Design Your Own CPU

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How can we design a processor?

General principle: Step-by-step

- Design and test simple components
- Connect simple components to form more complex component, test again
- Hide complexity: Complex component becomes simple

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Sounds familiar?

- In RS, we saw a simple processor and how it works
- Implementing CPU completely on our own without any help would be difficult
- Take a simplified version of the MIPS processor as an example
- Learn the skills necessary to design and test a simple CPU
- Apply learned skills to design more sophisticated systems

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- Simulate digital circuits for testing
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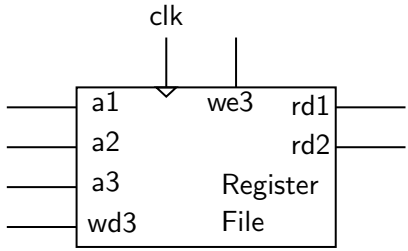
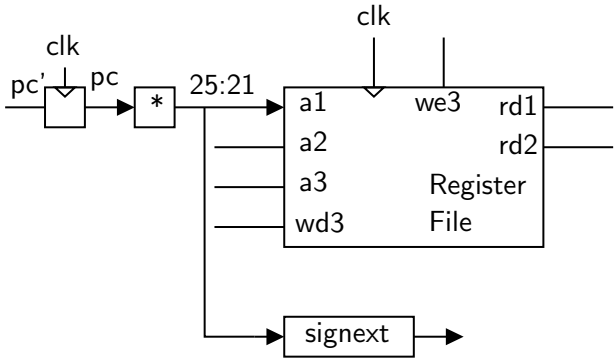
Learning VHDL has many benefits!

- Used widely in the industry by many leading companies
- Design digital systems from scratch
- Run designs in simulators and on real hardware
- Preparation for jobs on digital design

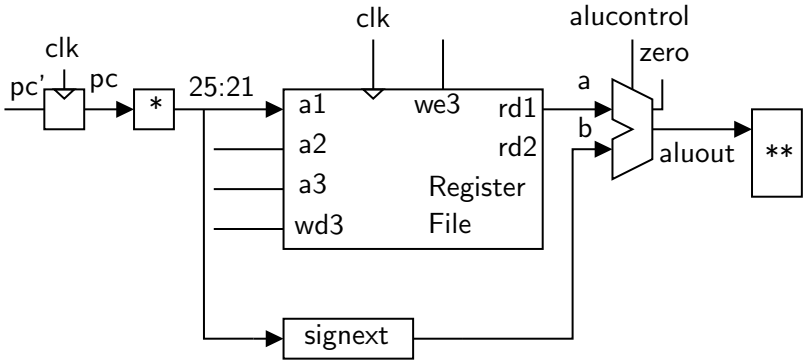
How to build a CPU: State Elements



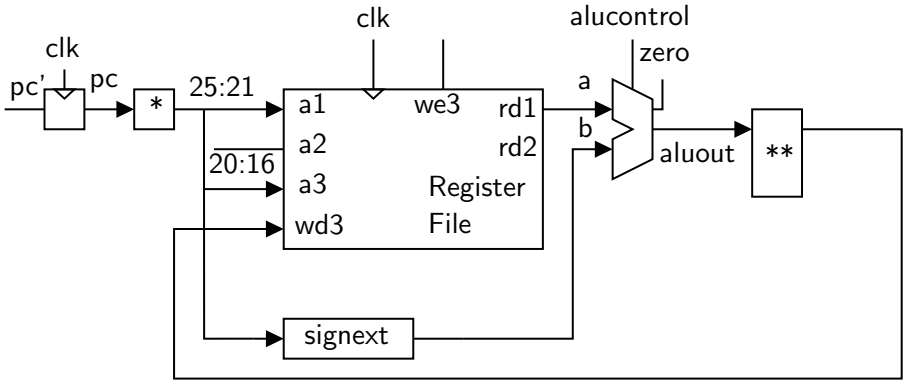
How to build a CPU: Connect State Elements



