400 MS/s, 16-Bit I/Q Signal Generator

NI PXIe-5450 *NEW!*

- Dual-channel, differential I/Q signal generation
- 16-bit resolution, 400 MS/s sampling rate per channel
- 98 dB close-in SFDR at 1 MHz
- 145 MHz analog bandwidth for generating 290 MHz bandwidth RF signals
- ±0.15 dB flatness to 120 MHz with digital flatness correction
- 25 ps channel-to-channel skew
- <-140 dBc/Hz phase noise density for 10 MHz tone (1 kHz offset)
- -160 dBm/Hz average noise density
- 128 or 512 MB of deep onboard memory
- Continuous data streaming >600 MB/s from host
- 1 V_{pk-pk} output, 2 PXI slots

Operating Systems

- Windows Vista/XP/2000

Recommended Software

- LabVIEW
- LabWindows™/CVI
- LabVIEW SignalExpress
- Measurement Studio

Included Software

- NI-FGEN driver
- NI-FGEN Express VIs
- NI Modulation Toolkit
- NI Analog Waveform Editor
- FGEN Soft Front Panel
- LabVIEW Real-Time driver

Calibration

- Self-calibration with gain and channel alignment; offset correction
- 1-year external calibration cycle

Overview

The NI PXIe-5450 is a 16-bit, 400 MS/s, dual-channel arbitrary waveform generator optimized for I/Q communications signals. Each of the differential outputs features 98 dB of close-in spurious-free dynamic range (SFDR) at 1 MHz (without harmonics), better than -140 dBc/Hz phase noise density at 10 MHz (1 kHz offset), and less than 25 ps channel-to-channel skew. The NI PXIe-5450 is the ideal instrument to test devices with I/Q inputs or to serve as the baseband component of an RF vector signal generator. It also features onboard signal processing (OSP) functions that include pulse shaping and interpolation filters, gain and offset control, and a numerically controlled oscillator (NCO) for frequency shifting. Common applications include prototyping, validating, and testing of semiconductor components and communications, radar, and electronic warfare systems.

With its NI Synchronization and Memory Core (SMC) architecture, the NI PXIe-5450 helps you integrate mixed-signal test systems by enabling synchronization with other instruments such as vector signal analyzers/generators, high-speed digitizers, digital waveform analyzers/generators, and other signal generators. You can also synchronize multiple arbitrary waveform generators to form a phase-coherent multichannel generator for applications such as MIMO (multiple-input, multiple-output) or beamforming antenna schemes.

Signal Quality

With 16 bits of resolution, the NI PXIe-5450 achieves a close-in SFDR (without harmonics) of 98 dB at 1 MHz. Including harmonics and measured from DC to 200 MHz, it achieves a 1 MHz SFDR of 75 dB and a wideband SFDR of 70 dB at 60 MHz. This ensures the dynamic range and out-of-band performance needed to meet the stringent demands of baseband I/Q signal generation (Figure 1).

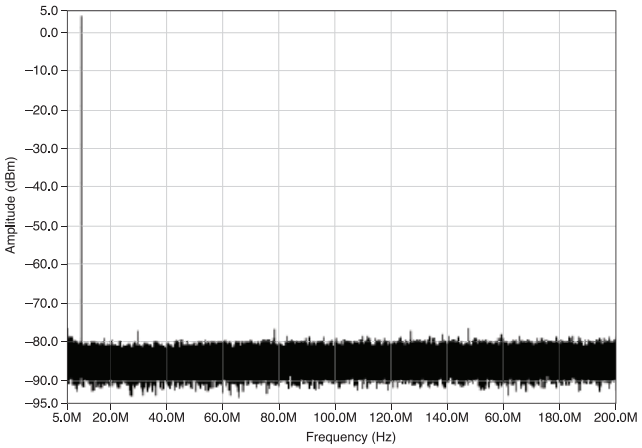

Figure 1. With its high sample rate and resolution, the NI PXIe-5450 generates low-distortion, high-SFDR signals over a very high bandwidth (the noise floor is limited by the measurement device).

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The NI PXIe-5450 also delivers exceptional passband flatness (Figure 2). While the -3 dB analog bandwidth is 145 MHz, the digital flatness correction filter provides ±0.15 dB of flatness from DC to 120 MHz.

