Charles Darwin University

Final Examination

Family Name	
Given Name/s	
Student Number	
Teaching Period	Semester 2, 2017

ENG476 – Control Engineering	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes

INSTRUCTIONS TO CANDIDATES

1. Answer all questions.
2. Note that questions ARE NOT of equal value.
3. Read ALL questions carefully.
4. Do not commence writing until instructed to do so.

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a RESTRICTED OPEN BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

Any hard copy, unannotated English dictionary is permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
Lecture Textbook/s (Unannotated)	1 x 20 Page Book

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Question 1 (4 marks)

An open loop system with transfer function

$$G(s) = \frac{c(s)}{u(s)} = \frac{4}{s^2 + 2s + 2}$$

The open loop system is controlled by a lead compensator applying unit negative feedback. The following performance specifications are desired for the closed loop feedback system

- overshoot M_p = 4 [%]
- rise time t_r = 0.8 [s]

Question 1.1 (1 mark)

Determine the damping ratio, ζ, undamped natural frequency, ω_n [rad/s], and the location of the desired dominant closed loop poles for the closed loop system.

Question 1.2 (1 mark)

Compute the angle deficiency at the location of the desired dominant closed loop poles.

Question 1.3 (1 mark)

Determine the location of the pole and the location of the zero of the compensator $G_c(s)$ which will approximately achieve the above mentioned performance specifications. Compute T and α.

Question 1.4 (1 mark)

Using the magnitude condition for $G_c(s) \cdot G(s)$, compute K_c of the compensator.

Question 2 (5 marks)

An engineer is called in to trouble shoot a unit negative feedback control system in a process plant that does not function properly, as it exhibits oscillations. There is no documentation available about the control system. The engineer decides to disconnect the feedback loop, control module (controller) and open loop system (system without controller). He measures the step response of the control module as well as the frequency response of the open loop system without the controller. The results are shown in Figure 1 and Figure 2 below.

