OPX1000

Modular, high-density control platform for quantum computers at scale

Unrivaled Scalability | Processor-Based Quantum Controller™
Cutting-Edge Analog Frontend | Easy-to-Use | Data Center Ready

Trusted by builders of the largest and most advanced quantum computers in the world

OPX1000 - scale up your quantum computer while enhancing flexibility and performance

OPX1000 is a state-of-the-art controller designed for large-scale quantum computers. This modular solution features an unmatched density of channels and is easily expandable to cost-efficiently control even the largest quantum processors available.

Benefits

- **Processor-Based Quantum Controller™:** Unmatched processing power of up to 10 high-end FPGAs, allowing the execution of complex quantum algorithms with the fastest run-times and best results.
- **Highest channel density:** Up to 80 analog channels within 3U rack units - the highest density of analog control and readout channels in its class.
- **Unmatched fidelity:** State-of-the-art analog specifications, and ultra-fast calibrations utilizing real-time parametric feedback - push the limits of gate and circuit fidelities achievable with any quantum devices.
- **Intuitive Programming:** QUA – Python-embedded, pulse-level programming language allows, allows agile and flexible coding of the most complex quantum programs.
- **Digital Direct Synthesis (DDS) inside:** DDS for Microwave signal generation is a must-have for advanced quantum research! Avoids calibration and delivers unmatched signal purity with lowest jitter and outstanding phase coherence and stability.
- **Easy to scale:** QSync synchronization and any-to-any data sharing streamline scaling. Expand effortlessly by adding modules and OPX1000 units as your QPU grows.
- **Long-term operation:** Robust chassis design with hot-swappable critical components and compliance with FCC and CE safety standards, ensuring uninterrupted continuous operation.
- **HPC ready:** Native GPU hardware and SLURM software integration, multi-QPU support, out-of-the-box workflows.

OPX1000 Chassis
Hosts up to 8 modules, 3 rack units (U) height

Stream Processing Unit (SPU)
Optimizes and accelerates communication with external servers

Pulse Processing Unit (PPU)
Designed for quantum control, includes quantum-classical integration and ultra-fast feedback

Analog Outputs
Up to 64 output channels @2 GSa/s, 16 bits

Analog Inputs
Up to 16 input channels @2 GSa/s, 12 bits

Real-Time Processing (Turing-complete):

- Arithmetic and trigonometric functions
- Vector operations
- Casting of variable types
- Bayesian and error estimations
- Syndrome tracking and more

Comprehensive Control Flow

- If/else
- For loops
- While loops
- Switch case, pulse sequence timing control

Fully Parametric Waveform Generation

- Loop over parameters in real-time: durations, frequencies, phase, amplitude, bandwidth, real-time chirp, etc.
- Built-in compensations for pulse imperfections and crosstalk
- Manipulate waveforms without memory loading

Waveform Acquisition and Manipulation

- High-resolution analog-to-digital conversion
- User-defined flexible integration and demodulation (weighted, accumulated, sliced, etc.)
- Time tagging and TTL counting (< 50 ps jitter)

QUA Pulse-Level Programming Language

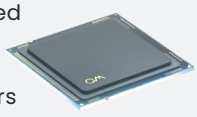
Extremely easy coding

QUA codes run on the FPGA-based PPUs, providing the industry's most advanced real-time capabilities and fastest runtime. Synchronization across all PPU cores is managed by QUA, no manual alignment is required.

Pulse Processing Unit (PPU)

Best real-time performance

Every FEM accommodates a PPU. PPUs across one or more OPX1000 units function as a unified processor-based controller, orchestrating both classical and quantum operations on a quantum timescale. This configuration delivers the industry's most advanced quantum performance and highest fidelity.



OPX1000 Specs

Chassis General	
Height	3U
Maximum capacity	8 low-frequency and microwave modules, in any combination
Mounting options 19" rack and desktop	19" rack and desktop
Management ports	1 : 2 (2x 1 GbE, 1x 100 GbE)
Clock input ports	1 : 1, (10 MHz, 2 GHz more options per request)
Clock output ports	4
Fans	5 + 1, hot swap
Power supplies	2 + 1, hot swap (100 - 240 VAC, 50 - 60 Hz)

System & Real-Time	
Minimal feedback latency - analog input to digital output	100 ns
Minimal feedback latency - analog to analog (LF FEM)	< 200 ns within FEM < 300 ns within OPX1000 < 500 ns between OPX1000
Minimal feedback latency - analog to analog (MW FEM)	< 100 ns within FEM < 200 ns within OPX1000 < 400 ns between OPX1000
Between modules added latency	100 ns intra-chassis 300 ns inter-chassis
Operation latencies	Amplitude update < 16 ns Phase update < 32 ns Frequency update < 150 ns

