Design in and discussion of portable open electrical impedance tomography (EIT) system

Wei He, Peng Ran, Zheng Xu, Kang Ju, Bing Li

State Key Laboratory of Power Transmission Equipment & System Security and New Technology, Chongqing University, Chongqing 400030, China

Abstract

Breast cancer is a common disease of women, traditional imaging methods do not suitable for suburb and community hospitals. Moreover, the EIT functional medical imaging technology reflects changes of tissue function without invasive, and features of the portable equipment size and inexpensive examining costs. As these advantages, this technology is capable of early inspection for breast disease. According to the requirements of portable open EIT, our team designed a system of small size with low power consumption, high speed, wideband, and which capable of two ways incentive: frequency sweeping and frequency mixing mode.

To overcome the shortcoming of lacking of information in two-dimensional EIT, we developed 8*8 electrode array detector. By the distinction of power comparison among stimulation patterns, we employed the constant current source with complex back electrode as auxiliary. Considering of the electrical characteristics of breast tissue, we designed a system of high input impedance at reasonable consumption, with small crosstalk between acquisition channels. The use of high performance FPAG, integrated the functions, excitation control, digital frequency synthesis, high-speed phase sensitive detection, signal pre-procession and fast Fourier transform to demodulate the measurement signal, to a single chip, which extremely reduced the system complexity and enhanced the reliability and portability.

Keywords: electrical impedance tomography, open EIT, portable, frequency mixing

1. Introduction

EIT is considered to be an adjunct to early detection of breast cancer, as it could detect functional failure [1]. For the physiological and structural feature of breast, the traditional closed EIT system is difficult to apply in detection for fitting the appropriate shapes and positions. The other advantage of open EIT is the convenience of inspecting manipulation. Simply placing the measuring probe upon the object would avoid the trouble of individually affixed discharge electrode, and more alike to be accepted by the patients and doctors.

The previous reported open EIT systems as, TS2000 system of Israel [2],[3], MEIK® system of Russia [4], ACT-4 of Rensselaer Polytechnic Institute [5], were evaluated to be available and even applied in clinic examination, but limited in narrow band, processing speed or its inconvenience due to the large volume. Moreover, the detection depth, the output impedance from injection source and the asymmetric contact resistance from electrodes are remained to be researched and improved as well.

The work presented here describes an EIT system that has multi-frequency broadband capabilities suitable for use in a clinical setting. It must, therefore, possess a fast acquisition rate to minimize exam time at high accuracy and include patient safety considerations. Also, because of 3D artifacts present in 2D imaging systems, it is necessary to incorporate 3D measurement capabilities. In the following, we detail the design and implementation of an EIT system with these specifications.

2. System Design

Since we aim to build a portable system which could be used outdoors and as flexible clinical monitoring purpose, the structure of EIT system should be compact, but functional in terms of the system will achieve the extend of measurement and calculation of complex tasks. This results of high precision, robust, flexible measurement front-end and general communication method.

