

Development of Experimental Simulator via Arduino-based PID Temperature Control System using LabVIEW

H. Muhammad Asraf, K.A. Nur Dalila, A.W. Muhammad Hakim and R.H. Muhammad Faizzuan Hon
*Faculty of Electrical Engineering, Universiti Teknologi MARA,
Kampus Pasir Gudang, Jln Purnama, Bandar Seri Alam, 81750 Masai, Johor, Malaysia
nurdalila306@johor.uitm.edu.my*

Abstract—Studies on temperature control systems have been continued until today even though it has already been well established due to its growing applications in the industrial process, household appliance for cooling/heating, and etc. With a proper tools and a detailed study, a good control system can be designed to be robust and relatively free from instabilities. For this, LabVIEW and Arduino are recommended as tools for users to express their design creativity and implement ideas on creating systems for temperature control. This is useful for educational purposes especially for university students to use in their design projects. This paper proposes a PID control scheme implemented by using an Arduino microcontroller and Virtual Instrumentation (VI) software called LabVIEW for monitoring and controlling the temperature of a heating element which is sensed by thermocouple as the measuring device. The temperature is varied accordingly to the several setpoint, and error will be generated when the measured temperature does not reach the originally set point. Experimental results show that PID controller is capable to track and control the heater temperature towards the designated reference temperature. The small scale of this system and the ease of use allows Arduino to be practical in laboratory setting and also as a teaching platform for basic control programming.

Index Terms—Arduino; Virtual Instrumentation (VI); LabVIEW; PID Controller; Heater.

I. INTRODUCTION

Temperature control is a necessity in industrial process, even more strongly in residential or commercial appliances for building cooling/heating where environment control is crucial. Proper control system design is essential to ensure that the environment or process is always operated at optimal conditions [1]. There are many researches that have been conducted previously using Proportional Integral and Derivative (PID) controller design in several applications. N.Hayatee et.al [2] have designed a PID control for controlling the temperature of the refrigerator. A PID was developed and evaluated with on-off temperature controller to regulate its inner temperature using MATLAB Simulink software which proves that PID controller is better than conventional system [2]. Another interesting study that was developed by Y.Yan et.al has implemented the controller of PID combined with fuzzy logic for controlling water temperature. Authors [3] claimed that control via conventional PID system could not result in a precise control because its controlling parameters are fixed. Thus, the study introduces fuzzy control theory which has the feature of better dynamic performance with the advantages of the

traditional PID control method which has a high stability, precision and strong robustness. Another research has also been made by Ranjan et.al [4] regarding an effective PID controller implemented using Atmel16 microcontroller to regulate the temperature of the air-conditioning in a room. The research also implements the tuning of the PID controller via Ziegler-Nichols method to achieve optimum temperature. Muslim et.al [5] also investigate the best temperature controller for vacuum distiller using Arduino Mega 2560 board. Results showed that PID controller is less superior than fuzzy logic controller in terms of settling time and overshoot response. In relation to research work using Arduino for virtual instrumentation has been conducted by Branzila et.al [6], authors have investigated the biosignals monitoring in medical sector for accelerating the pre-diagnosis process by developing the system using several toolkits available in LabVIEW for signal processing i.e. advanced signal processing and digital filter design for developing the virtual instrumentation. They claimed the biosignal processing could be developed in shorter time and low cost product prototyping. Haider et.al [7] have also used Arduino based virtual instrumentation to conduct research on monitoring solar panels of the DC power supply remotely. In this case GUI via LabVIEW was constructed and implemented in real time using low cost Arduino Mega2560 board instead of LabVIEW Digital Acquisition (DAQ) card to control, observe and record the readings on voltage, current and power for providing the information of power consumption. The authors claimed to successfully built the system at minimal cost. Meanwhile, Teikari et.al [8] proposed a stimulator to be used in vision research field. In this project, light intensity from light emitting diode (LEDs) has been controlled via Arduino microcontroller integrated with LabVIEW. Authors [8] developed an open source component to reduce complexity of design process which is suitable for education sector that has limited source or fund while requiring no advanced technical skills.

To summarize, most of the previous research work focus either partly on controller design, or on monitoring certain parameter in the system. There is rarely any works on implementing both elements in a laboratory as a teaching platform. The lack of virtual controller software and complexity in using controllers during project design process impairs new users to implement any new ideas during project. Designing a system for a case study (for example, temperature measurement and control) and controlling the system virtually using a widely used LabVIEW software will

make the understanding of the control design process much easier. Therefore, this work aims to propose the use of Virtual Instrument (VI) along with PID-based controller implemented within Arduino microcontroller to design a basic heater control system as a sample case study. Using thermocouple as a measuring element for a basic case study of temperature control system design is considerably novel, and was rarely pursued before due to the nonlinearity effect that usually accompanies with the use of thermocouple. This explains why most existing control system that have been studied typically integrates thermistor, thermostat or Resistance Temperature Detector (RTD) for their sensing applications [9-11]. The instrumentation is developed for use in laboratory setting which the simulator will be able to replicate and model the behavior and response of actual equipments and instruments. Arduino is selected due to its low cost and easy implementation as compared to other microcontroller boards such as chipKIT and NI-Rio. From this study, it can benefit users in terms of overcoming the steep learning curve of designing a control system, while at the same time provide on-hand, practical learning through implementing the acquisition and monitoring concept towards a physical, realizable system.

