

# Experimental industrial signal acquisition board in a large scientific device

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**Abstract**—In order to measure the industrial signal of neutrino experiment, a set of general-purpose industrial data acquisition board has been designed. It includes the function of switch signal input and output, and the function of analog signal input. The main components are signal isolation amplifier and filter circuit, ADC circuit, microcomputer systems and isolated communication interface circuit. Through the practical experiments, it shows that the system is flexible, reliable, convenient and economical, and the system has characters of high definition and strong anti-interference ability. Thus, the system fully meets the design requirements.

## 1. Introduction

Data collection is the object of the various parameters (which can be physical, can also be chemical, biomass, etc.) through a variety of sensors will be converted into electrical signals into electrical signals, and then by signal conditioning, sampling, quantization, coding and Transmission and other steps, and finally sent to the controller for data processing, analysis, storage and display process [1]. Such a system is called a data acquisition system. With the rapid development and popularization of computer science and technology, data acquisition system has been applied to many fields, including: radar, communication, underwater acoustic, remote sensing, geological exploration, vibration engineering, voice processing, intelligent instruments, industrial automation and biomedical Engineering and so on. These acquisition system is characterized by powerful data processing capabilities, friendly human-machine interface, and then generally have a network interface to facilitate networking, but the price is high. Which makes its scope of application has been greatly limited.

A large scientific device experimental industrial signal acquisition board requires the ability to collect the standard industrial voltage signal, current signal, switch input signal and contains the switch output function[2~4], The acquisition board communicates with the data center via Ethernet. So these requires the data acquisition system to both miniaturization, high reliability, and to have the network interconnection function.

The whole system is divided into voltage, current, switch input and switch output of four modules, each module is independent work, do not interfere with each other, the acquisition module and the host computer communication interface Use the RS485 interface. So that the reliability of the system will be a very good guarantee, even if one of the modules out of the fault will not affect the normal work of



other modules. Users can also choose according to their own needs which module to install, you can flexible combination and on-demand with, so that both the convenience of the collection board module debugging and troubleshoot, but also saves the cost of the system.

## 2. System overall design

Describing the composition of each module architecture in Fig.1~Fig.2, where each block on the dotted line that part is the same, the task is responsible for the signal acquisition and processing and implementation of the data communication with the host computer.

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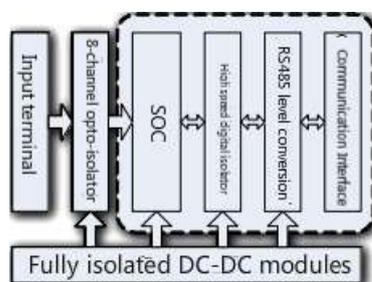


Figure 1 Switch block input block structure diagram

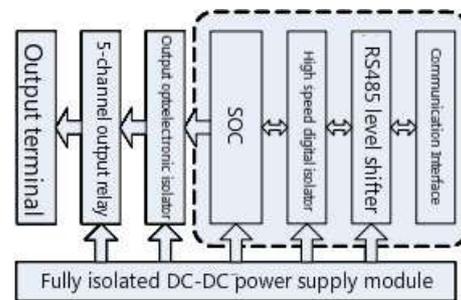


Figure 2 Switch Output Module Block Structure Diagram

## 3. Design and Implementation of System Module

### 3.1 Power section

Power is the basic element for every circuit to work properly, Especially in the industrial signal acquisition circuit, the power circuit design directly affects the circuit accuracy and performance. The energy source of this acquisition system have been split into multiple parts, different circuit have different power supply, that becomes complicated. The energy source system mainly includes Microcontrollers, power supply section of digital isolator, the switch input panel provides the isolated power supply unit, ADC power supply unit, buffer amplifier out put terminal isolated power supply unit. Because of the different request of voltage, power, power ripple factor and so on of above of power supply circuit, we chosen multiple model of DC-DC power modules.

#### 3.1.1 Digital circuit power supply design

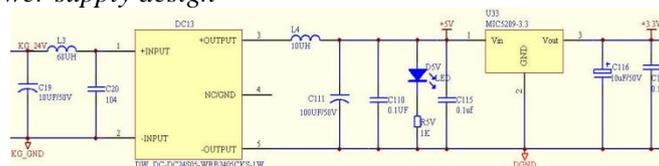


Figure 3 5V and 3.3V power supply circuit

Each input power acquisition module board is 24V, so to back level digital circuit power supply first isolated buck 5V and 3.3V power supply, wire and digital circuit has an independent digital network, in order to avoid the interference of high frequency noise in digital circuit simulation circuit. As shown in Figure 3, the front end of the large pressure differential of the selected DC-DC module, model WRB2405CKS-1W. WRB series product is designed for the layout space is narrow, and the

