Embedded Systems
Examination session of January 2018

Notes or documents of any kind forbidden. Duration: 3 h 30.

Each question must be answered on a different sheet with your name and section.

1. (a) How are the master and the slave of a transaction determined, in the case of an I^2C bus with more that two connected devices? [1/20]

   (b) What are the five possible states of a process in a real-time operating system? Explain briefly the purpose of each of them. [1/20]

   (c) What is priority inversion? When does it occur? Why is it problematic? How can it be solved? [2/20]

2. Consider the following set of periodic tasks $\tau_i = (C_i, T_i)$:

$$\{\tau_1 = (3, 13),\ \tau_2 = (1, 3),\ \tau_3 = (\alpha, 5)\},$$

   where α is a parameter.

   (a) Compute the maximum value of α for this set of tasks to be schedulable. [2/20]

   (b) Verify your answer with a graphical simulation. [1/20]

3. A 3D printer is equipped with a microcontroller that takes care of the printing process. Printing instructions are contained in a precomputed queue data structure, that enumerates the successive sets of coordinates by which the printing head must pass. The printing process consists in first popping a set of coordinates from the queue and processing it, which takes 0.2ms. Then, the motors are driven in order to move the printing head to those coordinates. This requires to command the motors every millisecond, which takes (each time) 0.1ms. When the printing head has reached the target coordinates, the controller pops the next instruction from the queue and repeats the same process, until the queue is eventually empty.

   Additionnally, the microcontroller has to perform the following tasks:

   - A task τ_1 monitoring the temperature of the printing head heater every 10ms. This task requires 0.5ms to execute.
   - A task τ_2 updating a LCD display with the current status of the printing process every 20ms. This task requires 5ms to complete, but can be freely paused at any time in order to perform other operations.

   (a) What is the best software architecture for this system? Justify carefully your answer. [3/20]

   (b) Using pseudocode, give the global structure of this software. [3/20]

4. In mountain areas, electricity can be produced by hydroelectric power plants. This is usually done by conveying water from high altitude lakes to a set of turbines that generate electricity.

   In this problem, we consider a lake with a capacity of $2 \times 10^6 \text{m}^3$, refilled by a river whose flow varies between 100 and 5000m^3/hour. The lake is equipped with a spillway that automatically evacuates excess water when the lake has reached its maximum capacity.

   The operation of the power plant follows a cycle. During the day, between 8am and 5pm, the flow of water sent to the turbines is between 0 and 250m^3/hour, depending on the electricity demand. In the evening, between 5pm and 10pm, this flow is between 0 and 500m^3/hour. During the night, the power plant is completely shut down.

   Finally, if at any time the amount of water stored in the lake drops below $0.5 \times 10^6 \text{m}^3$, the power plant is immediately shut down until the lake contains again at least $1 \times 10^6 \text{m}^3$ of water.

   (a) Model this system with a hybrid system, assuming that it is initially 6am and that the lake is at full capacity. [5/20]

   (b) Give the first three steps of the state-space exploration of this system. [2/20]