MECHANICAL PARAMETERS ACQUISITION TEST BASED ON WIRELESS SENSOR NETWORK

Hongjuan **LI***, Gening **XU**, Lidong **ZHOU**

ABSTRACT: In order to design wireless sensor that meets high precision acquisition of mechanical signal, dual core processor architecture is proposed in this paper. In addition, four-channel signal input is designed, and the key factors affecting the accuracy of frequency precision of data acquisition amplitude are analyzed. What's more, the data acquisition method of wireless sensor network with high precision mechanical testing is put forward. The accuracy test results show that the noise caused by parameter acquisition system constant current drive is little, and self-inhibition power supply noise constant current is feasible. The frequency error of 0kHz and 2kHz acquisition signal was 0%. It indicates that the acquisition signal frequency error is within FFT frequency resolution, and verifies the accuracy of node sampling frequency.

Key words: mechanical signal, wireless sensor, high precision data acquisition

1. INTRODUCTION

Based on the shortcomings of high deployment cost, poor maintainability, lack of flexibility and so on of wired connected mechanical equipment condition monitoring system, especially in a sealed environment and mechanical rotating environment, the wire connection is difficult to achieve. At home and abroad, researchers have begun to study mechanical equipment state monitoring method based on wireless sensor network [1]. at present, for the wireless sensor network node that can be used for mechanical testing, the parameter acquired is single and the sampling frequency is low. And the high frequency mechanical vibration signals that reflect the mechanical equipment performance are difficult to well obtain. While the crystal oscillator drift and task conflict of wireless sensor network node makes the reduction of sampling frequency accuracy under high frequency acquisition more prominent. Moreover, in the application environment, the electromagnetic interference, node power noise, and conditioning circuit ripple reduce the A/D conversion amplitude accuracy. And a large amount of test data due to multi parameter high frequency acquisition makes the node data transmission become a bottleneck [2].

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To solve this problem, this paper uses the dual core processor architecture, and designs four-channel signal input with the ability of multi parameter acquisition. For low amplitude accuracy and frequency precision of signal acquisition, study is conducted from multiple power management, IEPE sensor drive, high precision data conversion and other aspects, so as to reduce the noise of multi parameter wireless sensor nodes and to improve the amplitude accuracy and frequency precision of signal acquisition.

2. SYSTEM DESIGN

This paper uses the dual core processor architecture, and designs four-channel signal input with the ability of multi parameter acquisition. For low amplitude accuracy and frequency precision of signal acquisition, study is conducted from multiple power management, IEPE sensor drive, high precision data conversion [3] and other aspects, so as to reduce the noise of multi parameter wireless sensor nodes and to improve the amplitude accuracy and frequency precision of signal acquisition.

2.1 Overall architecture design

The mechanical test wireless sensor network node performance is generally low, and the sampling rate is not high. For solving this problem, the dual core processor architecture is adopted, to control data acquisition and wireless communication, respectively. The node dual core processor architecture is shown in figure 1.

