SPECIFICATIONS

PXIe-5654

250 kHz to 20 GHz RF Analog Signal Generator

These specifications apply to the PXIe-5654 RF Analog Signal Generator with up to 10 GHz or 20 GHz frequency and the PXIe-5696 Amplitude Extender.

When not otherwise specified, these specifications refer to both the PXIe-5654 and the PXIe-5654 with PXIe-5696 system.

Contents

NATIONAL INSTRUMENTS

Definitions

Warranted specifications describe the performance of a model under stated operating conditions and are covered by the model warranty.

Characteristics describe values that are relevant to the use of the model under stated operating conditions but are not covered by the model warranty.

- *Typical* specifications describe the performance met by a majority of models.
- *Nominal* specifications describe an attribute that is based on design, conformance testing, or supplemental testing.

Specifications are *Warranted* unless otherwise noted.

Conditions

Minimum or maximum specifications are warranted under the following conditions unless otherwise noted.

- Over ambient temperature ranges of 0 °C to 55 °C
- 30 minutes warm-up time
- Calibration cycle maintained
- Chassis fan speed set to High
- NI-RFSG instrument driver used

Notice Do not disconnect the cable that connects RF AMP OUT to ATTN IN. Removing the cable from or tampering with the RF AMP OUT or ATTN IN front panel connectors voids the product calibration, and specifications are no longer warranted.

Typical specifications are valid under the following condition unless otherwise noted.

- Over ambient temperature ranges of 23 °C ± 5 °C

Frequency

Range	250 kHz to 20 GHz
Resolution	0.001 Hz
Accuracy	Refer to the *Reference Clock* section.

Frequency Settling Time

Table 1. Frequency Settling Time (Nominal)

Device Option	Settling Time[1, 2, 3]
Standard[4,5]	1 ms
Fast tuning[4,5,6]	100 µs

Reference Clock

Internal Clock

Initial accuracy	±0.1 ppm, maximum
Temperature (15 °C to 35 °C)	±0.2 ppm, maximum
Aging (per day, after 30 days)	±0.01 ppm, maximum
Aging (over 10 years)	±1.25 ppm, maximum

Internal Reference Output 1

Connector name	REF OUT
Frequency	10 MHz
Amplitude	+5 dBm ± 2 dB

1 The settling time is within 0.1 ppm of the target frequency.
2 The frequency settling time specification includes only frequency settling and excludes any residual amplitude settling that may occur as the result of a large frequency change.
3 To obtain the best determinism and accuracy for frequency switching speed, use an external clock source as a trigger.
4 Add 1 ms to the frequency settling time for fast tuning or 850 µs for standard tuning when transitioning from >250 MHz to <250 MHz.
5 The frequency settling time is 150 µs between 250 kHz and 250 MHz.
6 Automatic Power Search must be disabled.

Coupling	AC
Output impedance	50 Ω

Internal Reference Output 2

Connector name	REF OUT 2
Frequency	100 MHz
Amplitude	+5 dBm ± 2 dB
Coupling	AC
Output impedance	50 Ω

External Reference Input

Connector name	REF IN
Frequency	1 MHz to 20 MHz in 1 MHz steps
Amplitude	-10 dBm to +10 dBm
Input impedance	50 Ω
Lock time to external reference	<2 s

