Temperature Measurement & Control of Biomedical Analyzers

Anju Varghese P, Divya Unni

Department of Electronics, Vidya Academy of Science and Technology, Thrissur, Kerala, India

***Abstract*—Temperature measurement describes the process of measuring a current local temperature for immediate or later evaluation. The clinical laboratory environment uses temperature to maintain stability of testing samples. So the laboratory environment, analytical reactions, instrumentation and materials must be monitored and controlled to required temperatures. Clinical laboratories need to measure a range of physical parameters, among them humidity, pressure, and air flow. But paramount is temperature. It is the basic building block of most analytical measurements. Most test systems used for in vitro tests are of biological origin. In vitro tests are performed with microorganisms, cells, or biological molecules outside their normal biological context. They are usually highly sensitive, so their control conditions (such as incubator temperatures) are very important. Physical properties can also change as temperatures vary. The stability of reagents kept at room temperature decreases if the temperature exceeds about 350°C. Under atmospheric pressure, aqueous liquid viscosity decreases with increasing temperature, generally by about 2% per 0°C. This module is used for maintaining specific temperatures for different biomedical tests.Temperature is measured using thermistor and it is controlled by applying PID Algorithm. They are usually employed in instrumentation and measurements below about 2000°C because of their smaller size, smaller thermal mass, and reasonable response time.**

***Index Terms*—PID Algorithm, Thermistor, Incubator Temperature**

I. Introduction

Temperature control is a process of changing the temperature of a sample, and the heat energy is passed into or out of the space to achieve a desired temperature. A temperature sensor constantly checks the room temperature and controls the current temperature using a heater or air conditioner to increase or decrease the temperature according to the settings. A thermostat makes the heater or air conditioner on or off. It varies the amount of heating or cooling given by the heater or cooler, depending on the difference between the desired temperature and the original temperature. This is Proportional control. Other methods using the integrated error signal and the rate for which the error is changing (Derivative) are used to form complex PID Controllers which is usually seen in the industry. When heat energy moves into a object,it's temperature increases and the kinetic energy of its atoms also increases. Temperature lowers when heat energy leaves an object. Heat flows by three different processes: conduction, convection and radiation. In conduction, the heat energy is passed from one atom to another by direct contact. In convection, heat energy passes by conduction into fluid and the fluid moves which carries heat with it. At some point the heat energy of the fluid is usually transferred to other object by means of conduction. In radiation, the heated atoms make electromagnetic emissions taken by other atoms, whether nearby or at long distance. For example, the Sun radiates heat as both visible and invisible electromagnetic radiations. Light is a small portion of the electromagnetic spectrum.

The temperature increases if more energy is received than is lost. If the amount of energy received and going out are same, the temperature remains as constant. There is thermal balance, or thermal equilibrium.

Factors involving in thermal control systems are

- Interaction with the environment.
- Collection of heat.

It removes the dissipated heat from the equipment which is created to prevent unwanted increases in the temperature.

- Transportation of heat

It takes heat from where it is created to a radiating device.

- Rejection of heat.

The heat collected and transported has to be rejected to a heat sink. It depends on the amount of heat in the system, the temperature to be controlled and the temperature of the environment.

- Provision and storage of heat.

It maintains a desired temperature level and suitable heat storage capacity.

The main factors in the design of the thermal control system are the temperature requirements of the instruments and equipment on board.

