

EIT Based on Virtual Instrument

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Abstract

Design of a electrical impedance tomography system based on virtual instrument, the author firstly introduced the virtual instrument into the electrical impedance imaging from the perspective of hardware and software. The system use DAQ of NI to simplify the hardware structure and improve the stability. Software of system combines the advantages of LABVIEW and MATLAB, and verify some algorithms. Using NI virtual instrument, the system has strong expansion and do good basis for enhancing the performance of electrical impedance imaging system.

Keywords: virtual instrument, electrical impedance tomography, MATLAB, LABVIEW

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1. Introduction

With the rapid development of science and technology, two-phase system (liquid, gas-solid, liquid-solid, liquid-liquid, etc.) becomes more and more important in the national economy and human life. In many cases, the detection techniques of two-phase have been a constraining factor of studying two-phase. The process tomography as a new two-phase detected technique has been increasing emphasis by domestic and foreign researchers [1-2]. As a process tomography, EIT were transplanted in industrial in the late 1980s. Because it is a visual, non-invasive, low-cost, no radiation-line inspection technology, it is attended by the worker in the two-phase / multiphase flow testing and medical testing [3].

In 1986, National Instruments (National Instruments USA) first proposed a "virtual instrument" (Virtual Instrumentation) concept and gradually change the approach of measurement and automation of engineers and scientists. It consists of three parts: computer, instrument hardware, application software. Because of its flexible, easy to build, and users can define their own special instrument system, so it is widely applied in research, development, measurement, testing, measurement, monitoring and control and so on.

In the current electrical impedance tomography system, the entire system is based on DSP and FPGA or CPLD to collection and processing of data, then send the processed data to a PC for image display. However the authors combined the advantages of virtual instruments and MATLAB to design a digital electrical impedance imaging system based on virtual instrument.

2. The Design of Hardware System

2.1. System Structure

As shown in Figure 1, The system is constitute with the excitation source, driven and measurement channel, signal processing, LABVIEW data processing and image reconstruction.

System uses the current drive - voltage measurement pattern, the driving frequency for the single frequency is 10KHz. Firstly, The voltage-controlled current source generated the current signal (sinusoidal).The current signal through the driving channel with constitute of the multi-channel switch and CPLD, reach the imaging objectives surrounded by electrode. The two measured voltage signal which is extracted by the channel array through the band-pass filter enter into the front differential amplifier. Then the signal which is differential amplifier output is re-amplified by the PGA. The band-pass filter filters out interfering signals.PXI-6251's analog

input change the analog signals into digital signals, the digital signals are transmission to the host computer. lastly, the host computer reproduce the goal image through the image reconstruction algorithms.

