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Program Design for Polymerase Chain Reaction System Besed on Fiber Bragg Gratings

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Abstract: Fiber bragg grating sensors, which are widely used in health monitor system as high-performance intelligent sensor, are an important tool for Polymerase Chain Reaction (PCR) system. The cycling reactions of the system include three major steps: Denaturation, Annealing and extension and the program design in this paper is focus on the application program in order to achieve precise temperature control, friendly user interface and extremely low-power operation. However, the most commonly measuring method using FBG to get the date effectively is to obtain the wavelength shift information at maximum reflectivity, according to the linear relationship between the wavelength shift and the temperature applied to the axis of the FBG. The inputting signals of thermo-block of the system are constructed with intelligent sensors from a block with 96 narrow tube positions and data storage of the system which are transmitted from Fiber Bragg Gratings is realized in the system. The successful operation is dependent upon its reliable operation under high-precise temperature operating conditions besed on Fiber Bragg Gratings. The experimental results demonstrate that the proposed method is stable and efficient.

Key words: Data storage, program design, polymerase chain reaction, fiber bragg gratings

INTRODUCTION

Fiber bragg grating sensors, which are widely used in health monitor system as high-performance intelligent sensor, are an important tool for polymerase chain reaction system (Aguilera *et al*., 2005). As an essential preliminary step, Polymerase Chain Reaction (PCR) is helping in the investigation and diagnosis of a growing number of diseases (Hansen and Nussbaum, 1996). Hill found the photosensitivity of optical fiber in 1978 and manufactured the world's First Fiber Bragg Grating (FBG). Polymerase chain reaction system is a real-time control system (Higuchi *et al*., 1992), with an emphasis on reacting to precise temperature control, friendly user interface and extremely low-power operation (Mullis, 1990). The cycling reactions include three major steps (Markham, 1993): Denaturation, Annealing and extension. After about 30 cycles, billions of copies of a single piece of DNA can be produced (Mullis and Faloona, 1987).

The program design in the Polymerase chain reaction system is a set of subsystems or components that are included as-needed in applications (Takhistov, 2001). The purpose of software design is to describe the design and the architecture of the system (Robert, 1995). The most commonly measuring method using FBG to get the date effectively is to obtain the wavelength shift information at maximum reflectivity, (Naber, 1994) according to a good linear relationship between the wavelength shift and the temperature applied to the axis of the FBG. The inputting signals of thermo-block of the system are constructed with intelligent sensors from a block with 96 narrow tube positions.

Design of key board interface and LCD display: The keyboard of the system is connected to a control model through a serial interface similar to the COM port. When a key is pressed, the keyboard sends a scanning code for that key to control model and when the pressed key is released, the keyboard sends a key-code to the control model. As the complexity and functionality of the system continues to grow, in order to reduce cycle time and system cost, LCD module in this system is based around the 16 bit CPU. It consists of the four components:

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Table 1: Main manue function

Index	Descriptions Item	Functions
1	Start	Select a program to select an user application
2	Edit	Edit a program
3	New	Create a new user, or new program
4	Setting	Set the parameters

Backlight module, polarizer module and glass substrate and thin film transistor ,The standard resolution of LCD monitor panel is 320×240.At power on, the initialisation screen identifying the LCD unit will be displayed. The first menu to be displayed is the Main Menu through which all aspects of the programming are accessed. The summary of the main Menu functions is as Table 1.

Main menu functions: Architecture of data in memery: a record in the memery is a character sequence.The configuration of the record includes ID and counter, ID denotes the user identification and counter is the numbers of user program. The programs of a user includes P-ID and Length, P-ID denotes the identification of the program and the Length is the numbers of the codes.

Design of data acquisition: The system is architected with several modules, such as the User-machine interface module (UI), Control Module (CM), Storage schedule module (SS), USB module (US) and Program System (PS). Figure 1 shows the architecture. The hardware of temperature control of PCR includes several chips or modules, such as Cnl-1, Cnl-2 and CNl-3, converters, amplifiers, executers and so on.

