ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Design of Industrial Temperature Monitoring System Using RTD and Servo Motor with PID Algorithm

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ABSTRACT: Nowadays automated control has become one of the most important criteria of any industrial process and systems. This paper mainly aims at controlling the temperature of a process operating under high temperature with a help of a servo motor. To achieve this goal Resistance Temperature Detector (RTD) is used as the temperature sensing device and a Servo Motor is used as the final control element of the temperature feeding unit. This complete project is programmed with the help of the graphical user programming language called Laboratory View Engineering Workbench (LabVIEW), following PID algorithm. The open source prototyping platform Arduino is used as the central controller of this system.

KEYWORDS: RTD, Servo Motor, LabVIEW, Arduino, PID Algorithm, Graphical User Interface(GUI).

I. INTRODUCTION

In this era of 21st century the demand for automatic control has prevailed almost all types of industries operating which generally under various process parameters. Temperature is one of the most common such process parameter, controlling of which is supreme importance of many industries such as steel industry, power generating industry, food and beverages industries and etc. A very small discrepancy in temperature can ruin the entire process and cause a huge loss.

The main concern of this paper is to design an interactive temperature monitoring and control system which maintains the temperature at a desired level and tries to improve the performance of the overall system. The control algorithm which is implemented to achieve this is a proportional control algorithm which means, after measuring the temperature and comparing it with the desired set point an error signal will be calculated and accordingly an appropriate control signal will be generated following PID algorithm [1] which in turn will cause the servo to rotate accordingly and control the knob of the feeding device. For the measurement purpose a PT100 Resistance Temperature Detector (RTD) [2] is used. Arduino Uno, which is powered by AtMega 328 microcontroller, is used as the main controller and is programmed using LabVIEW 2013. The temperature feeding device is connected to the mains through a relay. It trips the temperature feeding device if the process temperature is much above the set point, thus generating a constant error for a particular user defined amount of time and saves the process from undesirable damages.

II. RELATED WORKS

The practical implementation of this work involves several previous research works. In this paper the approach of designing a hardware PID controller for temperature measurement with RTD is given[3]. In this paper the focus is on the application area of automotive industry sector. Here the design and development of platinum thin film sensors for exhaust gas temperature measurement is shown[4]. In this research paper the design and development of monitoring followed by controlling and maintaining the temperature of instruments interfaced with custom made GUI for logging and plotting is represented[5].

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III. METHODOLOGY

A. *Proportional Control:* The proportional (P) mode alone is the simplest linear control algorithm. It is characterized by a proportional relationship between the controller input and output. It is generally used in first order process.
Integral Control: The integral (I) control mode is also sometimes called reset mode because after a load change, it returns the controlled variable to set point and eliminates the offset, which the plain proportional controller cannot do.
Derivative Control: The proportional mode considers the present state of the process error, and the integral mode looks at the past history of the error, while the derivative mode anticipates the future values of the error and acts on that prediction.
The mathematical equation of the PID control is given by,

$$MV = K_p e + \frac{K_p}{T_i}\int_0^t e dt + K_p T_d \frac{de}{dt} + b$$

Where MV is the manipulated variable, e is the error and b is the initial bias. $K_p$is the proportional gain, T_i is the integral time constant and T_d is the derivative time constant whose values can be selected depending upon the process requirement. The more the proportional gain the less the steady state error it generates and it also improves the process response in terms of rise time but excessive proportional gain can also increase the overshoot of the process which in turn can make the process oscillatory, thus the value of process gain is selected wisely [6]. The integral part helps to remove the offset as well as to improve process response but it can again make the process response oscillatory therefore derivative part is used to reduce process overshoot and maintain the process in a stable condition thus the proportional, integral and derivative control together works to maintain the process variable at its desired set point.
B. *Temperature Measurement using RTD:* Resistance Temperature detector or RTD is a device whose resistance increases with increase in temperature. Pt100 is one such RTD. Pt100 indicates that it has a resistance of 100Ω at a temperature of 0^0centigrade. Resistance temperature detector (RTDs) is constructed of a resistive material with leads attached and usually placed into a protective sheath. The resistive material may be platinum, nickel, or copper, with the most common by far being platinum. Platinum resistance thermometers are now the international standard for temperature measurements between the triple point of hydrogen at 13.81K and the freezing point of antimony at 1167.35°F (630.75°C) [7]. The laboratory application of platinum resistance thermometers recognizes the unsurpassed stability and repeatability of this noble metal sensor. Platinum resistance thermometers for rugged industrial applications also retain their advantage over other conductors. Another advantage of using RTD is that the response curve of it is almost linear.
C. *Servo Motor:* Servo motors or servos are such kind of motors which enables us to know its absolute position without using an external encoder or similar device. Servo motors can be commanded to move to rotate to a particular angular position and it will remain there until it's commanded to move to a new angular position. Its precise movement makes it enable to control many systems like robotic arms, actuating door lock and many. In this prototype an 180^0 rotational servo [8] is used which operates at 5V. It generally has three pins i.e. supply, ground and control. The control pin can be connected to the Arduino to give appropriate control signals.