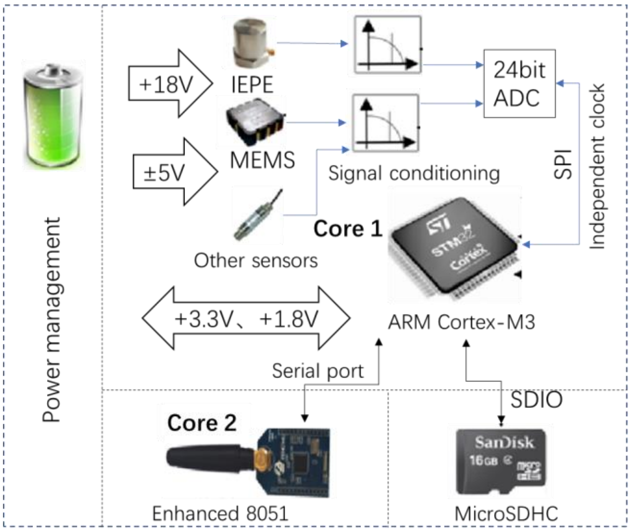

Fig.1 The dual core architecture of wireless sensor networks node

Core 1 is a STM32F103 micro-controller with high performance 32-bit ARMCortex-M3 core, which is responsible for the acquisition parameters configuration of each channel, the control of A/D sampling frequency, the acquisition and storage of multi parameter data and so on tasks. Its running frequency reaches 72MHz, and it has the command execution efficiency of 1.25DMIPS/MHz. It adopts independent crystal oscillator as external clock, and controls A/D sampling [4] after frequency division. In addition, it has enough ability to realize high frequency data acquisition. What's more, core 1 has SDIO interface with large capacity MicroSD card, using 4bitDMA for data storage. As a result, it can greatly improve the speed of data storage, and ensure the real time storage of a large amount of data in multi parameter and high frequency data acquisition [5].

Core 2 is a wireless RF chip CC2530 with low power enhanced 8051 core. Because of its relatively low performance, it is only used for the formation and maintenance of wireless sensor networks, command receiving and sending, as well as data transmission. In idle case, core 2 needs to communicate periodically with its parent node, and the rest of the time, it is in sleep state, so as to save node energy.

The serial communication is applied between the two cores to exchange command and data. Core 2 is responsible for monitoring network information, receiving host computer command, and sending the command to core 1 through the serial port. In consequence, the high frequency acquisition of core 1 is not affected by factors such as network maintenance, and it ensures the stability of the high frequency data acquisition.

2.2 Design of signal acquisition node

In this paper, the multi parameter acquisition of wireless sensor network node designs 5V DC power supply and 2mA constant current source, to meet the drive demand of most mechanical testing sensor. While for the sensor with large power consumption, it requires external power supply. In terms of signal acquisition, AC coupling and DC coupling two types of voltage input are designed, and the input range is ±10V. For the signal transfer board dedicated to other types of sensor output signal, the signal is converted into voltage that corresponds to the input range, to achieve the collection purpose [6].

The multi parameter wireless sensor network node must meet the multi-channel signal input capability, and the A/D conversion chip is more common in single channel, 4 channels and 8 channels. If several single channel A/D converters are used to correspond to each channel in a node, it will greatly increase the cost and power consumption of nodes. On the other hand, because the node capacity is limited, it is difficult to achieve 8 channels' high frequency data sampling. Therefore, the 4 channels A/D converter is chosen at last, and multi parameter wireless sensor network node is designed as 4-channel input.

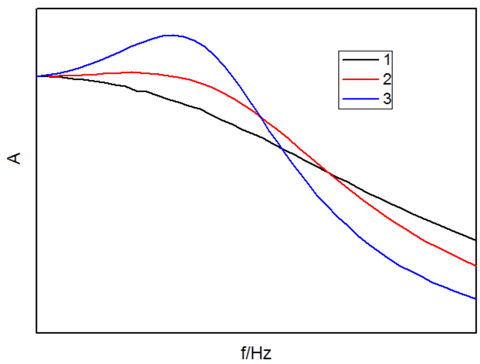

Fig. 2 Multi-channels power management

3. INFLUENCING FACTORS OF DATA ACQUISITION ACCURACY

3.1 Analysis of influencing factors of data acquisition accuracy

The accuracy of data acquisition mainly refers to the amplitude precision and frequency accuracy, and both play an important role in the final mechanical condition monitoring and fault diagnosis. The use of the high accuracy collected data can earlier find fault mechanical operation and timely deal with it.

The amplitude of the signal indicates the intensity of the mechanical parameter signal, and the magnitude of the amplitude can be used as an index to evaluate the running condition of the current mechanical equipment, and the factors that influence the amplitude of the signal collected are as follows:

The first one is the quantization error and inherent noise of sensor. First of all, the sensitivity of the sensor is directly related to the supply voltage of it. Even a low dropout linear regulator (LDO) is applied, it is difficult to guarantee the consistence of power supply voltage of each node. As a result, it is bound to influence the sensitivity of the sensor and affect the amplitude accuracy. Secondly, the sensor has its inherent noise, which will impact the sensitivity of sensors.

