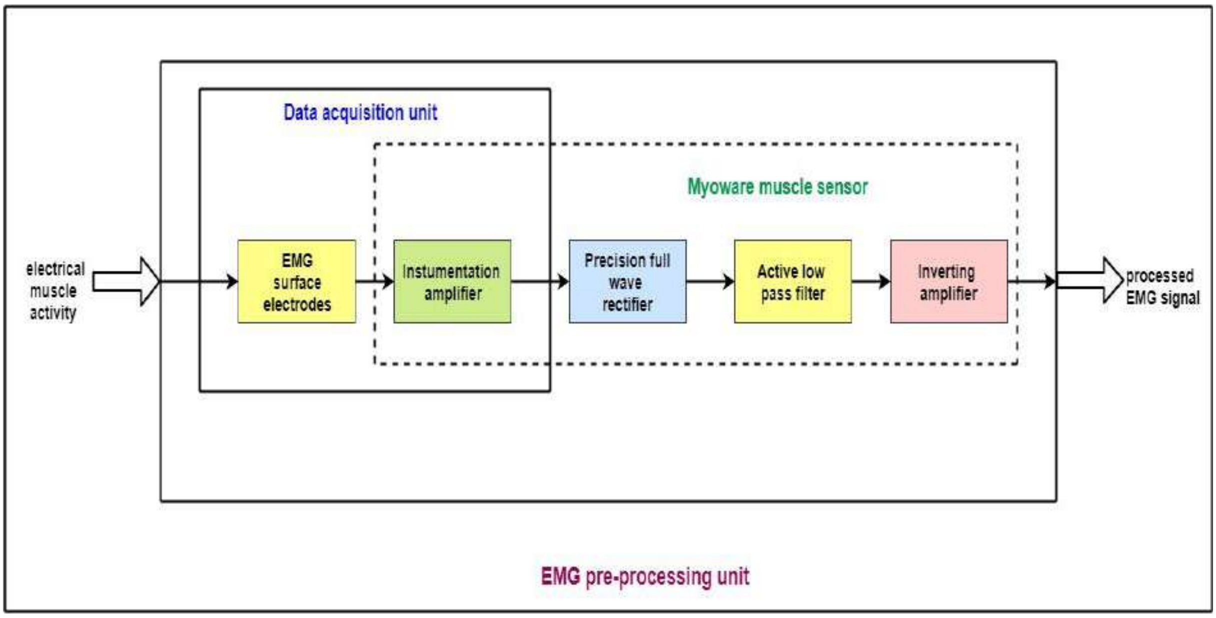


Fig. (3.1): Basic steps of EMG preprocessing unit.

Practically, each muscle requires three electrodes to be placed on. Two electrodes in bipolar configuration at the middle and end of muscle. While the other electrode, which is considered the ground, is placed near the target muscle, specifically on the bone [64]. Figure (3.2) gives a view about bipolar configuration of electrodes [64].

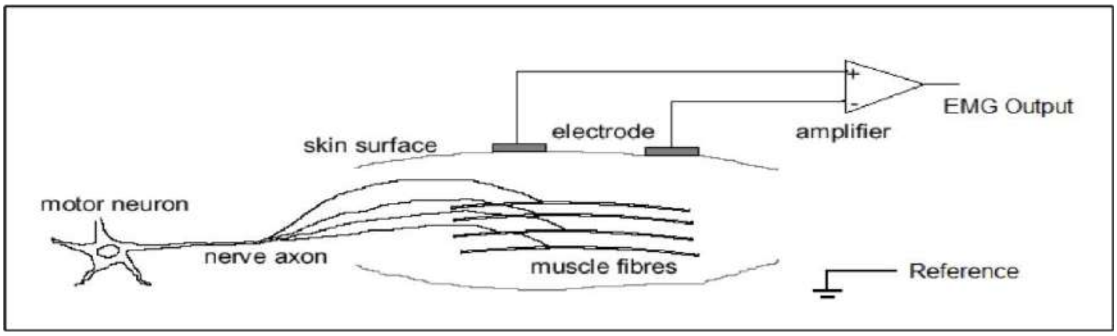


Fig. (3.2): Bipolar setting of EMG surface electrodes [64].

B. AD8221 Instrumentation Amplifier (Data Acquisition Unit):

An instrumentation (or instrumentational) amplifier is a class of differential amplifier that contains input buffer amplifiers, which eliminate the need for input impedance matching. Therefore, this feature makes the amplifier particularly proper for utilizing in measurement devices, such as sensors. The working principle of this amplifier is to detect the signals at two sites which are positive and negative input from the electrodes. It also amplifies the difference between two input signal voltages while refusing any signals that are common to both inputs voltages. So, it has the ability to fulfill very important job of extract small voltage signals from signal sources [65]. In general, precision instrumentation amplifier of type AD8221 is used as a preamplifier in the employed EMG processing unit [66]. Figure (3.3) presents the electrical circuit of AD8221. The transfer function of the AD8221 is explained in Equation (3.1) [66]:

$$G=1+\frac{49.4\ \text{k}\Omega}{RG} \qquad \ldots\ldots \quad (3.1)$$

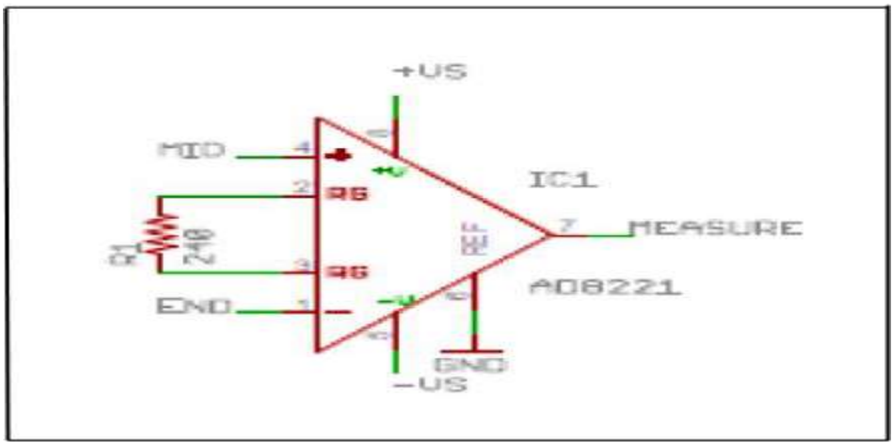


Fig. (3.3): AD8221 instrumentational amplifier circuit [67].

C. Precision Full Wave Rectifier (Rectification Unit):

Since the amplitude of hand nerve signals is tiny, it is not practical to be rectified by conventional rectifier. Thus, the precision full wave rectifier is adopted to average the EMG signal and to fetch suitable output in unidirectional positive level signal. This type of rectifier is preferred because it is low level operating voltage and less exposure to noise [65], [68]. Indeed, the natural behavior of EMG signals is stochastic as it is fluctuating in the range between positive and negative levels during the activation of muscles fibers. Therefore, it must be rectified to avoid the problems of averaging at zero [69]. Figure (3.4) shows the electrical circuit of precision full wave rectifier [67].

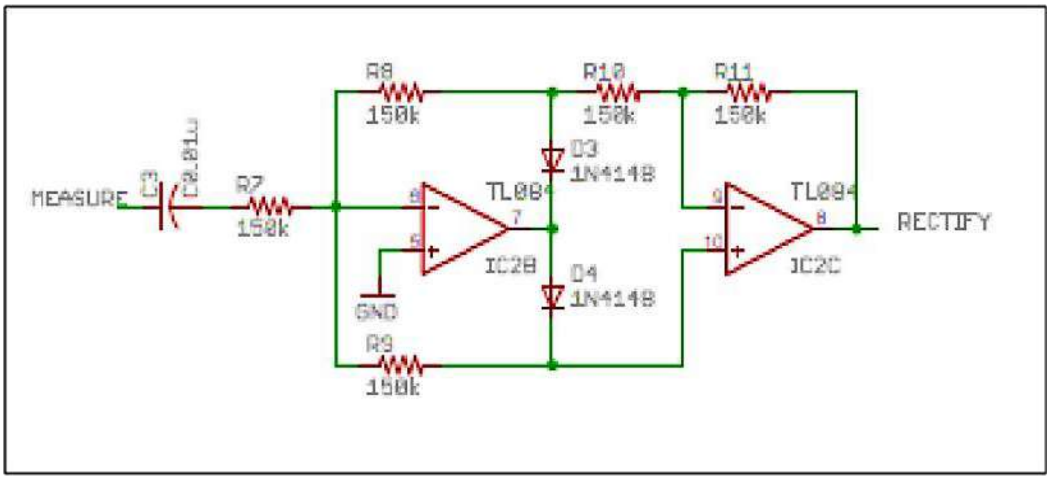


Fig. (3.4): Precision full wave rectifier circuit [67].

D. Active Low Pass Filter (Integration Unit):

After rectifying EMG signals, it is necessary to smooth the fluctuation signal and obtain an envelope of the acquired EMG signal. So, it is important to adopt an active low pass filter to improve EMG signals by eliminating high frequency noises and permits only low frequency signals to pass according to the specified cutoff frequency. Low pass filter benefit confers a smoother form of the EMG signals by reducing the short term fluctuations and leaves as much as possible the long term trends. Hence, it produces smoother signals [10]. Figure (3.5) presents an active low pass filter circuit [67].

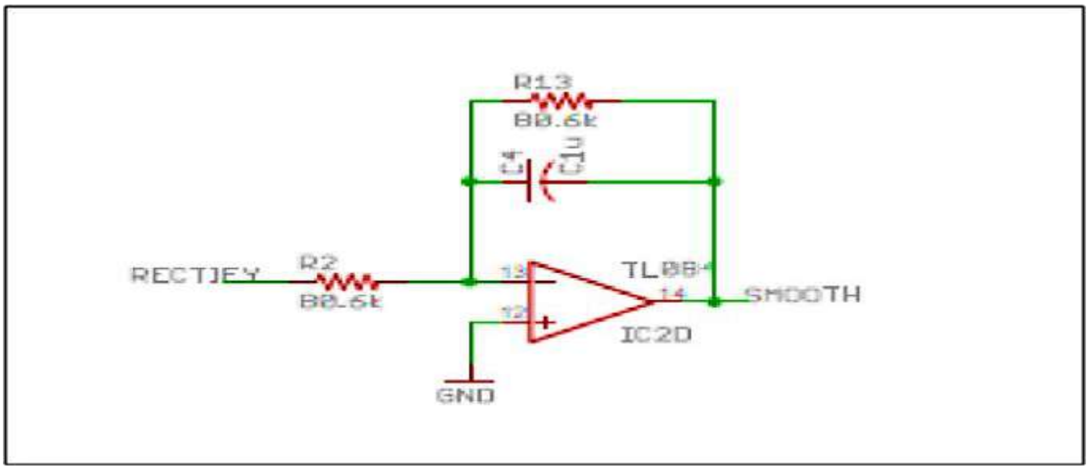


Fig. (3.5): Active low pass filter circuit [67].

E. Inverting Amplification (Amplification Unit):

After the EMG signal has passed to low pass filter for smoothing purposes and filtered fairly with a suitable band of EMG frequency, it must be amplified again with the help of an inverting amplifier (operational amplifier). This is done with acceptable gain and relies on the values of resistors. It amplifies the EMG signal that is sufficient enough in amplitude [68]. Hence, an inverting final amplifier is employed in EMG processing unit to amplify and invert the output signal of the low pass filter waveform. Figure (3.6) shows the inverting amplifier circuit [67].

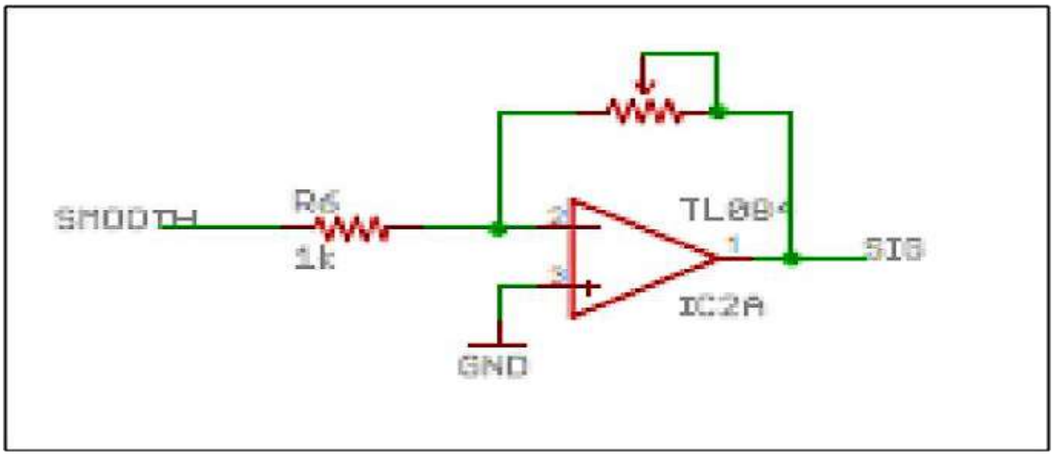


Fig. (3.6): Inverting amplifier circuit [67].

Fortunately, the Myoware muscle sensor that is adopted in this project has been specifically designed to be directly utilized with a microcontroller such as Arduino boards. Therefore, Myoware outputs are not only a raw EMG signal but rather it can produce an amplified, rectified and integrated signal. These outputs are working well with analog to digital convertor microcontrollers. Figure (3.7) illustrates the primary differences between raw EMG signals and enhanced EMG signals [22].

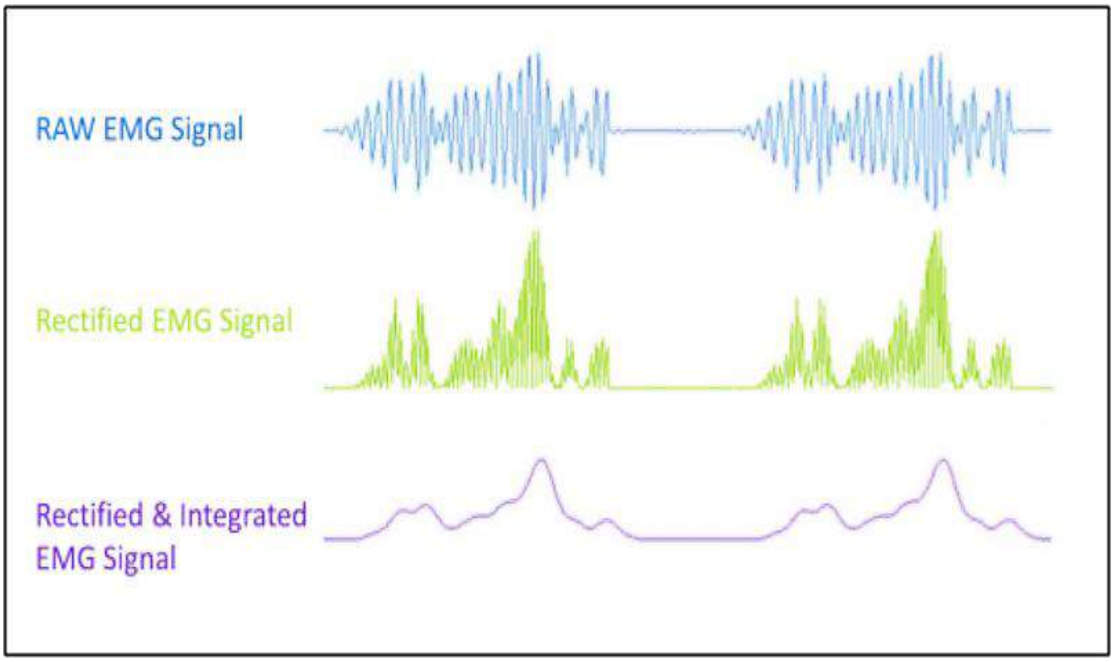


Fig. (3.7): Types of EMG signals from Myoware muscle sensor [22].

3.2.2 Proposed Algorithm of Hand Nerve Readings

The proposed algorithm of hand nerve readings is designed to generate different EMG control signals using the received EMG measurements from hand nerve signals of bilateral amputees. Minutely, one efficient smart algorithm has been structured in the transmission side to manage and classify the acquired hand nerve signals which are represented by EMG signals based on the precise computed threshold ranges. The readings of EMG signals are varying and their degree of variation depends on the amount of force of the contraction of the target muscle in terms of the number of motor units generated by the central nervous system. In proportion to this variation, the algorithm proposes different threshold frequency values for classifying hand gestures.

Actually, ten control signals are acquired and can be exploited to manage the movements of wheelchair. This project gives high performance wireless communication control system by structuring high efficiency algorithms at two sides of the total system with low cost hardware equipments and excellent wireless transmission and reception of hand nerve signals for acceptable distance without any diffculities.

However, these hand motions need to be more accurate and done in well actions by users. The users (patients) are required to take a training course for adapting their muscles with the fixed electrodes. Figure (3.8) shows the proposed algorithm of hand nerve readings at the transmission side as a flowchart.

