Försättsblad till skriftlig tentamen vid Linköpings Universitet

Datum för tentamen	2013-03-22
Sal (1) Om tentan går i flera salar ska du bifoga ett försättsblad till varje sal och <u>ringa in</u> vilken sal som avses	TER4
Tid	14-18
Kurskod	TDDD07
Provkod	TEN1
Kursnamn/benämning **Provnamn/benämning**	Realtidssystem Skriftlig tentamen
Institution	IDA
Antal uppgifter som ingår i tentamen	5
Jour/Kursansvarig Ange vem som besöker salen	Simin Nadjm-Tehrani och Massimiliano Raciti
Telefon under skrivtiden	Simin 013-282411, 0702-282412 Massimiliano 013-282416, 0762-388815
Besöker salen ca kl.	
Kursadministratör/kontaktperson (namn + tfnr + mailaddress)	Liselotte Lundberg 013-281278
Tillåtna hjälpmedel	Engelskt – Svenskt – Engelskt lexikon, kalkylator
Övrigt	
Vilken typ av papper ska användas, rutigt eller linjerat	
Antal exemplar i påsen	35

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 22 March 2013
TID: 14-18
PLATS: TER4
ANSVARIG JOURLÄRARE: Simin Nadjm-Tehrani (013-282411, 0702 282412)
Massimiliano Raciti (013-282416, 0762 388815)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 5

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. Further, 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 the question number.

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. You may answer the questions in English (the course language) or Swedish.

Hints: Make sure your answer is to the point and relevant for the question asked, by reading the question carefully. 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 the interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than April 11th 2013.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

a) ABB's current industrial robots are a major improvement over the previous ones, since the same control system is now able to manage several robots at the same time, making the production process more efficient. For example, one robot can hold a metal surface that is supposed to be welded in position while another robot performs the welding. Then the holding robot can move the surface during operation so that the welding point is always facing up.
The computer can steer several activities:

- Positioning of the robots, for which regulator processes with a sampling interval of 20 ms are used
- Trajectory definition, by a process P_T which creates the sequence of desired positions for the positioning regulator
- Fault monitoring, done by a process P_F that looks for deviations from a robot expected behaviour, and adjust or signal the operator if needed.

The computer used for running these processes can be used to steer several robots. In the first version of the system an analysis of the utilisation of the processor for two robots is performed, whereby each robot has three positioning processes, one fault monitoring process, and one trajectory process (altogether 10 processes in the system).

Assume that every positioning process (i.e. in X, Y, Z axis for each robot) has a maximal computational time of 1 ms. Assume further that the trajectory generation and the fault monitoring processes have max. computation times of 5ms and 10 ms respectively. The sampling interval for trajectory generation is 30 ms.

1) Assume that faults do not take place more often than once every 100 ms and the fault monitoring process can take care of one fault at a time. Is the task set schedulable with rate monotonic scheduling?
(4 points)
2) In part 2) above it was assumed that scheduling has negligible CPU utilisation. Give one other assumption that is needed for your solution in part 2) to be applicable. (1 point)
3) Assume that the minimum inter-arrival time for faults is 1 second. Assume further that positioning and trajectory generation processes can be optimised so that their maximal computation times are halved. Using the same processor and with EDF as a scheduling mechanism, how many robots in total can be served by the same processor? (2 points)

b) Assume that a new task P_D is to be added to the task set under a) in order to update the control panel displayed for the human operator every second. This task estimates the current position for each robot with a max computation time 6 ms of which 2 ms is for displaying the current position. The display panel can be considered as a shared resource on which also the trajectory generation and the fault monitoring processes can write to display their current output. Assume that the locking of the display for the write operations by P_T and P_F is 1 ms. Using the rate-monotonic policy, the four processes use the immediate ceiling protocol to avoid priority inversion and deadlock related problems. Compute the maximum blocking time for each of the tasks P_D, P_T, and P_F in the system.

