Lab # 2

Performance of Control Systems under Proportional, PI, PD, and PID Control

Introduction

Project Objectives

This Lab project is a Simulink simulation to analyze performance of systems under various controllers. In the first part of the Project, you will investigate three basic modes of Controller operation: Proportional (P) Control, Proportional + Integral (PI) Control, and Proportional + Derivative (PD) Control. In the second part of the Project you will design/tune a full three-mode PID Controller. Your objectives are therefore to:

- Increase your understanding of basic operations of a control system under the three modes of control (P, PI and PD), including tracking of a reference signal both in the transient state and in the steady state, and of implications of the different modes of control on the performance of closed loop systems.

- Achieve an improvement of the closed loop system response by finding the "best" settings of the PID Controller so that the defined response specifications are met.

Logistics

All Winter 2022 labs are to be conducted in person. However, as per Ryerson announcement about delaying the return to campus until January 31, 2022, the first lab sessions will be conducted online using Zoom teleconferencing, switching to sessions in the Control Systems Lab (ENG413), starting on January 31, 2022.

Zoom links are posted on our D2L Course Shell. Students can also contacts TAs and the Course Professor, Dr. Zywno, by email. Please note that only emails sent from the official Ryerson account will be responded to, and for Zoom lab sessions you will be required to log in with your Ryerson credentials.

Lab # 2 is completed over a period of four weeks. ELE639 lab sessions are short – 1.5 hours/week, and will be used mostly for the logistics of the projects. Once all the logistical issues are attended to, the students are free to complete all their simulations outside the lab time. The TAs will be available for the full duration of each scheduled lab, and students can use this time to get their help, if needed. Students should download Matlab/Simulink software and complete simulations on their own laptops/computers.

You are allowed to choose your partner. Please read the document “ELE639 Lab Rules” about details on partnerships, changing partners, equal contributions, etc. All partnerships will be finalized and approved by your Lab Instructor during the first session of each lab project. **If you continue working with your partner from Project # 1, use the previously assigned data set.** If you changed partners, your new partner has worked with a different data set. You must inform the Instructor about the change, and consult with them as to which data set you should continue with.

Lab # 2 reports are due before the start of the first Lab # 3 session. You have to submit your lab report on D2L using menu “Assessment/Assignments”. Failure to submit the report will result in a 20% mark deduction per day.

Please check the Course Outline and Course Schedule posted on D2L website for the exact due date for your lab section, and for more details. The written report is a collaborative part and you will receive 80 points (out of 100) for it. The remaining 20 points is an individual component and will depend on how you answer questions in a short interview with the Lab Instructor. Note that for Winter 2022, the interviews are suspended, and replaced with a 10-minute D2L Lab Quiz. The Lab Quiz for Lab # 2 will be available on Monday, March 7, 2022 from 8:00 am till 11:45 pm.

Pre-Lab: Creating SIMULINK Simulation Diagram

This part of the project is to be completed individually before coming to the Controls Lab.

The Pre-Lab consists of creating a functional SIMULINK simulation diagram for comparisons between different modes of Control (P, PI, and PD) - use the simulations you created for Lab Project # 1 as a starting point. Figures 1A and 1B show two examples of such comparisons. Recall the PD Controller accuracy issues connected with an imperfect implementation of the `Derivative` Block – see the Appendix for Lab # 1 where this issue was discussed at length.

The first diagram shows a "workaround" where the PD Controller function is combined with an additional pole with a time constant equal to 0.01 of the Derivative Time Constant, i.e. negligible. This "Approximate Derivative" representation is not perfectly accurate, but its simplicity is appealing, and in simulations that do not need to be as precise as in Lab Project # 1 where we dealt with stability, this method is acceptable.

