Data Provided: 1 × Bode paper (Q3)

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2009-2010 (2 hours)

Introduction to Avionics 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1.

a. Give a brief description of task automation avionic systems. **(6)**

b. Give a brief description of an air data system. **(6)**

c. The true airspeed of a certain aircraft flying in the troposphere region is V_T = 560 km/h, the static air temperature is T_S = -34.5 ^{o}C and the static pressure is P_s=37.65 kPa:

i. Calculate the Mach number M .
ii. Calculate the altitude of the aircraft.
iii. Calculate the air density ρ .
iv. Calculate the calibrated airspeed V_c . **(8)**

The following may be assumed:

Gas constant for unit mass of dry air : R_a *=287.0529 J/^{o}K .kg*

Impact pressure = $P_0\left(\left(1+\frac{(\gamma-1)(V_c/A_0)^2}{2}\right)^{\gamma/(\gamma-1)}-1\right)$ *and*

$$\frac{P_T}{P_s}=\left(1+\frac{(\gamma-1)}{2}M^2\right)^{\frac{\gamma}{(\gamma-1)}}$$

$\gamma=\frac{\text{specific heat of air at constant pressure}}{\text{specific heat of air at constant volume}}$ *and* P_T *is the total pressure.*

At sea level: the static pressure P_0 *=101.325 kPa, the absolute static air temperature is* T_0 *=288.15 ^{o}K, the air density* ρ_0 *=1.225 kg/m^3 and the speed of sound* $A_0=340.3$ *m/s.*

2.

a. Sketch a figure illustrating the main components of a MIL STD 1553B data bus system and summarise its main features. **(5)**

b. Summarise the main advantages of a Fly-By-Wire flight control system, and sketch a figure illustrating its essential features. **(6)**

c. The typical failure rate of a Fly-By-Wire channel is $\lambda = 3.35 \times 10^{-4}$ /hour. Therefore, in order to meet stricter reliability requirements, an n Fly-By-Wire channel redundancy configuration is usually employed. Calculate the probability of failure of the redundancy configuration during a 10-hour flight:

i. When $n = 3$ and a majority voting scheme is adopted.
ii. When $n = 4$ and a non-adaptive majority voting scheme is adopted.
iii. When $n = 4$ and an adaptive majority voting scheme is adopted. **(9)**

The following may be assumed:

Reliability function for *m*-out-of-*n* system (active):

$$R(t) = \sum_{k=m}^{n} \frac{n!}{k!(n-k)!} \left[e^{-\lambda k t}\right]\left[1 - e^{-\lambda t}\right]^{n-k}$$

Reliability function for *m*-out-of-*n* system (passive): $R(t) = e^{-\lambda m t} \sum_{k=m}^{n} \frac{(m\lambda t)^{k-m}}{(k-m)!}$

3.

a. Describe what is meant by the term 'System Type' <u>and</u> the effect it has on the steady-state error of the resulting closed-loop system for step, ramp and parabolic inputs. **(6)**

b. Figure 3.1 shows a dynamic model of a remote camera positioning system. The system is controlled using only a proportional compensator, K_p.

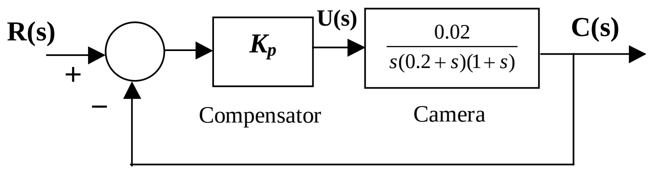

Figure 3.1: Remote camera positioning system

For the system shown in Figure 3.1, determine the value of K_p to provide an open-loop Phase Margin of 45°, by following the steps below:

(i) Using asymptotes as an aid, construct the Bode plot of the open-loop plant transfer function $\dfrac{0.02}{s(0.2+s)(1+s)}$. **(6)**

(ii) From the Bode plot estimate the value of K_p which is required to provide a Phase Margin of 45°. Estimate the resulting closed-loop bandwidth of the system with this value of K_p. **(4)**

(iii) If a gain of $K_p = 100$ were selected, what Gain Margin and Phase Margin would the system possess? Will the system be stable or unstable? **(4)**

{ENSURE YOUR BODE DIAGRAM IS ATTACHED TO YOUR ANSWER BOOKLET}

4.

A spacecraft has the short-period dynamic behaviour characterised by the state-variable description in the equation below, where $\delta_f(t)$ is the perturbed control fin deflection, $\tau(t)$ is the tilt angle, and $r(t)$ is the roll rate.

$$\begin{bmatrix} \dot{\tau} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} -0.32 & 1 \\ -3.70 & -0.48 \end{bmatrix} \begin{bmatrix} \tau \\ r \end{bmatrix} + \begin{bmatrix} -0.03 \\ -2.80 \end{bmatrix} \delta_f$$

Or: $\dot{x} = Ax + B\,u$

where: $x = \begin{bmatrix} \dot{\tau} \\ \dot{r} \end{bmatrix}$, $A = \begin{bmatrix} -0.32 & 1 \\ -3.70 & -0.48 \end{bmatrix}$, $B = \begin{bmatrix} -0.03 \\ -2.80 \end{bmatrix}$, and $u = \delta_f$

a. Calculate the Eigenvalues of the open-loop system in above equation, and thereby suggest why the spacecraft may need the addition of a control system to provide adequate flying qualities. **(5)**

b. Calculate the Controllability Matrix, C, and thereby show that the spacecraft is fully controllable. **(3)**

c. Using Ackermann's method, design a state-feedback controller $u = -k\,x$, such that the resulting closed loop system has Eigenvalues at:

$$\lambda_1 \; -1.95 + j2.49$$
$$\lambda_2 \; -1.95 - j2.49$$

That is, calculate an appropriate state-feedback gain matrix, k **(7)**

d. Sketch the block diagram structure of the resulting closed loop system — include appropriate integrators, states and the controller gain terms. **(5)**

KA / KM