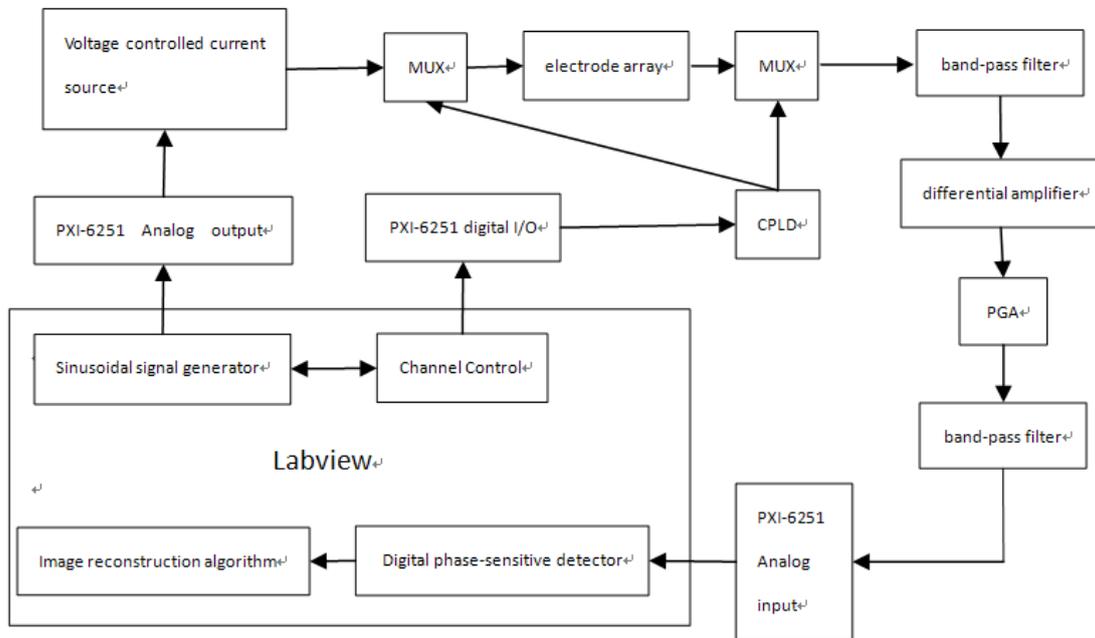


Figure 1. System structure

2.2. Excitation Source

As LABVIEW generated high precision and less interference signal, LABVIEW generate a frequency of 10KHz, amplitude of 1.5V the sinusoidal voltage signal in the system. Then voltage-controlled current source change the voltage signal into current signal. Voltage-controlled current source circuit shown in Figure 2[4-5].

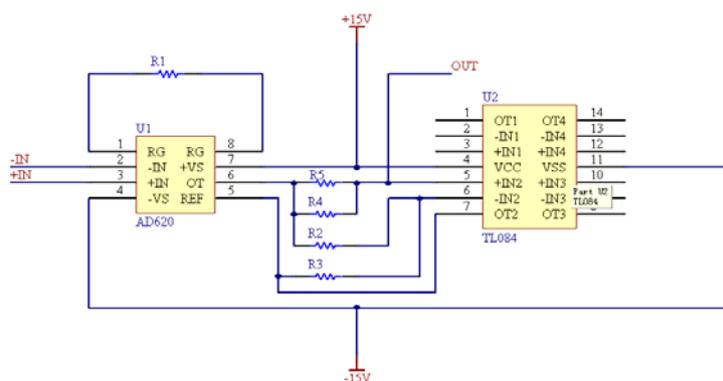


Figure 2. Voltage-controlled current source

2.3. Driven and Measurement Channel

Sensor electrode array is the media of building and accessing to market sensitive information. Therefore, it is very important to select the appropriate electrode. The selecting of electrode mainly takes into account the material, shape and size. Relative to the point electrode,

a rectangular electrode can significantly improve the uniformity of current density distribution [6-7]. So the system uses a rectangular electrode. According to the size of the experimental device, the electrode size is 15mm width and 32mm length. The schematic diagram of experimental apparatus and electrode array are shown in Figure 3.

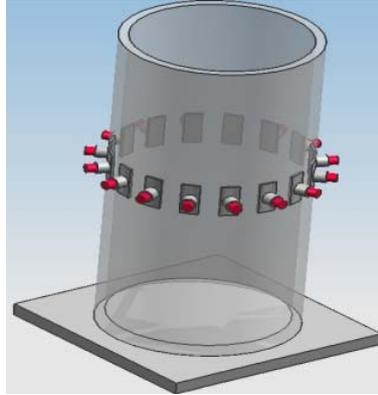


Figure 3. Experimental apparatus and electrode array

Multiplexers switch and channel array are 16-to-1 analog multiplexer switching devices. MAX306 which MAXIM produced is CMOS16 channel analog multiplexer. Its maximum resistance is 100 ohms. The maximum resistance matching error between channels is 5 ohms, the switching time is less than 400ns, and the crosstalk between channels is less than -92db. To-ground leakage current is less than 2.5nA, equivalent capacitance to ground is less than 140pF[8-9]. Its performance meets our design requirements. CPLD turn on and turn off the drive and measurement channels. We choice EPM7128SLC84-15 of MAX7000S series which is introduced by Altera Corporation. The control sequence shown in Figure 4.

