Sinara: An Open Hardware Ecosystem for Quantum Physics

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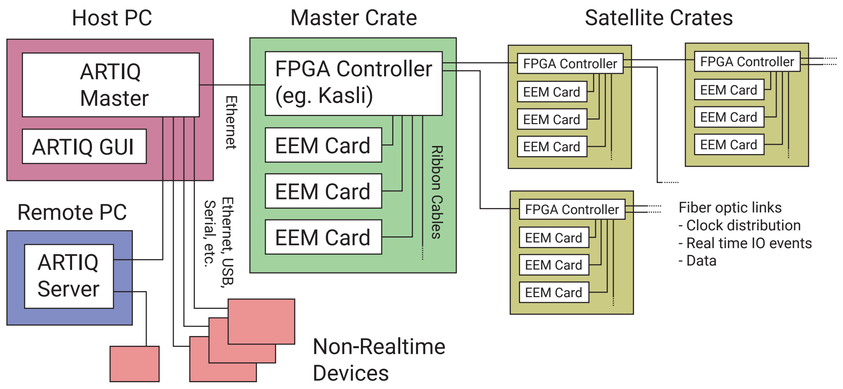
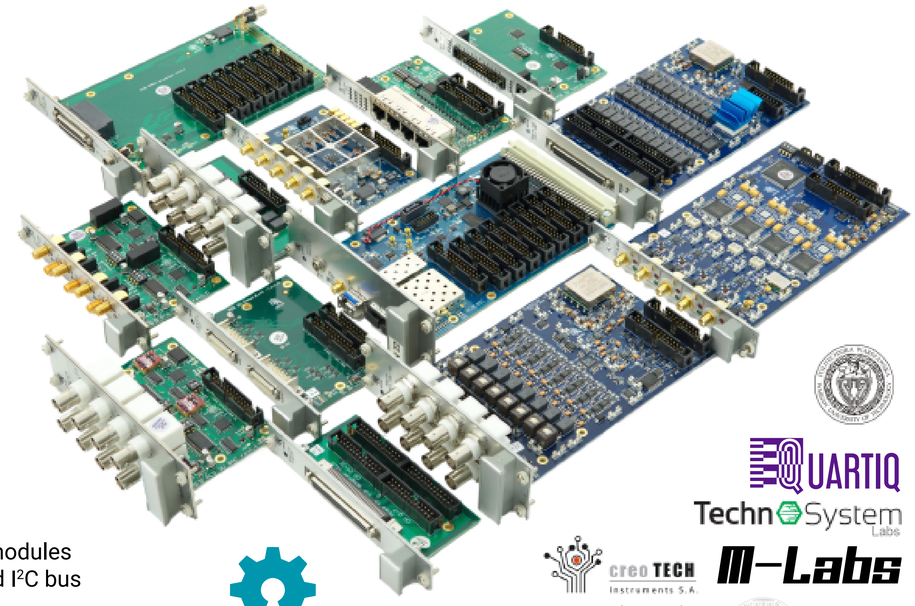
Abstract

