

Test of Pearl 000 — Binary logic and computer architecture
Pearls of Computer Science (202001022)
Bachelor module 1.1, Technical Computer Science, EEMCS
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- You may use 1 A4 document with your own notes for this exam and a *simple* calculator.
- Scientific or graphical calculators, laptops, mobile phones, books etc. are not allowed.
Put those in your bag now!
- Questions marked with **MC** must be answered on the separate multiple-choice form, at the number indicated in the circle.
- Other questions have a **box** in which you can write the answer on this paper; this paper must be handed in.
- Total number of points: 100.
Total number of pages: 6.

Your name:

Your student number:

1. Binary numbers

4 pt

(a) What is the decimal number -9 expressed as a 5-bit 2-complement binary number?

- A. 00110
- B. 01001
- C. 10110
- D. 10111
- E. 11000
- F. 11001
- G. a 5-bit 2-complement number cannot represent -9

MC01

4 pt

(b) Suppose someone sends you a 1-complement binary number, but you think it's a 2-complement binary number. What error will this introduce?

- A. You get the sign wrong.
- B. You get the sign wrong, but only if the number is negative.
- C. You're off by one.
- D. You're off by one, except when the number is zero, then there's no error.
- E. If the number is positive, no error; if it's negative, you're off by 1.
- F. No error, except when the sender used the negative 0 possibility of 1-complement; in that case, you're off by one.

MC02

4 pt

(c) Convert hexadecimal 2A2 to hexadecimal.

- A. 302
- B. 428
- C. 674
- D. 690
- E. 1282
- F. 2306
- G. this is not a valid hexadecimal number

MC03

4 pt

(d) Convert the hexadecimal number E2 to binary:

- A. 101110
- B. 00101110
- C. 10111000
- D. 11100010
- E. 11110100
- F. 1110000010
- G. 1111000100

MC04

4 pt

(e) Suppose we shift a 5-bit unsigned binary number X one position to the right, thus dropping its right-most bit, and insert a zero bit at the left. Which statement is true?

- A. This calculates $X/2$, rounded down to an integer
- B. This calculates $X/2$, rounded up to an integer
- C. This calculates $X/2$, but does not round it
- D. This calculates $X/2$, rounded depending on the left-most bit
- E. This calculates $2X$, rounded down to an integer
- F. This calculates $2X$, rounded up to an integer
- G. This calculates $2X$, but does not round it

MC05

4 pt

(f) Which of the following is true about 8-bit 2's complement numbers?

- A. There are two ways of representing the number 0.
- B. They can represent -127 up to and including $+127$ (but not outside this range).
- C. Inverting all bits is the same as changing the number's sign.
- D. There are no numbers that can be represented in multiple ways.

MC06

2. Boolean logic

4 pt

(a) Consider the following system.

Input X is 1 if and only if a student passed the exam.

Input Y is 1 if and only if the student cheated.

Give the truth table for an output that is 1 if and only if the student passed without cheating.

Note that you have to answer 4 multiple choice questions here: for 0 choose A, for 1 choose B.

X	Y	output
0	0	MC07
0	1	MC08
1	0	MC09
1	1	MC10

12 pt

(b) Consider the following derivation in Boolean algebra. For each step, indicate on the multiple-choice

form which relationship is used, using the following options:

form which relationship is used, using the following options:	{	A commutative property
		B identity property
		C complement property
		D distributive property
		E DeMorgan's theorem
		F this step is not correct

(Note: check each step for equality only to the previous line. So if one step is incorrect (option F), the next step by itself can still be correct, even though of course it's no longer equal to what we started with.)

$$R(\overline{P} + \overline{Q}) + PQ + R + 0$$

MC11	= $R(\overline{P} + \overline{Q}) + PQ + R$
MC12	= $R(\overline{P} + \overline{Q}) + PQR$
MC13	= $R\overline{P}\overline{Q} + PQR$
MC14	= $\overline{P}\overline{Q}R + PQR$
MC15	= $(\overline{P}\overline{Q} + PQ)R$
MC16	= R

6 pt

(c) Sketch a diagram implementing the following formula with only NOR gates: $\overline{\overline{A + C}} + \overline{\overline{A \cdot B}}$

4 pt

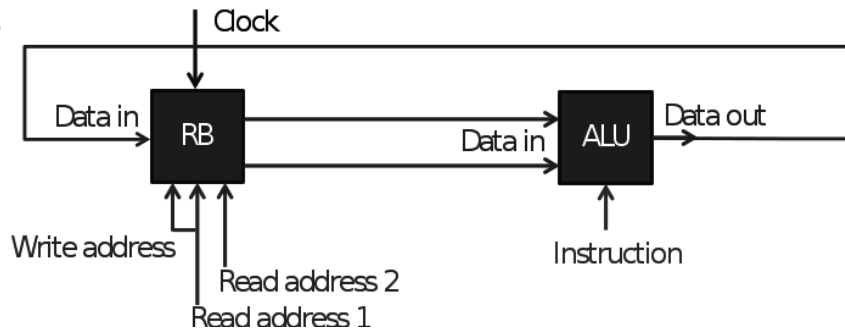
(d) Suppose you take two 2-input NOR gates, and feed their outputs into a third 2-input NOR gate. Does this as a whole work as a 4-input NOR gate?

MC17

- A. Yes, it does.
- B. No, a 4-input NOR gate is not well-defined.
- C. No, for that we should replace the third NOR gate by an OR gate.
- D. No, for that we should replace the first two NOR gates by OR gates.
- E. No, for that we should do both of the above-mentioned changes.
- F. No, for that we should replace the third NOR gate by a NAND gate.
- G. No, for that we should replace the first two NOR gates by NAND gates.

12 pt

3. Problem 3



The ALU of the processor above has two instructions: 0 = 'ADD' and 1 = 'MUL'. The register bank (RB) contains four 8-bit registers. Give for this processor the program for computing $R1 \times R2 \times (R1 + R1)$ and storing the result into R1. (You may not need all timeslots.)

	read address 1 / write address	read address 2	instruction
Timeslot 0			
Timeslot 1			
Timeslot 2			
Timeslot 3			
Timeslot 4			

Continued on next page...

5 pt (b) How many clock cycles does the program (of the previous page) take? Explain.

15 pt **5. Problem 5**

What is the mathematical function that is computed by the code below?
Assume that X and Y are larger than 0; the result is available in R19.
Write as a function of X and Y, e.g. $f(X, Y) = X + Y$, and explain.

```
LDI R17, $X
LDI R18, $Y
LDI R19, $00
LDI R21, $01
label1:
ADD R19, R17
ADD R19, R18
SUB R18, R21
BRNE label1
```

End of this exam. — Scratch space below this line