HEAT PUMP DESIGN USING PELTIER ELEMENT FOR TEMPERATURE CONTROL OF THE FLOW CELL

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ABSTRACT

In biochemistry analyzer the temperature play crucial role as many of the health parameters are tested at precise temperature. In automated bio-chemistry analyzer, precise temperature control is achieved by using the peltier device as heat pump and PID control action. The temperature is measured at the flow cell using the LM-35 temperature sensor and set point temperature is set by using the PWM output of a microcontroller employed for the control action. In the presented work, the temperature control is achieved at an accuracy of ±0.1 ^{0}C by controlling the design parameters of the heat pump circuit. Further, besides controlling the temperature at desired set point, the temperature achieving rate has to made as fast as possible. This is made by using an enhanced current source by suitable designing the peltier driving circuit.

KEYWORDS

PWM → Pulse width modulation, PID→ Proportional integral Differential, Peltier device, SPT→ Set point temperature, Heat pump, Peltier effect, Biochemistry analyzer.

1. INTRODUCTION

In all thermal processes, maintain the certain temperature is the main requirement. In presented work the fast thermal response is achieved by using the peltier element. Peltier element works on the principal of Peltier Effect. It states that the passage of an electric current through the junction of two dissimilar wires can either cool or heat the junction depending on the direction of current. Heat generation or absorption rates are proportional to the magnitude of the current and also the temperature of the junction. In this presented work, Set Point Temperature is achieved by using the PWM output micro-controller followed by low pass filter. Temperature is measured at flow cell using LM-35 temperature sensor. The set point voltage so obtained as above is compared with the current temperature (CT) and an error signal is generated by using an operational amplifier circuit and sends to PID algorithm to take up the necessary action. Moreover, controlling the temperature at desired set point, the temperature achieving rate has to made as fast as possible. This is made by using an enhanced current source by suitable designing the peltier driving circuit.

2. SYSTEM DESCRIPTION

Proposed system comprises of various modules, these modules are explained with the help of figure 1 and detail of modules is given below:

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2.1. Microcontroller unit

The NXP P89C51RD2 is an Generic 8051 Compatible High-speed Microcontroller, having 16-bit Timer/Counters, 256 Bytes Scratch Pad RAM, 9 Interrupt Sources with 4 Priority Levels Integrated Power Monitor, ISP (In-System Programming) 64K Flash on-chip, 1792 bytes on-chip XRAM, Dual Data Pointer, Serial Peripheral Interface bus, 16-bit Program counter array, Pulse width modulation, Universal Asynchronous Receiver/Transmitter, watchdog timer.

2.2. Pulse width modulation

A Pulse Width Modulation (PWM) module in addition with a low pass filter circuit can produce different analogue voltages. In the proposed work, this analogue voltage is used to give set point temperature voltage. A PWM of frequency, FPWM = 1 KHz is generated using a microcontroller Input/output port pin as shown in fig. 1. A low pass filter circuit of frequency FLP = 5 KHz, using R = 1K and C = 1μF, gives a good quality set point temperature voltage.

2.3. Heat Pump

A heat pump is a device that transfers heat energy from a heat source to a heat sink against a temperature gradient. Heat pumps are designed to move thermal energy opposite the direction of spontaneous heat flow. A heat pump uses some amount of external high-grade energy to accomplish the desired transfer of thermal energy from heat source to heat sink. While compressor-driven air conditioners and freezers are familiar examples of heat pumps.

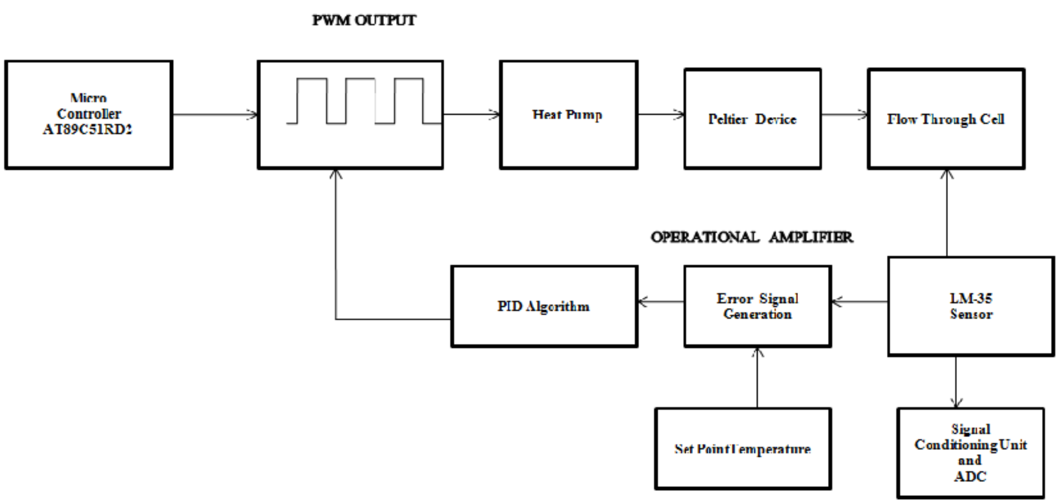

Figure 1. Block diagram of the presented work

2.4. Principle of operation

The basic principal of the proposed system is based on reverse of see-back effect and is known as Peltier effect. A pettier element consists of a heat conducting material along with two wires, if the flow of current is reversed through the wires, then the sides of the peltier device show the reverse temperature effect. Peltier device is shown in figure 2.
Peltier elements have following features;

It is in solid state; Need no maintenance, long service life-time.

