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Bio-impedance Detection Using AD5933 Impedance Converter Analyzer

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Abstract: ***The biomedical devices are playing major role in diagnosis of diseases, analysis of physiological processes and transferring the medical data all over the world. Analyzing the impedance of biological samples has gained importance in the last decade. Presently all the bio-impedance analyzer available in the market are heavy and costly. In this paper, an attempt has made to develop a portable, low cost bio-impedance analyzer. The main aim of this paper is to detect the human Bio impedance using AD5933 Impedance Converter Analyzer that can be used to diagnose various diseases like skin cancer, viral fevers and so on . This paper is based on the prototype of bio-impedance measurement system using AD5933 of Analog Devices, ARM LPC2148 low power MCU and unique disposable strip electrode system. Impedance converter generates excitation signal, which is applied to tissue under study (TUS) through electrodes. The response signal from TUS is measured using different electrode pair and processed internally in impedance converter to obtain real and imaginary values. These values are obtained at each sweeping frequency and transferred to ARM LPC2148 MCU trough I2C interface. ARM LPC2148 is low power MCU, useful to develop portable or battery operated system. For further processing the data is transferred to PC through USB interface. The developed device was successfully operated in a frequency range of 100 Hz to 1 MHz to measure impedance of various samples. The prototype operates from 100Hz - 1MHz and covers the impedance range of 1kΩ - 10 MΩ in four sub ranges. It is also capable of measuring of 100 Ω to 1k Ω with additional circuitry. The system is operated from a PC and the software required for operation and control has developed. The main target of these systems is personal and home monitoring.***

Keywords: Bio-impedance, AD5933, TUS, MCU.

1. Introduction

The Bio-impedance[1] measuring system is based on AD5933 Impedance Converter[2] or Network Analyzer of Analog Devices, ARM7 LPC2138 low power MCU and unique disposable strip electrode system and the developed software application that uses bio-impedance, obtained from measuring system to analyze various diseases like skin cancer[3][4], viral fevers, to monitor the ECG, body composition and so on.

2. Methodology

The impedance network converter integrated circuit AD5933 is the core of the measurement system[5][6]. The impedance measurement system by itself is the evaluation board for the AD5933 circuit provided by the Analog Devices Inc., the EVAL AD5933EB[2]. The Analogue Front End[7] is implemented along with the instrumentation amplifiers, general application op-amp circuits and voltage references. The software used to control AD5933 and display the impedance measurements is provided with the evaluation board[8]. This software application has been adapted for correct two-electrode operation with Visual Basic 6.0. The following figure 1 shows the functional block diagram of measurement of Bio-impedance.

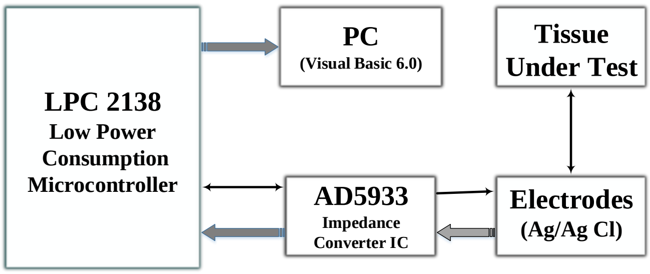

Figure 1: Block Diagram of Bio-impedance measurement system [8]

Impedance converter generates excitation signal, which is applied to tissue under study (TUS) through electrodes. The response signal from TUS is measured using different electrode pair and processed internally in impedance converter to obtain real and imaginary values[9]. These values are obtained at each sweeping frequency and transferred to LPC2138 MCU trough I2C interface. LPC2138 is low power MCU, useful to develop portable or battery operated system[10]. For further processing the data is transferred to PC through USB interface. Software used are CCS v5 IDE and C compiler.

