Design and analysis of multi-channel signal acquisition circuit based on FPGA

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Abstract: This paper designs and implements a real-time underwater acoustic signal acquisition system based on FPGA. The system can collect and transmit the noise generated by ships. It provides the basis and guarantees for the subsequent research and analysis of noise.

1. Introduction
The signal acquisition circuit is the hardware basis of the signal analysis system. High precision signal acquisition circuits play an important role in underwater acoustic signal acquisition systems, motor noise acquisition systems, and other engineering practices[1-2]. In this paper, a 24 channel signal acquisition circuit is designed, and the sampling accuracy of the circuit is improved by voltage drop compensation and mean filtering.

2. Materials and Methods

2.1 Overall system design scheme
This design processes the signal by the filter amplification circuit and then sampled synchronously by three ad7606 chips. After the sampling signal is transmitted to FPGA, it is sent to the host computer in RS-485 communication protocols.

The System design framework is shown in Figure 1:

![System design framework](image)

2.2 System hardware design

2.2.1 Power module design
The schematic diagram of the power module is shown below. The power module uses the asm1117 chip to provide an FPGA control chip with 1.2V core voltage, 2.5V auxiliary voltage and 3.3V IO pin voltage. In addition, the tps7a470x provides a stable power supply to the ad7606 chips.
2.3. Filter amplifier circuit design

As shown in Fig. 3, this design uses the circuit structure of a 4-order low-pass filter and a 4-order high-pass filter to filter the signal to obtain better passband flatness. At the same time, the signal is amplified ten times by an integrated operational amplifier circuit.

2.4 Design of AD sampling module

The design of the sampling module is illustrated in Fig. 4. This design uses ad7606 as the sampling chip, and the sampling rate can reach 200KSPS. The method of synchronous sampling of three ad7606 chips can sample 24 analogue signals at the same time. The sampling circuit of the ad7606 is shown in the figure below. The chip selection signals CS1, CS2 and CS3 of the three ad7606 can be...
enabled respectively, making efficient use of the bus and saving hardware resources. The convert signal is connected together, enabling the chip selection signal to enable the data conversion of three ad chips simultaneously. After data conversion, read the respective data successively with the three read signals of RD1, RD2 and RD3 of three chips to realize the function of synchronous acquisition of 24 channel analogue signals.

3. Results & Discussion

3.1 Power spectrum analysis of signal based on signal tap and MATLAB

The system is tested with 5KHz sine wave signal, and the sampling results are saved as data files with a Quartus integrated signal tap logic analyzer. Import the data file into Matlab and analyze its performance[4]. The collected data visualized by MATLAB and the power spectrum are shown in the figure below. It can be seen that the collected waveform is relatively smooth without waveform distortion., and the noise is very small, which ensures the requirements of signal integrity.
3.2 Measurement accuracy analysis
Since the 24 channel acquisition requires three ad7606 chips synchronous acquisitions, it is necessary to analyze the voltage accuracy and sampling voltage consistency of the three ad7606 chips. We configure one ad7606 chip as the internal reference mode and the other two ad7606 chips as the external reference mode. The chip working in the internal reference mode is the chip working in the external reference mode. In order to make the reference voltage collected by the three ad7606 chips consistent, we let one ad7606 chip supply power to the other two ad7606 chips.

We print the data collected by each channel through the serial port assistant and then analyze the data. We get the conclusion that the error of the circuit is about 1.5mv, within the input range of -10V ~ +10V, which has met our design requirements very well. In the field of higher precision applications, through voltage drop compensation and mean filtering of the sampled data, a multi-channel sampling circuit with an error of less than 1.5mv can be obtained.

4. Conclusions
In this paper, a multi-channel and high-precision signal acquisition system is designed. By acquiring input waveform and spectrum analysis, this paper verifies that the system can better restore the
sinusoidal signal at the input. Comparing the acquisition voltage of each channel can prove the consistency of each channel in voltage acquisition. It can be seen that the signal acquisition system realizes the function of signal acquisition and restoration. The design has circuit design reference value and practical application value in underwater acoustic signal acquisition and application.

References
[1] Sun, X. X., Liu, L., Liu, Y. D., Ning, H. Y. Wireless communication motor protector based on FPGA[J]. DESIGN AND ANALYSIS. 2018(46)11:58-61.
[2] Wu, L. F., Wu, J. W., TIAN, P. Y. Noise acquisition and analysis system based on STM32 and LoRa [J]. Modern Electronics Technique. 2021(44)21:30-34.
[3] Zhang, B. X., Jia, X. R. Analysis of multi-channel parallel communication signal acquisition system based on FPGA Technology [J]. CHINA PLANT ENGINEERING. 2021:101-102.
[4] Lu, F., Tian, H. R., Wang, Y. P., Huang, Y. A real-time underwater acoustic information acquisition system based on FPGA and DSP [J]. Electronic circuit design and scheme. 2020.9:5-7.