

## Programmable Digital Bio-Impedance Measurement System

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**Abstract:** *The field programmable gate array is the fastest growing technology. The bio-impedance measurement system is implemented in reconfigurable field programmable gate array hardware. The design of bio-impedance measurement system using Xilinx system generator is more convenient and cheaper for revising, if the Bio-impedance measurement system requires parameters changes in practical use, since no new hardware device is needed to make revise. The presented system is time saving, fast, adjustable system parameter and easy to use.*

**Keywords:** *Electrical Bio-impedance, field programmable gate array, Direct digital synthesizer, Xilinx system generator tool, Matlab & simulink.*

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### 1. INTRODUCTION

Over a decade the electrical bio-impedance is being investigated as a potential technique for detecting cancerous tissue, tumors meningitis, for analyzing body composition and bovine milk quality. The field of field programmable gate array is a fastest growing technology. The projected system used field programmable gate array reconfigurable hardware to implement bio-impedance measurement system. The FPGA technology is programmable, fast and inexpensive. It is very advantageous can directly program on hardware and easily change the hardware as per the requirement [9]. The presented bio-impedance system is programmable, fast, adjustable system parameters, quick, simple and easy to use.

The many bio-impedance measuring systems are currently available. In balancing bridge method is used as an indirect way to obtain bio-impedance. The Current- Voltage method is obtained by measuring tissue voltage when a reference signal is injected in extremely high frequency bio-impedance measurement is achieved using radio frequency reference signals [1].

The one of the most common techniques to compute the bio-impedance in Current-Voltage method is based on phase difference detection between the voltage and current in the measuring cell. Particularly in four electrode measuring configuration, the phase difference is obtained between a reference current signal, injected to the tissue through a pair of electrodes and measured voltage. The Synchronous phase detection system is used in computing this voltage-current phase difference[2]. This system also known as phase sensitive detector. A fully analog solution of bio-impedance measurement system has disadvantage like small band width, signal synchronous problem and extremely for high quality of analog component are required for bio-impedance measurements.

A fully digital solution of bio-impedance measurement system based on a microprocessor board measures only narrow frequency range of bio-impedance signal. In DSP based bio-impedance measurement system required large no of instruction cycle for bio-impedance measurement [4].

The paper we have presented a reconfigurable bio-impedance measurement system. The presented bio-impedance system is adjustable, fast, simple, and easy to use.

The reconfigurable bio-impedance measurement system is design in MATLAB & SIMULINK software by using Xilinx block and XILINX system generator tool converts the Xilinx blocks into compatible VHDL code that is suitable to implement in field programmable gate array Spartan 3E Board and other EDA design software to complete the synthesis, net list generation and FPGA configuration download.

The Design of signal source using Xilinx System generator tool is more convenient and cheaper for revising if Bio-impedance measurement requires parameter changes in practical use, since no new hardware device is needed to make the revise. Therefore the design is time saving and cheaper.

## **2. BIO-IMPEDANCE**

The Bio impedance is the term used to describe the response of a biological tissue to an externally applied electric current. The bio-impedance is defined as the relation of the tissue complex voltage and its complex current. The most important element in bio-impedance measuring process is the electrodes. The electrodes is interface between the ionic current of the biological tissue and electric current sensed by measuring system.

There are several type of electrodes are used according to the application. Four electrodes measuring configuration is considered in this work

## **3. XILINX DIRECT DIGITAL SYNTHESIZER**

The direct digital synthesizer, or numerically controlled oscillator (NCO) are important component in digital system. the basic principle of DDS is to produce a sine wave based Numerical Controlled Oscillator[9]. The frequency, phase, amplitude is adjustable.

The output frequency of DDS Compiler is calculate by equation (1).

$$f_{out} = \frac{f_{clk} \Delta\theta}{2^{B_{\theta(n)}}} \quad (1)$$

Equation (1)

$f_{out}$  is output frequency,

$f_{clk}$  is system clock frequency,

$B_{\theta(n)}$  is number of bits,

$\Delta\theta$  is phase accumulator and phase increment value

The Xilinx DDS Compiler 4.0 is used to generate two reference signals.

