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The Design of Electrical Wheelchairs with Electromyography Signal Controller for People with Paralysis

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Abstract The paralytics suffering the paralysis almost in all parts of the body particularly hands and feet are not able to move the wheelchair with a manual controller, joysticks or button. This condition certainly needs an alternative controller to move the electric wheelchair. This research attempts to develop the innovation alternative controlling technology to the wheelchair for those suffering from paralysis particularly to feet and hand by doing an engineering of the electric wheelchair using the control of electromyography (EMG) signal from the result of the muscle relaxation. The EMG signal was tapped from 4 muscle spots as the command to turn right, turn left, move forward and backward. The change of the amplitude value of EMG signal when the muscles did contraction was used as the trigger of electric wheelchair motor. The EMG signal that had the amplitude in the order of millivolt must be strengthened to be the volt order purposely to be capable of being read by the range of the analogue to digital converter. In addition, the EMG signal obtained from the tapping still contained more noise signals. Microcontroller functioned to receive the digital signal from the circuit of analogues to digital converter to be later processed and used for the control of the wheelchair. This research used the control system we call as *Bioelectric Adjustable Threshold System* (BAST) to detect the power of the muscle contraction of the user at the beginning of the usage to later be saved and used as the value of the voltage reference to run the control system of wheelchair. The result of the test on the system by giving 50 times of command for movement showed that the forward movement had the best performance with the error value of 0% and the worst one was found in the command of turning left with the error value of 50%.

Keywords Wheelchair, Electromyograpy, Paralysis

1. Introduction

The result of the National Socioeconomic survey conducted by BPS (Indonesian Statistics Bureau) in 2012 revealed that the number of disabled people in Indonesia reached 6.008.661 people, 616.387 and more or less 2.401.592 of whom were those with the body disability and doubled disabilities respectively. The population of the number of such disabilities certainly could be more in consideration to the existence of many remote areas that cannot be accessed by the survey agents. The high rate of the people with such disability certainly becomes the concern of the government not simply regarding the facilities in the form of building, road or any transportation modes but also the program to improve the life quality in the form of physical therapy. The physical therapy is a paralysis management focused on the movement. It is useful to help the paralytics by using the muscles that can function normally to prevent any shortening muscles and physical defect. The physical therapy can be done by means of the suitable aid in the form of body support and wheelchair.

The technology of wheelchair has been more developed. The manual wheelchair moved from using the pushing power by hands designed with a very light, small and foldable shape to the one that could be moved with joystick or buttons has been improved to ease and give comfort in mobility for the paralytics. However, for those suffering the paralysis in most of parts of their body particularly hands and feet and unable to move the wheelchair using the joysticks or button, a technology innovation is required move the electric wheelchair with an alternative controller.

The research using the alternative controller of the electric wheelchair has been widely developed. Some of the alternative controllers for the electric wheelchair have been more studied such as the controller with the sound command (Pires, et al., 2001), and the controller with the head movement (Kalantri, et al., 2003) but the most widely used alternative controllers in the research recently is the one by using the bioelectric signals produced by body cells.

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Barea, et al., 2003 used the electrooculograph signal (EOG) – a bioelectric signal resulted from the movement of the eyeballs to control the electric wheelchair. Nikhil, et al., 2016 used the electroencephalograph signal (EEG). Taslim, et al., 2012, Sahebjad, et al., 2012, Mohammad, et al., 2008, Xu, et al., 2013, and Sathish, et al., 2016 used the EMG signal as the alternative controller for the electric wheelchair. Tien, et al., 2011 and Ahire, et al., 2015used the controller of the electric wheelchair by combining the electromyographsignal (EMG) and EOG. The EMG signal was used for the command to move forward and back and to turn right and left. Meanwhile, the EOG signal was used to manage the motor speed.

