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Air Compressor Energy Efficiency Detection System Design

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Air Compressor Energy Efficiency Detection System Design

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Abstract. This paper develops an air compressor energy efficiency detection system, including the detection terminal hardware system and the detection terminal software system. The detection terminal hardware system includes a communication interface module and a data acquisition and processing module. The detection terminal software system includes an A/D acquisition program and a communication protocol program. The system can provide technical support for mastering the operating efficiency of the air compressor, and provides an important basis for formulating energy saving measures for air compressors and reducing the power consumption of air compressors.

1. Introduction

Compressed air systems are an important part of modern industrial enterprises, especially in traditional large industrial enterprises such as textile, chemical, automotive enterprises. The air compressor is the core equipment of the compressed air system, which is responsible for converting mechanical energy into compressed air energy and providing a source of air for all pneumatic components of the production line. According to statistics, the electricity consumption of large-scale industrial equipment in various industries accounts for as much as 60% of China's total electricity consumption, of which air compressors account for about 15% [1]. It can be seen that whether the air compressor is operating efficiently is of great significance to the smooth advancement of energy saving and emission reduction work in society and enterprises. However, due to the control method of loading and unloading, the traditional air compressor has a large starting current when the electric motor starts under frequent loading and unloading conditions, which will cause a great impact on the power grid [2]. In addition, this control method cannot adjust the number of air compressors in time according to the actual compressed air demand in the field, which will result in a large amount of electric energy wasted. Therefore, it is very important to carry out regular energy efficiency testing and performance qualification test after the air compressor is put into use. After the performance test, corresponding measures can be taken according to the actual test results to ensure the efficient and economic operation of the air compressor.

However, there is still a lack of research and development on air compressor energy efficiency detection systems in China. Most researchers only focus on laboratory testing platforms, and there are few portable and online testing equipment. In addition, although foreign countries have carried out corresponding research on this aspect of the system, but because of the different standards and methods of testing, it is unable to fully meet the needs of domestic air compressor energy efficiency testing. Based on this, this paper carries out the design research of air compressor energy efficiency detection system and provides technical support for energy efficiency testing of air compressor.

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2. System architecture

The components of the system are: 1) Sensor module (current sensor, pipeline air pressure sensor, pipeline temperature sensor, pipeline flow sensor, dew point meter); 2) Sensor signal processing module (electric parameter acquisition module, high precision A/D conversion module); 3) Display module (7 inch touch resistance screen); 4) Storage module (SD card and U disk); 5) Communication module (GPRS wireless module, RS232 serial port module, TCP/IP module); 6) Main controller module (Microprocessor); 7) Power conversion module (24V to 12V, 12V to 5V, 12V to 3.3V); 8) Backup power module (24V lithium battery).

The design scheme of the system is: the sensor detects each detection point, and obtains real-time working parameters of the air compressor, such as electrical parameters, flow rate, pressure and temperature, through corresponding functional circuits (filtering, amplification, conversion). The system stores and calculates these parameters, and displays the data in real time. The inspector can observe the changes of each parameter from the display screen, and upload the measured data to the upper PC for data reprocessing through the upload function. The system mainly includes two aspects: the detection terminal hardware system design and the detection terminal software system design, as follows:

(1) Detection terminal hardware system

The overall design flow of the detection terminal hardware is as follows: the microprocessor is the core, supplemented by the powerful peripheral analog digital circuit function module, which realizes the acquisition of multi-channel data through the operation of averaging, temperature compensation, etc. The value of the measured parameter is stored and displayed in real time, and the data is uploaded to the upper computer at the same time to realize the automation of the detection process.

(2) Detection terminal software system

The software system will support the normal operation of the hardware system. The software system mainly includes the following aspects: (1) Detection parameter data acquisition program; (2) System operation parameters, acquisition data storage and reading program; (3) Serial communication program; 4) Wired and wireless internet communication program; (5) Test data display program in real time on display screen; (6) Sensor operation parameter setting function program; (7) System online update program.

3. Terminal hardware system design

3.1. Communication interface circuit design

The communication interface circuit mainly comprises an electrical parameter acquisition module communication circuit, a local serial port device and a display communication circuit and a wired network communication circuit.

