FINAL REPORT 22.8.2007
Team: SO-SIG

Forewords:

When I sent my interim report to Lena Engdahl only few days before the mid-summer eve and my summer vacation, I mentioned that unfortunately the project is not going any further during my vacation, which lasted until 1.8.2007. After returning to work I have had about two weeks time until I received, somewhat surprisingly, a query concerning this final report. During this two weeks time, there has been small advances in the project, which are described in the end of this document (cf. Chapter: Situation Today). Otherwise, this document is the same, which was sent to you as an interim report.

Although the Innovate Nordic competition is over, the work described in this document continues in the form of Licenciate’s Thesis. In addition, there is also one student starting to work towards his Master’s Thesis (under my guidance) in the middle of September. His work will be based mostly on the DE1 board and the results described in this document.

Introduction:

The initial idea here, was to implement an FPGA design, which would estimate the human posture by measuring the acceleration of his/her arm. The acceleration would be measused with an accelerometer attached to his/her hand.

It was expected, that because the subsequent signal processing and analyzation differs from an application to another, the FPGA should be used for implementation as this allows the basic design to be flexible, which can be easily extended into several application areas.

The Current Research Object:

During the course of time, the whole concept of the project has changed to a biosignal measurement system. In practice this means, that in addition to the accelerometer, a temperature sensor and a self-made pulse oximeter have been attached to the FPGA.

The system comprises of three sensors, namely accelerometer, temperature sensor and pulse oximeter. The two former are located on the same circuit board, which is connected via the pulse oximeter’s circuit board to the FPGA (DE1 board). As the pulse oximeter and the temperature sensor are analog sensors, there is a need for an external A/D-converters. The block diagram of the whole system is depicted in Figure below

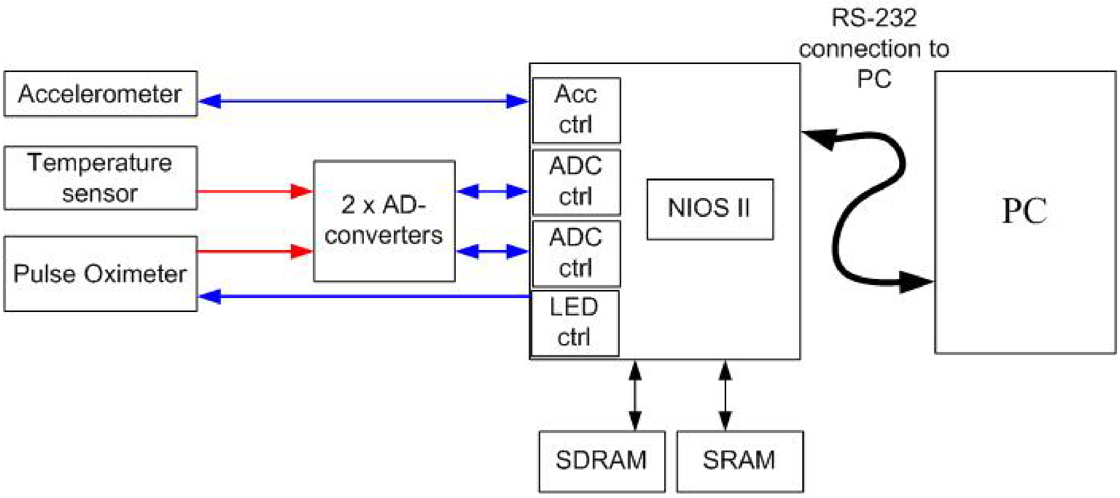

Figure 1. Block diagram of the measurement system

The Role of the FPGA:

Controllers

As the accelerometer is a digital device, communicating via 4-wire SPI bus, there is a need for a controller (Acc_crtl), which uses a special protocol, depicted in Figure 2 (see VTI3000-E04 datasheet for more details). The controller reads all the three axes of the accelerometer data from the specific addresses with a single command. In addition, as the data is received in serial form, the controller converts the data into parallel form. This data is sent to the NIOS II-processor.

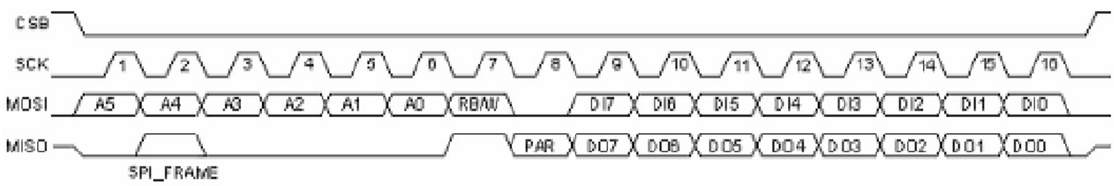

Figure 2. 4-wire SPI protocol in VTI3000-E04 accelerometer

The ADCs require somewhat similar controllers. The controllers differ somewhat from each other in detailed level, as the ADCs are different from each other. However, common to both of the controllers is to initiate the AD-conversion, read the obtained result and finally put the ADC to sleep mode, in order to conserve power. The obtained results are converted into parallel form if necessary and then sent to the NIOS II-processor.