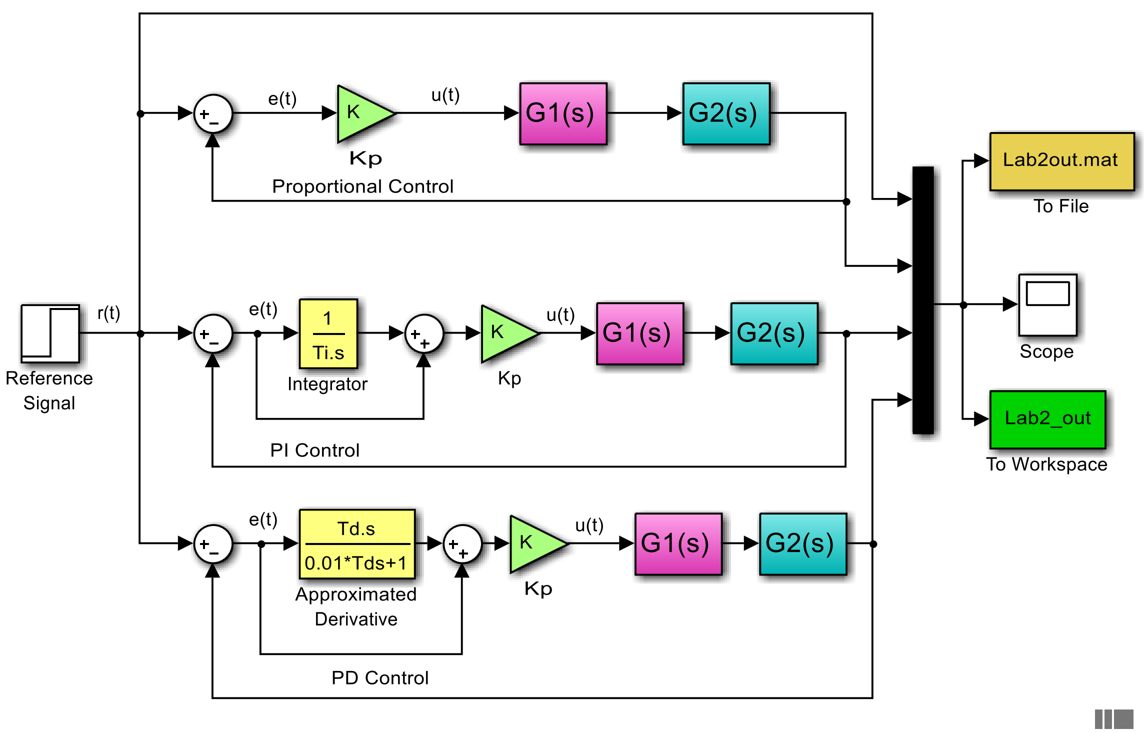

Figure 1A: Simulink Diagram for Comparisons between Various Modes of PID Control – Approximate Version

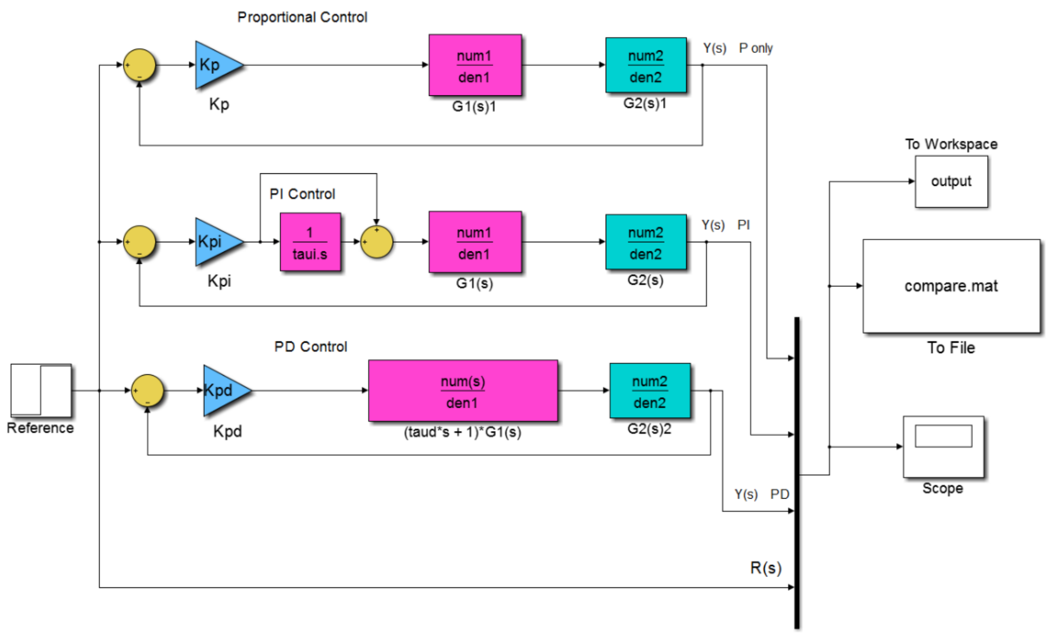

Figure 1B: Simulink Diagram for Comparisons between Various Modes of PID Control – Accurate Version

The second diagram shows another "workaround" for the PD controller. It is the same approach used in Stability calculations in Lab # 1 where the accuracy of the simulation was very important. It was ensured by combining the controller zero with one of the process transfer functions – see the Appendix for Lab # 1 where this issue was discussed at length.

In Lab # 2 you can choose either one of these two approaches.

To demonstrate the functionality of your simulation, set the Integral Time Constant τ_i to 5 seconds and the Derivative Time Constant τ_d to 2 seconds, and use the Proportional Gain setting such that you operate safely within the stable range of all three controller configurations, as calculated in Lab # 1.

The Pre-Lab is individual. Both you and your partner will demonstrate how your simulation diagrams work to the Lab Instructor. The Lab Instructor will then make a note of it in his/her spreadsheet. Please note that the Lab Instructor may not have enough time to check all individual Pre-Labs in the first session, in which case you are required to log in to the second Zoom lab session at the time indicated by the Lab. Failure to demonstrate the Pre-Lab simulation will result in a 20 points deduction from your individual lab report total. Pre-Lab Checks suspended in Winter 2022 to mitigate the in-person contact within the lab.