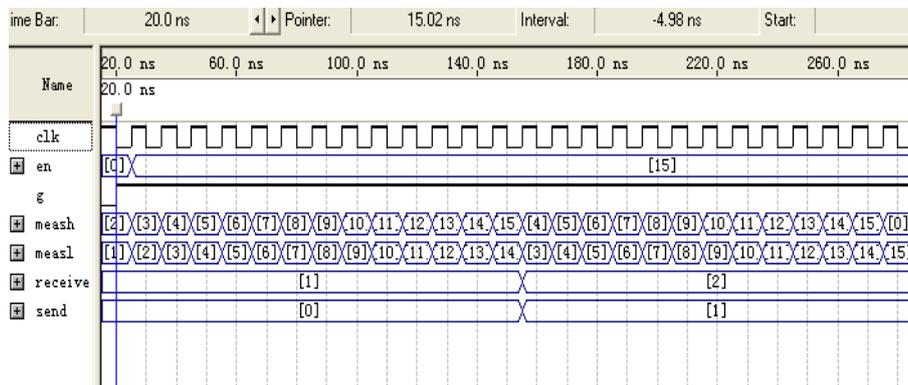


Figure 4. Conduction timing control

2.4. Signal Processing

Front differential amplifier should have high input impedance and common mode rejection ratio, low noise and drift. Selected chip is AD620, its CMRR is up to 100db.

Because of different electrode have the distinct resistance, the signal have big diffence after the liquid conductivity. Agilent's LCR meter measure the resistance of the electrode as showing in Figure 5 and Figure 6. Figure 5 is an empty field. Figure 6 is the comparison chart between the empty field and placing objects. In order to improve the accuracy of signal acquisition, we require the use of a programmable gain amplifier for signal amplification. TI's THS7002 chips is selected for Programmable gain amplifier.

When the signal transmission in the liquid, due to the asymmetric electrode electrolysis, galvanic action and other factors, the output voltage signal may contain DC components. At the same time in the EIT measurement system, the frequency of noise signal may not meet the sampling theorem, so that follow-up sampling will show aliasing phenomenon. In order to prevent the interference signal, this system uses the band-pass filter which is Maxim's MAX263.

