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Keysight Electronic Calibration Modules

RF Two-Port
85091C 85092C 85093C 85096C 85098C 85099C

Microwave Two-Port
N4690B N4690C N4691B N4692A N4693A N4694A N4696B

RF Four-Port
N4431B

Microwave Four-Port
N4432A N4433A

KEYSIGHT TECHNOLOGIES

Reference Guide

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Table of Contents

1. General Information
Manual Overview . . . 1-1
Prerequisite Knowledge . . . 1-1
Clarifying the Terminology of a Connector Interface . . . 1-1
Accuracy of Electronic Calibration versus Mechanical Calibration . . . 1-2
When to Calibrate . . . 1-3
Models and Options . . . 1-4
8509x Modules (RF Two-Port) . . . 1-4
N4431B Modules (RF Four-Port) . . . 1-6
N469xA/B/C Modules (Microwave Two-Port) . . . 1-7
N4432A and N4433A Modules (Microwave Four-Port) . . . 1-9
Discontinued ECal Models . . . 1-10
Compatible Network Analyzers . . . 1-13
Service and Recertification . . . 1-14
Contacting Keysight . . . 1-14
Returning Devices to Keysight . . . 1-14
Recertification of ECal Modules . . . 1-15
Safety and Regulatory Information . . . 1-17
Safety Notices . . . 1-18
Instrument Markings . . . 1-18
Compliance Notices . . . 1-19

2. Preparing ECal for Use
Inspecting the ECal Kit . . . 2-1
Inspect the Kit Contents . . . 2-1
Locate the Two Serial Numbers . . . 2-1
Record the Serial Numbers . . . 2-2
Verify Electrical Performance . . . 2-3
Equipment Required but Not Supplied . . . 2-3
8509x Series Kit Contents . . . 2-4
8509x Options . . . 2-4
N4431B Series Kit Contents . . . 2-5
N4431B Options . . . 2-5
N469xA/B/C Series Kit Contents . . . 2-6
N469xA/B/C Options . . . 2-8
N4432A and N4433A Series Kit Contents . . . 2-8
N4432A Options . . . 2-9
N4433A Options . . . 2-9

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Operating and Safety Precautions 2-9
ESD Damage 2-9
Connector Care 2-10
Input Power Level 2-11
Operating Temperature 2-11
Connecting and Disconnecting ECal Module 2-12
Connect ECal Module to PNA or ENA Analyzer 2-12
Connect ECal Module to VNA Analyzer 2-14

3. Operating ECal Module
Setting Up a Calibration 3-1
Required Procedure for All Calibrations 3-1
Calibration Types Available 3-2
When to Correct for Isolation 3-2
Calibration Methods for Non-Insertable Devices 3-4
Finding More Information on Performing a Calibration 3-6
Validating a Calibration 3-7
ECal Confidence Check – Basic Validation of the Calibration 3-7
System Verification Procedure – Traceable Accuracy Validation of the Calibrated Measurement System 3-8

4. Use, Maintenance, and Care of the Devices
Electrostatic Discharge 4-1
Visual Inspection 4-3
Look for Obvious Defects and Damage First 4-3
Inspect the Mating Plane Surfaces 4-3
Inspect Female Connectors 4-5
Cleaning Connectors 4-6
Cleaning Coax Connectors 4-6
Cleaning Precision 7 mm Connectors 4-8
Gaging Connectors 4-9
Connector Gage Accuracy 4-9
When to Gage Connectors 4-10
Recognizing Gage Types 4-10
Reading the Connector Gage 4-10
Gaging Procedures 4-14
Making Connections 4-16
3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, Type-N, 7-16, and Type-F Devices 4-16
7 mm Devices 4-16
Final Connection Using a Torque Wrench 4-17
Separating Connections 4-20

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Handling and Storage 4-21
ECal Kit Storage Box (Option 150) 4-22

5. Specifications and Characteristics
Specifications: Terminology and Definitions 5-1
Environmental Specifications 5-2
Operating Temperature and Accuracy Enhancement 5-2
Barometric Pressure and Relative Humidity 5-2
Characteristic Performance 5-3
8509x Series 5-3
N4431B (3.5 mm) 5-6
N4431B (Type-N 50 Ω) 5-7
N4432A (Type-N 50 Ω) 5-8
N4433A (3.5 mm) 5-8
N469xA/B/C Series 5-9
Mechanical Characteristics 5-12
Pin Depth 5-12
Type-N Characteristics 5-13
Typical Pin Depth Values 5-15
Supplemental Mechanical Characteristics 5-18
Mechanical Dimensions of the Modules 5-20
Measurement Uncertainty Calculator 5-24
Download the Vector Network Analyzer Uncertainty Calculator 5-24

6. Replaceable Parts
Description of This Chapter 6-1
7 mm Modules and Accessories. 6-2
Type-N (50 ohm) Modules and Accessories 6-3
3.5 mm Modules and Accessories 6-4
7-16 Modules and Accessories 6-5
2.92 mm Modules and Accessories 6-6
2.4 mm Modules and Accessories 6-7
1.85 mm Modules and Accessories 6-8
Type-N (75 ohm) Modules and Accessories 6-9
Type-F Modules and Accessories 6-10
Other ECal Accessories 6-11

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Keysight Electronic Calibration Modules
RF/Microwave Two Port and Four Port

Reference Guide

1 General Information

Manual Overview

The purpose of this manual is to help you use your Electronic Calibration (ECal) module confidently and effectively. ECal is a precision, single-connection calibration technique which uses fully traceable and verifiable electronic standards. Each module has unique S-parameter data that is stored in the module's memory. During calibration, ECal uses this data to calculate the error terms for your network analyzer.

This manual provides instructions for operating and maintaining your ECal module. Also included are mechanical specifications and replaceable parts available for each model.

RF Modules

The 8509x and N4431B series provide two-port and four-port calibration solutions with operating frequencies starting as low as 9 kHz and ending as high as 13.5 GHz.

Microwave Modules

The N469xA and N469xB/C series (which replace the 8506x series) and the N4432A and N4433A series provide two-port and four-port calibration solutions with operating frequencies starting as low as 300 kHz and ending as high as 67 GHz.

Prerequisite Knowledge

This manual assumes you are trained in proper connector care. Because an accurate calibration depends on the integrity and cleanliness of the connector interface, a damaged connector will invalidate the calibration achieved with that module. Refer to the “Principles of Microwave Connector Care Quick Reference Card” located at the back of this manual.

Clarifying the Terminology of a Connector Interface

In this manual, adapters, ECal modules, and gage masters are referred to by way of their interface connector. For example:

- A female adapter has a female interface.
- A male adapter has a male interface.

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A connector gage is referred to by way of the connector it measures. For example:

– A male connector gage has a female interface so it can measure male devices.

– A female connector gage has a male interface so it can measure female devices.

Accuracy of Electronic Calibration versus Mechanical Calibration

As the number of DUT test ports increases, the required number of calibration measurements also increases. This boosts the probability of bad connections and bad calibrations when mechanical calibration standards are used rather than ECal. Also, test port cable repeatability and stability errors are amplified by the increased number of connections and disconnections. To perform an SOLT 4-port calibration, a minimum of twelve 1-port standards and three 2-port (thru) standards are measured, requiring a total of eighteen connections. The same calibration using a 4-port ECal module (N4431B, N4432A and N4433A) requires only four connections.

Ignoring connection related errors, the following table compares the accuracy of ECal versus mechanical calibration in various calibration options.

Mechanical Calibration Type	ECal Thru Type	Measurement	ECal	Mechanical Calibration
1-Port, calibration constant (**not** data-based) SOL	NA	Reflection	++	
1-Port, short, open, sliding load	NA	Reflection	+	
1-Port, data-based, expanded	NA	Reflection		+
2-Port TRL	All types	Reflection Transmission		++ ++
≥2-Port, calibration constant SOL, flush thru[a]	Characterized	Reflection Transmission	++	++
	Internal unknown	Reflection Transmission	++	
	External flush[a]	Reflection Transmission	++	
≥2-Port, calibration constant SOL, unknown thru	Characterized	Reflection Transmission	++	++
	Internal unknown	Reflection Transmission	++ =	=

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Mechanical Calibration Type	ECal Thru Type	Measurement	ECal	Mechanical Calibration
≥2-Port, data-based, expanded, flush thru[a]	Characterized	Reflection Transmission		+ ++
	Internal unknown	Reflection Transmission		+ +
	External flush[a]	Reflection Transmission		+ +
≥2-Port, data-based, expanded, unknown thru	Characterized	Reflection Transmission		+ ++
	Internal unknown	Reflection Transmission		+ +
++ better; + slightly better; = same				

a. Flush thru should NOT be used when the test port connectors are not the same type as the calibration standards. SMA and 3.5 mm connectors are mateable but are NOT the same type.

When to Calibrate

A network analyzer calibration remains valid as long as the changes in the systematic error are insignificant. This means that changes to the uncorrected leakages (directivity and isolation), mismatches (source match and load match), and frequency response of the system are small (<10%) relative to accuracy specifications.

Change in the environment (especially temperature) between calibration and measurement is the major cause in calibration accuracy degradation. The major effect is a change in the physical length of external and internal cables. Other important causes are dirty and damaged test port connectors and calibration standards. If the connectors become dirty or damaged, measurement repeatability and accuracy is affected. Fortunately, it is relatively easy to evaluate the general validity of the calibration. To test repeatability, remeasure one of the calibration standards. If you can not obtain repeatable measurements from your calibration standards, maintenance needs to be performed on the test port connectors, cables and calibration standards. Also, maintain at least one sample of the device under test or some known device as your reference device. A verification kit may be used for this purpose. After calibration, measure the reference device and note its responses. Periodically remeasure the device and note any changes in its corrected response which can be attributed to the test system. With experience you will be able to see changes in the reference responses that indicate a need to perform the measurement calibration again.

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Models and Options

This section provides the model number, operating characteristics and connector options available with Keysight RF and microwave ECal modules. You can order ECal modules by selecting the model number followed by the desired options.

8509x Modules (RF Two-Port)

ECal modules from this series are available with the connector types and frequency ranges shown in Table 1-1 on page 5. Mixed connector options allow you to configure the module with a different connector type at each port (as shown in Figure 1-2).

Figure 1-1 Model 85092C Option M0F

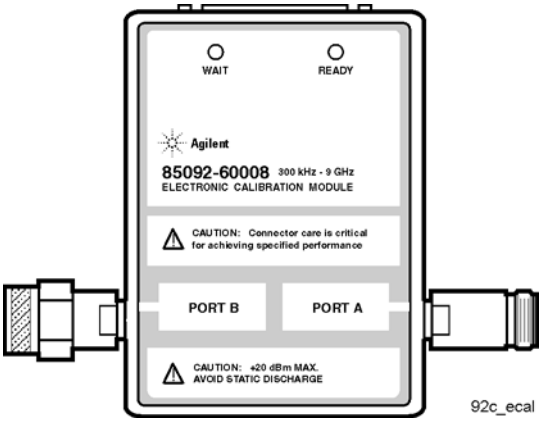
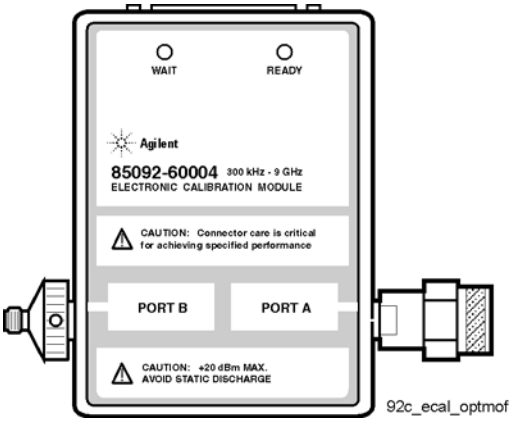


Figure 1-2 Model 85092C Option 104, 201



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Table 1-1 8509x Modules

Model Number	Connector Type	Operating Frequency	Port A and B Option		
			-m- and -f-	-m- and -m-	-f- and -f-
85091C	7 mm	300 kHz to 9 GHz	No Connector Option 85091-60004		
85092C	Type-N 50 ohm	300 kHz to 9 GHz	M0F 85092-60008	00M 85092-60009	00F 85092-60010
	Mixed connector types – see Table 1-2	300 kHz to 9 GHz	See Table 1-2 85092-60004		
85093C	3.5 mm	300 kHz to 9 GHz	M0F 85093-60008	00M 85093-60009	00F 85093-60010
	Mixed connector types – see Table 1-2	300 kHz to 9 GHz	See Table 1-2 85092-60004		
85096C	Type-N 75 ohm	300 kHz to 3 GHz	M0F 85096-60007	00M 85096-60008	00F 85096-60009
85098C	7-16	300 kHz to 7.5 GHz	M0F 85098-60007	00M 85098-60008	00F 85098-60009
	Mixed connector types – see Table 1-2	300 kHz to 7.5 GHz	See Table 1-2 85092-60004		
85099C	Type-F	300 kHz to 3 GHz	M0F 85099-60009	00M 85099-60010	00F 85099-60011

Table 1-2 8509x Mixed Connector Options

Model Number	Port A Option			Port B Option					
	Type	-f-	-m-	Type	-f-	-m-	Type	-f-	-m-
85092C	Type-N 50Ω	103	104	3.5 mm	201	202	7-16a	205	206
85093C	3.5 mm	101	102	Type-N 50Ω	203	204	7-16a	205	206
85098C	7-16[a]	105	106	3.5 mm	201	202	Type-N 50Ω	203	204

a. Limits ECal module high frequency to 7.5 GHz.

