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Multichannel RF Signal Generation and Acquisition

NI PXIe-5663E, NI PXIe-5673E *NEW!*

Multichannel RF Signal Analyzers
- 2-, 3-, and 4-channel versions
- Up to 8 channels in multichassis configuration
- 10 MHz to 6.6 GHz frequency range
- 50 MHz analysis bandwidth
- 16-bit quantization
- <500 ps channel-to-channel baseband skew
- <0.1 deg RMS typical channel-to-channel carrier skew
- 256 MB memory per channel
- Record-to-disk capabilities of up to 250 MB/s per channel (50 MHz)

Phase-Coherent Generators
- 2-, 3-, and 4-channel versions
- Up to 8 channels in multichassis configuration
- 85 MHz to 6.6 GHz frequency range
- 100 MHz vector signal generator bandwidth
- 16-bit quantization
- <500 ps channel-to-channel baseband skew
- <0.1 deg typical channel-to-channel carrier skew
- 512 MB memory per channel
- Record-from-disk capabilities of up to 500 MB/s per channel (100 MHz)

Operating Systems
- Windows 7/Vista/XP

Programming Language
- LabVIEW
- LabWindows™/CVI
- C/ C++ /.NET

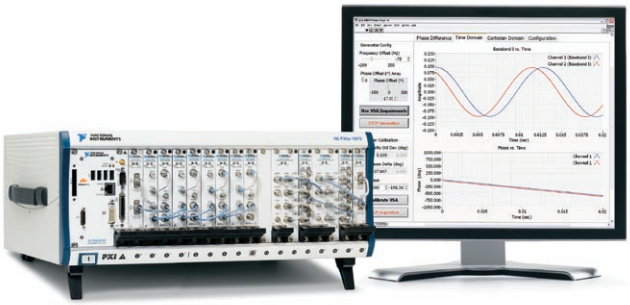




Figure 1. Typically Configured PXI System with Two-Channel Vector Signal Generator and Four-Channel Vector Signal Analyzer

Overview

National Instruments provides flexible software and modular RF instrumentation for phase-coherent RF measurement systems. Based on the NI PXIe-5663E 6.6 GHz RF vector signal analyzer and the NI PXIe-5673 6.6 GHz RF vector signal generator, RF measurement systems can be configured with up to four channels of phase-coherent signal generation or four channels of phase-coherent signal acquisition. This modular system uses a common local oscillator (LO) for each multichannel generator and analyzer and shared analog-to-digital converter or digital-to-analog converter sample clocks for baseband synchronization.

You can use NI RF phase-coherent measurement systems for a variety of applications including multiple input, multiple output (MIMO) system prototyping, MIMO receiver testing, beamforming, and direction finding. Because the baseband interface for both the generator and receiver uses the high-speed PCI Express data bus, the system also supports record and playback using high-capacity RAID (redundant array of inexpensive disks) volumes. For example, a typical four-channel RF signal acquisition system with two RAID volumes continuously records each 50 MHz of bandwidth from each channel for more than two hours (using a 2 TB volume).

System Components

NI RF phase-coherent measurement systems consist of a PXI system equipped with:
- PXI multichannel RF vector signal generators or analyzers
- NI LabVIEW application software
- LabVIEW example code for phase-coherent RF signal generators
- NI PXIe-1075 chassis
- PXI embedded controller
- Optional RAID system

RF Signal Analyzer: NI PXIe-5663E (N-Channel Vector Signal Analyzer)

Phase-coherent RF signal acquisition is based on the NI PXIe-5663 6.6 GHz RF vector signal analyzer. This analyzer features a modular design with a common LO. Using additional downconverters and digitizers, you can expand a one-channel RF signal acquisition system to up to four channels in a single PXI chassis. In addition, multichassis configurations support up to eight or more channels. A block diagram and front panel connections of a four-channel vector signal analyzer are illustrated in figures 2 and 3.