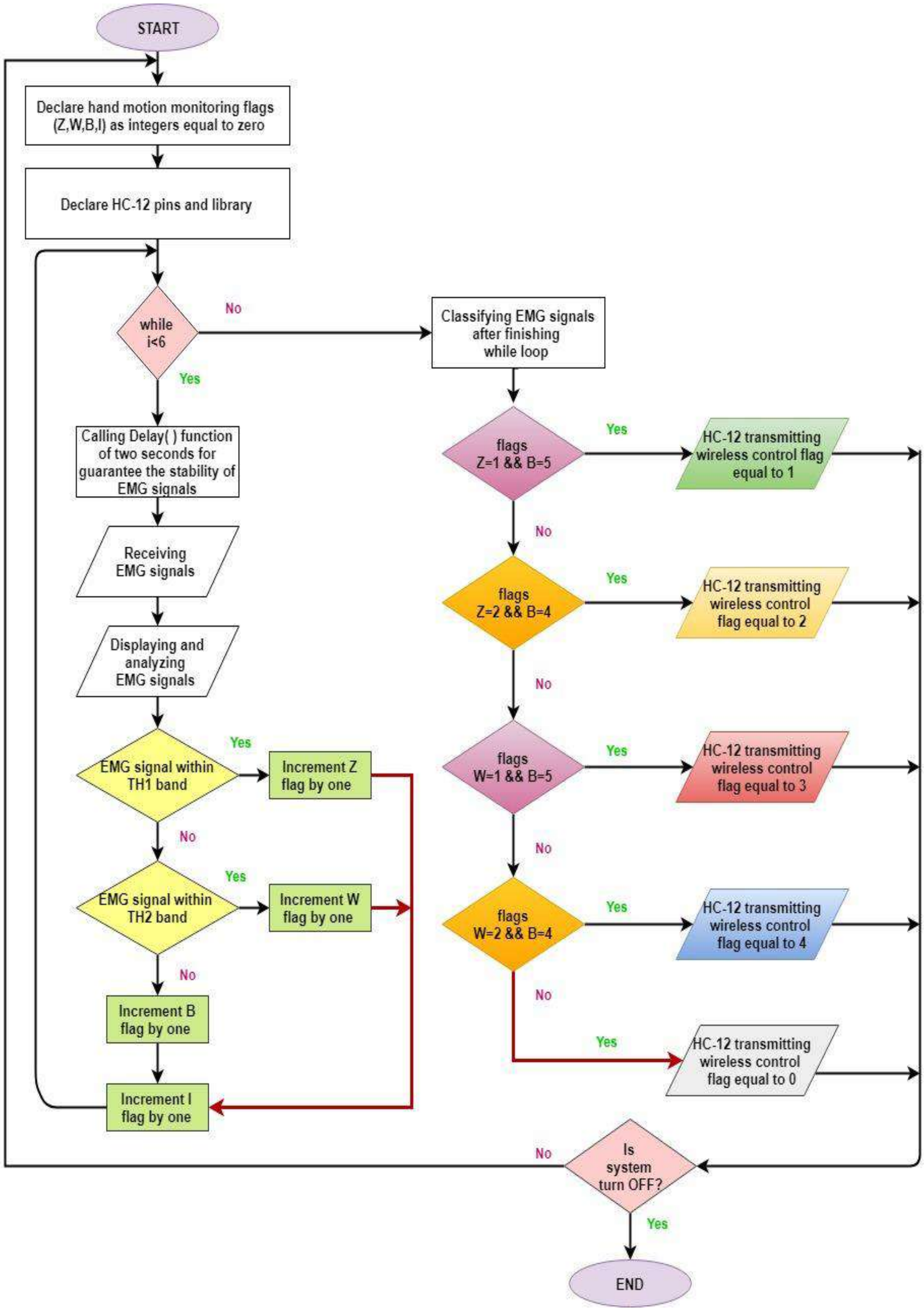


Fig. (3.8): The proposed algorithm of transmission sub-system.

Based on the flowchart of Figure (3.8), the transmission sub-system proposed algorithm goes through the following steps:

- Initially, the sensing software declares the software serial library for performing the required wireless communication between the microcontrollers at the transmitter side of hand nerve signals and the receiver side. These EMG signals are employed in this wireless communication control application using two HC-12 wireless modules.
- The sensing software declares flag *I* as integer equal to zero for controlling the loop of six counts, this loop repeated continuously.
- Inside the loop, the following steps are performed:
    - The sensing program causes delay of two seconds until the muscle sensor obtains the sense of hand nerve signals.
    - Reading and displaying EMG signals on the serial plotter of Arduino Nano microcontroller.
    - Analyzing these signals based on opening serial monitor of Arduino Nano and show the digital values of EMG signals to make decision according to the specified conditions inside the sensing program.
    - Hand motion monitoring flags (*Z*, *B*, *W*) depend on how strong the muscle contraction is.
    - The smooth contraction of the desired muscle for only one time within the assigned loop period makes the value of the flag *Z* increase once.
    - The smooth contraction of the desired muscle for only two times within the assigned loop period makes the value of the flag *Z* increase twice.
    - The strong contraction of the desired muscle for only one time within the assigned loop period makes the value of the flag *W* increase once.

  - The strong contraction of the desired muscle for only two times within the assigned loop period makes the value of the flag *W* increase twice.
  - Relaxing the desired muscle within the assigned loop period makes the value of the flag *B* increase once at each relax.

- ➢ Outside the loop: after the period of the loop is completed, the classification process for acquired EMG signals will be performed for generating the appropriate decisions in form of control commands to control the wheelchair state (MOVE/STOP) depending on the values of the hand motion monitoring flags (*Z, W, B)* and threshold ranges inside the program.
- ➢ HC-12 wireless module performs the necessary wireless communication by activating the handshaking process with its corresponding counterpart via adapting wireless controlling flags and transmitting these flags to the HC-12. So that every sent flag expresses a control command.
- ➢ Finally, this loop is repeated continuously for another hand actions after HC-12 transmits the flag with the appropriate control command.

3.2.3 Hardware Design for Hand Nerve Readings

In general, the structure of the proposed system involves different hardware equipments. Each of which has a specific function for completing the required job with efficient compatibility among these components. The overall proposed system is concentrated and subdivided into two sub-systems. One at the sending end of the hand nerve signals from the amputated people and the other at the receiving end of the transmitted nerve signals for adapting them in moving the wheelchair as required and needed by the amputated people. Figure (3.9) illustrates the physical connection of hardware equipment at the transmission sub-system.

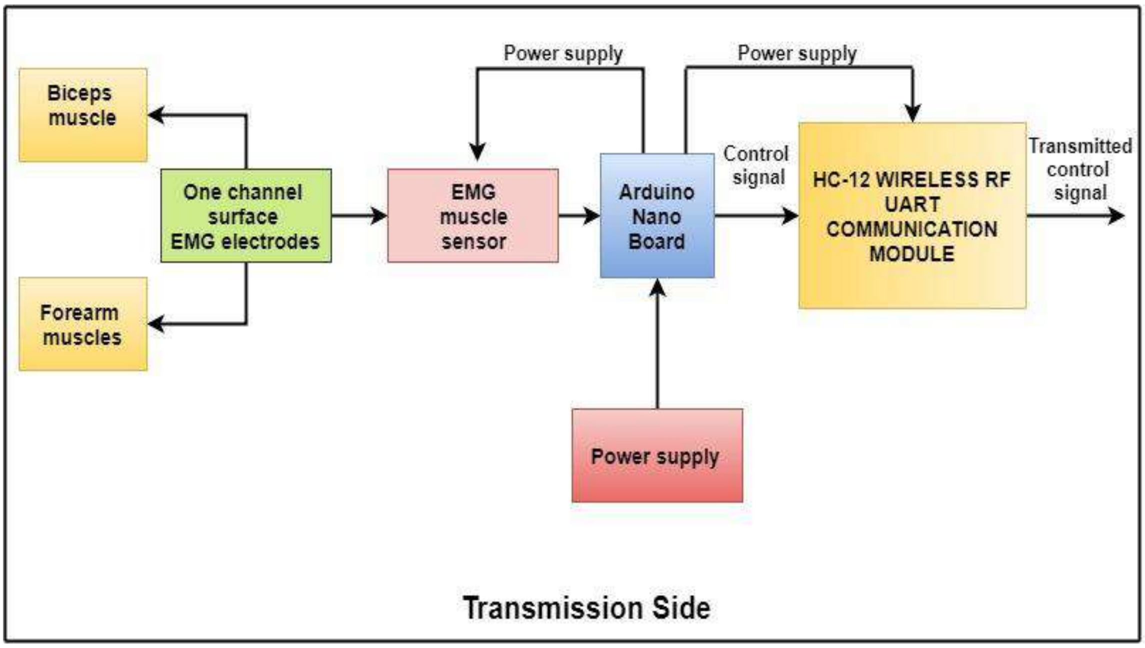


Fig. (3.9): Hardware connection at the transmission sub-system.

Certainly, the flow work of the transmission sub-system in the adopted two case studies can be interpreted in details as follows:

Step1: preparing the skin by performing the hair removing process to enhance the adhesion of the surface electrodes on the skin and cleaning the skin to expel dead skin cells.

Step2: Placing one channel surface EMG electrodes with EMG muscle sensor at the middle of the desired muscle according to the following set up:

- The first electrode is placed at the middle of the desired muscle and directly connected to the cable snap connector of EMG muscle sensor.
- The second electrode is placed at the one end of the desired muscle and directly connected to the other cable snap connector of EMG muscle sensor.

- The third electrode is placed on bony near the desired muscle and directly connected to the cable snap connector of EMG muscle sensor.

Step3: Using 9 volt external battery to equip the microcontroller board with power supply.

Step4: Establishing wire connection between EMG muscle sensor and Arduino Nano microcontroller for managing and controlling these processed and enhanced hand nerve signals and also to be converted from analog form to digital form for analyzing it easily in the computer to be sufficiently adopted in control applications. In addition to that, this step guarantees the powering up of Myoware muscle sensor from 5v Arduino Nano.

Step5: Setting up wire connection between Nano and HC-12 to power up HC-12 with 5v and to deliver the suitable command to the reception side.

Step6: Structuring the proposed control algorithm of hand nerve readings that is assigned to the sending center for hand nerve signals and converting it in a form of program to sensing ten muscles movements. In addition, loading the sensing program into the Arduino Nano in the transmission side.

Step7: Opening the serial plotter of Arduino IDE and then activating the desired muscle/muscles group to analyze the receiving hand nerve signals that are recorded by muscle sensor. This analysis relies on hand motion monitoring flags values and level of muscle flexing in order to produce the wanted control signal that is responsible for driving wheelchair in the desired direction.

Step8: HC -12 wireless RF UART serial port communication module is enlisted in this transmission side as a transceiver for long distance wireless transmission of the generated control signals.

In addition, the overall proposed system should explain the mechanisms of connecting the physical components on the receiving side. Furthermore, Figure (3.10) illustrates the physical connection of hardware equipment at the reception sub-system.

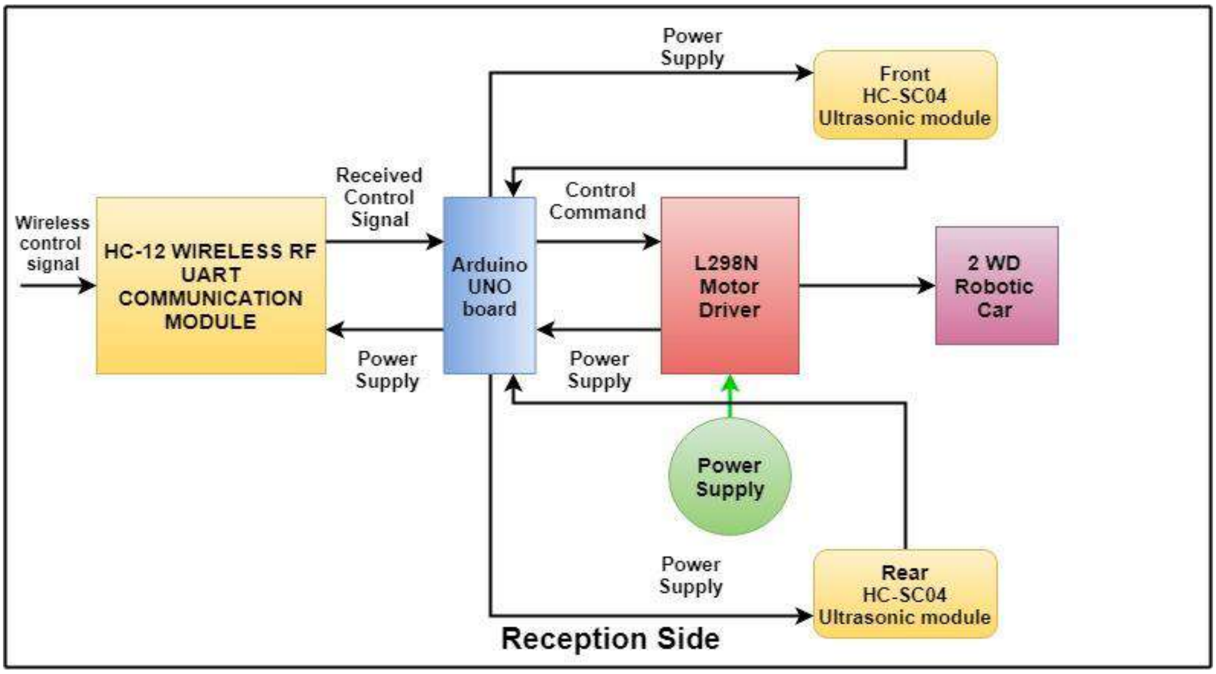


Fig. (3.10): Hardware connection at the reception sub-system.

Actually, the flow work of the reception sub-system in the adopted two case studies, can be interpreted in details as follows:

Step1: HC -12 wireless module is imposed in this reception side as a transceiver to receive the control signals sent to it wirelessly from its counterpart.

Step2: Setting up wire connection between HC-12 and Arduino Uno for managing the received wireless control signals to be utilized in controlling the state of wheelchair also to power up HC-12 with 5v.

Step3: building the proposed algorithm of control system that is assigned to the receiving center of control signals and converting it in a form of program that is loaded to Arduino UNO for controlling the state of wheelchair according to the logic level signals of the L298N motor driver.

Step4: powering up L298N motor driver from Li-Po battery, thus the microcontroller is equipped with power from two power pins of L298N motor driver.

Step5: Arduino UNO board is exploited in this reception sub-system as microcontroller for generating the appropriate control commands according to the uploaded program to it and then delivering control order to L298N motor driver pins for controlling the speed and direction of two DC motors of robotic car.

Step6: Two HC-SC04 ultrasonic sensors are added at the front and rear of the 2WD robotic car to read the distance to an object in its path for the purpose of obstacles detections to prevent robotic car from colliding with these obstacles. These two sensors are powered up with 5v from power pins of Arduino UNO.

Step7: Finally, 2WD robotic car is moved in one of four directions according to the classification criteria's of hand movements.

3.3 Classification Criteria of Hand Motions

In this work, ten types of fingers and arm movements are exploited for classification criteria in two different case studies of amputated people. The success rate of these classification criteria depends on the level of muscle flexing and hand motion monitoring flags within the same loop period in the suggested control algorithm of hand nerve readings at transmitter side according to Table (3.1) for first case study and Table (3.2) for second case study, respectively.

Table (3.1) Classification criteria of first case study.

Target muscles	**Level of muscle flexing**	**Hand motion monitoring flags values**	**Classification symbols**
Hand closure	High (hardly)	W=1	F1
Hand closure	High (hardly)	W=2	F2
Ring and middle fingers	Low (softly)	Z=1	F3
Ring and middle fingers	Low (softly)	Z=2	F4
All fingers relaxed	Relax	Z=0 & W=0	F5

Table (3.2) Classification criteria of second case study.

Target muscles	**Level of muscle flexing**	**Hand motion monitoring flags values**	**Classification symbols**
Biceps muscle	Low (softly)	Z=1	F6
Biceps muscle	Low (softly)	Z=2	F7
Biceps muscle	High (hardly)	W=1	F8
Biceps muscle	High (hardly)	W=2	F9
Biceps relaxed	Relax	Z=0 & W=0	F10

In general, the accuracy of selecting the appropriate location of EMG surface electrodes with Myoware muscle sensor on the surface of upper limb is very important to have more precise and stable information about each movement. This is to guarantee the validation of classification criteria and reduce the conflict between EMG signals. Hence, the correct order reaches the reception side of system. As a useful summary, the number of movements possible for giving high classification rate is directly dependent on the location of the muscle sensor on the target muscles.

3.4 Robot Car Platform Assistant System

In fact, it is difficult for people with severe and chronic deformities in their limbs to drive wheelchairs freely for completing their daily activities. Therefore, the proposed system, which is enlisted in providing the independence for those injured by building a system in robot car, controls the driving of robot car by acquiring the hand nerve signals and translating them into control orders. This section is divided into two sub-sections for facilitating the reading flow.

3.4.1 The Proposed Algorithm of Assistant System

On the other side of the whole system, the microcontroller is ready to activate the handshake process with its counterpart at the other side via receiving wireless controlling flags that are sent to it through HC-12. Thus, it enables the appropriate control command according to the received flag value in order to manage the required state of the wheelchair. The proposed algorithm also gives safety procedures for amputees to prevent them from collision with solid entities while driving by analyzing the mechanisms of detecting objects. Figure (3.11) illustrates the proposed algorithm of the control system at the reception side as a flowchart.

Based on the proposed algorithm represented as a flowchart in Figure (3.11), the reception sub-system proposed algorithm goes through the following steps:

- Initially, this algorithm advertises the following software instructions for simulating the hardware equipment used in this side of project and as follows:
    - the software serial library should be declared for performing the required wireless communication between the microcontrollers by adapting two HC-12 wireless RF UART serial port communication modules to receive the intended signals.
    - L298N motor driver pins are declared as integer variables for controlling the direction and speed of DC motors robotic cars are configured.
    - HC-SC04 ultrasonic sensors pins are declared as integer variables to control the measurement of distances between the robotic cars/ wheelchairs and the obstacles that guide them while driving the wheelchair/robotic car.
    - Declaring counters as flags for wheelchair state management (MOVE/STOP) as integer variables.