(1) Communication circuit design of electrical parameter acquisition module

The electrical parameter acquisition module communicates with the MAX3485 interface chip, which is an RS-485 chip from Maxim Corporation. It is a 3.3V low-power transceiver for RS-485 and RS-422 communication. Each device has a driver and a receiver with a slew-rate driver that reduces reflections caused by improper termination matching cables for error-free data transfer up to 250kbps. The specific circuit is as follows:

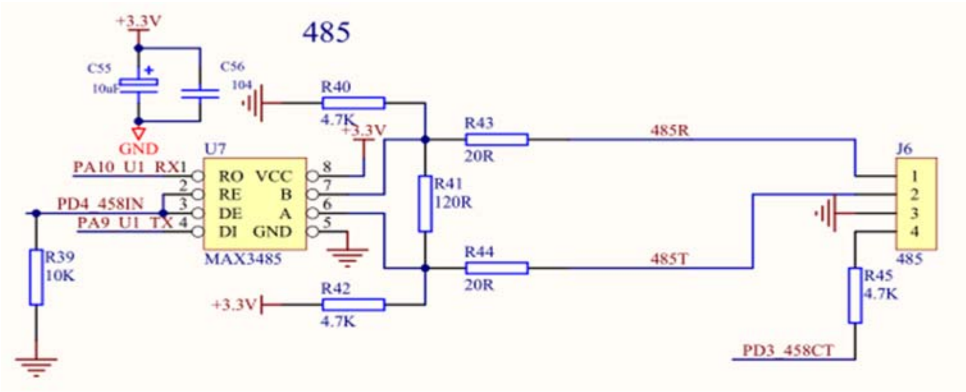

Figure 1. Communication circuit schematic of electrical parameter acquisition module

(2) Local serial device and display communication circuit design

The local serial device and display communication circuit use MAX323 chip to collect data. The chip uses a proprietary low dropout transmitter output stage that utilizes a dual charge pump to achieve true RS-232 performance when powered from a 3.0V to 5.5V supply. The MAX323 ensures a data rate of 120kbps while maintaining the RS-232 output level. The specific circuit is as follows:

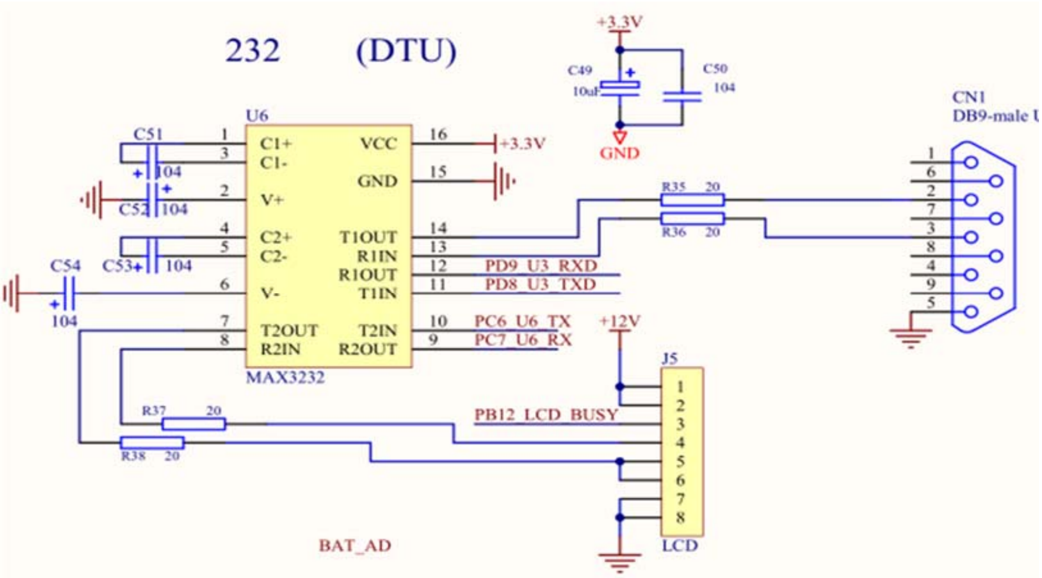

Figure 2. Local serial device and display communication circuit schematic

(3) Wired network communication circuit design

The wired network communication adopts the super network port USR-K3 of Jinan Personal Network Technology Co., Ltd., which is a small-sized serial-to-Ethernet module. It can realize transparent data transmission between the RJ45 network port and the UART interface. The device is equipped with Cortex-M4 processor, which has low power consumption, high speed and high stability. The device is equivalent in size to the ordinary RJ45 socket, and the length is less than twice that of the ordinary network port. The specific circuit design is as follows:

