Project I:

Closed-Loop Control of Elevator System

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**Course:** SY202 Cyber Systems Engineering

**Enclosures:** (a)Txt file with mbed elevator control program (from Task VII)

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Metric** | **Weight** | **Quality** | | | | | **Max**  **Score** | **Midn**  **Score** |
| **0** | **1** | **2** | **3** | **4** |
| Use of Lab Template | 1 | No |  | Partially |  | Yes | 4 |  |
| Introduction | 1 | Problem, purpose, and objectives are unclear |  | Problem stated but purpose/objectives unclear |  | Well discussed | 4 |  |
| Calibration | 3 | Wrong or missing key data/results |  | Incomplete details or partially wrong, no discussion on sensor characteristics |  | Well described, presented and discussed | 12 |  |
| Logic Control | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Proportional Control | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Proportional-Integral Control | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Proportional-Integral-Derivative Control | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Effects of Sampling Period | 2 | Not described or discussed |  | Described but not discussed or analyzed |  | Described and well-analyzed | 8 |  |
| Comparison | 3 | Poorly discussed or missing several observations |  | Result are well presented, but missed some relevant observations to substantiate comparison |  | Correct interpretation of results and well-discussed | 12 |  |
| Figures and Tables | 2 | Figures and Tables are not correctly labeled or are hard to read |  | Figures and Tables are missing some important features |  | Figures include a descriptive caption, are well identified, and are easy to read | 8 |  |
| Conclusions | 1 | Not included or poorly summarize main results |  | Included but inaccurate or vague |  | Included and cohesively summarize results | 4 |  |
| Enclosures | 1 | Not included |  | Partially |  | Included | 4 |  |
| Grammar, organization, & Professionalism | 1 | Poor grammar and use of slang, missing use of units |  |  |  | Professional engineering writing | 4 |  |
| Demo of your project  (Task VII) | 5 | Not presented |  | Partially presented or wrong |  | Successful demonstration | 20 |  |
| **Total Points** | | | | | | | **128** |  |
| **Normalized Report Score = (Total Point / 128) x 100** | | | | | | | **Letter Grade:** | **100** |

# Introduction

**This should be in paragraph form (3-4 paragraphs)**. In this section you should discuss the following items.

Problem Statement and Objectives: Describe the purpose of the lab, the physical system being modeled or controlled, the problem, and the lab objectives. Describe the equipment used to control the system.

# Calibration

Describe purpose of calibration. What is being calibrated? Why? Describe the process of your calibration.

## Calibration Results

Include the results from your calibration, **including the equation** relating voltage (or counts) with distance in inches, the calibration curves (plots), and any other information you may have. Discuss accuracy and precision of both sensors. Discuss advantages and disadvantages of both and justify the decision of using encoder over IR sensor.

|  |  |
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Figure . Example of Calibration Curve for IR Sensor and Encoder

# Logic Control

Describe your logic control. Include pseudocode for the logic control (if-else logic statements). Be sure to indicate in your discussion the duty cycle levels used for ascending, descending, and holding the elevator in place.

## Results

Include results from your logic control. Include a plot for the **height vs time** response of the elevator going from its lowest position to 16 inches (or some similar range). Discuss any time response characteristics (such as Overshoot, settling time, peak time, and steady-state error). Include also a plot of the **PWM duty cycle vs time**. **Discuss possible sources of errors**.



Figure 2. Example of Logic Control Response

Discuss response of system to disturbances, when adding weight. Include a plots of **Heights vs Time** and **PWM duty cycle vs Time** similar to Figure 3 below.



Figure . Example of Logic Control with Disturbances between t=8 sec and t=22 sec

# Proportional Control

Describe your proportional control law by providing the equation with proportional gain.

## Results

Include results from your proportional control. Include a plot for the response of the elevator going from lowest position to 16 inches (or a similar range). Discuss any time response characteristics (such as Overshoot, settling time, peak time, and steady-state error). Include a plot of the PWM duty cycle vs time. Discuss possible sources of errors.



Figure . Example of Figures for Proportional Control

Discuss response of system to disturbances, when adding weight. Include a plots of **Heights vs Time** and **PWM duty cycle vs Time** similar to Figure 3.

# Proportional-Integral Control

Provide the equation for the PI control including gains.

## Results

Include a plot for the response of the elevator going, height vs time. Discuss any time response characteristics (such as Overshoot, settling time, peak time, and steady-state error). Include a plot of the PWM duty cycle vs time. Discuss possible sources of errors.



Figure . Example of Figures for PI Control

Discuss response of system to disturbances, when adding weight. Include a plots of **Heights vs Time** and **PWM duty cycle vs Time** similar to Figure 3.

# Proportional-Integral-Derivative Control

Provide the equation for the PID control including gains.

## Results

Include a plot for the response of the elevator going, height vs time. Discuss any time response characteristics (such as Overshoot, settling time, peak time, and steady-state error). Include a plot of the PWM duty cycle vs time. Discuss possible sources of errors.

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# Effect of Sampling Period on Closed-Loop Control Performance

Discuss the behavior of the system to different sampling frequencies. Include plots heights vs time for both logic and proportional controllers when using a frequency of 4 Hz. Compare your results with those of Figure 2 and 4.



Figure . Logic Control with Sampling Frequency of 4 Hz

# Control Performance Comparison

Discuss and compare the performance of your four controllers. Plot in the same figure the four responses (**height vs time**) of the elevator. Use appropriate axis labels, different line styles, and a legend. **You can summarize performance criteria (like OS, settling time, rise time, ss error, etc) in a Table**. In addition, based on your observation, discuss how disturbances affected the response of each controller and discuss which controller performed the best.



Figure . Performance of all Controllers

# Conclusion

Summarize your final results here. Which controller had the fastest response, the most accurate response, the fastest settling time, etc… Which controllers was better coping with disturbances, etc.

Among many other things, tell us if you consider your effort a success. If it was not, discuss possible error sources, or invalid assumptions.

# Comments

Here you can feel free to provide constructive feedback on the lab experience.