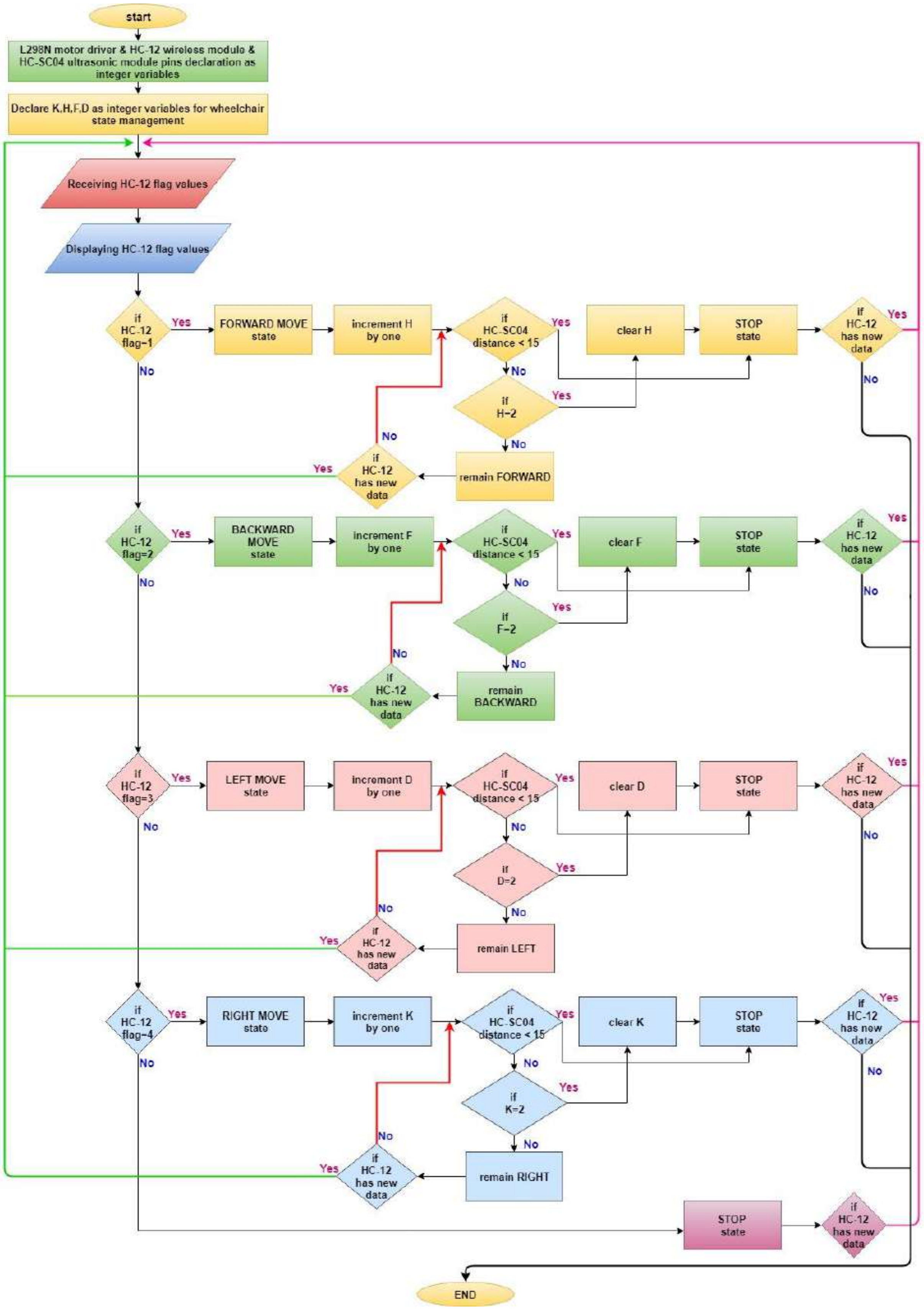


Fig. (3.11): The proposed algorithm of reception sub-system.

- In the case that HC-12 buffer has data from its counterpart, then verifies the received wireless control flags and then match the received flags with the corresponding control orders and thus the controlling operations are consummated by Arduino Uno at the receiver side of project as:
    - When HC-12 received wireless control flag equal to one, wheelchair becomes in MOVE state and will be steering in forward direction and simultaneously the algorithm enables H counter to be incremented by one. Then, when H value is equal to two which means the same hand action is repeated and thus the state of wheelchair will be turned to STOP and counter is cleared at the same time for the next action.
    - When HC-12 received wireless control flag equal to two, wheelchair becomes in MOVE state and will be steering in backward direction and simultaneously the algorithm enables F counter to be incremented by one. Then, when F value is equal to two which means the same hand action is repeated and thus the state of wheelchair will be turned to STOP and counter is cleared at the same time for the next action.
    - When HC-12 received wireless control flag equal to three, wheelchair becomes in MOVE state and will be steering in left direction and simultaneously the algorithm enables D counter to be incremented by one. Then, when D value is equal to two which means the same hand action is repeated and thus the state of wheelchair will be turned to STOP and counter is cleared at the same time for the next action.
    - When HC-12 received wireless control flag equal to four, wheelchair becomes in MOVE state and will be steering in right direction and simultaneously the algorithm enables K counter to be incremented by one. Then, when K value is equal to two which means the same hand

action is repeated and thus the state of wheelchair will be turned to STOP and counter is cleared at the same time for the next action.

- In addition to the above four control orders, the state of wheelchair is turned from MOVE to STOP by Arduino Uno in the case that the readings of HC-SC04 ultrasonic sensors are less than 15 centimeters as there is an obstacle in the wheelchair passage path.
- Wheelchair remains at the same MOVE state when counter values are not equal to two and also when HC-SC04 ultrasonic sensors measurements are not less than 15 cm.

3.4.2 The Implemented Prototype

In general, this section gives an explanation of the aggregation of robotic car with its accessories in a concrete manner as shown in Figure (3.12).

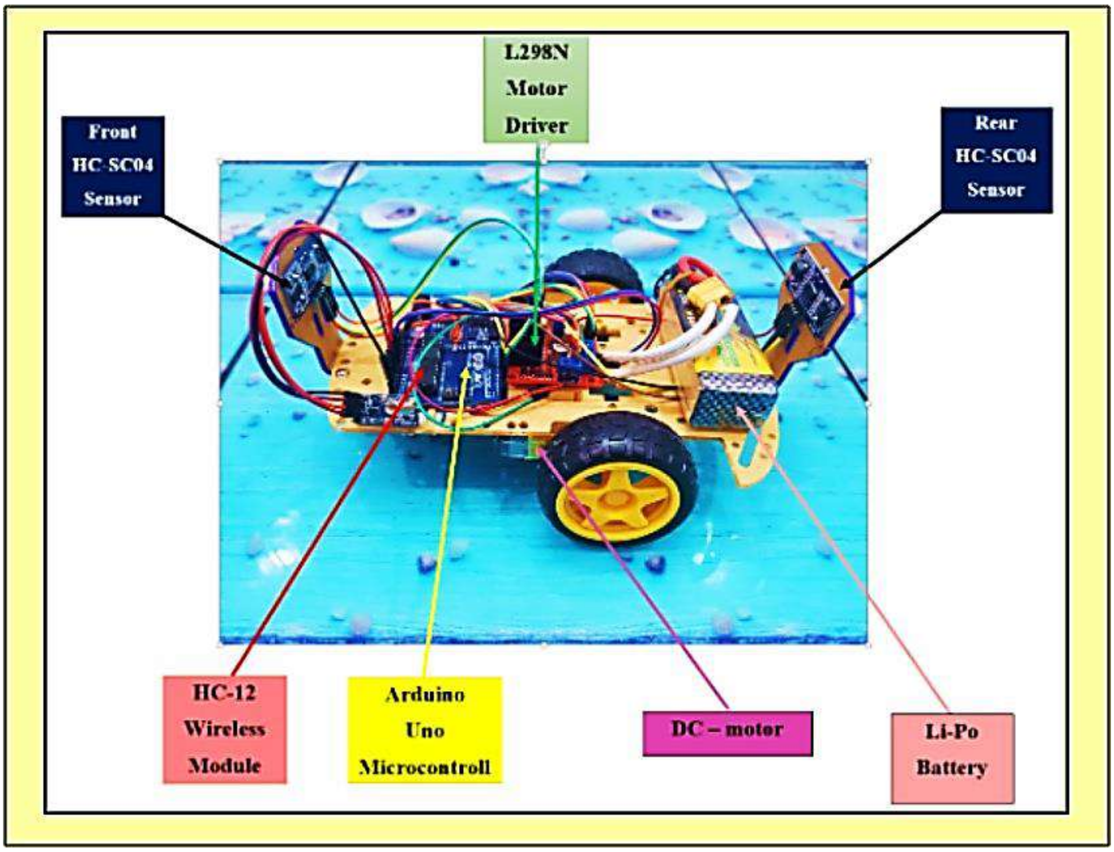


Fig. (3.12): Hardware system of reception sub-system.

Moreover, this section provides a brief synopsis of control programming to simulate robotic car parts. These interpretations can be summarized in two levels and as follows:

A. Robotic car setup:

Two wheel driver (2WD) robotic car is utilized in this project as a prototype model. Moreover, this robotic car is ready for operation and work when it is equipped with many physical accessories, including:

- ***L298N motor driver:*** L298N motor driver is a high voltage, high current, small size H-bridge module designed to accept Transistor-Transistor Logic (TTL) levels and has the ability to control the directions and velocity of two DC motors separately [70]. This module is preferred to use with DC motors that have a voltage between 5 v and 35 v DC [71]. L298N motor driver has the ability to reverse the polarity of the connected two DC motors by receiving the proper instructions from microcontroller. Basically, this feature gives the robotic car the freedom to move with 360 degree on soft surfaces with multiple directions [72]. In addition, this module contains bidirectional drive current of 1A and maximum power for driving of 75 W [72].
- ***Lithium Polymer batteries:*** It is also referred to as "Li-Po" batteries and it is a modern type rechargeable battery of lithium-ion technology using a polymer electrolyte instead of a liquid one. Li-Po is the most popular type for any project looking for long run times and high power [70]. Besides, the discharge rate of Li-Po is much lower. Therefore, it can withstand up to 4 hours. However, it is necessary to charge Li-Po batteries with Li-Po compatible charger in order to ensure fast charging [71].

- ***DC–motors:*** DC motor is an electrical tool that converts the electrical direct current into mechanical action and requires a voltage difference between its terminals to be rotated in specific direction according to the exchange of positive and negative terminals of DC motor. In general, the speed of this motor depends on the applied voltage and the load and precisely measured by the number of rotations per minute. The direction of these motors depends on the direction of the applied current [71], [73]. Practically, DC motors current range varies from 50 mA to 2A [74].

B. Robotic car controlling

In the previous sub-section, a brief overview of the robotic vehicle and its accessories is presented. The prototype structure is proposed to be ready for control purposes with the aim of assisting amputees. In this sub-section, it is necessary to draw attention to the mechanisms of control in the car in terms of programming connectivity relying on the controller Arduino and C programming language to simulate the parts of the car. This paragraph can be divided into two parts namely driving the car and obstacles avoidance.

Driving the car**:** In a nutshell, the driving of this robotic car is carried out wirelessly by means of using wireless technology, which is HC-12. The received signals represent the control orders sent from the hand nerve. Then, the wireless control flag is sent serially to the Arduino Uno microcontroller by wiring connection pin 7 and pin 8 from Arduino Uno to RX pin and TX pin of HC-12 respectively. Thus, the microcontroller continues to receive the automatic control signals, which are the signals of the actual hand nerve as long as the buffer of HC-12 has data. According to the order received, Arduino Uno controls the movement of the robotic car by transmitting logical level signals to the motor driver pins and thus the motor driver will control the movement and direction of the DC motors of car connected to it. In addition to that, Li-PO battery unit provides energy to all equipment in reception side. L298N motor driver takes the required voltage from Li-Po battery and contribute to equip the power to Arduino Uno and HC-12 as well as this driver module supplies a high current and high voltage to DC motors that are connected to it.

Generally, the left motor of this car is connected through OUT1 and OUT2 pins of L298N but the right motor is connected through OUT 3 and OUT 4 pins of motor driver. These motors are controlled through the PWM and digital pins of Arduino. Based on that, the logic level signals that are applied to these DC motors are controlled by UNO to be moved in the desired direction as per the instruction captured in association with H-bridge motor driver board. Table (3.3) describes the logic level signals between HC-12, Arduino Uno, and the motor driver of robotic car to recognize the ultimate output control commands.

In order to ensure staying on the same control command and the required direction of the car itself. This system has proposed a method to reduce the inconsistency between the signals of the received control, which may lead to the movement of the car in the undesirable direction as a result of the hand movement which is not voluntary. This method includes receiving the same control order twice, regardless of the time period between the two movements. This is explained by the fact that the first command is responsible for moving the car towards the desired direction as required by the user and the second is to cancel the activation of this movement and thus stops the car. Besides, the stop action of car can happen immediately in the presence of obstacle detection as explained in the next paragraph.

Table (3.3): Behavior of the programmatic connection of robotic car.

HC-12 flag to Uno	**Uno to L298N**		**DC motors states**	**Robotic car action**
	Left motor	Right motor		
1	High	High	Turn **ON** two motors in forward direction.	Forward
2	High	High	Turn **ON** two motors in reverse direction.	Backward
3	High	Low	Turn **ON** the left motor in forward direction and **OFF** the right motor.	Left
4	Low	High	Turn **OFF** the left motor and **ON** the right motor in forward direction.	Right
0	Low	Low	Turn **OFF** the two motors.	Stop

Obstacles avoidance: In robotic car control applications, the task of detecting and avoiding obstacles is very important to satisfy the driver of robotic car and enhance the protection conditions to prevent the robotic car from colliding. Therefore, two HC-SC04 ultrasonic sensors are adopted in this project. They are placed at the front and rear of robotic car to achieve the safety principles by detecting the existence of obstacles that are faced by car while driving in the forward and backward directions by measuring the distance between the existed obstacle and the car. When the measured distance is less than 15 centimeters, here Arduino Uno controller takes the necessary measures by stopping the car immediately to avoid collision. The car remains in the waiting mode until the obstacles are removed or the direction of the car is changed by receiving a new control order from the hand nerve.

3.5 The Whole Proposed System

In this section, the overall proposed control application is precisely illustrated in Figure (3.13) as a block diagram.

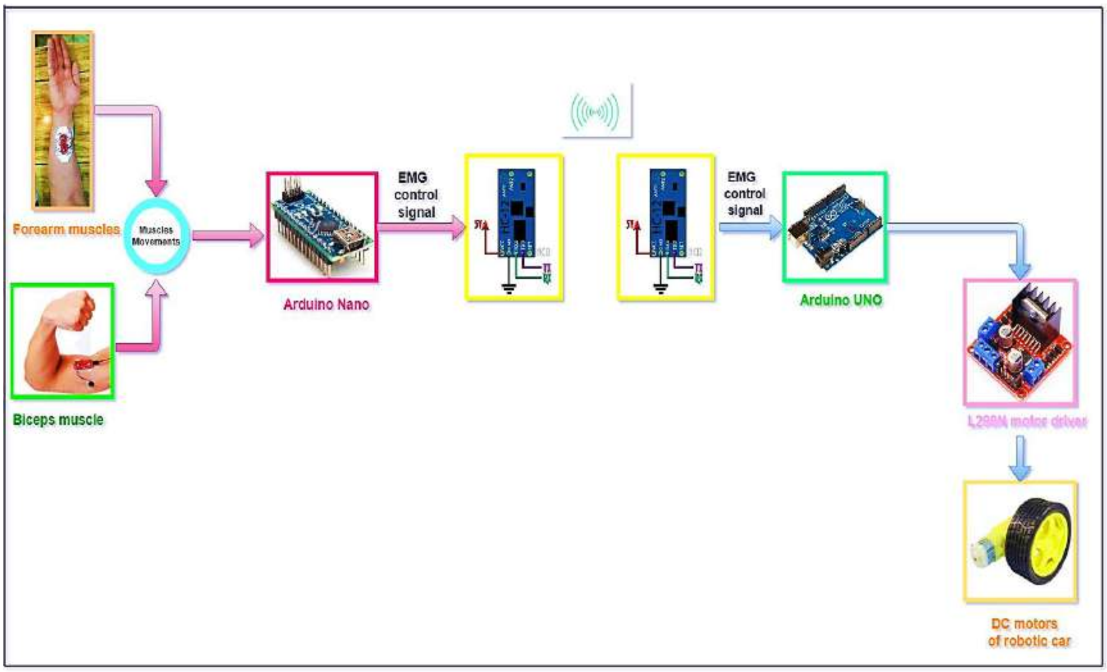


Fig. (3.13): Overall proposed system block diagram.

At the first, it is necessary to acquire signals from hand nerves by placing one channel surface electrode with Myoware muscle sensor exactly on the middle of the target muscle according to which case study those amputees belong. It is known that hand nerve signals suffer from weakness and noise. So this work employs high quality EMG processing unit to enhance these signals to be passed correctly to microcontrollers. Then, the essential work of Arduino Nano is to convert the received analog signals to digital for further processing and classification to be easy analyzed in the classification strategy according to the suggested threshold ranges and hand motion monitoring flags. Moreover, the EMG control signals are transmitted wirelessly with the assigned wireless control flags that related to them by HC-12 module. All these regulated operations occur at the transmitter side as explained in details in Figure (3.14).

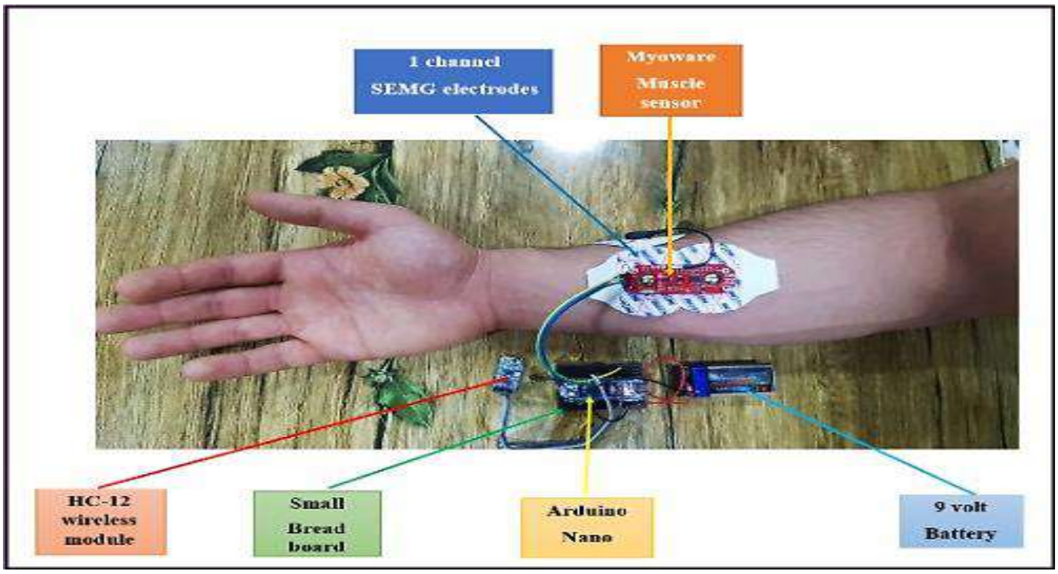


Fig. (3.14): Hardware system of transmission sub-system.