Other Options	Description
00A	Adds one -m- to -m- and one -f- to -f- adapter.
UK6	Adds commercial calibration certificate with measured data.

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N4431B Modules (RF Four-Port)

ECal modules from this series are available with the connector types and frequency ranges shown in Table 1-3. Mixed connector options (shown in Table 1-4) allow you to configure the module with a different connector type at each port.

Figure 1-3 Model N4431B Option 010

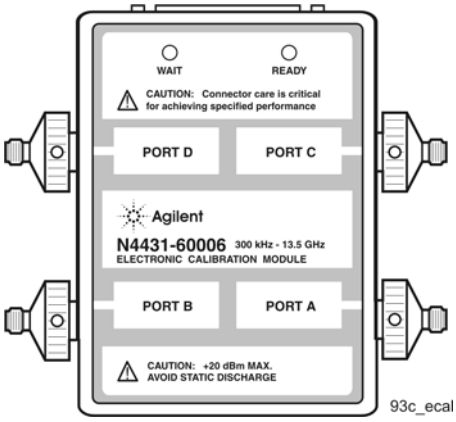


Table 1-3 N4431B Modules

Model Number	Module Number	Connector Type Port A,B,C,D	Operating Frequency	Option
N4431B	N4431-60006	3.5 mm -f-	9 kHz[a] to 13.5 GHz	010
	N4431-60007	Type-N 50Ω -f-	9 kHz[a] to 13.5 GHz	020
	N4431-60008	Mixed connector types – see Table 1-4, “N4431B Mixed Connector Options”, on page 7	9 kHz[a] to 13.5 GHz	See Table 1-4, “N4431B Mixed Connector Options”, on page 7

a. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.

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Table 1-4 N4431B Mixed Connector Options

Connector Type	Port A Option	Port B Option	Port C Option	Port D Option
3.5 mm -f-	101	201	301	401
3.5 mm -m-	102	202	302	402
Type-N 50Ω -f-	103	203	303	403
Type-N 50Ω -m-	104	204	304	404
7-16 -f-[a]	105	205	305	405
7-16 -m-a	106	206	306	406

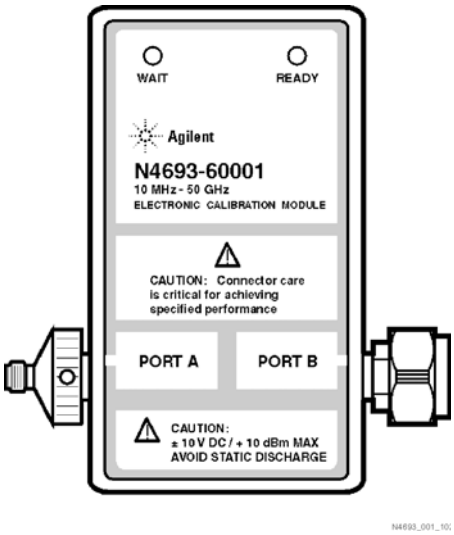
a. Limits ECal module high frequency to 7.5 GHz.

Other Options	Description
UK6	Adds commercial calibration certificate with measured data.

N469xA/B/C Modules (Microwave Two-Port)

ECal modules from this series are available with the connector types and frequency ranges shown in Table 1-5. Mixed connector options are not available with this series. The new N4690C module has shorter female connectors than the N4690B.

Figure 1-4 Model N4693A Option M0F



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Table 1-5 N469xA/B/C Modules

Model Number	Connector Type	Operating Frequency	Port A and B Option		
			-m- and -f-	-m- and -m-	-f- and -f-
N4690B	Type-N 50Ω	300 kHz to 18 GHz	M0F	00M	00F
			Module Part Number		
			N4690-60004	N4690-60005	N4690-60006
N4690C	Type-N 50Ω	300 kHz to 18 GHz	M0F	00M	00F
			Module Part Number		
			N4690-60007	N4690-60008	N4690-60009
N4691B	3.5 mm	300 kHz to 26.5 GHz	M0F	00M	00F
			Module Part Number		
			N4691-60004	N4691-60005	N4691-60006
N4692A	2.92 mm	10 MHz to 40 GHz	M0F	00M	00F
			Module Part Number		
			N4692-60001	N4692-60002	N4692-60003
N4693A	2.4 mm	10 MHz to 50 GHz	M0F	00M	00F
			Module Part Number		
			N4693-60001	N4693-60002	N4693-60003
N4694A	1.85 mm	10 MHz to 67 GHz	M0F	00M	00F
			Module Part Number		
			N4694-60001	N4694-60002	N4694-60003
N4696B	7 mm	300 kHz to 18 GHz	No Connector Option		
			Module Part Number		
			N4696-60004		

Other Options	Description
00A	Adds one -m- to -m- and one -f- to -f- adapter (not available with N4696B).
UK6	Adds commercial calibration certificate with measured data.

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N4432A and N4433A Modules (Microwave Four-Port)

ECal modules from this series are available with the connector types and frequency ranges shown in Table 1-6. Mixed connector options (shown in Table 1-7) allow you to configure the module with a different connector type at each port.

Figure 1-5 Model N4433A Option 010

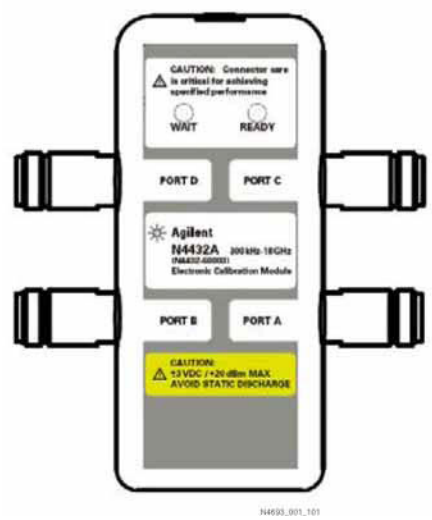


Table 1-6 N4432A and N4433A Modules

Model Number	Module Number	Connector Type Port A,B,C,D	Operating Frequency	Option
N4432A	N4432-60003	Type-N 50Ω -f-	300 kHz to 18 GHz	020
	N4432-60005	Mixed connector types – see Table 1-7, “N4432A Mixed Connector Options”, on page 10	300 kHz to 18 GHz	See Table 1-7, “N4432A Mixed Connector Options”, on page 10
N4433A	N4433-60003	3.5 mm -f-	300 kHz to 20 GHz	010
	N4433-60004	Mixed connector types – see Table 1-8, “N4433A Mixed Connector Options”, on page 10	300 kHz to 20 GHz	See Table 1-8, “N4433A Mixed Connector Options”, on page 10

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Table 1-7 N4432A Mixed Connector Options

Connector Type	Port A Option	Port B Option	Port C Option	Port D Option
3.5 mm -f-[a]	101	201	301	401
3.5 mm -m-[a]	102	202	302	402
Type-N 50Ω -f-	103	203	303	403
Type-N 50Ω -m-	104	204	304	404

a. Frequency range of ECal module limited by other connectors.

Other Options	Description
UK6	Adds commercial calibration certificate with measured data.
1A7	Adds ISO 17025 compliant calibration.
A6J	Adds ANSI Z540 compliant calibration.

Table 1-8 N4433A Mixed Connector Options

Connector Type	Port A Option	Port B Option	Port C Option	Port D Option
3.5 mm -f-	101	201	301	401
3.5 mm -m-	102	202	302	402

Other Options	Description
UK6	Adds commercial calibration certificate with measured data.
1A7	Adds ISO 17025 compliant calibration.
A6J	Adds ANSI Z540 compliant calibration.

Discontinued ECal Models

Discontinued ECal models are no longer available for purchase, but may be returned to Keysight for service and recertification.

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Table 1-9 Discontinued ECal Models

Discontinued Model Number	Keysight Part Number	Connector Type	Operating Frequency	Description	Replacement Model
85060A[a]	85060-60001	7 mm	1 to 18 GHz	2-Port Microwave Electronic Calibration Module	N4696B
85062Aa	85062-60001	3.5 mm	1 to 26.5 GHz		N4691B
85064Aa	85064-60001	Type-N 50Ω	1 to 18 GHz		N4690B/C
85060B	85060-60002	7 mm	1 to 18 GHz		N4696B
85062B	85062-60002	3.5 mm	1 to 26.5 GHz		N4691B
85064B	85064-60002	Type-N 50Ω	1 to 18 GHz		N4690B/C
85091A	85091-60001	7 mm	30 kHz to 6 GHz	2-Port RF Electronic Calibration Module	85091C
85092A	85092-60001	Type-N 50Ω			85092C
85093A	85093-60001	3.5 mm			85093C
85096A	85096-60001	Type-N 75Ω	300 kHz to 3 GHz		85096C
85098A	85098-60001	7-16	300 kHz to 7.5 GHz		85098C
85099A	85099-60001	Type-F	300 kHz to 3 GHz		85099C
85091B	85091-60003	7 mm	300 kHz to 9 GHz		85091C
85092B	85092-60003	Type-N 50Ω			85092C
85093B	85093-60003	3.5 mm			85093C
85096B	85096-60003	Type-N 75Ω	300 kHz to 3 GHz		85096C
85098B	85098-60003	7-16	300 kHz to 7.5 GHz		85098C
85099B	85099-60003	Type-F	300 kHz to 3 GHz		85099C

Continued on next page

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Table 1-9 Discontinued ECal Models

Discontinued Model Number	Keysight Part Number	Connector Type	Operating Frequency	Description	Replacement Model
N4431A					
N4431A-010	N4431-60003	3.5 mm; all -f-	300 kHz to 9 GHz	4-Port RF Electronic Calibration Module	N4431B
N4431A-020	N4431-60004	Type-N 50Ω; all -f-			
N4431A-101, -102, -103, -104, -105, -106, -201, -202, -203, -204, -205, -206, -301, -302, -303, -304, -305, -306, -401, -402, -403, -404, -405, -406	N4431-60005	Mixed connector types – see Table 1-4, "N4431B Mixed Connector Options", on page 7			
N4690A					
N4690A-M0F	N4690-60001	Type-N 50Ω; one -f-, one -m-	10 MHz to 18 GHz	2-Port Microwave Electronic Calibration Module	N4690B/C
N4690A-00M	N4690-60002	Type-N 50Ω; both -m-			
N4690A-00F	N4690-60003	Type-N 50Ω; both -f-			
N4691A					
N4691A-M0F	N4691-60001	3.5 mm; one -f-, one -m-	10 MHz to 26.5 GHz	2-Port Microwave Electronic Calibration Module	N4691B
N4691A-00M	N4691-60002	3.5 mm; both -m-			
N4691A-00F	N4691-60003	3.5 mm; both -f-			

a. 8506xA series modules with serial numbers below 800 need to be retrofitted for operation with the 85097B VNA interface kit. The retrofitting must be done by a qualified Keysight Technologies service office. See "Contacting Keysight" on page 14.

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Compatible Network Analyzers

ECal modules operate with the network analyzer models shown in Table 1-10. Not all ECal module and network analyzer combinations have the same features or capabilities. See your network analyzer user guide or online Help.

Table 1-10 Compatible Network Analyzers

Network Analyzers	ECal Module Series					Interface Required
	8509xC	N4431B [a]	N443xA	N469xA/B/C	8506x[b]	
PNA Network Analyzers						
E8356/7/8A	Yes	Yes	Yes	Yes[c]	No	USB
E8801/2/3A	Yes	Yes	Yes	Yes[c]	No	USB
N3381/2/3A	Yes	Yes	Yes	Yes[c]	No	USB
E8362/3/4 A/B/C	Yes	Yes	Yes	Yes[c]	No	USB
E8361A/C	Yes	Yes	Yes	Yes[c]	No	USB
N5230A/C	Yes	Yes	Yes	Yes[c]	No	USB
N5241/2/4/ 5A	Yes	Yes	Yes	Yes[c]	No	USB
ENA Network Analyzers						
E5070A/B and E5071A/B/C	Yes	Yes	Yes	Yes[d]	No	USB
E5061/2A	Yes	Yes	N/A	N/A	No	USB

a. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
b. 8506x modules are no longer available for purchase.
c. PNA firmware revision 3.0 required with N4692A, N4693A, and N4694A.
d. Exception: the N4693A and N4694A are not supported on the ENA.

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Service and Recertification

If your ECal module requires service or recertification, contact the Keysight office nearest you for information about where to send it. The performance of your ECal module can only be verified by specially manufactured equipment and calibration standards from Keysight.

Contacting Keysight

Assistance with test and measurements needs and information on finding a local Keysight office are available on the Web at:
www.keysight.com/find/assist

If you do not have access to the Internet, please contact your Keysight field engineer.

