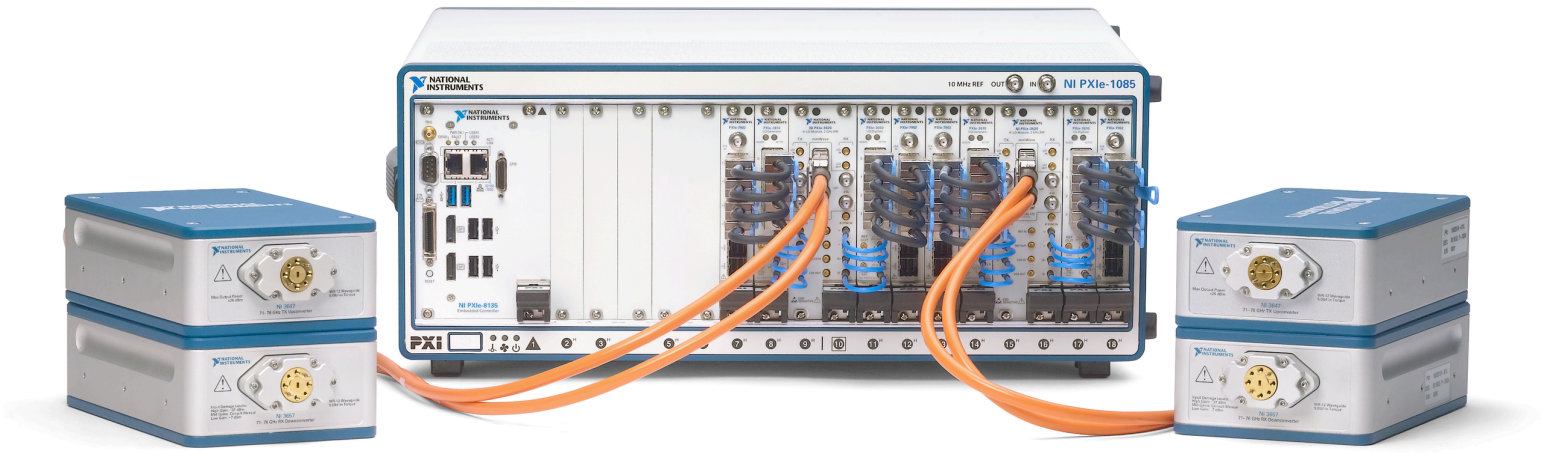
71-76 GHz Millimeter-wave Transceiver System



Introduction

The mmWave Transceiver System (MTS) is a modular set of hardware that can be used for a variety of applications from channel sounding to prototyping real-time two-way communications systems. The same modules can be used to build simple systems like a single channel unidirectional system and complex multi-channel bidirectional systems. The mmWave radio heads themselves are also modular and can be replaced with other front ends to investigate multiple different frequencies with the same baseband set of hardware and software.

Typical Applications

- 5G Communications Prototyping
- Channel Sounding

Features

- SISO and MIMO support for unidirectional or bidirectional systems
- Shared LO for MIMO
- 2 GHz real-time bandwidth
- 71-76 GHz radio heads
- Real-time coding capability

Configurations

The system is available in the following configurations:

- SISO unidirectional
- SISO bidirectional
- MIMO unidirectional
- MIMO bidirectional

A full millimeter-wave transceiver system consists of the following modules:

NI 3647 TX	71 to 76 GHz Upconverter
NI 3657 RX	71 to 76 GHz Downconverter
PXIe-3620	8.5 to 13.5 GHz I/Q (de)modulator
PXIe-3610	Baseband Generator
PXIe-3630	Baseband Digitizer
PXIe-7902	FPGA Processing Unit

In addition to a full millimeter-wave system, IF only and baseband only systems are available.

Datasheet Organization

This document describes nominal and/or expected performance of the IF and baseband sub-systems of the *Millimeter-Wave Transceiver System*. The information provided in this document is based on both simulation and/or measurement and should not be considered to be typical or warranted specifications. Data is taken at room temperature unless otherwise specified.

This datasheet is broken up into several sections. The *System Performance & Characteristics* section describes the expected performance of the full 71-76 GHz transceiver. Subsequent sections describe the performance and characteristics of the various modules used in the system.

⚠ Caution

The system installation must adequately protect users' eyes from exposure to mmWave radiation output and input signals from the transmitter and receiver.