Actually, in the other side of overall system as shown in Figure (3.12), the transmitted wireless control flags are received by the second HC-12 module to activate the handshaking operation between Arduino Nano and Arduino UNO. This happens to manage the control signals that translate five hand actions in two case studies to achieve the lofty goal of managing the state of robotic car by enabling L298N motor driver pins through sending logic level signals to these pins for controlling the directions and speeds of DC motors. Finally, the robotic car is driven depending on the amputees real-time hand action.

Chapter Four

Results and Evaluation of Hand Nerve Signals Based Assistant System

4.1 Introduction

Two case studies of bilateral amputation of people have been adopted in current research work. Therefore, this chapter displays evidence as results by focusing on many scenarios which are conducted. The results are recorded in real time in order to test the accuracy and effectiveness of the designed system in terms of response time and accuracy of classification for different gestures. These gestures are produced by the hand of bilateral amputees through the nerve signals to simulate wheelchair.

In addition, this system provides a percentage evaluation of the performance of the experiments and calculates the accuracy of the wireless transmission of these signals. This chapter takes into account the ideal conditions under which the system should operate and summarizes a full assessment of the proposed system in all respects.

4.2 Considered Case Studies of Bilateral Amputation

As mentioned previously, amputation (which is within the classification of motor disability) represents the loss of an organ of the body as a result of an accident or injury. In general, the amputation can be in whole or part depending on the type of injury. It is possible to restore the amputated organ through modern organ transplantation processes. But, the mechanism of finding nerves that control the amputated organ limits the conduct of such processes. Therefore, modern engineering techniques provide solutions to compensate those people.

One of the solutions, developed in the proposed system, is the recruitment of hand nerve signals of those people for the purpose of controlling the means of assistance provided to them which are represented by wheelchair. However, this system focuses on the bilateral amputation of the limb in two diagnoses as two case studies.

4.2.1 First Case Study

Diagnostic and medical analysis of this case study focuses on upper limb amputations at the following sites:

1. ***Wrist Disarticulation Level (Amputation at the Wrist Joint)***
   The body part of hand is amputated at the wrist point. This type of amputation occurs specifically at the anatomical region surrounding the wrist bones and includes the distal parts of the forearm bones, which is close to the bones of the five hand comb [75].
2. ***Amputation in the Palm of the Hand (Metacarpophalangeal Disarticulation)***
   This type of amputation is performed at the part of the inner surface of the hand that extends from the wrist to the bases of the fingers. This amputation makes the hand lose its proficiency and strength due to loss of fingers together [75].
3. ***Digit Fingers Amputation or Partial Hand Amputation (Transcarpal)***
   Hand fingers injuries are considered to be very common problems all over the world and the most common from other amputations, including all or part of the thumb finger, all or part of the remaining fingers such as the index, long, ring, or little finger digits [75].

4.2.2 Second Case Study

This case study is quite different from the other. This case study adapts the diagnosis of upper limb amputations in the following places:

1. ***Below The Elbow, (Transradial)***

   This level of amputation occurs at any place on the forearm from just below the elbow joint to the wrist joint and it can be accurately described in the forearm area [75].

2. ***At The Elbow, (Elbow Disarticulation)***

   This level of amputation occurs exactly in the joint that connects the forearm with the upper part of the upper limb, called elbow joint [75].

4.3 Results of Single Action Control Signal Generation

In the beginning, the behavior of the hand gestures is directed and adapted to perform the single action in terms of the movement responsible for activating the control signal. This signal is required only once with an unlimited physical time to accomplish each hand movement to ensure a quick and immediate response time for people with bilateral amputation to control the movement of wheelchairs. But the issue that faces this method is that this method is not able to perform these movements freely and smoothly. This is because the criteria for the classification of these movements and the actual ways to distinguish them within the proposed algorithm were based on the principle of mathematical angles. Each movement must be accomplished at a specific angle for the purpose of accurate classification. The next step can cause a great burden to the patient in the course of training because the performance of the proposed movements can be inconvenient and needs a high concentration. All that is mentioned as a result of the threshold range values converged between control signals, included in the proposed algorithm.

The method of generating single-action control signals can be tested in two case studies of amputation that are explained in the previous paragraph. Furthermore, ten experiments of single generating are adopted to record the average of classification accuracy of the ten hand motions in the adopted case studies of the amputees people by stabilizing the location of the muscle sensor in each case study.

However, to achieve high performance in distinguishing the measured signals from another side, observing and tracking the forms of signals generated and observing the pattern of these signals are required. This indicates their amplitudes in numerical values, which depends on the extent of muscle contraction required. Moreover, the number of motor units are performed within the muscle fibers according to the contraction intensity of these muscles, which represent their limits at the suggested threshold ranges during the training period of amputees. Therefore, these discriminatory patterns can be tracked in each proposed motion in all experiments of single action control signal generation technique.

4.3.1 First Case Study Results

In the first case study of the bilateral amputation people should pay attention to the mechanism and measurements of the location of the muscle sensor in order to ensure the classification of movements resulting from muscle contraction and thus obtain high accuracy to guarantee the efficiency of application. Therefore, the muscle sensor with electrodes should be placed on the skin of the front layer of the forearm, represented by four muscle tissues: flexor carpi ulnaris, palmaris longus, flexor carpi radialis and pronator teres. While, the reference electrode should be placed near the target muscle and specifically on the bone. The four muscle tissues, which are actually control the digit fingers and wrist joint, have been linked with the fingers through the strings. Table (4.1) represents the details of first case study in terms of the hand muscles actions, classification symbols and the generated control orders. Figure (4.1) illustrates the site of Myoware muscle sensor on the forearm muscles in first case study.

Table (4.1) First case study of single action control signal generation.

Classification symbols	Control command	Single action control signal
E1	MOVE forward	Pinky finger muscle is active softly
E2	MOVE right	Both the pinky and ring finger muscles are active strongly at the same time
E3	MOVE backward	The palm of the hand is active hardly with 90 angle between the palm and the forearm
E4	MOVE left	Pinky, ring and middle finger muscles are active at the same time
E5	STOP	All muscles are relaxed

Fig. (4.1): Location of Myoware muscle sensor for first case study.

1- The result of the first experiment (E1), as first muscle movement in single action method is appeared at the receiver side on the wheelchair to activate the MOVE state in the forward direction with flushing GREEN led as an indicator (first action in 1’st CS), as shown in Figure (4.2).

2- The result of the second experiment (E2), where the second muscle movement in single action method can be observed at the receiver side on the wheelchair to activate the MOVE state in the right direction with illumination

YELLOW led as an indicator (second action in 1’st CS), as shown in Figure (4.3).

3- The result of the third experiment (E3), which is considered the third muscle movement in single action method appears at the receiver side on the wheelchair to activate the MOVE state in the backward direction with lighting RED led as an indicator (third action in 1’st CS), as shown in Figure (4.4).

4- The result of the fourth muscle movement which is the fourth experiment (E4), in single action method can be easily seen at the receiver side on the wheelchair by activating the MOVE state in the left direction with flushing BLUE led as an indicator (fourth action in 1’st CS), as shown in Figure (4.5).

5- The result of fifth muscle movement, which is classified as fifth experiment (E5), in single action method is shown at the receiver side on the wheelchair to activate the STOP state with flushing WHITE led as an indicator (fifth action in 1’st CS), as explained in Figure (4.6).

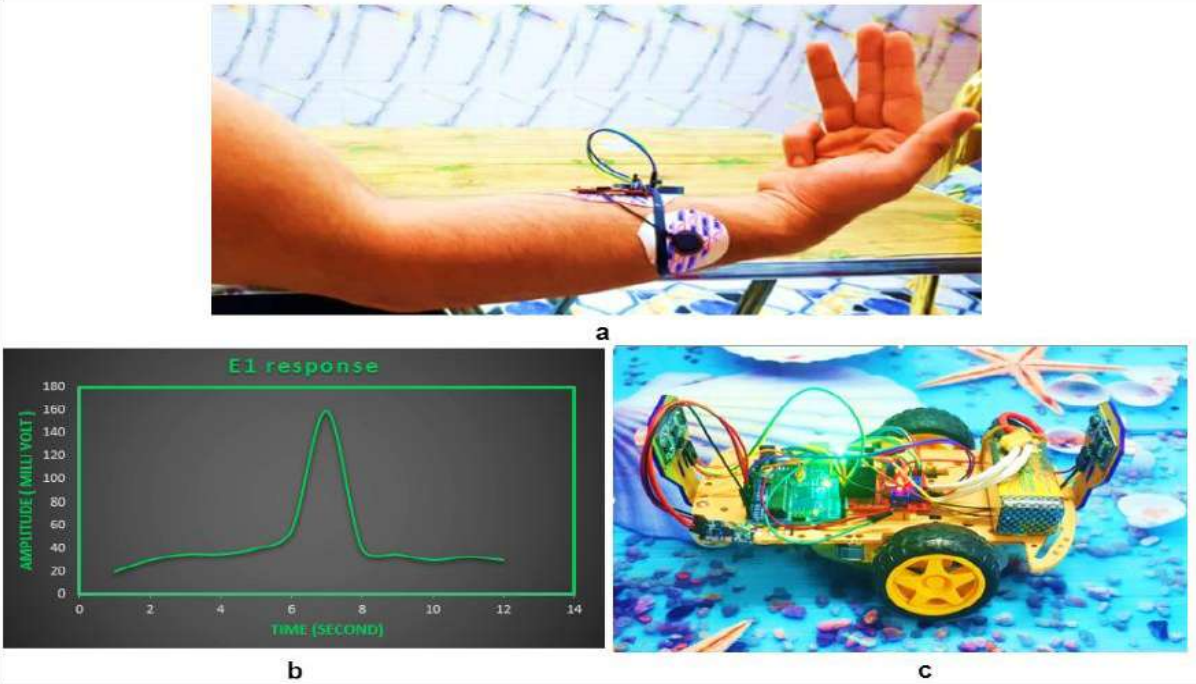


Fig. (4.2): Testing result of E1 (a) first muscle movement, (b) E1 signal shape and (c) forward direction with respect to E1 response.

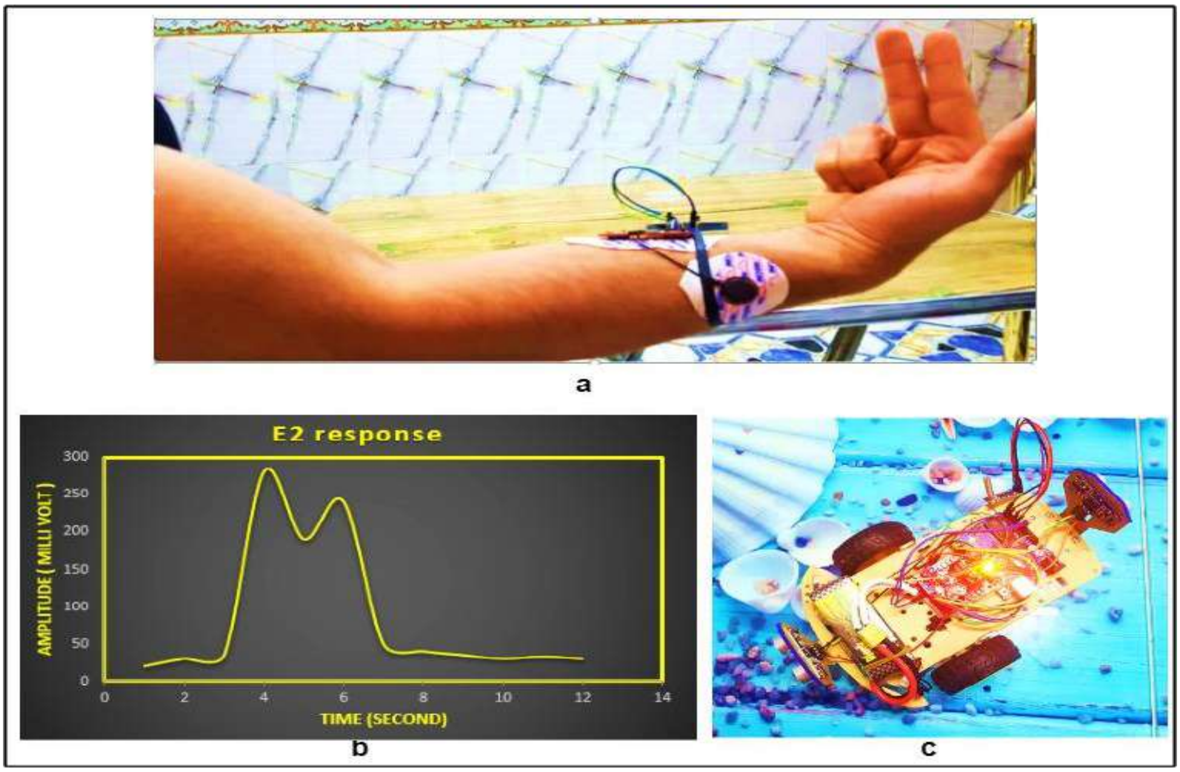


Fig. (4.3): Testing result of E2: (a) second muscle movement, (b) E2 signal shape and (c) right direction with respect to E2 response.

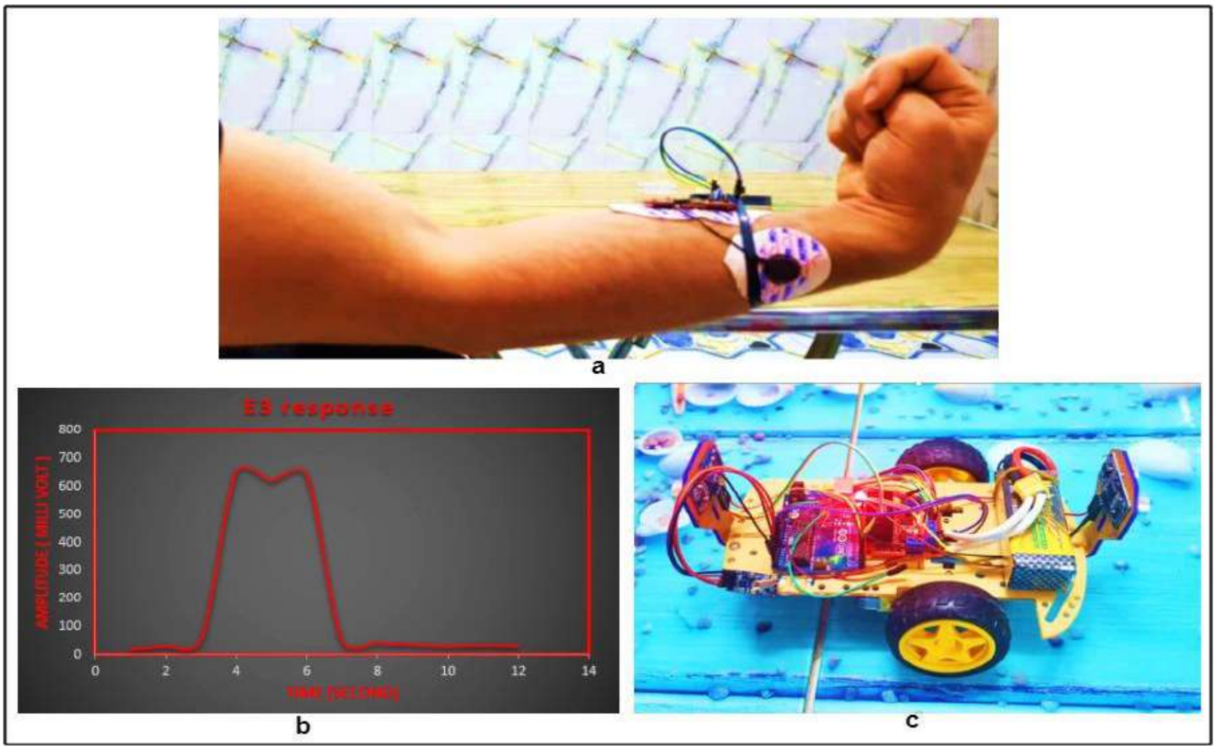


Fig. (4.4): Testing result of E3: (a) third muscle movement, (b) E3 signal shape and (c) backward direction with respect to E3 response.

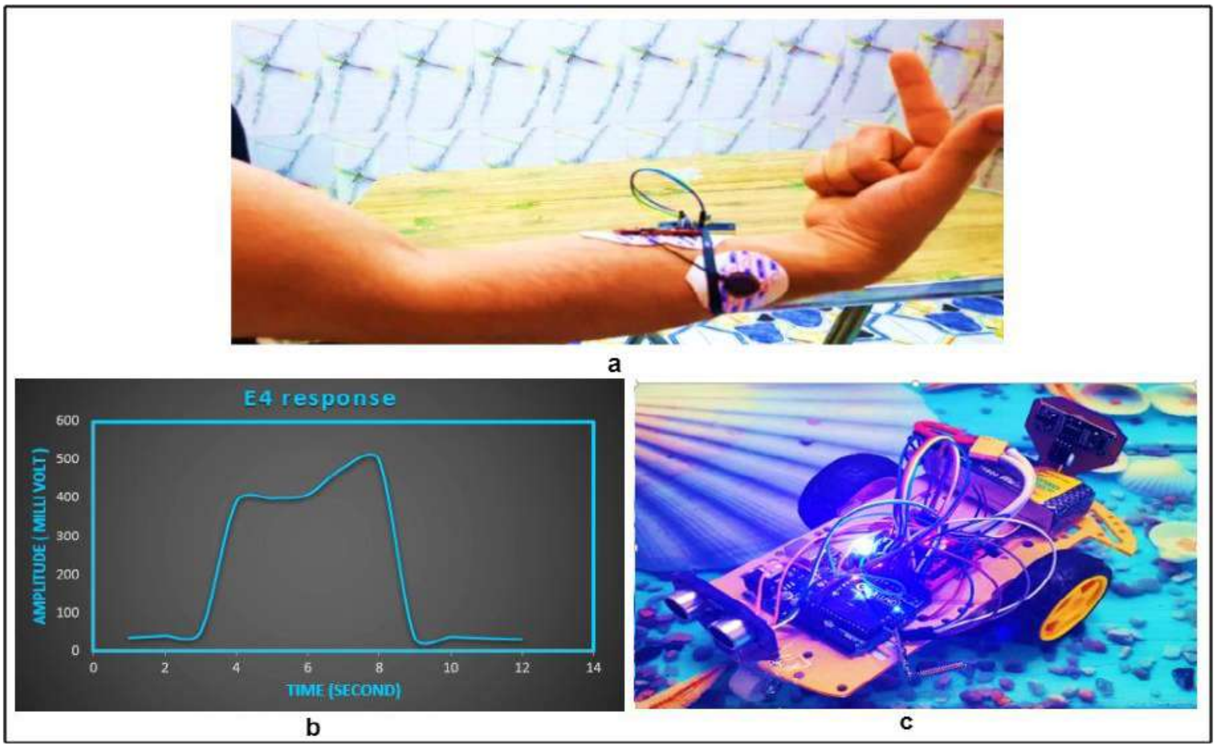


Fig. (4.5): Testing result of E4: (a) forth muscle movement, (b) E4 signal shape and (c) left direction with respect to E1 response.

