Design of locomotive bearing fault signal collector based on ARM

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Abstract

Railway transportation plays an important role in China's transportation industry. Locomotive vehicles, as an important part of the power transmission of the entire catalogue, are directly related to the development of China's economy. According to statistics, 30% of locomotive failures are caused by locomotive bearing failures. Therefore, the detection of the state of the locomotive bearing to avoid damage to the locomotive safety due to bearing failure is of great significance to the safety of the locomotive. The ARM-based locomotive bearing fault signal collector designed in this paper collects, transmits and stores the vibration signal and temperature signal during the operation of the bearing through the cooperation of software and hardware system, and diagnoses the potential fault of the locomotive bearing through later analysis and diagnosis. Carry out timely warning and handling to ensure the safe operation of the locomotive. The core module of the system is the control module. The design is directly related to whether the signal acquisition can be completed at high speed and accurately.

Keywords

ARM, STM32, signal acquisition, locomotive safety.

1. Introduction

As one of the basic measures to ensure the safety of locomotive operation, the locomotive bearing fault signal acquisition can make predictions on locomotive bearing faults, and propose countermeasures or suggestions through later analysis, which plays a great role. With the modernization of enterprise equipment management, how to make train equipment contact reliable, safe and efficient operation is a very important issue. In order to make the locomotive run safer and more efficient, it is necessary to have a comprehensive understanding of the deterioration of the train components and the fault state. The acquisition and analysis of locomotive bearing signals is a relatively new technology. At present, there is no complete scientific system. It involves many kinds of sciences such as mechanical vibration, sensors, computers, signal processing, artificial intelligence, automatic control, etc. A new type of discipline with strong comprehensiveness. With the development of science and technology and the introduction of new analytical methods, with the adoption of new technologies such as sensors, computer control and wireless communication, higher requirements are placed on the accuracy, sensitivity, reliability and maintainability of the detection system. At present, there are many universities and scientific research institutions in China conducting research in this area. With the deepening of research and the great value of its practical application, people will realize that the acquisition of locomotive bearing fault signals is very important for the safe and reliable operation of trains.

2. Overall Structural Design of The System

ARM-based locomotive bearing fault signal acquisition system mainly utilizes the advantages of ARM processor peripheral interface rich and fast processing speed, and can complete data communication and other functions in idle time, and vibration signal and temperature of locomotive bearing during operation. The signal is collected, and the signal acquisition transmission channel is selected by the ADG5408 chip, and the collected signal data is transmitted to the storage unit through the CAN bus for later analysis and processing. The signal acquisition system consists of two parts: the hardware system and the software system. Through the cooperation between the software system and the hardware system, the high-speed and accurate acquisition of the bearing signal is achieved.

3. Hardware system

The design of the hardware system plays a vital role in the realization of the functions of the signal acquisition system. The hardware system mainly includes: the core control system, the signal acquisition system (including the vibration signal and temperature signal), the signal conditioning system, and the power system. , signal transmission systems (including A / D conversion systems and multiplex systems) and CAN bus transmission systems. The various parts of the hardware system are interlocked to achieve the acquisition of the bearing signal.

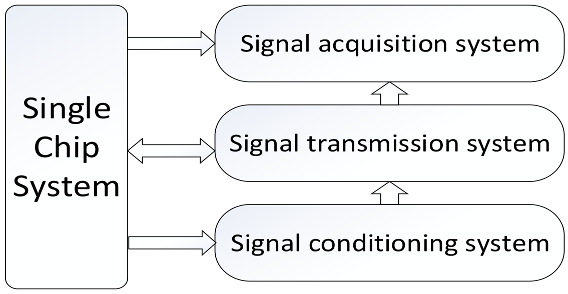


Fig.1. Hardware system structure

3.1 Core Control System

The core control system has always been regarded as the "heart" of embedded systems. After years of development, the core controller has made great progress. In order to meet the requirements of the test system, the core processor must meet the requirements in terms of operating temperature, electromagnetic interference resistance, reliability, etc., and ensure the stability and scalability of the embedded system. In the signal collector designed in this paper, we chose the STM32F4 series microprocessor STM32F407ZTG6 with ARM as the core as the core part of the locomotive bearing signal acquisition system. The microprocessor STM32F4ZTG6 is a high performance microprocessor based on the ARM CortexTM-M4. It has many advantages such as low power consumption, low gate count, short interrupt latency, etc., and it simplifies complex programming, resulting in higher performance, lower power consumption, and lower cost. Operating at 168MHz, high-performance peripherals and operating temperatures from -40°C to 85°C, withstand very low or very high temperature variations.

