Implementation of Electric Wheelchair with Microcontroller

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***Abstract*—This paper presents the design of electric wheelchair. We build machine that is capable to attach with any traditional wheelchair, and to control its movement semi-automatically. This helps handicapped person who has difficult body-movement to be able to travel simply. The machine comprises of power-driven system including a metal tube frame, wheels, motor, brake and accelerator, and electronic control department based H-bridge circuit and programmable microcontroller with the ATmega168. Software was developed in C++ language for programming microcontroller. Technical test was done on H-bridge circuit to confirm an accurate functioning in controlling direct current motor. Running test was on flat straight and slope courses. Result showed that it achieved a maximum load is 100 kilograms with a top speed of 8.42 kilometres per hour, and the average of battery lifetime is up to 1 hour and 30 minutes. Thus, we build a cost effective machine to provide an opportunity to translate conventional wheelchair to be an electric wheelchair.**

***Index Terms*—microcontroller, wheelchair, H-bridge circuit**

I. Introduction

Population of elderly people and disabilities in Thailand possibly changes in the next decade. Currently, disabled people and elderly person who have difficulty in a body-movement, have to use a conventional wheelchair to travel daily. They control and operate an affordable wheelchair with their hands using the force and torque in a muscle and joint, all these forces come out from the triceps muscle at their both upper arms. Nevertheless, person regularly used a wheelchair, it may lead to stiff muscles and tight muscles, and limited ranges of arm and hand activity [1].

Previous studies confirmed that a wheelchair is a crucial mobility device [2], [3], and there were several techniques have been proposed to improve a wheelchair. Takahashi and Matsuo 2011 [4] revealed technique to develop advanced wheelchair using a natural solar energy integrated with electrical power for enhancement of a battery lifetime and running distance. They concluded that their machine can be performed in double of running times by comparison with electric battery, and another prospect is to improve a running distance. Maruno *et al.*, 2012 [5] proposed front drive type wheelchair using electric power battery, and they mainly concerned the control department to overcome the driving problems. Hence, their study designed a new control unit using a yaw movement method. Running test was done on the slope and flat courses, and results showed that the driving problems was improved, however, there were some vibration problem caused while driving and further driving paths is required to test with this control system.

In this paper, we demonstrate the design and implementation of our machine to assemble with a conventional wheelchair to be an electric wheelchair with controlling its movement semi-automatically. Fig. 1 reveals our completed electric wheelchair.

Figure 1. Photographic of unassembled electric wheelchair (top), and completed electric wheelchair (bottom)

II. Methods

The purposed machine consists of three sections, power-driven components, electronic components and computer software. In addition, the block diagram of this system is shown in Fig. 2.

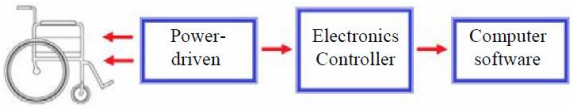

Figure 2. Block diagram of proposed scheme

A. Machanical Design

The power-driven system composed of front wheel, tire, brake, chain, electric motor, battery, battery metre,

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accelerator, handlebars, console switches and connection part to wheelchair, as shown in Fig. 3. In addition, the connection part (use to assemble to the front part of wheelchair) is adaptable to make a perfectly connection to any wheelchair.

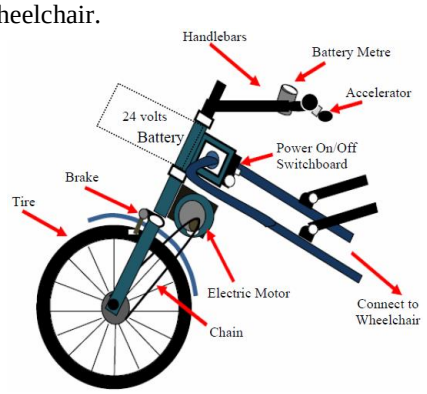

Figure 3. The power-driven system and connection side with conventional wheelchair (see Fig. 1)

B. Electronic Design

As shown in Fig. 2, electronic components integrated the ATmega168 microcontroller and the designed H-Bridge circuit to drive the motor and mainly control stepper motor using programming in the next section. A simple explanation of electronic design is shown in Fig. 4.

