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Computer systems architecture

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Modules:

- I. Basics of computer architecture and programming in assembler
- II. Hardware design in Verilog: combinatorial and sequential circuits
- III. Overview of modern computers architecture

Lectures:

1. Introduction to computer architecture. Von Neumann architecture.
2. Introduction to programming in X86 assembler. Memory and registers. Format of instruction. Basic instructions for moving data and integer arithmetic.
3. Basic addressing modes. Branching and loops. Calling libc functions.
4. Subroutine call. Modular software design.
5. Using stack to allocate subroutine parameters and local variables. Recursive functions.
6. Floating point arithmetic and data conversion.
7. Computer memory organization: cash, segments, pages. Special registers. Processor state word.
8. Basics of communication with external devices. Interrupts. Input/output ports.
9. Case study – hardware design with Verilog: sequential and sequential-parallel adders.
10. Overview of basic combinatorial circuits.
11. Synthesis and minimization of state machines. Elementary state machines.
12. Synthesis of sequential logic circuits in Verilog.
13. Operational and control automata. Microprogramming. Typical scheme of MIPS processor.
14. Overview of computer architecture for embedded application.
15. Overview of modern high-performance computing systems architecture.

Laboratory:

1. Data representation in computer: text, integer numbers, float numbers. Task: provide computer representation for given data; implement addition and subtraction of integer numbers.
2. Run and trace work of simple assembler program. Task: calculate arithmetic expression; source data are stored; output the result.
3. Develop assembler program. Task: a given mathematical function as a series (Taylor) partial sum.
4. Benchmarking programs. Task: from C or other language call assembler math function and compare its performance with standard library function on a random array of data.

5. Adders' circuits design. Task: synthesize and minimize Boolean functions for a one bit full adder; specify the circuit in Verilog and create its scheme; test the circuit work; synthesize sequential and parallel-sequential n bit adders hierarchically using 1 bit adder.
6. Basic combinatorial circuits design. Task: design and test, using Verilog, a given circuit – comparator, multiplexor, de-multiplexor, scrambler, de-scrambler etc.
7. Abstract synthesis and minimization of state machines. Task: synthesize a state machine for a given application, minimize state machine. Variant example – chocolate bar vending machine.
8. Synthesis of sequential logic circuits. Task: for a given abstract state machine implement it using specified gates and triggers (flip-flops); obtain sequential logic circuit scheme using Verilog; test the circuit work.
9. Oral presentation of a historical computer's architecture. Up to 10 slides. List of computers: <https://www.computerhistory.org/timeline/computers/>
10. Oral presentation of a modern supercomputer's architecture. Up to 10 slides. List of computers: <https://top500.org/>

Tools:

- A. Assembler: <https://www.jdoodle.com/compile-assembler-gcc-online/>
- B. Verilog: <http://digitaljs.tilk.eu/>

Literature:

1. Sarah L. Harris and David Money Harris, Digital Design and Computer Architecture, 2016.
2. Richard C. Detmer, Introduction to 80X86 Assembly Language and Computer Architecture, Jones & Bartlett Learning, 2015.
3. Vaibbhav Taraate, Digital Logic Design Using Verilog: Coding and RTL Synthesis, Springer, 2016.

Supplementary literature:

1. Peter Barry and Patrick Crowley, Modern Embedded Computing, 2012.
2. Hesham El-Rewini, Mostafa Abd-El-Barr, Advanced Computer Architecture and Parallel Processing, Springer, 2005.
3. Mi Lu. Arithmetic and Logic in Computer Systems. John Wiley & Sons: New Jersey, 2004.
4. Mark Burrell, Fundamentals of Computer Architecture, MIT Press, 2017.
5. Andrew S. Tanenbaum, Todd Austin, Structured Computer Organization, International Edition, Pearson Education, 2013.
6. S. Salivahanan, Digital Circuits and Design, Oxford University Press, 2018.