Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007-2008 (2 hours)

Systems Engineering 1

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.** Draw and explain the tree/branch type hierarchy structure for a generic system. **(4)**

b. Draw a diagram for the 3 Phase Design Cycle. **(2)**

c. Draw and describe the 7 Phase Design Cycle. Show how the 7 Phase Design Cycle is related to the 3 Phase Design Cycle. **(4)**

d. You are project managing a time of engineers who are developing a microwave oven.

i) Identify the major components of a typical microwave oven

ii) Draw a block diagram of the microwave oven partitioned from the chief design engineer's point of view.

iii) Describe how you would choose to represent the microwave oven if you were writing a user guide. **(8)**

e. Explain what is meant by the process of abstraction and describe how it is used in a systems engineering context. **(2)**

2. You have been given the job of designing an uninterruptable power supply (UPS) system for use in safety critical applications. The role of the UPS is to provide a 240V RMS sinusoidal voltage in the event of a power cut (usually referred to as a blackout) suitable for delivering a maximum current of 13A to its load. The UPS uses a 12V lead acid battery for buffer storage. As the lead engineer working on this project you are responsible for designing:

- A battery charging circuit to manage the battery to ensure that it is always charged
- A power electronic circuit called an inverter which converts the 12V lead acid battery voltage to a 240V RMS sinusoidal waveform which emulates the AC mains waveform
- A control subsystem which controls the switchover from the standard mains input to the inverter emulated waveform during blackout conditions. The control subsystem also performs safety monitoring functions such as warning the user of poor battery conditions.

a. Draw a block diagram of the UPS system that includes elements from the above description and their interconnections. **(6)**

b. In addition to specifying the nominal terminal voltage, battery manufacturers' also specify a battery's capacity in Amphere-hours (Ah). A 12V lead acid battery will have a terminal voltage of 14.4V when fully charged. When the same battery can no longer provide any useful energy its terminal voltage will have fallen to 10.8V. In order to simplify the battery selection process you have made the assumption that the inversion process (i.e. the conversion of the 12V DC battery voltage to 240VAC RMS sinusoidal) has an efficiency of 90%.

What is the minimum Amphere-hour capacity battery is required if the UPS is to operate correctly for at least 2 hours before the battery exceeds its useful operating range?

Hint, use the principles of conservation of energy. **(4)**

c. The battery charger that you have been asked to develop as part of the overall UPS system is to provide a fast charging feature which rapidly charges the battery if the terminal voltage is less than 13V and a trickle charging facility for gradually replenishing the battery when above this voltage. The charging system also has a fault condition which alerts the user if the terminal voltage falls below 10.8V. Since this fault condition most likely indicates a battery failure, the UPS system is disabled and the battery charger must be reset to clear this condition. When the inverter is in operation the charger is disabled.

Draw a state-machine diagram for the battery charger system showing the operating states and transitions between them. **(7)**

d. During the testing phase of the project you realise that you have forgotten to include a warning system that alerts the user during blackout situations. You also decide to include a shutdown facility which disables the inverter to ensure that the lead acid battery voltage is not discharged beyond 10.8V during blackout conditions.

Write a piece of pseudo-code that would implement blackout warning and battery monitoring functions. **(3)**

3. **a.** Explain why modelling is vital to the systems engineering process. **(3)**

b. What is a transfer function and why are they useful for the modelling systems? **(3)**

c. Explain what is meant by the term 'linear system' in the context of system modelling.

Why do engineers prefer to deal with linear systems?

Provide a comparison between a linear system and a non-linear system in example in your answer. **(4)**

You have designed and built a linear actuator and you would like to derive a mathematical that can be used to predict its behaviour. You have assumed that the actuator can be represented by the circuit in Figure 3.1.

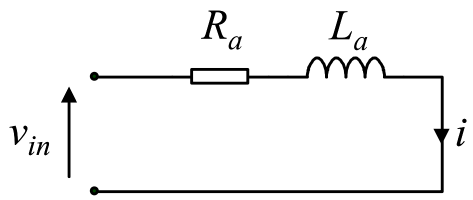

Figure 3.1

d. Derive an expression for the current i that flows in the circuit. Rearrange this expression to form a transfer function. **(3)**

e. The force F developed by the actuator can be determined from the expression,

$F=\alpha i$, where α represents the relationship between force and current.

Draw a transfer function diagram showing the relationship between the input voltage v_{in} and the force F developed by the actuator. **(4)**

f. During the testing phase you measure the force-current characteristic of the actuator and find it exhibits a non-linear response. To simplify the design of a control system you decide to approximate the force-current characteristic with a gain term α_{linear} by linearising the response about its nominal operating point. Using the data presented in Table 3.1, determine an appropriate value for α_{linear}. Justify any assumptions that you have made to obtain this approximation.

Current (A)	Force (N)	Current (A)	Force (N)
-5	-1.9565	1	1.4793
-4	-1.9404	2	1.7755
-3	-1.9079	3	1.9132
-2	-1.7865	4	1.9401
-1	-1.5020	5	1.9582
0	0.053		

Table 3.1 **(3)**

4. **a.** If the time-to-failure of a system can be described by an exponential density function, then the reliability of the system at time, t, is given by:

$$R = e^{-t/MTBF} = e^{-\lambda t}$$

where MTBF is the mean-time-between-failures and λ is the failure rate, where

$$\lambda = \frac{\text{number of failures}}{\text{total operating hours}}$$

Consider a system that has to operate for T hours and during that time a certain number of failures are expected to occur. There are two types of failures:

i) non-serious failures (represented by symbol $F_{n\text{-}s}$) which are easily repaired and incur a down time of $D_{n\text{-}s}$ hours.

ii) serious failures (represented by the symbol F_s) incur a system down-time D_s for repair.

Write an expression for the failure rate λ which accounts for the effects of both the serious and non-serious failures on the system.

Determine the failure rate for the system when operated for 10,000 hour period during which it has 6 non-serious failures each of which require 1 hour to repair, and 2 serious failures each of which requires 20 hours to repair.

What is the reliability of the system for 250 hours of operation? **(6)**

b. Draw the typical bath-tub curve representing failure rate as a function of time.

Briefly describe the major parts of the curve and the relationship of each part to a system's life.

Highlight where on the curve the reliability equation $R = e^{-\lambda t}$ can be used to make reliability predictions. **(4)**

c. Write down an expression for the Arrhenius equation and define each of the terms used in the equation.

With reference to the Arrhenius equation, explain how component de-rating can be employed to improve system reliability. **(3)**

d. Determine the reliability of the overall system connected between α and β shown in Figure 4 if it is expected to operate for 2000 hours.

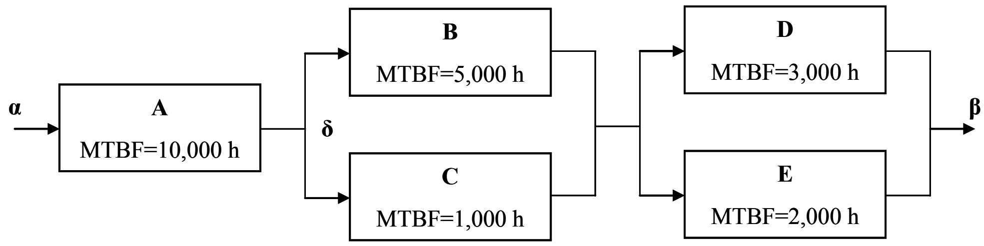

Figure 4 **(4)**

e. Assuming it is possible to connect a further element F between points δ and β on Figure 4, what value of MTBF would element F required to achieve a reliability of 0.5 for 2000 hours of operation? **(3)**

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