

Design of PID Control System Assisted using LabVIEW in Biomedical Application

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Abstract – *Temperature variation of modern incubator produced inaccuracy and aging. This causes problem in maintaining temperature at a required level. Thus, overheating will damaging and interrupt data under measured. In order to maintain the temperature at a require level, an economical and reliable of a Proportional, Integral and Derivative (PID) acquisition control system assisted using LabVIEW has been developed. The PID acquisition control system uses feedback from the temperature sensor to calculate and vary converted voltage to heat a heating element at a required level. Results show that, the PID acquisition control system able to control the temperature at the required level of 38 °C. Copyright © 2015 Penerbit Akademia Baru - All rights reserved.*

Keywords: Temperature, Control system, Proportional, Integral, Derivative, LabView

1.0 INTRODUCTION

Studies have proven that temperature variation may cause inaccuracy and aging which result to problem in controlling temperature at a required level. For an example to therapy a jaundice patient, the incubator temperature should be maintained between 37 °C and 38 °C. Mortality is seen if the temperature drops below 35.6 °C or rises above 39.4 °C for a number of hours. Thus, overheating is more critical than under heating. In order to promote a complex system yet provide simplicity effect on control strategies, one must use a high level programming language. One of the generic control strategies is the Proportional, Integral and Derivative (PID) control algorithm. The PID controller represents the ultimate in control of a continuous process for which a specific mathematical description such as Transfer Function (TF) cannot be written [2]. The usage of PID control algorithm is much easier and less error prone compare to other programming languages [6]. An excellent representative of high level languages is LabVIEW programming. The major advantage of LabVIEW over conventional high level languages is the Graphical User Interfacing (GUI), which is built-in, intuitive in operation and simple to apply [1]. Moreover, it is easy to apply and modify, in other words it is user friendly. Therefore, a system that is economical and reliable of a PID acquisition control system assisted using LabVIEW 8.1 of National Instruments for incubator to control the temperature at the required level between 37 °C – 38 °C has been developed.

2.0 METHODOLOGY

This paper highlight the development of a PID acquisition control system assisted using LabVIEW 8.1 for incubator temperature system. It consists of three main stages as illustrated in Figure 1.

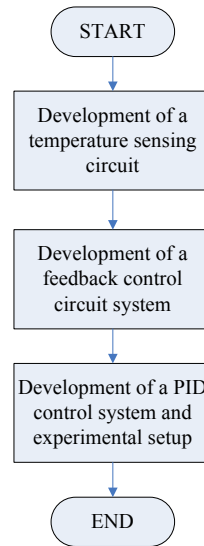


Figure 1: The flow chart of the development of a PID acquisition control system

In this experiment, the semiconductor temperature sensor of LM35DZ is used as a temperature sensor to convert measured temperature degree to voltage. The temperature sensor output voltage is linearly dependent with temperature and it is easy to compute measured temperature from the temperature sensor output voltage [3]. Moreover, an ideal temperature sensor output is exactly 10 mV/degC. Therefore, the mathematical relation of temperature – voltage are shown as per below equation.

$$\text{Temp} (^{\circ}\text{C}) = \text{Vout} \times 100 \quad (1)$$

A complete circuit diagram of temperature sensor was developed based on close-loop fundamental of a temperature controller variable as shown in Figure 2. This is to acquire process of an acquisition control system to control temperature at a required level [2]; [3]; [6].

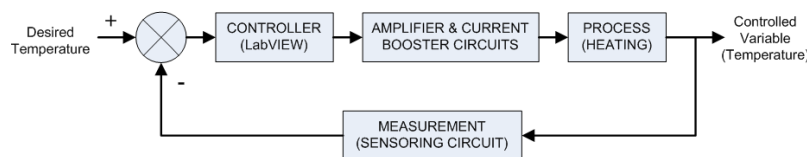


Figure 2: The close-loop fundamental of a temperature controller variable

Figure 3 below consists of a controller (LabVIEW), an amplifier and current booster circuitry, the process of heating 5 Watt of power resistor and a measurement block of temperature sensing circuit. The 5Watt of power resistor is applied to function as a controller variable in order to generate heat at a required level. Earlier, the amplifier and current booster circuitry

