Design of Automobile Engine Fault Diagnosis Instrument Based on STM32 and LabVIEW

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Abstract—The designer designed an engine fault diagnosis instrument with STM32 single chip microcomputer combined with LabVIEW technology for automobile engine failure. The system will use the eddy current sensor to collect the engine vibration signal and send it to the host computer program written by LabVIEW for high-order spectrum analysis. In this way, the working status of the engine can be obtained in real time. Experimental results show that the designed diagnostic instrument is highly efficient and highly reliable. It can meet the real-time diagnosis requirements of engine status.

1. INTRODUCTION

As the power source of the car, the engine's working state is directly related to the operation of the whole car [1-2]. Moreover, the engine has been vibrating during the operation of the car. When the engine fails, the vibration signal contains the engine's failure information. Using the vibration signal of the engine to analyze the working state of the engine can effectively solve the problem of detecting the working state of the engine without disassembling the engine [3-5]. The engine fault diagnosis instrument based on high-order spectrum analysis uses STM32F103 single-chip microcomputer as the lower computer, which is responsible for signal acquisition and data transmission. It can transmit the vibration signals collected by the lower computer to the PC through asynchronous serial communication [6], and store and analyze the collected vibration information on the PC side. The traditional vibration signal analysis method is to use the power spectrum for analysis, but the power spectrum lacks phase information between frequency components, which cannot satisfy the processing of complex vibration signals. Therefore, the use of modern signal spectrum analysis methods to analyze the vibration signals of automobile engines has become a current hot spot [7]. At present, there are many methods for vibration signal analysis using modern signals. The high-order spectrum can not only analyze the phase information between the vibration signal frequencies when analyzing the vibration signal, but also suppress the Gaussian background noise (colored or white) in the vibration signal. The vibration signal analysis of high-order spectrum analysis has obvious advantages. Therefore, designing an automobile engine fault diagnosis system that uses high-order spectra for analysis can realize real-time detection of the working status of automobile engines during driving.

2. OVERALL SYSTEM DESIGN

The overall design of automobile engine fault diagnosis instrument based on high-order spectrum is divided into upper computer design and lower computer design, as shown in Figure 1. The upper computer uses LabVIEW to design the serial port setting window, data storage window and high-order
spectrum analysis display window for data communication on the PC side. The lower computer mainly completes data collection and transmission. It mainly includes an eddy current sensor, a signal conditioning module, a button setting module, a power management module, an alarm indication module, and an interface module for asynchronous serial communication. The eddy current displacement sensor can convert the vibration signal of the engine into a current signal. The signal conditioning module can realize the conversion from current signal to voltage signal and the conversion from voltage signal to digital signal. In order to increase the anti-interference ability of the system, we also designed an isolation amplifier circuit for electrical isolation and a filter circuit for filtering in the signal conditioning module. The button setting module in the lower computer is used to start and stop the system and set some system parameters. The alarm indication module is used for system start and stop indication and buzzer warning when the system fails, and the power management module provides a stable and reliable power supply voltage for the entire lower computer.

Figure 1. System Overall Design Block Diagram

3. HARDWARE CIRCUIT DESIGN
The hardware circuit design is mainly the design of the lower computer circuit, which includes the design of the power supply circuit, signal conditioning circuit, button circuit, UART circuit and alarm indication circuit. The power supply circuit uses a linear voltage regulator chip to achieve two-level voltage stabilization output. Its output DC voltage level is ±15V and ±5V, which can meet the supply voltage requirements of STM32F103 single-chip microcomputer and other active devices. The signal conditioning circuit uses a dedicated precision current loop receiver chip RCV420 to achieve current/voltage conversion. The button circuit adopts low-level trigger mode to realize system start-stop control and parameter setting. The alarm indication circuit uses light-emitting diodes to indicate the start and stop of the system. When the system is abnormal, the alarm indicator will flash at a certain frequency to indicate the alarm. The asynchronous serial communication circuit adopts CH340G voltage conversion chip to realize USB to TTL, and complete the information exchange between the upper computer and the lower computer.

3.1 Signal Conditioning Circuit
The signal conditioning circuit uses RCV420 to design the I/V conversion circuit with adjustable gain. RCV420 is a precision current loop receiver chip, which can convert the input 4-20mA current signal into a 0-5V voltage signal output through a simple peripheral circuit. The circuit uses the 10V voltage output by the internal 10V reference voltage source, which can be divided by the internal voltage divider resistor to obtain a stable 6.25V voltage. Moreover, it has an internal OPA237 to form an emitter follower for isolation, which can provide a 6.25V stable voltage signal to the Ref In and RCV Com ports. Therefore, the entire peripheral circuit only needs to connect the output terminal of the eddy current sensor to the first pin of RCV, and connect the 14th pin to the input signal terminal of AD7810 to form a current and voltage conversion circuit.
3.2 Asynchronous Serial Communication Circuit

The asynchronous serial communication circuit realized by CH340G is shown in Figure 3. USB is widely used in the development of embedded devices because of its simple interface and convenient use. In order to better apply the system to different PCs, the system uses USB to communicate with the lower computer. But the level logic of the lower computer is different from that of the PC. Therefore, we need to perform level conversion, and use CH340G for level conversion without peripheral circuits, and the signal transmission in the communication process is safe and reliable. On the circuit connection, data+ and data- of USB are connected to UD+ and UD- of CH340G respectively. The TXD and RXD of CH340G are respectively connected to the RXD and TXD pins of the microcontroller, so that asynchronous serial communication between the microcontroller and the PC can be realized.
5. PC Programming

The program design of the upper computer of the system mainly involves the serial port setting, data storage and analysis. The system mainly initializes the serial port in the serial port settings, as shown in Figure 5. The host computer mainly realizes the opening of the serial port in the serial port setting window. In order to facilitate the operation of the system, the selection of the serial port and the setting of the baud rate, parity bit, data bit and stop bit are realized through the drop-down list node, and the data read by the serial port is sent to the subsequent program through the VISA configuration port at the same time. For data preservation, the system will use the MathScript node in LabVIEW to realize the interconnection between LabVIEW and MATLAB. The system needs to perform high-order spectrum analysis on the collected data in MATLAB to realize real-time data processing. The system can obtain different working states of the engine by comparing high-order spectrograms of different states to realize the purpose of engine fault diagnosis.
6. CONCLUSION
The automobile engine fault diagnosis instrument designed in this paper uses the single-chip STM32F103 as the lower computer. Not only can it collect and transmit signals, but its signal acquisition circuit is simple, the sampling frequency is high, and the system error is small. The host computer can use LabVIEW to process the collected signals. The analysis result will realize the visualization of the fault diagnosis result through the graphical display interface. Asynchronous serial communication is adopted between the upper computer and the lower computer, and the communication is safe and reliable.

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