NOTE

In any correspondence or telephone conversation, refer to the Keysight product by its model number and full serial number. With this information, the Keysight representative can determine whether your product is still within its warranty period.

Returning Devices to Keysight

If you are returning the product to Keysight, please include a service tag (located near the end of this manual) on which you provide the following information:

- your company name and address
- a technical contact person within your company, and the person's complete telephone number including country code and area code
- the model number and serial number of the case
- the part number and serial number of each device
- type of service required
- a detailed description of the problem and how the device was being used when the problem occurred (such as calibration or measurement)

NOTE

When transporting the module, use original or comparable packaging.

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Recertification of ECal Modules

CAUTION

Only Keysight calibration laboratories use the most accurate reference standards - directly traceable to national and international primary standards - to calibrate ECal modules to their warranted specifications. Calibration services performed by unauthorized calibration service providers will cause ECal modules to perform substantially below specifications. Keysight is not responsible for the poor performance of ECal modules that are calibrated by such unauthorized calibration service providers.

The suggested interval for recertification is 12 months. After reviewing the results of the initial recertification, you may establish a shorter interval that reflects greater use and wear of the module.

Where to Send a Module for Recertification

Contact Keysight for information on where to send your kit for recertification. See "Contacting Keysight" on page 14. Refer to "Returning Devices to Keysight" on page 14 for instructions on the preparation of returning the device.

How Keysight Verifies Your ECal Module

Keysight verifies the specifications of these devices as follows:

1. **The residual microwave error terms of the test system are verified with precision airlines and shorts or low frequency resistance that are directly traced to the National Institute of Standards and Technology (NIST). The airline and short characteristics are developed from mechanical measurements. The mechanical measurements and material properties are carefully modeled to give very accurate electrical representation. The mechanical measurements are then traced to NIST through various plug and ring gages and other mechanical measurements.**
2. **Each module is electrically tested on this system to the specification listed in Chapter 5, "Specifications and Characteristics."**

These two steps establish a traceable link to NIST for Keysight to the extent allowed by the Institute's calibration facility. The specifications data provided for the module are traceable to NIST through Keysight Technologies.

What Is Provided with a Recertification

- a new calibration sticker affixed to the module
- a certificate of calibration
- a list of United States National Institute of Standards and Technology (NIST) traceable numbers

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- a calibration report for each traceable module listing measured values, specifications,
  and uncertainties
- a new set of S-parameter data (embedded in module memory) if the old set of S-parameters data no longer allows for a calibration that meets all performance specifications

Keysight Technologies offers different types of calibration for the recertification of the module. For more information, contact Keysight. See “Contacting Keysight” on page 14.

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Safety and Regulatory Information

Review this section to familiarize yourself with safety markings and instructions before you operate the ECal module. This product has been designed and tested in accordance with international standards.

WARNING

The WARNING notice denotes a hazard. It calls attention to a procedure, practice, or the like, that, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

CAUTION

The CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like, that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

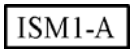
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Safety Notices

CAUTION Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally.

Instrument Markings

Table 1-11

	The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the documentation.
	This symbol indicates separate collection for electrical and electronic equipment, mandated under EU law as of August 13, 2005. All electrical and electronic equipment are required to be separated from normal waste for disposal (Reference WEEE Directive, 2002/96/EC.
	The CE marking is a legal compliance marking of the European Community. This CE marking shows that the product complies with all the relevant European Legal Directives.
	This mark designates the product is an Industrial Scientific and Medical Group 1 Class A product (reference CISPR 11, Clause 5).
	This ISM device complies with Canadian ICES -001. Cet appareil ISM est conforme a la norme NMB du Canada.
	The RCM mark is a registered trademark of the Australian Communications and Media Authority.
	China RoHS regulations include requirements related to packaging, and require compliance to China standard GB18455-2001.
	Korean Certification (KC) mark; includes the marking's identifier code which follows the format: KCC-REM-YYY-ZZZZZZZZZZZZZZ or MSIP-REM-YYY-ZZZZZZZZZZZZZZ

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Table 1-11



This symbol indicates compliance with China RoHS regulations for paper/fiberboard packaging.

Compliance Notices

This product has been designated and tested in accordance with accepted industry standards, and has been supplied in a safe condition. The documentation contains information and warnings that must be followed by the user to ensure safe operation and to maintain the product in a safe condition.

EMC and Safety Information

EMC

Complies with the essential requirements of the European EMC Directive as well as current editions of the following standards (dates and editions are cited in the Declaration of Conformity):

- IEC/EN 61326-1
- CISPR Pub 11 Group 1, class A
- AS/NZS CISPR 11
- ICES/NMB-001
  This ISM device complies with Canadian ICES-001.
  Cet appareil ISM est conforme a la norme NMB-001 du Canada.000

South Korean Class A EMC declaration

This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home.

A 급 기기 (업무용 방송통신기자재) 이 기기는 업무용 (A 급) 전자파적합기기로서 판 매자 또는 사용자는 이 점을 주 의하시기 바라 며 , 가정외의 지역에서 사용하는 것을 목적으 로 합니다 .

Safety Information

European Low Voltage Directive is not applicable for these products.

Declaration of Conformity

A declaration of conformity for any of these ECal modules is available at http://www.keysight.com/go/conformity or by contacting Keysight - see “Contacting Keysight” on page 14.

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2 Preparing ECal for Use

Inspecting the ECal Kit

Inspect the Kit Contents

Verify the case and its contents are not damaged and that all parts are included (see items listed in Table 2-2, Table 2-3, Table 2-4, Table 2-5 and Table 2-6). If the case or any device appears damaged, or if the shipment is incomplete, contact Keysight. Keysight will arrange for repair or replacement of incomplete or damaged shipments without waiting for settlement from the transportation company. See “Contacting Keysight” on page 14.

Locate the Two Serial Numbers

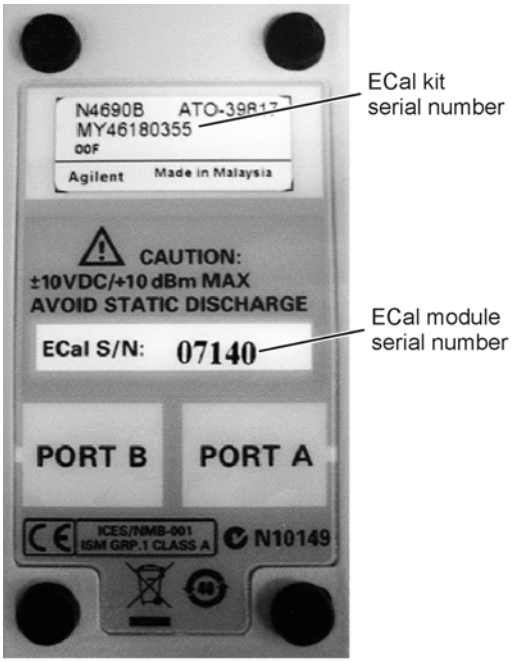
Your ECal kit has a serial number and your ECal module also has a serial number. Both serial numbers are printed on a label on the backside of the ECal module.

ECal Kit Serial Number

The serial number with the MY/US prefix on the backside of the ECal module is assigned to the ECal **kit**. Refer to Figure 2-1. The ECal kit contains the ECal module and, depending on the option configuration, accessories such as wrenches and adapters.

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Figure 2-1 Serial Numbers on the Backside of the ECal Module



NOTE Older ECal modules may not have the label on the backside.

The ECal kit serial number is intended for identification purposes whenever an ECal kit is returned to Keysight for repair or recertification.

ECal Module Serial Number

The five digit serial number on the backside of the ECal module is assigned to the ECal **module**, and is labeled “ECal S/N.” Refer to Figure 2-1. Each ECal module is unique and is individually serialized. The serial number is stored in the ECal module memory and may be accessed by a network analyzer when the ECal is used to perform a calibration. Test reports for an ECal module will refer to this serial number as the “ECal S/N.”

Record the Serial Numbers

Record the serial numbers and the date of initial use as a reminder for annual recertification. See “Recertification of ECal Modules” on page 15.

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Table 2-1 Table for Tracking Serial Numbers

ECal Kit Model Number	ECal Kit Serial Number (contains MY/US prefix)	ECal Module Serial Number (contains five digits)	Date of Initial Use

Verify Electrical Performance

To verify electrical performance of the module, see "Validating a Calibration" on page 7.

Equipment Required but Not Supplied

Pin Depth Gages

Gages for measuring recession or protrusion are not provided in the kit. See Chapter 6, "Replaceable Parts." or contact Keysight to order gages and other test accessories.

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8509x Series Kit Contents

The following table lists the items in each 8509x kit. The ECal module listed in the table with each kit has a male and female connector (Option M0F). See Table 1-1 on page 1-5 for the part number of other configurations.

Table 2-2 8509x Kit Contents

Qty	Description	Part No.
85091C		
1	RF Module, 7 mm	85091-60004
1	Torque Wrench 3/4”, 1.3 N-m	8710-1766
1	USB A-B Cable, 1.8 m	8121-0506
1	Extractor, 7 mm Collet	5060-0370
1	Reference Guide	N4693-90001
85092C		
1	RF Module, Type-N 50 ohms	85092-60008
1	Torque Wrench 3/4”, 1.3 N-m	8710-1766
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
85093C		
1	RF Module, 3.5 mm	85093-60008
1	Torque Wrench 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench 5/16”, 0.9 N-m	8710-1765
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001

Qty	Description	Part No.
85096C		
1	RF Module, Type-N 75 ohms	85096-60007
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
85098C		
1	RF Module, 7-16	85098-60007
1	Torque Wrench 1 1/16”, 2.2 N-m	8710-2175
1	Open-end Wrench 15/16”	8710-2174
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
85099C		
1	RF Module, Type-F	85099-60009
1	Type F Wrench	8710-1841
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001

8509x Options

- Option 00M configures the module with two male connectors.
- Option 00F configures the module with two female connectors.
- Option M0F configures the module with one male connector and one female connector.
- Option 00A adds one -m- to -m- and one -f- to -f adapter (not available with 85091C).

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– Option UK6 adds a commercial calibration certificate with measured data.
– Option 150 adds a storage box for the ECal module and accessories.

N4431B Series Kit Contents

NOTE **The N4431A is no longer available for purchase, but may be returned to Keysight for service and recertification.**

The following table lists the items in each N4431B kit. Option 010 is configured with 3.5 mm -f- connectors on all ports and Option 020 is configured with type-N -f- connectors on all ports. See Table 1-4 on page 7 for other configurations available.

Table 2-3 N4431B Kit Contents

Qty	Description	Part No.
N4431B Option 010		
1	RF Module, 3.5 mm	N4431-60003 or N4431-60006[a]
1	Torque Wrench 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench 5/16”, 0.9 N-m	8710-1765
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001

Qty	Description	Part No.
N4431B Option 020		
1	RF Module, Type-N 50 ohms	N4431-60004 or N4431-60007[a]
1	Torque Wrench 3/4”, 1.3 N-m	8710-1766
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
-	N/A	-

a. Shipped only with N4431B.

N4431B Options

– Option 010 configures the module with 3.5 mm -f- connectors on all ports.
– Option 020 configures the module with Type-N 50 ohm -f- connectors on all ports.
– Option UK6 adds a commercial calibration certificate with measured data.
– Option 150 adds a storage box for the ECal module and accessories.

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N469xA/B/C Series Kit Contents

NOTE The N4690/1/6A are no longer available for purchase, but may be returned to Keysight for service and recertification.

The following table lists the items in each N469xA/B/C kit. The ECal module listed in the table with each kit describes a unit having a male and female connector (Option M0F). See Chapter 6, "Replaceable Parts." for the part number of other configurations.

Table 2-4 N469xA/B/C Kit Contents

Qty	Description	Part No.
N4690B		
1	Microwave Module, Type-N	N4690-60004, or N4690-60005, or N4690-60006
1	Torque Wrench, 3/4", 1.3 N-m	8710-1766
1	Open-End Wrench, 1/2" to 9/16"	8710-1770
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
N4690C		
1	Microwave Module, Type-N	N4690-60007, or N4690-60008, or N4690-60009
1	Torque Wrench, 3/4", 1.3 N-m	8710-1766
1	Open-End Wrench, 1/2" to 9/16"	8710-1770
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
N4691B		
1	Microwave Module, 3.5 mm	N4691-60004, or N4691-60005, or N4691-60006
1	Torque Wrench, 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench, 5/16", 0.9 N-m	8710-1765
1	Open-End Wrench, 1/2" to 9/16"	8710-1770
1	Spanner Wrench	08513-20014
1	USB A-B Cable, 1.8 m	8121-0506

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Table 2-4 N469xA/B/C Kit Contents

Qty	Description	Part No.
1	Reference Guide	N4693-90001
N4692A		
1	Microwave Module, 2.92 mm	N4692-60001
1	Torque Wrench, 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench, 5/16”, 0.9 N-m	8710-1765
1	Open-End Wrench, 1/2” to 9/16”	8710-1770
1	Spanner Wrench	08513-20014
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
N4693A		
1	Microwave Module, 2.4 mm	N4693-60001
1	Torque Wrench, 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench, 5/16”, 0.9 N-m	8710-1765
1	Open-End Wrench, 1/2” to 9/16”	8710-1770
1	Spanner Wrench	08513-20014
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
N4694A		
1	Microwave Module, 1.85 mm	N4694-60001
1	Torque Wrench, 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench, 5/16”, 0.9 N-m	8710-1765
1	Open-End Wrench, 1/2” to 9/16”	8710-1770
1	Spanner Wrench	08513-20014
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
N4696B		
1	Microwave Module, 7 mm	N4696-60004
1	Torque Wrench, 3/4”, 1.3 N-m	8710-1766
1	Open-End Wrench, 1/2” to 9/16”	8710-1770

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Table 2-4 N469xA/B/C Kit Contents

Qty	Description	Part No.
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001

N469xA/B/C Options

- Option 00M configures the microwave module with two male connectors.
- Option 00F configures the microwave module with two female connectors.
- Option M0F configures the module with one male connector and one female connector.
- Option 00A adds one -m- to -m- and one -f- to -f- adapter (not supplied with N4696B).
- Option UK6 adds a commercial calibration certificate with measured data.
- Option 150 adds a storage box for the ECal module and accessories.

