DATA ACQUISITION USING FPGA

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ABSTRACT:

In this, Data acquisition system using FPGA, integrates 3 different features in a single system: an oscilloscope with FFT capabilities and a maximum sampling rate of 100 MSPS, a heart rate measurement module (based on plethysmograph method) and a galvanic skin response (GSR) module. Besides of these features, the entire project is powered from a Li-Po battery which provides galvanic isolation of the entire system with the main socket supply. The entire project is controlled by an ARTIX-7 FPGA based board, NEXYS 4 DDR, which communicates with the user through a GUI (Graphic User Interface) developed in LabVIEW. In this environment, the user can see the waveforms, and can also set all of the adjustments, which are converted in commands, and finally sent to FPGA.

KEYWORDS: Data acquisition, plethysmography, measurement

INTRODUCTION:

Data acquisition systems are used by most engineers and scientists for laboratory research, industrial control, test and measurement to input and output data to and from a computer. Security of information such as text, digital and analog data is considered important in defense applications. System is to be designed for acquiring analog information along with maintaining privacy and security of information for defense store. The system implemented is made secure by use of cryptographic algorithm. The system is designed on Spartan FPGA platform providing high reliability of designed system.

Data acquisition process involves collection of environmental/input signal and conversion of such signals into digital form for processing. The Data Acquisition System (DAS) consist of sensors, digital to analog convertor, analog to digital convertor and DAS measurement hardware. Data acquisition systems were traditionally implemented on micro controllers and microprocessors.

Now with the advent of signal processing domain and more sophisticated platforms data acquisition systems are preferred to be implemented on FPGA platform. It provides more reliability, less complexity and greater storage and retention of data. Security of data (text, video, audio, e-mail) in today's connected world is important as information is a vital parameter for end users. Cryptography provides and ensures security of data and is widely accepted in various fields.

LITERATURE REVIEW:

The plethysmography is used to measure different changes in volume, from fluctuations in the amount of the blood or how much air it contains. In our case, the method will be used to detect the heart rate of a human subject by measuring the amount of oxygen pumped in blood. The measurement test point will be chosen to be a finger.

The galvanic skin response is a phenomenon that can be influenced by several factors. Simplified, the term of galvanic skin response refers to the capability of the skin to lead the electricity, when an external voltage source is applied. Usually the galvanic skin response is measured in micro Siemens (µS) and is the inverse of electrical resistance.

In the galvanic skin response measurement techniques, there were used DC sources and also sources of alternative current (AC). Thus, DC sources based measurements, in where the voltage at the skin contact is kept constant, is called skin conductance measurement, and the one when the current at the level of the skin contact remains constant is called skin resistance measurement. The AC measurement, in which the effective value of the voltage at the level of the skin contact remains constant is called skin admittance measurement. Similar, when the current is maintained constant using alternative power sources, the process is called skin impedance measurement.

The most practical method is to measure the skin conductance within the experiments for interpretation the psychological states, because the constant voltage source are easy to be achieved and used. The most complex device in this range, currently used to detect the emotional states, is the polygraph which, besides the skin conductance, also measures the pulse, the blood pressure, the body temperature and the respiratory rhythm. The first polygraph was the polygraph of John A. Larson from the University of California, which measured both the skin conductance and the blood pressure.

DATA ACQUISITION SYSTEM USING FPGA:

