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## Signal Monitoring System for Power Supply with High Current

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#### Abstract

Superconducting magnet power supply is required to provide 4000A large current for the magnet. In order to guarantee the power supply normal work, monitor the working state of the each device under the rated power internal the power supply. This article analyzes the advantages of CAN bus, the interface and performance of the sensor for the detection elements and designs superconducting magnet power supply detection system based on CAN bus. Transmit the data collected to the upper monitor and real-time display through the CAN bus, design the monitoring system interface with PC using the graphical programming software LabVIEW of NI. Drive CAN interface card and complete data reception through LabVIEW programming then save data and real-time curve display. Through judgment in the program, fault display and transmit data. Finally realize the automation of data acquisition, judgment and process. Ensure the magnet normal work effectively.

Key words: MICROPROCESSOR PIC18F248, MULTICHANNEL AND MULTIPOINT TEMPERATURE MEASUREMENT, FAN SPEED, CAN BUS, LABVIEW.

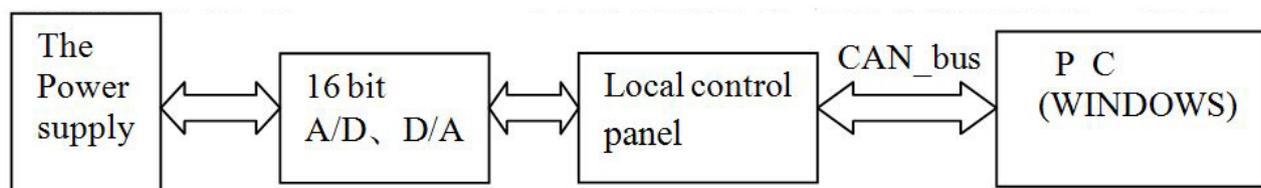
### 1. Introduction

A superconducting magnet power supply is provided 4000A/10V steady flow for magnet. It may adjust slowly and evenly especially there should be no obvious wobble. In order to ensure the stability of the superconducting magnet to get stable magnetic field, the power supply has a small ripple and has a certain degree of stability. The power supply must have the Automatic cutting device for power to protect superconducting coil and power supply itself in the excitation and demagnetization process or sudden power failure. The circuit breaker will start to isolate the power supply and the magnet when the detectors find to be out of the superconductor (superconducting coil is transferred to the normal state) and release energy in a short time. So need to monitor the state of the magnet power supply in time in order to ensure the normal work.

With the development of field bus technology and the industrial control Ethernet Technology, they have a fierce competition in the field of control. People can

access control system through Ethernet, remote diagnosis, maintenance and service. There is a trend to replace the field bus. But the combination of different types of field bus is conducive to reduce the cost. CAN bus plays its potential fully in the application of monitoring power [1].

In order to realize power supply system can provide high current stably, monitor and control the working state of the device within the power. By Microprocessor PIC18F248 collect each state includes the temperature of some parts such as transformer, reactor, IGBT, Schottky diode and bus bar. Install six wind turbines on the top of the power supply to facilitate the internal heat, so the system need measure the speed. The local PC with WINDOWS system communicates through the CAN bus. The upper monitor uses LabVIEW language to design interface and drive CAN card to receive data, then finish the display and judge. The control diagram is shown in Figure 1.



**Figure 1.** The control diagram of the power supply

This system completes the selection, interface and performance analysis of various signal acquisition sensors, analyses and designs the main processing module of the hardware system and the conditioning circuit of the sensors. Solve the problem of driving load capacity and anti-interference. Cover the theory, application and hardware of the CAN bus. Using LabVIEW language to drive CAN card and design interface for real-time display. Through the experiments and field operation this system has the advan-

tage of moderate cost, reliable performance, the ideal control effect, so it has extensive practical value.

## 2. The hardware analysis and software design

The monitoring system should have the characteristics of the measure, transmission, processing and display for the object to be measured. A monitoring system is the organic combination of sensor, pre-processing circuit and data processing and other data communication device. A typical monitoring system is shown in Figure 2 [2].