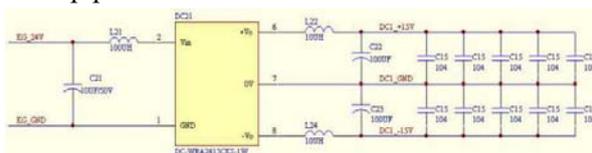
input power supply circuit applications voltage range, input and output must be isolated and design. The typical input voltage is 24V, allows the input voltage range is 18~36V, maximum 40V, output voltage 5V, output current minimum 20mA, maximum 200mA, load adjustment rate is 0.5%, the ripple is 25mVp-p, the work efficiency is as high as 78%. This product applies for:

- (1) Input voltage range is less than 2:1
- (2) Isolation requirements between input and output less than 1.5KVDC
- (3) The output voltage stability and output ripple noise requirements are higher.

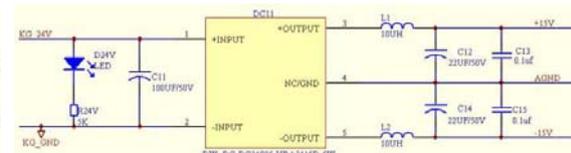
The working voltage of ADC chip MAX1270 of 5V, and The 5V supply ripple factor provided by the WRB2405CK5-1W has been able to meet its requirements for power supplies. Therefore, the MAX1270 power supply of the WRB2405CK5-1W is supplied by the output of the 5V through the RC filter circuit and the decoupling capacitor. The ground wire of the MAX1270 is separated from the digital ground wire, and is an independent ground wire network, so as to improve its anti-interference ability and guarantee its conversion accuracy.

### 3.1.2 Analog Circuit Power Supply Design

In the voltage/current acquisition boards, the input signal between each input channel and the ADC chip, between the channel and the channel need to be isolated, so their power supply is also need to be isolated, so as not to interfere with the signal through the power into the various channels. Figure 4 shows the isolation amplifier ISO122 input power supply circuit, ISO122 dual power supply  $\pm 15$  power supply, each ISO122 front end should be configured such a separate power supply. The DC-DC power supply model for the WRA2415CK5-1W, the output voltage of  $\pm 15$ V, the maximum output current of  $\pm 33$ mA, the efficiency of 83%. ISO122 from the official document to know its input and output power supply maximum absorption of 20mA current, so the current is completely enough of the. Figure 5 shows the ISO122 isolated back-end power supply circuit, the power supply part of the five ISO122 output and five OP07 by the low-pass filter circuit, this part of the circuit total operating current is less than 100mA, and VRA2415D-5W Of the output current up to 166mA. The above-mentioned DC-DC power supply module ripple basically meet the needs of the system, but in order to further reduce the input and output ripple, in the input and output connected to an LC filter network, you can get better ripple parameters, Capacitors can not be selected too much, otherwise it may cause startup problems.



**Figure 4** ISO122 Input Power Circuit



**Figure 5** Isolates The Back-end Power Circuit

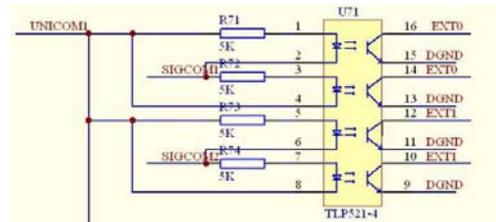
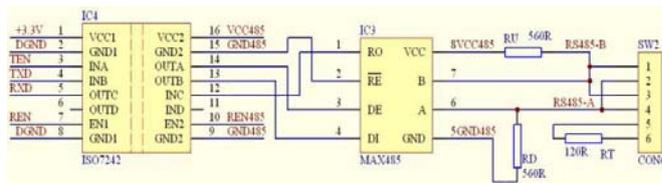
### 3.2 CPU Control Module Section.

We chose the P89LPC933/934/935/936 is a monolithic micro controllers that use low cost packaging. It uses a high-performance processor architecture, instruction execution time only 2 to 4 clock cycles. 6 times the standard 80C51 device[5]. The P89LPC933/934/935/936 integrates many system -level features that greatly reduce the number of components and board area and reduce the cost of the system. The system selected single-chip model is PLCC28 package P89LPC935FA, the first board on the PLCC28 IC socket welding, then the single-chip can be loaded up, you can download the code can be downloaded to facilitate debugging. SCM front-end data input and output part is based on the actual needs of the distribution, the specific distribution is as shown in the table(1). Single-chip microcomputer serial port connected directly to the RS485 after isolation level translator, reoccupy two IO mouth control of RS485 transceiver can realize communication interface. The micro controller IO port have redundancy and PCB space, we can use a spare IO mouth drive several LEDs indicating

the performance of the circuit, such as our collection program running state signals on a plate and a serial port to send and receive data indicating lamp, etc.

