Embedded Systems
Examination session of August 2023

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

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

1. (a) Why is it important to keep interrupt routines short and efficient? [1/20]

   (b) In which case is the waiting queue architecture more suited than the round-robin with interrupts for solving a particular problem? [1/20]

   (c) What does it mean for a set of periodic tasks to fully use the processor? [1/20]

   (d) Explain the purpose of synchronized transition labels in hybrid systems. Under which conditions can a transition with such a label be followed? [1/20]

2. The embedded firmware of a deep space probe needs to manage the following tasks:

   - A task τ_1 that receives scientific data from a dedicated payload device. This is done by querying the device every 100 ms and downloading in one batch the data that it has produced during this time interval. This download operation can take up to 5 ms, and cannot be suspended once started.

   - A task τ_2 that processes the data obtained by τ_1 and compresses the result of this processing. The time needed for this operation is highly variable and has no specified upper bound. It is however known that the onboard processor is sufficiently powerful for performing this operation on all incoming data in the long run.

   - A task τ_3 that sends over a radio link the processed and compressed data produced by τ_2. The transmissions are started every 30 minutes, and proceed until all the relevant data has been sent, which typically needs less that 5 minutes. If required, transmissions can be temporarily suspended and resumed later.

   (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, with enough details to show data communication between tasks, as well as with interrupt routines (if any). [3/20]

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

$$\left\{\tau_1 = (2, 6),\ \tau_2 = \left(\frac{3}{4}, 2\right),\ \tau_3 = (\alpha, 3),\ \tau_4 = \left(\frac{3}{4}, 7\right)\right\},$$

where α is a parameter.

(a) Compute the maximum value of α for this set of tasks to be schedulable. [3/20]

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

4. An industrial CNC machine is protected by a safety mechanism that works as follows:

- There are two safety buttons installed at different locations. At any time, each button has a state that is either *on* or *off*. The state of a button is independent from the state of the other button. Initially, both buttons are *on*.
- When a button is pressed when it is *on*, it immediately becomes *off*.
- When a button is pressed when it is *off*, it becomes *on* only if the two following conditions are both satisfied:
  - the button has been pressed without interruption for at least 5 seconds, and
  - at every moment during this time interval, the other button was either *on* or pressed (or both).

(a) One wishes to check whether it is possible for this system to end up in a situation where a button is *off*, and there does not exist a way of turning it *on* again. Model the behavior of the safety mechanism with a hybrid system, in such a way that this property can be checked by state-space exploration. (*Note:* This requires to include a model of the environment in which any button can be pressed at any time.) Explain how you would perform this check. [4/20]

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