N4432A and N4433A Series Kit Contents

The following tables list the items in each N4432A and N4433A kit. For the N4432A kit, Option 020 is configured with type-N 50 ohm -f- connectors on all ports. For the N4433A kit, Option 010 is configured with 3.5 mm -f- connectors on all ports. See Table 1-7 on page 10 and Table 1-8 on page 10 for other configurations available.

Table 2-5 N4432A Kit Contents

Qty	Description	Part No.
N4432A Option 020		
1	Microwave Module, Type-N 50 Ohm -f-	N4432-60003
1	Torque Wrench 3/4”, 1.3 N-m	8710-1766
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001
-	N/A	-

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Table 2-6 N4433A Kit Contents

Qty	Description	Part No.
N4433A Option 010		
1	Microwave Module, 3.5 mm -f-	N4433-60003
1	Torque Wrench 20 mm, 0.9 N-m	8710-1764
1	Torque Wrench 5/16”, 0.9 N-m	8710-1765
1	USB A-B Cable, 1.8 m	8121-0506
1	Reference Guide	N4693-90001

N4432A Options

- Option 020 configures the module with Type-N 50 ohm -f- connectors on all ports.
- Option UK6 adds a commercial calibration certificate with measured data.
- Option 1A7 adds ISO 17025 compliant calibration.
- Option A6J adds ANSI Z540 compliant calibration.
- Option 150 adds a storage box for the ECal module and accessories.

N4433A Options

- Option 010 configures the module with 3.5 mm -f- connectors on all ports.
- Option UK6 adds a commercial calibration certificate with measured data.
- Option 1A7 adds ISO 17025 compliant calibration.
- Option A6J adds ANSI Z540 compliant calibration.
- Option 150 adds a storage box for the ECal module and accessories.

Operating and Safety Precautions

Observe the following guidelines before connecting or operating your ECal module.

ESD Damage

Protection against electrostatic discharge (ESD) is important while handling and operating your ECal module. Static electricity can build up on your body and can easily damage sensitive components when discharged. Static discharges too small to be felt can cause permanent damage to the unit. To prevent damage from ESD:

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- Use a grounded antistatic mat in front of your test equipment and wear a grounded wrist strap attached to it when handling or operating the ECal module.
- Wear a heel strap when working in an area with a conductive floor.
- Ground yourself before you clean, inspect, or make a connection to an ECal module. You can, for example, grasp the grounded outer shell of the analyzer test port or cable connector briefly.
- Avoid touching the center conductor of the test ports.

For more information about preventing ESD, see "Electrostatic Discharge" on page 1.

Connector Care

Because connectors can become defective due to wear during normal use, all connectors should be inspected and maintained to maximize their service life. For more detailed information, see "Visual Inspection" on page 3.

- Inspect the mating surface each time a connection is made. Metal particles from connector threads often find their way onto the mating surface when a connection is made or disconnected.
- Clean dirt and contamination from the connector mating surface and threads. This simple step can extend the service life of the connector and improve the quality of your calibration and measurements.
- Gage connectors periodically. This not only provides assurance of proper mechanical tolerances, and thus connector performance, but can also indicate situations where the potential for damage to another connector may exist.

CAUTION

ECal modules can be damaged if you apply excessive torque to the connectors. See Table 4-1 on page 20 for required torque settings.

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Input Power Level

Before performing a calibration, make sure the input power and DC levels do not exceed the values indicated in Table 2-7.

Table 2-7 Input Power Limits

Parameter	ECal Module Series			
	8509x	**N4431x**	**N4432A and N4433A**	**N469xA/B/C**
Typical Maximum Input Power [a], [b]	+9.0 dBm	+7.0 dBm	-7.0 dBm	-5.0 dBm
Typical Maximum DC Level Applied to Test Port	± 20 Volts	± 3 Volts	± 3 Volts	± 10 Volts
Typical Damage Level	+20.0 dBm	+20.0 dBm	+20.0 dBm	+10.0 dBm

a. If the maximum input power is exceeded when calibrating, compression may occur.
b. When using the PNA-X, the power level can be increased after calibration with minimal impact on measurement accuracy.

Operating Temperature

The temperature of the ECal module must be within the following temperature range to meet the operating specifications.

- 8509x Series: +20 °C to +30 °C
- N443xA/B Series: +20 °C to +30 °C
- N469xA/B/C Series: +20 °C to +26 °C

For more details, see “Environmental Specifications” on page 2.

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Connecting and Disconnecting ECal Module

ECal modules connect to PNA or ENA network analyzers with the USB cable (supplied with the kit).

You can connect (or disconnect) ECal modules when the analyzer is on or off, but should avoid doing so while data transfer is in progress.

Connect ECal Module to PNA or ENA Analyzer

ECal modules are controlled and powered by the analyzer through a USB cable. When you connect the module to the analyzer, the analyzer automatically recognizes the type of module, frequency range, and connector type.

CAUTION

Exercise the necessary ESD precautions before connecting the ECal module to the analyzer. See "Electrostatic Discharge" on page 1.

To connect ECal module to the PNA or ENA network analyzer:

1. Connect one end of the USB cable to the ECal module as shown in Figure 2-2 on page 13.
2. Connect the other end of the cable to the USB port on the front or rear panel of the analyzer (as shown in Figure 2-3 on page 13). Depending on available USB ports, two or more ECal modules may be connected to the analyzer.

NOTE

When you connect an ECal module that has a serial number never before seen by that PNA, and you have Administrator privileges (the default setting), the **Welcome to the Found New Hardware Wizard** appears to assist you in completing the first-time registration for the module. If **"Can Windows connect to Windows Update to search for software?"** appears, select **"No, not this time."** Click Next or Finish at the remaining dialog prompts.
You must be logged on to the PNA with Administrator privileges (the default setting), or know the Administrator login and password, to complete the first-time registration process. For more information on privileges, view the PNA online Help table of contents and click on **"Administrative Tasks."** To view the PNA online Help, refer to "Finding More Information on Performing a Calibration" on page 6.

3. The LED (on the module) indicates WAIT until the ECal module reaches operating temperature.
4. When the green LED turns on, the module is ready for use.

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Figure 2-2 USB Connection to Module

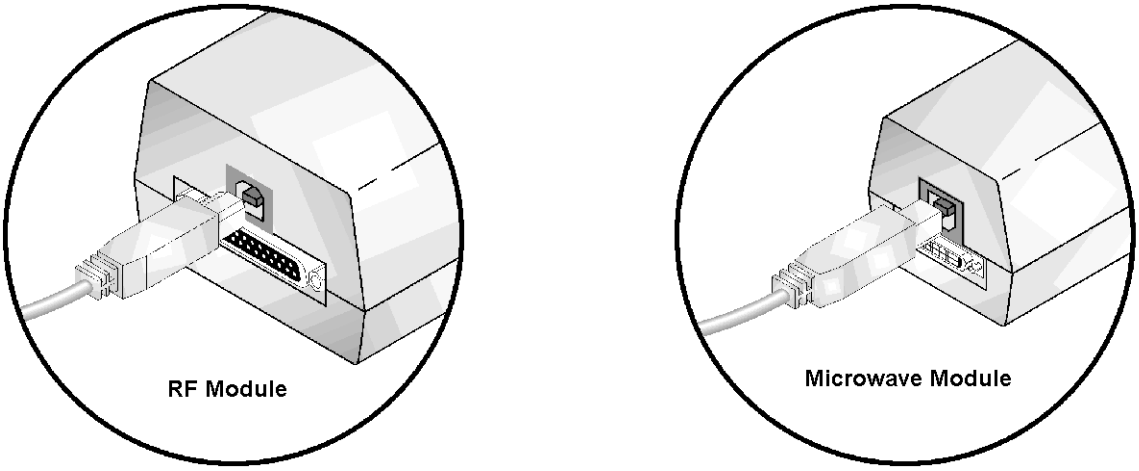
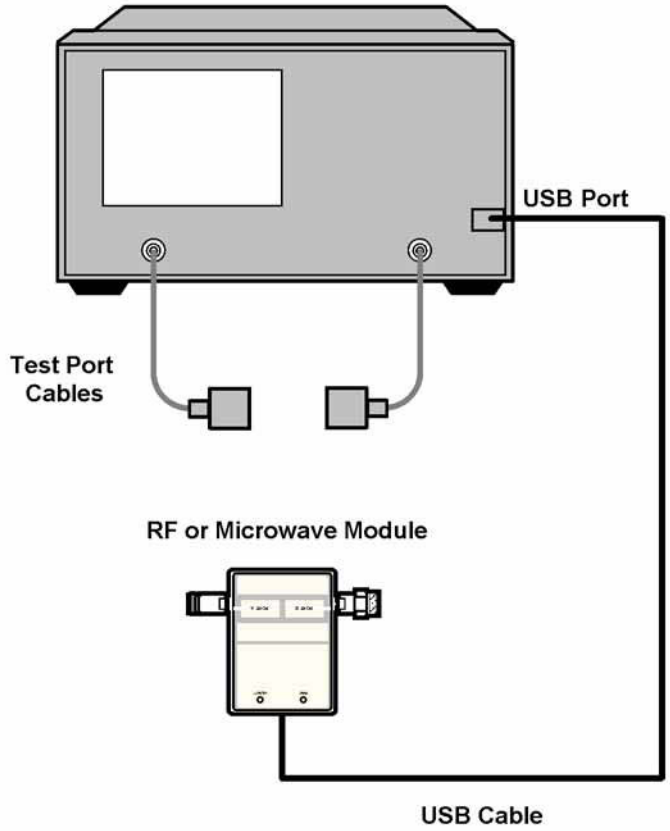


Figure 2-3 USB Connection to PNA or ENA Analyzer



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Connect ECal Module to VNA Analyzer

NOTE This section is for REFERENCE ONLY. VNA analyzers, the 85097B Interface Kit, and the 8121-1047 adapter cable are discontinued products.

VNA network analyzers require the 85097B Interface Kit, which supplies power and allows data transfer between the analyzer and the ECal module.

The interface kit contains an interface unit, power supply, and cables to connect the interface unit to the analyzer and the ECal module.

An adapter cable, supplied with Option 100, is required to connect microwave ECal modules (N469xA/B/C series) to the interface unit. This cable may also be ordered separately. For more information about the 85097B, refer to "Other ECal Accessories" on page 11.

CAUTION Exercise the necessary ESD precautions before connecting the ECal module to the analyzer. See "Electrostatic Discharge" on page 1.

To connect ECal module to the VNA network analyzer:

1. Connect interface unit to VNA:
   a. Connect one end of the DB25 to DB25 cable to the connector on the interface unit labeled "DB25 Interface to Parallel Interface on Network Analyzer."
   b. Connect the other end of the cable to the connector labeled "PARALLEL PORT" on the rear panel of the VNA.

CAUTION Connecting the DB25 cable to any other connector on the analyzer WILL cause damage.

2. Connect an RF Module:
   a. Connect one end of the DB25 to DB25 cable to the parallel port connector on the ECal module. See Figure 2-4 n page 2-16.
   b. Connect the other end of the cable to the connector on the interface unit labeled "DB25 Interface to ECal Module A" or "DB25 Interface to ECal Module B." See Figure 2-5 n page 2-16. Two ECal modules may be connected at the same time.
3. Connect a Microwave Module (requires adapter cable, part no. 8121-1047):
   a. Connect the miniature (36-pin) connector on the adapter cable to the parallel port connector on the ECal module. See Figure 2-4 n page 2-16.

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b. Connect the DB25 connector on the adapter cable to the connector on the interface unit labeled “DB25 Interface to ECal Module A” or “DB25 Interface to ECal Module B.” See Figure 2-5 n page 2-16.

4. Connect the interface power supply to the interface unit and then connect to AC power.

NOTE

The LED on the ECal module indicates WAIT until the unit reaches operating temperature.