This paper is organized as following: An overview of proposed system with its methodology is presented in section 2. Section 3 discussed the controller design technique and interfacing section. Section 4 contains results and discussion obtained from actual implementation of the plant, followed by conclusions derived from the outcome in section 5.

II. PROPOSED SYSTEM

The proposed system to be used in this study is a miniaturized heater model - constructed using of a nichrome wire as heating element mounted on base platform, with a thermocouple sensor that are encapsulated within a small chamber and a microcontroller. The system block diagram and its schematic can be referred to Figure 1 and Figure 2 respectively. A transistor is used as switching device to turn on and off the heater temperature accordingly to the measured value. Initially the user sets the desired reference temperature by adjusting the Pulse Width Modulation (PWM) to a certain target value. During operation, the thermocouple will then measure the heating element temperature and compares it to the initial set temperature. Based on the difference of these two values, error signal will be generated and converted to voltage reading into built-in ADC in microcontroller. The signal will then be accordingly processed by the designed PID (known as Proportional, Integral and Derivative) controller and the output signal will be sent to the transistor to adjust the temperature of the heater. This will be then sensed by the thermocouple, which will be compared to the reference temperature, restarting the process. This process loop repeats until the heater reaches desired set temperature. The temperature detection process is translated into programming via LabVIEW which will need to be installed in the Personal Computer (PC). In order to integrate LabVIEW graphical programming to the measurement signal of the heater system, the interfacing toolkit called LINX is required to be installed as well. Therefore the toolkit serves as a gateway to connect between the developed programming and the real time heater system.

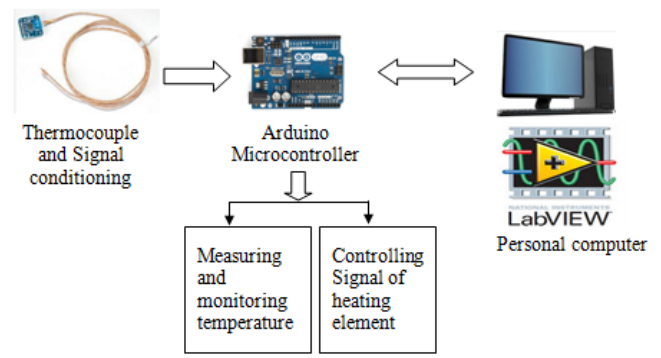


Figure 1: Block diagram of the system

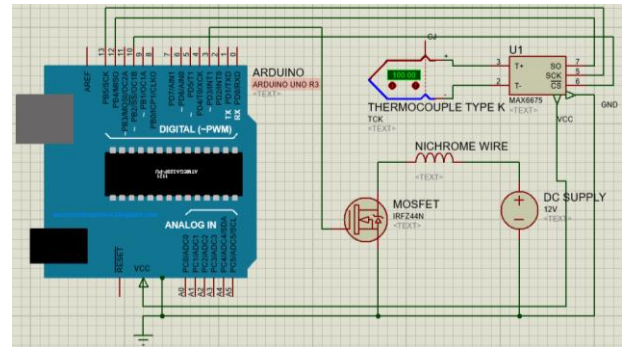


Figure 2: Schematic diagram

A. Controller Selection via Arduino Uno

For this study, Arduino Uno was proposed to be used for controller hardware, which is well known for its implementation simplicity. The Arduino Uno is the smallest in dimension scale among the Arduino series microcontroller board, and is suitable for entry level programming. As a single board microcontroller, the development platform via Integrated Development Environment (IDE) is written in C-language [12]. The Arduino Uno [12] is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It is able to power up by just using USB or 5V DC power supply [12]. The used of Arduino can be implemented in learning and understanding the concept of data acquisition, monitoring and control system. Its small size and easy execution allows it to be used in laboratory where only basic level of programming is required, or in educational environment as a teaching aid for introductory course in programming.

B. Temperature Measurement of the heater

Several methods [13] have been investigated and developed for measuring temperature which include but not limited to thermistor, Resistance Temperature Detector (RTD), and thermocouple. These sensors [14] rely on measuring the characteristic of sensor material that is affected by the temperature. In this system, thermocouple is selected as a measuring element. A thermocouple [15] is a sensing device consisting of two dissimilar conductors in contact with each other, where a temperature differential experienced by the different conductors will induce an electrical potential difference due to the Seebeck effect. The Seebeck coefficients [16] generally vary with respect to function of temperature, and depend strongly on the conductor types. Thermocouple wire size and attachment method may have an

thermocouple then with Arduino SPI Digital Pin (13 SCK, 12 SO and 10 CS) to allow LabVIEW to read data from Arduino directly using SPI. Firstly, the connection of Arduino with LabVIEW is initialized with the help of LINX. The SPI is configured before entering the loops and the data are obtained from array of digital data on Arduino. The data is stored in array and converted into temperature in the LabVIEW. The output displays the temperature which is connected to the PID process variable (sensor). The PID value can be adjusted using PID gain and output range on the front panel. The output of the PID is connected to the Duty Cycle to control PWM of the Arduino, thus adjusting the temperature of the system.