The second one is the influence of signal conditioning circuit and A/D conversion. As shown in Fig. 2, from curves 1 and 3, it is seen that, due to the unreasonable selection of filtering parameters, the useful signal is not stable in terms of gains in the pass-band. And both attenuation or amplification of the signal will have a serious impact on the later analysis. On the other hand, the A/D conversion bits also affect the amplitude accuracy. The higher the number of A/D bits is, the stronger the signal restoration ability is, and the higher the amplitude accuracy is [7].

The third one is the influence of power supply noise. Most of the wireless sensor network nodes use the on-chip A/D for analog digital conversion. Digital and analog power supply only use a simple "π" filter for processing. The digital circuit will make instantaneous power increases in the implementation of A/D conversion, data storage and instant wireless data transmission. Therefore, the power supply voltage is low, and the strong interference signal will crosstalk the analog part. It not only affects the filter conditioning circuit, but also affects the signals output of the sensor, and seriously damage the signal acquisition [8].

In view of the above multi parameter wireless sensor network node functional requirements and accuracy influencing factors, the research is carried out from the following aspects: first of all, the scheme of multi-channel power management is designed; secondly, the noise suppression sensor driver is designed; finally high precision independent clock is used to control A/D sampling.

3.2 Power management

Considering the cost and portability of installation and maintenance, the nodes acquisition uses two 14500 lithium batteries series for power supply. 3.3V power supply that the processor running needs is obtained through the step-down of lithium batteries. While 1.8V power supply that a digital circuit work of A/D conversion chip needs is obtained through the step-down of 3.3V power that has performed step-down. The simulation circuit has high demand of the power supply noise, so the linear regulator is used to get 5V power supply. -5V power supply is obtained with low power negative pressure chip, and finally the IEPE excitation voltage [9] is got by double voltage and step-up scheme. The multi-channel power management scheme is shown in figure 3.

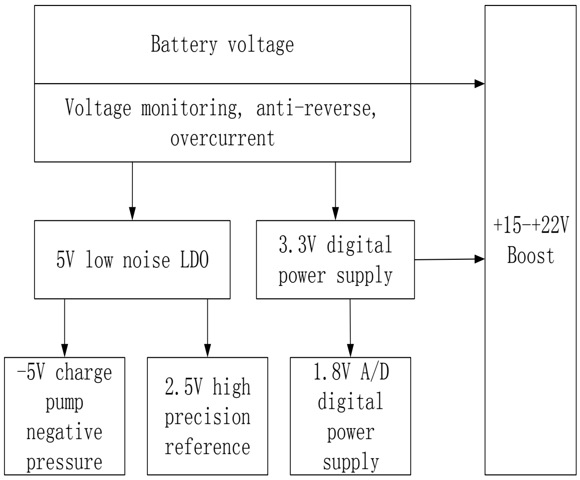

Fig.3 Multi-channels power management

3.3 Self restraining power supply noise IEPE sensor driver

The excitation voltage of IEPE sensor is relatively high, and under constant current condition, high power supply voltage will bring high power consumption. In addition to providing 2mA constant current, the excitation voltage also needs to supply power for a constant current control circuit. But the constant current control circuit device belongs to the micro power level, and the working current is less than 1mA. Therefore, the low band load capacity MIC2141 boost chip is selected, which can meet the load requirements. The relationship between the load and the conversion efficiency is shown in Fig. 4. When the size of the load current is 3mA, the conversion efficiency reached 90%, with a high energy utilization rate.