### 3.3 RS485 Communication part

RS485 interface has good noise resistance, long transmission distance and multistation interconnection capacity and so on, these advantages make it the first choice of the serial interface. Because half duplex network composed of RS485 interface, typically require two cords, so often adopted RS485 interface is shielded twisted-pair cable transmission.



**Figure 6** RS485 Communication Circuit In Isolation      **Figure 7** Switch Input Signal Isolation Input Circuit

Need another idea in the process of RS485 network problems is terminal load resistance, the less equipment, short distance without terminal load resistance under the condition of the whole network can be a very good job, but the performance will reduce with the increase of distance. In theory, at the end of each receive data signal sampling, as long as the reflected signal attenuation at the beginning of the sampling can not consider matching to a low enough. But that is actually difficult to grasp, the article mentioned a MAXIM company have empirical principle can be used to determine in what kind of data rate and the length of the cable need to be match: when the signal conversion time (up or down time) more than one-way time needed for transmission of electrical signals along the bus can not match when more than three times. General termination to the terminal resistance method, RS485 should be in the beginning and end of the bus cable and terminal resistance. Terminal resistance take  $120\ \Omega$  in RS485 network. The characteristic impedance of the resistance of cable, because most twisted-pair cable characteristic impedance about  $100\sim 120\ \Omega$ , this method is simple and effective matching, in most in most practical applications.

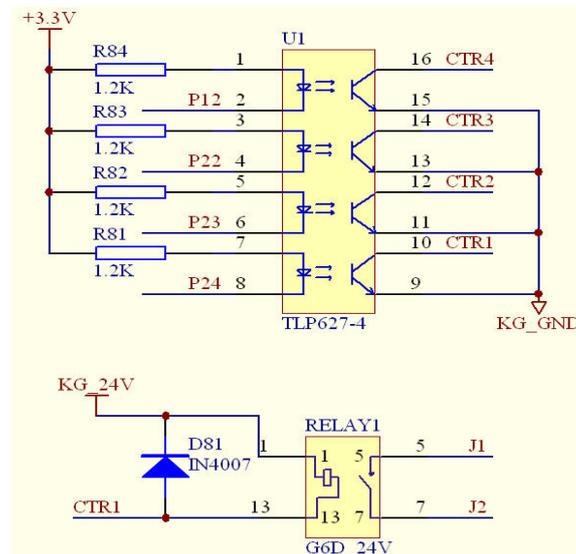
Acquisition system of each module of the communication interface is directly on the communication bus, directly connects with the outside world, there are may introduce external interference signal, so must be isolated. Between the single chip microcomputer interface and MAX485 level conversion chip, we use the digital isolator ISO7242 signal for the very good isolation. ISO7242 is of a high speed digital isolator TI company, high data transfer rate of 150 MBPS, with 4 kv ESD (electrostatic discharge) protection, and the isolation can be used at both ends of 3.3 V or 5 V power supply. ISO7242 has two input channel and output channel, input and output channels have enabled port, can cooperate MAX485 makes end can control data transceiver.

### 3.4 Switch input module

Switch input module design and has eight input channel, every 4 channel has a public side. On the module with two 1 w power 24 v to 5 v DC - DC isolation power supply to provide the necessary switch input and driving power supply. Figure 7 shows the two channels of the circuit principle diagram, can be seen from the diagram, photoelectric isolation chip TLP521-4 connection is very clever, we will isolate the chip into a channel with two channels, its isolation at the input is reverse parallel two light-emitting diodes (LEDs), to isolate the output transistor is two parallel, the principle is similar to the OC output after resistance pull-up access IO port, so that we will switch from the outside signal series of our foreign provide access module again after the 24 v isolation power supply input channel, so no matter we are the amount of power supply and switch the input signal is pick up or reverse connection, there will be a channel in the optical coupling light-emitting diodes (leds, the output photosensitive diode conduction and then the signal can be smoothly transfer came in. The

microcontroller periodically scans these input IO ports, Once with a new switch input, the microcontroller will update the input signal status cache, waiting for the host computer to read.

### 3.5 Switch Output Module



**Figure 8** Switch Output Signal Isolation Output Circuit

The switch output module is designed with 5 channels. First by the micro controller IO output digital signal, through the optocoupler TLP627-4 isolation directly after the drive relay, And finally output switch signal through the relay. Figure 8 shows the specific circuit schematic. Figure 8 is the internal structure of TLP627-4. TLP627-4, which is produced by Toshiba company, is a superior performance of optical coupling isolation device, whose output is darlington structure. And its biggest characteristics is that the output driving capability (the maximal ic can reach 150 ma) and CTR ( $I_c/I_f=4000$ ) are high. Its output end can directly drive the delay, which greatly simplifies the driving circuit of the rear relay, making the system more reliable. The type of relay selected here is omron G6D-1A-ASI(24V). This relay is specially designed for high density installation and sensitive to area requirements. Its size is: Wide 6.5 mm, long 17.5 mm, high 12.5mm. Although the G6D's volume is small, its performance is brilliant, which has the ability of open and close 5A(AC250V DC30V). When it turns to 2A (AC250V DC30V), it has the high durability of 300,000 times to open and close, while its rated working current is only 8.3mA. The physical object of G6D-1A is shown in figure 8.