Spectral Purity

Table 2. Single Sideband (SSB) Phase Noise at +8 dBm Output Power

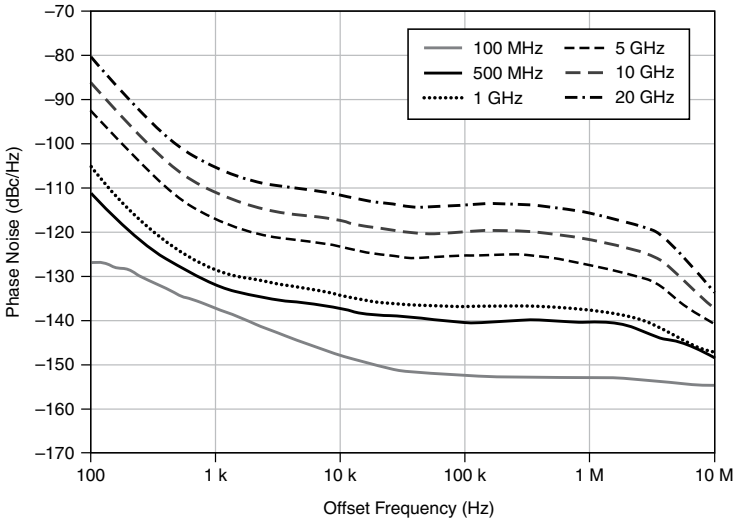
Frequency (GHz)	Phase Noise (dBc/Hz)					
	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz
0.5	-111, typical	-131, typical[7]	-137, typical	-139, typical	-140, typical	-147, typical
	-107, max	-127, max[7]	-135, max	-137, max	-138, max	—
1	-105, typical	-125, typical	-133, typical	-133, typical	-134, typical	-141, typical
	-101, max	-121, max	-130, max	-131, max	-132, max	—
5	-91, typical	-111, typical	-124, typical	-125, typical	-127, typical	-136, typical
	-87, max	-109, max	-120, max	-122, max	-125, max	—

[7] Degrades by 1 dB when using the PXIe-5654 with PXIe-5696.

Table 2. Single Sideband (SSB) Phase Noise at +8 dBm Output Power (Continued)

Frequency (GHz)	Phase Noise (dBc/Hz)					
	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz
10	-85, typical	-105, typical	-117, typical	-119, typical	-121, typical	-136, typical
	-81, max	-103, max	-114, max	-117, max	-119, max	—
20	-79, typical	-99, typical	-111, typical	-113, typical	-115, typical	-130, typical
	-75, max	-97, max	-108, max	-111, max	-113, max	—

Figure 1. Typical Phase Noise (Spurs Not Shown)

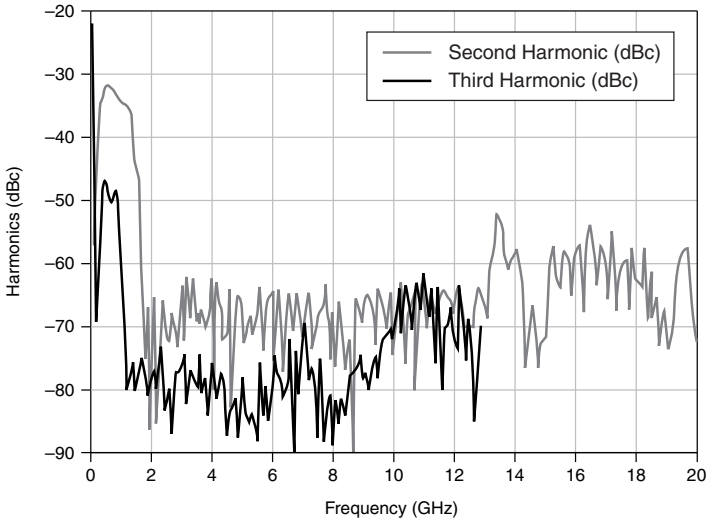


Spurious Responses

Table 3. Typical Harmonics

Frequency	Harmonics (dBc)	
	PXIe-5654[8]	PXIe-5654 with PXIe-5696[9]
250 kHz to <25 MHz	≤-18	≤-20
25 MHz to <250 MHz	≤-20	≤-20
250 MHz to <1 GHz	≤-25	≤-25
1 GHz to <2 GHz	≤-30	≤-30
2 GHz to <12 GHz	≤-40[10]	≤-55
12 GHz to 20 GHz	≤-40	≤-50

Figure 2. PXIe-5654 with PXIe-5696 Typical Harmonic Levels at +8 dBm Output Power



[8] Measured at +10 dBm output power.
[9] Measured at +8 dBm output power.
[10] Degrades to -35 dBc between 4.35 GHz and 4.45 GHz.