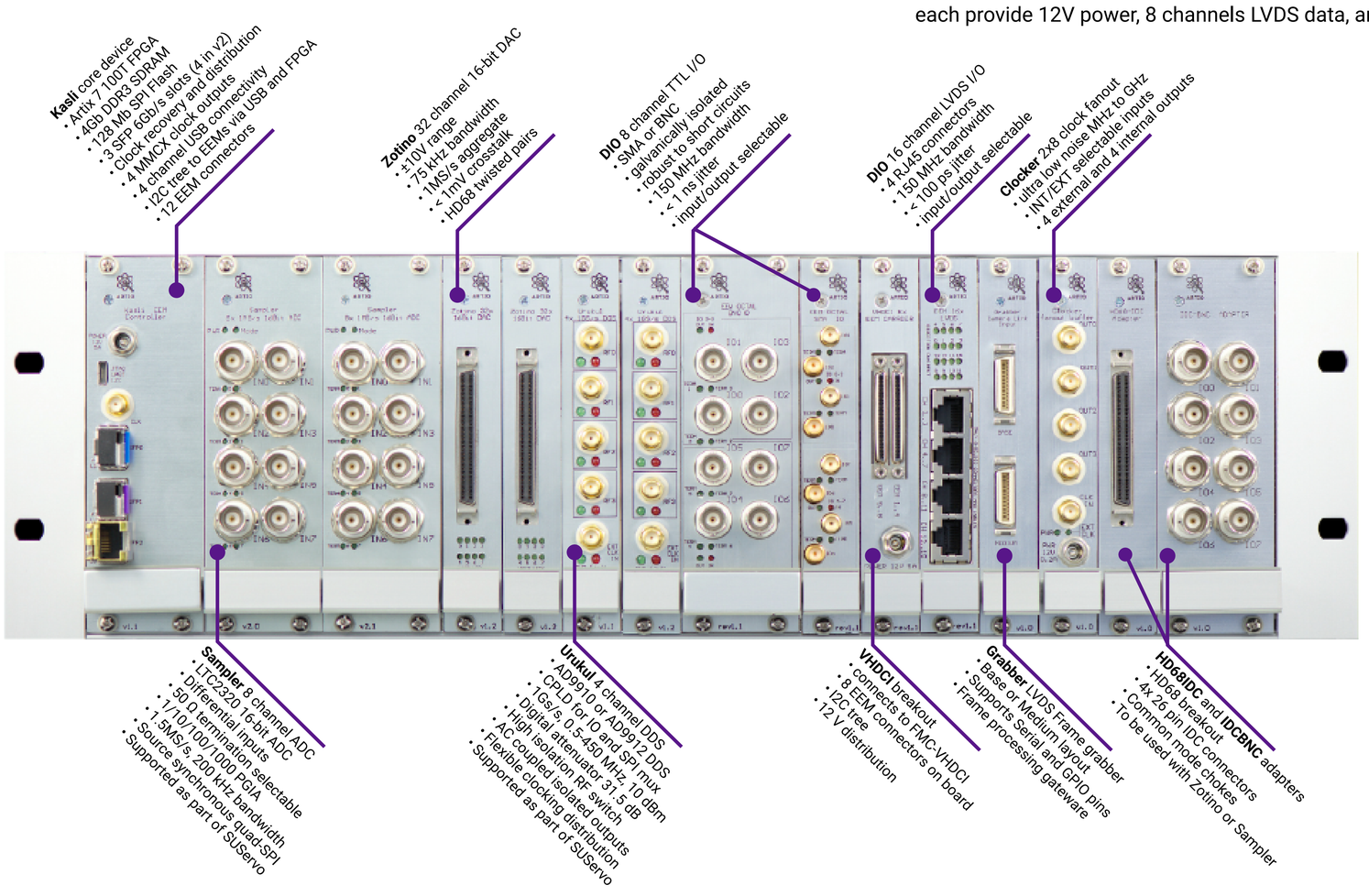
Sinara is a modular, open-source measurement and control hardware ecosystem dedicated to quantum applications that require deterministic high-resolution timing. It is based on industrial standards and consists of over 50 scalable card-based modules built to perform a variety of analog (dc to microwave), and digital input and output tasks with precision timing. The hardware is controlled and managed by the ARTIQ open-source software platform, which provides nanosecond timing resolution and sub-microsecond latency via a high-level programming language.





Production Hardware

Over 100 crates deployed in labs worldwide



Eurocard Extension Module (EEM) standard:
- 4HP or 8 HP 100x160mm Eurocards
- Ribbon cables between controllers and extension modules each provide 12V power, 8 channels LVDS data, and I²C bus

Prototype Hardware

Prototype modules have been produced in small quantities and tested but require further revision before being released to production.

Stabilizer CPU-based servo
- Dual 16-bit 2MS/s ADC with PGA
- Dual 16-bit 2MS/s DAC
- Cortex M7 CPU @400MHz
- Ethernet (+PoE) and EEM interfaces
- Capable of PID with 500kHz bandwidth

Pounder 2-ch PDH lock generator
- Add-on card for Stabilizer
- 4-ch 500MS/s DDS + phase detectors

Phaser 2-ch arbitrary waveform generator
- 4-ch 1.25 GS/s 16-bit DAC
- 2-ch IQ mixer upconversion to 0.3-4.8 GHz
- 2-ch of 5 MS/s ADC
- Artix XC7A100T FPGA

