Embedded Systems
Examination session of August 2019

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 sender and the receiver of an I^2C transaction determined? [1/20]

   (b) Explain why special care must be taken when performing data exchange operations between an interrupt routine and the rest of the code. Illustrate your answer with an example. [2/20]

   (c) When is a scheduler said to be preemptive? [1/20]

   (d) Let τ_1 and τ_2 be two periodic tasks with respective periods and execution times T_1, T_2 and C_1, C_2. We assume that these tasks satisfy $T_1 < T_2$, that they both initially start at $t = 0$, that they fully use the processor, that they are scheduled under the RMS policy, and that τ_1 is not idle (i.e., it is running) at $t = T_2$. [2/20]

   Under those hypotheses, express the processor load factor in terms of C_1, T_1 and T_2, carefully justifying your developments. Show graphically how this load factor varies with C_1, when T_1 and T_2 are assumed to be constant.

2. A drone is equipped with a small module that estimates its orientation in space. This module contains a microcontroller relying on the measurements from an accelerometer, a gyroscope, and a magnetometer to compute this estimation.

   The microcontroller performs the following tasks:

   - Reading measurements from the sensors. This task requires 0.1 ms to complete, and the delay between two successive runs of this task must be as precisely as possible equal to 5 ms.
   - Processing measurements after reading them, which takes 0.2 ms.
   - Estimating the orientation of the module from processed measurements. This task must run 100 times per second, and lasts for 0.4 ms.
   - Sending the results of the computation over a radio link. If this task is implemented in an interrupt routine triggered by the radio transceiver, it takes negligible time.

   (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]

3. A factory production line contains a loading system where finished products in their packaging box are loaded onto pallets. This loading system is composed of three main components:

   - A table on which boxes are delivered by the production line conveyor belt at a rate of 1 box every 2 seconds.

- A pallet on which 200 boxes have to be stacked.
- A robotic arm that picks up boxes from the table and stacks them on the pallet.

The robotic arm is able to transfer up to 1 box per second from the table to the pallet. Once the pallet is full, the loading operations stop during the time needed for replacing the pallet with an empty one. This operation takes between 15 and 30 seconds, after which loading operations resume. The table can contain up to 20 boxes. When the table becomes full, the production line has to stop until some space is freed (by the robot picking up a box).

(a) Model the flow of boxes on the table with a hybrid system. Both the table and the pallet can be assumed to be initially empty. [5/20]

(b) Explain how to check, with the help of the model obtained at the previous step, whether there exists a risk of having to stop the production line because the table becomes full (with the current parameters of the system). Illustrate your answer by carrying out in detail the first three steps of the procedure. [3/20]