Embedded Systems
Examination session of August 2017

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) Describe the mechanism that prevents electrical conflicts when two devices connected to an I^2C bus send different values at the same time. [1/20]

   (b) In a system controlled by a real-time operating system, when are tasks in the blocked state? [1/20]

   (c) What are the conditions for a set of periodic tasks to fully use the processor? Give an algorithm for checking whether a given set of tasks fully uses the processor. [2/20]

2. Let τ_1 and τ_2 be periodic tasks with the respective periods T_1, T_2 and execution times C_1, C_2, such that $T_1 = 10$ μs, $T_2 = 25$ μs, and $C_1 < 5$ μs. The priority of τ_1 is higher than the one of τ_2. This pair of tasks fully uses the processor.

   (a) Represent this problem graphically. [1/20]

   (b) Compute the value of C_2 as a function of C_1. [2/20]

3. A nanosatellite in charge of taking pictures of the earth is controlled by an embedded system. This system is equipped with a radio transceiver that receives telecommand data packets from a ground station. Upon receiving a data packet, the radio transceiver sends an interrupt request to the onboard microcontroller. Such requests are always separated by a delay of at least one second.

   The microcontroller has to perform the following tasks:

   - τ_1 fetches and processes the data packets communicated by the radio transceiver;
   - τ_2 performs computations for estimating the position of the satellite, every 10 ms;
   - τ_3 regulates a DC/DC power converter, every 2 ms;
   - τ_4 acquires an image from a camera, after telecommand data requesting to perform this operation has been received from the ground station. It then performs image processing operations.

   Tasks τ_1 and τ_3 execute in less than 0.1 ms; task τ_2 needs 1 ms. The execution of task τ_4 may require up to 500 ms of CPU time, depending on the image processing operations that must be carried out.

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

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

4. A computer processor must be cooled down to avoid overheating. We consider a system composed of a heatsink with an attached PWM controlled fan. The heatsink can be seen as a heat reservoir that accumulates heat produced by the processor, and dissipates it at a rate that depends on the fan spinning speed. This cooling system operates on the following principles:

   - The processor generates heat at a rate between 25 W at idle and 100 W at full load. The load of the processor can change unpredictably at any time.
   - The heatsink dissipates heat at a rate of 40 W when the PWM duty cycle of the fan is 50% and at 120 W for a duty cycle of 100%, provided that its temperature is greater than 20°C. (Otherwise no heat is dissipated.)
   - Let Δ_P be the difference between the power generated by the processor and the power dissipated by the heatsink, expressed in Watts. The rate of variation of the heatsink temperature is equal to $0.001\Delta_P$ °C per second.
   - The system includes a controller that sets the PWM duty cycle of the fan at 50% when the heatsink temperature is below 40°C, and at 100% otherwise.

   (a) Model this cooling system with a hybrid system, assuming that the initial temperature of the heatsink is between 25°C and 35°C. [5/20]

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