Table 4. Typical Subharmonics

Frequency	Subharmonics (dBc)	
	PXIe-5654[8]	PXIe-5654 with PXIe-5696[9]
250 kHz to <10 GHz	-65	-65
10 GHz to <12 GHz	-60	-60
12 GHz to 20 GHz	-50	-45

Table 5. Typical Nonharmonic Spurs

Frequency	Nonharmonic Spurs (dBc)	
	PXIe-5654[8]	PXIe-5654 with PXIe-5696[9]
250 kHz to <8 GHz	-65	-65
8 GHz to <10 GHz	-60	-60
10 GHz to 20 GHz	-60	-55

Figure 3. PXIe-5654 Typical Spectrum at 2.4 GHz

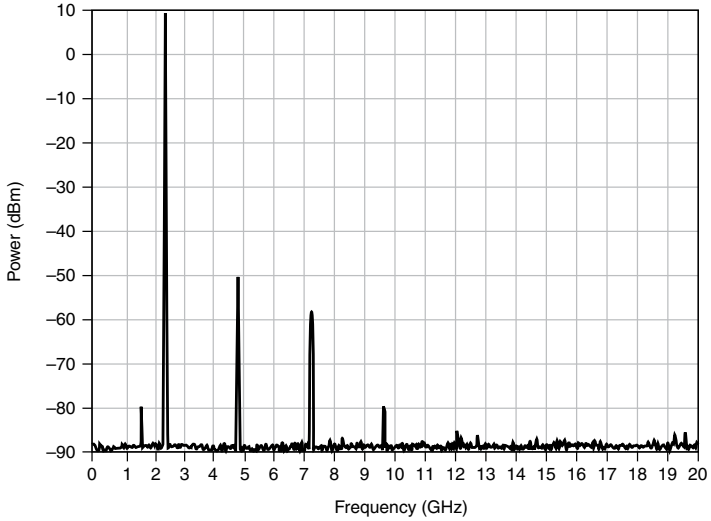


Figure 4. PXIe-5654 with PXIe-5696 Typical Spectrum at 2.4 GHz

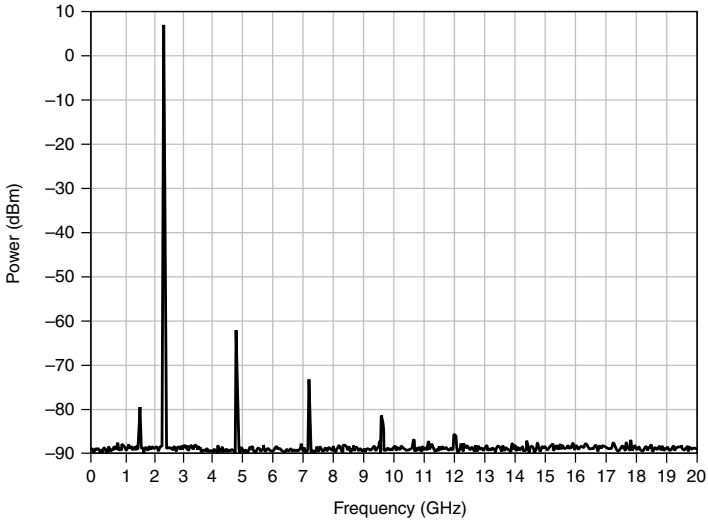


Figure 5. PXIe-5654 Typical Spectrum at 10 GHz

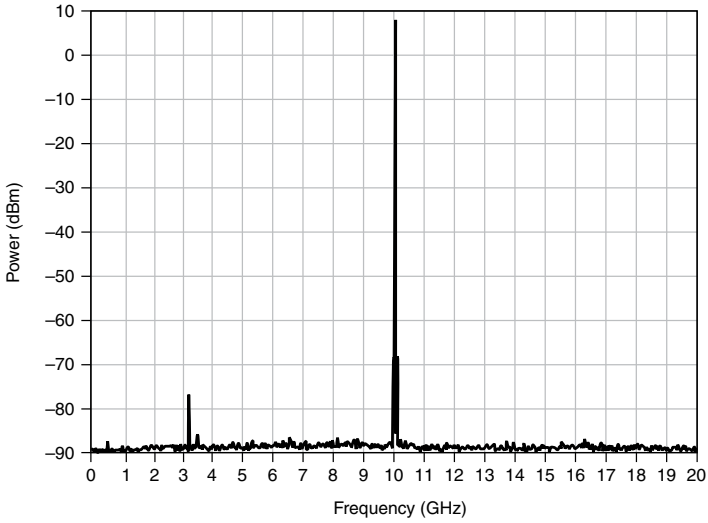
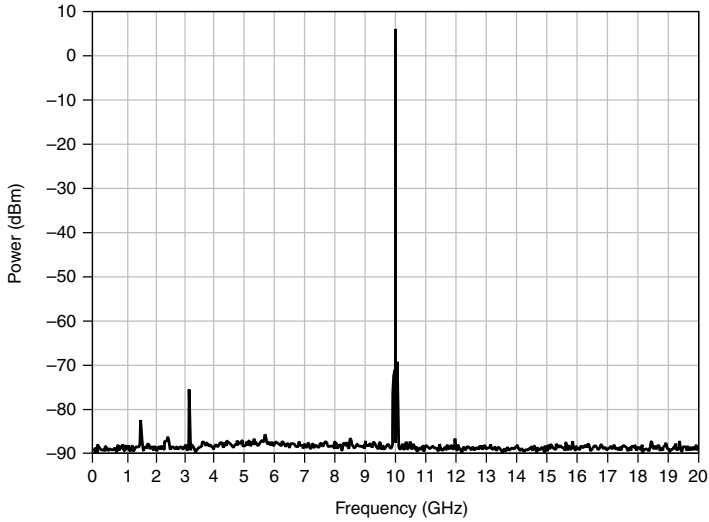


Figure 6. PXIe-5654 with PXIe-5696 Typical Spectrum at 10 GHz



Amplitude

Output Power

Table 6. Maximum Leveled Output Power (dBm)

Frequency	PXIe-5654		PXIe-5654 with PXIe-5696	
	Specification	Typical	Specification[11]	Typical