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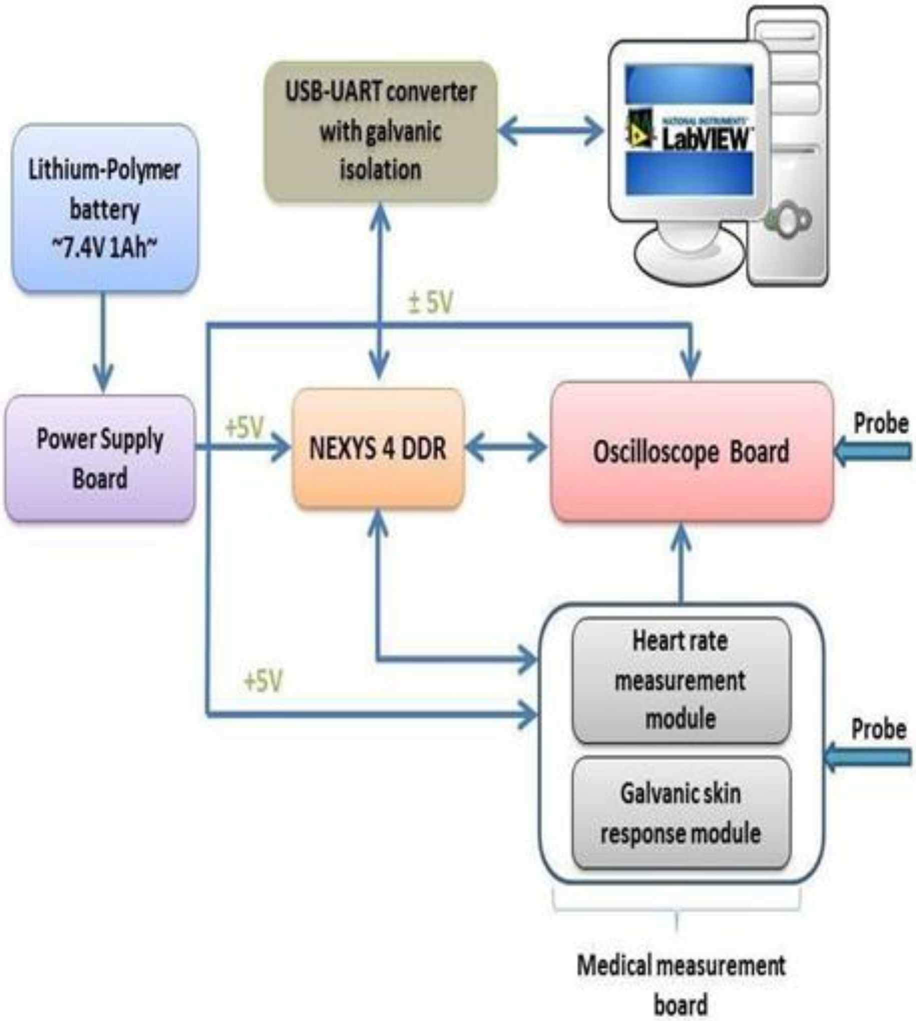

Fig: Proposed block diagram

OBJECTIVE:

The main idea of this project is to create something that encapsulates some measuring tools in a DIY DAQ system. In this way, a wide range of users can benefit from this, because, having a FPGA board and reproducing some modules, they could create their own tool. The features are:

High speed oscilloscope with FFT (Fast Fourier Transform);

Heart rate monitoring by using a non invasive method (Plethysmograph);

Galvanic skin response (GSR), by measuring the voltage across 2 electrodes, placed in specific parts of the human body;

Full galvanic isolation by using a battery for power supply board and galvanic isolated communication with PC.

NEXYS 4 DDR:

The Nexys 4 DDR is a drop-in replacement for our cellular RAM-based Nexys boards. Featuring the same Artix™-7 field programmable gate array (FPGA) from

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Xilinx®, the Nexys 4 DDR is a ready-to-use digital circuit development platform designed to bring additional industry applications into the classroom environment.The Nexys 4 DDR is compatible with Xilinx's new high-performance Vivado Design Suite as well as the ISE toolset, which includes Chip Scope and EDK. Xilinx offers free Web PACK versions of these tool sets, so designs can be implemented at no additional cost.

NEXYS 4 DDR BOARD:

THE OSCILLOSCOPE BOARD:

It use a 10 bit high speed ADC with parallel interface which can reach about **100 MSPS**. For processing the signal under test before it goes in ADC, an analogic part was developed, and it performs operations like Buffering, Dividing, Amplification/attenuation control.

As the ADC has differential inputs and the analogic part used for processing the signal was single-ended, a differential driver was included to realize the conversion. This module is capable of waveform analysis and it can also compute the FFT for the signal under test.

THE MEDICAL MEASUREMENT BOARD:

It contains two sub-modules on the same board. First module is used to measure the galvanic skin response (GSR) of a human subject by measuring the skin conductance (G), the value of GSR is measured with the oscilloscope board and it can be used in medical applications and also in psychological experiments. The second module is used to monitor the heart rate of a human by measuring the alteration of blood volume pumped by the heart. This feature uses an IR diode which sends IR light to the human tissue and a photo-transistor as main sensor receives

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the transmitted IR light, but it will be modified by the alteration of the blood volume. That is how is obtained the heart rate.