Part 1: Exploring Control Modes (P, PI and PD)

Part 1.1: Proportional Control

Consider the system under Proportional Control, as shown in Figure 1, that you are familiar with from Lab Project # 1.

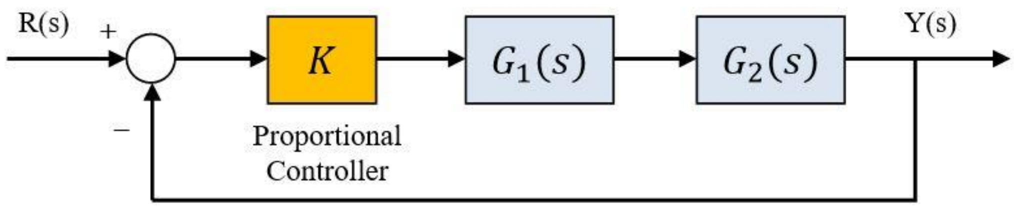

Figure 1: Unit Feedback System under Proportional Control

You already have a working SIMULINK simulation diagram for this system, which you can continue using for now. Alternatively, you can start working with the simulation diagram that you created in this Pre-Lab – if you do so, please remember to disconnect the PI and PD parts of your simulations.

You will be experimenting with the Proportional Controller Operating Gains, K_{op} within the stable range, i.e. $0 < K_{op} < K_{crit}$. Your objectives are to determine the effect of gain changes on the *steady state errors* as well as on the *transient response*. You will use two standard normalized unit inputs for the steady state error analysis: a unit step and a unit ramp. You will only use the step input to explore the transient response.

1. Determine how the Proportional Controller Gain changes affect the Steady State Error (in %), $e_{ss(step)\%}$ when a unit step input is used. Make sure that you can see the system response setting into a *steady state*.
2. Determine how the Proportional Controller Gain changes affect the Steady State Error, $e_{ss(ramp)}$, when a unit ramp input is used. Make sure that the observation (simulation) time is long enough to ascertain what happens to the ramp error. Check if that is consistent with what you know about the Type 0 system response. See Chapter 5 of the Course Notes for definitions and steady state error analysis.
3. Determine how the Proportional Controller Gain changes affect the following Transient Specifications: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. See Chapter 4 of the Course Notes for definitions of transient specifications.
4. Collect and save data for representative values of the Controller gain (for example, low-medium-high), to illustrate your conclusions for the report.

   Generate the following table and record your results for comparison.

Proportional Control	**Proportional Gain** K_P	**Rise-time** $t_{r(0-100\%)}$	**Maximum overshoot** **%O.S.**	**Settling-time** $t_{s(\pm 2\%)}$	**Steady-state error** $e_{ss(step)}$	**Steady-state error** $e_{ss(ramp)}$
Low-Gain						
Medium-Gain						
High-Gain						

Table 1: Time Response Characteristics for Unit Feedback System under Proportional Control

NOTE: You may find it useful to use the MATLAB files posted on the course website ("`stepeval`" and "`rampeval`") which will allow you to easily obtain the numerical values of the specs. Please use them in a mindful way, to verify your results – you still need to demonstrate in your lab report how you found, say the Percent Overshoot, by showing it on a plot. As well, please do not use screen captures from MATLAB, showing numerical values of the specs as computed by MATLAB – instead, word-process and tabulate the specs.

"Benchmarking" the System

You will now establish a "benchmark" for your system performance, which you will later attempt to improve by applying different modes of Control.

1. To obtain the benchmark, set the Operating Proportional Controller Gain, K_{op} such that the so-called "Quarter Decay" response is obtained. Consult the Appendix on what the "Quarter Decay" response is.
2. Save the step response data for that controller setting, plot it in MATLAB and take the record of: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Obtain the unit ramp response for that controller gain setting to illustrate the Steady State Error, $e_{ss(ramp)}$. Use "`stepeval`" and "`rampeval`" functions to assist you.

Generate the following table and record your results for comparison.

Benchmarked Proportional Control	Operational Proportional Gain K_{OP}	Rise-time $t_{r(0-100\%)}$	Maximum overshoot %O.S.	Settling-time $t_{s(\pm 2\%)}$	Steady-state error $e_{ss(step)}$	Steady-state error $e_{ss(ramp)}$
Ziegler-Nichols "Quarter Decay"						

Table 2: Time Response Characteristics for Unit Feedback System under Proportional Control Tuned by Ziegler-Nichols Ultimate Gain Method ("Quarter Decay")

Establishing System Performance Specifications

When an improvement in the system performance is required, we work to meet a set of "desired" specifications for the system response, defined based on the user requirements and on your knowledge, as a designer, of what constitutes an "acceptable" response of a control system in question. For this Project, the performance specifications are defined as follows:

- Steady State Error (in %) of the response to a unit step input is to be equal to zero: $e_{ss(step)\%} = 0\%$;
- Steady State Error of the response to a unit ramp input is to be as small as possible: $e_{ss(ramp)} \to 0$;
- Percent Overshoot of the response to a unit step input is to be less than 15%;
- Settling Time, $T_{settle(\pm 2\%)}$ of the response to a unit step input is to be one-half, or less, of the Settling Time as measured for the "benchmarked" response.

