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# The research of ECT system based on AD7745

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**Abstract:** The AD7745 is a high precision capacitance-to-digital converter, which has the advantages of low power consumption, stable performance, high integrity easy to operate and so on. Applying the AD7745 to the system of electrical capacitance tomography can reduce the power consumption of the system, improve the anti-jamming capability of the system and reduce the volume of the system. This paper studies from both hardware and software, realizing the test on dielectric constant of 2.5. The experimental results show that the stability of the system meets the detection requirements of the ECT system.

**Key words:** Multiphase flow, AD7745, ECT,  $\Sigma - \Delta$  modulator, Digital filter

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In recent years, with the rapid development of sensor technology and process imaging technology, process tomography technology has been greatly improved in the field of detection. As the first branch of the process tomography, electrical capacitance tomography mainly reflects the distribution of each phase medium by measuring the change of the capacitance of the array electrode and constructing the image distribution of the medium of the measured object.

At present, in order to make it have strong resistance to stray capacitance, the capacitance tomography system generally uses AC excitation method to measure micro-capacitance. The system usually includes C/V conversion and AC filter amplifier circuit, analog-to-digital conversion circuit, measuring and selecting circuit and signal demodulation circuit, which makes the system structure complex, low integration and high power consumption.

AD7745 is a capacitor digital converter with 24-bit  $\Sigma - \Delta$  regulator, digital filter, temperature sensor, and I2C bus interface introduced by AD company. It has

the advantages of low power consumption, easy operation, stable performance, high integration characteristics, and the chip has a very high resolution, the range is in  $\pm 4.096$  pF. At the same time, the interior integrates high-precision converters and multiplexer, which can simplify the PCB layout of the ECT system, reduce the volume of the system, improve the stability of the system, thus provide the possibility for the realization of ECT's wide applications.

## 1 The structure design and working principle of the system

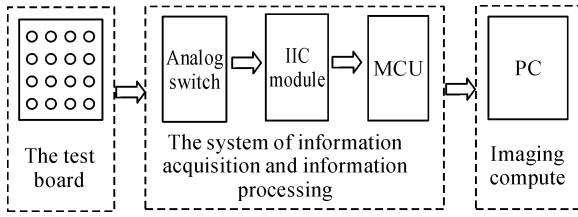
### 1.1 The overall design of the ECT system

The capacitance tomography system based on AD7745 is divided into the following parts: (1) The sensor system composed of array type electrode capacitance sensitive system; (2) The system of data acquisition and signal processing based on FPGA; (3) The computer for image reconstruction and analysis. The overall structure is shown in Fig. 1:

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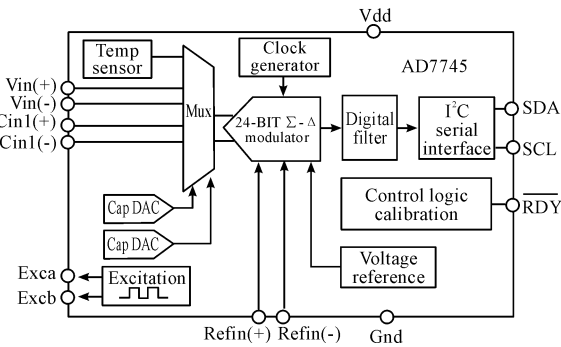


**Fig. 1 Schematic diagram of ECT system**

The system adopts the IP core of FPGA to control the acquisition switch of ECT system and the sequential of AD7745; The data is filtered and quadrature demodulated by controlling the AD7745 as well as transmitted to the computer by the means of USB communication, so as to realize the upper and lower level machine parallel work.

### 1.2 Data acquisition system module design

AD7745 is a capacitor digital converter with high precision, which includes not only a  $\Sigma$ - $\Delta$  regulator, a digital filter, but also a temperature sensor, a clock generator and so on [1]. The main internal structure is shown in Fig. 2.

