

Design of Temperature Controllers for Industrial Applications using Lab VIEW

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Abstract- LABVIEW technology is used to design and implement the ON / OFF, proportional and PID temperature control system cycle. This covers data acquisition, data storage and data display. An ON / OFF regulator is designed to measure temperature and the digital LABVIEW instrument is used to monitor temperature and ensure temperature does not reach a set point. In industry, feedback control is used to improve and regulate response and the outcome of a number of processes and systems. The development and design of a feedback control system that maintains the process temperature at a predefined set point is discussed in this paper. Using Lab VIEW, an additive, integral and derivative controller is deployed. The developed controller as it integrates PID controllers can have very good accuracy than any other temperature controller.

Index terms- Temperature, controller, Lab VIEW, PID

I. INTRODUCTION

Controlling the temperature of processes involved in manufacturing and factories is very critical nowadays. In such critical manufacturing factories, temperature controller must be used for this purpose. Small changes in the setting point of the temperature contribute to problems of large scale. The controller used must be accurate and respond immediately to the changes. The controller designed for industrial and commercial applications using the PID controller is very suitable. In LabVIEW code, the PID controller is configured. We can easily monitor the results graphically in LabVIEW [1]. LabVIEW TM (Laboratory Virtual Instrument Technology Workbench), a product of National Instruments TM, is a powerful data collection, instrument management, and data storage and data presentation software system. All the visual programs of LabVIEW, called Virtual Instruments [2] or VIs,

include a front panel and a block diagram. Front Panel has different controls and indicators, while the Block Diagram is made up of a variety of functions. Within the Block Diagram, the functions (icons) are wired where the wires reflect the data flow. The execution of a VI is data-dependent; meaning that a node within the block diagram will only be executed if the data is available. Lab VIEW operates a single system of data acquisition, evaluation and presentation. Lab VIEW supports IEEE-488 (GPIB) and RS-232 protocols as well as other D / A, A / D interface boards and digital I / O interface boards to acquire data and control instruments.

II. ON/OFF TEMPERATURE CONTROLLER

A control system is made up of components and circuits that work together to keep the process at a desired point of operation. Growing home or industrial plant has a temperature control that holds the temperature at the setting of the thermostat. A control system can be used in industry to regulate any aspect of parts output or to maintain a motor's speed at the desired level. Although an open loop style control system may be, use of negative feedback is more common. The diagram of the blocks shown in Fig. 1 The basic structure of a traditional loop control system is demonstrated. The method is any physical function that must be preserved at the desired point of operation. The temperature in this paper is to be held at the optimal level.

The aim of the feedback is to provide the system variable's real or current value. A solid state temperature sensor is used for controlling the temperature in this application. This generates a voltage that is too low for practical purposes, usually within the range of millivolts. The following sequence of signal conditioning amplifies this signal

to a useful level. For measurement purposes, the signal conditioning block can also be used by scaling the voltage from the sensor to the appropriate temperature. The aim of [3] is to provide the system variable's real or current value. A solid temperature sensor is used in this application to control the temperature. It produces a voltage that is too small for practical purposes, typically within the range of millivolts. The following sequence of signal conditioning amplifies this signal to a useful level. For measurement purposes, the signal conditioning block can also be used by scaling the voltage from the sensor to the appropriate temperature. The block of the controller is the core of a control system. It accepts the [5] VE error signal and produces a suitable output. There may be one of several types of regulation in practice: ON / OFF, Proportional, Proportional plus Integral and Proportional plus Integral plus Derivative (PID). Such controllers vary in the way the Error signal is handled and stored. Having negative feedback is the secret to a control system's proper operation. Figure 1 displays the closed loop control system.

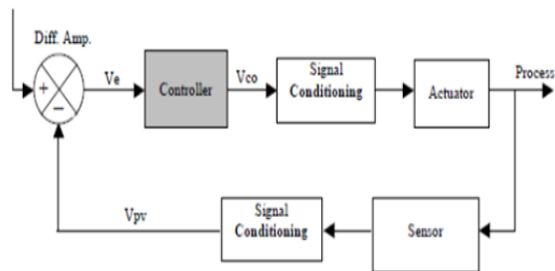


Fig 1. Closed Loop Control System

As shown in a block diagram in Fig, the data acquisition board (DAQ board) acts as the computer-real world interface. 2. It is built on the Windows operating PC. MIO-16E -10 panel has been used in this application. Net. 0, wired to the external temperature sensor is one of the analog input streams. Channel.1 is connected to the D / A Ch.0, one of the DAC output ports, and to the fan as well. Thus the current temperature data is entered via the analog input channel into the system. 0 and the fan control signal from the machine via D/A output Ch.0 to control the fan operation. Therefore, analog input Channel.1 controls the fan's operation as it receives from the device the same signal as the fan does. The ON / OFF control system block diagram is shown in Figure 2.