NOTE 1: The Percent Overshoot requirement is the same for all data sets and will result in the same value of the equivalent closed loop damping ratio ς – see Chapter 7 of the Course Notes for a full explanation. However, the Settling Time depends both on the equivalent closed loop damping ratio, ς as well as on the equivalent closed loop frequency of natural oscillations, ω_n which will be different for each different process. As a result some of the data sets describe uncompensated systems that are much slower than others. Setting a single value of the Settling Time specification for all groups to meet may thus prove challenging for those working with data sets representing slower systems. To make the "Improvement Challenge" more equitable across all the different data sets, we only require that the Settling Time improvement is against your own "benchmarked" response, hence the "relative" definition of the requirement as **one-half** of the "benchmarked" Settling Time value.

NOTE 2: It should be already clear to you that Proportional Control will not allow you to meet all of these requirements at the same time. However, exploring the properties of the PI and PD modes of Control will show you that these seemingly conflicting requirements can indeed all be met with the "right" combination of PID Controller parameters. This will become your task for PID Design of your Project.

Part 1.2: Proportional + Integral (PI) Control

Next, consider the system under Proportional + Integral Control (where τ_i is the Integral Time Constant), shown in Figure 2, that you are already familiar with from Project # 1.

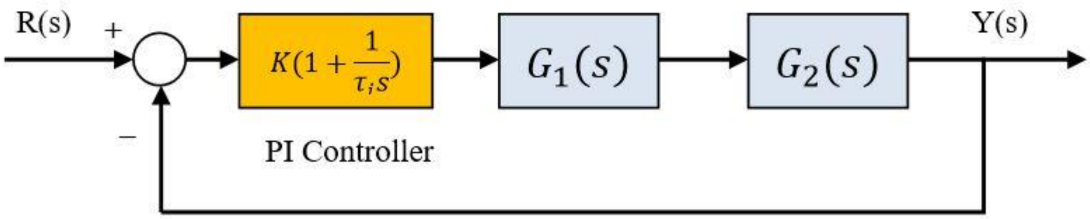

Figure 2: Unit Feedback System under PI Control

In this part of the project, you will be experimenting with both the Proportional Gain, K_P and with the Integral Time Constant, τ_i of the PI Controller, to find out what their effect is on the system performance.

Your objectives are to:

1. Determine the effect of the Controller parameters on the *steady state errors* as well as on the *transient response*. You will use two standard normalized unit inputs for the steady state error analysis: a unit step and a unit ramp. You will only use the step input to explore the transient response.
2. Compare the performance of the system under PI Control with the system under Proportional only Control. To do so, select and save some representative samples of PI system responses. Make comparisons with reference to the "benchmarked" response obtained under Proportional only Control.
3. Attempt to improve the "benchmarked" performance with respect to the following specifications: Step Steady State Error, $e_{ss(step)\%}$, Ramp Steady State Error, $e_{ss(ramp)}$, Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Is it possible to meet the required performance specifications? What are the issues here?

In order to facilitate easy comparisons between PI Control and Proportional Control, use the simulation diagram you created in the Pre-Lab. Make sure to "disable" the PD part of the simulation. Set the Proportional Gain in Proportional only Control part of the simulation to the value found in the "benchmarking" exercise, i.e.K_{op}.

When experimenting with changing the value of the Integral Time Constant, be aware that your relative stability range will also change, since your Project # 1 calculations were done for $\tau_i =$ 5 seconds. In your simulations, when using a different value of the Integral Time Constant, adjust the Proportional Gain accordingly so that you always operate within the stable range of system responses.

Recall from Chapter 5 that most of the "heavy-lifting" of your Controller work should be done by the Proportional part of the Controller, as it is the Proportional Gain value that determines the accuracy of tracking in the steady state. Integral and Derivative modes should be used sparingly. Think of Proportional control as a "main meal" and of Integral and Derivative as condiments to improve its taste ☺.

Once you are satisfied with your "best" choices of PI Controller parameters, save the step response data, plot it in MATLAB and take the record of: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Obtain the unit ramp response for that controller gain setting to illustrate the Steady State Error, $e_{ss(ramp)}$. Use "`stepeval`" and "`rampeval`" functions to assist you.

Generate the following table and record your results for comparison.