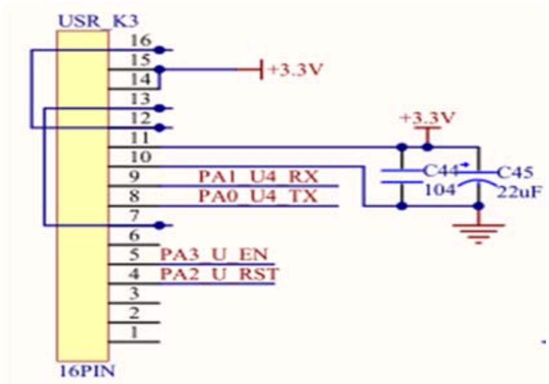

Figure 3. Wired network communication circuit schematic

3.2. Data acquisition and processing module

The data collected by each sensor is transmitted to the MCU main control board module, which is responsible for the control of all functional modules of the system and the collection and processing of data. This system uses a STM32F4 high-performance microcontroller developed by ST (Sino Semiconductor Group). It uses a 90-nm NVM process and a adaptive real-time memory accelerator, which has high performance and ensures smooth calculation and processing of acquired data. The specific circuit is as follows:

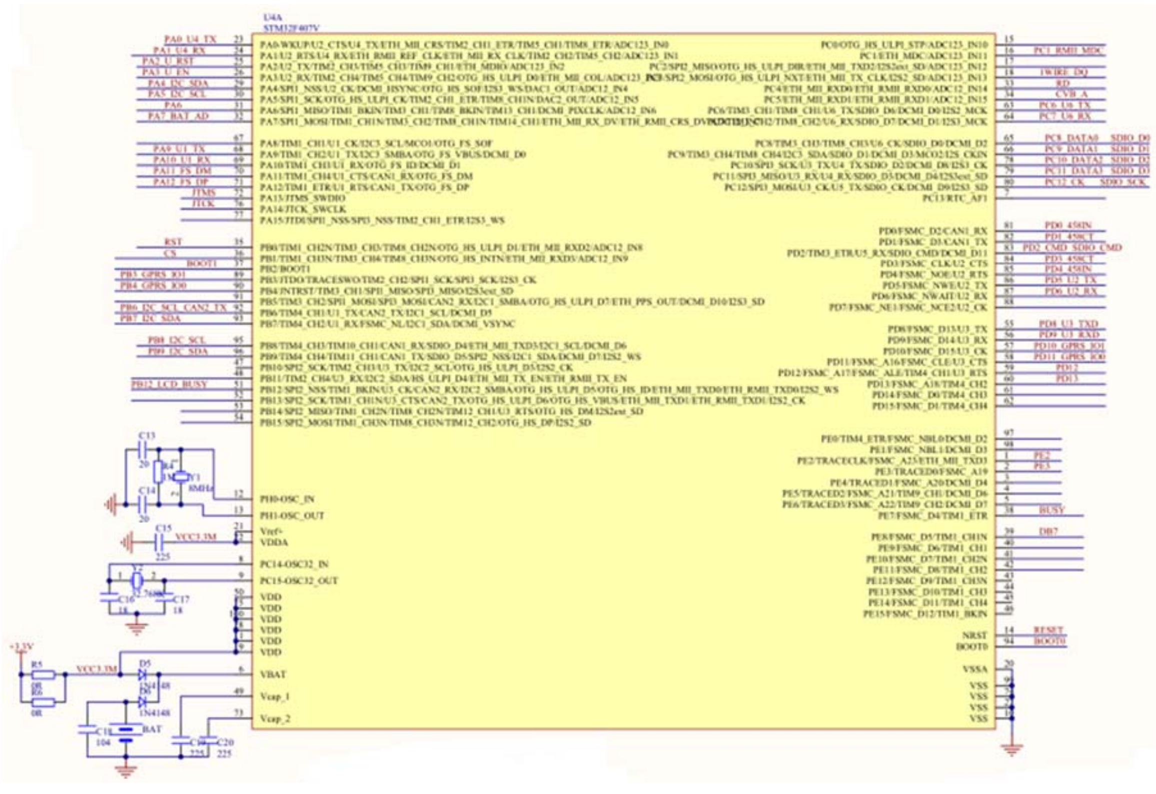

Figure 4. Data acquisition and processing circuit schematic

4. Terminal software system design

The program development environment for this device is the Keil µVision5 IDE. This development environment integrates compiler, assembler, real-time operating system, project manager, debugger, and supports ARM7, ARM9 and the latest Cortex-M4, Cortex-M7 core processor. The system automatically configures the boot code, integrates the Flash programming module, and features powerful device simulation and performance analysis. Its flexible window management system allows developers to use multiple monitors and provides a visual view of the entire position of the window anywhere.

(1) A/D acquisition program

