Design of High-precision Underground Storage Electronic Pressure Gauge

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Abstract: In order to measure formation pressure data more accurately, the paper developed a high-precision underground storage electronic pressure gauge. The pressure gauge consists of two parts: downhole instrument and ground processing. Downhole instrument uses87C652 microcontroller as the core to complete the collection and storage of well pressure and temperature. The ground processing part realized downhole data playback and processing. The paper detailing the structure and indicators of the instrument, as well as the system hardware design and software design. The instrument can be achieved within the pressure range of 0Mpa ~ 70Mpa (temperature -40℃~ 150℃) measurement, the pressure accuracy up to 0.05%, which meets the requirements of the underground test.

Keywords: Formation pressure; High-precision; Electronic pressure gauge; Microcontroller; Pressure measurement

1. Introduction

Formation pressure data is an extremely important information of reservoir characteristics research and reservoir performance control in oilfield development. To determine the wells formation pressure, there's a need for long-time continuous monitoring to the downhole pressure and temperature, in order to obtain accurate pressure data. Downhole measurements is an essential work to the process of oilfield development, and downhole pressure is an important parameter to measure[1]. In the exploration wells process, the measurement of oil reservoir pressure can get the original data. In the drilling process, the downhole pressure changes can be obtained by the downhole pressure measurements, balance and underbalanced of downhole can be predicted by analysis of pressure data， in order to develop and adjust development programs. According to the above requirements, this paper designs a high-precision storage electronic pressure gauge based on 87C652 microcontroller.

2. The Overall System Design

2.1. Instrument structure and main technical indicators

The electronic pressure gauge is mainly composed of ① plug, ②pressure guide hole,③ sensor, ④shell, ⑤circuit board, ⑥communications connector, ⑦battery sleeve, ⑧ rope caps. The structure is relatively simple, and it is easy construction, easy disassembly. Its structure is as shown in Fig.1.

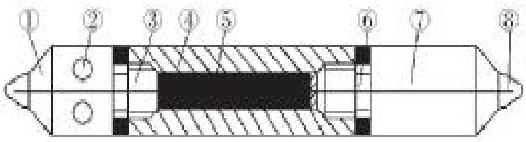

Figure 1. Structure of electronic pressure gauge

Specifications:
Temperature range: - 40℃ ~ 40℃
Pressure range: 0Mpa ~ 70MPa
Pressure measurement accuracy: 0.05%
Temperature measurement accuracy: 0.1 ℃

2.2. System design objectives

The system design objective is to reduce system power consumption as much as possible, to simplify the circuitry and reduce the volume of the instrument[2], this paper mainly adopt the following method to be realized:
1) selection of 87C652 microcontroller produced by Philips[3], it is the most external resources saving and low power consumption small microcontroller;
2) peripheral devices using CMOS low-power chips;
3) combine the characteristics of the selected device, reduce power consumption from the software design;
4) The I2C bus technology, simplify the circuit, reducing board size, thereby reducing the size of the entire instrument, and improve the reliability of the instrument at the same time.

2.3. The working principle of pressure system

Downholepressure gauge system is divided into downhole instrument and ground processing parts. Downhole instrument iscomposed of the pressure sensor, the opera-

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tional amplifier circuit, microcontroller, external data memory, a serial communication interface circuit battery parts, downhole acquisition part responsible for signal acquisition, signal processing, data storage. Among them, the microcontroller is the core component of the entire acquisition system, which controls the system signal acquisition, processing, data storage, communication and other signals set the host clock parameters of the ground[4]. Here we have chosen the 87C652 microcontroller produced by Philips. It has an external resource saving and low-power speciality, strong anti-interference characteristics. ground handling section cooperate with the use of downhole equipment. Preparing the ground the PC software to realize the downhole data playback and processing works, as follows: set the working range sampling interval and time by the ground PC software, depending on the geological conditions. And then, put the downhole instruments into the well ,in real time to automatically collect and store the well pressure and temperature. After the testing completed, remove the instrument to the ground, through the serial port to store the data read into the PC for data playback, processing, analysis and printing[5]. Overall system design shown in Fig.2.

