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Design and Construction the Ankle Movement Machine for the Hemiplegia Patients

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***Abstract*— The purpose of this paper was to design and construction of ankle movement machine for the hemiplegic patients. This machine has adopted the principle of passive and assistive motion exercise for the patient. The designed machine composed of 3 main parts: 1) the set of foot movement consists of machine supporting foot systems and DC motor, 2) the hardware part comprises of microcontroller Arduino Mega 2560 R3, display screen (LCD4 x 20) and electronic circuits and 3) the software for controlling the operation of the machine program with C language. The results of functional testing found that the machine can be bobbing up to 20 degree and down to 39 degree. Testing result of the timer accuracy for the ankle movements with a stop watch, Casio, Model HS-5 showed that the accuracy was 100 percent.**

***Keywords*—Passive Motion, Hemiplegia Patients**

I. INTRODUCTION

Paralysis of the left or right half of the body is result of damage to one side of the main motor nerve pathways which runs down from the surface of the brain to the spinal cord. The hemiplegia occurs on the side opposite the brain disorder. The hemiplegia is a cardinal sign of stroke but can be caused by multiple sclerosis, brain inflammation, brain tumor or injury. The arm was usually more severely affected than the leg and the face may or may not be involved [1]. The lock ankle is also a problem for the hemiplegic patients for walking, the generally treatment from physiotherapist was done by the motion ankle procedures [2-3].

In this paper, we focus on design and construction the ankle movement machine for the hemiplegic patients, instead of treatment by the physiotherapist [4]. Normal angle values for ankle flexion is 20 degree and the ankle extension is 40 degree, respectively [5].

II. OPERATING PRINCIPLE/SYSTEM DESIGN

The block diagram ankle movement machine was shown in Fig.1. The button switches were used to control the machine operations. The microcontroller was the main component that controls all the operations such as DC motor, DC motor driver, alarm and display respectively. The mechanical movement part was used support the foot and leg, include of the ankle motion.

A. Concept of ankle movement by the physiotherapist

Ankle was pushed up (ankle flexion) with a 20-degree angle and pushed down (ankle extension) below a 40 degree by physiotherapists for the ankle exercise in hemiplegia patient as shown Fig.2.

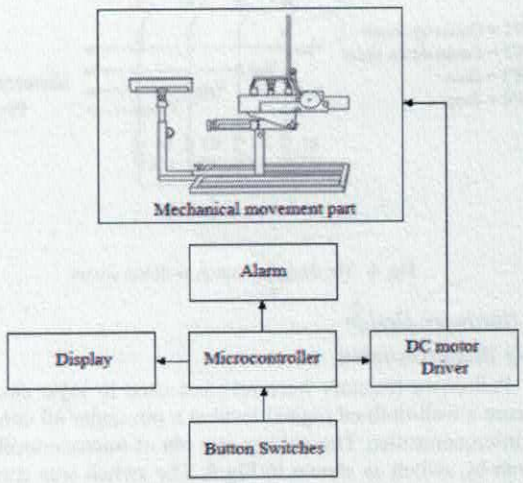

Fig. 1. The block diagram ankle movement machine for the hemiplegic patients.

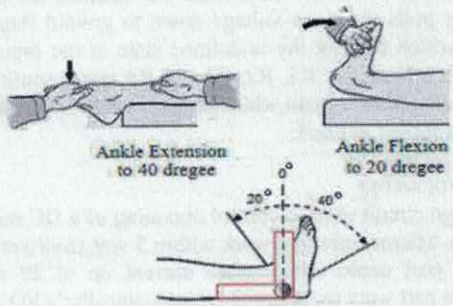

Fig. 2. Ankle movement angle of the hemiplegia patient [5].