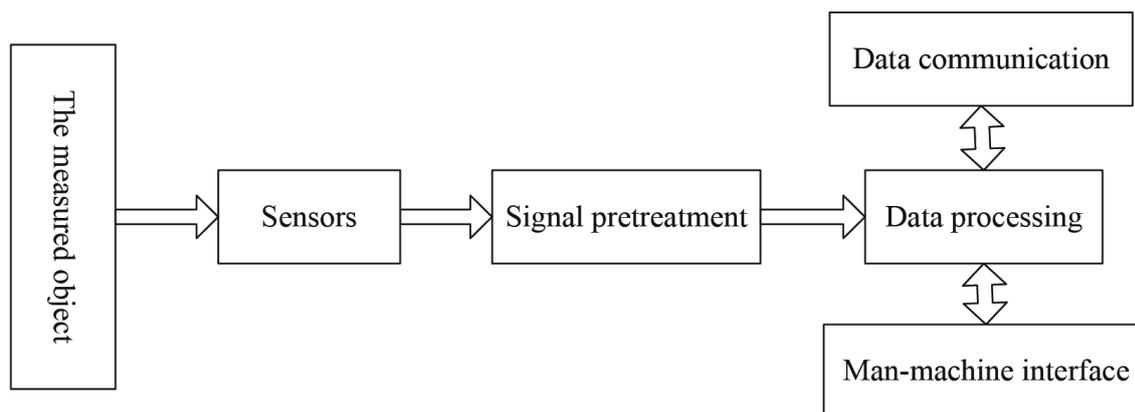


Figure 2. The general control system block diagram

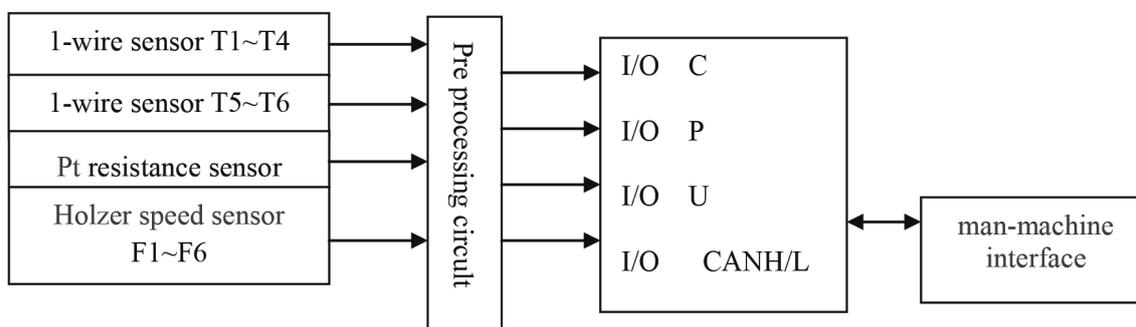


Figure 3. The composition block diagram of this system

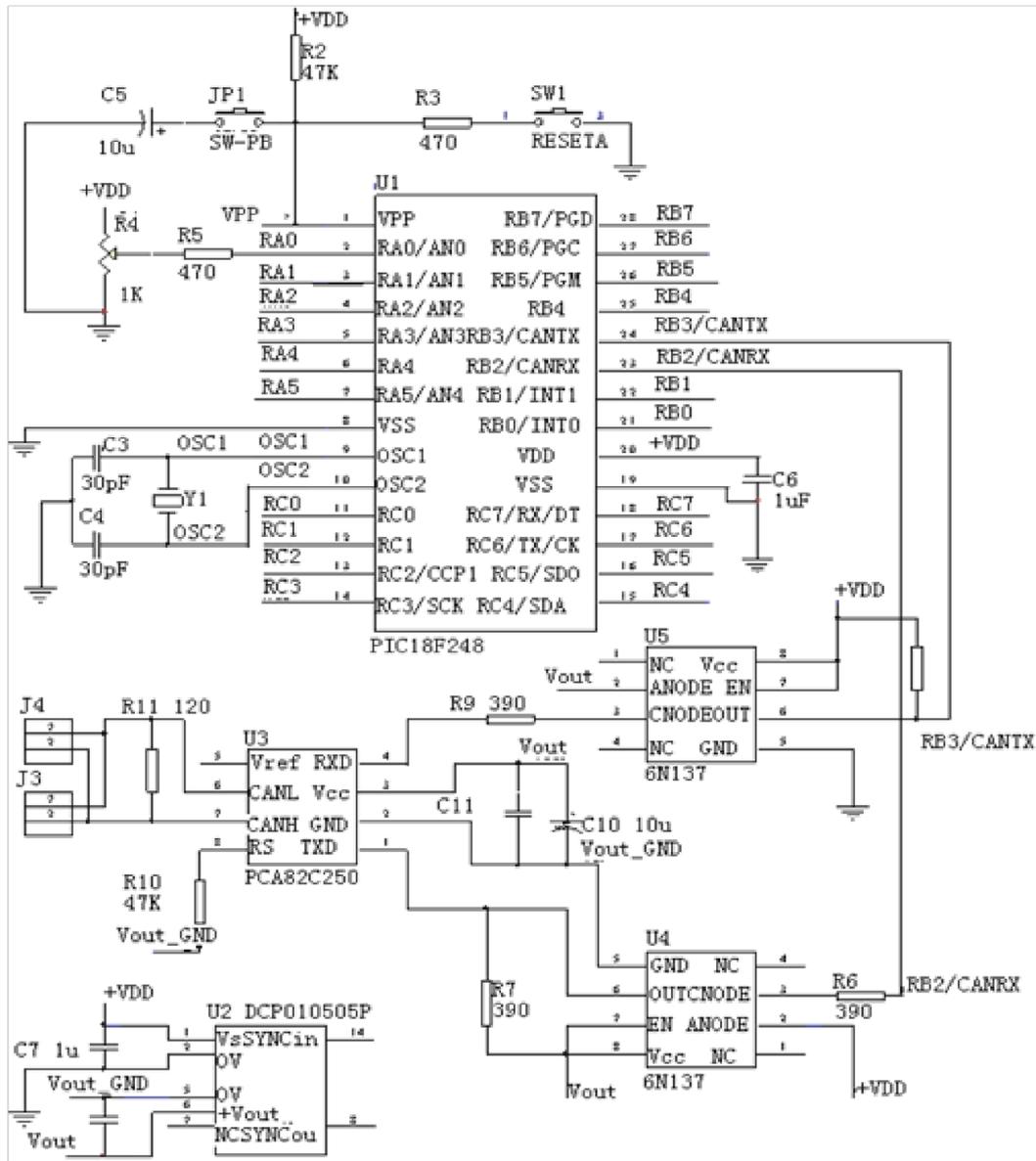
The temperature monitoring points of the system is divided into four groups of twelve points, among which the three groups were expressed as T1, T2, T3, T4, they were installed in four IGBT heat sinks, the two reactors, four transformers and two Schottky diode eat sinks. The temperature of the busbar is divided into two groups of sixteen points which were treated with T5, T6. Platinum resistance includes three groups of three points, expressed as T7, T8, T9, the rotating speed of the fan is composed of a single point expressed as F1~F6. The block diagram of this system is shown in Figure 3.

### 2.1 The microprocessor minimum system

The instruction execution structure type of single chip can be divided into centralized instruction set (CISC) and reduced instruction set (RISC). The

data line and the command line of the SCM with RISC is separate, which makes the instruction and data fetch simultaneously and achieves more efficient faster implementation. The structure of PIC series of Microchip belongs to RISC, so choice PIC18F248. In addition there is ISO CAN bus module in line with international standards. Its CAN agreement is consistent with the CAN 2.0B version, which makes the peripheral circuit of MCU need to add the driver chip and not need to add the CAN controller chip, so the hardware circuit is simple. Inside PIC18F248 chip there are the circuit with a power on reset circuit (POR) and a watch dog timer (WDT) on-chip RC oscillator. It has the function with a programmable code protection. The processor transmits the data to the host computer through the CAN bus. As long as

