Release notes

QOP2.2

Quantum Orchestration Platform (QOP)

Product Team

Contents

About QOP and OPX

The Quantum Orchestration Platform (QOP) is a comprehensive firmware and software package that drives QM's quantum control system - OPX, along with its add-on products such as the Octave. OPX is an ultra-fast quantum controller, purpose-built by quantum experimentalists and engineers for quantum physics. Extremely agile and flexible, OPX has unmatched capabilities, allowing the fastest runtime for complex quantum programs. At the heart of OPX is a multi-core Pulse Processing Unit (PPU). PPU combines, in real-time, classical calculation with quantum control pulses and control flow. Instead of playing pulse sequences from memory, PPU generates and manipulates them on-the-fly, reducing uploading times and memory usage to near zero. OPX is programmed using QM's intuitive pulse-level language - QUA. QUA programs are executed in real-time by PPU - enabling running complex quantum algorithms right out of the box, including multi-qubit calibration, Bayesian estimation, QEC, and more. With over 200 successful installations, OPX with its QOP firmware is a field-proven solution, adopted by leading quantum computer manufacturers, HPC centers, and research labs worldwide.

Key OPX benefits -

- **Accelerate experiments** - advanced control flow and parametric scans – no more waiting for waveforms to upload
- **Easily code complex algorithms** - benefit from hardware performance while saving months of tedious FPGA coding
- **Unmatched toolbox for quantum experiments** - calibration, characterizations, adaptive ground state preparations, and even QEC and real-time Bayesian estimations
- **Simplify experimental setups** - compact, easy-to-use all-in-one device
- **Supports a wide span of qubit technologies** - superconducting, trapped ions, defect centers, spin qubits, neutral atoms, and photons
- **Scalable** - seamless scalability by connecting multiple units, no central controller, no software redesign, ultra-fast readout distribution between all the qubits, and assured accurate synchronization

QOP firmware release V2.2 further enhances OPX with new powerful tools for circuit verification and simulation, as well as additional capabilities that offer increased flexibility and automation, resulting in even faster time-to-result for complex quantum experiments running on any quantum computer.

Affected Products

Products affected by this release include:

#	Product	Affected	Comment
1	OPX	No	
2	OPX+	Yes	For software release V2.2 use QUA SDK version 1.1.3 or above
3	Octave	Yes	OPX+ add-on, RF up/down-conversion
4	OPT	Yes	OPX+ add-on, clock distribution
5	OPD	No	OPX+ add-on, additional digital inputs
6	Observe	No	OPX+ add-on, optics control integration
7	QDAC	No	Ultra-Low-Noise 24-Channel DAC, DC and low-frequency voltage source generators

New Features

For API, examples and more technical information, please refer to the documentation website

1. Enhanced circuit verification and simulation

Most relevant qubit technology: All

Executing quantum circuits at the pulse level and with real-time processing can be daunting, and QM products are all about making this task more accessible to end users. QOP V2.2 includes two complementary features that empower users to design, execute, and test their desired quantum circuits.

- **Command timestamps**
  Starting from QOP V2.2, users have the capability to retrieve the precise timestamp of any play() and measure() commands from the beginning of the program. This capability covers real-time logic with non-deterministic outcomes (measurements) and compiler scheduling due to optimizations unknown to the user. This feature is particularly useful for tracking qubit phases during operations and accurately measuring delays between pulses in real experiments.
- **Simulator waveform report and visualizer**

  Simulating all analog and digital outputs, the OPX Simulator is an essential tool for experimentalists as they work on developing their desired pulse sequence. With the release of QOP V2.2, the OPX Simulator has been further enhanced. Now, it provides detailed reports and plots of all simulated operations, waveforms, and ADC acquisition times. A waveform report object holds all the information associated with a specific command and can be used for circuit validation. Additionally, this information can be readily plotted and sorted by elements to help experimentalists analyze quantum circuits at the pulse level and compare them to their desired gate-level circuit, making the OPX Simulator an even more valuable tool.

2. Enhanced digital pulse functionality and API

Most relevant qubit technology: All

New capabilities were added to the digital markers used for triggering auxiliary instruments and managing fast switches.

- **Sticky elements with digital markers and an improved API**

  When an element is defined as sticky, the last analog value played at the end of a pulse will be held until the next pulse begins. This is useful, for example, for semiconductor qubits where one wants to avoid the noise associated with the switching of the bias voltage.

  Starting from QOP V2.2 an element can be defined as *sticky* using a clearer API. Additionally, it is now possible to set the digital marker associated with the sticky element to be sticky as well,

holding the last value of the digital marker until the next pulse begins. Once a ramp-down has been initiated to the analog pulse, the digital marker will stop at the beginning of the ramp.

