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REMOTE DATA COMMUNICATION TECHNOLOGY OF MULTI-SENSOR FUSION IN UNDERGROUND MINE

Yanning Yu[1], Zhenyang Xu[1*], Houguang Sun[2] and Hui Luan[2]

* College of mining engineering, University of Science and Technology Liaoning, Anshan, Liaoning, China;
[2]Anqian mining limited liability company, Anshan, Liaoning, China.

Email: xuzhenyang10@foxmail.com

ABSTRACT

For the purpose of the production information remote can transmitted automatic real-time in underground coal mine, in order to improve the system reliability of big-data transmission, and make the development and maintenance of system more convenience. Proposed a solution method that based on the single chip of μC/OS-II, the multi-sensor data remote transmission is realizated by using the Combination of real-time system platform, High speed MCU hardware platform and MODEM communication. The research results show that: The design method can improve the system development and maintenance convenience , the real-time monitoring data transmission could be high stability; The information of underground can be remote transmitted to a security zone in 20 kilometers through the telephone cable; the mine equipment can be remote detected and controlled in the control room, that can reduced the number of works in dangerous environment; Multi-sensor design can improve the volume of data transferred based on Bayesian estimation.

1. INTRODUCTION

Coal production occupies an important position in national economy as a pillar industry of our country's energy production. It has great influence to the national construction and development of industrialization and the national economy and people's livelihood, safety production of the coal mine is an important guarantee of healthy and orderly development of coal industry, but the production safety situation of China's coal industry is not optimistic, frequent accidents of coal mine safety, caused heavy casualties and huge economic losses [1-3]. Therefore, it is important to the process of coal mine safety production of coal production, equipment running status and coal mine environment status information with remote transmission and monitoring, the paper had designed the coal mine with data remote transmission system which was to meet the needs of the coal mine information remote transmission.

2. SYSTEM DESIGN BASIS

The system was designed in bad working conditions of the coal mine field, coal related products tested strictly test environment, the reliability of the system hardware circuit which need high level and good performance of components must be fully considered. The anti-interference ability of the system and the use of photoelectric isolation device for signal in isolation must be considered; In addition, the system must be reliable and accurate to transfer data from the coal mine to inoue, this is the key to the system. As far as possible considering the limited transmission rate (MC145442 is 300 baud rate transmission), as far as possible to compress the data, make a second transfer more effective data, and write concise, readable and relevant code with software design.

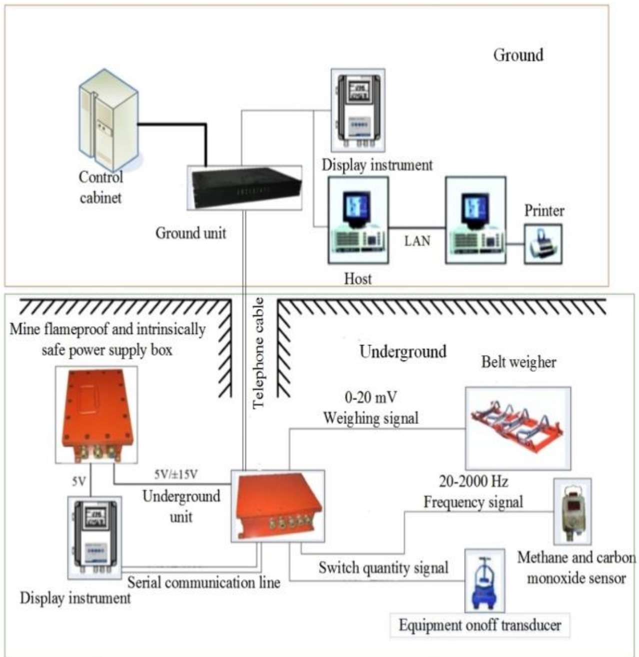

Figure 1. The function diagram of the system

As shown in Figure 1, the paper had designed four parts of the coal mine data remote transmission system, including the coal mine unit, ground unit, flameproof and intrinsically safe power supply box, the upper computer software and PC software.

3. MODEM MODE

In order to reduce costs, a remote communication system usually used telephone lines as a transmission medium, and the passband is 300 - 3400 hz, regular telephone lines namely cannot transfer data within the range. The method to solve this problem had been to use MODEM which could change digital square wave signal into sine wave signal within 300 - 3400 Hz.