System Performance & Characteristics

EVM vs. Loopback Attenuation

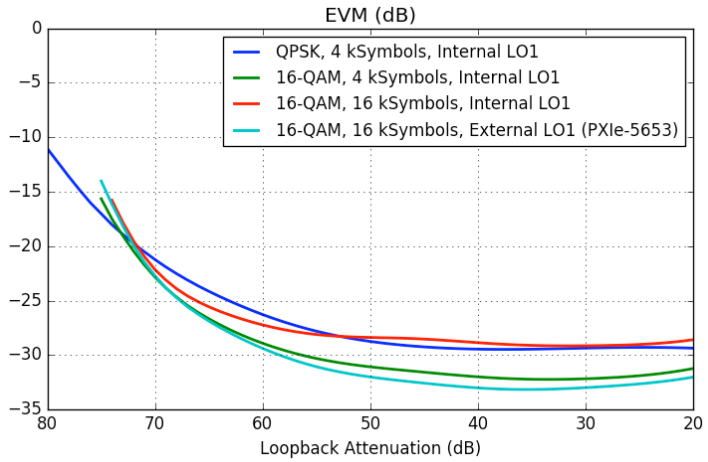


Figure 1: A variable attenuator is placed between the transmitter and receiver to simulate path loss at 73 GHz. The EVM of various single-carrier signals at a symbol rate of 1536 MBaud (RRC filter α = 0.3) is shown. Single-point calibration is used to correct for image rejection and an equalizer is used to correct for amplitude ripple and phase nonlinearity within the instantaneous bandwidth. The internal LO2 is utilized for all measurements. Separate LO1s are utilized for the TX and RX in all measurements. Results obtained from a representative setup.

Recommended Gain vs. Loopback Attenuation

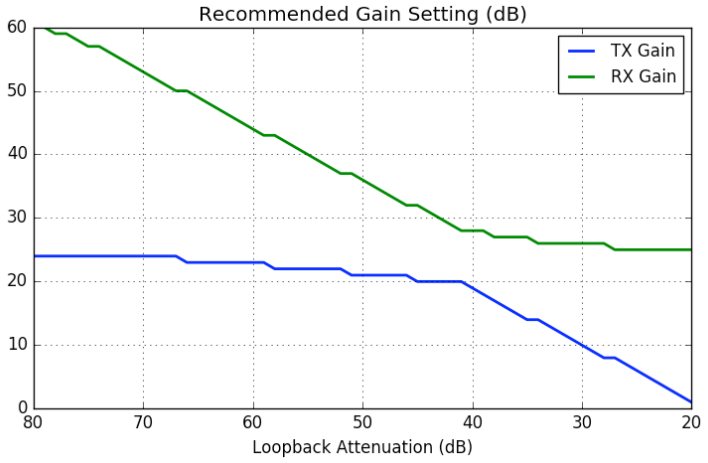


Figure 2: The TX and RX gain settings used for EVM in Figure 1. Results obtained from a representative setup.

Characteristics

Receiver	
Tuning Range	71 to 76 GHz
Instantaneous BW	2 GHz
Interface	WR-12
Analog Gain Range	55 dB
1 dB Gain Compression[4]	-12 dBm
Noise Figure[3]	6 dB
Image Rejection[1]	>80 dB
Transmitter	
Tuning Range	71 to 76 GHz
Instantaneous BW	2 GHz
Interface	WR-12
Analog Gain Range	55 dB
Saturated Power[3]	+24 dBm
Output IP3[3]	+30 dBm
LO Re-radiation[2]	<-90 dBm

1. *Refers to super-heterodyne image*
2. *Refers to super-heterodyne LO*
3. *At maximum gain*
4. *Near minimum gain. For lower gain settings, 1 dB compression is higher than full-scale.*