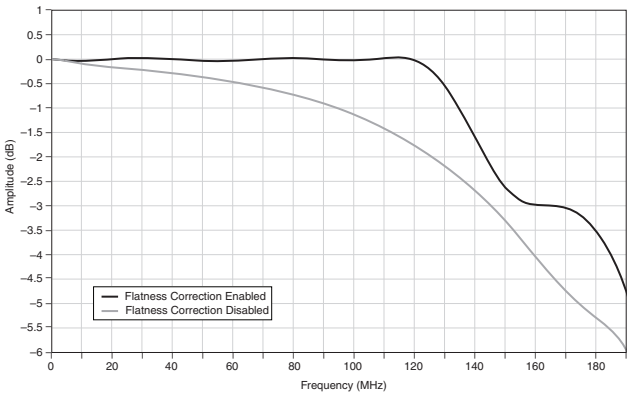

Figure 2. Passband flatness is significantly improved with the use of digital flatness correction in the NI PXIe-5450 FPGA.

For maximum signal purity, the phase noise of this module is extremely low. The phase noise density of a tone generated at 10 MHz drops from -121 dBc/Hz at a 100 Hz offset to -150 dBc/Hz at 100 kHz, yielding an integrated system output jitter of less than 500 fs. Its highly stable phase-locked loop (PLL) and high-resolution oscillator provide an output sample rate resolution less than 5.7 µHz, enabling low phase noise signal generation at any frequency with microhertz resolution.

An essential attribute for I/Q generation is tight synchronization between channels. The NI PXIe-5450 features high-performance circuitry that calibrates the channel skew to within 25 ps. You can achieve even more alignment with a 10 ps resolution programmable skew, useful in calibrating out cable length mismatches. This tight level of synchronization minimizes the phase error between channels, especially at high frequencies, which is essential for accurately generating high-bandwidth I/Q signals (Figure 3).

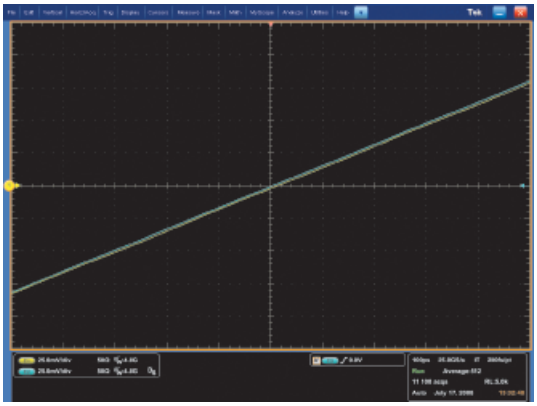

Figure 3. Dedicated channel-alignment circuitry automatically calibrates the two channels on the NI PXIe-5450 to within 25 ps. This particular module exhibits less than 13 ps of skew, demonstrated on a 100 MHz sinusoid.

High-Speed Data Streaming

In addition to tight synchronization, the SMC architecture on the NI PXIe-5450 takes advantage of the PCI Express bus to continuously stream data from the host controller at more than 600 MB/s in dual-channel mode or at 360 MB/s when generating a single channel. This enables the module to continuously output I/Q waveforms at 150 MS/s or, when upconverted, approximately 120 MHz RF bandwidth, either from host memory or a high-speed storage solution such as the NI HDD-8264 3 TB RAID array. With this technology, you can generate terabyte waveforms of unique, high-bandwidth data for several hours. Applications that benefit from this capability include RF and baseband recording and playback for signal intelligence and communications system design, validation, and verification.

Onboard Signal Processing

OSP significantly extends waveform playback time and shortens waveform download times (Figure 4). A field-programmable gate array (FPGA) on the NI PXIe-5450 implements the OSP functionality, which enables several signal processing and I/Q-related functions. These functions include those listed on page 3.

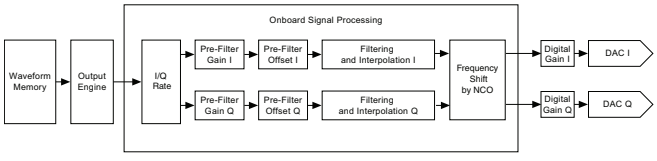

Figure 4. OSP on the NI PXIe-5450 FPGA performs inline processing of waveform data before it is sent to the digital-to-analog converter (DAC) .