250 kHz to ≤250 MHz	+10	+12	+10	+13
250 MHz to ≤1 GHz	+13	+14	+20	+23
1 GHz to ≤3 GHz	+13	+14	+24	+27
3 GHz to ≤6 GHz	+13	+15	+23	+26
6 GHz to ≤8 GHz	+13	+15	+20	+25
8 GHz to ≤12 GHz	+13	+14	+20	+22
12 GHz to ≤15 GHz	+13	+15	+20	+21

[11] Specifications apply over the 25 °C ± 10 °C temperature range.

Table 6. Maximum Leveled Output Power (dBm) (Continued)

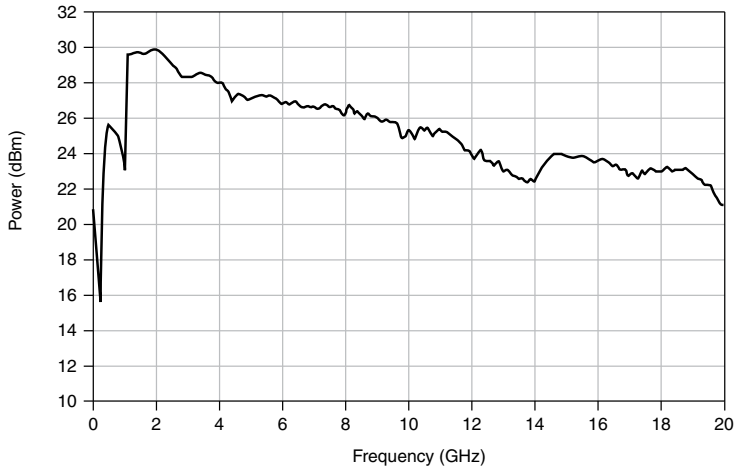
Frequency	PXIe-5654		PXIe-5654 with PXIe-5696	
	Specification	Typical	Specification[11]	Typical
15 GHz to ≤18 GHz	+13	+15	+18	+21
18 GHz to ≤20 GHz	+12	+14	+18	+20

Table 7. Nominal Minimum Power (dBm)

Frequency	PXIe-5654	PXIe-5654 with PXIe-5696
250 kHz to <250 MHz	-10	-110
250 MHz to <2 GHz	-7	-110
2 GHz to <18 GHz	-7	-110
18 GHz to 20 GHz	-7	-110

Resolution 0.01 dB

Figure 7. PXIe-5654 with PXIe-5696 Typical Maximum Available Power



[11] Specifications apply over the 25 °C ± 10 °C temperature range.