3.2 Signal Acquisition System

3.2.1. Temperature Signal Acquisition System.

The temperature signal is measured by the DS18B20 sensor. The DS18B20 digital temperature sensor is easy to connect. It can be used in a variety of applications after packaging, and it can be changed according to the application. The temperature range of DS18B20 is: -55°C~+125°C. The accuracy is +0.5°C at -10°C~+85°C. The measurement result directly outputs the temperature signal. In the sensor, TH and TL are temperature alarm triggers to prevent The temperature exceeds the range of measurable temperature, and has strong anti-interference and error correction capability. The temperature sensor is connected to the ARM control chip to directly read the temperature detection data.

3.2.2. Vibration Signal Acquisition System.

At present, there are three main types of sensors for locomotive bearing vibration signal acquisition: piezoelectric acceleration sensor, piezoresistive acceleration sensor and variable capacitance acceleration sensor. The piezoelectric acceleration sensor is selected in this system. The sensor is suitable for long-term measurement of wide frequency band, low frequency, high sensitivity and long distance, and can perform multi-point cluster measurement, has strong overload capability, and has excellent working ability in harsh environments, and signal conditioner Connect and pass the collected signal to the computer for storage. In addition, its advantages are also reflected in the high signal-to-noise ratio, light weight and other aspects, in line with the requirements of the signal acquisition system.

3.3 Signal Conditioning System

The output impedance of the piezoelectric accelerometer is very high, so the output voltage signal is very small, so the collected signal is relatively weak, so the special average preamplifier must be used for impedance transformation and amplification; the vibration signal has a certain bandwidth, which is divided into Two parts within the work frequency band and outside the work frequency band. The frequency components within the working frequency band are effective. Under actual conditions, the characteristic frequency of the locomotive bearing, the fundamental frequency and the higher harmonic frequencies synthesized by these frequencies are generally between several hertz and 10 kHz, and the system sampling frequency is 20 kHz, which basically satisfies the actual situation. Need; at the same time, in order to make the signals collected by multiple sets of sensors in the same magnitude, and to prevent signal distortion, the signal conditioning system is added.

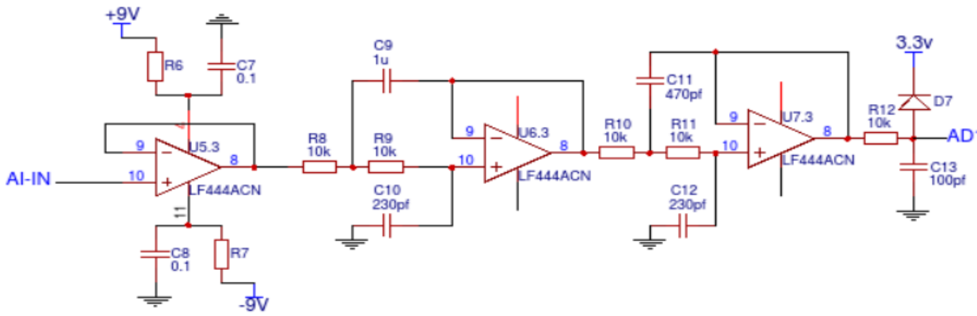


Fig 2. Signal conditioning circuit diagram

3.4 Signal Transmission System

3.4.1. Multiplex System.

The purpose of the multiplex system is to read the data of multiple sets of sensors on the locomotive bearing wheel, so as to reduce the error. The function of the multiplexer circuit is done by the chip ADG5408. The ADG5408 high voltage latch-proof 8-channel multiplexer is responsible for the gating of the bearing signal transmission channel. The ADG5408 is a single-chip CMOS analog multiplexer with 8 single channels and 4 differential channels. The ADG5408 switches one of the eight input signals to the common output based on the address determined by the 3-bit binary address lines A0, A1, and A2.