D. *Design of the Hardware Module:* To measure the temperature using RTD a bridge network is designed to measure the change in resistance of RTD. For this purpose two 220Ω resistor is used in two arms of the bridge, a 10k potentiometer is used in another arm and the RTD is used in the fourth arm of the bridge. The potentiometer is used to balance the bridge. A 9v battery is used as a power supply for the bridge. The output of the bridge is converted into a voltage signal within the range of 0-5V using suitable signal conditioner which consists of two voltage follower and a differential amplifier circuit. As the output of the bridge was in millivolt range thus it was needed to be amplified and bring the output to the Arduino readable voltage range that is usually 0-5V. The Figure 1 represents the circuit diagram of the temperature measurement using RTD. This circuit is implemented using LM324 IC due to its low power, high gain and internally frequency compensated architecture. The output of LM324 is connected to Arduino analog pin A0 [9]. The servo motor's control pin is

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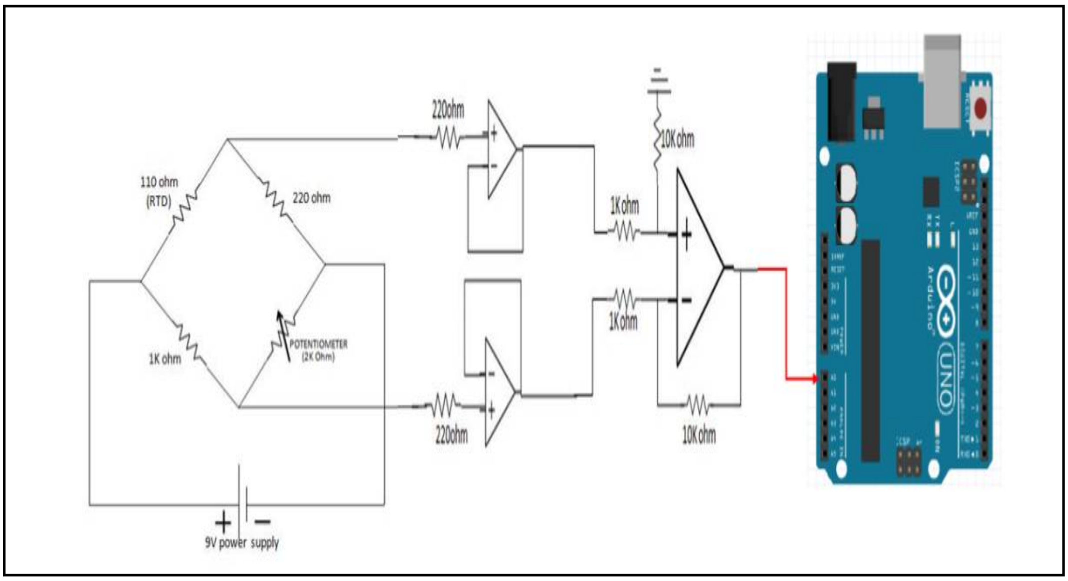

Figure 1: Circuit Diagram of Temperature Sensing with Arduino

connected to the PWM pin of the Arduino which sends signal to control the position of the servo. The relay is connected to another digital pin of Arduino through a transistor so that precise switching can be achieved to protect the system from overheating damages.