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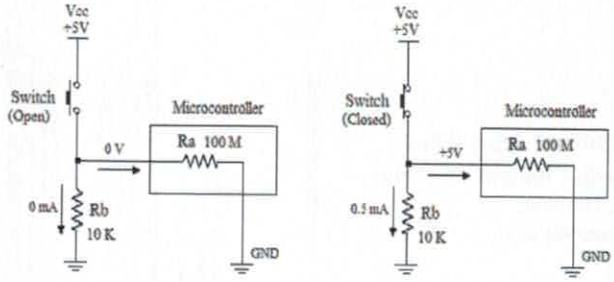

Fig. 3. Equivalent circuit of interfacing between button switch and microcontroller

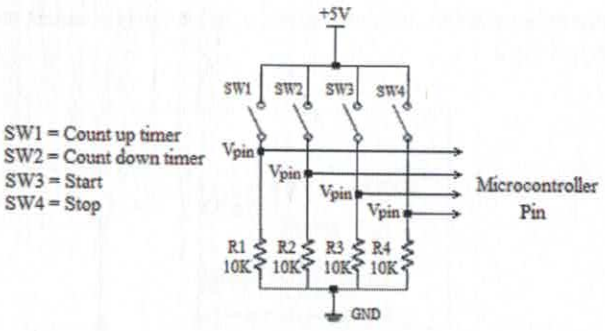

Fig. 4. The designed button switches circuit.

B. Hardware Design

1) Button Switches

Pull-down resistors were resistors used in logic circuits to ensure a well-defined logical level at a pin under all conditions of microcontroller. The voltage at a pin of microcontroller was given by switch as shown in Fig.3. The switch was connected between the supply voltage (Vcc) and a microcontroller pin. When the switch was closed, the microcontroller input was at a logical high level, but when the switch was opened, the pull-down resistor pulls the input voltage down to ground (logical zero value) which prevent the undefined state at the input of microcontroller. Note that R1, R2, R3 and R4 was essential in order to prevent a short circuit while each switch (SW1 – SW4) was closed as shown in Fig.4.

2) DC Motor Driver

This design circuit used to control operating of a DC motor (ON or OFF). Microcontrollers work within 5 volt environment and the I/O port could only handle current up to 20 mA. Therefore this part want to design the microcontroller's I/O port can link to different voltage level circuit for drive a DC motor used current more than 20 mA. We need to use the interface circuit with relay (SRD-12VDC-SL-C) and transistor (2N3904) as switch function. From the datasheet of the 2N3904 shows $I_{C\,max}$ = 200mA, h_{FE} = 100, V_{BE} = 0.65V and V_{CE} saturate = 0.2V and the datasheet of the relay (SRD-12VDC-SL-C) shows coil voltage=12V, coil current =37mA and contact rating = 30V, 10A. It could to calculate the I_B and R_B values using the Ohm's law as follow:

$$I_B = I_C/h_{FE} \quad (1)$$

$$R_B = (V_{Pin} - V_{BE})/I_B \quad (2)$$

I_B = 37 mA / 100
I_B = 0. 37mA
R_B = (5 V – 0.65V) / 0.37mA
R_B = 11.75KΩ.

This design chosen a resistor 12KΩ (R5) as shown in Fig.5.

3) Alarm

This alarm design used to generate the sound with buzzer (AI-1622-TWT-5V-R) when timer of ankle movement has finished. From the datasheet for this buzzer shows rated voltage 5 V and rated current 30 mA and the datasheet of transistor (2N3904) was as same as above. This circuit could to calculate the I_B and R_B values using the Ohm's law as shown in equation (1and 2).

I_B = 30 mA / 100,
I_B = 0. 3mA
R_B = (5 V – 0.65V) / 0. 3mA
R_B = 14.5KΩ.

This design chosen a resistor 14KΩ (R6) as shown in Fig.6.

