The design of micropower field data collector based on MSP430 microcontroller

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Abstract. Field data collectors are widely used in industrial control and information monitoring. According to the design requirements of micropower consumption and reliability, combined with MSP430 microcontroller, this paper expounds the design scheme of a new type of micropower field data collector, and discusses the overall design of the system and the implementation method of main functional units.

1. Introduction
In many application fields such as industrial measurement and control, automation control, and information monitoring, it is often necessary to collect and process various types of status information on the monitoring site to achieve effective on-site monitoring and control functions. In a typical application environment, it is often necessary to use network transmission technology to set up a measurement and control network in the field environment, and transmit relevant data to the remote central station of the measurement and control system for subsequent analysis and processing. Therefore, how to achieve data acquisition, storage and transmission in the field measurement and control environment with lower hardware cost, lower power consumption, smaller size and higher reliability is a problem that application engineers often need to consider and solve in actual design.

2. The System Design
The field data collector is a typical microcontroller application system. The system can be used as a local measurement node of the distributed measurement and control network to collect various kinds of on-site information (including various status information and image information) in real time, and can store and process useful monitoring data. As shown in Figure 1, through the various sensors, measurement unit, functional units, built-in control program and various functional programs in the system, the functions of information monitoring, acquisition and storage at the measurement and control site can be completed.

The data collector is used in the field of measurement and control, so the system is a battery-powered application system. Micropower design is an important part of the overall design of the system. At the same time, the overall technical architecture, hardware and software design of the system also need to meet the requirements of cost, volume and reliability.

The system's micropower design includes intrinsic low power design, operational power analysis, and power management [1]. The low-power circuit structure and devices with essentially low power consumption should be preferred. At the same time, it is necessary to comprehensively analyze the power consumption of each device in the operation of the system, and seek a task arrangement that can
minimize the average power consumption of the system. Workflow optimization and intelligent power management for micropower design can be achieved through a combination of software and hardware. At the specific software design level, the control program and various functional programs of the system are designed based on the interrupt program structure to achieve refined power management.

As shown in Figure 1, all kinds of measured information from the measurement and control site can be converted into electrical signals by the corresponding sensors, amplified, shaped and filtered by the signal conditioning unit, and input to the central control unit after A/D conversion.

The 16-bit microcontroller MSP430F5419 with outstanding micropower characteristics is selected as the central control unit of the system. The chip has many peripheral function modules [2], which is powerful, which helps to improve the system's advancement and integration, and reduces the design difficulty.

The data storage unit is used to store various types of on-site monitoring data from the forward channel. According to different data types and storage time intervals, data storage chips of different forms and storage capacity can be selected.

The display and keyboard interface unit provides a Chinese human-computer interaction interface for the operation of the system, and realizes functions such as operation setting, function menu display, prompt and status information display. The system adopts OLED12864 liquid crystal display module with resolution of 128×64, supports multiple interfaces, uses low voltage power supply, and has the advantages of small size, good shock resistance and wide viewing angle.

The power supply unit supplies power to both the analog and digital circuit parts of the system at the same time, provides a stable power supply voltage, and cooperates with the system control program to implement power partition management. At the same time, it has a high power output quality to meet the requirements of output efficiency, reliability and electromagnetic compatibility.

3. The Forward Channel
As shown in Figure 1, the sensors, the signal conditioning unit and the measurement unit are all forward channels in the system. On the one hand, various types of physical quantities (temperature, humidity, pressure, flow, etc.) in the field environment can be converted into electrical signals through various types of sensors. The output signals of the sensors need to be amplified, shaped and filtered by the signal conditioning unit. After A/D conversion, they become digital signals and are input to the central control unit. On the other hand, in the actual design, according to the requirements of system integration, cost, volume, etc., it is also possible to directly select a specific functional module that can be used for secondary development as a measurement unit in the system, such as a blood oxygen saturation module capable of measuring blood oxygen saturation and heart rate or a dedicated image monitoring module. The measurement unit composed of a specific functional module is capable of
outputting a digital signal or a digital image of a certain format, which is directly received by the central control unit. Some sensors integrated with signal conditioning and A/D conversion function can also directly output digital signals, which can be directly selected in combination with cost and volume requirements. The design method of directly selecting the digital sensor or the integrated measuring module eliminates the signal conditioning unit in the system, and the output digital signal does not require analog-to-digital conversion, which improves the system integration and reduces the design difficulty.

Due to cost, integration and volume constraints, in many cases it is still necessary to design a signal conditioning unit separately for the output signal of the sensor. The signal conditioning unit performs signal amplification, noise filtering and shaping on the sensor output signal, and the electrical signal (usually a voltage signal) with a small amplitude of the sensor output is amplified or adjusted without distortion, and is finally converted into a voltage signal that can be directly sampled by the A/D conversion module. The signal conditioning unit mainly includes signal amplifying circuit, filtering circuit and voltage reference circuit to realize signal amplification, filtering and shaping functions. The structure of the signal conditioning unit should be adapted to the signal form of the output from the front stage sensor.

The signal conditioning unit of this system should meet the following design requirements:

1. The amplification of the sensor output signal can be completed, and the useless signal outside the effective signal band can be filtered out;
2. It can provide the required voltage reference and adjust the sensor output signal to the full-scale range of the A/D converter module;
3. Its input and output have less influence on the front stage sensor and the A/D conversion module of the latter stage;
4. Its accuracy, sensitivity, linearity and frequency response range are able to meet system requirements;
5. It uses single-supply and low-voltage power supply with low static and dynamic power consumption.