- **Independent I and Q prefilter gain and offset** – Adds gain and offset imbalance impairments and I and Q prefilter gain. You can adjust the offset before or during the generation of an output signal (Figures 5, 6).

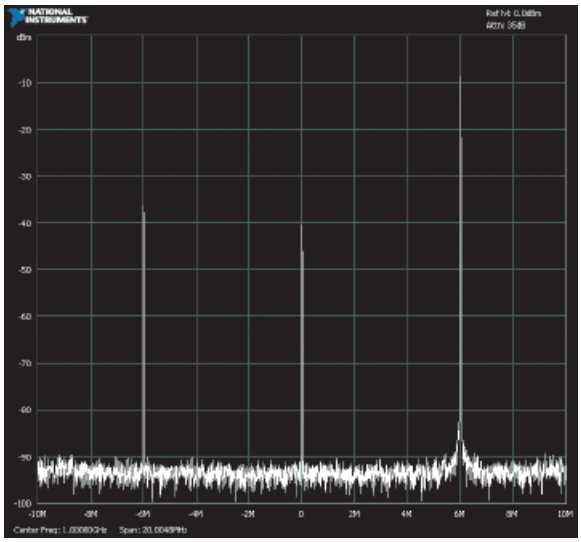

Figure 5. LO leakage and poor image rejection of a quadrature modulator cause undesired RF emissions.

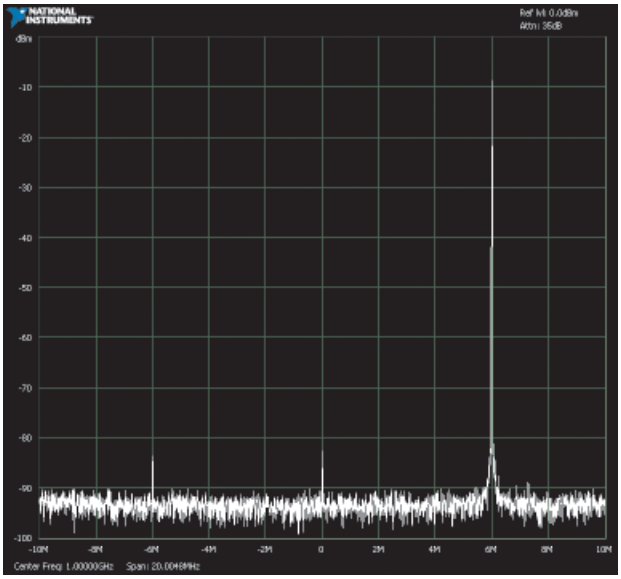

Figure 6. On-the-fly-adjustable parameters on the NI PXIe-5450 correct for the quadrature modulator impairments seen in Figure 5.

- **Pulse-shaping finite impulse response (FIR) filter** – Shapes and interpolates the waveform data. FIR filter types include flat, raised cosine, and root raised cosine, with a programmable α parameter. Digital interpolation factors range from 2 to 32,768 times.
- **Numerically controlled oscillator (NCO)** – Produces sinusoidal waveform data for complex (I/Q) frequency shifts before or during generation with up to a ±86 MHz shift and 710 nHz resolution. NCO tuning time is 250 µs.
- **Baseband interpolation** – Generates smooth baseband signals. You can use the NI PXIe-5450 OSP block to interpolate low-sample rate waveforms to a much higher sample rate, thereby improving the output frequency spectrum by relocating zero-order sample-and-hold reconstruction images to higher frequencies. With the images at higher frequencies, the device's image suppression filter greatly suppresses them without disturbing the signal's amplitude response or phase information.

Waveform Sequencing and Triggering

You also can program the NI PXIe-5450 to sequence and loop a set of waveforms. You can choose from several methods to step through the sequence of waveforms. In cases when you know the duration of each waveform in advance, you can program the generator to loop them a specified number of times. When you do not know the duration before the start of generation, you can use a hardware or software trigger to advance the generator to the next waveform in the sequence. The NI PXIe-5450 implements advanced triggering behavior with four trigger modes: single, continuous, burst, and stepped. In addition, scripting provides the ability to link and loop multiple waveforms together, managing triggers and markers. For a detailed discussion of these modes, consult the *NI Signal Generators Help* guide available at **ni.com/manuals**.