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Figure 2-4 Parallel Port Connection to Module

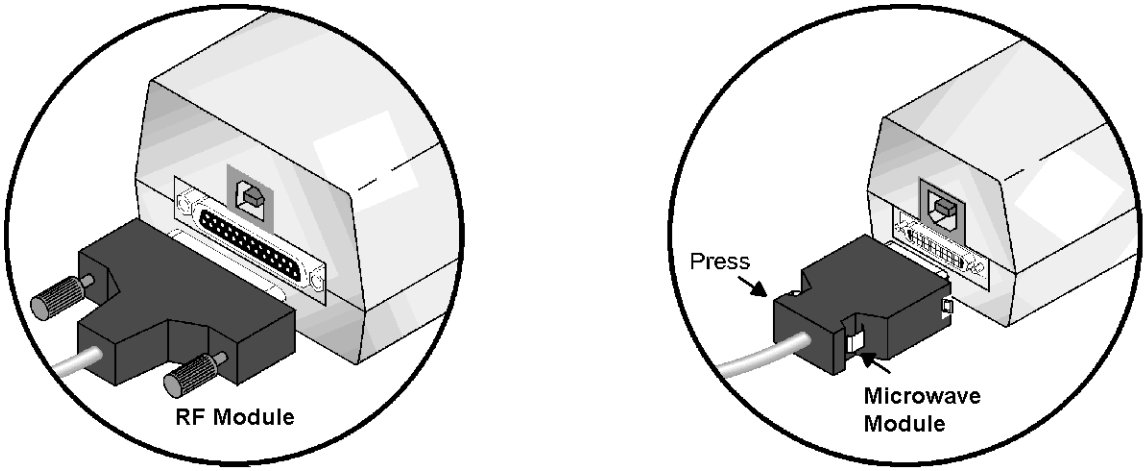
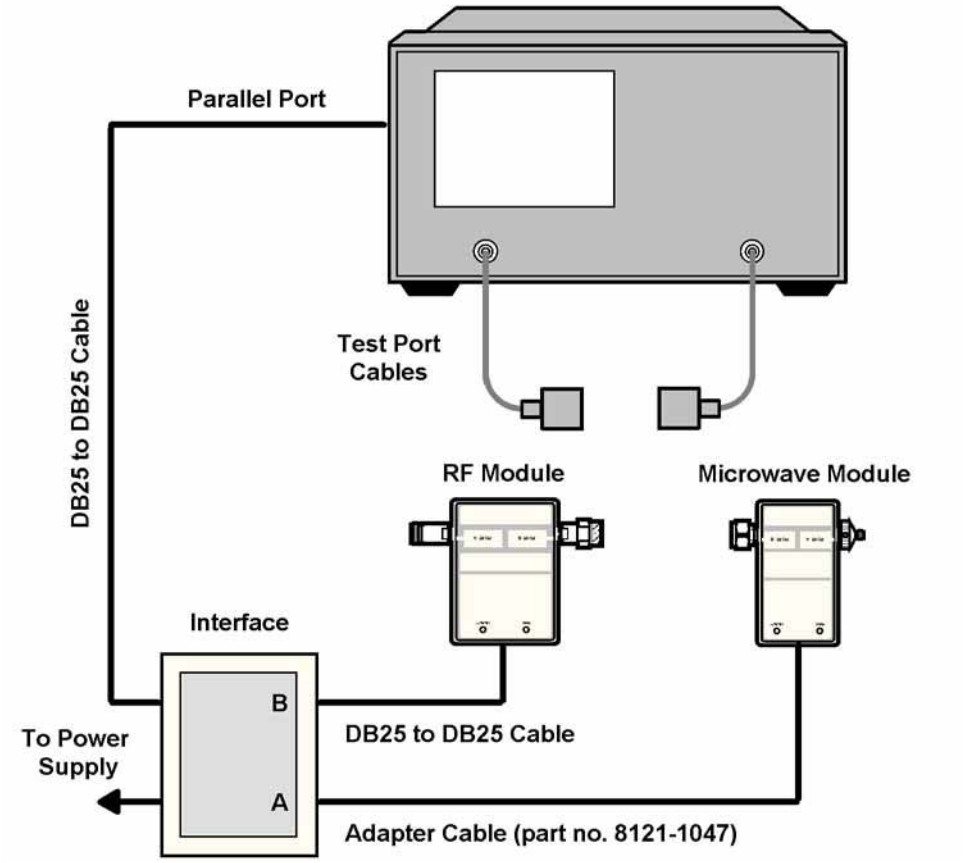


Figure 2-5 Interface Connections to VNA Analyzer



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Keysight Electronic Calibration Modules
RF/Microwave Two Port and Four Port

Reference Guide

3 Operating ECal Module

Setting Up a Calibration

Use the following procedure as a starting point for calibrating the network analyzer with an ECal module. For more detailed information about adjusting the settings of your analyzer, refer to the appropriate user guide or online Help.

Required Procedure for All Calibrations

For all calibration types, complete the following steps:

1. Connect an ECal module to the analyzer having the appropriate frequency range and connector type. See "Connecting and Disconnecting ECal Module" on page 12.
2. Allow the module to warm up for 15 minutes (20 minutes for a four-port module) or until the module indicates READY.
3. Set up the analyzer and the device under test (DUT) in the measurement configuration. Select the frequency, power, sweep and other stimulus settings.
4. View the response (uncorrected) and optimize the analyzer settings as needed.
5. Remove the DUT from the measurement ports and connect the ECal module.
6. Select the desired calibration type and perform the calibration.
7. Remove the ECal module and re-connect the DUT.

CAUTION Excessive torque can damage ECal module connectors. See Table 4-1 on page 20 for the required torque setting for each connector type.

NOTE Terminate any unused ECal ports with a 50 ohm load for optimal performance.

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Calibration Types Available

The following table contains the calibration types and advanced settings available for all compatible network analyzers:

Table 3-1 Calibration Types and Advanced Settings Available

Calibration Types	Network Analyzer Series	
	PNA	**ENA**[a]
1-Port Reflection	Yes	Yes
Full 2-Port	Yes	Yes
Full 2-Port (with isolation)[b]	Yes	Yes
Full 3-Port	Yes	Yes
Full 4-Port	Yes	Yes
Enhanced Response	Yes	Yes
QSOLT	Yes	No
Advanced Settings		
Adapter Removal	Yes	No
Flush (zero length) THRU	Yes	No
Unknown THRU	Yes[c]	No
User-Characterization	Yes	Yes[d]

a. The N4693A and N4694A are not supported on the ENA.
b. 8509xC only.
c. Unknown THRU setting available with E835xA and E836xA,B analyzers.
d. User-Characterization available with firmware revision A.03.50 (February 2003).

When to Correct for Isolation

Correction for isolation is a consideration when measuring high-loss devices such as saw filters or diplexers. When maximum dynamic range is required, correction for isolation can remove the errors due to crosstalk (between test ports) for transmission measurements.

When you include isolation with a two, three, or four-port calibration, the analyzer automatically applies averaging to reduce noise in the measurement. Without averaging, you will have noise in the measurement of the crosstalk, and could raise the noise floor when the analyzer uses this in its error correction.

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The analyzer system isolation is normally sufficient for most measurements, and correction for it is usually unnecessary. As long as crosstalk is below the noise floor, it is best NOT to correct for isolation using ECal. As of PNA firmware release 4.26, measuring isolation as part of the ECal process is no longer supported.

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Calibration Methods for Non-Insertable Devices

A “non-insertable” device means that the measurement ports cannot be connected together to establish a THRU connection during calibration for transmission. Because the module typically forms the THRU path, you can use one of the following methods to perform a calibration for non-insertable devices:

Configure ECal Module the Same as Device

The simplest way to calibrate for non-insertable devices is to configure an ECal module with the same connector types as the DUT. RF ECal modules can be configured with mixed connectors to match the connector types on the DUT. Refer to “Models and Options” on page 4. You can also configure the module with different connector types by performing a User-Characterization (see below).

Use Adapter Removal Calibration

Adapter removal provides an accurate way to calibrate for non-insertable devices, but requires extra calibration steps to characterize the adapter. The adapter type used for this calibration must be a -m- to -m- or -f- to -f- and have the same connector type as the module. In addition, the module must have a male connector on one test port and a female connector on the other test port (of the same connector type).

Use Unknown Thru Calibration

Unknown Thru calibration is currently available with all PNA network analyzers except the E8801/2/3A. It is easy to perform and can be used on any two ports when using a multiport PNA. It causes minimal cable movement if the Thru standard has the same footprint as the DUT. In fact, the DUT can often be the Thru standard. A 1-port calibration is performed on both ports. The unknown Thru is connected between the two ports and measured. Next, the user must confirm the Estimated Delay. This requires knowing the phase response to within 1/4 wavelength. If the phase response is unknown, the Delay value can be measured independently and entered in the dialog box.

Perform a User-Characterization

Normally, when you perform a calibration with an ECal module, the error terms for a calibration are computed using the factory characterization (data) stored in the module. User-Characterization allows you change the characterization of the module in two ways:

– Change the connector configuration: allows you to add an adapter or fixture to the test port of the module and embed the effects into the characterization of the module. The result of the new characterization extends the reference plane from one or more of the module’s test ports to those on the adapter (or fixture).

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– Modify the state settings: allows you to specify the number of data points (1601 max.) or other stimulus settings the module uses to perform a calibration.

When you perform a User-Characterization, the factory characterization data remains stored in the module's memory. At calibration, you can select the factory characterization or any of the user-defined characterizations stored in the module. The module can store up to five user-defined characterizations (in addition to the factory characterization data).

User-Characterization is currently available with PNA and ENA network analyzers.

To perform a User-Characterization, a calibration kit (having the same connector type as the new reference plane) is required.

For detailed information on calibration methods using an ENA or PNA series network analyzer, refer to the appropriate user guide or online Help. To use the Internet to view the ENA or PNA online Help, use the steps listed in "Finding More Information on Performing a Calibration" on page 6.

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Finding More Information on Performing a Calibration

For detailed information on performing a calibration using an ENA or PNA series network analyzer, refer to the appropriate user guide or online Help.

- To view the ENA or PNA Help file that is embedded in the analyzer, press the Help key on the front panel of the network analyzer.
- To view a user guide or Help file on the Internet, use the following steps:

1. Go to www.keysight.com.
2. Enter your analyzer model number (Ex: N5242A) in the search function and click Search.
3. Click on the Manuals hyperlink.
4. Open the PDF of the User Guide or Help.

CAUTION

Do not perform a calibration procedure unless you have cleaned and visually inspected all connectors and have taken the necessary ESD precautions.

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Validating a Calibration

The accuracy of a completed calibration should be validated periodically, because the following sources of error that can invalidate it:

- bad cables
- dirty or worn connectors
- operator error
- measurement uncertainties from interpolation

The following paragraphs discuss two methods of validating the accuracy of a calibration:

1. **Performing the ECal module's ECal Confidence Check.**
2. **Performing the analyzer's System Verification Procedure using standards in a Keysight verification kit.**

Which method you choose depends largely on the level of accuracy required and the availability of a Keysight verification kit.

ECal Confidence Check – Basic Validation of the Calibration

The ECal Confidence Check allows you to measure an impedance state in the ECal module – called the confidence state – and compare your measurement data with factory measurement data stored in ECal memory (of the same confidence state). The ECal Confidence Check overlays the two measurement traces so that the differences between your data and the factory data can be easily viewed.

- The ECal Confidence Check provides a basic validation that you have completed the ECal calibration correctly and that the calibration is activated.
- The ECal Confidence Check is not a method for system verification. The ECal Confidence Check's impedance state physically shares some of the same hardware as the ECal calibration impedance states. System verification requires a verification kit because it has devices that are physically different from those in a calibration kit.
- Keysight recommends that upon receipt of a new ECal module, you perform the ECal Confidence Check and save the measurement results as a baseline for future reference.
- Periodically, it is recommended that additional ECal confidence checks be performed and the test results compared to the baseline data.
- The interpretation of how much variation is acceptable between your data and the factory data is determined by your level of confidence in the calibration, based on your historical records of baseline data.

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Before performing the ECal Confidence Check, the analyzer must be calibrated and the calibration type should be appropriate for the measurement being made. For example, you cannot measure the confidence state with an S22 measurement if an S11 1-port calibration is active.

NOTE **Terminate any unused ECal ports with a 50 ohm load.**

NOTE **ECal Confidence Check is not available with ENA-L series network analyzers.**

For detailed information on performing an ECal Confidence Check using an ENA or PNA series network analyzer, refer to the appropriate user guide or online Help. To use the Internet to view the ENA or PNA online Help, use the steps listed in "Finding More Information on Performing a Calibration" on page 6.

System Verification Procedure – Traceable Accuracy Validation of the Calibrated Measurement System

NOTE **This method of validating the calibration requires a Keysight verification kit.**

Using your analyzer's built-in System Verification Procedure to measure the standards in a Keysight verification kit provides a traceable accuracy validation of your calibrated measurement system. Following the measurement of each standard, the System Verification Procedure provides a pass/fail result, determining if your calibration provides measurements that meet the limits of uncertainty.