the isolation circuit of CAN bus is added which com- poses the minimum circuit shown in Figure 4 [3, 4].



**Figure 4.** The minimum system circuit of the monitoring system

## 2.2 monitor multi-channel and multi point temperature

Select the typical one-wire sensor DS18B20 to measure temperature. It can output temperature by the digital form with the additional power supply mode, which will enhance the anti-jamming capability and ensure the stability of the work. The output current of the PIC microprocessor I/O is up to 25mA, and the operating current of DS18B20 is up to 1.5mA, so drive the I/O port load directly. But when the probe number increases and the connection cable is long, need improve the driving ability and anti-interference ability further [5].

### 2.2.1 The pull-up resistor problem

The input/output of DS18B20 requires an external pull-up resistor  $R_L$  (4.7K resistance in PDF data). The

state of the bus is a high level when it is idle. No matter what the reason, if the bus needs to be suspended temporarily during the transmission process that can continue, the bus must be in idle state. No limit of recovery time between the transmission of each two bits as long as the bus is idle during the recovery period (high level). If the bus keeps low level more than 480ms, all the devices on the bus will be reset. When the load increases on the bus that is increase the number of probe or length the connecting cable, the port driving capability is not up to the requirements unable to read the temperature data correctly. Reduce the pull-up resistance to improve the ports driving capability. Because the interference signal abides Ohm's law, select the smaller pull-up resistor in the presence of interference situations, thus the voltage that inter-

ference signal generated is smaller [6].

