UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EEE 354 – Digital Control Systems
[Sistem Kawalan Digit]

Duration : 3 hours
[Masa : 3 Jam]

Please check that this examination paper consists of **TEN (10)** pages printed material and **TWO (2)** pages of Appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH (10)** mukasurat bercetak beserta Lampiran **DUA (2)** muka surat bercetak sebelum anda memulakan peperiksaan ini.]*

Instructions: This question paper consists **SIX (6)** questions. Answer **FIVE (5)** questions. All questions carry the same marks.

[***Arahan:*** *Kertas soalan ini mengandungi **ENAM (6)** soalan. Jawab **LIMA (5)** soalan. Semua soalan membawa jumlah markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. Persamaan kebezaan untuk suatu sistem kawalan diberikan seperti di bawah.

The difference equation for a digital control system is given below.

$$2\,y[k+2] - 10\,y[k+1] + 12\,y[k] = 6\,x[k+1] + 10\,x[k]$$

(a) Lukiskan gambarajah simulasi untuk persamaan kebezaan yang mewakili sistem tersebut.

Draw the simulation diagram for the difference equation that represents the system.

(20 markah/*marks*)

(b) Tentukan fungsi pindah sistem berdasarkan persamaan kebezaan tersebut.

Determine the transfer function of the system based on the difference equation.

(20 markah/*marks*)

(c) Andaikan masukan adalah unit langkah dan y(kT) adalah kausal, kirakan 5 sebutan pertama bagi y(kT) menggunakan:

Assuming that the input is a unit step and y(kT) is causal, calculate the first 5 terms for y(kT) using:

(i) Kaedah berjujukan.

Sequential method.

(20 markah/*marks*)

(ii) Kaedah jelmaan-Z.

Z-transform method.

(20 markah/*marks*)

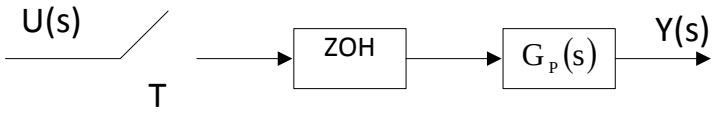
(d) Tentu sahkan bahawa teorem nilai akhir boleh digunapakai bagi y(kT).

Validate that the final value theorem holds for y(kT).

(20 markah/*marks*)

2. Suatu sistem kawalan gelung terbuka boleh diwakili oleh Rajah 2 berikut:

An open-loop control system can be represented by Figure 2 diagram:



Rajah 2
Figure 2

Jika,

If, $$G_p(s) = \frac{s}{\left(s^2 + 7s + 12\right)}$$

(a) Dengan menyatakan andaian yang dibuat, tentukan fungsi pindah denyut kepada sistem tersebut.

By stating any assumptions made, determine the pulse transfer function of the system.

(20 markah/*marks*)

(b) Tentukan sambutan sistem tersebut pada kala pensampelan bagi 2 fungsi masukan yang berbeza.

Determine the system response at the sampling interval for 2 different types of input functions.

(55 markah/*marks*)

(c) Bina sambutan sistem tersebut pada kT = 1s, untuk salah satu fungsi masukan yang diberikan dalam (b).

Construct the system response at kT = 1s, for one of the input function given in (b).

(10 markah/*marks*)

(d) Ulangi (a) menggunakan jelmaan-Z terubahsuai jika,

Repeat (a) using modified Z-transform if,

$$G_p(s) = \frac{e^{-0.9s}s}{(s^2 + 7s + 12)}$$

(15 markah/*marks*)

3. Rajah 3(b) mewakili gambarajah blok untuk suatu sistem kawalan.

Figure 3(b) represents the block diagram for a control system.

(a) Dengan menyatakan sebarang andaian yang dibuat, dapatkan fungsi pindah sistem tersebut.

By stating any assumptions made, obtain the transfer function of the system.

