

# Research on Embedded Electrical Impedance Measurement System

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**Abstract.** Based on S3C2440 processor and Linux3.6.6 kernel, we developed an embedded impedance measurement system. This embedded system employs AD5933 as the impedance sensor, and data communication between AD5933 and S3C2440 processor is implemented with IIC communication protocol. In addition, the measurement results are displayed on the interface that is developed with QT. After modeling and solving the inverse problem by Newton Gauss algorithm, the distribution images of the object in the field are finally reconstructed satisfactorily. The research work offers a feasible and portable solution for clinical application of digital medical technology.

## Introduction

Biomedical electrical impedance tomography (BEIT), as a newly noninvasive medical imaging technique, has been attracted much attention in the field of biomedical engineering [1,2,3]. Compared to traditional imaging techniques, it has many advantages such as low cost, reusable, non-destructive, et al [4]. The BEIT technique which can monitor the impedance variations between different tissues and organs, provides a new way to diagnose diseases [5,6,7,8].

Currently, the data acquisition module of most impedance measurement systems are implemented with field-programmable gate array (FPGA) or digital signal processor (DSP) or PCI extensions for Instrumentation (PXI) and the collected experimental data is sent to the computer with USB or serial port to reconstruct the images of the diseased tissue [9,10,11]. However, it is quite inconvenient for moving these equipment when displaying the reconstructed images on computer monitors. It doesn't come near to the standard of current intellectualized medical instrument. In this regard, we in this paper develop a portable system that is used for bioelectrical impedance measurement. ARM processor and Linux system are integrated into this embedded system. Impedance data are collected at the measuring end of this system, and the collected data are displayed with QT platform. This portable embedded based impedance measurement system integrates more convenient and efficient when used for diagnosing diseases.

## Hardware Design

### System Structure

The system structure of this portable system is shown in Fig.1. As we can see, the communication between the S3C2440 and AD5933 is implemented with the I<sup>2</sup>C protocol. The impedance data are measured and displayed with manipulating the

buttons on the touch screen. Also, the data curves can be analyzed and displayed with QT platform.

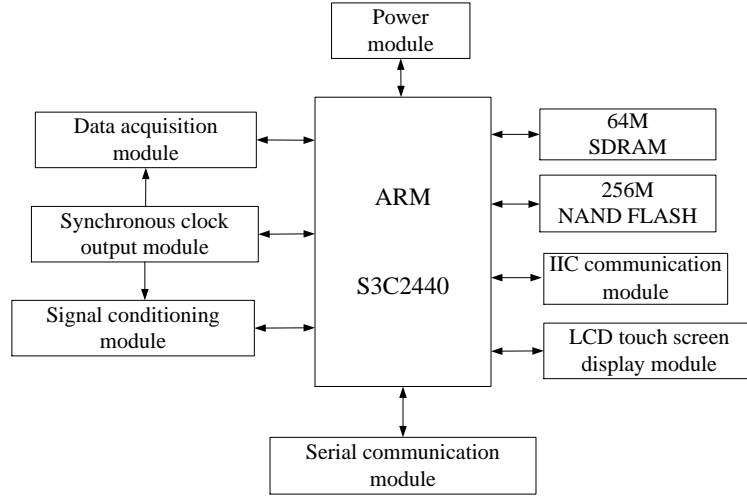


Fig. 1 System structure of the impedance measuring system.

With this framework, we construct an eight electrode embedded EIT system. the system main controller controls each electrode with IIC bus, while each electrode employs a single AD5933 to achieve the excitation and measurement. This embedded system includes a power module, a signal processing module, a IIC communication module, a data acquisition module, a synchronous clock module and a serial communication module.

### Signal Conditioning Module

The sinusoidal exciting signal is generated with the phase accumulator (DDS) in AD5933 and excited into the measurement field. Then the measured voltage are collected by using the on-board analog-to-digital converter (ADC) and processed with discrete Fourier transform (DFT) algorithm to obtain the real part (R) and imaginary part (I) of the collected signals. According to the manual, when choose the 1.98Vp-p the output DC bias is 1.48V, while, the current voltage (I-V) amplifier bias voltage of AD 5933 is  $VDD/2 = 1.65V$ . In this regard, the existed phase difference would lead to inaccuracy of the measurement. To solve this problem, we use the following strategy to eliminate this affection. First, we pre-process the output voltage by using a high-pass filter to eliminate the affection of DC component which would keep the same DC bias between measurement and excitation. Also, we design the voltage follower by using a low output resistance COMS amplifier AD8606 to eliminate the affection of output impedance. Furthermore, we improve the accuracy of I-V conversion by using a external I-V converter. This design not only eliminates the error involved by polarization, but also enlarges dynamic range of the internal ADC which would greatly improve the performance of the circuit.

### Data Acquisition Module

We in this paper employ an eight electrode impedance measurement system. During a sampling period, one of the eight electrodes is excited and the experimental data are collected from the other 7 electrodes. Take electrode 1 as exciting electrode for example, the other 7 electrodes are assigned measurement electrode. During the next sampling period, electrode 2 is assigned as exciting electrode and the other as measurement electrode, and so on. After all the 8 electrodes are excited, a frame of data collection is finished which include 56 data section. So, one frame data collected

by this impedance measurement system include  $N*(N-1)$  data sections, where  $N$  denotes the number of electrodes in the impedance measurement system. These collected frames can be used for image reconstruction. Fig.2 shows the schematic of the 8 electrode impedance measurement system.

