Design of arm layered oil recovery data monitoring system

Jia Huiqin¹,a, Cheng Cheng²,b, Dang Ruirong³,c, Li Gan⁴,d

¹Shaanxi Key Laboratory of Drilling Rig Control, Xi’an Shiyou University, Xi’an, China
²Shaanxi Key Laboratory of Drilling Rig Control, Xi’an Shiyou University, Xi’an, China
³Shaanxi Key Laboratory of Drilling Rig Control, Xi’an Shiyou University, Xi’an, China
⁴Shaanxi Key Laboratory of Drilling Rig Control, Xi’an Shiyou University, Xi’an, China

a–mail: jiahq@xsyu.edu.cn
b–mail: cc18329314226@163.com
c–mail: 1061085600@qq.com
d–mail: L360138912@163.com

Abstract—Aiming at the different characteristics of different reservoirs between oil wells, this paper studied and designed a layered underground oil recovery data acquisition system based on ARM Cortex-A7 architecture. This system mainly consists of three parts, namely sensor, measurement circuit and data acquisition and processing. I.mx6ull is selected as the main control chip, and a data acquisition platform is built with the peripheral device AD8229 instrument amplifier. The SPI protocol and state machine are used to communicate with the downhole multi-reservoir data, and ESP8266 module is used to transmit the down hole multi-parameter data to the Alibaba Cloud server. Through the software and hardware experiment system test, it shows that the designed system has the characteristics of good real-time performance, high precision and low cost.

1. Introduction

Smart Wells have different physical characteristics from reservoir to reservoir, based on the downhole temperature, pressure, moisture content and real-time traffic data monitoring¹, analysis and control downhole multi-branch wells around the period of the flow of production, the data real-time transmission system face difficulties such as downhole high temperature and high pressure conditions², the ARM architecture compared with other types of ARM, has advantages of fast speed, high across platforms and integration, has been widely used in industrial field. However, due to its low accuracy, it cannot meet the requirements of high performance. However, the design of arm-based layered oil recovery data monitoring system can greatly improve the measurement accuracy, and the real-time acquisition of data signals is a key part of the monitoring system. Most of the current collection system controller using single-chip microcomputer or DSP, the process of completing the task is to command to perform a detailed³, if its branch Wells as the main controller to read data, because of program execution time delay, it is difficult to get branch well data of the same time, and the traditional
monitoring technology can not satisfy the direct-reading detect each layer monitoring is working correctly\cite{4}, affect the reliability of data transmission.

Aiming at the above problems, this paper designs a layered oil recovery data acquisition system based on ARM Cortex-A7, which is composed of hardware design and data acquisition software. With THE ARM with the chip model I.MX6ULL as the controller, the real-time data acquisition of temperature, pressure, moisture content and flow rate of downhole multi-branch Wells can be realized through the development of various modules such as SPI communication protocol module, storage module and serial communication module. The system has the advantages of good reliability, high safety performance and fast response speed.

2. Architecture of layered oil recovery data monitoring system

Based on the ARM layered oil recovery data monitoring system, real-time data acquisition of multi-branch Wells is carried out simultaneously by the controller. Downhole monitoring of multiple parameters respectively and flow parameters such as pressure, temperature, moisture content, the system selects the ARM architecture series I.MX6ULL chip as the controller, and peripheral AD8229 instrumentation amplifier design of peripheral circuit, through the SPI protocol and communicate from all data acquisition circuit of the machine, with double port RAM data module to assign different address MAX232 serial port communication, the realization and the upper machine of downhole multi-branch Wells data collection, and is verified by experiment platform, to ensure the real time acquisition system reliability. Figure 1 is the block diagram of the overall scheme of the system.

The data acquisition node mainly collects temperature, pressure, flow rate, moisture content and other information of each branch well through sensors, and sends the data to the sink node through a single core cable after processing\cite{5}. The data sink node and the acquisition node network, receive the sensor node data in the reservoir, and wirelessly send the data to the supreme computer or Ali Cloud server through ESP8266 module. The upper computer displays the data between different reservoirs of each branch well in real time, and gives early warning according to the set data threshold, which improves the reliability and stability of data acquisition.

3. System hardware design

The system hardware design of the microprocessor chip I.MX6ULL, the chip operating frequency up to 180MHz, with 2M Flash memory, at the same time has a rich I2C, SPI, ADC, UART and other communication interfaces, can meet the functional design requirements of the instrument\cite{6}. The downhole hardware system structure includes power supply, data acquisition node, data sink node and gateway node, etc. To meet the impact of various harsh downhole environments, high-temperature and high-pressure resistant equipment is selected. The hardware system block diagram is shown in Figure 2.
3.1. Amplifier circuit design
AD8229 instrument amplifier, as shown in Figure 3, is used for measuring small signals at high common mode voltage and high temperature. Dielectric isolation process is adopted to avoid leakage current at high temperature. The AD8229 has a high common mode rejection ratio (CMRR), which prevents interference signals from damaging data acquisition. CMRR increases with gain and provides high suppression performance when most needed.