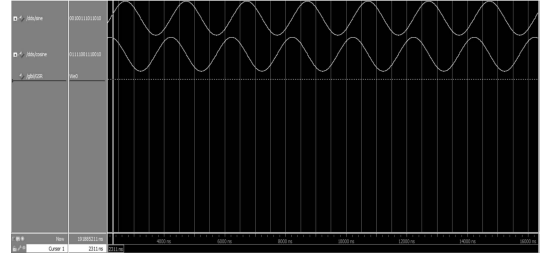


**Fig. 2 AD7745 internal structure diagram**

When the system needs to measure the fixed capacitance value, the AD7745 adopts single ended the input mode, the EXCA pin connects with the capacitor side to transmit the excitation signal, and the CIN1 (+) pin accepts the electrode to collect the signal.

When an unknown form is to be measured or the object is difficult to connect while using a AD7745 pin, the sensor test board is connected to the measured object. At this time, in order to save resources and improve the anti-interference degree of the signal, using the DDS kernel embedded in FPGA, the DDS signal needed in design can be produced directly. The sinusoidal excitation signal shown in Fig. 3 is the digital signal generated by DDS and simulated by the simula-

tion software Modelsim10.1 a.



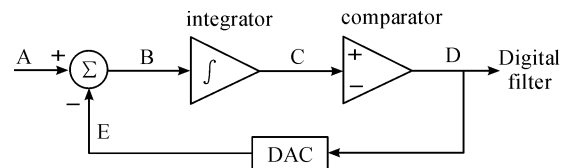
**Fig. 3 Sine excitation signal**

For the determination of fixed-value capacitance, using AD7745 chip's  $\Sigma$ - $\Delta$  technology and implemented by changing the fixed value on the chip capacitance and balanced variable voltage input; The C/V physical circuit with strong resistance to stray capacitance is used in the external sensor, by the data processing system, at the same time, the USB interface of PC is used to send the control instruction to the data acquisition system, adjust the collected data, and reconstruct the image by using the corresponding image reconstruction algorithm, thus reconstructing the distribution section of the measured material on the sensor.

### 1.3 Signal processing system module design

After passing AD7745  $\Sigma$ - $\Delta$  regulator, the analog signal is adjusted by the digital filter, the Fourier Transform is carried out in the DSP engine, besides, the real part and the imaginary part of the unknown impedance are outputted through the I2C serial interface. Traditional analog demodulation limited the speed of data acquisition because of the stable time of low-pass filter, but it can be optimized by  $\Sigma$ - $\Delta$  regulator and digital filter for the AD7745 data acquisition system.

$\Sigma$ - $\Delta$  technology is a mature demodulation technology, which has been used to require a high performance A/D conversion of 16 bit or higher resolution in recent years, the  $\Sigma$ - $\Delta$  regulator consists of integrators, comparators and actuators, which together form a feedback link, as is shown in Fig. 4.



**Fig. 4 Schematic diagram of  $\Sigma$ - $\Delta$  regulator**

A is the analog signal sampling value to be converted, and D is a digital signal that has been quantified. The quantization process of the  $\Sigma$ - $\Delta$ regulator is to sum the input analog signal A with the feedback signal E, and get the quantized error signal B. Then, the error signal B enters the integrator integral, the output signal C is inputted to the quantizer for quantification, and the number sequence D consists of 0 and 1.

## 2 Software programming

### 2.1 Signal acquisition system design

The program of ECT signal acquisition based on AD7745 is divided into the following parts: AD7745 setting, data reading and transmission. The detailed flowchart can be seen in Fig. 5. Firstly, the system will complete the AD7745's configuration work. Secondly, the FPGA core will process information after the AD7745 complete a signal acquisition. And finally data will be sent to the highest-level machine to complete the measurement works by the USB.

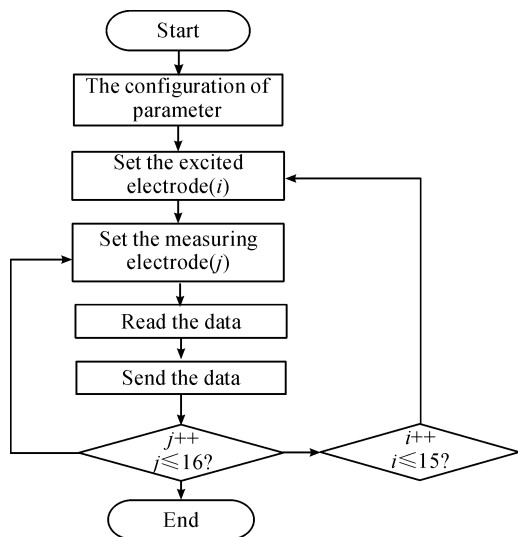


Fig.5 Flowchart of software design

### 2.2 Signal transmission system design

In order to reduce the difficulty of FPGA programming, shorten the development cycle, the system uses CY68013A chip produced by Cypress Company as USB interface control chip, besides, it works in the SLAVE FIFO mode, its internal microprocessor is not involved in the transmission of data. The internal FIFO of CY7C68013A is read directly by FPGA chip. The FPGA and CY7C68013A connections are shown in Fig. 6.