Low-Frequency FEM Analog Output channels		
Maximum tones per channel		16
Jitter		Internal clock: < 350 fs External clock: < 250 fs
Crosstalk channels isolation		> 80 dB @ 100 MHz > 70 dB @ 500 MHz
Crosstalk compensation matrix Built-in		Built-in
FIR/IIR distortion compensation filters		Built-in
Total harmonic distortion		> 65 dBc
SFDR (direct mode)		> 60 dBc @ DC - 700 MHz > 55 dBc @ 700 - 750 MHz
Controllable skew adjustment resolution		10 ps
Output Mode	**Direct**	**Amplified**
Voltage	1 Vpp (50 Ω load)	5 Vpp (50 Ω load)
Bandwidth	750 MHz	330 MHz
Rise time	< 400 ps @ 0.8 V step	< 900 ps @ 5 V step < 600 ps @ 0.5 V step
Voltage Noise (PSD)	< 1 μV/ √Hz @ 1 Hz < 13 nV/ √Hz @ 10 kHz < 10 nV/ √Hz @ 100 kHz < 6 nV/ √Hz @ 1 MHz < 4 nV/ √Hz @ 10 MHz	< 3.5 μV/ √Hz @ 1 Hz < 40 nV/ √Hz @ 10 kHz < 30 nV/ √Hz @ 100 kHz < 20 nV/ √Hz @ 1 MHz < 15 nV/ √Hz @ 10 MHz
Voltage Noise (RMS)	< 100 μVrms	< 300 μVrms

Low-Frequency FEM Analog Input Channels	
Bandwidth	750 MHz
Controllable gain	32 dB
Time tagging resolution	< 50 ps

Front-End Module (FEM) General	
FPGA	UltraScale+TM XCVU13P
Pulse Processing Unit (PPU) cores	16, parallel operation, all-to-all connectivity
Channels	8 analog output / 2 analog input / 8 digital I/O
Analog channels resolution	16 bits DAC / 12 bits ADC
Analog channels sampling rate	LF-FEM: 2 GSa/s MW-FEM: 2 GSa/s (1 GSa/s per I and Q, normal mode)

Front-End Module (FEM) Digital I/O	
Digital I/O channels sampling rate	1 GSa/s
Voltage	3.3 V (LVTTL) / 5 V (TTL)
Output rise time	< 0.4 ns
Controllable skew adjustment resolution	1 ns

Microwave FEM Analog Output Channels	
Frequency range	0.05 - 10.5 GHz
Instantaneous bandwidth	800 MHz (normal mode) 1.6 GHz (double-rate mode)
Power	-40 dBm to 10 dBm
Maximum tones per channel	8
Phase noise at 6 GHz with 10 kHz offset	< -125 dBc/Hz
SFDR across all supported frequency range	> 60 dBc
Total harmonic distortion (THD) outside bandwidth	> 40 dBc
Noise floor @ -10 dBm	< -155 dBm/Hz

Microwave FEM Analog Input Channels	
Frequency range	0 - 1.8 GHz or 1.8 - 10.5 GHz
Power	-40 dBm to -10 dBm

** Full specifications document is available upon request.*

*** Due to continuous improvements, specifications are subject to change.*

QUANTUM MACHINES

Contact us for more information and demos

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quantum-machines.co

Quantum Control Systems

OPX1000

- Processor-based quantum controller™
- Scaled-up and modular platform
- Powerful real-time computations and fastest feedback
- State-of-the-art analog specifications, with DDS technology

OPX+

- Processor-based quantum controller™
- Powerful real-time computations and ultra-fast feedback
- All-in-one unit, control and readout

QDAC-II Compact

- Advanced DC and low-frequency signal generation
- 24 channels, with 25 bit resolution
- Compact single 1 rack unit solution

QSwitch

- Software-controlled break-out box
- Configuring 24 outputs, by floating, grounding, and connecting to 24 inputs or 8 BNCs

About Quantum Machines

Quantum Machines (QM) accelerates the realization of practical quantum computing that will disrupt all industries. Our comprehensive portfolio includes state-of-the-art control and cryogenic electronic solutions that support a wide span of qubit technologies. QM's OPX family of processor-based quantum controllers™ leverages a unique Pulse Processing Unit (PPU) technology to deliver unprecedented performance, scalability, and productivity.

Easily programmable at the pulse level, OPX controllers are extremely agile and flexible capable of running even the most complex quantum algorithms right out of the box – including quantum error correction, multi-qubit calibration, mid-circuit frequency tracking, and more. With hundreds of deployments, Quantum Machines' products and solutions have been widely adopted by national and academic research labs, HPC centers, full-stack quantum computer manufacturers, and cloud service providers. For more information, please visit - quantum-machines.co