Application of μc/os - II in the Design of Mine dc Electrical Prospecting Instrument

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Abstract

The traditional DC electrical prospecting instrument has some disadvantages such as high power consumption, small storage capacity, hard operation and poor software maintainability. These restrict the application of DC electrical prospecting instrument to a certain extent. This paper firstly improves the hardware of the traditional DC electrical prospecting instrument utilizing STM32 microcomputer based on Cortex-M3 core and 24-bit Σ - Δ ADC component, then ports a real time operating system μc/os-II to the hardware platform newly designed, finally divides software system of mine dc electrical instrument into six tasks according to some principles and programs them in C language. The experiment proves that the new instrument has the advantage of high accuracy, low power consumption, large storage capacity, and friendly man-machine interface compared with traditional DC electrical prospecting instrument.

Keywords: ARM Cortex-M3 core, operating system, porting, dc electrical instrument;

1. Introduction

The DC electrical prospecting instrument plays an important role in the safety production and the mine coal production, and related researchers have paid much attention to it [1-3]. As for the hardware design, the traditional DC electrical prospecting instrument often uses 8-bit microcontroller to design the related circuit, which has disadvantages of high power consumption and small storage capacity. The main
program of software designing is an infinite loop constituted by for statements or while statements in C. The program detects the occurring of events in the loop so as to turn to different tasks. The disadvantages of this program development model are poor software maintainability, reliability and uncertain response time of different tasks. While developing application program on the operating system µc/os-II, the programmers only need to be concerned with each task itself, the task schedule will be completed by operating system. The developed system will have good maintainability, reliability and certain response time [4]. So it is necessary to reform and update the traditional DC electrical prospecting instrument to meet the coal production’s new demands.

2. Construction of new DC electrical prospecting instrument’s hardware platform

2.1. Selection of ARM processor

2.1.1 µc/os-II’s requirements for processor

To run µc/os-II normally, the processor of the new instrument should meet the requirements as followings [4]:

- 1) Processor should support interrupts and can generate timed interrupts;
- 2) Processor should have instructions to read stack pointers and values of other CPU’s register and store them into stack and memory;
- 3) Processor should support data storage and hardware stack;
- 4) The C compiler of processor can generate reentrant code;
- 5) Interrupts can be opened and turned off by C.

2.1.2 Introduction of ARM processor based on Cortex-M3 core

In this paper, we choose STM32F103VE chip, which is a 32-bit microprocessor based on ARM Cortex-M3 core. The chip contains 512kB Flash, 64kB SRAM, 8 timers and other resources. The nested vector interrupt controller can support software/hardware interrupt. It adopts three-level pipeline and runs at 72MHz with faster coding execution speed and lower power consumption [5,6]. Its developing environment, RealView Microcontroller Development Kit (MDK), uses IDE environment µVision, in which there are ARM professor compiler named RVCT, tool for debugging analysis, RTX real-time library, automatic generation tool for startup code and other utility tools. It also has the ability to generate reentrant code, which meets the requirement of running µc/os-II normally.

2.2. Composition of hardware platform

The hardware platform of mine DC electrical prospecting instrument is shown as Figure 1. DC voltage outputted by battery packs generates 100V high voltage through an isolated rising-voltage circuit, and then emits output through current-limiting circuit and current-sampling circuit. That is to say, DC voltage is provided by electrodes A and B to build a whole space stable artificial electric field in the rocks surrounding the underground tunnel; the induced voltage signal enters preamplifier circuit and impedance inverter circuit through electrodes M and N, and then, it is transferred to microcontroller by SPI serial port after being transformed into digital voltage pulse signal by 24-bit A/D converter. The apparent resistivity can be calculated by measuring received voltage and supply current. The related parameters, voltage, current, and apparent resistivity will be stored into SD card if the testing result is reasonable. The monitor will display operation menu, parameters, testing result, and so on. The data in the SD card will be transferred into PC, in which the conversion of data and drawing of result map will be completed through USB bus.
3. Porting μc/os-II

