Design of Safety Analog Voltage Acquisition Module

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ABSTRACT

Based on the demand of trackside control unit about analog voltage safety acquisition, a safety analog voltage acquisition module is designed in this paper. it is implemented by using the method of heterogeneous hardware design and two out of two software design. The module realizes the safety acquisition of single ended and differential voltage signals within the specified frequency range for the first time. It has the characteristics of miniaturization and lightweight. It is suitable for application scenarios with safety acquisition requirements in the field of rail transit.

CCS CONCEPTS

• **Hardware**; • **Hardware validation**; • **Physical verification**;

KEYWORDS

Analog voltage, Secure acquisition, Isomerism, Two out of two

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1 INTRODUCTION

In the railway control system, the logic control unit obtains the working state of the execution unit by collecting the working voltage of the execution unit, and issues the driving command accordingly. If the voltage is wrongly collected, it will lead to the wrong triggering of the driving command, which will lead to major accidents. Therefore, the accuracy of analog voltage acquisition data is very critical.

The existing voltage acquisition methods mainly focus on the performance of multi-channel voltage acquisition [1-2], improving sampling accuracy [3-4], improving sampling rate [5-6], reducing volume [7-8], intrinsic safety [9]. Literature [1-8] focuses on improving voltage acquisition accuracy and reducing device volume. Literature [9] realizes a mining intrinsic safety voltage acquisition device, they are not involved functional safety acquisition all. At present, no functional safety voltage acquisition method that can be used in the field of functional safety has been found. The non functional safety voltage acquisition device can not be used in scenes with functional safety requirements in the field of rail transit.

Based on the safety requirements of trackside control unit in the field of rail transit, this paper adopts two out of two and heterogeneous design methods to realize a safety analog voltage acquisition module. This module realizes the safety acquisition of analog voltage for the first time. The module supports 8-way single ended or differential AC / DC voltage signal acquisition. At the same time, it has the advantages of lightweight and miniaturization, and is suitable for the application field with functional safety requirements.

2 MODULE DESIGN SCHEME

2.1 Overall Scheme

The module adopts two out of two, heterogeneous hardware circuit and inversed input voltage design methods. It realizes the safety acquisition of multi-channel AC / DC differential or single terminal voltage signals by eliminating the common mode fault of the circuit and comparing the same source input by two computers.

Figure 1 is the overall structure diagram of the safety analog voltage acquisition module. The dual sets simultaneously acquire the same source input voltage and compare their respective acquisition voltages interactively. If the acquisition voltages of the dual sets are consistent, it is considered that the acquisition is correct, and if they are inconsistent, it is considered that the acquisition fails; This module makes digital isolation between the voltage acquisition circuit and the data safety operation circuit to prevent external signals from interfering with the safety operation circuit.

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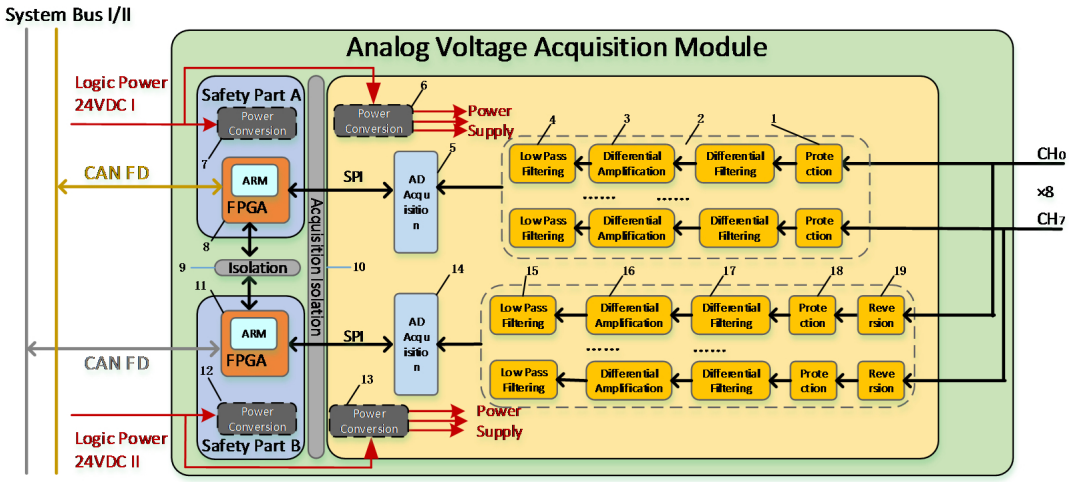

Figure 1: Overall Block Diagram of Analog Voltage Acquisition Module.

