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实时个人剂量监测管理系统

REAL-TIME PERSONAL DOSE MEASUREMENT AND MANAGEMENT SYSTEM

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摘 要

实时个人剂量监测管理系统由三部分组成：电子个人剂量仪、数据读出器和计算机控制管理系统软件。文章着重介绍了该系统的硬件构成、软件系统组成及界面特点，系统适用于核电站等放射性控制区的个人剂量在线实时监测、管理与其它控制。

关键词：个人剂量仪，实时监测，管理系统，计算机软件

Real-Time Personal Dose Measurement and Management System

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ABSTRACT

The composition and design of a real-time personal dose measurement and management system are described. Accordingly, some pertinent hardware circuits and software codes including their operation modes are presented.

Keywords: Personal dosimeter, Real-time measurement, Management system, Computer software

INTRODUCTION

Nowadays, because of the features like fast response, automatic and remote control, different types of real-time personal dose measurement and management systems are playing an important role in nuclear industry and radioactive application fields. It will be more beneficial if it is optimized for radiation protection and radiation safety.

To meet the needs of radiation protection in nuclear industry, especially the needs of nuclear developing countries like China, we developed a real-time personal dose measurement and management system. The system is basically composed of three parts, (1) personal dosimeters, (2) data readers, and (3) a computer system for management software operation. The link frame of the system is illustrated in Fig. 1.

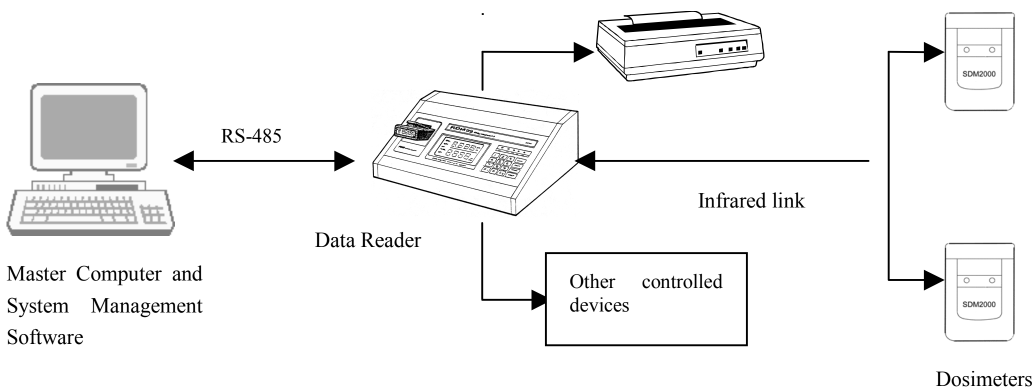


Fig. 1 The link frame of the system

1 PERSONAL DOSIMETER

The personal dosimeter comprises a special designed preamplifier and a main amplifier. Its control function and data process is realized by using a digital circuit around a powerful micro-control unit (MCU). The function frame of the dosimeter is shown in Fig. 2. The results of personal accumulated dose equivalent, Hp(10), and dose equivalent rate, Hp(10), can be directly read out by a dosimeter's LCD. The measurement results and some parameters will be kept in a EEPROM. All of the data stored in dosimeter can be transmitted into a data reader through an infrared link. The alarm thresholds of dose and dose rate can be adjusted successively over their whole measurement ranges. If an alarm level has been reached, the user is alerted by both of optical and acoustical.

1. 1 Detector and Measurement Circuit

The detector used in the dosimeter is a PIN Silicon photodiode. By choosing an appropriate reverse bias voltage for the detector, the noise caused by its dark current and the diode capacitance may be minimized. In our case, a bias voltage, 3.5 V, is given by a battery, the typical values of leakage current and junction capacitance are about 1 nA and 15 pF respectively.

When the signal output from the detector is very weak, a low noise charge sensitive preamplifier becomes an elementary requirement. In the circuit illustrated in Fig. 3, an AC coupling mode is used between the preamplifier and detector. A kind of JFET is as a input of the preamplifier. Because the equivalent noise charge of the preamplifier significantly depends on the JFET noise source, the JFET must be in low noise and high trans-conductance. To minimize the size of the amplifier circuit, two IC chips of op-amps, U1 and U2, are adopted. The op-amps can be powered in a mono-polarity and low voltage supply within 2.7 and 6.0 V. Also, low noise, low power consumption and an adequate unity-gain bandwidth must be required.

