Development of the low-cost hot plate temperature controller using Arduino Uno R3

A Thedsakhulwong * and P Hernmek

Department of Physics, Faculty of science, Ubon Ratchathani University, Warinchamrab, Ubon Ratchathani, 34190, Thailand.

*Email: amorn.t@ubu.ac.th

Abstract. The low-cost hot plate temperature controller was developed using Arduino Uno R3 microcontroller board. The controller composed of the Arduino microcontroller which was the controller main part, a temperature sensor part and a 7-displays part for monitoring temperature values. The K- type thermocouple connected to MAX31850 IC was established for a temperature sensor. The 4-digit 7 segment display was used for temperature monitoring. The controller program consists of measurement, display and controls the PID parameters was developed in Arduino IDE. The hot plate which has 24-ohm heater wire was applied to this experiment. The result has shown that the temperature in the range of 25-500 degree Celsius was controlled with the resolution of 0.25 degree Celsius. Using the trial and error method for the PID parameter varied the target temperature can be reached with the maximum error was 3 degree Celsius.

1. Introduction

At present, The temperature controller is essential in various research such as the materials processing [1-2], the heater system [3], the cooling system [4], micro-incubator applications [5]. The design and construction of a temperature control system are very important in controlling the temperature to the target point. Ali Etem Gurel and Ilhan Ceylan are used the PID controller for a heat pump fluidized bed dryer [6]. Qu Minglu et al. study a control strategy for cascade air source heat pump water heater to adjust the load variation through the PID controller [3]. Armando M et al. are designed the system for measurement glucose and design necessary elements to performed a study on water mixed glucose-impedance at different temperatures and cell growth in the maintain temperature with the PID controller [5]. The PID controller system was achieved the stable and accurate target temperature [7]. Aekarin Sungthonga et al. has shown the PID controller can be achieved the performances by compared with the conventional approaches such as Ziegler Nichols and Genetic Algorithm [8]. F. A. Candelas et al. were used the Arduino for PID temperature controller system in a laboratory experiment of the Automatic control [9]. Armando M. Guidote et al. were build a temperature control system has introduced a PID method which controls the temperature in the range of room temperature to 500 ° C [10] but the temperature instability occurs with this research.

In this paper, the study of the temperature controller on a hot plate using an Arduino Uno R3 board microcontroller with the PID method. The Arduino is selected due to its low cost and easy implementation as compared to other microcontroller boards. The K-type thermocouple connected to MAX31850 IC was the temperature sensors for measuring the temperature of the system and displayed the target temperature on 4-digit 7 segment display. The test details are shown in part 2. Analysis and experimental results are provided in section 3 and the results are shown in section 4.

2. Experimental

The basic idea of the PID controller based on the closed-loop systems as shown in figure 1. The temperature was measured with the sensor, then calculate the desired actuator output value. The proportional, integral, and differential parameters were used with the calculation process. The output value was tuned by the parameters adjusted.

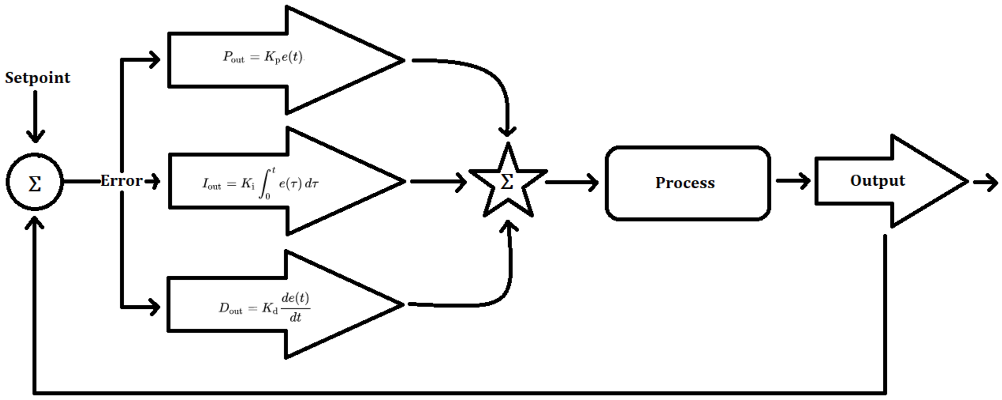

Figure 1. The block diagram of a typical closed loop system.

