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The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2012-2013 (2 hours)

EEE217 Avionic Systems 2

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. Summarise the main advantages of a Fly-By-Wire flight control system, and sketch a figure illustrating its essential features. **(5)**

b. 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 °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. **(9)**

c. When the aircraft is flying at a higher altitude, the static pressure is P_s=22.63 kPa, the calibrated airspeed is V_c= 520 km/h and the true airspeed is V_T= 900 km/h, calculate the static air temperature T_s. **(6)**

Gas constant for unit mass of dry air : R_a=287.0529 J/°K .kg

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

$\gamma = \dfrac{\text{specific heat of air at constant pressure}}{\text{specific heat of air at constant volume}}$, P_T is the total pressure and A_0 is the speed of sound at sea level.

At sea level: the static pressure P_0=101.325 kPa, the absolute static air temperature is T_0=288.15 °K, and the air density ρ_0=1.225 kg/m^3.

2. **a.** Describe briefly a typical RST (Reliability Shake-Down Testing) cycle. **(5)**

b. The dominant failure mechanism of a certain integrated circuit (IC) is purple plague with an effective activation energy $\frac{E_a}{n}$=1.0eV. When operating at 85°C, the mean time to failure (*MTTF*) was found to be 24000 hours. Assuming that the failure process behaves as a chemical process with a reaction rate $Q(T) = Q_o\, e^{(-E_a/kT)}$ and that the drift in parameters is proportional to $t^n\, Q(T)$, where k, T and t are the Boltzman's constant, the absolute temperature and time respectively:

i. Show that the $MTTF = t_o\, e^{(E_a/nkT)}$.

ii. Calculate the *MTTF* of the IC when operated at 30°C.

(6)

c. A large aircraft is equipped with four engine-driven AC generators each of which are rated at 90kW. It is assumed that the four generators have a failure rate $\lambda = 1.0 \times 10^{-4}$ / hour and they share the electrical power generation. For a 10-hour flight:

i. Calculate the probability of losing the capability of generating 270kW of electrical power from the engines driven generators.

ii. Calculate the probability of losing the capability of generating 180kW of electrical power from the engines driven generators.

iii. Calculate the mean time to failure MTTF of the engines driven electrical generation system to produce 270kW.

iv. Calculate the mean time to failure MTTF of the engines driven electrical generation system to produce 180kW.

(9)

<u>*The following may be assumed:*</u>

Reliability function for <u>*m-out-of-n system (active):*</u> $R(t) = \sum_{k=m}^{n} \frac{n!}{k!(n-k)!} \left[e^{-\lambda k t}\right]\left[1 - e^{-\lambda t}\right]^{n-k}$

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

In general the mean time to failure is given by: $MTTF = \int_0^{\infty} R(t)\,dt$

3. **a.** An electromechanical actuator consisting of a servo motor, a nut and a screw with a pitch length $\lambda = 10$ mm, figure 3.1, is driving a load with a mass m =35000 kg. The motor has a back-emf constant $k = 0.15$ V.s/rad, an armature resistance R=18 mΩ, and a rotor inertia $J_m = 1.5\times10^{-3}$ kg.m^2. Furthermore, the gear ratio between the nut and the motor is 10:1. Assume the mechanical transmission to be lossless.

i. Calculate the load inertia J_r referred to the shaft of the servo motor.

ii. Calculate the required motor torque T_m in order to achieve a load acceleration $\gamma_m = 1.0$ m/s^2.

iii. Calculate the armature current I and the copper loss P_c of the motor.

iv. When only the copper loss is considered, show that the efficiency of the motor is given by:

$$\eta = \frac{1}{1 + \frac{R}{k^2}\frac{T_m}{\Omega_m}}$$

where Ω_m is the speed of the motor.

(11)

b. The actuator is controlled so as to have a maximum linear displacement x_m in a time T, following a sinusoidal velocity profile.

i. Show that the linear displacement of the actuator is given by:

$$x(t) = \frac{V_m T}{\pi}\left(1 - \cos\left(\frac{\pi}{T}t\right)\right)$$

ii. Calculate the maximum speed V_m of the actuator for a displacement x_m=5mm and for T=1s.

iii. Calculate the sum of the forces, F_{tot}, applied to the mass m, when V_m= 1 m/s and t =0 s.