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Multichannel RF Signal Generation and Acquisition

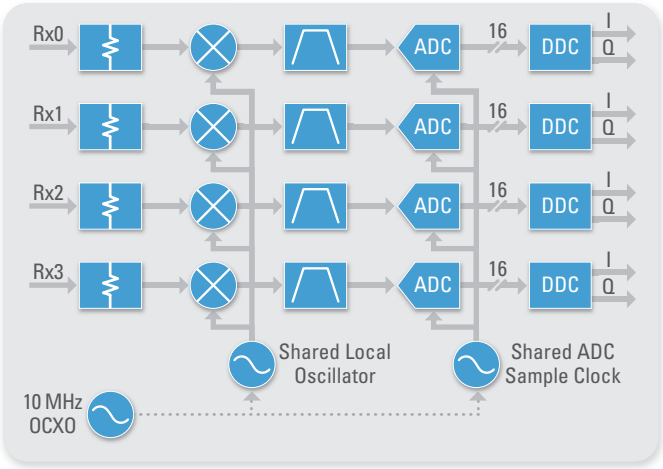


Figure 2. Simplified Block Diagram of Four-Channel Vector Signal Analyzer

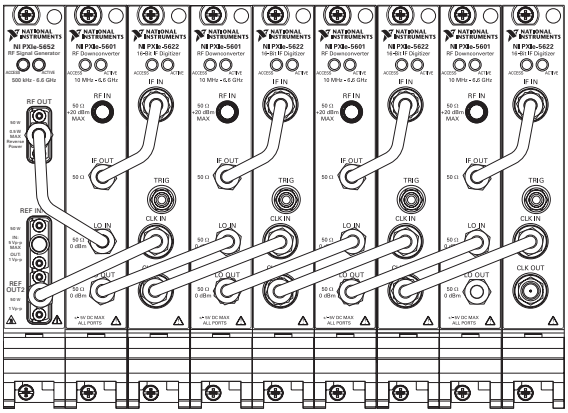


Figure 3. Front-Panel Connection for Four-Channel NI PXIe-5663 Vector Signal Analyzer

RF Signal Analyzer System Components

- **NI PXIe-5652 6.6 GHz RF continuous wave generator** – The NI PXIe-5652 serves as the common LO for the system and produces -110 dBc/Hz phase noise at a 10 kHz offset and center frequency of 1 GHz.
- **NI PXIe-5601 6.6 GHz RF downconverter** – A single-stage downconverter with 50 MHz of IF bandwidth, the NI PXIe-5601 downconverts the RF signal to an intermediate frequency (IF) for use by the NI PXIe-5622 digitizer.
- **NI PXIe-5622 IF digitizer** – With 16-bit quantization and a 150 MS/s sample rate, the NI PXIe-5622 provides wideband and high-dynamic-range IF digitization. The IF signal is digitally downconverted to baseband I and Q samples inside the NI PXIe-5622 IF digitizer.

Note that to ensure true phase coherency, each LO, sample clock, and start trigger is shared between each channel. As a result, all I/Q waveforms acquired from each channel maintain a constant channel-to-channel phase relationship. Typical multichannel vector signal analyzer applications include two-, three-, and four-channel systems. In scenarios where more channels are required, multiple PXI chassis can be synchronized for x8 and x16 configurations.

Feature	Specification	Notes
Frequency range	10 MHz to 6.6 GHz	Continuous frequency coverage
RF bandwidth	50 MHz	–
ADC quantization	16-bit	–
Memory	256 MB per channel	64 MS per channel
RF record-to-disk bandwidth	250 MB/s per channel	62.5 MS/s to RAID volume
I/Q gain imbalance range	-4 to 4 dB	Settable on digitizer DDC
I/Q gain imbalance resolution	0.01 dB	16-bit I/Q sample resolution
Maximum baseband delay	0 to 500 ns	Vector signal analyzer channel-to-channel skew adjustment
Baseband delay resolution	≤4 ps	ADC sample clock adjustment
Quadrature skew	-180 to 180 deg	Settable on digitizer DDC
Quadrature skew resolution	0.0055 deg	16-bit NCO resolution
I/Q delay range	-2 to 2 ns	I versus Q skew adjustment (within one vector signal analyzer channel)
I/Q delay resolution	1 ps	–

Table 1. N-Channel Vector Signal Analyzer Features

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Typical Vector Signal Analyzer (VSA) RF Input Performance

Note that specifications are defined as the worst-case performance from 0 to 50 °C. Typical performance is defined as operation over 25 °C, ±5 °C, within 5 °C of self-calibration temperature.

