Syntacore™
Custom cores and tools

SCRx family of the RISC-V compatible processor IP: compact MCU to octa-core SMP Linux

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RISC-V Day Tokyo
November 2020

Outline

- Company intro
- RISC-V compatible IP
- Customization services

Syntacore introduction

Semiconductor IP company, founding member of RISC-V foundation

Develops and licenses state-of-the-art RISC-V cores

- Immediately available, silicon-proven and shipping to volume
- 5+ years of *focused* RISC-V development
- Core team comes from 10+ years of highly-relevant background
- SDKs, samples in silicon, full collateral

Full service to specialize CPU IP for customer needs

- One-stop workload-specific customization for 10x improvements
  - with tools/compiler support
- IP hardening at the required library node
- SoC integration and SW migration support

Company background

Est 2015 , 60+ EEs

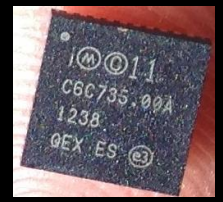
HQ at Cyprus (EU)

- R&D offices in St.Petersburg and Moscow (Russia)
- Representatives in APAC, EMEA, US

  Japan: Syncom Co.,LTD

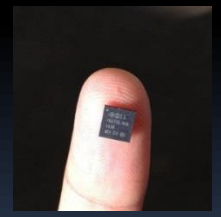
Team background:

- 10+ years in the corporate R&D (major semi MNC)
- Developed cores and SoC are in the mass productions

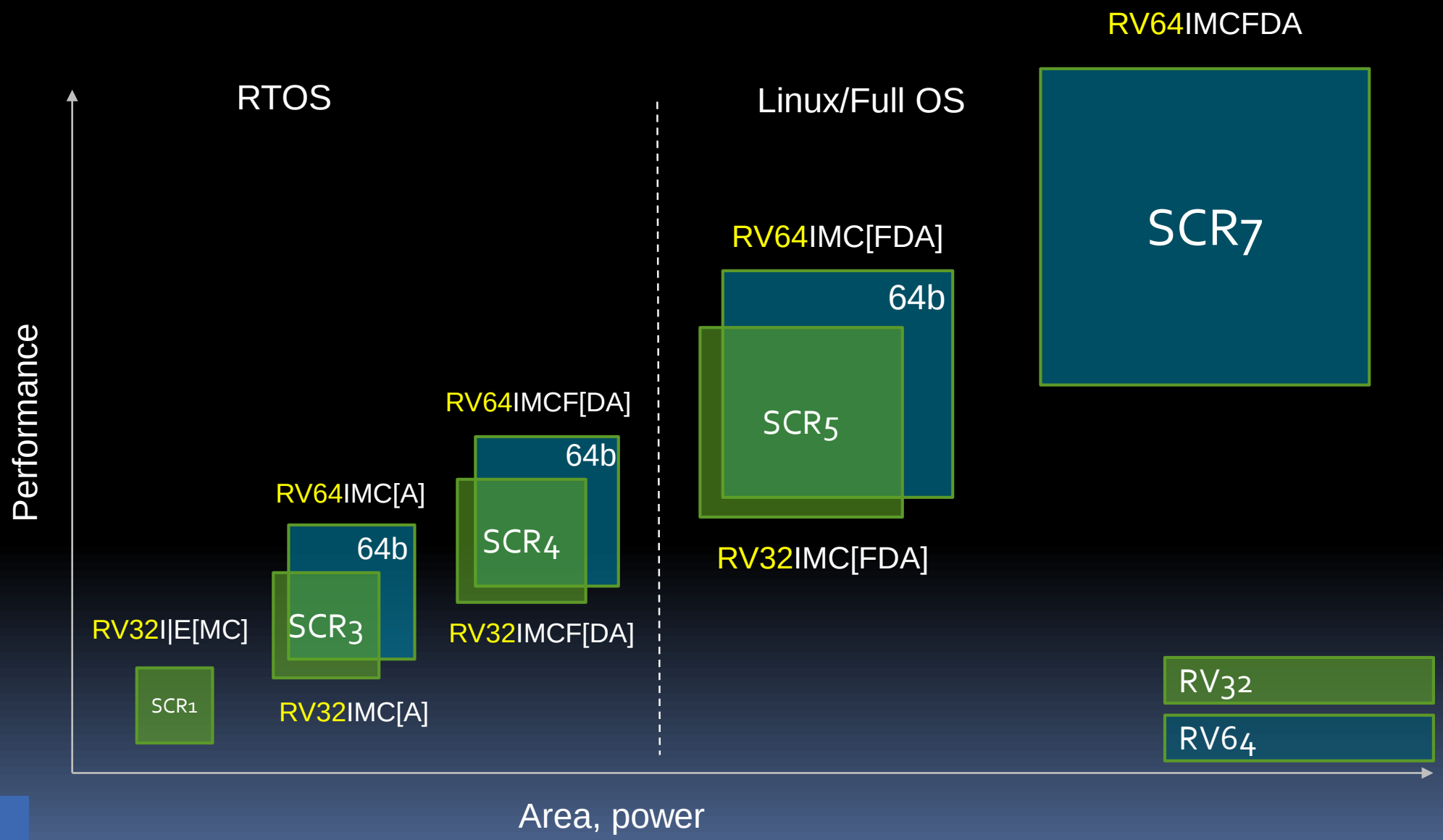


Expertise:

- high-performance and low-power embedded cores and IP
- ASIP technologies and reconfigurable architectures
- Architectural exploration & workload characterization
- Compiler technologies



SCRx baseline cores



State-of-the art RISC-V CPU IP

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Features			RTOS/ Bare Metal			Linux/ "Full" OS	
			SCR1* (FREE!)	SCR3	SCR4	SCR5	SCR7
Width		32bit	●	●	●	●	
		64bit		●	●	●	●
ISA			RV32I|E[MC]	RV[32|64]IMC[A]	RV[32|64]IMCF[AD]	RV[32|64]IMC[AFD]	RV64IMCAFD
Pipeline type			In-order	In-order	In-order	In-order	Superscalar
Pipeline, stages			2-4	3-5	3-5	7-9	10-12
Branch prediction				Static BP, RAS	Static BP, RAS	Static BP, BTB, BHT, RAS	Dynamic BP, BTB, BHT, RAS
Execution priority levels			Machine	User, Machine	User, Machine	User, Supervisor, Machine	User, Supervisor, Machine
Extensibility/customization			●	●	●	●	●
Execution units	MUL/DIV	area-opt	●	○	○		
		hi-perf	○	●	●	●	●
	FPU				●	●	●
Memory subsystem	TCM [w/ECC|parity]		○	○	○	○	○
	L1$ [w/ECC|parity]			○	○	●	●
	L2$ [w/ECC]					○	○
	MPU			●	●	●	●
	MMU, virtual memory					●	●
Debug	Integrated JTAG debug		●	●	●	●	●
	HW BP		1-2	1-8 adv ctrl	1-8 adv ctrl	1-8 adv ctrl	1-8 adv ctrl
	Performance counters		○	○	○	○	○
Interrupt Controller	IRQs		8-32	8-1024	8-1024	8-1024	8-1024
	Features		basic	advanced	advanced	advanced+	advanced+
SMP support				up to 4 cores with coherency			up to 8-16 cores
I/F options	AHB		●	○	○	○	
	AXI4		○	●	●	●	●
	ACE						○

* Download SCR1 free at www.github.com/syntacore/scr1

Baseline cores:

- Clean-slate designs in System Verilog
- Configurable and extensible
- 100% compatible with major EDA flows

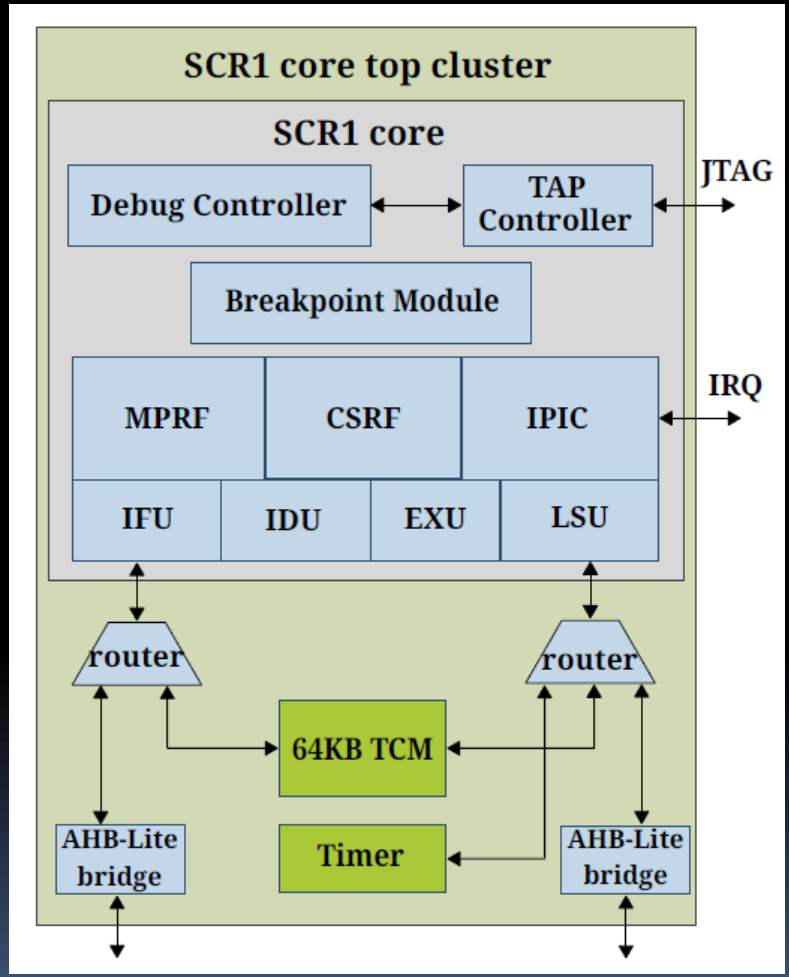
SCR1 overview

Industry-grade compact MCU core for deeply embedded applications and accelerator control