3. Bio-impedance Instrumentation

3.1 AD5933 Impedance Converter[11]

The AD5933 is a high precision impedance converter system solution that combines an on-board frequency generator with a 12-bit, 1 MSPS, analog-to-digital converter (ADC). The frequency generator allows an external complex impedance to be excited with a known frequency. The response signal from the impedance is sampled by the on-board ADC and a discrete Fourier transform (DFT) is processed by an on-board DSP engine. The DFT algorithm returns a real (R) and imaginary (I) data-word at each output frequency. It includes a serial I2C port as communication interface that allows the adjusting of several operation parameters as well as the transmission with an external Host of the impedance data results.

3.2 Analogue Front End[12][13]

The interface between the AD5933 and the TUS is named as AFE(Analogue Front End). It is the combination of two voltage- to- current converters(V2CC), one from AD5933 side to TUS and another from TUS side to AD5933. The dc bias component is removed from the output voltage of AD5933 with a high-pass filter at the input of the first V2CC. as shown in the below figure 2.

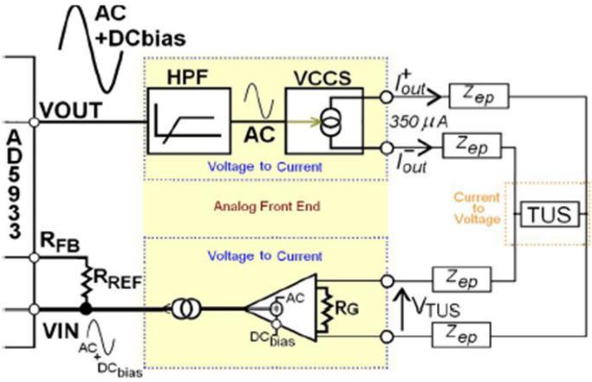

Figure 2: Functional Block diagram of AFE

The ac voltage from Vout drives a voltage-controlled current source (VCCS) injecting an ac current Iout into the TUS. Iout is directly proportional to Vout. The ac current Iout causes a voltage drop at the TUS, which is sensed by the second V2CC and, since the voltage drop at the TUS drives the second V2CC, an ac current proportional to the voltage drop in the TUS is generated. Finally, a dc component is added to the ac current generated. This added dc component is equivalent to dc bias originally removed from Vout.

4. Impedance Estimation [14][15]

For the impedance estimation the AD5933 implements the Discrete Fourier Transform on DSP cover over the sampled current signal and the reference sinusoidal injecting signal. The DSP calculates as 1024 points DTF transform for each frequency point in the frequency sweep obtaining the real and imaginary components. The impedance can be directly estimated by applying the Ohm's law in the frequency domain:

$$\frac{1}{Z(w)} = \frac{Vout(w) - Vin(w)}{Iload(w)} \tag{1}$$

where Z(w) is the impedance the measured frequency V(out) and V(in) are the output and input voltage of the sensing stage and I(load) is the current that flows through the impedance that we want to measure. As result the DFT provides with the Fourier Coefficients the relationship between the voltage signal controlling the excitation and the current signal through the load. From those coefficients the magnitude and the phase of the measure can be calculated from each frequency.

$$Magnitude = \sqrt{R^2 + I^2} \tag{2}$$

$$Phase = Tan^{-1}({}^{I}/_{R}) \tag{3}$$

5. Impedance Calibration [16]

It is important to notice that the voltage signal used as a reference enters into the DSP straight from the DDS while the exciting voltage applied on the load, and true responsible for the current following through the load is the signal at the output. This process creates an error that it is necessary to solve in order to obtain a correct value of impedance that is done by the calibration. In the calibration a load with a known impedance value is placed between the exciting leads. Since the calibration load is knows the calibration factor can be calculated to compensate the error occurred. In this project the calibration is calculated at every single frequency point contained in a spectroscopy measurement. This way for known single frequencies we can know the appropriate gain factor:

$$Gfactor = \frac{Admitance}{Magnitude} \tag{4}$$

$$Impedance = \frac{1}{Gfactor \times Magnitude} \tag{5}$$

where $Gfactor$ is the gain factor applied to correct the measure.

