SHFPPC
Parametric Pump Controller

Zurich Instruments

Control of up to 4 parametric amplifiers in a single instrument

Product Leaflet
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Key Features

- Operation of up to 2 or 4 readout lines with parametric amplifiers
- Ultra-stable pump tone signal generator with automatic level control
- Pump tone cancellation with automatic recalibration
- Combination of probe and pump tone on a single output
- Plug-and-play solution to simplify and accelerate system tune-up

Introduction

The Zurich Instruments SHFPPC Parametric Pump Controller is a fully integrated system for operating Josephson parametric amplifiers. Leveraging the benefits of parametric amplification, the SHFPPC enables high-fidelity readout at the quantum limit for the measurement of superconducting or spin-based qubits.
Each channel features a microwave source with automatic level control to generate the required pump tone with high power and low phase noise. To suppress the residual pump tone in the return signal path, each channel comprises a cancellation circuit that can be calibrated automatically. The bi-directional operation of this circuit supports the two main application use cases: cancelling the pump tone at room temperature or in the cryostat.
To achieve optimal readout fidelities, parametric amplifiers need to be operated at a point of large gain and maximal signal-to-noise ratio. The SHFPPC lets you find the optimal operation point quickly thanks to dedicated software routines and the ability to add independent pump and probe tones on one output port. This also enables regular performance monitoring and re-optimization without rewiring during a measurement session.

The SHFPPC is best operated in combination with one or more Zurich Instruments Quantum Analyzer channels - for example with the SHFQA Quantum Analyzer or the SHFQC Qubit Controller. The SHFPPC seamlessly integrates into a Quantum Computing Control System (QCCS) and can be controlled through the LabOne Python APIs, the LabOne QCCS Software, or the LabOne graphical user interface, enabling fast tune-up and stable operation during long experiment cycles.

Your Benefits

- Integrated room temperature controller for optimal operation of parametric amplifiers, enabling higher readout fidelity and speed
- Software-controlled solution for swift and convenient amplifier tune-up
- Stable readout performance thanks to low drift, automated monitoring, and automated re-optimization within the LabOne QCCS Software
- Seamless integration into the QCCS to support automated characterization and control of your readout chain, making the QCCS more than the sum of its parts
- A scalable solution for superconducting quantum computing thanks to the high channel density and reliable operation

Applications

Characterization and operation of Josephson parametric amplifiers

- Travelling-wave parametric amplifiers
- Lumped-element parametric amplifiers
- Josephson parametric converters

Supported qubit types

- Superconducting qubits
- Spin qubit/superconducting resonator hybrids

Other applications

- Operation of parametrically driven qubits
- Signal-to-noise ratio characterization of readout chains
- Optimization of readout chains for quantum microwave photonics experiments

QCCS instrumentation compatibility

SHFQA Quantum Analyzer / SHFQC Qubit Controller

- Reduced cabling and setup time of readout electronics
- A fully software-controlled readout system including microwave signal generation and detection
- Integrated software features for fast readout tune-up
- Step-by-step instructions that help you tune-up your parametric amplifier

UHFQA Quantum Analyzer

- Integrated software features for fast readout tune-up
- Step-by-step instructions that help you tune-up your parametric amplifier

Other readout instrumentation is not supported.

