Proceedings - 19th International Conference - IEEE/EMBS Oct. 30 - Nov. 2, 1997 Chicago, IL. USA

A Multichannel Programmable DSP-Based FES System

Chih-Lung Lin*, Han-Chang Wu, Yan-Cheng Kuan
Maw-Huei Lee, and Te-Son Kuo
Department of Electrical Engineering National Taiwan University Taipei 10617,Taiwan
*E-mail: cllin@cc.ee.ntu.edu.tw

Abstract -- A low cost, programmable, galvanically isolated bipolar eight channel stimulator for patterned electrical stimulator has been developed. The design is based on a newly developed concept. A TMS320C31 DSP-based stimulator is used to generate a wide range of either arbitrary current waves or biphasic current pulses. The DSP-based stimulator can process the stimulated electromyographic (EMG) signal simultaneously. A user-friendly interface for programming of the stimulator has been developed for the host computer, using Windows environment and a push-button control for functional application of the system.

I. INTRODUCTION

Numerous stimulators have been designed for surface stimulation of neuro-muscular structures, from simple single-channel, to very sophisticated multichannel units.[1-3], Several commercially available stimulators (4Ch)-DES, Novi Sad, Yugoslavia, (4Ch)-Quadstim, Biomech Design, Edmonton, Alberta), developed for standing and gait restoration, have been used in humans suffering paraplegia, It became obvious that each of these systems is meant for a specific application, hence it was almost impossible to use them differently than suggested by the manufacture.

We established the design criteria focusing on functionality, electrical safety, reliability, ease of use, rugged construction and portability. Programmability was incorporated to enable researchers to study and control stimulation sequence more effectively.

The stimulator can generate a wide range of either arbitrary current waveforms or biphasic current pulses. The two modes are all produced by the friendly graphics user interface of the host computer and the users can draw arbitrary stimulus waveforms on the computer screen by the computer's mouse. The biphasic pulse mode can also be produced by the standalone stimulator using keypads without the computer. These parameters, such as amplitude, frequency, and pulse width, are fully controlled and programmed through the computer or the keypad.

It is an another goal to try to develop a closed loop stimulator by the fast operation ability of digital signal processor (DSP). The output current is controlled by the DSP output so users can vary the amplitude at will. The input/output interface between the two units has been optocoupled.

The system is intended for stimulation of the primary motor cortex with the aim of evoking a muscle twitch or movement. The next section describes the system specifications, the hardware implementation of the stimulator and its associated software.

II. METHODS

A. Implementation of Hardware

The hardware is divided into a host computer, a main system part , power supply, and some peripheral devices. Fig. 2. illustrates a simplified block diagram of the multichannel electrical stimulator. The host computer transmitted the parameters of the arbitrary stimulation signal to the DSP-based stimulator by the parallel port.

The main system part includes a 32 bit floating point TMS320C31 digital signal processor, the analog part, and the feedback part. The DSP has a fast operation ability , so it allows a sharp control of time to deliver arbitrary stimulation sequence. The analog part consists of 8 similar channels. Each one contains an 8-bit digital-to-analog converter (DAC), switch capacitor filter, and a programmable current-source. The output of each current-source is connected to an appropriate electrode for delivery of the stimuli. The output current is controlled by DSP so users can vary the amplitude at will. The feedback part includes the analog to digital converters to fetch the stimulated EMG signal.

A switch-mode power supply to provide high voltage to keep the constant current source operating normally. The input/output interface between the two units has been optically isolated.

The peripheral devices include an external memory , a liquid crystal display, and a keypad. The keypad is used to setup the parameters of the general biphasic stimulation pulse when the stimulator is not connected to the host computer. The LCD is used to display the stimulator information to the operator.

B. Implementation of Software

The programming structure is divided into two parts. The first one is a DSP-based stimulator software

incorporating the control program and the signal processing program. The control program receives the parameters of the stimulation signal from the host computer or the keypad to control the stimulator. The main function of this software is to provide all the utilities to enable it as a current monitor at the startup, deliver a controlled width pulse on each channel and manage all the driver function. The signal processing program can analyze the EMG signal activated by the stimulator. The analysis of the EMG signal can provide the help for the modification of the parameters of the next stimulation current pulse. The other software part is a PC's program. The software has been written with Microsoft Visual C++ 4.0. It provides the functionality for the host computer to download waveform descriptions to the each channel of the stimulus system. The prototype user interface allows specification of waveforms via a graphical editor. The parameters that describe the stimulation signal are independently controlled by the user via a PC under the Windows environment.

