GX654

OLLSCOIL NA hÉIREANN
The National University of Ireland

National University of Ireland, Galway.

Trinity Examinations, 1989/99.

B.E. Degree (Mechanical & Electronic) Examination

COMPUTER CONTROL OF ELECTRO-MECHANICAL SYSTEMS

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Attempt *Five* Questions
Time allowed: 3 Hours
Tables for Laplace, Z and W Transforms are provided.

1(a) Figure 1 depicts a separately excited armature controlled dc motor being used as a position control system. If the armature inductance is negligibly small, determine a block diagram representation for the system. Reference voltage and shaft angular position are input and output, respectively. **(6)**

Derive also the open-loop transfer function relating output to error signal. **(6)**

(b) The above system is to be used in a digital control system. The differential amplifier is used to produce the error signal between the reference input and measured output, as before. An ideal sampler and zero-order-hold filter are included before the power amplifier.

Write down the z-domain transfer function for the system. It is not necessary to derive any formulae used. **(8)**

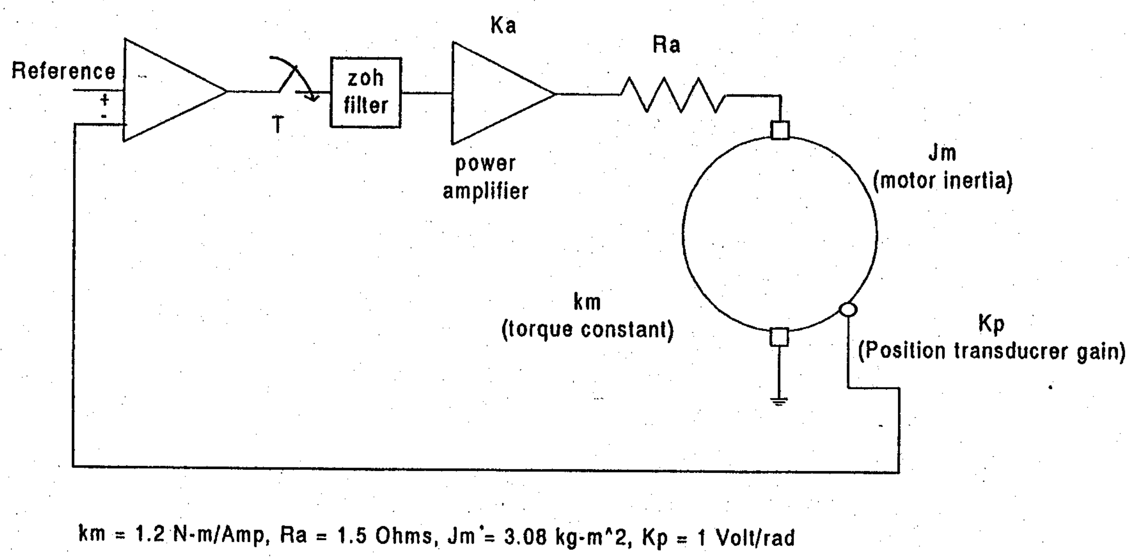


Figure 1

2(a) State the sampling theorem and briefly discuss its practical implications. Include in your answer a brief explanation of what is meant by aliasing. **(8)**

(b) A particular analogue system has the frequency response given in Table 2.

What is the minimum sampling frequency (in Hertz) which the Sampling Theorem would indicate ? **(6)**

Sketch the frequency response for the sampled system under the following two conditions :

(i) Sampling frequency is sufficiently high

(ii) Sampling frequency is too low

(6)

Frequency (Hertz)	**Amplitude**
0	1.00
.2	1.05
.4	1.10
.6	1.20
.8	1.40
1.0	1.75
1.2	1.30
1.4	1.0
1.6	0.50
1.8	0.20
>2.0	~0

Table 2

3(a) Figure 3 depicts a control system used to control the thickness of sheet metal in a hot rolling mill. If load reaction is neglected, derive a block diagram representation for the system. State any assumptions made. **(10)**

