Zurich Instruments

QHub
Quantum System Hub

Synchronization and communication hub for large Quantum Computing Control Systems

Product Leaflet
Release date: 29.08.2023

Key Features

- Scale your quantum system up to 448 microwave channels
- Plug-and-play operation through automated instrument synchronization
- Perform low-latency feedback between any instrument in <550 ns
- Perform demanding quantum error correction algorithms through large processing power
- Intuitive system control through LabOne Q

Introduction

The Zurich Instruments QHub enables scalable quantum processor control through automated synchronization and low-latency communication between all components of a Quantum Computing Control System (QCCS). It provides high-level software access to powerful real-time capabilities designed for the most pervasive use cases in quantum computing.

With 56 ZSync ports, the QHub supports systems with up to 448 microwave channels for precisely timed and stable gate and readout operations. Central data processing enables feedback methods that require global information of the system state, e.g. for quantum error correction, with a latency down to 550 ns including all signal processing.

Decoding algorithms can be efficiently implemented on a powerful FPGA core using a ready processing infrastructure accessible in Python. Optional direct programming of the FPGA provides the flexibility required in developing novel decoder algorithms.

Applications

Quantum computing applications

- Large scale quantum computing
- Quantum simulation
- QAOA
- Quantum error correction
- Surface codes
- Qubit frequency stabilization
- Optimal control

Supported qubit types

- Superconducting qubits
- Spin qubit/superconducting resonator hybrids
- NV centers
- Qubits, qutrits, and ququads

Highlights

Proven system scalability

Up to 56 instruments can be synchronized through a QHub, leading to coordinated readout and control of up to 300 fixed frequency qubits using only SHFQCs, or up to 200 tunable-frequency qubits. New instruments can be added by plugging one cable without rework of the existing system.

Simplified feedback programming

The QCCS comes with the LabOne Q software interface that lets users control feedback operations on the system level. LabOne Q translates a user's high-level sequence into real-time instructions for all components of the QCCS so they can operate in sync, with QHub at the center. A Python API gives users the full flexibility to integrate QHub into their own software.