E. *Virtual Instrumentation:* Virtual Instrumentation [10] has opened up a new era of computer programming. It enables the user to design interactive system by programming it graphically using VIs provided in LabVIEW software. It frees the programmer from hardcore coding to build a graphical user interface and helps to design otherwise difficult control systems with ease. The basic idea of virtual instrument aims at replacing the traditional electronic instrument and gradually replacing the traditional instrument with the virtual instruments to implement some functions such as the collection, analysis, display and storage of data.

F. *System Operation:* In this project, a GUI will continuously run that will check the temperature measured with a RTD from Arduino analog pin and will compare it with a user defined set point (SP). As the temperature rises above set point the LabVIEW will send appropriate control signal to the Arduino and servo will thus rotate in a corresponding direction. As the temperature falls below the set point LabVIEW will send another control signal through Arduino making the servo rotate in opposite direction. There is also a provision of logging the process variable that is the temperature into an Excel Sheet which then further can be used for future references. Figure 2 shows corresponding Data Logging VI. Figure 3 shows the servo control VI within an If Else block which runs only if there is a deviation of PV from SP. Thus the servo will rotate according to the deviation of process variable (PV) i.e. temperature from the user defined set point making it a proportional controller. Figure 4 shows the PID VI which sends the PID control signals to the servo. If the temperature rise above set point and there remain a continuous

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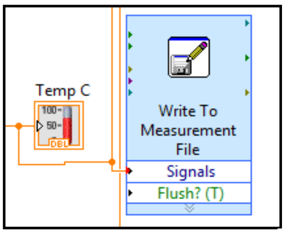

Figure 2: Data Logging VI

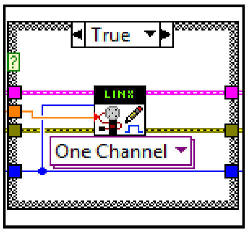

Figure 3: Servo Control VI

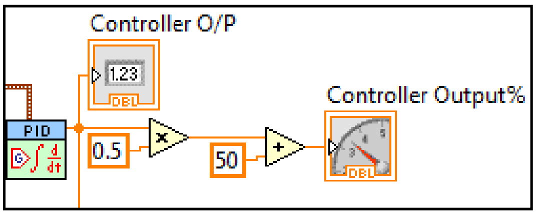

Figure 4: PID Controller VI

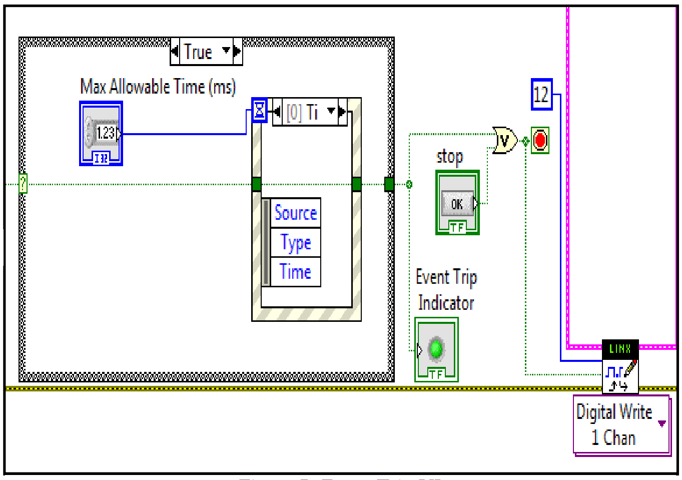

Figure 5: Event Trip VI

error for a user defined duration then the LabVIEW will send a signal through Arduino to the relay [11] to switch off the temperature feeder and the entire process will trip. Thus it is protecting the entire system from undesirable damages. Figure 5 shows the corresponding Event trip.

VI. FLOW CHART

The below displayed diagram (Figure 6) represents the flowchart of the entire process. After sensing the temperature, the data is processed and compared in LabVIEW which then decides which conditional statement is true and continue the Process accordingly