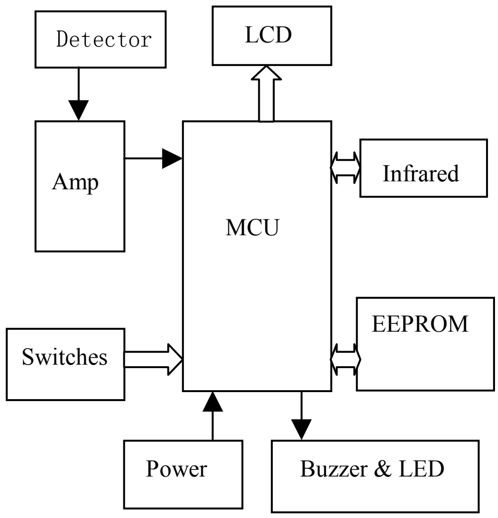


Fig. 2 Function frame of the dosimeter

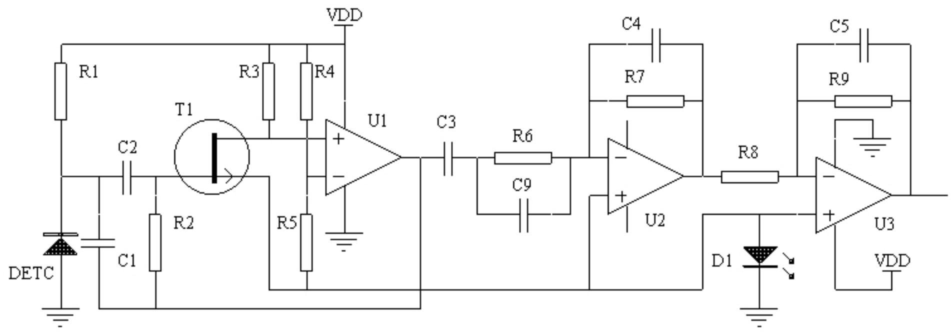


Fig. 3 Diagram of a dosimeter circuit

In this circuit, the zero electrode level and pulse discrimination can be adjusted. The ratio of signal and noise of the preamplifier, S/N, is >3. The preamplifier's power consumption is about 150 μA.

1. 2 Design of Function Program

The code of the micro-controller unit is designed with an assembly language. It includes a main routine and three interrupt routines (counter interrupt, timer interrupt and pushbutton interrupt). The flowchart of the main program is shown in Fig. 4.

A routine timer is used to give a time interval for dose equivalent rate calculation. The time interval can be changed from 200 s to 1 s automatically according to the coming pulse speed. The lower of the count rate, the longer of the timing interval. Usually, as the count rate lower than a certain level, such as in 1 μSv/h dose rate level, the MCU is then in semi-sleep state, each signal pulse can wake up the MCU. The dosimeter is turned into a power saving mode.

Three main operation modes of the code are as follows:

(1) Standby mode

In this mode, the MCU is in "stop" state. Measurement data are stored in EEPROM. The power supply for analog circuit (amplifier) is shut down.

(2) Active mode

It is a measuring mode. At the beginning of the operation, the calculation variables of dosimeter are initialized and the analog circuit is powered on. The MCU is awaiting a pulse or timer interrupt. The pulse signal is simultaneously sent to both an internal 8-bit counter and an external interrupt input. In low counting rate, the count interrupt is caused by an external signal. In high counting rate, a count interrupt will be caused by an internal 8-bit prescaler. Whenever a counting time is finished, the dose and dose rate is calculated and the results are updated on LCD. As soon as the thresholds of dose and dose rate have been passed, the alarm signal is occur. Pulse counting does not stop during the procedures above. Commonly, battery check is performed in every 8 minutes.

(3) Data exchange mode

As connecting with the data reader through a infrared link, dosimeter automatically goes to data communication with the reader.

For entry case, the dosimeter is powered on by the reader. Some information related to the person that stored in the system's database will be checked out and transferred to dosimeter. For exit case, the measuring results of dosimeter will be sent to the database through the data reader.

