100 MS/s, 16-Bit Arbitrary Waveform Generator with Onboard Signal Processing

NI PXIe-5442 *NEW!*

- Baseband and intermediate frequency generation
- Interpolation and pulse-shaping filters
- Carrier frequencies up to 43 MHz with 355 nHz resolution
- 16-bit resolution, 100 MS/s sampling rate
- 400 MS/s effective sampling rate with digital-to-analog converter (DAC) interpolation
- 32, 256, and 512 MB of onboard memory
- Multimodule synchronization with <20 ps_{rms} skew

Operating Systems

- Windows Vista/XP/2000/NT

Recommended Software

- LabVIEW
- LabWindows™/CVI
- LabVIEW SignalExpress
- Measurement Studio
- Digital Filter Design Toolkit

Included Software

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

Calibration

- Gain and offset self-calibration
- 2-year external calibration cycle

Overview

The National Instruments PXIe-5442 is a 100 MS/s arbitrary waveform generator with onboard signal processing (OSP). OSP functions include pulse shaping and interpolation filters, gain and offset control, a numerically controlled oscillator (NCO), and IQ mixing for quadrature digital upconversion. With 16-bit resolution and -91 dBc close-in spurious-free dynamic range (SFDR), the NI PXIe-5442 is ideal for baseband I/Q and intermediate frequency (IF) generation. Common applications include prototyping, validation, and testing of semiconductor components and communications, radar, and electronic warfare systems. The NI PXIe-5442 is also a full-featured arbitrary waveform generator capable of generating general-purpose test signals at a maximum output range of 2 V_{pk-pk} into a 50 Ω load.

With its National Instruments Synchronization and Memory Core (SMC) architecture, the NI PXIe-5442 aides in the integration of mixed-signal test systems by enabling synchronization with other instruments such as digitizers, digital waveform generator/analyzers, and other signal generators. In fact, you can synchronize multiple arbitrary waveform generators to form a phase-coherent multichannel generator for generating multiple I/Q signal pairs common in applications such as MIMO (multiple input, multiple output) or beamforming antenna schemes.

High-Speed Data Streaming

As a PXI Express instrument, the NI PXIe-5442 makes use of the PCI Express bus to continuously stream data from the host controller at rates up to 540 MB/s, much higher than the maximum output rate of the instrument. This enables the generator to continuously output waveforms at 100 MS/s (200 MB/s) from either host memory or other high-end storage solutions such as RAID hard drive arrays. Applications that benefit from this capability include RF/IF data streaming in signal intelligence, data record and playback, and scientific applications.

Onboard Signal Processing (Digital Upconversion)

Onboard signal processing (OSP) significantly extends waveform playback time and shortens waveform download times (see Figure 1). A field-programmable gate array (FPGA) on the NI PXIe-5442 implements the OSP functionality, which delivers several signal processing functions used to perform digital upconversion to an intermediate frequency. The signal processing functions include the following.

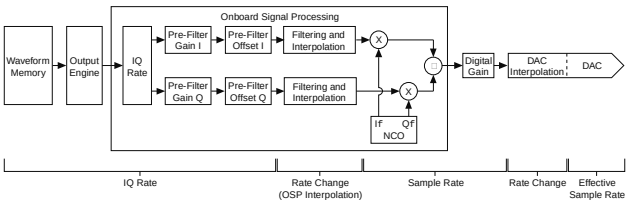

Figure 1. Onboard signal processing uses the NI PXIe-5442 module's FPGA to perform inline processing of the waveform data stored in the module's memory.

- 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.