- RV32I|E[MC] ISA
- 2 to 4 stages pipeline
- M-mode only
- Optional configurable IPIC
- Optional integrated Debug Controller
- Choices of the optional MUL/DIV unit
- Open sourced under SHL (Apache 2.0 derivative) since 2017
  - Unrestricted commercial use allowed

Open & free

- High quality, silicon-proven free MCU IP
- In the top System Verilog Github repos in the world
  - https://github.com/syntacore/scr1
- Full collateral – TB & verification suite, SDK, specs, SW…
- Best-effort support provided, commercial offered



SCR1 overview cont

Performance*, per MHz	DMIPS	-O2	1.28
		-best**	1.89
	Coremark	-best**	2.95

* Dhrystone 2.1, Coremark 1.0, GCC 8.1 BM from TCM
** -O3 -funroll-loops -fpeel-loops -fgcse-sm -fgcse-las -flto

Synthesis data:
Minimal RV32EC config: 11 kGates
Default RV32IMC config: 32 kGates
Range 10..40+ kGates

250+ MHz @ tsmc90lp {typical, 1.0V, +25C}

What's new:

- Extensive user guide and quick start collateral
  - works out-of-the-box in all major sims
- Verilator support
- More tests/sample: RISC-V compliance, others
- Taped-out @several companies
- Regular talk at ORCONF
- Updated and maintained

SCR1 SDK

Open & free

https://github.com/syntacore/scr1-sdk

Repository content:

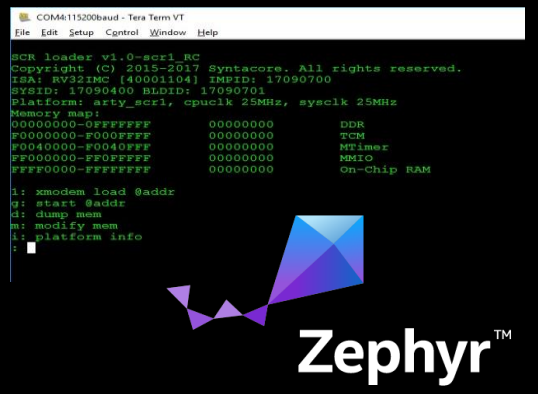
- docs - SDK documentation
- fpga - SCR1 SDK FPGA projects
- images - precompiled binary files
- scr1 - SCR1 core source files
- sw – sample SW projects

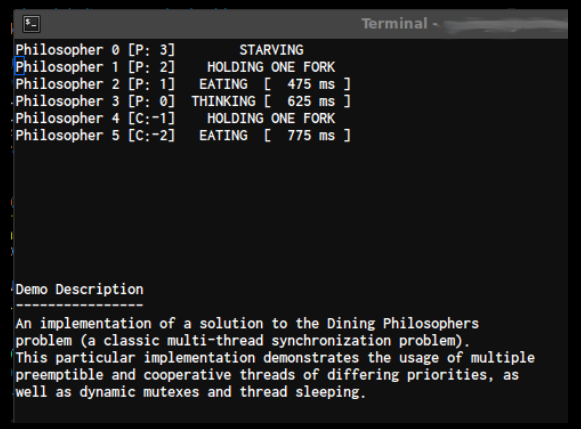
Supported platforms:

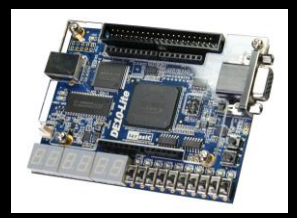
- Digilent Arty and Nexys 4 (Xilinx)
- Terasic DE10-Lite and Arria V GX starter (Intel)

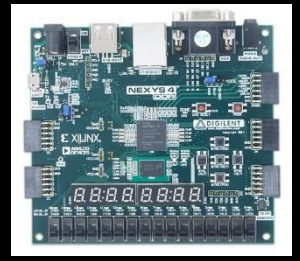
Software:

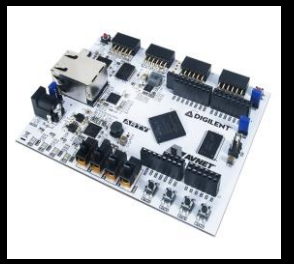
- Bootloader
- Zephyr OS
- Tests/sample apps
- Pre-built GCC-based toolchain (Win/Linux)