IV. SIMULATIONS, EXPERIMENTAL RESULTS, AND DISCUSSIONS

A simple experimental testing is aimed to demonstrate the output of the heater system. Shown from Figure 5 to Figure 7 is the output response for the system after the experiment has been conducted for 25%, 50% and 75% set points. It compares between reference temperature and the measured temperature. In order to test the system, the set point is varied accordingly to several values which are based on PWM indicator. The results can be seen on the graph which shows the differences between the setpoint value and the current temperature as well as the time taken. Taking the settling time and percent of overshoot as criterion, the PID controller needs to be tuned to result the best performance with less overshoot while reaching settling time at shorter time. Therefore the PID value will be adjusted accordingly until the system achieves good performance criterion.

From Figure 5 it can be observed that for the system to reach the desired temperature, it requires 119 seconds. First the system was set to heat up nichrome wire to 32.5°C. It rose slowly to the set point. Then when the temperature is reduced, the system takes longer time to reach the value. From Figure 6, the graph shows that with PID the time taken for the system to reach desired temperature is slower by 58 seconds. When the temperature is set to 51°C the PID gain value needs to be adjusted so that the desired criterion will be satisfied. From this exercise, this front panel can be used as a simulator for real time PID temperature tracking as well as PID control system.

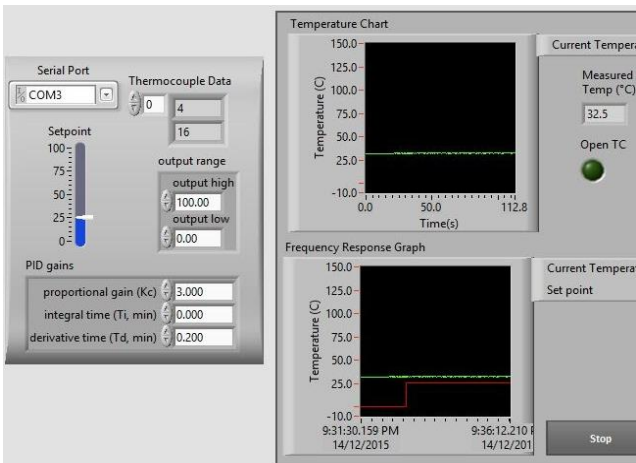


Figure 5: Setpoint is set at 25% with PID value adjusted

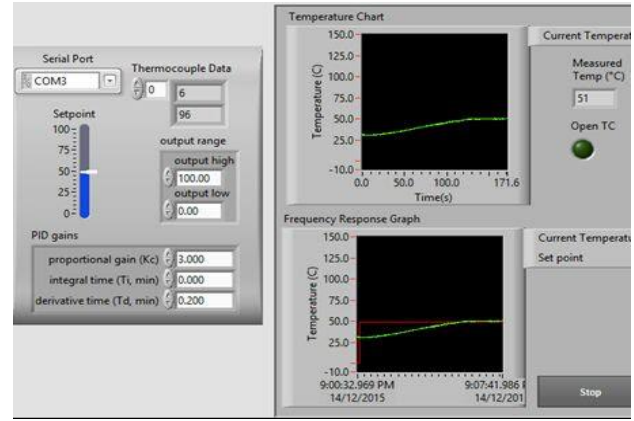


Figure 6: Setpoint is set at 50% with PID value adjusted

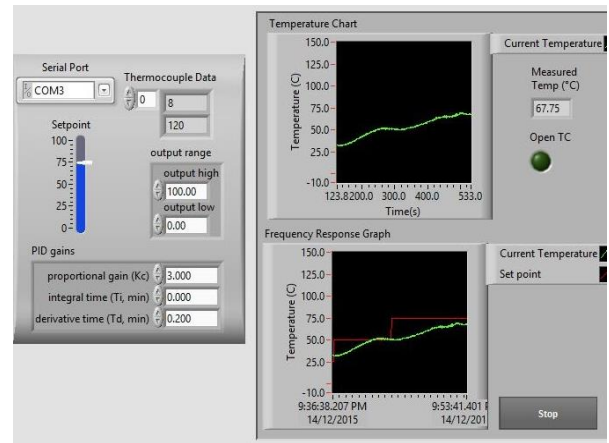


Figure 7: Setpoint is set at 75% with PID value adjusted

V. CONCLUSION

Designing temperature control system and other similar project can be made easier with the assistance of microcontrollers and LabVIEW software. This experiment shows the usefulness of using virtual instrumentation in design applications as it allows many virtual instruments that can be used directly without the need of physical devices to be connected to LabVIEW. It is recommended to practice and apply the use of Arduino Uno and LabVIEW especially for university students due to its simplicity, reduced cost and accessibility to entry level programmers without requiring too high of a technical skills. This experiment is a good demonstration of the use of the aforementioned tools as part of a system design project.

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