(9)

The following may be assumed: For a sinusoidal velocity profile: $v(t) = V_m \sin\left(\frac{\pi}{T}t\right)$,

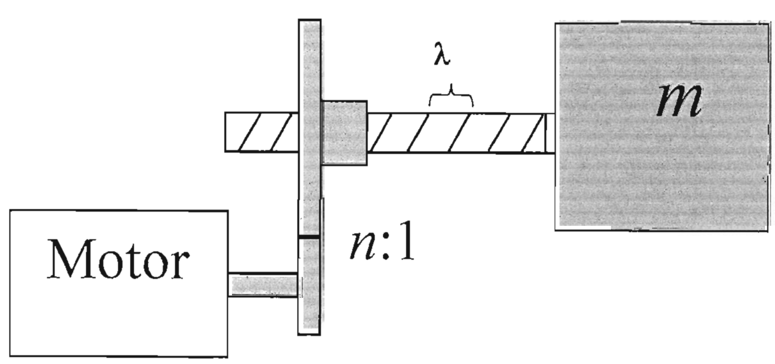

Figure 3.1 Schematic of electromechanical actuator.

4. **a.** Sketch a figure illustrating the main components of a STANAG 3910 data bus system and summarise its main features. **(4)**

b. A potentiometer used to measure angular position θ of an actuator, can measure a maximum angle of 160^o, has a resistance R_p=10kΩ and its output is converted to digital format using an n-bit analogue to digital converter (ADC).

i. Calculate the maximum error, when the potentiometer is loaded by a recorder with an input resistance $R_m = 90\,k\Omega$.
ii. Calculate the minimum number of bits n in order to achieve a resolution of at least 0.1 degree.
iii. What should be the minimum sampling frequency f_s of the ADC if the actuator follows a position profile with a period T=1s:
$\theta(t) = \theta_0 \sin\left(\frac{2\pi}{T}t\right) + \frac{\theta_0}{2}\sin\left(\frac{6\pi}{T}t\right) + \frac{\theta_0}{3}\sin\left(\frac{10\pi}{T}t\right)$. **(6)**

c. The output of the potentiometer is now converted to digital format using a 4-bit ($b_3\,b_2\,b_1\,b_0$) analogue-to-digital converter (ADC), which drives a logic circuit, controlling red, green and yellow LEDs, figure 4.1. The logic circuit was designed in order to ensure that:

- the red LED is ON when $\theta < 20^\circ$ or $\theta \geq 140^\circ$.
- the yellow LED is ON when $20^\circ \leq \theta < 70^\circ$ or $90^\circ \leq \theta < 140^\circ$.
- the green LED is ON when $70^\circ \leq \theta < 90^\circ$.

i. Construct the truth table of the logic circuit.
ii. Obtain the Sum-Of-Products (SOP) expressions of the logic functions Green and Red.
iii. Show that the logic function Red is independent of the least significant bit b_0 of the ADC.
iv. Obtain the Product-Of-Sums (POS) expression of the logic function Yellow.

(10)

The following may be assumed:

For a potentiometer the $Error\,(\%) = \dfrac{a(1-a)\dfrac{R_p}{R_m}}{1 + a(1-a)\dfrac{R_p}{R_m}} \times 100$; where $a = \theta/\theta_{\max}$

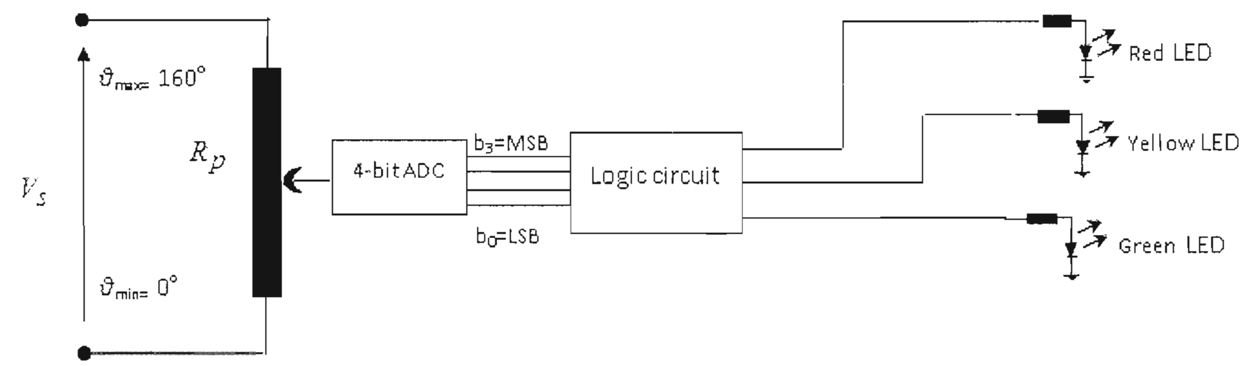

Figure 4.1 Logic circuit and LEDs.

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