High-fidelity feedback operations

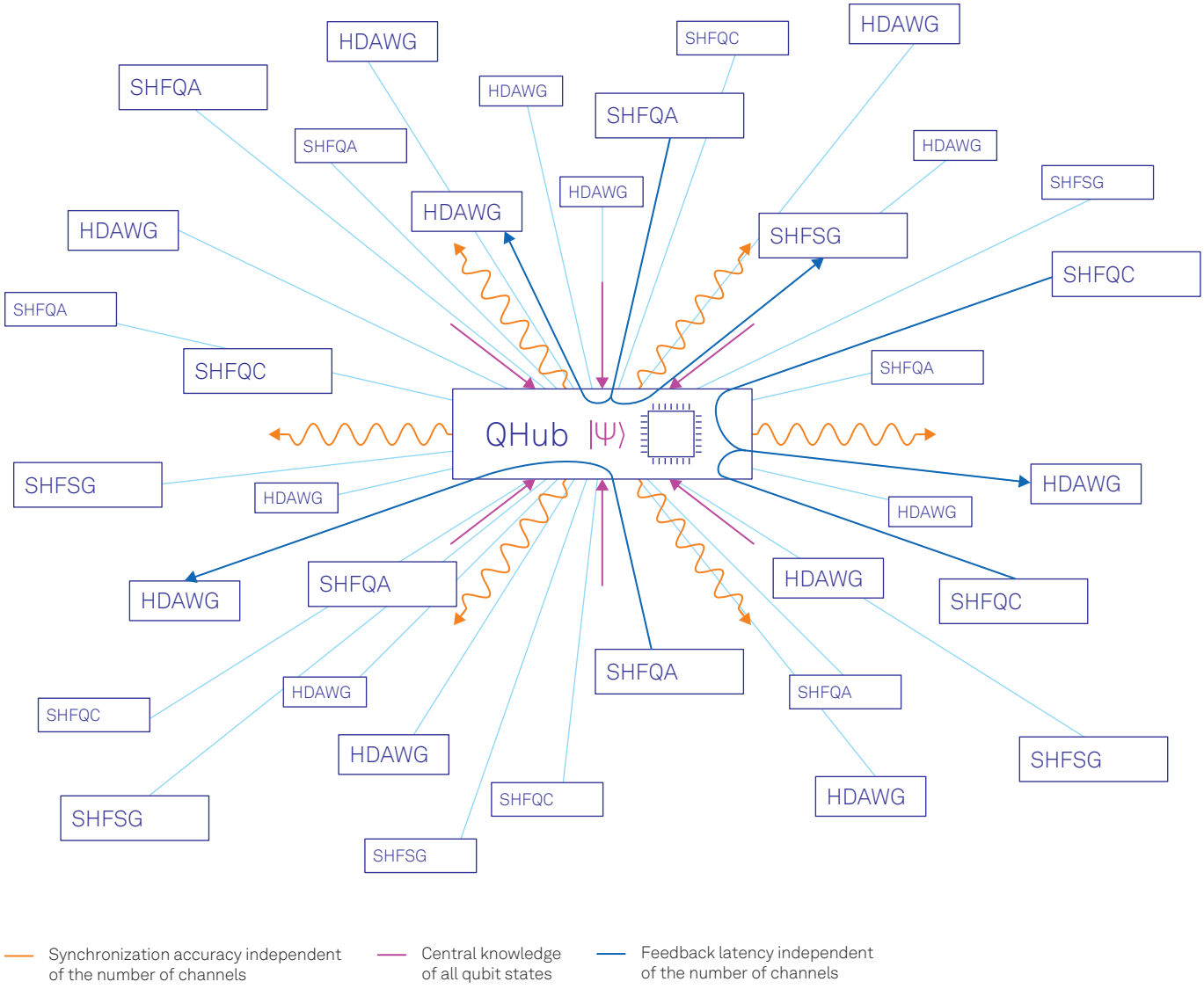
Due to the star topology of the QCCS architecture, QHub is able to evaluate the global state of all the qubits that it controls. This enables feedback methods that require global knowledge of the system state, such as Quantum Error Correction. The low-latency global feedback is complemented with local feedback operations inside the SHFQC Qubit Controller with further reduced latency. The powerful FPGA core of QHub enables the user to create advanced closed-loop feedback algorithms, while achieving a low and deterministic latency.

Reliable synchronization

The ZSync interface distributes all clocks and timing signals needed to synchronize the system. Automated calibration procedures make the synchronization stable across reboots and changing environmental conditions. You can count on weeks of operation without the need for delay calibration.

QCCS Instrumentation Compatibility

QHub is compatible with any combination of HDAWG, SHFQC, SHFSG or SHFQA. It is not compatible with the UHFQA. For combinations of HDAWG and UHFQA, it is recommended to use the PQSC for synchronization and feedback.



Advantages of the star architecture of the Quantum Computing Control System

Frequently Asked Questions

General

Where can I get a live demonstration of the QHub Quantum System Hub? Call us on +41 44 515 0410 or send us an email with your contact details and preferred time slot. We are happy to schedule an online demo to discuss your requirements and see whether there is a match with the QHub capabilities.

What kind of support will I receive if the instrument is purchased from a local partner and not from Zurich Instruments directly? All users receive support from Zurich Instruments independently of where the purchase took place. Local sales partners, where available, also provide first-level support in the local language. For extended support, instrument calibration or service, please check our Support page.

System integration

I want to control a system with few or few tens of qubits, what is the best solution? The PQSC is the right instrument for a system of such size. It can synchronize and distribute feedback across 18 instruments –up to 144 RF channels. That is suitable for around 50 tunable transmon qubits, depending on the specifics of the qubit technology.

I want to control a system with many qubits, up to hundreds. What is the best solution? QHub is the right instrument for system a of such size. It can synchronize and distribute feedback across 56 instruments –up to 448 RF channels. That is suitable for around 200 tunable transmon qubits, depending on the specifics of the qubit technology.

