UNIVERSITY OF EDINBURGH

FACULTY OF SCIENCE AND ENGINEERING

COMPUTER SCIENCE FOUR

EMBEDDED SOFTWARE

Friday 19 April 2002

09:30 to 11:00

Examiners:

Prof. K. Turner (External)

Prof. C. Stirling (Chairman)

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

1. (a) Discuss the significant differences between embedded and conventional software. *[10 marks]*

   (b) Define the following terms:

      i. Periodic Process $A(c, p, d)$
      ii. Major Schedule
      iii. Major Cycle Time (MCT)
      iv. Minor Cycle Time (mct)

   [7 marks]

   (c) Consider a system with three periodic processes, with the following characteristics:

      - $A(2, 9, 9)$
      - $B(4, 12, 12)$
      - $C(1, 15, 15)$

      i. What is the MCT for a cyclic executive schedule for this system?
      ii. Assuming that blocks are identical to the complete code for all the three processes, derive the possible values for mct. Justify your answers.

   [8 marks]

2. (a) Discuss the following approaches to software fault tolerance:

    i. N-version Programming
    ii. Recovery Blocks

    Compare and contrast the two approaches. [*10 marks*]

(b) Temporal logic is particularly applicable for specifying concurrent and reactive systems. Define the following unary temporal operators:

    i. $\Box P$
    ii. $\Diamond P$

    Assume that the following condition holds for the predicate `InAirspace(A)`:

    $$\texttt{InAirSpace(A)} = \begin{cases} \texttt{True}, & \text{if aircraft } \texttt{A} \text{ is in a given airspace} \\ \texttt{False}, & \text{otherwise} \end{cases}$$

    Using temporal operators and quantifiers, state the requirement that *all* planes inside a given airspace should leave at some future time. [*7 marks*]

(c) The following RTL (Real-time Logic) expression defines an alarm clock property in which the following events are used:

    - `AC`: alarm
    - $\uparrow$`BELL`: start-bell-ringing
    - $\downarrow$`BELL`: stop-bell-ringing
    - `STOP`: stop button

    Assuming that δ denotes the maximum delay between the `AC` & $\uparrow$`BELL` events, and between the `STOP` & $\downarrow$`BELL` events, explain, in words, the meaning of the following RTL expression:

    $$\begin{aligned} \forall i, t((@\texttt{AC}, i) = t) \Rightarrow\ & \exists j, t_1, t_2((@(\uparrow\texttt{BELL}, j) = t_1) \\ & \wedge(@(\downarrow\texttt{BELL}, j) = t_2) \wedge (t \leq t_1 \leq t + \delta) \\ & \wedge((t_2 = t_1 + 30) \vee \exists k, t_3((@(\texttt{STOP}, k) = t_3) \\ & \wedge(t_3 < t_1 + 30) \wedge (t_2 \leq t_3 \leq t_2 + \delta)))) \end{aligned}$$

    [*8 marks*]

3. (a) Explain what is meant by an *optimal* scheduling algorithm.

   Briefly describe the following scheduling algorithms, indicating whether or not each of them is optimal:

   i. Rate Monotonic (RM)

   ii. Least Compute Time (LCT)

   iii. Earliest Deadline First (EDF)

   [*10 marks*]

   (b) i. Define the term *Processor Utilisation (U)*.

   ii. Consider $P_1(1, 6, 6)$ and $P_2(3, 4, 4)$. Calculate the processor utilisation U.

   iii. Show how algorithm M would schedule the processes in (ii) above. [*7 marks*]

   (c) Consider two periodic processes, $P_1(15, 20, 20)$ and $P_2(10, 40, 40)$. Illustrate a feasible schedule using:

   i. the RM method

   ii. the EDF method.

   Does a feasible schedule exist using the LCT policy? Explain. [*8 marks*]