100 MS/s, 14-Bit Arbitrary Waveform Generator

NI 5412

- 14-bit resolution, 100 MS/s sampling rate
- 8, 32, or 256 MB of onboard memory
- 20 MHz analog bandwidth
- Multimodule synchronization with <20 ps_{rms} skew
- Function generator emulation mode
- External sample and reference clock inputs

Operating Systems
- Windows 2000/NT/XP
- LabVIEW Real-Time

Recommended Software
- LabVIEW
- LabWindows/CVI
- SignalExpress
- Measurement Studio

Driver Software (included)
- NI-FGEN
- LabVIEW Express VIs
- FGEN Soft Front Panel
- NI Analog Waveform Editor (32 and 256 MB models)

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

NEW

Product	Bus	Channels	Update Rate	Frequency Range (sine)	Resolution	Memory
NI 5412	PCI, PXI	1	100 MS/s	20 MHz	14 bits	8, 32, 256

Overview

National Instruments 5412 devices are 100 MS/s arbitrary waveform generators featuring 14-bit resolution and up to 256 MB of onboard memory in a compact 1-slot 3U PXI module or a single PCI board. Because an NI 5412 uses the PCI bus to communicate with the host computer, waveforms can be downloaded at up to 84 MB/s, far faster than traditional GPIB-based instruments. Using the Synchronization and Memory Core (SMC) architecture of NI 5412 generators, you can create mixed-signal test systems by synchronizing the generator with digitizers and digital waveform generator/analyzers, or synchronize multiple arbitrary waveform generators to form a phase-coherent multichannel generator.

Interpolation

NI 5412 generators use digital interpolation to improve the output signal quality of smooth waveforms. Every digital-to-analog converter produces reconstruction images in the frequency domain as a result of the conversion process. Appearing at $|f_o \pm nf_s|$, 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 Nyquist frequency of the generator (50 MHz for a 100 MS/s sampling rate). By using a high-order filter with such a low cutoff frequency, the imperfections of the filter, such as passband ripple and nonlinear phase, significantly affect generator performance. NI 5412 generators use digital interpolation to increase the effective sampling rate, relocating the reconstruction images to higher frequencies.

By doing so, the required analog filter cutoff frequency is increased, which reduces filter distortion effects. With the combination of digital interpolation and analog filtering, an NI 5412 can have excellent passband flatness and improved image rejection, ensuring a low-distortion output signal.

For sharp waveforms, such as square waves, pulses, and video signals, interpolation and analog filtering can be disabled, resulting in fast rise/fall times and low pulse aberration (overshoot, undershoot, etc.)

Waveform Sequencing and Triggering

An NI 5412 can be programmed to sequence and loop a set of waveforms. Several methods can be used to advance through the sequence of waveforms. In some cases, the duration of each waveform is known in advance, so the generator can be programmed to loop each waveform a specified number of times. When the duration is unknown before generation, a hardware or software trigger can advance the generator to the next waveform in the sequence. The NI 5412 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***.

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NATIONAL INSTRUMENTS™

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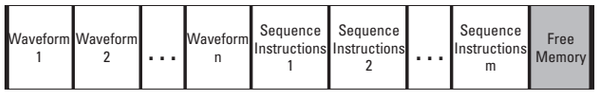

Figure 1. The National Instruments SMC-based arbitrary waveform generators increase test throughput by storing all the waveforms and sequences required for a set of test in onboard memory.

The NI SMC-based generators have the unique capability to store multiple sequences and their associated waveforms in the generator onboard memory (Figure 1). In automated test situations involving multiple tests, each requiring a different waveform sequence, all of the sequences and waveforms can be downloaded once at the beginning of the test cycle and held in onboard memory for the entire session. By downloading all required waveforms and sequences once, instead of repeatedly reloading them for each test, the SMC-based generators save test time and improve test throughput.

Timing and Synchronization

Using T-Clock synchronization technology, two or more NI 5412 generators can be synchronized for applications requiring a greater number of channels, such as component video generation. Because it is built into the SMC, T-Clock can synchronize an NI 5412 with SMC-based high-speed digitizers and digital waveform generator/analyzers for tight correlation of analog and digital stimulus and response. Using onboard calibration measurements and compensation, T-Clock can automatically synchronize any combination of SMC-based modules with less than 500 ps module-to-module skew. Differing from traditional synchronization methods, the skew between modules does not increase as the number of modules increases. To achieve even better performance, a high-bandwidth oscilloscope can be used to precisely measure the module-to-module skew. Using that measurement, T-Clock can achieve <20 ps module-to-module skew (Figure 2).