The K-type thermocouple was connected to the thermocouple Amplifier MAX31855 breakout board which established for a temperature monitoring. The Arduino Uno R3 microcontroller was collected the temperature value from the break board via SPI bus interfacing. The target temperature and PID parameter were applied by the key switch. The actuator put value was process by the Arduino Uno R3 and sent to a solid state relay for controls the on-off line supply. The 24 ohm hot-plate was heated by the sequence actuator output. The target temperature was shown on the 4-digit 7 segment display. The real-time monitoring of the hot-plate temperature can be done via the USB-port to a computer. The system has shown in figure 2.

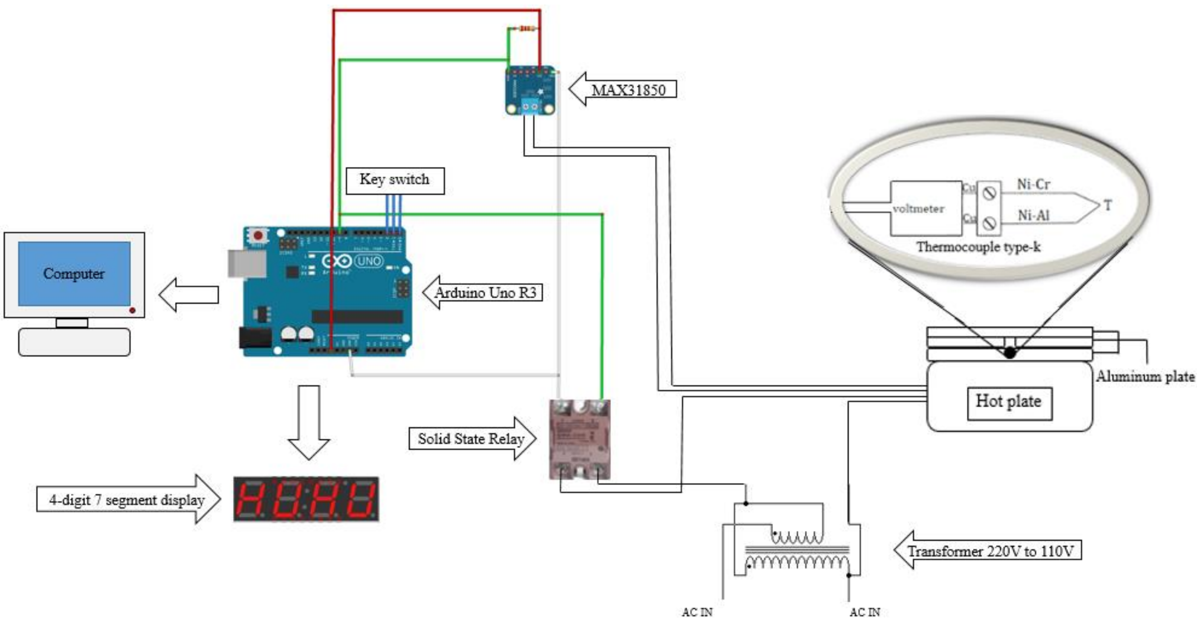

Figure 2. The block diagram of the low-cost hot plate temperature controls system.

3. Result and discussion

3.1 Manual tuning PID

The trial and error were applied to the system. Firstly, The K_i and the K_d parameter was set to zero then increase the K_p parameter until the temperature oscillates around the set point. Secondly, the K_p parameter was decrease to approximately half of the old value. Then the K_i parameter was increased until the offset of the process was corrected. Finally, the K_d value was increased until the temperature was at an acceptable level. The target temperature of various trial and error case was shown in Figure 3.