III. RESULT

The stimulator characteristic are:

1. portable, programmable, eight surface stimulation channels, eight digital input channels.
2. Pulse width from 50us to 1500ms
3. Pulse width, frequency and stimulation time are all under software control.
4. Each channel has a current source that can deliver from 0 to 120 mA and can generate a voltage output from 0 to 200 V with a typical 1.5 K ohms load impedance.

New features:

1. Each output is electrically isolated from the other outputs and from the power supply.
2. It incorporates a small keypad and liquid crystal display which allows entering the pulse width, frequency and stimulation time on each channel.
3. The arbitrary stimulation waveforms are independently controlled by a graphical editor via a PC under the Windows environment.
4. The input/output interface between the analog and digital modules is optocoupled.
5. The portable stimulator can analyze EMG signal by the DSP chip simultaneously.

IV. CONCLUSION

A flexible, powerful, low-cost, and DSP-based electrical stimulator is proposed. This electrical stimulator along with its associated software allows the user to specify arbitrary stimulation waveforms or the wide range of the biphasic constant current stimuli. Because the system has a DSP architecture, it is easy to process the stimulated EMG signal immediately and try to modify the parameters of the next stimulating pulse .

The features of the stimulator will allow it to be used for research purpose, and also for home and hospital use. It can be used for functional and for therapeutic surface application. The use of the TMS320C31 enables the future development of closed loop controllers.

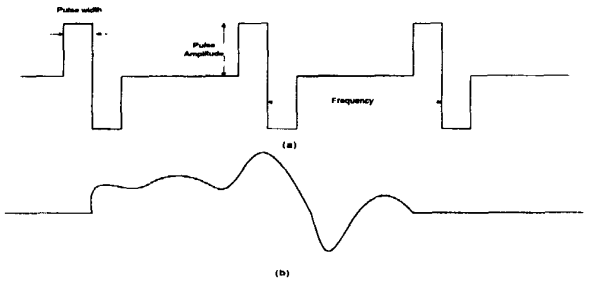

Fig. 1. (a) General characteristics of the biphasic current pulse, (b) Arbitrary stimulation waveform.

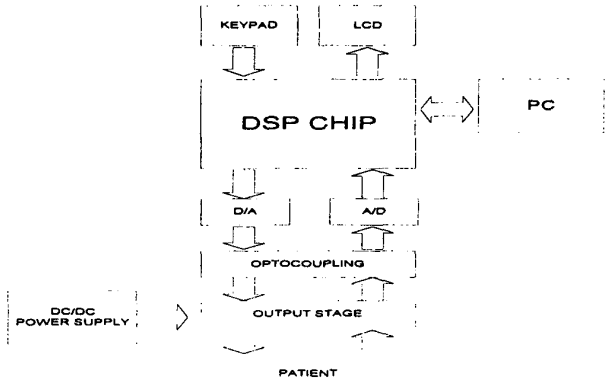

Fig. 2. a simplified block diagram of the multichannel electrical stimulator.

V. REFERENCE

[1] J. R. Buckett, P. H. Peckham, G. B. Thrope, S. D. Baraswell, and M. W. Keith, 'A flexible portable system for neuromuscular stimulation in paralyzed upper extremity,' *IEEE Trans. Biomed. Eng.*, vol. BME-35, pp. 897-904, 1988.

[2] M. Ilic, D. Vasiljevic, and D. B. Popovic, 'A Programmable Electronic Stimulator for FES Systems,' *IEEE Trans. Rehab. Eng.*, vol. 2, pp. 234-239, 1994.

[3] G. Ocadiz, and R. E. Mayagoitia, 'Programmable Eight Channel Surface Stimulator' *Proc. 16th Ann. Conf. IEEE/EMBS*, 1994