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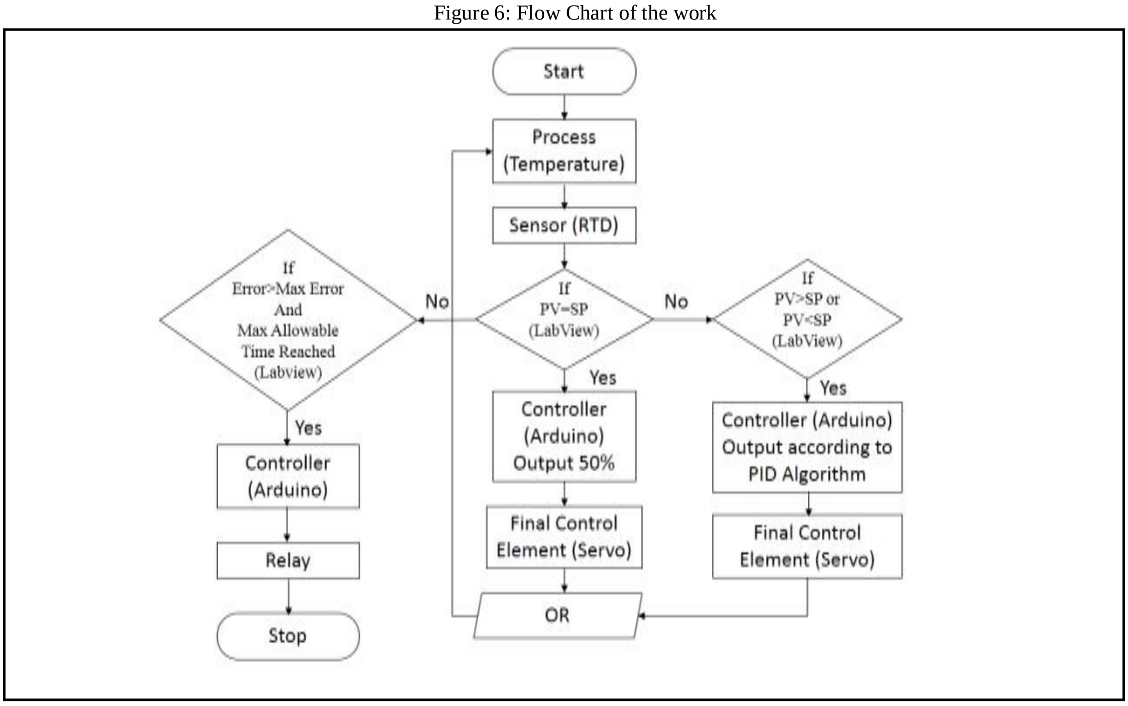
Figure 6: Flow Chart of the work



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VII. RESULTS

In this section the front panel of the entire temperature measurement and control system is shown. Figure 7 indicates the basic GUI [12] model of the temperature measurement and control panel. Figure 8 indicates the condition when the process variable is equal with the set point. It also indicates that the controller output is very close to 50%.

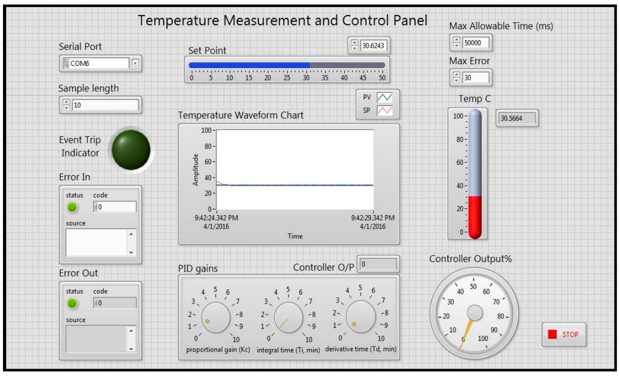

Figure 7: Basic GUI model

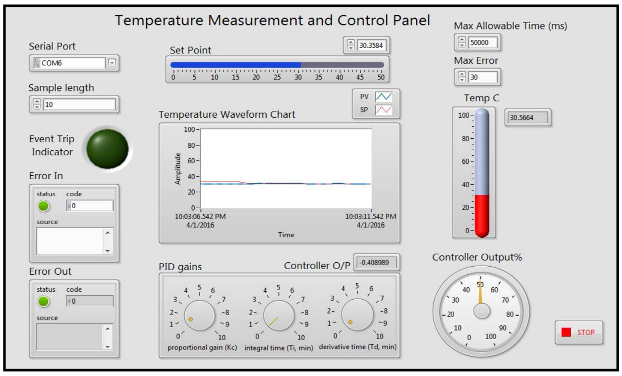

Figure 8: PV and SP at Equal condition

The Figure 9 and Figure 10 correspond to the condition when the PV is above SP and PV is Below SP respectively. The Figure 9 indicates the controller output is below 50% making the servo rotate in reverse direction when PV is below SP similarly Figure 10 indicates the controller output above 50% making the servo rotate in forward direction when PV is below SP.