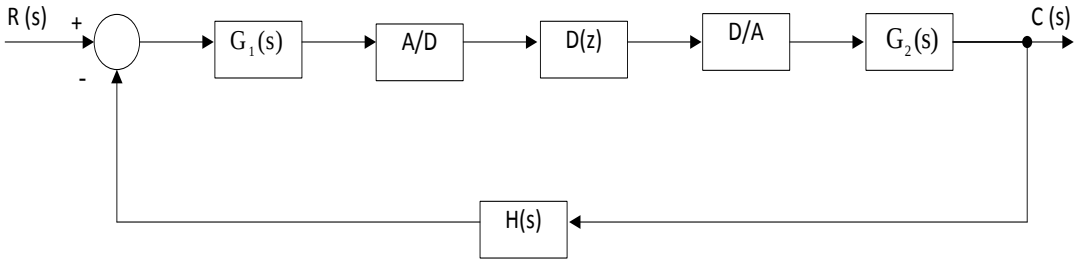
(30 markah/*marks*)

(b) Dapatkan C(z), sekiranya masukan adalah unit langkah dan:-

Obtain C(z), if input is unit step and :-

$$\mathrm{G_1(s) = s + 1;} \qquad \mathrm{G_2(s) = \frac{2}{s+2};}$$

$$\mathrm{D(z) = 2;} \qquad \mathrm{H(s) = 0.2}$$

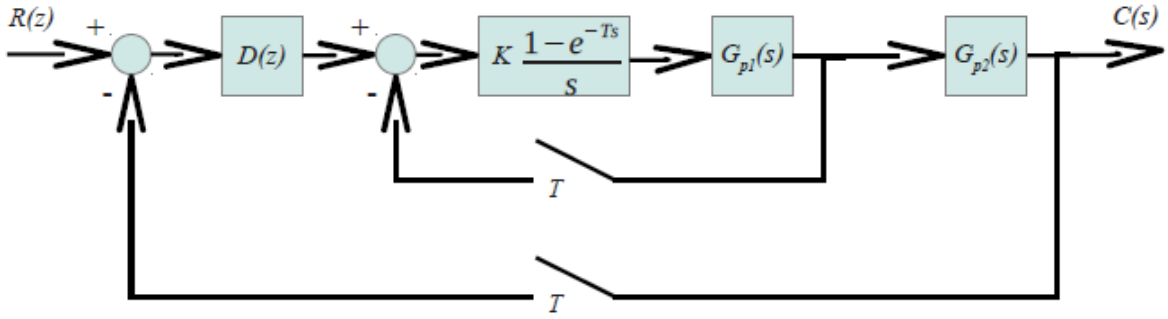


Rajah 3(b)
Figure 3(b)

(70 markah/*marks*)

4. (a) Pertimbangkan sistem dua gelung seperti Rajah 4(a).

Consider the two-loop system of Figure 4(a) below.



Rajah 4(a)
Figure 4(a)

Gandaan K digunakan untuk memberi ciri-ciri tertentu untuk gelung dalaman. Pengawal D(z) direka untuk mengimbangi keseluruhan sistem. Masukan R(z) dijana dengan menggunakan komputer, oleh sebab itu ia tidak wujud sebagai isyarat berterusan.

The gain K is used to give the inner loop certain specified characteristics. The controller D(z) is designed to compensate the entire system. The input R(z) is generated within the computer, thus does not exist as a continuous signal.

(i) Lukiskan graf aliran isyarat bagi system

Draw signal flow graph for the system

(20 markah/*marks*)

(ii) Tentukan C (z).

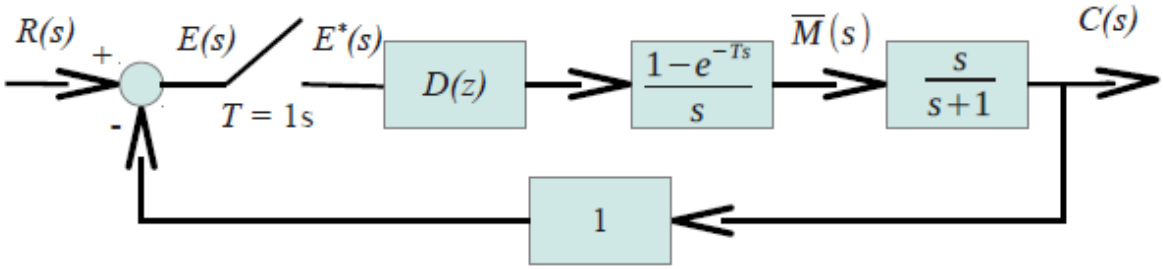
Determine C(z).