Peltier element has applications in deep space probes, microprocessor cooling, laser diode temperature stabilization, temperature regulated flight suits and air conditioning in submarines, Portable DC refrigerators, and automotive seat cooling/heating.

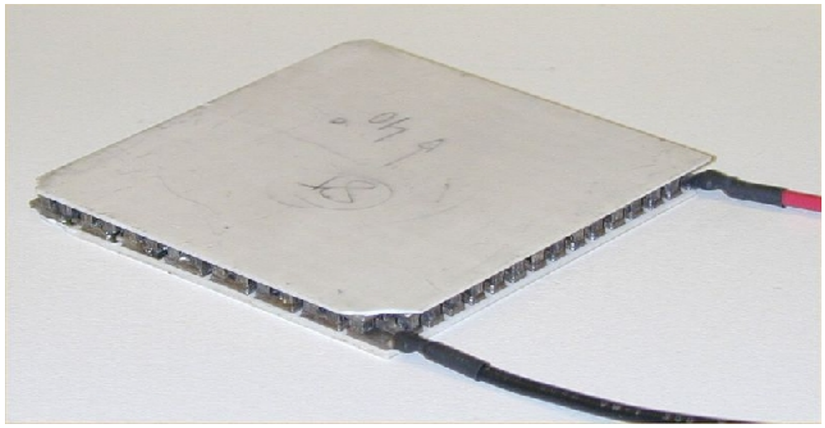

Figure 2. Peltier device

2.5. Temperature measurement

Temperature at flow through cell is measured using LM-35 temperature sensor. It gives 10 mv per degree centigrade change of temperature. The analog output of LM-35 is also given to Operational amplifier to compare the same with Set point. The error signal is generated thereafter and sends to PID algorithm to take up the necessary action, shown in figure 3.

2.6. Proportional integral derivative (PID) controller

The proportional integral derivative controller is used to control temperature of the system. The PID control is comprised of three terms proportional, integral, and derivative. These terms are summed to calculate the output of the PID controller. Defining U (t) as the controller output, the final form of the PID algorithm is:

$$\mathrm{u}(t) = \mathrm{MV}(t) = K_p c(t) + K_i \int_0^t c(\tau)\,d\tau + K_d \frac{d}{dt} c(t)$$

Where, Kp: Proportional gain, a tuning parameter, Ki: Integral gain, a tuning parameter, Kd: Derivative gain, a tuning parameter. Error =Set point temperature – current temperature, t=instantaneous time (the present), T: Variable of integration; takes on values from time 0 to the present t.