THE USB-UART CONVERTER:

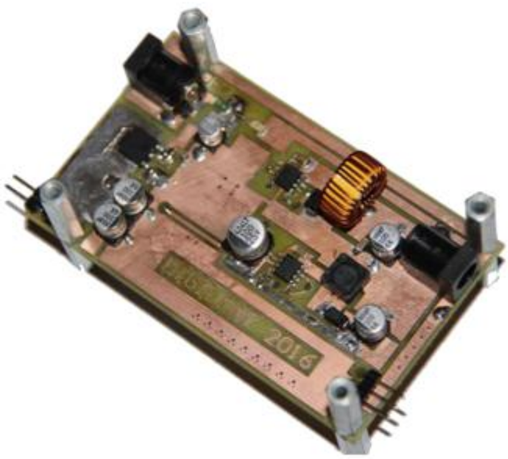
It uses a dedicated USB-UART bridge which can emulate a virtual serial port, used for the communication with the NEXYS 4 DDR board. In order to achieve galvanic isolation, a dedicated IC was used in this purpose.

POWER SUPPLY BOARD:

It contains 4 independent power supplies which give the voltages, referred to the ground like:

+5V with capability of 1A used for powering NEXYS 4 DDR board;

±5V with capability of 1A used for powering the analogic part of the project.

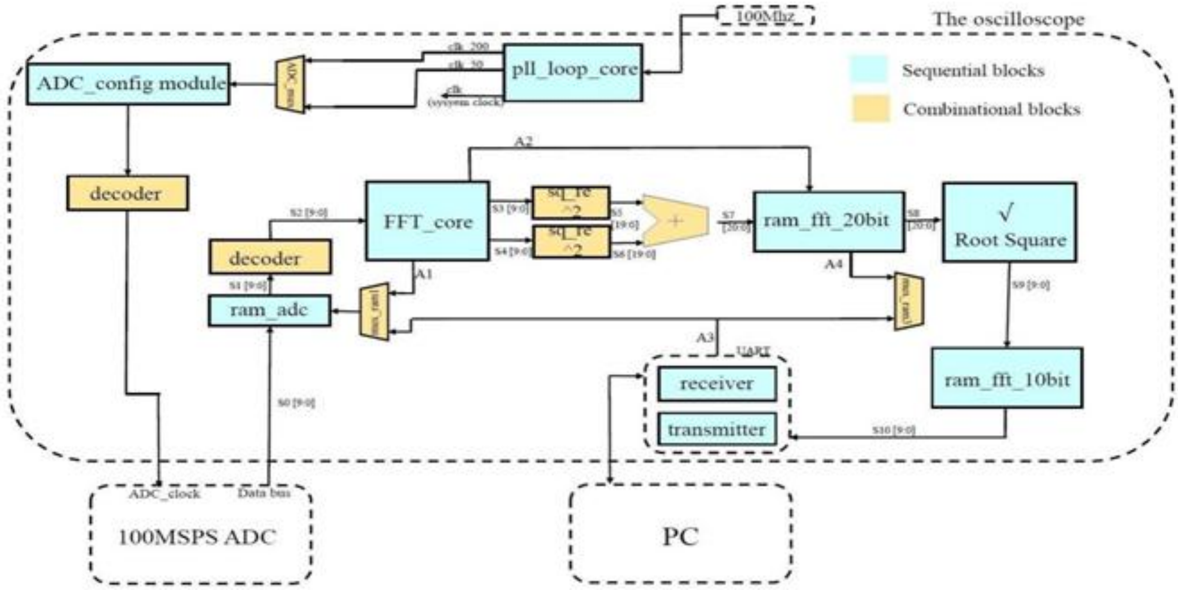


The input of the power supply board ranges from 7V to 15V, but in our case a Li-Po battery is used in order to achieve galvanic isolation from main socket supply.