EN is the enable terminal, A0, A1, A2 are control pins, S1~S8 are input pins, and D is an output pin. The control pin is used to determine the on and off of the eight sampling signal transmissions.

3.4.2. A/D Conversion Circuit.

The signal collected by the sensor is selected by the multiplexer switch, and then transmitted to the AD conversion module of the STM32 single-chip microcomputer with ARM as the core, and the collected analog signal is converted into a digital signal that can be read by the computer, which is convenient for subsequent operation. step. The 12-bit ADC is a successive approximation analog/digital converter. The A/D conversion of each channel can be performed in a single, continuous, scan or discontinuous mode. The results of the ADC can be stored in a 16-bit data register in left or right alignment. The analog watchdog feature allows the application to detect if the input voltage exceeds a user-defined high/low threshold to protect the controller from normal operation.

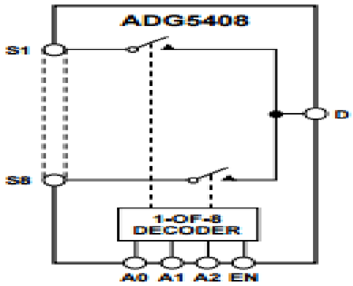


Fig 3. Schematic diagram of the ADG5408 chip

3.5 Power System

In the design of the acquisition system, the system requires a supply voltage of +24V or +12V, while the signal conditioning circuit requires a supply voltage of +5V and -5V. The minimum system of the microprocessor and the USB interface circuit require a supply voltage of +3.3V. . In this paper, in order to make the signal acquisition system stable operation, and considering the cost, the power conversion chip LM7810 is used to realize +12V to +5V and +10V. The voltage of 10V is converted into 1.5V and 3.3V by using a trimming circuit such as a transistor. The voltage is used to supply power to the MCU module, signal acquisition module, and CAN bus transmission module of the entire hardware system.

3.6 CAN Bus Transmission System

The application of CAN bus in embedded systems is also very extensive. The reliability of CAN bus communication in embedded systems is verified in a large number of practical applications. For a completed CAN communication, the hardware is essential for controller and drive selection. The main function of the controller is to convert the sent and received message information into a CAN frame that meets the requirements of the specification. The driver is also called a transceiver. The main function is to convert the logic level of the CAN controller to the differential level of the CAN bus. In addition, CAN The bus architecture terminal requires a 120Ω resistor to enhance the reliability of CAN-bus communication. The controller uses the controller's own bxCAN controller, and the CAN receiver uses the CTM8251chip. The CTM8251 chip is a universal CAN receiver chip with isolation. The transceiver and isolator are integrated to ensure the logic level is converted into differential power. It also has DC 2500v isolation function, which improves its anti-high frequency interference capability, and this transceiver is suitable for any CAN protocol, ensuring the normal operation of communication functions.

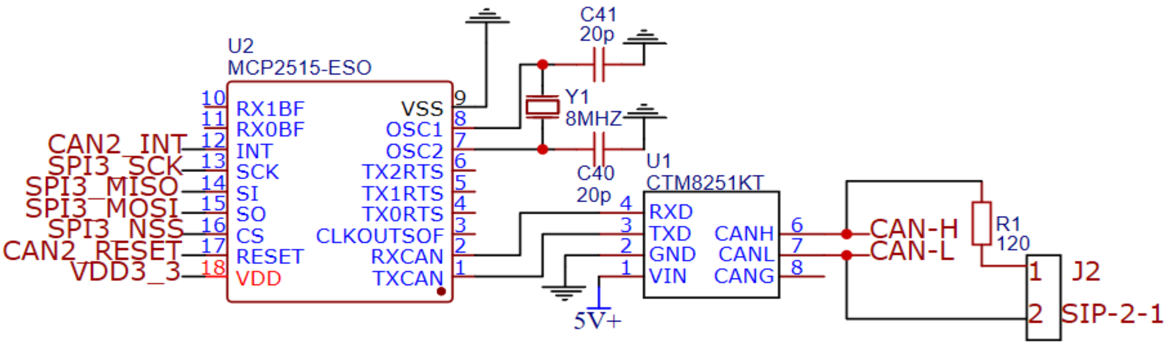


Fig 4. CAN bus communication circuit diagram

4. Software System

The hardware system is the basis of the whole system, and the software system is the key to whether the hardware system can complete its established functions. The software system is mainly divided into: initialization module data acquisition module and CAN bus transmission module.

