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Temperature control in PID controller by Labview

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Abstract

With the development and popularization of computer technology, digitizer is replacing analog device gradually. The measurement and control technology plays an important role in the process of production and scientific research. As the time going, the conventional instruments are emerging shortages. It becomes necessary to improve conventional instruments.

In this thesis, the conception of the virtual instrument and the merits of which against conventional instrument will be introduced. The program system and the programming environment of virtual instrument LabVIEW will be mentioned as well. Around the anticipant target which the PC-based virtual instrument in this thesis is expected to achieve, the design thoughts and the whole structure on which the virtual instrument was built are described in details. Following these thoughts as principles, a temperature control system will be designed.

Based on the virtual instrument (LabVIEW), the temperature control system will be designed to realize the data of the temperature of the objects. The sample input signals were analyzed and disposed to determine the size of the output signals by using the LabVIEW program, and the output signals was transferred to the external temperature control circuit, so the PID algorithm was used to achieve the control of a temperature control system.

Working on this thesis still needs more study. The program still needs further optimization and improvement in practicability.

Keyword: virtual instrument; LabVIEW; temperature control; PID

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1. Introduction

This chapter gives the background of virtual instruments, control system, the goal of this thesis and the research questions. The content outline runs through this whole thesis and affects the final results.

1.1 Project Background

With the continuous development of information science, the issues that need to be addressed have become increasingly difficult, the requirements of control system have also been more and more demanding. Besides, as the multiple analytic methods require convenient operability, the traditional control system tends to be a bit powerless in implementing various functions. The signal-processing circuit design of the traditional control system is rather complicated and has difficulty in updating. Moreover, traditional instruments will have no way to upgrade or update the calculating method when new calculating method or computing requirements are raised, which will hinder the control improvement [1].

Based on the rapid development of microelectronic technology, computer technology, software technology, network technology and modern measurement technology, a new kind of advanced instrument--virtual instrument, has been a hot spot of current system research. As a combination of various technologies and computer technology, virtual instrument has opened up a new era of instrument technology. The basic idea of virtual instrument aims at replacing the traditional electronic instrument and gradually replacing the traditional instrument to implement some functions such as the collection, analysis, display and storage of data [2].

According to the software development platform, virtual instrument perfectly integrates the computer hardware resources and instrument hardware. It also combines the strong data-processing capacity of computer, the measurements of instrument hardware and control capacity. Furthermore, the display, storage and analytic processing of data can be implemented through the software, and then the system control and the display of measurement data can be achieved by the interactive graphical interfaces. In addition, various functions are specified through using diagram modules. The adoption of IC temperature sensors and virtual instrument facilitates establishing a temperature measurement system. What's more, the peripheral circuit is simple and can be easily realized, which is conducive to hardware maintenance, function extension and software upgrading of the system [3].

As LabVIEW is regarded as a language development platform, a temperature control system will be designed in this thesis. Based on the serial communication between computer serial port and the object, the real-time measurement and control of temperature can be attained [4].

1.2 Goal

The goal of this thesis is to build a PID controller to control the temperature signal from an object. In order to achieve this goal, by using the data acquisition board to collect and analysis the signal from the heat device, then build a fuzz PID controller in LabVIEW and find the errors. After fix the errors by the system, the temperature signal could be controlled.

1.3 Outline

In chapter 2 we will write about the description of the hardware and software. The data acquisition board (NI-USB6008) and the temperature sensor (LM35-D) will be presented. Meanwhile, the software LabVIEW will be introduced. In the end of this chapter, the PID control principle will be presented in details.

In chapter 3, we will design a LabVIEW-controlled NI-USB-6008 temperature acquisition device which can accurately collect environment temperature. Write the program for the upper computer using LabVIEW so that it can receive the temperature information data sent by the lower computer and display the data on the screen. Write PID control system by using LabVIEW so that relatively accurate control of temperature can be realized.

In the last chapter we will conclusion and discussion the result. The advantages of LabView and PID controller will be presented.

2. Theory

This chapter mainly introduces the devices, the basic structure of LabVIEW system, and the PID control system. Therefore, it provides the basic theory of this study for readers.
Next chapter will explain the whole process and test which based on these theory knowledge.

2.1 Data acquisition board (NI USB-6008)

NI USB – 6008 has a basic data acquisition function, its applications include simple data record, a portable measurement and laboratory experiment of academic institutions. NI USB-6008 provides the basic data acquisition function for simple data recording, portable measurement and college laboratory experiments and so on. The price of this product is suitable for students, but its powerful functions are more than enough to deal with the complex measurement applications. Using NI USB - 6008 and its ready-to-use data recorder software which is included, the basic measurement can be completed within a few minutes. Or in other way, using LabVIEW or C language and included measurement service software programming can customize measurement system [5].

2.2 LM35-D

Lm35-D is a kind of temperature sensor which made by NS company. It has high precision and wide linear range. Therefore, compared with the Kelvin standard linear temperature sensor.LM35 has more advantages, for the most important part, it does not need external adjustment or trimming, the sensor allows the temperature between -55~150℃, could provides the common room temperature precision of +/- 4℃. It has 3 pins, pin1 is connects to Vcc, pin2 is connects to the output, pin3 is connects to the ground. Shown as Figure 1

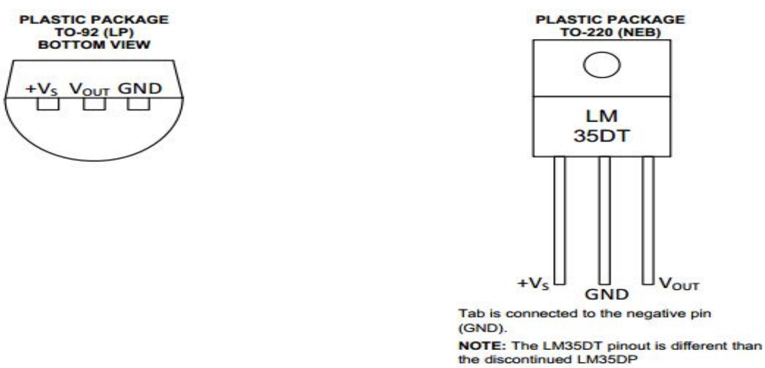


Figure1 Pins of the LM-D temperature sensor

2.3 Description of Labview

LabVIEW is an abbreviation for Laboratory Virtual Instrument Engineering Workbench designed by Doctor James Truchard, Doctor Jeff Kodosky, founders of NI Company, and their friend which names Jack McRiessen. It was first applied on the original Macintosh computer in May, 1986, which even predated the graphic operating system Windows launched by Microsoft.