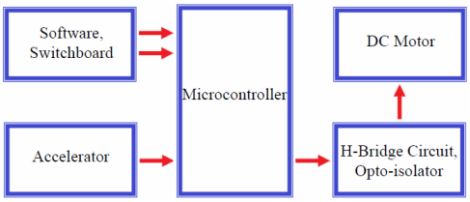

Figure 4. Block diagram of electronic design components

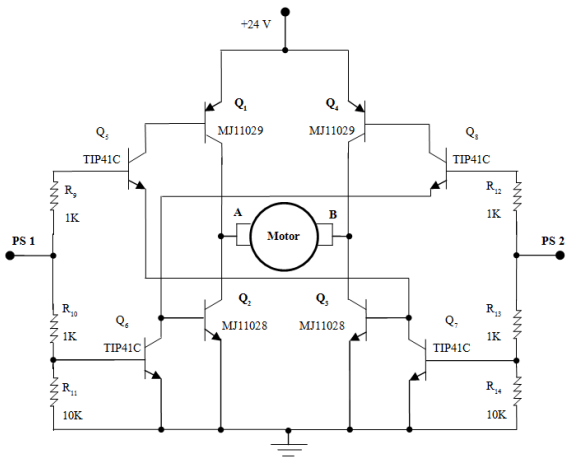

Figure 5. A designed H-bridge circuit

H-Bridge circuit is a switching circuit to drive the motor [6]. In general, the voltage divider on the motor (M) is equivalent to zero, and a Direct Current (DC) is also null, as shown in Fig. 5. To operate the motor, initially, DC 5 volts input at Pulse Signal 1 (PS1), this directs to active a transistor (Q), result to active Q1 and Q3 working together. So the voltage divider on the motor is changed, and voltage at A changes to drive motor in a clockwise direction. In the other hand, to reverse the rotation of a DC motor, input the pulse signal at PS2 with DC 5 volts, to active Q2 and Q4 working cooperatively, and voltage at B changes to drive the motor in counterclockwise direction. Fig. 5 reveals our designed H-Bridge circuit.

C. Microcontroller

Software programming electric wheelchair was written in C++ to program the microcontroller to generate a pulse signal for active H-bridge circuit, crucial importance to control motor to drive wheelchair by buttons on switchboard in Fig. 3. The control modes included buttons to turn on/off electric power supply, drive the motor forward/backward, and to reset the step motor to stop semi-automatically moving (partly control a direction by the user).

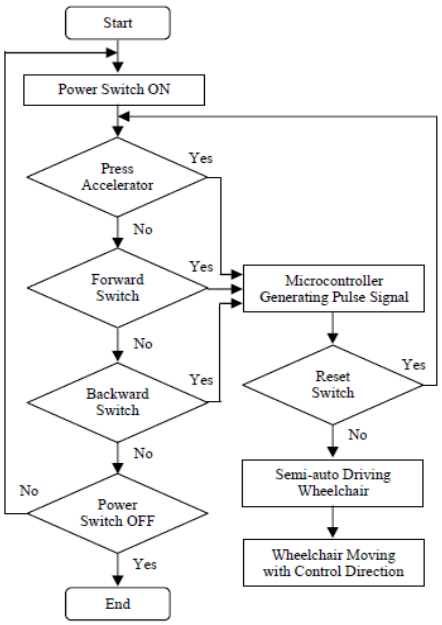

Figure 6. Wheelchair programming flowchart

Fig. 6 represents a design of the software programming, and the workflow illustrates how to function the electric wheelchair and its entire features. To develop the software, we proposed a scheme that is support the needs of disabilities and elderly people, for programming microcontroller, which are composed in four steps:

- Step 1: Assume that the system of electric wheelchair is completed; we then start to press the power switch on. There was a choice of motor controller by controlling pulse signal out of microcontroller to power and speed up/down the motor rotation.
- Step 2: Press accelerator, forward switch, and backward switch are the choices in controlling motor rotation.
- Step 3: one of the choices in step 2 has been selected, and then microcontroller generates the pulse signal for input of H-bridge circuit to drive the motor. Wheelchair is operated and kept running, in this state, the user have to control the driving direction of electric wheelchair.

- Step 4: Reset switch and power switch off are used to clear the choices to direct and to stop the controller system, respectively.

