Second Semester Examination
2017/2018 Academic Session

May/June 2018

EES502 – REAL-TIME OPERATING SYSTEM

Duration : 2 hours

Please check that this examination paper consists of SEVEN (7) pages printed material before you begin the examination.

Instructions: This question paper consists **FOUR (4)** questions. Answer any THREE (3) questions. All questions carry the same marks.

1. On February 25, 1991, a Patriot missile defense system operating at Dhahran, Saudi Arabia, during Operation Desert Storm failed to track and intercept an incoming Scud (missile). This Scud subsequently hit an Army barracks, killing 28 Americans. The Patriot battery at Dhahran failed to track and intercept the Scud missile because of a software problem in the system's weapons control computer. This problem led to an inaccurate tracking calculation that became worse the longer the system operated. At the time of the incident, the battery had been operating continuously for over 100 hours. By then, the inaccuracy was serious enough to cause the system to look in the wrong place for the incoming Scud.

   Please answer all following questions based on the scenario above.

   (a) What transpired in the scenario above?

   (20 marks)

   (b) How could this problem have been fixed in the design phase of the RT system (prior to patching the firmware)?

   (20 marks)

   (c) Why do you think the problem occurred in the first place? Align your answers with characteristics of RT Systems.

   (20 marks)

   (d) Which type of RTOS should the Patriot Missile System be deployed on? Explain briefly.

   (20 marks)

(e) Which scheduling algorithm should be used for the type of RTOS specified in Question 1 (iv) above? Briefly explain why?

(20 marks)

2. Answer the following questions. (100 marks)

(a) What are the two main classes of memory technologies that are available? Briefly elaborate.

(20 marks)

(b) Explain the concept of memory hierarchy along with how they are often used in computers.

(10 marks)

(c) What are the main differences between **Stack** and **Heap**.

(20 marks)

(d) What are the differences between a first-fit placement and best-fit placement?

(15 marks)

(e) Suppose that we have free segments with sizes: 3, 8, 15, 10, and 9 (as depicted in Figure 2.1) on our FreeRTOS heap. Place and depict (separately) how the heap looks (with corresponding remaining free space) after a program with size 8kB is fit in the free segment using **first-fit** and **best-fit**.

(20 marks)

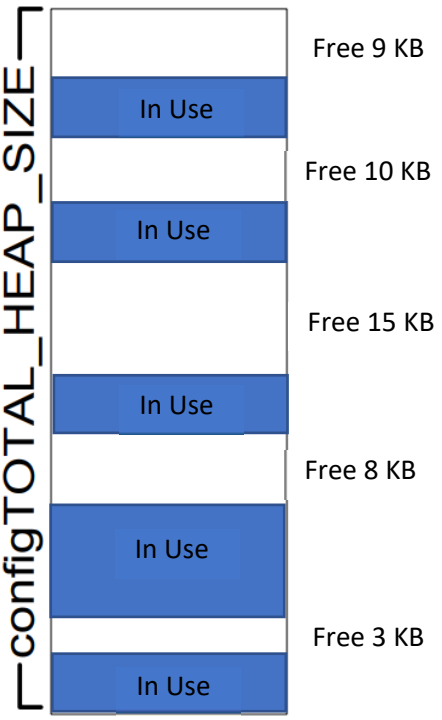

Figure 2.1

(f) Briefly explain what/how are the following used for?

(i)Semaphore (5 marks)

(ii) Mutex (5 marks)

(iii) Pulse Width Modulation (5 marks)

3. (a) At a top level (see Figure 3.1), a computer for real-time operating system consists of processor, memory and I/O components with one or more modules of each type. These components are interconnected in some fashion to achieve the main function of the computer, which is to execute programs. Thus, **describe FOUR main structural elements** as in Figure 3.1.