Highlights

Stable operation of parametric amplifiers

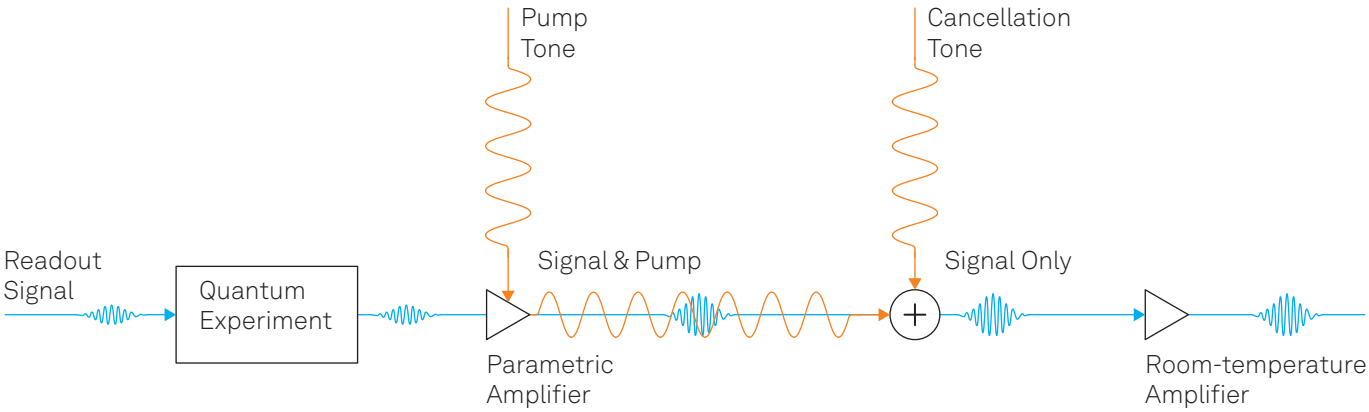
For the operation of parametric amplifiers, a high-power pump tone with low phase noise and high spectral purity is paramount. At the heart of the SHFPPC lies a microwave source which is optimized to provide such a pump tone in a wide frequency range from 1 to 12 GHz. The automatic level control unit ensures long-term output amplitude stability. Together with low temperature sensitivity and phase drifts, this ensures stable operating conditions for the parametric amplifier for achieving optimal readout fidelities.

Automatic cancellation of spurious pump tones

A residual pump tone in the readout return signal can compromise the linearity of subsequent amplification steps and affect the signal-to-noise ratio. The SHFPPC offers an interferometric cancellation of this spurious tone within its signal conditioning unit, with automatically tuned amplitude and phase. This allows for a suppression of up to 65 dB compared to the uncalibrated case at the click of a button.

Fast and intuitive characterization of the amplifier chain

Identifying and maintaining the optimal operating point of a parametric amplifier is critical for maximizing readout fidelity. The SHFPPC lets you save time when tuning up and monitoring the performance of the amplifier thanks to dedicated software routines and the possibility for adding a probe tone signal onto the pump tone, without the need for recabling.
Additionally, the SHFPPC can naturally be integrated into a Quantum Computing Control System enabling noise characterization, gain measurements, and more when using the Quantum Analyzer channels of the system. Trigger inputs and outputs as well as a digital input/output (DIO) port open the possibility for real-time communication with other instruments to control the timing of performance monitoring measurements.



Representation of a readout chain for a Quantum Experiment, featuring a Parametric Amplifier to amplify the Readout Signal. The Pump Tone driving the amplifier is generated and cancelled by the SHFPPC, leaving only the desired measurement signal.

Frequently Asked Questions

System Integration

With what software can I control the SHFPPC, and where can I get it? The LabOne software is freely available in our Download Center. LabOne also provides a single-click function to update the instrument firmware. The SHFPPC can also be controlled through freely included APIs for Python. The examples of Python APIs included with the software enable fast integration into other measurement frameworks. The LabOne software, LabOne QCCS Software, and LabOne APIs are produced by Zurich Instruments and upgraded on a regular basis, providing you with new features and functionality of the instrument.

Can I integrate the SHFPPC into my existing control software? If you rely on custom Python software, the integration is straightforward with the LabOne APIs. Additionally, LabOne helps you to find the right API command for a given instrument setting thanks to its command log feature.

Can I add the SHFPPC to my existing QCCS setup? Yes, the SHFPPC integrates seamlessly into both new or existing QCCS setups, and is especially suited for the operation together with a SHFQA Quantum Analyzer or a SHFQC Qubit Controller. The combination with third-party acquisition systems is not supported.