output signals computed via analogue output voltage of compact data acquisition (compact DAQ) are manipulated by the PID controller. This is to ensure that signal varies within the allowed level. The temperature sensor of LM35DZ is used to measure the temperature signal. The measured signal is then sampled at 1000 at 1 kHz by the temperature controller feedback via LabVIEW 8.1. This is to process, compare and control the required temperature level at a set point. The feedback signal is then algebraically subtracted to the set point by the summing point. Therefore, the required (desired) temperature is positive and the feedback signal is negative [2, 4, 8].

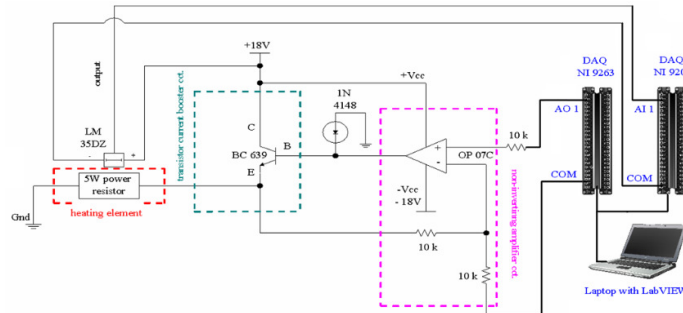


Figure 3: Schematic for the leading edge

The temperature controller variable schematic diagram of Figure 3 has been developed to ensure significant feedback control can be delivered appropriately as referred to Figure 2. The non-inverting amplifier is designed to produce a voltage gain (A_V) that's twice as large as the input. The input signal generated from the compact DAQ of NI 9263 is manipulated by the PID controller. The PID controller reads the heat produced from the heating element of 100Ω , 5Watt power resistor, via temperature sensor of LM35DZ. The data is then subtracted with the desired temperature via analogue input of compact DAQ of NI 9205. A transistor current booster circuit is designed to increase current up to 100 times of its base current. Therefore, allowing large current to flow from collector to the emitter to provide heat source with approximately 20V to the heating element, power resistor of 100Ω , 5 Watts. The PID controller consists of three Sub Virtual Instruments (VIs): Proportional, Integral, and Derivative [5, 7, 9]. The equation of PID controller algorithm applied in the controller system is as follows;

$$V_{\text{out}}(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt} \quad (2)$$

where $e(t)$ is an error, K_p is a coefficients of proportional (gain) action, K_i is a coefficients of integral action and K_d is a coefficients of derivative action. Therefore, the complete PID controller output is the sum of the outputs of the proportional, integral and derivative action [5, 7, 9]. Figure 4 shows the flow chart of complete PID controller applied in the system.

