EINDHOVEN UNIVERSITY OF TECHNOLOGY
Department of Mathematics and Computer Science

Written examination Real-time software engineering (2IN70) - Part II: Real-time Architectures on Friday, April 15th, 2016, 18:00h-21:00h.

Hand-in the answers to this 2nd part of the examination on separate sheets of paper, and make sure to put your name and identification number on the paper.

Read all the questions first. There are 4 questions in total. Points for each question are indicated between parentheses and sum up to 6 points. Many questions have a word limit, which must be observed. Good luck!

1. **Automotive domains and requirements**
   Five main functional domains have been distinguished for automotive, i.e. (i) powertrain, (ii) chassis, (iii) body (comfort), (iv) telematics/wireless, and (v) passive safety.
   (a) (0.5) Describe (in at most two sentences) how the requirement of safety differs qualitatively (e.g. low, high) for these domains.
   **Answer**: Slide 7 of introduction provides an overview. The safety requirements for (i) and (ii) are high, of (iii) and (iv) are low, and of (v) are very high.
   (b) (0.5) Describe (in at most three sentences) how the requirement of timeliness/predictability differs qualitatively for which these domains.
   **Answer**: See slide 27 and beyond of introduction. Because of the safety requirements, (i), (ii), and (v) have hard timing requirements and (iii) firm/soft timing requirements. Although (iv) has a low safety requirement, it also has hard timing requirements, because otherwise the connection may be lost.

2. **Microcontroller**
   (a) (1.0) Describe how a CPU executes instructions. **Hint**: describe the steps of a so-called load-store ISA.
   **Answers**: See slide 16 of microcontroller.
   (b) (0.5) Describe how programs can communicate with external devices via input and output ports in at most 3 sentences.
   **Answer**: See slide 22 of microcontroller. Keywords: ports are memory mapped, setup and control via control registers (also special memory addresses).

3. **Synchronization**
   (a) **Implementing mutual exclusion**:
      i. (0.5) Give a disadvantage of implementing mutual exclusion by disabling interrupts.
      **Answer**: see slide 5 of synchronization.
ii. (0.5) Give a disadvantage of implementing mutual exclusion by disabling the scheduler.

Answer: see slide 6 of synchronization.

(b) Deadlock:

i. (0.5) Describe the characteristics of a deadlock and give an example.

Answer: See slide 15 of synchronization and book.

ii. (0.5) Describe two approaches to avoid deadlocks.

Answer: See slide 17 + 19 of synchronization and book.

4. Analysis: The following table provides the characteristics of a task set $T$.

<table>
<thead>
<tr>
<th>$T = D$</th>
<th>$C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_1$</td>
<td>4</td>
</tr>
<tr>
<td>$\tau_2$</td>
<td>7</td>
</tr>
<tr>
<td>$\tau_3$</td>
<td>23</td>
</tr>
</tbody>
</table>

(a) (0.5) A sufficient condition for schedulability of the three tasks that is given by

$$U^T \leq n \left(2^{1/n} - 1\right),$$  \hfill (1)

where $n = |T| = 3$. What can be concluded from the fact that this condition does not hold for $T$, i.e. $U^T \approx 0.97 > 3 \cdot (2^{1/3} - 1) \approx 0.78$?

Answer: $T$ may but need not be schedulable.

(b) Assume fixed-priority pre-emptive scheduling, where $\tau_1$ has highest and $\tau_3$ has lowest priority.

i. (0.5) Draw a time line with a critical instant for task $\tau_3$.

Answer: See Figure 1. Note that $WR_3 = 20 < D_3 = 23$.

![Time line with a critical instant for task $\tau_3$.](image)

Figure 1: Time line with a critical instant for task $\tau_3$.

ii. (0.5) Are all tasks of $T$ schedulable?

Answer: From the timeline, we see $WR_1 = 2 < D_1 = 4$, $WR_2 = 7 \leq D_1 = 7$, and $WR_3 = 20 < D_3 = 23$. Hence, the taskset is schedulable.