4.1 Initialization Module

The initialization function in this system is to initialize the system resources and establish the zero state condition of the system program execution. The objects that need to be initialized include initializing the internal RAM of the STM32 controller, I/O port input and output status, working register area, timer, interrupt service register, etc., setting or initializing the status of the external device, reducing software vulnerabilities, and The future work preparation conditions of the system.

4.2 Data Acquisition Module

The software part of the acquisition system mainly involves two parts: sampling frequency selection and program flow design. The sampling frequency should conform to the sampling theorem. The accuracy of the selection determines the analysis accuracy of the subsequent signal processing and the running speed of the program. The two are mutually constrained; the design of the program flow ensures that the acquisition process runs smoothly, so the DMA direct memory access is used. The way to increase the speed of data collection.

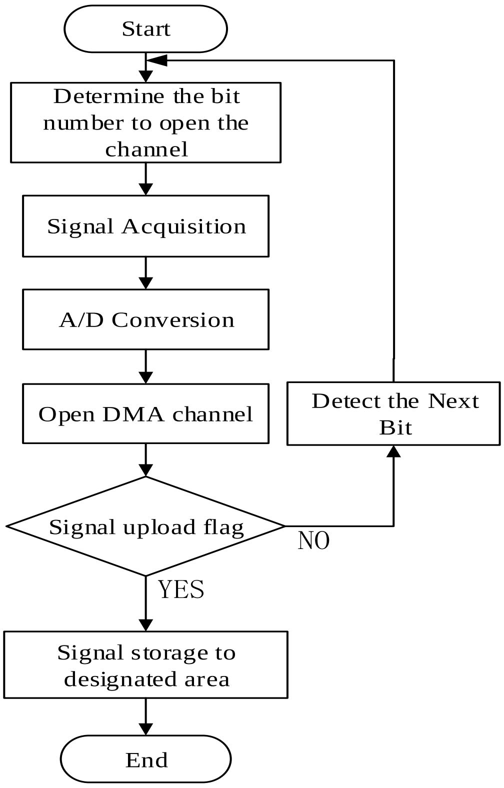


Fig 5. Signal collection process

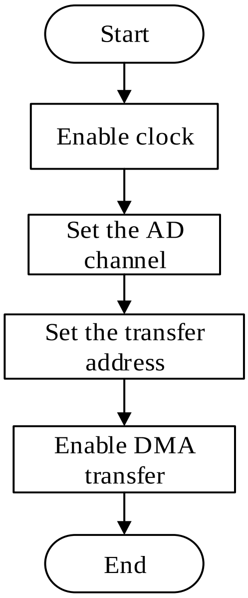


Fig 6. DMA initialization settings

4.3 CAN Bus Communication Module

The communication between the pre-processor and the subsystem uses the bxCAN controller, and the controller uses interrupts to ensure that information can be transmitted in time. The transmitted information is mainly axis position information, temperature information, system self-test information and vibration information. The difference of information types is mainly determined by the judgment of filtering frames. According to the requirements of the system design specification, the detection of temperature information needs to ensure the frequency of refreshing once in three seconds, which requires the real-time performance of CAN bus communication. The temperature signal is sent separately from the vibration signal for analysis. The temperature information and the self-test information are collected by a three-second timed interrupt detection, and the vibration signal corresponding to the axial position is collected and uploaded according to the received subsystem command axis position. The sampling process between the preprocessor and the subsystem is shown in the figure below.