The kernel code of μc/os-II is written with C by an American named Jean J. Labrosse. It is a system kernel of a real-time preemptive operation system. It has good portability and can support 64 tasks with different priorities at most. The smaller the number of the priority is, the higher the priority of the task is. The operation system always schedules the ready task with the highest priority to run. In this mode, the reliability is very good. The version of source code we used in the article’s porting process is V2.91. The porting for μc/os-II can be divided into two parts: need-to-be-modified part and non-need-to-be-modified part. The files need to be modified the source code are head file OS_CPU.H, C language file OS_CPU.C and assembler format file OS_CPU.ASM. The porting process can be found in [4, 7, 8]. However, the following 3 points need to be noted:

- The processor used in this paper supports full descending stack, and the related code in the head file OS_CPU.H should be modified as: #define OS_STK_GROWTH 1.
- The Thumb status bit of xPSR should be set to 1 when initialized, or there will be an exception called Invstate during executing code because the processor of Cortex_M3 core only supports Thumb and Thumb2 instruction sets. Only when the stacks’ PC and LR are initialized to the value of task’s entry address, can the task jump to the right address to run when task is being switched.
- Function OSTickISR is the interrupt service function of system clock beat. Processor STM32F103VET6 has a special system clock beat timer SysTick, which can generate a clock beat interrupt when porting. The interruption interval of our porting is 60 ms.

4. Software design of the DC electrical prospecting instrument based on μc/os-II

4.1. Task design & priority distribution

4.1.1 Partition principle
μC/OS-II can manage 64 tasks. It can provide 56 tasks to users because the 4 highest priority tasks and the 4 lowest priority are reserved for itself. The higher the task priority is, the lower the number of priority reflection will be. The task priority level can be used as the identifier of task. The principle of decision that one task conversion should be a single task or should be with other conversions is determined by the following principle or criteria:

- Dependency on Input/Output DEVICE
- Time-critical functions-Hard Deadline
- Heavy Computation function
- Functional relations
- Temporal relations
- Cyclic executing function

4.1.2 Task partition and task priority distribution

According to the above principles, the DC electrical prospecting instrument system will be divided into the following tasks:

- Keyboard task: in charge of the interaction with user;
- Launch task: in charge of the sampling and output of current;
- Measuring task: in charge of the sampling and calculation of AD;
- Display task: in charge of the display of input parameter value, measuring results, and calculating results;
- Storage task: in charge of the SD card memory of measuring parameter and results;
- Communication task: in charge of the communication with PC, the data transmission from SD card to PC.

It needs to set the task priority after task partition. The reasonability of the partition of task priority will influence the instantaneity and reliability of the system directly. Generally one abide by the following principle when setting the task priority [8]:

- Peripherals task has higher priority. If the priority is not high enough, it would lead to interrupt lost because peripherals task usually correspond to the interrupt service routine.
- The priority of tasks which take up the key resource should be as high as possible.
- The shorter the tasks’ executing period, the higher the priority should be.
- When the above conditions get close, the shorter the task time consuming the priority should be higher.

According to the above principles, keyboard, launch, measuring, display, save and communication task are one-time task and can be happened at the same time. So, we can rank the priority of four tasks to 6, 7, 8, 9. The keyboard task should be the first task when the system begins to work; it is supposed to be the lower priority in the 6 tasks. Set to 12. Display task, triggered by other related task, respond to display related data to the LED screen, should be set to the lowest priority. Set to 17. In the operational process, the system creates corresponding task according the detected input data when detect keyboard input. The corresponding task will send message to inform display task and then delete itself after or in the operational process.

4.2. Task realization

4.2.1 The realization of main function

First, initialize peripherals in the main realization, such as system clock, related I/O interface and so on. After that, initialize the operate system. And then, create keyboard task. Start multi-task condition at last. The program block diagram is shown as the Figure3.
4.2.2 Realization of keyboard task

The keyboard task mainly conducts periodic scanning. Its priority level is 12. Its program procedure is shown as Figure 2. For guaranteeing initialization completed after the execution of OSStart(), the keyboard task conduct objective board initialization first. And then, create display task, finish the initialization of screen. Create some operating system resource of task conversion.

