National Exams May 2019

04-Soft-A4 Real Time Systems

3 hours

Note

- If doubt exists as to the interpretation of any question, the candidate is urged to submit with the detailed answer paper, a clear statement of any assumptions made.
- Candidates may use one of the two calculators, the Casio or Sharp approved models. This is a Closed Book exam.
- Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- All questions are of equal value (20% each).

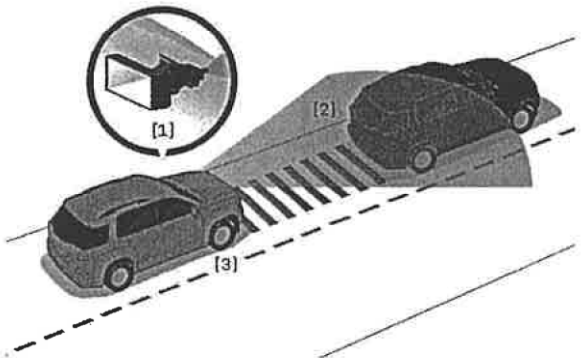
Question 1 (20%)

A simple concept of a real-time system is that the correctness of the computations not only depends on the correctness of the logic operation, but also on the time at which the result is produced. That is, a late answer is a wrong answer (even though the number, by itself, is correct). Please give examples of real-time systems in your daily activities with following characteristics. You need to explain your choices against these criteria:

1. Periodic real-time systems
2. Deadline-oriented real-time systems
3. Hard-deadline based real-time systems
4. Soft-deadline based real-time systems, and
5. Aperiodic task based real-time systems

Question 2 (20%)

Suppose that you are in charge of designing a collision avoidance system for an automobile.



You are using radar [1] to measure the distance of the object [2] in front of your car, and a warning will be issued to you when your car is within 15 meters to the object in front of you, so that you can stop your vehicle [3] by applying the brakes manually. If you are within 10 meters to the object, the collision avoidance system will deploy an automatic break to stop the car.

Support that you are traveling at 60 km/h, the breaking distance is 7 meters, the safe distance between your car and the object is 1 meters,

(1) Draw a complete state diagram of the operation of the collision avoidance system for a stationary object (parked car) and moving object (slower moving car)
(2) Analyse the real-time requirements of the sensor, decision-making unit, and the automatic break; and
(3) Derive a formula to link that the real-time requirements to the initial speed of the car and the breaking distance.

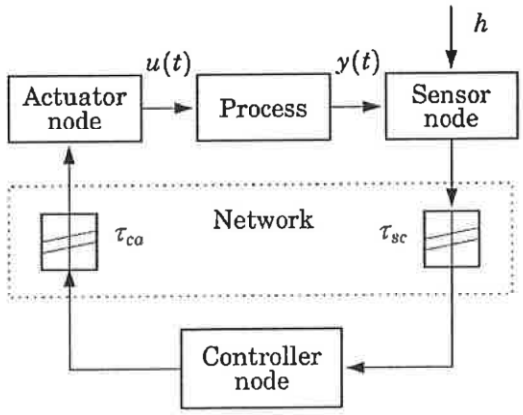
Question 3 (20%)

Answer the following questions:

1. What are the desired features of a RTOS (Real-Time Operating System)?
2. Why or why not the Microsoft Windows and Mac OS be used in real-time applications?
3. Can you list four commercially available real-time operating systems for real-time applications?
4. Define (explain) Hard vs. Soft real-time systems, and
5. What are the fundamental differences between a real-time system and a non-real-time system?

Question 4 (20%)

A real-time distributed control system is shown below, where the sensor, the controller, and the actuator reside on different nodes in a network. The network introduces a constant delay τ_{sc} between the sensor node and the controller node, and another constant delay τ_{ca} between the controller node and the actuator node. The open-loop process, itself, is an unstable system.



(1) Briefly describe a network protocol that fits the constant delay model.

(2) How would the network delay affect the performance of this closed-loop control system, such as stability?

(3) Suppose that a controller has been designed for the process assuming zero network delay. The phase margin in the design was $\phi = 45°$ and the crossover frequency $\omega_c = 3.5$ rad/s. How large can the total network delay ($\tau_{sc} + \tau_{ca}$) be without causing the closed-loop control system becoming unstable?

Question 5 (20%)

Four single-instance tasks are listed in Table below:

Task	Arrival Time	Computational time (ms)	Absolute deadline (ms)
T1	0	4	15
T2	0	3	12
T3	2	5	9
T4	5	2	8

(1) Schedule the tasks using First-Come-First-Serve (FCFS) scheduler, and draw a timing diagram to illustrate the scheme,
(2) Analyze the result from Step (1). Can FCFS scheduler meet all the deadlines? Explain the results of your analysis, and
(3) Re-schedule these tasks using EDF algorithm to meet the real-time requirements. Illustrate the task sequence by a timing diagram.

Question 6 (20%)

In a pre-emptive priority system, for each task, the time required to complete and the priority (1 being the highest) are given in Table below:

Tasks	Time required (ms)	Priority
Task 1	10	2
Task 2	20	1
Task 3	30	3
Task 4	40	4

If the tasks arrive in the order (1, 2, 3, 4) and if we assume that the interrupt latency is 1.0 ms,

(a) How much time does it take to complete task 3? and

(b) How much time would it take if the system uses cooperative scheduling?