(3 points)

c) What does the CPU utilization of a cyclic executive itself depend on (i.e. what factors influence the overhead of cyclic scheduling)? Provide three factors on which the executive CPU consumption depends.

(3 points)

Q2: Dependability and predictability

a) Describe two methods for tolerating system faults, one using static redundancy and with dynamic redundancy. How do these techniques relate to fault prevention?

(4 points)

b) Using clear arguments identify whether the failure described in the following two scenarios is to be classified as a timing failure. Motivate your answer!

1) The online newspaper The Province reported on 10th March 2013: "About 70 per cent of Shaw Communication's email customers were affected when the company was troubleshooting an unrelated email delay problem and an attempted solution caused incoming emails to be deleted. Shaw has about 1.9 million Internet subscribers across Canada, with the majority in Western Canada. Emails were deleted for a 10-hour period between 7:45 a.m. and 6:15 p.m. Thursday, although customers did not learn about the problem until Friday, and only then by calling customer service or accessing an online forum for Shaw Internet subscribers. Spokesman Chethan Lakshman said the problem was difficult to detect because Shaw was dealing with the email delay problem at the same time. About 98 per cent of email to any account is junk mail, Lakshman said, and the standard approach among email service providers is to filter and delete the spam immediately. The spam is not backed up. The error occurred when the Shaw server deleted all email, not just spam. As such, the emails were not backed up. Shaw promised to email affected customers sometime over the weekend with a list of deleted messages and details such as sender, subject and time sent. The actual content of the emails, however, is unrecoverable.".

2) Risk Forum reported on 10 March 2013: "Some radio synchronised clocks in USA unexpectedly switched to Daylight Saving Time (DST) yesterday hours ahead of schedule. According to the Time and Frequency Division of the National Institute of Standards and Technology (NIST), which operates radio station WWVB in Boulder, Colorado, the last two significant bits in the time code give a warning that DST changes tomorrow and the current state of DST (standard time or daylight saving time). Some clocks changed to DST when the warning bit appeared.

(4 points)

Q3: Real-time Communication

a) Ms. Klurig is an engineer at HighTech AB and currently responsible for determining whether an event-driven or a time-driven bus should be adopted by the company in its new development project. Describe two factors that may affect the decision whether to use a CAN bus compared to a TTP bus.

(2 points)

b) Assume now that the company has decided to use a CAN bus to schedule the messages in the development project. The list of messages that would have to be scheduled on the

CAN bus is presented below (where "Tx time" stands for worst case transmission time of a message on the bus). Ms. Klurig was asked to prioritise the messages for sending on the CAN bus. How should she answer the question?

Message	Period	Tx time
m_1	10	3
m_2	20	4
m_3	50	5
m_4	40	5

(1 point)

Q4: Application design & RTOS

a) Define the notion of modularity as a property of a system's design, and explain why modularity is harder to achieve in a real-time system.

(2 points)

b) Define the notion of platform in a real-time system, and describe one phase of system development that cannot be platform-independent.

(2 points)

c) One of the main functions in a real-time operating system is to implement and manage preemptions. Explain how does a typical real-time operating system achieve that.

(2 points)

d) Explain how treatment of faults at run-time (either by the application program or by the run-time environment) affects the timing aspects of a real-time system.

(2 points)

Q5: Distributed systems, Quality of Service (QoS)

a) How is jitter in a flow defined as a QoS parameter in a networked application? Give two example applications that would normally have jitter-related QoS specifications.

(3 points)

b) In the absence of synchronised clocks a distributed system can only relate computations at different nodes using local events. Clarify two ways of characterising local events.

(2 points)

c) How is the solution to the consensus problem, e.g. n distributed nodes agreeing on a common value, dependent on timing aspects?

(3 points)

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:

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

Schedulability test Earliest Deadline First:

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

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
τ_{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 $w_m^{\ 0}(q) = B_m + C_m q$)

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

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

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

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