A Robotic Arm Design for Stroke Patients

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Abstract - This paper presents a robotic arm for stroke patents. Two SEMG (Surface Electromyography) signals collected from bicipital muscle and triceps muscle of arm, which are used to control robotic arm. When patients want to flexile arm, the SEMG signal of bicipital muscle is larger than that of triceps muscle. On the other hand, when patient want to extend arm, the SEMG signal of triceps muscle is larger than that of bicipital muscle. The robotic arm's rotation direction is decided by the difference of two SEMG signals. The torque and speed of the robotic arm are controlled by the amplitudes of SEMG signals. The system is based DSP (Digital Signal Processor). H-bridge is used to drive DC motor. The experimental results show that the robotic arm can act correctly according to SEMG signals of human arm.

I. INTRODUCTION

Stroke or cerebro-vascular accident usually refers to the neurological symptoms and signs caused by disturbance in the blood vessels supplying blood to the brain. Stoke can cause significant impairment of neural which can affect the muscles' function. Stoke patients are normally suffering from disability. A lot of researches revealed that stoke patients' muscle volume reduced, muscle fiber shorted [1, 2]. Rehabilitation is clinically important for stoke patients. Muscle strengthening, resistance training are applied to counteract the muscle changes and the affected function [3-5]. Arm therapy has been proven to have positive effects on the rehabilitation progress of stoke patients by several studies [6, 7]. Some robotic arms have been developed and applied to help stroke patients' rehabilitation [8-15]. These researches mostly focused on the effects of robotic arm on therapy. Several studies described how to design robotic arm [6, 15]. Report on the six degree of freedom using minimum objective function is presented [16]. It is also flexible enough to handle other objective functions and constraints. Tobias [17] also presented a novel arm robot which had six-degrees of freedom and the control strategies were based on impedance and admittance architecture. Report on iterative learning robot has been reported and a robotic gait simulator has been developed [18]. There were few robotic arm based on SEMG signals of arm. In the paper, a robotic arm is designed that is based on SEMG signals of arm. The signal is processed so as to recognize as the input to control the robotic arm. A power electronic driver is developed to control the motor to activate the motion of the arm. The direction, torque and speed can be controlled by the SEMG. The device developed is a combination of a number of discipline including the control, DSP system, electronic circuit design, power electronics for motor drive and the rehabilitation engineering. The circuit, control and the drive method will be discussed and presented in details in this paper.

II. DESIGN OF THE ROBOT SYSTEM

A. H-bridge Converter for Robot DC motor drive

The PWM drive provides an efficient control for small motors. These drives operate at voltages and current levels limited by the power switches selected. The DC bus voltage provides the DC power for the H-bridge converter drive shown in Figure 1. The switches are switched on and off to provide an average DC voltage to the motor. The use of permanent magnet motors eliminated the need for field current regulators. For the present system, a low cost configuration is proposed. Therefore the component selection is also needed to consider simple and low cost units.

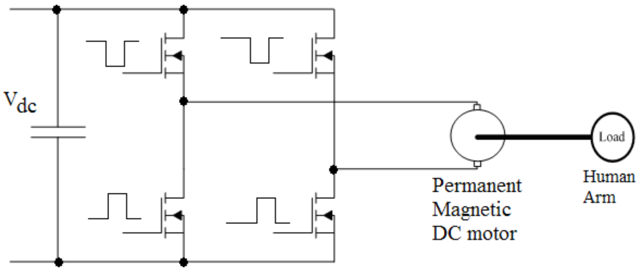

Figure 1: H-bridge converter for DC motor

The H-bridge converter consist of two inverter legs and each leg is formed by two transistor and is a MOSFET The transistor is controlled to on and off in pulse-width modulation (PWM) manner in order to provide the effective voltage to the motor. The PWM method is used to regulate the armature current for the motor and hence to control the motor torque. Sensor is put to regulate the motor position which is then control the patient arm or the robotic arm's movement.

The voltage applied to the motor can be expressed as:

$$v_m(t) = d(t)V_{dc} \tag{1}$$

The applied torque to the motor is:

$$\tau_m(t) = i_a(t)k \tag{2}$$

where $i_a(t)$ can be obtained from:

$$\begin{aligned} R_a i_a(t) + L_a \frac{di_a(t)}{dt} &= v_m(t) - k_e\dot{\theta} \\ &= V_m d(t) - k_e\dot{\theta} \end{aligned} \tag{3}$$

where R_a and L_a are the armature resistance and inductance of the motor.

