THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
ECX4242/ECD2215 – CONTROL SYSTEMS
FINAL EXAMINATION– 2005/2006

CLOSED BOOK

DATE: 17th April 2006

0930 hrs – 1230 hrs

Answer any 5 questions. All questions carry equal marks.

(1) (a) Draw the complete block diagram of a feedback control system and briefly explain each component. *(04 marks)*

(b) Name three reasons for using feedback control systems and at least one reason for not using them. *(04 marks)*

(c) The home bathtub is a system that keeps the water level constant. A constant flow from the tap yields a constant water level, because the flow rate through the drain decreases as the water level decreases. After equilibrium has been reached, the level can be controlled by controlling the input flow rate. A low input flow rate yields a lower level, while a higher input flow rate yields a higher level.

(i) Sketch a control system that uses this principle to control precisely the fluid level in the tank. You have to show the intake and drain valves, the tank, any sensors and transducers, and the interconnection of all components. *(06 marks)*

(ii) Draw a functional block diagram of the system identifying the input and the output signals of each block. *(06 marks)*

(2) The circuit shown in **Fig. 1** is called a differentiating circuit.

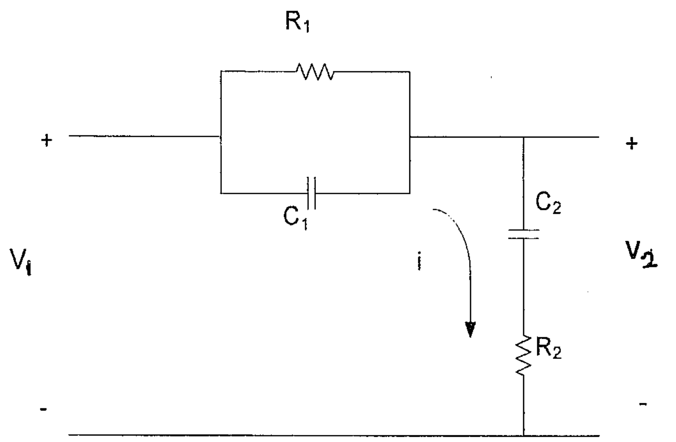

Fig. 1

(i) Find the transfer function $T(s) = {V_2(s)}/{V_1(s)}$ by deriving the necessary differential equations. *(06 marks)*

(ii) Determine $T(s)$ when $R_1 = 100K\Omega$, $R_2 = 200K\Omega$, $C_1 = 5\mu F$ and $C_2 = 1\mu F$. *(02 marks)*

(iii) Determine the poles and zeros of T(s). *(03 marks)*

(iv) Obtain an expression for the unit step response of the system. *(05 marks)*

(v) Predict the final value of $v_2(t)$ and the steady state error for the unit step input. *(04 marks)*

(3)