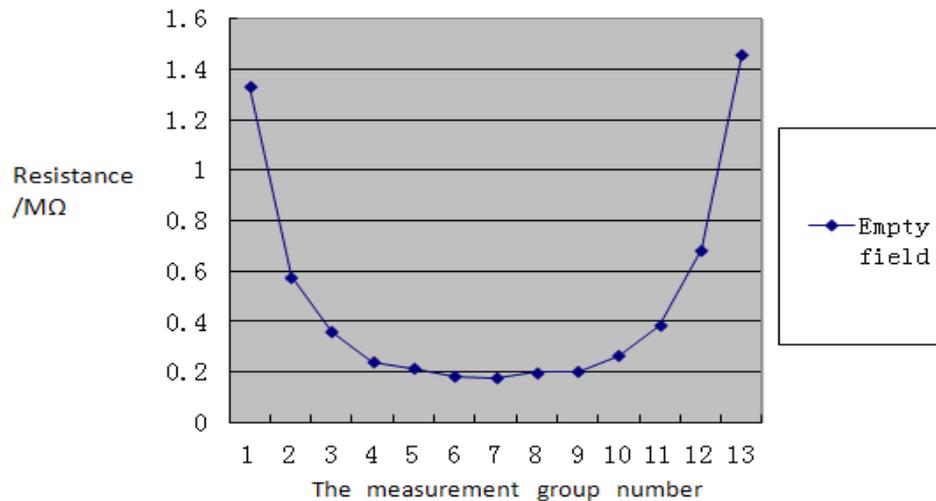


Figure 5. Empty field chart

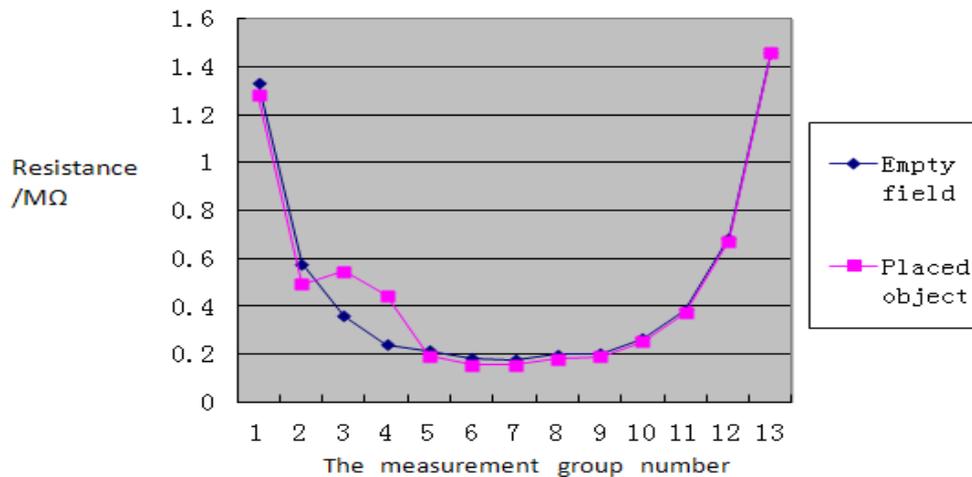


Figure 6. Comparison chart between the empty field and placed object (Blue curve is empty field, Pink curve is placed objects)

2.5. DAQ

The system will choose the PXI-6251 model of NI DAQ.

NI M Series high-speed multifunction data acquisition (DAQ) devices are optimized for superior accuracy at fast sampling rates. Specifications are as follows:

Analog input: Number of channels: 8 differential or 16 single ended. ADC resolution: 16 bits. Sampling rate: 1.25 MS/s single channel, 1.00 MS/s multi-channel (aggregate). Input range: ± 10 V, ± 5 V, ± 2 V, ± 1 V, ± 0.5 V, ± 0.2 V, ± 0.1 V. absolute accuracy at

full scale (+-10V) :1.92mV. Sensitivity (+-10V):0.112mV. absolute accuracy at full scale (+-0.1V) :52uV. Sensitivity (+-0.1V):6uV.

Analog input change analog signal into digital signal to provide data for follow-up digital processing. As the resolution of 16bits, the voltage can be broken down into 65536 copies. The minimum voltage can be detected is $V_{p-p}/65536V$ variation. This will improve measurement accuracy. Finally, the accuracy of the imaging system has been highly improved.

Analog Output: Number of channels:2. DAC resolution:16 bits. Maximum update rate: 1 channel: 2.86 MS/s.2 channels:2.00 MS/s. Output range: $\pm 10 V$, $\pm 5 V$. Output current drive: $\pm 5 mA$.

The analog output voltage signals is mainly create sinusoidal. The signal which is generated by DDS has harmonic interference. The use of LABVIEW and the card's analog output can effectively reduce the interference. Thereby reducing interference from the signal source can indirectly improve the accuracy of the system.

Digital I/O: Number of channels: 24 total. Maximum clock rate: 10MHz. Logic level: TTL. Maximum input range 0V-5V, the maximum output range of 0V-5V.

Digital I / O is the communication channel between host computer and CPLD. As its speed can reach 10MHz, the host computer can quickly control CPLD. CPLD can efficient control of different drive and measurement channel switching.

