UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1996/97

April 1997

EEE 452 - Sistem Kawalan Lanjutan

Masa : [3 jam]

ARAHAN KEPADA CALON :

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH** **(10)** muka surat bercetak dan **ENAM** **(6)** soalan sebelum anda memulakan peperiksaan ini.

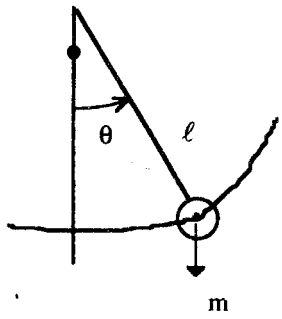
Jawab **LIMA** **(5)** soalan.

Agihan markah bagi soalan diberikan di sut sebelah kanan soalan berkenaan.

Jawab semua soalan di dalam Bahasa Malaysia.

1. Pertimbangkan pendulum mudah seperti di dalam Rajah 1 di bawah, di mana ℓ ialah panjang tangkai dan m ialah jisim bebola. Biarkan θ sebagai sudut tangkai dengan paksi tegak menerusi titik kisar.

Consider the simple pendulum shown in Figure 1 below, where ℓ denotes the length of the rod and m denotes the mass of the bob. Let θ denotes the angle subtended by the rod and the vertical axis through the pivot point.



Rajah 1 - Pendulum
(Figure 1 - Pendulum)

Persamaan pergerakan sepanjang tangent di beri oleh
The tangential equation of motion is given by

$$m\ell\ddot{\theta} = -mg\sin\theta - k\ell\dot{\theta}$$

apabila k ialah kofisien geseran
where k is the coefficient of friction.

(a) Dapatkan model ruang keadaan sistem menggunakan pembolehubah keadaan $x_1 = \theta$ dan $x_2 = \dot{\theta}$.

Obtain the state-space model of the system by using state variables $x_1 = \theta$ and $x_2 = \dot{\theta}$.

(10%)

...3/-

(b) Tentukan titik-titik tunggal (kedudukan keseimbangan) bagi sistem.

Determine the singularity points (equilibrium positions) of the system.

(10%)

(c) Dapatkan model ruang keadaan sistem yang baru apabila tork luaran T dikenakan.

Obtain the modified state space model of the system when an external torque T is applied.

(10%)

(d) Lakarkan potret fasa bagi persamaan pendulum menggunakan kaedah eka-cerun dengan nilai-nilai $g = \ell$ dan $k = 0.5m$.

Sketch the phase potrait of the pendulum equation using the isocline method using values of $g = \ell$ and $k = 0.5m$.

(40%)

(e) Tentukan model lelurus sepadan bagi sistem pada harmonik pertama dan kedua titik keseimbangan dan dapatkan nilai-nilai eigen bagi model lelurus titik-titik tersebut. Bincangkan kestabilan sistem pada titik-titik tersebut.

Determine the equivalent linearized model for the system at the first harmonic and second harmonic equilibrium points as well as the corresponding eigenvalues of the linear model at those points. Discuss the stability of the system at those points.

(30%)

2. Pertimbangkan sistem tak lelurus seperti di Rajah 2.1.

Consider a non-linear control system as shown in Figure 2.1.

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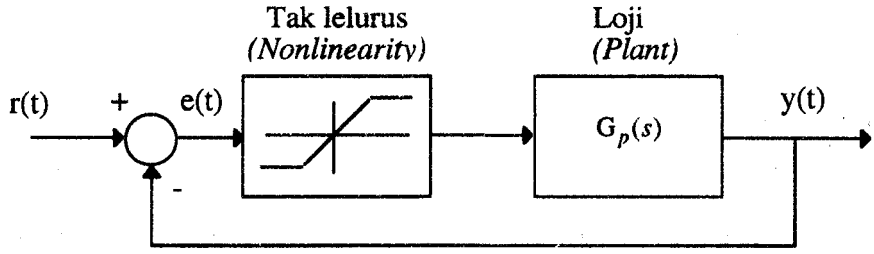
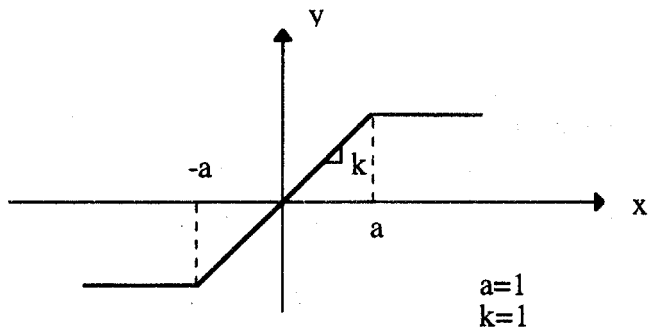


Rajah 2.1 - Kawalan Tak lelurus

(Figure 2.1 - Nonlinearity Control)

(a) Tentukan fungsi perihalan bagi elemen taklelurus tepuan seperti ditunjukkan di dalam Rajah 2.2. Lakarkan fungsi *N(A)* melawan *A*.