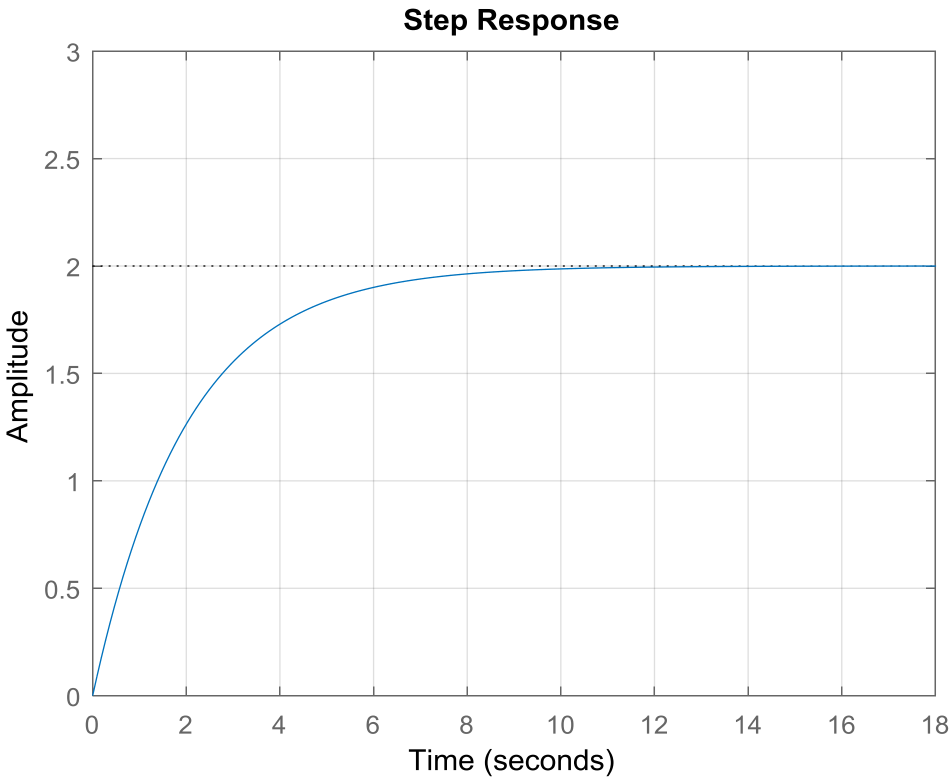


Figure 1, Step response of controller

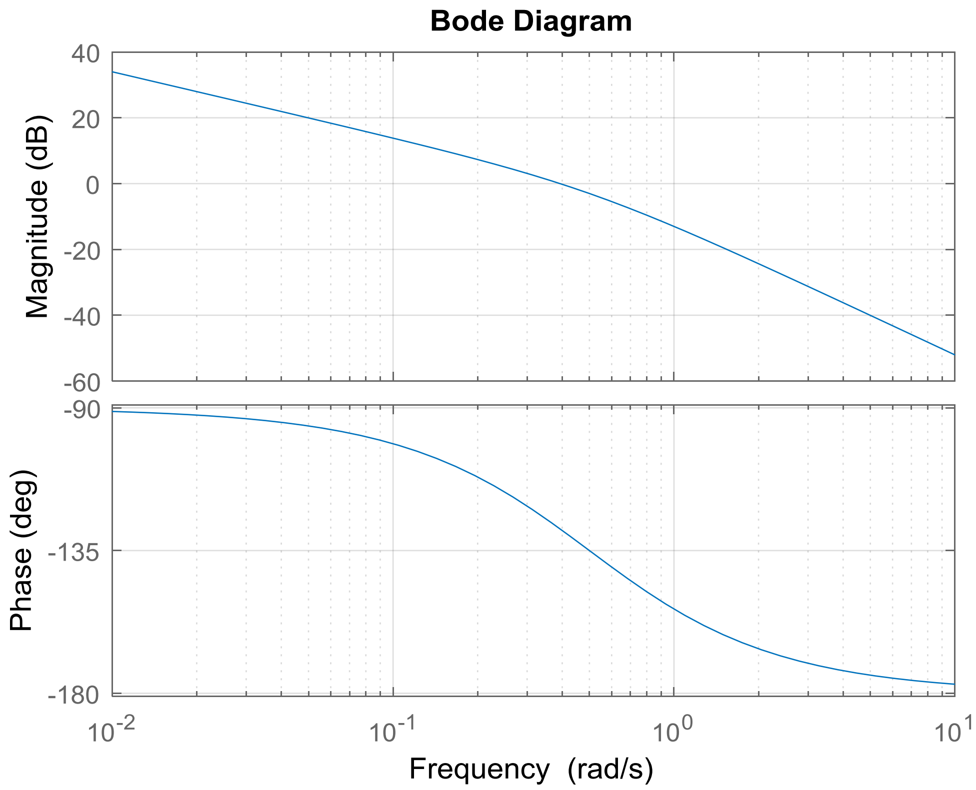


Figure 2, Frequency domain response of open loop system (system without controller)

Question 2.1 (1 mark)

Determine the transfer function of the controller.

Question 2.2 (1 mark)

Determine the transfer function of the open loop system (system without controller).

Question 2.3 (1 mark)

Determine the frequency of oscillation which caused the system not to function properly.

Question 2.4 (1 mark)

The engineer decides to replace the control module with a standard off the shelve PID control module. As an initial test, the engineer decides to only use the P action only of the PID controller. Determine the gain P so that a phase margin of 45 [deg] is achieved. What is the gain margin of the system for this setting of P?

Question 2.5 (1 mark)

Could the control loop be significantly improved by using the I action as well of the PID controller? Explain your answer.

Question 3 (3 marks)

An open loop system is described by the following transfer function:

$$\frac{y(s)}{u(s)} = G(s) = \frac{10}{s \cdot (0.2 \cdot s + 1) \cdot (0.4 \cdot s + 1)}$$

Question 3.1 (1 mark)

Calculate the magnitude and phase of the system for $\omega = 0, 1, 3.5, 5$ and ∞.

Question 3.2 (1 mark)

Sketch the polar plot of this system, using the findings of the question above.

Question 3.3 (1 mark)

Proportional unit feedback control is applied to the open loop system. Determine approximately the maximum value of the gain of the proportional controller before the roots of the characteristic equation cross over the $j\omega$ axis and go into the right half plane.

