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Operation Parameter Recorder for Construction Machinery Based on Embedded Technology

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Abstract. Conventional operation parameter monitoring device for construction machineries can only achieve sound (or light) alarm and control over over-limit status for operation parameters of construction machinery and it can not save any historical data, thus hinders accurate analysis, diagnosis and maintenance of the construction machinery. The operation parameter recorder for construction machinery developed based on industrial control computer and embedded technology can detect, record and manage the operation parameters. The real time fault alarm and historical data analysis can also be realized. The industrial computer, which is core module of this operation parameter recorder, controls the operation parameter acquisition module based on micro-controller ARMSTM32F103 to acquire and condition each operation parameter of the construction machinery. Application software running on the industrial computer processes the operation parameters and carries out alarm and control operations under abnormal conditions for fault protection. The abnormal data shall then be stored for later fault analysis. This operation parameter recorder can record many different types of operation data and has a large storage capacity, so it is applicable to many different types of construction machinery.

Introduction

Great progress has been made about operation parameter monitoring for construction machinery in recent years. For example, many construction machineries, such as the GJT 112 bulldozer, the GJW111 excavator, etc. have been equipped with electronic monitoring devices. These devices can carry out operation parameter monitoring and alarming operations for engine system, hydraulic system, pneumatic actuation system and electrical equipment system of construction machineries [1, 2]. But these devices can not record and save the large amount of monitoring data. So the operation and maintenance personnel can not carry out diagnosis to the system fault based on the operation condition data effectively in the case of maintenance or fault analysis. Currently, mostly imported construction machineries are equipped with electronic monitoring and control device with data storage function. So reliability, detectability and maintainability of the construction machineries are greatly improved. The operation parameter recorder for construction machinery developed in this paper based on ARM embedded- type chip and industrial computer can be used to monitor operation parameters of the construction machinery such as rotation speed, pressure, temperature, voltage and blockage condition, etc. and can display and record any abnormal data in real time. The maintenance personnel can carry out on-line check and troubleshooting to the construction machinery based on these recorded data. This may provide a sound basis for trouble diagnosis and condition-based maintenance of the construction machinery and improve the service efficiency and safety of the construction machinery.

Operation Principle and Structure of the System

Parameters to be recorded. This operation parameter recorder for construction machinery is composed of the core component (industrial computer and the solid state memory), the embedded type ARM chip and the modular management software. Through the sensors and alarming switches mounted on different parts of the construction machinery, this operation parameter recorder can monitor 10 channels of analog values and 2 channels of switching values and record the operation status of the construction machinery. The high backlit LCD can display real time values of the parameters under monitoring and logical status of the switching values. When abnormal conditions happen to the construction machinery, this operation parameter recorder can alarm and record the fault parameters based on the prescribed threshold fault values, and notice the operator to deal with the fault in time in order to prevent accidents and provide basis for fault check and analysis.
The whole system is composed of the recorder, the rotation speed sensor, 2 temperature sensors and 4 pressure sensors, as shown in table 1.

Table 1 Operation parameters to be recorded

Monitored item	Type of signal	Unit	threshold	Range
Battery voltage	Analog value	V	≤21, ≥29	0-35
Engine speed	Analog value	r/min	/	500-3000
Cooling water temperature	Analog value	ºC	≥98	0-150
Oil temperature of the torque converter	Analog value	ºC	≥118	0-150
Oil pressure	Analog value	MPa	≤0.083	0-0.8
Pressure of the front brake	Analog value	MPa	≤0.40	0-2.0
Pressure of the rear brake	Analog value	MPa	≤0.40	0-2.0
Oil temperature of the speed changer	Analog value	MPa	≤1.1, ≥2.1	0-4.0
Vehicle speed	Analog value	km/h		0-80
Liquid level	Analog value	%	≤10	
Oil filter	Switching value		Low level	

Operation Principle and Structure of the System. Operation parameters on each part (such as diesel engine, transmission box, torque converter, oil circuit, air circuit, etc.) of the construction machinery including temperature, pressure, voltage, liquid level, rotation speed, vehicle speed, etc. can be converted to voltage or current signals through the sensors mounted on each part of the construction machinery. These voltage or current signals are then converted to voltage values through the front end amplifier and then be transmitted to the input port of the operation parameter recorder. The data acquisition unit of the recorder then acquires these parameters and sends to the industrial computer via USB bus. In the meantime, the recorder processes these data in real time and outputs corresponding diagrams and digital signals to the LCD, gives out alarms if any and save the abnormal data in the solid state memory. Structure of the system is illustrated in figure 1.

The ECM－945GSE industrial computer is the core component of the recorder. It deals with management of the database for construction machinery parameter storage, data input and output, , monitoring, alarming, management and storage of the construction operation parameter, setting of the alarming threshold, etc. The signal acquisition system is developed based on embedded type ARM chip STM32F103 processor. It has a wide operation temperature range, high electromagnetic interference resistance and high reliability. Parameters of the construction machinery can be acquired and processed reliably. The custom Windows CE embedded operating system is used in the industrial computer. The detection software and the database management software are operated in the Windows CE environment [4].

