Design of data acquisition node based on CAN bus

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Abstract

Taking single chip microcomputer (SCM) STC90C58AD as control core, a universal CAN bus data acquisition node was designed using CAN bus controller SJA1000 and CAN bus transceiver PAC82C251. Also, the hardware circuit and software design of CAN bus communication were given. Before data collection, current signal has been I-V transformed, and voltage signal has been filtering processed and amplified. Such program is suitable for multi-sensor field data collection in industry.

Keywords: CAN bus, SJA1000, data acquisition

1 Introduction

CAN (Controller Area Network) is the only field bus with international standard at present. Compared to normal communication bus, the CAN bus possesses excellent characters of reliability, real-time and flexibility. As CAN is a multi-master bus, the communication media can adopt twisted pair line, coaxial cable or optical fiber, whose communication rate can reach 1Mbps, and distance can be 10km. CAN protocol adopts encoding the communication data instead of coding the traditional address. Due to its powerful error-correcting capability and support for the transceiver of difference signal, CAN bus has farther transmission distance in highly disturbed environment [1]. This work presents a design of data acquisition node based on the CAN bus. Such node can output the data collected by sensor in the form of digital quantity, which can easily connect to the PC via CAN network, thus simplifying systemic structure and improving accuracy. Meanwhile, several multiple data acquisition nodes can be mounted on CAN bus, realizing the network of data acquisition node. This design is suitable for the data acquisition system whose sensors are dispersed.

2 Topology of CAN bus

Figure 1 shows the topology of CAN bus. System mainly consists of host computer (PC) and data collector. Bus transmission medium adopts the shielded twisted-pair. As the core of the whole system, PC's function is to monitor and manage the system. The function of CAN bus intelligent adapter is to collect the data from each node transferred to PC, and transmit PC's orders to each node. With the multiple host structure of CAN, each node can send data to the bus according to requirements. Because of this, while being monitored by PC, each node can also monitor the bus, thus receiving useful data. Data acquisition node is composed of microprocessors and programmable CAN controller chip, and its function is field data collection and transmission.

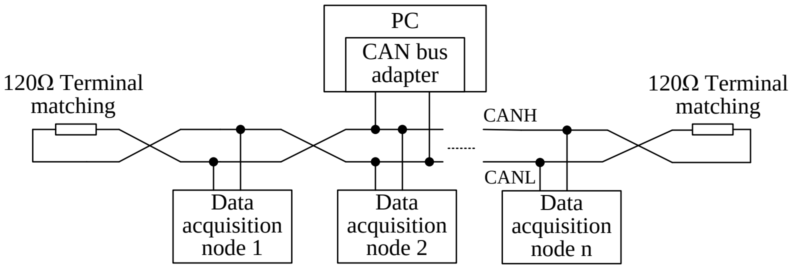

FIGURE 1 CAN bus topology

3 Hardware design of data acquisition node

The main function of data acquisition node includes: Changing the continuous analog signals into digital signals; converting the digital signals into information which is accord with CAN bus protocol; publishing the information on CAN bus. Figure 2 shows the structure diagram of data acquisition node. As shown, the information detected by sensor is sent to programmable amplifier consisted of instrument amplifier AD623 and digital potentiometer X9214. By changing the resistance of X9214, the amplification of signal can be regulated. After amplification, the information will be converted into digital signal by integrated 10-bit A/D converter inside

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SCM STC90C58AD. Then, the digital signal will be sent to the bus controller SJA1000. Finally, though photoelectric coupling based on CAN bus protocol, the information transferred from bus transceiver to CAN bus will be received by other nodes and PC.