II. Proposed ARCHITECTURE

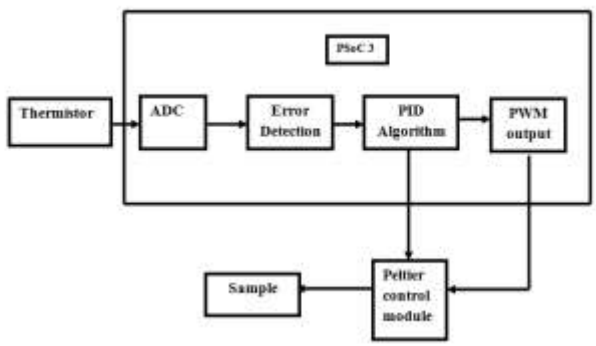

Fig. 1.Block diagram

This system consists of three parts - Temperature measuring part, sensing part and controlling part. The sample's temperature is measured by using a thermistor. It is a resistance thermometer, or a resistor whose resistance is dependent on temperature. The measured temperature is given to the PSoC controller. The measured temperature value is in analog form. It can be converted to digital value using ADC. The required temperature is set as a threshold value. And hence the error is calculated. The measured error is corrected using PID algorithm. The value from PID module is given to the PWM module. The temperature is controlled by peltier control module.

Measuring Part

Temperature of the sample is measured by using thermistor. A thermistor is a type of resistor whose resistance is dependent on temperature. Thermistors are different from resistance temperature detectors (RTDs) because the material used in a thermistor is a ceramic or polymer. RTDs are pure metals. RTDs are useful over wider temperature ranges. thermistors has large precision within a limited temperature range, from −90 °C to 130 °C.

Sensing Part

The difference between the measured value and the threshold value gives error in the system. This error is calculated and corrected by using PID algorithm. Proportional-integral-derivative (PID) controller is a commonly used control algorithm for many real-time control applications. FPGA based PID controller is one of the effective controller. A PID controller is a control loop feedback mechanism. It is used in industrial control systems and other applications. A PID controller finds the error value which is the difference between a desired set point and a measured value and it applies a correction based on proportional, integral, and derivative terms.

Controlling Part

The temperature is controlled by using peltier effect. Seeback effect is a condition in which the temperature difference causes the diffusion of electrons from the hot side to the cold side of a conductor. An electric current is generated by the motion of electrons. The Peltier effect is caused by semiconductor Peltiers which produce large thermal gradients. peltier cooler is a thermoelectric heat pumps which produce a temperature gradient that is proportional to an applied current.

III. HARDWARE COMPOSITION

The controller used in this system is the PSoC3 controller. The hardware components in this system are

- *Micro Processor*

PSoC is a true programmable System on Chip contains configurable analog and digital peripheral functions. It also contains a microcontroller and memory on a single chip. These chips contains a CPU core and several arrays of integrated analog and digital peripherals. A core, configurable analog and digital blocks, and programmable interconnect are included in a PSoC integrated circuit. The biggest difference of PSoC from other microcontrollers are the configurable blocks.PSoC 3 is a redesign kit of development tool chain. The analog blocks can be redesigned to achieve better performance and handling. PSoC 3 has 8051 core.

PSoC has three types of input output system as general purpose input output (GPIO), serial input output (SIO) and universal serial bus input output (USBIO). Here any GPIO can be connected to any peripheral routing. Any bus or path is wakeup on analog, digital or I2C match. In PSoC programmable slew rate reduces power and noise by using 8 different configurable drive modes. PSoC provide programmable input threshold capacity.

8051 specific SFR registers are present. The access port data registers through SFRs. External Data space (XDATA) is of 16 MB. Where upto 8 KB of SRAM on lead devices, all PSoC peripheral and configuration registers, EEPROM, flash memory and external memory interface (EMIF) are easily connect to PSoC kit.

PSoC is similar to an ASIC: blocks has a large range of functions and interconnected on-chip. No special manufacturing process is required to create the custom configuration.

PSoC is similar to an FPGA. In FPGA it must be configured at power up, but this configuration occurs by loading instructions from the built-in Flash memory.

PSoC is most closely similar to a microcontroller combined with a PLD. To interact with the user-specified peripheral functions (called "Components")code is executed, using automatically generated APIs. PSoC Creator generates the startup configuration code. Using configurable analog and digital blocks, designers can produce embedded applications. PSoC creator will create and connect components automatically. Digital signal interconnect (DSI) routing allows any function in the UDBs to communicate with other on-chip function or general purpose input output (GPIO) pin with 8- to 32-bit data buses.

