UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006

April/Mei 2006

EEE 354 – SISTEM KAWALAN DIGIT

Masa : 3 jam

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEBELAS (11)** muka surat termasuk **SATU** mukasurat **Lampiran** bercetak sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Semua soalan hendaklah dijawab dalam Bahasa Malaysia.

1. Persamaan kebezaan untuk suatu sistem kawalan diberikan seperti di bawah.
The difference equation for a discrete control system is given below.

$$y(k) - 3y(k-1) + 2y(k-2) = u(k)$$

$$u(k) = \begin{cases} 1, k = 0,1 \\ 0, k \geq 2 \end{cases}$$

$$y(-2) = y(-1) = 0$$

(a) Selesaikan persamaan kebezaan yang diberi dengan menggunakan:

Solve the given difference equation for y(k) using:

(50%)

(i) Teknik Jujukan.

The sequential technique.

(ii) Jelmaan Z.

The z-transform.

(iii) Adakah teorem nilai akhir akan memberikan nilai yang betul bagi y(k) apabila $k \rightarrow \infty$?

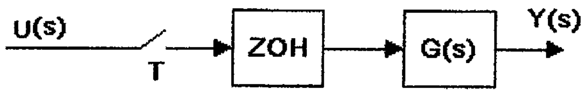
Will the final-value theorem give the correct value of y(k) as $k \rightarrow \infty$*?*

(b) Dengan merujuk kepada persamaan kebezaan yang diberi di bawah, bina dua model pembolehubah-ruang degan menggunakan teknik jelmaan-Z dan pengembangan pecahan separa. Rajah penyelakuan yang sesuai mesti digunakan untuk mendapatkan persamaan ruang bagi kedua-dua model.

By referring to the difference equation given below, construct two state-variable models using the z-transform and partial-fraction expansion techniques. Relevant simulation diagrams should be used to acquire the state equations for both models.

$$y(k+2) = u(k) + 1.7y(k+1) - 0.72y(k)$$ (50%)

2. Suatu sistem kawalan gelung terbuka boleh diwakili oleh gambarajah berikut:
An open-loop control system can be represented by the following diagram:



Rajah 1
Figure 1

Jika
If

$$G(s) = \frac{5}{(s^2 + 3s + 2)}$$

(a) Tentukan fungsi pindah denyut kepada sistem tersebut untuk T = 1s.
Determine the pulse transfer function of the system for T = 1s.

(20%)

(b) Tentukan sambutan sistem tersebut pada kala pensampelan bagi:
Determine the system response at the sampling interval for.

(i) Masukan unit langkah
Unit step input (25%)

(ii) Masukan unit rampa
Unit ramp input (30%)

(c) Apakah sambutan sistem tersebut pada kT = 5s, untuk kes (b) (ii).
What is the system response at kT = 5s, for case (b) (ii).

(10%)

(d) Ulangi (a) menggunakan jelmaan-Z terubahsuai jika,
Repeat (a) using modified Z-transform if,

$$G(s) = \frac{5e^{-0.5s}}{\left(s^2 + 3s + 2\right)}$$

(15%)

3. Rajah 2 mewakili gambarajah blok untuk suatu sistem kawalan.
Figure 2 represents the block diagram for a control system.

(a) Dapatkan fungsi pindah sistem tersebut, nyatakan Y(z) dalam sebutan R(z) dan U(z). Gunakan OFG, SFG dan formula untung Mason dalam terbitan anda.

Obtain the transfer function of the system, express Y(z) in term of R(z) and U(z). Use OFG, SFG and Mason's gain formula in your derivation.

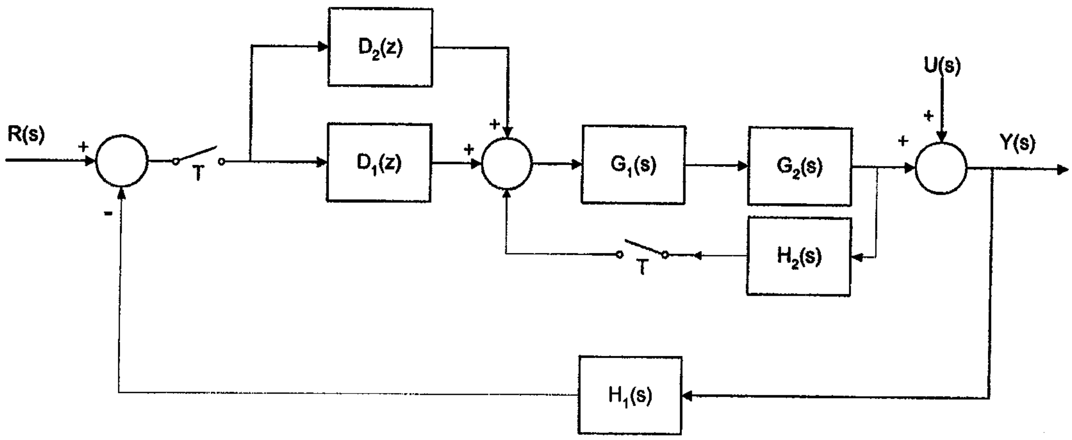
(70%)