- Pulse-shaping finite impulse response (FIR) filter—Shapes and interpolates the waveform data. The FIR filter coefficients are programmable and include flat, raised cosine, and root raised cosine. Digital interpolation factors range from one to 16,384 times.
- Numerically controlled oscillator (NCO)—Produces sine and cosine waveform data for quadrature digital upconversion and features 355 nHz frequency resolution and 0.0055 deg phase resolution for precise control of impairments such as frequency error and quadrature skew. You can adjust NCO frequency and phase before or during waveform generation.
- Quadrature digital upconversion with impairments—Upconverts signals, models channel effects, and tests receiver robustness. In quadrature upconversion, I and Q complex waveform data is stored in waveform memory and is passed to the DSP block. DSP then shapes and interpolates the baseband signal and upconverts it to a carrier frequency of up to 43 MHz. You can choose to suppress the lower or upper modulation sideband by adjusting the NCO in-phase and quadrature output phase settings. For modeling channel effects and testing the robustness of a receiver, you can use DSP to add several impairments to the signal during waveform generation. Add IQ gain imbalance and DC offset impairments by adjusting the per-filter gain and offset settings, and introduce quadrature skew and frequency error by adjusting the I or Q carrier phase and frequency.
- Baseband interpolation—Generates smooth baseband signals. You can use the NI PXIe-5442 DSP 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 NI PXIe-5442 seventh-order lowpass analog filter can greatly suppress them without disturbing the signals' amplitude response or phase information. For example, you can interpolate a waveform created at a 10 kS/s sample rate to 10.24 MS/s by using 1024 times digital interpolation in the DSP. The upsampled signal is then passed to the DAC, which can also interpolate by two, four, or eight times, resulting in an effective sampling rate of 81.92 MS/s (eight times DAC interpolation). Because you sample the original waveform at only 10 kS/s, rather than 81.92 MS/s, you achieve a 1:8,192 compression ratio, resulting in dramatically faster waveform computation and download times. Alternatively, you can use the resulting compression to efficiently store data in the NI PXIe-5442 onboard memory to gain significantly longer playback times. Extended generation is essential for improving the statistical significance of many communications measurements and displays such as bit error rate, trellis plots, and constellation plots.

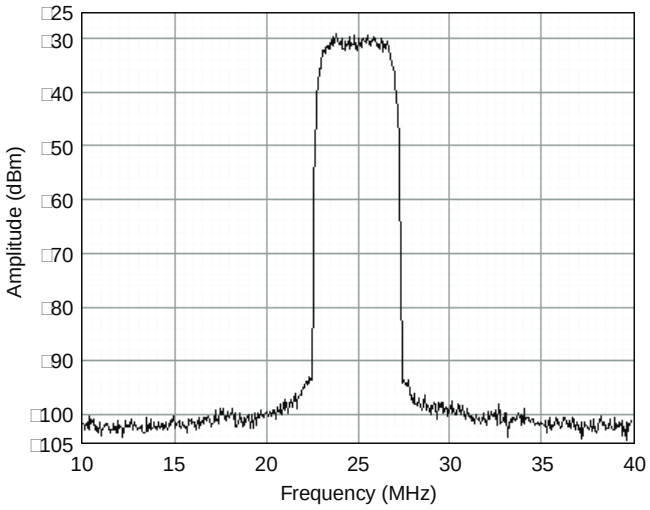

Figure 2. The NI PXIe-5442 with onboard signal processing digitally upconverts and generates the frequency spectrum of a W-CDMA physical layer signal. (external sample clock = 92.16 MHz)

- Amplitude modulation (AM)—Generates AM radio signals. By using only the in-phase (I) path of the DSP block, you can generate an AM radio signal by directly downloading the message signal into onboard memory. The message signal scales the amplitude of the NCO programmable frequency output.
- Single tone and function generation—Generates standard, user-defined waveforms. Using the DSP block NCO, the NI PXIe-5442 can generate sine, square, triangle, ramp, and other standard and user-defined waveforms just as a function generator does. You may adjust the frequency of the output waveform during generation with 355 nHz resolution for generating phase-continuous frequency sweeps and hops. You also can adjust the phase relative to other synchronized instruments, the PXI 10 MHz reference clock, or an externally supplied reference clock.

