

# CALIBRATION PROCEDURE

# NI PXI-5650/5651/5652

This document describes the processes to calibrate the NI PXI-5650/5651/5652 RF signal generator. This document provides performance tests to verify whether the instrument is performing within the published specifications. For more information about calibration, visit [ni.com/calibration](http://ni.com/calibration).

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# Conventions

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The following conventions are used in this manual:

» The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.



This icon denotes a note, which alerts you to important information.

**bold** Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

*italic* Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.

monospace Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

## Software Requirements

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To calibrate the NI PXI-5650/5651/5652, you must install NI-RFSG version 1.5 or later on the calibration system. You can download the latest version of NI-RFSG at [ni.com/idnet](http://ni.com/idnet).

For more information about calibration VIs, refer to the *NI RF Signal Generators Help*, which is accessible at **Start»All Programs»National Instruments»NI-RFSG»Documentation**.

**Table 1.** Calibration File Locations (NI-RFSG 1.5 or Later)

File Name and Location	Description
IVI\Bin\niRFSG.dll	NI-RFSG driver containing the entire NI-RFSG API.

# Documentation Requirements

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You might find the following documentation helpful as you perform the verification procedures:

- *NI PXI-565X RF Signal Generator Specifications*
- *NI RF Signal Generators Getting Started Guide*
- *NI RF Signal Generators Help*, including LabVIEW VI programming references

These documents are installed with NI-RFSG. You can also download the latest versions at [ni.com/manuals](http://ni.com/manuals).

## Password

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The default password for password-protected operations is `NI`.

## Calibration Interval

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The measurement accuracy requirements of your application determine how often you should calibrate your device. NI recommends that you perform a complete calibration for the NI 5650/5651/5652 at least once a year. You can shorten this calibration interval based on the accuracy demands of your application.

## Test Equipment

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Table 2 lists the equipment required to calibrate the NI 5650/5651/5652. If you do not have the recommended equipment, select a substitute calibration standard using the specifications listed in Table 2.

**Table 2.** Required Equipment Specifications for NI 5650/5651/5652 Calibration

Required Equipment	Recommended Equipment	Specifications
Spectrum analyzer	Rohde & Schwarz (R&S) FSU Spectrum Analyzer	Frequency range: 500 kHz to 9 GHz Noise floor: <-150 dBm/Hz
Power meter	Anritsu ML2438A with a MA2472 diode sensor	Range: -70 dBm to +20 dBm Frequency range: 10 MHz to 6.6 GHz Accuracy: 0.5%
Frequency reference	Datum 8040 Rubidium Frequency Standard	Frequency: 10 MHz Frequency accuracy: 1 ppb (typically $\pm 5 \text{ E-11}$ )

## Test Conditions

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Follow these guidelines to optimize the connections and the environment during calibration:

- Keep cabling as short as possible. Long cables act as antennae, picking up extra noise that can affect measurements.
- Verify that all connections, including front panel connections and screws, are secure.
- Ensure that the PXI chassis fan speed is set to HI, that the fan filters are clean, and that the empty slots contain filler panels. For more information, refer to the *Maintain Forced-Air Cooling Note to Users* document available at [ni.com/manuals](http://ni.com/manuals).
- Keep relative humidity between 10% and 90%, noncondensing.
- Maintain an ambient temperature of  $23 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$ .
- Allow a warm-up time of at least 30 minutes after the chassis is powered on. The warm-up time ensures that the NI 5650/5651/5652 is at a stable operating temperature.
- Each verification procedure requires a delay to be inserted in between configuring all devices and acquiring the measurement. This delay may need to be adjusted depending on the instruments used but should always be at least 1,000 ms for the first iteration and 100 ms for each subsequent frequency iteration.

# Calibration Procedures

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The calibration process includes the following steps:

1. *Initial Setup*—Install the device and configure it in Measurement & Automation Explorer (MAX).
2. *Verification*—Verify the existing operation of the device. This step confirms whether the device is operating within its specified range prior to adjustment.
3. *Adjustment*—Return the device to NI for a factory calibration to adjust the calibration constants.
4. *Reverification*—Repeat the verification procedure to ensure that the device is operating within its specifications after adjustment.

The verification procedure is described in more detail in the following sections.