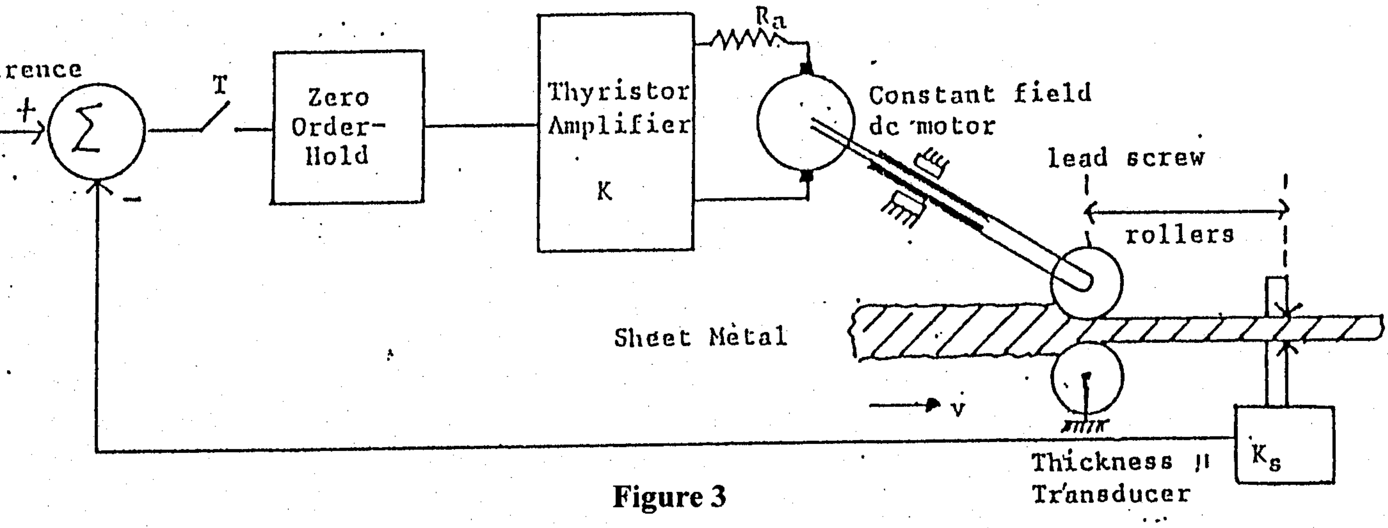


Figure 3

(b) Describe what is meant by transport lag in a control system and cite some typical applications where transport lag would be present. What is the Laplace transfer function for transport lag ? Sketch its frequency response (both Magnitude and Phase). Explaining why, state what effect would you expect transport lag to have on the stability of a control system ? Under what sampling conditions would the derivation of the z-domain transfer function for a process including a transport lag be particularly easy ?

(10)

4(a) Stating any assumptions made, determine the block diagram and transfer functions for the so-called state variable filter shown in Figure 4. Separate transfer functions are required for each of the three outputs.

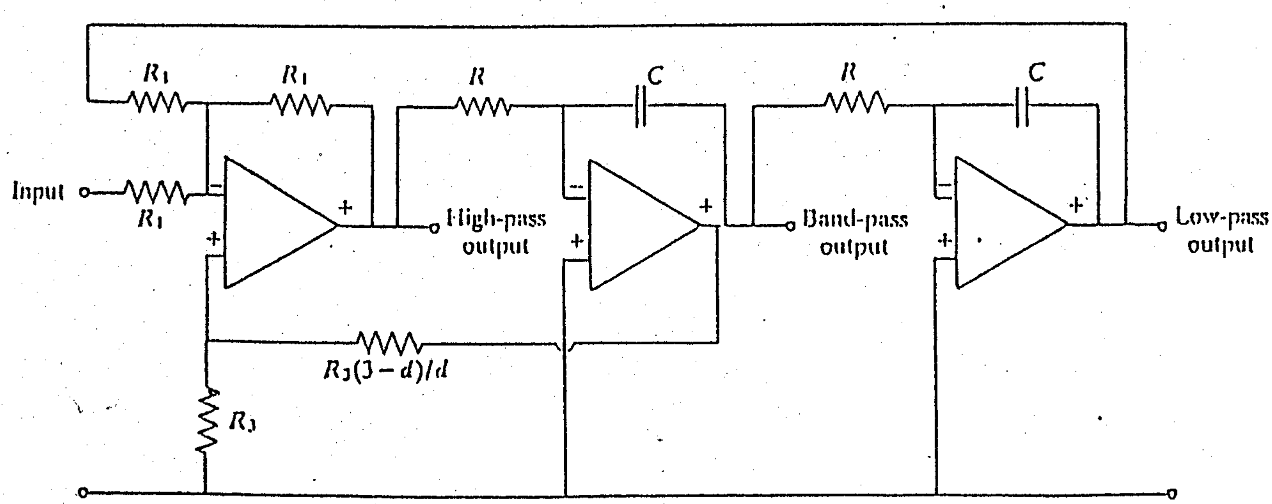


Figure 4

(b) Write down the state-space matrix representation for the above system and explain how the time response could be derived using the state transition matrix approach.

5(a) The electrical and mechanical circuits shown in Figure 5(a) and 5(b) are used as compensator elements in analogue control systems.