This research conducted a design of the electric wheelchair with the control of EMG signal from the result of the contraction muscles that still functioned in 4 different tap points for the forward and backward movements and the movement to turn right and left. To make this electric wheelchair can be right used though there has been a change of amplitude value of the EMG signal of the users for the muscle fatigue or the wheelchair being used by other users that have a different power of muscle contraction from the previous user, there is a need to be supported with a system that can cope with this problem. This system is able to store the power of the muscle contraction from the user in the beginning of the use to be later used as the reference amplitude. This system we name the *Bioelectric Ajustable Treshold System* (BAST).

2. Fundamental

Bioelectric signalis the signal occurred as a result of the displacement of Sodium (Na +) ions and Potassium (K +) ions from outside to inside the cell and vice versa due to the differences in the concentration value of the ions between the inside and outside of the cell. This phenomenon is called the electrical activity of cells that can occur as a result of stimulation from outside the cell in the form of electrical, mechanical and chemical stimuli.

EMG signal refers to bioelectric signal generated by nerve cells when the muscles are in contraction and relaxation. When the muscles do the contractions there will be an increase in the amplitude value of EMG signal and will return to the initial state when the muscles do relaxation. The amplitude values of EMG signal vary greatly based upon the condition and strength of muscles of an individual when doing measurement. These values are in the range 0 to 10 millivolts with the frequency spectrum in the range 0 - 500Hz. The dominant frequency spectrum of EMG signal is in the range of 50 to 150 Hz. Figure 1 shows the description of the frequency spectrum of EMG signal.

The measurement of EMG signal in body can be conducted in two methods: invasive method and noninvasive method. Invasive method is by placing the electrode directly on the muscle to be measured and the noninvasive one is by placing the electrode on the skin surface or so-called surface electrode. The position of surface electrodein EMG signal measurement is determined based upon three important considerations: signal-to-noise ratio, recorded signal stability and signal contamination from surrounding muscles that do not want to be detected (crosstalk). The contamination of crosstalk becomes an important consideration in the use of surface electrodes as this contamination could affect the characteristics of the recorded signal and eliminate the original information derived from the muscle to be detected [5].

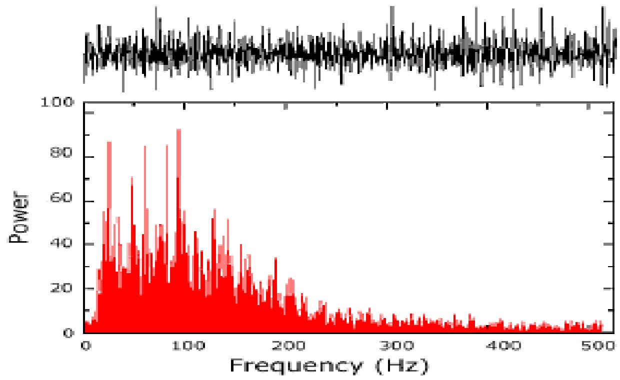

Figure 1. Spectrum of frequency signal [5]

3. Method

The diagram of the research block is shown in Figure 2 below.

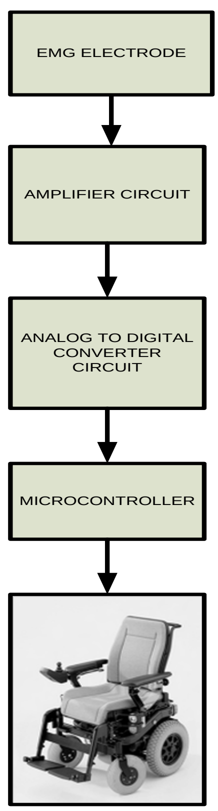

Figure 2. The Block Diagram of the electric wheelchair with the control of EMG signal