3. Labview

3.1. Digital Phase-Sensitive Detection

EIT demodulation method has three principal methods, such as switching demodulation, multiplication demodulation and digital demodulation. There is the inevitable interference in the process of switching amplifier for switch demodulation. As the accuracy and speed, multiplication demodulator cannot meet the design requirements of the system[10-11]. Thus it adopts all-digital orthogonal demodulation to realize digital phase-sensitive detection. Digital demodulation algorithm is shown in Figure 7.

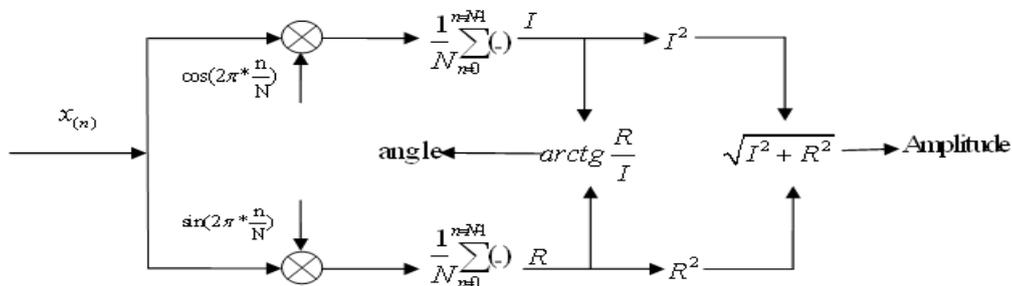


Figure 7. Digital phase-sensitive detector

The digital demodulation algorithm based on LABVIEW is shown in Figure 8. Input signal amplitude is 31, phase is 23 degrees. After demodulation amplitude is also 31, Phase is 23.001 degrees, satisfy the accuracy requirements.

3.2. Image Reconstruction Algorithm

Image reconstruction can be divided into dynamic imaging and static imaging[12]. Dynamic imaging including back-projection algorithm. Static imaging include Newton-Raphson algorithm, quasi-Newton algorithm, the generalized inverse matrix algorithm, NOSRE method, perturbation algorithm, neural network method, etc. The system first achieve quasi-Newton algorithm by MATLAB, then package into a COM component. Finally, call the COM component from the LABVIEW, to achieve image reconstruction.