DAC Interpolation

The NI PXIe-5442 uses digital interpolation to improve the output signal quality of smooth waveforms. Every DAC produces reconstruction images in the frequency domain as a result of the conversion process. Appearing at $|f_o - nf_s|$, where f_o is the frequency of the desired signal and f_s is the sampling rate, reconstruction images are undesirable for smooth signals, such as sine waves.

Typically, arbitrary waveform generators suppress the reconstruction images by using high-order lowpass filters with a cutoff frequency near the generator's Nyquist frequency (50 MHz for a 100 MS/s sample rate). By using a high-order filter with such a low cutoff frequency, the filter's nonidealities, such as passband ripple and nonlinear phase, significantly affect generator performance. The NI PXIe-5442 uses digital

interpolation to increase the effective sample rate, relocating the reconstruction images to higher frequencies.

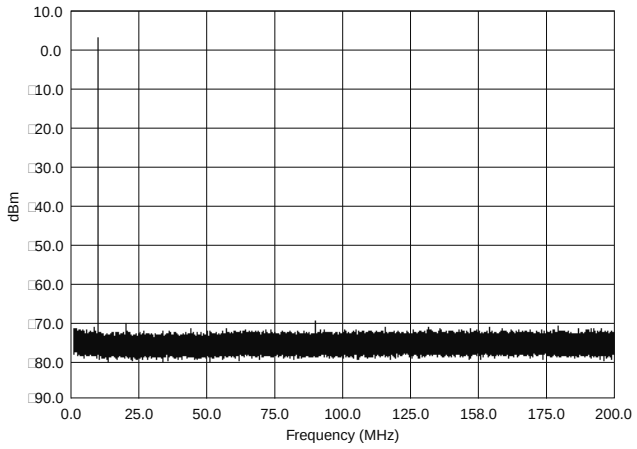

Figure 3. Using a combination of digital interpolation and analog filtering, the NI PXIe-5442 greatly reduces the DAC reconstruction images as shown for the 10 MHz sine signal generated at 100 MS/s using 4X interpolation for a 400 MS/s effective sampling rate. (The noise floor is limited by the measurement device.)

By doing so, the required analog filter cutoff frequency is increased, which lessens the filter's distortion effects. With the combination of digital interpolation and analog filtering, the NI PXIe-5442 has excellent passband flatness and improved image rejection, ensuring a low-distortion output signal.

For sharp waveforms, such as square waves and pulses, you can disable interpolation and analog filtering to produce fast rise/fall times and low pulse aberration (overshoot, undershoot, and so on).

Waveform Sequencing and Triggering

You also can program the NI PXIe-5442 to sequence and loop a set of waveforms. You can choose from several methods to advance through the sequence of waveforms. In some cases, you know the duration of each waveform in advance, so you can program the generator to loop each waveform 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-5442 implements advanced triggering behavior with four trigger modes: single, continuous, burst, and stepped. For a detailed discussion of these modes, please consult the *NI Signal Generators Help Guide* available at ni.com/manuals.

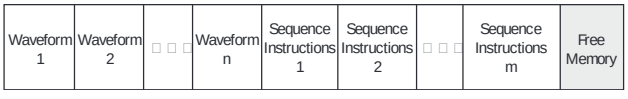

Figure 4. NI SMC-based arbitrary waveform generators increase test throughput by storing all the waveforms and sequences required for a set of tests in onboard memory.

NI SMC-based generators have the unique capability to store multiple sequences and their associated waveforms in the generator's onboard memory (see Figure 4). 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.

Timing and Synchronization

Using NI T-Clock (TClk) synchronization technology, you can synchronize multiple NI PXIe-5442 modules for applications requiring a greater number of channels, such as I/Q signal generation or multiple IF generation for MIMO systems. Because it is built into the SMC, TClk can synchronize the NI PXIe-5442 with SMC-based 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 (see Figure 5).