III. Results and Discussion

Electric wheelchair was tested by the following two running courses, flat straight and slope directions, respectively. Test results showed that an average speed reduced according to the slope course, and kept inconsistently average speeds on the smooth pathway, as shown in Fig. 7 and Fig. 8, respectively. In addition, Table I and Table II were presented a practical data accomplished to both line graphs in Fig. 7 and Fig. 8, accordingly. Furthermore, a maximum weight of 100kg was tested wheelchair running on the smooth direction with a long-running distance of 1 kilometre. As a result, average of the battery lifetime was approximately 1 hour and 30 minutes and achieving speed was 8.42 kilometres per hours.

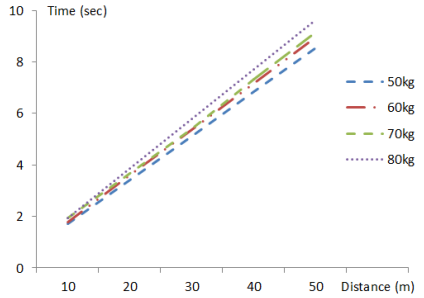

Figure 7. Wheelchair driving test on 8 ° slope pathway

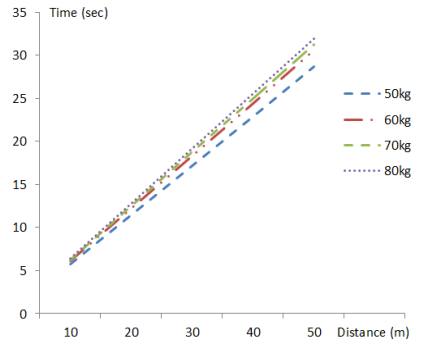

Figure 8. Wheelchair driving test on flat straight pathway

Electric wheelchair was tested at the joint location (connection part to assemble with convectional wheelchair, as shown in Fig. 3) for the maximum load of the user. Result showed that a user with 100 kg is the best in good conditions for handling handlebars, wheelchair operation and metal tube frame. The front part is located the battery department and revealed a heavy 24 volts battery was roughly 2 kilograms. Moreover, the driving test on the slope pathway showed the results that completely different to the smooth pathway, observed in Table I and Table II.

Fig. 7 presented a user with 80kg (purple line) used longer periods than the others while driving electric wheelchair on the 8 ° slope pathway, when comparison with similar distance. Early study reported that a slope environment was major problem in driving wheelchair, and the power assist control unit was useful for users to manoeuvre wheelchair under slope environment [7]. On the other hand, Fig. 8 presented a user with 50kg (blue line) obtained 1.74 meter per second of average speed, and this is the fastest speed in Table II. However, the better speed of a wheelchair driving is a greater number presented.

TABLE I. Wheelchair Driving Test on a Slope Direction

Persons with disability (kg)	Running distance (m)					Average speed (m/s)
	10	20	30	40	50	
50	1.71	3.42	5.13	6.84	8.55	0.58
60	1.79	3.60	5.37	7.16	8.95	0.56
70	1.93	3.67	5.40	7.32	9.15	0.54
80	1.93	3.86	5.79	7.72	9.65	0.52

TABLE II. Wheelchair Driving Test on a Flat Direction

Persons with disability (kg)	Running Distance (m)					Average speed (m/s)
	10	20	30	40	50	
50	5.73	11.46	17.19	22.92	28.65	1.74
60	6.11	12.22	18.33	24.44	30.55	1.64
70	6.25	12.49	18.75	24.99	31.25	1.60
80	6.38	12.76	19.14	25.52	31.90	1.56

H-Bridge circuit using transistor is the most common circuit for many applications in robotics engineering and automation. Initially, the step to get into the robotic control, the simple and practical structure of H-bridge circuit with eight transistors for controlling a DC motor, introduced in this project in Section B.

The technical test was done on the H-bridge circuit, characterised the working of H-bridge circuit to provide an inside into the driver circuit to get better understanding on how to control a DC motor in both clockwise and counterclockwise directions. Fig. 9 reveals outputs of the signal pulse from the microcontroller to H-bridge circuit, which is passed through the Opto-isolator circuit.