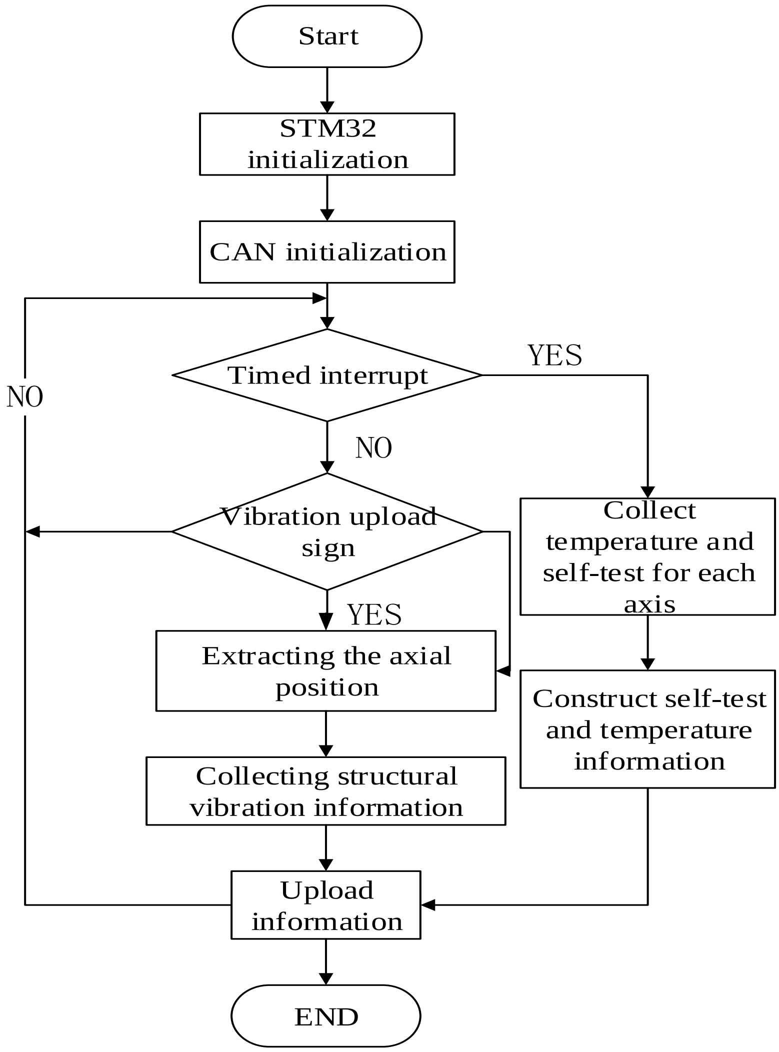
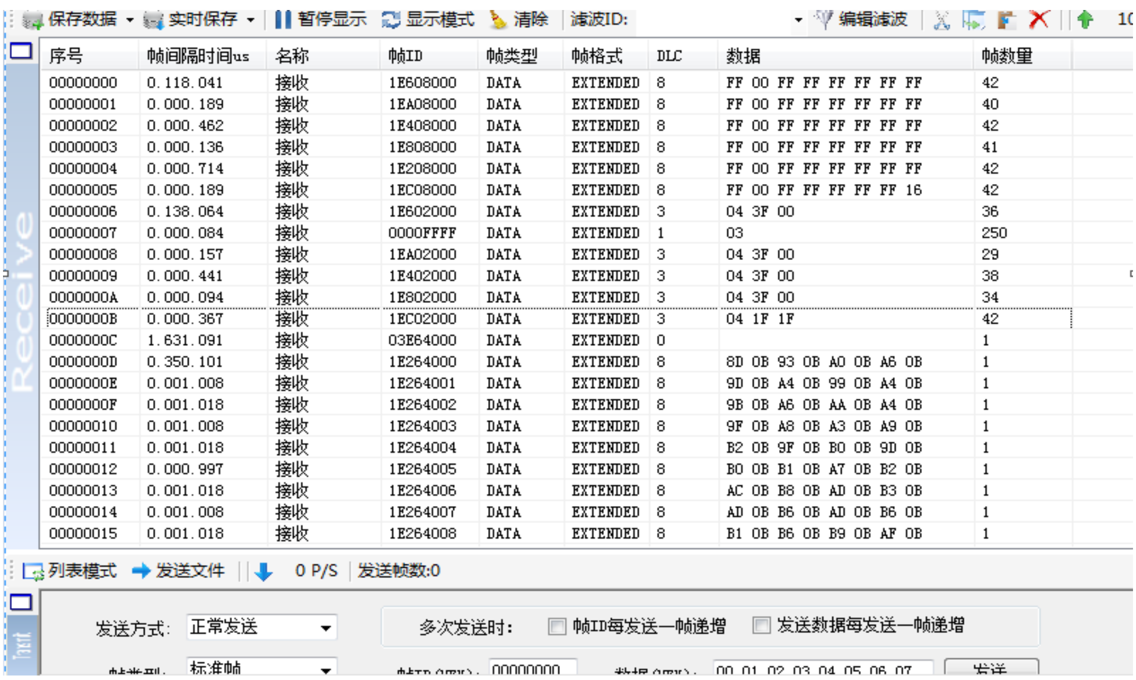