The A/D acquisition program is mainly composed of three parts: 1. The initialization of the acquisition program; 2. The timing acquisition program of each channel of the A/D module; 3. The A/D data processing and storage. The specific program as follows:

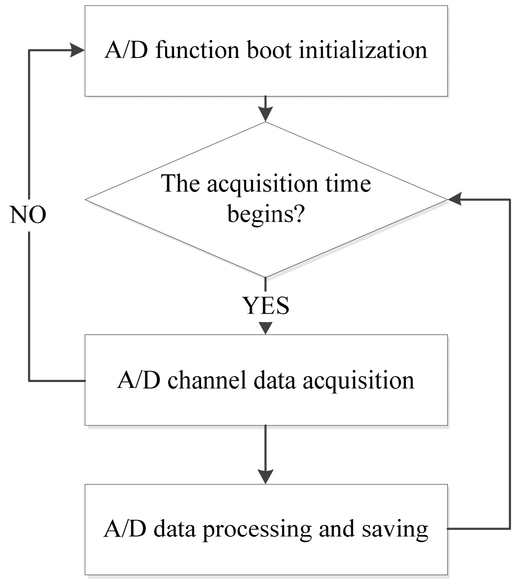

Figure 5. Data acquisition and processing schematic

(2) Communication protocol program

The collected data is transmitted in accordance with a fixed communication protocol, and the communication line can be RS232 or network (wired, wireless).

The protocol format and data sequence are as follows:

Date/Time; Intake Temperature/℃; Exhaust Temperature/℃; Inlet Dew Point/℃; Exhaust Dew Point/℃; Phase A Voltage/V; Phase B Voltage/V; Phase C Voltage/V; Phase A Current/A; B phase current/A; C phase current/A; Phase A power factor/V; Phase B power factor; Phase C power factor; Phase A active power/W; Phase B active power / W; Phase C active power/W; average power factor; frequency/Hz; total active power/W; instantaneous unit consumption/Wh/m^3; cumulative time/s; cumulative input energy/kW·h; cumulative displacement/m^3; cumulative intake/m^3; Inlet and out air temperature difference/ ℃ ; average unit consumption /Wh/m^3; suction pressure/kPa; exhaust pressure/kPa; intake flow rate/m^3/h; exhaust flow rate/m^3/h; positive active power accumulation/kW·h; positive reactive power accumulation/kW·h; reverse active power accumulation/kW·h; reverse reactive power accumulation/kW·h.