The control of EMG signal in the electric wheelchair for the forward, backward, turning right and left movement was obtained from 4 different tap points. The increase of the amplitude of EMG signal would occur when the muscle did the contraction and again decreased when the muscle did a relaxation. Such change of amplitude was used as the trigger of the movement of the electric wheelchair. The EMG signal that had the amplitude in the order of millivolt must be strengthened to be the volt order purposely to be capable of being read by the range of the analogue to digital converter. In addition, the EMG signal obtained from the tapping still contained more noise signals. For this, it needed to be filtered to remove the disturbing signals. Microcontroller functioned to receive the digital signal from the circuit of analogues to digital converter to be later processed and used for the control of the wheelchair. BAST system that acted to detect the value of the amplitude as the result of the muscle contraction of the user was then stored and used as the reference amplitude to run the system of the wheelchair movement. Each of electric wheelchair movement included the forward and backward movement as well as turning right and left movement, each of which had reference amplitude. This system was made using programming language in the microcontroller.

4. Result and Discussion

In this research, the frame of the manual wheelchair was overhauled and assembled into the electric wheelchair by adding 2 electric motors on the wheel part. The electrical motor used to mobilize the wheelchair was in the type of the DC motor (direct current) with the power supply of 5 volts. This electrical motor was then installed on the overhauled manual wheelchair to the wheelchair that in the first time moved using the human power but now moved with the electric motor power.

Figure 3. DC Electric Motor of 5 Volts

The electronic circuit protection system for leakage current in this research is not discussed in details but this system must be able to make leakage current not exceeding the threshold score which can endanger human body, i.e. 0,5 mA. According to IEC 60601-1, the leakage current that can endanger the human body is more than 5 mA. The protection can be done by giving a fuse with no more than 0,5 mA in the EMG electrode cable which is connected to skin surface so if there is current leakage that is more than 0,5 mA, the fuse will immediately break.

The design of the wheelchair with the installation of the electrical motor is shown in Figure 4.

Figure 4. The overhauled manual wheelchair

The analogue circuit in this research refers to the circuit functioned to tap the EMG signal produced by the muscles as a result of the contraction and the relaxation of the muscles. In this research, there were 4 units of circuit of EMG made in which each of unit functioned to tap the EMG signal to trigger the wheelchair to move forward and backward and to turn right and left. The electrode of EMG was placed in the 4 different points in the muscle that can still have a contraction. Each of muscle point was given a pair of measuring electrode to have a pair of measuring electrodes. For the reference electrode, one electrode was placed.

The electrical circuit of EMG consisted of a circuit of instrumentation support, circuit of the *High Pass Filter* (HPF) with the frequency of the *cut off* 10 Hz, circuit of the *Low Pass Filter* (LPF) with the frequency of *cut off* 500 Hz, circuit of the *Notch Filter* 50 Hz and adder circuit.

The instrumentation support acted to strengthen the amplitude of EMG signal in the milli-order i.e. 200 times to be the volt-order.

The filter high-pass circuit of 10 Hz and the filter low-pass of 500 Hz functioned to remove the disturbing signals to control the electrical wheelchair as the characteristics of EMG signal was located in the range of 10 – 500 Hz.

The circuit of the notch filter 50 Hz acted to remove the noise signals coming from the electrical nets.

From the result of the adder circuit, it can be seen the increase of the value of the amplitude of the EMG signal when the muscle contraction occurred.