The operation of the pulse oximeter is based on the different absorption spectra in red light wavelength and in infrared wavelength (IR). Therefore, a LED controller is needed here. The purpose of the controller is to alternatively light one of the two LEDs (red or IR) and to keep a small pause between the light periods. This scheme is depicted in Figure 3

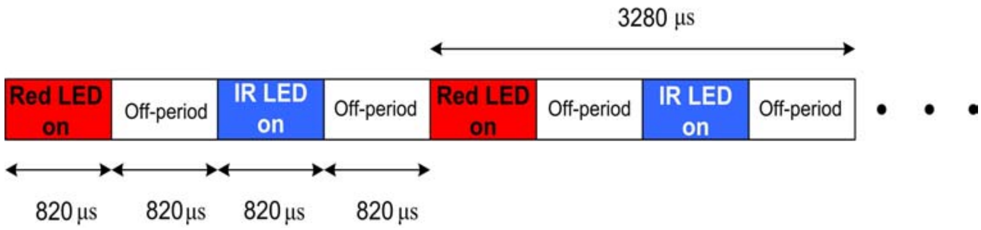

Figure 3. LED controlling scheme

NIOS II – processor

The data sent to the NIOS II –processor from the controllers cause an interrupt event. If an interrupt is detected, the measurement results from all the different channels connected to the NIOS II- processor are saved into the memory. The different channels are as follows: Acceleration (in x,-y- and z-directions), temperature, received light from pulse oximeter (red light, IR-light and the light when both LEDs are off).

When the installed SRAM (512kB) and SDRAM (8 MB) are full of measurement data or alternatively the conducted test is over, the NIOS-II processor opens the serial port and the data is sent to the PC via RS-232. Figures 4a and 4b show an example of measured data.

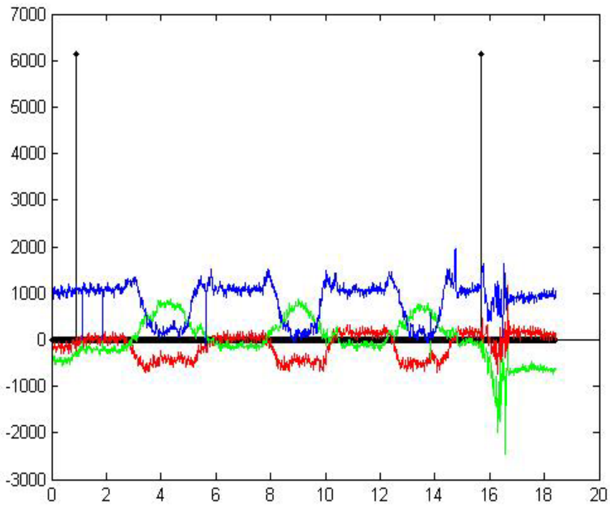

Figure 4a. Measurements from the accelerometer (x-axis = red, y-axis = green, z-axis = blue)

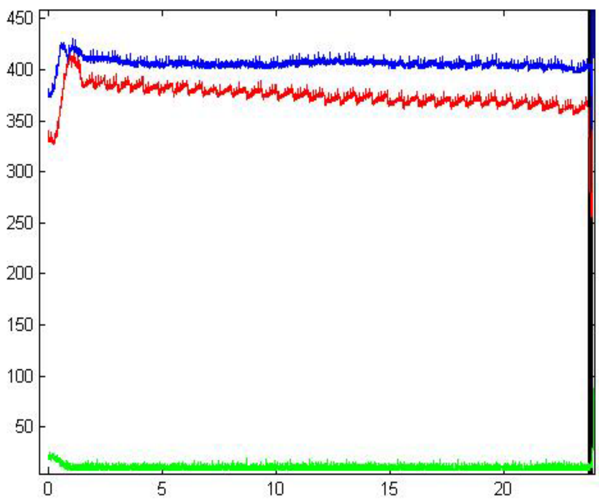

Figure 4b. Measurements from the pulse oximeter (red LED = red, IR-LED = blue, both LEDs off = green)

Conclusion:

Initially the project was supposed to have an accelerometer and an algorithm, which would compute the posture of a person. However, during the course of time, the project focus was shifted towards a **portable biosignal recorder,** which includes more sensors than just the mentioned accelerometer. Due to this reason, the required algorithms were never implemented but the main focus has been in developing an the hardware (electronics and VHDL code) for the biosignal recorder.

In the future, there is an intention to improve the system in many areas, including the digital signal on FPGA and connecting the DE1 board to PC using a wireless ZigBee technology. However, this won't be ready due to the deadline of the competition in August.

Situation Today:

In this two weeks time, there has been quite a lot misfortune in the development of measurement electronics. The output from the temperature sensor oscillated for some unknown reason, which caused the breaking of the operational amplifier, the A/D-converter's voltage reference and one of the A/D-converters. These parts were changed. In addition, there was a second order filter added into the analog temperature channel to filter out the 50 Hz power line hum.

In the NIOS-II development, it was discovered that the original idea, where the incoming data from each sensor caused an interrupt to the processor, was unsuitable for the data collection. This data collection scheme led to a situation, where the time between subsequent interrupts (and thus samples from the sensors) was forever changing instead of being constant. This of course causes problems in the further development of the algorithms as the sample times were not absolute but relative to each other. As an improvement, a controller keeps track of the time and after three consecutive samples from the pulse oximeter, which has the highest sampling rate, are received, the NIOS-II processor stores the data from **all** the sensors. In this way, we know the absolute time interval between different samples.

There are many advances planned in the future. These include the following:

1) One additional sensor, namely a capacitive touch sensor, will be added to the biosignal recorder. The information from this sensor can be used to deduce, whether the biosignal recorder is being worn by the user and whether the positioning of the device is correct. The development begins as soon as the electronic components are received

2) The wireless link will be developed between the biosignal recorder and a PC. This link will be based on a wireless personal area network (WPAN) technique e..g Bluetooth or ZigBee. The development begins in the middle of September.

3) The algorithm development begins with collecting data. The aim is to develop such algorithms, that can extract important medical data from the raw data. This data can be used for e.g. alarming the nursing staff or it can be used for measuring physiologic feedback for some stimuli e.g. a stress in physiological experiments. The developed algorithms should utilize the parallel processing capability offered by the Cyclone II FPGA.