FPGA-Based Implementation of EEG Analyzer

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I. INTRODUCTION

During the last decades, understanding of the brain activity became a topic of major interest. Fast rhythm of life and everyday stress raised significantly the role of mental disorders in our society. Modern methods of brain imaging are applied nowadays to get objective information about changes in brain physiology characteristic for mental diseases and disorders. A new method for detection of depressive disorder based on analysis of the EEG frequency spectrum was proposed in [1]. The method is capable of determining depressive disorders or other mental disorders that are related to similar brain imbalances. The presumption is that the EEG beta band (13-30 Hz) includes useful information for evaluation of depression, whereas the EEG theta band (4-8 Hz) is stable and not affected by a disease. A spectral asymmetry index (SASI) is calculated as a relative differences in power of two EEG special frequency bands selected higher and lower of the EEG spectrum maximum. The EEG central frequency band around the spectrum maximum (alpha band) is excluded from the calculations. The input data for the calculation, stored on SD-card, is the EEG signal recorded for 20 minutes from 2 electrodes.

The SASI calculation algorithm has been previously implemented as a MatLab program running on a PC connected to a commercial EEG signal capturing equipment. The main challenge was to develop a portable device with the same functionality. Such dedicated portable device would offer more convenience for obtaining experimental data, real-time analysis and acceleration of the calculation procedure. In addition, the SASI calculation algorithm contains Digital Signal Processing (DSP) modules that can be used also for other analysis tasks. This will allow building an FPGA-based device for health monitoring that is re-configured depending on the task to be solved. Re-configurability is beneficial because most of the analysis tasks, like the same EEG analysis, are executed over long time intervals and the space occupied by the modules can be used for other purposes in meantime. The developed prototype consists of three main parts – EEG analyzer, VGA output generator for 8” LCD display and SD-card controller. All modules fit into a Spartan-3S1000 chip.

II. EEG ANALYZER

SASI calculation can be divided into four main steps [1]:

1. power spectral density computation of the EEG signal;
2. boundary frequencies selection of the lower and higher specific EEG frequency bands;
3. EEG signal power calculation in the selected bands; and
4. calculation of SASI as a combination of the EEG powers in the selected bands.

The power spectral density of the recorded EEG signal was calculated by means of Welch’s averaged periodogram method. For this, the input signal is divided into series of overlapped segments of 2048 points that are multiplied by Hanning window function. The periodogram is calculated by applying Fast Fourier Transform (FFT) to windowed segment and calculating squared magnitude of the result. All periodograms are then time-averaged. Since the segments are overlapped 50%, only 1024 points are needed for every periodogram calculation (except for the very first segment).

FFT was implemented using two modules. One of them is butterfly module that calculates partial results and another one is transform module that reorders the butterfly inputs and outputs. FFT is calculated using complex number arithmetic and sine and cosine trigonometric functions. Results of the partial butterfly calculations are saved back into FFT points block RAM by replacing them to save memory resources.

After FFT is performed, squared magnitude of the resulted values is calculated by spectrum module. For SASI calculation only 40 Hz region of the power spectrum is required, so only 256 points of spectrum out of 1024 are calculated. The spectrum module makes use of polynomial fitting by least-squares fitting method. SASI calculation requires fitting of the parabola onto specific region of the 4 Hz wide power spectrum thus limiting the needed numper of points to 21. Final and simpler calculations are made by borders calculation module, which calculates borders for lower and higher EEG frequency bands, power calculation unit, which finds EEG frequency bands signal powers, and SASI calculation module, which finds the final result to be displayed.

III. VGA GENERATOR AND SD-CARD CONTROLLER

The VGA output generator creates signal for LCD display. The display has 800x600 pixels and is used to show not only the final result – is the patient stresses or not (the SASI value) – but also intermediate data (power spectrum, etc.) to help the medical specialist in border cases. The functionality of the SD card [2] controller is limited to card’s initialization, identification and reading a text file with data.

REFERENCES

[1] H. Hinrikus, A. Suhhova, M. Bachmann, K. Aadamsoo, Ü. Võhma, J. Lass, V. Tuulik, Electroencephalographic spectral asymmetry index for detection of depression. Medical & Biological Engineering & Computing, 47, 1291 – 1299, 2009.

[2] SD Card Association. http://www.sdcard.org/