There are three channels to be controlled; the process of temperature control is with several inputs and an output that is to be controlled for every channel, the block diagram of a control system is as shown in the follow equivalent. The equivalent Laplace domain Eq. is:

$$Y(s) = [G_c(s)*R(s)* E(s)+G_e(s)*X_e(s)+G_1(s)*X_1(s)]*G_0(s) \quad (1)$$

Where, Xe(s) □ is a environment disturbance temperature, X1(s) is a outside disturbance R(s) is the inputting set-point, E(s)is the execution coefficient of CM, P(s) is the executer and Y(s) is the inputting data scanned by the FBG and the output of the CM.

The method can not identify the strain according to the shift of wavelength at maximum reflectivity when a bigger strain gradient occurs in the FBG sensor area. Thus, it has become a widespread concern:

$$\Delta\lambda_B(t) = \alpha_T \bullet \Delta T(t) \quad (2)$$

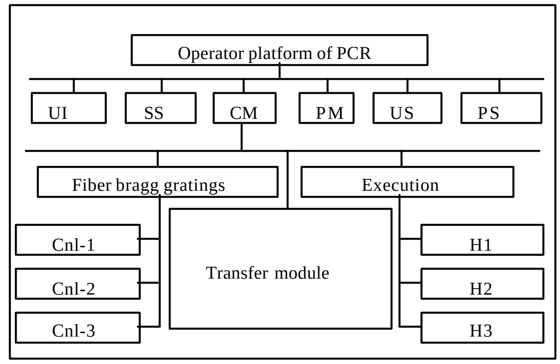

Fig. 1: Architecture of PCR system

Where:

$$\alpha_T = k_T \bullet \lambda_B$$

In the process of PCR, α_T Is a function of temperature,the fiber λ_B is constantly changing according to the DNA samples.Central reflection wavelength of the optical fiber λ_B is typically 1200 nm, temperature sensitivity coefficient kT is 7.5×10-6/C. Equation 2 is a linear relationship between the temperature, but the temperature change is large, the spatial resolution for parameter t is between 0-9.88. The present invention uses a conventional module unit 96 as shown in Fig. 2 and 3 and data control unit is arranged in three columns of sensors.

Specification of program: In the User-machine interface module, program commands The specification of the interface codes is as Table 2. All the commands of the current program should be implemented into the interface before the program running. The sentences of program includes Index, Command Type, Former Command, Next Command, Parameters and so on.

In the process of a program, the interaction between modules is bidirectional: Commands are invocations from the interface model to both the executer and the display unit.The transfer module must implement the sense data, which represents results of the implementation through Fiber Bragg Gratings. If the data is out of the range, the Control Module (CM)will throw out the data and call the Error diagnostic function, Executer must implement the sense-data. For example, in the every cooling stage of a circle in temperature controlling, the influence of interference is bigger, suppose first point T1 is 95°C and second point T2 is 55°C, at the end of the cooling