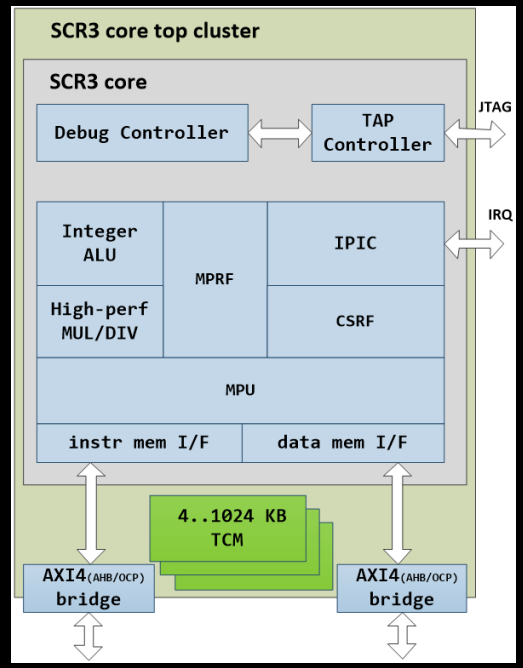
Fully open SDK designs + pre-build images

One of the easiest paths to start with RISC-V

SCR3: 32 or 64 bit

High-performance multicore capable MCU-class core

- RV32I[MCA] or RV64I[MCA] ISA
- Machine and User privilege modes
- Optional MPU (Memory Protection Unit)
- Optional Tightly Coupled Memory (TCM), L1 caches ECC/parity
- 32|64bit AHB or AXI4 external interface
- Optional high-performance or area-optimized MUL/DIV unit
- Integrated IRQ controller and PLIC
- Advanced debug with JTAG i/f
- Multicore configs up to 4 SCRx cores
  - SMP and heterogeneous
  - with memory coherency



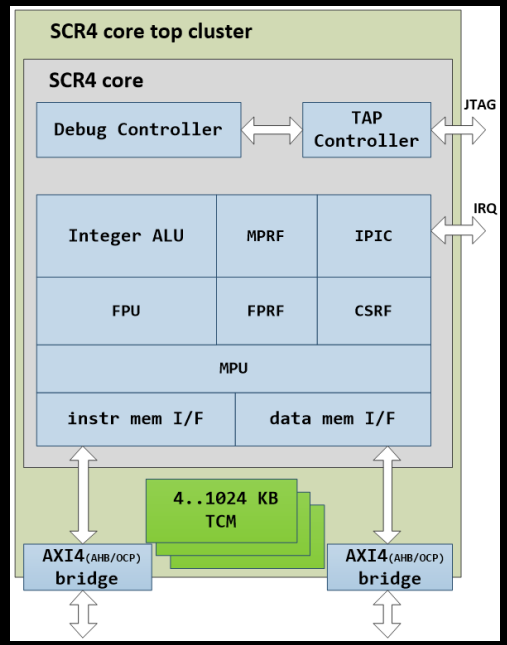
			RV32	RV64
Performance*, per MHz	DMIPS	-O2	1.86	1.97
		-best**	2.937	3.27
	Coremark	-best**	3.30	3.40

* Dhrystone 2.1, Coremark 1.0, GCC 8.1 BM from TCM
** -O3 -funroll-loops -fpeel-loops -fgcse-sm -fgcse-las -flto

SCR4: 32 or 64 bit

High-performance multicore capable MCU core with FPU

- RV32IMCF[DA] or RV64IMCF[DA] ISA
- U- and M-mode
- Configurable advanced BP, fast MUL/DIV
- Integrated IRQ controller and PLIC
- 32|64bit bit AHB or AXI4 external interface
- Optional MPU, TCM, L1 caches w/ECC
- Advanced debug controller with JTAG
- Configurable SP or DP FPU
  - IEEE 754-2008 compliant
- Multicore configs up to 4 SCRx cores
  - SMP and heterogeneous
  - with memory coherency



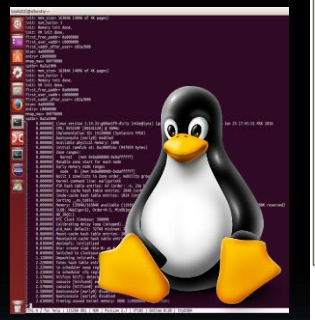
			RV32	RV64
Performance*, per MHz	DMIPS	-O2	1.86	1.97
		-best**	2.96	3.27
	Coremark	-best**	3.30	3.40
	DP Whetstone	-best**	1.22	1.22