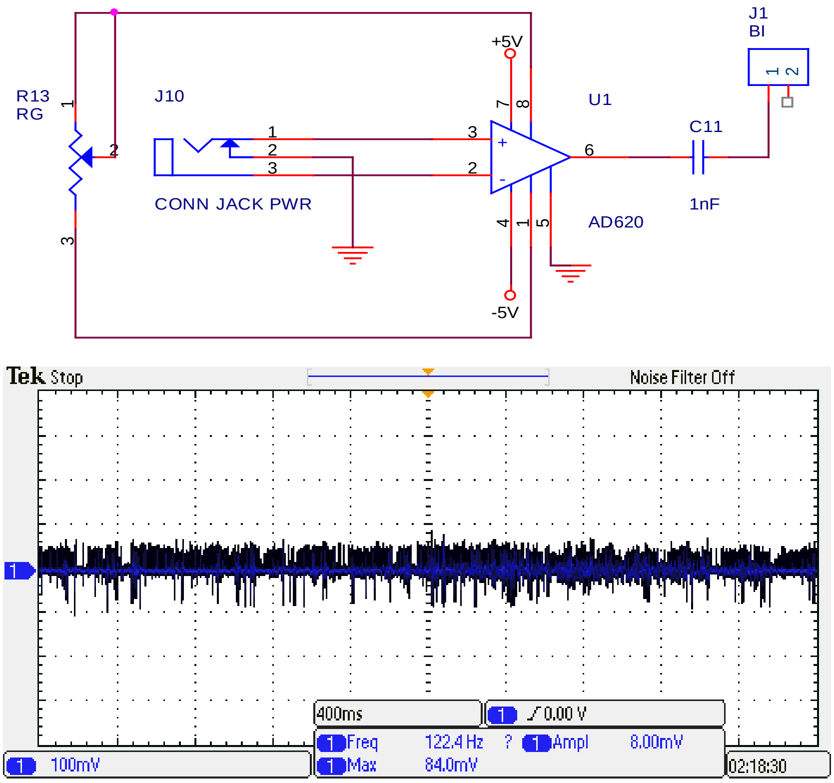

Figure 5. The circuit and the result of the instrument support

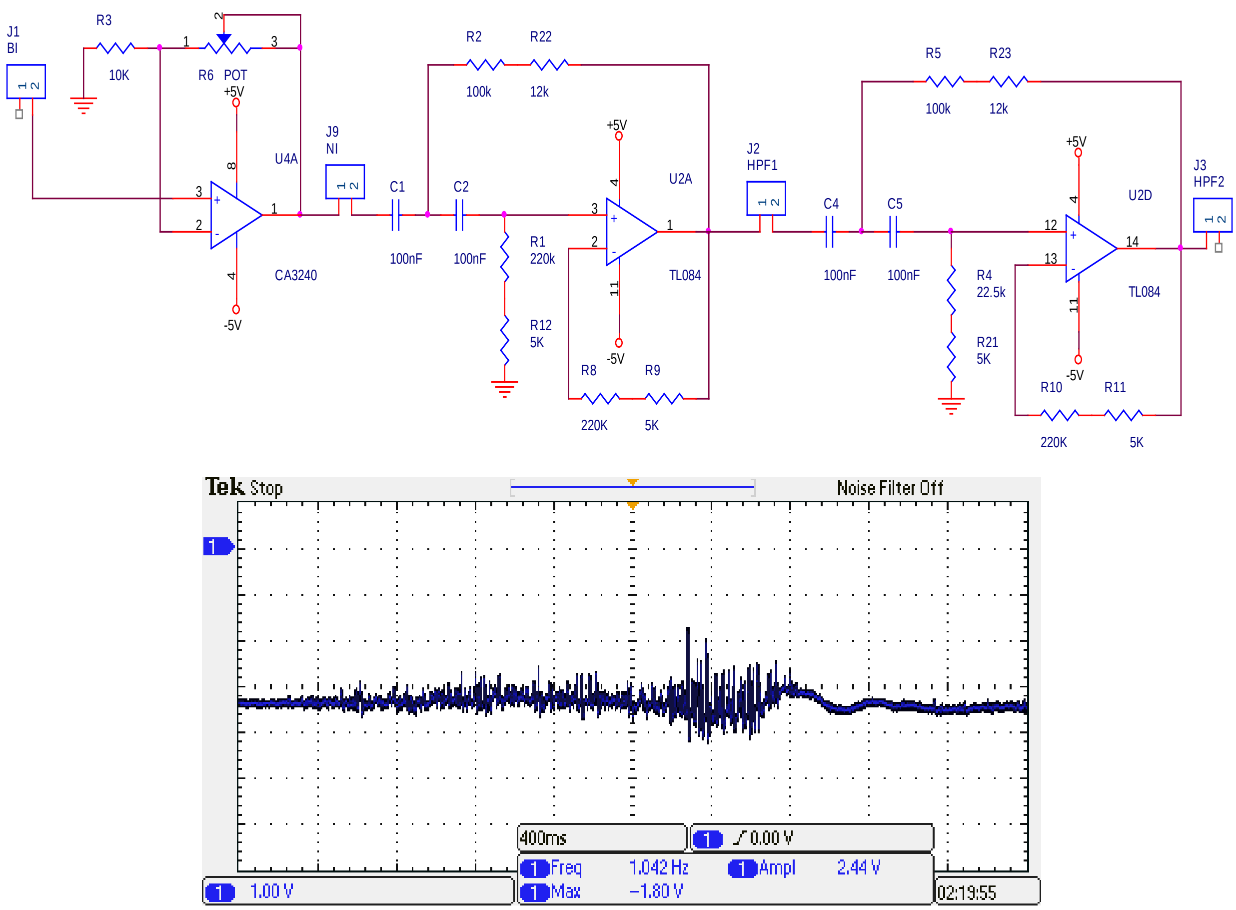