Derive the transfer functions and sketch the frequency response. **(10)**

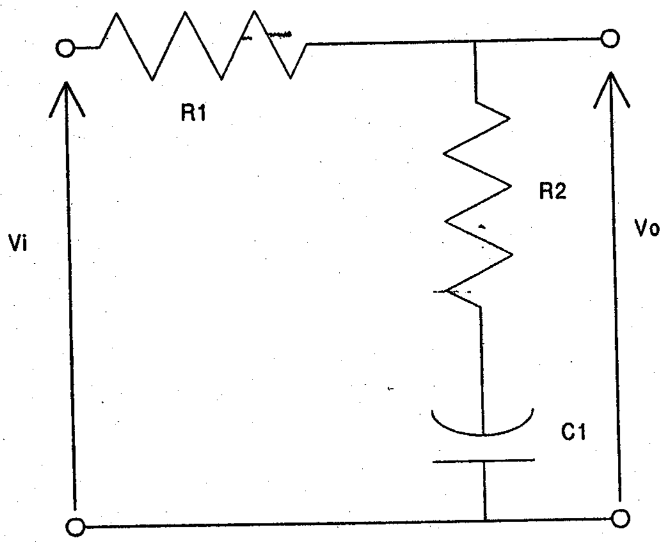


Figure 5(a)

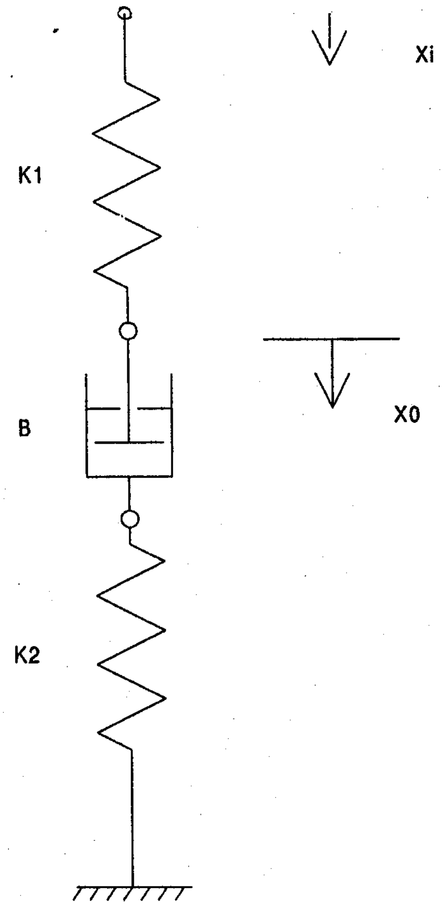
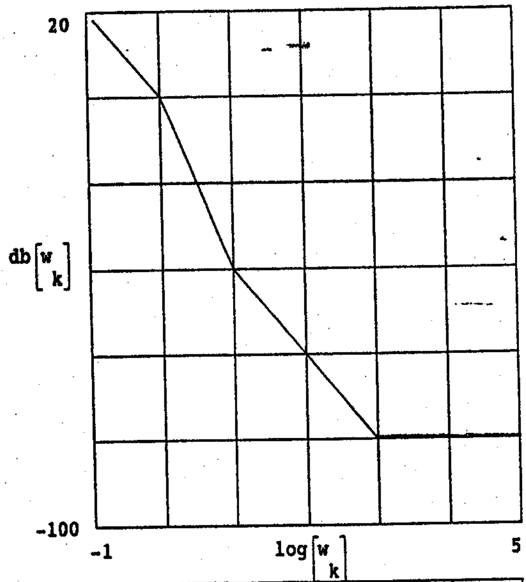


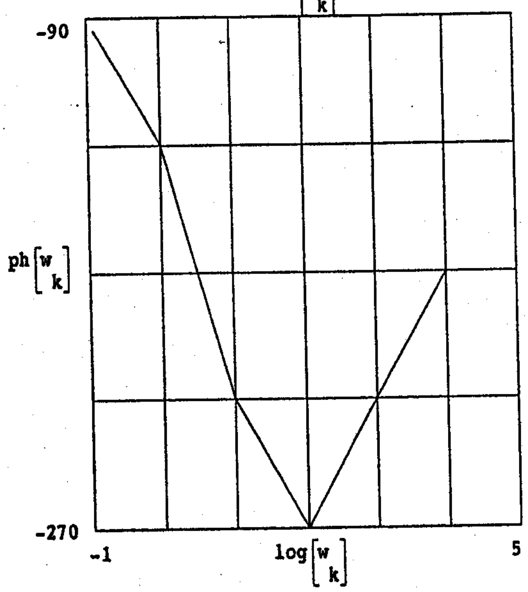
Figure 5(b)

(b) Describe the general rationale for the use of digital equivalents and list the main approaches used in deriving such equivalents. Using any appropriate approach, determine an equivalent for the compensator described in Figure 5(a). State any constraints on the sampling period. **(10)**