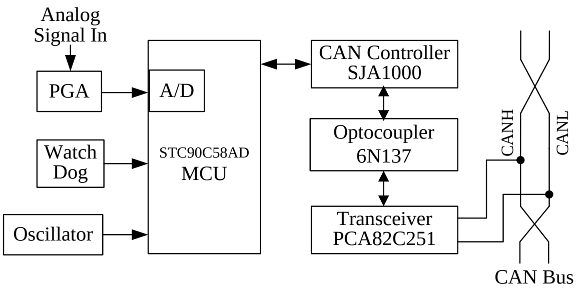

FIGURE 2 Overall block diagram of data acquisition node

3.1 SCM STC90C58AD

Figure 2 shows SCM STC90C58AD, the core processor of data acquisition node. As a new generation introduced by STC, SCM STC90C58ADSTC has the advantages of super anti-interference, high-speed and low-power. Such SCM can work under harsh industrial environments with the features of high speed data acquisition and long working hours. Besides, its instruction code is compatible with traditional 8051 SCM, with the frequency range of 0~40MHz. This SCM has the function of EEPROM for a 40K application space and integrated 256+4096 byte RAM. Moreover, this SCM also supports ISP and IAP for its inner couplers of Watchdog, eight-channel 10-bit A/D converter and three 16-bit timer/counters. In a word, such SCM includes all the unit modules required during data acquisition and controlling. So this SCM is a system with high reliability but low cost.

3.2 DESIGN OF I/V CONVERTING CIRCUIT

The standard current signal outputted by sensor is 4~20mA. To perform A/D conversion and achieve good conversion effects and accuracy, field current signal should firstly be converted into standard voltage 0~5V. It cannot eliminate common mode interference by using circuit network to directly change current signal into voltage signal, and the conversion accuracy cannot be guaranteed. Using the precision current-loop receiver chip RCV420 produced by U.S. company BURR-BROWN, this design can transfer the input signal 4~20mA into 0~5V output signal by current-loop technology. Figure 3 shows the converting circuit with second-order low-pass filter. Both the positive and negative electrodes of RCV420 should connect to a 1μF decoupling capacitor. Besides, two electrodes should be placed close to the amplifier. To avoid the gain and CMR errors introduced by external circuits, the electrodes should connect to ground as the method shown in Figure 3, thus ensuring the minimum grounding resistance. The unused Ref IN pins should be grounded to maintain a high CMRR.

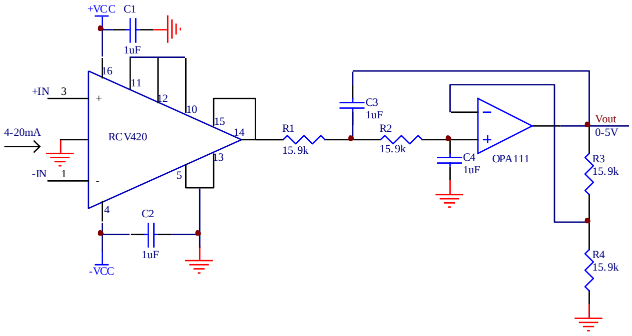

FIGURE 3 I/V converting circuit

3.3 PROGRAMMABLE GAIN AMPLIFIER CIRCUIT

Normal analog voltage signal transformed from industrial sensors includes: 0~5V, 0~10V, ±5V and ±10V. It is impossible for A/D transfer to match all the conditions. If single gain amplification is used, the range of A/D conversion chip cannot be maximized. Furthermore, the measured signal may be saturated, resulting in large measurement error or even damages to A/D chip. Therefore, the gain of preamplifier should be changed according to the output of sensor to obtain the maximum measuring accuracy. This design used the programmable gain amplifier consisted of instrument amplifier AD623 and digital potentiometer X9214. Figure 4 shows the schematic diagram of programmable control amplifier circuit.

