Final Assessment for EEET 1368

Instructions

1. Your submission of the assessment paper consists of only one word document with your name and student number and the document will be sent to my email address: liuping.wang@rmit.edu.au.
2. Question 2, Question 3, Question 4 and Question 5 require that you copy and paste your MATLAB and Simulink programs into the same document. However, you do not need to include the MATLAB functions.
3. The submission time is 1:30 PM on the 12th of June. You are only permitted to submit your assessment paper once.

QUESTION 1 Multiple Choices (30 marks)

1. The Laplace transfer function of a continuous-time system is given by

$$G(s) = \frac{2s - 0.5}{s^3 + 2s^2 + 3s + 2}.$$

   (a) The poles of the system are $-0.5 \pm j1.3299$, -1 and the zero of the system is 0.25. The system is unstable.

   (b) The poles of the system are $0.5 \pm j1.3299$, 1 and the zero of the system is -0.25. The system is unstable.

   (c) The poles of the system are $-0.15 \pm j1$, -1 and the zero of the system is 0.25. The system is stable.

   (d) None of the above.

2. The Laplace transfer function of a system is given by

$$G(s) = \frac{0.5}{s^2(s+3)}.$$

   The steady-state value of a unit step response is

   (a) $\frac{0.5}{3}$;

(b) 0;

(c) ∞;

(d) none of the above.

3. A proportional plus derivative controller has the Laplace transfer function $C(s) = \frac{5(s+10)}{s+1}$. In order to implement this controller, the proportional control gain K_c, derivative gain τ_D and derivative filter τ_f are calculated as:

   (a) $K_c = 5$, $\tau_D = 10$ and $\tau_f = 1$;

   (b) $K_c = 10$, $\tau_D = 5$ and $\tau_f = 1$;

   (c) $K_c = 5$, $\tau_D = 9$ and $\tau_f = 1$;

   (d) none of the above.

4. A nonlinear system is described by the following differential equation:

$$\ddot{y}(t) = 0.2y(t)^3 + 0.4u(t)^4$$

   The operating condition for this system is chosen to be $y^0 = 0$ and $u^0 = 1$. The linearized model is

   (a) a second order system with both poles at 0;

   (b) a third order system with poles at 0.2;

   (c) a fourth order system with poles at 0.4;

   (d) none of the above.

5. The transfer function of a system is given by $G(s) = \frac{1}{(s+1)^2}$ and the proportional controller is $K = 2$. The complementary sensitivity function $T(s)$ is calculated as

   (a) $T(s) = \frac{2}{s^2+2s+4}$;

   (b) $T(s) = \frac{2}{s^2+2s+3}$;

   (c) $T(s) = \frac{s^2+2s+1}{s^2+2s+3}$;

   (d) none of the above.

QUESTION 2 (20 marks)

A continuous time system is described by the first order plus delay transfer function

$$G(s) = \frac{5e^{-5s}}{20s+1}$$

	K_c	τ_I	τ_D
P	$\frac{0.13+0.51L}{K_{ss}}$		
PI	$\frac{0.13+0.51L}{K_{ss}}$	$\frac{d(0.25+0.96L)}{0.93+0.03L}$	
PID	$\frac{0.13+0.51L}{K_{ss}}$	$\frac{d(0.25+0.96L)}{0.93+0.03L}$	$\frac{d(-0.03+0.28L)}{0.25+L}$

Table 1: Wang-Cluett tuning rules with reaction curve ($L = \tau_M/d$)

1. **(10 marks)** Find the controller parameters K_c, τ_I and τ_D using the tuning rules given in Table 1, where K_{ss} is the steady-state gain, τ_M is the time constant, and d is the time delay.

2. **(5 marks)** Simulate closed-loop response with sampling interval $\Delta t = 0.1$ and simulation time $T_{sim} = 400$ (sec). A unit step reference signal enters the system at time $t = 0$ and an input disturbance with amplitude of one entering the system at $t = 200$ (sec). In the simulation, both proportional control and the derivative control are implemented on the output only. The derivative filter time constant is chosen to be $0.1\tau_D$. Plot the control signal and output signal.

3. **(5 marks)** Let u_{max} and u_{min} denote the maximum and the minimum values of the control signal. What is u_{max}? What is u_{min}?

QUESTION 3 (15 marks)

Use the disturbance-observer based approach to design a PID controller for the following system:

$$G(s) = \frac{2}{s^2 + 1}$$

1. **(5 marks)** Choose the desired closed-loop characteristic polynomial for the proportional plus derivative controller as $s^2 + 2\xi w_n s + w_n^2$ where $\xi = 0.707$ and $w_n = 3$, while the pole for the estimator is -4. What are the values of K_1, K_2 and K_3?

2. **(5 marks)** Simulate the closed-loop step response and input disturbance rejection where the derivative filter time constant $\tau_f = 0.1\tau_D$. In the simulation, the reference signal $r = 1$ and the input disturbance

has an amplitude of -3 entering the simulation at half of the simulation time. The sampling interval $\Delta t = 0.01$ and the simulation time $T_{sim} = 10$. Present the output signal and control signal. What are the maximum and minimum values of the control signal?

3. **(5 marks)** Evaluate the effect of constraints on the control signal where the constraint parameters u^{max} and u^{min} are chosen to be 90 percent of the control signal's maximum and minimum amplitude from the previous step. Present the output signal and control signal.

QUESTION 4 (15 marks)
The desired reference signal for a system is given as

$$r(t) = 3sin(t) + 2.$$

Use the disturbance-observer based approach to design a resonant controller so that the output will track this reference signal without steady-state error. Here, the system is described by the following transfer function:

$$G(s) = \frac{2}{s}$$

1. **(5 marks)** Choose the desired closed-loop characteristic polynomial for the proportional controller as $s + 3$, while for the estimator, $w_n = 4$ and $\xi = 1$ are chosen. What are the values, γ_1 and γ_2?

2. **(5 marks)** Simulate the resonant control system using the disturbance observer based approach. In the simulation, the reference signal $r(t) = 3sin(t) + 2$. The sampling interval $\Delta t = 0.01$ and the simulation time $T_{sim} = 20$. Present the output signal and control signal. What is the maximum of the control signal?

3. **(5 marks)** Evaluate the effect of constraints on the control signal where the constraint parameter u^{max} is chosen to be 80 percent of the control signal's maximum amplitude from the previous step. We do not need to constrain the minimum of the control amplitude so you can choose $u^{min} = -100$. Present the output signal and control signal together with the maximum constraint.

QUESTION 5 (20 marks)
A complex system is controlled by the cascade PID control system as illustrated in the following figure, where the inner-loop controller is a proportional controller and the outer-loop controller is a PID controller. The outer-loop

system is a second order with time delay having the following transfer function model:

$$G_2(s) = \frac{e^{-ds}}{(s+0.1)^2}$$

where d is known to be less than 2.

1. **(10 marks)** Design a cascade control system. In the cascade control system design, the closed-loop pole for the inner-loop system is positioned at -10 and all closed-loop poles for the outer-loop system are positioned at -0.2. Because the time delay is much smaller than the time constant in the outer-loop system, you can neglect it in the PID controller design and you can use pidplace.m to find the controller parameters.

2. **(10 marks)** Evaluate closed-loop stability of the cascade control system where the maximum time delay $d = 2$ is considered. This task is to be completed using Nyquist stability criterion. Present the Nyquist plot for this cascade control system. What are the gain margin and phase margin?