Proportional Integral Control	Proportional Gain K_P	Time Constant τ_i	Rise-time $t_{r(0-100\%)}$	Maximum overshoot %O.S.	Settling-time $t_{s(\pm 2\%)}$	Steady-state error $e_{ss(step)}$	Steady-state error $e_{ss(ramp)}$
PI Controller							

Table 3: Time Response Characteristics for Unit Feedback System under PI Control

Part 1.3: Proportional + Derivative (PD) Control

Next, consider the system under Proportional + Derivative Control (where τ_d is the Derivative Time Constant), shown in Figure 3, that you are already familiar with from Project # 1.

In this part of the project, you will be experimenting with both the Proportional Controller Operating Gains, K_{op}, and with the Derivative Time Constant, τ_d, to find out what their effect is on the system performance.

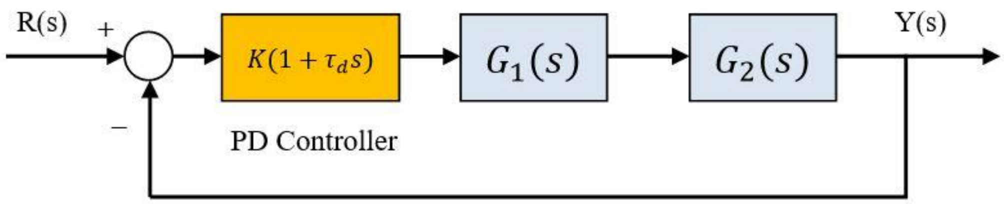

Figure 3: Unit Feedback System under PD Control

Your objectives are to:

1. Determine the effect of the Controller parameters on the *steady state errors* as well as on the *transient response*. You will use two standard normalized unit inputs for the steady state error analysis: a unit step and a unit ramp. You will only use the step input to explore the transient response.
2. Compare the performance of the system under PD Control with the system under Proportional only Control. To do so, select and save some representative samples of PD system responses. Make comparisons with reference to the "benchmarked" response obtained under Proportional only Control.
3. Attempt to improve the "benchmarked" performance with respect to the following specifications: Step Steady State Error, $e_{ss(step)\%}$, Ramp Steady State Error, $e_{ss(ramp)}$, Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Is it possible to meet the required performance specifications? What are the issues here?

In order to facilitate easy comparisons between PD Control and Proportional Control, use the simulation diagram you created in the Pre-Lab. Make sure to "disable" the PI part of the simulation. Set the Proportional Gain in Proportional only Control part of the simulation to the value found in the "benchmarking" exercise, i.e.K_{op}.

When experimenting with changing the value of the Derivative Time Constant, be aware that your relative stability range will also change, since your Project # 1 calculations were done for $\tau_d = 2$ seconds. In your simulations, when using a different value of the Derivative Time Constant, adjust your Proportional Gain accordingly so that you always operate within the stable range of system responses.

Recall from Chapter 5 that most of the "heavy-lifting" of your Controller work should be done by the Proportional part of the Controller, as it is the Proportional Gain value that determines the accuracy of tracking in the steady state. Integral and Derivative modes should be used sparingly. Think of Proportional control as a "main meal" and of Integral and Derivative as condiments to improve its taste ☺.

Once you are satisfied with your "best" choices of PD Controller parameters, save the step response data, plot it in MATLAB and take the record of: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Obtain the unit ramp response for that controller gain setting to illustrate the Steady State Error, $e_{ss(ramp)}$. Use "`stepeval`" and "`rampeval`" functions to assist you.

Generate the following table and record your results for comparison.

Proportional Derivative Control	Proportional Gain K_P	Time Constant τ_d	Rise-time $t_{r(0-100\%)}$	Maximum overshoot %O.S.	Settling-time $t_{s(\pm 2\%)}$	Steady-state error $e_{ss(step)}$	Steady-state error $e_{ss(ramp)}$
PD Controller							

Table 4: Time Response Characteristics for Unit Feedback System under PD Control

Part 2: PID Control

In the second part of this Project, your task is to come up with a significant improvement of your system closed loop response by implementing the PID Controller, combining the observed benefits of both previously explored controller modes: PI and PD. Your objective is to meet (or exceed) the Performance Specifications established in Part 1. You will demonstrate the quality of your design by showing your system compensated response vs. the "benchmarked" response from Part 1.

You will have a large degree of latitude in deciding how best to accomplish that, and in the process of doing it, to demonstrate the mastery of the learned course material. The quality of your design will be judged by two factors:

- How dramatic the improvement is, compared with the Proportional only Control for your "benchmark" Operating Proportional Gain setting;
- How in-depth your approach is, i.e. how are you able to connect it with the theory learned in the course.

Start with the simplest approach to finding the "best" PID Controller setting that improve the system response – we can call it a "Trial-and-Error" approach. If you have already tuned satisfactory PI and PD Controllers in Part 1.2 and Part 1.3 respectively, obtaining a PID Controller with good performance should be easy. You can simply select the PID Controller parameters based on the previously tuned PI and PD Controller parameters. **Note that the Proportional Gain K_p, should be selected based on the PD Controller, and not PI.** Compare the time response specifications with those established in Part 1 – they should be better. If necessary, make adjustments – that is the “trial & error” part ☺.

