ENGINEERING TRIPOS PART IB

Thursday 5 June 1997 2 to 4

Paper 6

INFORMATION ENGINEERING

Answer not more than **four** *questions.*

Answer at least **one** *question from each section.*

The **approximate** *number of marks allocated to each part of a question is indicated in the right margin.*

Answers to questions in each section should be tied together and handed in separately.

(TURN OVER

SECTION A

1 For the feedback system of Fig. 1:

(a) calculate the closed-loop transfer function relating $\bar{y}(s)$ to $\bar{w}(s)$; [6]

(b) indicate, on an Argand diagram, the position of the open-loop and the closed-loop poles, and comment on the open-loop and closed-loop stability of the feedback system; [6]

(c) calculate and sketch the response of $y(t)$ to a unit step on $w(t)$, paying particular attention to the initial slope and final value of the response. [8]

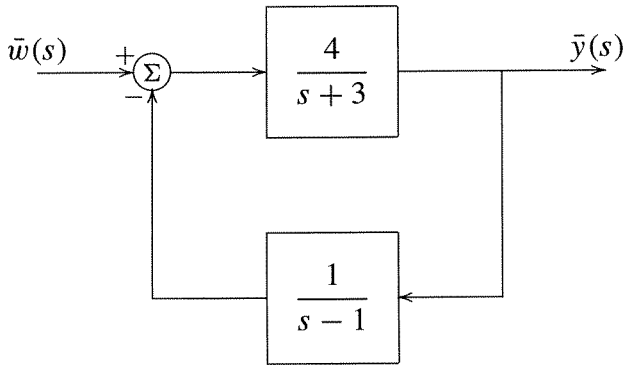

Fig. 1

2 The linearized differential equation relating deviations in car speed v to changes in engine power p and the inclination of the road θ is given by

$$1000\dot{v} + 50v + 10^4\theta = 30p.$$

A "proportional + integral" speed controller of the form

$$p(t) = -\left(k_p v(t) + k_i \int_0^t v(\tau)\, d\tau\right)$$

is implemented.

Draw a block diagram of the closed-loop system, showing clearly where the disturbance $\bar{\theta}(s)$ enters the loop, and verify that the closed-loop transfer function relating $\bar{v}(s)$ to $\bar{\theta}(s)$ is given by [8]

$$\bar{v}(s) = \frac{-10^4 s}{s(1000s + 50) + 30(k_p s + k_i)}\bar{\theta}(s).$$

Choose k_p and k_i such that the closed-loop poles lie at $s = -0.1 \pm 0.1j$, and sketch the speed variation $v(t)$ in response to the disturbance

$$\theta(t) = \begin{cases} 0 & t < 0 \\ 0.05 & t \geq 0 \end{cases}.$$

What is the maximum speed deviation in this case? [12]

3 A system with transfer function $G(s)$ is to be controlled by a proportional controller with gain k_p, as in Fig. 2.

(a) For an arbitrary value of k_p show, with the aid of a sketch, how the gain and phase margins of the feedback system may be found from the Nyquist diagram of $G(s)$ alone. [8]

(b) The Nyquist diagram of the system

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

is given as Fig. 3. Determine the range of values of k_p for which the phase margin of the feedback system is greater than $45°$.

If it is also required that

$$\left| \frac{k_p G(j\omega)}{1 + k_p G(j\omega)} \right| \geq 1$$

whenever $\omega < 1.5$, then what additional constraint does this place on k_p ? [12]

Note: An extra copy of Fig. 3 is provided on a separate sheet. This should be handed in if your solution involves graphical construction on it.

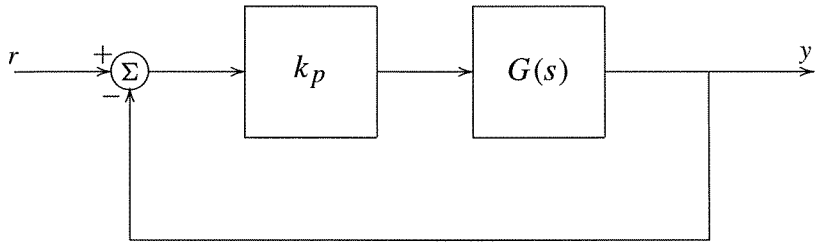

Fig. 2

(cont.

