The Modelling Design for Arm Strength Training Machine with Biofeedback

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Abstract - *This paper develops a friendly human interface for an arm strength training machine with biofeedback system to reduce the occurrence of improper operation of exercise machine by real time monitoring. In order to shorten the development schedule duration and reduce the manpower needs, the modelling design of the arm strength training machine with biofeedback is presented for the consideration of system integrity on chip in future work. Finally, a prototype of arm strength training machine with biofeedback system is implemented and demonstrated. The experimental results show the feasibility of the modelling designed system.*

Keywords: arm strength training machine, biofeedback

1 Introduction

A study indicates that chronic stroke patients who gained maximal functional benefits from the biofeedback intervention initially had greater active range of motion at all major upper extremity joints [1]. Consequently, the proper utilization of electromyographic biofeedback can lead to substantial improvements among select chronic stroke patients and can be of considerable functional benefit to others. Therefore, the usage of EMG not only can help the physical therapy but also achieve the more effective rehabilitation [2]. An arm strength training machine (ASTM) based on an embedded microcontroller system that utilizes a PMSM motor drive to simulate the stack of iron weights has better performance than that of the conventional exercise apparatus is presented in [3]. The ASTM with biofeedback system not only can help the physical therapist diagnose the progress of rehabilitation, but also raise the user exercise desire. The modeling design methodology has been widely applied to electronic device as well as electrical equipments for reduction of development schedule duration. Recent years, the highly development of semiconductors has made the system on chip become more easy to realize. Therefore, the modeling design of an arm strength training machine with biofeedback that includes a microcontroller module, protection circuit module, gate drive module, inverter module, speed and current sensor module, communication interface module, and the EMG amplifier module, is presented in this paper. The software programs are written in C language and programmed based on the MPLAB integrated development environment (IDE) tool by Microchip technology incorporate [4]. Finally, the experimental results show the feasibility and fidelity of the complete designed system.

2 The Modelling of ASTM

The modeling of an arm strength machine with EMG sensor based on an embedded microcontroller system is shown in Fig. 1. It consists of a microcontroller module, protection circuit module, gate drive module, inverter module, speed and current sensor module, communication interface module, and the EMG amplifier module. The embedded microcontroller, such as the dsPIC 30F4011, or TI TMS28F335, as well as integration of several peripheral assembling the embedded microcontroller module, is the core controller of the ASTM. The independent power source module provides a 5-volt and four sets of 15-volt voltage to microcontroller and the gate of MOSFETs, respectively. The gate drive module is designed to support PWM signal to the gate of switching MOSFET. The photocoupler TLP250 is used for electrical isolation module between the microcontroller system and the high DC voltage bus voltage as well as the independent power source. The motor currents are sensed through the speed and current detection module. The ACS 712-20 current sensor IC which has the resolution of 100 mV per ampere, is adopted for stator phase current detection.

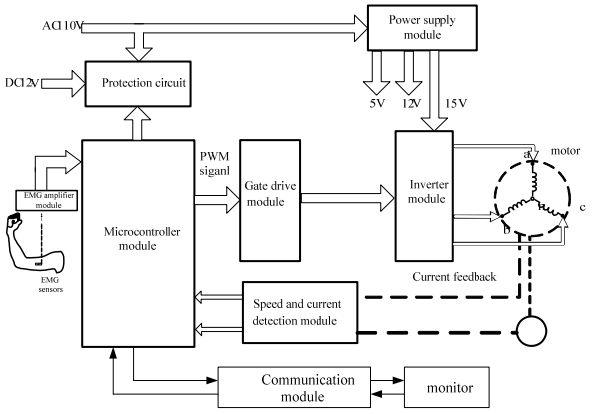

Fig. 1. The system modelling of ASTM with EMG.