Feature	Specification	Typical Performance
Baseband ADC channel-to-channel sample clock skew	–	<500 ps
Channel-to-channel LO skew (2.4 GHz)	<±1 deg RMS[1]	<±0.1 deg RMS[1]
Channel-to-channel skew (3.5 GHz) Over time/temperature	<±1 deg RMS[1]	<±0.1 deg RMS[1]
Channel-to-channel skew (5.8 GHz)	<±1 deg RMS[1]	<±0.1 deg RMS[1]
RF input WLAN EVM accuracy (-10 dBm and 2.4 GHz)	–	-44 dB, 0.6%[2]
RF input WLAN EVM accuracy (-10 dBm and 5.8 GHz)	–	-42 dB, 0.8%[2]
RF input WiMAX EVM accuracy (-10 dBm and 2.5 GHz)	–	-46 dB, 0.5%[2]
RF input WiMAX EVM accuracy (-10 dBm and 3.5 GHz)	–	-45 dB, 0.6%[2]
VSA noise density (at 2 GHz)	-155 dBm/Hz	-158 dBm/Hz
VSA noise figure (at 2 GHz)	–	16 dB
VSA absolute power accuracy (330 MHz to 6.6 GHz)	±1.7 dB	±0.65 dB
VSA IF flatness (10 MHz BW) (330 MHz to 6.6 GHz)	–	±0.25 dB
VSA IF flatness (50 MHz BW) (330 MHz to 6.6 GHz)	–	±0.7 dB

[1] 10 kS/s I/Q rate (8 kHz input bandwidth), full-scale input (0 dBm input signal measured using 0 dBm reference level).
[2] Find detailed information on typical performance for WLAN and WiMAX measurements in the data sheets for WLAN and WiMAX software.

Table 2. N-Channel Vector Signal Analyzer Specifications and Typical Performance

Carrier Phase Stability

The shared LO of the PXI N-channel vector signal analyzer results in tight channel-to-channel synchronization over long durations of time. Because each downconverter in an N-channel vector signal analyzer shares a common LO, each channel is able to maintain a stable relative phase offset. In this architecture, you can maintain channel-to-channel phase skew over a wide range of frequencies. Figure 4 shows a histogram of phase offset for a two-channel vector signal analyzer at three carrier frequencies. As the figure illustrates, the maximum channel-to-channel phase skew observed is less than ±0.1 deg RMS over a 1 second aperture time.

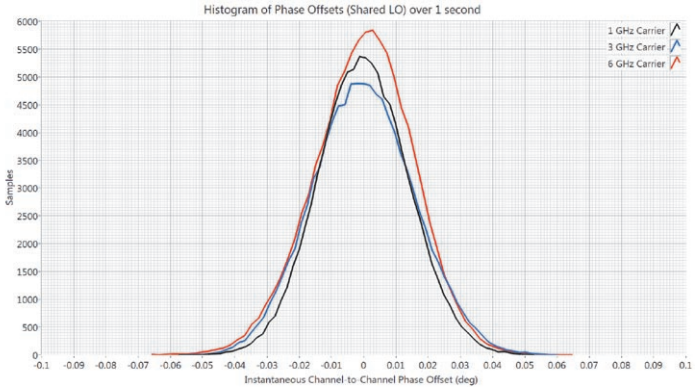


Figure 4. Channel-to-Channel Phase Skew for a 1 Second Aperture Window

Due to the shared LO architecture of the multichannel vector signal analyzer, channel-to-channel phase offset is dominated by signal-to-noise ratio. The channel-to-channel phase offset remains relatively constant across all frequency ranges (see Figure 4).

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RF Signal Generator: NI PXIe-5673E (N-Channel Vector Signal Generator)

Phase-coherent RF signal generation is based on the NI PXIe-5673E 6.6 GHz RF vector signal generator. This generator features a modular design with a common LO. Using additional arbitrary waveform generators (AWGs) and I/Q modulators, you can expand a one-channel RF signal generation system to up to four channels or more. Figures 5 and 6 show a block diagram and front panel connections on a four-channel RF signal generator.