NI SMC-based generators have the unique capability of storing multiple sequences and their associated waveforms in the generator's onboard memory (see Figure 7). In automated test applications involving multiple tests, each requiring a different waveform sequence, you can download all of the sequences and waveforms once at the beginning of the test cycle and store them in the generator's memory for the entire session. By downloading all required waveforms and sequences once to an SMC-based generator instead of repeatedly reloading them for each test, you save time and improve throughput.

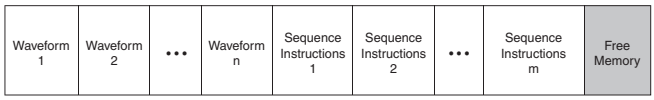

Figure 7. NI SMC-based arbitrary waveform generators increase test throughput by storing all the waveforms and sequences required for a set of tests in onboard memory.

Timing and Synchronization

Using NI T-Clock (TClk) synchronization technology, you can synchronize multiple NI PXIe-5450 modules for applications requiring a greater number of channels, such as I/Q signal generation for MIMO systems. Because it is built into the SMC, TClk can synchronize the NI PXIe-5450 with SMC-based vector signal analyzers and generators, high-speed digitizers, and digital waveform generators and analyzers for tight correlation of analog and digital stimulus and response. Using onboard calibration measurements and compensation, TClk can automatically

synchronize any combination of SMC-based modules with less than 500 ps module-to-module skew. Greatly improved from traditional synchronization methods, the skew between modules does not increase as the number of modules increases. To achieve even better performance, you can use a high-bandwidth oscilloscope to precisely measure the module-to-module skew. With the oscilloscope measurement for calibration information, TClk can achieve <20 ps module-to-module skew.

NI PXIe-5450 clocking is very flexible. Its internal, DDS-based clock is optimized for phase noise performance, and has better than 5.7 µHz frequency resolution. The module can also import its sample clock from the CLK IN front panel connector and multiply and divide this clock's frequency by integers. Finally, the NI PXIe-5450 can phase-lock its internal clock to an external reference or the PXI 10 MHz reference clock.

Driver Software

Accurate, high-throughput hardware improves the performance of a measurement system, but easy-to-use, reliable software reduces development time and ongoing support costs. NI-FGEN, the driver software for the NI PXIe-5450, is the world's most advanced and thoroughly tested arbitrary waveform generator software. It features:

- **Intuitive application programming interface (API)** – In NI LabVIEW and LabWindows/CVI as well as Microsoft Visual Basic and Visual C/C++, the NI-FGEN API is engineered to use the least number of functions possible while maintaining flexibility. Each driver function has thorough online searchable documentation. The *NI-FGEN Instrument Driver Quick Reference* guide further simplifies programming by providing an overview of each driver function's LabVIEW icon, function name, parameters, and data types.
- **LabVIEW Express VIs** – For generating an arbitrary repetitive signal, the LabVIEW Express VI is a configuration-driven method of programming the NI PXIe-5450 without accessing the underlying NI-FGEN functions.
- **Soft Front Panel** – For quick, nonprogrammatic use of the NI PXIe-5450, the Soft Front Panel supports arbitrary waveform generation.
- **Example Programs** – NI-FGEN provides 23 programming examples for LabVIEW, LabWindows/CVI, Visual C++ 6.0 and .NET, and Visual Basic 6.0, giving developers references on which to base custom applications.
- **LabVIEW Real-Time Support** – For remotely deployed, autonomous measurement systems or applications requiring the highest possible reliability, NI-FGEN works with the LabVIEW Real-Time Module.

Modulation Toolkit for LabVIEW[1]

The NI Modulation Toolkit for LabVIEW provides functions for signal generation, analysis, and visualization of custom and standard analog and digital modulation. With the Modulation Toolkit, you can develop and analyze custom modulation formats and generate these with the NI PXIe-5450. Some of the standard measurement functions include error vector magnitude (EVM), modulation error ratio (MER), and ρ (rho). Functions are also available for injecting impairments including IQ gain imbalance, quadrature skew, and additive white Gaussian noise (AWGN). Visualization functions include trellis, constellation, and 2D and 3D eye diagrams. This hardware and software combination gives you access to customizable functionality not available in traditional instrumentation.