- **Inverted digital marker**

  The digital marker can be configured to be inverted, for example, to suit both 'normally on' and 'normally off' switch types. This means that the HIGH state of the digital output will be the default state when the digital output is configured to be inverted, and the marker will switch to the LOW state when a digital pulse is played.

3. Cluster creation and device management in the network

Most relevant qubit technology: All

QOP V2.2 includes a major enhancement in the way users can manage QM devices in their network. The Admin panel (web interface) has been updated and improved, and now includes the following new capabilities:

- Support for static and DHCP IP address configurations, for OPX+ and Octave, either in the local user network or with the router provided by QM.
- Added new views, allowing automatic detection and easy identification of QM devices in the network.
- The functional state of the cluster and the connectivity status of the optical fibers and QSync lines between devices in the cluster are now indicated in the *topology* view, allowing easy overview and debugging.
- Support for multiple clusters in the same network is added, and the clusters can be accessed with a user-defined name, e.g., -

  ```
  qmm = QuantumMachinesManager(host=ip_addr, cluster_name="my_cluster")
  ```

  Conveniently, users can use an intuitive GUI to “mix & match” QM devices and re-cluster them in any configuration according to needs without approaching QM’s Customer Success team or being connected to the internet.

4. LED indication during boot

Most relevant qubit technology: All

The boot sequence has been optimized for faster performance and progress is now readily apparent to the user as a progress bar implemented by the OPX+ front-panel LEDs. This is valuable for diagnosing and debugging issues that might arise during the boot, leading to a faster resolution and more effective support from our team.

5. Fast frame rotation

Most relevant qubit technology: All

The latency associated with dispatching a frame rotation in QUA is limited by the real-time calculation of the trigonometric functions defining the rotation matrix given a certain rotation angle. This can now be circumvented by providing the rotation matrix explicitly, allowing almost immediate frame rotations.

Installation and Upgrade Process

You can find the QOP V2.2 version files and the update steps in the releases section of the documentation website. Please don't hesitate to contact QM support or your QM representative for assistance with the update procedure

Fixed Bugs

As with all previous software releases, significant efforts were invested in ensuring that QOP V2.2 is a highly reliable solution. The following is a partial list of known issues in previous software releases now fixed with software release QOP V2.2:

1. Fixed sub-ns ADC skews occurring after booting in some scenarios.
2. Improved phase locking algorithm to improve phase noise.
3. Fixed compilation issue when using amplitude scaling in real-time
4. Fixed several stream processing issues:
    a. Added a warning message when possible data corruption is detected.
    b. Fixed wrong timestamps when saving fixed-type variables.
5. Fixed bug preventing playing a digital pulse without defining analog input.
6. Fixed unexpected behavior when playing a pulse with a waveform defined with a different sampling rate.

Known Issues and Limitations

Following is the list of this release's known issues and limitations, and how to mitigate them.

1. A single OPX+ (with or without Octave) will not use an OPT connected to it. In such cases, when Octave is part of the setup, the Octave can output a 1 GHz clock to the OPX+, synchronizing both devices. An external clock can be used to provide clock input to both OPX and Octave.
2. In some programs, compiler optimization assigns variables to pulsers in a way that introduces unintended gaps. This can be managed by the user with the `assign_variables_to_element` function from *qualang_tools*.
3. Digital pulses can only be sticky (V2.2 new feature) if their related analog pulses are also sticky.
4. Unexpected behavior may occur when using `fast_frame_rotation` with an ill-defined rotation matrix. Since the calculation happens in real-time, no warnings are provided in such cases.
5. In a multi-cluster configuration - when adding a device to an existing cluster, all the clusters are restarted.
6. When renaming a cluster, the topology page still shows the previous cluster name and is only updated after the cluster reboot.

Latency performance updates:

Changes fefer to values from the previous version (QOP2.1)

1. Single-element conditional feedback latency increased by 1 cycle (4 ns). This will be fixed in the next major release.
2. For feedback with real-time calculations, the latency was reduced by up to 7 cycles (28 ns). This is a compiler optimization that will only apply to certain cases.
3. The digital to analog pulse latency has been decreased by 2 cycles (8 ns) following the newly introduced digital pulse features and now stands at 136 ns.
4. A conditional digital pulse now has a feedback latency of 100 ns (new feature).

The user may consider changing his calibration based on the above updates.

For more information on feedback latencies please check the quantum-machines.co for OPX+ product brochure.