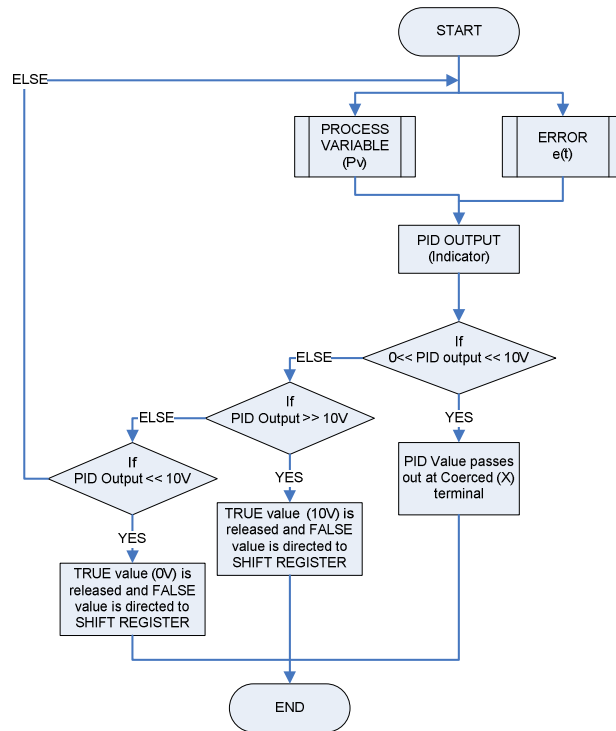


Figure 4: The flow chart of a complete PID controller system

Referring to Figure 4, the values of Process Variable (PV) and Error, $e(t)$, are directed to the PID VIs through the PV and error controls. The output of the PID depends on the case (If – Else) structure. The PID output indicator will only indicate released of successful value. If the output of the PID is within the range between upper and lower limits, it (PID output) will be released at the Coerced (x) terminal. However, TRUE Boolean value will be released at the In Range terminal of the In Range and Coerce functions. If the output of the PID VIs is larger than the upper limit, then the value of the upper limit is to be released and FALSE value is directed to SHIFT REGISTER. However, if the output of the PID VIs is less than the lower limit, the value of the lower limit is to be released and FALSE value is directed to SHIFT REGISTER [1, 7, 8, 9].

The feedback signal is wired to the summing point to be algebraically subtracted at the set point. The desired temperature is positive and the feedback signal is negative. This means the result actuating signal, error $e(t)$ is the difference between the set point and feedback signals. If a difference exists between the actual and desired temperatures, the controller will vary the analogue output voltage to the heating element (power resistor). This causes the analogue output voltage increase or decrease by the amount needed to correct the difference. Equation (3.0), shows the mathematical expression of the error action.

$$e(t) = T_{set} - T_{current} \quad (3)$$

where T_{set} is referred to as desired temperature and $T_{current}$ is referred to as an actual temperature.

3.0 RESULTS AND DISCUSSION

The signal conditioning measured from the temperature sensor circuit is connected to the analogue input device of DAQ Assistant NI 9205 of channel 1. The result of the measurement is controlled and detailed via GUI. The GUI control system for the analogue input channel 1 is shown in figure 5.

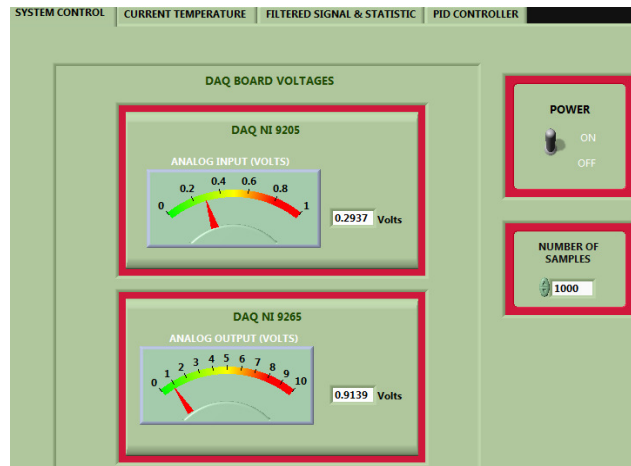


Figure 5: Graphical user interface of analogue input device control system

The GUI control system is integrated with the temperature controller variable and temperature sensor circuit. When the system is switched on, its initial temperature reading increased and the heating element of power resistor is then continuously increasing. Figure 6, shows the result of raw signal captured via GUI presentation under the signal conditioning property of 5W heat source voltage. The converted heat to voltage signal is then multiplied by 100. This is to achieve normal degree Celsius temperature rate. The results of raw signal input is then filtered at low cutoff frequency at 10 Hz and high cutoff frequency at 33 Hz ($10 < f_c < 33$) as shown in figure 7. This is to ensure that the nyquist criterion can be observed at a specified range gradually and unwanted signal (noise) can be minimized accordingly.