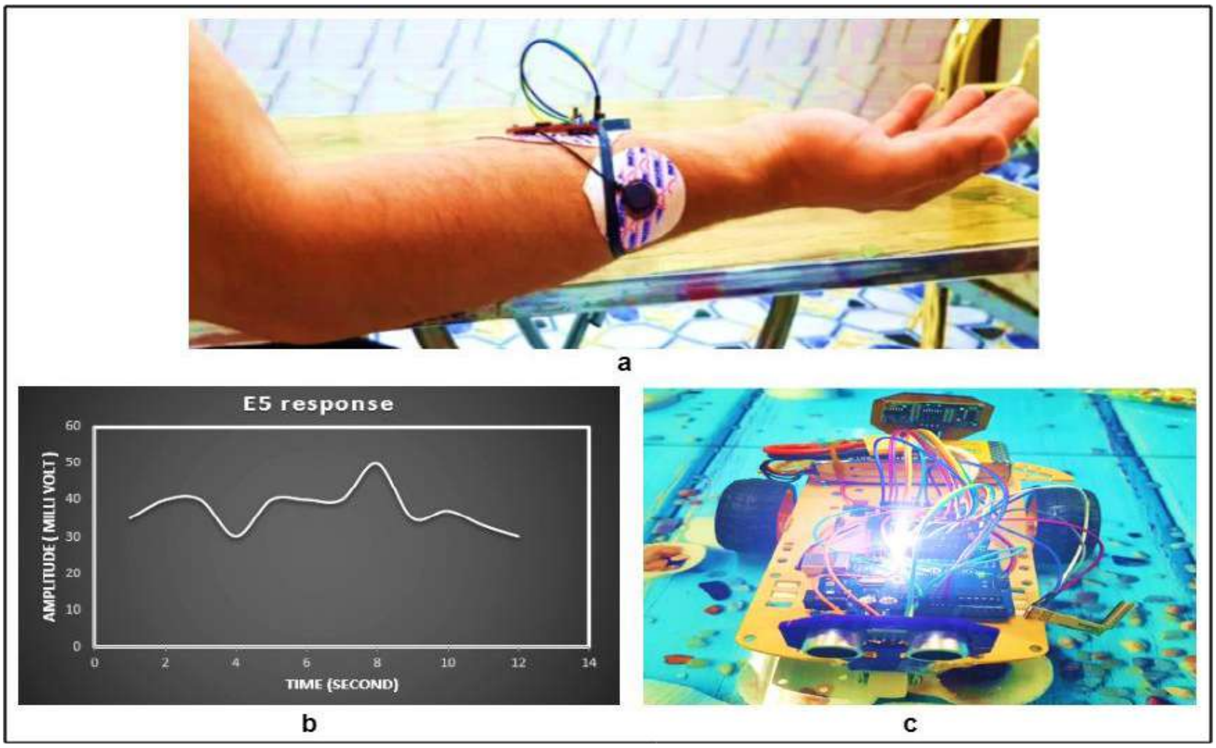


Fig. (4.6): Testing result of E5: (a) fifth muscle movement, (b) E5 signal shape and (c) stop state with respect to E5 response.

4.3.2 Second Case Study Results

The second case study of the bilateral amputation people, which has been diagnosed previously in terms of analysis of the levels of two amputation. Therefore, it should be paid attention to the mechanism of the precise position of the muscle sensor in order to ensure the validity of classification movements resulting from muscle contraction and thus obtain high accuracy to gurantee the efficiency of application. Therefore, the muscle sensor with two EMG electrodes should be placed on the skin of the biceps brachii muscles. The reference electrode should be placed on brachialis muscle toward the bone.

Figure (4.7) illustrates the locus of Myoware muscle sensor on the surface of biceps muscle in second case study. Table (4.2) represents the details of second case study in terms of the hand muscles actions, classification symbols and the generated control orders.

Table (4.2): Second case study of single action control signal generation.

Classification symbols	Control command	Single action control signal
E6	MOVE forward	The biceps muscle is activated with 165 degree as an angle between itself and the forearm
E7	MOVE right	The biceps muscle is activated with obtuse angle between itself and the forearm
E8	MOVE backward	The biceps muscle is activated with 90 degree as an angle between itself and the forearm.
E9	MOVE left	The biceps muscle is activated with acute angle between itself and the forearm nearly to 60 degree.
E10	STOP	relaxed Biceps muscles

Fig. (4.7): Location of Myoware muscle sensor for second case study.

6- The result of the sixth experiment (E6), that represents six muscle movement in single action method is appeared at the receiver side on the wheelchair to activate the MOVE state in forward direction with flushing GREEN led as an indicator (first action in 2’st CS), as shown in Figure (4.8).

7- The result of the seventh experiment (E7), where the seven muscle movement in single action method can be observed at the receiver side on the wheelchair to activate the MOVE state in the right direction with illumination YELLOW led as an indicator (second action in 2’st CS), as shown in Figure (4.9).

8- The result of the eighth experiment (E8), which considered the eight muscle movement, in single action method appears at the receiver side on the wheelchair to activate the MOVE state in backward direction with lighting RED led as an indicator (third action in 2’st CS), as shown in Figure (4.10).

9- The result of the ninth muscle movement, which is the nine experiment (E9), in single action method can be easily seen at the receiver side on the wheelchair by activate the MOVE state in left direction with flushing BLUE led as an indicator (forth action in 2’st CS), as shown in Figure (4.11).

10- The result of the ten experiment (E10), which stops wheelchair with flushing WHITE led as an indicator (fifth action in 2’st CS), as explained in Figure (4.12).

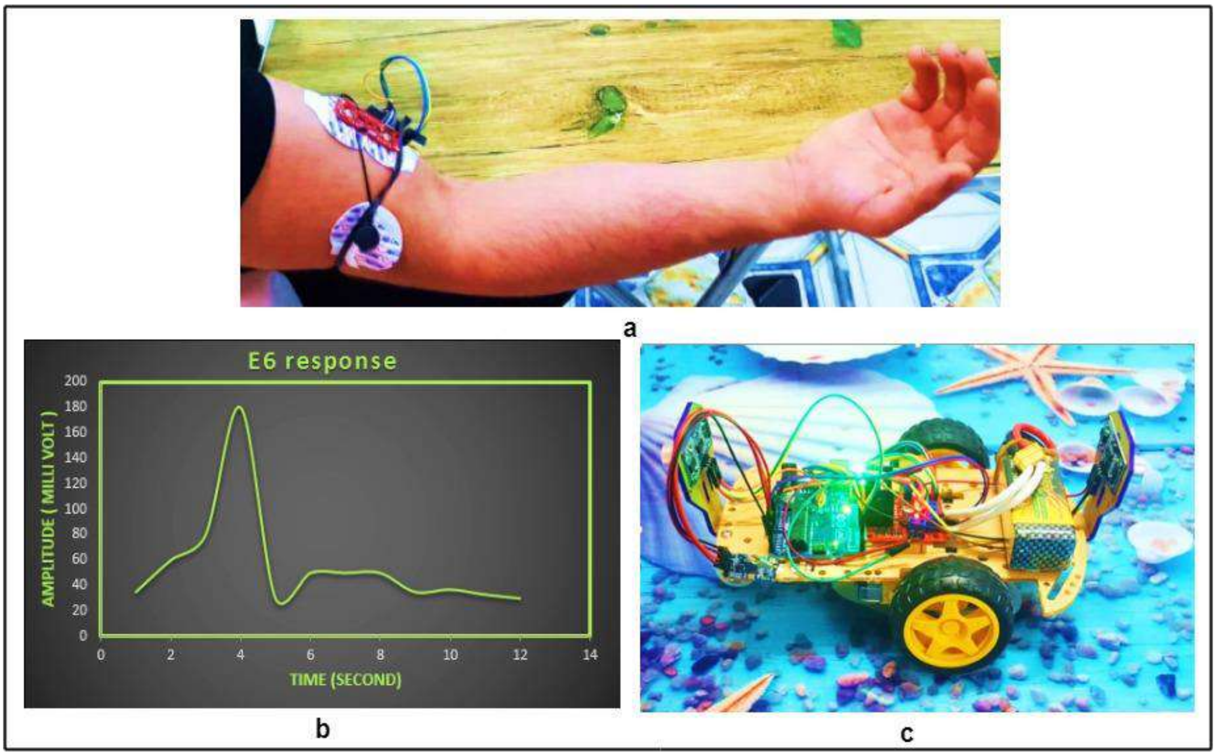


Fig. (4.8): Testing result of E6: (a) sixth muscle movement, (b) E6 signal shape and (c) forward direction with respect to E6 response.

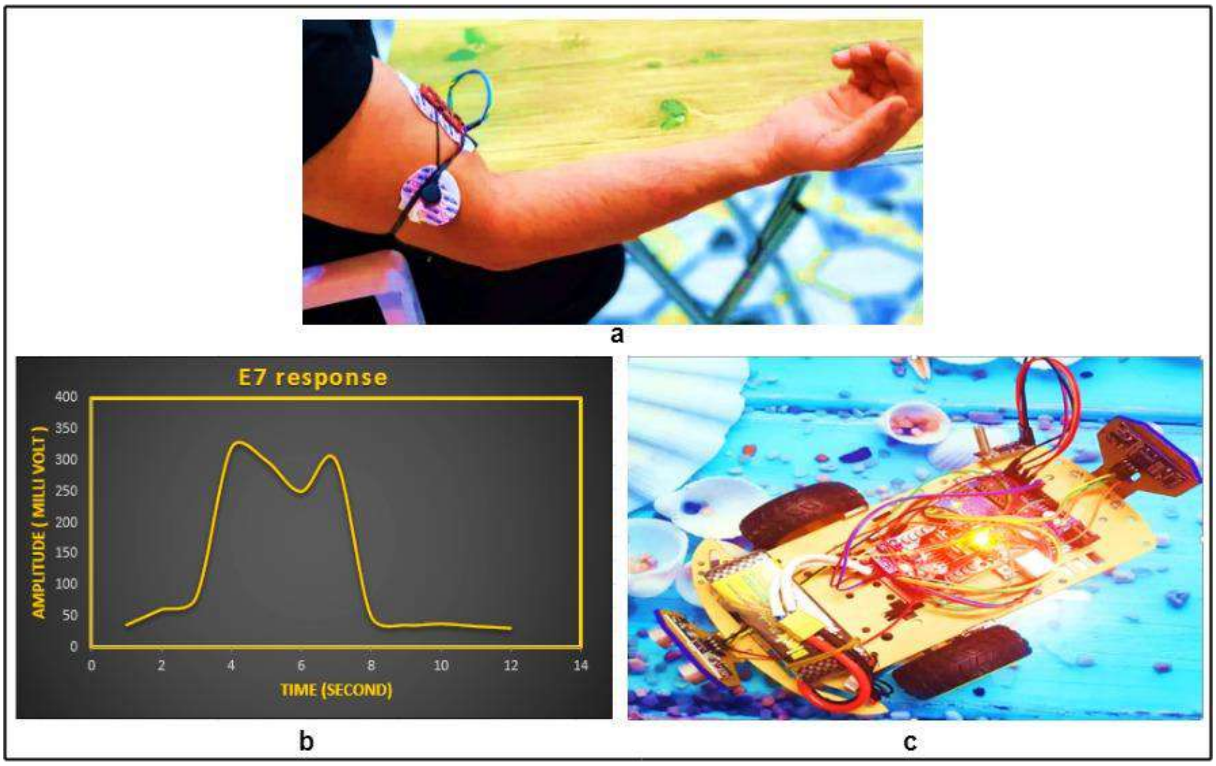


Fig. (4.9): Testing result of E7: (a) seventh muscle movement, (b) E7 signal shape and (c) right direction with respect to E7 response.

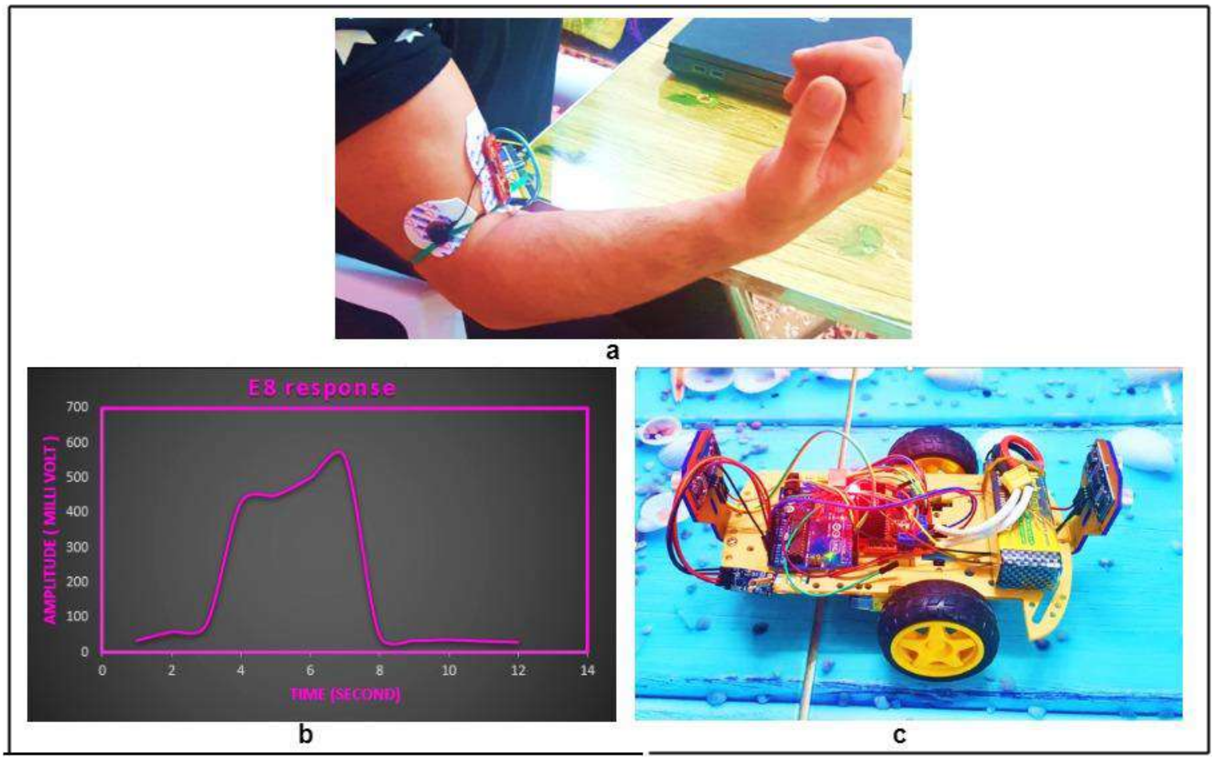


Fig. (4.10): Testing result of E8: (a) eighth muscle movement, (b) E8 signal shape and (c) backward direction with respect to E8 response.

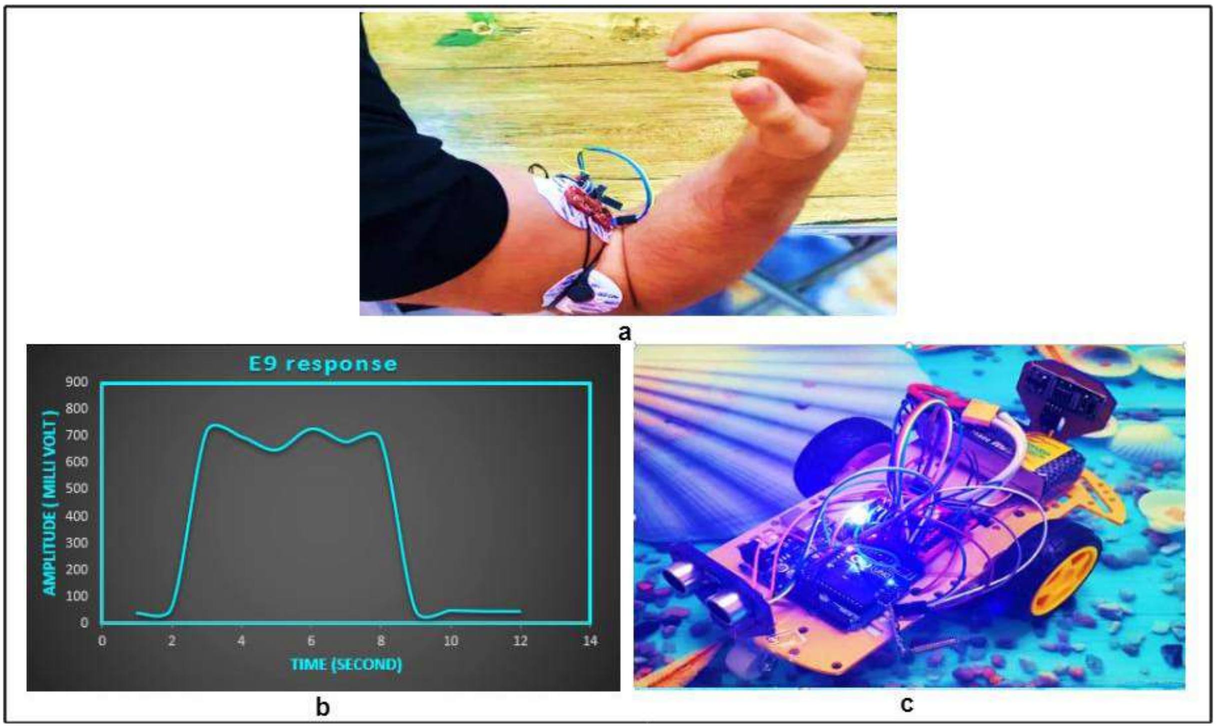


Fig. (4.11): Testing result of E9: (a) ninth muscle movement, (b) E9 signal shape and (c) left direction with respect to E9 response.