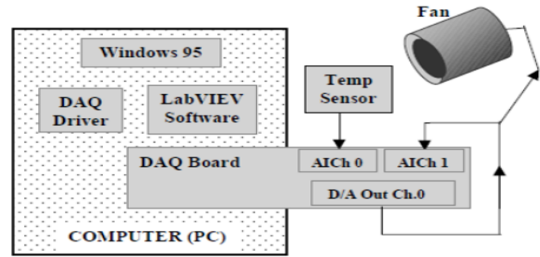


Fig 2. System Hardware Block Diagram of ON/OFF control

III. DESIGN OF TEMPERATURE CONTROLLER

A. Design of PID Controller

One of the simplest and most widely used controllers for decades is the PID controller. PID stands for proportional (P), integral (I) and derivative (D) controller. The PID controller block diagram is shown in Figure 3.

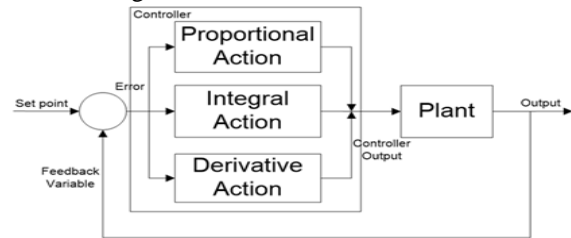


Fig 3. PID controller block diagram

The device under study is the plant that receives the required excitation to effectively achieve overall closed loop power. A PID controller $C(s)$ can be expressed as

$$C(s) = \frac{K_D s^2 + K_P s + K_I}{s}$$

$$C(s) = K_P + \frac{K_I}{s} + K_D s$$

Where K_P = Proportional gain, K_I = Integral gain and K_D = Derivative Gain

Time domain representation of the signal $u(t)$ fed to the plant is given by

$$u(t) = K_P e(t) + K_I \int e(t) dt + K_D \frac{de(t)}{dt}$$

The System Block Diagram for PID control is shown in Figure 4.

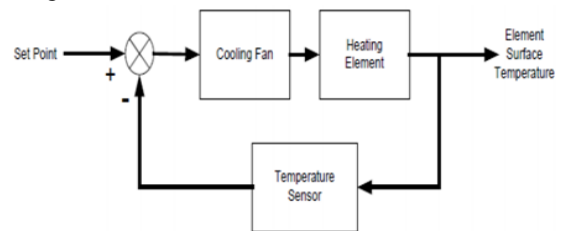


Fig 4. System Block Diagram for PID control

B. DAQ System

The system uses a system for data acquisition (DAQ) linked to a lab-based PC. It receives feedback from the system and provides the control element with output signals. On the PC connected to the DAQ device, a control algorithm is implemented. The custom data acquisition and control program is designed with Lab VIEW technology from National Instruments. The software calculates the process temperature, compares it to a predefined set point, and sends the desired control signal to the final control element. The signal controls the fan's rotational speed. The velocity of the fan rotation determines the rate of air flow over the heating element. The DAQ device combines the chassis and modules of the SCXI with the PC. It performs the conversion A to D and D to A necessary to interface the I/O signals to the PC. The card used is a PCI card NI 6040E. It has sixteen analog inputs, two 24-bit counters / timers, two analog outputs and eight digital I / O lines.

The analog input is an input unit for SCXI-1102C 32-Channel. It is very useful for the calculation of small outputs of current and voltage and consists of a Cold Junction Compensation circuit used with thermocouple sensors. There is a terminal block connected to the front of the SCXI-1102C. This block includes the cable terminals that are connected to external signals.

A SCXI-1124 6-Channel Analog Input Modul is used for analog input. It can provide up to six DC voltage or current signals slowly changing channels. The range of output voltage is chosen using the peak swing code between ± 10 volts.

