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Low Cost PC plug-in Card for Digital Processing of Transcranial Doppler Signal

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ABSTRACT

The paper presents hardware system for Digital Processing of Transcranial Doppler Signal in clinical environment. The system (DSP-TCD Card) is designed as single PC extension board and can be used both for development and evaluation of new algorithms, and for practical use in research job and diagnostic use.

1. INTRODUCTION

The meaning of continuous monitoring and analysis of blood flow velocity in neurosurgical diagnostics is still increasing [1, 2, 3]. Particularly useful is the possibility of simultaneous recording of blood flow velocity together with other signals [3]. To enable such recording it is necessary that the Transcranial Doppler Flowmeter (TCD) outputs the signal of blood flow velocity. However most of Transcranial Doppler Flowmeters (TCD) used in Polish hospitals do not provide such signal.

Additionally, estimation of maximal frequency of TCD signal is still a very interesting research topic, and new algorithms are being continuously developed and published [4, 5, 6].

Our research team is involved in development of algorithms for neurosurgical diagnostics, and algorithms for analysis of TCD signal. Therefore a decision was taken to build a system for on-line analysis of TCD signal, which will allow on-line testing and practical use of different algorithms of analysis.

2. TECHNICAL REQUIREMENTS OF THE SYSTEM

The system has to meet following requirements:

- It should have two analog inputs with sampling frequency at least 16 kHz, and resolution not less than 12 bits. (This requirement is associated with properties of TCD signal)

- It may not be a separate device with independent power supply (because such solution would lead to unacceptable increase of number of equipment and wires surrounding the patient, and obstructing the medical staff to access him). It is desirable, that the whole system should be placed on one, half-size PC extension card connected to ISA bus.
- The computational capacity of the system must be sufficient to calculate parameters of TCD signal at least every 20 ms. (It results from the blood flow dynamics, the blood flow pulse wave should be sampled with frequency not lower than 50 Hz, to assure accurate reconstruction)
- System has to be able to download TCD signal processing program from the host computer. (Because the system will be used also for debugging and evaluation of new algorithms, the modification of program must be easy and should be accomplished in software way)
- The RAM memory of the system should be big enough to allow implementation of complex algorithms.
- The system should cooperate with software for monitoring, recording and on-line analysis of biological signals elaborated by our team [7].

3. ARCHITECTURE OF THE SYSTEM

Considering the above requirements we have decided to use the fast, 24-bit digital signal processor DSP56002, working with 40MHz clock, as the CPU unit of our system. Its Host Interface provides communication with ISA Bus of the host computer with minimal hardware support (the system's ISA Bus interface contains only one 22V10 EPLD device). The built-in bootstrap code allows for downloading of processing algorithm without any additional external ROM. Interfacing to the external memory does not require any additional hardware, still providing relatively large address space: 32K x 24 bits. The memory is divided into two 16K areas, first mapped paralelly in X and P memory, and the second mapped in Y memory.

For the analog input we have decided to use two independent DSP56ADC16 sigma/delta A/D

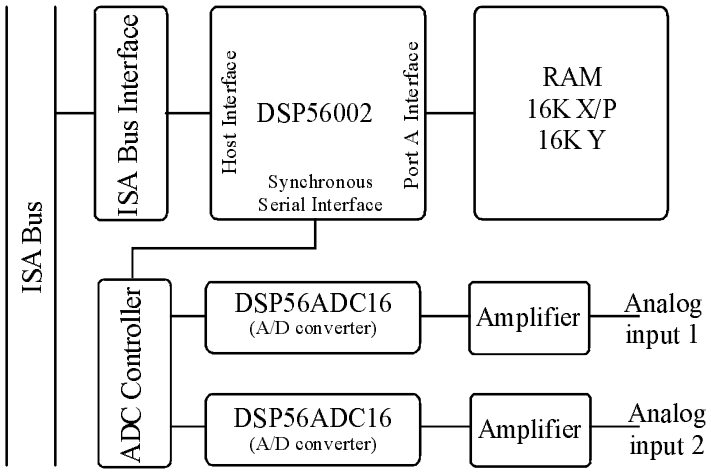

Fig. 1. Block diagram of the card for digital processing of Transcranial Doppler signal

converters with maximum sampling frequency equal to 100 kHz. Application of sigma/delta converters has eliminated the need for complex antialiasing filters. A/D converters have been connected to the Serial Synchronous Interface of DSP56002, using a simple ADC controller with one 22V10 EPLD device.

