1 General Requirements

1.1 Delivery Format

The assignment shall be delivered in both paper and electronic format, of which the latter shall be on CD or other electronic storage media, enclosed to the assignment submission sheet at the iCentre. The paper submission shall consist of the Report and the User Manual for Part B. The conciseness and the relevancy of the information provided in the report will have a significant contribution towards the mark achieved. The media on which the assignment is provided is not guaranteed to be returned to the student, although all endeavours shall strive to do just that.

1.2 Delivery Content

The assignment will consist of a collection of computer programmes and written descriptions or reports. All written documentation in electronic format shall be provided either in any version of Microsoft Word format (*.doc or *.docx) or Microsoft Excel (*.xls or *.xlsx), or in an Open Document Format (*.odt or *.ods). As access to any other format is at the marker's discretion, do not submit a report in any other formats. The printed report is not subject to the requirements of this paragraph.

All written reports shall use the font Arial with a Normal Text size of 10, 11 or 12. The written reports shall follow the same style as this document, with the Headings of font sizes that reflect their numbering scheme and in the format 1, 1.1, 1.1.1, etc. The actual content of the Headings is down to the student.

All references shall be specified in their own section in the report, confirming with the Harvard Referencing Guide, as required by Anglia Ruskin University.

1.3 Delivery Style Guide

All computer-related files, be it Matlab m-files, Simulink models and libraries, or even other scripts or files shall be presented in a documented folder structure on the electronic media. All files shall be appropriately commented and a suitable style guide should be employed. The style guide shall also be documented explicitly. Also, all computer programme source files or models shall include the Student ID of the author.

A list of all the Matlab components used, such as toolboxes, shall be documented. Also, any tools used other than Matlab and its components, shall be free software, with the Internet source address stated, and their licence terms provided in writing on the electronic media. All the files shall be compatible to be run and tested on a Windows PC, with any restriction in regards to the version of Windows clearly stated.

1.4 Assignment Contents

The assignment consists of two parts: Part A and Part B.

Each part will contribute to the overall assignment's mark. i.e. Part A is analytical and will bear a maximum mark of 70%, and Part B is research based and will bear a maximum mark of an extra 30%.

1.5 Delivery Deadline

The delivery deadline for the assignment is published on Canvas.

2 Part A of the Assignment

This part consists of 4 sets of assignments A1 to A4. Complete this assignment in conjunction with Matlab Tutorials 1 to 4 available Under Canvas modules. For each of the questions students should create scripts (m-files). Explain and evaluate the results for each exercise. A report should be handed in by the deadline. (Clearly label and print a copy of your code in an appendix at the end of your report or there is no need to include digital copies of the code in your submission)

2.1 Assignment A1

For each of the following questions create scripts (m-files). Explain and evaluate your results for each exercise. A report of your answers should be handed in by the deadline. (Clearly label and print a copy of your code in an appendix at the end of your report)

Q 1

A mass-damper-spring system has the following transfer function

$$T(s) = \frac{1}{(m.s^2 + c.s + k)}.$$

Find the step response of this system when m = 1 kg; c = 2 N.s/m; k = 25 N/m.

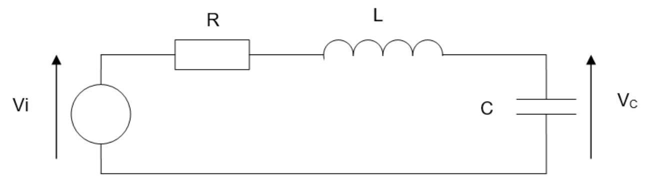
Investigate the effect of varying the damping (c) between zero and 20. What is the smallest value of c that prevents oscillation?

You may find it helps to create an m-file to carry out the investigation (its good practise, anyway.)

Q 2

The transfer function for a series RLC circuit above is:

$$\frac{V_C(s)}{Vi(s)} = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$



In the LCR circuit above, C = 400 μF and L = 1 H. For each resistor value below, find the transfer function and create a transfer function object in MATLAB (e.g. sys1, sys2, sys3);

a. R = 125 Ω
b. R = 100 Ω
c. R = 30 Ω.

Use ltiview() to compare

i. the step input responses
ii. the pole positions
iii. the ramp responses

Find (by trial and error but using an m-file) the resistor value and hence the damping ratio that gives the shortest settling time.