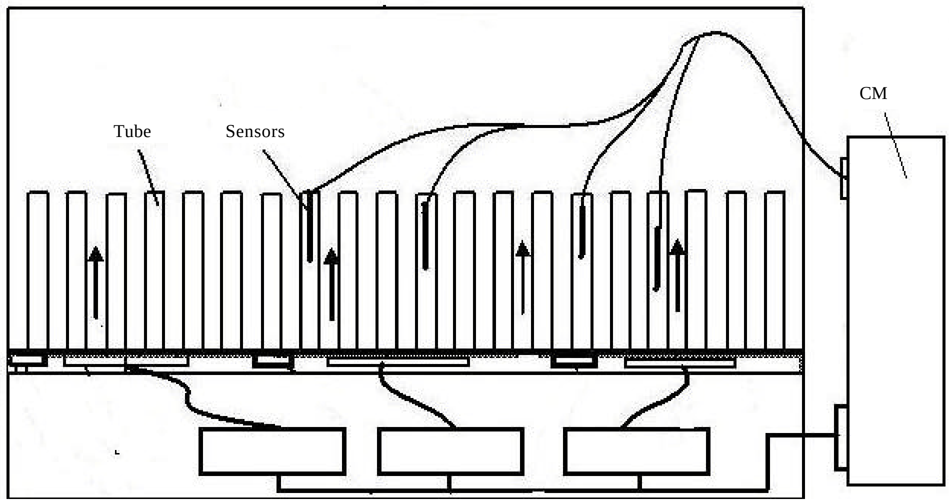

Fig. 2: Architecture of CM

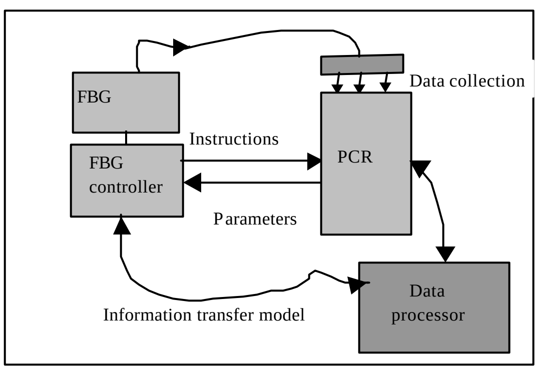

Fig. 3: Diagram of experimental testing system

procedure (such as from 95 to 55°C), the inner radiator temperature changes from 38 to 44°C, control works in the first half stage of the T2. However, if the temperature of inner radiator becomes smaller, less a given value in the later stage of T2, the control program stops.

Experimental data: As we know, PCR is to copy DNA. It uses repeated numbers of cycles, each of which consists of three steps, such as Denaturation, Annealing and Extension. Each step has its special temperature. For example, 94°C is for Denaturation step, 44°C is for Annealing step and 72°C is for Extension step. For every step, the set-point may be 94, 44 and 72°C or other data according to the programmed data code.

Based on the user program, the control software is the combination set. There are two dead-bands in the temperature control in PCR:

Table 2: Program

Items	Descriptions
Index	The index number for the command
Command type	Current command
Former command	The command before current command
Next command	The next command
Parameters of the command	The data of the current command, such as temperature, time, temperature increment
Parameters of the next command	Data of the next command, such as temperature, time, temperature increment
The remain time	Possible with temperature command and hold command only
Stage	The stage of the heating, cooling or holding
Circles	Describe the implementation times of the command
Actual data	Three-channel temperature data which sampled by FBG
Range of data	The range of the related data

- One is the dead-band of the set-point and it is a switch that stops on-off controller and starts the p-controller. The dead-band is different between the block mode and the tube mode in PCR. The other is the dead-band of the PID controller. It is used in PID control procedure

For every step of a PCR circle, an on-off controller may be used first in the heating or cooling procedure in a step. It simply switches the controller output only when the current temperature crosses the dead-band of the set-point. For instance, the controller output is on when the current temperature is below the dead-band of the set-point and off above the dead-band. Since the temperature crosses the dead-band to change the output state, the temperature will be cycling from below the dead-band to above and back below. In cases where this cycling occurs rapidly, an on-off plus p-mode is added to the controller operations.

If the error between the set-point and the outputting temperature is outside the dead-band of PID, the Bang-bang control begins, otherwise, the combination between the PID control and the Feed-forward control will be used in the special case that the outside interference exceeds a given value. If the influence of the outside is less the given value, the Feed-forward control does not work and in this case, the adaptive PID control starts.