(b) Jika fungsi pindah blok-blok tersebut adalah seperti berikut,
If the transfer functions of the blocks are as follows,

$$G_1(s)=\frac{10}{s+5},\ G_2(s)=\frac{1}{2s+1},\ H_1(s)=H_2(s)=1,\ D_1(z)=\frac{z}{z-1} \text{ and } D_2(z)=2.$$

Tentukan fungsi pindah sebenar sistem tersebut berdasarkan fungsi pindah yang didapati dalam bahagian (a), untuk T = 1s.
Determine the actual transfer function of the system based on the transfer function obtained in part (a), for T = 1s.

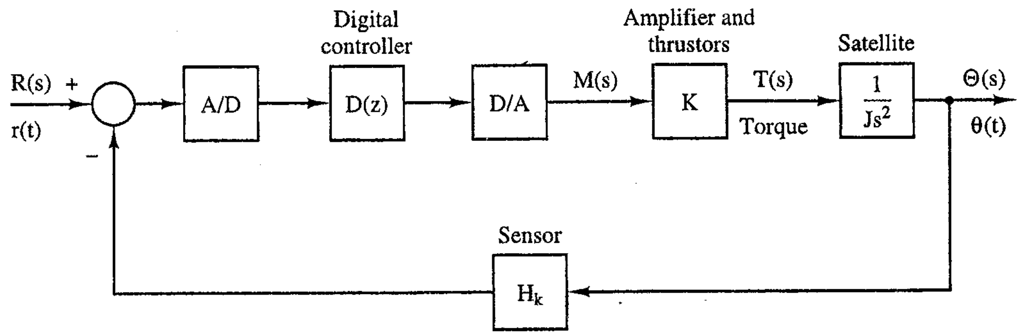
(30%)



Rajah 2
Figure 2

4. Rajah blok bagi sebuah sistem kawalan 'altitude' satelit ditunjukkan didalam Rajah 3. Gunakan T = 1 s, K = 100, J = 0.1, H_k = 0.02, dan D(z) = 1.

The block diagram of an altitude control system of a satellite is shown in Figure 3. Let T = 1 s, K = 100, J = 0.1, H_k = 0.02, and D(z) = 1.



Rajah 3
Figure 3

(a) Tentukan nilai nisbah lemati, frekuensi tabie, dan pemalar masa bagi sistem gelung terbuka tersebut. Sekiranya persamaan ciri sistem mempunyai dua nilai sifar nyata, tentukan apakah nilai dua pemalar masa berkaitan.

Find damping ratio, the natural frequency, and the time constant of the open loop system. If the system characteristic equation has two real zeros, find the two time constants.

(30%)

(b) Ulang langkah (a) bagi sebuah sistem gelung tertutup.

Repeat part (a) for the closed-loop system

(35%)

(c) Ulang langkah (a) dan (b) bagi sistem yang telah dibuang daripadanya penyampel, pengawal digital dan pemegang data, iaitu bagi sebuah sistem analog.

Repeat part (a) and (b) for the system with the sampler, digital controller, and data-hold removed, that is, for an analogue system.

(20%)

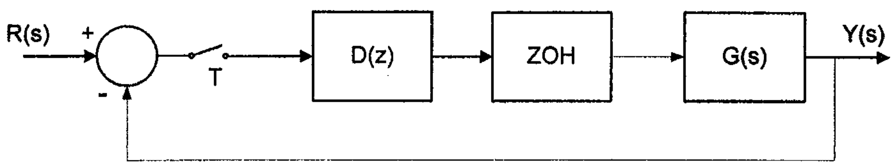
(d) Sistem gelung-tertutup data tersampel di atas dilihat sebagai tidak stabil, manakala sistem gelung-tertutup analog pula dilihat sebagai stabil berjidar. Sekiranya satelit tersebut dioperasikan dengan setiap sistem kawalan ini, huraikan pergerakan yang akan terhasil daripada sistem data tersampel dan sistem analog ini.