2.2 Assignment A2

Q 1

A brief investigation into steady state error, system type number and system error coefficient:

i) Type 0 system; step input error.

Having G = 1/(s + 1)(s + 10) ; This is a type 0 system.

Its position error coefficient K_P = 1/(1 x 10) = 0.1.

Its steady state error for a unit step input = 1/(1 + K_P) = 0.909090909090909 Use

sisotool to confirm this result. Reset the gain = 1; obtain a plot of the step response; read the final value; subtract this from one. The error = …………

Use the theory to predict the steady state error for a step input when

gain = 10, and when gain = 100

Use sisotool to confirm these results.

Increasing gain will reduce the error but is there a downside to using very high gain?

ii) Type 0 system; ramp input error.

In theory, this error in infinite – the output never manages to track the input. Use feedback() and ltiview() to confirm this.

iii) Type 1 system; step input error.

Create a type 1 system G2; for example G2 = G/s.

Import G2 into sisotool and find the step input response of the new feedback system.

What should it be?

Can you confirm this?

What is the effect on system stability?

iv) Type 1 system; ramp error

Find the ramp error for a unity feedback system based on G2.

Calculate K_V and hence predict the ramp input error.

Do your results agree?

Q 2

A unity feedback system has G = (s + 4)/(s + 1)(s^2 + 6s + 13). Obtain a plot of the root locus and estimate the gain required to give a settling time of 1.0s.

2.3 Assignment A3

Q 1

We have seen the effects of adding one integrator to the compensator in the Matlab tutorials. Now add a second integrator to the compensator and study the root locus diagram.

(i) Can this arrangement ever be stable?

(ii) What is the system type number?

(iii) What are the potential benefits of this system type?

Q 2

Repeat section 4 of Matlab tutorial 4 (below) but with the zero and pole reversed. Investigate and report the effects on the response and the error?

<u>Section 4 of Matlab Tutorial 4 -- Lead compensation</u>

This compensation has a zero and a pole with a larger coordinate, typically 10 times the zero coordinate.

Create G2 = zpk([],[0 –2 –5],1) and import G2 into sisotool.

(i) Adjust the gain to obtain the fastest settling time and note this value

Note that the steady state error for a step input is zero.

(ii) Find the steady state error for a ramp.

(iii) Now edit the compensator so that C = K.(s + 2)/(s + 20). Readjust the gain to find the best settling time; this should be improved.

(iv) Re-measure the steady state error for a ramp input. Obtain a Bode plot for the compensator and check that this is “implementable”.

2.4 Assignment A4

In MATLAB, use zpk() to create a system object with the transfer function below. Run sisotool and select G(s) (G0, G1and G2) as the transfer function for the plant in a unity feedback system

a) A type 0 system.

$$G0(s) = \frac{(s + 1)}{(s + 2).(s + 3)}$$ a type 0 system

Determine the steady state value and hence the error for a step input.

Calculate the Error Coefficient and hence the theoretical steady state error. Does this agree with the value obtained from MATLAB?

Increase the gain in the compensator to 10. How does this affect the accuracy in theory and according to MATLAB?

Check the response to a ramp input. A cheat way to create a ramp input is to use the Compensator Editor to add an integrator to the pre-filter F. When the input is a step, the signal that is applied to the feedback system is the integral of a step - a ramp. Observe the response using the analysis plot and note that it is continuously diverging from the correct value.

b) A type 1 system

$$G1(s) = \frac{(s + 1)}{s.(s + 2).(s + 3)}$$ a type 1 system

Return the gain to 1 and delete the integrator from the pre-filter. Observe the steady state response to a step input. What is the steady state error for any gain? Investigate the steady state error for a ramp input.

c) A type 2 system

$$G2(s) = \frac{(s + 1)}{s^2.(s + 2).(s + 3)}$$ a type 2 system

Repeat the above for G2. Confirm that the steady state error for both step and ramp inputs are as expected. This system is barely stable so you must increase the time limit on the analysis plots to see the final values.

2.5 Part A Marking Considerations

Part A will be marked up to a maximum of 70% of the whole assignment.

The following considerations will be applied when marking..

2.5.1 Assignment Format – 10%

Under this consideration all aspects related to the format of the assignment and its presentation will be included. Examples include: the structure of files and folders on the electronic medium, naming convention consistency, style guide definition and application, etc.