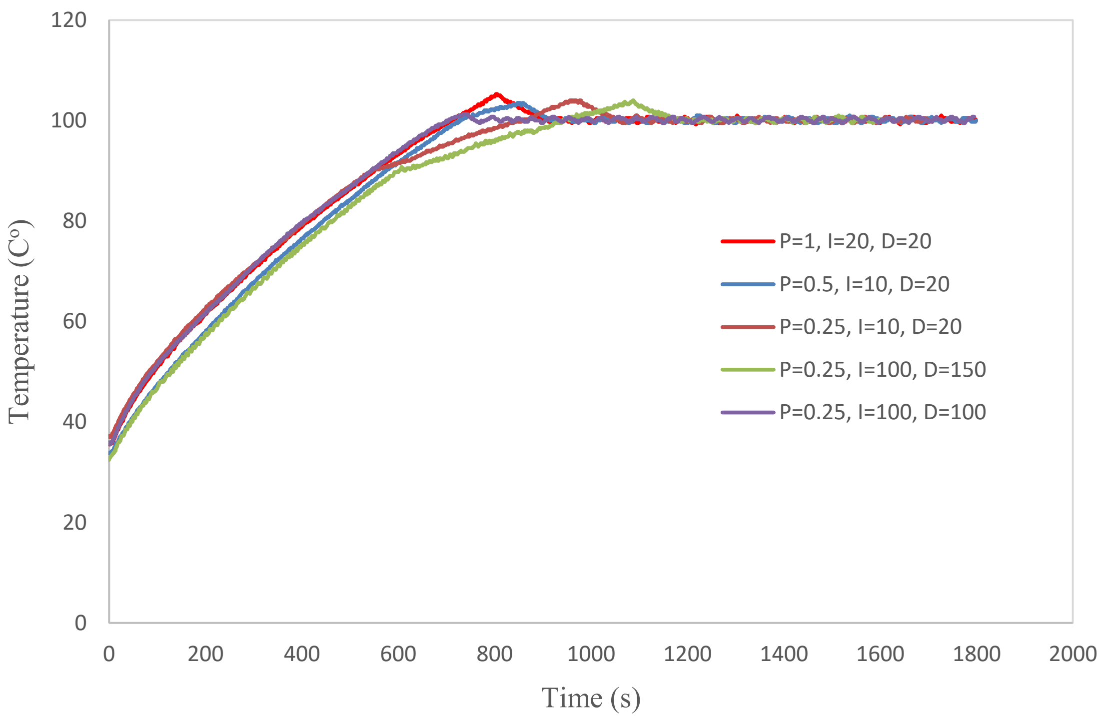

Figure 3. The target temperature with the various Kp, Ki, and Kd values.

In figure 3. The best parameter of the Kp, Ki, and Kd were found was 0.25, 100, and 100 respectively. The maximum error of actual temperature was 3 degree Celsius and setup time was around 750 second were observed.

3.2 Experiment results of temperature measurement.

Finally, the stability of the system was demonstrated with the target hot-plate temperature was set various set point with the best parameter value. The results was shown in Figure 4. The set temperature values was maintained and the maximum error of all target temperature were 3 degree Celsius.

Conclusion

In this research, the developed a low-cost hot plate temperature control system using the Arduino Uno R3 system. The temperature sensor we use K-type thermocouple connected to MAX31850 IC was established for a temperature sensor. All of the data sent to Arduino-board controller to store number data and monitoring the temperature and displayed on the 4-digit 7 segment display. The temperature was controlled with a range of 25 to 500 Celsius degrees and temperature were measured with the resolution of 0.25 Celsius degrees. The target temperature can be reached with the maximum error was 3 degree Celsius.

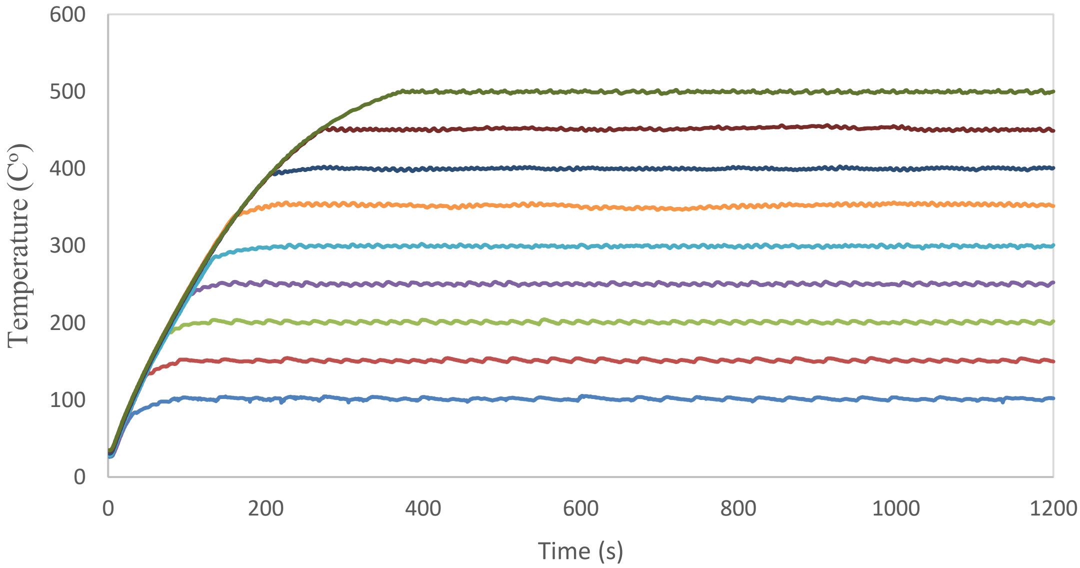

Figure 4. Temperature (C°) graph with time (s).

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