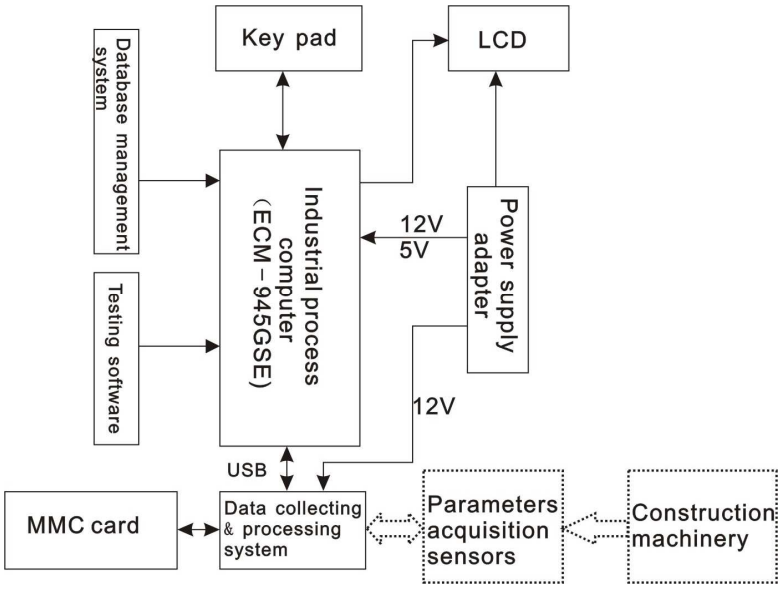

Fig.1 Structure of the parameter recorder

Hardware Design

Signal acquisition circuit. The signal acquisition and processing system is built with the ARM-based embedded system [5]. It provides the excitation power supply needed by the detection sensors and has 10 channels of 12 bit A/D conversion. It converts the conditioned pressure, temperature and rotation speed signals into digital values and transmits them to the main board of the industrial computer through USB bus for CPU treatment. Pulse signals of the engine speed and the vehicle speed can be acquired through the electromagnetic sensor and be transmitted to the input port of the two timers/counters of the MCU. Then they are converted back into the engine speed and the vehicle speed signals for later treatment such as, processing, display and data storage. The schematic diagram of the data acquisition system is shown in figure 2.

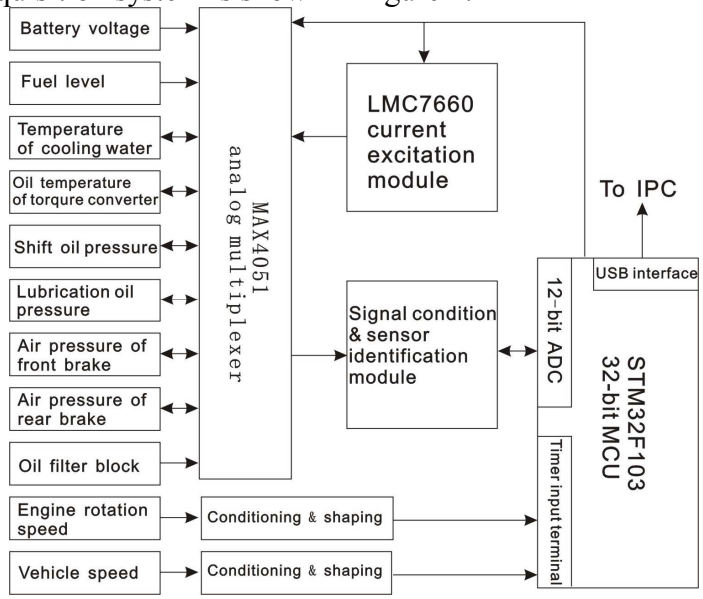

Fig.2 Flowchart of the signal acquisition and processing system

The Arm-based Embedded Microprocessor. The embedded microprocessor chip STM32F013 is the core component. This chip is a 32-bit ARM-based microcontroller with flash memory, USB, CAN bus. It has seven 16-bit timers, 2 ADC and 9 communication interfaces. This single-chip microcomputer uses the high quality ARM Cortex-M3 as the 32-bit RISC core with a frequency of 72 MHz and has built-in high speed memory (flash memory up to 128K and SRAM up to 20K). it also has an enhanced I/O port and peripherals connected to the two APB buses. This single-chip

microcomputer builds in an independent watch dog circuit which can reset the single-chip microcomputer in the case of system failure [6]. In the meantime, the watch dog is also provided in the software to ensure the reliability and stability of the signal acquisition system.

Large Capacity Buffer Data Storage. A 2GB external SD-MMC memory is expanded on the signal acquisition system. When data acquisition card is working, whether the acquired data shall be saved or not may be controlled by the software. So, the buffer data can be saved for future data restoration in the case of data system failure.