LI-PO BATTERY:

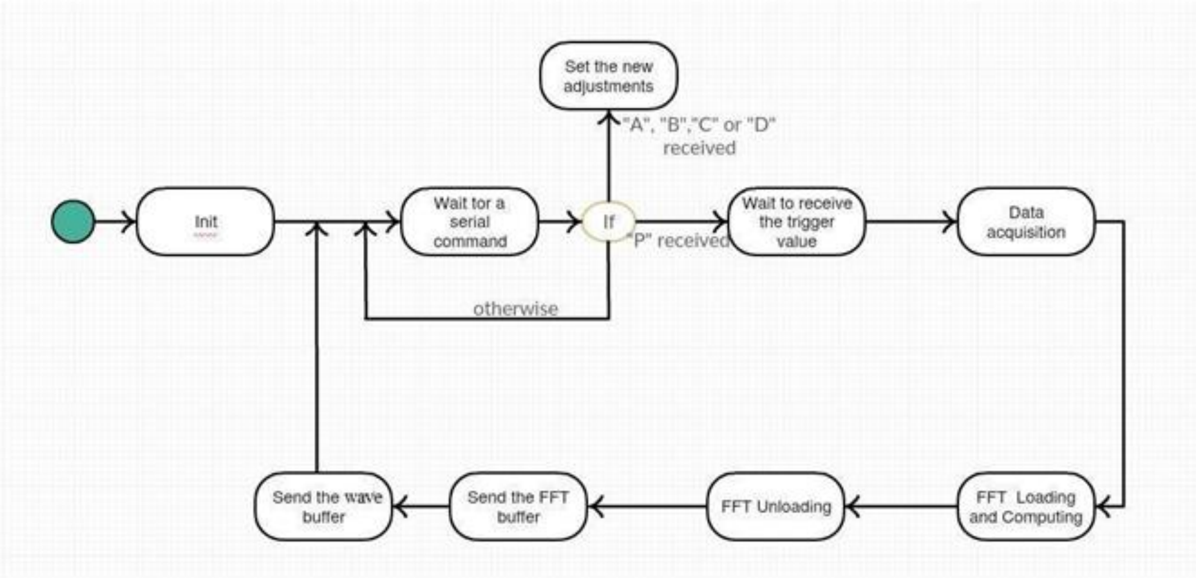
A lithium polymer battery is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of a liquid one. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide a higher specific energy than other lithium battery types and are being used in applications where weight is a critical feature - like tablet computers, cellular telephone handsets or radio-controlled aircraft.

THE TOP LEVEL BLOCK DIAGRAM



THE ALGORITHM

The entire system is commanded by three state machines. Two of those three are controlled by a clock signal (not the same clock), and the last one is controlled by a certain bit.



STEPS:

Wait_state: Waits for a serial command. If the command is A, B, C or D, it sets the adjustments, and stays in the same state. So, if one of those four letters is received, it allocates the next serial value for a specific adjustment.

Wait_state: If the serial command is P, it goes on in the acquisition state

Trig_state: In this state, the FSM waits for the signal to equal the trigger level value, and also to has the corresponding slope. The slope is evaluated by the second FSM, which runs in parallel with this. When trigger condition is met, the automaton goes in the next state

Acq_state: In this state, a buffer of 2048 samples provided by ADC is stored into ram_adc(the first SRAM). In this state, this FSM only check if the memory is full. The addressing is done by the second FSM, which is triggered by the ADC clock.

Fft_state: When the samples buffer is full, the system comes in this state, where he FF algorithm is started. Using the index address bus, the ram_adc memory is completely read by the FFT core. After this, the processing starts, until edone signals that the transform is done.

Fft_write_state: Now, data is unloaded from FFT block into ram_fft_20bit (the second SRAM); on every clock, a sample is unloaded. Between the two modules, there were introduced two square modules and an adder, so as to, if the FFT outputs a real part and an imaginary one, at the ram input it will be real^2+imag^2. These modules are combinational circuits, so they present a 0 latency.

