ME 4005 Lab Report 5 – Temperature Control

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Introduction

Lab five covers the experimental performance of temperature control systems on our heater block system similar to that used in Config 2 of lab 4, which will from this point forward be referred to as the thermal plant. Key objectives as outlined in the manual are for the student to quantify manual versus automatic control and understand the benefits and limitations of each. The student will evaluate the performance of the automatic control systems on tuning, robustness, and performance. The equations below define the models used.

$$e(t) = T_{desired} - T(t) \tag{1}$$

$$u(t) = K_P\left(T_{desired} - T(t)\right) \tag{2}$$

$$u(t) = K_I \int \left(T_{desired} - T(\eta)\right) d \tag{3}$$

$$u(t) = K_P e(t) + K_I \int e(\eta) d \tag{4}$$

As seen in the above equations equation one provides the error function equation, equations 2 through 4 refer to KP, KI and PI (both) control models.

Methods

In conducting lab two the student is tasked to collect data on the thermal plant temperature via use of the provided MSP432 DAQ, therefore the first step is to open the Graphical User Interface for the MSP432 via MATLAB. The MSP is set up to collect data via plugging in wires as seen below.

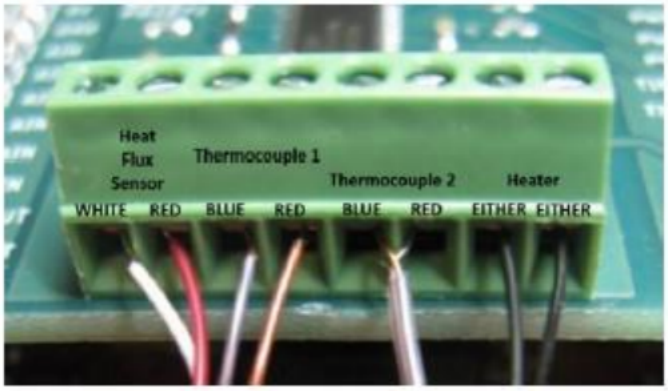


Figure 1: Requisite Wiring Configuration

The setup of the thermal plant is to be designed to match the diagram below with the thermocouple 2 wire inserted between the heater and Heat Flux Sensor(HFS).

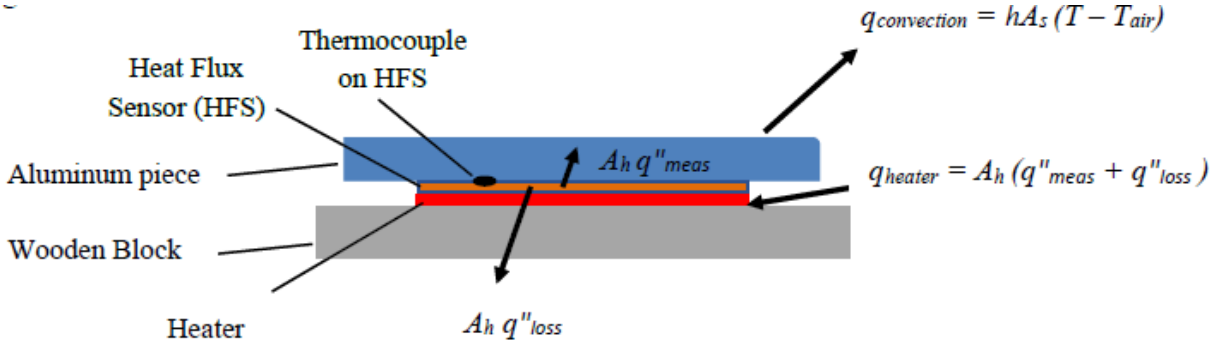


Figure 2: Configuration of Thermal Plant

The setup is now ready to support collection of data, the general order to take data in is to first take the steady state and test for the heater open loop values then to move on to take actual experimental data values. Firstly perform manual control as best as possible using heater on off to modulate the heating pulses, then allow for automat control and take data there while adjusting KI and KP values where necessary. Once 2 Manual control and 3 KI, KP , and PI results are obtained the student is ready to use the best PI model to record the temperature disturbance data. To disturb the temperature, use an ice cooled aluminum block placed on top of the thermal plant.

Results and Discussion

The plots and tables below detail the performance of the control systems used for further evaluation.