Mirny 4-ch programmable synthesizer
- 30 MHz to 6 GHz (12 GHz with planned Mezzanine board)
- CPLD for IO and SPI mux

Fastino 32-ch 16-bit DAC
- ±10V range
- 2 MS/s per channel, 1 GS/s aggregate
- High speed version of Zotino

Booster 8-ch power amplifier
- 40-500 MHz
- P1dB 36 dBm, 40 dB gain
- >35% total power efficiency
- Protection, monitoring
- Remote control

DIO_MCX 16-ch I/O
- MCX connectors
- 3.3V, 50R capable outputs
- Switchable direction & 50R term.

Thermostat 2-ch temperature controller
- Thermistor input
- 8W TEC/heater drive
- Cortex M4 CPU
- Ethernet interface (+PoE)

Humpback EEM carrier for single board computers
- Compatible with Nucleo 144, Beaglebone Black, Orange Pi Zero, ESP32, Wiznet WIZ550web
- Provides power, mounting, and connectivity

Banker Versatile 128-ch GPIO
- ICE40 FPGA
- 3.3V or 5V with 50R drive capability
- DIN-rail breakout boards for D-sub, BNC, SMA, screw term.

Planned Hardware

Kasli SoC Controller
- ZYnQ 7030 (dual ARM core)
- Kasli form factor

Shuttler 16-ch fast DAC
- 125 MS/s
- FMC form factor

Fast Servo FPGA servo
- Stabilizer form factor

Driver Diode laser current source
- 16-bit DAC
- 100, 150, or 200V range

Zapper 8-ch piezo driver
- 16-bit DAC
- 100, 150, or 200V range

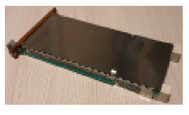
Aux PSU 3-ch power supply
- Switch selectable output voltages

Line Trigger 50/60Hz line trigger
- To sync yo experiments

Metlino/Sayma/RFSoC
- Multi-GS/s DACs and ADCs
- uTCA form factor
- Will allow Sinara to be used for Superconducting and spin qubits

Infrastructure Improvements

CPCIS
- Forthcoming upgrade for EEM ecosystem
- Switch from ribbon cables to CompactPCI backplane
- Passive adapter to convert existing boards
- Compatible with CERN Distributed I/O Tier (DI/OT)




uTCA
- For boards that need more IO, power, and cooling than is available in CPCIS

FAQ

How do I find out more about the hardware?
- The hardware designs are open source and available on our GitHub: https://github.com/sinara-hw
- Documentation uses the GitHub wiki: https://github.com/sinara-hw/meta/wiki
- Issue tracking is done using the GitHub issue tracker on each repository

Where do I obtain hardware?
- Two commercial vendors (Creotech and TechnoSystem) can supply bare tested boards
- Two systems integrators (M-Labs and Quartiq) can provide assembled and tested crates as well as access to gateware/software build system
- As the hardware is open, you are free to produce your own boards

Who develops Sinara?
- Sinara is a collaboration between electrical engineering academics, commercial software and hardware suppliers, and the AMO research groups who form the end users.
- G. Kasprowicz at Warsaw Technical University is the hardware lead.

Can physics groups without electrical engineers or FPGA developers contribute?
- Yes! Use production boards, submit bug reports, and make suggestions based on your lab experience
- Much of the documentation is user-contributed and there are many gaps that need filling
- Fund new gateware/software development to add new features and help bring prototype boards to production

I have a use case not covered by current or planned hardware:
- Open a new request for comments at: https://github.com/sinara-hw/meta/issues and we'll take it from there

ARTIQ control framework

- **A**dvanced **R**eal-**T**ime **I**nfrastructure for **Q**uantum physics, integrated software/gateware system that controls atomic physics experiments
- High performance -- nanosecond resolution, hundreds of ns latency
- Expressive -- describe algorithms with a few lines of code written in a subset of Python
- Portable -- treat hardware (FPGA boards) as commodity, make software quickly and reliably deployable
- Modular -- separate components as much as possible: managing/scheduling experiments, driving distributed devices, analyzing/displaying/archiving results
- Open -- developed with and for research groups worldwide as open source software (LGPLv3)

ARTIQ