- The analyzer's built-in System Verification Procedure provides a traceable accuracy validation that you have completed the ECal calibration correctly and that the limits of uncertainty are met.
- The System Verification Procedure is also a method for verifying the performance of your analyzer.
- Verification kits use accurately known standards with well defined magnitude and phase response. These kits include precision airlines, mismatch airlines, and precision fixed attenuators.
- Each verification kit standard is measured precisely by Keysight's accredited test laboratory. The measurement data and uncertainty of each standard are provided in each kit on a disk or USB storage drive.
- Verification kits may be re-certified by Keysight. Contact Keysight for information about ordering verification kits - see "Contacting Keysight" on page 14.

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For detailed information on using your analyzer's built-in System Verification Procedure, refer to the appropriate service guide or online Help. To use the internet to view the ENA or PNA online Help, use the steps listed in "Finding More Information on Performing a Calibration" on page 6.

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4 Use, Maintenance, and Care of the Devices

Electrostatic Discharge

Protection against electrostatic discharge (ESD) is essential while connecting, inspecting, or cleaning devices attached to static-sensitive circuits (such as those found in network analyzers and ECal modules).

Static electricity can build up on your body and can easily damage sensitive internal circuit elements when discharged. Static discharges too small to be felt can cause permanent damage. Devices such as calibration components and devices under test (DUTs), can also carry an electrostatic charge. To prevent damage to network analyzer components and devices:

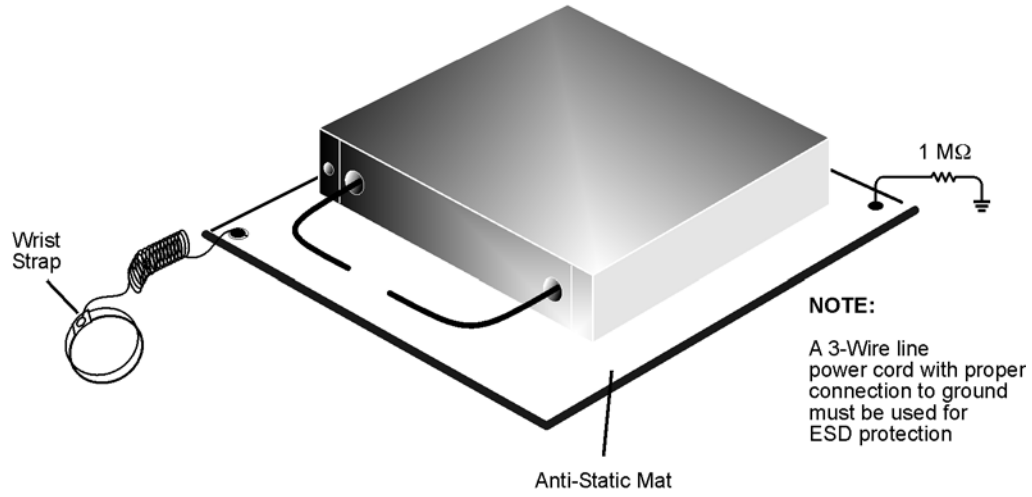
- **always** wear a grounded wrist strap having a 1 MΩ resistor in series with it when handling components and devices or when making connections to the test set.
- **always** use a grounded, conductive table mat while making connections.
- **always** wear a heel strap when working in an area with a conductive floor. If you are uncertain about the conductivity of your floor, wear a heel strap.
- **always** ground yourself before you clean, inspect, or make a connection to a static-sensitive device or test port. You can, for example, grasp the grounded outer shell of the test port or cable connector briefly.
- **always** ground the center conductor of a test cable before making a connection to the analyzer test port or other static-sensitive device. This can be done as follows:

    1. Connect a short (from your calibration kit) to one end of the cable to short the center conductor to the outer conductor.
    2. While wearing a grounded wrist strap, grasp the outer shell of the cable connector.
    3. Connect the other end of the cable to the test port.
    4. Remove the short from the cable.

For parts numbers for ESD protection supplies, refer to “Other ECal Accessories” on page 11.

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Figure 4-1 ESD Protection Using Mat, Wrist Strap, and Grounded Power Cord



esd_setup

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Visual Inspection

Visual inspection and, if necessary, cleaning should be done every time a connection is made. Metal particles from the connector threads may fall into the connector when it is disconnected.

CAUTION

Devices with damaged connectors should immediately be discarded or clearly marked and set aside for repair. A damaged device will in turn damage any good connector to which it is attached. Try to determine the cause of the damage before connecting a new, undamaged connector in the same configuration.

Magnification is helpful when inspecting connectors, but it is not required and may actually be misleading. Defects and damage that cannot be seen without magnification generally have no effect on electrical or mechanical performance. Magnification is of great use in analyzing the nature and cause of damage and in cleaning connectors, but it is not required for inspection.

Look for Obvious Defects and Damage First

Examine the connectors first for obvious defects and damage: badly worn plating on the connector interface, deformed threads, or bent, broken, or misaligned center conductors.

What Causes Connector Wear?

Connector wear is caused by connecting and disconnecting the devices. The more use the device gets, the faster it wears and degrades. The wear is greatly accelerated when connectors are not kept clean, or are not properly connected. This is especially true with electrically characterized devices such as ECal modules. ECal modules should have a long life if their use is on the order of a few times per week.

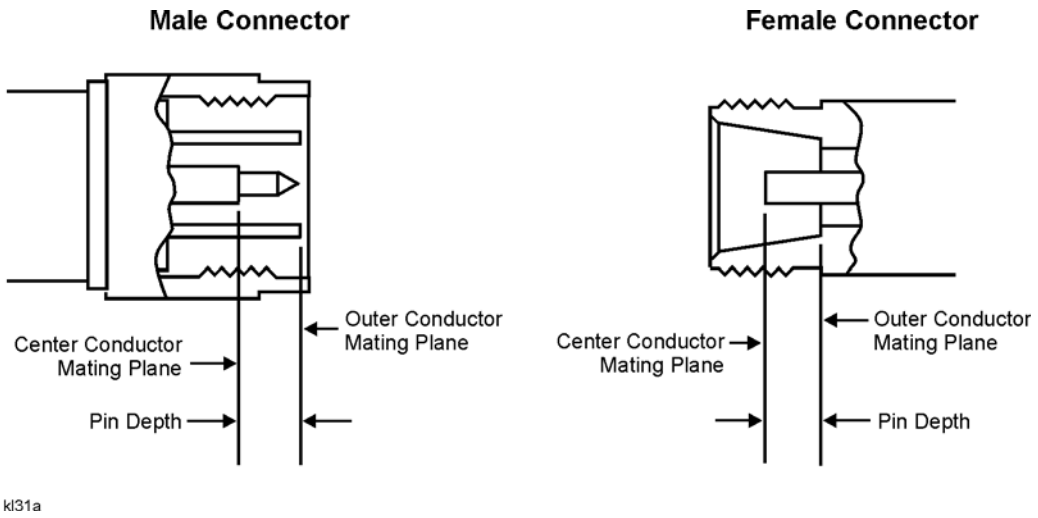
The test port connectors on the network analyzer may have many connections each day, and are therefore more subject to wear. It is recommended that an adapter be used as a test port saver to minimize the wear on the connectors. Replace devices with worn connectors.

Inspect the Mating Plane Surfaces

Uniform contact between the connectors at all points on their mating plane surfaces is required for a good connection. See Figure 4-2 for an example of locations of mating plane surfaces. Look especially for deep scratches or dents, and for dirt and metal particles on the connector mating plane surfaces. Also look for signs of damage due to excessive or uneven wear or misalignment.

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Figure 4-2 Type-N Connector Pin Depth and Mating Surfaces



Light burnishing of the mating plane surfaces is normal, and is evident as light scratches or shallow circular marks distributed more or less uniformly over the mating plane surface. Other small defects and cosmetic imperfections are also normal. None of these affect electrical or mechanical performance. If a connector shows deep scratches or dents, particles clinging to the mating plane surfaces, or uneven wear, clean and inspect it again.

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Inspect Female Connectors

When using slotless connectors like the 2.4 mm, 3.5 mm, or some type-N 50 Ω female connectors, pay special attention to the contact fingers on the female center conductor. These can be bent or broken, and damage to them is not always easy to see. A connector with damaged contact fingers will not make good electrical contact and must be repaired or replaced.

NOTE

Due to the tighter mechanical specifications of precision devices, inspection is particularly important when you are mating nonprecision to precision devices.

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Cleaning Connectors

Clean connector interfaces prolong connector life and produce more accurate and repeatable measurements.

NOTE The following cleaning procedure can be used for most coaxial connectors. For 7 mm connectors, refer to "Cleaning Precision 7 mm Connectors" on page 8.

WARNING Always use protective eyewear when using compressed air or nitrogen.

Cleaning Coax Connectors

1. **Use compressed Air or Nitrogen**

   Use compressed air (or nitrogen) to loosen particles on the connector mating plane surfaces.

   You can use any source of clean, dry, low-pressure compressed air or nitrogen that has an effective oil-vapor filter and liquid condensation trap placed just before the outlet hose.

   Ground the hose nozzle to prevent electrostatic discharge, and set the air pressure to less than 414 kPa (60 psi) to control the velocity of the air stream. High-velocity streams of compressed air can cause electrostatic effects when directed into a connector. These electrostatic effects can damage the device. For additional information refer to "Electrostatic Discharge" on page 1 earlier in this chapter.

WARNING Keep isopropyl alcohol away from heat, sparks, and flame. Store in a tightly closed container. Isopropyl alcohol is extremely flammable. In case of fire, use alcohol foam, dry chemical, or carbon dioxide; water may be ineffective.
Use isopropyl alcohol with adequate ventilation and avoid contact with eyes, skin, and clothing. It causes skin irritation, may cause eye damage, and is harmful if swallowed or inhaled. It may be harmful if absorbed through the skin.
Wash thoroughly after handling. In case of spill, soak up with sand or earth. Flush spill area with water.
Dispose of isopropyl alcohol in accordance with all applicable federal, state, and local environmental regulation.

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2. Clean the Connector Threads

CAUTION

Use ONLY isopropyl alcohol to clean connector surfaces. Any other solvent may damage the insulators, support beads, and seals in the connector.

Never immerse the connector in solvents of any kind. The solvent can become trapped within the assembly and cause SWR, phase, and insertion loss problems.

Moisten (don't soak) a lint-free swab or cleaning cloth with isopropyl alcohol to remove any dirt or stubborn contaminants that cannot be removed with compressed air or nitrogen. Refer to "Other ECal Accessories" on page 11 for cleaning swabs and other connector cleaning supplies.

a. Apply a small amount of isopropyl alcohol to a lint-free swab.

b. Clean the connector threads.

c. Let the alcohol evaporate, then blow the threads dry with a gentle stream of clean, low-pressure compressed air or nitrogen. Always completely dry a connector before you reassemble or use it.

3. Clean the Mating Plane Surfaces

a. Apply a small amount of isopropyl alcohol to a new lint-free cleaning cloth or swab.

b. Clean the center and outer conductor mating plane surfaces. Refer to Figure 4-2 on page 4. When cleaning a female connector; use short strokes to avoid snagging the swab on the center conductor contact fingers.

c. Let the alcohol evaporate, then blow the mating plane surface dry with a gentle stream of clean, low-pressure compressed air or nitrogen. Always completely dry a connector before you reassemble or use it.

4. Inspect Each Connector

Inspect the connector to make sure that no particles or residue are present.

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Cleaning Precision 7 mm Connectors

You do not have to remove the center conductor collet to clean a precision 7 mm connector.

With the Center Collet in Place

1. Dispense a small amount of isopropyl alcohol on the lint free cloth.
2. Retract the connector sleeve threads to expose the connector interface.
3. Gently press the contact end of the connector into the moistened cloth and rotate the connector. The cloth scrubs away dirt and contaminants on the connector interface without damaging it.
4. Blow the connector dry with a gentle stream of compressed air or nitrogen.

NOTE

When not in use, keep the cloth in a plastic bag or box so that it does not collect dust or dirt.

For Fixed Connectors (attached to a device that cannot be freely moved)

1. Fold a lint-free cleaning cloth several times.
2. Moisten the cloth with isopropyl alcohol.
3. Press the moistened cloth against the connector interface and rotate the cloth to clean the connector.
4. Blow the connector dry with a gentle stream of compressed air or nitrogen.

Cleaning a Removed Center Collet

Any time you remove the center conductor collet, clean and inspect the interior surfaces as described in “Cleaning Connectors” on page 6.

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Gaging Connectors

The gages available from Keysight Technologies are intended for preventive maintenance and troubleshooting purposes only. They are effective in detecting excessive center conductor protrusion or recession, and conductor damage on DUTs, test accessories, and ECal module test ports. Do not use the gages for precise pin depth measurements.

Connector Gage Accuracy

The connector gages are only capable of performing coarse measurements. They do not provide the degree of accuracy necessary to precisely measure the pin depth. This is partially due to the repeatability uncertainties that are associated with pin-depth measurements.

