lea.schoenberger [☺] tu-dortmund.de
nick.pietrass [☺] tu-dortmund.de

Exercises for
Cyber-Physical Systems Fundamentals
Summer Semester 19

Exercise Sheet 5

(18 Points)

Please note: Solutions to theory assignments must be submitted (individually or in pairs) until 24.06.2019 at 12:00 AM (post box in OH16, ground floor, in front of room E16). Submitting solutions via mail is *not* possible. Discussion: 26-27.06.2019.

1 Aliasing - Theory (2 Points)

What is aliasing? Consider an input signal with frequency 20Hz, e.g., the song of a fin whale. Which is the minimum sampling rate required to avoid aliasing?

2 Successive Approximation Converter - Theory (2 Points)

Draw a circuit diagram of a successive approximation converter with a resolution of 8 bit. Explain in your own words how this successive approximation converter works.

3 FPGA - Theory (1 Point)

Many FPGAs use look-up tables for Boolean functions. Earlier FPGAs used look-up tables for 4 variables (memories with 4 address inputs). Configurations could be used to implement any Boolean function of 4 variables. How many Boolean functions of 4 variables exist? We ignore symmetries and also count simple functions like constant functions.

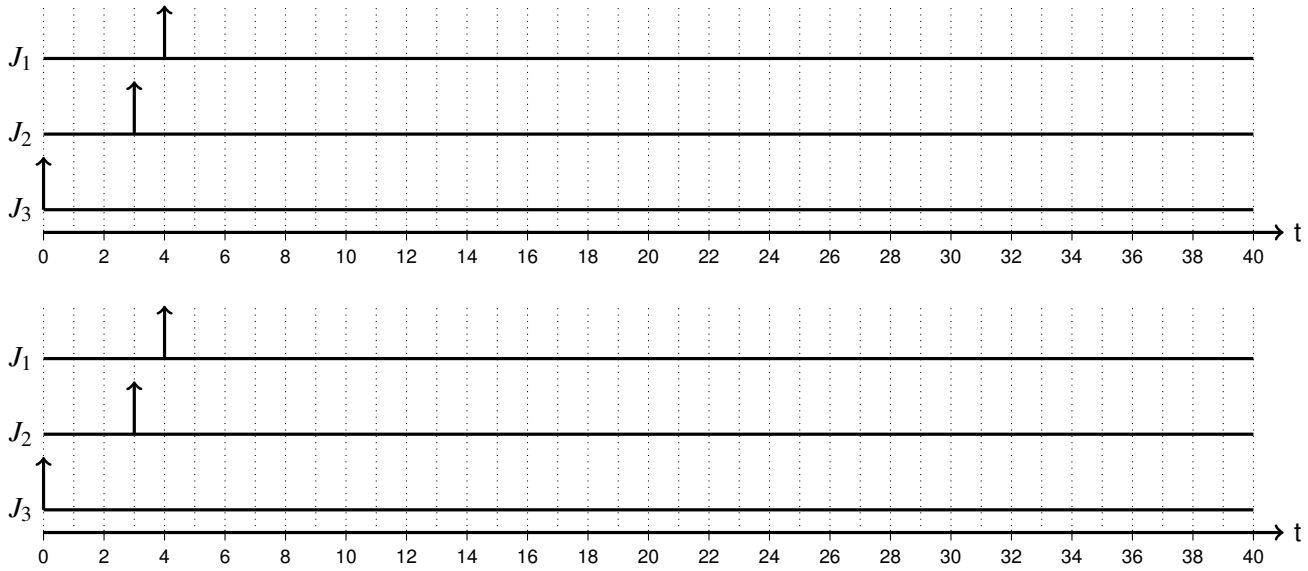
4 Priority Inversion - Theory (3 Points)

We are considering a system with three jobs J_1, J_2 and J_3. The priority of job 1 is assumed to be highest, the priority of job 3 is assumed to be lowest. These jobs become available as indicated in the following diagram.

- Job J_3 executes P(S) 2 time units after it becomes available and V(S) after 4 time units of execution time. (J_3 runs for 2 time units first and then enters the critical section. Its critical section length is 2 time units.) Its total execution time is 8 units of time.
- Job J_2 has a total execution time of 25 time units.
- Job J_1 executes P(S) after 2 units of execution time and V(S) after 5 units of execution time. (J_1 runs for 2 time units first and then enters the critical section. Its critical section length is 3 time units.) Its total execution time is 6 units of time.

What is the schedule of the system if we use pre-emptive, priority-based scheduling? Include calls to P(S) and V(S). Mark time intervals of priority inversion.

What is the schedule of the system if we use pre-emptive, priority-inheritance protocol (PIP)? Include calls to P(S) and V(S). Mark time intervals of priority inversion.



5 Preparation - Practice (0 Points)

Since our license for one of the required tools is restricted to certain computers, you have to establish a SSH connection from this VM to the respective computer by executing the command **ssh youraccount@ls12pc5.cs.tu-dortmund.de** in a terminal window using your account and the related password.

Whenever you start a new session, you have to re-register some components. For this reason, enter the following command into a terminal window:

- **cd wcet**
- **./env.sh**
- **m+ tricore-gcc**
- **m+ ait**

The files required for this exercise are already located in your home directory on the target server, more precisely, in the directory `wcet`. Please note that since it is not possible to use the VM's file browser due to the SSH connection, the command line must be used.

6 Step 1: Simple Analysis - Practice (5 Points)

Execute the command `cd ~/wcet/step1` to change in the directory used for this assignment. Compile the example program with the command **tricore-gcc -g -T ../tc1796.lds test.c** and inspect the source code, e.g., via `kate test.c`, `gedit test.c`, `gvim test.c`, or `cat test.c`.

What does the program do?

Then, execute the command `a3tricore` to start the Tricore analyzer. Under Configuration→Files, choose the file `a.out` as executable and the file `a.ais` as "AIS file". Click on the pen symbol in the "AIS file" line to start the AIS editor. **How are the loop bounds annotated by means of this file?**

Select the entry "Analyses→Create" in the navigation box on the left hand side and click on "aiT" (Safe WCET Analysis). In the newly opened screen displaying the analysis parameters, `main` must be chosen as symbol for the start of the analysis, before it can be started with a click on the "Play" button in the toolbar (the right one showing a triangle without a dot).

What is the WCET of the program? You can display additional details by clicking on the entry "WCET contributions" in the navigation box (left hand side).

Contemplate the control flow graph (Analysis→Control-Flow Graph).

How does the control flow graph represent the program? Consider carefully, how loops are represented in the CFG.

Repeat the analysis by means of the interactive analysis (play symbol with a dot). Examine the additional information shown in the boxes and open some of these via a double click. **Which information do they contain?**

7 Step 2: Scratchpad Allocation - Practice (5 Points)

A scratchpad (SPM, scratchpad memory) is a very fast, internal memory which is used as temporary storage for calculation results, data or program parts. In contrast to a cache, a scratchpad memory is maintained by the programmer and not automatically by the hardware.

Which parts of a program should be swapped out to an SPM?

Which are the differences between a "normal" system and a real-time system with respect to the usage of SPM?

Change to the directory `step2` (`cd ~/wcet/step2`), where a second version of the program considered in the previous assignment can be found. Here, two functions are swapped out to the SPM. Compile the program analogously to the `step1` program and perform an analysis with aiT.

Which impact does the usage of SPM have on the program's execution time?

If you could choose another function to be swapped out to the SPM, which one would you choose? Why?