Question 4 (1 mark)

A system has a transfer function of:

$$\frac{y(s)}{x(s)} = G(s) = \frac{10}{(s^2 + s + 4)}$$

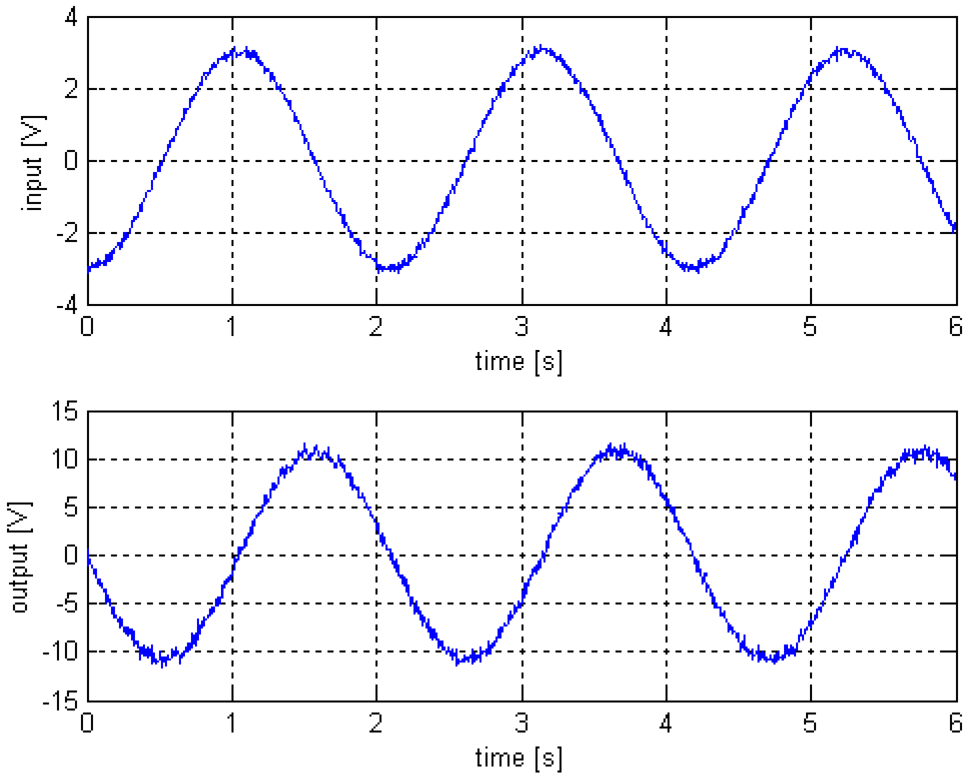
At t = 0 an input signal $x(t) = 2\sin(2t + 5\pi)$ is applied to this system.

Question 4.1 (1 mark)

Determine what the function of the output signal y(t) will be after a considerable time
($t > 10{,}000$ [s])?

Question 5 (2 marks)

An open loop system can be modelled as a second order system with transfer function G(s) and damping ratio ζ = 0.5. A measured frequency response of the second order system is shown in the figure below.



Question 5.1 (1 mark)

Determine the dominant frequency in [rad/s] of the signals shown in the figure above and the phase in [deg] of the system at this frequency.

Question 5.2 (1 mark)

Derive the transfer function G(s) of the second order system.

Question 6 (3 marks)

Given the state variable equations of an open loop system:

$$\frac{dx(t)}{dt} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \cdot x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} \cdot u(t) \text{ and } y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \cdot x(t)$$

State feedback is applied to this system with the feedback controller u(t) = -K·x(t). The following performance index is used to determine the optimal feedback matrix K:

$$J = \int_0^\infty (x_1^2 + 2 \cdot x_2^2 + u^2) dt$$

Question 6.1 (1 mark)

Determine the open loop transfer function G(s) that describes the input-output relation of the state space system in the Laplace domain. Is the open loop system stable? Explain your answer.

Question 6.2 (1 mark)

Determine the positive definite matrix P which solves the associated Ricatti equation and determine the feedback matrix K.

Question 6.3 (1 mark)

Determine the poles of the system with state feedback u(t) = -K·x(t) applied.