(20 markah/*marks*)

(b) Pertimbangkan pengawal sudut sistem antena radar seperti Rajah 4(b) di bawah, r(t) adalah sudut yang dikehendaki. Rangkap pindah motor dan gear diberikan sebagai $\frac{s}{s+1}$ oleh itu gandaan dc loji adalah sifar. Penapis digital D(z) diberi $m(kT) = e(kT) - 0.9e[(k-1)T] + m[(k-1)T]$

Consider control angle of radar antenna system of Figure 4(b) below, r(t) is the desired angle. Motors and gears transfer function is given by $\frac{s}{s+1}$ *hence the dc gain of the plant is zero. The digital filter D(z) is described by*

$$m(kT) = e(kT) - 0.9e[(k-1)T] + m[(k-1)T]$$



Rajah 4(b)
Figure 4(b)

(i) Tentukan jenis sistem?

What is the system type?

(20 markah/*marks*)

(ii) Tentukan sambutan keadaan mantap bagi masukan unit langkah, tanpa mencari C (z).

Determine the steady-state response for a unit-step input, without finding C(z).

(20 markah/*marks*)

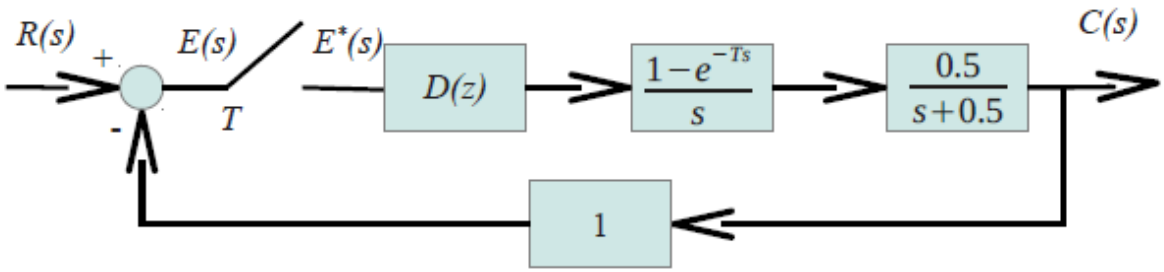
(iii) Cari masa anggaran bagi sistem untuk mencapai keadaan mantap.

Find the approximate time for the system to reach steady-state.

(20 markah/*marks*)

5. Pertimbangkan sistem seperti Rajah 5 di bawah.

Consider the system of Figure 5 below.



Rajah 5
Figure 5

(i) Kira dan plot sambutan unit langkah pada pensampelan, bagi kes apabila D (z) = 1.

Calculate and plot the unit-step response at the sampling instants, for the case that D(z) = 1.

(15 markah/*marks*)

(ii) Kirakan tindak balas unit-langkah sistem analog, dengan pensampel, pengawal digital, dan pemegang data dikeluarkan. Plot sambutan pada graf yang sama bahagian (i).

Calculate the system unit-step response of the analog system, with the sampler, digital control, and data hold removed. Plot the response on the same graph of part (i).

(15 markah/*marks*)

(iii) Biar D (z) = 1, dan T = 0.4s. Tentukan sambutan unit langkah dan plot keputusan ini menggunakan graf yang sama untuk bahagian (i) dan (ii).

Let D(z) = 1, and T = 0.4s. Determine the unit-step response and plot these results on the same graph used for part (i) and (ii).

(15 markah/*marks*)

(iv) Gunakan gandaan dc sistem tersebut untuk mengira sambutan keadaan mantap bagi setiap sistem bahagian (i), (ii) dan (iii).