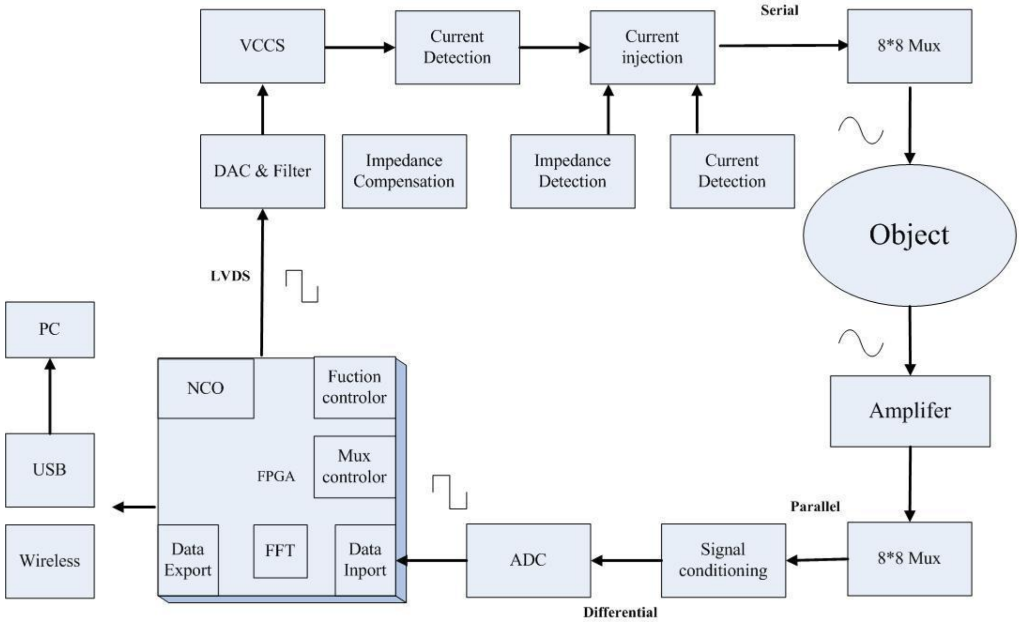

Figure 1. Block diagram of 64 electrodes portable open EIT

2.1 System overview

To satisfy the above-mentioned features, we choose Altera Stratix II series FPGA (EP2S60F484) as the processor. The chip configured, which of low power consumption and high speed(Up to 550 MHz internal clock frequency), works with internal RAM 9.3M bits for data processing and initiating the data acquisition sequence, besides a 512MB external Nand Flash for data storage. Current signal sinusoidal excitation waveforms, is generated by FPGA, and converted to analog voltages through a 14-bit DAC(AD2904,TI) rating at 125MHz, this voltage will be amplified and change to current for injection to the object by VCCS(Voltage Controlled Current Source) module. This model also works with output impedance measurement and compensation circuit to ensure the system precision.

At the signal measurement end, the analog switch array was built up from max4051, on the ground capacitance control 2pF, crosstalk between channels is also controlled at 90dB. The signal was amplified by a low noise variable gain amplifier AD8334, which provide gain from 7.5dB to 55.5dB with the input voltage noise down to 0.82 $nV/\sqrt{Hz}$. Direct voltage measurements are made on either side of the sense resistor using two 14 bit AD9259differential ADCs (Analog Devices) with a maximum throughput of 50MSPS, 98mW power consumption and 84dBc SFDR, which could minimize the influence in multi-frequency simulation.

The system communicate with the interface laptop via USB or wireless(GFSK Modulation, 490MHz ISM, RS-232 serial protocol operating at a rate of 115.2 kbps), and the data could be also saved on board in flash.

2.2 Electrode array and excitation mode

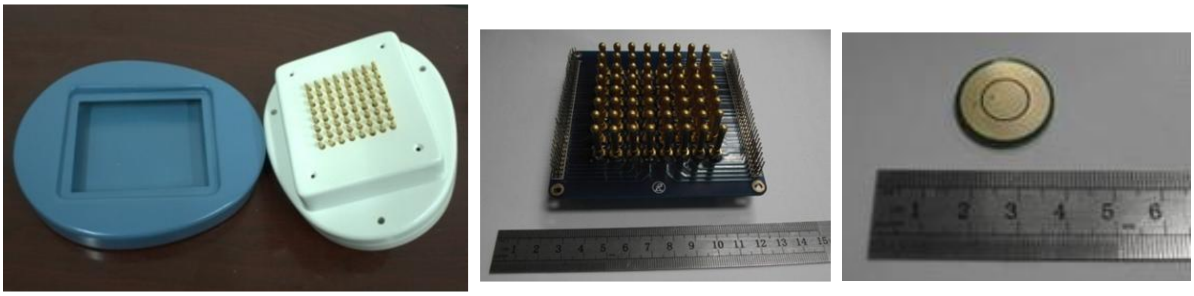

Figure 2. (a) Prototype (b) Electrode array (c) Back electrode

Although continuous progresses on the choice of electrode structure parameter in EIT have been made, the design of EIT electrode structure and parameter are still based on experience. These parameters restrict each other and their influence on EIT system are much complex [6]. As the application for breast disease detection, considering the breast shape and amount of information, we chose the gold-plated copper alloy electrode of contact resistance only 0.3mΩ. 64 electrodes constitutes a square 8*8 electrode array at distance of 8mm between each electrodes, as shown in Figure 2(a). A composite electrode disk was used as four-electrode measurements, which largely reduce the measuring electrode contact resistance. As the electrode outer and inner part of disk of very short distance, they are approximately of the same potential. (Figure 2(c))

(To be continued)

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