

Enhanced Tools for RISC-V Processor Development and Customization

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Who is Cudasip?



- The **leading provider** of RISC-V processor IP
- Company founded in 2014 in the Czech Republic
- Founding member of the RISC-V Foundation, www.riscv.org
- Member of several working groups in the Foundation
- Actively contributing to LLVM and other open-source projects
- Now **Cudasip GmbH**
 - Headquarters in Munich, Germany
 - R&D in Brno, Czech Republic
 - Offices in Silicon Valley, US, and Shanghai, Pudong PRC

Codasip Solutions

- **Codasip Bk** = portfolio of RISC-V processors
- **Codasip Studio** = unique design automation toolset for easy processor modification
 - Performance/power efficiency and low-cost
 - Algorithm acceleration (DSP, security, audio, video, etc.)
 - Profiling tools of embedded SW for tailoring processor IP
- **CodAL** = Codasip's own proprietary C-like language for processor architecture description



*Codasip introduced its first RISC-V processor
in November 2015*

Bk: Customizable RISC-V Cores

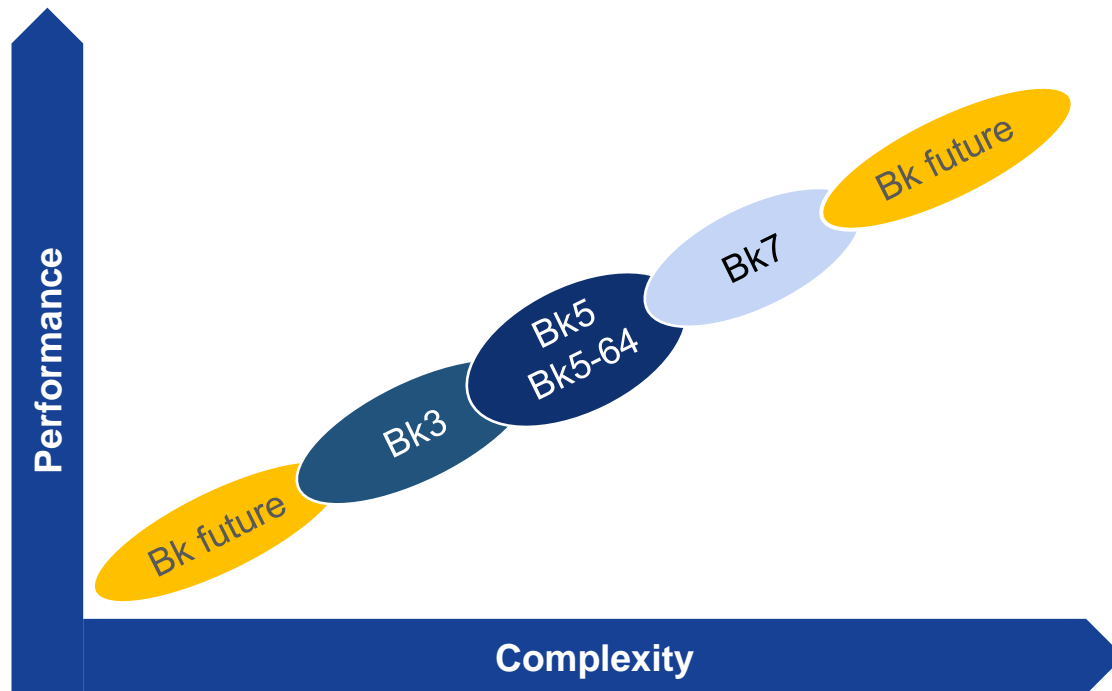


Bk = the Berkelium series, Cudasip's RISC-V processors

- ✓ **Available immediately**
- ✓ **Pre-verified, tape-out quality IP**
 - Users do not need to verify IP
- ✓ **Industry-standard interfaces**
 - AMBA for instruction and data bus
 - JTAG (4pin/2pin) for debugging
- ✓ **Fully customizable**
 - Support for all RISC-V ISA standard extensions
 - Enable easy creation of performance-enhancing resources, such as:
 - Custom registers for computations
 - Custom control-status registers
 - Novel interfaces such as GPIO, FIFO, scratch-pad memory
 - Even **pipeline modifications** are possible
 - Bk core CodAL source as the starting point for your own RISC-V core

Bk Cores Roadmap

Comprehensive offering including new advanced designs



Bk3

- Entry-level 32bit RISC-V core

Bk5, Bk5-64

- 32bit and 64bit RISC-V cores with balanced pipeline

Bk7

- Linux-ready 64bit RISC-V core

Future Bk

- High-performance RISC-V cores
 - Advanced pipeline
 - Advanced DSP features
- Energy-efficient/low power RISC-V cores

All Bks

- *Rich set of configuration options*
- *Fully customizable*

Standard and Custom Extensions

RISC-V offers a wide range of ISA modules:

- **I/E** for integer instructions
- **M** for multiplication and division
- **C** for compact instruction
- **F/D** for floating point operations
- WIP: **B**, **P**, **V**, ...