AD623 has the advantages of high-accuracy, low-drift and low-noise. And this amplifier can change signal gain by only adjusting the resistance R_G between pin 1 and 8. Moreover, AD623 is easy to be used. The signal gain equation is as follows [4]:

$$G = \frac{49.4k\Omega}{R_G} + 1$$

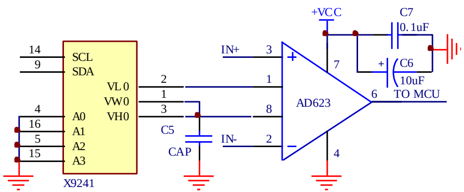

FIGURE 4 Programmable control amplifier circuit

Digital potentiometer X9214 has I2C interface. As shown in Figure 4, VL0 refers to the low end of potentiometer, VH0 the high end and VW0 the movable point. The resistance value of potentiometer between pin VL0 and VW0 can be changed through programming [5]. In specific use, SCM determines the signal range based on the signal value first collected. Then the highest magnification measurement accuracy will be obtained by certain algorithms. Finally, controlling the digital potentiometer X9241 by I2C bus, then the programmable amplification can be reached.

3.4 A/D CONVERTING CIRCUIT

Analog signal, after regulation, will be converted to digital signal by integrated 8-channel 10-bit A/D inside SCM STC90C58AD. The A/D converter interface of SCM STC90C58AD, whose speed can reach 250 KHz, lies in P1 interface. And the converter is a kind of successive approximations ADC. Users can set any one of the eight ways into A/D conversion through software, while the others continue acting as I/O interface. After conversion, the converter should be set at the A/D ending flag bit ADC_FLAG of control register ADC for program inquiring or interrupt application.

3.5 CAN CONTROLLING SJA1000

SJA1000 is an independent CAN controller, supporting the CAN2.0B protocol which has many new features. And the controller lies between the micro controller and transceiver. The CAN core module of SJA1000 is responsible for receiving and transmitting information frame of CAN, as well as realizing CAN protocol. Interface management logic manipulates the interface of the main controller outside. So the operation of STC90C58AD to SJA1000 is equal to that external RAM does [6]. After acceptance filter completes filtering the received information, the information frame that have passed acceptance filtering and without error will be sent to the receive FIFO buffers. Through read-write operation for built-in register of SJA1000, the master controller SCM can be set to CAN bus communication mode, thus achieving data transmitting and receiving. Then, the communication of SCM to CAN controller can be achieved by interrupt mode, which connects interrupt signal pin /INT of SJA1000 to the external pin /INT0 of STC90C58AD.

3.6 CAN TRANSCEIVER PCA82C251

The encoding and decoding of data transmission have been logically achieved by SJA1000. While to connect physical line, the driving capability of differential transmit and receive of CAN bus should be enhanced by means of bus transceiver PCA82C251. Such transceiver can transmit data between two differential voltage bus cables with a high speed of 1Mb/s. Both the CANH and CANL pins of transceiver can connect CAN bus by a thermistor, so as to protect itself from the impact of over-current when resistance heating value becomes larger. Between CANH and CANL, there parallel two small capacitors, which can filter the high frequency interference on bus, and shield electromagnetic radiation. As shown in Figure 5, TX0 and RX0 of SJA1000 are connected to PCA82C251 via high-speed optical coupler 6N137. It is to enhance the anti-jamming capability of CAN bus node and prevent crosstalk between lines. 6N137 is compatible with TTL and CMOS level, with a signal width of 10MHz. So it fully meets the requirement of a communication speed of 1Mb/s for CAN bus signals.

