Faculty of
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School of Electrical, Electronic & Computer Engineering

EERI 321

Practical 2: PI Controller

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Submitted to:

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ABSTRACT

The purpose of this Practical assignment is to design and simulate a PI controller to improve the transient response of the light bulb that was modelled in the previous practical assignment. The design specifications were used to calculate parameters for a PI controller that would meet them. The specifications were met and yielded a system that improved on the system designed in the previous assignment.

DECLARATION

I, MJ Bezuidenhout, declare that this report is a presentation of my own original work. Whenever contributions of others are involved, every effort was made to indicate this clearly, with due reference to the literature. No part of this work has been submitted in the past, or is being submitted, for a degree or examination at any other university or course.

Potchefstroom, October 2016

MJ Bezuidenhout, October 9, 2016

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ACRONYMS

PID Proportional,Integral & differential Controller

PI Proportional& differential Controller

Ts Settling Time

PO Percent Overshoot

INTRODUCTION

The purpose of this practical assignment is to design a PI controller that would improve the transient response of the system modelled in the previous assignment.The compensated system must yield a transient response with a PO and Ts below the specifications.
From the data in the previous practical, K was found to be 86.0213 and τ was 136.0407 by the amount of time it took to reach 67% of the steady state temperature. The transfer function was:

$$\begin{aligned} G(s) &= \frac{Y(s)}{C(s)} \\ G(s) &= \frac{K}{\tau s + 1} \\ G(s) &= \frac{\frac{K}{\tau}}{s + \frac{1}{\tau}} \\ G(s) &= \frac{0.63230}{s + (7.3507) * 10^{-3}} \end{aligned} \tag{1}$$

This system will be compensated by placing a PI controller in series with the transfer function in 1. The transfer function of a PI controller in general is given by:

$$\begin{aligned} G_c(s) &= K_c + \frac{K_i}{s} \\ G_c(s) &= \frac{K_c s + K_i}{s} \\ G_c(s) &= K_c \frac{s + z}{s} \end{aligned} \tag{2}$$

The parameters of the transfer function are therefore K_c and K_i. For purposes of calculation, $Z = \frac{K_i}{K_c}$. The calculation of these parameters are discussed in the problem statement.

PROBLEM STATEMENT

The following table shows the specifications that the system must adhere to:

Table 1: Specifications

Parameter	**Maximum Value**
Settling time(T_s)	300s
Percent Overshoot(P.O.)	10 %

The equations for Percent overshoot and settling time are given by:

$$P.O. = e^{\left(\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}\right)} \tag{3}$$

$$T_s = \frac{4}{\zeta\omega_n} \tag{4}$$

Furthermore, ζ and ω_n can be used to define a desired characteristic equation in the form:

$$Q(s) = s^2 + 2\zeta\omega_n s + \omega_n^2 \tag{5}$$

The problem statement can be summed up as the reconciliation of the desired characteristic equation 5 with the characteristic equation of the system, which is given by:

$$Q(s) = G(s)G_c(s) + 1 \tag{6}$$

With respect to the equations 1 and 2

First, equations 3 and 4 are solved using the specifications:
Solving ζ for a P.O of 10 % yields $\zeta = 0.5911550$.
Solving ω_n for a T_s of 300 seconds and the above ζ yields $\omega_n = 0.0225547163$.
In other words, $\zeta > 0.5911550$ and $\omega_n > 0.0225547163$
set:

$$\omega_n = 0.023 \tag{7}$$
$$\zeta = 0.8 \tag{8}$$

These values of ζ and ω are used to define a desired characteristic equation in the form of equation 5.

$$Q(s) = s^2 + 0.0368 + 5.29 * 10^{-4} \tag{9}$$

Using the equations 1 and 2 the characteristic equation of the compensated system is given by:

$$Q(s) = s^2 + ((7.3507 * 10^{-3}) + (0.63230K_c))s + 0.63230(K_c z) = 0 \tag{10}$$

Reconciling equations 9 and 10yield:

$$K_c = 0.04657 \tag{11}$$
$$K_i = 0.00084 \tag{12}$$

These calculated values will be simulated to confirm that the specifications are met: An offset of 20°C was used to simulate room temperature.