However, it may **not be enough** for your application domain or if you are looking for a key **differentiator...**



Why Customized Tools?

One of the biggest advantages of the RISC-V open ISA is **customization**.
However, a customized processor also needs a customized SDK...

Standard customization (manually adding custom ISA extensions):

1. Model and simulate a new instruction
2. Modify the compiler
3. Modify assembler
4. Add support in the debugger
5. Verify, verify, verify...

→ **Challenging, time-consuming, expensive**

Benefits of automatic generation of customized tools:

- ✓ Reduced time needed for tool modification
- ✓ Reduced cost of custom processor development
- ✓ The resultant processor is easily programmable using standard C/C++
- ✓ Proven open-source technologies and frameworks allow for easy integration

What is Cudasip Studio?

A unique collection of tools for **fast & easy modification** of RISC-V processors. **All-in-one**, highly automated. Introduced in 2014, **silicon-proven** by major vendors.

Customization of base instruction set:

- Single-cycle MAC
- Custom crypto functions
- And many more...

Complete IP package on output:

- C/C++ LLVM-based compiler
- C/C++ Libraries
- Assembler, disassembler, linker
- ISS (incl. cycle accurate), debugger, profiler
- UVM SystemVerilog testbench

Cudasip Studio

RTL Automation

Verilog **VHDL**

SDK automation



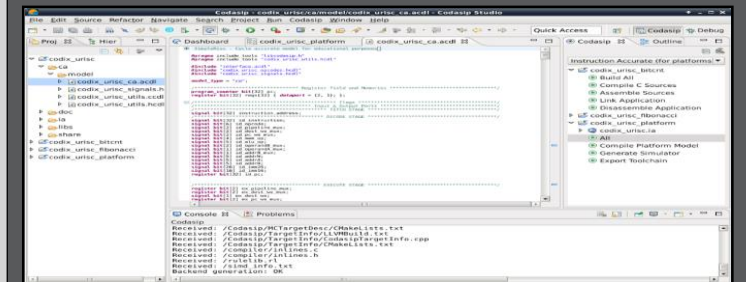
Verification Automation



CodAL – processor description language

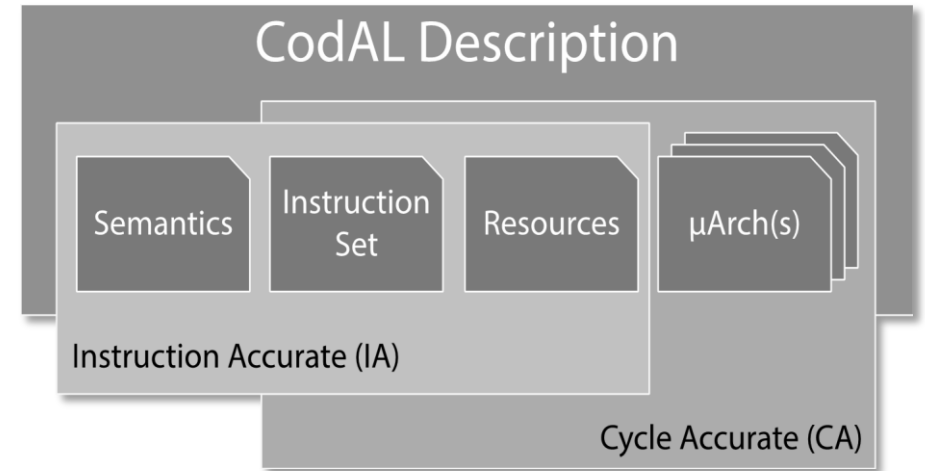
```
element i_mac {
  use reg as dst, src1, src2;
  assembly { "mac" dst "," src1 "," src2 };
  binary { OP_MAC dst src1 src2 0:bit[9] };
  semantics {
    rf[dst] += rf[src1] * rf[src2];
  };
};
```

