# Embedded Systems
# Examination session of September 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) A device connected to an $I^2C$ bus wants to transmit the byte 00111011 to another one. The address of the recipient is 0x20. Draw a diagram showing the bus signals corresponding to this transaction, assuming that the bus is initially idle. (Justify your answer by annotating this diagram.) [2/20]

   (b) Define the notion of interrupt latency. What are the parameters that influence this latency? How can this latency be reduced by the designer of a system? [2/20]

   (c) Explain the concept of the best lower bound $U_L$ on the processor load factor of a set of tasks that fully use the processor. What is the value of $U_L$ in the case of $n$ tasks? [1/20]

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

$$\{\tau_1 = (1, 4),\ \tau_2 = (3, 13),\ \tau_3 = (1, 10), \tau_4 = (\alpha, 7)\},$$

   where $\alpha$ is a parameter.

   Compute the largest value of $\alpha$ that makes this set of tasks schedulable. [2/20]

3. A simple running watch is equipped with a GPS chip and an Inertial Measurement Unit (IMU). These two sensors send their measurements to a microcontroller via a serial bus, respectively every second and every 0.01 s. The reception of a new measurement triggers an interrupt on the microcontroller. The user interface of the watch consists in a display showing the status of the watch, and a button that can be pressed to start or stop recording the user position.

   The microcontroller must perform the following tasks:

   - Processing the incoming data from the IMU (1 ms for each measurement).
   - Processing the GPS data and computing an updated position estimation (100 ms for each measurement).
   - Refreshing the display (5 ms, every 18 ms).
   - Monitoring the status of the button (negligible amount of computation time, every 18ms).
   - Writing the computed GPS position to a log file when recording is enabled (10 ms for each position).

   (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 the steel industry, the cold phase denotes the production lines that modify the properties of steel sheets by applying a series of treatments to the metal. In practice, the machinery for the cold phase is designed as a continuous process, in which a single continuous steel sheet is moved trough a production line at constant speed. This single sheet is made of coils that are unwound and welded end-to-end.

   The welding operation is performed at the entrance of the line. A coil is progressively unwound and moved trough the line until its end is reached. At that moment, the coil is stopped and held back in a welding machine until a new coil gets installed and gets welded at the end of the finished one. In order to prevent stalling the production line every time this operation has to be performed, the line is equipped with a dedicated device acting as a buffer. Its purpose is to maintain the speed of the steel sheet at its output equal to $v_o$ at all times.

   The buffer works by winding the steel sheet coming from the coil around two rollers, with one of them movable and the other fixed, as illustrated in the figure. When the input steel sheet is stopped for a welding operation, the movable roller moves to the left at the speed $v_o/2$, which makes the steel sheet leave the buffer at the speed $v_o$ even though the input coil is stopped. When the movable roller reaches its leftmost position (depicted by a grey dashed circle), the buffer becomes empty. This situation is problematic and must be avoided during normal operation.

   When the input sheet is released and moving again after completing a welding operation, the movable roller moves to the right at the speed $v_o/2$. The rotation speed of the input coil is adapted such as to have the steel sheet entering the buffer at the speed $2v_o$, which leads to an output speed equal to $v_o$. Finally, when the movable roller reaches its rightmost position, it stops, and the input coil is slowed down to an input speed equal to $v_o$.

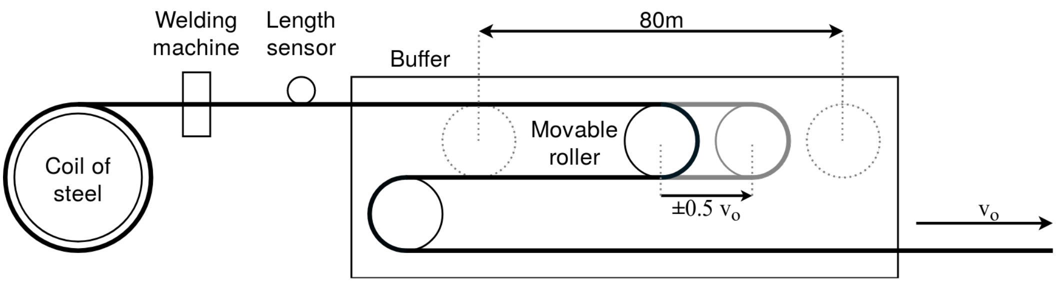
   The problem consists in modeling a buffer device according to the following specifications:

   - Input steel coils have a length of 200 m.
   - A sensor located at the entrance of the buffer measures the length of the steel sheet since the previous weld.
   - A welding operation takes between 30 seconds and 1 minute.
   - The movable roller can move up to 80 m ahead of its rest position.

   (a) Draw a hybrid system modeling the buffer device, suited for checking whether the buffer can get empty during the operation of the production line. [5/20]

   The initial configuration corresponds to a newly welded coil (meaning that the weld at the beginning of this coil is just entering the buffer), and the movable roller is located at the midpoint between its leftmost and rightmost positions.

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


Welding
machine
Length
sensor
80m
Buffer
Movable
roller
Coil of
steel
±0.5 v_o
v_o