



# Release V2.0

Quantum Orchestration Platform

*Product Team*

Doc V2.1

# Contents

About	3
QOP Benefits	3
Affected Products	4
New Features	5
1. Strict timing for sequences with zero gaps	5
2. Crosstalk matrix and improved digital filters	5
3. Advanced chirping	6
4. Input Stream for fast data transfer during runtime	6
5. High-resolution time tagging	6
6. Shareable ports	6
Installation and Upgrade Process	7
Fixed Bugs	7
Breaking Changes	7
Known Issues and Limitations	7

## About

With its patented pulse processor architecture, Quantum Machines' Quantum Orchestration Platform (QOP) is a comprehensive, full-stack hardware and software quantum control solution. QOP uniquely integrates parametric pulse programming, real-time classic processing, and ultra-fast analog feedback – enabling the platform to run the most advanced quantum algorithms out-of-the-box via an intuitive open-source programming language. Reliable and field-proven to accelerate quantum research and reduce costs, QOP has had over 200 deployments since 2018 in major quantum academic institutions, government facilities, and enterprises worldwide. Release 2.0 enhances QOP with state-of-the-art features that improve fidelity, allow simpler setups, and facilitate even greater flexibility to run the most advanced quantum experiments.

### QOP Benefits

- Fast research! Run tests in seconds instead of months, focus on actual physics and not on complex setups, and benefit from the power of an FPGA with no low-level hardware programming.
- Experiment with the most challenging quantum control sequences, impossible with other control solutions (frequency tracking, RB, QEC, VQA, weak measurements, etc.).
- Best fidelity with ultra-low latency feedback and simpler setups on top of great electronics.
- Reduces cost with an integrated apparatus, channel licensing (pay-as-you-scale), and split channels.
- Extremely scalable, 1 or 100 qubits – control complexity is handled by the compiler.
- Benefit from the growing QUA community – open source, use codes, and knowledge shared by other researchers.

## Affected Products

Products affected by this release include:

#	Product	Affected	Comment
1	OPX	No	
2	OPX+	Yes	For software version 2.0, use QUA version 1.0 or above
3	Octave	No	OPX+ add-on, RF up/down-conversion, up to 18GHz
4	OPT	No	OPX+ add-on, clock distribution
5	OPD	No	OPX+ add-on, additional digital inputs
6	Observe	No	OPX+ add-on, optics control integration
7	Entropy	No	Experiments workflow management
8	OQASM3.0	No	Open QASM 3.0 (gate level) to QUA (pulse level) compiler

# New Features

## 1. Strict timing for sequences with zero gaps

*Most relevant qubit technology: all*

One of the most powerful traits of QUA is that it allows users to program real-time classical processing operations that affect the quantum control sequence. Moreover, it allows doing so in the most intuitive way, while the QUA compiler takes care of the difficult part of scheduling these classical processing tasks to achieve what the user specified. The new strict timing feature allows users to describe better in which sections of the code they want precise timing that is fully defined by the user code, and in which sections of the code they "allow" some slack to schedule calculations that take extra time. In other words, strict timing allows users to specify where the code should be run as true real-time vs. near-real-time (not strict exact timing of pulses). Moreover, when strict timing is used, if new gaps (undefined by the user) need to be added to the sequence due to the required classical processing, the system will indicate from where in the code the issue originates. This feature enhances QUA as a language used to both describe mid-circuit measurements and feedback-based real-time responses, as well as programs that are much broader than a single shot (e.g., fast calibrations, embedded parameters estimations, etc.).

## 2. Crosstalk matrix and improved digital filters

*Most relevant qubit technology: superconducting and spin qubits*

The coupling between qubit control elements determines unwanted crosstalk that adds a layer of complexity in control sequences, as users cannot consider the lines individually. In addition, the RF components put in place to isolate qubits and keep them coherent can distort qubit control pulses. With the new crosstalk matrix and the improved digital filters implemented in version 2.0, researchers can now compensate for both these effects directly from OPX+. Based on the knowledge of the signal distortion, which can be obtained experimentally, it is possible to calculate the crosstalk terms and filter coefficients, introduce them to the configuration file and forget about distortions. From that moment onwards, it's possible to code sequences as if no distortion would apply, and the correction will be automatically applied. The combination of the crosstalk matrix and the digital filters provide researchers with a powerful abstraction tool to manage hardware imperfections, focusing on the actual quantum control level.