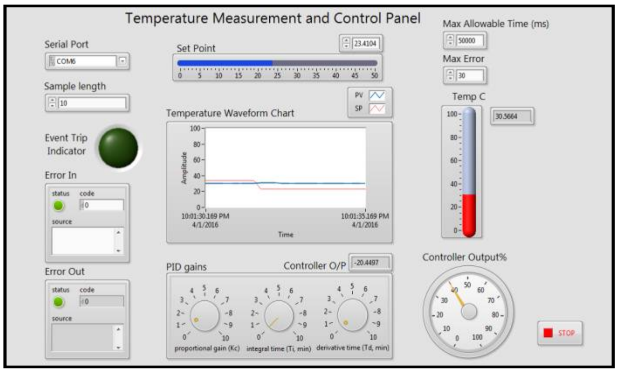

Figure 9: PV above SP condition

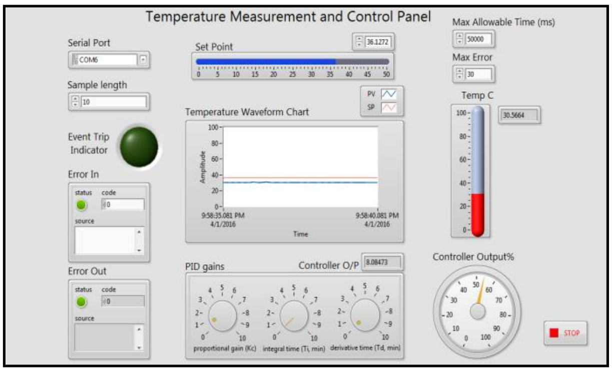

Figure 10: PV below SP condition

Figure 11 indicates the entire system has tripped. As the Error is much high than the desired limit as well as remains there for greater than the desired time thus the entire loop has stopped also the relay causes the temperature feeder to turn off. In the above experiment, in all cases the PV is kept constant at the ambience temperature, where the process is continued, and the set point is varied to determine the results. The process temperature may change according to the industrial environment. The value of the PID gains and time constant can also be figured out according to the process requirement. Figure 12 explains the proposed connection of servo with the knob of the temperature feeding device. In practice for different cases and conditions metal gear servo with required torque has to be attached for smooth and stable results.

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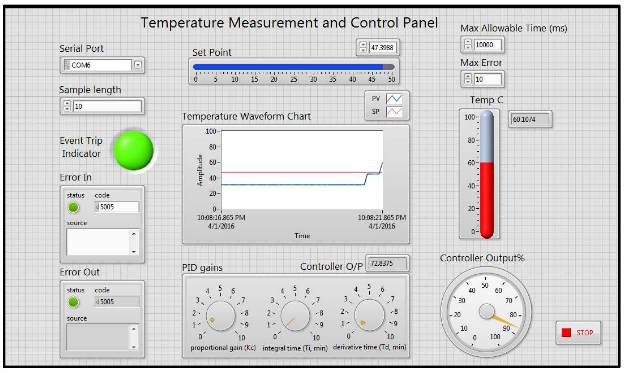

Figure 11: Event Trip Indicator

Figure 12: Servo Connection with Gas Knob

VIII. APPLICATION

Being a low cost and interactive system this design can be implemented in any Industrial ovens or temperature feeding systems [13] where a precise temperature has to be maintained continuously. It can largely be used in food and beverage industries, Factories producing food in large scale for midday meal purpose in countries like India. It can also be used in dairy industries. As we can log the data for future analysis thus this system can be useful in the field of Artificial Intelligence [14].

IX. CONCLUSION

With virtual instrument being the platform and the shortcomings of traditional temperature control system, this paper combines graphical programming language LabVIEW and the basic principles of P controller to conduct temperature control of a system. 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.

In this paper, temperature control system is designed in LabVIEW with Proportional (P) controller. The use of servo enables precise feeding of temperature, also the relay saved the entire system from unwanted damages. With the controller, the system controlled the temperature successfully. In this case, the P controller showed accurate in a system control as the result.