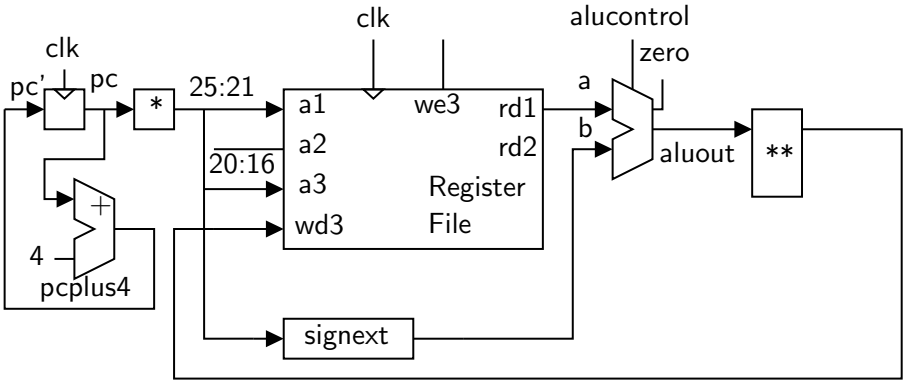
How to build a CPU: Connect ALU



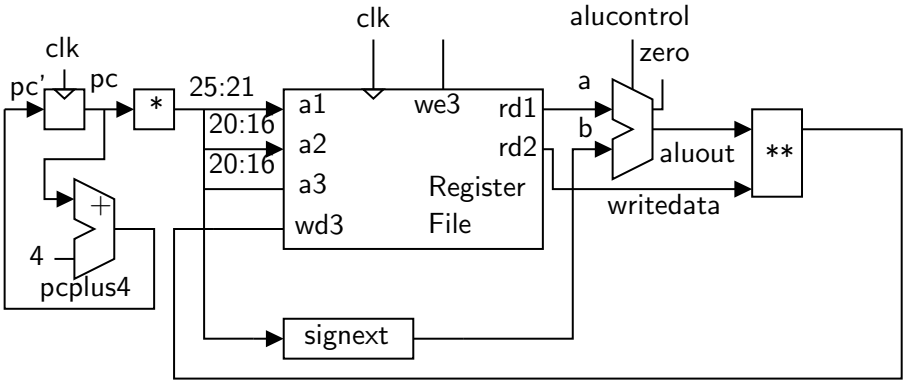
How to build a CPU: Load Word



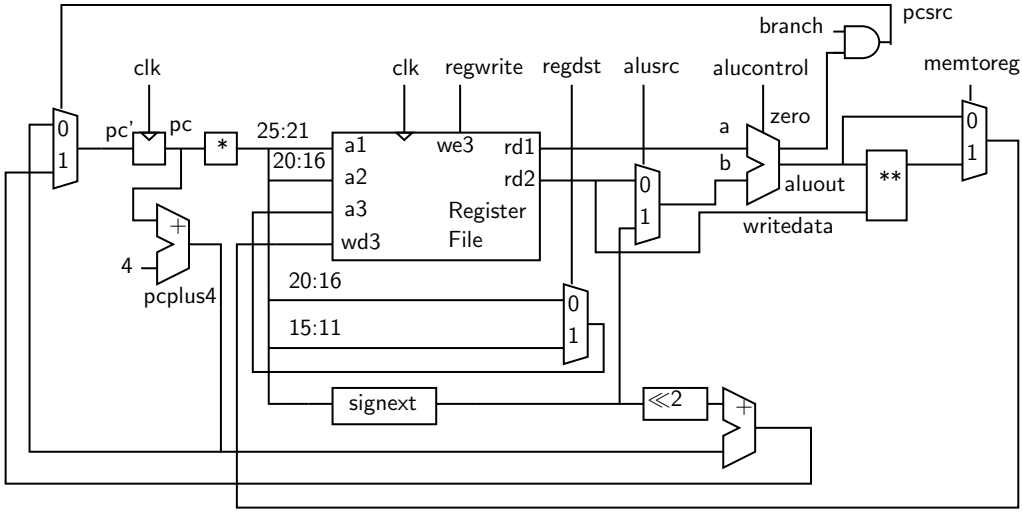
How to build a CPU: PC+4



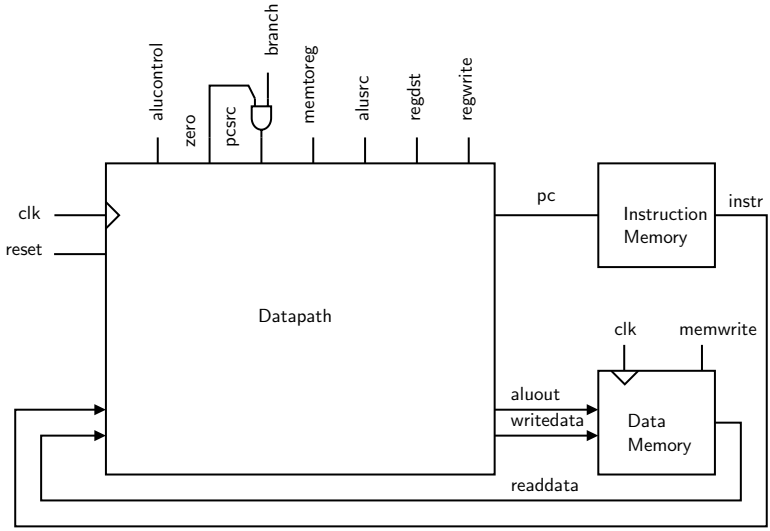
How to build a CPU: Store Word



How to build a CPU: Multiplexers for Control



How to build a CPU: Hide Complexity



Some Project Ideas

- Add support for more instructions
- Advance single cycle MIPS: Multicycle, pipelines, branch predictiors, superscalar, SIMD, and many more possibilities!
- Build extensions (e.g. for matrix-mul., neural networks, other ML, etc.)
- Design another CPU from scratch (RISC-V, older CPUs like Intel 8080, GameBoy processor, etc.)
- Modify another existing CPU microarchitecture
- ...
- Start here, continue as a bachelor thesis!

Fachprojekt: Design Your Own CPU

Timeplan

- Weeks 1-3: Crash course in VHDL and CPU Design
  - Basic concepts in VHDL
  - Tools: GHDL and GTKWave
  - Implementation of logic gates
  - Design process of MIPS CPU and testing
- Weeks 4-5: Seminar phase
  - Focus on topics that are interesting to you
  - Build your expertise
- From week 6 on: Finalize plans and work on project
  - Work in a group to realize your project idea
  - Focus on experience
  - You have time until the semester ends