Using MODEM WAY to change digital square wave signals into sine wave signal within 300 - 3400 Hz was a practical and ideal method on transmission of the telephone line. By means of telephone network transmit data between PC and single chip microcomputer; the signals must be modulated by the sender firstly to change digital signals into analog signals. Through the telephone network transmission, the receiving end had to analog signals back into digital signal by demodulation device [4]. A large number of external standard used RS - 232 interface, the MODEM could be directly connected to the PC with a serial port; And single-chip microcomputer serial port was not a standard RS - 232 interface, MODEM could not be directly connected to single chip microcomputer, it must be designed the corresponding level conversion interface. Between the two MODEM was through the telephone network carry signals. Only after the successful build a carrier link between them could carry out data transmission [5, 6].

There were many advantages that MODEM had be used for the remote communication: Firstly, the communication distance could be extended to dozens or even hundreds of kilometers, as long as a telephone line better quality basic unrestricted communication distance. Secondly, MODEM communication had used the telephone lines and exchange networks; it did not need to separate wiring, maintenance in person, and saving a large amount of energy and money. Moreover, without the need for data transmission, the lines could be used as a regular telephone lines to voice communication or sending faxes, etc., it was one line is multi-purpose. Finally, using some MODEM module communication could rate up to about 50 KBPS (depending on the line quality), and meet most of the design requirements, and MODEM itself technology mature, reliable performance, the price was not high also. Using the finished product of MODEM could also avoid the design of the communication interface debugging process, short the development cycle, reduce the cost of development, and at the same time improve the reliability of the system.

4. SYSTEM DEVELOPMENT OF MODEM MODE MC/OS-II DATA

4.1 Working principle and characteristics of μC/OS-II

The core working principles of μC/OS-II was to run the readiness and the highest priority task approximately. First, it shoud be done the MCU initialization, and then to the operating system initialization, mainly to complete the task control block of TCB initialization, TCB priority table initialization, TCB chain table initialization, the event control block (ECB) initialization list, empty task to create, etc. Then you could begin to create a new task, and in the newly created task to create other new tasks; The last called OSStart function start task scheduling. In task scheduling, it was ot be started timing starts ticks source, to be beated the source for the system to provide periodic clock interrupt signal, to be confirmed time delay and overtime.

4.2 μC/OS - Ⅱ transplantation advantage

μC/OS - Ⅱ was a miniature of the real-time operating system which included a most basic featured operating system, such as task scheduling, memory management, interrupt, task, communication management and so on, and this was a completely open real-time operating system, simple structure and rigorous style of code, it was suitable for new operating to learn and understand the concept of operating system, the structure, the working principle of the module, it was gradually extended to commercial operating systems[7].

It was portable to any external memory of single-chip 80 c51 system, also cuold be extended into the expensive business system perfectly.

Table 1. The resources configuration

Name	Port
UART0	P0.0, P0.1
UART1	P0.2, P0.3
Frequency output port	P1.0, P1.1
Watch dog input	P1.2
JTAG interface	TDO, TDI, TCK, TMS
The switch quantity input port	P2
The switch quantity output port	P3

The last and most important of which was embedded in the single chip microcomputer system would enhance the system reliability, and made the debugging process easier. It could use watchdog program to solve running or flying into an infinite loop of the traditional SCM development program, for the infinite loop, especially which involved complex mathematical calculations, it was only to set breakpoints, and spend a lot of time to slowly analysis. If μC/OS - Ⅱ was embedded in the system, things were much simpler. The whole program could be divided into many tasks, each task was relatively independent, and then settled the timeout function in each task, it must be surrendered the CPU using right after task time. Even if a task problems would not affect the operation of other tasks. This could not only improve the reliability of the system, at the same time also made it easy to debug the program.

5. THE DESIGN OF SYSTEM HARDWARE

5.1 The underground unit

The underground unit was a key part of the whole system. It was a flameproof and intrinsically safe apparatus placed in special flameproof enclosure. The functions were collecting and processing four load cell signals, two frequency signals and eight switching values signals of the explosion-proof belt scale, transmission the signals to the signal receiver unit on the ground by mine explosion-proof telephone cable and receiving switching value signals from the unit on the ground to control the underground equipment. Simultaneously, the underground unit had a RS232 serial communication interface which could communicate with other intrinsic safety instruments underground. This made it easy for the system to extend in the future. The hardware structure diagram of the underground unit was shown in Figure 2.