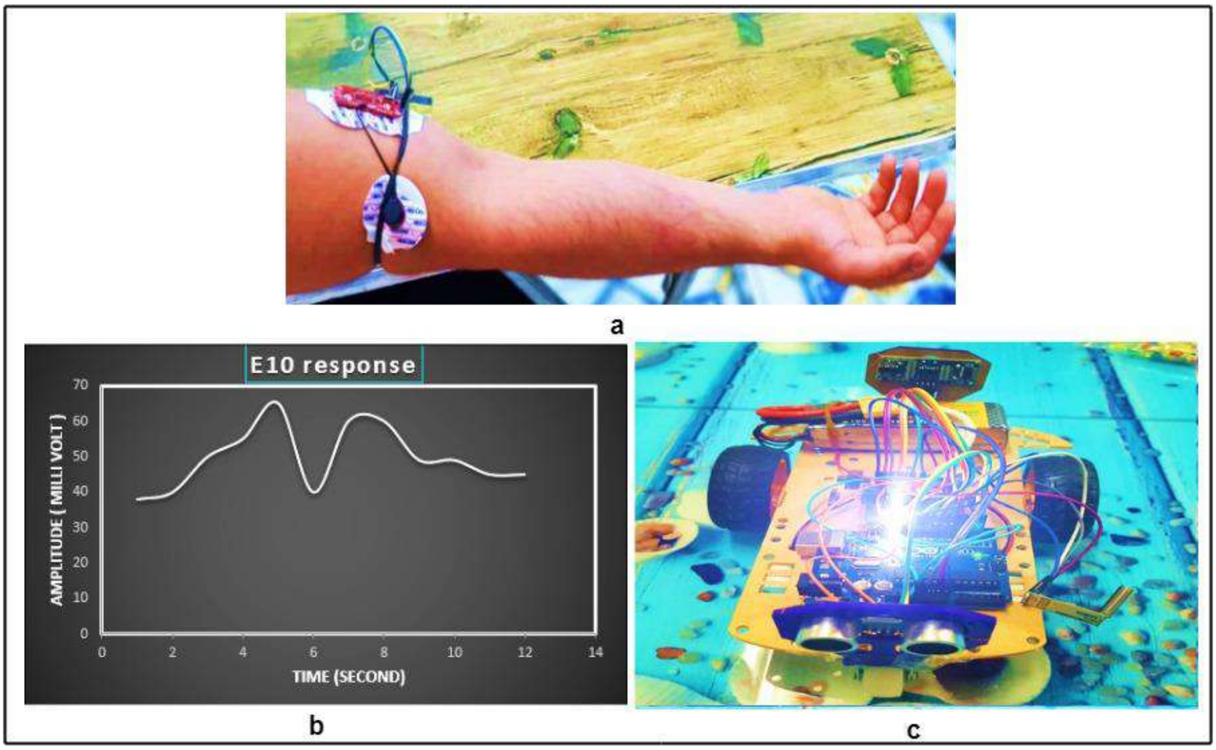


Fig. (4.12): Testing result of E10: (a) tenth muscle movement, (b) E10 signal shape and (c) stop state with respect to E10 response.

4.4 Results of Double Action Control Signal Generation

In general, analyzing the calculations of the results of the examination of the ten trials directly depends on the generation of single-action control signals. It proves that the results are relatively unsatisfactory because it requires a great effort in the training of amputees. This is due to the difficulty of the performance of these movements and the convergence values of threshold ranges, which reduces the accuracy of the classification of these movements, lead sometimes to a little conflict between those movements.

Therefore, the proposed system aims to devise a new and smooth technology to distinguish between these movements in order to increase the efficiency of the proposed system and to achieve high accuracy of classification without psychological and physical challenges to the injured.

The basic principle of this technique is to monitor the values of hand motion monitoring flags within a specific time range where the values of these flags increase at every muscle contraction momentary. This technique involves the enabling of single and double action in the limited time. Then, the decision is considered to be taken out of the required control order relative to the proposed conditions within the algorithm of hand nerve readings. This technique strives to codify the patterns of each signal used in the ten experiments of two suggested case studies for the purposes of high discrimination between these signals by observing the digital capacity of those signals.

4.4.1 First Case Study Results

This case study has been explained previously in (Section 4.3.1). However, in double action control signal generation technique, five trials are tested to measure the system's response to the proposed technology. Figure (4.1) illustrates the location of Myoware muscle sensor on the forearm muscles in first case study. Table (4.3) represents the first case study in details in terms of the hand muscles actions which are described in details in the classification criteria in chapter three, classification symbols and the generated control orders.

Table (4.3): First case study of double action control signal generation

Classification symbols	Control command	Double action control signal
F1	MOVE forward	Hand closure
F2	MOVE right	Ring and middle fingers
F3	MOVE backward	Hand closure
F4	MOVE left	Ring and middle fingers
F5	STOP	All fingers relaxed

1- The result of the first experiment (F1), which represents first muscle movement in double action technique, is appeared at the receiver side on the wheelchair to activate the MOVE state in the forward direction with flushing GREEN led as an indicator (first action in 1'st CS), as shown in Figure (4.13).

2- The result of the second experiment (F2), where the second muscle movement in double action technique can be observed at the receiver side on the wheelchair to activate the MOVE state in the right direction with illumination YELLOW led as an indicator (second action in 1'st CS), as shown in Figure (4.14).

3- The result of the third experiment (F3), which is considered the third muscle movement, in double action technique appears at the receiver side on the wheelchair to activate the MOVE state in the backward direction with lighting RED led as indicator (third action in 1'st CS), as an shown in Figure (4.15).

4- The result of the fourth muscle movement, which is the fourth experiment (F4), in double action technique can be easily seen at the receiver side on the wheelchair by activating the MOVE state in the left direction with flushing BLUE led as an indicator (fourth action in 1'st CS), as shown in Figure (4.16).

5- The result of the fifth muscle movement, which is classified as fifth experiment (F5), in double action technique is shown at the receiver side on the wheelchair to activate the STOP state with flushing WHITE led as an indicator (fifth action in 1'st CS), as explained in Figure (4.6).

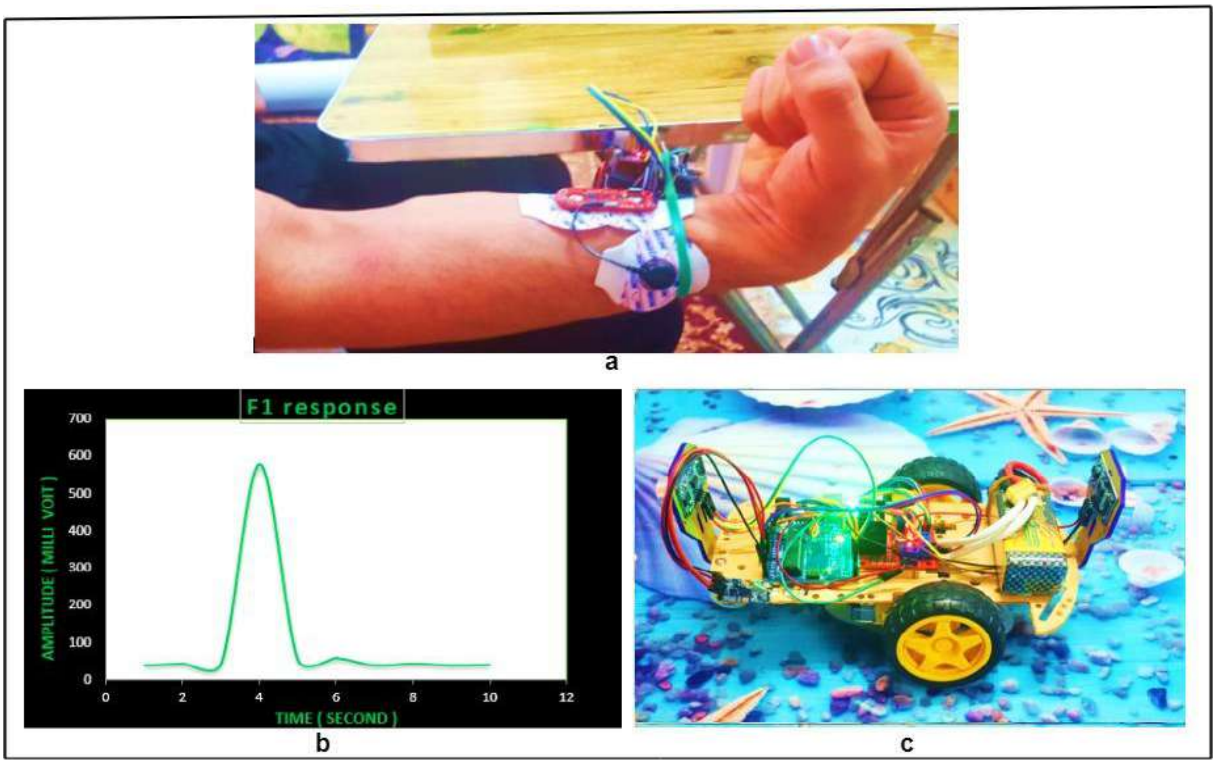


Fig. (4.13): Testing result of F1: (a) first muscle movement, (b) F1 signal shape and (c) forward direction with respect to F1 response.

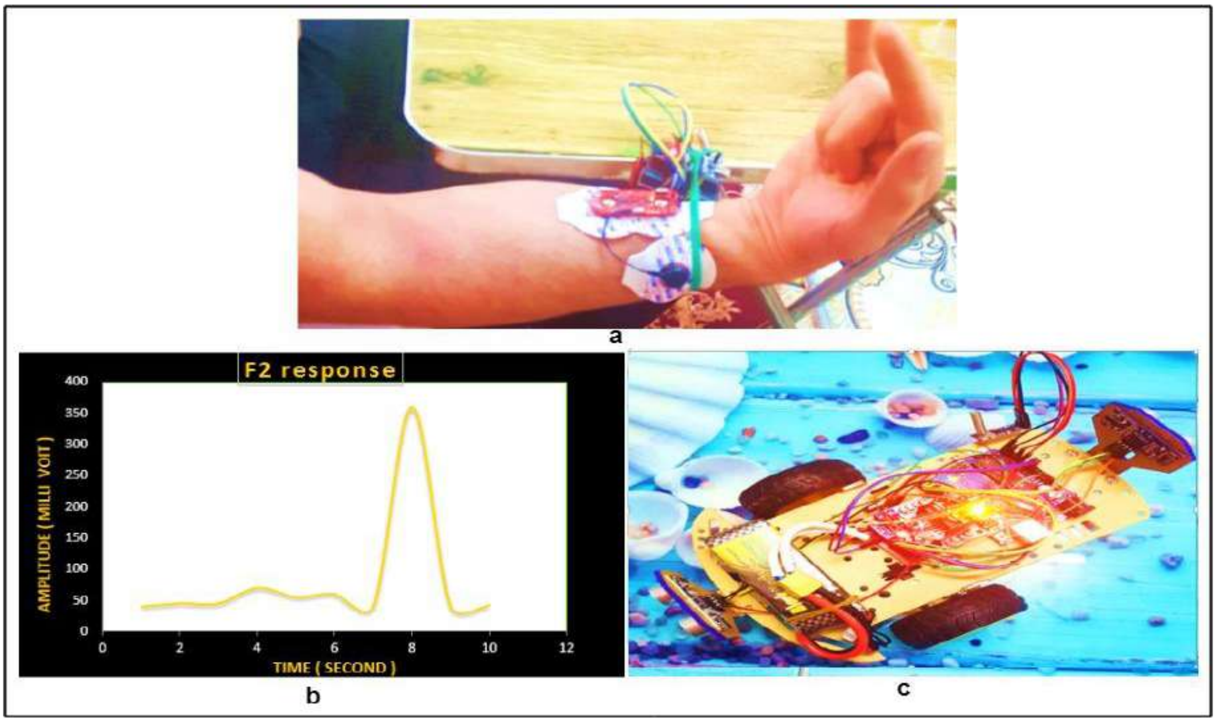


Fig. (4.14): Testing result of F2: (a) second muscle movement, (b) F2 signal shape and (c) right direction with respect to F2 response.

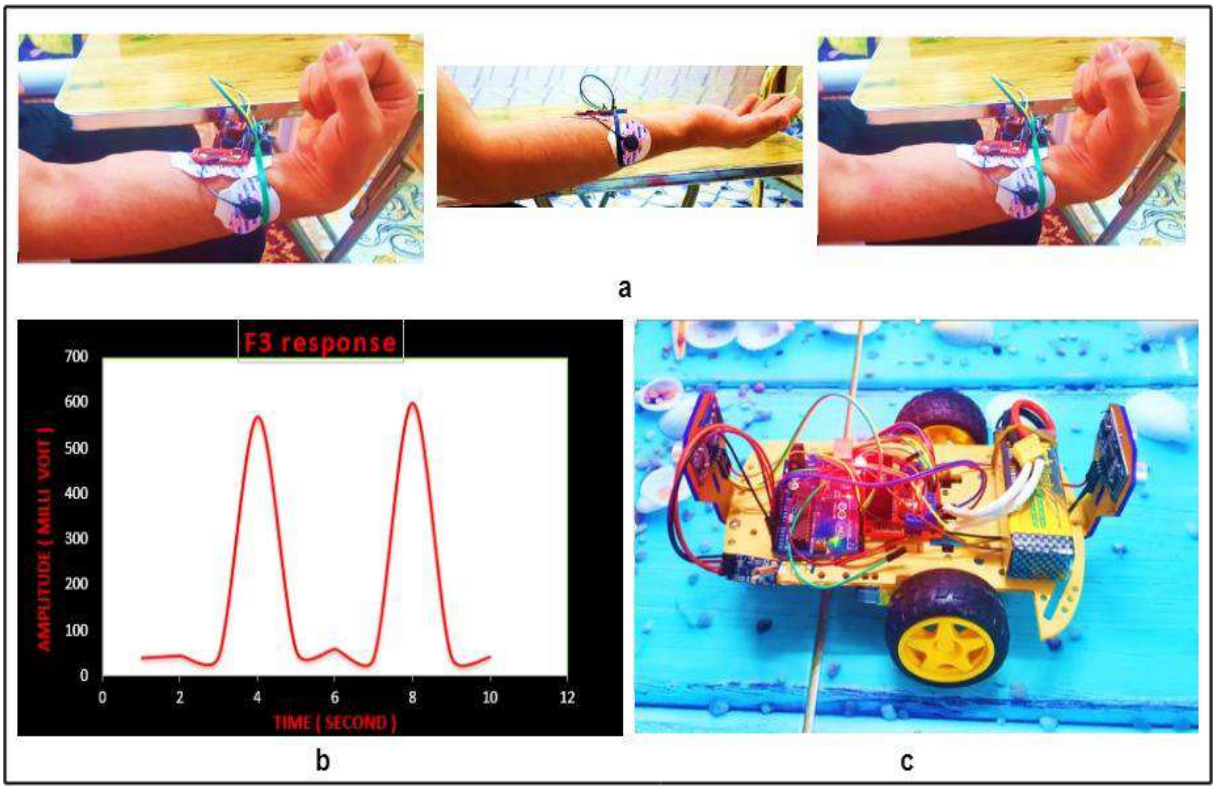


Fig. (4.15): Testing result of F3: (a) third muscle movement, (b) F3 signal shape and (c) backward direction with respect to F3 response.

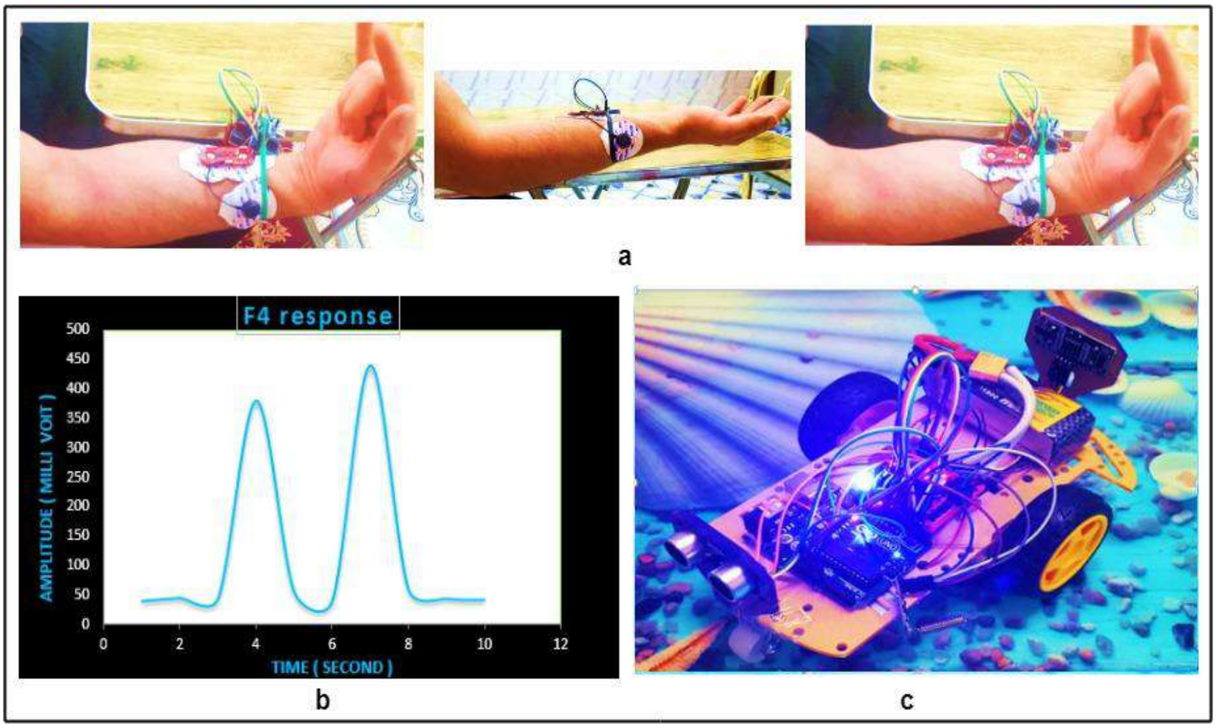


Fig. (4.16): Testing result of F4: (a) forth muscle movement, (b) F4 signal shape and (c) left direction with respect to F4 response.