Amplitude Accuracy

Open-loop mode[12, 13] ±2 dB, typical[14]

Table 8. PXIe-5654 with PXIe-5696 Amplitude Accuracy (dB) at 25 °C ± 10 °C, Closed-Loop Mode[15]

Center Frequency	>+13 dBm to Maximum Leveled Power	-10 dBm to +13 dBm[16]	-40 dBm to <-10 dBm	-80 dBm to <-40 dBm	-100 dBm to <-80 dBm	-110 dBm to <-100 dBm
≤250 MHz	—	±0.35, typical	±0.60, typical	±0.70, typical	±2.0, typical	±2.5, typical
	—	±0.80, max	±1.20, max	±1.50, max[17]	—	—
250 MHz to <8 GHz	±0.60, typical	±0.35, typical	±0.60, typical	±0.70, typical	±2.0, typical	±2.5, typical
	±1.20, max	±0.80, max	±1.20, max	±1.50, max	—	—
8 GHz to 20 GHz	±0.60, typical	±0.35, typical	±0.60, typical	±0.70, typical	±2.0, typical	±2.5, typical
	±1.30, max	±0.80, max	±1.20, max	±1.50, max	—	—

12 Specifies the amplitude accuracy for both the PXIe-5654 module and the PXIe-5654 with PXIe-5696 system device with automatic leveling control (ALC) disabled. Performing a power search improves the amplitude accuracy.