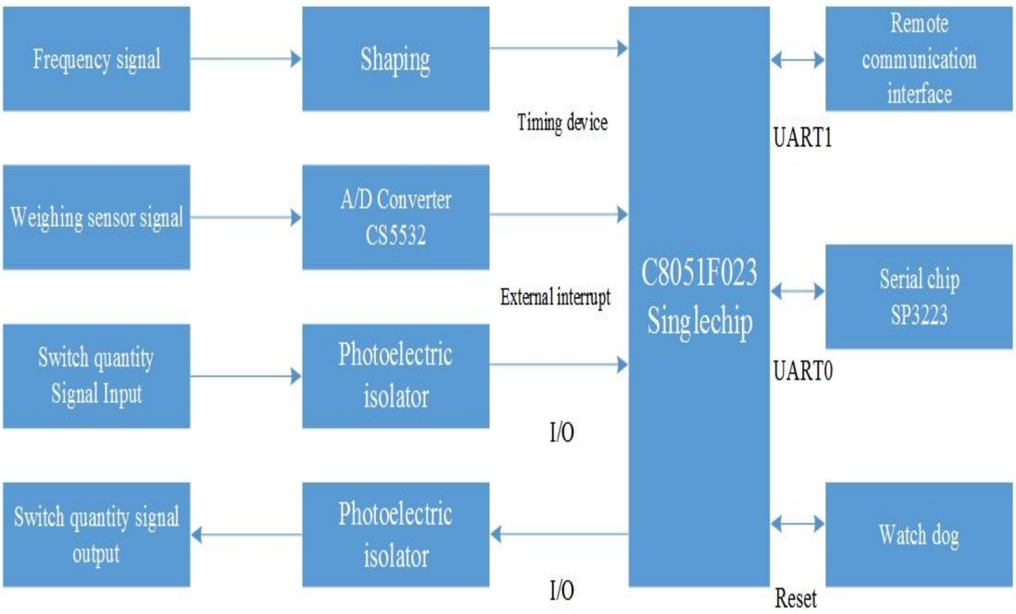

Figure 2. Hardware of the undergroundunit

5.2 The unit on ground

Unit on the ground was ordinary circuit installed by standard industrial chassis. Status of the system could be known by indicator lights on the industrial chassis. The unit on the ground had safety barrier circuit. The main functions of the unit on the ground were restoring the results of AD conversion, frequency signals and switching values signals from underground unit. It could not only indicate the status of underground equipment and output original signals on the corresponding output ports but also transmit the data to upper computer by RS232 serial communication interface and send eight switching values signals to the underground unit to control underground equipments remotely.

When the unit on the ground received the data from the underground unit, it would judge whether the received data was correct firstly. It would extract the AD value, two frequency data and switching values data from data frames, and then restore the different data by various ways. Frequency signals restored the original input frequency value in the shaft by controlling I/O port electrical level to product flip with timer interrupting. Switching data were assigned to the corresponding I/O port directly.

Circuit of the unit on the ground included data processing unit, remote transmission module, in-output circuit of switching values, outgoing circuit of frequency's recovery, serial communication circuit, JTAG interface circuit power module, etc.

5.3 Design of explosion-proof power

The underground unit must provide 3 power inputs. So a flameproof and intrinsically safe power box had to be design to provide electric power for the system. This flameproof and intrinsically safe power box would be designed with five power circuits (±15 V, +12 V and two +5 V standalone power circuit). The +5 V power circuit and ±15 power circuits were used by the underground unit. And the others could provide power for the equipment's under the ground.

In coal mine underground, 127 VAC was usually used for providing power. There were many high power load apparatuses in the power grid under the ground. Switching on and stopping of these equipment had a significant impact on the power supply. So the performance of the power supply must be taken into consideration in the design. AC/DC Integrated modular power could be used to fit the big voltage undulation under the ground. Its input voltage range was from 85 VAC to 265 VAC. The design of power supply module conformed with MT/T 408－1995 and MT/T 863－2000. The design principle of underground power supply was shown in Figure 3.