MTS Transmitter Noise & Distortion

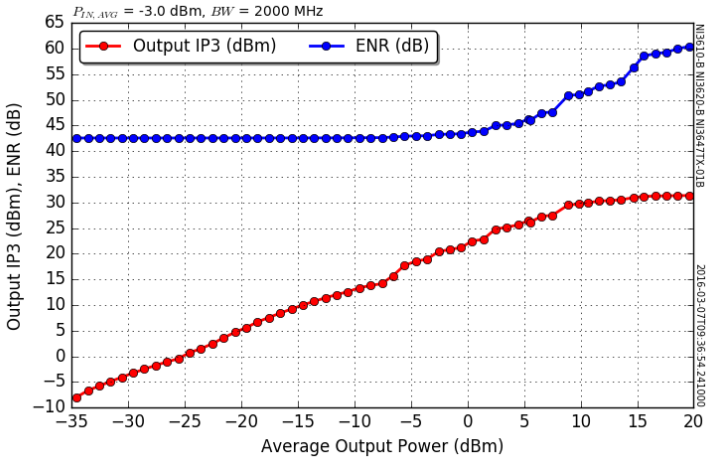


Figure 3: Simulated Output IP3 and Excess Noise Ratio (ENR) of the NI 3647 TX, when driven by the PXIe-3620 and PXIe-3610 with 2-tones at -7 dBFS.

MTS Receiver Noise & Distortion

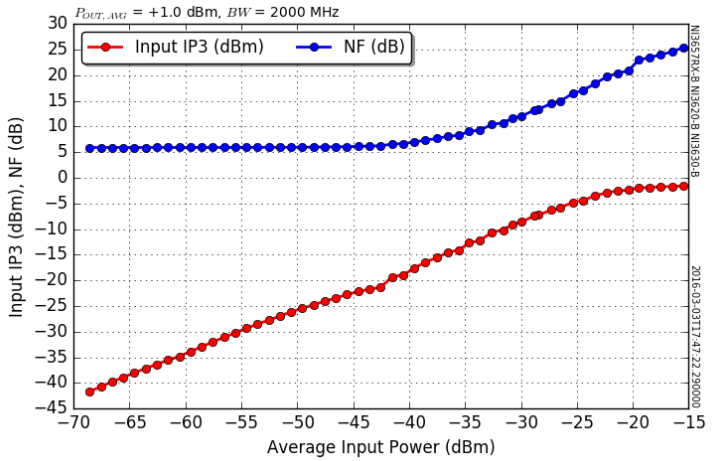


Figure 4: Simulated Input IP3 and Noise Figure of NI 3657 RX with PXIe-3620 and PXIe-3630 digitizer.

MTS Receiver Maximum Power (Damage)

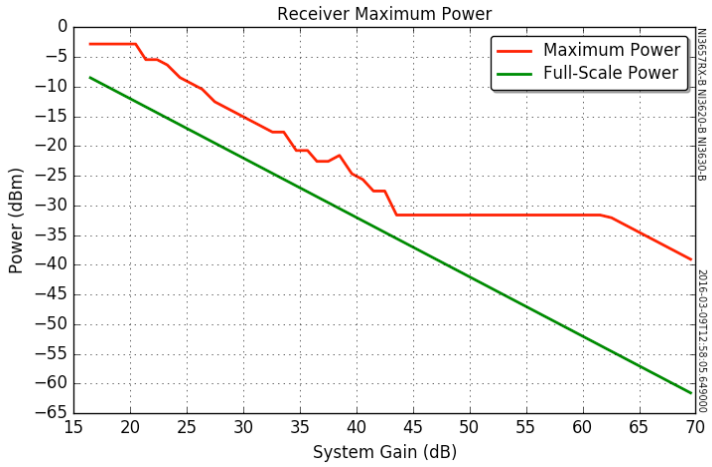


Figure 5: Maximum power refers to the input power at which the receiver could be damaged. It is advisable to keep the incident power less than or equal to the full-scale power.

PXIe-3620 Transceiver

The PXIe-3620 includes an 8.5 to 13.5 GHz transmitter and receiver capable of full-duplex operation with 2 GHz of instantaneous bandwidth. The module also contains two independently tuned LO synthesizers for driving external mmWave heads (NI 3647TX and NI 3657RX).

The flexible LO system not only drives external mmWave heads, but also allows LO sharing for MIMO applications. Furthermore, the module can accept external LO sources (such as PXIe-5653) when higher performance phase noise is required.

The PXIe-3620 has analog I and Q differential baseband ports which connect to the PXIe-3610 arbitrary waveform generator and PXIe-3630 digitizer.

IF Interface

IF Output	
Tuning Range	8.5 to 13.5 GHz
Linear Power	-40 to +7 dBm
IF Input	
Tuning Range	8.5 to 13.5 GHz
Linear Power	-25 to +20 dBm

All interfaces are 50 Ω with SMA connectors.

