UNIVERSITÄT DES SAARLANDES
FR 6.2 – Informatik
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Backup Exam
Embedded Systems
SS 2007

Name: ....

Matr.Nr.: ....

- The exam consists of **13 problems** and is worth **180 points**. You have **180 minutes** to complete it.
- Print your full name on every sheet of paper you use.
- In the table below, mark each problem for which you turn in a solution.
- Attach all pages of your solution to this problem set.

Sign here:

....

Problem	1	2	3	4	5	6	7	8	9	10	11	12	13	Σ
Submitted														
Score														
Max	20	20	20	20	10	10	10	10	10	10	10	10	20	180

Problem 1 (Statecharts) [20 points]

Draw a statechart modeling a traffic light controller that helps pedestrians cross a street.

Your model should contain two lights: A for the cars, and B for the pedestrians. Light A can be green, yellow, or red. Light B can be on, off, or blinking. Initially light A should be green, while light B should be off.

When light A is green and a request event is generated (meaning that a pedestrian wants to cross the street), then the following should happen:

Immediately: light A turns yellow;

After 10 seconds: light A turns red; light B turns on;

After 30 seconds: light B blinks;

After 1 minute: light A turns green; light B turns off.

Your model should include at least:

- states green, yellow, and red for light A;
- states on, off, and blink for light B;
- an external event request, generated when a pedestrian wants to cross the street;
- an internal event tick, periodically generated every second with the help of a timer.

Problem 2 (Petri nets) [20 points]

Draw a colored Petri net implementing the function

$$count(a, X)\,,$$

where

- a is an integer number;
- $X = \langle x_1, \ldots, x_n \rangle$ is a nonempty multiset of integer numbers;
- $count(a, X)$ is the number of occurrences of a in X. For instance, $count(1, \langle 1, 1, 2 \rangle) = 2$ and $count(1, \langle 2, 3 \rangle) = 0$.

Your net should contain two "input" places A and B. A initially contains one token labeled by a. B initially contains n tokens labeled by the elements of X. All other places should initially contain no tokens. After a finite number of transitions, your net should enter a deadlock, and a given "output" place R should contain one token labeled by $count(a, X)$. If necessary, you can assign priorities to the transitions of your net. When more than one transition is activated, assume that only a transition with the highest priority can fire.

Problem 3 (Kahn process networks) [20 points]

Draw a Kahn process network that generates the sequence

$$f(n) = n + 1\,, \qquad \text{for } n \in \mathbb{N}\,.$$

You can use only the following processes:

- (1) initially generates the number 1, then simply forwards its input;
- (D) duplicates a number;
- (+) sums two numbers;
- (S) receives a number and outputs nothing; this is the sink for the sequence $f(n)$.

Problem 4 (VHDL) [20 points]

Starting with the following VHDL declaration,

```
entity clb is
  port (a : in Bit;
        b : in Bit;
        x : in Bit;
        y : in Bit;
        c : out Bit);
end entity clb
```

you are to devise a CLB (configurable logic block) which can be configured in order to implement the logical gates `and`, `or`, `nand`, and `nor`. More precisely, the output c of the above CLB should be:

$$c = \begin{cases} a \wedge b\,, & \text{if } x = 0 \text{ and } y = 0\,, \\ a \vee b\,, & \text{if } x = 0 \text{ and } y = 1\,, \\ \neg(a \wedge b)\,, & \text{if } x = 1 \text{ and } y = 0\,, \\ \neg(a \vee b)\,, & \text{if } x = 1 \text{ and } y = 1\,. \end{cases}$$

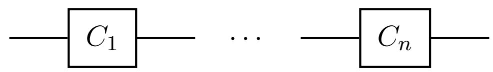
(a) Write a *behavioral* VHDL architecture for the CLB.

(b) Draw a hardware schematic, *whose basic components are the logical gates* `not`, `and`, *and* `or`.

(c) Assuming that each gate has a WCET of 10ns, what is the WCET of your CLB's structural architecture?