Block parameter of Xilinx Direct digital synthesizer is:

System clock: 50 MHz

Maximum signal frequency: 10 MHz.

Frequency Resolution: 0.25Hz

The Output of DDS Compiler is as shown in figure 1.

## **4. XILINX MULTIPLIER**

The Xilinx multiplier block implement a multiplier[9]. It computes the product of the data on its two inputs ports and producing result of its output port.

Block parameter of Xilinx multiplier block:

Precision : user defined

fixed point output type: Unsigned

Fixed point precision: No. of bit '1' and binary point '1'.

latency: '3'

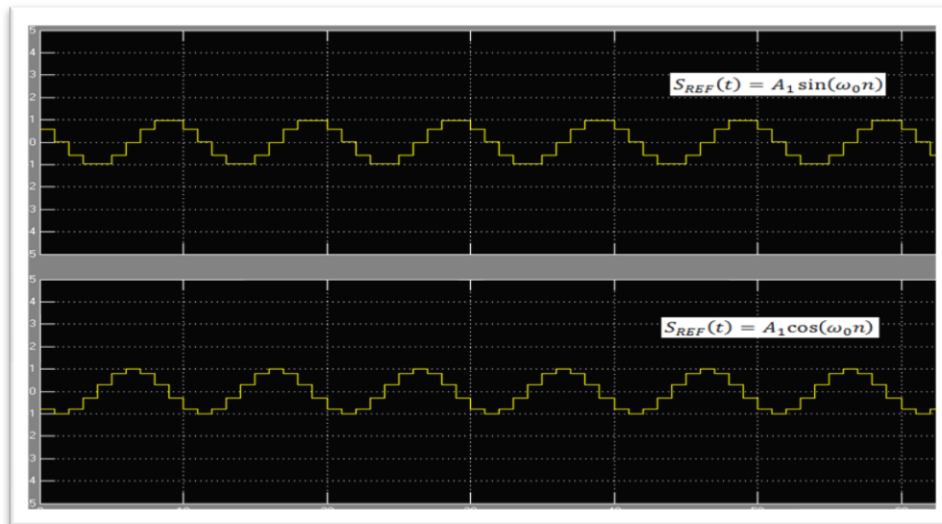


Figure1. Output of DDS compiler

### 5. XILINX N-TAB MAC FIR FILTER

The Xilinx n-tab MAC FIR Filter is a multiply accumulate base FIR filter. The specifying, implementing and simulating a FIR filter by using the FDA tool block[9]. The FDA tool block is used to define the filter order and coefficients. Drag and drop the FDA tool block into system model and link FDA tool with Xilinx MAC FIR filter by using commend:

```
xlfa_numerator('FDATool')
```

The Filter Design and Analysis tool for low-pass filter designed to eliminate high frequency noise in bio-impedance system:

Response Type: low-pass

Filter order: Minimum order

Frequency specification:

- Units: MHz

- Fs : 54000

- Fpass : 6000

- Fstop : 7725

Magnitude Specification:

-Units :dB

-Apass : 1

-Astop : 47

According to above parameters we design low-pass MAC FIR Filter.

### 6. BIO-IMPEDANCE MEASUREMENT SYSTEM

The electrical bio-impedance  $Z = R + jX$  is determined by measuring voltage response ( $V$ ) to the excitation current ( $I$ ) flow through the tissue or organ and computed by using equation(2)

$$Z = \frac{V}{I} \quad (2)$$

The complex voltage ( $V$ ) and current ( $I$ ) signal is obtained from synchronous phase detection system block.