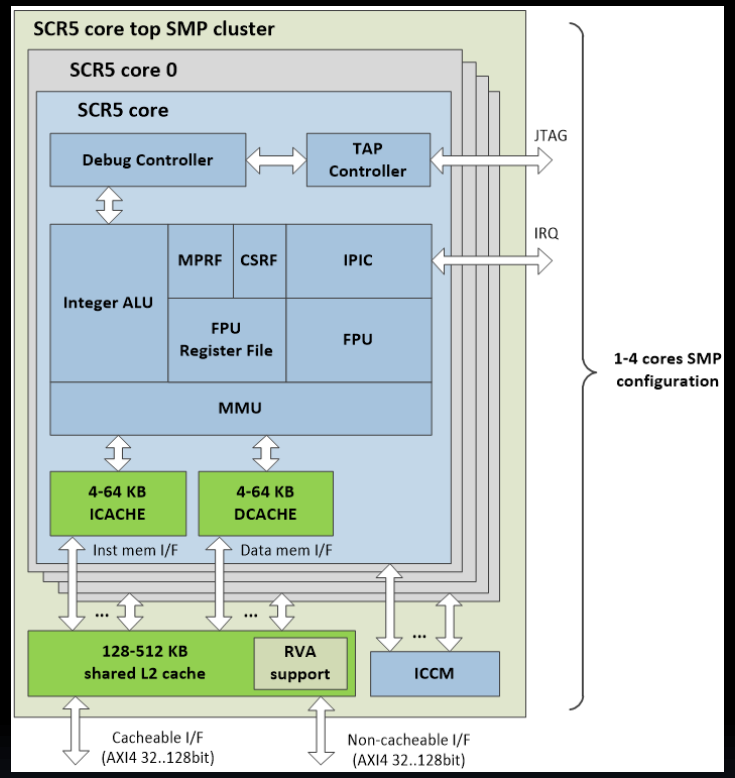
* Dhrystone 2.1, Coremark 1.0, GCC 8.1 BM from TCM
** -O3 -funroll-loops -fpeel-loops -fgcse-sm -fgcse-las -flto

SCR5: 32 or 64 bit

Efficient entry-level APU/embedded core

- RV32IMC[AFD] or RV64IMC[AFD] ISA
- Multicore configs up to 4 SCRx cores
  - SMP and heterogeneous
- Advanced BP (BTB/BHT/RAS)
- IRQ controller (integrated and PLIC)
- M-, S- and U-modes
- Virtual memory support, full MMU
- L1, L2 caches with coherency, atomics, ECC
- High performance double-precision FPU
- Linux and FreeBSD support
- 1GHz+ @28nm
- Advanced debug with JTAG i/f





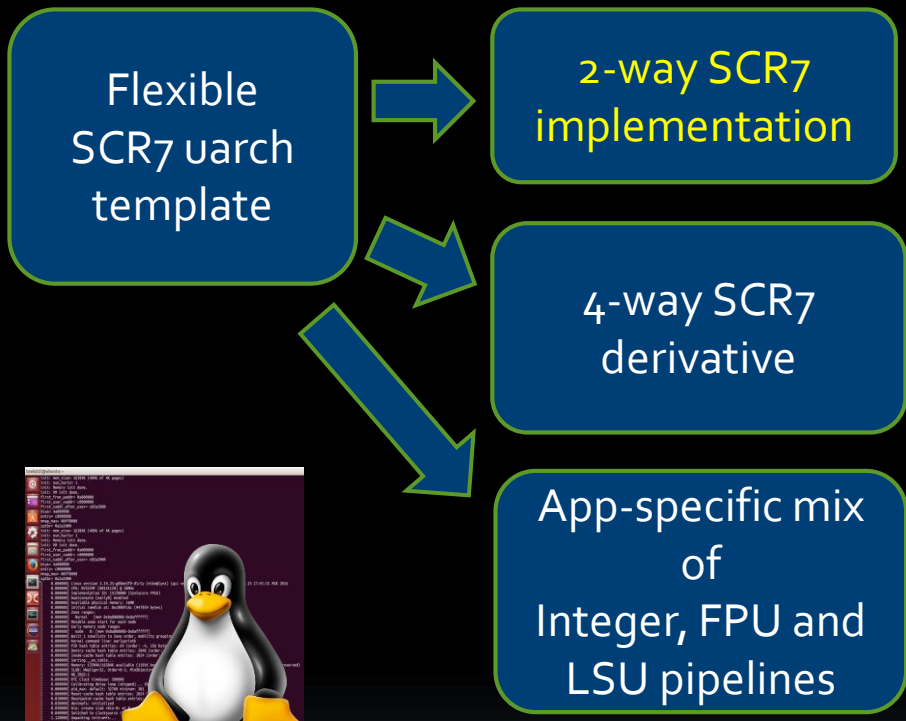
			RV32	RV64
Performance*, per MHz	DMIPS	-O2	1,60	1.70
		-best**	2,48	2.62
	Coremark	-best**	2,83	3.02

* Dhrystone 2.1, Coremark 1.0, GCC 8.1 BM from TCM
** O3-funroll-loops -fpeel-loops -fgcse-sm -fgcse-las -flto

RV64 SCR7

Efficient mid-range application core

- RV64GC ISA
- SMP up to 8, later 16 cores
- Flexible uarch template, 10-12 stage pipeline
- Initial SCR7 configuration:
  - Decode and dispatch up to two instructions per cycle
  - Out-of-order issue of up to four micro-ops
  - Out-of-order completion, in-order retirement
- M-, S- and U-modes
- Virtual memory support, full MMU, Linux
- 16-64KB L1, up to 2MB L2 cache with ECC
- 1.5 GHz+ @28nm
- Advanced debug with JTAG i/f



Performance*, per MHz	DMIPS	-O2	3.25
		-best**	3.80
	Coremark	-best**	5.12

* Preliminary data, 2-way implementation, Dhrystone 2.1, Coremark 1.0, GCC 8.1 BM
** O3-funroll-loops -fpeel-loops -fgcse-sm -fgcse-las -flto