1. 3 Main Specifications and Calibration

(a) Energy response

To meet the standard requirements, the detector of the dosimeter has been compensated for energy response. The energy response within 50 keV to 1.3 MeV is ≤±20% (relative to ^{137}Cs 662 keV). In calibration, the personal dosimeter was mounted on the slab water phantom and irradiated by narrow-spectrum X-rays with effective energy of 48, 65, 83, 100, 118, 161, 205 and 248 keV and by gamma rays of ^{137}Cs and ^{60}Co. The curve of the energy response is presented in Fig. 5.

(b) Angular response

With the same phantom like the energy response, the direction-related responses are shown in Fig. 6. The reference direction, zero degree, is appointed as the same direction that the incident ray is perpendicular to detector's active surface. Fig. 6 shows the energy response got with a 65 keV X-ray (the dot mark lines) and a 662 keV of ^{137}Cs gamma ray (the cross mark lines). Fig. 6 (a) and (b) present two different rotations of a dosimeter with a phantom. Fig. 6(a) shows a rotation in a horizontal section, while Fig. 6(b) in a vertical.

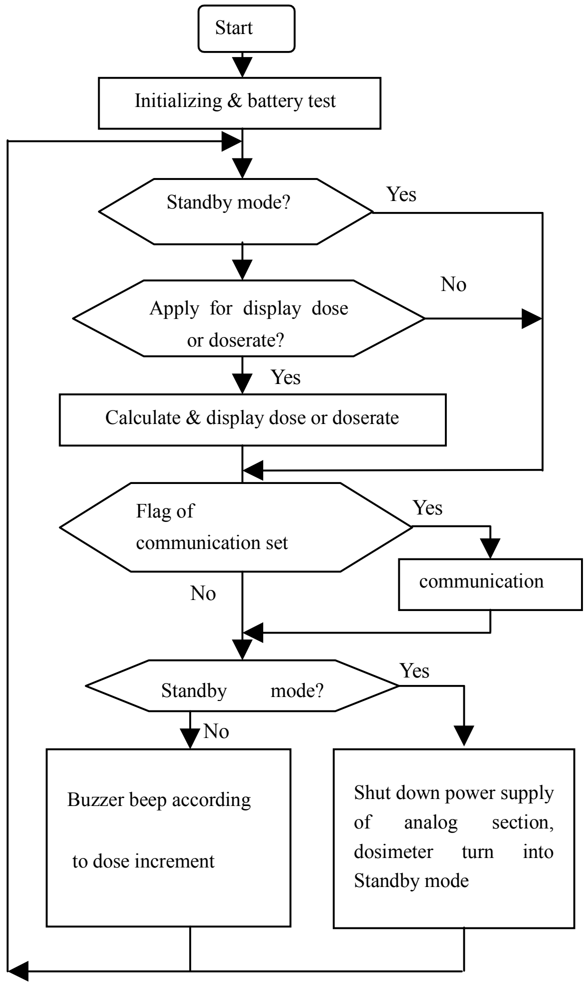
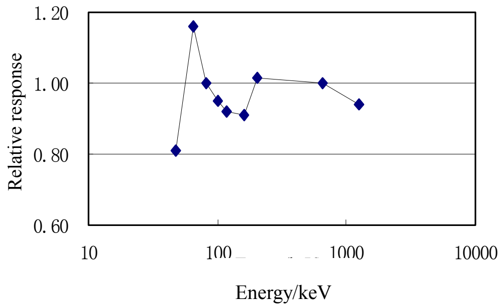


Fig. 4 The flowchart of main program

(c) Relative intrinsic error

The relative intrinsic errors of the dosimeter do not exceed ±10% over the whole effective measurement range. The measurement range of the accumulated dose is 0.1 ～10 Sv. The dose rate range is 1.0 μSv/h ～1 Sv/h. Fig. 7 presents the relative intrinsic errors of the dosimeter.