I have a single SHFQC. Do I need a QHub to use it? No, a single device doesn't require a QHub to run. It's required for systems with two or more instruments.

I have an existing QCCS setup and I want to extend it. Can I use QHub instead of PQSC? Yes, QHub is a drop-in replacement of PQSC. Please note that UHFQA are not supported with QHub, and SHFQC or SHFQA should be used instead.

Can I use one or more UHFQAs with QHub? The UHFQA is supported only with PQSC and the HDAWG using a bridge.

Can I use the SHFPPC Parametric Pump Controller with QHub? Yes, the SHFPPC is not directly connected to QHub, but it works with a Quantum Analyzer (SHFQC or SHFQA), which in turn can be connected to QHub.

Can I use QHub with instruments from another manufacturer? Yes, QHub can synchronize to an external reference clock or provide one. Triggers and markers of the SHF/HDAWG can be used to receive or send digital signals with other instruments.

Functionality

What is ZSync? ZSync is a Zurich Instruments proprietary interface to accurately synchronize instruments and enable low-latency feedback across them.

Do I need to calibrate trigger delays across runs or reboots to have stable skew across channels? No! QHub performs all the necessary calibrations when a new instrument is connected through ZSync, and that ensures that the skew is always stable.

Do I need an external clock source or clock distribution system? No, QHub generates and distributes a reference clock over the ZSync cables. QHub can optionally lock to an external 10 MHz reference clock and can provide an external copy of the internal reference clock on an SMA port.

Where do I find ZSync cables? One ZSync cable is provided with each SHF or HDAWG instrument. If you need more, please contact us through our Support page.

How long are ZSync cables? ZSync cables are always 3m (9.84') long. This ensures that latency is always consistent across instruments.

Are different hardware configurations available? No, QHub comes always with 56 ZSync ports. If you need fewer ports, the PQSC might be a better alternative.

What are the supported sample rates of the HDAWG when used with QHub? The HDAWG can run at 2.0 GSa/s when used together with QHub. This ensures accurate synchronization with the SHF instruments that always run at such rates.

Software

With what software can I control QHub, and where can I get it? The main control and programming interface is provided by LabOne Q. It controls not only QHub, but the entire QCCS, including all the instruments attached to QHub as a single system. LabOne Q streamlines and automates time-consuming tasks such as optimizing instrument settings, generating and uploading waveforms, and synchronizing pulses between multiple instruments. Even with this control and measurement automation, users still have complete low-level access to the instruments. The LabOne Q software is produced by Zurich Instruments and upgraded on a regular basis, providing you with new features and functionalities for the instrument.

Can I integrate QHub and the QCCS in general into my existing control software? If you are already using Zurich Instruments devices with the LabOne Q software, the integration of QHub is straightforward; it's just matter of declaring the new instrument and starting to use the new available channels like before. The LabOne Q software operates either as a standalone control software, or is integrated into most existing frameworks and control frameworks.

Specifications

QCCS system specifications	
Supported peripheral devices	SHFQC, HDAWG*, SHFSG, SHFQA
Supported system architecture	Star architecture
Maximum output channel skew	< 1.6 ns
Output channel skew repeatability over restarts	< 200 ps
Real-time communication latency	< 90 ns