The program LabVIEW developed by NI Company consists of three major functional parts: functional operation and graphic display of virtual instrument; design and edit of background programs; selection and connection of subprograms [6]. They are realized by the following three modules:

2.31 Front Panel

Front panel is a tremendously important part of virtual instrument. No matter the software operations, input, output, or results. All of these depend on the virtual graphical interfaces of the front panel, which make real interactions between computers and users possible.

2.32 Flowchart

Flowchart, which is the back panel of the program, realizes the function design of the software. It includes control signal acquisition, overall architecture of the software, calculations and so on. By editing the program of the back panel, the program icons of the back panel are corresponding to the control program of the front panel. Only some built-in functions and program frames are running in the background independently.

2.33 Icons and Connectors

If the program in LabVIEW is too complex, the master program will be modularized into several subprograms to command different functions. The subprograms are named as subordinate VI as well which are represented by icons that can be used by the master program with connectors.

2.4 Operation Panels of LabVIEW

In order to make the operations of users more convenient, LabVIEW provides three different sets of operating panels which appropriately classify different types of functional modules. Users can conveniently choose any of the three in their own needs, which include:

2.41 Tools Palette

As shown in Figure 2.1, the tools palette provides adjustment and modification tools for LabVIEW including icon lead selection, program debugging, text control, front panel color modification and so on. After users click one of the functions icons, the mouse pointer will turn into that icon which means the corresponding function will be activated. To choose any function in the tools palette by using a default choice is also available [7].

Figure 2.1 Tools Palette of LabVIEW

If the mouse pointer stops over the subprograms or the icons of the back panel, the corresponding tooltip window will appear.

2.42 Controls Palette

As shown in Figure 2.2, the control palette consists of the following subordinate palettes.

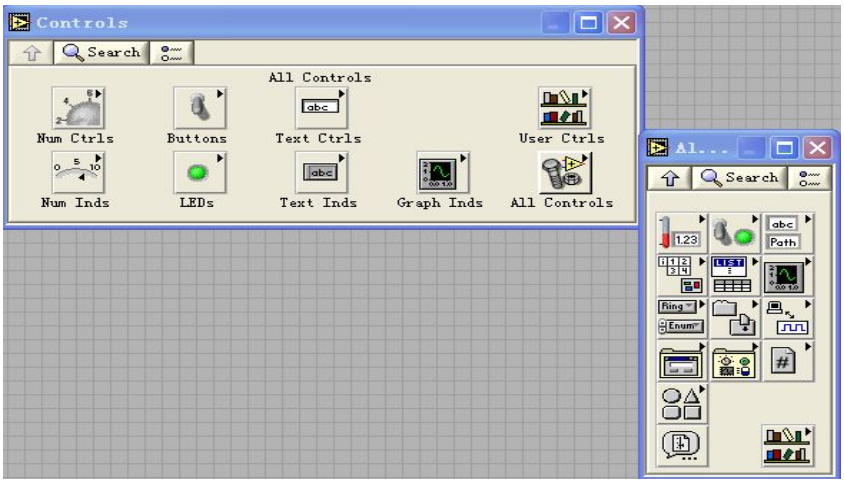


Figure 2.2 Control Palette of LabVIEW

This palette mainly adds various virtual control switches and VIO to the front panel. Users can not only add suitable virtual control icons according to different targets and accuracies of the design programs, but also beautify interactive interfaces by using this palette.

2.43 Functions Palette

The functions palette is a tool to set up the flowchart program, as shown in Figure 2.3. Each top-layer icon on the palette represents a subordinate palette. The functions palette includes all important program function modules. It includes the basic operations module, signal processing module and hardware interaction module. It is shown as Figure 2.3.

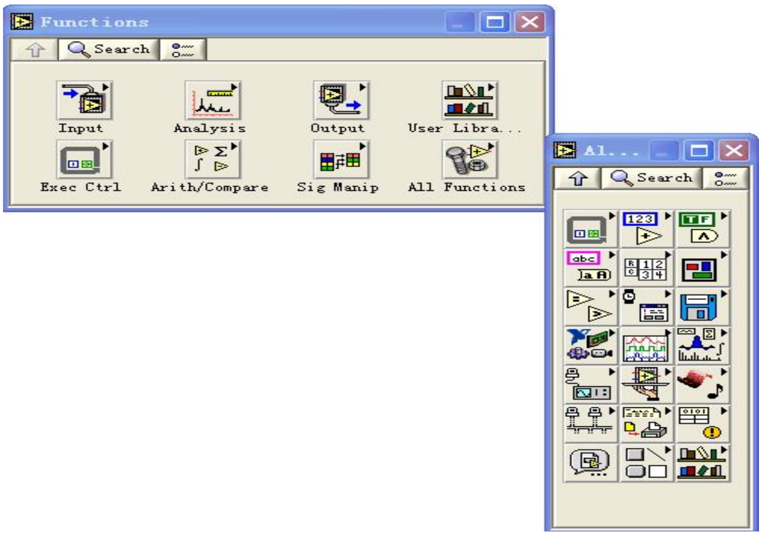


Figure 2.3 Functions Palette of LabVIEW

2.5 PID Control

A successful operations of automatic control system requires anti-jamming capability, stability and ability to meet the given performance index. Since the physical structure and the working process of the controlled object are constant, the output value of a given signal could not meet the needs of system. Therefore, a controller needs to be included.

The controller and the controlled object will form a closed-loop system which helps the output of the system meet the given performance index. In addition, the controller always utilizes various kinds of control rules [8].

PID (Proportional Integral Derivative) control is a widely used control method. It has huge advantage in the fields of control engineering. After a long period of engineering practiced, it has developed a complete program of control methods and a typical structure [9].