4.4.2 Second Case Study Results

This case study has been explained and analyzed previously. However, in double action control signal generation classification technique, five trials are tested to measure the system's response to the proposed technology. Figure (4.7) illustrates the site of Myoware muscle sensor on the forearm muscles in second case study. Table (4.4) represents the second case study in details in terms of the hand muscles actions which are described in details in the classification criteria in chapter three, classification symbols and the generated control orders.

Table (4.4): Second case study of double action control signal generation

Classification symbols	Control command	Double action control signal
F6	MOVE forward	The biceps muscle is activated softly only one time within the loop period
F7	MOVE right	The biceps muscle is activated hardly only one time within the loop period
F8	MOVE backward	The biceps muscle is activated softly only two times within the loop period
F9	MOVE left	The biceps muscle is activated hardly only two times within the loop period
F10	STOP	Biceps muscle is relaxed

6- The result of the sixth experiment (F6), represented as six muscle movement, in double action technique is appeared at the receiver side on the wheelchair to activate the MOVE state in the forward direction with flushing GREEN led as an indicator (first action in 2’nd CS), as shown in Figure (4.17).

7- The result of the seventh experiment (F7), represented as seventh muscle movement in double action technique can be observed at the receiver side on the wheelchair to activate the MOVE state in the right direction with illumination

YELLOW led as an indicator (second action in 2’nd CS), as shown in Figure (4.18).

8- The result of the eighth experiment (F8), which is considered the eight muscle movement, in double action technique appears at the receiver side on the wheelchair to activating the MOVE state in the backward direction with lighting RED led as an indicator (third action in 2’nd CS), as shown in Figure (4.19).

9- The result of the ninth muscle movement, which is the nine experiment (F9), in double action technique can be easily seen at the receiver side on the wheelchair by activate the MOVE state in the left direction with flushing BLUE led as an indicator (forth action in 2’nd CS), as shown in Figure (4.20).

10- the result of the ten experiment (F10), is shown at the receiver side on the wheelchair to activate the STOP state with flushing WHITE led as an indicator (fifth action in 2’nd CS), as explained in Figure (4.12).

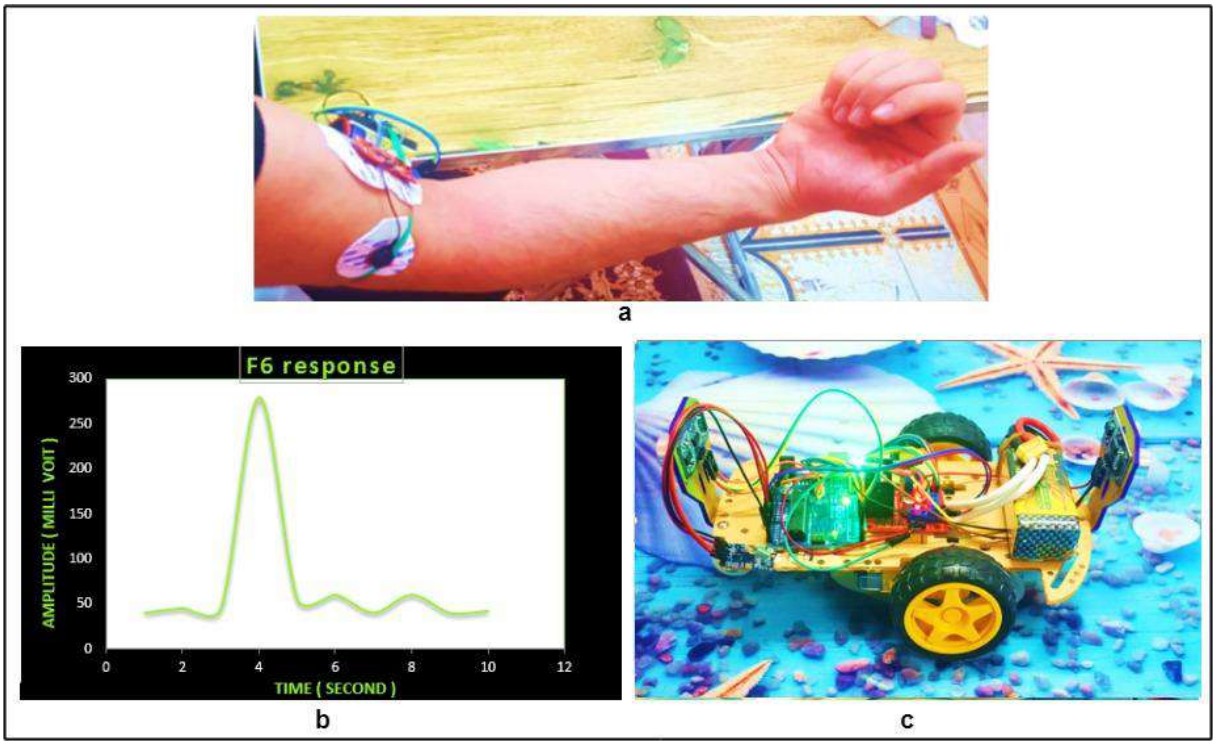


Fig. (4.17): Testing result of F6: (a) sixth muscle movement, (b) F6 signal shape and (c) forward direction with respect to F6 response.

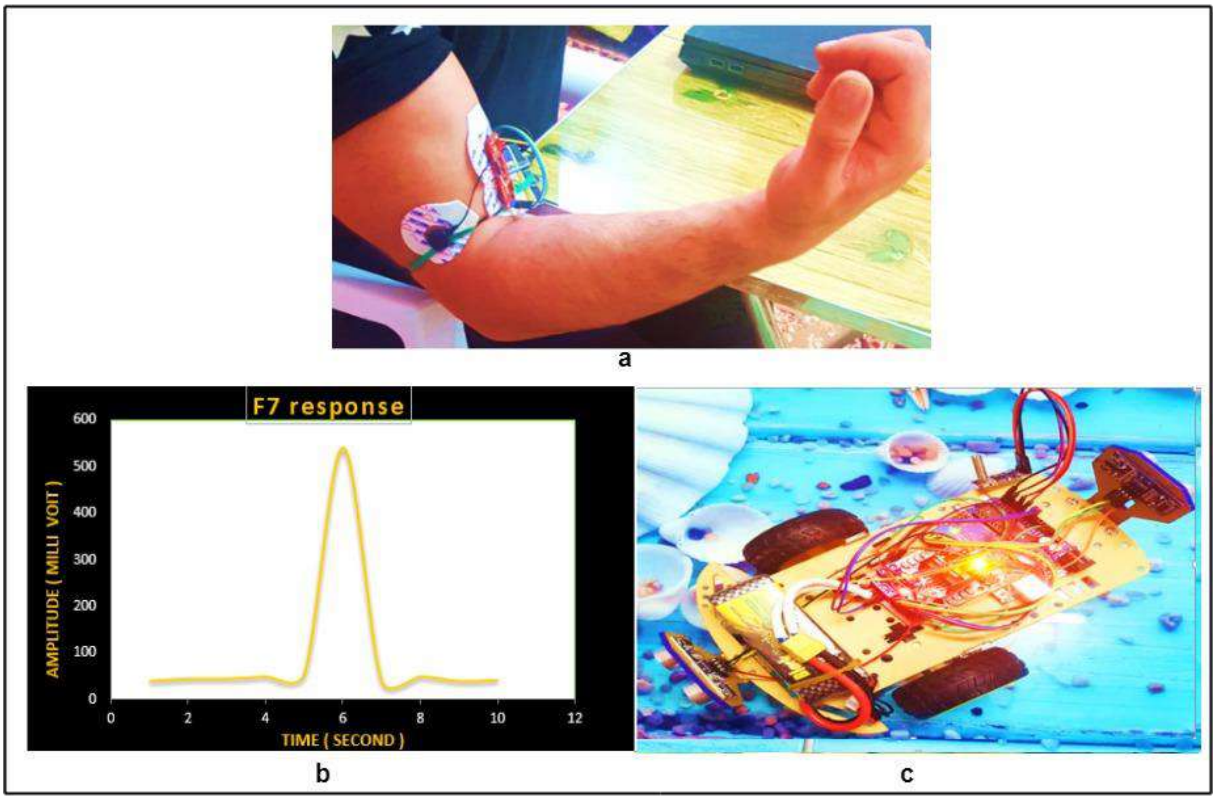


Fig. (4.18): Testing result of F7: (a) seventh muscle movement, (b) F7 signal shape and (c) right direction with respect to F7 response.

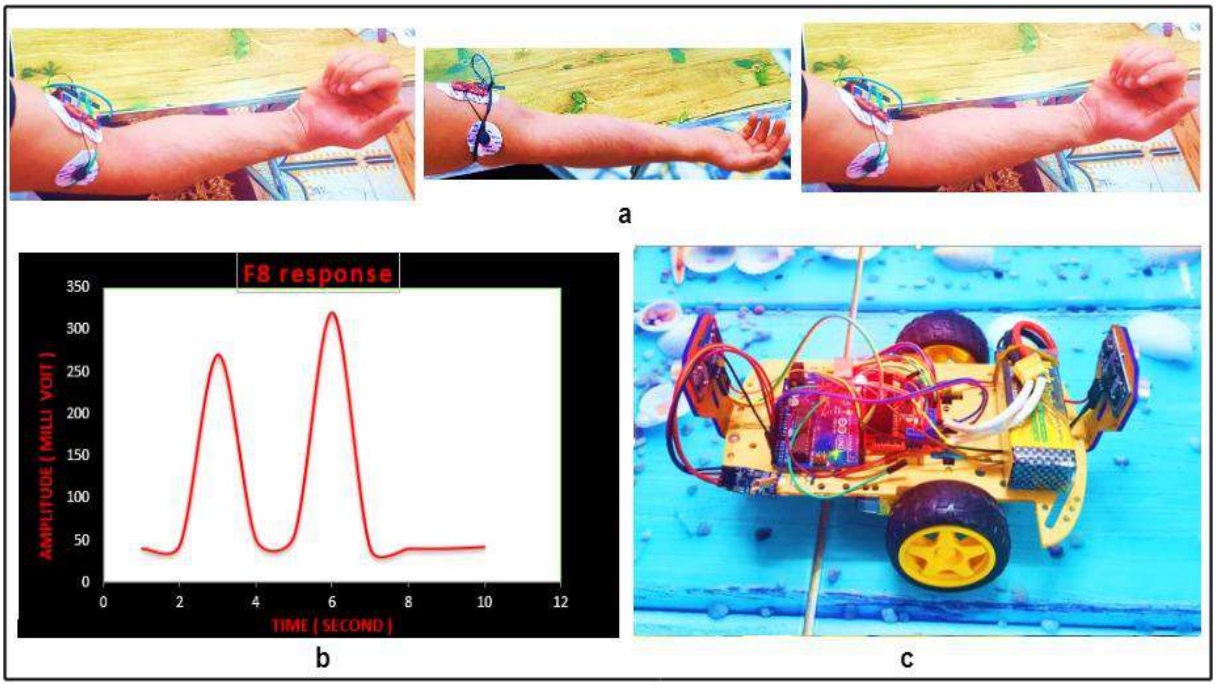


Fig. (4.19): Testing result of F8: (a) eighth muscle movement, (b) F8 signal shape and (c) backward direction with respect to F8 response.

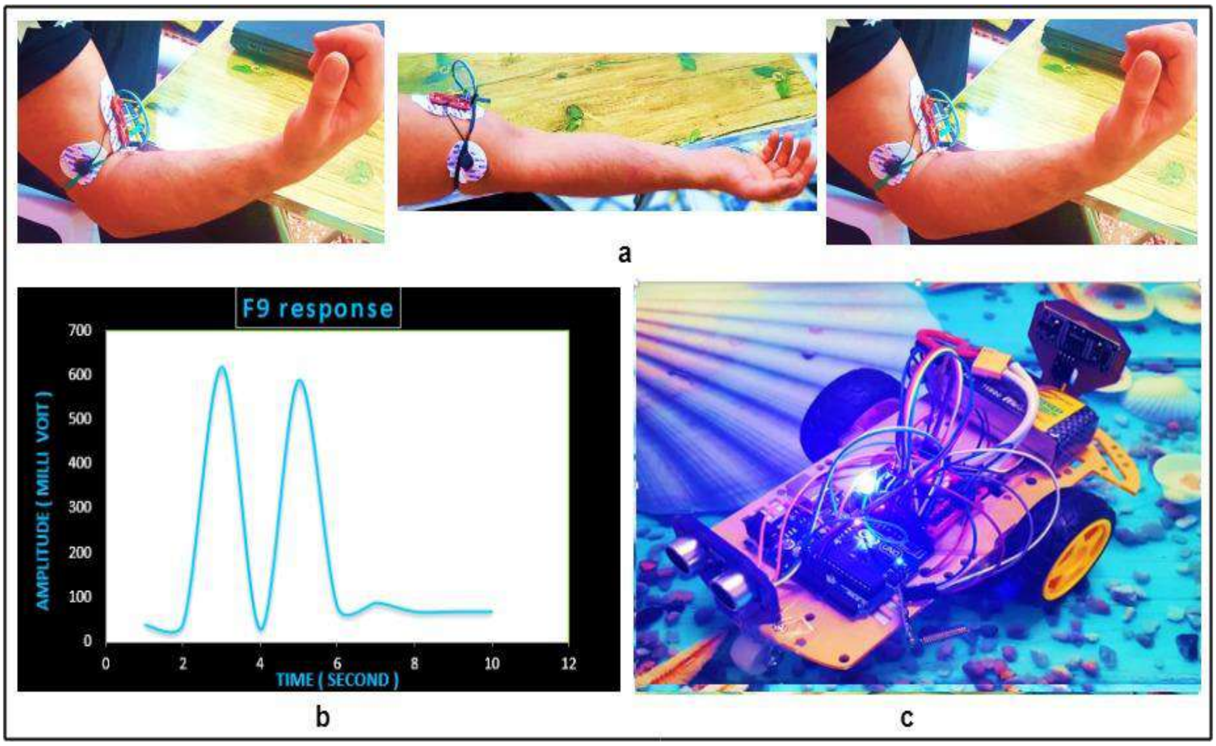
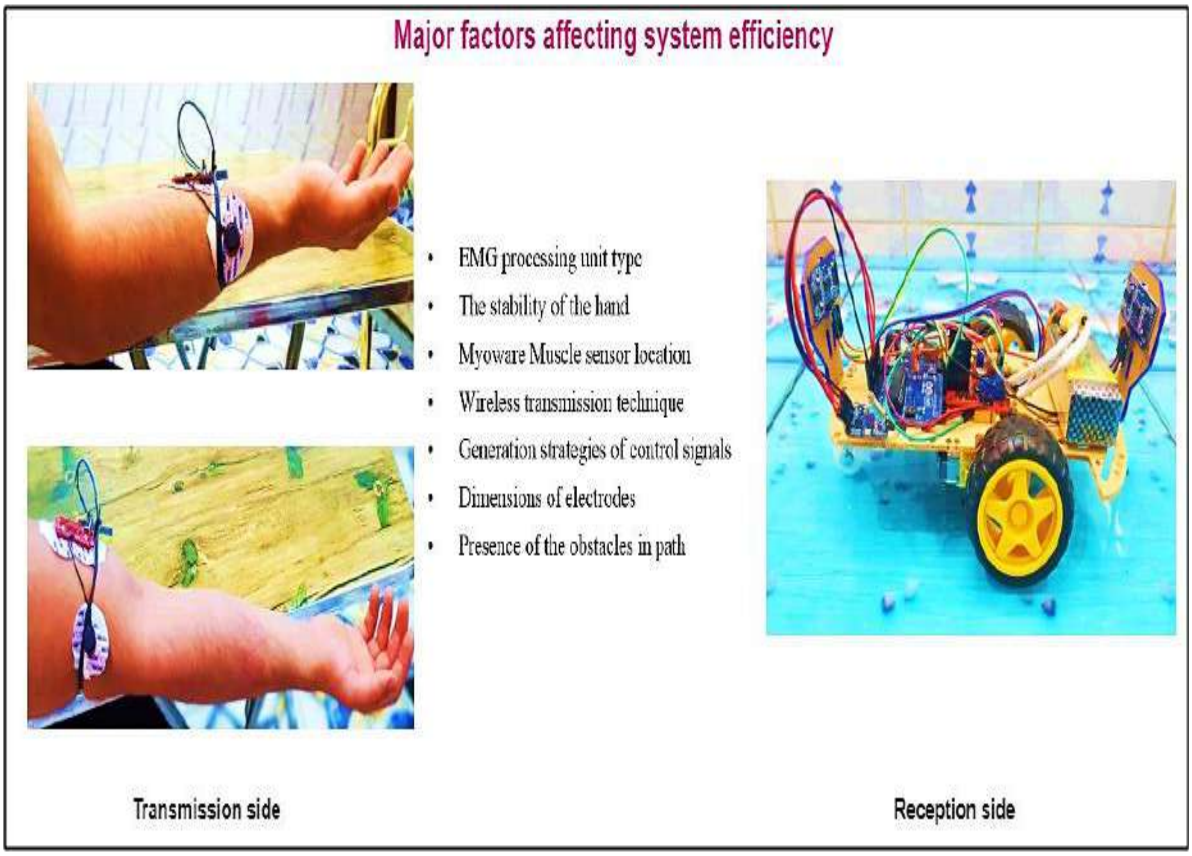


Fig. (4.20): Testing result of F9: (a) ninth muscle movement, (b) F9 signal shape and (c) left direction with respect to F9 response.

4.5 Efficiency Evaluation of the Proposed System

As shown in the Figure (4.21), there are many factors that can limit the efficiency of the system and vary ratios of its impact on the system as a whole. Some of them have a sharp impact and therefore require careful analysis in order to avoid them and the others cause slight impact and can be easily overcome. Ultimately, all of them have side effects on the overall system performance regardless of whether they are direct or indirect.