Figure 6. The circuit and the result of the filter high-pass support at *10 Hz*

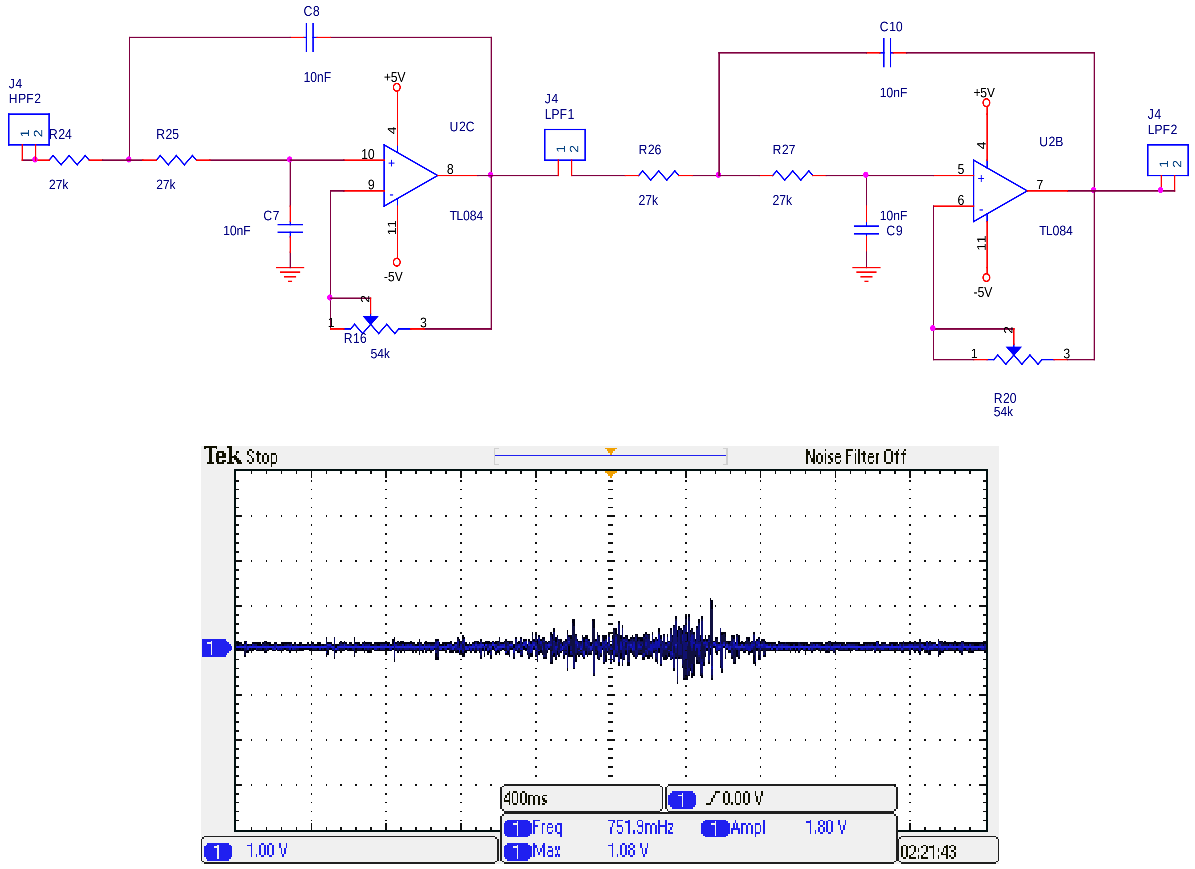

Figure 7. The Circuit and the Result of the