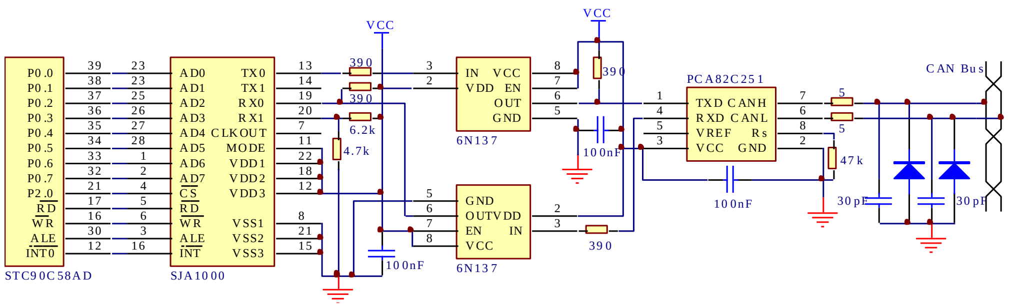

FIGURE 5 Schematic circuit of CAN communication node

4 Communication software design of CAN bus

Communication software design of CAN bus mainly includes SJA1000 initialization, CAN transmitting and receiving programs. Besides, there are some auxiliary functions, like interrupt processing, information processing, bus sleep and awaking treatment, bus error handling and overloading treatment. The modular and structured program design of software design enable the software has good portability.

4.1 FLOW CHART OF MAIN PROGRAM

Figure 6 shows the overall flow chart of software design for system node. When system powered up, part of the reset work would be first completed. Entering the initialization stage, the software would complete the initialization of the rest modules. Following that, system enters the wait state. When received the order of data acquisition from PC, note begins to collect the measured physical signal. Firstly, the analog signal received from the front end of sensor, after be amplified and filtered, should be sent to A/D converter inside SCM for analog/digital conversion. After completion of the signal conversion, results will be temporarily stored in RAM. Then, the data should be processed into CAN data frame until the SJA1000 CAN controller receives the command of data transmission. When PC requires data transmission, interrupt subroutine will start up to transmit data frame. Once transmission finished, system will jump out subroutine. If the data frames on bus need being received, system will receive it. And there is not confliction between transmission and reception, namely the two processes can work simultaneously. While receiving the command of finishing data acquisition from PC, node will return to the wait state.

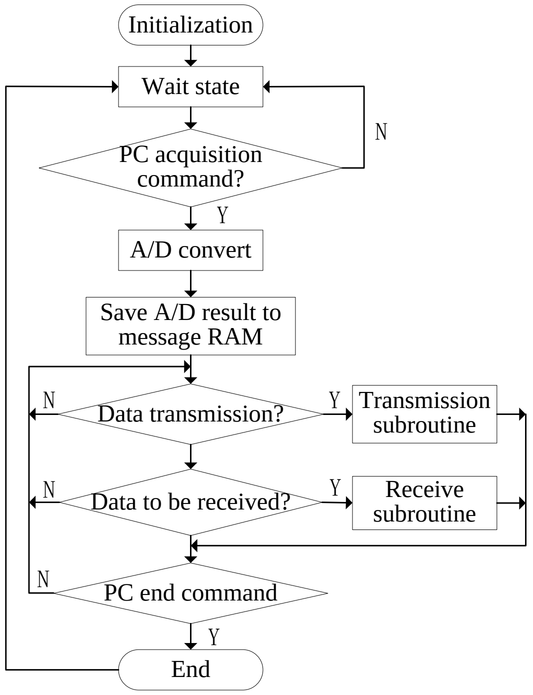

FIGURE 6 Flow chart of the main program

4.2 INITIALIZING PROGRAM OF SJA1000

When using the CAN controller, operator should allocate related registers according to the tasks, namely setting their initialization parameters. However, the initialization of SJA1000 performs only in reset mode. The initialization procedures of SJA1000 mainly includes: selecting work mode, setting interrupt system, setting the bite rate of bus, setting acceptance filter, and setting the output mode and configuration of CAN bus output pins. Actually, these settings refer to the write operations for some registers inside SJA1000. When initialization was completed, the reset request of SJA1000 should be removed. Then, SJA1000 can transmit and receive messages.