LO1 Interface

LO1 TX/RX Input	4 to 8 GHz
Nominal Input Level	+9 dBm
Damage Level	+18 dBm
LO1 TX/RX Output	4 to 8 GHz
Max Power	+8 to +15 dBm
LO1 TX/RX mmWave Output	4 to 13.7 GHz
Max Power	+10 to +15 dBm
Interface	SMA (50 Ω)

All interfaces are 50 Ω with MMPX connectors unless otherwise noted.

LO2 Interface

LO2 Input	2.8 to 4.5 GHz
Nominal Input Level	+9 dBm
Damage Level	+18 dBm
LO2 Output	2.8 to 4.5 GHz
Max Power	+11 to +13 dBm
LO2 Ref In/Out	10 MHz
Nominal Level	1.6 V_{P-P}
Damage Level	5 V_{P-P}

All interfaces are 50 Ω with MMPX connectors.

Baseband Interface

I/Q Output	DC to 1 GHz
Nominal Level	+5 dBm
Common-Mode	0 V_{DC}
I/Q Input	DC to 1 GHz
Nominal Level	+1 dBm
Damage Level	+20 dBm
Common-Mode	0 V_{DC}

All interfaces are 100 Ω differential with MMPX connectors. All levels

refer to power in a single (I or Q) differential port.

IF Transmitter Noise & Distortion

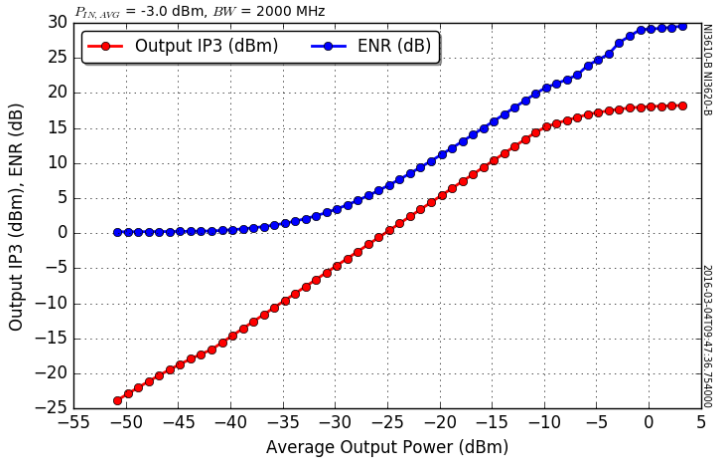


Figure 6: Simulated Output IP3 and Excess Noise Ratio (ENR) of the PXIe-3620 when driven by the PXIe-3610 DAC with 2-tones at -7 dBFS.

IF Receiver Noise & Distortion

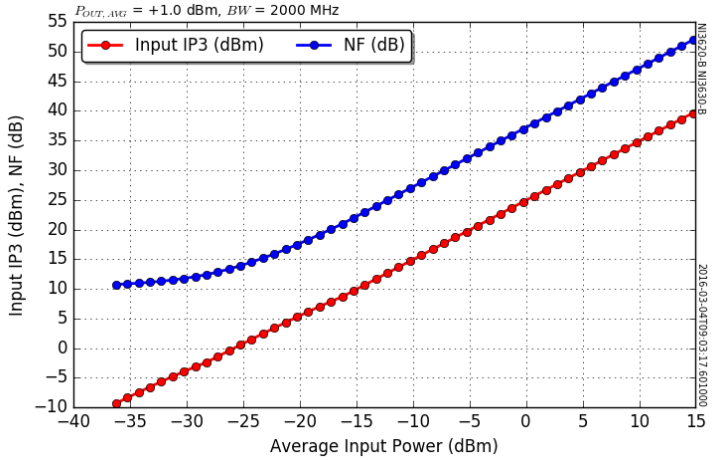


Figure 7: Simulated Input IP3 and Noise Figure of PXIe-3620 with PXIe-3630 digitizer.

SSB Phase Noise

Offset	LO1 (dBc/Hz)	LO2 (dBc/Hz)
100 Hz	-70	-70
1 kHz	-92	-92
10 kHz	-98	-98
100 kHz	-104	-104
1 MHz	-130	-130

Table 1: Nominal single sideband phase noise for internal LO1 and internal LO2 on PXIe-3620. The phase noise added at the NI 3647TX and NI 3657RX are nominally $20 \times \log_{10}(8)$ dB higher.