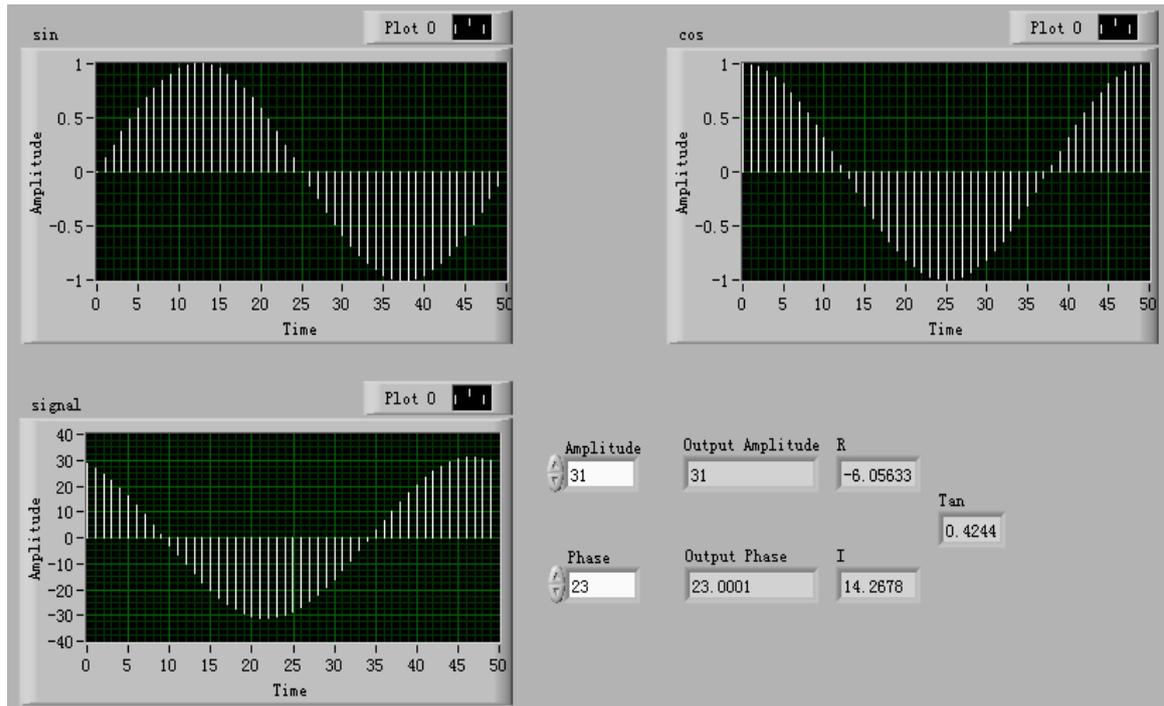


Figure 8. Digital demodulation algorithm based on LABVIEW

4. Experimental Results

This system is 16 electrodes, each electrode is 15mm width and 32mm length. Cylindrical tank of 28cm diameter and 40cm high filled with a certain conductivity of salt water. We placed plastic plates in anywhere within the tank. Figure 9 is the physical location image, Figure 10 for the target reconstructed image. As the poor conductivity of plastic plates, so the blue part of the image (figure 10) is the plastic plates. Reconstruction of the target's position is also consistent with the actual location of the object.

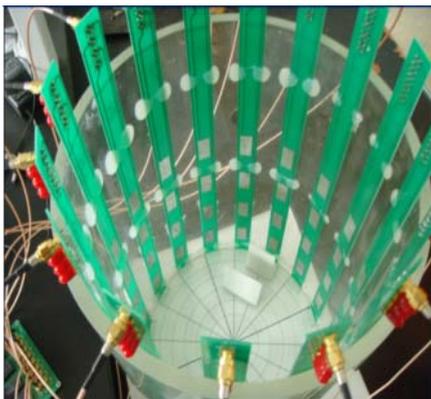


Figure 9. Physical location image

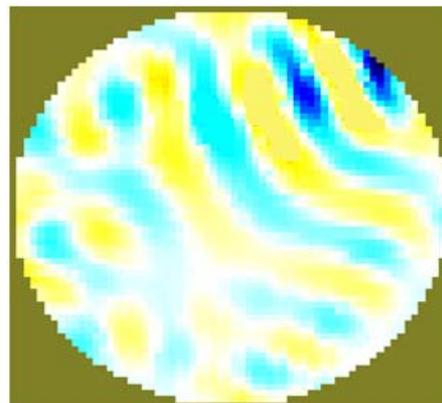


Figure 10. Target reconstructed image

5. Conclusion

The paper firstly introduce virtual instrument into the electrical impedance tomography from the perspective of the hardware and software. This way simplify the hardware system and enhance system scalability. DAQ use the NI PXI-6251 boards to improve the

system accuracy. Integration advantages of LABVIEW and MATLAB for processing data can enable the system to handle large amounts of data in a timely manner. Excitation source generated by the LABVIEW can easily change the frequency of excitation signal. So it becomes easy to develop a multi-frequency measurement system. On this basis, adaptive frequency system which automatic choose a suitable frequency according to the measured object can be designed. Measured object in a different environment (such as temperature, humidity, etc.) have some differences in impedance, so the system can add the monitoring of environmental conditions based on virtual instrument. Virtual instrument platform developed by LABVIEW can be remote control via Internet, Thus virtual instrument technology makes the system connect the Internet of things in the future. With the PC, semiconductor and software development in the future, virtual instrumentation system provides an excellent model for designing of electrical impedance tomography.

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