4) Display

The result of time was shown through the LCD screen for the user to see. We interfaced the LCD display(LCD 4 x 20) with microcontroller according to Fig.7

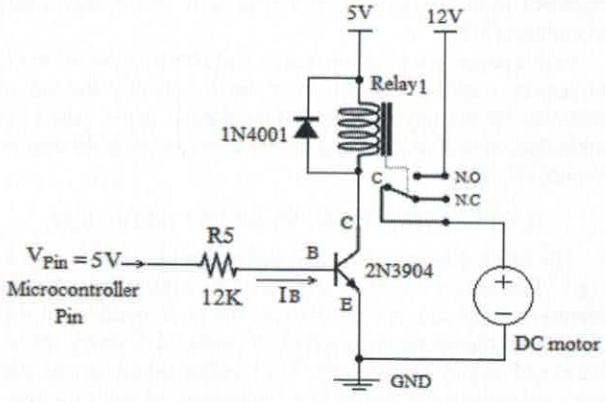

Fig. 5. DC motor driver circuit

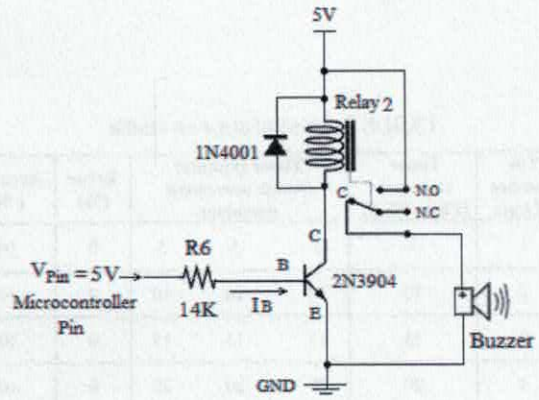

Fig. 6. Alarm circuit

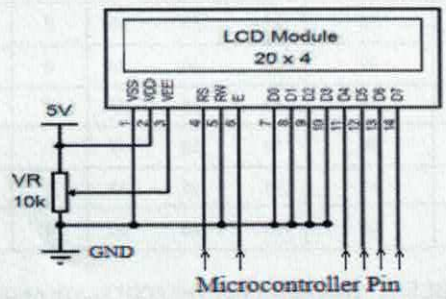

Fig. 7. Display circuit

5) Mechanical movement part

This part composed of 3 main parts: DC motor, foot plate (movement part when the DC motor rotation) and platform to support the leg as shown in Fig.8.

C. Software Design

The software for control the operation of the machine was programed with C- language by flowchart as shown in Fig.9.

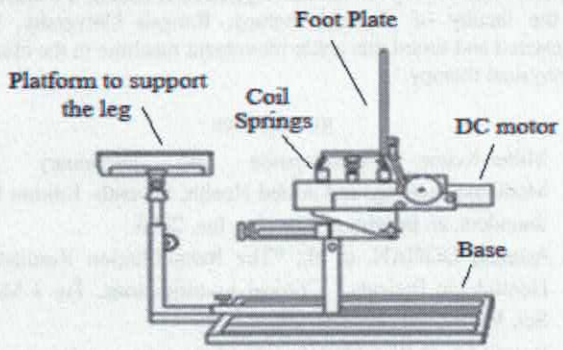

Fig. 8. Mechanical movement part

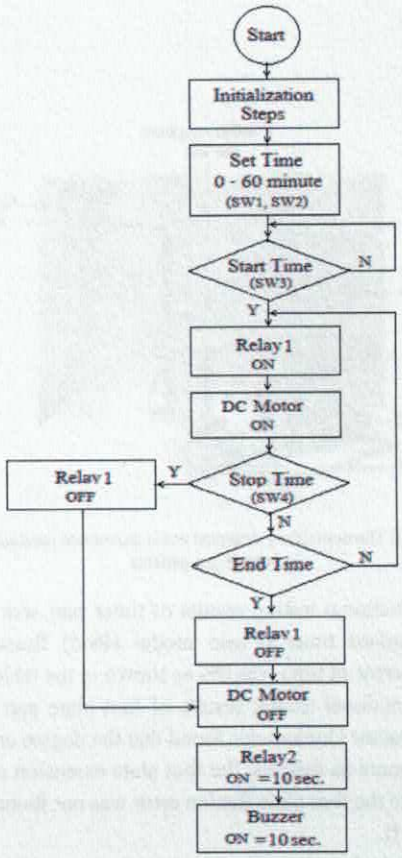

Fig. 9. Main flow chart of operating process

III. Results and Discussion

The results of design and construction of an ankle movement machine of hemiplegia patients for medical equipment application was shown as follow:

1. The completely designed ankle movement machine was shown in Fig.10. It was composed of 6 parts: 1) the foot plate (movement part), 2) the DC motor, 3) the DC power supply, 4) the platform support the leg, 5) the control panel and 6) the base .