(20 Marks)

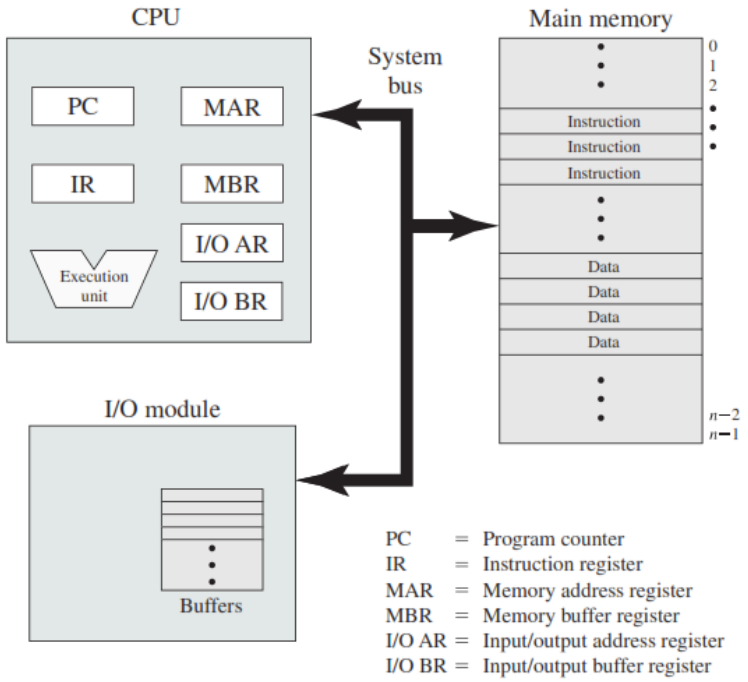

Figure 3.1: Computer Components Top Level View.

(b) Describe **three** important characteristics in Real Time system

(15 marks)

(c) What is an embedded system? Differentiate between embedded system and real-time system.

(10 marks)

(d) What are the **two** categories of RTOS? Briefly explain each of them with relevant examples

(20 marks)

(e) As an 'Embedded Design Engineer at XYZ Company', you are required to propose a general method for system development using real-time components which support early analysis of the timing behaviour as well as the synchronization and communication between components. The method enables high-level analysis on the architectural design level. This analysis is important to avoid costly re-design late in the development due to the detection in the integration test phase that the system as developed does not fulfil the timing requirements. Draw the '**Design Component Based-Real Time System**' and **explain each component** which relate to your proposed design.

(35 marks)

4. (a) What is a FreeRTOS co-routine?

(10 marks)

(b) In FreeRTOS, describe the function of 'Mutex'?

(10 marks)

(c) Identify the differences between binary and counting semaphores?

(10 marks)

(d) A computer has a cache main memory, and a disk is used for virtual memory. If a referenced word is in the cache, 20ns are required to access it. If it is in main memory but not in the cache, 60ns are needed to load it into the cache, and then the reference is started again. If the word is not in the main memory, 12ms are required to fetch the word from disk, followed by 60ns to copy it to the cache, and then the reference is started again. The cache hit ratio is 0.9 and the main memory hit ratio 0.6.

What is the average time in ns required to access a referenced word on this system?

(30 marks)

(e) Figure 4.1 demonstrates how tasks are scheduled when a fixed priority pre-emptive scheduling with time slicing algorithm is used. Figure 4.1 shows the sequence in which tasks are selected to enter the Running state when all the tasks in an application have a unique priority.

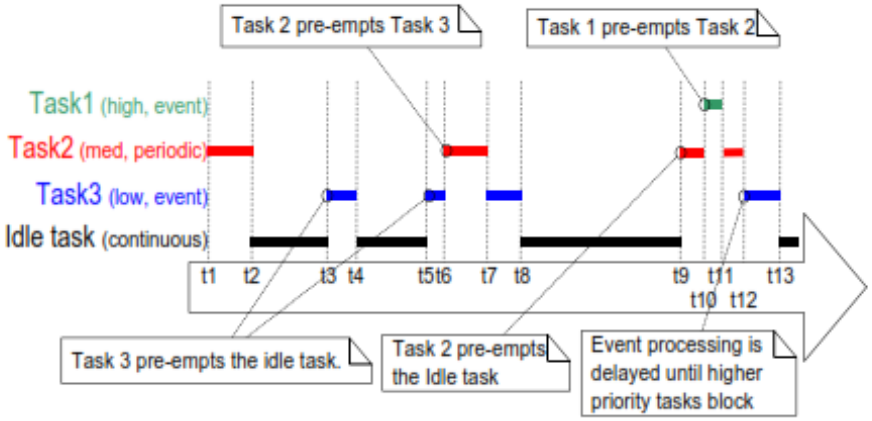

Figure 4.1: Execution pattern highlighting task prioritization and pre-emption in a hypothetical application in which each task has been assigned a unique priority.

By referring FreeRTOS concept, describe the activities of the Idle task, Task 3, Task 2 and Task 1.

(40 marks)

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