Written exam for
IE1204/5 Digital Design
monday the 28/10 2013 9.00-13.00

General Information
Examiner: Ingo Sander.

Teacher: William Sandqvist, phone 08-790 4487 (Kista IE1204)
Exam text does not have to be returned when you hand in your writing.

Aids: No aids are allowed!
The exam consists of three parts with a total of 12 tasks, and a total of 30 points:

Part A1 (Analysis) contains eight short questions. Right answer will for six of the questions give you one point and for two of the questions one or two points. Incorrect answer will give you zero points. The total number of points in Part A1 is 10 points. To pass the Part A1 requires at least 6p, if fewer points we will not look at the rest of your exam.

Part A2 (Methods) contains two method problems on a total of 10 points.
To pass the exam requires at least 11 points from A1 + A2, if fewer points we will not look at the rest of your exam.

Part B (Design Problems) contains two design problems of a total of 10 points. Part B is corrected only if there are at least 11p from the exam A-Part.

NOTE! At the end of the exam text there is a submission sheet for Part A1, which can be separated to be submitted together with the solutions for A2 and B.

For a passing grade (E) requires at least 11 points on the exam.
Grades are given as follows:

<table>
<thead>
<tr>
<th>0 –</th>
<th>11 –</th>
<th>16 –</th>
<th>19 –</th>
<th>22 –</th>
<th>25</th>
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</thead>
<tbody>
<tr>
<td>F</td>
<td>E</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

The result is expected to be announced before Monday 18/11 2013.
Part A1 (Analysis).

Only answers are needed in Part A1. Write the answers on the submission sheet for Part A1, which can be found at the end of the exam text.

1. 2p/1p/0p

A function \( f(x, y, z) \) is described on normal form as a product of maxterms (product-of-sums)
\[
f(x, y, z) = \{PoS\}_{\text{normal}} = (x + y + z)(x + y + z)(x + y + z)(x + y + z)
\]
a) write the function on its normal form as a sum of minterms (sum-of-products)
\[
f(x, y, z) = \{SoP\}_{\text{normal}} = ?
\]
b) write the function as a minimal sum-of-products
\[
f(x, y, z) = \{SoP\}_{\text{min}} = ?
\]

2. 2p/1p/0p

The 4-bit number 0011\(_2\) is connected to a 4-bit fulladder which is connected as shown in the figure (the adder is of the same type 74283 as you have experienced at lab).

a) What will the sum \( S_4S_3S_2S_1 \) be, and what will the outgoing carry-bit \( C_{OUT} \) be?

b) What signed decimal number, does \( S_4S_3S_2S_1 \) represent if we are using 2-complement 4-bit representation?

3. 1p/0p

The figure at right is a Karnaughmap of a function of four variables.
Write the function as a minimal sum-of-products, it’s SoP-form.

(“-” in the map stands for ”don’t care”)
\[
f(a, b, c, d) = \{SoP\}_{\text{min}} = ?
\]
4. 1p/0p
NOR is a complete logic, all other gates could be constructed with only NOR-gates.
Write a simplified expression of 
\( Q = f(A, B) = ? \) so that it will be clear which function it is.

5. 1p/0p
Write the logical expression that is realized by the CMOS-circuit in the figure?

\[ Y = f(A, B, C) = ? \]

6. 1p/0p
An synchronous sequential circuit starts in the state \( q_1q_0 = 00 \). Write the states \( q_1q_0 \) for the following three clockpulses.

\( (q_1q_0) = 00 \rightarrow ?? \rightarrow ?? \rightarrow ?? \)

7. 1p/0p
Fill in \( Q \) in the time-diagram. \( D \) is a synchronous input, \( S \) and \( R \) are asynchronous inputs. You will also find the figure on the submission sheet.
8. 1p/0p
VHDL-code describes a known circuit/component. Which one is it? Choose between:

a. An EXOR-gate.
b. An EXNOR-gate.
c. A JK-flipflop.
d. A D-flipflop.
e. A T-flipflop.
f. A SR-latch.

```vhdl
entity circuit is
Port ( X : in std_logic;
      CLOCK : in std_logic;
      Y : out std_logic
    );
end circuit;

architecture Behavioral of circuit is
begin
  process (CLOCK, X)
  begin
    if (CLOCK = '1' and CLOCK'event) then
      if (X = '1') then
        Y <= NOT Y;
      else
        Y <= Y;
      end if;
    end if;
  end process;
end Behavioral;
```
Part A2 (Methods).