IV. SIMULATION CIRCUIT

A. Block Diagram

The Block Diagram is the graphical system showing the temperature control process data flow. Unlike a high-level language system, such as the C language in which instructions are executed in the order in which they are written, the execution of a Lab VIEW VI depends solely on data flow: a specific object within the Block Diagram will only execute if data is available or present at all of its input terminals. At every node that has the data, the execution continues. Figure 5 shows the specifics of the block diagram that can be used to explain the ON / OFF controller

operation while Figure 6 shows the ON / FF controller operation hysteresis as the error signal differs between $-2\sigma F$ and $+2\sigma F$. The process begins with a search to see if the controller is ON or OFF. This is achieved by VI 2 (AI Sample Channel.vi) and the C1 comparator. C1's output is either TRUE or FALSE. If TRUE, the controller is OFF and the controller is ON if FALSE. VI 2 takes its input from System 1 channel 1 (DAQ number of the board). Analog input Channel 1 as defined above is physically wired to DAC output Ch. 0 that regulates the fan's activity. Thus the DAC performance Ch is checked. Whether the controller is ON or OFF can be determined. This will position the operating point of the controller on either the lower segment or the upper hysteresis loop section. Lab VIEW Block Diagram for ON/OFF control and Hysteresis Loop of ON/OFF control is shown in Figure 5 and Figure 6.

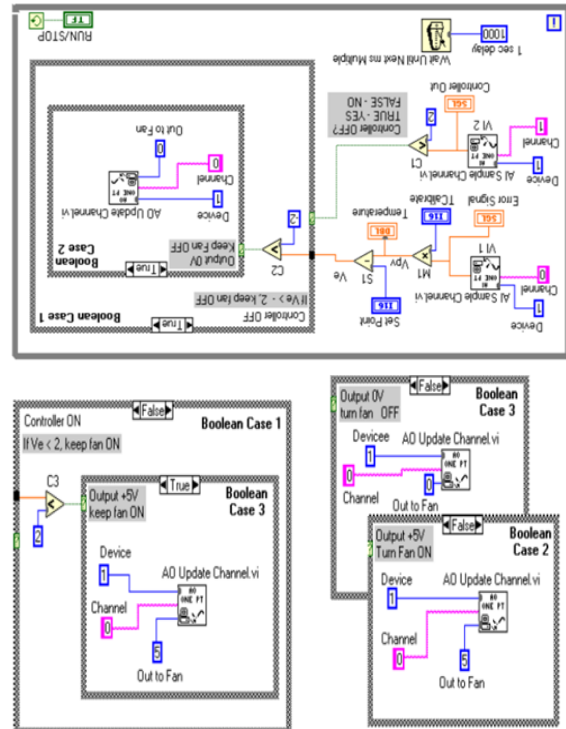


Fig 5. Lab VIEW Block Diagram for ON/OFF control

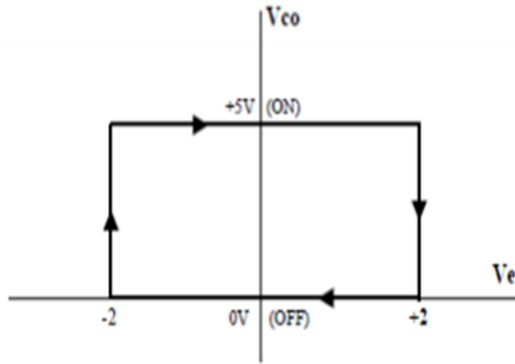


Fig 6 Hysteresis Loop of ON/OFF control

The Error signal (VE) value is calculated at this time by V1, M1 and S1. V1 takes the analog input Ch temperature test. 0 The temperature sensor is attached to. M1 multiplies the sample temperature by the scaling factor (T Calibrate) and S1 subtracts this value from the digital set point (VSP) of the front panel. The effect is the indicator of mistake. The controller must decide whether to turn the fan ON or OFF. For nested Boolean Case structures, this decision-making method is applied. The reader will follow Figure 6's hysteresis loop and Boolean Cases 1, 2 and 3's code. If Comparator C1's output is False, then Boolean Case 1's False Frame will be executed. The controller must be OFF and at the lower segment of the hysteresis loop in Figure6 and it is working stage. If the error signal is greater than -2oF , we should search next. This is achieved within the Boolean Case 1 True Frame 1.