filter low support of *500 Hz*

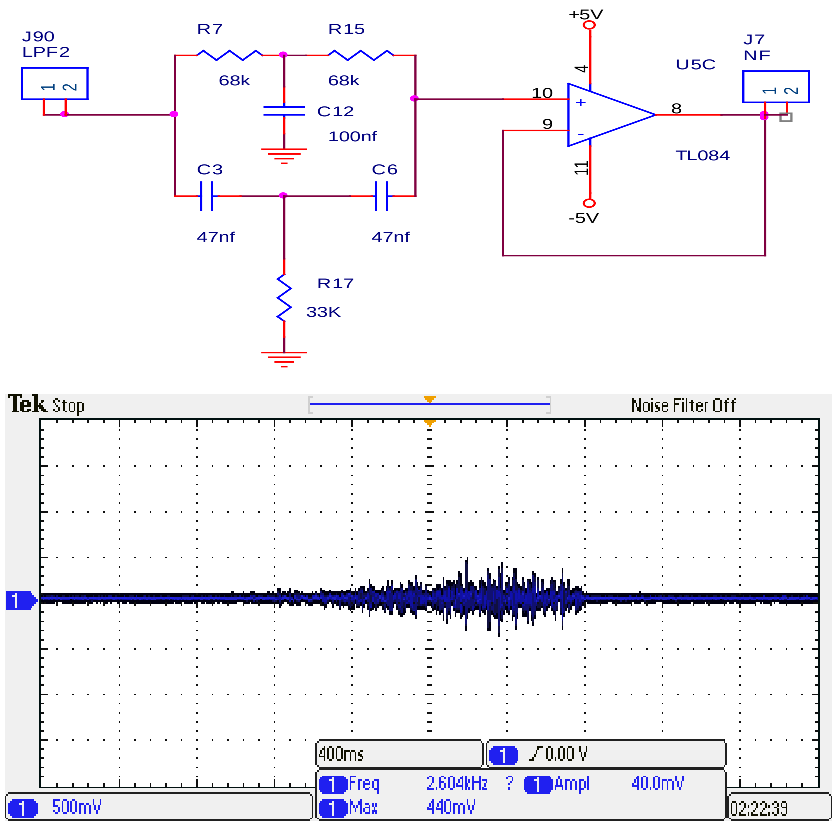

Figure 8. The Circuit and the Result of the support of the of *notch filter 50 Hz*