Once you are satisfied with your “best” choices of PID Controller parameters, save the step response data, plot it in MATLAB and take the record of: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Obtain the unit ramp response for that controller gain setting to illustrate the Steady State Error, $e_{ss(ramp)}$. Use “`stepeval`” and “`rampeval`” functions to assist you. Record the values in the table below.

A more organized empirical approach to finding the “best” PID Controller setting that improve the system response is to follow a “tuning” method. We suggest the Ziegler-Nichols “Ultimate Gain” method – refer to the Appendix for their detailed description. You will need to determine the Ultimate Gain, K_u and the Period of Oscillations, T_u. You can simply use the critical gain, K_{critP} and the critical frequency of oscillations, ω_{critP} from lab Project # 1 to calculate K_u and T_u as follows:

$$K_u = K_{critP} \quad T_u = \frac{2\pi}{\omega_{critP}}$$

Determine the PID Controller parameters, save the step response data, plot it in MATLAB and take the record of: Percent Overshoot, PO, Settling Time, $T_{settle(\pm 2\%)}$, and Rise time, $T_{rise(0-100\%)}$. Obtain the unit ramp response for that controller gain setting to illustrate the Steady State Error, $e_{ss(ramp)}$. Use “`stepeval`” and “`rampeval`” functions to assist you.

Generate the following table and record your results for comparison.

Proportional Integral Derivative Control	Proportional Gain K_P	Derivative Time Constant τ_d	Integral Time Constant τ_i	Rise-time $t_{r(0-100\%)}$	Max. overshoot %O.S.	Settling -time $t_{s(\pm 2\%)}$	Steady -state error $e_{ss(step)}$	Steady-state error $e_{ss(ramp)}$
PID Controller “Trial & Error” Approach								
PID Controller Ziegler-Nichols Approach								

Table 5: Time Response Characteristics for Unit Feedback System under PID Control

Please note that while there are several variations of the PID Controller structure (see the Appendix), the parallel structure is the most intuitive to use for direct time domain experimentation. The "Trial-and-Error" approach as well as both Ziegler-Nichols methods described in the Appendix define parameter values for the parallel structure.

PID Controller Simulation Diagram

In order to facilitate easy comparisons between responses of your system under PID Control and under "benchmarked" Proportional Control, you will have to modify the simulation diagram you created in the Pre-Lab by removing the PI and PD parts of your simulation and replacing them with a full PID Controller. Note that the PID Controller transfer function will present the same accuracy challenges as the PD Controller, because of the way SIMULINK Derivative Block is implemented. Again, there are two ways you can solve this problem.

One possibility to configure your Simulink simulation diagram is shown in Figure 5A, which is a modified version of the diagram in Figure 1A.

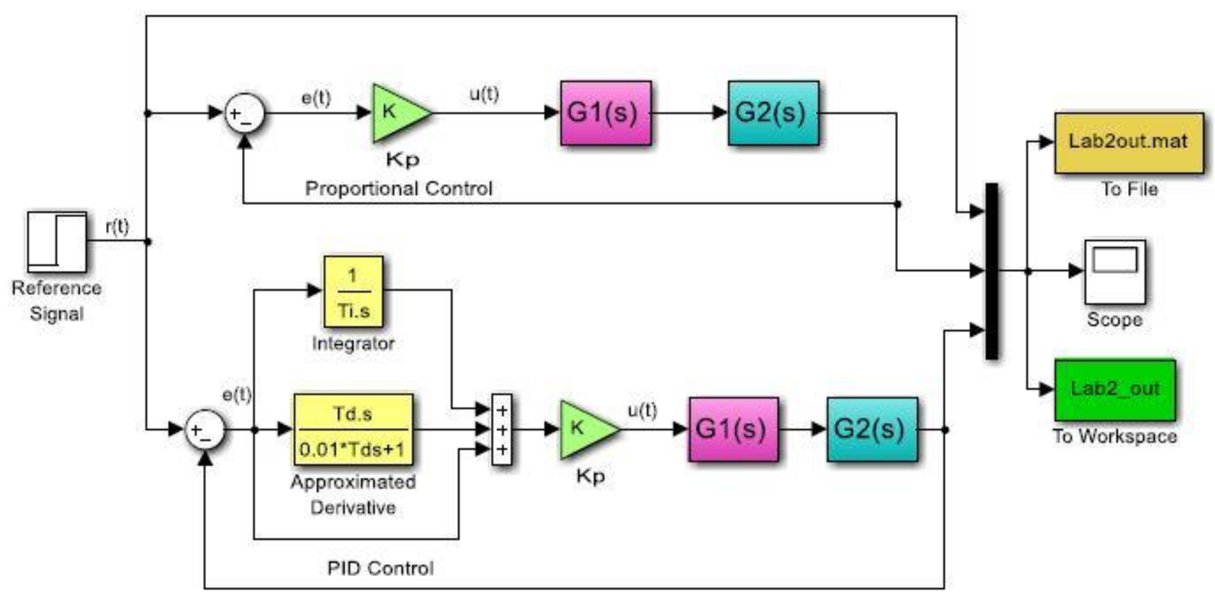

Figure 5A: Simulink Diagram for Comparisons between P and PID Control – Approximate Version