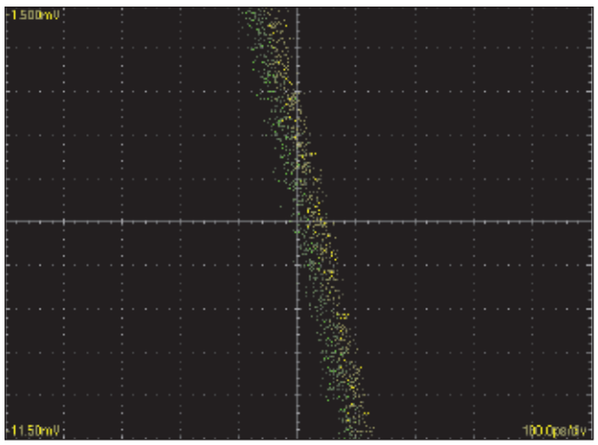

Figure 2. Using the SMC T-Clock synchronization, two or more NI 5412 generators can achieve less than 20 ps channel-to-channel skew.

The NI 5412 sample clock has three modes – Divide-by-N, High-Resolution, and External. The direct digital synthesis-based high-resolution sample clock has a sample rate resolution of 1.06 µHz. This offers exceptional stability and sampling rate flexibility. An NI 5412 can also import its sample clock from the CLK IN, PXI star trigger and PXI trigger bus. In addition, you can phase lock the NI 5412 oscillator 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 your development time and ongoing support costs. NI-FGEN, the driver software for the NI 5412 generators, is advanced and thoroughly tested arbitrary waveform generator software that features:

- **An intuitive application programming interface (API)** – In LabVIEW, LabWindows/CVI, VisualBasic, 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 the LabVIEW icon of each driver function, the function name, parameters, and data types.

- **LabVIEW Express VIs** – For generating an arbitrary repetitive signal, the LabVIEW Express VI is a configuration-driven way to program an NI 5412 without accessing the underlying NI-FGEN functions.

- **Function generator emulation** – Although an arbitrary waveform generator can generate virtually any waveform, often a standard sine, square, or triangle wave at a given frequency is all that is required. The NI-FGEN function generator emulation mode handles the details of computing and downloading the sample data of the desired signal and presents the same controls as a function generator (frequency, amplitude, offset, etc.)

- **A soft front panel** – For quick nonprogrammatic NI 5412 use, the soft front panel provides both arbitrary and standard waveform generation.

- **Example programs** – NI-FGEN provides over 23 programming examples for LabVIEW, LabWindows/CVI, VisualC++ 6.0 and .Net, and VisualBasic 6.0 so you do not have to start from scratch.

- **LabVIEW Real-Time compatibility** – For remotely deployed autonomous measurement systems or applications requiring the highest reliability, NI-FGEN is fully compatible with the LabVIEW Real-Time Module.

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Analog Waveform Editor

The NI Analog Waveform Editor is an interactive software tool for creating and editing analog waveforms. In the editor, each waveform is comprised of different segments, where each segment is comprised of 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 importing data from a file. Waveform primitives can then be combined, point by point, using addition, multiplication, or division to create more complex segments (Figure 3).

Waveform Primitives

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

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

You can concentrate 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 waveform segments. Once complete, all the settings you chose to create the waveform are stored alongside the raw sample data of the waveform, making it easy to reload the waveform in the editor and modify the settings of a particular segment or primitive. The Analog Waveform Editor is included with the 32 and 256 MB modules and is also available separately.

Figure 3. More than 20 different waveform primitives can be point-wise combined to create more complex waveforms.

Ordering Information

NI PCI-5412 .....779177-0M[1]
NI PXI-5412 .....779176-0M[1]
Includes SMB 112 cable, NI-FGEN driver, FGEN Soft Front Panel, NI Analog Waveform Editor (32 and 256 MB models)
[1]M = onboard memory – 1 (8 MB); 2 (32 MB); 3 (256 MB)

Recommended PXI Switch
NI PXI-2593 778793-01
Note: All images show typical results for one production-quality NI 5412.

BUY NOW!
For complete product specifications, pricing, and accessory information, call (800) 813-3693 (U.S. only) or go to ***ni.com/modularinstruments****.*

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Specifications

General

Number of channels 1
DAC Resolution ..... 14 bits
Maximum Sample Rate ..... 100 MS/s
Maximum Effective
Sample Rate with Interpolation ..... 400 MS/s
Bandwidth ..... 20 MHz
Output Paths ..... Driver or user-selected low-gain amplifier or the high-gain amplifier
Recommended Maximum Frequencies
Sine ..... 20 MHz
Square ..... 5 MHz
Triangle, Ramp ..... 1 MHz