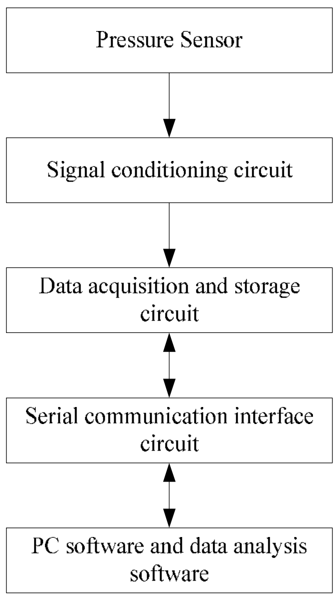

Figure 2. The system block diagram

3. Hardware Design

3.1. High-precision conversion module

To improve the measurement precision of, use 87C652 microcontroller internal A/D converter can do the oversampling A/D conversion to the analog signal twice. Firstly, use 87C652 internal A/D converter for signal coarse, second use 87C652 to do the exact calculation, calculating the error value, and finally the two measurements are added according to the right to get high accuracy the measurement results. Advantage of this program is to achieve a high-accuracy D/A converter is much easier than achieve a similar accuracy of the A/D converter, but high accuracy is dependent on higher accuracy D/A converter. Specific conversion principle is: first sample: microcontroller control switch logic of the operational amplifier 1 times, microcontroller do A/D conversion to Vx directly, thus completing the coarse; the second sampling: microcontroller control switching logic, so that operational amplifier 100 times, A/D converter circuit turned measure magnified 100 times the first rough error value (Vx-VDA) generated during testing, then the microcontroller handles value of the two measurements[6]. Fig.3 shows the schematic diagram of two sampling A/D conversion.

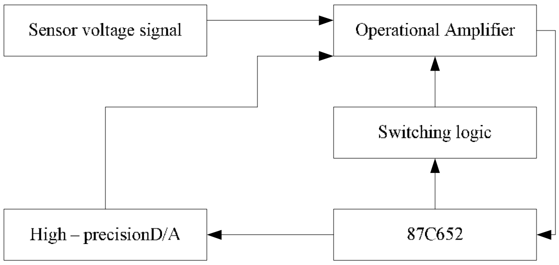

Figure 3. A/D conversion Schematic

4. Data Storage Module

Storage module uses 6 EZP to store sample data. The first E2PROM's I2C bus address to A2H (WRITE) and A3H (READ), second E2PROM's I2C bus address to A4H (WRITE) and A5H (READ), and so on, the sixth of E2PROM's I2C bus address to ACH (WRITE) and ADH (READ). Each E2PROM which stores up to 1365 sets of data. Therefore, when the sampling frequency is greater than 1365, WRITE + 2 is transferred to the next E2PROM storage. I2C bus is a two-wire serial bus, it provides a small network systems, electrical bus shared by two public bus, a serial data line (SDA), a serial clock line (SCL).

Serial communication module

Serial communication module generally work process is as follows: first initialize the parameters of the serial port, and then determine whether Rl serial interrupt flag is set, and if so, clean RI bit and transferred to serial communications, a start bit is received and determine whether the 7EH, if digits plus 1 receives the next one, until the number of bits is 10, that finished receiving a frame, into the serial processing subroutine that, according to the command word of the frame, with the frame agreement for the corresponding treatment. Otherwise, wait for the next interrupt re-received start bit.

5. Software Design

System software is divided into two parts: downhole instrument software and ground PC software.

5.1. Downhole instrument Software Design

Downhole instrument software that is SCM software, gauge data acquisition, data access and communication with the host computer functions. After power-up, first AD microcontroller initialization, including initialization port initialization, ADinitialization, SPI initialization, UART initialization and timer initialization. After initialization is complete, Initialization is completed, the system judging level of high and low pressure gauge is working in or underground inoue by detecting P0.0 pin, then the corresponding inoue data processing; Downhole data acquisition and access flow chart as shown Fig.4.