IF Receiver Maximum Power (Damage)

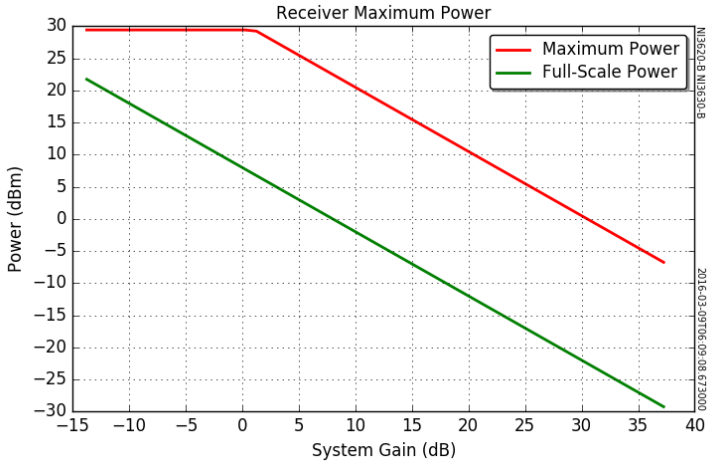


Figure 8: Maximum power refers to the input power at which the receiver could be damaged. It is advisable to keep the incident power less than or equal to the full-scale power.

PXIe-3610 Baseband Generator

The PXIe-3610 is a 14 bit, 3 GS/s DC-coupled arbitrary waveform generated with 2 GHz of complex bandwidth and differential I and Q outputs.

Characteristics

Range	DC to 1 GHz (MMPX)
Full-scale[1]	+1 dBm; 1000 mV_{P-P}
Sample Rate	3072 MS/s
Common Mode Voltage[1]	0 V_{DC}
Impedance	100 Ω differential
DC Offset	±40 mV
Flatness[1]	±1.5 dB
2nd Harmonics	-60 dBc
3rd Harmonics	-65 dBc
IMD3[1,2]	-75 dBc at 100 MHz -65 dBc at 1000 MHz
I/Q Amplitude Mismatch[3]	±0.2 dB
I/Q Phase Mismatch[3]	±0.5°
Noise Density[1]	-155 dBm/Hz
Ref In/Out Interface	MMPX (50 Ω)
Ref In/Out Frequency	10 MHz
Ref In Power	0 to +13 dBm
Ref Out Power	+10 dBm
Digital Input	MiniSAS-HD

1. *I or Q channel*
2. *2-tones as -7 dBFS*
3. *Calibrated*

PXIe-3630 Baseband Digitizer

The PXIe-3610 is a 12 bit, 3 GS/s DC-coupled digitizer with 2 GHz of complex bandwidth and differential I and Q inputs.

Characteristics

Range	DC to 1 GHz (MMPX)
Full-scale[1]	+5 dBm; 1590 mV_{P-P}
Sample Rate	3072 MS/s
Common Mode Voltage[1]	0 V_{DC}
Impedance	100 Ω differential
DC Offset	±10 mV
Flatness[1]	±3.0 dB
2nd Harmonics	-60 dBc
3rd Harmonics	-60 dBc
IMD3[1,2]	-65 dBc at 100 MHz -60 dBc at 1000 MHz
I/Q Amplitude Mismatch[3]	±0.2 dB
I/Q Phase Mismatch[3]	±1.5°
Noise Density[1]	-148 dBFS/Hz at 100 MHz -143 dBFS/Hz at 1000 MHz
Ref In/Out Interface	MMPX (50 Ω)
Ref In/Out Frequency	10 MHz
Ref In Power	0 to +13 dBm
Ref Out Power	+10 dBm
Digital Output	MiniSAS-HD

1. *I or Q channel*
2. *2-tones as -7 dBFS*
3. *After Calibration*

NI 3647TX 71 to 76 GHz Transmitter

The NI 3657RX is a super-heterodyne upconverter that accepts an LO signal from PXIe-3620 and upconverts the IF input signal centered at 12 GHz to and RF output frequency from 71 to 76 GHz.

Characteristics

RF Input	
Tuning Range	71 to 76 GHz
Interface	WR-12
IF Output	
Frequency Range	11 to 13 GHz
LO Input	
Frequency Range	7375 to 8000 MHz
Power	+5 dBm
DC Power	1.8 A @ +12 V
Weight	4.8 lbs
Size (L × W × H)	7.5 in × 4.6 in × 2.4 in

All interfaces are 50 Ω with SMA connectors unless otherwise noted.