PID controller has simple structure, excellent stability, reliable performance and convenient adjustability. When the structure and the parameters of the controlled object cannot be completely acquired or cannot manifest a clear mathematic model, PID control technology becomes more useful. Because it was designed for the situation where users cannot thoroughly learn about a system with a controlled object, or cannot obtain the system parameters by using the effective measuring methods.

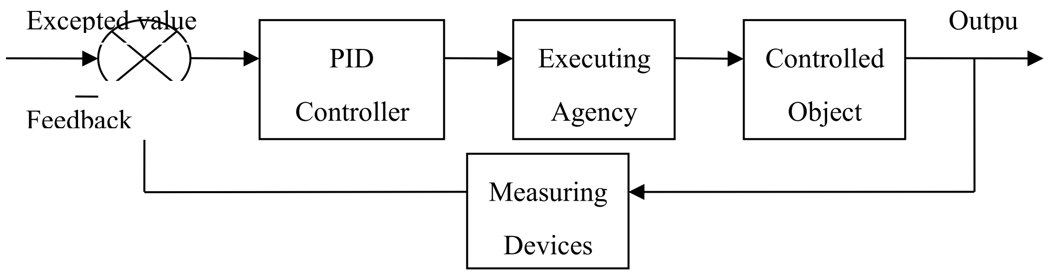


Figure 2.4 the PID control system

PID, as its name implies, utilizes the proportion, the derivative and the integral to work out controlled quantity based on the system errors. These three elements are mutually independent and have respective functions. Users can choose any of the three based on the practical situation.

The transfer function of a standard PID controller is generally written in the way:

$$\begin{aligned} G(s) &= K_p + K_i \frac{1}{s} + K_d s \\ &= K_p \left(1 + \frac{1}{T_i s} + T_d s \right) \end{aligned} \qquad (1)$$

Where K_p is the proportional gain, K_i is the integral gain, K_d is the derivative gain, T_i is the integral time constant and T_d is the derivative time constant.

As a linear controller, it according to a given value r(t) and the actual output value y(t) to control deviation e(t), the deviation in proportion, integral, and differential through linear combination constitute control u(t), to control the controlled object. For the output of the controller input relations is shown as:

$$u(t) = K_p\left[e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d\frac{de(t)}{dt}\right] \quad (2)$$

Where u(t) is the output of PID controller, e(t) is the input. Shown as Figure 2.5

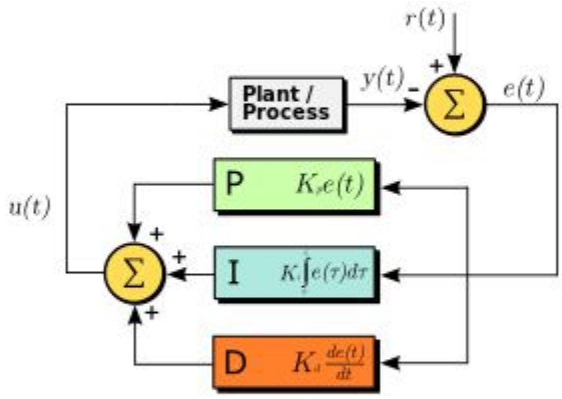


Figure 2.5 theory of a PID controller in a feedback loop

To get a PID control, we have to learn about P control, I control and D control first. Then we will combine these three controllers into PID controller.

2.51 P-Control (Proportional Control)

If the output of controller is only proportional to the error, that is, $u(t)=K_p\varepsilon(t)$, then a proportional controller will be formed. It is thus obvious that a proportional controller is actually a variable gain amplifier (VGA).By changing the proportional action factor (K_p), the proportional controller can adjust the output. The P control is shown as Figure2.6

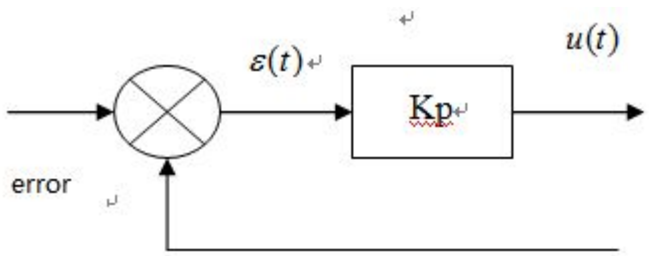


Figure 2.6 the Proportional Control

From the Figure 2.6 we can know that the P control is:

$$u(t) = K_p \varepsilon(t) \tag{3}$$

Although the proportional controller is sensitively responsive to the error, there is always a steady-state error between the output and the value of expectation. The steady-state error can only be eliminated by manual reset, which causes huge inconvenience in practical application. Increasing K_p can increase the open-loop gain of the system, reducing the steady-state error and increasing the rapidity of the system. Nevertheless, it is likely to cause not only the stability of the system to deteriorate but also the oscillation of the system becoming more frequently. In the other hand, decreasing the value of K_p will make the system action becomes slowly, thus the corrective the problem which the system seldom uses P control alone [10].

2.52 I-Control (Integral Control)

Because the steady-state error needs resetting manually, people find that the steady-state error can be eliminated by introducing an integral term. The output of the proportional controller is in direct proportion to the error signal, that is $\frac{1}{T_i}\int_0^t \varepsilon(t)d(t)$.

And then the output of PI controller is:

$$\begin{aligned} u(t) &= K_p\left(\varepsilon(t) + \frac{1}{T_i}\int_0^t \varepsilon(t)d(t)\right) \\ &= K_p\varepsilon(t) + \frac{K_p}{T_i}\int_0^t \varepsilon(t)dt = K_p\varepsilon(t) + K_i\int_0^t \varepsilon(t)dt \end{aligned} \tag{4}$$

The integral term will integrate the error and increases over time. Thus, as long as there is an error, the output will continue working. In this way, even if the error is very small, integral term will keep increasing over time. Then, by increasing the output of the controller to make the steady-state error reduced to zero if the further all the time, the way to eliminate the steady-state error can be achieved. But the integral of time will inevitably affect the fast dynamic performance of system. Sometimes, when a system adjusted overshoot, there will be some situations, among which the worst even can cause a system breakdown [11].