X. FUTURE SCOPE

The prototype is developed for the initial testing purpose only using P control for simplicity and fast response. As such, many improvements can be made upon this initial design. The design can be again modified to adaptive controller [15] for the modification of the temperature range according to the need, thus making it completely autonomous. Again, this system can be fuzzified to make it more efficient and increase controllability and can be used in the field of Artificial Intelligence. The entire system can also be made wireless using proper wireless control mechanism.

REFERRENCES

[1] Jagdish P. Mandhare, Sharad P Jadhav, "LabVIEW based PI Controller for a Level Control System", International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868, Foundation of Computer Science FCS, New York, USA, International Conference & workshop on Advanced Computing 2014 (ICWAC 2014) – www.ijais.org

[2] Alan Tong, "Improving the accuracy of temperature measurements", Sensor Review, Vol. 21 Iss: 3, pp.193 – 198

[3] Susmita Das, Bansari Deb Majumder, Arijita Das, Anilesh Dey and Dibyendu Sur, Department of Electronics and Instrumentation Engg. , Narula Institute of Technology/WBUT, India, Approach of Designing a PID Temperature Controller using RTD, **INTERNATIONAL CONFERENCE ON APPLICATIONS OF ENGINEERING, science & TECHNOLOGY - 2015** *ICAET-2015*,13th, April 2015 Organized by **Madurai Institute of Engineering and Technology, Madurai, Tamilnadu, India.**

[4] Anthony Maher, BorgWarner BERU systems Ireland Ltd Tralee, Ireland; Vijayalakshmi Velusamy, School of Engineering, Manchester Metropolitan University Manchester, UK; Daniel Riordan, Joseph Walsh, IMAR Research Centre Institute of Technology Tralee Tralee, Ireland; "Modelling of Temperature Coefficient of Resistance of a Thin Film RTD Towards Exhaust Gas Measurement Applications", Proceedings of the 8th International Conference on Sensing Technology, Sep. 2-4, 2014, Liverpool, UK.

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ISSN (Online): 2278 – 8875

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[5] Janhvi Chauhan, Electronics & Communication Engineering L. D. College of Engineering Ahmedabad, Gujarat; Prof. Usha Neelakantan, Electronics & Communication Engineering L. D. College of Engineering Ahmedabad, Gujarat; "An experimental approach for precise temperature measurement using platinum RTD PT1000", International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT) – 2016.

[6] Desborough Honeywell, "Chapter 10: PID Control",2000

[7] National Instruments, "Measuring Temperature With RTDs-A Tutorial", Application Note 046, 340557B-01, © Copyright 1996 National Instruments Corporation, All rights reserved, November 1996

[8] Jeremy Blum, "Exploring Arduino Tools and Techniques For Engineering Wizardy",Published by John Wiley & Sons Inc, ISBN: 978-1-118-54936-0, pp 80-86

[9] Granado Navarro, Miguel Angel, "Arduino Based Acquisition System For Control Appliances", Master Of Science In Telecommunication Engineering And Management, Treballs Academics, UPCommons

[10] S Nuicco, C Spataro, "Approaches To Evaluate The Virtual Instrumentation Measurement Uncertainties", Instrumentation and Measurement, IEEE, Volume 51, Issue 6, 2002

[11] JD Warren, J Adams, H Molle, "Arduino For Robotics", Springer, 2011, pp 51-54

[12] LabVIEW for Everyone: Graphical Programming Made Easy and Fun, Jeffrey Travis, Jim Kring, Third Edition. Prentice Hall Professional, 2007 ISBN-10: 0131856723.

[13] Y TAN, J Shen, LU Zong, "STUDY OF IMMUNE PID CONTROLLER FOR SURPERHEATED STEAM TEMPERATURE CONTROL SYSTEM [J]" Z LU - Proceedings of the Csee, 2002

[14] Santosh KV, B K Roy, "An Improved Intelligent Temperature Measurement by RTD using Optimal ANN", International Conference On Advances In Computer Electronincs and Electrical Engineering, ISBN: 978-981-07-1847-3, SEEK Digital Library

[15] Berengual M. Yebra, L.J., Rodriguez, F., "Adaptive Control Strategies For Green House Temperature Control", European Control Conference(ECC), 2003