Experiment 81 – Design of a Feedback Control System

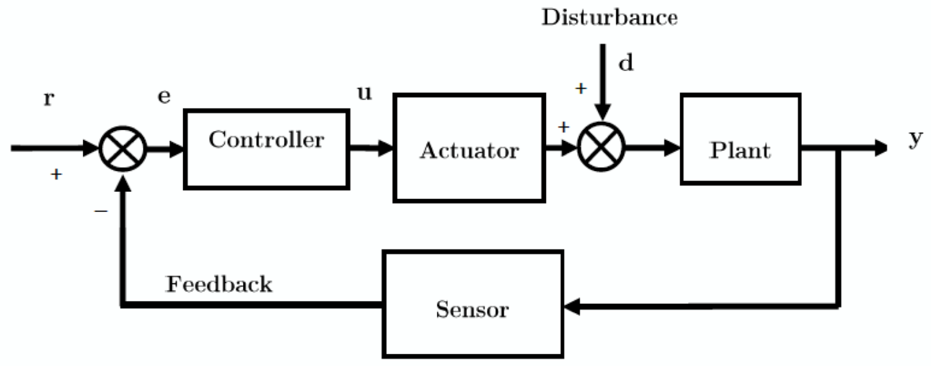
Department of Electrical Engineering & Electronics

September 2019, Ver. 1.1

Experiment specifications

Module(s)	ELEC207
Experiment Code	81
Semester	2
Level	2
Lab location	PC lab, third/fourth floor
Work	In groups
Timetabled time	7 hrs
Subject(s) of relevance	Control Systems, Feedback, PID Controller
Assessment method	Formal Report, see Section 4 for guidelines and marking scheme
Submission deadline	On Friday midnight, 7 days after the date of the laboratory, submitted in Microsoft Word or PDF format via VITAL only.

Important: Marking of all coursework is anonymous. Do not include your name, student ID number, group number, email or any other personal information in your report or in the name of the file submitted via VITAL. A penalty will be applied to submissions that do not meet this requirement.



Instructions:

- **This is a design experiment. You are expected to do independent reading and work before attending the lab.**
- **Read this script carefully before attempting the experiment. Check VITAL for more resources. Use ELEC207 lecture notes (Control part) for theoretical background.**
- **Review MATLAB Simulink before attempting the experiment. Check VITAL for Simulink resources (Learning Resources→Supporting Material folder). See online material and resources as well.**
- **Try to finish as many parts as you can during the lab day with the support of the demonstrators. Complete the work later at home if you cannot do it all in the lab.**
- **Keep a record of all measurements taken, designs and screenshots.**
- **If you have any feedback on your laboratory experience today, please write it down on the last page of this script.**

1 Learning outcomes

At the end of this lab, you will:

- be able to build a control system using MATLAB Simulink.
- be able to investigate the control of a process using a proportional (P) and proportional-integral (PI) controllers.

2 Objectives

It is required to design and build a P and PI controllers to control a process.

3 Experimental work

The following transfer function represents a model of a certain process (plant):

$$G(s) = K/(\mathrm{T}s + 1)^2$$

Choose values for the plant parameters using your date of birth such as:

K = day of birth

T = month of birth

Part I: First-order Plus Time Delay Approximation

Using MATLAB Simulink, simulate the process with a unit-step change input (open-loop). Approximate this process with a **first-order plus time delay** model (see Appendix A) and simulate with a unit-step input as well. Compare both responses and find the steady-state error, %OS (percentage overshoot), settling time and the rise time for both cases.

Part II: The P Controller Design

Design a P controller for the process and simulate the closed-loop response to a step input. Investigate the effect of changing (increase and decrease) the controller gain on the controlled response in terms of the steady-state error, %OS, settling time and rise time. [Hint: To design the controller for this part (and even the next part), you may use a method that is provided to you in module ELEC207. Alternatively, you are advised to use Ziegler-Nichols method (check VITAL resources)].

Part III: The PI controller Design

Design a PI controller for the process and simulate the closed loop response to a step input. Compare the response with the previously designed P controller in terms of the steady-state error, %OS, settling time and rising time. Investigate the effect of changing the controller gain on the controlled response. Investigate the effect of changing the integral action time on the controlled response.

Part IV: The Effect of disturbance

Include a step disturbance at the input of the process (see Figure 1). Obtain the unit-step responses for using the P and PI controllers. Measure and compare the maximum output response, settling time and steady-state error in both cases. Which controller can remove the effect of the disturbance in steady-state? Why?

