# Försättsblad till skriftlig tentamen vid Linköpings universitet

| | |
|---|---|
| **Datum för tentamen** | 2019-08-24 |
| **Sal (1)** | TER4(7) |
| **Tid** | 8-12 |
| **Utb. kod** | TDDD07 |
| **Modul** | TEN1 |
| **Utb. kodnamn/benämning**<br>**Modulnamn/benämning** | Realtidssystem<br>Skriftlig tentamen |
| **Institution** | IDA |
| **Antal uppgifter som ingår i tentamen** | 6 |
| **Jour/Kursansvarig**<br>Ange vem som besöker salen | Simin Nadjm-Tehrani |
| **Telefon under skrivtiden** | 0702282412 |
| **Besöker salen ca klockan** | 9.15 |
| **Kursadministratör/kontaktperson**<br>(namn + tfnr + mailaddress) | Veronica Kindeland Gunnarsson |
| **Tillåtna hjälpmedel** | Miniräknare |
| **Övrigt** | Rutigt papper |
| **Antal exemplar i påsen** | |

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

**TENTAMEN TDDD07 Realtidssystem**

DATUM: 24 August 2019
TID: 8-12
PLATS: TER4
ANSVARIG JOURLÄRARE: Simin Nadjm-Tehrani (0702282412)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 6

Total no. of points: 40

Preliminary grade limits for grades: 3, 4 and 5

| | |
|---|---|
| 3: | 20 - 26 p |
| 4: | 27 - 33 p |
| 5: | 34 - 40 p |

**INSTRUCTIONS:**
Please write your anonymous ID on each sheet of paper that you hand in. Pages should only contain answer to **one question per page** (answers to sub-questions can be on the same page). You are asked to only write on one side of each paper. Please **sort** all the sheets that you hand in, in the order of question numbers.

Make sure that **all** answers are **motivated** and supported by **clear** explanations. Figures or charts can be used to provide a clearer explanation but should be accompanied by a **textual description**. Points will not be given to answers for which the reasoning cannot be followed or that cannot be read due to bad handwriting. Wrong answers/reasoning which is embedded in partially correct ones will lead to deduction of points.

**Hints:** Read the question carefully to find the focus of the question. Make sure your answer is to the point and relevant for the question asked. Take the opportunity of asking questions about unclear issues during the exam session. Otherwise, whenever in doubt about the question, write down your interpretation and assumptions, and answer the question based on that interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than 10th September 2019.

Good luck!

Simin Nadjm-Tehrani

## Q1: Scheduling

A space stationed telescope that has been sent to take pictures of far away stars has three different functions that are implemented on the same CPU: A position stablizer that uses a gyro to stabilize the movement around own axes; A star-follower process that tries to fix the orientation so that sharp pictures can be taken; An energy management system that deals with charging of batteries and adaptation to sun hours and angles. Assume that the position stablizer is run every 50 ms and takes maximally 5ms to run, that the energy manager is run every 30 ms with a maximal computation time of 10ms, and the star-follower process takes a picture from a given star every 20 ms and takes maximally 5ms to to fix orientation with the help of the picture.

a) Assume that the star follower process is jitter sensitive and thereby aim to schedule it with no jitter. Construct a cyclic schedule for the above process set and present the minor and major cycles, respectively. Comment on the jitter experienced by the other two processes in your constructed schedule.

(5 points)

b) Compute the response times of the three processes (in part a above) using the Rate-monotonic scheduling approach.

(3 points)

c) Assume now that the process set is scheduled using rate monotonic scheduling (RMS) and we want to increase the above functions (on the same CPU) with 2 new ones. A picture storage process that shares common (data) memory with the star-follower process, and a communication process that shares position data with the position stabilizer (i.e. two pairs of processes sharing one memory resource each). The length of execution in critical sections for all processes is provided in the following table. Assume that we use immediate ceiling protocol for managing access to common resources, and that picture storage process has a periodicity of 50ms and communication process has a periodicity of 100ms. Compute the blocking time for the processes that share common resources.

| Process | WCET for running while holding a resource |
|---|---|
| Position stablizer | 1 ms |
| Star follower | 2 ms |
| Picture storage | 2 ms |
| Communication | 1 ms |

(4 points)

d) Consider the following periodic processes and their parameters (in *ms*):

| Process | WCET | Period | Deadline |
|---|---|---|---|
| P1 | 3 | 10 | 10 |
| P2 | 4 | 16 | 8 |
| P3 | 2 | 12 | 12 |

Given the above parameters, can utilisation-based tests be used for guaranteeing schedulability with RMS? Motivate your answer!

(2 points)

e) What is meant by a sporadic task in a real-time system? Give two examples of such tasks.