Analog Output

Amplitude Range (Full Scale)
Main Output Path ..... 12 V_{pp} to 5.64 mV_{pp} (50 Ω load)
Offset Range ..... ±25% of amplitude range
Output Impedance ..... 50 Ω or 75 Ω, software-selectable
DC Accuracy ..... ± 0.4% of amplitude ± 0.05% of offset ± 1 mV
AC Amplitude Accuracy ..... ± 1.0% of amplitude ± 1 mV at 50 kHz
Passband Flatness ..... ± 1.0 dB (DC to C MHz)
Rise/Fall Time ..... < 20 ns for low gain path
Pulse Abberation ..... < 5%

Spectral Characteristics	Frequency	Low Gain Path (dBc)	High Gain Path (dBc)	
Spurious Free Dynamic Range without Harmonics	1 MHz	-70	-70	Amplitude -1 dBFS
	10 MHz	-65	-65	Measured from
	20 MHz	-60	-60	DC to 50 MHz
Total Harmonic Distortion (THD)	1 MHz	-59	-51	Amplitude -1 dBFS
	10 MHz	-52	-40	2nd through
	20 MHz	-45	-37	6th harmonics

Spectral Characteristics	Path	Amplitude Range Vpk-pk	Amplitude Range dBm	Average Noise Density nV/√Hz	Average Noise Density dBm/Hz	Average Noise Density dBFS/Hz
Average Noise Density	Low gain	2	10.0	45	-134	-144
	High gain	12	25.6	251	-119	-145

Sample Clock

Sources ..... Internal Divide-by-N, Internal High-Resolution, External CLK IN, PXI Star Trigger, PXI_TRIG <0:7>
Frequency Resolution
Divide-by-N ..... (100 MS/s) / N where 1≤ N ≤ 4,194,304
High-Resolution ..... 1.06 µHz

System Phase Noise and Jitter	System Phase Noise Density	System Output Jitter	
NI PXI-5412	-120 dBc/Hz (10 kHz offset)	< 6.0 ps_{rms}	10 MHz carrier
NI PCI-5412	-120 dBc/Hz (10 kHz offset)	< 7.0 ps_{rms}	

Onboard Clock (Internal VCXO)

Clock Source ..... Phase locked to reference clock or derived from onboard VCXO frequency reference
Frequency Accuracy ..... ±25 ppm
PLL Reference Sources ..... PXI_CLK10, CLK IN

Start Trigger

Sources ..... PFI <0:1>, PXI_TRIG<0:7>, PXI star trigger, software, immediate
Modes ..... Single, continuous, stepped, burst

Markers

Destinations ..... PFI <0:1>, PXI_TRIG <0:6>
Quantity ..... 1 marker per segment

Waveform and Instruction Memory Utilization

Onboard Memory Size	8 MB Standard	32 MB Option	256 MB Option
	8,388,608 bytes	33,554,432 bytes	268,435,456 bytes

Output Modes ..... Arbitrary waveform mode and arbitrary sequence mode
Loop Count ..... 1 to 16,777,215. Burst trigger: Unlimited

Memory Limits	8 MB Standard	32 MB Option	256 MB Option	
Arbitrary Waveform Mode Maximum Waveform Memory	4,194,176 Samples	16,777,088 Samples	134,217,600 Samples	Refer to detailed specifications for all trigger modes
Arbitrary Sequence Mode Maximum Waveform Memory	4,194,120 Samples	16,777,008 Samples	134,217,520 Samples	Condition: One or two segments in a sequence
Arbitrary Sequence Mode Maximum Waveforms	65,000	262,000	2,097,000	Condition: One or two segments in a sequence
Arbitrary Sequence Mode Maximum Segments in a Sequence	104,000	418,000	3,354,000	Condition: Waveform memory is < 4,000 samples

Power

Total Power ..... 22 W (typical)

Physical

Dimensions
NI PXI-5412 ..... Single 3U PXI slot
NI PCI-5412 ..... 34.07 x 10.67 x 2.03 cm
Front Panel Connectors
CH0 ..... SMB (Jack)
CLK IN ..... SMB (Jack)
PFI 0 ..... SMB (Jack)
PFI 1 ..... SMB (Jack)

Environment

Operating Temperature
NI PXI-5412 ..... 0 °C to +55 °C (Meets IEC-60068-2-1 and IEC-60068-2-2)
NI PCI-5412 ..... 0 °C to 45 °C
Storage Temperature ..... -25 °C to +85 °C (Meets IEC-60068-2-1 and IEC-60068-2-2)
Operating Relative Humidity ..... 10% to 90%, non-condensing (Meets IEC 60068-2-56)

Calibration

Self-Calibration ..... DC gain and offset
External Calibration Interval ..... 2 years

Certifications and Compliances CE

CE Mark Compliance

Note

Unless otherwise noted, the following conditions were used for each specification:

A. Interpolation set to maximum allowed factor for a given sample rate
B. Signals terminated with 50 Ω
C. Low-gain amplifier path set to 2 V_{pp} and high-gain amplifier path set to 12 V_{pp}.
D. Sample clock set to 100 MS/s

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