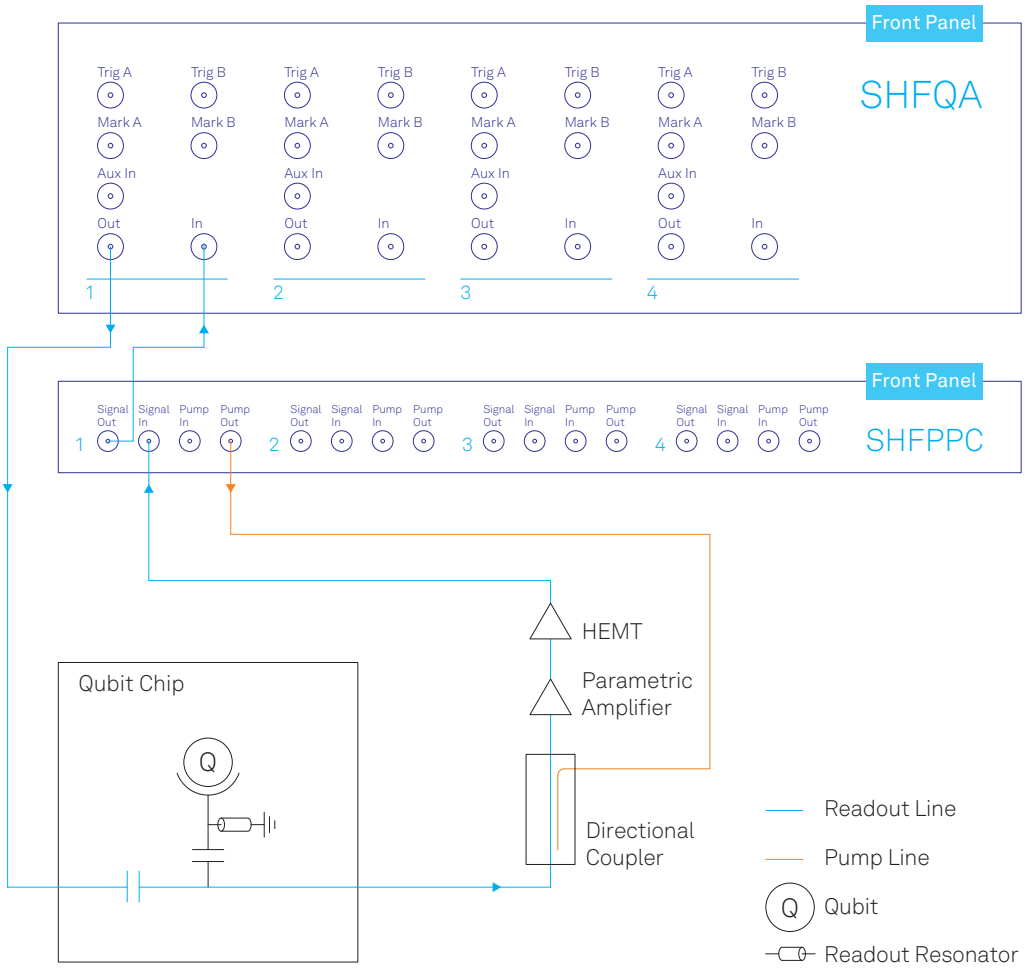
Functionality

Are different hardware configurations available? Yes, a 2-channel and a 4-channel configuration (SHFPPC2 and SHFPPC4) are available. The SHFPPC2 cannot be upgraded to the SHFPPC4.

How many readout lines can I drive with one SHFPPC? The fully featured 4-channel SHFPPC allows you to optimally control up to 4 parametric amplifiers on up to 4 readout lines.

For what qubit types and readout methods is the SHFPPC suitable? The SHFPPC is best suited for qubits or other systems that can be read out with microwave signals in the band of 5 to 10 GHz, for example superconducting circuits or hybrid superconducting/ spin qubit systems.

What tools are provided to help me with my experiments? With every release of our LabOne software, we provide new tools and features. We also offer a library of Python notebooks and tutorials that help you setup and control your SHFPPC as quickly as possible.



Wiring diagram for the setup of a full readout chain, including the SHFQA Quantum Analyzer and SHFPPC Parametric Pump Controller.