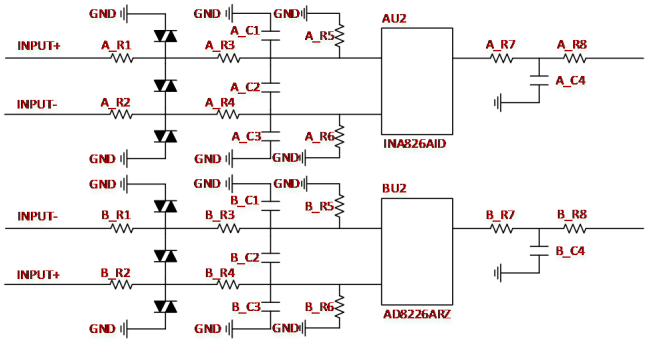

Figure 2: Inlet Conditioning Circuit Diagram.

Figure 3: Circuit Design Diagram of AD Acquisition Chip.

This module adopts the heterogeneous design method of hardware: the acquired voltage signal is input into the A and B acquisition circuits in reverse phase, and each input signal passes through the protection, filtering, differential amplification and filtering circuits in turn, and finally enters the AD acquisition chip; A、B two sets use different types of integrated chips, including differential amplifier and AD acquisition chip.

2.2 Hardware Heterogeneous Design

2.2.1 Heterogeneous Design of Input Conditioning Circuit. Figure 2 is a comparison diagram of the conditioning circuit, which A and B signals will go through before input into the AD acquisition chip. It is processed by protection, filtering, differential amplification and filtering in turn. A and B two sets are designed heterogeneously: the input signals of A and B dual sets are inverted; A and B dual sets adopt different types of differential amplifiers. Using different types of differential amplifiers can reduce the probability of common mode failure; Input signal reverse processing can quickly identify common mode faults and eliminate the influence of common mode faults on input signals. The heterogeneous design can prevent the common mode failure of the differential amplifier from leading to the failure of taking two out of two. For example, when the same temperature drift occurs in the differential amplification circuits of systems A and B because of the same fault, the single terminal voltage signal output by the differential amplification circuit of the two systems will have the same acquisition bias F compared with the actual input voltage signal. Due to the inversed input voltage, the single terminal voltages output by the differential amplification circuit of the two systems are V + F and -V + F respectively, at this time, two out of two comparison can identify the acquisition error caused by hardware common mode failure, because the absolute values of single terminal voltage signals output by the two systems are not equal.

In order to prevent high input voltage from damaging other components on the voltage acquisition board, bidirectional TVs is used at the inlet of each input voltage to process overvoltage of the input differential signal; In order to filter the high-frequency interference of the signal, low-pass differential filtering is done before the signal is input into the differential amplifier; According to different frequency of the acquired voltage, a low-pass filter is designed at