2.53 D-Control (Differential Control)

Integral Control's dynamic property is poor. However, a differential term can just make up for this. The output of differential controller is in direct proportion to the differential of error signal, and then the output of PD Controller is：

$$u(t) = K_p\left(\varepsilon(t) + T_d \frac{d}{dt}\varepsilon(t)\right) = K_p\varepsilon(t) + K_pT_d \frac{d}{dt}\varepsilon(t)$$

$$= K_p\varepsilon(t) + K_d \frac{d}{dt}\varepsilon(t) \qquad (5)$$

D-action (Differential action) reflects the change rate of error signal, so it is predictive to the system control and can predicts the change trend of error. Thus it can produce advanced control function. Even before the formation, the errors may have been eliminated by differential action regulation. If the appropriate D-action time is selected, the overshoot and the setting time of the system will be reduced, greatly improving the dynamic performance of the system.

Differential control in practice is often used to offset the unstable trend produced by integral control. Because its reaction is to change the rate of the error so that the differential control is not often used alone but only plays a part in the dynamic process. What's more, differential control has amplification effect on noise jamming, so the differential term can become a disadvantage to the anti-interference ability of the system [12].

2.54 The PID Control

PID control is namely the combination of proportional control, integral control and differential control, thus integrating the advantages of such three kinds of controllers. In practical application, there is no need to use all these three parts, but only proportional control unit is indispensable. For the PID controller, the output is:

$$u(t) = K_p\left(\varepsilon(t) + \frac{1}{T_i}\int_0^t \varepsilon(t)dt + T_d\frac{d}{dt}\varepsilon(t)\right) = K_p\varepsilon(t) + \frac{K_p}{T_i}\int_0^t \varepsilon(t)dt + K_pT_d\frac{d}{dt}\varepsilon(t)$$

$$= K_p\varepsilon(t) + K_i\int_0^t \varepsilon(t)dt + K_d\frac{d}{dt}\varepsilon(t) \qquad (6)$$

Where K_p = Proportional gain, K_i= Integral gain, K_d = Derivative gain.
Finally we can get a complete PID control.

PID control actually means setting these three parameters, namely, K_p, T_i and T_d, in order to get applicable output value to control the system. The specific details on how to set them are different based on different situations. Currently, PID is not only widely applied but also rapidly developed. The intelligent controllers which can self-tune these three parameters have been massively invented [13].

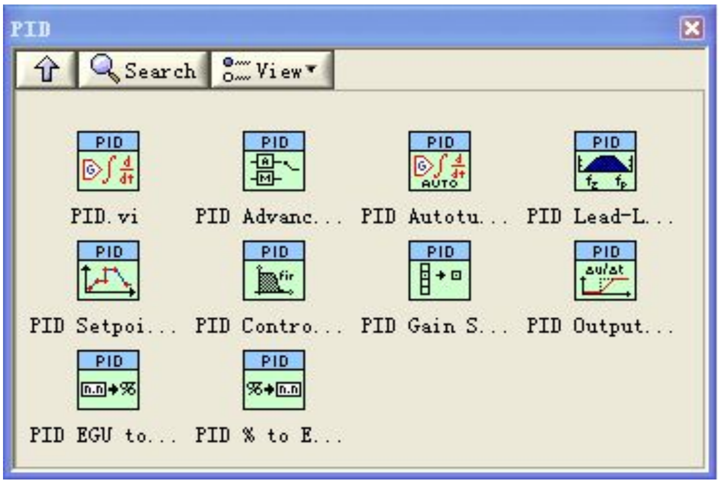
After the combination between PID and digital controllers such as computer, the design method of digital PID has also emerged, whose specific principle still follows the traditional ones.

2.6 PID Modules in LabVIEW

NI Company provides PID control toolkit used in LabVIEW, which can help engineers quickly and efficiently build a digital PID controller by combining with the NI data acquisition device, thus a complete system requires accurately and reliably. Installing LabVIEW PID

Control Tookit in NI CD Tookit software can generate the toolkit in LabVIEW which showns as Figure 2.7

After installation, open a new VI, right click the program block diagram， choose “control design and simulation” on the “function” panel , and the PID toolkit which consists of 10 VI can be seen.



Using PID.vi can set up a simple PID controller. Keying in three parameter gains, namely, process variable, set point into the input of vi, the output value then can be measured. Besides, the vi can control the range of the output [14].

PID Advanced.vi is such a kind of vi designed for experts, which has been added some advanced functions, such as setting set point range, manual control and linearity and so on. PID Advanced.vi is designed for the PID system which needs to be self-toned. Having been given several fundamental requirements, it has the function of self-toning then [15].

3. Process and results

The previous chapter 2 has recounted the historical characteristics and application prospects of virtual instrument, the status quo and the development of signal processing system. This chapter will concentrate on PID control principle. PID control algorithm is one of the most sophisticated control rules so far and it has been widely applied in continuous control systems [7].

3.1 Connections

Using USB cable to connect the port of data acquisition board, another side of the cable connects to the port of PC. Connect the temperature sensor (which has been introduced in the previous Figure1) to the data acquisition board (which shown as Figure3.1). Where the GND of the temperature sensor is connects to the Port32 (ground) of the digital side on the data acquisition. The $+V_S$ of the temperature sensor is connects to the Port31 of the data acquisition where Port31 expresses input voltage (+5V). The Vout of the temperature sensor in connects the Port17 where Port17 expresses the output. Then connect the temperature sensor to the heat device. The port of data acquisition board is shown below:

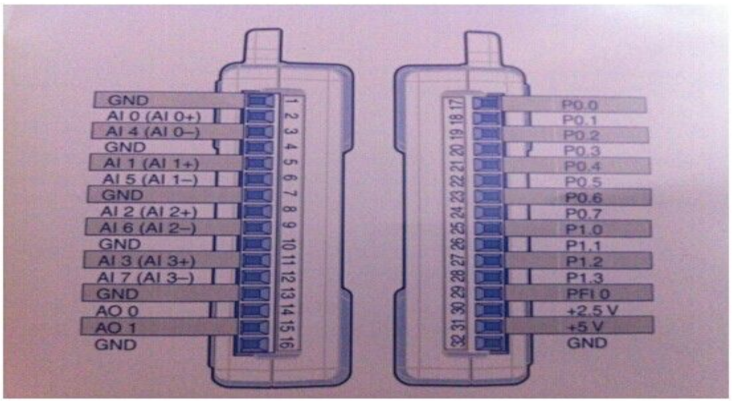


Figure 3.1 port of the DAQ board

The overall hardware connections is shown as Figure 3.2

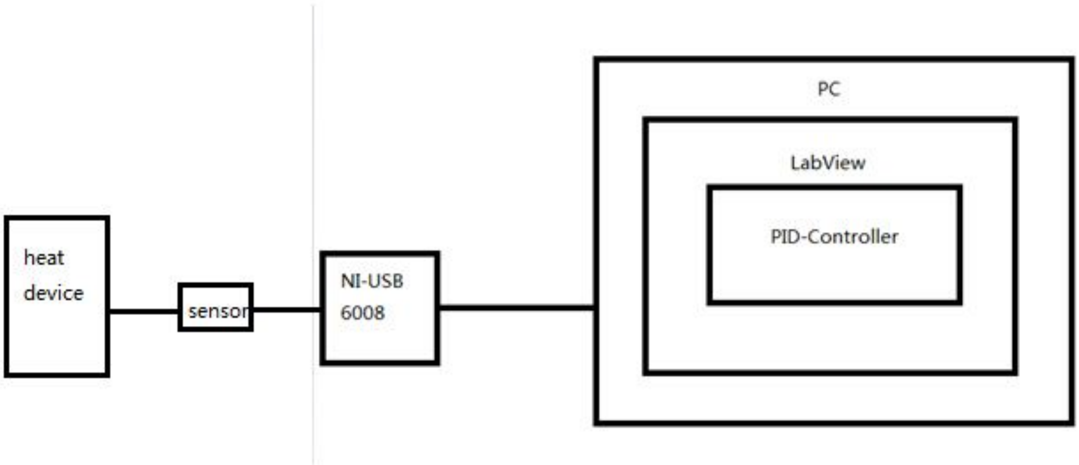


Figure 3.2 hardware connection

This kind of system is made up of computer, temperature measurement module NI USB-6008 and LabVIEW control system. By integrating the computer, powerful graphical programming software and modularized hardware and by setting up flexible measurement and control schemes based on computer, the system becomes one that can meet the requirements.

The system works like: using sensor NI USB-6008 to obtain the temperature signal; then using the LabVIEW program operating on computer to analyze and process input data; finally using computer to show the final results. Meanwhile, by using computer USB to sample the input signals and using the PID control algorithm in LabVIEW, the value of system output signals can be figured out. Then, by transmitting output signal through serial port to the external temperature control circuit, the aim of controlling the temperature can thus be realized.

3.2 Design

In the previous parts, the design analysis of virtual instrument module and the establishment of the virtual instrument have been briefly described. In this section, we will present the specific process of the design which is mainly about the designing aspects of software. We have designed the front panel and program chart of PID temperature control system. What's more, we have focused on the design of PID module program [16].

3.21 Front Panel Design

The front panel interface design is an important part of virtual instrument. The functions of instrument parameters setting and test results displaying are realized by using the software, which requires a simple, direct and convenient software interface [17]. The Figure 3.3 shows the front panel of the temperature control system.

The main functional areas of the interface include parameter input area, data display controls and results display area.

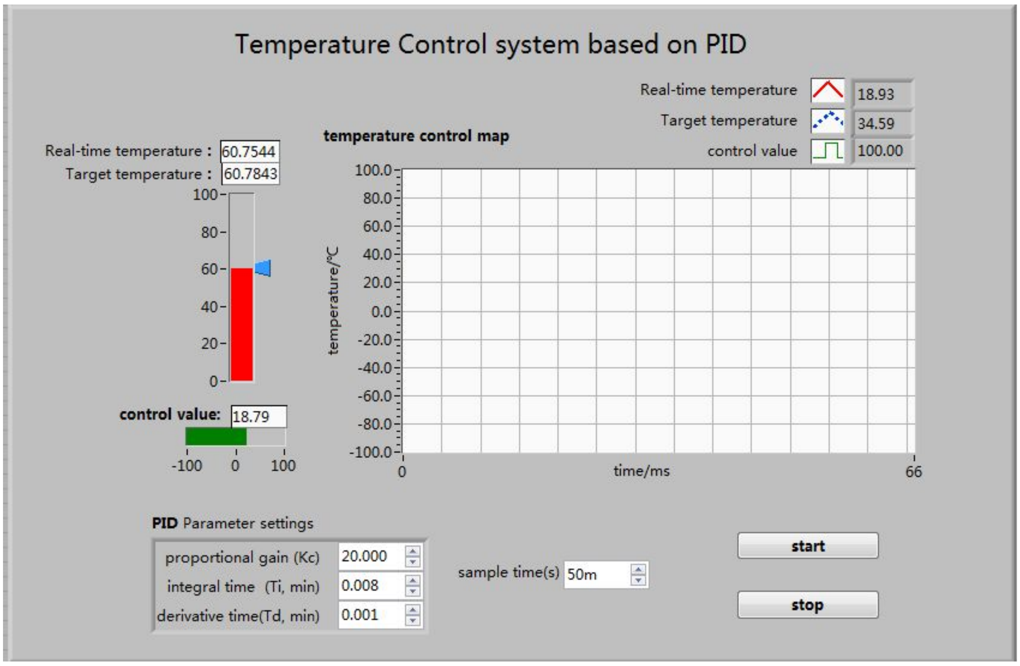


Figure 3.3 Front Panel of the Temperature Control System

3.22 Back panel design

The Figure 3.4 shows the chart of the back panel program.