Let the complex voltage and current be defined as  $V = a + jb$  and  $I = c + jd$  then bio-impedance  $Z$  can be expressed by using equation (3).

$$Z = \frac{V}{I} = \frac{a+jb}{c+jd} = \frac{ac+bd}{c^2+d^2} + j \frac{bc-ad}{c^2+d^2} \quad (3)$$

System generator provides direct support for MATLAB through MCode Block the logic of bio-impedance computing is put in Xilinx MCode block. The bio-impedance computing file saved in same directory of the model file[2]. Once the file has been saved to appropriate place then browse that file in Xilinx MCode box.

### 7. XILINX GATEWAY IN AND GATEWAY OUT

The Xilinx gateway in blocks are the inputs into the Xilinx position of your Simulink design and gateway out blocks are the output from the Xilinx portion of your simulink design. In our design have the two gateway in and four gateway out blocks [9]. The gateway in and gateway out blocks is nothing but input output pins of FPGA.

### 8. IMPLEMENTATION

The presented system is implemented on a Xilinx XC3S500 FPGA using a Digilent Spartan 3E development board. The implemented bio-impedance measurement system is shown in Figure(2)

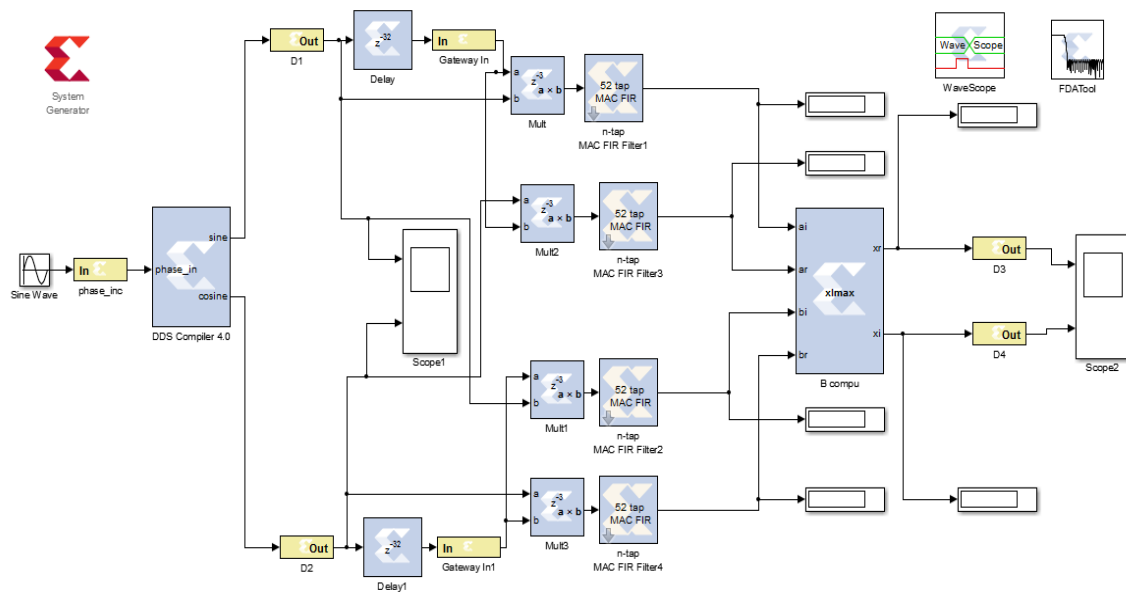


Figure2. Programmable digital Bio-impedance measurement system

The synchronous phase detection system inputs and reference signals are multiplied using Mult block available in Xilinx system generator tool. The filtering process is implemented with the MAC FIR filter block of Xilinx system generator tool. The signal generation block is based on direct digital synthesis (DDS). This DDS has three output signals namely the injected current to tissue and two reference signals. These signals are generated through the DDS compiler 4.0 block of Xilinx system generator.

The presented system goal is to achieve a digital Bio-impedance system implementation in high frequency bio-impedance computing application. The developed system is used as a part of the digital stage in bio-impedance measuring system and the system is implemented in reconfigurable hardware.