2.5.2 Assignment Documentation – 15%

This relates to the content of the project in terms of documentation and explanations, rather than the format, as in the previous paragraph. Examples include: the comments in various computer-related files, font and heading compliance, clarity and neatness, grammar and punctuation, clarity and conciseness, diagrams, spreadsheets, etc.

2.5.3 Assignment Functional Requirements – 30%

This covers the assessment of how well the specifications of the assignments are modelled, as well as how well the requirements in the question are captured in the design and in the model.

2.5.4 Assignment Novelty – 15%

In order to encourage innovation, any new ideas brought to the assignment by the student that was not explicitly covered during the lab sessions or during the lectures shall be given special consideration and marking. ‘Thinking outside the box’ is encouraged and rewarded.

2.6 Final Comments

The tutor will be available during the laboratory sessions to provide guidance and feedback to the students present.

3 Part B of the Assignment

Mathematical Analysis and Modeling of Mechanical Systems Using Matlab

3.1 Part B General Requirements

You are required to analyse a systems control considerations using the Matlab/Simulink tool chain. Any other tools or computer languages, if used, shall comply with paragraph 1.3, and can be used only to provide functionality not readily available in Matlab and its associated components licensed by Anglia Ruskin.

3.2 Part B Functional Requirements

In this assignment, you will have the opportunity to select a electrical, mechanical or electromechanics control system from the following list and perform mathematical analysis and modeling using Matlab:

- Motor Speed
- Motor Position
- Suspension
- Inverted Pendulum
- Aircraft Pitch
- Ball and Beam
- Other models can be agreed with the module tutor.

Your task is to choose one of these systems and undertake the following steps:

1. **System Selection:** Choose one of the control systems listed above based on your interest and preference.
2. **Mathematical Analysis:** Reference a comprehensive mathematical analysis of the selected system. This analysis should include relevant equations, formulas, and mathematical descriptions that define the system's behaviour.
3. **Modeling:** Create a mathematical model of the chosen mechanical system. This model should accurately represent the system's dynamics and behaviour under various conditions.
4. **Matlab Implementation:** Utilise Matlab to implement and simulate your mathematical model. You should demonstrate your understanding of Matlab's capabilities in simulating the selected system.
5. **Analysis and Interpretation:** Analyse the results obtained from your Matlab simulations. Interpret the system's behaviour under different scenarios and conditions. Discuss any noteworthy observations or insights.
6. **Documentation:** Prepare a well-structured report documenting your entire process, from system selection to Matlab implementation and analysis. Your report should include clear explanations, equations, diagrams, and visualizations to support your findings.

3.3 Part B General Considerations

The specifications in the previous paragraphs are minimal, and should be fulfilled first. Should a student wish to explore the requirements in more depth, the minimal requirements should be met first, then additional features can be added later. In this way the core of the requirements will be met for standard marks.

Excellent support has been provided at http://ctms.engin.umich.edu/CTMS/index.php?aux=Home that includes topics above and some analysis however the expectation from you in the assignment is clear demonstration of the understanding of the concepts and original writing based on your understanding (text taking from the website will not be accepted). The mark is heavily loaded on original thinking and critical analysis. To show understanding, user a variety of references.

3.4 Part B Marking Considerations

Part B will be marked up to a maximum of 30% (optional extra) of the whole assignment.

3.4.1 Assignment Format – 5%

Under this consideration all aspects related to the format of the assignment and its presentation will be included. Examples include: the structure of files and folders on the electronic medium, naming convention consistency, style guide definition and application, etc.

3.4.2 Assignment Documentation – 5%

This relates to the content of the project in terms of documentation and explanations, rather than the format, as in the previous paragraph. Examples include: the quality of the User Manual, the comments in various computer-related files, font and heading compliance, clarity and neatness, grammar and punctuation, diagrams, spreadsheets, etc.

3.4.3 Assignment Functional Requirements – 10%

This covers the assessment of how well the functional requirements, as laid out in paragraph 2.2, are implemented.

3.4.4 Assignment Novelty – 10%

In order to encourage innovation, any new ideas brought to the assignment by the student that was not explicitly covered during the lab sessions or during the lectures shall be given special consideration and marking. ‘Thinking outside the box’ is encouraged and rewarded.

3.5 Final Comments

The tutor will be available during the laboratory sessions to provide guidance and feedback to the students present.

END OF DOCUMENT CONTENT