## Initial Setup

Refer to the *NI RF Signal Generators Getting Started Guide* for information about how to install the software and hardware and how to configure the device in MAX.

## Verification

This section describes the steps you must follow to verify the published specifications for the NI 5650/5651/5652.

Verification tests the following NI 5650/5651/5652 specifications:

- Frequency accuracy
- High power level accuracy
- Low power level accuracy
- Single side-band phase noise at 10 kHz offset
- Harmonics at less than or equal to 0 dBm output power level
- Subharmonics at less than or equal to 0 dBm output power level
- Nonharmonics at less than or equal to 0 dBm output power level (1 kHz and 100 kHz offsets)

Verification of the NI 5650/5651/5652 is complete only after you have successfully completed all tests in this section.

## Verifying Frequency Accuracy

Complete the following steps to verify the frequency accuracy of the NI 5650/5651/5652 module using a spectrum analyzer.

1. Connect the NI 5650/5651/5652 RF OUT front panel connector to the spectrum analyzer RF INPUT front panel connector.
2. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer REF IN rear panel connector.
3. Configure the spectrum analyzer with the following settings:
  - Center Frequency: 400 MHz
  - Reference Level: -20 dBm
  - Resolution Bandwidth: 100 Hz
  - Span: 100 kHz
  - Reference Clock Source: External
4. Generate a signal after setting the following NI-RFSG property settings:
  - Frequency (Hz): 400 MHz
  - Power Level (dBm): -20 dBm
  - Generation Mode: CW
  - Reference Clock Source: Onboard Clock
5. Use the spectrum analyzer to measure the frequency of the peak tone.
6. Verify that the measurement in step 5 is within the limits in Table 3, with respect to 400 MHz.

**Table 3.** Frequency Accuracy Test Limit

Device	Test Limit
NI 5650/5651/5652	9 ppm

## Verifying High Power Level Accuracy

Complete the following steps to verify the high power level accuracy of the NI 5650/5651/5652 module using a power meter.

1. Connect the NI 5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the NI 5650/5651/5652 RF OUT front panel connector to the power meter Sensor A.
3. Generate a single-tone signal after setting the following NI-RFSG property settings:
  - Frequency (Hz): 10 MHz
  - Power Level (dBm): -35 dBm

- Generation Mode: CW
  - Reference Clock Source: RefIn
4. Use the power meter to measure the RF OUT power. Compare the measured RF OUT power to the *Test Limit* listed in Table 4.
  5. Repeat steps 3 through 4 for every power level up to the *Stop Power* level listed in Table 4, using a 5 dB step size.
  6. Repeat step 5 for the remaining frequencies listed in Table 4.

**Table 4.** High Power Level Accuracy Test Points and Limits

Device	Frequency	Stop Power (dBm)	Test Limit (dB)
NI 5650/5651/5652	10 MHz	5	±0.75
	20 MHz	5	
	50 MHz	10	
	100 MHz	10	
	150 MHz	10	
	200 MHz	10	
	500 MHz	10	
	1 GHz	10	
NI 5651/5652	1.5 GHz	10	±0.75
	2 GHz	10	
	2.5 GHz	10	
	3 GHz	10	
	3.3 GHz	7	
NI 5652	3.5 GHz	7	±1.0
	4 GHz	7	
	4.5 GHz	7	
	5 GHz	7	
	5.5 GHz	0	
	6 GHz	0	
	6.6 GHz	0	

## Verifying Low Power Level Accuracy

Complete the following steps to verify the low power level accuracy of the NI 5650/5651/5652 module using a power meter.

1. Connect the NI 5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the NI 5650/5651/5652 RF OUT front panel connector to the power meter Sensor A.
3. Generate a single-tone signal after setting the following NI-RFSG property settings:
  - Frequency (Hz): 10 MHz
  - Power Level (dBm): -50 dBm
  - Generation Mode: CW
  - Reference Clock Source: RefIn
4. Use the power meter to measure the NI 5650/5651/5652 RF OUT power. Compare the value to the *Test Limits* listed in Table 5.