### 2.2.2 The impedance matching problem

Match a 50 ohms resistor between the DS18B20 and the bus in actual use can improve system stability. Because DS18B20 connects with the data line through the open drain, the matching resistor can effectively limit the current and avoid the chip damage as a result of the breakdown of field effect transistor. At the same time the multiple probes on the bus will cause the impedance mismatch, the reflection wave from the end returned will affect other devices on the bus. So reduce the impedance mismatch effectively through series resistor on the bus to reduce the reflection energy and not to produce additional DC load for drivers [7].

### 2.2.3 The anti-interference problem

During test the monitor system, the temperature probes can be disturbed and timing errors occurred in the environment welding near and the power supply works under full power state. The analysis indicated that the interference signal is the common mode interference voltage because of a lot of electromagnetic interference from the space coupling to the cable.

Connecting a common mode choke coil to inhibited the common mode interference in the input end of the bus. Wind three enameled wire of the same length on a hollow ring. The number of turns and phase are the same (winding in the same direction). One end is connected to the terminal and the other end is connected to the corresponding three wires of DS18B20 respectively. By this method when the normal current

in circuit is through the common mode inductor, the current produces the reverse magnetic field in the induction coil winding of the same phase, then the magnetic field is offset and the normal signal current is mainly affected by the coil resistance. The common mode current that flows through the coil will produce the same direction magnetic field increasing coil inductance due to the same direction of the common mode current. So the coil is high impedance which produces strong damping effect to decay the common mode current and achieve the goal of filtering. The anti-electromagnetic interference ability of the system is enhanced with certain number of common mode coils.

### 2.2.4 The multi points temperature measurement

Read the serial numbers of all the DS18B20 through read ROM (33H) command before the host enters the operating procedures. When an operation is implemented to one of the online DS18B20s, give the match ROM (55H) direction first of all, then the host provides 64 ID number. The next operation is based on the corresponding DS18B20, skip ROM and start all the DS18B20 to converse temperature. After that by matching the ROM, read the temperature data of each DS18B20 one by one. The circuit connection diagram is shown in Figure 5. The software flow diagram is shown in Figure 6. Because an I/O port drives limited probe spaces and numbers, in fact use multiple I/O ports to drive that is multi channels [8].