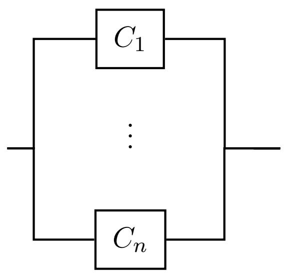
Problem 5 (Reliability) [10 points]

If n independent modules with reliability $R(t) = e^{-\lambda t}$ are composed sequentially, what is the mean time to failure (MTTF) of the whole system?



Problem 6 (Reliability) [10 points]

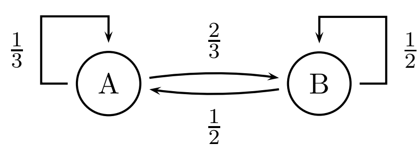
You are to build a system S by composing in parallel n components $C_1, \dots, C_n$.



Each component C_i has reliability $\frac{1}{2}$ and costs 100 euros. What is the minimal cost of system S, if its reliability is at least $\frac{9}{10}$?

Problem 7 (Markov processes) [10 points]

Given the following Markov process, compute $s_{\text{lim}}(A)$ and $s_{\text{lim}}(B)$.



Problem 8 (A/D conversion) [10 points]

Consider the problem of converting an analog value ranging between $U_{\text{min}} = 3V$ and $U_{\text{max}} = 18.5V$ into a corresponding 5-bit digital value ranging between 00000_2 and 11111_2. Using the successive approximation method, carry out the conversion of the input voltages $U_{\text{in}} = 9.2V$ and $16.4V$ into the corresponding binary values. In each case, and for each step of the conversion, show the arranged comparison voltage U_{ref} as well as the binary value after each comparison.

Problem 9 (Scheduling) [10 points]

Let $\mathcal{J} = \{J_1, \ldots, J_5\}$ be an aperiodic synchronous task set with

$$
\begin{array}{ll}
C_1 = 6 & d_1 = 3 \\
C_2 = 4 & d_2 = 8 \\
C_3 = 4 & d_3 = 13 \\
C_4 = 3 & d_4 = 16 \\
C_5 = 9 & d_5 = 24
\end{array}
$$

Construct a schedule σ_{max} that minimizes the maximum lateness L_{max}, as well as a schedule σ_{late} that minimizes the number of late tasks N_{late}.

Problem 10 (Scheduling) [10 points]

Construct a periodic task set Γ with the following properties:

1. each task τ_i has phase $\Phi_i = 0$;
2. Γ is schedulable by EDF;
3. Γ is not schedulable by RM;

For each task τ_i, specify the period T_i, the relative deadline D_i, and the computation time C_i.

Problem 11 (Scheduling) [10 points]

Construct a periodic task set Γ with the following properties:

1. each task τ_i has phase $\Phi_i = 0$;
2. Γ is schedulable by DM (Deadline Monotonic);
3. Γ is not schedulable by RM (Rate Monotonic).

For each task τ_i, specify the period T_i, the relative deadline D_i, and the computation time C_i.

Problem 12 (Scheduling) [10 points]

Construct a periodic task set Γ with the following properties:

1. each task τ_i has phase $\Phi_i = 0$;
2. $U(\Gamma) = \frac{1}{2}$;
3. Γ is not schedulable by EDD.

For each task τ_i, specify the period T_i, the relative deadline D_i, and the computation time C_i.

Problem 13 (Scheduling) [20 points]

Consider the problem of scheduling a set of synchronous aperiodic tasks on a uniprocessor machine. The algorithm SJF (shortest job first) executes the tasks in nondecreasing order of computation time.

For each of the following criteria, determine whether the SJF algorithm minimizes it:

(a) maximum lateness $L_{max} = \max_i(f_i - d_i)$;

(b) average response time $\overline{R} = \frac{1}{n}\sum_{i=1}^{n} f_i$;

(c) total completion time $T_c = \max_i(f_i)$;

(d) weighted sum of completion times $T_w = \sum_{i=1}^{n} w_i f_i$;

(e) number of late tasks $N_{late} = \sum_{i=1}^{n} (\mathit{if}\ \ f_i > d_i\ \ \mathit{then}\ 1\ \mathit{else}\ 0)$.

For each criterion, if SJF minimizes it, give a formal proof; otherwise give a counterexample.