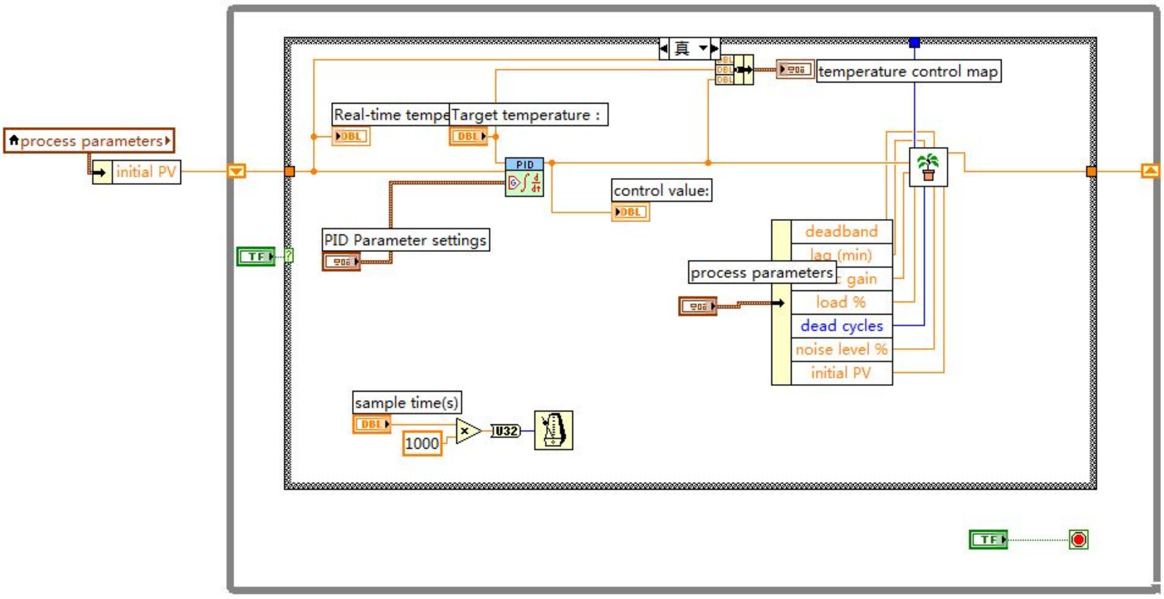


Figure 3.4 Chart of the Temperature Control System

In the part, the process parameters and the PID parameter settings will be design. After that the real-time temperature and the target temperature will be collect by the system which will pass through the PID controller with the control value. Finally we can check how the program running in the temperature control map

3.23 Overall Design

First of all, we have conducted the overall construction of the framework of the temperature control program based on LabVIEW. In this module, we have conducted controlled temperature signal simulation, added PID control program and achieved heating control through which real-time temperatures change along with target temperatures. The response time and the accuracy of temperature control can be adjusted through the adjustment of the proportional element, the integral element and the derivative element, as shown in Figure 3.5

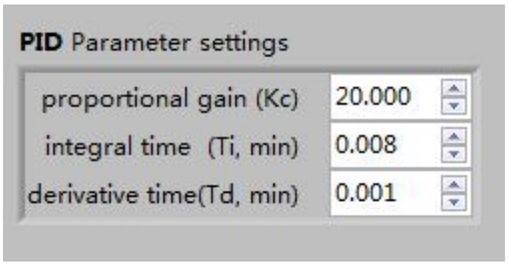


Figure 3.5 PID Parameters Settings

Then build the program chart in LabView by using the PID principle which has been introduced in the previous chapter 2.5. The Figure 3.6 shows the program chart.

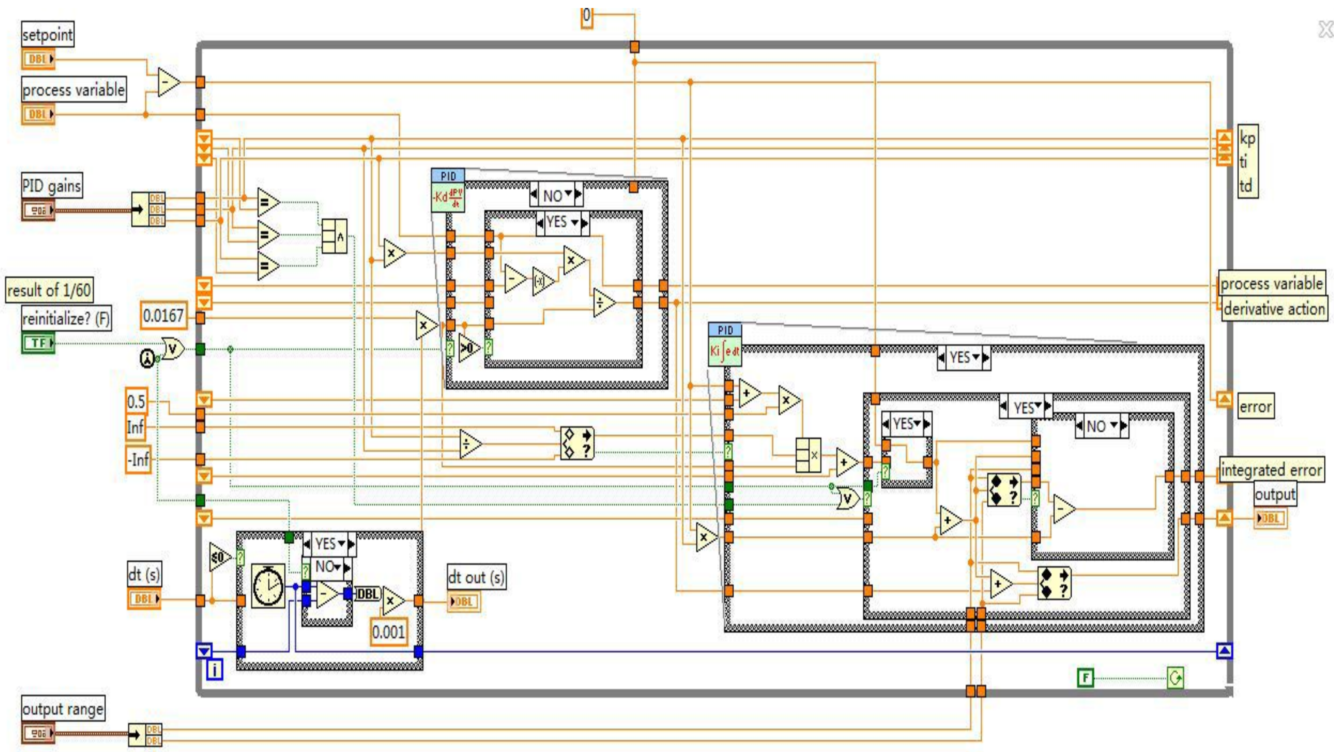


Figure 3.6 PID Control Program Chart

3.3 Running the program

In the previous chapter 3.2 we have designed the system, now we will run the program.