The closed-loop sampled-data system is seen to be unstable and the closed-loop analogue system is seen to be marginally stable. If the satellite is operated with each of these control systems, describe the resulting movement for both the sampled-data system and the analogue system.

(15%)

5. Gambarajah blok yang dipermudahkan bagi suatu sistem kawalan suapbalik suhu adalah seperti yang ditunjukkan dalam Rajah 4.

The simplified block diagram of a temperature feedback control system is as shown in Figure 4.



Rajah 4
Figure 4

Jika pengawal tersebut dipilih sebagai,
If the controller is selected as,

$$D(z) = K,$$

fungsi pindah loji ialah
the plant transfer function is

$$G(s) = \frac{18}{s(0.4s+1)}$$

dan boleh dibuktikan bahawa:
and it can be proved that:

$$\frac{z-1}{z} Z\left[\frac{1.8}{s^2(0.4s+1)}\right] = \frac{0.021z + 0.019}{z^2 - 1.779z + 0.779}, \quad \text{untuk } T = 0.2s$$

(a) Tentukan persamaan ciri sistem kawalan gelung tertutup tersebut dalam domain-z dan domain-w sebagai fungsi K.

Determine the characteristic equation of the closed loop system in z-domain and w- domain as a function of K.

(30%)

(b) Gunakan kaedah Routh-Hurwitz untuk menentukan julat K supaya sistem tersebut kekal stabil.

Use Routh-Hurwitz method to determine the range of K such that the system will remain stable.

(20%)

(c) Semak jawapan anda dalam (b) menggunakan ujian kestabilan Jury.
Check your answer in (b) using Jury's stability test.

(20%)

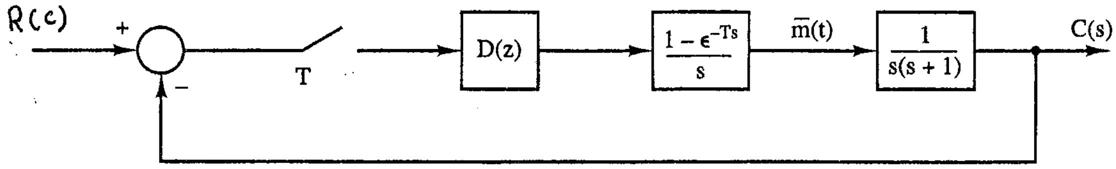
...9/-

(d) Tentukan kestabilan sistem menggunakan ujian Jury jika,
Determine the system stability using Jury's test if,

$$D(z) = 5\left(\frac{1.2z-1}{z-1}\right)$$

(30%)

6. Pertimbangkan sistem yang ditunjukkan di dalam Rajah 5 dengan T = 0.2 s
Consider the system of Figure 5 with T=0.2 s.



Rajah 5
Figure 5

(a) Tentukan fungsi pindah denyut bagi loji yang diberi
Determine the pulse transfer function of the plant given.

(20%)

(b) Sambutan frekuensi bagi G(z) adalah seperti yang diberi di dalam Jadual 1. Daripada sambutan frekuensi ini, lakarkan rajah Bode dan Nyquist untuk sistem yang tidak terpampas, yang menunjukkan jidar untung dan jidar fasa.

The frequency response for G(z) is given in Table 1. From this frequency response, sketch the Bode and the Nyquist diagrams for the uncompensated system, indicating the gain and phase margins.

(30%)

(c) Tentukan nilai $G(j\omega_w)$ apabila $\omega_w \rightarrow \infty$. Anda tidak perlu untuk mencari nilai $G(w)$ untuk mengira nilai ini.

Calculate the value of $G(j\omega_w)$ as $\omega_w \rightarrow \infty$. *It is not necessary to find G(w) to calculate this value.*

(10%)

...10/-

(d) Gunakan keputusan yang diperolehi daripada bahagian (b) untuk menganggar lajakan bagi sambutan unit langkah.

Use the results in part (b) to estimate the overshoot in the unit-step response.