Integrated processor development environment



CodAL Models

- Easy-to-understand C-like language that models a rich set of processor capabilities
- All Cudasip processors are created and verified using CodAL
- Multiple microarchitectures can be implemented in a single CodAL model
- CodAL models are provided to Cudasip IP customers as a starting point for their own processor optimizations and modifications



```
/* Multiply and accumulate: semantics  
dst += src1 * src2 */  
  
element i_mac {  
    use reg as dst, src1, src2;  
    assembler { "mac" dst " " src1 " " src2 };  
    binary { OP_MAC:8 dst src1 src2 0:9 };  
    semantics {  
        rf[dst] += rf[src1] * rf[src2];  
    };  
};
```

Example: B Extension *Functional* Model

- Written in CodAL
 - in 10 days by a single engineer
- 900 lines of code
- Software development kit (SDK) automatically generated by Studio, including
 - Instruction set simulator (ISS)
 - Profiler to check the impact of the extensions
 - C compiler
 - Able to use a subset of instructions automatically (rotations, compact instructions, shifts, etc.)

```
element i_gzip
{
  use opc_gzip as opc;
  use reg_any as dst, src1;
  use shift_imm as imm ;
  assembler { opc dst ", " src1 ", " imm};
  binary { opc[OPC_FRAG_SHIFT] imm src1 opc[OPC_FRAG1] dst opc[OPC_FRAG0] };
  semantics
  {
    rf_gpr_write (dst, gzip_uhlen(rf_gpr_read(src1), imm));
  };
};
set isa_b += i_gzip;
```

```
uXlen gzip_uhlen (const uXlen rsc1 , const uXlen mode)
{
  uint32 zip_mode, x ;
  x = rsc1;
  zip_mode = mode & 31;
  if(zip_mode & 1)
  {
    if(zip_mode & 2)
      x = gzip_stage (x, MASK_ZIP2_L, MASK_ZIP2_R, 1);
    if(zip_mode & 4)
      x = gzip_stage (x, MASK_ZIP4_L, MASK_ZIP4_R, 2);
    if(zip_mode & 8)
      x = gzip_stage (x, MASK_ZIP8_L, MASK_ZIP8_R, 4);
    if(zip_mode & 16)
      x = gzip_stage (x, MASK_ZIP16_L, MASK_ZIP16_R, 8);
  }
}
```

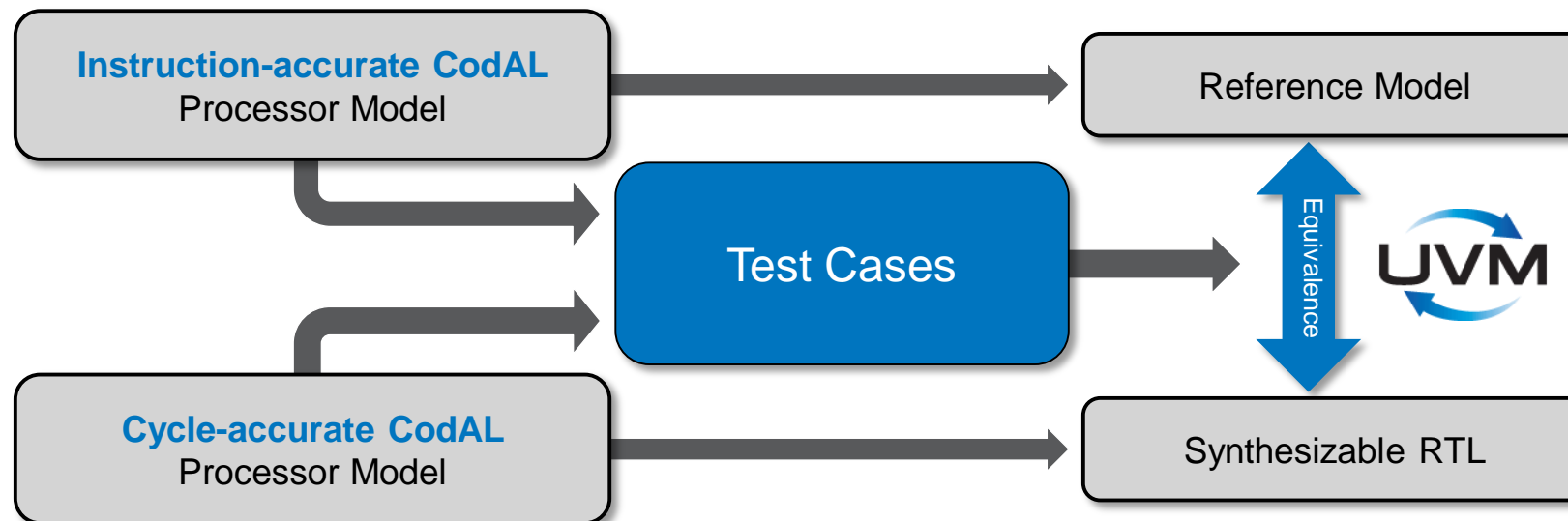
Example: B Extension *Implementation* Model