6(a) Briefly explain what is meant by W-transform method for analysing digital control systems. What are its main advantages in deriving the frequency response as compared with direct substitution of $e^{j\omega t}$ in the z-domain transfer function ? Is the method exact or is there some inherent approximation ? Over what frequency, v, in the W-domain should the response be determined and what is the corresponding range in ω ? **(10)**

(b) The Bode asymptotic W-domain frequency response of a control system is shown in Figure 6 (on following page). Write down the W-domain transfer function. Can you infer what the sampling period used was ? **(10)**





w k	db[w k]	ph[w k]
0.126	18	-94.5
0.158	16	-99
0.2	14	-103.5
0.251	12	-108
0.316	10	-112.5
0.398	8	-117
0.501	6	-121.5
0.631	4	-126
0.794	2	-130.5
1	0	-135
1.259	-4	-144
1.585	-8	-153
1.995	-12	-162
2.512	-16	-171
3.162	-20	-180
3.981	-24	-189
5.012	-28	-198
6.31	-32	-207
7.943	-36	-216
10	-40	-225
12.589	-42	-229.5
15.849	-44	-234
19.953	-46	-238.5
25.119	-48	-243
31.623	-50	-247.5
39.811	-52	-252
50.119	-54	-256.5
63.096	-56	-261
79.433	-58	-265.5
100	-60	-270
125.893	-62	-265.5
158.489	-64	-261
199.526	-66	-256.5
251.189	-68	-252
316.228	-70	-247.5
398.107	-72	-243
501.187	-74	-238.5
630.957	-76	-234
794.328	-78	-229.5
1000	-80	-225
1258.925	-80	-220.5
1584.893	-80	-216
1995.262	-80	-211.5
2511.886	-80	-207
3162.278	-80	-202.5
3981.072	-80	-198
5011.872	-80	-193.5
6309.573	-80	-189
7943.282	-80	-184.5
10000	-80	-180

Figure 6

7(a) Explain the difference between getting the inverse of a z-domain transform and simulating the response of the system given its z-domain transfer function.
Briefly describe an algorithm for :

(i) getting the inverse Z-transform, and

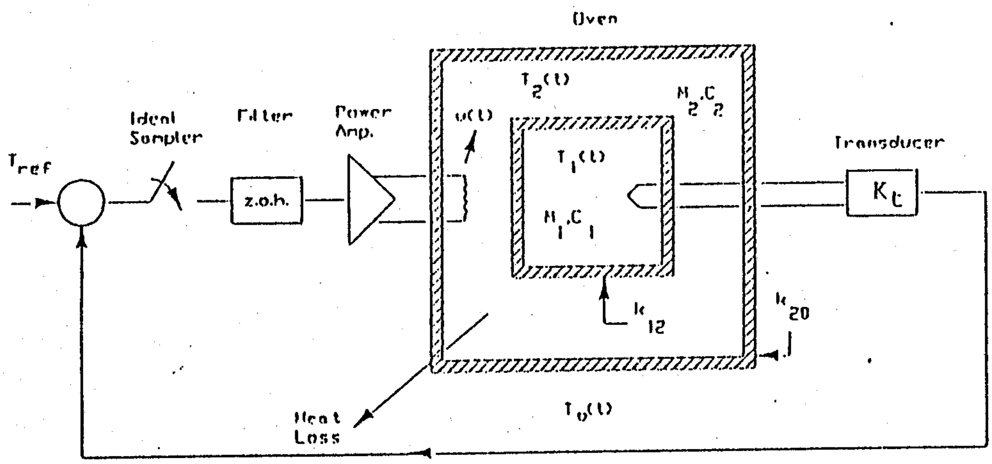
(ii) simulating or realising a discrete transfer function. **(12)**

(b) A digitally controlled industrial process has a Z-domain transfer function:

$$\frac{0.95\,(z + 0.7480)}{(z - 0.4327)\,(z - 0.9634)}$$

The sampling period is 0.25 seconds. Determine the steady state response for the open loop response to a harmonic input of frequency of 1 Hertz. **(8)**

8. Figure 8 shows an industrial oven that is being digitally controlled.



$M_1C_1 = 0.5$ kJ/K
$M_2C_2 = 2.0$ kJ/K
$K_t = 1.0$ v/k
$K_{20} = 0.5$ kW/K
$K_{12} = 1.0$ kW/K

Figure 8

(a) Stating any assumptions being used, determine the block diagram representation for the system. Inputs are reference voltage (analogue for reference temperature) and environment temperature (disturbance input). **(8)**

(b) Explicitly stating any necessary assumption, derive the z-domain transfer functions relating output temperature to reference and disturbance inputs, respectively. **(6)**

(c) If the z-domain transfer function is:

$$\frac{0.024\,K\,(z + 0.7480)}{(z - 0.4327)\,(z - 0.9634)}$$

Sketch the root locus and determine the maximum gain for stability. **(6)**