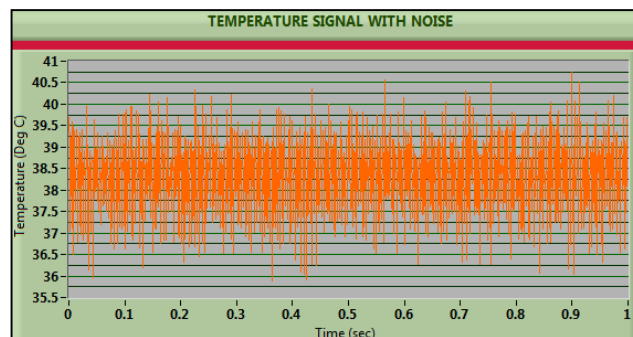


Figure 6: Raw signal captured at 38.5°C in average using graphical user interface

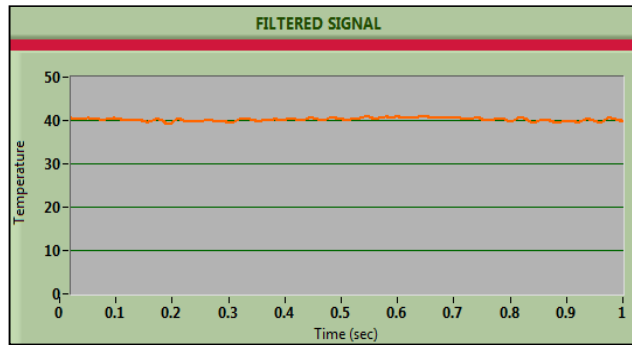


Figure 7: Filtered raw signal captured increase at 40°C in average using graphical user interface

The experimental result on temperature variable controller system was focused on amplifier input generated from analogue output 1 (AO 1) via compact DAQ and current booster circuitry which was manipulated by the PID controller to maintain the desire temperature as tabulated in Table 1.

Table 1: The experimental result on temperature controller variable system

DAQ channel 1 (AO 1 = Volts)	Current gain I_E (mA)	DAQ channel 1 (AO 1 = Volts)	Current gain I_E (mA)
0	0	6	39
1	3.2	7	46
2	9.5	8	56.6
3	16.7	9	111.4
4	24	10	111.8
5	31		

The result in table 1 shows a consistency increase in signal response and voltage measured is linearly proportional to PID controller data manipulator. By using Microsoft Excel, each significant point within the stacked line of linear graph is considered. Therefore, coordinates based on table 1 were computed to be plotted in a straight-line, as shown in figure 8. As a result, a linear graph with gradual increase in voltage is plotted. This shows that the temperature variable controller system is linearly correlated with the PID controller data manipulation and this shows that the developed system is reliable and consistent.

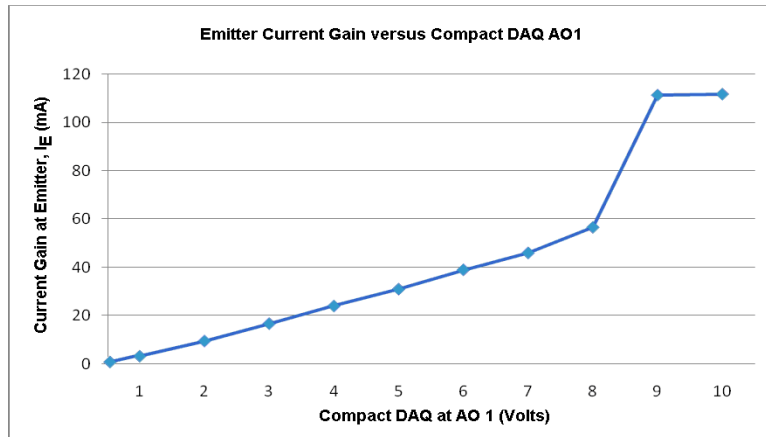


Figure 8: The statistical graph based on temperature controller variable system experimental results between emitter current gain and analogue output voltage channel 1 of Compact data acquisition

Based on the above experimental results, the PID controller algorithms can be used to manipulate the temperature controller variable system. In which, the used of control parameters; Proportional (K_p), Integral (K_i) and Derivative (K_d), were obtained by automated tuning based on the programming algorithm. Optimal values for the parameters were selected based on minimum of overshooting, oscillation and steady state error as shown in figure 9 below.