MMC is a type of small high-speed flash memory with large storage capacity and it has been widely used in intelligent equipment, eg., mobile phones. The MMC card features small dimension, light weight, impact resistance and 300,000 times of read and write ability, so it is applicable to portable detection instruments. The MMC card has two operation modes: MMC and SPI [7]. The SPI mode is selected to be used in this parameter recorder. This operation mode has many advantages: it can be connected and exchange data conveniently with DSP and MCU. The interface design also becomes very easy when the SPI mode is used. The power supply has 3 wires and the data operation also needs a 3-wire serial bus. In addition, several MMC cards can be connected for larger storage capacity. Communication frequency of the MMC card is up to 18mbit/s, so it has a very high data access rate. So data of the construction machinery can be saved and protected in time.

Signal Conditioning and A/D Conversion. Take the temperature signal conditioning circuit as example to illustrate the principle for signal conditioning. Temperature parameters during the working process of the construction machinery such as temperature of the cooling water, oil temperature of the torque converter, etc. can be obtained through the PT 100 sensor. The temperature input circuit uses a three-wire system. The 100Ω resistor on the data acquisition card and the PT 100 constitute the two adjacent arms of the bridge. The resistors R4 and R5 on the conditioning card constitute the other two arms of the bridge. The three-wire system can effectively compensate the error caused by the lead resistance. Output signal of the PT100 is first amplified through the OP07 amplifier and then amplified and buffered through the RC4558 amplifier, then output to the A/D converter for A/D conversion. The detail circuit diagram is shown in figure 3.

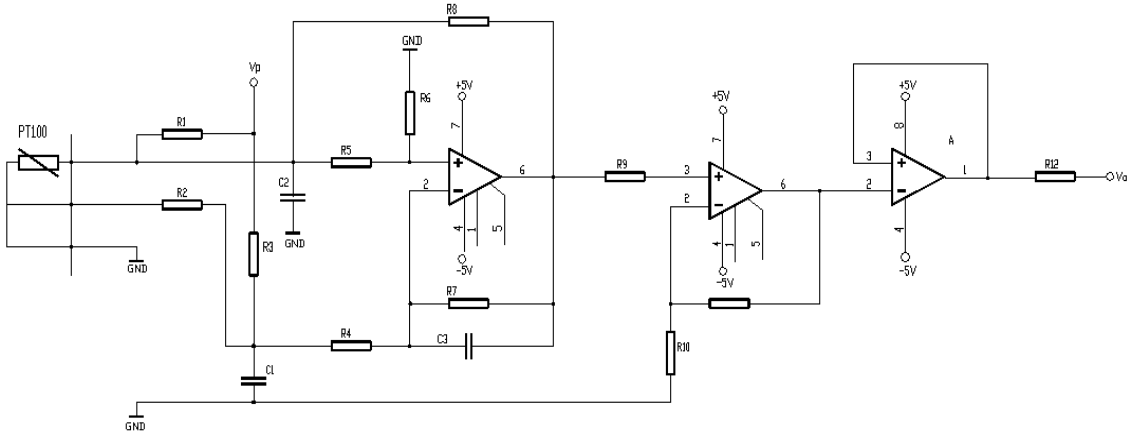

Fig. 3 The temperature conditioning circuit

The embedded microcomputer builds in two 12-bit A/D converter (ADC). Each ADC has up to 16 external channels. can realize single or scan conversion. Under the scan conversion mode, the conversion is carried out automatically on the group of selected analog inputs.

The ADC uses DMA operation. The analog watch dog function allows accurate monitoring of 1 channel, or more or all selected channels. When the signal under monitoring exceeds the preset threshold, the interruption is generated and the data acquisition system is switched to the interruption process. With this technical scheme, stability and interference resistance of the system is improved. Precise monitoring and accurate conversion of the input sensor signal can be guaranteed. In this way, the precision of the data acquisition is improved. Figure 4 shows flowchart of the A/D conversion.

System Software Design

Software of the operation parameter recorder is based on the Windows CE embedded operating system and is developed on the platform of Microsoft Visual Studio2005 [8]. The program language Visual C++.net can manipulate the hardware register. It features high speed, high design flexibility. The whole system uses a multi-layer modular architecture which combines the data acquisition module, the recording function module, the board or card drive module and the record database module together. The software has clear hierarchy, good portability and good openness. The software can be upgraded easily. During the working process of the construction machinery, the recorder can remind the user of the recorder's operation status in real time and tell the user how to perform the detection operation. The user can select different diction module through pressing corresponding keys on the film keyboard and perform the detection operation according to the instructions displayed in the "operation instructions" box. The self-check screen of the recorder is shown in figure 5.

Conclusion

The operation parameter recorder for construction machineries developed based on embedding technology, industrial computer and signal processing technology can acquire, process and save operation parameters of the construction machinery during working and perform alarm function. Compared with conventional electronic monitoring device, this parameter recorder has many advantages such as large storage capacity, high work stability, high reliability and friendly operation interface. The recorder can keep operation parameters of the construction machinery comprehensively and accurately. It can help the maintenance personnel to carry out fault diagnosis and trend analysis and improve the quality of construction machinery maintenance. This parameter recorder is applicable to many different types of construction machinery. It has a competitive advantage and wide market expectation.

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