Data Provided: None

The University of Sheffield

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2004-2005 (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. Verification, validation and testing are fundamental to the systems engineering process.

a. Explain the system testing process, and, where relevant, draw parallels with the system hierarchy. Use diagrams to aid your explanation. **(5)**

b. Explain what a test plan is, and why it is required. Highlight the main features of a test plan. **(3)**

c. You are designing a 2^{nd}–order low-pass analogue filter to be used in a very powerful subwoofer audio system. Explain what characteristics of the filter you would test to ensure your design meets the specification. Also, explain how you would undertake such tests. **(3)**

d. Digital systems are very complicated and special measures must be taken to ensure a system can be tested. What is a fault model and how is it used? **(4)**

e. Explain what a boundary scan test is, and how it is used. **(3)**

f. Explain the difference between verification and validation. **(2)**

2. You work for a small consultancy firm specialising in microcontroller-based solutions for the leisure industry. A client asks you to develop a microcontroller-based drive system for controlling the speed of a DC electric motor for an electric powered speedboat.

They issue you with the following requirements:

1.) Speed of the motor to be controlled by a variable resistor operated from 5V. Require a resolution of at least 0.25%.

2.) Motor speed to be measured by an optical sensor.

3.) System should display demanded speed and current speed using 7-segment display.

4.) System should have high-efficiency to maximise battery life.

From the specification:

a. Identify the inputs and outputs of this system and explain their interfacing requirements. **(4)**

b. Draw a block diagram of this system from input to output. Also illustrate the signal types (analogue/digital) interfacing each sub-system on the diagram. **(5)**

c. Identify the main functions that the microcontroller needs to perform and draw a simple flowchart including these functions. **(4)**

d. Assuming an analogue-to-digital converter (ADC) is being employed to measure the speed demand from the variable resistor, what is the minimum resolution required.

Using this answer, what value would 2.2V from the demand variable resistor be assigned in hexadecimal. **(2)**

e. Assuming the micro-controller has both Pulse Width Modulation outputs and analogue voltage output capabilities (e.g. built-in PWM unit and DAC), discuss which method you would employ to drive the electric motor to achieve the specification requirements. You must justify your choice. **(2)**

f. During acceptance testing the client notices that the power electronics sub-system is damaged when the boat is operated at full power for long periods of time. After discussions with the client you decide to add a sensor to measure the motor current (to an accuracy of 1%) and then modify the control software to limit the available power to the motor under these conditions. The current sensor provides an analogue voltage signal, but unfortunately, the microcontroller has only one analogue voltage input port.

Suggest a modification to the system that would facilitate the current sensor measurement. Use diagrams in your explanation. You can assume that microcontroller has a spare digital output pin and digital input pin. **(3)**

3. **a.** Explain what mean-time-between-failures (MTBF) is, and how it is mathematically defined. **(3)**

b. Consider the 5-component system shown below.

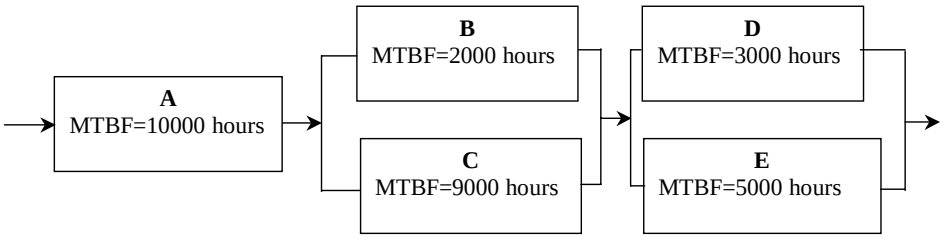

Figure 3.1

Each component has the associated MTBF given in the figure.

Determine the reliability, *R*, of the whole system in Fig. 3.1 if it is expected to operate for 1500 hours. **(5)**

c. What is the reliability of the system in Fig. 3.1 if the MTBF of A is reduced to 8000 hours and an additional system, called F, is placed in parallel with system E with a MTBF of 4000 hours? **(3)**

d. Consider a system that has to operate for T_h hours, and, during that time, F_h failures are expected to occur. On each failure, the down-time of the system is D_h hours. Write an expression for the failure rate λ in terms of T_h, F_h and D_h. For the specific example of a system that operates for 250 hours, and during this time has 5 failures, calculate the failure rate (λ) and MTBF if the downtime after each failure is 2 hours.

What is the reliability of the system for 25 hours of operation? **(5)**

e. Describe 2 methods for increasing the reliability of a system. **(4)**

4. Most systems follow a typical life cycle (whether they are biological, mechanical, electrical or software). Systems engineers use the key stages identified in the life cycle to develop fundamental systems engineering concepts.

a. At the highest hierarchical level, explain the main features of a generic system. **(2)**

b. Draw and explain the elements of a tree system hierarchy for a generic system. **(4)**

c. Taking a computer system (PC, monitor, mouse, keyboard and printer) as an example, draw a hierarchical diagram. In particular describe the PC in detail in your diagram. **(4)**

d. Describe what a reconvergent hierarchy is. Provide an example. Use diagrams in your explanation. **(3)**

e. With the aid of diagrams explain the Waterfall Process Model. **(4)**

f. With the aid of an example explain what is meant by abstraction and why it is used. **(3)**

MPF/CMB **END OF PAPER**