Use the system dc gains to calculate the steady-state responses for each of the systems of parts (i), (ii) and (iii).

(15 markah/*marks*)

(v) Cari pemalar masa sistem.

Find the time constant of the system.

(20 markah/*marks*)

(vi) Sekarang, andaikan bahawa kelewatan masa yang sesuai 0.2s telah ditambah kepada loji, oleh itu rangkap pindah loji kini adalah $G_p(s) = \frac{0.5e^{-0.2T}}{s+0.5}$. Cari pemalar masa sistem tersebut jika kelewatan masa dimasukkan.

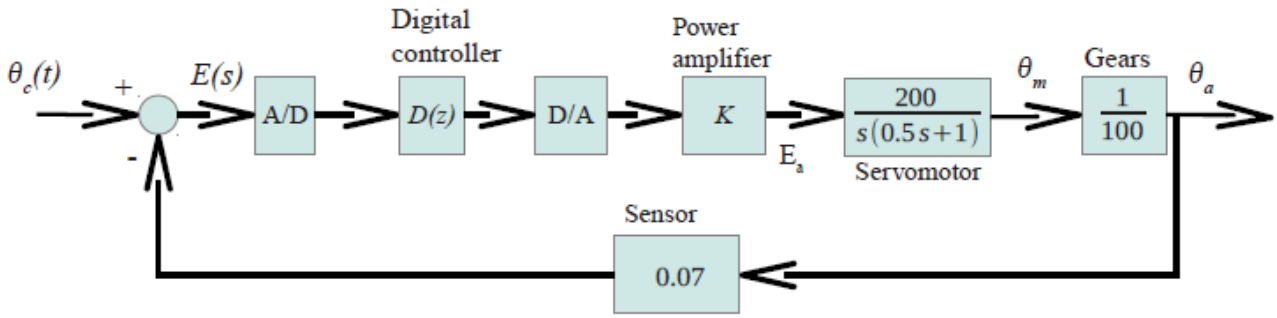
Now, suppose that an ideal time delay of 0.2s is added to the plant, such that the plant transfer function is now given by $G_p(s) = \frac{0.5e^{-0.2T}}{s+0.5}$. *Find the time constant of the system if the time delay is included.*

(20 markah/*marks*)

6. Pertimbangkan sistem kawalan sendi robot seperti gambarajah blok di bawah (Rajah 6). Bagi sistem ini, T = 0.1 s dan D (z) = 1. Diberi:

Consider the robot joint control system of block diagram below (Figure 6). For this system, T = 0.1 s and D(z) = 1. Given:

$$Z\left[\frac{1-e^{-Ts}}{s}\ \frac{4}{s(s+2)}\right] = \frac{0.01873z + 0.01752}{(z-1)(z-0.8187)}$$



Rajah 6
Figure 6

(i) Tentukan persamaan ciri sistem gelung tertutup.

Determine the closed-loop system characteristic equation.

(20 markah/*marks*)

(ii) Dengan menggunakan kriteria Routh-Hurwitz, cari julat K untuk kestabilan.

By using Routh-Hurwitz criterion, find the range of K for stability.

(20 markah/*marks*)

(iii) Dengan menggunakan kaedah ujian Juri, cari julat K untuk kestabilan.

By using Jury test method, find the range of *K* for stability.

(20 markah/*marks*)

(iv) Tentukan lokasi semua punca-punca persamaan ciri dalam kedua-dua satah-w dan satah-z bagi nilai K> 0 bila mana sistem adalah stabil jidar.

Determine the location of all roots of the characteristic equation in both w-plane and the z-plane for the value of K > 0 for which the system is marginally stable.

(20 markah/*marks*)

(v) Pertimbangkan keputusan bahagian (iv), tentukan kedua-dua frekuensi satah-s dan frekuensi satah-w, di mana sistem akan berayun apabila mencapai kestabilan jidar.

Consider the results of part (iv), determine both the s-plane frequency and the w-plane frequency at which the system will oscillate when reaching marginal stability

(20 markah/*marks*)

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