**Table 5.** Low Level Accuracy Test Points and Limits

Device	Frequency	Stop Power (dBm)	Test Limit (dB)
NI 5650/5651/5652	10 MHz	-40	±1.8
	20 MHz	-40	
	50 MHz	-40	
	100 MHz	-40	
	150 MHz	-40	
	200 MHz	-40	
	500 MHz	-40	
	1 GHz	-40	
NI 5651/5652	1.5 GHz	-40	±1.8
	2 GHz	-40	
	2.5 GHz	-40	
	3 GHz	-40	
	3.3 GHz	-40	

**Table 5.** Low Level Accuracy Test Points and Limits (Continued)

Device	Frequency	Stop Power (dBm)	Test Limit (dB)
NI 5652	3.5 GHz	-40	±2.0
	4 GHz	-40	
	4.5 GHz	-40	
	5 GHz	-40	
	5.5 GHz	-40	
	6 GHz	-40	
	6.6 GHz	-40	

5. Repeat steps 3 through 4 for every power level up to the *Stop Power* listed in Table 5, using a step size of 5 dB.
6. Repeat steps 3 through 5 with the remaining frequencies listed in Table 5.

## Verifying Single Sideband Phase Noise at 10 kHz Offset

Complete the following steps to verify the single sideband (SSB) phase noise of an NI 5650/5651/5652 module using a spectrum analyzer.

1. Connect the NI 5650/5651/5652 RF OUT front panel connector to the spectrum analyzer RF INPUT front panel connector.
2. Connect the NI 5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
3. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
4. Generate a signal after setting the following NI-RFSG property settings:
  - Frequency: 1 GHz
  - Power Level: 0 dBm
  - Generation Mode: CW
  - Reference Clock Source: RefIn
5. Configure the spectrum analyzer with the following settings:
  - Frequency: 1 GHz
  - Reference Level: 0 dBm
  - Resolution Bandwidth: 10 Hz

- Frequency Span: 100 Hz
  - Reference Clock Source: External
6. Measure the maximum power within the configured span of the spectrum analyzer and record this data. Reference this measurement for steps 7 through 12.
  7. Reconfigure the spectrum analyzer with the following settings:
    - Frequency: 1 GHz + 10 kHz offset
    - Reference Level: 0 dBm
    - Resolution Bandwidth: 10 Hz
    - Frequency Span: 100 Hz
    - Reference Clock Source: External
    - Trace Averaging: 20 traces
  8. Measure the mean value within the configured span of the spectrum analyzer and record this value.
  9. Apply the following equation to the value measured in step 8:

$$phase\ noise_{SSB}\ at\ 10\ kHz\ offset = Measurement - 10\log(RBW) - reference\ level$$

10. Subtract the measurement recorded in step 6 from the value calculated in step 9.
11. Verify that the value calculated in step 10 meets the *Test Limits* as specified in Table 6.
12. Repeat steps 4 through 11 for the remaining frequencies listed in the *Frequency* column in Table 6, if applicable to the device.

**Table 6.** Single Sideband Phase Noise at 10 kHz Offset

Device	Frequency (GHz)	Test Limit (dBc/Hz)
NI 5650/5651/5652	1	<-105
NI 5651/5652	2	<-98
	3	<-95
NI 5652	4	<-93
	5	<-90
	6.6	<-90



**Note** The main frequency synthesis occurs between 1.5 and 3.3 GHz using one of four voltage-controlled oscillators (VCO). Frequencies outside this range are generated by using dividers or multipliers. For frequencies lower than 1 GHz, the SSB phase noise can

be characterized by the following relationship (use the 1 GHz measurement as your reference):

$$SSB\ Phase\ Noise_{TEST} = SSB\ Phase\ Noise_{REFERENCE} - 20\log(n)$$

where  $SSB\ Phase\ Noise_{TEST}$  = SSB phase noise at the center frequency of interest in dBc/Hz

$SSB\ Phase\ Noise_{REFERENCE}$  = SSB phase noise at the referenced center frequency of interest in dBc/Hz

$n = Reference/Test$  in Hz/Hz

## Verifying Harmonics

Complete the following steps to verify the harmonic levels of the NI 5650/5651/5652 module using a spectrum analyzer.