B. Hardware circuit Implementation of the robot system for rehabilitation

1) *Block Diagrams of the System:* As shown in Figure 2, the 12V dc voltage is obtained by using 220VAC input switching mode power supply. DC/DC power modules are also used for the power conversion of 12V to other dc levels, such as -12V, +5V, +3.3V.

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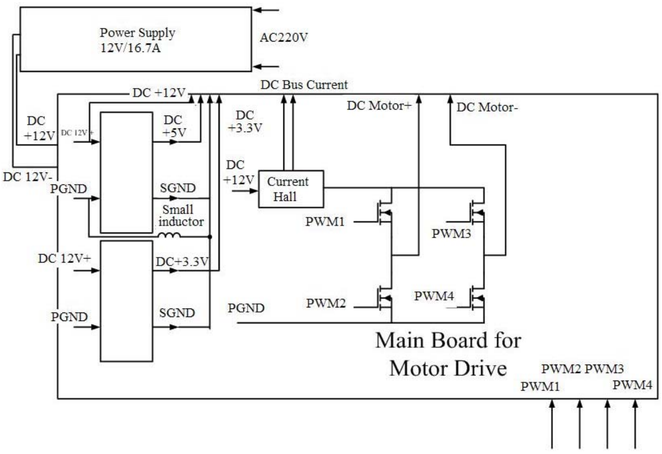


Figure 2: Block diagram of Main board for motor drive

The dc bus current is monitored by using a Current Hall. The dc motor is controlled by the output of the H-bridge converter. The power rating of the DC motor is 200Watt. The input maxim current of the dc motor is 16Amp. The output torque ranges from 0 to 10Nm with gear box ratio 40:1.

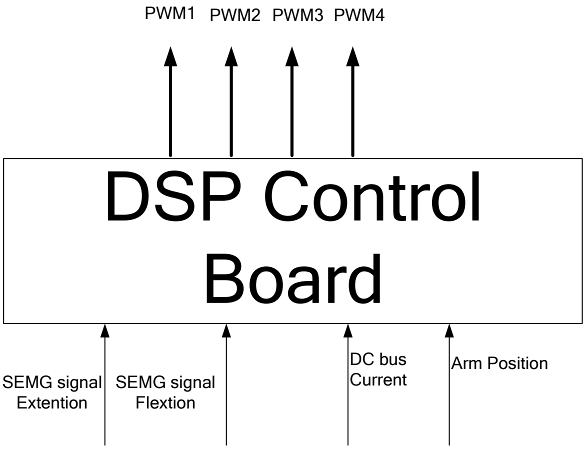


Figure 3: Block diagram for control board

As shown in Figure 3, the dc bus current, arm position, SEMG signal of Extension and Flexion are measured and sent to the DSP control board. Four channels of PWM control signals are generated form the DSP control board to trigger the power switches for controlling the dc motor.

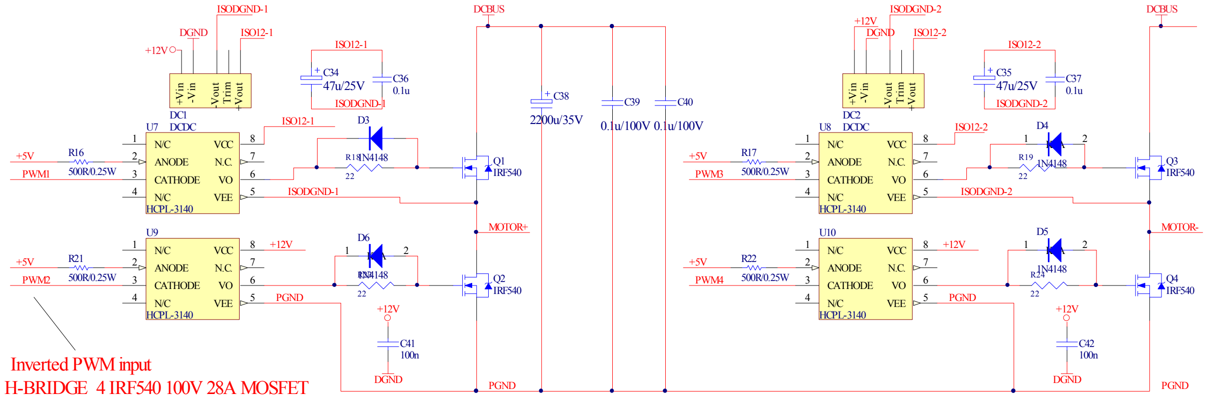


Figure 4: Schematic of H-bridge converter for dc motor

2) Hardware Implementation:

The schematic of main circuit(H-bridge) are shown in Figure 4, where the power switches MOSFET IRF540 with power rating 100V 28A as well as the driver IC HCPL-3140 are selected for this design. The driver of the upper power MOSFETs of the two legs are both supplied by an isolated power 12V-12V dc/dc converter. Figure 5 shows the prototype of the main board which consists of the power supply, power electric motor drive and the gate control electronics. , and Figure 6 shows the control board of the motor drive. The system control is implemented by using a TMS320F2808 DSP controller.