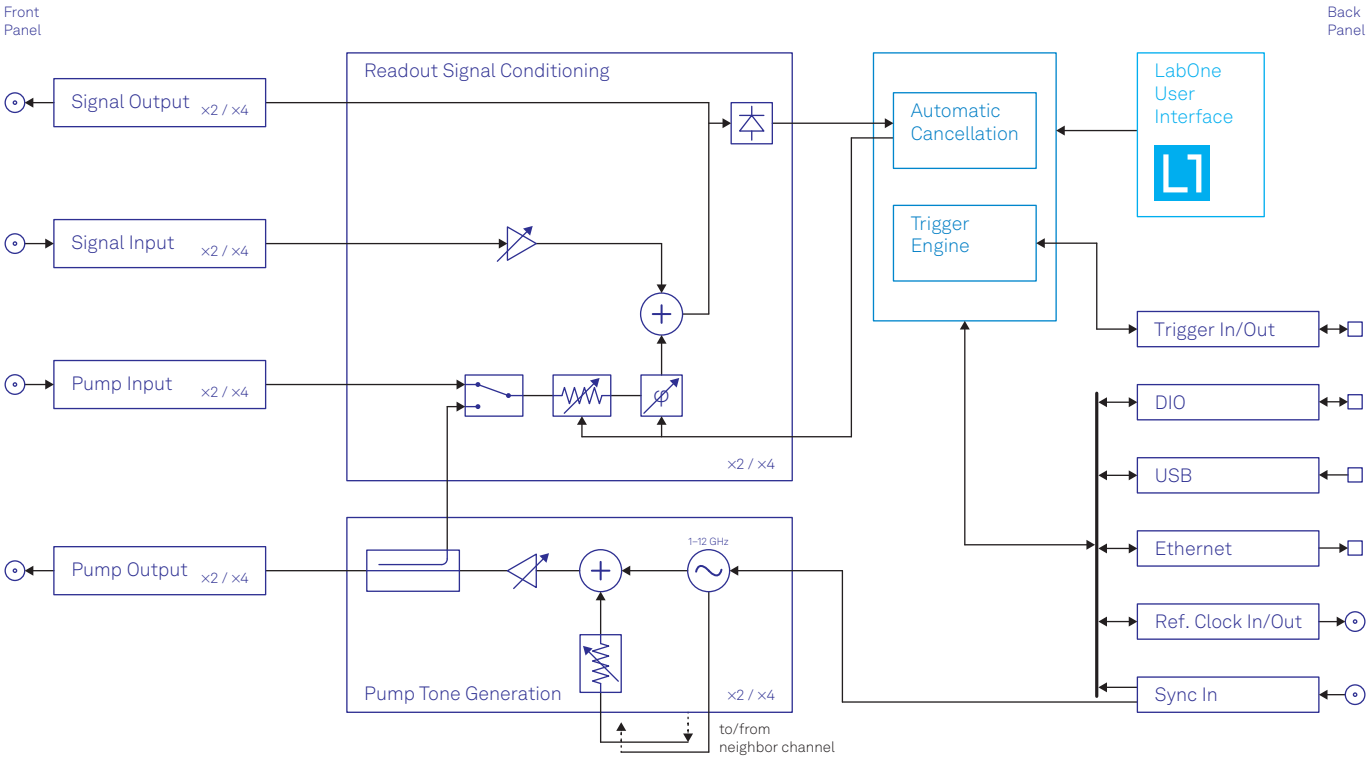
Specifications

General	
Number of channels	2 or 4
Dimensions	19” rack, 1U
Weight	6.5 kg (15 lb)
Power supply	AC: 90 – 260 V, 50/60 Hz
Connectors	SMA, DIO, LAN, USB
Trigger	4 inputs, 4 outputs

Readout signal conditioning	
Frequency range	5 - 10 GHz
Pump tone suppression	up to 65 dB (based on frequency selective power measurement)
Span of variable attenuator	50 dB
Span of variable phase shifter	> 360 deg
Measurement features	Integrated power detector Power spectral density measurements provided by Quantum Analyzer channel

Pump tone generation	
Frequency range	1 - 12 GHz
Frequency resolution	1 kHz
Output phase noise (at 7 GHz)	-100 dBc/Hz @ 1 kHz -110 dBc/Hz @ 10 kHz -110 dBc/Hz @ 100 kHz
Phase stability	0.1 deg/h <1 deg/°C
Level stability	<0.01 dB/h <0.01 dB/°C (with automatic level control)
Output impedance	50 Ω
Output coupling	AC
Multi-tone signal	Yes, allows for combined pump and probe tone

Functional Diagram



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