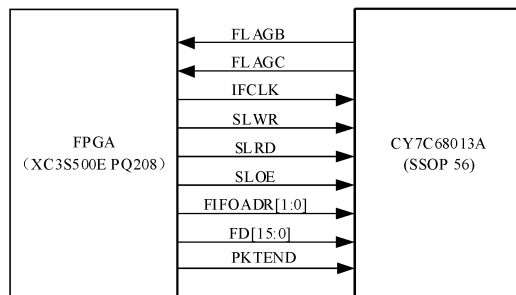


Fig.6 Connection diagram of FPGA and CY7C68013A

## 3 Experimental test and analysis

### 3.1 Fixed-value capacitance detection

The test board is disconnected from the system, and a 3PF value capacitor is placed on the EXCA side of the AD7745 and the CIN(+) side, and after repeated testing, the test results are shown in table 1.

Table 1 Fixed-value capacitance test results

Test times	Test results/pf	Test times	Test results/pf
1	3.046 543	4	3.039 873
2	3.047 231	5	3.039 578
3	3.046 447	6	3.047 356

The experimental results show that in the AD7745's measurement, if using the same capacitance in the same measurement system, the capacitance error basically meets the measurement requirements.

### 3.2 Image reconstruction test

The measured object is selected which the dielectric constant is 2.5, as is shown in Fig. 7. The reconstructed image is shown in Fig. 8, and the shape shown in the reconstructed image basically meets the requirements of ECT detection system.

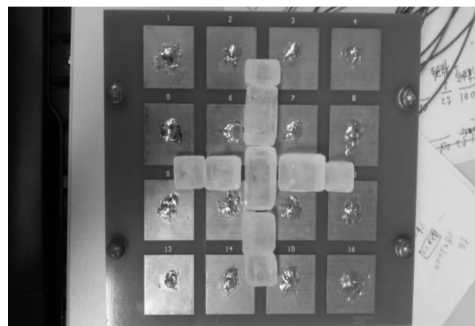


Fig.7 The tested object

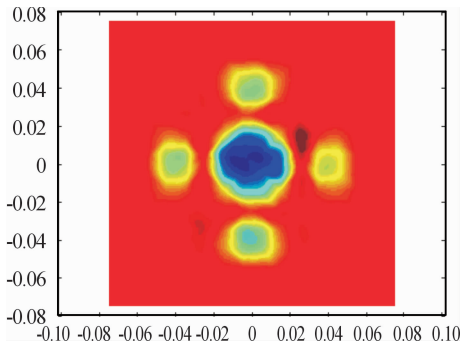


Fig. 8 The reconstructed image

## 4 Conclusions

ECT has the characteristics of non-invasive and high security, and the AD7745 chip has low power consumption, stable performance, easy to operate and other advantages. Utilizing AD7745—the special integrated capacitor conversion chip, we can realize the analog-to-digital conversion which requires a large number of discrete components in the past, at the same time, simplify the design of the phase-sensitive

demodulation and AD data conversion module of the traditional ECT detection system so as to reduce the cost greatly and make the system have some practicability and flexibility.

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## 基于 AD7745 的 ECT 系统研究

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**摘要:** AD7745 作为一款高精度的电容数字转换器, 具有功耗低、性能稳定、集成度高、易于操作等特点, 将 AD7745 应用到电容层析成像系统中, 可以降低系统的功耗、提高系统的抗干扰能力、减少系统的体积。从硬件和软件两个角度进行研究, 实现了对介电常数为 2.5 物质的测试。仿真实验结果表明: 该系统的稳定性和精度能够满足 ECT 系统检测的要求。

**关键词:** 多相流; AD7745; ECT;  $\Sigma$ - $\Delta$  调节器; 数字滤波器