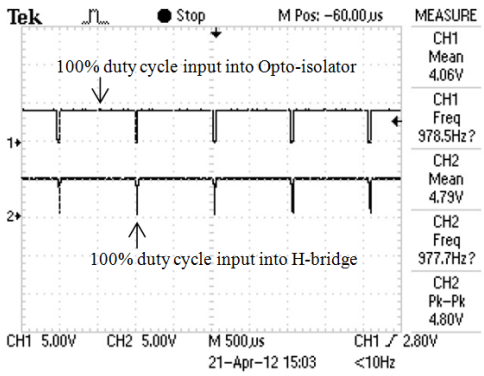

Figure 9. 100% of signal pulse generated by microcontroller to H-bridge circuit, which is passed throughout the Opto-isolator circuit associated parameters in Table III

For example, Fig. 9 demonstrates 100% of duty cycle input into Opto-isolator (signal on the top) and H-bridge circuits (signal on the bottom), in that order. The technical test was resulted in Fig. 9, confirmed that H-bridge function precisely received the PS1 and PS2 (see Fig. 5) for a stable rotating DC motor. For the period of the technical test, a wheelchair was in static condition. Then the accelerator was changing the positions to vary pulse width modulation to the H-bridge function, and the mean voltage variation in H-bridge was measured incorporating with forward and backward switches, referenced to the voltage inputs into Opto-isolator as shown in Table III.

TABLE III. TECHNICAL TEST ON VOLTAGE CHANGE TO H-BRIDGE CIRCUIT DURING THE ACCELERATION

Duty Cycle	**Voltage Reference**	**Mean Voltage Alteration while Increasing Accelerator in Forward/Backward**		**Alteration (%)**	
		Input into Opto-isolator	Input into H-bridge	Input into Opto-isolator	Input into H-bridge
0	0.00	0.15	0.04	15	3
25	1.20	1.13	1.24	6	4
50	2.40	2.05	2.33	14	10
75	3.60	3.08	3.60	14	7
100	4.80	4.06	4.79	15	8

Electric wheelchair was estimated a time consumption of using a power driver component assembled with traditional wheelchair as well as a disassembled task. Table IV reported five times in performing both assembled and disassembled tasks. Consequently, it was reported that it spent longer period in assembled electric wheelchair than deconstructed its components. The averages time consumptions in both assembled and disassembled electric wheelchair were 108.04 s and 33.08 s, respectively. Therefore, it seems that the assembled task was used more time than disassembled mission because the user is taking time in alignment of the connection part (see Fig. 3) in the power driven component to perfectly joint with a traditional wheelchair and checking its.

TABLE IV. TECHNICAL TEST ON TIME CONSUMPTION IN BOTH ASSEMBLED AND DISASSEMBLED ELECTRIC WHEELCHAIR

No.	**Time Consumption for Translation of Electric Wheelchair (s)**	
	Assembly	Disassembly
1	121.06	33.37
2	105.5	31.31
3	102.26	36.50
4	104.21	32.17
5	107.16	32.16
Average	108.04	33.10

IV. CONCLUSION

In this work, we proposed the electric wheelchair that built from a convectional wheelchair. Microcontroller is a key to success in programming wheelchair movement (partly control direction). A practical driving assessment of our wheelchair demonstrated that it achieved a reasonable performance, and the driving test was done on the flat straight and roughly eight degree slope courses. The results showed that the wheelchair obtained the best speed while running on the smoothed pathway with load of 50kg driving volunteer, and the speed was reduced accordingly to the driving on the slope course. Besides, the technical test was considered on H-bridge function to rotate a direct current motor during the static wheelchair including the accelerator was varies. Technical test result demonstrated that H-bridge circuit is correctly received the pulse width modulation, and adequate voltages to control a DC motor. The time consumption in constructed electric wheelchair was spent for 2 minutes roughly. Battery weight was a limitation of this work and it may be affected to the driving speeds.

Future work includes improvement of the battery life and power supply unit to reduce the weight of the battery, the driving force/speed on a study of gear and chain driven (a mechanical advantage), and lastly the safety performance with inclusion of brake directly connected to stop direct current flowing to microcontroller.

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Nuntachai Thongpance is currently associate professor and head of Division of Biomedical Engineering, Department of Physics, Rangsit University. He is one of a key person to drive the biomedical engineering education in Thailand. He established undergraduate course in medical instrumentation and biomedical engineering at Rangsit University. Nuntachai received his Master of Engineering in nuclear technology from Chulalongkorn University in 1988, and his Bachelor of Science in physics with the second-class honours from Prince of Songkla University in 1984. His research interests include medical device, bioinformatics, biomedical engineering and healthcare management engineering.