Data Provided: None

The University of Sheffield

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2005-2006 (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. Most systems follow a typical life cycle (whether they are biological, mechanical, electrical or software). Systems engineers use the key stages identified in the system's life cycle to develop fundamental systems engineering concepts.

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

b. Using a 1st-order RC low-pass filter as an example, show how abstraction can be applied to develop a generic low-pass filter building block (i.e. normalisation) regardless of its implementation. **(4)**

c. Partitioning is an important concept in systems engineering. Often a design team will use several representations for a given system to ease development.

i) Identify the major components of a typical washing machine.

ii) Draw a block diagram representing the system partitioning from the chief design engineers point of view.

iii) Describe how you would partition the system if you were writing a user guide for the washing machine. **(8)**

d. With the aid of diagrams and drawing parallels with the systems life cycle, explain the Vee Process Model. **(4)**

2. You work for a small consultancy firm specialising in microcontroller-based solutions for the manufacturing industry. A client asks you to develop a small data acquisition system to measure the weight of a chemical mixing vessel and transmit the reading over a serial communications link to a master controller. Your client produces cleansing agents for the bio-tech industry which are made by discharging the chemicals into a mixing vessel. For each chemical the controller requires an accurate measure of weight.

They issue you with the following requirements:

- Weight transducer provides a uni-polar analogue voltage of maximum 20mV.
- Weight transducer sensitivity is 0.1mV/kg.
- Sensor output is non-linear and requires processing before it can be used.
- Unit should be based around a microcontroller.
- Unit must have a 7-segment L.E.D. based numerical display driven by a microcontroller.
- The system must transmit the measured weight using serial communications.

From the specification:

a. Draw a block diagram of this system from input to output. Also illustrate the signal types (analogue/digital) to and from each sub-system on the diagram. **(6)**

b. Identify the main functions that the microcontroller needs to perform and draw a simple flowchart including these functions. **(6)**

c. The microcontroller has a built-in analogue-to-digital converter that has an internal reference voltage of 2.5V. What value of amplification is required to obtain ADC full scale?

Draw a simple circuit that could achieve this. **(3)**

d. The built-in ADC has a resolution of 14-bits. What weight does an ADC output of $2FFF_{hex}$ represent? **(1)**

e. It has now been several weeks since the data acquisition system has been installed on site and the client has noticed that the unit sometimes produces erratic readings that never appear to settle. When the weight transducer voltage is measured using an oscilloscope you noticed that the DC output voltage had an addition high-frequency component associated with it. What extra features could be included in the system to overcome these problems? **(4)**

3. Reliability is an important issue in systems design.

a. Draw a bath tub curve reliability characteristic and describe its relationship to a product's life. **(4)**

b. Explain what is meant by mean-time-between-failures (MTBF), and how it is defined mathematically. State what part of the bath tub curve MTBF is valid for. **(3)**

c. Consider the 5-component system shown below.

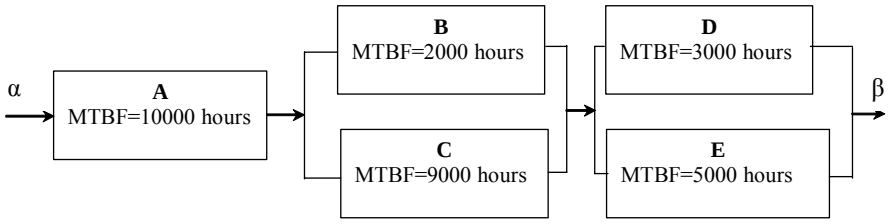

Figure 3.1

Each component has an associated MTBF as given in Fig. 3.1.

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

d. What is the reliability of the system in Fig. 3.1 if the MTBF of A is increased to 12000 hours, an additional sub-system, called F, is placed in parallel with system E with a MTBF of 6000 hours, and a further sub-system, called G, with a MTBF of 8000 hours is connected between the points α and β? **(4)**

e. With reference to the Arrhenius equation, explain how component de-rating can be employed to improve system reliability. **(4)**

4. 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 in your explanation. **(6)**

b. With reference to digital systems, explain what combinatorial explosion is and what implications it has for digital system design. **(3)**

c. Digital systems are very complicated and special measures must be taken to ensure a system can be tested.

i) Explain what is meant by a 'stuck at logic level' fault model.

ii) Explain how test patterns for digital systems are generated using stuck at logic level fault models. **(6)**

d. You are part of a design team developing a disco lighting system that flashes strobe lights to the beat of the music. Your system consists of a band-pass filter used to select specific frequencies and a comparator that is used to trigger a strobe light module when a certain threshold voltage has been exceeded. Assuming the lighting system is driven from the line output of the mixing desk, what tests would you perform on these circuits to ensure they are working correctly? **(5)**

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