## 4. System test and result analysis

**Table 1** Test data record of voltage acquisition module

Input Voltage (V)	Output Voltage (V)	Error Value (V)	Error Rate (%)
0.5000	0.4998	-0.0002	-0.002
1.0000	1.0052	0.0052	0.052
1.5000	1.5043	0.0043	0.043
2.0000	2.0035	0.0035	0.035
2.5000	2.4933	-0.0067	-0.067
3.0000	3.0054	0.0054	0.054
3.5000	3.5079	0.0079	0.079

4.0000	4.0094	0.0094	0.094
4.5000	4.5092	0.0092	0.092
5.0000	4.9988	-0.0012	-0.012
5.5000	5.5098	0.0098	0.098
6.0000	5.9989	-0.0011	-0.011
6.5000	6.5098	0.0098	0.098
7.0000	7.0087	0.0087	0.087
7.5000	7.5092	0.0092	0.092
8.0000	8.0078	0.0078	0.078
8.5000	8.4934	-0.0066	-0.066
9.0000	9.0073	0.0073	0.073
9.5000	9.5063	0.0063	0.063
10.0000	9.9947	-0.0053	-0.053

The experiment requires that the system linearity is better than 0.1%, which depends directly on the control of the system error. The output module of the switching quantity input and the output of the switch is normal and stable after the test work, which does not exist in the measurement error. For the voltage collection module, the input voltage measurement points are selected on the signal input port of the module, and the output voltage measurement points are selected on the input pins of the module's ADC chip. For the current acquisition module, the input current measurement method is to connect a current meter on the input signal (note: we can use the sampling resistor of 250  $\Omega$ ), and the measuring point of the output voltage is also the input pin of the ADC chip in the module.

The test equipment is as follows:

Desktop multimeter: ESCORT 3146A 5 bits and half display

Power Supply : GW GPS-3303C 3CH

Oscilloscope: RIGOL DS5022ME 25MHz bandwidth

**Table2** Test data record of current acquisition module

Input Current (mA)	Theoretical Output voltage (V)	Actual output voltage (mA)	Error Value (V)	Error Rate (%)
5.0000	0.2500	0.2549	0.0049	0.098
6.0000	0.5000	0.4978	-0.0022	-0.044
7.0000	0.7500	0.7548	0.0048	0.096
8.0000	1.0000	1.0018	0.0018	0.036
9.0000	1.2500	1.2458	-0.0042	-0.084
10.0000	1.5000	1.4955	-0.0045	-0.090
11.0000	1.7500	1.7508	0.0008	0.017
12.0000	2.0000	1.9969	-0.0031	-0.063
13.0000	2.2500	2.2489	-0.0011	-0.023
14.0000	2.5000	2.4966	-0.0034	-0.068
15.0000	2.7500	2.7528	0.0028	0.056

16.0000	3.0000	2.9965	-0.0035	-0.070
17.0000	3.2500	3.2500	0.0000	0.000
18.0000	3.5000	3.4975	-0.0025	-0.050
19.0000	3.7500	3.7525	0.0025	0.050
20.0000	4.0000	3.9985	-0.0015	-0.030

The error value in table 1 and table 2. As can be seen from table 1, the maximum offset of the voltage value is less than 9.8mV, the full range is 10V, and the linearity is better than 0.1%. As can be seen from table 2, the maximum offset of the voltage value is less than 4.9 mV, the full range is 5V (the voltage obtained by the sampling resistance of the current signal), and the linearity is better than 0.1%.

Therefore, the measurement accuracy of the system can meet or exceed the design requirement. If the software is added to the digital filter, the precision of the system can be further improved.

## 5. Conclusion

A complete industrial signal acquisition system needs to build a hardware platform that meets the requirements, and then the data collection processing and communication software that runs on the MCU. The task of this paper is to design a hardware circuit that meets the requirements. The system also includes an embedded network interface core board based on ARM9, which is also not in the scope of this article.

After some efforts, finally designed prototype effect is satisfactory, in each case by four small signal processing board and network interface core board assembly, when applied, according to the types of signals to the front, is free to configure the type of these four pieces of small signal processing board.

In this way, the configurability of the system has been greatly improved, which is more favorable to the full and effective utilization of system resources, thus reducing the overall cost. Moreover, the system is stable, independent and easy to maintain.

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