Fully featured SW development suite

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Stable IDE in production:

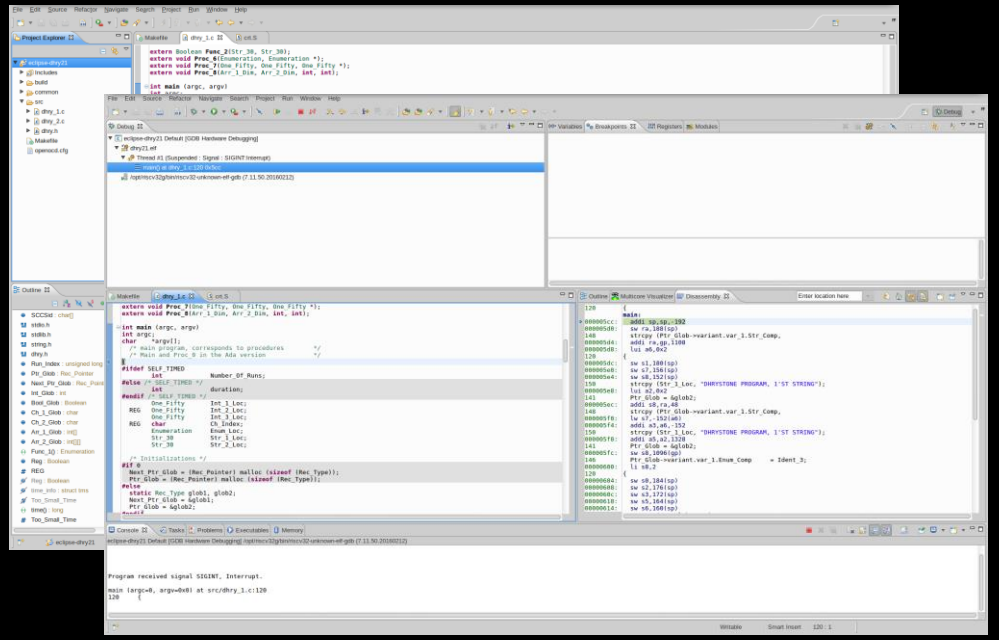
- GCC 10.2
- GNU Binutils 2.31.0
- Newlib 3.0
- GNU GDB 8.0.50
- Open On-Chip Debugger 0.10.0
- Eclipse 4.9.0

Hosts: Linux, Windows

Targets: BM, Linux (beta)

Also available:

- LLVM 5.0
- CompCert 3.1
- 3rd party vendors



Simulators:

- Qemu
- Spike
- 3rd party vendors

JTAG-based debug solutions:

Supports: Segger J-link, Olimex ARM-USB-OCD family, Digilink JTAG-HS2, more vendors soon

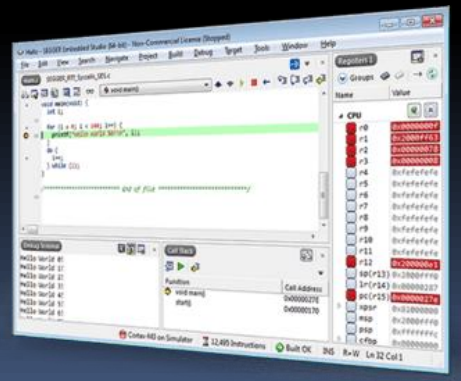
Wide support by 3rd party tools and SW vendors