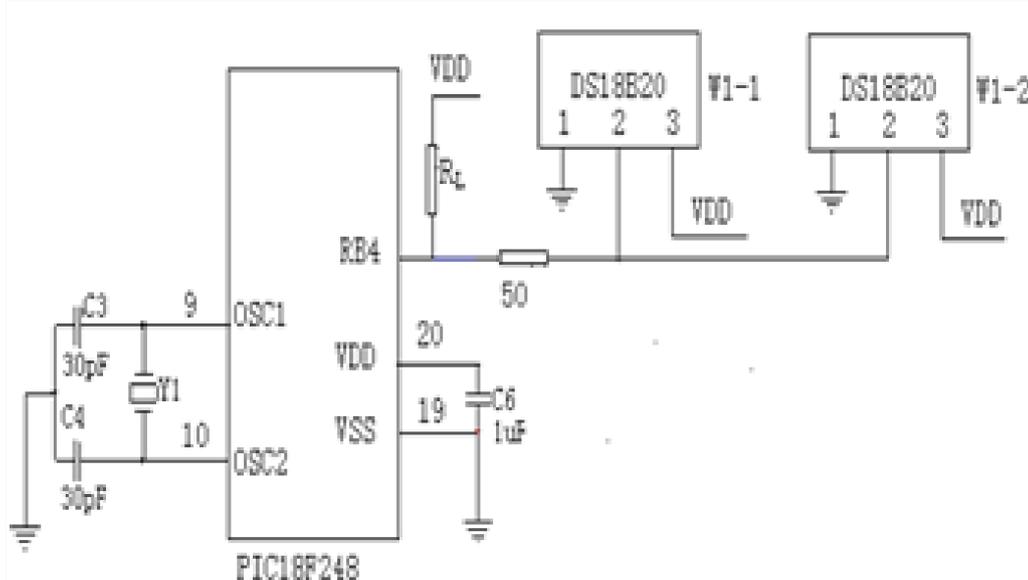


Figure 5. A multipoint connection diagram

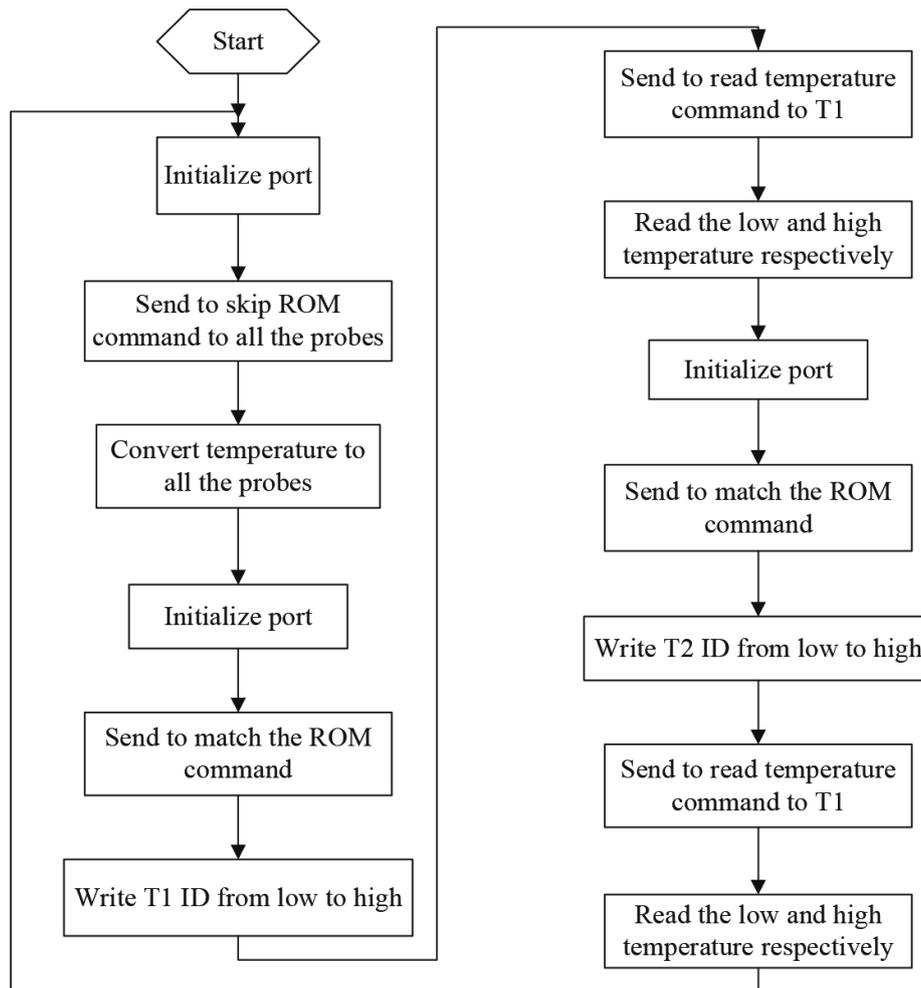


Figure 6. The temperature conversion process of single channel two probes

### 2.3 Monitor fan speed

This system uses the Hall switch sensor DN6837 to measure speed. This sensor is an open collector (OC door), so connect a 1.5K resistor between the output terminal and the power supply. In order to improve its driving load capacity, the output end is

connected with a triode amplifying circuit. There are voltage stabilizing circuit Schmidt circuit in DN6837. The pulse signal output of the collector of the output transistor connects directly to the I/O port of PIC18F248 and analyzes. the circuit of fan speed is shown in Figure 7.