Note! Part A2 will only be corrected if you have passed part A1 (≥6p).

9. 4p
A Boolean function $f$ of three variables $c b a$ has it’s truthtable in the figure at right.

a) (1p) Show how this function can be realized with a 8:1 MUX (according to the figure).

b) (1p) Realize the function minimized with the use of only NAND-gates. No inverted input signals are available, all inverting must be done NAND-gates.

c) (2p) Realize the function with a 4:1 MUX. Only the input signals $c b a$ are available. Find a solution that doesn’t use any inverters (and no gates).

10. 6p
The figure shows a statediagram for a synchronous counter with an input $x$.

a) (1p) Draw the counters coded state table

\[
q'_1 q'_0 = f(q_1, q_0, x) .
\]

b) (2p) Give the functions for the next state

\[
q'_1 = ? \\
q'_0 = ?
\]

c) (1p) Realize the counter with D-flipflops and any gates. Draw the circuit diagram.

d) (2p) An other synchronous sequential circuit has the state table shown in the figure at right. Minimize the number of states and draw the minimized state diagram.

$z$ is the output signal and $w$ is the input signal, $S$ stands for the states (A …E).
Part B (Design Problems).

Note! Part B will only be corrected if you have passed part A1+A2 (≥11p).

11. 5p
A synchronous Moore-machine has two input signals \( w_1w_0 \) and one output signal \( z \). For the input sequence \( w_1w_0 10, 11 \) the output signal should be \( z = 0 \). For the input sequence \( w_1w_0 01, 11 \) the output signal should be \( z = 1 \). For \( w_1w_0 01, 10 \) the output signal \( w \) should change its value. For all other input sequences the output signal should remain the same.

Present the Moore-machine’s state table, minimize it as far as possible. Draw the minimized state diagram.

12. 5p
An optical pulsesensor (as in your computer mouse) consists of two fotoce ll’s \( A \) and \( B \) and a disk that interrupts the light for the sensor according to how the disk is rotated.

You should construct an asynchronous Moore-compatible statemachine with two inputs \( A \) and \( B \) and one output \( U \), which will have \( U = 1 \) if, and only if, the three latest input signals being exactly \( AB \): 00 10 11.

(This sequence will appear when the disc is rotating in clockwise direction, cw, se the figure above. The figure also shows that this sequence will not appear when the disc is rotating in the counterclockwise, ccw, direction).

Your answer should contain a statediagram, a flowtable, a suitable state code, an excitation table free from race conditions, and equations for the next state without hazards, and an output function. You don’t have to draw the actual circuit diagram.

Good luck!
Submission sheet for Part A1  Sheet 1

( remove and hand in together with your answers for part A2 and part B )

Last name: ___________________________  Given name: ___________________________

Personal code number: ___________________________

Write down your answers for the questions from Part A1 (1 to 8)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
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</table>
| 1 2/1/0 | a) $f(x, y, z) = \{SoP\}_{\text{normal}}$ = ?  
          | b) $f(x, y, z) = \{SoP\}_{\text{min}}$ = ?  |
| 2 2/1/0 | a) $S_4S_3S_2S_1$ ? och $C_{\text{OUT}}$?  
          | b) $S_4S_3S_2S_1$ Decimal number with sign?  |
| 3 1/0   | $f(a, b, c, d) = \{SoP\}_{\text{min}}$ = ?  |
| 4 1/0   | $Q = f(A, B)$ = ? (name?)  |
| 5 1/0   | $Y = f(A, B, C)$ = ?  |
| 6 1/0   | $(q_1q_0) = 00 \rightarrow ?? \rightarrow ?? \rightarrow ??$  |
| 7 1/0   | Name of the circuit (a, b, …, f):  |
| 8 1/0   | This table is completed by the examiner!  |

This table is completed by the examiner!

<table>
<thead>
<tr>
<th>Part A1</th>
<th>Part A2</th>
<th>Part B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>9</td>
<td>10</td>
<td>11</td>
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