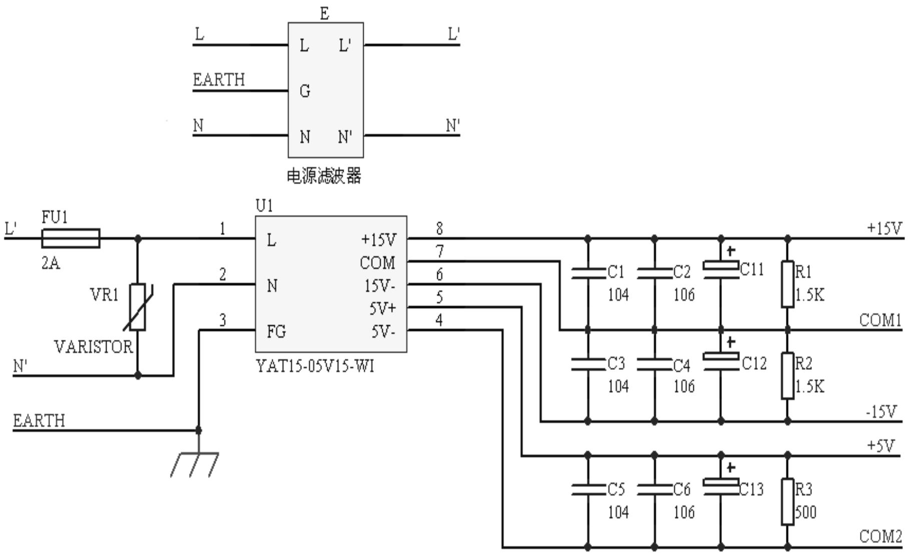

Figure 3. Underground unit power circuit diagram

6. MULTISENSOR DATA COMMUNICATIONS

For information element, it was lacked in gaining exterior information exactly, reliably and steadily. With the scale of underground mine production was getting bigger and bigger, the degree of automation was getting higher and higher, the intergraded intelligent supervision in coal mine was the future direction. The use of multi-sensor data fusion technology could improve the coal mine comprehensive management level of the equipment. The single sensing element could only provide partial and inaccurate information, multi-information fusion technology of multi-sensors had the essential difference with single sensor single processing technology, the key was multi-sensor information which had the more complex forms, and the information could be fusion and integration at different levels. After fusion of multi-sensor data had the following characteristic: the redundancy of information fusion had great practical significance in coal mine monitoring system, mine safety was the safety of all personnel security, was the precondition of all normal work. Because of the limitation of time and ability, in the process of the design of this system, it did not use multi-sensor fusion technology; here were just a development direction in the future extended function of the system. The following article introduced the multi-sensor fusion technology.

The multi-sensor fusion technology included multi-sensor target detection, data association, tracking and identification, assessment and predication. Data fusion’s purpose was gaining more data than the separate each input data integrating information. This was the result of the synergy; the effectiveness of the system was enhanced due to the effect of common of the multi-sensor. It was multi-source information’s integrated technology; it could achieve measured object and its optimal consensus estimated by analyzing and synthesizing the data from different sensors.

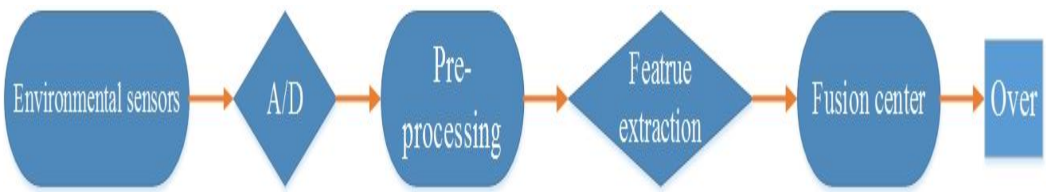

Figure 4. Data syncretize process

The process of data fusion was shown in figure 4, because the object to be tested had non-electricity with different characteristics, the temperature, pressure. So first of all, they should turn into electrical signals, and then turned into digital processing by computer by the A/D transformation. After digitally, electrical signals was pretreated in order to filter out the interference and noise in the process of digital collection. To extract characteristic the useful signal which was processed and then fused data, or fused signal data directly and finally output the integration of results.

Data fusion used Bayesian-estimation in the matrix estimation, total probability its maximum, the maximum likelihood method. After all under the condition of the unknown parameter θ as a random variable parameter to discuss the parameter estimation. If you could provide some additional information of unknown parameter θ in advance, it would be beneficial to the estimate of the parameter θ. This was the basic idea of the Bayesian-estimation [8].