Determine the describing function for a "saturation" non-linear-control element as shown in Figure 2.2. Plot the function N(A) against A.



Rajah 2.2 - Tepuan

(Figure 2.2 - Saturation)

(25%)

(b) Pertimbangkan model loji yang diberi oleh rangkap pindah lelurus

Consider a plant model given by a linear transfer function

...5/-

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

Tentukan sambutan frekuensi bagi sistem dan lakarkan carta Nyquist.

Determine the frequency response of the system, and plot the Nyquist chart.

(25%)

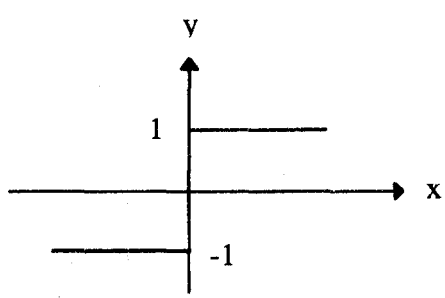
(c) Bincangkan kemungkinan sistem keseluruhan (loji dan elemen tak lelurus) mempunyai ayunan kekal.

Discuss the possibility that the overall system (nonlinearity plus linear plant) will have a sustained oscillation.

(25%)

(d) Pertimbangkan isyarat signum di bawah seperti ditunjukkan dalam Rajah 2.3.

Consider a signum nonlinearity as shown in Figure 2.3.



Rajah 2.3 - Fungsi Signum

(Figure 2.3 - Signum Function)

Buktikan bahawa fungsi perihalannya diberi oleh

Prove that the describing function is given by

$$N(A) = \frac{4}{\pi A}$$

...6/-

Bincangkan kemungkinan sistem keseluruhan (signum dan loji) akan mempunyai ayunan kekal.

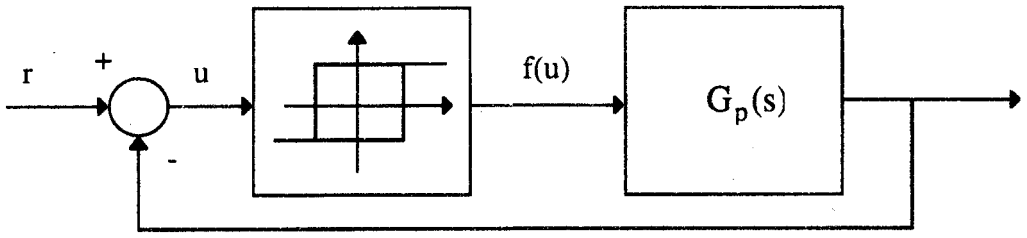
Discuss the possibility that the overall system (signum nonlinearity plus linear plant) will have a sustained oscillation.

(25%)

3. Sistem kawalan tak lelurus mengguna peralatan "relay" sebagai pengawal di tunjukkan dalam Rajah 3.1. Elemen "relay" tersebut mempunyai ciri seperti dalam Rajah 3.2. Rangkap pindah bagi logi tersebut adalah diberi oleh

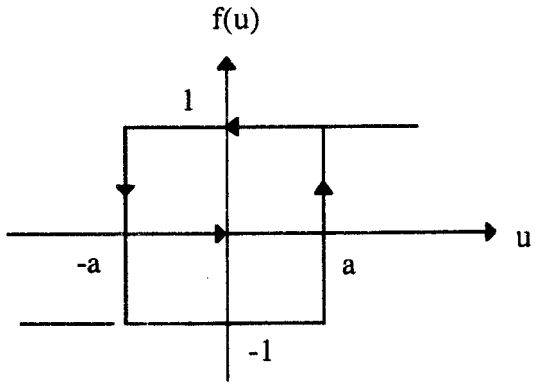
A nonlinear control system using a relay device as controller is shown in Figure 3.1. The nonlinear relay element has a characteristic as shown in Figure 3.2. The plant transfer function is given by

$$G_p(s) = \frac{K}{s(s+1)}$$



Rajah 3.1

(Figure 3.1)



Rajah 3.2
(Figure 3.2)

(a) Tentukan syarat kitaran had dengan terlebih dahulu membuktikan fungsi perihalan ialah

Obtain the limit cycle condition by first proving that the describing function is given as

$$N = \frac{4}{\pi a} = \left\{ \sqrt{1 - \frac{a^2}{u^2}} - j\frac{a}{u} \right\}$$

(30%)

(b) Dapatkan perwakilan ruang keadaan sistem. Gunakan kaedah jelmaan titik untuk menentukan kehadiran kitaran had.