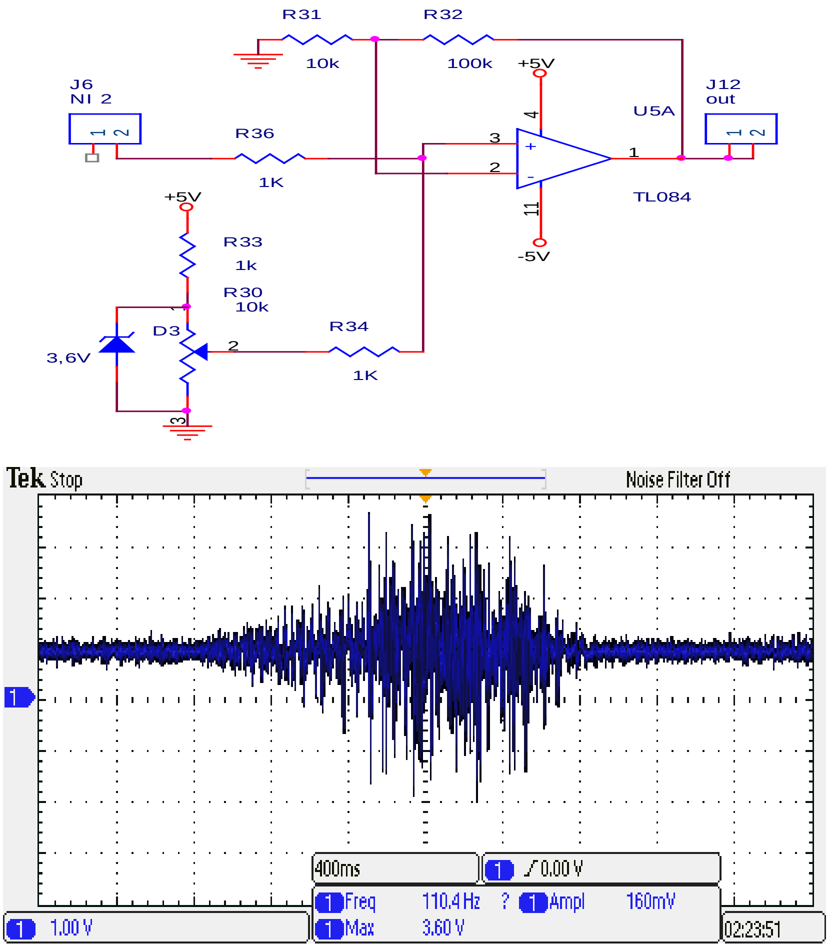

Figure 9. Circuit and the Result of adder

Figure 10. Electrode position on the right neck for the movement of turn right

Figure 11. Electrode position on the left neck for the movement of turn left

Figure 12. Electrode position on the forehead for the forward movement

Figure 13. The electrode position on the shoulder for the backward movement

Figure 14. The position of reference electrode

Four EMG electrodes in this research were placed on the different muscle spots for the movement of turning right and left and the movement to turn left and turn right. The positions are shown in Figure 10-13.

From the result of the measurement of the voltage value on the adder circuit, it was found that in the muscle relaxation, the amplitude of the EMG signal resulted was at 2 Volts but in the muscle contraction, the value of the amplitude of EMG signal increased on the right neck with the average value of 4.4 Volts, left neck at 4.3 Volts, forehead at 3.84 Volts and in the arm at 3.38 Volts. Such value of the amplitude then became the input in the microcontroller circuit for the needs of the electrical wheelchair control.

BAST system acted as the comparator comparing the amplitude of EMG signal as the result of the muscle contraction and the amplitude of reference that has been stored in the beginning of the use of the wheelchair.

The process to obtain the reference amplitude was conducted at the phase of "Taking the Front, Back, Right and Left Data" until the phase of "Data Verification". This data was then stored and used as the reference amplitude in the part of comparator processing. The excellence of the BAST system is that the reference amplitude can be replaced if the electric wheelchair is used by a user that has the value of the amplitude of EMG signal different from the previous user.