Practically, the choice of hand nerve signal processing unit is the most important factor in determining the efficiency of systems. There are low quality muscle sensors, such as muscle sensor V3, super simple EMG muscle sensor and most utilized is the processing unit that is manufactured manually on the bread board.



Major factors affecting system efficiency

- EMG processing unit type
- The stability of the hand
- Myoware Muscle sensor location
- Wireless transmission technique
- Generation strategies of control signals
- Dimensions of electrodes
- Presence of the obstacles in path

Transmission side

Reception side

Fig. (4.21): Major factors affecting overall system efficiency.

Moreover, all the mentioned units are not portable on the hand because they are installed on the bread board and are connected with the hand electrodes through cables. This restricts the movement of amputees and is the source of many of the noise mentioned in the second chapter. All of the above issues have been bypassed by recruiting a high-quality muscle sensor and portable on hand which is Myoware muscle sensor.

In addition, it is necessary to guarantee the right wireless transmission mechanism for the control signals in terms of signal transmission range to be received accurately in long distances. The obtained least impediments are another important point in testing the efficiency of the system. As mentioned, the system is designed primarily to control the wheelchair of the amputees who are very tense group in social networking. Therefore, bluetooth has been excluded from this task because its frequency makes it a major obstacle to security threat. So, it can penetrate the walls in addition to the short transmission range. For this reason, it is not recommended to adopt bluetooth to transmit vital signals, such as biomedical signals. Therefore, HC-12 has been set up in this project as it guarantees high connection speed to connect the wireless control signal. Therefore, the HC-12 must be quick to receive control orders and process them directly with a fast transmission time after signal transmission and acceptable distances without any delay.

However, care should be taken when starting to read the signal of the hand nerve in terms of full hand stabilization with the aim of stabilizing the signals until acquiring a valid control order and watching the result on the wheelchair. So the stability of the hand is a factor that should be largely focused on it. This is because any unintended hand movements can cause the activation of new control command and move the wheelchair suddenly. In fact, there is a fundamental point that is not taken into account and it is possible to be considered as a factor that reduces system efficiency. This factor is the dimensions of the electrodes. In general, most studies encourage the selection of small sizes electrodes and shorter inter-electrode spacing about 2 cm to make the crosstalk affect ultimately smaller. Fortunately, Myoware muscle sensor is designed with standard static dimensions between the conductors of the electrodes to eliminate this impact.

As mentioned above, the proposed system follows two techniques to generate signals, one of them is single action, while the other is double action. However, the analyzing of the results for ten test experiments in each technique in terms of accuracy of classification, the system tends to generate double action control signals to ensure high efficiency and excellent accuracy. Accuracy of classification means the accuracy of the system as a whole. Minutely, the durability and efficiency of the system can be enhanced by ensuring the safety of chair owners through placing ultrasonic sensors to stop the chair when facing obstacles. In addition to all the above factors, there exist another important factor limiting the efficiency of these designed systems is the appropriate and sensitive location of the muscle sensor on the muscles of the upper limb.

As the random and unlearned choosing of the muscle sensor location can lead the system to a number of risks including lack of accuracy for the classification between hand gestures. Therefore, the system needs to additional EMG channels, which increase the cost of systems designed. It also reduces the response time to amputees. This is because of requiring different classification techniques of nerve signals for the purpose of increasing its accuracy to employ them properly in these systems.

The system has proved the low cost of roughly (534$) by assembling its physical components at reasonable prices, which formed the system as a whole as an initial model that can be exploited from all levels of bilateral amputees. In practice, this system can be applied in a real wheelchair at a reasonable cost compared to conventional commercial chairs with prices above (5,000$).

As a rule, final and more concise evaluation of the efficiency for the system is carried out through the percentages of the ten hand gestures test experiments in two case studies for each control signal generation technique. Table (4.5) represents single action control signal generation technique and Table (4.6) represents double action control signal generation technique with measurement of classification accuracy rate of all discussed movements according to Equation (4.1) [76].

$$\text{Classification Accuracy} = \frac{\text{correct classification attempts}}{\text{total classification attempts}} * 100\% \qquad \ldots\ldots \quad (4.1)$$

Table (4.5): Results evaluation of single action control signal generation

First case study			**Second case study**		
Digital Threshold range	**Experiment**	**accuracy**	**Digital Threshold Range**	**experiment**	**accuracy**
120 -180	**E1**	90%	100 - 200	**E6**	90%
200 - 300	**E2**	80%	230 - 340	**E7**	70%
>620	**E3**	90%	400 - 620	**E8**	80%
350 - 600	**E4**	80%	> 630	**E9**	80%
<120	**E5**	80%	< 100	**E10**	90%
E1+E2+E3+E4+E5		84%	**E6+E7+E8+E9+E10**		82%
Total classification accuracy of single action control signal generation = 83%					

Table (4.6): Results evaluation of double action control signal generation

First case study			**Second case study**		
Digital Threshold range	**Experiment**	**accuracy**	**Digital Threshold Range**	**experiment**	**accuracy**
>500	**F1**	100%	120 - 450	**F6**	100%
140 - 480	**F2**	82.3%	> 480	**F7**	82.355
>500	**F3**	88.2%	120 - 450	**F8**	94.11%
140 - 480	**F4**	88.2%	> 480	**F9**	88.23%
<140	**F5**	100%	< 120	**F10**	100%
F1+F2+F3+F4+F5		91.74%	**F6+F7+F8+F9+F10**		92.93%
Total classification accuracy of double action control signal generation = 92.335%					

On the other hand, the evaluation of the overall system can be tested from obstacles detection side and thus two HC-SC04H ultrasonic sensors are located on the front and rear of robotic car. This is to detect obstacles objecting in the way when driving wheelchair in forward and backward direction. In case of obstacles within 15 cm away, the wheelchair takes a stop state automatically and the WHITE led is lit as a marker of discrimination as shown in Figure (4.22) and Figure (4.23) for detecting solid object in forward direction and backward directions respectively. As a useful evaluation by conducting ten test experiments for each sensor, the detection accuracy is reached up to 90%.

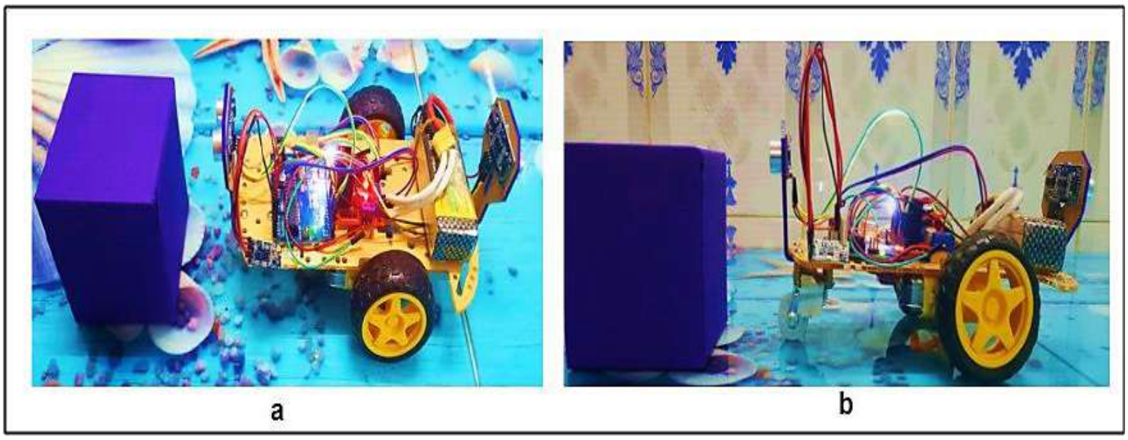


Fig. (4.22): Obstacle detection at forward direction: (a) the result recorded from the top, (b) the result recorded from one side.

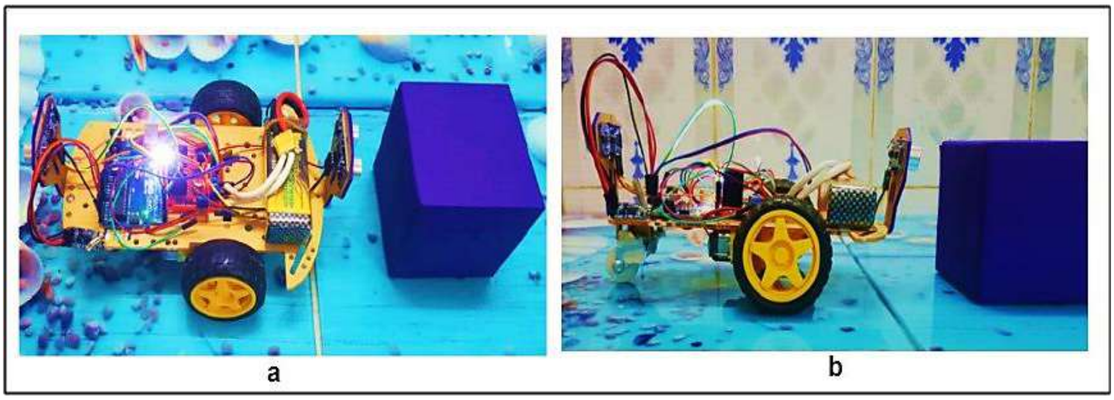


Fig. (4.23): Obstacle detection at backward direction: (a) the result recorded from the top, (b) the result recorded from one side.

Chapter Five

Conclusions and Suggested Future Works

5.1 Conclusions

In this thesis, an efficient assistant system was proposed for bilateral amputation people. The proposed system was based on hand nerve signals for managing and controlling wheelchair which was represented by two wheel driver robotic car as a prototype. Different points of conclusions can be written based on the work steps that have been experienced through the design and implementation of the system as follows:

1. The proposed system consists of two main hardware sub-systems, one at the transmission side of hand nerve signals and the other at the reception side of the transmitted signals.
2. Initially, at the transmission side, hand nerve signals that were represented by EMG signals acquired by one channel surface EMG electrodes with one muscle sensor. This was to guarantee the low cost with high quality and efficiency detection of EMG signals. It is important to note that the implementation is reduced efficiently in comparison with the research so far with acceptable accuracy ratio. The previous research works that were illustrated in Table (5.1) used more sensor units and channels for applying the similar job of the proposed system.
3. The adopted channel was sited on the skin surface of forearm and biceps muscles in two proposed case studies of bilateral amputation. In fact, these signals were low in amplitude and noisy, and they needed to be improved to be easily handled by the microcontroller. Thus, this work had led to the recruitment of a newly invented muscle sensor to solve the problems of medical signals. The utilized EMG sensor (Myoware) was

considered to be the finest and most suitable nerve signal processing units. The signal processing included different functions, such as amplification, filtering and reshaping.

4. In this aspect, the proposed hand-nerve reading algorithm played an effective role in the classification of the pulled signals according to the hand motion monitoring flags. The muscle contraction level was also translated through these flags to ensure that the signals were isolated.
5. The system proved to be reliable through the seamless wireless transmission of the rated signals with high success and distances of up to 1 km roughly. Thus, increasing the flexibility and reliability of the system could be done by eliminating the need for wires from hand to wheelchair.
6. At the other side of the overall system, the handshaking problem process was carried out with the reception of the wireless control flags, which were transferred to the heart of this side. This was represented by the exquisite Arduino Uno for the purpose of managing wheelchair states in terms of direction and speed according to the geometric layout.
7. This system had become more robust by employing HC-SC04 ultrasonic sensors which were placed at the front and rear of the wheelchair to achieve the lofty goals of reducing risks of collisions in presence of obstacles. This is to offer more satisfaction for the patients and achieve safety.
8. As a useful summary, the system proposed and implemented two techniques to generate control signals. The first was relied on the performance of single action when generating the signals and gave the results of the classification accuracy of 83%. The other went to change the pattern of generating signals through the development of double action performance and proved its worth by reaching an excellent classification accuracy of 92.335%. Thus, the system had finally adopted the double action of generation operation and trained the patients in this way to

facilitate the use and reduce the cost. However, this method may experience very little delay in actual response time.

Table (5.1): Previous Researches Based on EMG Signals.

Researches	No. of EMG channels	Electrodes Location	No. of Control Orders	Average Classification Accuracy
In 2006, Tsenov, et al. [77]	Two	Forearm muscles	Four	92.64%
In 2009, Tenore, et al. [78]	Thirty two	residual limb muscles	Ten	90%
In 2012, Al-Timemy, et al. [79]	Twelve	Below elbow muscles	Nine	96%
In 2016, Gregory Luppescu, et al. [80]	Ten	Arm muscles	Six	93%
The proposed work	One	Forearm and biceps muscles	Ten with two case studies	92.335%

5.2 Suggestions for Future Works

Additional points can be adopted to increase the potential of the system and make it more scalable, these points can be summarized and listed below as suggested future works:

1. The system can be copied and applied to a real wheelchair with addition some of the others hardware components.
2. The system can be made responsive to people suffering from loss of one of the lower extremities with change of muscle sensor location on the target muscles of the lower limbs.

3. The proposed system could be modified for people with atrophy or burns in biceps muscles and the recruitment of triceps muscles as an alternative.
4. The proposed system could be advised to help patients with the shoulder disarticulation.
5. The proposed system can apply the modern adaptive algorithms for the purpose of precise the samples for digital threshold values among patients.

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Appendix-A

Myoware Muscle Sensor

General Electrical Specification of Myoware Muscle Sensor

Parameters	Min	Typical	Max
Supply voltage	+2.9 v	+ 3.3 v or + 5 v	+ 5.7 v
Input impedance	--	+ 110 GΩ	--
Supply current	--	9 mA	14 mA
Input bias	--	1 pA	--
Common mode rejection ratio (CMRR)	--	110	--
Adjustable Gain potentiometer	0.01Ω	50 kΩ	100 kΩ
EMG envelope	0 v	--	+ Vs
RAW EMG centered about (+Vs/2)	0 v	--	-Vs

Appendix-B

Publications from Thesis

Two papers have been published from this thesis and one pending decision which are:

1. Ahmed Majid Abdel Abbas and Dr. Muayad Sadik Croock, "Efficient Control System Based on Hand Nerve Signals", Iraqi Journal of Computers, Communications and Control & Systems Engineering (IJCCCE), Vol. 19, no. 3, 2019.
2. Ahmed Majid Abdel Abbas and Dr. Muayad Sadik Croock, "Low Cost Control Signals Generating System Based On Hand EMG Measurements", accepted in JATIT Telecommunication, Computing, Electronics and Control, 2019.
3. Ahmed Majid Abdel Abbas and Dr. Muayad Sadik Croock "One Channel EMG Sensor Based Wheelchair Control System for Bilateral Amputation People", submitted to (clarivate analytics indexing) Ad Hoc and Sensor Wireless Networks, 2019.

الخلاصة:

في الآونة الأخيرة ، أبدى الباحثون اهتمامًا كبيرًا بتوظيف دراساتهم لمساعدة مبتوري الأطراف في العديد من الجوانب. الدراسات الحديثة في التطبيقات المساعدة القائمة على إشارات العصب اليدوي قادرة على تلبية احتياجات أولئك الأشخاص الذين يعانون من قيود في حركة الأطراف العلوية. في العمل الحالي ، تم اقتراح نموذج أولي للكراسي المتحركة ، يتم تمثيله بواسطة سيارة روبوتية ، كنظام مساعد يتم تخصيصه لاشخاص البتر الثنائي بناءً على إشارات العصب اليدوي. يتم تمثيل هذه الإشارات كإشارات تخطيط كهربية (EMG) ، يتم تجميعها باستخدام مستشعر EMG لـ (Myoware) ويتم إرسالها لاسلكيًا عبر تكييف وحدتي اتصال لاسلكي HC-12. هذا لأداء الاتصالات اللاسلكية المطلوبة بين اثنين من ميكروكنترولر في جانب الارسال والاستقبال من النظام العام.

من المهم ملاحظة أن استخدام جهاز استشعار EMG واحد وأقطاب قناة واحدة هو التحدي الذي يواجه هذا البحث من أجل الحصول على نظام منخفض التكلفة وفعال. بالإضافة إلى ذلك ، يعمل متحكم Arduino Nano في جانب جهاز الإرسال كمحول تناظري الى رقمي لهذه الإشارات العصبية اليدوية. بالإضافة إلى ذلك ، يستخدم جانب المتلقي متحكم Arduino UNO للتحكم في حالة السيارة الآلية (STOP / MOVE). أصبح هذا النظام أكثر قوة من خلال استخدام أجهزة الاستشعار بالموجات فوق الصوتية HC-SC04 ، لأغراض الحد من مخاطر الاصطدامات ، لتوفير المزيد من السلامة للمرضى في وجود عقبات. من ناحية أخرى ، يتم الحصول على إشارات EMG من سطح جلد عضلات الساعد والعضلة ذات الرأسين لاستخدامها في توليد أوامر تحكم مختلفة.

يتبنى هذا البحث دراسة حالتين لمبتوري الأطراف الذين يحاكون حالات بتر اليد المختلفة ، كل دراسة حالة مع خمس حركات عضلات للطرف العلوي. تم الحصول على الحركات العشر المعتمدة للعضلات التي تم النظر فيها في دراستين حالة في نوعين من السيناريوهات. أول واحد يأخذ بعين الاعتبار حركة العضلات المفردة لأمر تحكم فردي بدقة تصنيف (٨٣٪) ، بينما يتبنى الثاني حركة مفردة ومزدوجة مع وقت تسجيل محدود لتوليد الإشارة مع دقة تصنيف (٩٢,٣٣٥٪) لعشر حركات يد في اثنين من دراسات الحالة التي تجعل أداء النظام المقترح ممتازا. وبالتالي ، اعتمد النظام أخيرًا الإجراء المزدوج لعملية توليد الإشارات المقترحة.

جمهورية العراق
وزارة التعليم العالي و البحث العلمي
الجامعة التكنولوجية
قسم هندسة الحاسوب

نظام مساعدة البتر الثنائي بالأعتماد على اتصالات إشارة عصب اليد اللاسلكية

رسالة
مقدمة الى قسم هندسة الحاسوب في الجامعة التكنولوجية كجزء من
متطلبات نيل شهادة الماجستير في هندسة الحاسوب

من قبل
احمد ماجد عبد العباس

بإشراف
أ.م.د. مؤيد صادق كروك

١٤٤٠هـ ٢٠١٩م