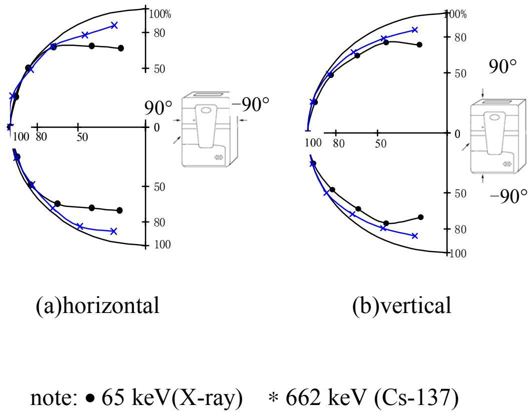


Fig. 5 Energy response

Fig. 6 Angular response

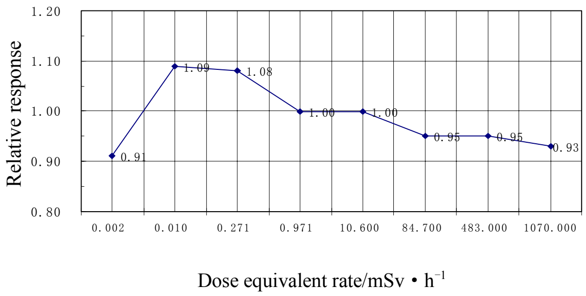


Fig. 7 Relative intrinsic errors

2 DATA READER

2. 1 Main Composition of the Reader Circuit

The reader circuit is constructed around a type of MCS-51micro-controller unit, 80C31. Its main frequency is given by a 6 MHz quartz oscillator. A 32 kB RAM is used for data memory and a 16 kB ROM for code memory. With a general-purpose interface, 82C55, the reader is extendible to connect a dot matrix character LCD, a 4×4 keypad, a beeper and several LEDs. A special infrared communication circuit was designed for data exchange with the dosimeters. The circuit frame of the reader is illustrated in Fig. 8.

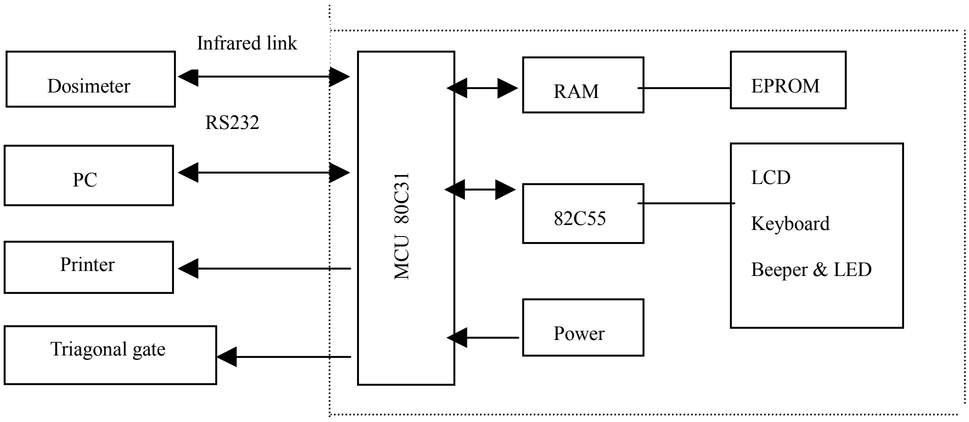


Fig. 8 Synoptic of the data reader circuit

2. 2 The Reader Code Design

The control code of the reader is designed in a MCS-51 assembly language. Main functions of the reader include data communication with dosimeter and computer, data process, data store and data print out. For activating other controllable equipment, such as a triagonal-gate or alarm devices, the reader can output trigger signal. If the data reader connected with the host computer, all of the data got from dosimeters will be transferred to the computer. If no computer linked, it will work in stand-alone, all data then will be stored in it or printed out by a connected printer.

To realize the communication with a dosimeter through a infrared link, a non-synchronic series transmission mode is used between the reader and the dosimeter. The signal's mod-and-demodulation is achieved by the MCU's code. Two carrier frequencies of 6 kHz and 12 kHz are used separately for binary data of "0" and "1". The Baud rate used in data transmission is 600 bps. Consequently, if a counting number is 10 in one second in a receiver, it is the meaning of that a binary "0" has been transmitted. If the counting number is 20, then "1" has been transmitted.

3 THE SYSTEM SOFTWARE

The software of the system has been programmed with Microsoft Visual Basic 5.0. A main communication form is shown in Fig. 9.

3. 1 Data Communication

For receiving or transferring data with a dosimeter, a data reader will be connected to the computer as an intelligent interface. The computer communication code was designed by means of a Microsoft Communications Controller. The Event-driven is a basic method for data exchange with other communication devices. During communication, the functions of OnComm and CommEvent are used to monitor and respond to various events and errors that may be encountered during a serial connection. By event-driven method connecting with other commands, data communication between the host computer and the data reader will automatically take place.