The device provides three data transmission interfaces, namely RS232, local network, and GPRS wireless network. The circuit diagrams are as follows:

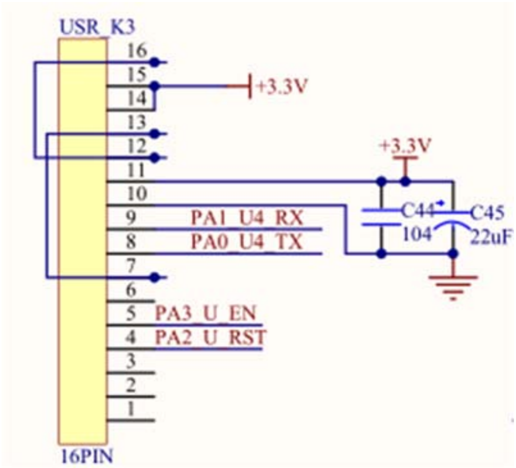

Figure 6. RS232 circuit schematic

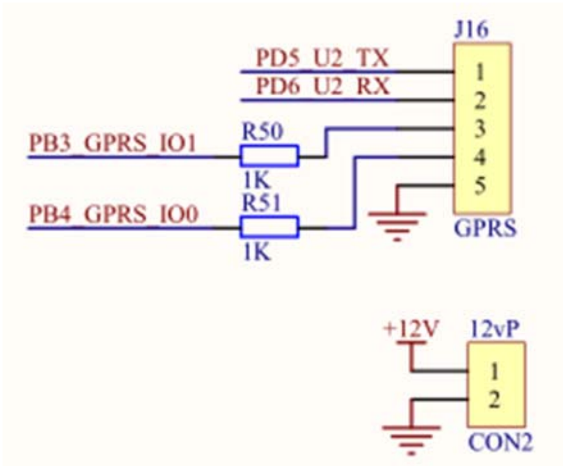

Figure 7. Local network circuit schematic

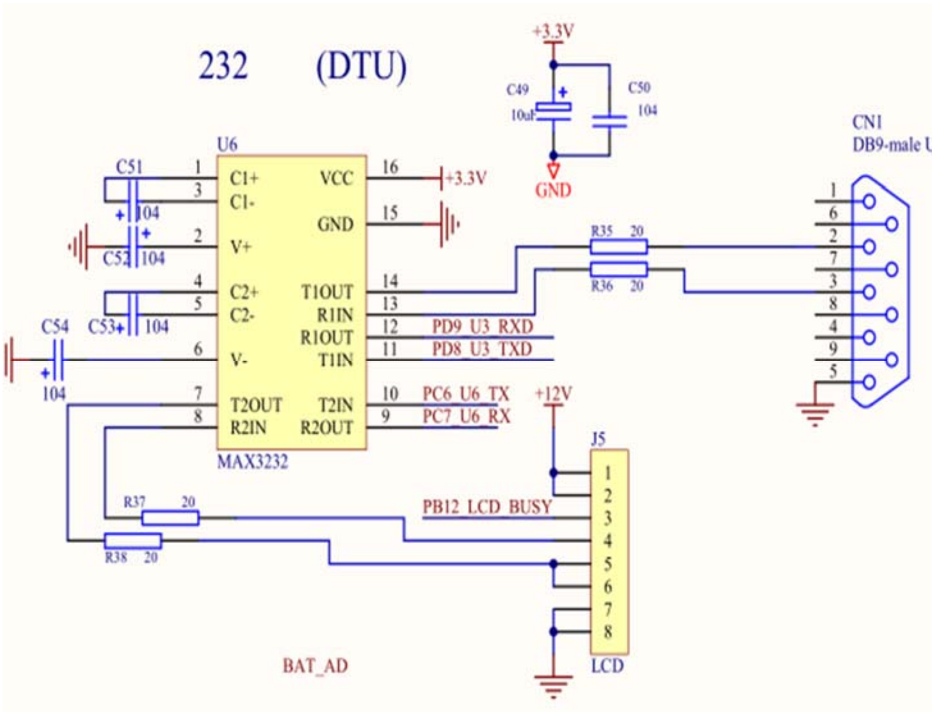

Figure 8. GPRS wireless network circuit schematic

5. Conclusion

This paper develops an air compressor energy efficiency detection system, which is easy to operate, has the advantages of small size, low cost and portability. The system has the characteristics of high energy efficiency detection accuracy, complete detection parameters, good anti-interference, large storage space, real-time output efficiency and energy consumption. The popularization and application of the detection system is of great significance to improve the operating efficiency of the air compressor, which can effectively reduce the power consumption of the compressed air system.

Acknowledgments

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