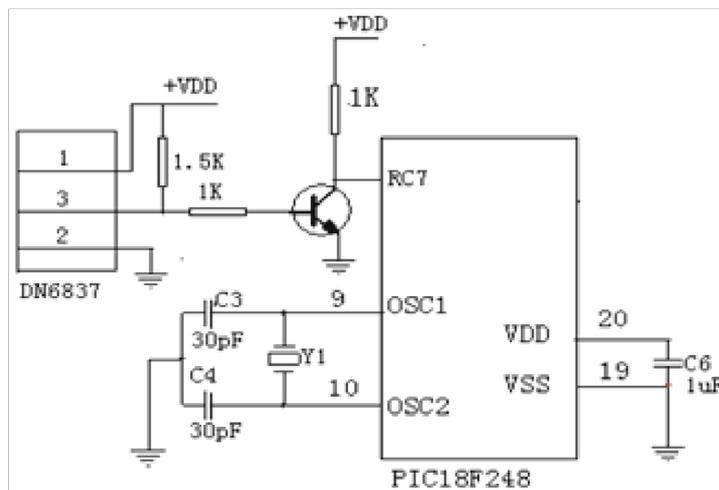
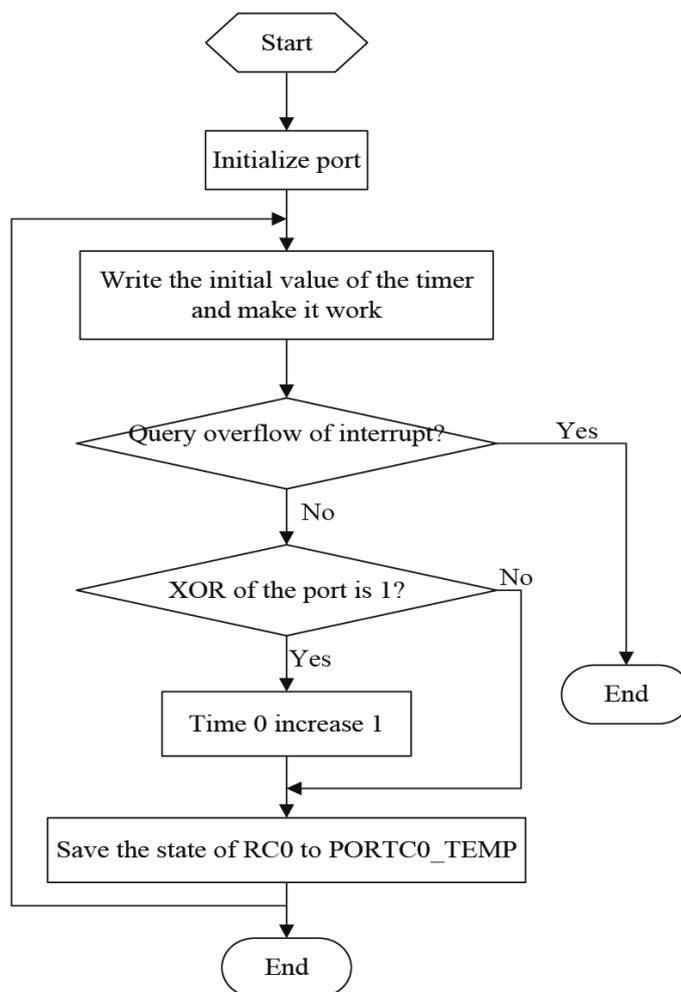


Figure 7. The measuring circuit diagram of fan speed



**Figure 8.** The flow diagram of the fan speed

### 3. The realization of CAN bus transmission function

#### 3.1 The hardware implementation

The PIC18F248 microcontroller integrates CAN control module which is a communication controller and implements Bosch standard CAN 2.0B protocol. The circuit uses CAN bus transceiver interface circuit of PCA82C250 in order to strengthen the differential transmission and reception capacity. This connection can reduce the radio frequency interference (RFI) and anti- strong-electromagnetic interference (EMI). Access photoelectric coupler (high-speed optocoupler6N137) between the CAN bus interface and PCA82C250 can enhance the anti-interference ability of the system. Both sides of the photo coupler should adopt the DC-DC isolation power 5V. Consider the problem of impedance matching bus at both ends, access 120 ohm resistor to improve the anti-interference reliability of the whole communication system. The hardware control circuit is shown in Figure 9 [9].

#### 3.2 CAN bus high-level communication protocol

The CAN bus solves the access conflict through

ID of frame. The smaller the frame ID is, the higher priority is. When two nodes send data frames to the bus at the same time, the node of high frame priority access control and the low priority node turn into the receiving state, then send data again after listening the bus free next time. Carry on the strict distribution on the frame ID in order to ensure the reliable operation. The data frame of determined ID is only sent by the certain node to avoid different nodes to send the same data frame ID at the same time. All the CAN controllers work in Basic CAN in this design and the data frame is standard that the ID is for 11. Node number is less than 32 according to the scale of the CAN system, so distribute 5 bit node codes of each module. It is not repeated of the node codes in the same system. Define the 6 high bits as the command code. The node code 11111 expresses the broadcast data that can receive from all the nodes [11]. Take the DS18B20 data frame as an example to illustrate the data frame format. The descriptor is 2 bytes by 11 bit ID, remote transmission request bit (RTR), the length of data bit. The length of received data is 8 bytes that turn into 4 temperature data. The format is as the Table 2.