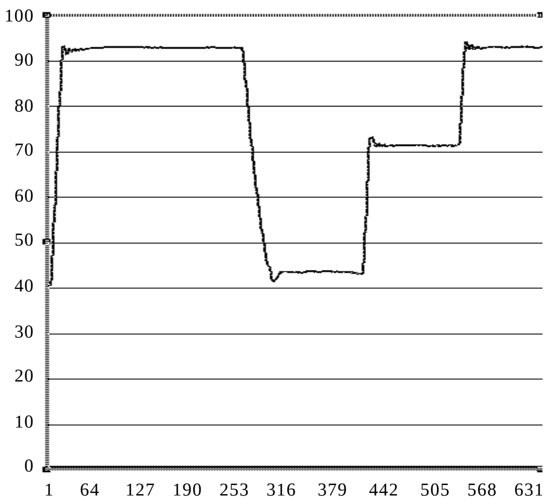

Fig. 4: Temperature profile obtained in our system

EXPERIMENTAL RESULTS

Temperature profile obtained in our system is shown in Fig. 4 and 5. In Fig. 4, the one circle is made with the block mode, where, the denaturation is 94°C, elongation is 72°C and the initial annealing is 44°C. From the testing data, the system is stable and efficient and the time taken for the temperature circle is short.

CONCLUSION

In this study, we describe our software designs that we used in our temperature control system. The inputting signals are constructed with Fiber Bragg Gratings. The experimental results demonstrate that the method is stable. Based on the FBG, the user program are discussed. The implementation for the system maintains a high reliability and flexibility. The results are measured by Driftcon instrument.

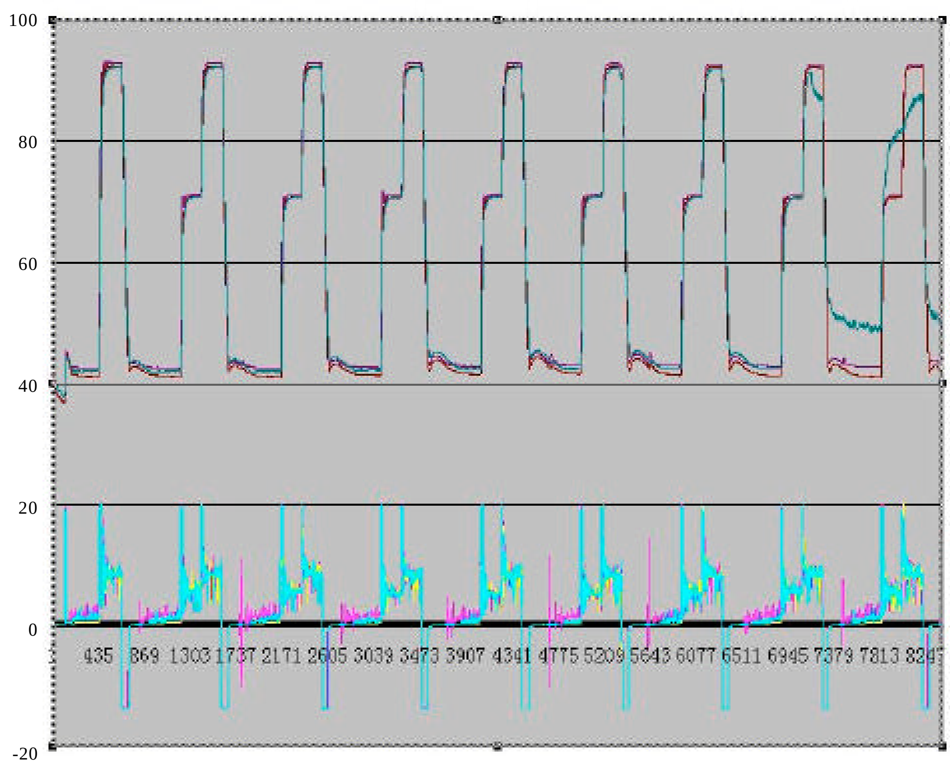

Fig. 5: Temperature profile with system voltage

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