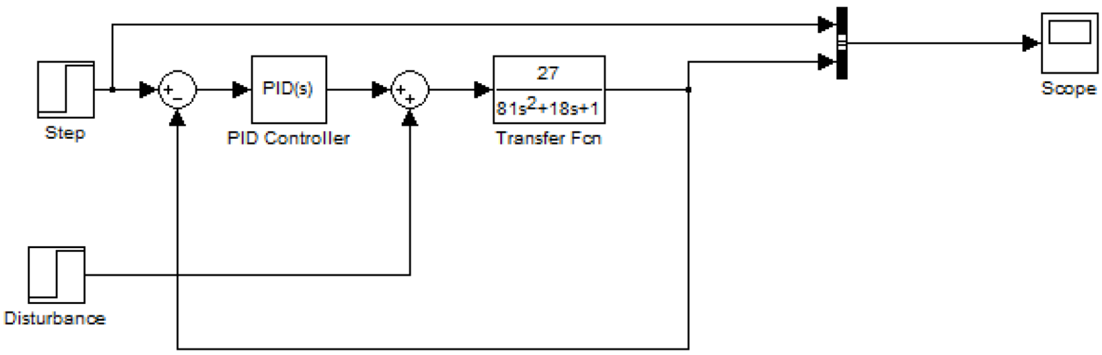


Figure 1. The complete system for *K*=27 and *T*=9 in MATLAB Simulink

Part V: Extra Work (Bonus)

Design a PID controller to control the process (using Ziegler-Nichols method or otherwise). Find the parameters of the controller and test your system against disturbance. Hence, obtain the unit-step response of the system with a step disturbance at the input of the process.

4 Report marking scheme

Include a separate section for each of the main parts above. Each section should include (where appropriate) methods used and explanations, appropriate diagrams (e.g. SIMULINK diagrams, simulation results) and a discussion of the results.

[N.B. Additional investigations, theoretical proofs and comparisons, results and analysis are encouraged]

The marking scheme of the report is as follows:

- Part I with method used, results, explanation and comments: **15 Marks**
- Part II with method used, results, explanation and comments: **25 Marks**
- Part III with method used, results, explanation and comments: **30 Marks**
- Part IV with method used, results, explanation and comments: **20 Marks**
- Overall report presentation: **10 Marks**

[N.B. The better your designs are the higher the marks you get]

5 Plagiarism and Collusion

Plagiarism and collusion or fabrication of data is always treated seriously, and action appropriate to the circumstances is always taken. The procedure followed by the University in all cases where plagiarism, collusion or fabrication is suspected is detailed in the University's Policy for Dealing with Plagiarism, Collusion and Fabrication of Data, Code of Practice on Assessment, Category C, available on http://www.liv.ac.uk/tqsd/pol_strat_cop/cop_assess/appendix_L_cop_assess.pdf.

Follow the following guidelines to avoid any problems:

a) Do your work yourself.
b) Acknowledge all your sources.
c) Present your results as they are.
d) Restrict access to your work.

References

[1] MATLAB Simulink Tutorial, 2014.

Appendix A

The first-order plus delay model (or first-order plus dead time FOPDT) is used to approximate the response of complicated processes. It is defined by the following transfer function:

$$G(s) = \frac{K_p e^{-t_d S}}{(T_p s + 1)}$$

Where:

t_d is the process delay (dead) time

T_p is the process time constant

Kp is the process gain

There are many methods to obtain the values for the above mentioned parameters. See VIATL and online resources for more details.

Version history:

Name	Date	Version
Dr M López-Benítez	September 2019	Ver. 1.1
A Al-Ataby	February 2015	Ver. 1.0

Feedback:

If you have any feedback on your laboratory experience for this experiment (e.g. timing, difficulty, clarity of script, demonstration...etc) and suggestions to how the experiment may be improved in the future, please write them down in the space below. This feedback is important for future versions of this script and to enhance the laboratory process, and will not be assessed. If you wish to provide this feedback anonymously, you may do so by detaching this page and submitting it to the Student Support Centre (fifth floor office).

Script re-writing award
If you think that this experiment could do with enhancement or changes and you have some ideas that you'd like to share, why not re-write this script yourself and you may get an award from the lab organisers with an official letter of thanks, and your name will be added to the version history list in future versions of the script. Something good for your CV.
Contact one of the lab organisers for more details.