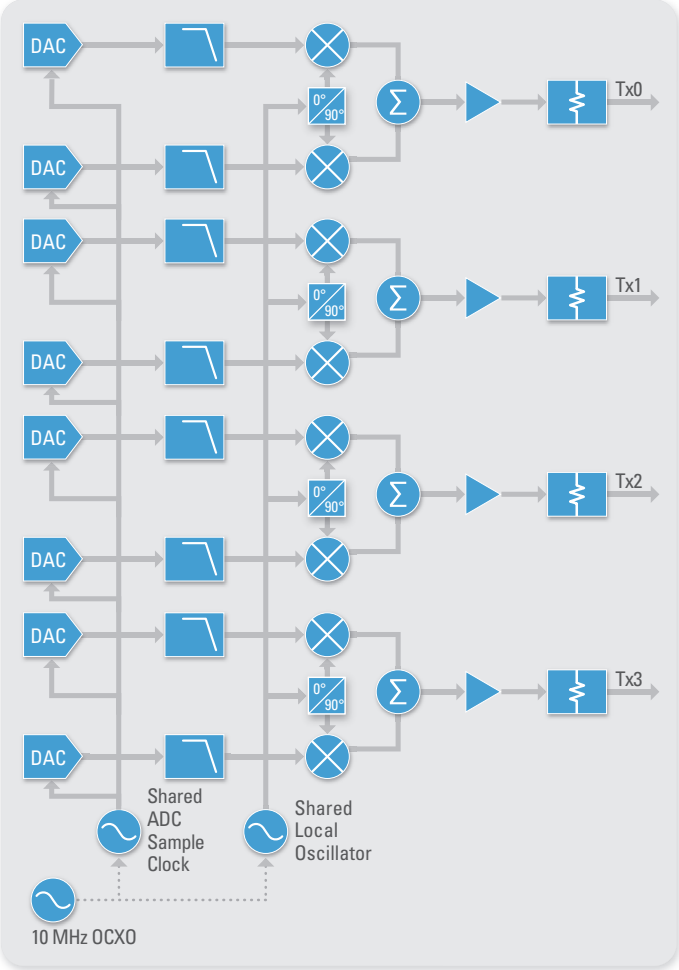


Figure 5. N-Channel Phase-Coherent RF Vector Signal Generator

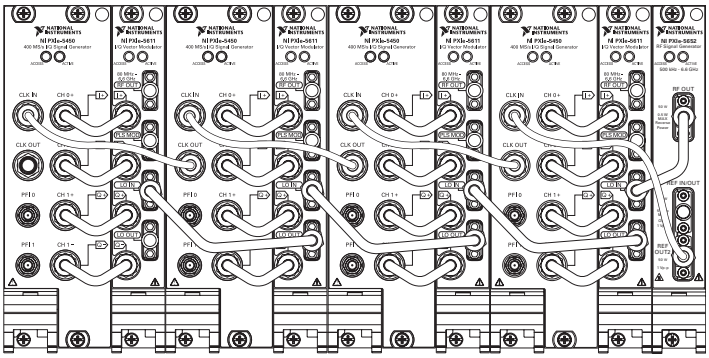


Figure 6. Front-Panel Connection for Four-Channel NI PXIe-5673 Vector Signal Generator

RF Signal Generator System Components

- **NI PXIe-5652 6.6 GHz RF continuous wave generator** – The NI PXIe-5652 serves as the common LO for the system and produces -110 dBc/Hz phase noise at a 10 kHz offset and center frequency of 1 GHz.
- **NI PXIe-5450 arbitrary waveform generator** – With more than 100 MHz of bandwidth at 16-bit quantization, the NI PXIe-5450 provides high dynamic range and wide analog bandwidth.
- **NI PXIe-5611 6.6 GHz I/Q modulator** – The NI PXIe-5611 performs direct upconversion of differential I/Q baseband waveforms. This module enables more than 100 MHz of RF bandwidth.

Feature	Specification	Notes
Frequency range	85 MHz to 6.6 GHz	Continuous frequency coverage
RF bandwidth	100 MHz	–
DAC quantization	16-bit	–
Memory	512 MB per channel	128 MS per channel
Maximum stream-from-disk rate	500 MB/s	125 MS/s from RAID volume
I/Q gain balance range	-1 to 1 dB	Settable on AWG DUC
I/Q gain balance resolution	0.01 dB	–
I/Q skew range	-2 to 2 ns	–
I/Q skew resolution	1 ps	Vector signal generator channel-to-channel skew adjustment
Maximum baseband delay	0 to 2 ns	DAC sample clock adjustment
Baseband delay resolution	10 ps	–
Quadrature skew	-30 to 30 deg	Settable on AWG DUC
Quadrature skew resolution	0.01 deg	16-bit NCO resolution
I/Q delay range	-2 to 2 ns	I versus Q skew adjustment
I/Q delay resolution	1 ps	–

Table 3. N-Channel Vector Signal Generator Features

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Typical Vector Signal Generator RF Performance

Note that specifications are defined as the worst-case performance from 0 to 50 °C. Typical performance is defined as operation over 25 °C, ±5 °C, within 5 °C of self-calibration temperature.