The most accurate way to implement the PID transfer function is the same "workaround" solution described in Lab Project # 1 Appendix w.r.t. PD transfer function, where the PID Controller transfer function will be combined with the transfer function $G_1(s)$ - see the Pre-Lab simulation diagram # 1. Let us consider the parallel structure of the PID Controller:

$$G_{PID}(s) = K_p\left(1 + \frac{1}{\tau_i s} + \tau_d s\right) = K_p\left(\frac{\tau_d \tau_i s^2 + \tau_i s + 1}{\tau_i s}\right)$$

The transfer function $G_{PID}(s)$, followed by the transfer function $G_1(s)$, is equivalent to the gain block K_P followed by a transfer function block $\left(\frac{\tau_d \tau_i s^2+\tau_i s+1}{\tau_i s}\right) \cdot G_1(s)$.

The coefficients of the PID Controller are now combined with the coefficients of the first process transfer function block $G_1(s)$ to create a proper transfer function with two zeros, belonging to the PID Controller, and three poles, one (the integrator) belonging to the PID Controller, and two belonging to the process $G_1(s)$. Note that we can use the convolution (MATLAB function *conv*) to multiply the two s-polynomials in the denominator of the new block. This implementation is shown in Figure 5B, which is a modified version of the diagram in Figure 1B.

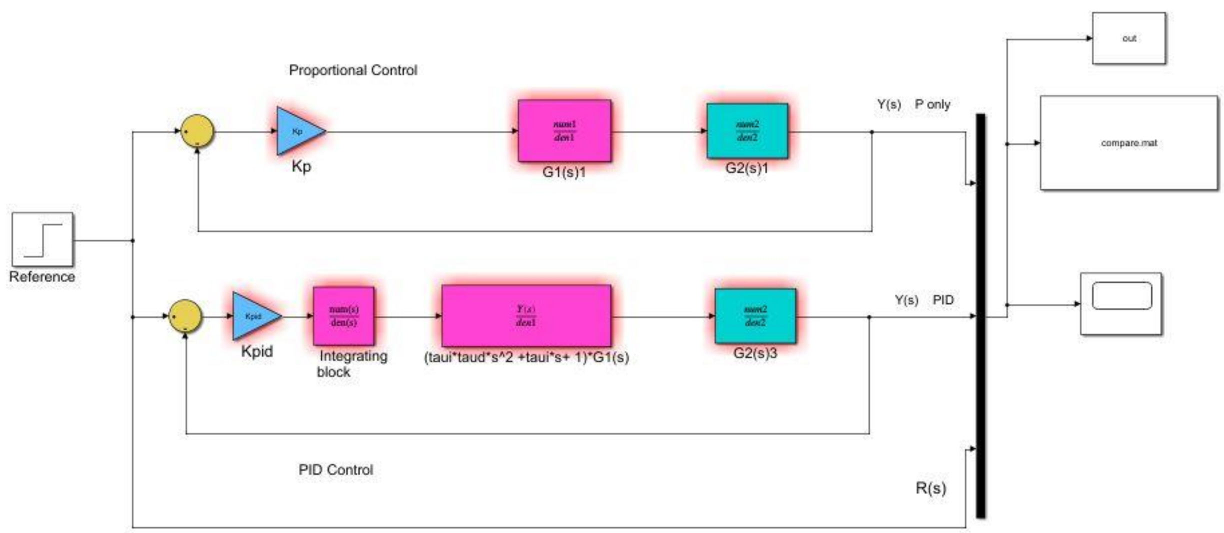

Figure 5B: Simulink Diagram for Comparisons between P and PID Control – Accurate Version

As previously, either one of these implementations will be fine. In either case, make sure to set the Proportional Gain in Proportional Control part of the simulation to the value found in the "benchmarking" exercise, i.e.K_{op}.

Discussion

In this section you should analyze the steady state as well as the transient response of your control system under the three different configurations of the controller (P, PI and PD), and describe the combined benefits of these as illustrated by your PID Controller design. The issues to discuss include:

1. How does each of the Control modes affect the steady state error in the step response? In the ramp response? Which of the Controller parameters need to be adjusted to control the errors, and in what way? Connect your observations to theory. What are the implications for choosing the "best" settings of parameters?