PSoC has three types of input output system as general purpose input output, serial input output and universal serial bus input output. Any GPIO can be connected to any peripheral routing. In PSoC slew rate reduces power and noise by different configurable drive modes. PSoC provides programmable input threshold capability for SIO also auto and custom/lock-able routing is present in PSoC creator.

Analog blocks are of two types. Some chips of PSoC present with lots or less analog systems. The PSoC3/5 architecture has a huge portfolio of analog IP. Exact configuration depends on the product family. PSoC provide flexible routing to all GPIO which are analog input/output, delta-sigma ADC up to 20-bit resolution. PSoC creator

PSoC Creator is the second generation software IDE to design, debug and program the PSoC 3 / 4 / 5 devices. PSoC Creator consists of two basic building blocks. Cypress publishes component packs several times a year. PSoC Creator also allows much freedom in assignment of peripherals to I/O pins.

- *Thermistor*

Thermistor is a type of temperature sensor. The resistance of the thermistor is changed with the change in temperature (like RTD). Thermistors are made from manganese and oxides of nickel, which make them susceptible to damages. So, these materials are called ceramic materials. This thermistor offers higher sensitivity than the resistor temperature detectors. Most of the thermistors have a negative temperature coefficient. So when the temperature increases the resistance decreases.

A thermometer is a device used to measure the temperature of solids, liquids, or gases. Thermometer is a combination of thermo – means heat, and meter means to measure.

The thermometer has a calibrated scale to indicate the temperature. The temperature can be recorded in these scales: Fahrenheit, Kelvin or Celsius.

- *ADC*

In electronics, an analog-to-digital converter (ADC, A/D, or A-to-D) is a system that converts an analog signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal. An ADC may also provide an isolated measurement such as an electronic device that converts an input analog voltage or current to a digital number proportional to the magnitude of the voltage or current.

Typically the digital output is a two's complement binary number that is proportional to the input, but there are other possibilities.

There are several ADC architectures. Due to the complexity and the need for precisely matched components, all but the most specialized ADCs are implemented as integrated circuits (ICs).

A digital-to-analog converter (DAC) performs the reverse function; it converts a digital signal into an analog signal. The conversion involves quantization of the input, so it necessarily introduces a small amount of error. Furthermore, instead of continuously performing the conversion, an ADC does the conversion periodically, sampling the input. The result is a sequence of digital values that have been converted from a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal.

An ADC is defined by its bandwidth and its signal-to-noise ratio. The bandwidth of an ADC is characterized primarily by its sampling rate. The dynamic range of an ADC is influenced by many factors, including the resolution, linearity and accuracy (how well the quantization levels match the true analog signal), aliasing and jitter. The dynamic range of an ADC is often summarized in terms of its effective number of bits (ENOB), the number of bits of each measure it returns that are on average not noise. An ideal ADC has an ENOB equal to its resolution. ADCs are chosen to match the bandwidth and required signal-to-noise ratio of the signal to be quantized. If an ADC operates at a sampling rate greater than twice the bandwidth of the signal, then perfect reconstruction is possible given an ideal ADC and neglecting quantization error. The presence of quantization error limits the dynamic range of even an ideal ADC. However, if the dynamic range of the ADC exceeds that of the input signal, its effects may be neglected resulting in an essentially perfect digital representation of the input signal.

- *PID Algorithm*

A proportional–integral–derivative controller (PID controller)is a control loop feedback mechanism.As the name suggests, PID algorithm consists of three basiccoefficients: proportional, integral and derivative which arevaried to get optimal response. The entire idea of this algorithm revolves around manipulating the error. The erroras is evident is the difference between the Process Variable and the Setpoint.

ERROR = PV – SP

These 3 modes are used in different combinations:

- P – Sometimes used
- PI - Most often used
- PID – Sometimes used
- PD – Very rare, useful for controlling servomotors.