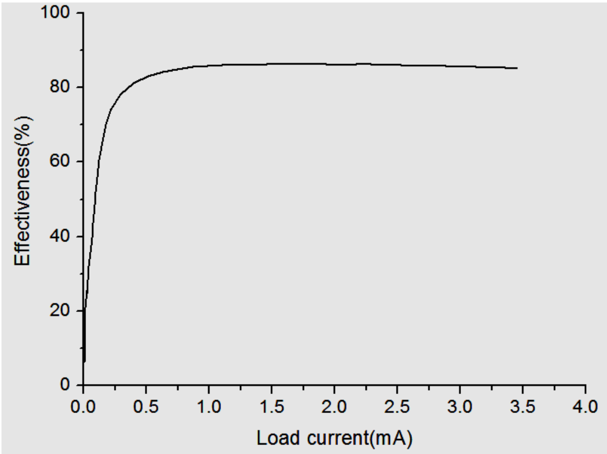

Fig. 4 MIC2141 load current VS efficiency

3.4 High precision data conversion

The node, through the acquisition module processor and sampling rate requirement, sets PWM wave that output corresponds to, and the duty ratio is 50%. While the PWM clock is provided by frequency by high precision active crystal with an external frequency of 10.2400MHz. After dividing frequency, it is taken as A/D clock, to ensure the stability of clock source. After the PWM output setup is complete, the processor intervention is unnecessary. And it will not interrupt PWM timing because of the processor interrupt and so on operations, so as to ensure the stability of the sampling interval [10].

The processor and ADS1274 use SPI communication mode, and it is started the acquisition by synchronous input pin SYNC negative pulse. When the data transfer is completed, the DRDY pin will produce negative pulse to prompt that data has been prepared.

The DRDY signal is set as the external interrupt source of processor, falling edge triggered interruption, and in the interruption, processor gets A/D conversion results through the SPI.

4. PRECISION ACQUISITION TEST OF MULTI PARAMETER WIRELESS SENSOR NETWORK NODE

4.1 Noise testing

Set the sampling rate of 10KH. In the absence of vibration signal input, a piece of data is acquired when the sensor is still. In this way, we can get the noise level of node in the case of various signal input, as shown in fig. 5- 8. When the node is connected to the MEMS sensor, the noise of the acquisition signal is the largest, and the effective value is 4.1mV, which is due to the inherent noise of the ADXL001-70MEMS sensor. The noise effective value of the sensor at 15KHz bandwidth is 8.18mV, where partial noise signals are suppressed by limiting bandwidth. And then the value of the IEPE sensor is only 128.24μV, slightly larger than the theoretical value of 352C03 sensor noise, which is introduced by constant current driving noise and node inherent noise. From the effective value of AC coupling noise of 110.72 V, it can be seen that, the inherent noise nodes accounted for the major part of the noise, and a constant current drive is introduced rarely. It has proved the feasibility of self restraining power noise of constant current source designed in this paper. The effective value of noise is the minimum in the DC coupling, but the signal in the presence of a small amount of bias is due to unbalanced voltage in the amplifier input end of DC pathway in the DC coupling. It can be adjusted until it is balanced through adjusting the compensation resistance. It can be seen from the test results that the acquisition node can effectively suppress the noise, and the selection of the appropriate sensor according to the application situation can meet the acquisition of the mechanical parameter signal.