The block diagram of our system is shown in the figure 1.

The whole system has been mounted as single half-size PC extension board on one two-layer printed board (and therefore it is called „DSP-TCD Card").

4. SUPPORTING SOFTWARE

Programs executed by the DSP-TCD Card are written in the assembly language of the DSP56002 processor and compiled to the „LOD" format.

The special loader has been developed (based on the original „SLOADER.ASM" program from Motorola's BBS), which makes possible to download the „LOD" file through the Host Interface.

To make possible easy implementation of different algorithms, two automatic code generators have been created. The first one is an extension module to the SNNS 4.1 package[1], which automatically creates the assembly code implementing feed-forward neural network. The other one is an automatic code generator, creating the assembly code for digital filters designed with Scilab[2] package.

To enable integration of our card into the existing system for on-line monitoring, recording and analysis of biomedical signals [7], an additional driver routine has been written, which outputs the calculated maximum frequency of TCD signal in the additional, simulated channel of the A/D converter used sampling of another monitored signals.

5. IMPLEMENTED ALGORITHMS OF ANALYSIS OF TCD SIGNAL

Following algorithms for estimation of maximum frequency in TCD signal have been implemented:

a) Simple „percentile" algorithm [8]

b) „Geometrical" algorithm described in [4]

c) Newly developed neural-network based algorithm described in [9]

All implemented algorithms worked correctly and could be used for analysis of TCD signal.

6. OBTAINED RESULTS

Testing of the analog input of DSP-TCD Card has shown the efficient resoution of 12 to 13 bits, which is quite good result, concerning noisy environment of PC computer.

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[1] SNNS - Stuttgart Neural Network Simulator is the package for creating, training and testing of neural networks. It is freely available from:
http://www.informatik.uni-stuttgart.de/ipvr/bv/projekte/snns/snns.html

[2] Scilab - is a scientific software package for numerical computations in a user-friendly environment. Scilab is particularly useful for developing of DSP algorithms. It is freely available from:
http://www-rocq.inria.fr/scilab/

The hardware can handle sampling frequency up to 100 kHz in each of two input channels. The sampling frequency can be modified in two ways: by hardware - with appropriate selection of crystal oscillator, and by software - by decimation of acquired input samples.

Times of execution of implemented algorithms are presented in the table 1.

TABLE 1 Comparison of execution time of implemented TCD signal processing algorithms

Algorithm	Percentile	Geometrical	Neural Network
Time of execution (in processor's clock cycles)	~30000	~40000	~10000
Time of execution (in μs, with 40 MHz clock)	750	1000	250
Theoretical maximum frequency of estimation of f_{max} (in Hz)	1333.33	1000	4000

The described card and implemented analysis algorithms have been tested in different computers (ranging from 386SX/25MHz to 486/66MHz) using real TCD signal recorded on tape. Obtained results has shown that designed board is useful for required tasks. Therefore it has been introduced into the practical use in the Department of Neurosurgery of Polish Academy of Sciences for monitoring of blood flow velocity in brain vessels during the neuropsychological investigations.

7. FURTHER DEVELOPMENT

The further development of our board should be focused on following topics:

- The ISA Bus interface should be extended to enable to make use of the built-in on-chip emulation (OnCE) circuitry of DSP56002 processor. It will be particularly useful for debugging of newly implemented algorithms and for use of board as a didactic tool in our students' laboratory of Digital Processing Biomedical Signals.

  Of course in this case a dedicated user interface for OnCE should also be written.

- The user interface supporting creating of different algorithms from „blocks" implementing various, typical signal processing routines (like FFT, calculation of autocorrelation function).

8. CONCLUSIONS

Our DSP-TCD Card appeared to be an useful tool for on-line analysis of TCD signal. The sampling frequency and resolution of analog input channels are sufficient for this task. The processor capacity allows to calculate maximum frequency of TCD signal with higher than desired frequency, so it should be possible to use our card even with more complex algorithms.

The presented DSP-TCD Card may also be used as an didactic tool in teaching of Digital Signal Processing.

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