1. Connect the NI 5650/5651/5652 RF OUT front panel connector to the spectrum analyzer RF INPUT front panel connector.
2. Connect the NI 5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz reference signal front panel connector.
3. Connect the rubidium 10 MHz reference signal to the spectrum analyzer REF IN rear panel connector.
4. Generate a signal after setting the following NI-RFSG property settings:
  - Power Level (dBm): 0 dBm
  - Frequency (Hz): 10 MHz
  - Generation Mode: CW
  - Reference Clock Source: RefIn
5. Configure the spectrum analyzer with the following settings:
  - Center Frequency: 10 MHz
  - Reference Level: 0 dBm
  - Resolution Bandwidth: 1 kHz
  - Frequency Span: 500 kHz
  - Reference Clock Source: External
6. Measure the peak signal value of the fundamental frequency using the current settings on the spectrum analyzer. Record this value.
7. Reconfigure the spectrum analyzer with the following settings:
  - Center Frequency: The center frequency from step 5  $\times$  2.
  - Reference Level: 0 dBm
  - Resolution Bandwidth: 1 kHz

- Frequency Span: 500 kHz
  - Reference Clock Source: External
8. Measure the peak signal value of the 2nd harmonic using the settings of the spectrum analyzer configured in step 7. Record this value.
  9. Subtract the measurement in step 6 from the measurement in step 8.
  10. Verify that the result calculated in step 9 meets the *Test Limit* of the minimum difference from the generated signal power (dBc) as shown in Table 7.
  11. Repeat steps 4 through 10 for the remaining frequency points shown in Table 7.

**Table 7.** Harmonics at Less Than or Equal to 0 dBm Output Power

Device	Frequency	Test Limit (dBc)
NI 5650/5651/5652	10 MHz	<-15
	20 MHz	
	50 MHz	
	100 MHz	
	150 MHz	
	200 MHz	
	1 GHz	
NI 5651/5652	1.5 GHz	<-25
	2 GHz	
	2.5 GHz	
	3 GHz	
	3.3 GHz	
NI 5652	3.5 GHz	<-20
	4 GHz	
	4.5 GHz	
	5 GHz	
	5.5 GHz	
	6 GHz	
	6.6 GHz	

## Verifying Subharmonics on the NI 5652

Complete the following steps to verify the subharmonic levels of a calibrated NI 5652 RF signal generator using a spectrum analyzer.

This verification is valid *only* for the NI 5652 RF signal generator.

1. Connect the NI 5652 RF OUT front panel connector to the spectrum analyzer RF INPUT front panel connector.
2. Connect the NI 5652 REF IN/OUT front panel connector to the rubidium 10 MHz reference signal.
3. Connect one available end of the rubidium 10 MHz reference signal to the spectrum analyzer REF IN rear panel connector.
4. Generate a single-sideband signal after setting the following NI-RFSG properties:
  - Frequency (Hz): 3.3 GHz
  - Power Level (dBm): 0 dBm
  - Generation Mode: CW
  - Reference Clock Source: RefIn
5. Configure the spectrum analyzer with the following settings:
  - Center Frequency: The frequency listed in Table 8
  - Reference Level: 0 dBm
  - Resolution Bandwidth: 1 kHz
  - Span: 500 kHz
  - Reference Clock Source: External
6. Measure the peak power of the fundamental tone using the spectrum analyzer and record the value.
7. Reconfigure the spectrum analyzer with the following settings:
  - Center Frequency: Half the frequency used in step 5
  - Power Reference Level: 0 dBm
  - Resolution Bandwidth: 1 kHz
  - Span: 500 kHz
  - Reference Clock Source: External
8. Measure the peak power of the half harmonic using the spectrum analyzer with the settings from step 7 and record the value.
9. Subtract the measurement in step 6 from the measurement in step 8.
10. Verify that the measured signal power in step 9 is within the *Test Limit* specified in Table 8.

11. Repeat steps 4 through 10 for the remaining frequencies in Table 8.

**Table 8.** Subharmonics for the NI 5652

Center Frequency (GHz)	Subharmonic Frequency (GHz)	Test Limit (dBc)
3.3	1.65	<-30
3.5	1.75	
3.7	1.85	
3.9	1.95	
4.1	2.05	<-25
4.3	2.15	
4.5	2.25	
4.7	2.35	
4.9	2.45	
5.1	2.55	
5.3	2.65	
5.5	2.75	
5.7	2.85	
5.9	2.95	
6.1	3.05	
6.3	3.15	
6.5	3.25	
6.6	3.3	

## Verifying Nonharmonics at Less than or Equal to 0 dBm Output Power

Complete the following steps to verify the nonharmonic levels of an NI 5650/5651/5652 module using a spectrum analyzer.