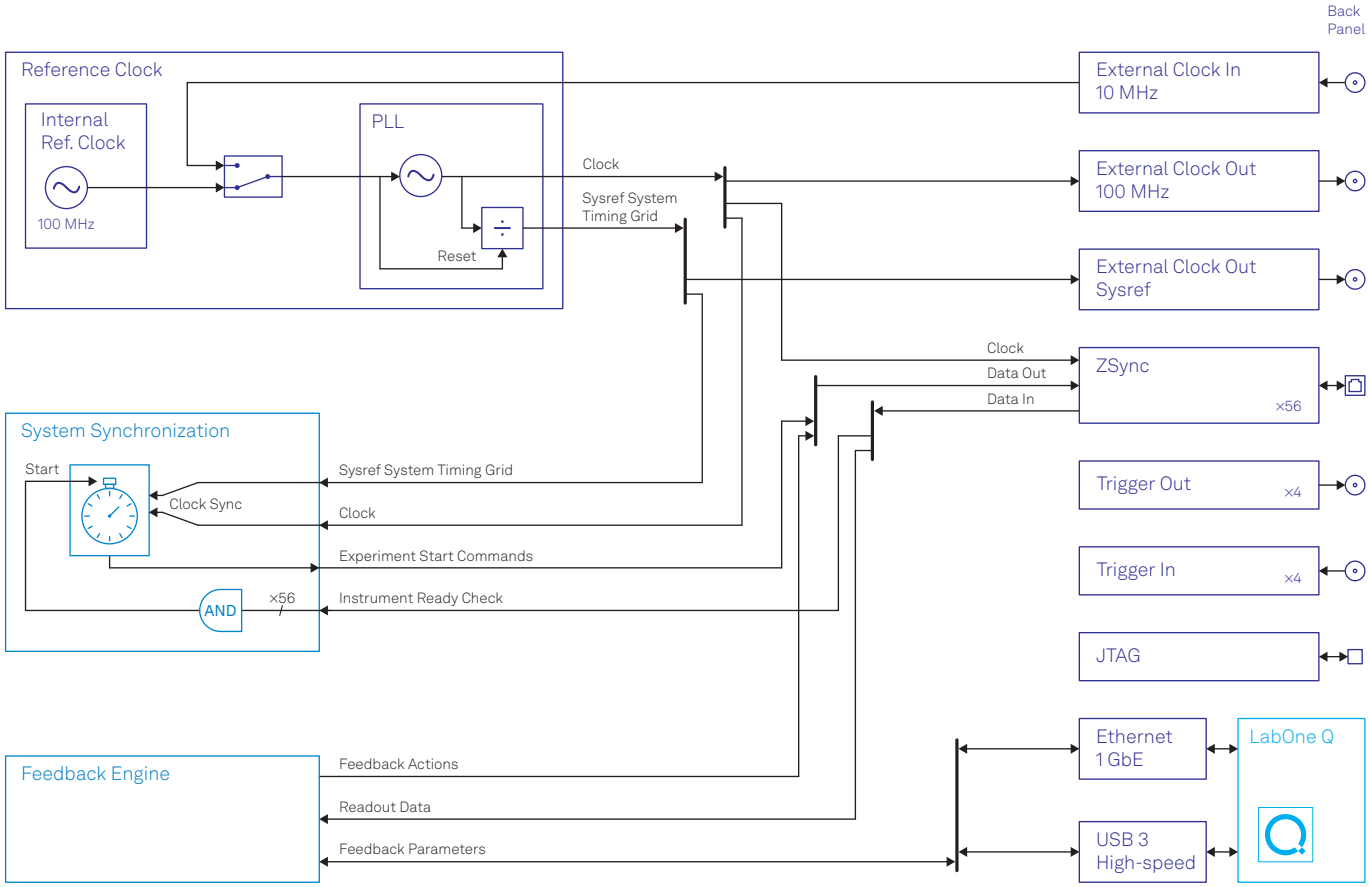
* Only with sample rate 2.0 GSa/s

Synchronization and real-time data exchange	
Interface type	ZSync proprietary
Number of ports	56
Cable length	3 m

Clock	
Interfaces	Input, Output and Sysref output
Input frequency	10 MHz
Output frequency	100 MHz

Triggers	
Trigger inputs	4
Trigger outputs	4
Output voltages	LVTTL (0 V low, 3.3 V high)

General	
Dimensions	449 × 460 × 145 mm 17.6 × 18.1 × 5.7 inch
Weight	8 kg (18 lb)
Power supply	AC: 100 – 240 V; 50/60 Hz 120 W maximum
Host connection	LAN, USB 3.0 JTAG (over USB)



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