3.2. Temperature measurement
In order to meet the purpose of temperature monitoring in branch Wells, the temperature sensor must be selected to meet the requirements of wide range of operating temperature and high precision. As shown in Figure 4, the system adopts three-wire constant-current source drive method to drive the platinum resistance\[7\]. Hardware circuit is used to eliminate the fixed resistance of the platinum resistance sensor and directly measure the resistance change of the sensor.

3.3. Pressure measurement
Through the branches of well pressure monitoring can be real-time monitoring of underground crude oil liquid level height, concluded that the oil motor efficiency and lift head, ensure that always located in the crude oil in the oil motor, can prevent oil motor no-load work and burned, so you can through the ground change production speed of the motor frequency conversion control system, causing the oil motor work in the optimal state.
The schematic diagram of the pressure measurement circuit is shown in Figure 5. In the dotted box is the pressure bridge, which converts external pressure into voltage signal. MAX1452 BDR end of the drive end of the bridge is provided to the bridge with VSS port voltage, INP and INM for pressure test of bridge side, and will monitor the feedback voltage to the MAX1452, make the MAX1452 the detected voltage compensation and correction [8], will eventually after compensation voltage value through the MAX1452 AMPOUT end to XTR116 chip IIN port, after XTR116 chip convert current signal through voltage XTR116 IO port back to the ground, The upper computer processing shows the final downhole actual pressure status.

4. System software design

4.1. SPI communication protocol

The communication protocol between the controller and the peripherals is Serial peripheral interface (SPI). As the SPI protocol is full-duplex, it can quickly realize the synchronous information interaction between the host and the peripherals. It is mainly a master-slave communication [9], usually a master-slave communication or a master-slave communication. The standard SPI is four wires, usually occupying only four terminals on the chip, as shown in Figure 6. MOSI and MISO share one wire when there are only three wires, which can only be used for one-way transmission.

4.2. Design of SPI communication state machine

The SPI communication protocol state machine is designed to convert the 32-bit data transceiver process into four 8-bit transmissions. Take the sending process as an example, it can be divided into IDLE, WAIT, R_mem, W_reg and stop. First, the signal State ~ 22 is started by pressing the button, and idle State is entered. If the enabling signal of the falling edge is received, the State of WAIT is entered and the 8-bit data of the first time is cached. The judgment is based on wait_cnt [3] = = 1'b1. After sending, enter r_MEM cache state, then enter W_REG, send 8-bit data successively, then enter WAIT state again, repeat 4 times until 32-bit data is sent, and finally enter stop state [10]. At this time, slice is selected as high. After the end of one transmission, idle is returned again and waits for the receiving slice selection enabling.
signal to start the next round of data transmission. The SPI communication state machine transition diagram is shown in Figure 7.

![Figure 7 SPI communication state machine transition diagram](image)

**4.3. Data acquisition and reading**

Based on ARM software programming environment, the hierarchical oil recovery data acquisition process drives signal and register transmission by controlling each clock. The flow chart of the data acquisition system is shown in Figure 8.

![Figure 8 Data acquisition system diagram](image)

**5. Test and experiment**

**5.1. Maintaining the Integrity of the Specifications**

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**5.2. ARM communication Settings**

Connect the data acquisition circuit board and ARM experimental board on the desktop, connect the power to the upper computer; Then, by pressing the button on the ARM experimental board, an initial signal is given to the slave to read the data. Finally, the results of each data are displayed on the upper computer, and the real-time data is plotted as a graph. Fig.9 is the upper computer interface diagram for the test communication.
5.3. Temperature measurement experiment

The temperature acquisition node must be resistant to high temperature and high pressure in practical application, so the temperature measurement circuit is put in the oven for monitoring, and the linear equation can be obtained by fitting the data obtained through the test. Due to the good linearity of the data, only one equation can be fitted within the range of 20-120 °C. The fitting linear equation is:

$$y = 9.6241x - 87.528$$

(1)

By writing the fitting formula (1) into the MCU, the original temperature value collected can be corrected. The modified system conducts a temperature test by placing the circuit with a temperature sensor into the oven and comparing the modified temperature displayed on the panel with the actual temperature of the oven.

It can be seen from Fig.10 that, after fitting, the temperature output is still relatively ideal, because compared with the actual temperature of the oven and the temperature displayed on the ground of the monitoring equipment, the trend of the two curves is basically the same, so the temperature fitting achieves the purpose of temperature output correction.

6. Conclusion

In this article, an ARM-based layered oil recovery data monitoring system is designed. I.mx6ull's ARM system was adopted as the main controller for signal acquisition, and a peripheral circuit composed of four acquisition circuits was built. The feasibility of the program was verified through timing simulation, and real-time data reading between the host and the slave was realized through testing, thus ensuring the reliability of the data.
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