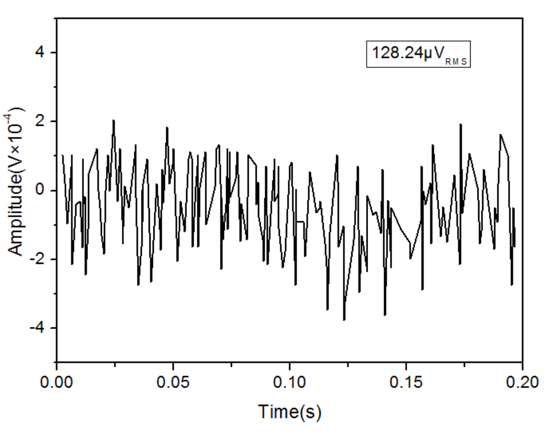

Fig. 5 IEPE Noise test results of different input signals

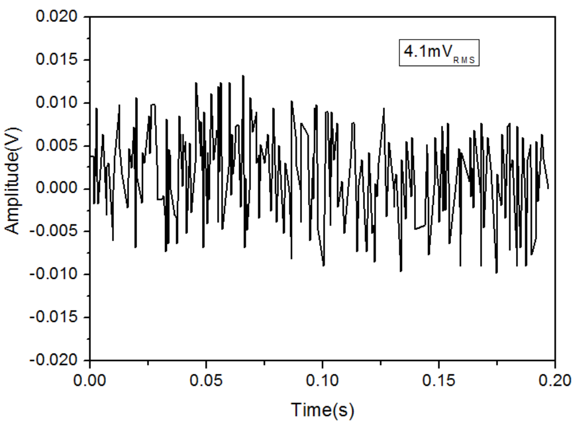

Fig. 6 MEMS Noise test results of different input signals

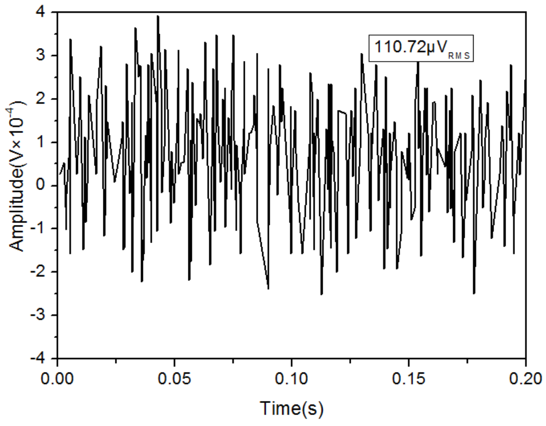

Fig. 7 AC Noise test results of different input signals

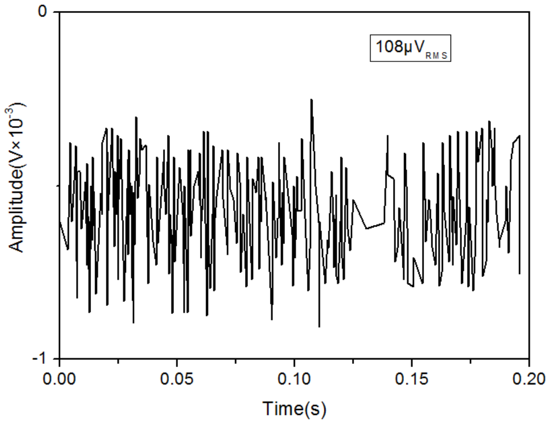

Fig. 8 DC Noise test results of different input signals

4.2 Frequency accuracy test

The frequency accuracy test uses Agilent33522A function generator as a standard reference signal, respectively setting node sampling rate of 10kHz and 2kHz. The standard sine signal of acquisition function generator is combined for FFT analysis, to get the frequency and amplitude of signal acquisition. In order to avoid the error caused by energy leakage during FFT, the nodes should be sampled in the whole period. If the number of analysis points is 32768, the frequency resolution is 0.305Hz and 0.061Hz, respectively. Three groups of signals were collected and analyzed, and the results were shown in table 1. The frequency error of 10kHz and 2kHz acquisition signals is 0%, which indicates that the frequency error of acquisition signal is within FFT frequency resolution, and the accuracy of sampling frequency is verified.

Table 1 Frequency error of node acquisition

	2kHz			10kHz	
33522A	Node	Error	33522A	Node	Error
31.25	31.52	0%	158.8	158.8	0%
123	123	0%	628	628	0%
628	628	0%	2550	2550	0%

5. CONCLUSION

This paper mainly researched the mechanical testing of multi parameter wireless sensor network node high precision data acquisition, and put forward the dual core processor architecture. It also implemented high frequency signal acquisition, designed multi parameter four-channel signal input, and analyzed the factors affecting the accuracy of data acquisition. What's more, it designed multi way power management scheme, which effectively reduced the noise of simulation power supply. For IEPE sensor drive, dynamic excitation voltage is designed, to achieve high precision constant current drive and dynamic adjustment of excitation voltage, and to reduce the power consumption of the nodes. Additionally, the independent high precision clock source is used to drive A/D acquisition, which decreases the shake of sampling interval and clock drift, and improves the frequency precision of signal acquisition. According to the above design methods, reasonable distribution is conducted with considering the function module and signal flow. And the high-precision acquisition node of mechanical testing multi parameter wireless sensor network is realized.

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