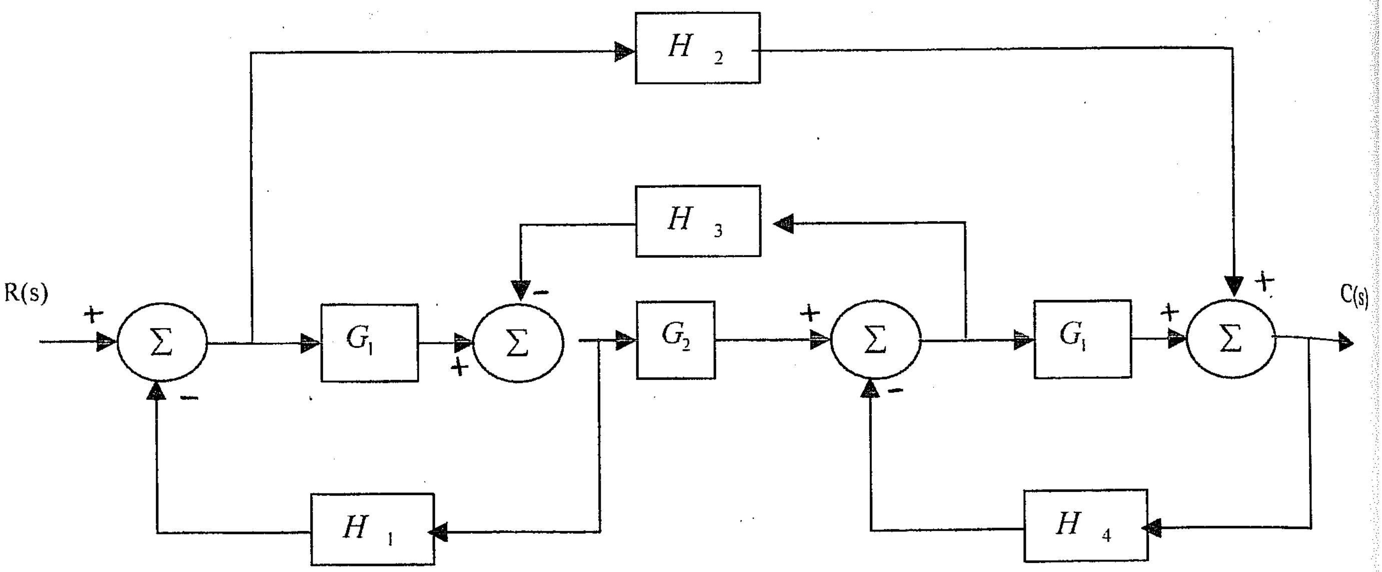

Fig. 2

(a) Develop the signal flow graph for the above block diagram in **Fig. 2**. *(08 marks)*

(b) Use the signal flow graph found in part (a) along with Mason's rule to find the closed loop transfer function . *(12 marks)*

(4) (a) What is Root Locus? *(03 marks)*

(b) Sketch the Root Locus for a unity negative feedback control system where forward path transfer function is,

$$G(s) = \frac{K}{(s+1)(s^2+4s+5)}$$

You should clearly show the necessary steps used to draw the Root Locus. *(10 marks)*

(c) Hence find,

(i) the range of K to keep the system stable. *(03 marks)*

(ii) the value of K for which the closed loop transfer function will have a pole on the real axis at s =–3. *(04 marks)*

(5) (a) Write the advantages of Bode Plot. *(02 marks)*

(b) A unity negative feedback control system has a forward path transfer function,

$G(s) = \dfrac{4s}{(s+2)(s^2+4s+25)}$. Construct **the <u>asymptotic</u> Bode Plot.** Clearly show all the steps taken. *(14 marks)*

(c) Mark the phase margin and gain margin and hence comment on the stability of the system. *(04 marks)*

(6) The open loop transfer function of a unity negative feedback control system is,

$$G(s) = \frac{K}{(s+4)(s+5)}$$

(a) Sketch the Nyquist plot. *(10 marks)*

(b) Apply the Nyquist criterion to determine the range of K for stability. *(05 marks)*

(c) Compare your results by applying Routh Hurwitz criterion. *(05 marks)*

(7) (a) Define (i) Rise time
(ii) Peak overshoot
(iii) Settling time
(iv) Steady state error for a standard second order system

You must use necessary graphs to illustrate your answer. *(08 marks)*

(b) Briefly explain how the above parameters affect the stability of a control system. *(04 marks)*

(c) Briefly explain how PID control can be used to adjust the above parameters for a system to be stable. *(03 marks)*

(d) A standard second order system has a damping ratio of 0.5 and a natural frequency of 40rad/s. Calculate the damped resonant frequency, the rise time, the peak value and the 2% settling time for a unit step input. *(05 marks)*

(8) The table below gives the open loop frequency response in the range $0.2 < \omega < 1.6$ for a unity negative feedback system with the open loop transfer function, $G(s) = \frac{2}{s(s+1)(s+2)}$.

ω	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Magnitude	4.9	2.3	1.4	0.91	0.63	0.46	0.34	0.26	0.2	0.16
Magnitude (dB)	13.8	7.1	2.7	-0.9	-4	-6.8	-9.4	-11.8	-14	-16
Phase angle (degrees)	-107	-123	-138	-150	-162	-171	-179	-187	-193	-198

Table 1

(a) Using the data in **Table 1** mark the $G(j\omega)$ locus on the Nichol's chart. *(05 marks)*

(b) Using results from the Nichol's plot create a frequency response for the closed loop system and demonstrate that it resembles the plot for a typical standard second order system. *(05 marks)*

(c) Using the above plots find,
(i) Maximum magnitude
(ii) The resonant frequency of the system
(iii) Bandwidth (BW) of the system
(iv) The phase margin
(v) The gain margin *(10 marks)*