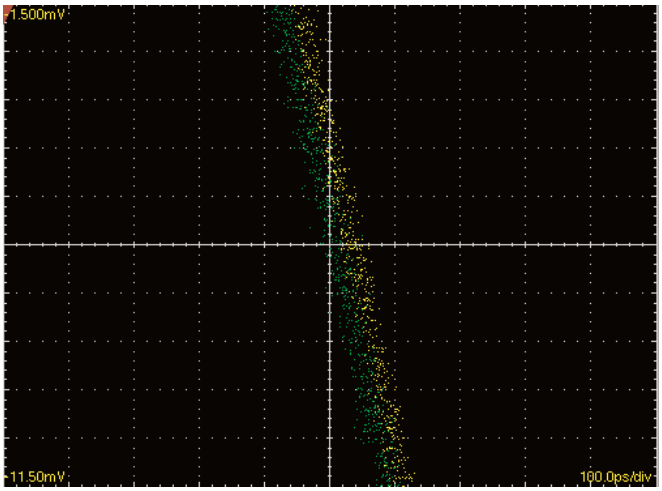

Figure 5. Using SMC TClk synchronization, multiple NI PXIe-5442 modules can achieve <20 ps channel-to-channel skew.

The NI PXIe-5442 sample clock has three modes: Divide-by-N, High-Resolution, and External. The direct digital synthesis (DDS)-based

high-resolution sample clock has a sample rate resolution of 1.06 mHz. This offers exceptional stability and sampling rate flexibility. The NI PXIe-5442 can also import its sample clock from the CLK IN, PXI star trigger, and PXI trigger bus. In addition, you can phase-lock the oscillator in the NI PXIe-5442 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-5442, 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 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-5442 without accessing the underlying NI-FGEN functions.
- Function generator mode Using the CSPs numerically controlled oscillator, the NI PXIe-5442 can behave as an arbitrary function generator with 355 nHz frequency resolution. Using function generator mode, you can generate phase-continuous frequency sweeps and hops.
- Soft Front Panel For quick, nonprogrammatic use of the NI PXIe-5442, the Soft Front Panel supports arbitrary waveform and standard 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-5442. Some of the standard measurement functions include error vector magnitude (EVM), modulation error ratio (MER), and r (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, p/4DQPSK
- AM, FM, PM

Modulation Analysis Functions

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

Visualization and Analysis

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

Modulation Impairments

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

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

Analog Waveform Editor[1]

The NI Analog Waveform Editor is an interactive software tool for creating and editing analog waveforms. In the editor, each waveform comprises different segments, and each segment comprises a collection of primitives. You can create a new waveform segment by selecting from a library of more than 20 waveform primitives (see 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, multiplication, or division to create more complex segments (see Figure 6).

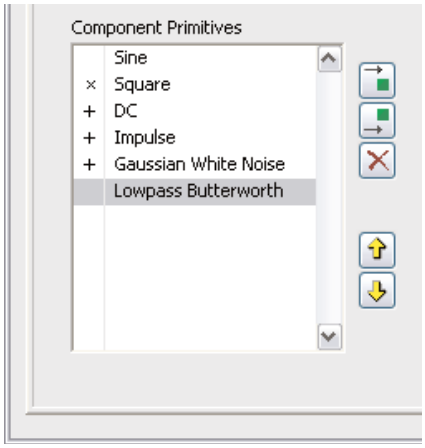

Figure 6. You can combine more than 20 different waveform primitives to create more complex waveforms.

You can 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 settings you chose to create the waveform are stored alongside 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.

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

Waveform Primitives

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

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

Specifications

Full specifications for the NI PXIe-5442 can be found online at ni.com.

Ordering Information

NI PXIe-5442 .....780109-0M[1]

[1] M (onboard memory): 1 (32 MB), 2 (256 MB), 3 (512 MB)

Includes SMB 112 cable, NI-FGEN driver, FGEN Soft Front Panel, NI Modulation Toolkit for LabVIEW, and NI Analog Waveform Editor.

Recommended PXI Switch

NI PXI-2593.....778793-01

Note: All images show typical results for one production-quality NI PXIe-5442.

BUY NOW!

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

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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.

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