3. FLOW DIAGRAM OF THE SYSTEM

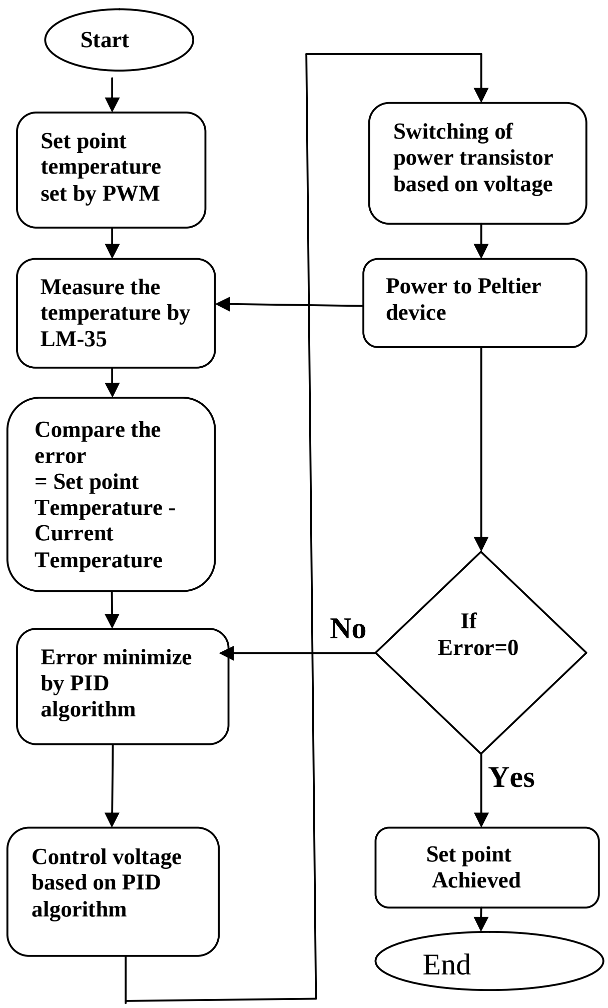

Figure 3. Flow chart of the presented work

4. RESULTS

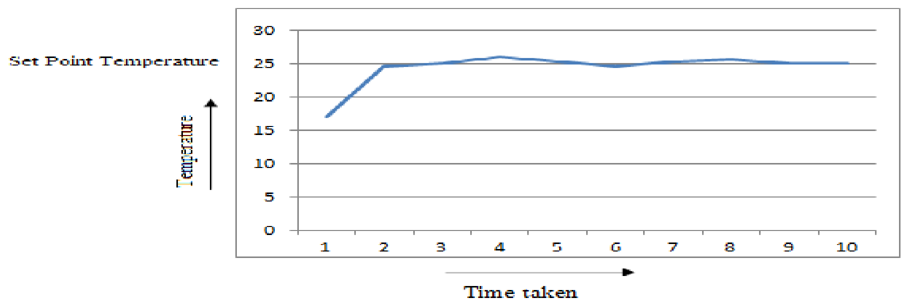

Figure4: Set point temperature for 25°C output

Table1: shows the result of the graph drawn between temperature and time taken

Serial no.	Set Point Temperature	Current Temperature	Control Temperature	Time Taken
1	25°C	24°C	25.1°C	2 sec
2	25°C	30°C	24.9 °C	3 sec
3	25°C	40°C	25.2 °C	5 sec

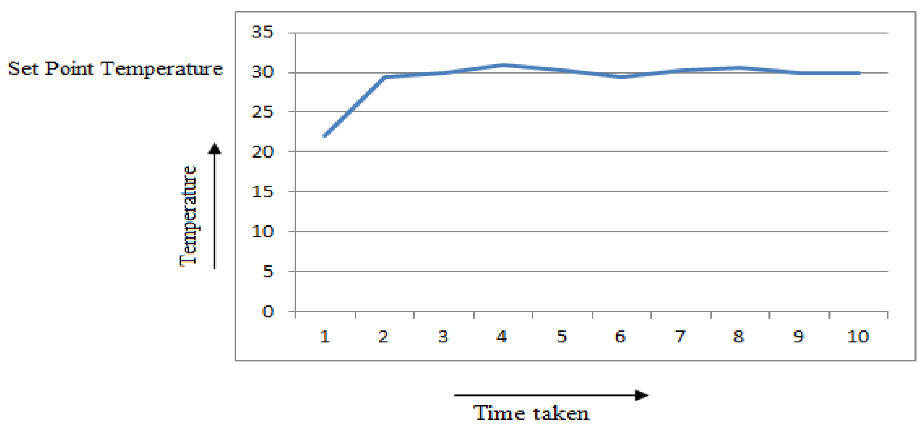

Figure 5: set point temperature for 30°C

Table2. Illustrates the results of the temperature and time

Serial no.	Set Point Temperature	Current Temperature	Control Temperature	Time Taken
1	30 °C	25°C	30.01 °C	2 sec
2	30°C	27°C	30.2 °C	1 sec
3	30°C	40°C	29.7 °C	3 sec

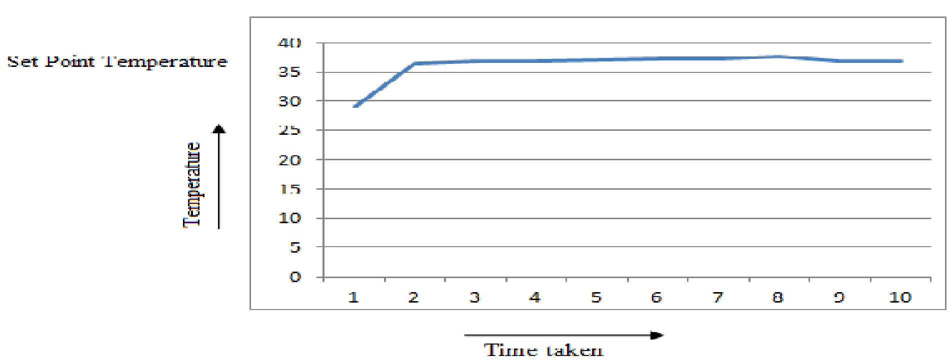

Figure 6: Figure for set point temperature at 37°C

Table3. Depicts the results of the temperature and time

Serial no.	Set Point Temperature	Current Temperature	Control Temperature	Time Taken
1	37 °C	25°C	37.1 °C	5 sec
2	37°C	30°C	36.9 °C	3 sec
3	37°C	41°C	37.2 °C	2 sec

5. CONCLUSION

The presented system has been tested in prototype model of fully automated bio-chemistry analyzer at C-DAC, Mohali. Attainability of the temperature within the required time limit has been achieved to appreciable limit. The main task is only to achieve the temperature within the permitted time period and it can further be improved by using peltier device of high current rating if available in the required mechanical system design size. However, there is a trade-off between the fast response and the current requirement. If fast response is desired, high current source will be used and vice versa.

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