1. Connect the NI 5650/5651/5652 RF OUT front panel connector to the spectrum analyzer RF INPUT front panel connector.
2. Connect the NI 5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz reference signal.

3. Connect one available end of the rubidium 10 MHz reference signal to the spectrum analyzer REF IN rear panel connector.
4. Generate a signal after setting the following NI-RFSG property settings:
  - Frequency (Hz): 35.125 MHz
  - Power Level (dBm): 0 dBm
  - Generation Mode: CW
  - Reference Clock Source: RefIn
5. Configure the spectrum analyzer with the following settings:
  - Frequency: 35.125 MHz
  - Reference Level: 0 dBm
  - Resolution Bandwidth: 1 kHz
  - Span: 500 kHz
  - Reference Clock Source: External
6. Measure the peak power of the fundamental tone using the spectrum analyzer and record the value. This value will be your reference value for steps 7 through 15.
7. Reconfigure the spectrum analyzer with the following settings:
  - Center Frequency: 35.125 MHz + 50.5 kHz offset
  - Power Reference Level: 0 dBm
  - Span: 99 kHz
  - Reference Clock Source: External
  - Resolution Bandwidth: 100 Hz
8. Measure the peak power using the spectrum analyzer with the settings from step 7 and record the value. This value is the highest peak between 1 kHz and 100 kHz offset from the fundamental frequency.
9. Subtract the measurement in step 6 from the measurement in step 8.

10. Verify that the result calculated in step 9 is within the  $>1$  kHz Offset limits listed in Table 9.

**Table 9.** Nonharmonics at Less Than or Equal to 0 dBm Output Power

RF Output Frequency	Test Limits	
	> 1 kHz Offset (dBc)	> 100 kHz Offset (dBc)
500 kHz to 50 MHz	<-65	<-75
50 MHz to 3.3 GHz	<-65	<-70
3.3 GHz to 6.6 GHz	<-50	<-65

The following steps measure the nonharmonic levels  $\text{freqOffset} > 100$  kHz where  $\text{freqOffset}$  is the frequency offset from the tone being generated.

11. Configure the spectrum analyzer with the following settings:
  - Center Frequency: 200 MHz
  - Power Reference Level: 0 dBm
  - Resolution Bandwidth: 500 Hz
  - Span: 100 kHz
  - Reference Clock Source: External
12. Measure the peak power using the spectrum analyzer with the settings from step 11 and record the value.
13. Subtract the measurement from step 12 from the measurement in step 6.
14. Verify that the result is within the  $>100$  kHz Offset limits specified in Table 9.
15. Repeat steps 11 through 14 for the remaining frequencies listed in the *Test Point (MHz)* column in Table 10.

**Table 10.** Test Points for Nonharmonic Test

Device	Test Point (MHz)
NI 5650/5651/5652	200
	400
	600
	800
	1,000
	1,200

**Table 10.** Test Points for Nonharmonic Test (Continued)

Device	Test Point (MHz)
NI 5651/5652	1,400
	1,600
	1,800
	2,000
	2,200
	2,400
	2,600
	2,800
	3,000
	3,200
	NI 5652
3,600	
3,800	
4,000	
4,200	
4,400	
4,600	
4,800	
5,000	
5,200	
5,400	
5,600	
5,800	
6,000	
6,200	
6,400	
6,600	

16. Repeat steps 4 through 15 using the *Center Frequency (MHz)* shown in Table 11.

**Table 11.** Center Frequencies for Nonharmonic Test

<b>Device</b>	<b>Center Frequency (MHz)</b>
NI 5650/5651/5652	35.125
	1235.125
NI 5651/5652	3235.125
NI 5652	6535.125

# Where to Go for Support

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The National Instruments Web site is your complete resource for technical support. At [ni.com/support](http://ni.com/support) you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electromagnetic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting [ni.com/certification](http://ni.com/certification). If your product supports calibration, you can obtain the calibration certificate for your product at [ni.com/calibration](http://ni.com/calibration).

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at [ni.com/support](http://ni.com/support) and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

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