- Lauterbach Trace32

https://www.lauterbach.com/frames.html?pro/pro__syntacore.html

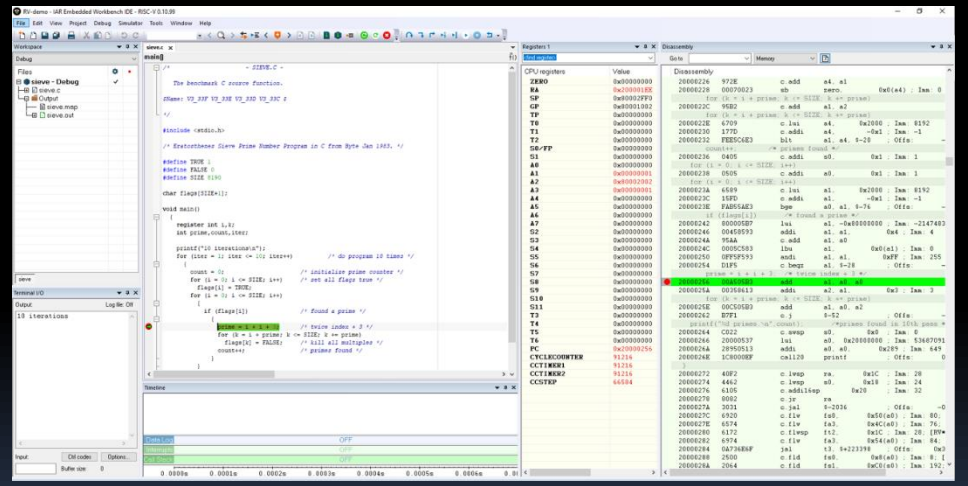
- Segger Embedded Studio

https://wiki.segger.com/Syntacore_SCR1_SDK_Arty



- IAR Embedded Workbench

https://www.iar.com/iar-embedded-workbench/#!?architecture=RISC-V



…more in 2020

Fully integrated FPGA-based SDKs

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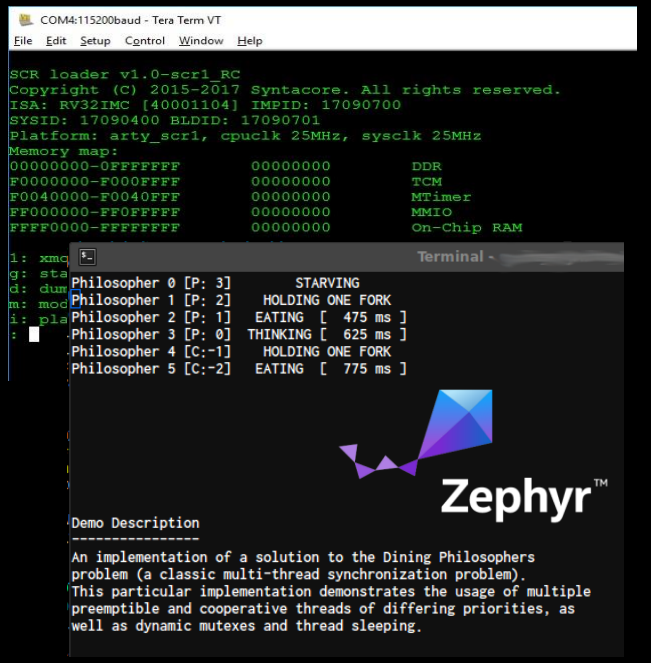
Stable Eclipse/gcc based toolchain with IDE:

- GCC 10.2
- GNU Binutils 2.31.0
- Newlib 3.0
- GNU GDB 8.0.50
- Open On-Chip Debugger 0.10.0
- Eclipse 4.9.0

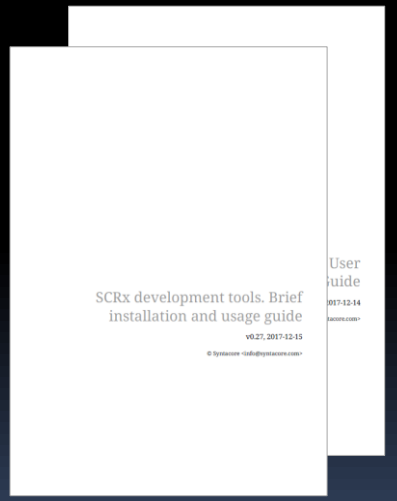


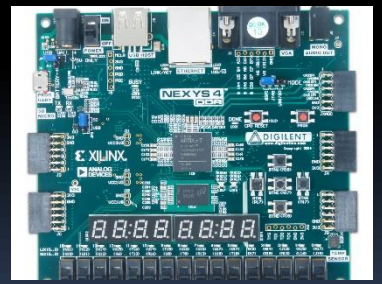
HW platform based on standard FPGA dev.kits

- Multiple boards supported (Altera, Xilinx)
- Low-cost 3rd party JTAG tools
- Open design for easy start

SW:

- Bootloader
- OS: Zephyr/FreeRTOS/Linux
- Application samples, tests, benchmarks