13 For the PXIe-5654 with PXIe-5696, refer to the *Amplitude Accuracy* table for amplitude accuracy < -100 dBm.

14 Typical specifications are ±2.5 dB for frequencies < 20 MHz.

15 Closed-loop mode requires the PXIe-5696 amplitude extender module and indicates that the ALC is enabled.

16 Performance is guaranteed to +10 dBm for frequencies ≤ 250 MHz.

17 Specification is ±1.75 dB maximum for frequencies < 20 MHz.

Figure 8. PXIe-5654 with PXIe-5696 Typical Power Accuracy at -40 dBm

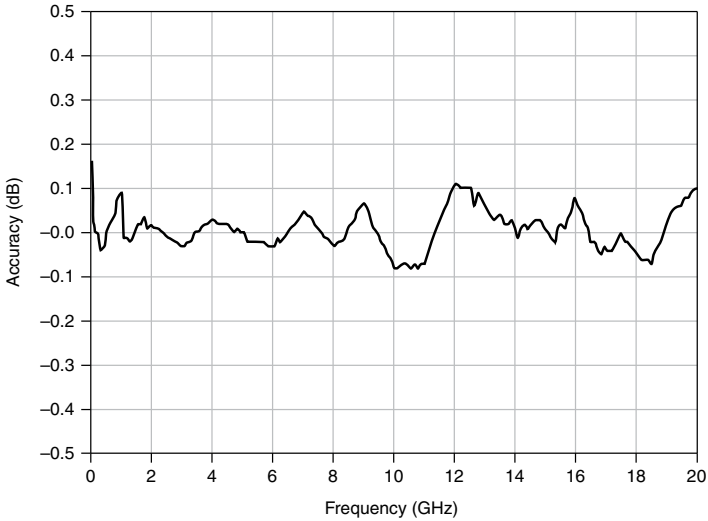


Figure 9. PXIe-5654 with PXIe-5696 Typical Power Accuracy at -70 dBm

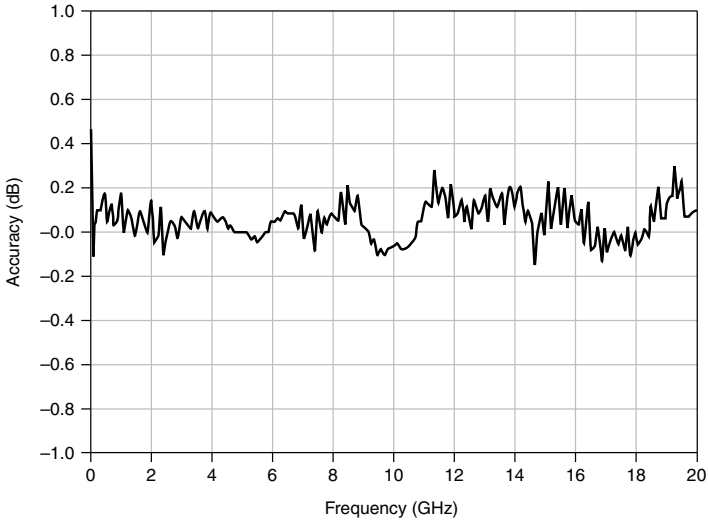
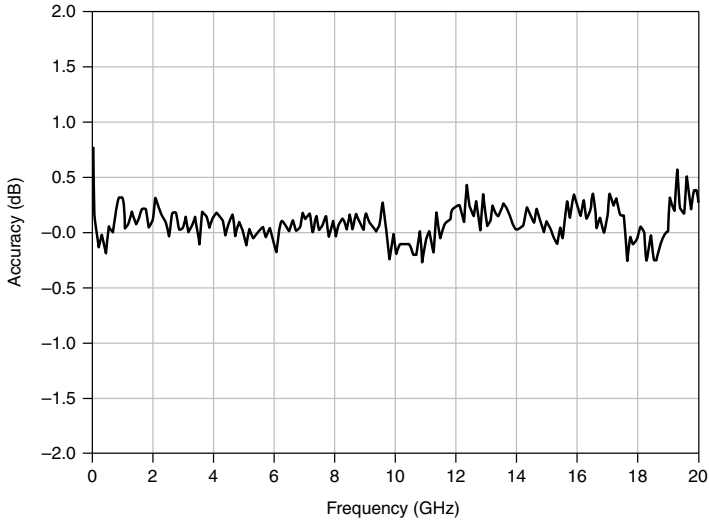


Figure 10. PXIe-5654 with PXIe-5696 Typical Power Accuracy at -100 dBm



Amplitude Settling Time

Table 9. Typical Amplitude Settling Time

Final Frequency	PXIe-5654[18]		PXIe-5654 with PXIe-5696 (Open-Loop Mode)[19]		PXIe-5654 with PXIe-5696 (Closed-Loop Mode)[20, 21]	
	1.5 dB Settling Time	2 dB Settling Time	1.5 dB Settling Time	2 dB Settling Time	0.2 dB Settling Time	0.5 dB Settling Time
<250 MHz	4 ms	3.5 ms	4 ms	3.5 ms	4 ms	3 ms
>250 MHz	500 µs	300 µs	500 µs	300 µs	4 ms	3 ms

0.2 dB amplitude settling time[22] 25 ms, typical

[18] The minimum frequency settling time in open-loop mode is 1 ms (typical) for the standard tuning option and 100 µs (typical) for the fast tuning option.

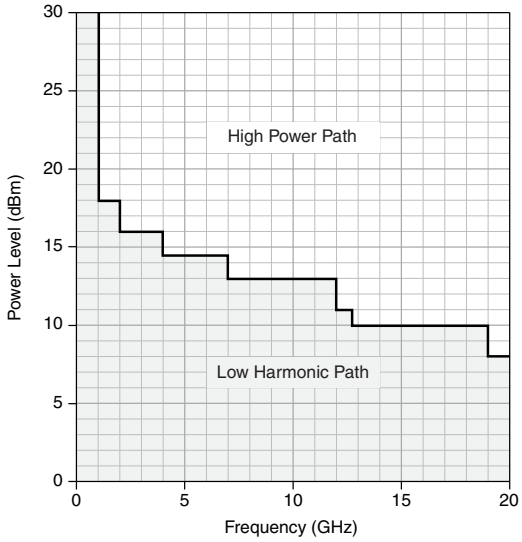
[19] Add 1 ms to the settling time values when entering the 250 MHz to 2.4 GHz frequency range. For frequency changes within the 250 MHz to 2.4 GHz range, no additional settling time applies.

[20] Add 2.5 ms to the settling time values when crossing 250 MHz.

[21] Add 2.5 ms to the settling time values when switching from the low harmonic or high power paths. Refer to the *Transition Power Level* figure for more information about path switching.