NI 3657RX 71 to 76 GHz Receiver

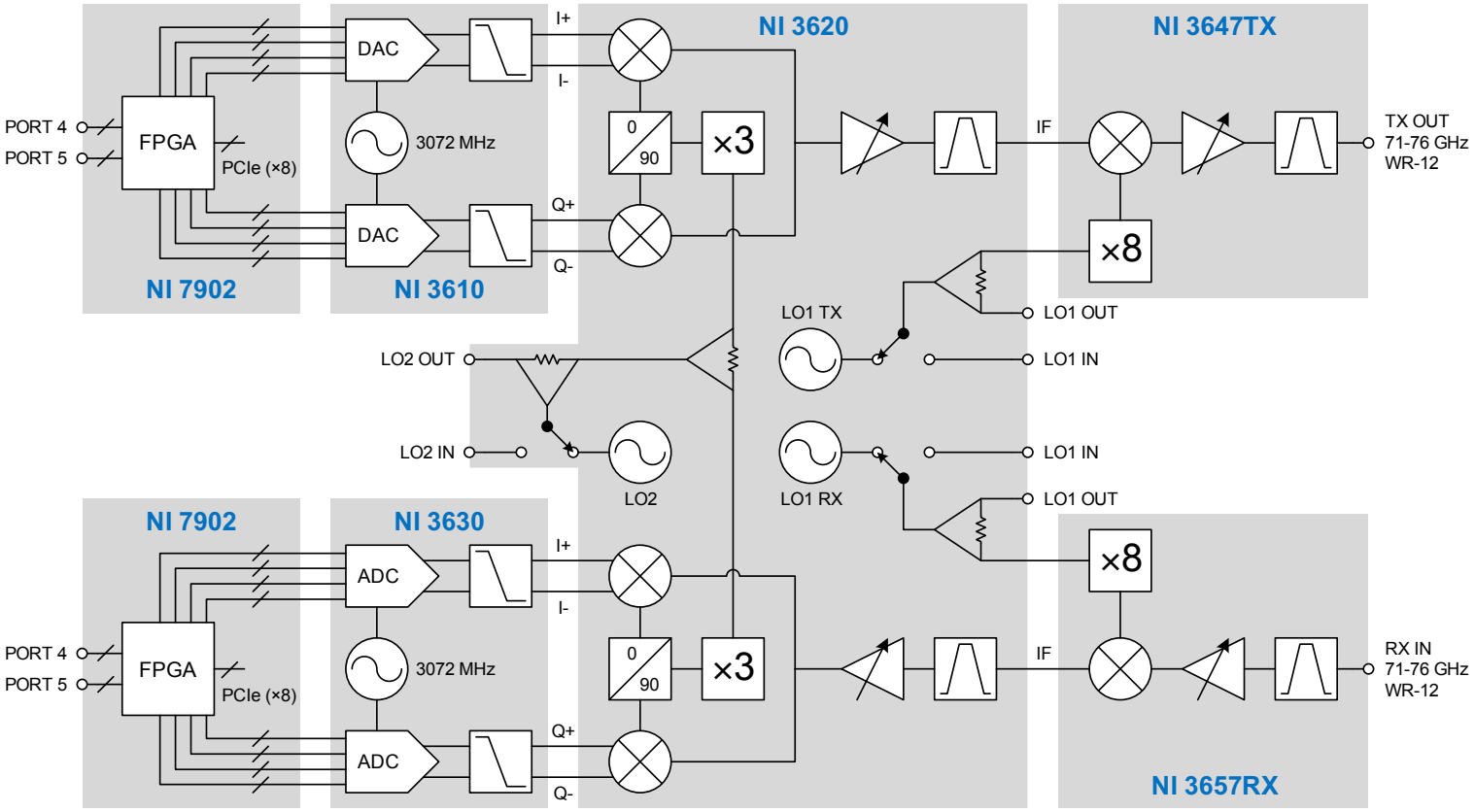
The NI 3657RX is a super-heterodyne downconverter that accepts an LO signal from PXIe-3620 and downconverts the RF input signal to an IF output centered at 12 GHz.