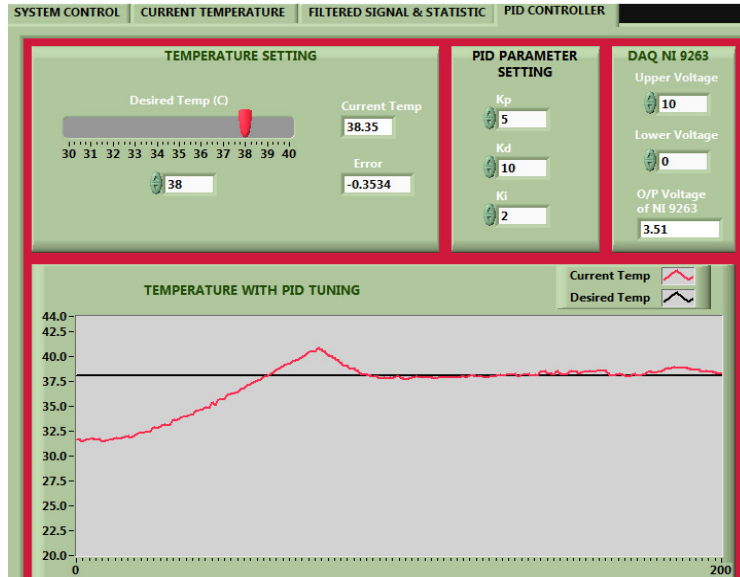


Figure 9: The parameter of PID selection based on minimum value of overshoot, oscillation and steady state error.

Figure 10 below, shows the experimental result of PID acquisition control system measured upon selected of the control parameter; Proportional (K_p), Integral (K_i) and Derivative (K_d). Results shows that the initial starting point required to be increased were based on heat produced is in the range between 30°C to 32.5°C depending on the room temperature. It is

clearly shown that the value of detected temperature increased from 32.5°C drastically, as time domain is increased. At 75ms, the incremental temperature break through the set point temperature level at 38°C as shown in figure 10. This shows an increase until it reached 41.5°C at 81ms, a peak level is reached. This is due to the mathematical process taken by the PID algorithms to calculate the different between the set point of temperature level and the actual temperature data received via data acquisition based on time domain set. The different of data measured were then force to symmetry with the required set point of temperature level at 38°C as clearly shown in GUI temperature setting of figure 9.

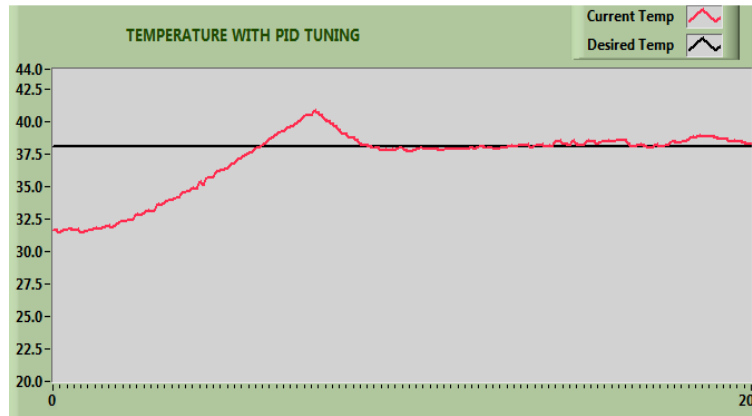


Figure 10: Experimental result of PID acquisition temperature control system

4.0 CONCLUSION

It has been proven by integrating the hardware system with PID VIs control algorithms, the development of the PID acquisition control system assisted using LabVIEW 8.1 to control the temperature at the required level between 37 °C – 38 °C has been successfully, accurately and locally developed. It is important to control and maintain an incubator at the desired temperature level consistently. Based on the experimental and analytical results, it was found that the developed system is able to control and maintain desired temperature level between 37°C and 38°C, consistently. Experimental results also proven that temperature variation such as inaccuracy and aging can be controlled easily without any difficulty by using PID controller data manipulator. Thus, this will help to improve the temperature control system to control desired temperature level accurately and consistently without fail. As a result, the development of a PID acquisition control system assisted using LabVIEW 8.1 for biomedical application can be applied to improve regulated heat consistently and accurately in the incubator temperature control system.

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