First of all, set the point. Second, set the maximum value and minimum value in the front panel of Labview. Third, connect the heat device to power.
After a while the temperature of water increased, the temperature sensor gained the real-time temperature data of water and send it to the data acquisition board, the board collected the data and communicated with PC. Meanwhile, the system will analyze and processing the data by using PID controller. Shown as Figure 3.7

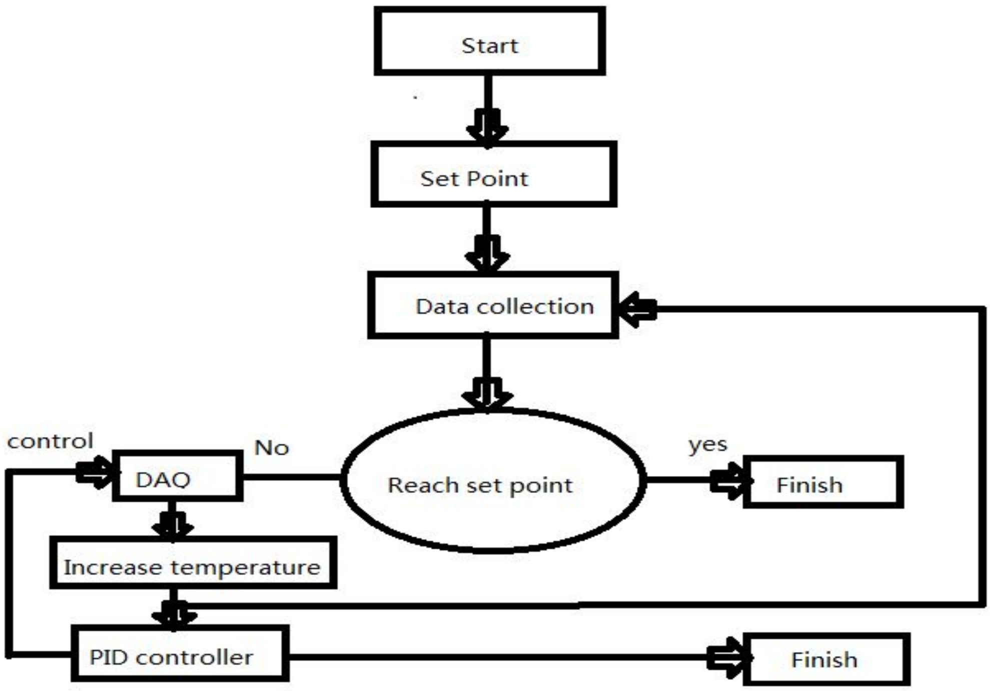


Figure.3.7 running the program

When the temperature reaches the set point, the system will finish the task. If not, the data acquisition board will give a feedback value to the system, by adjusting of the PID controller, the system will keep the heat device increase the temperature till it reaches the set point and finishes the task.

3.4 Results

When we set the target temperature at 40℃, inputted the parameters and clicked the run button, the system starts running. The temperature increased slowly. After a while, the temperature reaches 40 degree. The results were as follows shown in Figure 3.8.

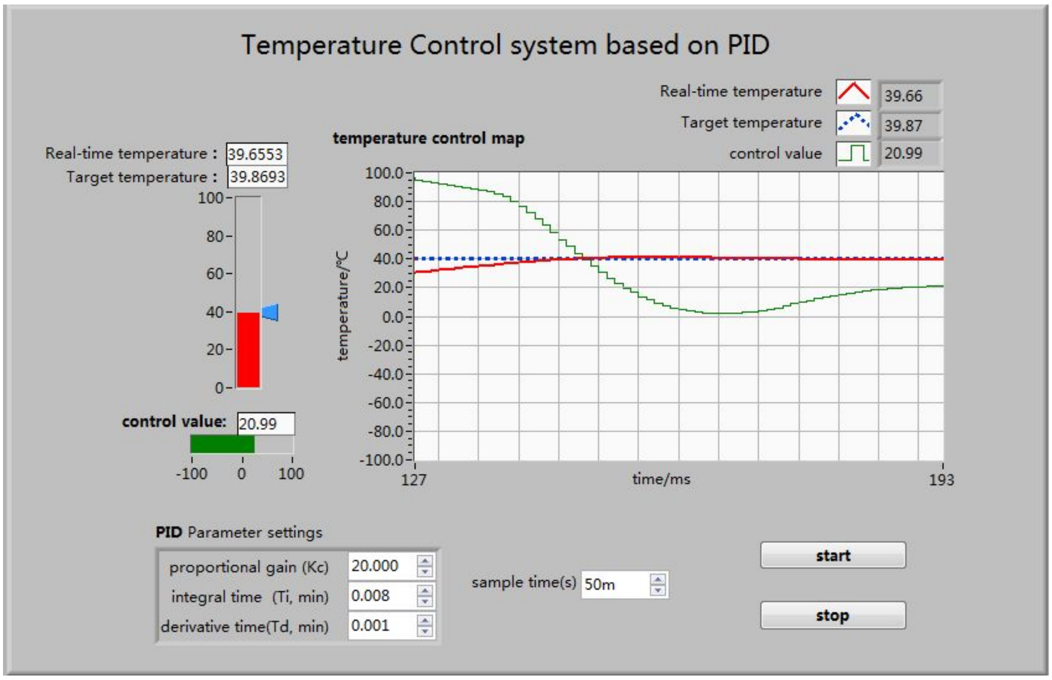


Figure 3.8 Temperature Control System Results at 40℃

After changing the target temperature, we can guess that the controlled temperature will make timely adjustments. By testing the target temperatures at 60℃ and 80℃ to prove the system will make timely adjustments. Figure 3.9 and Figure 3.10 show the results.

Changing the temperature to 60℃ which shown as Figure 3.9. The red curve expressed the real-time temperature of the target. We can see that the curve increases stable, after a while, when it reaches 60℃. The curve stopped increasing.