With proper technique, the gages are useful in detecting gross pin depth errors on device connectors. To achieve maximum accuracy, random errors must be reduced by taking the average of at least three measurements having different gage orientations on the connector. Even the resultant average can be in error by as much as ±0.0001 inch (±0.0025 mm) due to systematic (biasing) errors usually resulting from worn gages and gage masters. The information in "Typical Pin Depth Values" on page 15 assumes new gages and gage masters. Therefore, these systematic errors were not included in the uncertainty analysis. As the gages endure more use, the systematic errors can become more significant in the accuracy of the measurement.

The measurement uncertainties are primarily a function of the assembly materials and design, and the unique interaction each device type has with the gage. Therefore, these uncertainties can vary among the different devices.

The observed pin depth limits add in these uncertainties to the typical factory pin depth values to provide practical limits that can be referenced when using the gages.

NOTE

When measuring pin depth, the measured value (resultant average of three or more measurements) contains measurement uncertainty and is not necessarily the true value. Always compare the measured value with the observed pin depth limits (which account for measurement uncertainties) in "Typical Pin Depth Values" on page 15 to evaluate the condition of device connectors.

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When to Gage Connectors

Gage a connector at the following times:

- Prior to using an ECal module for the first time: record the pin depth measurement so that it can be compared with future readings. This serves as a good troubleshooting tool when you suspect damage may have occurred to the device.
- If either visual inspection or electrical performance suggests that the connector interface may be out of typical range (due to wear or damage, for example).
- If a module is used by someone else, or on another system or piece of equipment.
- Initially after every 100 connections, and after that as often as experience suggests.

NOTE

When using the 7 mm module, you must remove the 7 mm collet before gaging the pin depth of the connectors. Use the collet extraction tool provided in your 7 mm module to remove the collet.

Recognizing Gage Types

A gage is referred to by the sex of the connector it measures. For example, a male gage measures male connectors and therefore has a corresponding female connector.

- See Figure 4-3 on page 4-11 for an illustration of a typical gage for 3.5 mm, 2.92mm,
  2.4 mm, and 1.85 mm connectors.
- See Figure 4-4 on page 4-12 for an illustration of a typical gage for type-N connectors.
- See Figure 4-5 on page 4-13 for an illustration of a typical gage for 7 mm connectors.

NOTE

A 3.5 mm gage set can measure 3.5 mm and 2.92 mm connectors.
A 2.4 mm gage set can measure 2.4 mm and 1.85 mm connectors.

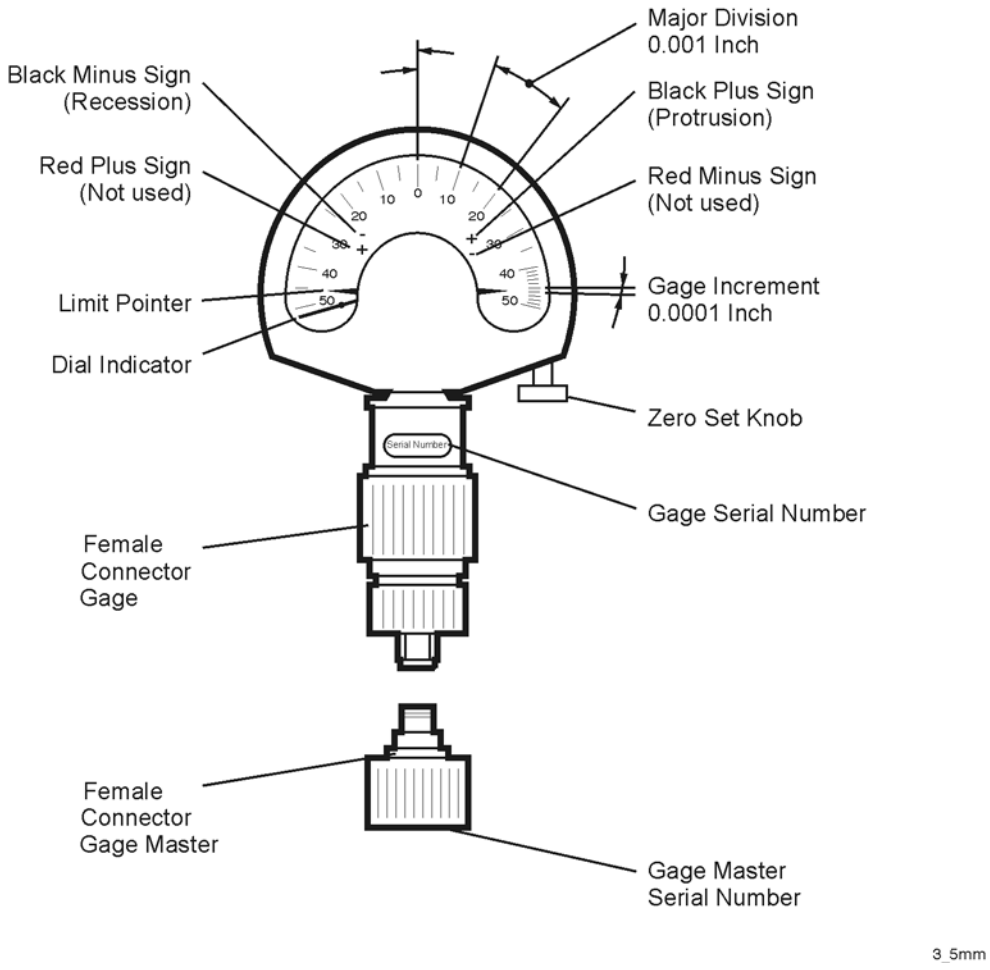
Reading the Connector Gage

The gage dial is divided up into increments of 0.0001 inch (0.0025 mm) and major divisions of 0.001 inch (0.0025 mm). For type-N gages, see Figure 4-4 on page 4-12. For each revolution of the large dial, the smaller dial indicates a change of 0.01 inch (0.025 mm). Use the small dial as the indicator of multiples of 0.01 inch (0.0025 mm). In most connector measuring applications, this value will be zero.

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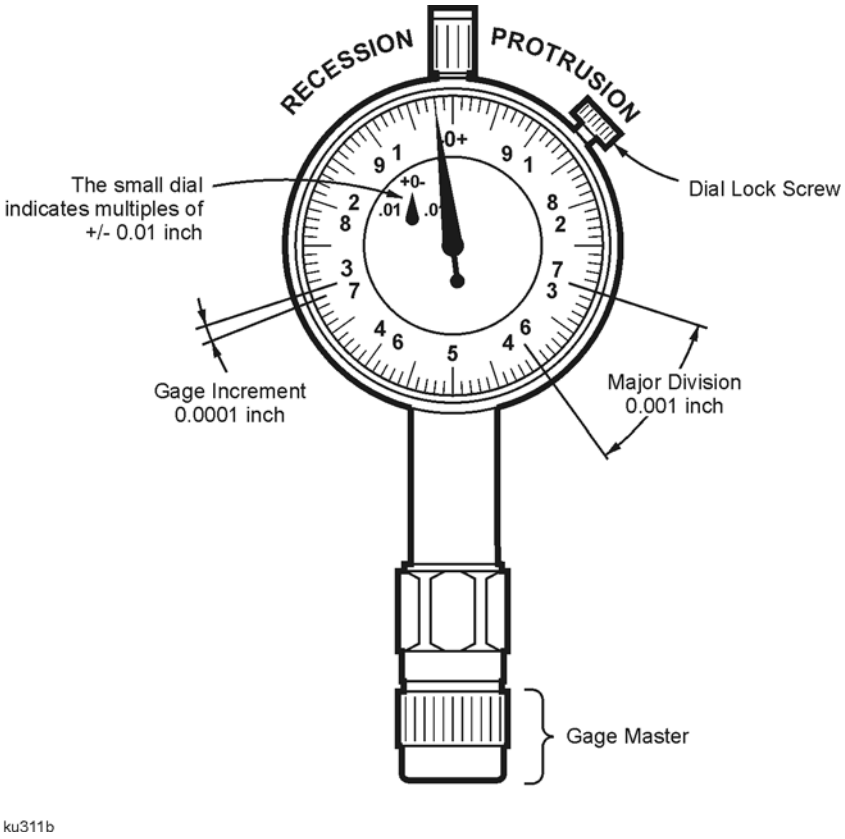
When making a measurement, the gage dial indicator will travel in one of two directions. If the center conductor is recessed from the zero reference plane, the indicator will move counterclockwise to determine the amount of recession, which is read as a negative value. If center conductor protrudes, the indicator will move clockwise to measure the amount of protrusion, which is read as a positive value. Refer to "Typical Pin Depth Values" on page 15 for definitions of protrusion and recession.

Figure 4-3 Typical Gage: 3.5 mm, 2.92 mm, 2.4 mm and 1.85 mm Connectors



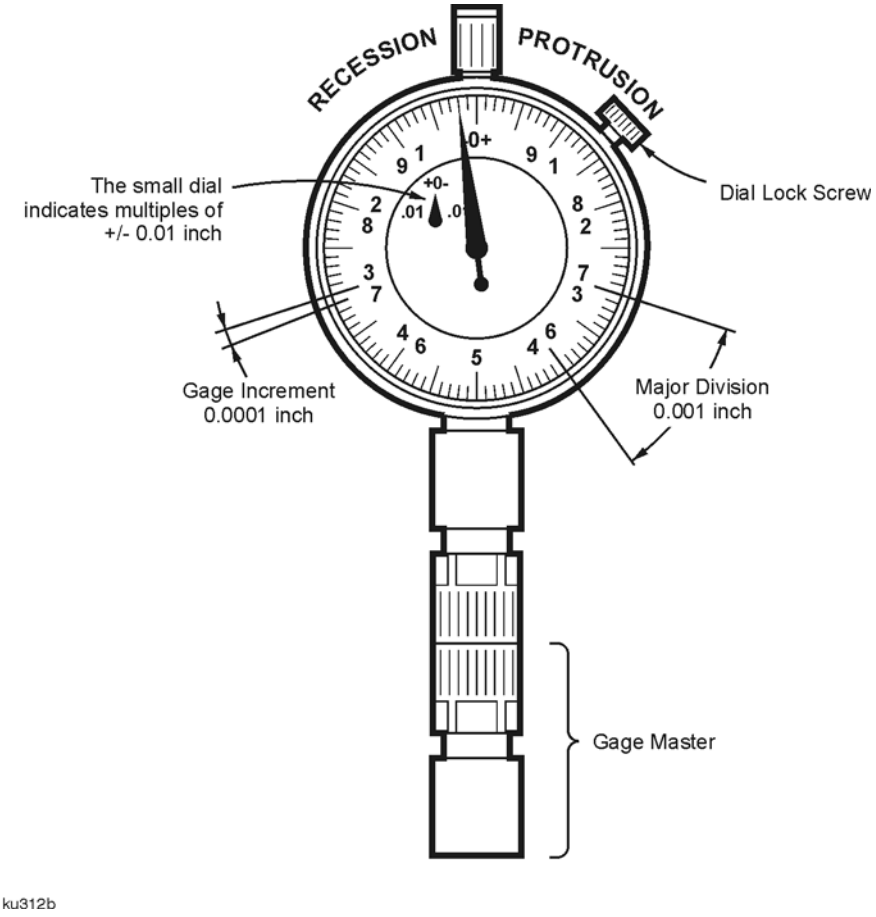
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Figure 4-4 Typical Gage: Type-N Connectors



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Figure 4-5 Typical Gage: 7 mm Connectors



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Gaging Procedures

Zeroing Connector Gages

For type-N gages, the paired gage master is labeled with an offset value to compensate for its inaccuracy with its gage. This label appears on the bottom of all type-N gage masters that have been paired with gages. When setting a type-N gage with its master, always set the gage to the master offset value shown on the label, not to the zero, unless that is the offset value indicated.

The design of the gages used to measure 3.5 mm, 2.92 mm, 2.4 mm, 1.85 and 7 mm connectors are different than the type-N gage design. The primary difference is that the type-N gages require an offset to compensate for inaccuracies in the gage masters.

1. Select the proper gage for your connector. Always use gages that are intended for pin depth measurements. Refer to Chapter 6, "Replaceable Parts." for gage model numbers listed with the associated connector types.
2. Inspect and clean the gage, gage master, and device to be gaged. Refer to "Visual Inspection" on page 3 and "Cleaning Connectors" on page 6.

CAUTION

Before continuing, make sure you are familiar with the proper connection and torque techniques for your connector type. Refer to "Making Connections" on page 16.

3. While holding the gage by the barrel, attach the gage to the gage master. Connect the gage master finger tight. Do not overtighten.
4. Use the torque wrench recommended for use with your connector type to tighten the connecting nut to the gage master. Refer to Table 4-1 on page 20.
5. Type-N: Loosen the dial lock screw on the gage and rotate the gage dial so that the pointer corresponds to the correction value noted on the gage master. Do not adjust the gage dial to zero unless the correction value on the gage master is zero.

   3.5 mm, 2.4 mm, and 7 mm: The gage pointer should line up exactly with the zero mark on the gage. If not, adjust the zero set knob or rotate the gage dial until the gage pointer lines up exactly with zero.
6. Tighten the dial lock screw and remove the gage master.
7. Attach and torque the gage master once again to verify that the setting is repeatable. Remove the gage master.

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Gaging Technique

CAUTION

Remove the collet when gaging 7 mm connectors.