Fig 7. Pre-processor CAN communication flow chart



序号	帧间隔时间us	名称	帧ID	帧类型	帧格式	DLC	数据	帧数量
00000000	0.118.041	接收	1E608000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF FF	42
00000001	0.000.189	接收	1EA08000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF FF	40
00000002	0.000.462	接收	1E408000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF FF	42
00000003	0.000.136	接收	1E808000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF FF	41
00000004	0.000.714	接收	1E208000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF FF	42
00000005	0.000.189	接收	1EC08000	DATA	EXTENDED	8	FF 00 FF FF FF FF FF 16	42
00000006	0.138.064	接收	1E602000	DATA	EXTENDED	3	04 3F 00	36
00000007	0.000.084	接收	0000FFFF	DATA	EXTENDED	1	03	250
00000008	0.000.157	接收	1EA02000	DATA	EXTENDED	3	04 3F 00	29
00000009	0.000.441	接收	1E402000	DATA	EXTENDED	3	04 3F 00	38
0000000A	0.000.094	接收	1E802000	DATA	EXTENDED	3	04 3F 00	34
0000000B	0.000.367	接收	1EC02000	DATA	EXTENDED	3	04 1F 1F	42
0000000C	1.631.091	接收	03E64000	DATA	EXTENDED	0		1
0000000D	0.350.101	接收	1E264000	DATA	EXTENDED	8	8D 0B 93 0B A0 0B A6 0B	1
0000000E	0.001.008	接收	1E264001	DATA	EXTENDED	8	9D 0B A4 0B 99 0B A4 0B	1
0000000F	0.001.018	接收	1E264002	DATA	EXTENDED	8	9B 0B A6 0B AA 0B A4 0B	1
00000010	0.001.008	接收	1E264003	DATA	EXTENDED	8	9F 0B A8 0B A3 0B A9 0B	1
00000011	0.001.018	接收	1E264004	DATA	EXTENDED	8	B2 0B 9F 0B B0 0B 9D 0B	1
00000012	0.000.997	接收	1E264005	DATA	EXTENDED	8	B0 0B B1 0B A7 0B B2 0B	1
00000013	0.001.018	接收	1E264006	DATA	EXTENDED	8	AC 0B B8 0B AD 0B B3 0B	1
00000014	0.001.008	接收	1E264007	DATA	EXTENDED	8	AD 0B B6 0B AD 0B B6 0B	1
00000015	0.001.018	接收	1E264008	DATA	EXTENDED	8	B1 0B B6 0B B9 0B AF 0B	1

Fig 8. Data received by the CAN bus analyzer

5. System simulation

After the software system is compiled, the compiled software program is downloaded to the hardware circuit board through the JTAG+SWD emulator download interface. After the emulator is successfully connected to the hardware circuit board, the CAN bus analyzer is used to transmit and receive data from the CAN bus. Observe and observe whether the read data is the same as the expected data, so that the experiment meets the original experimental requirements.

As shown in the figure, the data of 04 1F 1F indicates that the sixth set of axial signals is acquired, and the data of FF 00 FF FF FF FF FF 16 indicates that the sixth set of axial temperatures is 16 °C. The simulation results show that the collected data is completely consistent with the expected results and achieves the purpose of data collection.

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