National Exams May 2013

# 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 answer paper, a clear statement of any assumptions made.

- Candidates may use one of 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) Use your own words to explain what a real-time system means to you.

(b) Provide three examples of real-time systems in operation and provide detailed real-time requirement analysis, tasks, execution sequence and deadlines for those three example systems.

(c) Why real-time systems are critical in these applications?

Question 2 (20%)

A round water tank is shown in the figure below:
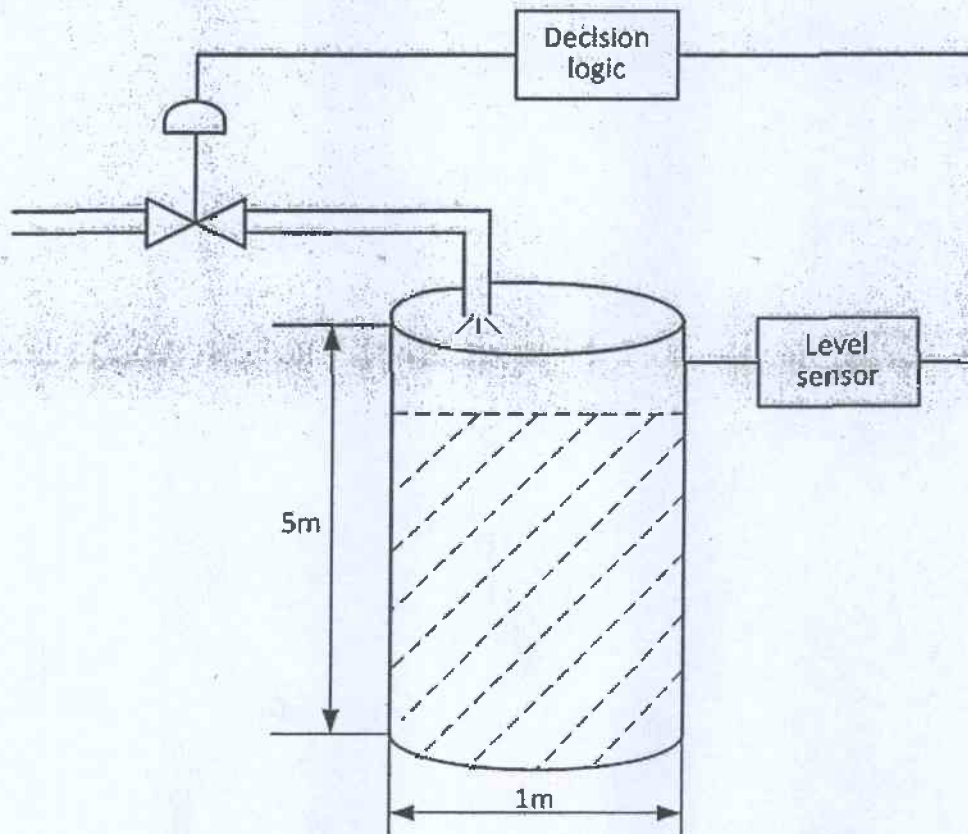
The inlet valve is controlled by the measured water level and the desired set point. Suppose that diameter of the tank is 1 m and the height is 5 m. The flow rate of the inlet is 400 liters/minute. Whenever the water level reaches to 4.9 m, a command signal will be issued to shut-off the inlet valve to avoid spill over.

Determine what the largest time delay that the decision logic function can afford, before a spill-over can occur. (Assuming that the closed-loop system is over-damped.)

Question 3 (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). Does FCFS scheduler work in this case?

(3) Re-schedule these tasks using EDF algorithm to meet the real-time requirements. Illustrate this by a timing diagram.

Question 4 (20%)

Consider that a traffic intersection has red, yellow and green lights in all four directions, and pedestrian walk push buttons on four corners with eight push button states.

(1) Draw a finite-state model representation of a traffic control model for this intersection.

(2) Assuming that it takes 20 sec for pedestrians to walk across the road and 30 sec for vehicles to stop in time when the light changes, design an intersection traffic controller for the safety of pedestrians and passing vehicles.

Question 5 (20%)

Suppose that you are the engineer to design a control system for a household washing machine. The washing machine has several operational states, such as load in the cloth, close the lid, open-up the inlet water, spinning, and drain the water, etc.

(1) Draw a state transition diagram for the washing machine control

(2) List all the conditions that can cause transitions from one state to another (such as opening the lid while the machine is spinning)

(3) What sensors are needed to implement an embedded real-time control system for this washing machine?

(4) Choose one of these conditions and specify the actions that the real-time control system must take to maintain correct system operation.

Question 6 (20%)

A distributed control system is shown in the figure 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.
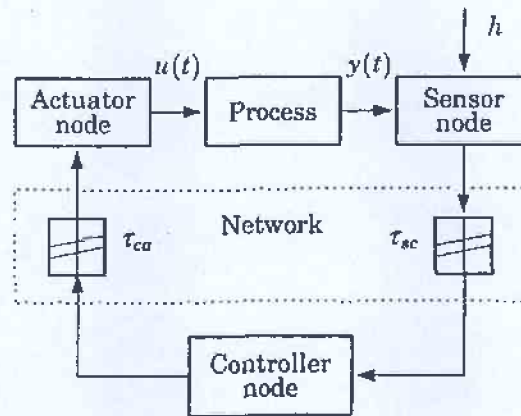
(1) Briefly describe a network protocol that fits the constant delay model.

(2) How would excessive delay affect the performance of this closed-loop system?

(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?