Feature	Specification	Typical Results
Baseband ADC channel-to-channel sample clock (time record) skew	–	<500 ps
Channel-to-channel LO skew (2.4 GHz)	<±1 deg RMS[1]	<±0.1 deg RMS[1]
Channel-to-channel LO skew (3.5 GHz)	<±1 deg RMS[1]	<±0.1 deg RMS[1]
Channel-to-channel LO skew (5.8 GHz)	<±1 deg RMS[1]	<±0.1 deg RMS[1]
RF output WLAN EVM accuracy (-10 dBm and 2.4 GHz)	–	-42 dB, 0.8%[2]
RF output WLAN EVM accuracy (-10 dBm and 5.8 GHz)	–	-40 dB, 1.0%[2]
RF output WiMAX EVM accuracy (-10 dBm and 2.5 GHz)	–	-48 dB, 0.4%[2]
RF output WiMAX EVM accuracy (-10 dBm and 3.5 GHz)	–	-45 dB, 0.6%[2]
Vector signal generator power accuracy	±0.75 dB	±0.6 dB spec; ±0.3 dB typical
Vector signal generator output noise floor at -10 dBm	-146 dBm/Hz	-150 dBm/Hz

[1] 10 kS/s I/Q rate and RF output power of 0 dBm were used to perform this measurement.
[2] Find detailed information on typical performance for WLAN and WiMAX measurements in the data sheets for WLAN and WiMAX software.

Table 4. N-Channel Vector Signal Generator Specifications and Typical Performance

Software

NI phase-coherent RF measurement examples are a suite of ready-to-use LabVIEW example code for phase-coherent measurements. The suite contains examples for both multichannel and multichannel/multichassis RF signal analyzers and supports up to eight channels of synchronized acquisition. The suite also contains multichannel and multichannel/multichassis RF signal generator examples, which support up to eight channels of phase-coherent RF signal generation. Note that the examples for both generation and acquisition also support the streaming of I/Q data to and from a hard disk. Figure 7 shows a screen shot of a two-channel RF signal acquisition example.

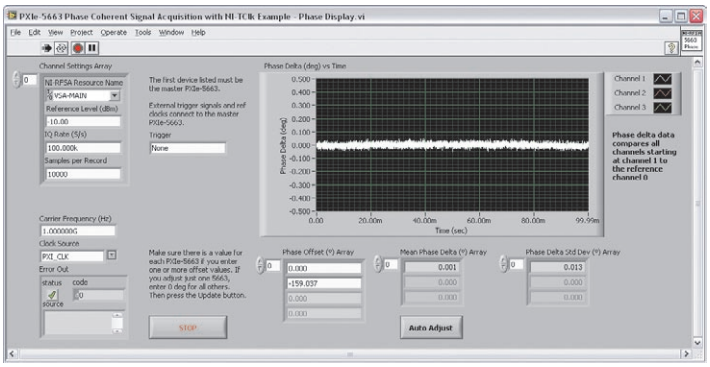


Figure 7. Two-Channel RF Signal Acquisition Example

PXI Chassis and Controller with Cover

The recommended PXI chassis for MIMO configurations is the NI PXIe-1075 18-slot PXI Express chassis. With 18 PXI Express slots (eight of which are hybrid), the NI PXIe-1075 enables a wide range of module configurations.