[22] (PXIe-5654 with PXIe-5696, mechanical attenuator state changed)

Figure 11. Transition Power Level (dBm)[23]



Broadband Noise Floor

Broadband noise floor[24]	<-145 dBc/Hz, typical at >20 MHz offset

Voltage Standing Wave Ratio (VSWR)

Table 10. PXIe-5654 with PXIe-5696 VSWR

Amplification Path[25]	Frequency Range	VSWR
Low harmonic path	250 kHz to 8 GHz	<1.6 : 1
	8 GHz to 20 GHz	<2.0 : 1
High power path	1 GHz to 20 GHz	<2.0 : 1

Output impedance	50 Ω

[23] This figure represents the default path switching used in NI-RFSG. The PXIe-5654 with PXIe-5696 specifications were measured using the default path switching.

[24] Measured at +10 dBm output power for the PXIe-5654. Measured at +8 dBm output power for the PXIe-5654 with PXIe-5696.

[25] Refer to the *Transition Power Level* figure for more information about the low-harmonic path versus the high-power path.

Modulation

Supported modulation types[26]	Amplitude modulation (AM), frequency modulation (FM), phase modulation (PM), and pulse modulation

Amplitude Modulation

Connector name	AM IN
Modulation rate	DC to 100 kHz
Input level	±1 V, nominal
AM range[27]	±10 dB, nominal
Maximum input level	+2 V
Minimum input level	-2 V
Input impedance	50 Ω, nominal

Frequency Modulation and Phase Modulation

Connector name	FM IN

Table 11. FM Operating Modes

Modulating Signal Rate	FM Band
100 Hz to 1 kHz	Narrowband
1 kHz to 10 kHz	
10 kHz to 100 kHz	
>100 kHz	Wideband

Table 12. PM Operating Modes

Modulating Signal Rate	PM Mode
DC	Low phase noise
DC to 100 kHz	High deviation

[26] AM, FM, and PM modulation types are specified as a capability, not a warranted specification.

[27] Measured at +3 dBm output power for the PXIe-5654. For the PXIe-5654 with PXIe-5696, the AM range varies with frequency and power as well as the selected amplification path. Under worst-case combinations, the AM range may go to 0 dB.

Figure 12. Representative FM Deviation (Wideband FM)

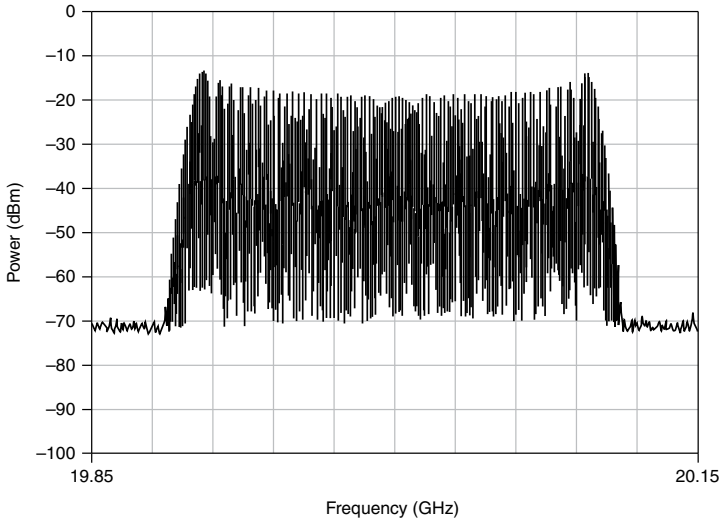


Table 13. FM and PM Division Constants[28]

Frequency Range (MHz)	Division Number (*N*)
10,400 to 20,800	1
5,200 to 10,400	2
2,600 to 5,200	4
1,300 to 2,600	8
650 to 1,300	16
325 to 650	32
250 to 325	64