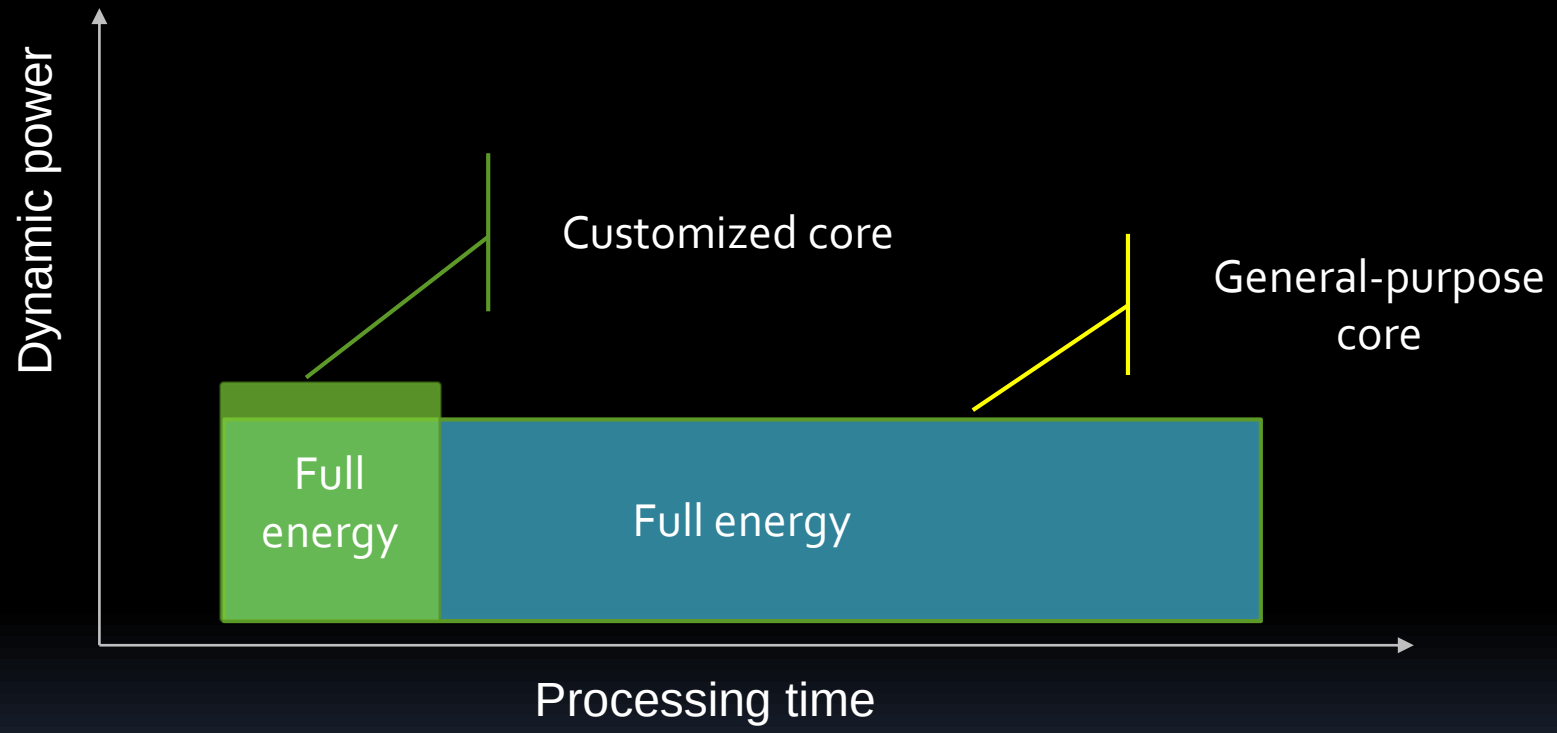




https://www.xilinx.com/products/boards-and-kits/1-6olhwl.html

https://www.altera.com/products/boards_and_kits/dev-kits/altera/kit-arria-v-starter.html

Extensibility/customization: how it works



Workload-specific customization

Extensibility features:

- Computational capabilities
  - New functions using existing HW
  - New Functional Units
- Extended storage
  - Mems/RF, addressable or state
  - Custom AGU
- I/O ports
- Specialized system behavior
  - Standard events processing
  - Custom events

Domain examples:

- Computationally intensive algorithms acceleration
- Specialized processors (including DSP)
- High-throughput applications
  - CV/ML/AI
  - Wireless/Comms
  - Network/DPI/real-time processing

SCRx extensibility example

Custom ISA extension for AES & other crypto kernels acceleration for SCR5

- Data
  - RV32G – FPGA-based devkit, g++ 5.2.0, Linux 4.6, optimized C++ implementation
  - Rv32G + custom – same + intrinsics
  - Core i7 6800K @ 3.4GHz, g++ 5.4.0, Linux 64, optimized C++ implementation
- 60..575x speedup @ modest area increase: 11.7% core, 3.7% at the CPU cluster level

Details in paper @EW2018 conference

Platform	Fmax, MHz	Encoding throughput, MB/s			Normalized per MHz, MB/s			RV32G + custom speed-up		
		Crypto-1	Crypto-2	AES-128	Crypto-1	Crypto-2	AES-128			
RV32G	20	0.025	0.129	0.238	0.00125	0.00645	0.0119	575.00	117.74	60.93
RV32G + custom	20	14.375	15.188	14.502	0.71875	0.7594	0.7251			
Core i7	3400	79.115	235.343	335.212	0.02327	0.06922	0.09859	30.89	10.97	7.35
Core i7 + NI	3400			3874.552			1.13957			0.64

Disclaimer: Authors are aware AES allows for more efficient dedicated accelerators designs, used as example algorithm

Getting access/evaluation

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SCR1

- Is fully open: https://github.com/syntacore/scr1 and https://github.com/syntacore/scr1-sdk
- SHL-licensed with unrestricted commercial use allowed
  - Commercial SLA-based support is available

SCR 3|4|5|7

- Full package* access is available after simple evaluation agreement

For more info: evaluation@syntacore.com

(*) sufficient for evaluation and tapeout

Summary

- Syntacore offers high-quality RISC-V compatible CPU IP
  - Founding member, fully focused on RISC-V since 2015
  - Silicon-proven and shipping in full-wafer production
  - Turnkey IP customization services
    - with full tools/compiler support

  - Local contact in Japan: Syncom Co.,LTD
    - Mr. Katsuhiro Katayama katayama@synkom.co.jp

info@syntacore.com

Thank you!