4.2.3 Realization of launch task

The launch task’s main works are setting related parameter and transmit related parameter to display task. The priority level is 6.

4.2.4 Measuring task

The measuring tasks’ main works are connecting radiating circuit, starting A/D converter for sampling data and conducting related calculation. A/D converter adopt 24 bits \(\Sigma - \Delta\) serial ADC. It sets the programmable gain and former gain of ADC according the data that ADC pre-collected when sampling. The data ADC collected go to the processor STM32F103VE through SPI data bus. The total array of sampling data storage adopts mutual exclusion quantity of information to protect itself from data errors that occurred in the sending and reading one piece of data. The applying of mutual exclusion quantity of information must have done before the opening interrupt, or it will come up with data lose. Its block diagram showed as Figure 4.

4.2.5 Storage task

The storage task’s main work is to store the related parameter, AD collected results and related calculating results into SD card. SD card connect with processor STM32F103VE by SPI. In order to make the information saved on the SD card can be visited by the windows system, the SD card adopt FAT16 file system.
4.2.6 Communication task

The main task of communication task is adopting USB serial port transmit data from SD card to computer. It makes the related picture and analysis work available. USB serial port transmission model follow the standard of USB2.0 and USB high-capacity save. User use USB cable to connect devices with computer after the task worked. And then, the computer will detect one new removable driver. The operation of reading, writing and formatting is the same as other mobile storage devices.

4.2.7 Display task

The main functions of display task are the initialization of screen, the display of operation results and calculation results of keying. The priority level is 17. The block diagram of display task is shown as Figure 5.

5. Performance comparison between the new DC electrical prospecting instrument and the traditional instrument

Compared to the traditional DC electrical prospecting instrument, the new instrument has the following advantages:

- Due to being used 32 ARM processors, the new instrument has the faster computation speed and the stronger handling ability. The apparent resistivity can be figured out directly.
- 1GBit storage capacity.
- Because of being enhanced the output voltage, the new instrument can provide the big output electric current even if the electrode contact resistance is big.
- By using USB to transmit data rather than RS232, the data transmission speed increase significantly.
- Since porting μ e/os-II Operating system to the hardware platform newly designed, the new instrument has good software maintainability and reliability.
Table 1. Comparison parameters

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<thead>
<tr>
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<th>the traditional instrument</th>
<th>the new instrument</th>
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<tbody>
<tr>
<td>processor</td>
<td>8 bit</td>
<td>32 bit</td>
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<tr>
<td>storage capacity</td>
<td>256Kbit</td>
<td>1GBit</td>
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<tr>
<td>output voltage</td>
<td>90V</td>
<td>95V</td>
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<tr>
<td>Outout current (max)</td>
<td>70mA</td>
<td>68mA</td>
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<tr>
<td>display</td>
<td>current</td>
<td>apparent resistivity</td>
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<td>Transmission method</td>
<td>RS232</td>
<td>USB</td>
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6. Experiment and conclusion

We conducted ground experiment of new and old instruments in the field for testing the performance of instrument. The distance of measuring supply current electrode of A1, A2, A3 is 5m. And the receiver current electrode is 5m. Figure 6 is the results of experiment. The results show: the measurement of apparent resistivity anomaly area of low resistance consists with the measurement of traditional DC electrical prospecting instrument.

7. Conclusions

This article begins with the working principle of dc electrical instrument, adopts high performance and low power consumption 32-bits STM32F103 processor, and redesign the hardware platform of dc electrical dsinstrument. Then port a real time operating system μc/os-II to the newly designed hardware platform. Divide system task to 6 tasks according related principles, lower the consumption of circuit and improve the control, calculation capability and measure accuracy of system. The experiments confirmed that the newly designed dc electrical instrument is superior to the traditional dc electrical instrument on these aspects: detection accuracy, save capacity, operation simplicity and consumption. However, the newly designed dc electrical instrument has its own disadvantages. The partition of task could be optimized, and the operation interface could be further perfect.
References


