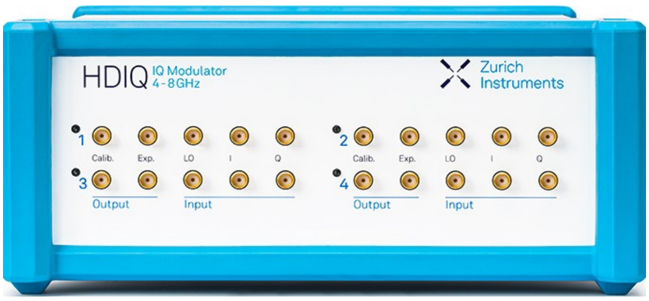
HDIQ
IQ Modulator

4 - 8 GHz, 4 channels

Product Leaflet

Release date: February 2021

Zurich Instruments

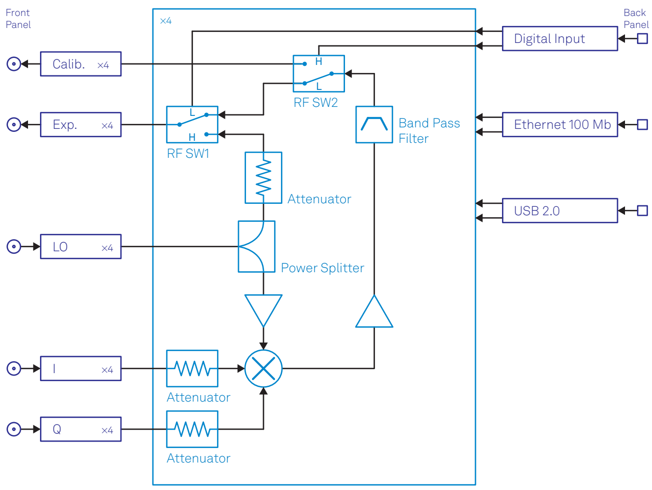


Key Features

- 4-channel IQ modulator
- RF frequency range 4 - 8 GHz
- Intermediate frequency range DC - 6 GHz
- Switchable output port for RF and direct LO
- Separate output port for mixer calibration
- AC-coupled RF circuit design preventing ground loops
- Python programming support for mixer calibration

Summary

The Zurich Instruments HDIQ IQ Modulator is a frequency up-conversion device designed for superconducting quantum computing experiments. The HDIQ can be used to manipulate 4 qubits when combined with the 8-channel HDAWG Arbitrary Waveform Generator (HDAWG8) and an external microwave generator. The design of the HDIQ allows users to switch between different operating modes without cable reconnection, therefore reducing complexity and increasing reliability. Python programming for automated mixer calibration of single and multiple HDIQs is also supported. The HDIQ as an accessory of the HDAWG is part of the Zurich Instruments Quantum Computing Control System (QCCS).



Hardware

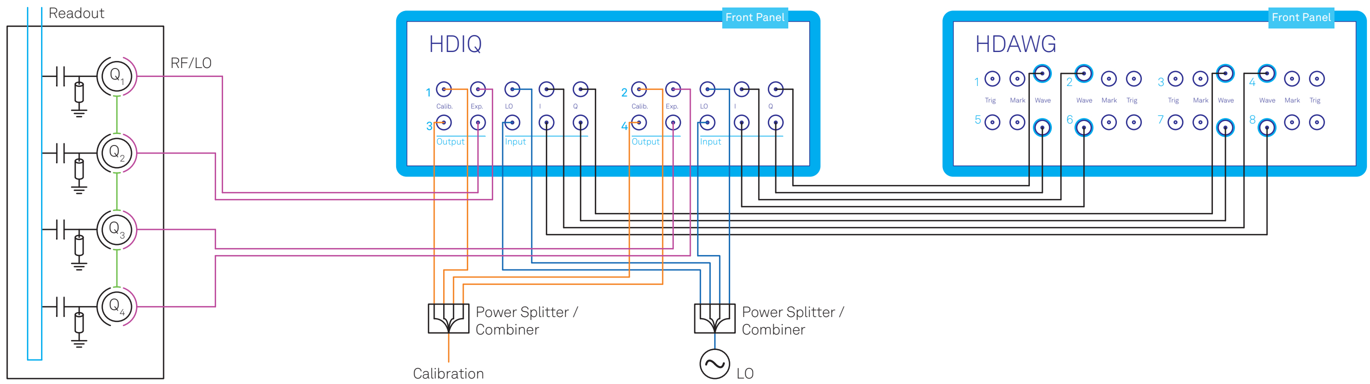
The HDIQ has 4 identical frequency up-conversion boards. Each of them counts 3 inputs, I (in-phase), Q (quadrature) and LO (local oscillator), and two outputs, Exp. (experiment) and Calib. (calibration). The amplified and filtered up-converted signal after the IQ mixer goes either to the calibration port for mixer calibration or to the experiment port for qubit experiments. The experiment port can also output the attenuated LO signal, which can then be used for qubit spectroscopy. The switchable operating modes (calibration, RF and LO) are controlled by a host computer via an Ethernet connection or by external TTL signals directly. Thanks to the AC-coupled RF circuit design, there are no extra ground loops.