Taking a common piezoresistive sensor as an example, the output signal generally includes two parts: a common mode signal and a differential mode signal. Moreover, the equivalent resistance of the sensor changes with the measured physical quantity. Therefore, the signal amplifying circuit should have a large input resistance, and should have strong common mode rejection and differential amplification capability, that is, have a high common mode rejection ratio. The signal amplifying circuit should also have a lower input offset current and a smaller temperature drift to further reduce the effect of sensor bridge resistance variation on accuracy.

In summary, the signal amplifying circuit of the system should use an amplifier with a non-inverting input differential structure. Specifically, a non-inverting input differential structure composed of two high-quality operational amplifiers can be employed. This structure is advantageous for increasing the input impedance of the amplifying circuit itself, and the differential structure has a strong suppression capability for the common mode signal output by the sensor. The use of two parallel operational amplifiers also facilitates mutual compensation for drift. In the specific implementation method, an instrument-level amplifier with an adjustable gain and a non-inverting input differential structure can be selected, which is advantageous for reducing design difficulty and improving system integration. When there is a higher flexibility requirement for the signal amplification range, a digital potentiometer can be used instead of the adjustable resistor to achieve programmable gain amplification.

The filter circuit is used to filter out unwanted signals outside the frequency band of the wanted signal, and the high frequency harmonics introduced by the power supply circuit or electromagnetic radiation can be pre-filtered before sampling to eliminate noise. In order to simplify the design, an active filter circuit composed of an operational amplifier of the same phase structure and an RC network is used in the system. This form of filter circuit has a high input impedance and a certain gain and buffering effect.
The gain range $G$ of the signal amplifying circuit in the signal conditioning unit can be calculated by the following equation.

$$G = \frac{{\text{full scale voltage range of the amplified signal}}}{{\text{voltage range of measured signal} \times \text{sensor's sensitivity} \times \text{passband gain of the filter}}}$$

4. The Central Control Unit

This system uses TI's new 16-bit microcontroller MSP430F5419 as the central control unit. The MSP430F5419 integrates four independent serial interfaces, 14 channels of high-precision A/D conversion module, 128KB of program memory and 16KB of RAM [2], enabling efficient data acquisition without the need for a dedicated A/D converter chip. It has an RTC real-time clock module and an on-chip CRC check module based on the CRC-CCITT standard, which provides technical guarantee for further improving the reliability of data storage and transmission.

The MSP430F5419 has five low power modes. Depending on the low power mode, you can choose to keep the data in RAM or turn it off directly. Each of its internal functional modules can be turned off by software operation when idle. With the micropower characteristics of the MSP430F5419, the main control program and each function program of the system can be designed based on the interrupt structure, which can make MSP430F5419 in a low-power sleep mode during idle time and be wakened up by various interrupt request signals, and perform functions such as data acquisition and data storage in interrupt service routine.

5. Data Collection

The MSP430F5419 microcontroller integrates an A/D converter module ADC12, which provides 14 external channels for 12-bit A/D conversion with a sampling rate of 200ksps. The ADC12 module includes an ADC core with sample/hold function, sample and conversion timing circuitry, conversion memory logic, an internal reference level generator and a variety of clock sources. And there are four A/D conversion modes of single channel single, single channel repetition, sequence channel single and sequence channel repetition. These internal functions of the ADC12 module can be individually set as needed, providing a high degree of flexibility for data acquisition of the system.

Since the system needs to continuously collect multiple measured signals at the measurement and control site, the useful frequency range of each measured signal should be combined to determine the highest frequency component to be retained. The sampling frequency suitable for the system is then determined according to the requirements of Nyquist's sampling law. In order to retain more frequency components and detailed information of the measured signal as much as possible, the sampling frequency of the system can be appropriately increased to ensure that the measured signal can be restored without distortion according to the collected data.

The data acquisition program of this system adopts the conversion mode of sequence channel repetition. In this mode, the sampling order of each channel can be flexibly set as needed. The sampling control signal, clock source, and reference level also need to be set in the data acquisition program.

Writing the acquired data to the data storage chip requires a certain write time. In order to ensure that the data acquisition and data storage processes do not affect each other, two dedicated buffers of the same size should be opened in the RAM area of the MSP430F5419. During the data acquisition process, the MSP430F5419 temporarily stores the collected data in these two buffers. When the buffer is full, the data of this buffer is written to the memory chip, and the other buffer continues to temporarily collect the data. By switching between the two buffers and combining the page data writing function of the data storage chip, the collected data can be stored in a timely and reliable manner, which effectively improves the system reliability.

The specific process of the data acquisition program is shown in Figure 2. In order to effectively reduce the average power consumption of the system, the data acquisition program uses an interrupt program structure. That is, during the A/D conversion process, MSP430F5419 is kept in the low power sleep mode. At the end of each A/D conversion, the A/D conversion interrupt flag ADC12IFG
is automatically set to wake up MSP430F5419 and process the acquired data in the interrupt service subroutine. The trigger signal for each start of sampling is generated by the on-chip hardware timer of MSP430F5419, and its timing time corresponds to the sampling frequency. The data acquisition program based on the interrupt structure in the system reduces the running time and the unnecessary waiting state of MSP430F5419, and achieves the purpose of accurately controlling the running power consumption.

The flow chart of data acquisition program is shown in Figure 2.

**Figure 2.** The flow chart of data acquisition program
6. Conclusions
This paper combines the design principles of micropower consumption and reliability to design a micropower data collector suitable for various industrial control and information monitoring sites. The data collector is powered by battery, and can realize real-time monitoring, collection and storage of various types of information in the measurement and control field.

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