Set parameter θ as random variables in the total distribution function $F(X,\theta)$, for any decision function $d(\xi_1,\xi_2,\cdots,\xi_n)$, if there was there was

$$B(d^*) = \min\{B(d)\} \tag{1}$$

In Eq.(1), d^* was the Bayesian-estimator of parameter θ, $B(d)$ was regarded as the Bayesian risk of the decision function $d(\xi_n)$。

Take Quadratic loss function as

$$L(\theta, d) = [\theta - d(\xi_1, \xi_2, \cdots, \xi_n)]^2 \quad (2)$$

The Bayesian estimator of θ was

$$d(\xi_1, \xi_2, \cdots, \xi_n) = E[\theta|(\xi_1, \xi_2, \cdots, \xi_n)] = \int_\Omega P[\theta|(\xi_1, \xi_2, \cdots, \xi_n)]d\theta \quad (3)$$

$P[\theta|(\xi_1, \xi_2, \cdots, \xi_n)]$ could be calculated in order to know the Bayesian-estimator of θ.

Among the measurement data which came from m sensors, the consistency measurement data set was

$$X = \{x_1, x_2, \cdots, x_t\},\ t \le m \quad (4)$$

In the following, Fusion was centralized information integration into a best data by the Bayesian estimation method, and regarded them as the end result of measured parameters.

There was

$$P(\mu|x_1, x_2, \cdots x_t) = \frac{P(\mu; x_1, x_2, \cdots x_t)}{P(; x_1, x_2, \cdots x_t)} \quad (5)$$

If the parameters μ and X_k obeyed $N(\mu_0, \sigma_0^2)$, and $\alpha = P(x_1, x_2, \cdots, x_t)^{-1}$, α was a constant data which had nothing with μ, so there was

$$\begin{aligned} &P(\mu|x_1, x_2, \cdots x_t) \\ &= \alpha \prod_{k=1}^{t} \frac{1}{\sqrt{2\pi}} \exp\{\frac{1}{\sqrt{2\pi}}(\frac{x_k - \mu}{\sigma_k})^2\} \\ &\times \frac{1}{\sqrt{2\pi}\sigma_0} \exp\{-\frac{1}{2}(\frac{\mu - \mu_0}{\sigma_k})^2\} \\ &= \alpha \exp\{-\frac{1}{2}\sum_{k=1}^{t}(\frac{x_k - \mu}{\sigma_k})^2\} \\ &-\frac{1}{2}(\frac{\mu - \mu_0}{\sigma_k})^2\} \times \prod_{k=0}^{t} \frac{1}{\sqrt{2\pi}\sigma k} \end{aligned} \quad (6)$$

In Eq.(5), index part was quadratic function about μ, so $P(\mu|x_1, x_2, \cdots, x_t)$ was normal distribution, if it obeyed $N(\mu_0, \sigma_0^2)$,

$$P(\mu|x_1, x_2, \cdots, x_t) = \frac{1}{\sqrt{2\pi}\sigma_N} \exp\{-\frac{1}{2}[\frac{\mu - \mu_N}{\sigma_N}]^2\} \quad (7)$$

Compared the two type parameters from Eq.(6) and Eq.(7), then

$$\mu_N = [\sum_{k=1}^{t} \frac{x_k}{\sigma_k} + \frac{\mu_0}{\sigma_0^2}] / [\sum_{k=1}^{t} \frac{1}{\sigma_k^2} + \frac{1}{\sigma_0^2}] \quad (8)$$

So the $\hat{\mu}$ which was the Bayesian-estimation of μ was

$$\hat{\mu} = \int_\Omega \mu \frac{1}{\sqrt{2\pi}\sigma_N} \exp\{-\frac{1}{2}[\frac{\mu - \mu_N}{\sigma_N}]^2\} du = \mu_N \quad (9)$$

So, $\hat{\mu}$ was the optimal data fusion of μ. After getting the measured value of the sensor, then calculate the variance, computers would fuse the consistency of data by the Bayesian optimal data fusion, it can improve The measured results obviously.

7. CONCLUSIONS

(1) Transplanting real-time operating system into C8051F023 MCU, not only it can improve the real-time performance, stability and reliability of the system, but also makes the application development easier. The design process is greatly simplified, and the maintenance and modification is easy.

(2) It is completed the system hardware circuit design, including the signal collection circuit, watchdog reset circuit, remote communication circuit, peripheral interface circuit and microprocessor peripheral circuit, etc., it is combined action of multiple sensors for target detection, data association, tracking and identification, assessment and prediction, enhancing the effectiveness of the system.

(3) It is completed the design of coal mine unit, ground unit and the upper computer, and implemented the transplanted code. In the program, it is implemented a variety of signal acquisition and processing, after the transplantation of the operating system, it can be integrated in the coal mine information of various sensors, the system can make the right response, decision-making and controlling, then it can improve the level of the mine production and management.

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