In Proportional Only mode, thecontroller simply multiplies the error by the Proportional Gain (Kp) to get the controller output.The Proportional Gain is thesetting that we tune to get ourdesired performance from a “Ponly” controller.The proportionality constant usedfor P-Control is KP. The proportional corrects instances of error, the integral corrects accumulation oferror, and the derivative corrects present error versus error the last time it waschecked.The effect of the derivative is to counteract the overshoot caused by P and I.When the error is large, the P and the I will push the controller output. Thiscontroller response makes error change quickly, which in turn causes thederivative to more aggressively counteract the P and the I.

- *PWM*

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial[definition needed] loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being maximum power point tracking.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. The rate (or frequency) at which the power supply must switch can vary greatly depending on load and application, for example

Switching has to be done several times a minute in an electric stove; 120 Hz in a lamp dimmer; between a few kilohertz (kHz) and tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100 being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

- *Peltier module*

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers.

IV. DESIGN OF THE SOFTWARE FOR THE CONTROL SYSTEM

Verilog is used in this system. Verilog is a hardware description language. It is used to model electronic systems. It is most commonly used in the design and verification of digital circuits at the register-transfer level of abstraction. It is also used in the verification of analog circuits and mixed-signal circuits, as well as in the design of genetic circuits. A Verilog design consists of a hierarchy of modules. Modules encapsulate design hierarchy, and communicate with other modules through a set of declared input, output, and bidirectional ports. Internally, a module can contain any combination of the following: net/variable declarations (wire, reg, integer, etc.), concurrent and sequential statement blocks, and instances of other modules (sub-hierarchies). Sequential statements are placed inside a begin/end block and executed in sequential order within the block. However, the blocks themselves are executed concurrently, making Verilog a dataflow language.Verilog's concept of 'wire' consists of both signal values (4-state: "1, 0, floating, undefined") and signal strengths (strong, weak, etc.). This system allows abstract modeling of shared signal lines, where multiple sources drive a common net. When a wire has multiple drivers, the wire's (readable) value is resolved by a function of the source drivers and their strengths.

V. CONCLUSION

This paper presents the method for measuring and controlling the temperature of the sample..PSoC controller is used in thismodule which supports both C and Verilog programming. Verilog shows more advantage overC because of their parallel execution property. This provides more efficiency, less memory and reduced time consumption for the system.

ACKNOWLEDGMENT

We would like to show our gratitude towards Dr. Sudha Balagopalan, Principal, Vidya Academy of Science and Technology for giving us sole co-operation and encouragement. We thank Dr. S. Swapna Kumar, HOD for assistance and Sruthi. M, Co-ordinator for the comments that greatly improved the manuscript. We thank our colleagues who provide insight and expertise that greatly assisted the project work.

REFERENCES

[1] Miguel Cabello, Carmen Aracil, Francisco Perdigones and José M. Quero,"Conditioning Lab on PCB to Control Temperature and Mix Fluids at the Microscale for Biomedical Applications", IEEE.

[2] ShumitSaha, Md. Jahiruzzaman, ChandanSaha, Md. Rubel Hosen, Atiq Mahmud,(2015) "FPGA Implementation of Modified Type-C

PID Control System",2nd Int'l Conf. on Electrical Engineering and Information & Communication Technology (ICEEICT).

[3] Prabhjot Kauri and Lini Mathew (2012),"Design and Development of a Graphical UserInterface for Real Time Monitoring and Analysis of Vital Human Body Parameters",.

[4] Rohan Srivastava, Bhavanesh Kumar and Yogesh K. Chauhan(2013)," Generation Of PWM Using Verilog In FPGA" International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) - 2016.

[5] Zsolt Albert Barabas, and Alexandru Morar (2014),High Performance Microstepping Driver System based on Five-phase Stepper Motor (sine wave drive),The 7th International Conference Interdisciplinarity in Engineering, , Vol. 12, PP.90-97.

[6] Mrs. Urmila Meshram (Thulkar) Mr. PankajBande Mr. P. A. Dwaramwar and Mrs. R. R. Harkare(2009), "Robot Arm Controller using FPGA",IEEE .