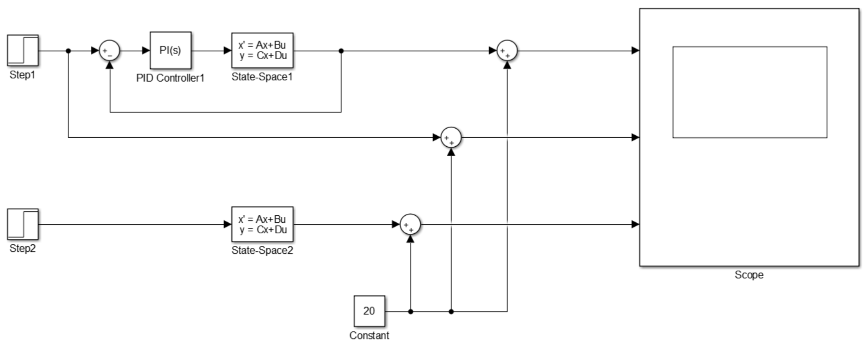

Figure 1: Simulink model of the compensated and uncompensated systems

RESULTS

Figure 2 shows the output of the simulation as illustrated in Figure 1:

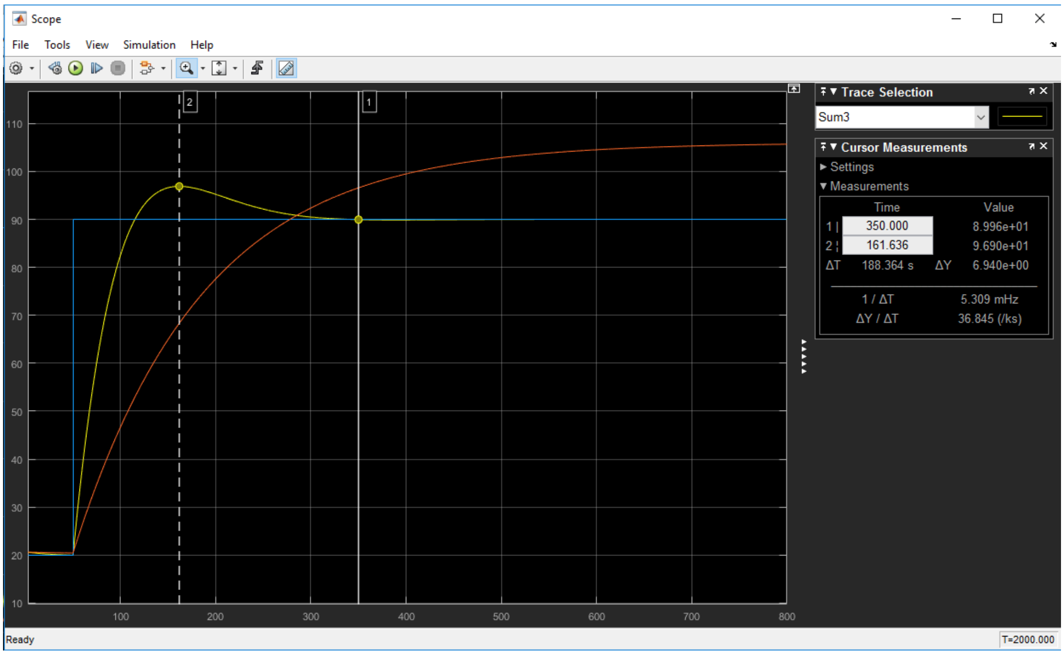

Figure 2: Output of the simulation

Figure 2 shows that the maximum value reached by the compensated system was 96.90°C, and that after 300 seconds, the value was 89.90°C. This relates to less than 10% overshoot and a settling time that is significantly less than 300 seconds. The design specifications were therefore met. Table 2 tabulates the results

Table 2: Results

Parameter	**Value**
Settling time(T_s)	267.7s
Percent Overshoot(P.O.)	9.85 %

It is also clear that the compensated system has a lower settling time than the uncompensated system. This will briefly be discussed in the conclusion.

CONCLUSION

The specifications were met and in that regard the assignment was successful. Furthermore the system from the first assignment was improved. The assignment illustrated the technical aspects of a PID implementation effectively and completely.

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