(20%)

(e) Berdasarkan keputusan daripada bahagian (d), adakah nilai-nilai sifar bagi persamaan ciri sistem tak terpampas nyata atau kompleks? Kenapa?

Based on the results in part (d), are the zeros of the uncompensated system characteristics equation real or complex? Why?

(20%)

Jadual 1: Sambutan Frekuensi bagi soalan 6

Table 1: Frequency Response for question 6

ω_w	ω	$\lvert G(j\omega_w)\rvert$	$\lvert G(j\omega_w)\rvert_{dB}$	$\angle G(j\omega_w)$
0.1	0.100	9.95054	19.95	−96.28
0.2	0.200	4.90325	13.80	−102.45
0.3	0.299	3.19331	10.08	−108.41
0.4	0.399	2.32198	7.31	−114.08
0.5	0.499	1.78990	5.05	−119.40
0.6	0.599	1.43046	3.10	−124.36
0.7	0.698	1.17191	1.37	−128.95
0.8	0.798	0.97794	−0.19	−133.17
0.9	0.897	0.82799	−1.63	−137.05
1.0	0.996	0.70945	−2.98	−140.61
2.0	1.974	0.22743	−12.86	−164.43
3.0	2.914	0.10973	−19.19	−177.74
4.0	3.805	0.06511	−23.72	−187.04
5.0	4.636	0.04372	−27.18	−194.33
6.0	5.404	0.03186	−29.93	−200.38
7.0	6.107	0.02459	−32.18	−205.55
8.0	6.747	0.01980	−34.06	−210.03
9.0	7.328	0.01646	−35.67	−213.95
10.0	7.854	0.01403	−37.05	−217.40
20.0	11.071	0.00558	−45.07	−236.77
30.0	12.490	0.00352	−49.07	−243.95
40.0	13.258	0.00259	−51.73	−246.94

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Lampiran: *Jadual Penjelmaan Z* [EEE 354]
Appendix: Z-Transform Tables