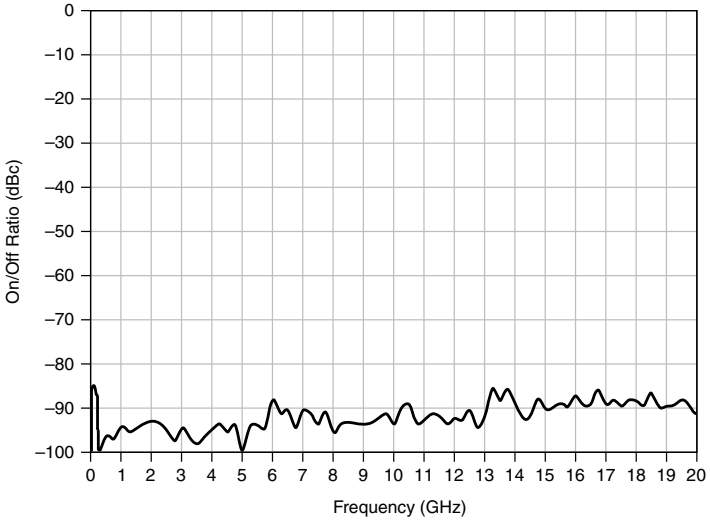
Pulse Modulation[29]

Connector name	PULSE IN
Repetition frequency	DC to 10 MHz

[28] For any FM or PM setting, achievable deviation degrades in each band by a factor of 1/*N* as the frequency changes.

Input level	
RF on	TTL high
RF off	TTL low
Maximum	+5.5 V
Minimum	-0.5 V
Input impedance	>100 kΩ
Carrier on/off ratio (250 MHz to 20 GHz)[30]	80 dB

Figure 13. Pulse Modulation On/Off Ratio



Minimum pulse width (250 MHz to 20 GHz)	50 ns, typical
Rise/fall time (250 MHz to 20 GHz)	15 ns
Maximum pulse width compression[31] (250 MHz to 20 GHz)	15 ns, nominal
Delay time (250 MHz to 20 GHz)	<35 ns, nominal
Pulse overshoot (250 MHz to 20 GHz)	<10%

[29] At maximum available power.
[30] Carrier on/off ratio is 80 dB (typical) from 12.75 GHz to 13.75 GHz. Degrades by 3 dB over 0 °C to 55 °C.
[31] At 10 MHz repetition frequency, 50% duty cycle.

Power Requirements

Table 14. PXIe-5654 DC Power Requirements

Voltage (V_{DC})	Maximum Current (A)	Typical Current (A)
+3.3	2.5	1.9
+12	3	2.4

Table 15. PXIe-5696 DC Power Requirements

Voltage (V_{DC})	Maximum Current (A)	Typical Current (A)
+3.3	3	2.2
+12	2.8	1.6

Calibration

Interval	2 years

Physical Characteristics

PXIe-5654 RF signal generator	
Size	3U, three slot, PXI Express module 6.1 cm x 13.0 cm x 21.4 cm (2.4 in. x 5.1 in. x 8.4 in.)
Weight	1,328 g (46.8 oz)
PXIe-5696 amplitude extender	
Size	3U, two slot, PXI Express module 4.1 cm x 13.0 cm x 21.4 cm (1.6 in. x 5.1 in. x 8.4 in.)
Weight	894 g (31.5 oz)

Environment

Maximum altitude	2,000 m (800 mbar) (at 25 °C ambient temperature)
Pollution Degree	2

Indoor use only.

Operating Environment

Ambient temperature range	0 °C to 55 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 low temperature limit and MIL-PRF-28800F Class 2 high temperature limit.)
Relative humidity range	10% to 90%, noncondensing (Tested in accordance with IEC 60068-2-78.)

Storage Environment

Ambient temperature range	-40 °C to 71 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 limits.)
Relative humidity range	5% to 95%, noncondensing (Tested in accordance with IEC 60068-2-78.)

Shock and Vibration

Operating shock[32]	30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC 60068-2-27. Meets MIL-PRF-28800F Class 2 limits.
Random vibration	
Operating	5 Hz to 500 Hz, 0.3 g_{rms} (Tested in accordance with IEC 60068-2-64.)
Nonoperating	5 Hz to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC 60068-2-64. Test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

[32] Internal mechanical attenuator may change state during shock application.

Compliance and Certifications

Safety Compliance Standards

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 C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label or the *Product Certifications and Declarations* section.

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 *Product Certifications and Declarations* section.

CE Compliance CE

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)

Product Certifications and Declarations

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for NI products, 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`.)

376151E-01 October 10, 2018