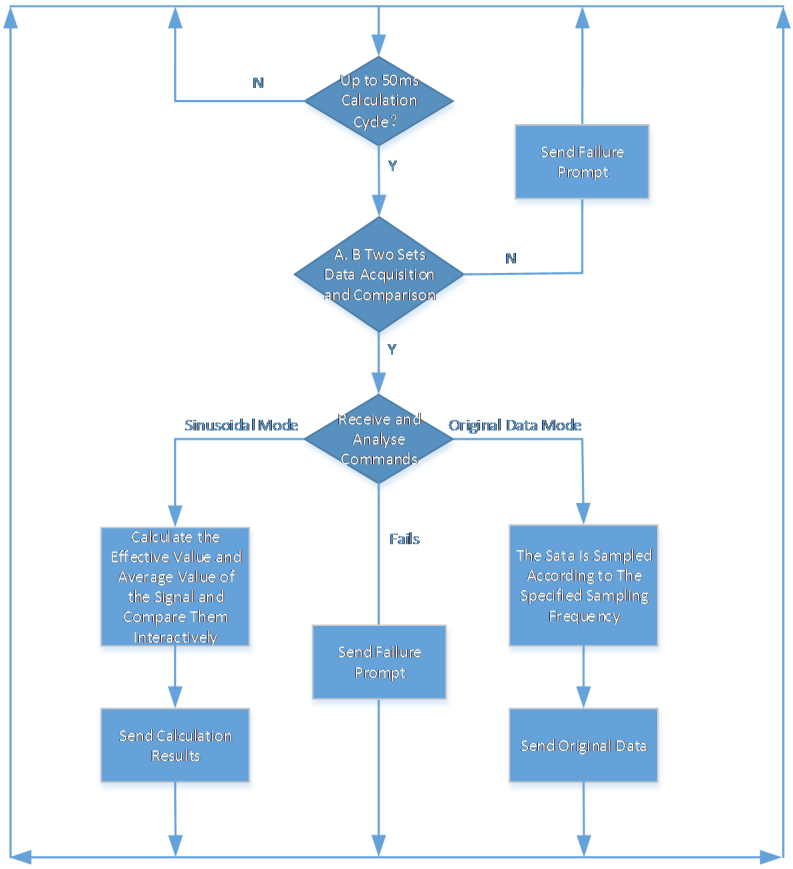

Figure 4: Software Flow Chart.

the output end of the differential amplifier to filter the signal that is not needed in the circuit and ensure the accuracy of the acquisition. The differential amplifier can convert the differential signal into a single ended signal and adjust the magnification of the signal.

2.2.2 Heterogeneous Design of AD Acquisition Circuit. Figure 3 is the circuit design diagram of AD acquisition chip. A and B two systems use different types of AD acquisition chips. The peripheral circuits of the two AD acquisition chips are completely consistent, so the AD acquisition program is also completely consistent, which not only achieves the design purpose of heterogeneous hardware, but also reduces the difficulty of software design. The maximum sampling frequency of AD acquisition chip is 20kHz and supports oversampling mode. At present, the single channel sampling rate of the module is set to 8kHz. According to the sampling theorem, the maximum frequency of the collected signal cannot exceed 4kHz. Therefore, the module limits the signal frequency to 3kHz.

2.3 Two Out of Two Software Design

The module supports two safe acquisition modes, which can acquire both sinusoidal signals and signals with arbitrary waveform (within the acquisition voltage range of - 10V to + 10V and frequency range of 0Hz to 3KHz defined by the module); At the same time, the module can adjust the sampling frequency according to the demand, and supports four sampling frequencies: 8kHz, 4kHz, 2KHz and 1kHz. When collecting sinusoidal signal, the module outputs the average value and effective value of sinusoidal signal; When collecting arbitrary waveform signal, the module outputs the acquired original data, and the main control unit can use the acquired original data for corresponding processing. Figure 4 is the flow chart of module software design [10-11]. The sampling period of the module is 50ms and data acquisition and operation processing are performed every 50ms. After entering the sampling process, A and B two sets conduct data acquisition and interactive comparison. If the former step succeeded and then enter the next step otherwise send a collection failure prompt to the main control unit and wait for the next cycle of data acquisition. When the data comparison between set A and set B is successful, the software will obtain and analyze the acquisition command of the main control unit. If the analysis succeeded, it will carry out sinusoidal mode data processing or original data sampling according to the main control command. If the analysis failed, it will send a collection failure prompt to the main control unit and wait for the next cycle of data collection.

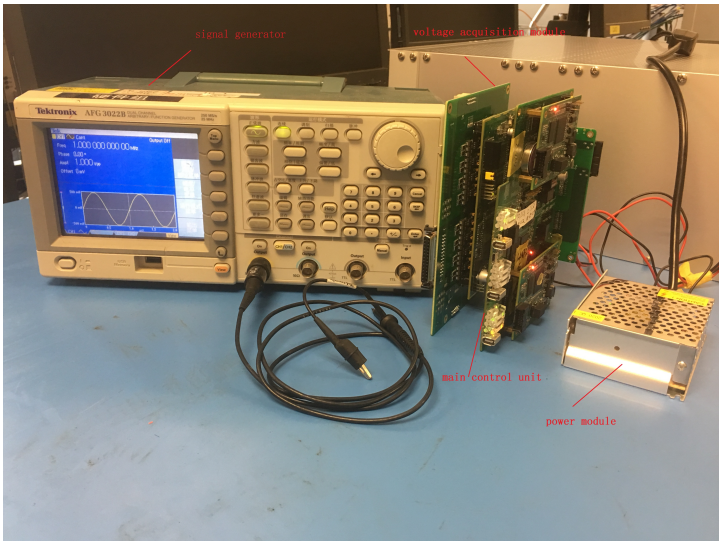

Figure 5: Module Environment Diagram of Analog Voltage Acquisition Experiment.