Set up the state space respresentation of the system. Use the point transformation method to determine the existence of limit cycle.

(40%)

(c) Gunakan kaedah Tyspkin untuk membuktikan kitaran had yang sama diperolehi.

Use the Tyspkin method to show that the same limit cycle is obtained.

(30%)

...8/-

4. Pertimbangkan sistem tak lelurus diberi oleh

Consider the nonlinear system given by

$$\dot{x}_1 = -3x_1 + x_2$$
$$\dot{x}_2 = x_1 - x_2 - x_2^3$$

(a) Tentukan model lelurus pada asalan dan tentukan kestabilan sistem tak lelurus yang asal.

Determine the linearized model at the origin and determine the stability of the original nonlinear system.

(30%)

(b) Tentukan fungsi tenaga Lyapunov yang sesuai dan buktikan kestabilan sistem.

Determine an appropriate Lyapunov energy function that will prove the stability of the system.

(40%)

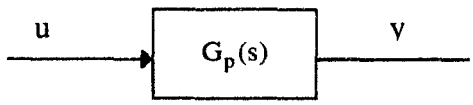
(c) Menggunakan kaedah Krasowski, tentukan kestabilan sistem.

Using the generalized Krasowski method, determine the stability of the system.

(30%)

5. Pertimbangkan loji dengan masukan u dan keluaran y yang diperihalkan oleh model lelurus dengan rangkap pindah seperti dalam Rajah 5, dengan pemalar b dan c.

Consider a plant with input u and output y, which is described by a linearized model having a transfer function as shown in Figure 5, with some constants b and c.



$$G_p(s) = \frac{b}{s(s+c)}$$

Rajah 5
(Figure 5)

(a) Jika *b* dan *c* diketahui, rekabentuk pengawal berkadaran dan kamiran supaya sistem gelung tertutup mempunyai rangkap pindah diberi oleh

If b and c are known, design a proportional and derivative controller so that the system will have a closed loop transfer function given by

$$G_{CL}(s) = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

(25%)

(b) Bina model rujukan menggunakan rangkap pindah gelung tertutup di atas dalam sistem kawalan model rujukan dan tentukan isyarat ralatnya.

Construct a reference model using the closed loop transfer function above to be used in a model reference adaptive control and determine the error signal.

(25%)

(c) Rekabentuk kaedah penerapan bagi untung supaya wujud fungsi Lyapunov dengan ciri-ciri yang menjamin kestabilan sistem dan penumpuan ke sifar bagi perbezaan untung dan isyarat ralat keluaran.

Design the adaption rule for the gains in such a way that there exists a Lyapunov function whose properties will guarantee the stability of the system and also the convergence to zero of the gain deviations as well as the output error signal.

(50%)

6. Pertimbangkan sistem yang diberi di bawah

Consider the system given below

$$\dot{x}_1 = -x_1$$
$$\dot{x}_2 = -x_2 + x_1 x_2^2$$

(a) Gunakan kaedah gradien berubah untuk mendapatkan kadar perubahan tenaga yang separa pasti negatif, $-\dot{V}(t)$

Use the variable gradient method to obtain a negative semidefinite rate of change of the energy function $-\dot{V}(t)$.

(40%)

(b) Menggunakan hasil-hasil dari bahagian (a) tentukan fungsi Lyapunov.

Using results from part (a), determine the Lyapunov function.

(30%)

(c) Pilih $a_{11} = 1; a_{12} = x_2^2; a_{21} = 3x_2^2$ dan $a_{22} = 3$. Buktikan bahawa fungsi yang dihasilkan ialah fungsi Lyapunov.

Select $a_{11} = 1; a_{12} = x_2^2; a_{21} = 3x_2^2$ *and* $a_{22} = 3$. *Prove that the resulting function is also a Lyapunov function.*

(30%)

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