Fig. 9 Main operation form of the system operation

All of the data received by the host computer will be analyzed and verified before the data to be transferred to their database. The database refuses to be updated if some data are failure with a data validation. Table 1 shows a format of a primitive data table in a database.

Table 1 The primitive data table format

Number of records	Time/Date	Data content
Automatically occur, long integer, to be index	General type, Hh:mm:ss/dd-mm-yy	Text type, 90 characters

3. 2 Control Function for a Controlled Area

When someone wants to come into a radioactive controlled area, the system code will automatically check one's pertinent information and decide whether the person can be allowed or not. If someone is allowed for entry, the alarm thresholds for him will be transferred to his dosimeter. The entrance gate, like a triagonal gate, will be active and his dosimeter will be powered on.

Connecting with the Crystal Reports in the Visual Basic, the code has the function to cerate some tables, lists and paragraphs for statistics report. The work can be done by means of menu selection on a screen form. It includes summary of the personal dose equivalent in different period, collective dose statistics, dose rate distribution in time, and so on. Fig. 10 shows a chart of a personal accumulated dose equivalent distribution in one year.

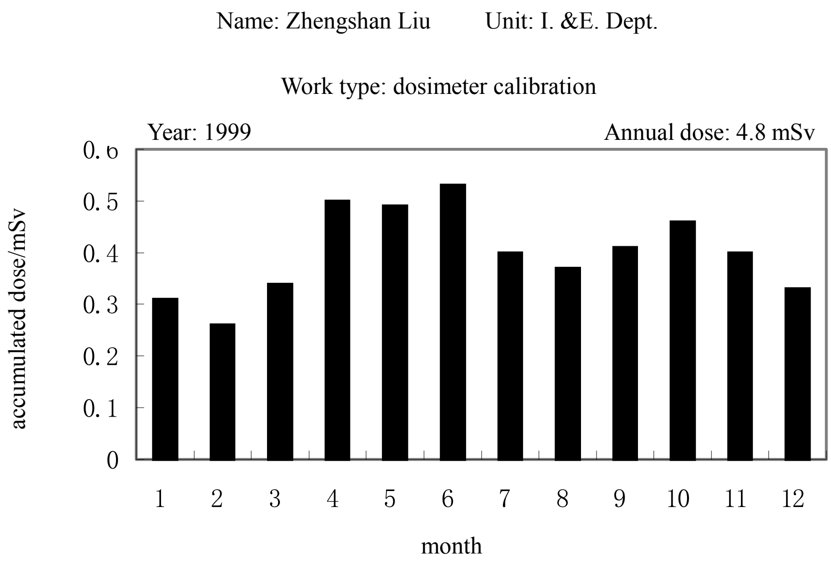


Fig. 10 Personal dose statistics for one year

3. 3 The System Database

The system database was designed by a relative database of Microsoft Access 97. The relative database software provides powerful tools for design a database, such as Data Manager, Data Control, Data Access Object (DAO), and so on. In our case, the database was formed with some data tables that includes primitive data table, classified data table, personal information table, dose and dose rate thresholds table, historical data table, inquiry data table, and so on. Table 2 shows a typical construction of a classified data table.

For safety use, the database has two different secret levels of password. The first level is authorized to inquire and/or edit the database. The second level is only allowed to inquire and review the database. But for any secret level, the primitive data table does not allow to edit.

Table 2 The classified data table format

Fields name	Data type	Fields size (byte)	Decimal digit	Index
Record No.	Auto format			Yes (no repeat)
Reader No.	Text	15		
In/out area	Text	15		
Dosimeter No.	Text	15		
Acc. Dose Equiv.	Dig	Single precision	2	
Max. Dose Rate	Dig.	Single precision	2	
Threshold of dose	Dig.	Single precision	2	
Threshold of D. Rate	Dig.	Single precision	2	
Person's No.	Text	15		Yes
Work No.	Text	15		
State of dosimeter	Dig	1		
Entry time	Date/time			Yes
Out time	Date/time			Yes
Work time	Dig.	Long integer	0	
Time of max. Rate occur	Dig.	Long integer	0	

4 CONCLUSION

The system is now operating on a host computer. For advance, it will be modified for running on a computer workstation. It is also needed to add some functions to the existing system.

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