Characteristics

RF Input	
Tuning Range	71 to 76 GHz
Interface	WR-12
IF Output	
Frequency Range	11 to 13 GHz
LO Input	
Frequency Range	7375 to 8000 MHz
Power	+5 dBm
DC Power	1.2 A @ +12 V
Weight	4.8 lbs
Size (L × W × H)	7.5 in × 4.6 in × 2.4 in

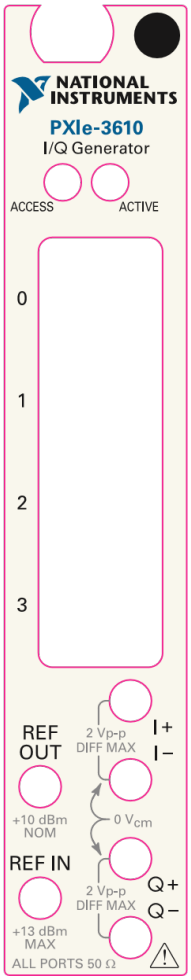
All interfaces are 50 Ω with SMA connectors unless otherwise noted.

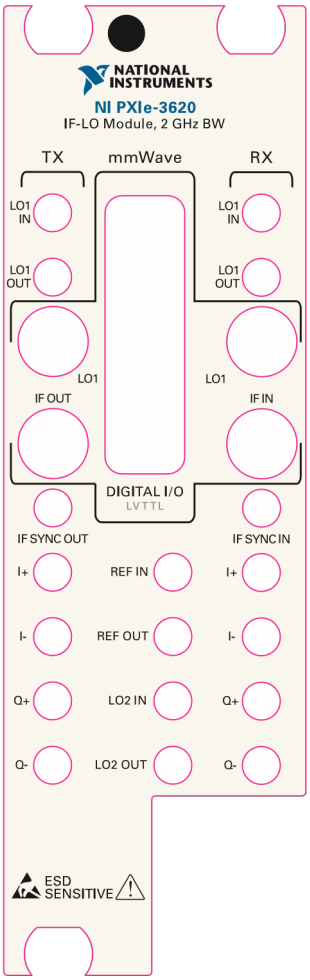
Block Diagram

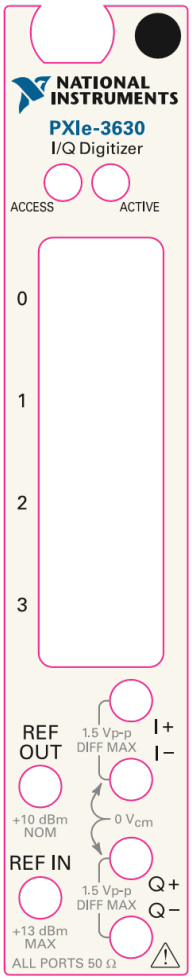


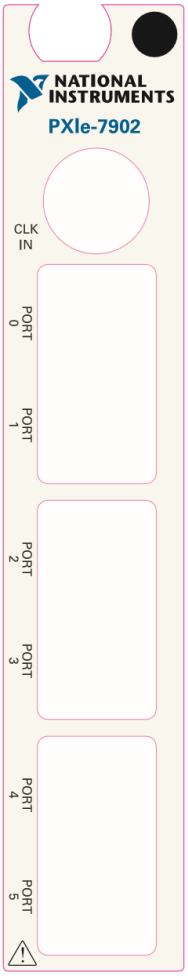
Physical Characteristics

PXIe Modules' Front-Panels

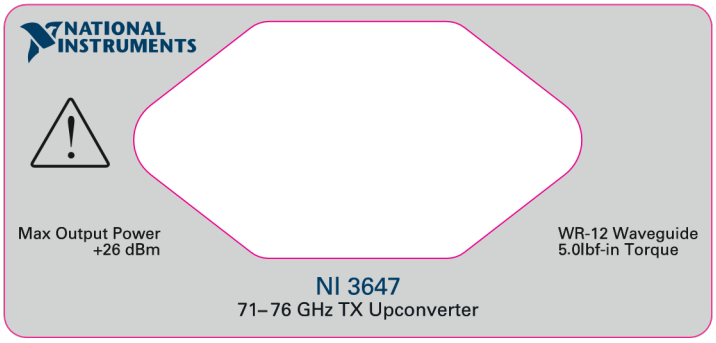


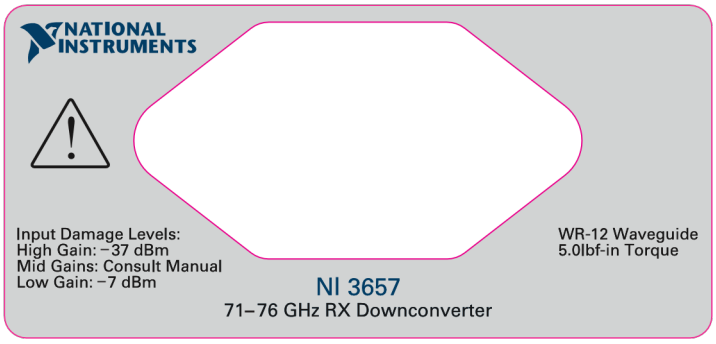


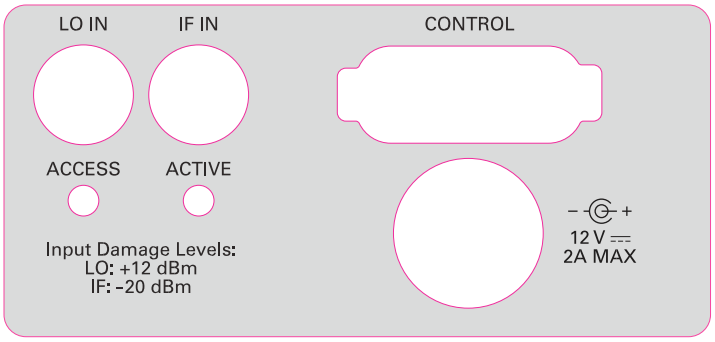


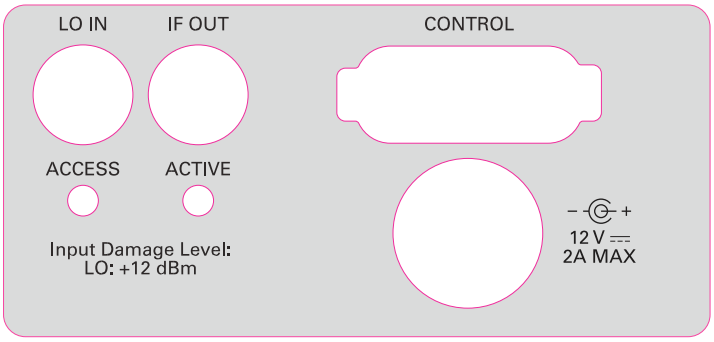


NI 3647TX and 3657RX Panels









Environment

Indoor use only.

Maximum alitiitude[1]	2,000 m (800 mbar)
Pollution degree	2

1. *At 25 °C ambient temperature*

Operating Environment

Ambient temperature[1]	0 to 40 °C
Operating temperature	0 to 40 °C
Relative humidity[2]	10% to 90%, noncondensing

1. *Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2*
2. *Tested in accordance with IEC 60068-2-56*

Compliance

Safety

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use: IEC 61010-1, EN 61010-1, UL 61010-1, CSA 61010-1.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

EN 61326-1 (IEC 61326-1)	Class A emissions; Basic immunity
EN 55011 (CISPR 11)	Group 1, Class A emissions
EN 55022 (CISPR 22)	Class A emissions
EN 55024 (CISPR 24)	Immunity
AS/NZS CISPR 11	Group 1, Class A emissions
AS/NZS CISPR 22	Class A emissions
FCC 47 CFR Part 15B	Class A emissions
ICES-001	Class A emissions

NOTE: In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia, and New Zealand (per CISPR 11), Class A equipment is intended for use only in heavy-industrial locations.

NOTE: Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generate radio frequency energy for the treatment of material or inspection/analysis purposes.

NOTE: For EMC declarations, certifications, and additional information, refer to the Online Product Certification section.

CE Compliance

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/35/EU; Low-Voltage Directive (safety)
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/ certification, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the Minimize Our Environmental Impact web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of the product life cycle, all NI products must be disposed of according to local laws and regulations. For more information about how to recycle NI products in your region, visit ni.com/environment/weee.

电子信息产品污染控制管理办法（中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物 质指令(RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

⚠ Caution

This product is not approved or licensed for transmission over the air using an antenna. As a result, operating this product with an antenna may violate local laws. Ensure that you are in compliance with all local laws before operating this product with an antenna.