4.3 MESSAGE TRANSMISSION PROGRAM OF CAN

Message transmission, namely transforming the information into frame message with required formats, can be automatically accomplished by SJA1000 CAN based on bus protocol. While transmitting CAN message, SCM should first check the state of SJA1000 register. If the state register satisfies transmitting conditions, the data inside SCM will be sent to the transmission buffer of SJA1000. Then, the "transmission request bit" on register will be started by write command. SJA1000 can automatically set the "transmission completion bit" to 0, which means under transmitting. As long as there is another node on bus, such node will transmit acknowledgment (ACK) signal to the bus. If the ACK signal was received by bus, then the node will set to "status bit of transmission completed", which means transmitting successfully. If SJA1000 didn't receive the ACK signal, which means there is no other node on bus. Then SJA1000 will retransmit, and the error register will add one. Before each transmission, it is necessary to read the corresponding bit of state register. And the next frame data can only be loaded when transmission buffer is free. Figure 7 shows the transmission flow of CAN bus.

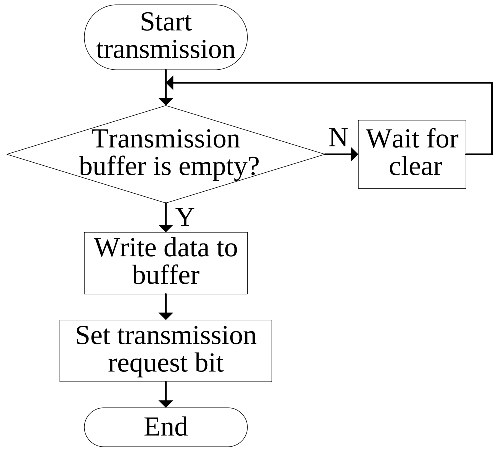

FIGURE 7 CAN bus transmission sequence

4.4 MESSAGE RECEIVE PROGRAM OF CAN

Receive subroutine is mainly responsible for reading the value of receive buffer and dealing with it. For message receive, both inquiry mode and interrupt mode can be used. This work adopts the interrupt mode, which is better than inquiry mode in terms of real-time. When the CAN bus controller SJA1000 receives a valid frame message (have passed filtering acceptance), the pin $\overline{INT}$ of SJA1000 will jump to low level, and the external interrupt 0 of microprocessor will be triggered. If the message was transmitted to microprocessor via interrupt subroutine, then the receive buffer would be released. Figure 8 shows the interrupt receive program sequence of SJA1000.

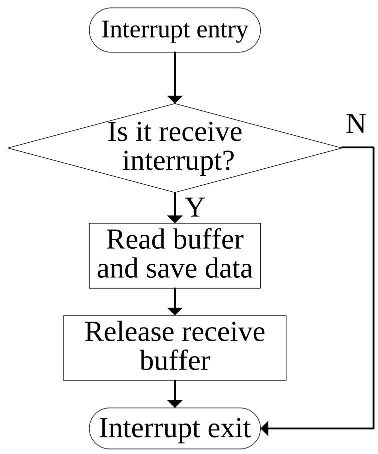

FIGURE 8 Interrupt receive program sequence of SJA1000

5 Conclusions

Due to the use of CAN bus, the system has the advantages of low-cost, small-capacity, multi-channel, high-precision, easy updating, high flexibility and strong extension ability. Analog signal acquisition front is compatible with the old industrial sensors. Therefore, it can well complete the acquisition of field information, as well as simple data processing and communication, with the features of noise immunity and low error rate. The system consists of such nodes can be used as the distributed control system, with complex working environment, various sensors and high real-time requirement.

References

[1] Cena G, Valenzanon A 1997 *IEEE Transactions on Industrial electronics* **44**(4) 553-64
[2] Hong J 2011 Technology Inc STC90C58AD series single chip microcomputer manual
[3] Burr-Brown 1997 Precision 4mA to 20mA Current Loop Receiver RCV420 data sheet
[4] Analog Devices Inc. 2004 Low Cost, Low Power Instrumentation Amplifier AD623 data sheet
[5] Xicor Inc 1996 Quad E2POT™ Nonvolatile Digital Potentiometer X9241 data sheet
[6] Philips Electronics 1997 SJA1000 Stand-alone CAN controller data sheet

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