(3 points)

## Q2: Dependability and predictability

a) During five hours on June 2nd, 2019, Google Cloud services at the East coast of US and parts of Europe were unavailable for millions of users. This affected Gmail, Calendar, Hangouts, and to some extent YouTube and Snapchat. Initially, the problem was blamed on networking issues. Later, a more detailed description attributed the outage to the following chain of events:

"In essence, the root cause of Sunday's disruption was a configuration change that was intended for a small number of servers in a single region. The configuration was incorrectly applied to a larger number of servers across several neighboring regions, and it caused those regions to stop using more than half of their available network capacity. The network traffic to/from those regions then tried to fit into the remaining network capacity, but it did not. The network became congested, and our networking systems correctly triaged the traffic overload and dropped larger, less latency-sensitive traffic in order to preserve smaller latency-sensitive traffic flows, much as urgent packages may be couriered by bicycle through even the worst traffic jam.".

Identify the IFIP WG10.4 fault-error-failure causality relations in the scenario provided and explain if the fault was permanent, intermittent or transient.

(2 points)

b) What is the difference between introducing fault tolerance through redundancy in time vs redundancy in space? Are they both effective against the same fault models? Why? Why not?

(3 points)

c) Take a stand (true/false) on each of the following statements and motivate your answer!

(1) Dependability as a concept has no relationship to security.

(2) Fault detection in today's hardware is so fast that it does not impact timing constraints for any real-time application.

(3) Diffserv is a scheme through which Internet-based services can provide end-to-end timing guarantees.

(3 points)

## Q3: Real-time Communication

a) Describe one benefit of the TTP bus in comparison to the CAN bus and illustrate with an application domain in which this aspect would be clearly beneficial.

(2 points)

b) Considering the priority-based schedulability problem in buses and in CPUs, what is the main difference between how worst-case response time for CAN is calculated and how this is done for Rate-monotonic scheduling in CPU. Explain the underlying reason for this difference.

(3 points)

## Q4: Application design & RTOS

a) MARTE uses a refined version of model-driven architecture to support design and implementation of real-time embedded systems. Describe three types of models that the MARTE-based approach requires the engineer to provide in the development cycle.

(3 points)

b) Explain three functionalities that are present in a real-time operating system which need not be present in a normal operating system?

(3 points)

## Q5: Distributed systems, Quality of Service (QoS)

a) Briefly explain two example methods for scheduling packets in an Internet context that help enforce QoS requirements across end-to-end flows.

(2 points)

b) What is the main difference between the characteristics of the incoming task sets in a telecom base station and task sets running in a car? (use the terminology you learnt in this course to explain the difference)

(2 points)

## Q6: Bonus points

In this question you state if you have any bonus points allocated to your attempts at bonus exercises 1, 2, and 3 during the course. Please sum up all three (if any) of your attempted exercises and write the total attained points here.


## Notation for Processes

$C$ = Worst-case execution time
$B$ = Worst-case blocking time
$D$ = Relative deadline
$n$ = Number of processes
$T$ = Period
$R$ = Worst-case response time
$J$ = Release jitter

## Schedulability test for Rate Monotonic:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq n(2^{1/n}-1)$$

## Schedulability test Earliest Deadline First:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq 1$$

## RMS Response time analysis

$$w_i = C_i + B_i + \sum_{\forall P_j \in hp(P_i)} \left\lceil \frac{w_i + J_j}{T_j} \right\rceil C_j$$

$$R_i = w_i + J_i$$

$hp(P_i)$ is the set of processes with a higher priority than process $P_i$.

## Timing Analysis of CSMA/CR

$B$ = blocking time
$C$ = transmission time of entire frame
$T$ = period
$\tau_{bit}$ = transmission time of one bit
$w$ = response time for the first bit of a frame to be sent
$R$ = total response time
$J$ = Jitter
$t$ = Longest busy interval
$lp(m)$ = set of frames with lower priority than $m$.
$hp(m)$ = set of frames with higher priority than $m$.
$hep(m)$ = set of frames with higher or equal priority than $m$.
$n$ = number of bytes in message (data field)

$$R_m = \max_{q=0..Q_m-1}(R_m(q))$$

$$R_m(q) = J_m + w_m(q) - q \cdot T_m + C_m$$

$$w_m(q) = B_m + q \cdot C_m + \sum_{\forall j \in hp(m)} \left\lceil \frac{w_m(q) + J_j + \tau_{bit}}{T_j} \right\rceil \cdot C_j$$

(with $w_m{}^0(q) = B_m + C_m q$)

$$Q_m = \left\lceil \frac{t_m + J_m}{T_m} \right\rceil$$

$$t_m = B_m + \sum_{j \in hep(m)} \left\lceil \frac{t_m + J_j}{T_j} \right\rceil \cdot C_j \qquad (\text{with } t_m{}^0 = C_m)$$

$$C_m = \left( 8n + 47 + \left\lfloor \frac{34 + 8n - 1}{4} \right\rfloor \right) \tau_{bit}$$

$$B_m = \max_{j \in lp(m)}(C_j)$$