If the error signal is greater than -2oF , Boolean Case 2's True Frame will display 0V , holding the fan OFF. But if the error signal is equal to or less than -2oF , Boolean Case 2's False frame will emit $+5\text{v}$ to turn the fan ON. If C1 output is FALSE, the Controller must be ON. Comparator C3 inside the False frame of Boolean Case 1 checks the Error signal if it is less than $+2\text{oF}$. If TRUE, the True frame of Boolean Case 3 outputs $+5\text{ V}$ to keep the fan ON. And if FALSE then the False frame of Boolean Case 3 outputs 0v thus switching the fan OFF. This operation is inside the While Loop which is enabled by the RUN/STOP switch in the Front Panel. As long as the switch is in the RUN position, its terminal counterpart in the Block Diagram outputs a TRUE to the condition terminal keeping the While Loop enabled; a FALSE disables the While Loop. As long the While Loop is enabled, the code inside the loop is

repeatedly executed. This results in acquiring a temperature sample once a second. To stop the operation, the user must click on the RUN/STOP switch. The two Waveform Charts in the Front Panel show the error signal and the Controller Output. The Wait until Next ms Multiple function provides 1 s time delay between the data points.

B. Front Panel

The front panel enables us to monitor and control the operation. This consists of electronic controls and indicators identical to physical controls like LEDs, sliders, buttons, and maps. The screenshot of the front panel is shown below as Figure 7.

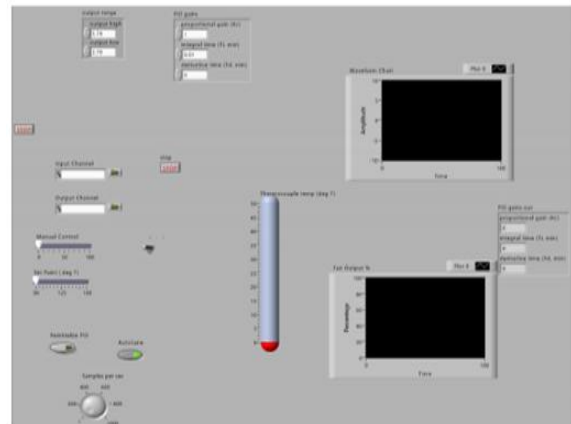


Fig 7. Front Panel for PID control

In a thermometer-style indicator, the system temperature is shown. It's registered on a strip map as well. Also the strip map is the set point value. You can easily see how the device responds to any adjustment in the set point by showing all calculated values and set point on the strip map. While deciding the right PID constants, this is very helpful. It also has a dial for manual adjustment of the fan speed and one for automatic control of the temperature set point. For switching between automatic and manual power, a toggle switch is used. There is a dial switch which controls the frequency of sampling. It regulates the code loop's speed. In a numerical control box, the PID values can be entered. Two push button switches are situated below the PID control boxes. An automatic tuning routine begins with the one marked Autotune. The procedure attempts to find the best values for P, I, and D by using the ultimate gain model of Zeigler-Nichols. Then the new PID values are inserted into the control box automatically.

V. HARDWARE IMPLEMENTATION AND RESULTS

A. Power Supply

A 12-volt DC supply is used to power the electronics and the fan. The positive 12-volt supply operating the fan and op-amp circuits can be supplied with a voltage regulator IC. As a consequence, it needs only one external power link. A connection to a 15-volt power supply is required to supply the entire circuit with a controlled 12-volt supply.

B. Heat Circuit

A circuit of heater resistance is used as the heating element of the device. It is made by parallel wiring of two 270 buffer resistors. Such resistors are directly connected to the DC power supply of 12 volts. They dissipate 1.2 Watts of power when the resistors heat up. Nearly all this is given up as heat. It is a simple way to design a source of heat dissipation that can exceed 160 ° F.

C. Temperature Sensor

A temperature sensor is connected to the heating element's surface. This sensor provides the control system with feedback. The temperature sensor used is a thermocouple sensor type J that is widely used in industrial applications. Temperatures from 32-90 degrees Fahrenheit can be sensed. It is ideal for use with the SCXI system because the signal conditioning system can handle the cold.

D. Fan Interface Circuit

To control the DC fan, a customized interface circuit is required. The easiest way is to connect the fan directly to the output unit of SCXI-1124. Sadly, for a variety of reasons, this is not necessary. Next, the module is not supposed to handle the amount of current that the fan needs to operate. The fan is designed to operate at a current of about 60mA and 12 volts DC. When used as a source of voltage, the device can provide a maximum current of 5mA. For the fan to work properly, an interface circuit is required. The circuit should be able to supply the fan's power. Even if the device can produce the requisite current, the voltage range of the module is different from that of the fan. Heating and Fan Interface Circuit is shown in Figure 8.

