VLSI Implementation of Neural Signal Processor for Multi-Channel Spike Analysis

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Abstract— Neural signal processor (NSP) used for monitoring or manipulating brain activity typically require on-chip real-time processing of multichannel neural data computation. The EEG signal is given as the input signal, the waves of these signal is converted from analog form to digital form and is then stored in a memory. A random signal which is the input will be sent to analog to digital converter and its sent to NSP. The output from the NSP is compared from the memory and corresponding output is concluded.

Keywords — A/D Converter, EEG Signal, Neural Signal processor, Pattern Recognition Spike Sorting.

I. INTRODUCTION

Neural signal processor has been recognized as a powerful synthesizer in helping patients to detect neural disorders. Its works with the computation of the activity of the brain signals. It provides greater energy efficiency is to enable longer periods of operation with little available power.

Electroencephalography is a medical imaging technique that reads scalp electrical activity generated by brain structures. The electroencephalogram (EEG) is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media [1]. The EEG measured directly from the cortical surface is called electrocardiogram while when using depth probes it is called electro gram. EEG is measured from the scalp of the head surface. Thus EEG readings are completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with no risk.

II. EEG WAVES

The wave shapes of brain wave patterns are commonly sinusoidal. It is measured from the value of peak to peak is normal in amplitude, which is nearly 100 times lower than ECG signals. The raw EEG signal is derived from the Fourier series transform. Different frequencies of sine wave are visible in power spectrum contribution. The spectrum is continuous, from 0 Hz up to one half of sampling frequency, making certain frequencies of the brain state of the individuals are dominant. Brain waves are categorized into four main groups.

<table>
<thead>
<tr>
<th>Wave Type</th>
<th>Frequency</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta</td>
<td>&gt;13 Hz</td>
<td>Active, busy, anxious thinking</td>
</tr>
<tr>
<td>Alpha</td>
<td>8-13 Hz</td>
<td>Binaural, focus; monitor human and animal brain development</td>
</tr>
<tr>
<td>Theta</td>
<td>4-8 Hz</td>
<td>Assist in experimental cortical excision of epileptic focus; monitor human and animal brain development test</td>
</tr>
<tr>
<td>Delta</td>
<td>0.5-4 Hz</td>
<td>Assist in experimental cortical excision of epileptic focus; monitor human and animal brain development test</td>
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Applying of EEG are monitor alertness, coma and brain death, locate areas of damage following head injury, stroke, tumour, etc.; test afferent pathways (by evoked potentials); monitor cognitive engagement (alpha rhythm); produce biofeedback situations, alpha, etc.; control anaesthesia depth (“ servo anaesthesia”); investigate epilepsy and locate seizure origin; test epilepsy drug effects; assist in experimental cortical excision of epileptic focus; monitor human and animal brain development test.

III. NEURAL SIGNAL-PROCESSING BLOCK DIAGRAM AND ARCHITECTURE

Neural systems provide an important description of the central nervous system for interpreting the brain activity. [1]. Neural prosthesis systems involve the analysis of multichannel recordings from different relevant neurons for predicting intended behaviour, retentive/corrective/assistive actions. The neural signal processor have included active components [11]-[8], relatively few efforts toward embedding significant computational components for intelligent processing of the acquired neural data in a closed-loop framework have been taken.
Fig. 2 shows the interface among different constituent blocks of a typical implantable system.

Neural data is encoded as packets containing the information about the detected spikes. To de-noise the data, multi-resolution wavelet analysis [17] of the recorded signal is used and then spikes are sorted, and recognized as meaningful burst patterns across multiple channels. The process is implemented in VHDL. Fig. 2 shows the simulation results for spike detection from extracellular neural data.

The intracellular recording showing the actual action potentials to check the accuracy of spike for spike detection from the extracellular data. The original noisy data is predicted with the de-noised data and superimposed over them. The four different spikes are enlarged to show the quality of the reconstructed spikes. The DWT block constitutes the central part in the NSP unit. The wavelet transform [24] decomposes the input signal in time and frequency domains, giving rise to low-frequency coefficients, and high-frequency coefficients, called the “approximations” and “details” which help to highlight the presence of spikes by de-emphasizing the noise. The multi-resolution wavelet transform is normally realized as high-pass and low-pass filters [21].

Based on area of minimization, the integer arithmetic lifting approach [22] is suitable for sequential implementation. Each of the five lifting steps requires similar computational hardware, “processing element” (PE) as the basic computational block for the DWT module. It consists of two signed multipliers and two signed adders, as shown in Fig.4. For the overall DWT architecture, a parallel implementation is chosen, as shown in Fig.5, where the windowing module buffers enough samples before the lifting operations take place.

Overlapping window scheme (8-samples overlap in a 72-sample window) in order to avoid missing spikes on the window edges. It takes five clock cycles for the five steps to be computed. The remaining cycles required for collecting all samples of the next window are used for other processing steps, such as thresholding (32 cycles for comparing 32 approximation coefficients).
For neural signal processing, the frequency range of interest, which determines the sampling frequency, is on the order of a few kilo hertz. Considering a sampling frequency of 10 kHz, a new data sample each channel arrives every 100 s. If we consider 20 channels with time-multiplexed operation, the five-cycle DWT operations in each PE need to be complete in 5 seconds, giving a minimum operating frequency target of 1 MHz. The remaining operations overlap with the computation of wavelet coefficients for other channels.

IV. SIMULATION AND ITS OUTPUT

The figure (6-10) below shows the corresponding output of the paper which explains the four different types of waves and its digital form is taken and compared with the details that are already stored in the memory. The simulation is done by using VHDL Language. The simulation involves the formation of delta wave (0-4Hz), Theta (4-7Hz), Alpha (8-12Hz), beta (13-30Hz).
Apart from the EEG as the signal given to the input EMG and ECG signals can be traced out and compared. Also data can be analysed efficiently with low power and low noise. The simulation can be done by vhdl, veriog, matlab.

REFERENCES


V. CONCLUSION

The Neural signal processor accepts the random wave form of brain as input and it processes the functioning .Its digital values already stored in the memory is compared with the neural signal processors output. This helps the physicians to make a confirmed conclusion of the problem of the diseased patients. Future work will involve the application of the approach to other neural signal-processing steps as well as other biomedical signal-processing.