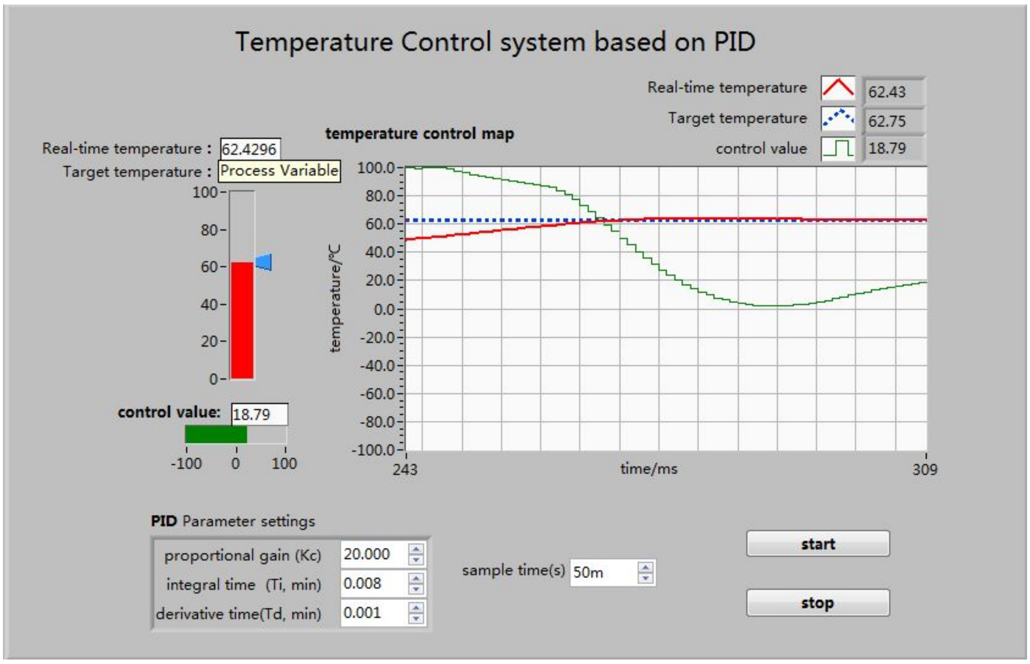


Figure 3.9 Temperature Control System Results at 60℃

Then change the temperature to 80℃ to test if the system will adjust by itself. Shown below:

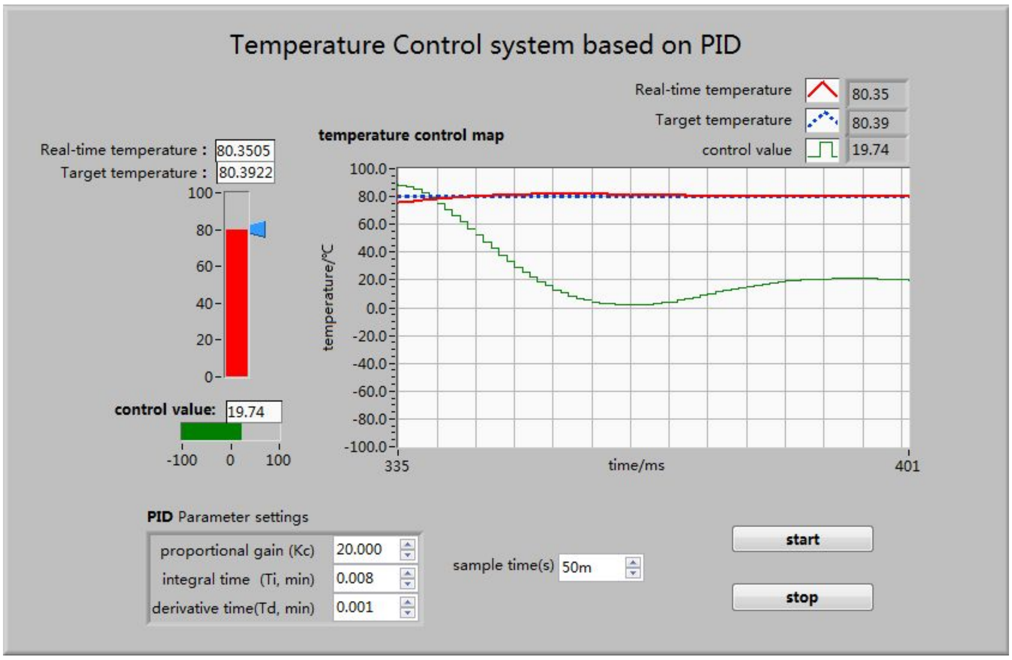


Figure 3.10 Temperature Control System Results at 80℃

The result shows that when the red curve increased to 80℃, the system becomes stable and the temperature stopped increasing. Then we can know the system will make timely adjustments.

With the well-running program and the results, we can control the temperature of target very well by using the PID controller.

3.5 Chapter summary

This chapter describes the entire process of the realization of the software design and achieves the design of a PID temperature control system. With some modifications, a temperature control system suitable for different conditions can be established very quickly and easily. The flexibility and scalability of virtual instruments will display exhaustively.

4. Conclusion

With virtual instrument being the platform and the shortcomings of traditional temperature control system, this thesis combines graphical programming language LabVIEW and the basic principles of PID to conduct temperature control. The virtual instrument technology inherits the advantages of traditional instrument and avoids the shortcomings. Users can change and redefine the functions of the instrument based on their own needs [18].

This thesis has achieved digital replacement of traditional instrument through the design of the virtual instrument of the temperature control system and obtained some results. It turns out to be that using technologically advanced virtual instrument technology to replace traditional measuring and testing technology is not only feasible, but also better and more systemically stable.

This thesis provides ideas for the development of similar instruments and paves the way for the full digitalization of traditional instrument. Because the technology is an emerging technology which involves novel theoretical knowledge and integrates multiple disciplines, and my experience is rather limited, the program is in need of further improvements especially in terms of software, which can expand the functions of the system through further optimization of its algorithms [19].

In this thesis, the temperature control system is designed by Labview with Proportional Integral Derivative (PID) controller. With the controller, the system controlled the temperature successfully. In this case, the PID controller showed accurate in a system control as the result.

No matter P-controller, PI controller, PD controller, PID controller and so on, all the types controllers designed in Labview will be very simple, because running a program in Labview does not need any code since it follows the graphical coding. All the principle is shown as graphical so that Labview is the simplest software to build control system.

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