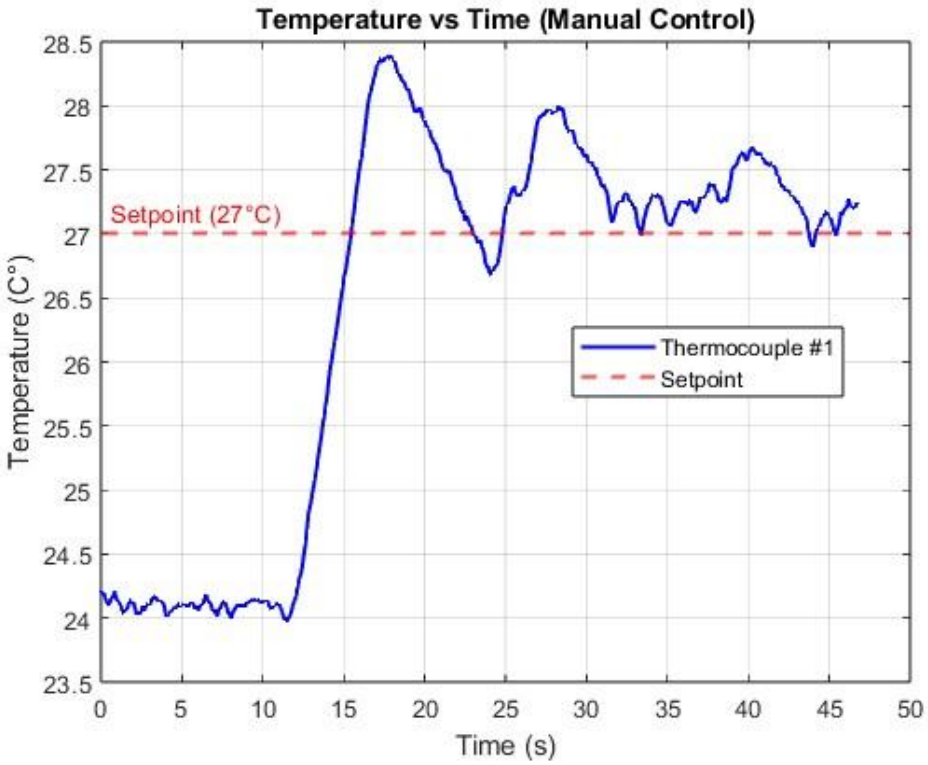


Figure 3: Manual Control Plot

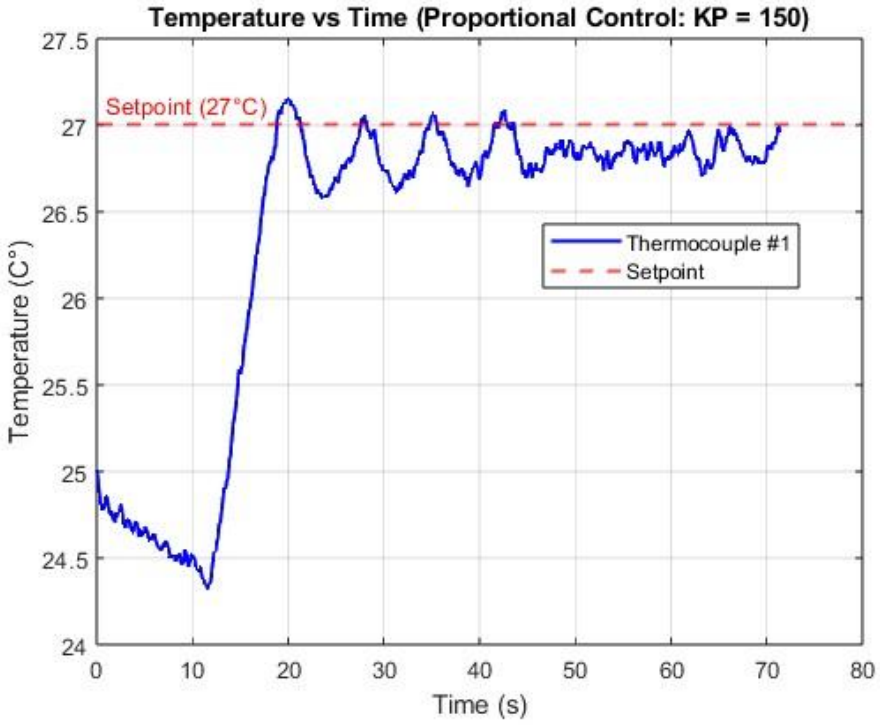


Figure 4: Proportional Control Plot

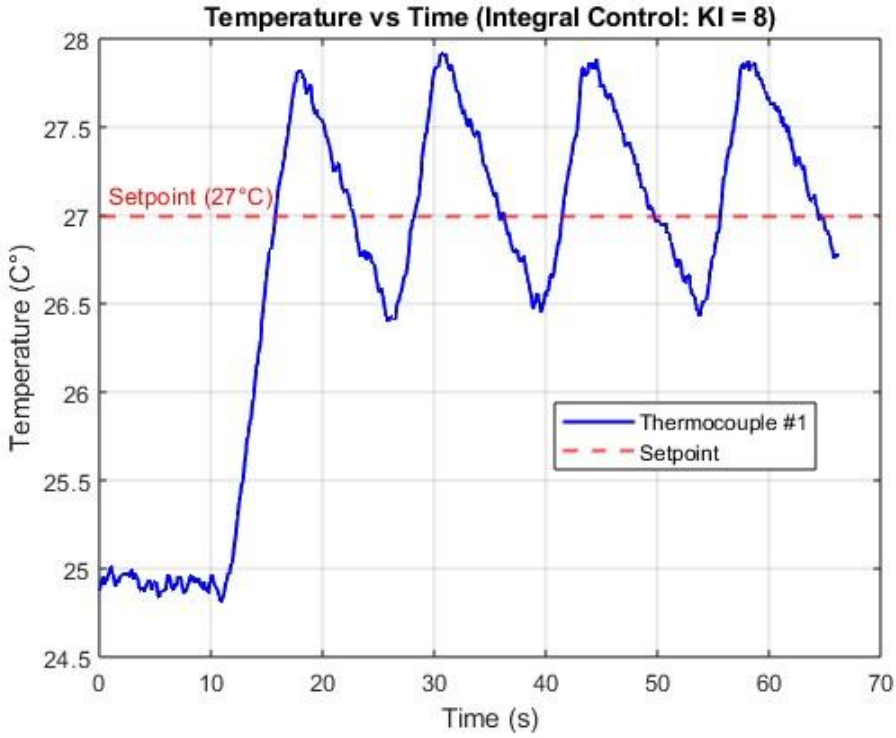


Figure 5: Integral Control Plot

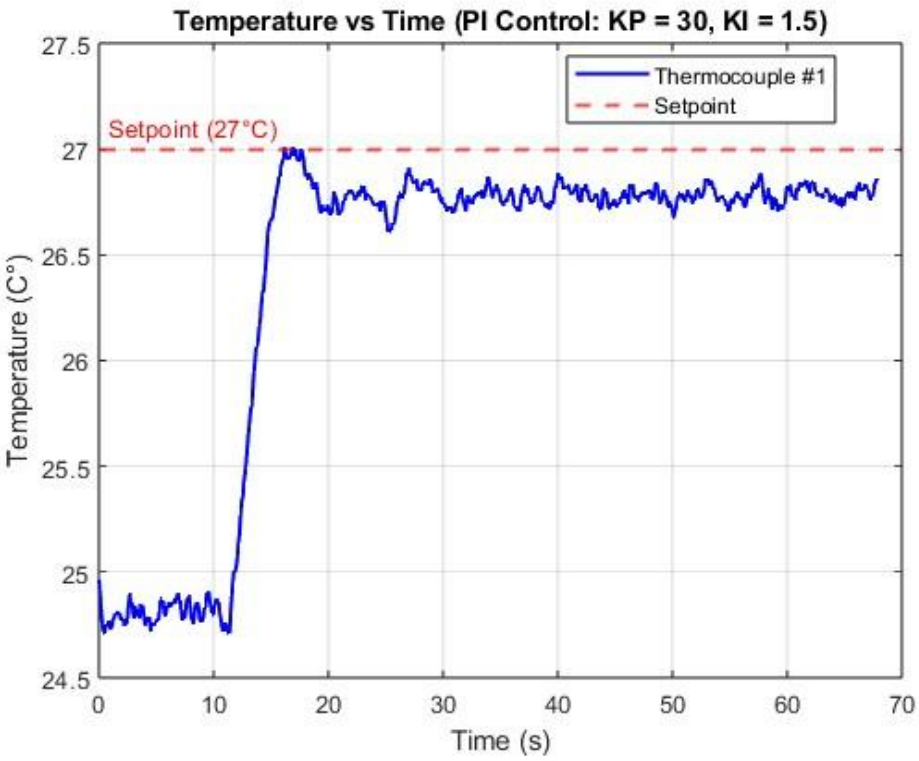


Figure 6: PI Control Plot

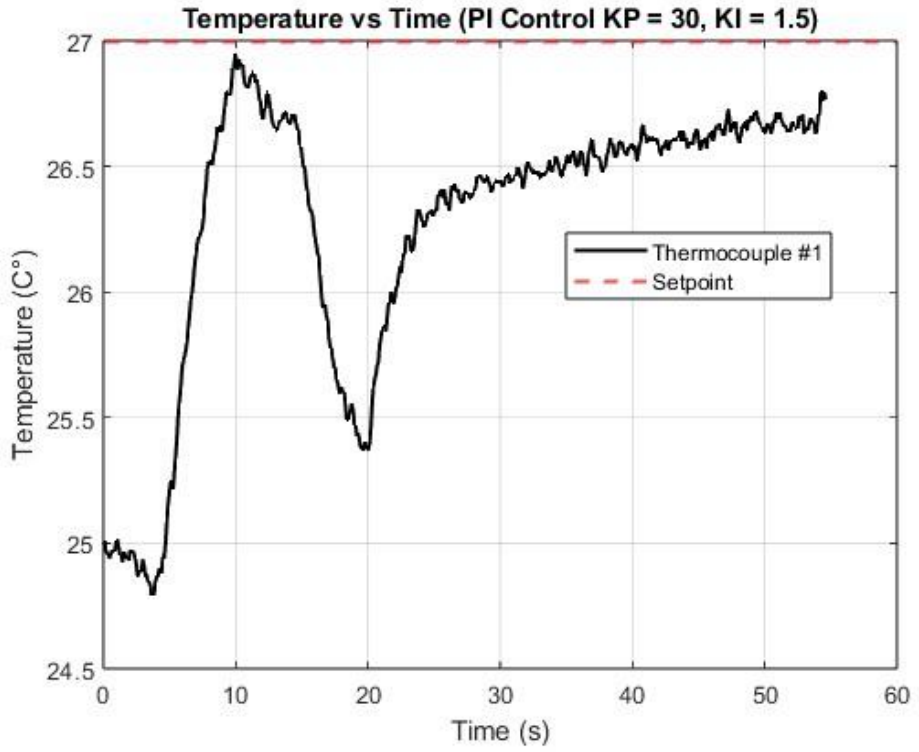


Figure 7: Thermal Disturbance Response Plot

Table 1: Experimental Data Values

Experiment	Mean Value (C°)	Steady-State Error (C°)	Peak Absolute Error (C°)
Manual control	27.449	-0.449	1.39
Proportional Gain (KP = 150)	26.843	0.157	0.421
Integral Gain (KI = 8)	27.2	-0.2	0.919
KP and KI Gain (KP = 30, KI = 1.5)	26.786	0.214	0.389

As can be seen in the mean values as well as simple visual observations, the wors performing control option is Manual. This is expected and due to human error, innate input delay, and the inability to partially activate the heater during manual control (ie no on at 30% only off or on at 100). In contrast the best performance option was the Proportional Gain control system. This is likely because my used KP only value was close to ideal while my PI values were not close to ideal even in my best dataset. If given infinite time to find the best values or if a optimization program was used to find optimal values the expected result would be that PI control would yield the best results. Something worth noting however is that while my KP had better steady state error the peak absolute error was lower on the PI dataset. The data above shows the expected outcome as far as shape goes for PI KP and KI data. KI should approximate a sawtooth look as it attempts to overshoot the setpoint as little as possible, KP should (somewhat) look like a sinewave with the peaks at the setpoint, PI should chop off the overshoots from PI and retain the sinusoid of KP. The seen response to outside low temperature stimuli shows better the integral portion of my PI control as the initial “acceleration” of temperature return to the setpoint was far greater than the near setpoint temperature change. This is as robust of a performance as expected given the materials used in lab. Overall, as mentioned while my PI control did not achieve better than KP control steady state operational error its external stimulus response and lack of optimization comparative to the optimization done on KP show that a better designed PI (better values of KP and KI) would perform the best.

References

[1] ME 4005 Course Materials. Available: https://canvas.vt.edu/courses/187828