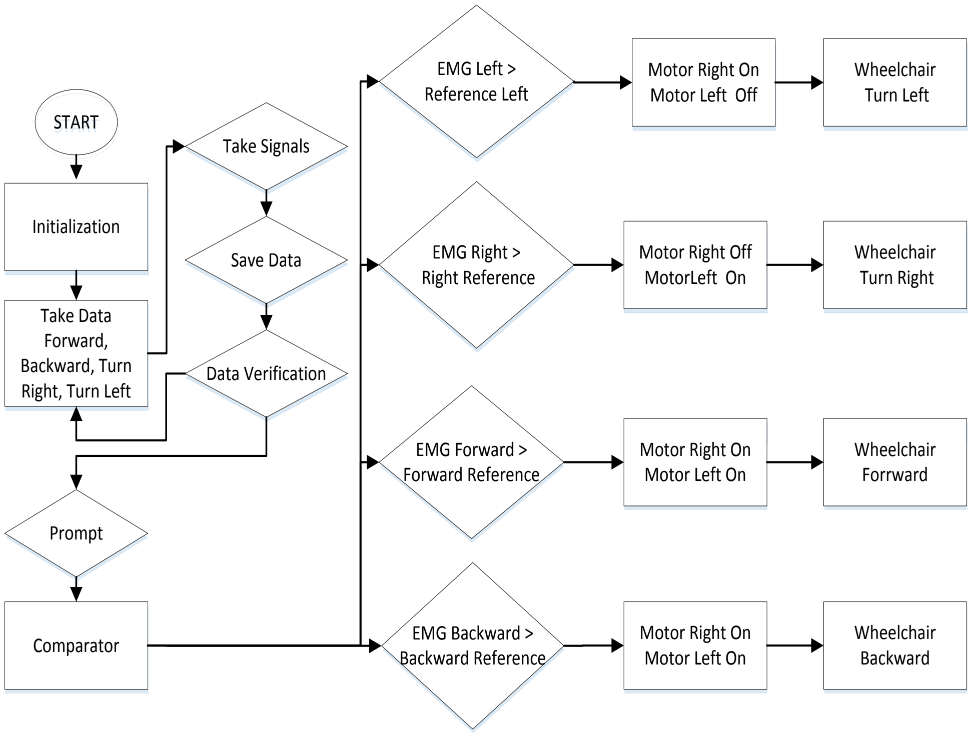

Figure 15. Flowchart of BAST system

Table 1. Result of the test to each command

	MOVING DIRECTION				
	MUTE	FORWARD	BACKWARD	TURN RIGHT	TURN LEFT
CORRECT DIRECTION	50	50	48	49	25
WRONG DIRECTION	0	0	2	1	25
ERROR	0%	0%	4%	2%	50%

When the user would move the wheelchair to the left, then the EMG signal of the user would send the signal to the system later compared to the left reference amplitude that has been stored in the beginning of the use. If the amplitude of EMG signal of the user is larger compared to the left reference amplitude, then the wheelchair would turn to the left. This condition is applicable for all commands of the forward, backward, turning right movement. The test of this system was conducted for each command (idle, moving forward, backward, turning right and left). Each of command was given as many as 50 times.

The result of the test showed that the commands for idle and moving forward were the movements with the lowest error value from 50 commands (0%) but the command to turn left had the highest error at 50%.

The high error which reached 50% in turn-left command needs improvement in the next research. The improvement can be done in the BAST system that is in the EMG signal data collecting stage to get reference amplitude. The EMG signal data collecting stage to get reference amplitude in this research is done once for each movement command, i.e go forward, go backward, turn right, and turn left. The improvement in this stage is undertaken by increasing the EMG signal data collecting more than once for each movement command. The EMG signal data average is then calculated so that the amplitude reference obtained is more valid.

5. Conclusions

1. The change of the amplitude value of the result of the contraction and relaxation of the muscle in the range of 3.4 – 4.4 volts in the contraction and 2 volts in the relaxation can be used as the controller of the electric wheelchair movement.
2. From the test, it can be obtained that the poorest performance of the wheelchair system was in the command to turn left with the error of 50%. It was because when the test, the user more dominantly used the right part of the body. This then has made the left part of the muscle just resulted in the EMG signal with little amplitude due to the weak muscle contraction.

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