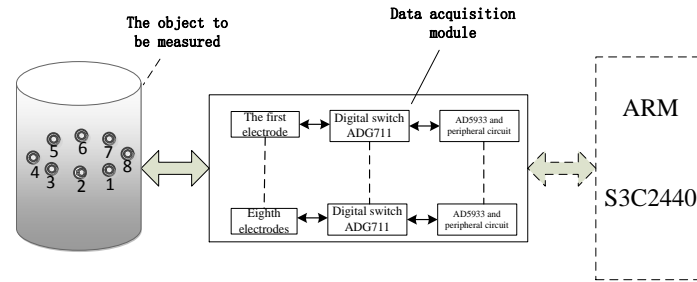


Fig. 2 Schematic of the 8 electrode impedance measurement system.

### Synchronous Clock Module

In order to ensure the synchronization during the data collection, we use AD9520-5 chip to generate the synchronous clock. There are two working modes for AD9520-5, i.e. low frequency mode and high frequency mode [12]. We choose the low frequency mode in the senses that the typical frequency of AD5933 internal clock is 16.776 MHz. There is no internal Vector-Controlled Oscillator (VCO) in AD9520-5, so we use external crystals and set the frequency coefficients to obtain the oscillation which can ensure the synchronization.

### Software Design

The system operation process is as follows: first, the system is initialized and logged into the operation interface of QT platform. Then system parameters such as scanning parameters, clock frequency are set on the operation interface. After that electrode working mode is also chosen. Execute the command to control AD5933 for collecting the experimental data. The measured data are saved in the system flash. Fig.3 shows the flow chart of the main program of this system.

Slot is a function that can be called to deal with a particular signal. Also, QT can be added to a custom slot. As shown in Fig.4, based on the added custom slot, we develop a system user interface to deal with the signals more efficiently. As shown in Fig.5, we can click the 'AD933set' button to complete the initialization process. It is worth nothing that due to the different settings and amount of collected data, the system initialization time will be different.

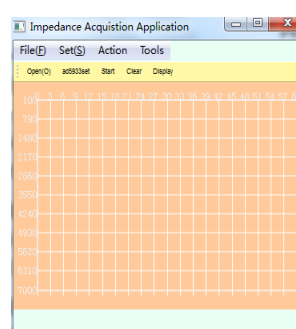
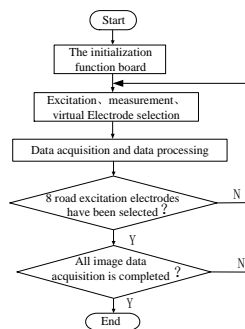


Fig. 3 Main program flow

Fig.4 QT interface

Fig.5 AD5933 initialization

## Experimental Verification

As shown in Fig.6, the object to be measured is a 15cm-diameter 25cm-high plexiglass cylindrical tank which filled with saline. The conductivity of the filled saline is 0.36S/m, and the ambient temperature is 15°C. The imaging target is a 4cm diameter cylindrical plexiglass rod. Eight 4mm titanium metal electrode are uniformly distributed around the inner side of the tank.

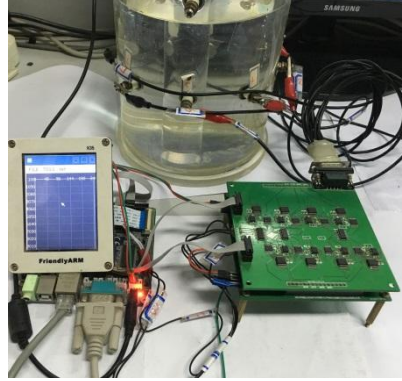
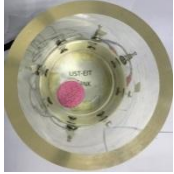
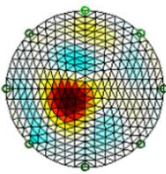
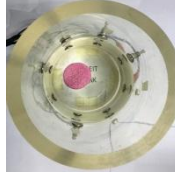
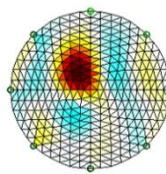
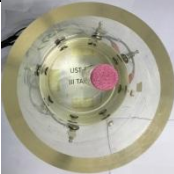
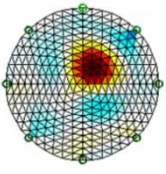
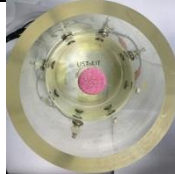
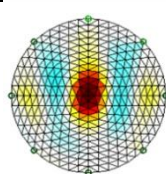


Fig.6 Measurement system

Under the COMSOL environment, a simulation model is established to calculate amplitude and sensitivity matrix. Newton Gauss algorithm is adopted for the image reconstruction. We use four images in different locations to demonstrate the imaging quality.

Table1 Experimental reconstruction results

NO	Original distributions	Reconstructed by Newton-Gauss algorithm	NO	Original distributions	Reconstructed by Newton-Gauss algorithm
1			2		
3			4		

As can be seen from the table 1, the embedded impedance measurement system can accurately demonstrate the shape, size and position of the organic glass rod.

## Conclusions

In this paper, the measurement and displaying is realized with the embedded impedance measurement system of eight electrodes. After modeling, solving and reconstructing the image algorithm, the distribution of the object in the field is finally obtained. In addition, the system can also use the AD5933 to sweep frequency. Select two electrodes to work independently and set 100 KHz for two port impedance data measurement. Due to the constraint of memory and computing resources of S3C2440 processor, it is difficult to implement complex reconstruction algorithm on this

embedded system. With the development of embedded technology, it is expected that the function of measurement, display and imaging can be integrated into one.

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