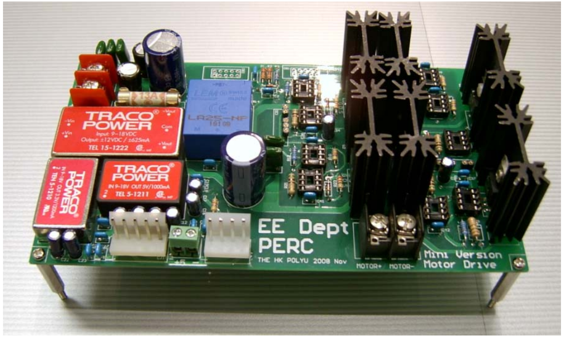


Figure 5: Prototype of the main board

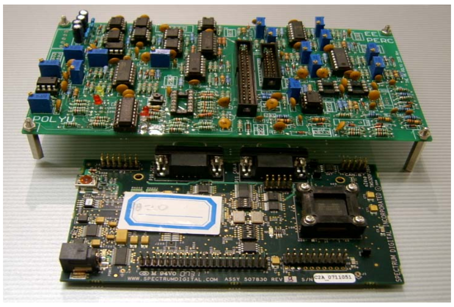


Figure 6: Prototype of the control board

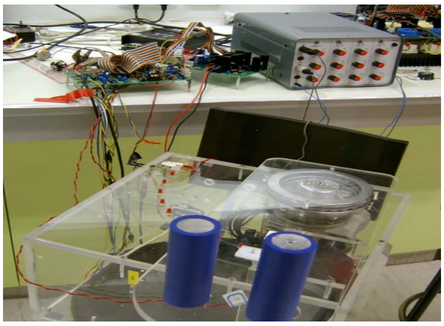


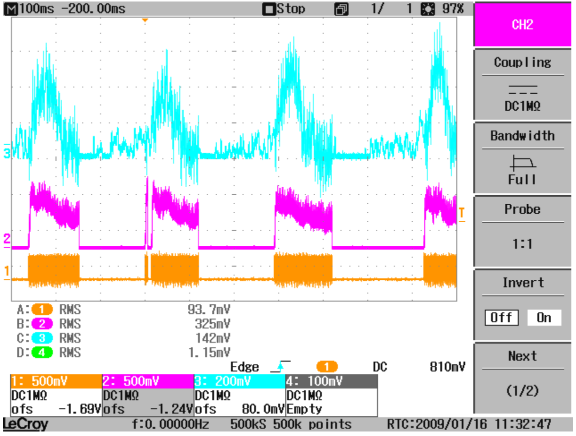
Figure7: Robot system prototype

III. EXPERIMENTAL RESULTS

The robot system prototype shown in Figure 7 is constructed in laboratory. The system is a mini-version as compared to the robotic arm for rehabilitation in a hospital. The direction of the arm movement is indicated by the 10 LEDs that are installed on the panel as shown. The rotation range is 90 degrees. Each end is protection by a micro-switch that provides a secondary protection for the limit of angle range. The arm rest that is formed is shown in the picture that is constructed by the plastic piece with two blue pillars for hand hold. The motor is connected to arms. The arm rest is connected to the motor through a 90 degree gear fixture. Using the gearbox allows the fully utilization of the mechanical advantage and reduce the overall motor size and power.

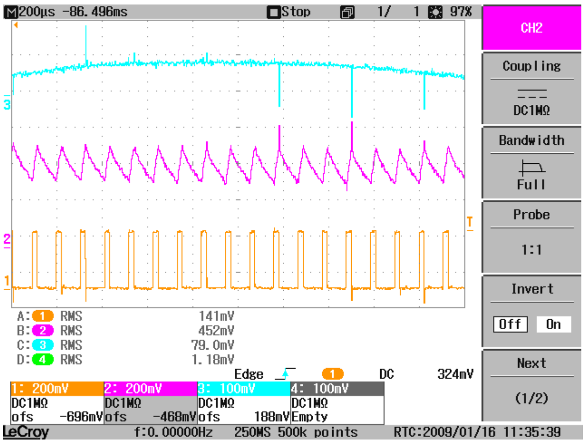
The switching frequency of the triangle carrier for PWM generation is 10 kHz. The modulation parameter for the study ranges from 0.1 to 0.5 (Max). Figure 8 shows the experimental results of flexion movement for the robot system, where CH1~CH3 show the PWM signals for power MOSFET, Motor winding current, and SEMG signal of the flexion, respectively.