2. How does each of the Control modes affect the percent overshoot in the step response? Which of the Controller parameters need to be adjusted to control the overshoot, and in what way? Connect your observations to theory. What are the implications for choosing the “best” settings of parameters?
3. How does each of the Control modes affect the settling time in the step response? Which of the Controller parameters need to be adjusted to control the settling time, and in what way? Connect your observations to theory. What are the implications for choosing the “best” settings of parameters?
4. In your PID design, analyze your compensated system behaviour based on theory learned in the course. Did you meet the required performance specifications? If yes, explain how you did it. If not, what do you think that is?

Instructions for the Write-up

Following are some general guidelines on the write-up for this Project.

1. The written report is to be word-processed, including any formulae that you may need. The first page is a standard cover page (posted on the website) which has to be signed by both partners. The report will not be accepted without both original, hand-written signatures. Please note that electronic signatures are not acceptable.
2. The second page is a grading sheet - please write the names of both partners in appropriate boxes, and the assigned data set number. Each of the partners has to complete the Pre-Lab and to make sure the Lab Instructor made a note of it in his/her files. If the Pre-Lab was not verified by the Lab Instructor, 20 points will be deducted from your individual lab report score.
3. The third page is a one-page Executive Summary - your “bottom line” results and observations have to be stated here, and then expanded on in the discussion. It is best to write the Executive Summary last, when you have a clear overview of the entire report.
4. A maximum of sixteen (16) single-sided pages of content (i.e. not counting the cover, grading sheet and Executive Summary pages) are allowed. To make your report easy to follow, use separate headers for each part of the project. Use page numbering! Use at least point 11 font size throughout the report.
5. Figures have to be properly labeled and referred to in the body of the report. Plots have to be created in MATLAB, with all traces properly labeled, large enough to be easily legible, and included in the main body of the report.
6. Quality of writing, spelling, clarity and overall presentation is very important in an engineering report and the Canadian Engineering Accreditation Board (CEAB) requires that we pay attention to developing good writing skills. Accordingly, a significant part of your mark will depend on how you write your observations and conclusions, not just on whether your numerical results are correct.

CHECK LIST

Before you hand in the report, please go through this check list to make sure you have not missed something important. Note that this check list is just for you and your partner and you do not submit it in your report.

Form: layout, figures, etc.

- ☐ Did you use the correct parameter set? The Lab Instructor will check if you used the set assigned to you, and if you used the wrong set, you will receive a zero mark for the report.
- ☐ On your Grading Sheet, do you have the signatures of your Lab Instructor confirming that both of you completed the Pre-Lab? If you do not have that signature, your individual lab report mark will be discounted by 20 points. Rule suspended Winter 22
- ☐ Did both partners sign the Cover page? The report **will not be marked** without these signatures.
- ☐ Are the content pages of your lab report numbered? If not, you will lose points.
- ☐ Did you count content pages? If you have more than 16 content pages you will lose points.
- ☐ Did you write your data set number in the appropriate space on the Grading Sheet? If it is missing, you will lose points.
- ☐ Did you write and include a one-page Executive Summary?
- ☐ Did you include a Simulink diagram for each simulation performed?
- ☐ General impression: is your report easy to read and visually pleasing? Are the results easily located? Do you have separate headings for each of the parts? Consider using Tables to present your results. Break up large blocks of text into separate paragraphs, make sure that there is enough "white space" in your report to make it easy to read. If you are not sure, ask a friend to have a look at your report and get his/her feedback.
- ☐ Are all your numerical results and equations properly type-set? Any hand-written equations, as well as for equations copied from MATLAB will cause deductions.
- ☐ Are all the Figures you included in the report essential and contributing to your discussions? You will lose points for any Figures that are not discussed in the report.
- ☐ Do your Figures have proper time scales? Are the traces smooth? If not, you will lose points.

- ☐ Are all traces in your Figures easily identifiable? Do all your Figures have legends to identify each trace? If not, you will lose points.
- ☐ Are all your Figures properly labeled? Are they included in the body of your report, not at the end? Also remember that any reference to a Figure must be made before the Figure appears in the text, not after.
- ☐ Did you check your report for spelling, punctuation, grammar errors and logical flow of your narrative? There will be deductions for poor basic writing skills.

Content: calculations, discussions, observations, etc.

- ☐ Did you include the value of the Proportional Gain that resulted in the "Quarter-Decay" response, and the steady state and transient specifications for your "benchmarked" system response?
- ☐ Did you discuss P, PI and PD Control in terms of how they affect the steady state and the transient responses?
- ☐ For the steady state analysis, did you calculate, and show, the step as well as the ramp errors?
- ☐ Did you present the PID compensated system response specifications?
- ☐ Did you present the details of your PID design?

Academic Integrity

- ☐ Are all figures, text and equations included in this report created by you and your partner and 100% original? Remember that your signature on the Cover Page signifies that it is, and that you are fully aware of the consequences should it be otherwise.
- ☐ Are any of the components of your report copied from the Course Notes, Lecture Slides or Lab Instructions? If so, this is your last chance to remove them, because you do not have permission to copy any of the course materials, whether or not you make a reference to the source.