### 3. Advanced chirping

*Most relevant qubit technology: AMO*

Chirping capabilities have been improved in this release. Previous versions enabled advanced piecewise chirping, but in the new version, this can be calculated on-the-fly while the pulse is playing. The on-the-fly frequency and amplitude calculations, (AM/FM modulation) enable very long and complicated chirping that allows more precise control of qubits.

### 4. Input Stream for fast data transfer during runtime

*Most relevant qubit technology: All*

Sometimes a large amount of data needs to be transferred from the lab computer to OPX+ during the runtime of a program. This was always possible using Input/Output variables, (IO variables). However, it was not fully optimized for large amounts of data transfer. The new "input stream" capability in version 2.0 allows fast data transfer - 1024bits in less than 10ms.

### 5. High-resolution time tagging

*Most relevant qubit technology: optically addressable spin qubits*

For some applications, time tagging in the picosecond regime is a necessity. This is the case, for example, when working with optical readout decays of less than a few nanoseconds or with single-photon sources and heralded entanglement. With Version 2.0, the OPX+ analog inputs offer high-resolution time tagging with a guaranteed accuracy (jitter) of less than 50ps, allowing state-of-the-art time-tagging solutions for experiments that require picosecond tagging to access the full power of the system's real-time control.

### 6. Shareable ports

*Most relevant qubit technology: all*

In previous QOP releases, it was possible to split the OPX resources and run multiple quantum machines in parallel, each connected through allocated different ports. With version 2.0, it is now possible to have multiple quantum machines sharing the same ports. This is useful when multiplexed readout is used or when monitoring input in one quantum machine regardless of other quantum machines.

## Installation and Upgrade Process

Contact your QM customer success team representative to obtain software version 2.0 installation files and for any assistance in upgrading your OPX+.

Following are the steps for upgrading the QOP:

1. Open a web browser on a computer that can access the system and type in its IP address to access the admin panel.
2. Go to the "Versions" tab in the admin panel, then click on the blue "Change" button.
3. Upload the QOP200.tar.gz.age file by dragging and dropping or selecting it from the prompt.
4. Refresh the version list using the refresh button on the right.
5. QOP2.0 should appear in the list of available versions; hover your mouse over it and click install.
6. The installation may take up to 10 minutes.
7. Once the version is installed, click "Finish" and refresh the page using CTRL+F5.

*Contact your QM customer success team if you encounter any difficulties or have any questions.*

## Fixed Bugs

As with all previous QOP releases, significant efforts were invested in ensuring that QOP version 2.0 is a highly reliable solution. Listed below are issues that have been fixed in this release:

1. The FIR taps were erroneously limited to 19 instead of 23, with 3 IIR poles.
2. Fixed rare incidents in which non-sequential cases inside a "switch case" statements were played incorrectly.
3. Fixed rare incidents in which consecutive pulses on the same element with dynamic duration would not be played correctly.

## Breaking Changes

The new version 2.0 requires some changes to the connectivity scheme:

1. The external trigger should be connected to the port labeled "Ext. trigger (3.3V)" (Or "AUX1 (3.3V)" in old back panels). See the external trigger documentation for further details.
2. In a multi-OPX system, the OPT trigger connection can be removed. Instead, connect the "QSync" connections as explained in the documentation.

## Known Issues and Limitations

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

1. Constant pulse duration is limited to 67ms in the config. If you wish to play a constant pulse for longer than 67ms, you should use the duration key in the QUA play command.
2. The system will falsely boot successfully when set to an external clock, even when the external clock is not connected. If you are working with an external clock, ensure it is connected to the external reference clock port on the back panel.
3. When using time stamping, the saved timestamps may be wrong for fixed type variables when using the QUA command save(). If time stamps are required, use the QUA command save\_all().
4. Playing a pulse with a different sampling rate on a "sticky element" will result in the wrong amplitude being maintained.