6. Results

The proposed prototype is tested against the two type of human tissue samples out of which one is 30% Burnt Female Human Skin and is other Normal Human Skin. It is found that the values of the burnt female skin and normal female skin are same in magnitude but differs in the phases. The test is carried out with the frequency sweep of 100KHz, programmable gain of 1 and frequency count of 10. The table 1 and table 2 shows the values of magnitude, phase and impedances of the is 30% Burnt Female Human Skin and is other Normal Human Skin respectively in the real time.

Table 1: Impedance values of 30% Burnt Skin (Female)

frequency	*impedance*	*phase*	*real*	*imaginary*	*magnitude*	*time*	*date*
100000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
101000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
102000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
103000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
104000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
105000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
106000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
107000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
108000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015
109000	4163215	26.565	292.000	146.000	362.4659247149	8:01:29PM	26/06/2015

Table 2: Impedance values of Normal Human Skin (Female)

frequency	*impedance*	*phase*	*real*	*imaginary*	*magnitude*	*time*	*date*
100000	4163215	57.171	280.000	434.000	516.4842688795	8:18:35PM	26/06/2015
101000	4163215	57.171	280.000	434.000	516.4842688795	8:18:35PM	26/06/2015
102000	4163215	57.171	280.000	434.000	516.4842688795	8:18:35PM	26/06/2015
103000	4163215	57.171	280.000	434.000	516.4842688795	8:18:36PM	26/06/2015
104000	4163215	57.171	280.000	434.000	516.4842688795	8:18:36PM	26/06/2015
105000	4163215	57.171	280.000	434.000	516.4842688795	8:18:36PM	26/06/2015
106000	4163215	57.171	280.000	434.000	516.4842688795	8:18:37PM	26/06/2015
107000	4163215	57.171	280.000	434.000	516.4842688795	8:18:37PM	26/06/2015
108000	4163215	57.171	280.000	434.000	516.4842688795	8:18:37PM	26/06/2015
109000	4163215	57.171	280.000	434.000	516.4842688795	8:18:37PM	26/06/2015

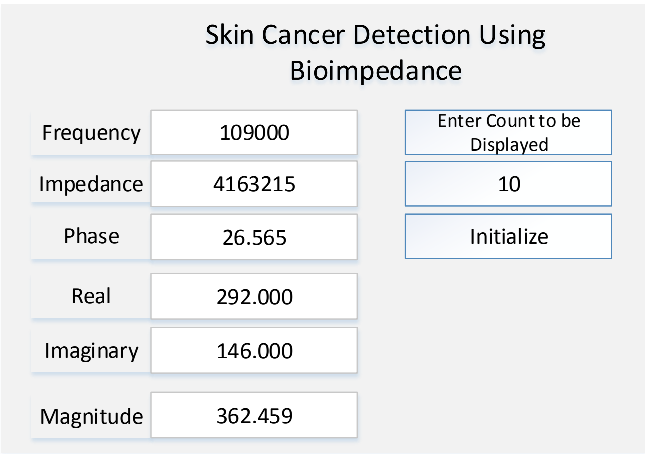

Figure 3: GUI window in Visual Basic 6

The above figure 3 shows the GUI window in Visual Basic 6 for accepting the initial start frequency and frequency count for frequency sweep operation. The user can open this file and choose from the different start frequency within range 1K to 10MHz. Then there are a set of buttons, "initialize" is the button that starts the sweep operation. This button calls a function that first sends all the start parameters calibrates the system and then receive the result from the microcontroller. From the result the system phase and magnitude using (2) and (3) are calculated and stored to the hard drive.

7. Conclusion

Thus in this paper a methodology is implemented that explains the Bio-impedance measurement system using AD5933 in which a constant voltage of 1.98 Vp-p is applied as a excitation signal to the TUS which in turn involves the injection of a constant current into the tissue at different frequencies and resultant voltages is measured. Discrete Fourier transform can be used to approximate any signal as the sum of infinite sine and cosine functions. The results of Discrete Fourier transform operation are complex numbers which comprise of real and imaginary part. Impedance is a complex number and hence AD5933 uses Discrete Fourier Transform for impedance conversion.

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