Modulation/Demodulation

- 4-, 8-, 16-, 32-, 64-, 128-, 256-QAM
- 2-, 4-, 8-, 16-FSK
- MSK and GMSK
- 8-, 16-, 64-PSK
- BPSK, QPSK, OQPSK, DQPSK, π/4DQPSK
- AM, FM, PM

Modulation Analysis Functions

- ρ (rho)
- Phase error
- IQ gain imbalance
- Frequency deviation
- Burst timing measurements
- Error vector magnitude
- DC offset
- Quadrature skew
- Bit error rate (BER)
- Additive white Gaussian noise
- Modulation error ratio (MER)

Visualization and Analysis

- Trellis diagrams
- Constellation plot
- 2D and 3D eye diagrams

Modulation Impairments

- Multitone
- Fading profile
- Quadrature skew
- DC offset
- Frequency offset
- IQ gain imbalance

[1] *The NI Modulation Toolkit data sheet is available separately.*

Analog Waveform Editor[2]

The NI Analog Waveform Editor is an interactive software tool for creating and editing analog waveforms. In the editor, each waveform comprises different components, and each component comprises a collection of primitives. You can create a new waveform segment by selecting from a library of more than 20 waveform primitives (Table 1), by entering a mathematical expression, or by importing data from a file. You can then combine waveform primitives point-by-point using addition, subtraction, multiplication, or division to create more complex segments (Figure 8). You can also concatenate multiple segments to make a larger waveform. To further process the waveform, you can apply standard or custom FIR and IIR filters or smooth any discontinuities between different waveform segments. Once complete, all the waveform settings are

stored along with the waveform's raw sample data, making it easy to reload the waveform in the editor and modify the settings of a particular segment or primitive.

[2]*The NI Analog Waveform Editor data sheet is available separately.*

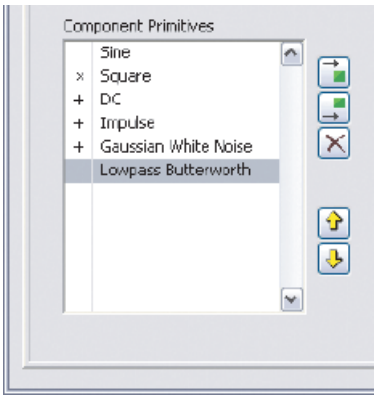

Figure 8. You can combine more than 20 different waveform primitives to create more complex waveforms.

Waveform Primitives		
Sine	Triangular noise	Trapezoid
Square	Gaussian noise	Stairstep
Triangle	Sinc	Haversine
Sawtooth	Gaussian pulse	Impulse
Uniform noise	Exponential rise/decay	Lorentzian pulse

Table 1. Partial List of Configurable Waveform Primitives Available in the NI Analog Waveform Editor

Specifications

For complete specifications, see the *NI PXIe-5450 Specifications* manual at **ni.com/manuals**.

Ordering Information

NI PXIe-5450 .....780419-0M[1]

[1]M (onboard memory): 1 (128 MB), 2 (512 MB)

Includes NI-FGEN driver, FGEN Soft Front Panel, NI Modulation Toolkit for LabVIEW, and NI Analog Waveform Editor.

Recommended PXI Switch

NI PXI-2546.....778572-46

Note: All images show typical results for one production-quality NI PXIe-5450.

BUY NOW!

For complete product specifications, pricing, and accessory information, call 800 813 3693 (U.S.) or go to **ni.com/signalgenerator**.

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Hardware Services

NI Factory Installation Services

NI Factory Installation Services (FIS) is the fastest and easiest way to use your PXI or PXI/SCXI combination systems right out of the box. Trained NI technicians install the software and hardware and configure the system to your specifications. NI extends the standard warranty by one year on hardware components (controllers, chassis, modules) purchased with FIS. To use FIS, simply configure your system online with **ni.com/pxiadvisor**.

Calibration Services

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