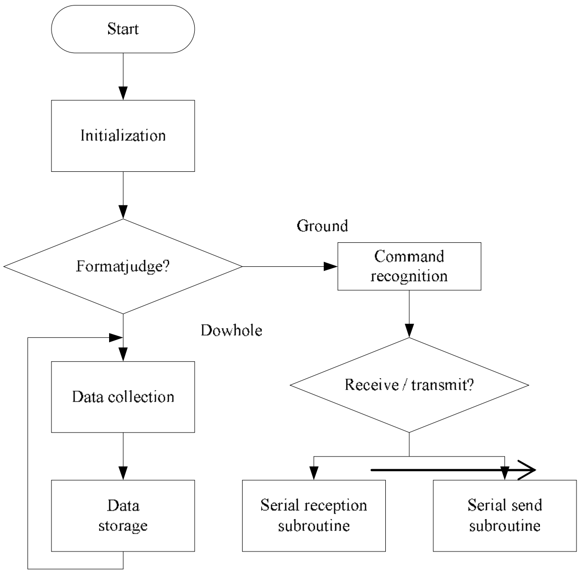

Figure 4. Software flow chart of downhole instrument

5.2. Ground PC software design

Ground PC software design adopted mold design, Delphi software development functional block diagram is shown in Fig.5.

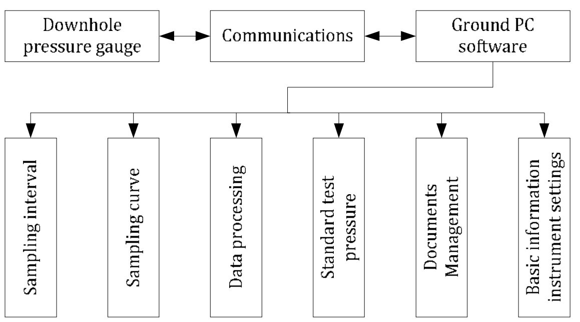

Figure 5. Software block diagram of ground PC system

PC software is the pressure gauge system platform for data management, including communications ports, basic information about the instrument settings, data transmission, data fusion, data playback and save the curve[8]. After processing data archiving, report generation, printing, pressure calibration and so on.

In the data processing section, one of the main work is non-linear error correction. This is because the oil pressure Well Testing (temperature -40℃ ~ 150℃), the impact of errors due to temperature changes caused by its measurement accuracy is very large. Non-linear calibration and temperature compensation method for improving the precision of the system. The pressure, temperature sensor calibration data collection. With n-order polynomial curve segment is divided temperature and pressure section curve fitting:

$$T = c_0 + c_1 V_t + c_2 V_t^2 + \ldots + c_n V_t^n \quad (1)$$

$$p = a_0 + a_1 V_p + a_2 V_p^2 + \ldots + a_n V_p^n \quad (2)$$

Wherein, c0, c1, c2 …cn is directly calculate the temperature fit coefficient

a0 ,a1, a2 …anis test ambient temperature Tpressure calibration coefficients. Vt and Vp are temperature sensors and pressure sensors collected calibration data. PT is the actual pressure and temperature values by curve fitting to find a smooth curve segment temperature or pressure. The original value of the parameter in terms of the actual pressure and temperature data and corrected. The design pressure to fit a 3-order temperature fit also uses 3-order.

6. Summary

Well test plays an important role in the evaluation of exploration, reservoir description and preparation of oil and gas well development programs of work, it is a technical means of significant economic benefits to accelerate the exploration and development of oil and gas wells and oil and gas fields of dynamic monitoring. Determine the well formation pressure is one of the main purpose of well testing. The measured pressure data is the process of developing an oil field vital information to study the dynamic characteristics of the reservoir, it is an important means to check the oil extraction process on the ground. Therefore, formation pressure measurements are essential to the process of field development work. Storage electronic pressure gauge favored by the majority of oil users because of its high success rate test, the data is accurate and reliable, easy to use features. Meanwhile, the storage electronic pressure gauge has become a hot topic in the field. This paper designed the storage-type deep electronic pressure gauge. Generally speaking, well testing instrument as an essential tool for oilfield system, now it is in the early stages of the intelligent and digital development, and there's a need to constantly introduce new hardware design and software programming algorithm, which involves well testing theoretical knowledge , electronic technology, testing technology and computer science and other fields of knowledge. This design is still in the early design stage, it remains to find out the problems (including design and applied aspects), to further improve and perfect the production practices in specific applications. Of course, this also needs discussion and study more in-depthin relevant theory and technology.

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