Laplace transform $E(s)$	Time function $e(t)$	z-Transform $E(z)$	Modified z-transform $E(z,m)$
$\frac{1}{s}$	$u(t)$	$\frac{z}{z-1}$	$\frac{1}{z-1}$
$\frac{1}{s^2}$	t	$\frac{Tz}{(z-1)^2}$	$\frac{mT}{z-1}+\frac{T}{(z-1)^2}$
$\frac{1}{s^3}$	$\frac{t^2}{2}$	$\frac{T^2z(z+1)}{2(z-1)^3}$	$\frac{T^2}{2}\left[\frac{m^2}{z-1}+\frac{2m+1}{(z-1)^2}+\frac{2}{(z-1)^3}\right]$
$\frac{(k-1)!}{s^k}$	t^{k-1}	$\lim_{a\to 0}(-1)^{k-1}\frac{\partial^{k-1}}{\partial a^{k-1}}\left[\frac{z}{z-\epsilon^{-aT}}\right]$	$\lim_{a\to 0}(-1)^{k-1}\frac{\partial^{k-1}}{\partial a^{k-1}}\left[\frac{\epsilon^{-amT}}{z-\epsilon^{-aT}}\right]$
$\frac{1}{s+a}$	ϵ^{-at}	$\frac{z}{z-\epsilon^{-aT}}$	$\frac{\epsilon^{-amT}}{z-\epsilon^{-aT}}$
$\frac{1}{(s+a)^2}$	$t\epsilon^{-at}$	$\frac{Tz\epsilon^{-aT}}{(z-\epsilon^{-aT})^2}$	$\frac{T\epsilon^{-amT}[\epsilon^{-aT}+m(z-\epsilon^{-aT})]}{(z-\epsilon^{-aT})^2}$
$\frac{(k-1)!}{(s+a)^k}$	$t^k\epsilon^{-at}$	$(-1)^k\frac{\partial^k}{\partial a^k}\left[\frac{z}{z-\epsilon^{-aT}}\right]$	$(-1)^k\frac{\partial^k}{\partial a^k}\left[\frac{\epsilon^{-amT}}{z-\epsilon^{-aT}}\right]$
$\frac{a}{s(s+a)}$	$1-\epsilon^{-at}$	$\frac{z(1-\epsilon^{-aT})}{(z-1)(z-\epsilon^{-aT})}$	$\frac{1}{z-1}-\frac{\epsilon^{-amT}}{z-\epsilon^{-aT}}$
$\frac{a}{s^2(s+a)}$	$t-\frac{1-\epsilon^{-at}}{a}$	$\frac{z[(aT-1+\epsilon^{-aT})z+(1-\epsilon^{-aT}-aT\epsilon^{-aT})]}{a(z-1)^2(z-\epsilon^{-aT})}$	$\frac{T}{(z-1)^2}+\frac{amT-1}{a(z-1)}+\frac{\epsilon^{-amT}}{a(z-\epsilon^{-aT})}$
$\frac{a^2}{s(s+a)^2}$	$1-(1+at)\epsilon^{-at}$	$\frac{z}{z-1}-\frac{z}{z-\epsilon^{-aT}}-\frac{aT\epsilon^{-aT}z}{(z-\epsilon^{-aT})^2}$	$\frac{1}{z-1}-\left[\frac{1+amT}{z-\epsilon^{-aT}}+\frac{aT\epsilon^{-aT}}{(z-\epsilon^{-aT})^2}\right]\epsilon^{-amT}$
$\frac{b-a}{(s+a)(s+b)}$	$\epsilon^{-at}-\epsilon^{-bt}$	$\frac{(\epsilon^{-aT}-\epsilon^{-bT})z}{(z-\epsilon^{-aT})(z-\epsilon^{-bT})}$	$\frac{\epsilon^{-amT}}{z-\epsilon^{-aT}}-\frac{\epsilon^{-bmT}}{z-\epsilon^{-bT}}$
$\frac{a}{s^2+a^2}$	$\sin(at)$	$\frac{z\sin(aT)}{z^2-2z\cos(aT)+1}$	$\frac{z\sin(amT)+\sin(1-m)aT}{z^2-2z\cos(aT)+1}$
$\frac{s}{s^2+a^2}$	$\cos(at)$	$\frac{z(z-\cos(aT))}{z^2-2z\cos aT+1}$	$\frac{z\cos(amT)-\cos(1-m)aT}{z^2-2z\cos(aT)+1}$
$\frac{1}{(s+a)^2+b^2}$	$\frac{1}{b}\epsilon^{-at}\sin bt$	$\frac{1}{b}\left[\frac{z\epsilon^{-aT}\sin bT}{z^2-2z\epsilon^{-aT}\cos(bT)+\epsilon^{-2aT}}\right]$	$\frac{1}{b}\left[\frac{\epsilon^{-amT}[z\sin bmT+\epsilon^{-aT}\sin(1-m)bT]}{z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT}}\right]$
$\frac{s+a}{(s+a)^2+b^2}$	$\epsilon^{-at}\cos bt$	$\frac{z^2-z\epsilon^{-aT}\cos bT}{z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT}}$	$\frac{\epsilon^{-amT}[z\cos bmT+\epsilon^{-aT}\sin(1-m)bT]}{z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT}}$
$\frac{a^2+b^2}{s[(s+a)^2+b^2]}$	$1-\epsilon^{-at}\left(\cos bt+\frac{a}{b}\sin bt\right)$	$\frac{z(Az+B)}{(z-1)(z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT})}$ $A=1-\epsilon^{-aT}\left(\cos bT+\frac{a}{b}\sin bT\right)$ $B=\epsilon^{-2aT}+\epsilon^{-aT}\left(\frac{a}{b}\sin bT-\cos bT\right)$	$\frac{1}{z-1}$ $-\frac{\epsilon^{-amT}[z\cos bmT+\epsilon^{-aT}\sin(1-m)bT]}{z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT}}$ $\frac{+\frac{a}{b}\{\epsilon^{-amT}[z\sin bmT-\epsilon^{-aT}\sin(1-m)bT]\}}{z^2-2z\epsilon^{-aT}\cos bT+\epsilon^{-2aT}}$
$\frac{1}{s(s+a)(s+b)}$	$\frac{1}{ab}+\frac{\epsilon^{-at}}{a(a-b)}$ $+\frac{\epsilon^{-bt}}{b(b-a)}$	$\frac{(Az+B)z}{(z-\epsilon^{-aT})(z-\epsilon^{-bT})(z-1)}$	$A=\frac{b(1-\epsilon^{-aT})-a(1-\epsilon^{-bT})}{ab(b-a)}$ $B=\frac{a\epsilon^{-aT}(1-\epsilon^{-bT})-b\epsilon^{-bT}(1-\epsilon^{-aT})}{ab(b-a)}$