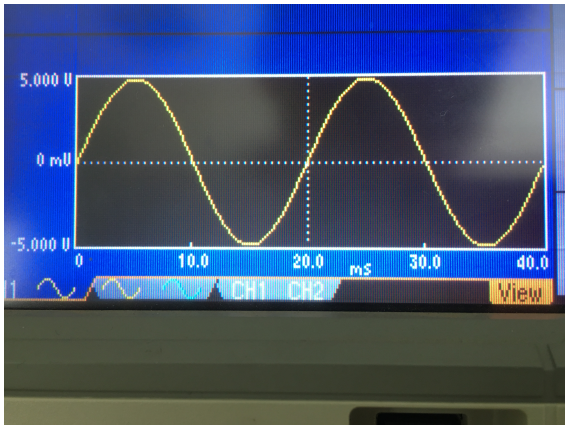

Figure 6: Input Waveform Diagram of Analog Voltage Acquisition Module.

3 EXPERIMENT AND DATA ANALYSIS

Based on the above analysis, an analog voltage acquisition experimental environment is built, including signal generator, analog voltage acquisition module, power module and main control unit, as shown in Figure 5

Under the above experimental environment, the experimental verification is carried out in the laboratory. The input signal is a sinusoidal signal with amplitude of 5V and frequency of 50Hz, as shown in Figure 6

The analog voltage acquisition module acquires the input voltage signal of the signal generator, and the acquired data are shown in the table.

According to the acquired data in Table 1, the data fitting of voltage acquired data is carried out, and the fitted acquired voltage waveform is as follows.

Table 1: Single Cycle Voltage Acquisition Data

SN	1	2	3	4	5
V	-3.82	-3.27	-2.64	-1.95	-1.21
SN	6	7	8	9	10
V	-0.43	0.34	1.12	1.86	2.57
SN	11	12	13	14	15
V	3.21	3.77	4.24	4.61	4.86
SN	16	17	18	19	20
V	4.99	5.00	4.89	4.66	4.31
SN	21	22	23	24	25
V	3.86	3.31	2.69	2.00	1.25
SN	26	27	28	29	30
V	0.48	-0.30	-1.08	-1.82	-2.53
SN	31	32	33	34	35
V	-3.17	-3.73	-4.20	-4.57	-4.82
SN	36	37	38	39	40
V	-4.95	-4.97	-4.85	-4.62	-4.27

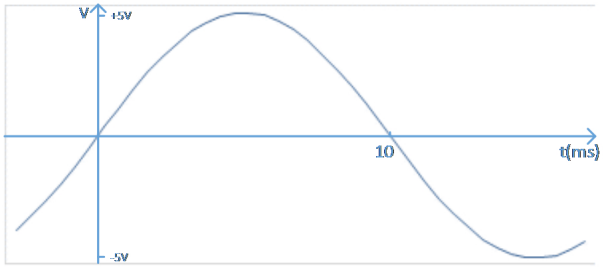

Figure 7: Single Cycle Acquisition Waveform.

Comparing the waveforms of Figure 6 and Figure 7, it can be seen that this module can accurately collect the sinusoidal input signal, and can accurately calculate the effective value and average value of the sinusoidal signal, so as to achieve the expected effect. Compared with the existing analog voltage acquisition device, this module has fault leading safety function, which can identify voltage false acquisition and ensure the safety of output collected data.

4 SUMMARY AND PROSPECT

In the field of rail transit, trackside control equipment has safety requirements for analog voltage acquisition, and no analog voltage acquisition method that can realize safety acquisition has been found at present. This paper proposes a safe analog voltage acquisition method, which realizes the multi-channel safety acquisition of analog voltage acquisition in the safety system of rail transit for the first time by means of heterogeneous hardware and two out of two. Through experimental verification, this module can realize the safe and accurate acquisition of voltage signals with specified frequency, which lays a solid foundation for the future distributed control system.

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