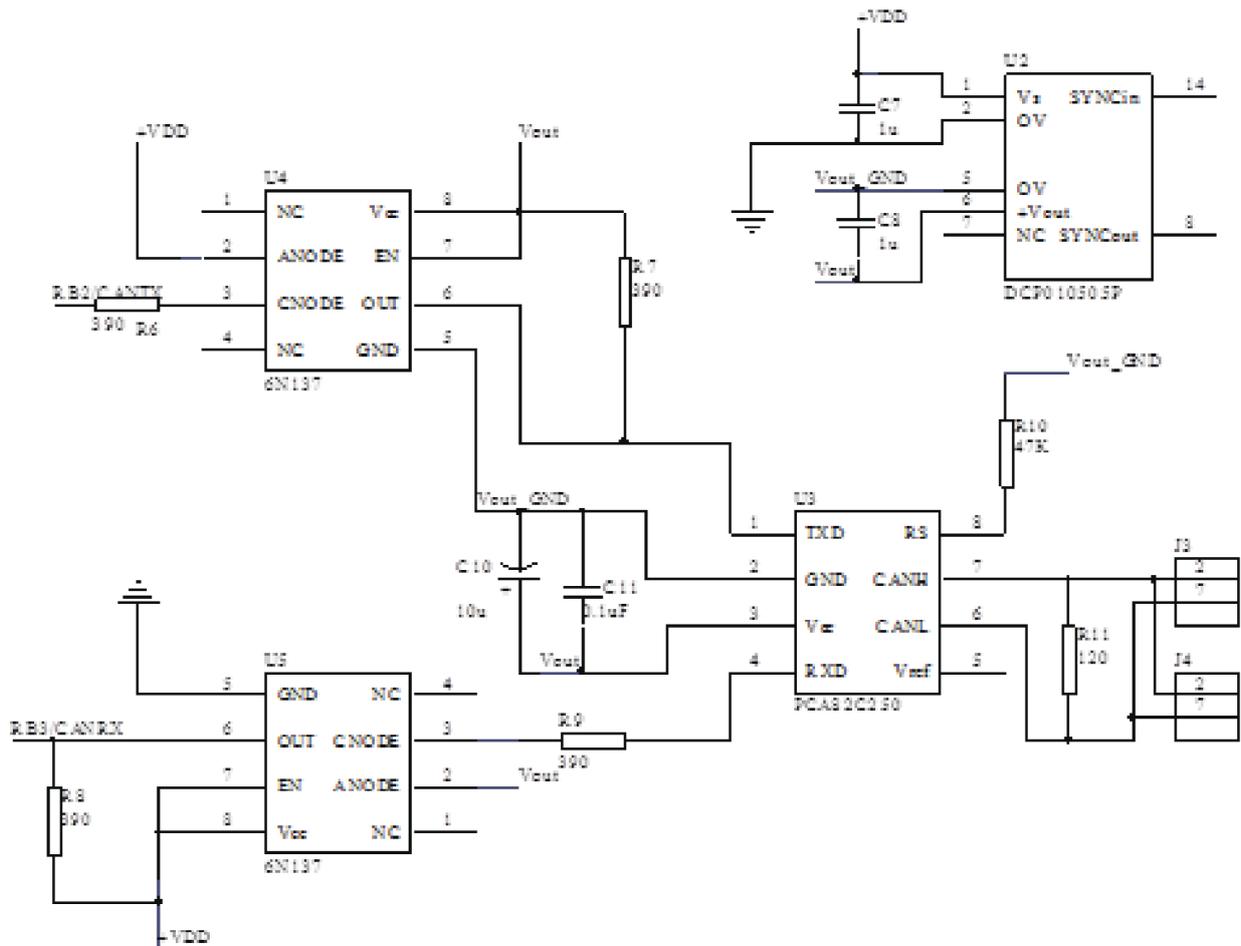


Figure 9. The hardware connection diagram of CAN bus

Table 1. DS18B20 data frame list

Identification code byte 1								Identification code byte 2							
ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0	RTR	DLC3	DLC2	DLC1	DLC0
0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0
Command code						Node coding				RTR	length of the data bits				

Table 2. DS18B20 temperature data table

D0	D	D2	D3	D4	D5	D6	D7
High byte	Low byte						
Temperature 0		Temperature 1		Temperature 2		Temperature 3	

3.3 The software design

Take CAN self-test mode to debug in the condition of uninstalled CAN card. The self test sends and receives data between the send buffer and receive buffer and lets the information not transmit to the CAN bus. This work mode is applied to development of test procedure. The device can receive from its own information such as information from other nodes. The program receives in interrupt mode and sends in a query mode. The program flow is shown in Figure 12.