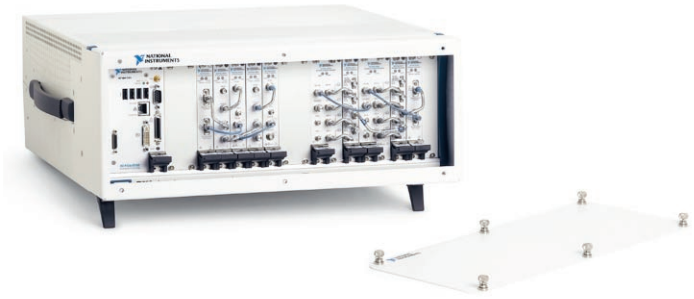


Figure 8. NI PXIe-1075 18-Slot PXI Express Chassis with Embedded Controller, Front-Panel Protector, and Two-Channel Vector Signal Analyzer and Vector Signal Generator

NI embedded PXI controllers offer features that you can tailor to your measurement needs. Choose the NI PXIe-8130 general-purpose embedded controller when you need high-bandwidth stream-to-disk capability. For applications where greater signal processing power is required, choose the NI PXIe-8108 embedded controller. Systems containing a multichannel vector signal analyzer or vector signal generator also feature a mountable front-panel cover for cable protection. The front-panel cover (shown in Figure 8) is installed during factory system configuration and is shipped with the PXI chassis, controller, and modules.

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Optional RAID Drive

For applications requiring continuous data streaming to or from hard disk, you can add optional RAID volumes to the MIMO test system. You can record and play back continuous I/Q waveforms from hard disk using the PXI Express RAID volume. For example, using the NI HDD-8264 RAID volume, you can record each channel of a two-channel vector signal analyzer at 62.5 MS/s for more than one hour. In addition, you can play back the same hour-long waveform from disk using a two-channel vector signal generator.

Choose from several PXI Express RAID options, ranging from embedded hard disks to external disks interfaced through cabled PCI Express, for your RF record and playback applications (see Table 5).

Product	Disk Size	Disks	Read/Write Speed	Form Factor
NI HDD-8260	1 TB	4	250 MB/s	3-slot 3U PXI Express
NI HDD-8263	1 TB	4	200 MB/s	1-slot 3U PXI Express with 1U external rack
NI HDD-8264	3 TB	12	600 MB/s	1-slot 3U PXI Express with 3U external rack

Table 5. PXI Express RAID Options

Embedded Three-Slot PXI RAID Volume: NI 8260



The NI 8260 provides an in-chassis solution for stream-to-disk applications. This module consumes three PXI slots. Thus, an 18-slot chassis with a PXI controller has 14 remaining slots for RF modules when configured with the NI 8260.

External Rack Mount RAID Volumes: NI HDD-8263/4



The NI HDD-8263 and HDD-8264 provide 1 TB and 3 TB solutions for RF record and playback applications. With each of these RAID solutions, the PXI Express interface consumes only one PXI slot. Note that for multichannel stream-to-disk applications, you can use multiple RAID volumes for multiple channels. In a four-channel RF record-to-disk application, consider using two HDD-8263 volumes for maximum recording bandwidth.

Ordering Information

Multichannel Vector Signal Analyzers

NI PXIe-5663E 6.6 GHz 2-channel phase-coherent MIMO RF vector signal analyzer 781339-02
NI PXIe-5663E 6.6 GHz 3-channel phase-coherent MIMO RF vector signal analyzer 781339-03
NI PXIe-5663E 6.6 GHz 4-channel phase-coherent MIMO RF vector signal analyzer 781339-04
NI PXIe-5663/5663E 1-channel extension kit 780486-01

Multichannel Vector Signal Generators

NI PXIe-5673E 6.6 GHz 2-channel phase-coherent MIMO RF vector signal generator 781340-02
NI PXIe-5673E 6.6 GHz 3-channel phase-coherent MIMO RF vector signal generator 781340-03
NI PXIe-5673E 6.6 GHz 4-channel phase-coherent MIMO RF vector signal generator 781340-04
NI PXIe-5673/5673E 1-channel extension kit 780485-01

Other Products

NI LabVIEW Full Development System for Windows 776670-29
NI PXIe-1075, 18-slot 3U PXI Express chassis 780291-01
NI PXIe-8130 dual-core controller downgraded to Windows XP 780031-01
NI PXIe-8108 dual-core controller downgraded to Windows XP 781033-01
NI HDD-8264 12-drive, 3 TB, 2U 780066-01
NI 8262 x4 cabled PCI Express module for PXI Express 780064-01
x4 MXI-Express cable, 3 m 779725-03
NI 8260, 4-drive, 1 TB HDD high-speed data storage module 780980-01

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