Embedded Systems
Examination session of August 2022

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 can a microcontroller determine how many devices are connected to an I^2C bus? [1/20]

   (b) What is priority inversion? Give a concrete scenario showing how it can happen. [2/20]

   (c) Is it possible for a set of three tasks to be schedulable and have a processor load factor exactly equal to 100%? (If yes, give a concrete example of such a set of tasks. If no, give a proof that this is not possible.) [1/20]

2. An embedded application software needs to manage the following tasks:

   - A task τ_1 that is run every 40 μs, and that requires up to 5 μs of processor time. The period of this task must be respected with a high accuracy.
   - A task τ_2 that performs a long computation when triggered, with no upper bound given on its completion time. Once started, this task must always be able to eventually complete its computation.
   - A task τ_3 with a runtime of up to 20 μs, that processes the data received from a sensor, and is called when an A/D converter signals the end of a conversion. Two invocations of τ_3 are always separated by at least 80 μs.
   - A large number of additional tasks, with negligible execution time, that should be run as soon as possible when they are triggered (by a signal sent by a communication device).

   (a) What is the best software architecture for this system? Justify carefully your answer. [2/20]

   (b) Using pseudocode, give the global structure of this software, with enough details to show data communication between tasks, as well as with interrupt routines. [3/20]

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

$$\left\{\tau_1 = \left(\frac{3}{2}, 10\right),\ \tau_2 = (2, 8),\ \tau_3 = (\alpha, 3)\right\},$$

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]

4. An industrial camera for monitoring a production line is equipped with an autofocus system that works as follows:

- A phase-detection sensor is constantly measuring the distance between the camera and the intended target. This distance is changing unpredictably in the interval $[5, 15]$ mm.
- The autofocus system is initially inactive. It begins its operation when it receives a signal from an external trigger, and terminates when focus is successfully achieved.
- Whenever the autofocus system is active, it compares the distance measured by the phase-detection sensor to its current setpoint. If the difference is less than $1/10$ mm, then focus is considered to be achieved. Otherwise, the system increases or decreases its setpoint in the appropriate direction, by discrete steps of $1/100$ mm. Each such step requires 100 μs.

(a) Model the behavior of this device with a hybrid system, assuming that the external trigger signal can be received at any time. [5/20]

(b) Give the first three steps of the state-space exploration of this system. [3/20]