This system selects PCI-51XX intelligent CAN interface card of ZLG MCU company (PCI-5110) [10].

4. The interface design of monitoring system

4.1 Communication between CAN card and computer

LabVIEW is a graphical programming language. It adopts data flow programming not traditional text programming that the icon represents a variable or function module and the connection expresses the data transfer direction. The sensor data from MCU is

through CAN Bus transmitted to the upper computer using LabVIEW to design the interface to complete real-time display. The interface function includes: drive CAN card (open, start, reset, close), receive and display the data of temperature / speed, set the threshold and compare, alarm for abnormal situation [11].

The menu item refers to the device operation of CAN card including start, reset, close and exit. The control item contains ready to receive button, save the data path and start CAN card lamp. The display item is consist of temperature internal the power supply, the fan speed and the bus-bar temperature. Display the corresponding data using digital and graphic form in the sub part. Set the threshold in the program. The indicating lamp changes light when the temperature is too high or the speed is also slow.

## 4.2 Receive and display data

Then take data receiving and display as an example. Use VCI\_CAN\_OBJ structure and VCI\_Receive function of LabVIEW library functions in receiving data. VCI\_CAN\_OBJ is used in the transmission of CAN message frame that is Boolean array composed of message ID, TimeStamp (identification of received information frame time), TimeFlag (whether to use time logo), SendType (transmission frame type), RemoteFlag (long-rang frame), ExtendFlag (extended frame), DataLen (data length), Data (packet data) and so on. Message ID is consisted of 11 bit binary numbers in which the lower 5 are for the node code, the high 6 are for the command code. Different ID can receive different data. Turn the data to the decimal number through the mathematical calculations in order to show in the chart and observe the change history curve directly [12].

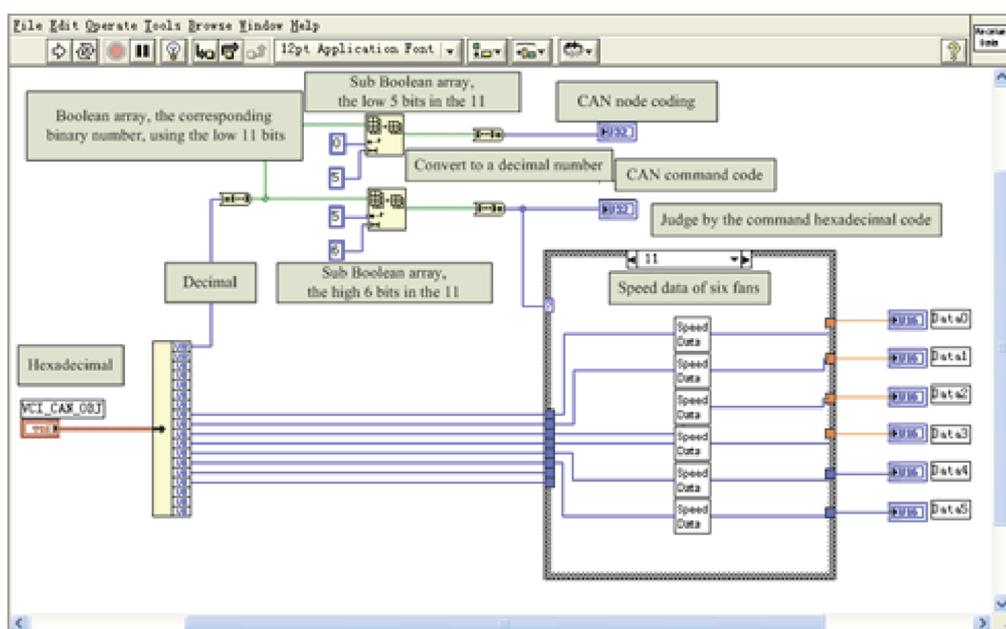


Figure 10. The source data receiving data

## 5. Conclusions

The system based on CAN bus designs the reliable communication interface circuit and transmits the monitoring data to the upper computer to make comprehensive analysis. Design the hardware circuit and the sensor interface. Realize the software running normally. Write Vis to open device, save data, receive data in LabVIEW. Add different function module in the menu not affect the original module to finish display interface design. After debugging it shows that the system can work normally. CAN bus transfers reliably and no error rate, all the indexes reach the design requirements.

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