The EMG amplifier module consists of the EMG electrodes, the EMG amplification circuits and the bandpass filter. Two electrodes of EMG sensor are attached to the surface skin of an arm. A third electrode is attached to the common point for

voltage reference. The potential difference is generated when the muscle group contracts and then fed into the instrumentation amplifier for amplification. Therefore, system modelling design described above, such as embedded microcontroller module, gate drive module, speed and current sense module and EMG amplifier module bring the design more friendly and thus shorten the development schedule.

3 The Experimental Results

The prototype of arm strength training machine is tested under different load conditions in which are fulfilled with the dynamometer. Fig. 2 shows the command setting of desired force 2 kg and desired speed of 10 cm/sec. The waveform of EMG signal is also displayed in the lower part of Fig. 2, so that the user can monitor the muscle action in real time when she/he operates the ASTM. This proves that the EMG signal biofeedback can reflect the muscle contraction and be displayed on the human interface when user operates the ASTM. The current response while the ASTM being manipulated by 2 kg force is shown in Fig. 3. The experiment is repeated by the same cycle of 60 seconds. Observing the waveform of Fig. 9, it can be seen that the motor draws about the 300 mA current to counter the force exerted by the user. This verifies the system design feasibility. The data displayed in Fig. 3 is firstly saved in the memory and then sketched by using the Microsoft EXCEL software. The integrity of complete system design by modelling each function block of the embedded microcontroller module, independent power module, communication interface module, gate drive module, and inverter module, speed and current sensors as well as the EMG amplifier module together has been verified by experimental tests. Finally, the practical system configuration of designed ASTM with EMG sensor is shown in Fig. 4.

Fig. 2. The test for force 2 kg-cm, speed 10 cm/sec and EMG

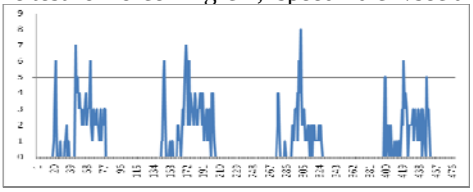

Fig. 3. The current response for 2 kg-cm being applied and released

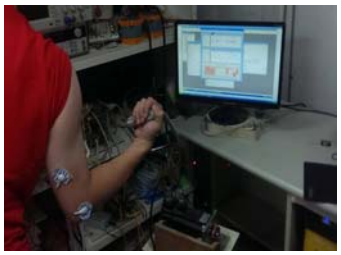

Fig. 4. The practical system of ASTM with EMG sensors.

4 Conclusions

The establishment of interactive communication between ASTM and the user, can make the exercise and rehabilitation therapy become more friendly. This paper develops a friendly human interface for ASTM with EMG system to reduce the occurrence of improper operation of exercise machine by real time monitoring. The experimental results demonstrated by using the human interface display, has verified the system integrity for system hardware and software design. The modelling design of the arm strength training machine with biofeedback is also presented for the consideration of system integrity on chip in future work. The experimental results show the feasibility and fidelity of the complete designed system. Therefore, system modelling design described above, such as embedded microcontroller module, isolation module, current module and EMG module can bring the design more friendly and thus shorten the development schedule.

5 Acknowledgment

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6 References

[1] Steven L. Wolf and Stuart A. Binder-Macleod, “Electromyographic Biofeedback Applications to the Hemiplegic Patient,” Physical Therapy, Journal of American Physical Therapy, vol. 63, no. 9, pp 1393-1403, Sep. ,1983.

[2] Tony Boucher, Sharon Wang, Elaine Trudelle-Jackson, Sharon Olson, “Effectiveness of surface electromyographic biofeedback-triggered neuromuscular electrical stimulation on knee rehabilitation,“ North American Journal of Sports Physical Therapy, vol. 4, no. 3, pp 100-109, August 2009.

[3] Tze-Yee Ho, Mu-Song Chen, Hung-Yi Chen, and Po-Hung Chen, “The Design and Implementation of Arm Strength Training Machine”, IEEE EUROCON 2013, July 1-4, 2013, Zagreb, Croatia.

[4] dsPIC30F4011/4012 Data Sheet, Microchip Technology Inc., 2005..