### 9. OBTAINED RESULT

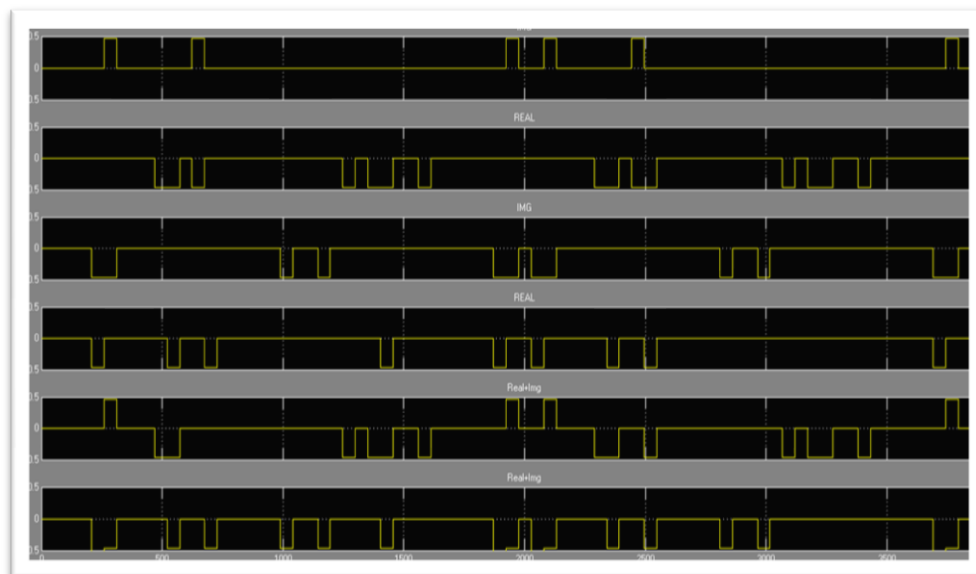
The Presented system is implemented on a Xilinx XC3S500 within a Digilent Sparten 3E development board. The resulting bio-impedance value is observed on observed on digital storage oscilloscope.

The Several bio-impedance measuring test were done for different measurement frequencies and phase differences and observe output on virtual LCD in Simulink software. The obtained bio-impedance result is shown Table I.

**Table1.** Bio-impedance Result

Phase ( $\phi$ )	Stage I		Stage II	
	Real	Imag.	Real	Imag.
-288	0.807941	0.2624	0.616180	-0.447757
-216	0.752223	0.244380	-0.68738	0.499328
-144	0.640781	0.208168	-0.42662	0.309902
-72	0.835800	0.271533	-0.59257	0.430442
0	0.000045	0.761749	0.585044	0.190059
72	-0.195075	-0.063419	-0.52148	0.378786
144	-0.195075	-0.63419	0.473976	-0.344444
216	0.055667	0.081051	0.292694	-0.402969
288	-0.808040	-0.262580	-0.63054	0.592475

The Table I. show the real and imaginary output of two parallel processing bio-impedance system. The fig.(3) Show the output of presented bio-impedance measurement system.



**Figure3.** Output of presented bio-impedance measurement system

**10. CONCLUSION AND DISCUSSION**

The electrical bio-impedance technique has a potential to detecting cancerous tissue, tumors meningitis, analyzing body composition and bovine milk quality. The field of field programmable gate array is fastest growing technology. The presented system is implemented in reconfigurable hardware Spartan 3E FPGA board. The design of bio-impedance measurement system using Xilinx system generator is more convenient and cheaper for revising, if the Bio-impedance measurement system requires parameters changes in practical use, since no new hardware device is needed to make revise. The presented system is time saving, fast, adjustable system parameter and easy to use.

The system we have define is a Reconfigurable, Adjustable system parameter, easy to use, no need to change hardware, time saving and cheaper

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