- Written in CodAL
 - in 3 weeks by a single engineer
- 1500 lines of code
- Hardware design kit (HDK) automatically generated by Studio, including
 - RTL
 - Testbench
 - UVM-based verification environment

```
#ifndef OPTION_EXTENSION_B
    case SLO:
        ex_result = ones_shifter_32(SLO, ex_aluop1, ex_aluop2);
        break;
    case SRO:
        ex_result = ones_shifter_32(SRO, ex_aluop1, ex_aluop2);
        break;
    case ANDC:
        ex_result = (uxlen)ex_aluop1 & (~ ex_aluop2);
        break;
    case ROTR :
        ex_result = ex_aluop1 >>> ex_aluop2;
        break;
    case ROTL :
        ex_result = ex_aluop1 <<< ex_aluop2;
        break;
    case CTZ :
        ex_result = codasip_ctlz_uint32(ex_aluop1);
        break;
    case CLZ :
        ex_result = codasip_cttz_uint32(ex_aluop1);
        break;
#endif
```

Processor IP Verification

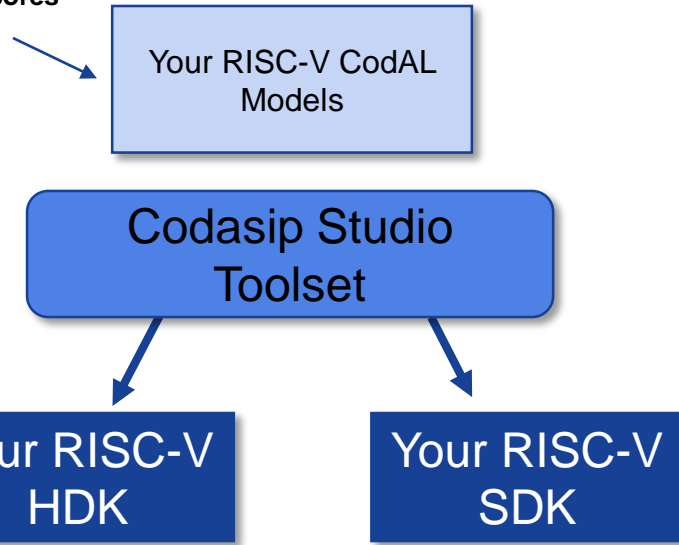
- Strong methodology based on standardized approach, simulation, and static formal analysis
- Consistency checker
- Random assembler program generator
- UVM verification environment
 - Environment in SystemVerilog generated automatically by Cudasip Studio
 - Checking if RTL corresponds to specification



Bk Core Customization with Codasip Studio

Start from Bk3/5/7 cores

1. Add instructions
2. Add resources
3. Modify pipeline
4. ...



Your RISC-V HDK

Hardware Design Kit

- RTL models
- Synthesis scripts
- Verification models and simulators
- Virtual prototypes

Your RISC-V SDK

Software Design Kit

- Compiler
- Assembler
- Linker
- Debugger
- IDE

Profiling of embedded application SW enables processor optimizations

ISA extensions are quickly implemented and analyzed during design space exploration

Instruction	Used Instruction	Sequence length	Sequence length %
ADDI	ADDI	154	64%
ADDI	ADDI	1	1%
ADDI	ADDI	84	24%

Summary

1. Cudasip is the leading provider of commercial-quality RISC-V IP

- Comprehensive **off-the-shelf** portfolio
 - From 32bit embedded to 64bit Linux-ready cores
 - Complete, fully verified IP packages
 - **Available immediately**
- Full-time, highly professional customer support staff

2. Cudasip offers easy, automatized way to customize RISC-V

- Customization brings more **performance**, lower **power/area**, and **differentiation**
- Cudasip provides a complete set of tools and resources to customize:
 - **CodAL** – C-like language for processor description
 - **Cudasip Studio** – a complete customization toolset

Thank you!

Questions?



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www.codasip.com

Codasip GmbH