Applications

The HDIQ is a compact and dedicated instrument for frequency up-conversion in experiments with superconducting qubits. The high-quality IQ mixers of the HDIQ allow users to suppress LO leakage and the sideband to < -55 dBc. The amplifiers and filters of the HDIQ ensure high output power with low higher-order harmonics and spurs, therefore enabling fast and high-fidelity gate operation. Two examples of application for 4-qubit systems are qubit experiments and mixer calibration.

Qubit Experiments

To generate the qubit driving pulses, an external LO source and an HDAWG are required. In default mode, i.e.,



with both RF switches in logic “low”, the RF output signal from the HDIQ Exp. port goes to the physical system for qubit manipulation.

For qubit spectroscopy, sweeping over a wide frequency and amplitude ranges is often required. This can be achieved by operating the HDIQ in LO output mode without cable reconnection.

For qubit readout, the HDIQ can be used for readout pulse generation with the UHFQA Quantum Analyzer and an external LO source. An external RF switch can be used to switch between readout signal analysis and mixer calibration without any additional cabling work.

Mixer Calibration

LO leakage and image sideband suppression of IQ mixers are both frequency-dependent, and any non-negligible LO leakage and image sideband may cause off-resonant and unwanted excitations. To eliminate this effect, all IQ mixers have to be calibrate

The mixers can be calibrated by measuring the Calib. output signal of the HDIQ in calibration mode with the UHFQA FFT function while scanning the IQ pulse parameters generated by the HDAWG.

User Benefits

- Supports mixer calibration, qubit spectroscopy, and qubit manipulation
- Full software controllability without the need for cable reconnection, straightforward to set up
- Scalable solution designed for superconducting quantum computing thanks to high channel density
- Saves administrative work and development time
- Cost-effective compared to all other options

Specifications

General	
Dimensions (including bumper)	28.3 × 23.2 × 10.2 cm 11.1 × 9.1 × 4.0 inch
Weight (including bumper)	3.2 kg; 7.1 lbs
DC power inlet	12 V, 2 A

Operating modes	
Switchable modes	Calibration, RF (default), LO

Gain	
Maximum gain[1]	-5 dB @ 4 GHz

Power	
RF/Calibration 1 dB compression point[2]	+5 dBm
LO input power	Min. +1 dBm Typ. +5 dBm Max. +7 dBm
I/Q input 1 dB compression point[2]	+10 dBm

Frequency response	
Channels	4
RF/LO frequency	4 - 8 GHz
IF frequency	DC - 6 GHz

Carrier leakage, sideband suppression and crosstalk	
Carrier leakage suppression[3]	< -55 dBc
Sideband suppression[3]	< -55 dBc
Crosstalk	< -50 dB @ 8 GHz typ. < -65 dB
SFDR	> 40 dBc

RF switches	
LO/RF isolation[4]	> 57 dB
Switching time	< 0.1 s

[1]The max. gain is defined as $P_{\mathrm{RF,Exp.}}/P_{\mathrm{I}}$ or $P_{\mathrm{RF,Exp.}}/P_{\mathrm{Q}}$.
[2]This is limited by the amplifier and not by the IQ mixer.
[3]The results are obtained after mixer calibration.
[4]The isolation is defined as $P_{\mathrm{LO,input}}/P_{\mathrm{LO,Exp.}}$ in RF mode.

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