It can be seen that the SEMG signal is clean. The signal has also been filtered digital in order to reduce the noise level. The PWM signal is amplified by the Gate driver to provide a 15V to drive the Mosfet.



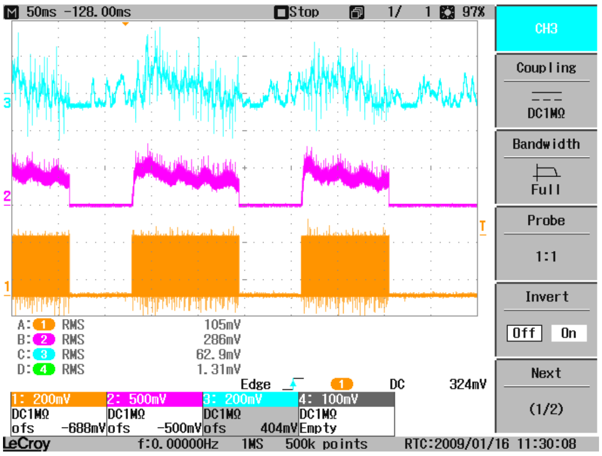
(a) Larger scale

(ch1: 0.5V/div, ch 2: 0.5V/div, ch3: 0.2V/div; time base 0.1s/div)

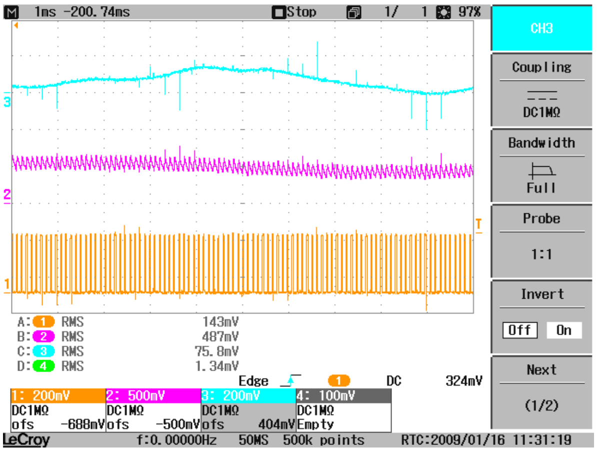


(b) Enlarge

Figure 8: Experimental results. CH3: SEMG signal of flexion; CH2: Motor current; CH1: PWM signals for Power MOSFET (ch1: 0.2V/div, ch 2: 0.2V/div, ch3: 0.1V/div; time base 200µs/div)



(a) Large scale



(b) Enlarge

Figure 9: Experimental results. CH3: SEMG signal of Extension; CH2: Motor current; CH1: PWM signals for Power MOSFET

Figure 9 shows the experimental results of extension, where CH1~CH3 show the PWM signals for power MOSFET, Motor winding current and SEMG signal of the extension, respectively.

The experiment has shown that the robotic arm can successfully provide a training for the stoke patent. Patient can has SEMG signal measured from the arm can usually improve their arm movement with a few months. The torque generated from their arm can be increased from 2N to more than 5 Nm.

A calibration program has also been implemented in the system. Each patient will be calibrated for his/her maximum torque provide by his/her arm. This data is correlated with the SEMG signal. Different power ratings is then set that is used to train the patient with the max torque and SEMG as the reference.

IV. CONCLUSION

In the paper, a detailed implementation of the robot arm system, including main circuit design and control circuit design, is presented. The H-bridge converter is used for controlling the input voltage of the DC motor. Two SEMG signals collected from bicipital muscle and triceps muscle of arm are used to control robotic arm. The robotic arm's rotation direction is decided by the difference of two SEMG signals. The torque and speed of the robotic arm are controlled by the amplitudes of SEMG signals. The machine can be regulated with different levels of the torque in order to provide different training need for the patient. The device is small and portable. It is expected the machine can provide a home-based solution for stoke patient instead of the training conducted in hospital. The experimental results show that the robotic arm can act correctly according to SEMG signals of human arm.

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