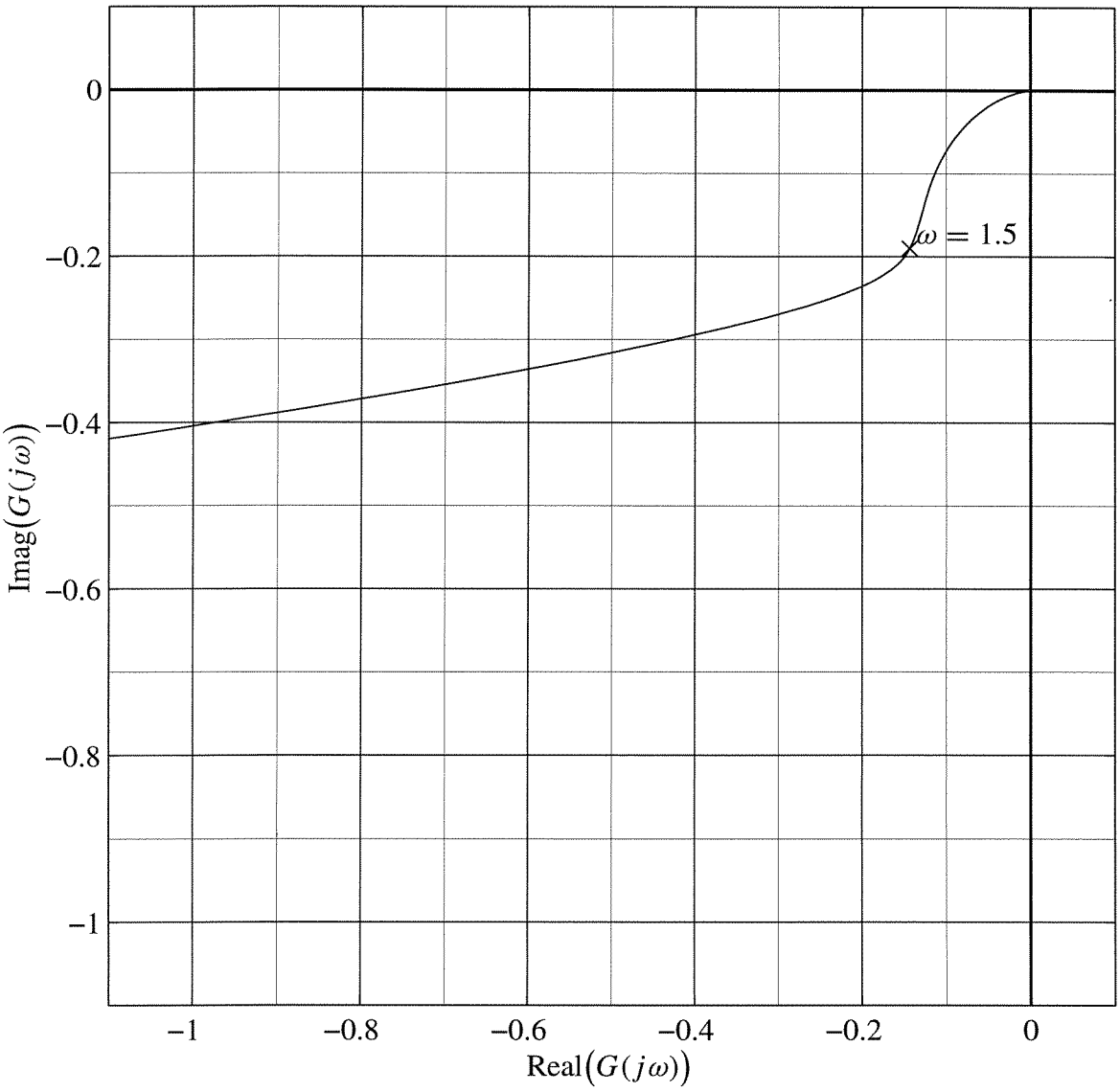

Fig. 3

(TURN OVER

4 A system G with transfer function

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

is to be controlled using a compensator $K(s)$ as in Fig. 4.

(a) Initially a constant gain compensator

$$K(s) = k_p$$

is to be used.

Sketch the Bode diagram of $G(s)$, and verify that the feedback system is stable provided that $k_p < 2$.

Determine the gain margin and approximate phase margin of the feedback system if $k_p = 0.4$. [10]

(b) A phase lead compensator

$$K(s) = \frac{2(3s+1)}{s+3}$$

is now used instead. Determine the new phase margin.

In what way is the performance of the feedback system improved by using this new compensator? [10]

Note: Semi-log paper for sketching Bode diagrams is available.

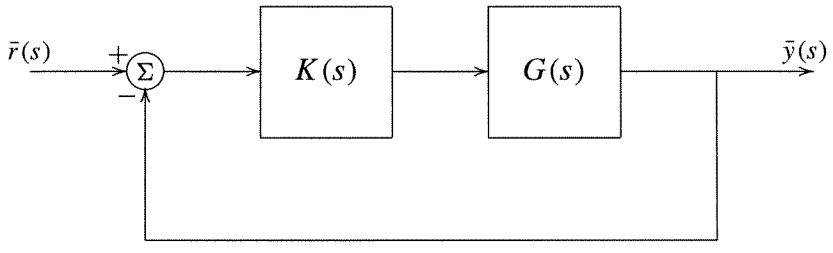

Fig. 4

SECTION B

5 (a) Explain why 44 kHz is a suitable sampling rate for use in compact disc (CD) players, and why the number of sampling levels needs to be approximately 64K. Calculate the basic bit rate required for a CD player to produce a stereo pair of audio signals. [8]

(b) Video sequences for a computer game are to be stored on a similar type of compact disc. The sequences are digitized with a 256-colour palette at a resolution of 400×300 pixels, and require a frame rate of 10 frames per second. Determine the speed-up factor required for the CD player if it is to be able to play real-time video in this format instead of just audio. Assume that no video compression is employed. [8]

(c) Estimate the required bandwidth for the optical reader and associated circuitry in the case of the video CD player of part (b). [4]

6 (a) Carson's rule for frequency modulation states that:

$$\text{Bandwidth} = 2(f_D + f_M)$$

Explain the meaning of this rule, and the significance of the symbols involved, both for modulation by a single sinusoid and for modulation by more complex signals. [8]

(b) An analogue mobile phone system has been allocated a radio band from 850 to 900 MHz. Estimate the maximum number of simultaneous speech transmissions that could be accommodated in a given local geographical area if frequency modulation with a peak frequency deviation of 5 kHz is employed and a gap of 2 kHz is required between adjacent speech channels. Why is the 2 kHz gap needed in practice? [8]

(c) Briefly discuss alternative forms of modulation which might allow more users to be accommodated in this band, giving advantages and disadvantages of each method. [4]

END OF PAPER