2. The specification of an ankle movement machine was used with 220 Vac, 50Hz power supply. This machine had 2 functions of operating. The first function was the timer part which displayed on the panel of machine, it could be set count up (SW1) in rang 0 - 60 minutes , count down (SW2) in range 60 - 0 minutes, and start /stop (SW3 / SW4) by pressing each button switch. The second function was the mechanical movement parts which consisted of a foot plate, it could move normally as follow: the foot plate extension to 40 degree and the foot plate flexion to 20 degree according to the physiotherapist treatment as described in Fig.2.

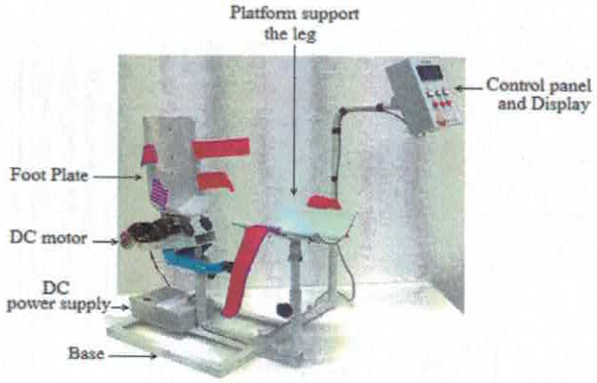

Fig.10 The completely designed ankle movement machine for the hemiplegia patients

The functional testing results of timer part was compared with a standard timer (Casio model HS-5) found that the percentage error of time was 0% as shown in the table I.

The functional testing results of foot plate part compared with a Protractor Goniometer found that the degree error of foot plate movement as follows: the foot plate extension error was 1 degree while the foot plate flexion error was not found as shown in the table II.

The clinical testing an ankle movement machine was done by lecturers from the faculty of physical therapy, Rangsit University. We test on the 10 volunteers and 3 hemiplegia patients. The clinical testing result was accepted by the lecturers from the faculty of physical therapy.

IV. Conclusion

In this paper, we focused on the design and construction the ankle movement machine of hemiplegia patients aims to protect the stick ankle. This machine composed of 6 main parts: foot plate, DC motor, DC power supply, platform support the leg, control panel and base respectively. The operating of this machine had 2 main functions as follow: the timer part could be set count up (SW1) in range 0 - 60 minute, count down (SW2) in range 60 - 0 minute, and start / stop (SW3 / SW4) by pressing each button switch and mechanical movement part, the foot plate could maximal movement as follow: the foot plate extension can move up to 40 degree and the foot plate flexion can move up to 20 degree. The result of functional test of timer found that the percentage error of time was 0%. The function testing result of foot plate part compared with a Protractor Goniometer found that the degree error of foot plate movement for the foot plate extension error was 1 degree and the foot plate flexion error was not found. The clinical testing of machine was acceptable by the lecturer from faculty of physical therapy, Rangsit University.

TABLE I. TEST RESULT OF TIMER

The number of tests	Timer (minute) (Casio HS-5)	Timer (minute) (Ankle movement machine)			Error (%)	Accuracy (%)
1	5	5	5	5	0	100
2	10	10	10	10	0	100
3	15	15	15	15	0	100
4	20	20	20	20	0	100
5	25	25	25	25	0	100
6	30	30	30	30	0	100
7	35	35	35	35	0	100
8	40	40	40	40	0	100
9	45	45	45	45	0	100
10	50	50	50	50	0	100
11	55	55	55	55	0	100
12	60	60	60	60	0	100

TABLE II. TEST RESULT OF THE FOOT PLATE ANGLE

Set the foot plate angle (degree)	Protractor Goniometer (measurement) (degree)					Error (degree)
20	20	20	20	20	20	0
40	39	39	39	39	39	1

Acknowledgment

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