Square_state: In this state, a square root operation is applied for every sample from

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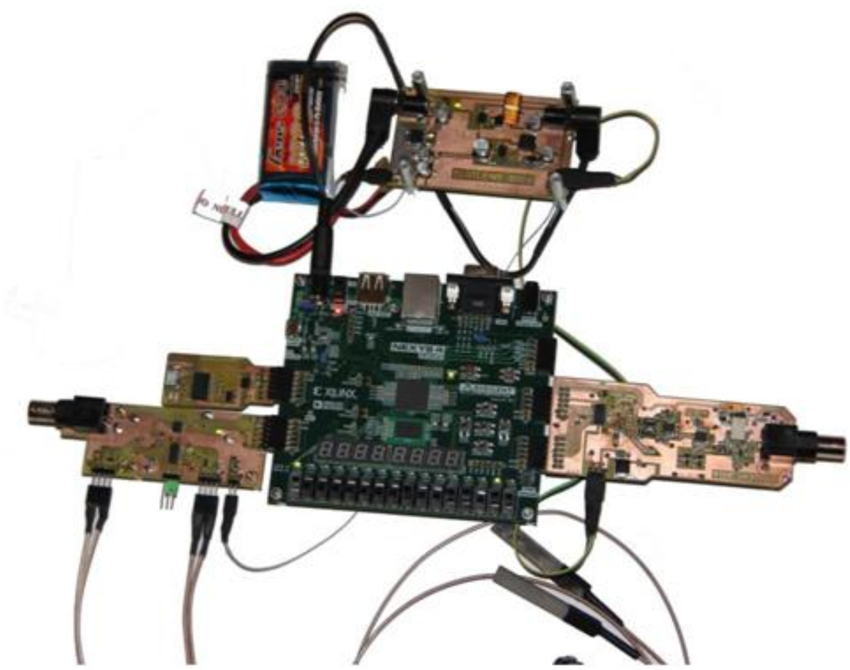
ram_fft_20bit, and stored in the third ram(ram_fft_10bit). The square root value is not a zero latency one, and it lasts a few clock cycles. When sqr_rdy is high, the module outputted the data, and it is stored, and memory location is incremented, to process a new sample. These operations are made during other four similar states(Square_state2, Square_state3, Square_state4, Square_state5)

As soon as the data has been processed, and a correct samples set for the spectral analyses was stored in the last ram(ram_fft_10bit), the send state can begin

In this state, the array with FFT is sent at first, then three control characters ('F', 'F', 'T'). After those, the waveform buffer (from ram_adc) is also sent. The data sending process is controlled by a third state machine. In final, the system goes in the first state

HARDWARE OVERVIEW OF THE PROJECT



CONCLUSION:

The present work has been concentrated on the design and development of both hardware and software for cost effective data acquisition system (DAS), which are used for measuring slowly varying physical variables. Physical parameters such as temperature, humidity, light intensity etc., which are generally

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considered as slowly varying signals, are measured by the designed DAS. Design consideration of the PC based data acquisition system has been made, based on commonly available ports of the personal computers (PCs) viz. parallel port, serial port and USB (Universal Serial Bus). Simple cost-effective methods and techniques have been proposed for the design and development of PC based DAS for measuring some physical parameters. They are - Design and development of parallel port, serial port (RS 232) and USB based DAS. It includes the hardware design i.e. PCB design and fabrication for circuits like power supply, clock generator, signal conditioner and DAS.

For serial port (RS 232) based DAS, it uses PIC12F675 microcontroller and for USB it uses PIC18F4550 microcontroller. It has built-in 10-bit resolution ADC. For proper functioning of the device, firm wares have been developed using 'C'.

Application programs for communication with the designed H/W have been developed using

'C', and Visual Basic. Observations were taken using the temperature and humidity sensors.

FUTURE SCOPE

The present work is focused around the design and development of cost effective PC based data acquisition system (DAS), both hardware and software. The designed systems are having 10-bit resolution only. Resolution can be further increased by using high resolution external ADCs. To make the designed system more flexible with better performance, the following modifications can be made

i ADC: ADC's resolution can be increased by selecting high resolution ADCs,

ii Microcontroller: selection of advanced version of microcontroller for higher speed, resolution and better performance,

iii Sensor: selection of high quality sensors, integrated or smart sensors to get faster response speed with higher resolution and better performance,

iv Hardware and software: hardware and software modifications to enable long distance acquisition, remote access (wired and wireless) etc.,

v Miniaturization: Miniaturization of the designed system by using surface mount devices (SMD components).

Then , the scope and applicability of the designed system will be increased. It can be used for the applications in various fields in physics, chemistry, life sciences, engineering, medical, geological applications etc.

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