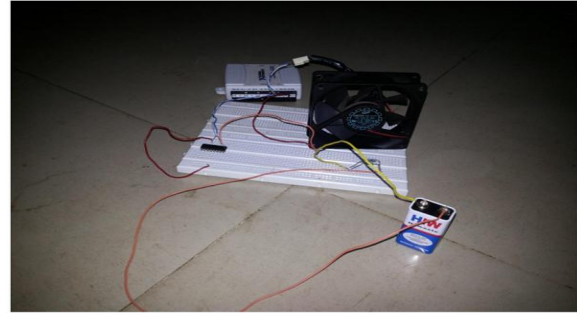


Fig 8. Heating and Fan Interface Circuit

The simplest method is to differ between the maximum and minimum values of the input voltage given to the fan. It means that the voltage ranges from 0 to 12 volts. Using an adjustable voltage regulator is the easiest method. A typical regulator provides a current of up to 1 Amp which is enough to power the fan. But the issue with this approach is that the regulator is misusing a large amount of power in the form of heat dissipated. Furthermore, the fan is designed to operate under its full 12 volt supply. Running the fan below this at voltages shortens the DC motor's life.

E. Simulation Results

Because of the construction and design constraints, the system worked well. When operating at maximum speed, the fan cools the heated component at a temperature of 110 ° F. Using manual control, the user can easily adjust the speed of the fan from zero to almost full speed. The system uses automatic monitoring to keep the temperature close to the target set point. This is so even if the loop is not set for optimum control. For example, when it was set as proportional only control, the temperature was kept constant with an offset of about five degrees from the set point. Figure 9 below is a screenshot displaying a graph of the set point and measured values.

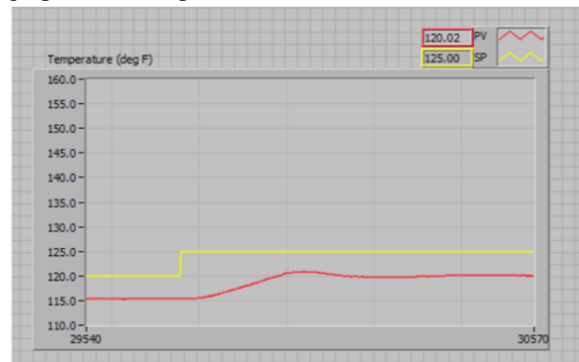


Fig 9. Gain for proportional controller

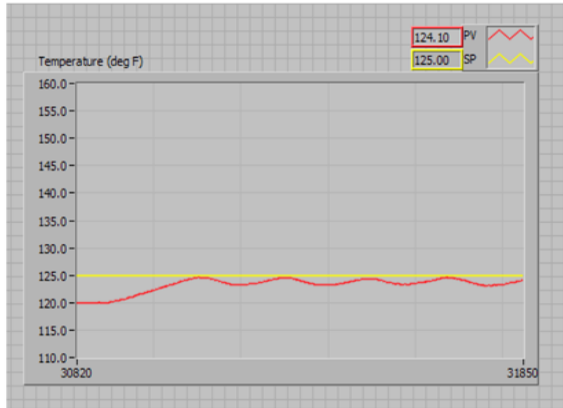


Fig 10. Minimal offset with oscillation

The Figure 9 displays the response of the system to a set point step change of about 5 degrees. The temperature arrives at a steady state, but with 5 degree offset. The offset reduces with increase in the proportional gain. As the proportional gain is increased, the offset is reduced; however, oscillation is introduced into the system. This is shown in Figure 10.

VI. CONCLUSION

Using the Lab VIEW Circuit Design and Simulation tool, the temperature control system is designed with different controllers. Specific controls used to model the regulator for boiler are on / Off, Proportional (P), Proportional Integral Derivative (PID). Comparison is studied between different controller outputs and as a result the PID controller response is more reliable than other controllers. For the temperature control unit, this controller is chosen. Within Lab VIEW, all types of controllers are also planned. Many tools may be used to model control system, but the easiest of all is Lab VIEW. It's because it uses the concept of drag and drop and it doesn't need any code to run the software since it follows graphical coding.

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