1. Connect and torque the device being measured to the gage.
2. Gently tap the barrel of the gage with your finger to settle the gage reading.
3. Type-N and 7mm: Read the gage indicator dial. If the needle has moved clockwise, the center conductor is **protruding** by an amount indicated by the black numbers. If the needle has moved counterclockwise, the center conductor is **recessed** by an amount indicated by the red numbers.

   3.5 mm and 2.4 mm: Read the gage indicator dial. Read only the black ± signs; not the red ± signs.
4. For maximum accuracy, measure the connector a minimum of three times and take an average of the readings. After each measurement, rotate the gage a quarter-turn to reduce measurement variations that result from the gage or the connector face not being exactly perpendicular to the center axis.
5. Compare the average reading with the observed pin depth limits in the tables located in “Typical Pin Depth Values” on page 15 for each type of connector.

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Making Connections

Good connections are essential for accurate calibrations and measurements and require a skilled operator. **The most common cause of measurement error is poor connections.**

3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, Type-N, 7-16, and Type-F Devices

1. Handle the devices at a static-safe work station, only. See "Electrostatic Discharge" on page 1.
2. Carefully align the connectors. The male connector center pin must slip concentrically into the contact finger of the female connector.

CAUTION

Do not turn the device body. Only turn the connector nut. Damage to the center conductor can occur if the device body is twisted.

3. Push the connectors straight together and tighten the connector nut finger tight. Do not twist or screw the connector together. As the center conductors mate, there is usually a slight resistance
4. The preliminary connection is tight enough when the mating plane surfaces make uniform, light contact. Do not overtighten this connection.

   A connection in which the outer conductors make gentle contact at all points on both mating surfaces is sufficient. Very light finger pressure is enough to accomplish this.
5. Make sure the connectors are properly supported. Relieve any side pressure on the connection from long or heavy devices or cables.
6. Torque the connection according to the procedures described in "Final Connection Using a Torque Wrench" on page 17.

7 mm Devices

1. Fully extend the connector sleeve on one of the connectors. Spin its knurled connector nut to make sure the threads are fully extended. Fully retract the sleeve on the other connector. The extended sleeve creates a cylinder into which the other connector fits.

   If one of the connectors is fixed (such as on a test port), fully extend that connector sleeve and fully retract the sleeve on the movable connector.
2. Carefully align the connectors. As you make the actual connection, be sure the connectors align perfectly.
3. Push the connectors straight together. Do **not** twist or screw the connectors together.

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4. Engage the connector nut (of the connector with the retracted sleeve) over the threads of the other connector (the connector with the extended sleeve). Turn only the connector nut. Let the connector nut pull the two connectors straight together.
5. Do not overtighten this connection. A connection in which the outer conductors make gentle contact at all points on both mating surfaces is sufficient. Very light finger pressure is enough to accomplish this.
6. Make sure the connectors are properly supported. Relieve any side pressure on the connection from long or heavy devices or cables.
7. Torque the connection according to the procedures described in the following section.

Final Connection Using a Torque Wrench

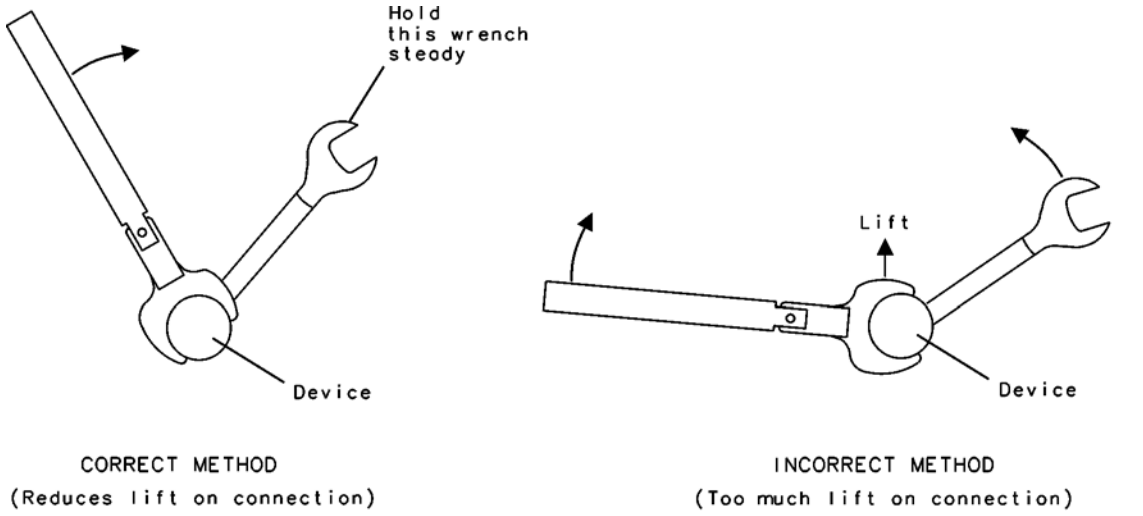
Using a torque wrench guarantees the connection is not too tight, preventing possible connector damage. It also guarantees that all connections are equally tight.

Use the recommended torque wrench to make a final connection. Table 4-1 on page 4-20 provides information on the torque wrench recommended for use with each connector type.

1. Turn the connector nut. This may be possible to do by hand if one of the connectors is fixed (as on a test port). However, it is recommended that you use an open-end wrench to keep the body of the device from turning.
2. Position both wrenches within 90 degrees of each other before applying force. Wrenches opposing each other (greater than 90 degrees apart) will cause a lifting action that can misalign and stress the connections of the device involved. This is especially true when several devices are connected together. Refer to Figure 4-6.

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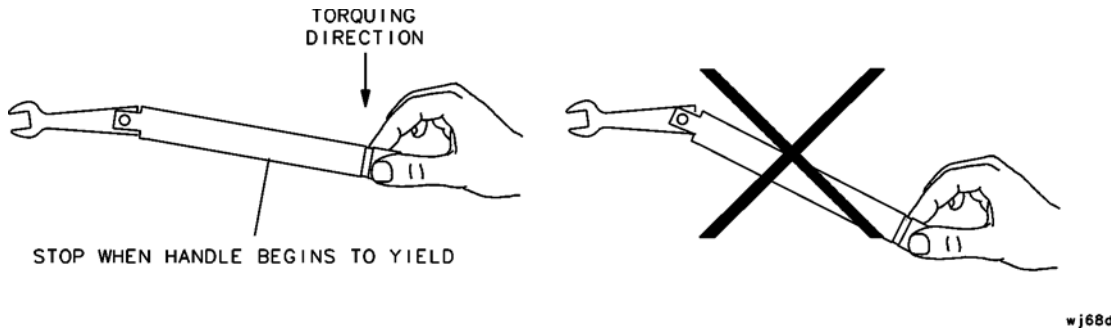
Figure 4-6 Wrench Positions



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3. Hold the torque wrench lightly, at the end of the handle only (beyond the groove). See Figure 4-7.

Figure 4-7 Using the Torque Wrench



4. Carefully align the connectors. As you make the actual connection, be sure the connectors align perfectly.
5. Push the connectors straight together. Do not twist or screw the connectors together. Engage the connector nut over the threads of the other connector. Turn only the connector nut. Let the connector nut pull the two connectors straight together.

   Do not over tighten this connection. A connection in which the outer conductors make gentle contact at all points on both mating surfaces is sufficient. Very light finger pressure is enough to accomplish this.
6. Make sure the connectors are properly supported. Relieve any side pressure on the connection from long or heavy devices or cables.
7. Apply force downward to the wrench handle. This applies torque to the connection through the wrench.

   Do not hold the wrench so tightly that you push the handle straight down along its length rather than pivoting it, otherwise you apply an unknown amount of torque.

CAUTION You don't have to fully break the handle of the torque wrench to reach the specified torque; doing so can cause the handle to kick back and loosen the connection. Any give at all in the handle is sufficient torque.

8. Tighten the connection just to the torque wrench break point. The wrench handle gives way at its internal pivot point. Do not tighten the connection further. See Figure 4-7.

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Table 4-1 ECal Module Torque Wrench Information

Connector Type	Torque Wrench Part Number	Wrench Opening	Torque Setting	Torque Tolerance[a]
3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm (test port)	8710-1764	20 mm	90 N-cm (8 in-lb)	±9 N-cm (±0.8 in-lb)
3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm (adapters)	8710-1765	5/16 in	90 N-cm (8 in-lb)	±9 N-cm (±0.8 in-lb)
Type-N 50 Ω, 75 Ω	8710-1766	3/4 in	135 N-cm (12 in-lb)	±13.5 N-cm (±1.2 in-lb)
7 mm	8710-1766	3/4 in	135 N-cm (12 in-lb)	±13.5 N-cm (±1.2 in-lb)
7-16	8710-2175	1 1/16 in	226 N-cm (20 in-lb)	±22.6 N-cm (±2 in-lb)

a. Many older Keysight calibration module manuals list different torque tolerances for the various torque wrenches. The correct torque tolerance for Keysight torque wrenches is ±10% of the torque setting as listed in this table.

Separating Connections

To avoid lateral (bending) force on the connector mating plane surfaces, always support the devices and connections.

CAUTION

Do **not** turn the device body. Only turn the connector nut. Damage to the center conductor can occur if the device body is twisted.

1. Use an open-end wrench or spanner wrench to prevent the device body from turning.
2. Use another open-end wrench or the torque wrench to loosen the connector nut.
3. Complete the separation by hand, turning only the connector nut.
4. Pull the connectors straight apart without twisting, rocking, or bending.

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Handling and Storage

- Use the plastic end caps and store the calibration devices in the foam-lined storage case when not in use.
- Never store connectors loose in a box, in a desk, or in a bench drawer. This is the most common cause of connector damage during storage. Keysight recommends that you purchase the optional ECal Storage Box (not included with an ECal kit). Refer to "ECal Kit Storage Box (Option 150)" on page 22. This is a container for securing your ECal module and accessories, such as a USB cable, wrenches, and adapters. For ordering information, see "Other ECal Accessories" on page 11.
- Keep connectors clean.
- Do not touch mating plane surfaces. Natural skin oils and microscopic particles of dirt are easily transferred to a connector interface and are very difficult to remove.
- Do not set connectors contact-end down on a hard surface. The plating and the mating plane surfaces can be damaged if the interface comes in contact with any hard surface.

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ECal Kit Storage Box (Option 150)

The ECal kit storage box is a wooden box that can be ordered separately as Option 150. It is a container for securing the contents of your ECal kit – the ECal module and accessories, such as a USB cable, wrenches and adapters. Inside the storage box, these items are safely placed within the ESD-safe foam cutouts, so they are protected from the work environment and are easily located when needed.

The ECal kit storage box is not designed for shipping. Please retain the original shipping container to ship the ECal module and accessories back to Keysight for repair and recertification.

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5 Specifications and Characteristics

Specifications: Terminology and Definitions

The following terms and definitions apply to Keysight's 8509x, N443xA/B, and N469xA/B/C series of ECal modules. The definitions are specific to these modules and are not necessarily valid definitions for other Keysight Technologies products.

Table 5-1 Specifications and Characteristics Terminology

Terms	Definitions
Operating Temperature Range	The temperature range over which the ECal modules maintain conformance to their specifications.
Error-Corrected Temperature Range	The allowable network analyzer ambient temperature drift during measurement calibration and during measurements when network analyzer correction is turned on. It is also the range over which the network analyzer maintains its specified performance while correction is turned on. If this temperature range is exceeded, the error-corrected performance of the network analyzer is degraded.
Measurement Calibration	This calibration determines the corrections necessary for accuracy-enhanced (correction on) measurements.
Connector Pin Depth Values	Pin depth is a relative measurement value between the center conductor and outer conductor mating surfaces. All references to pin depth in this manual treat positive (+) values as protrusions of the center conductor, and negative (–) values as recessions of the center conductor. See "Typical Pin Depth Values" on page 15
Electrical Specifications	Warranted performance. Specifications include guard bands to account for the expected statistical distribution, measurement uncertainties, and changes in performance due to environmental conditions. Included with Option UK6.
Characteristic Performance	A performance parameter that the product is expected to meet before it leaves the factory, but is not verified in the field and is not covered by the product warranty. A characteristic includes the same guard bands as a specification.
Typical Corrected Performance	Expected performance of an average unit which does not include guard bands. It is not covered by the product warranty.

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Environmental Specifications

NOTE

Samples of this product have been type-tested in accordance with the Keysight Environmental Test Manual and verified to be robust against the environmental stresses of storage, transportation and end-use; those stresses include but are not limited to temperature, humidity, shock, vibration, and power-line conditions. Test methods are aligned with IEC 60068-2 and levels are similar to MIL-PRF-28800F Class 3.

Table 5-2 Environmental Specifications for all ECal Modules

Specifications	Limits
Temperature	
Operating (8509xC series)	+20 °C to +30 °C
Operating (N443xA/B series)	+20 °C to +30 °C
Operating (N469xA/B/C series)	+20 °C to +26 °C
Storage	–40 °C to +70 °C
Error-corrected range	±1 °C of measurement calibration temperature
Relative Humidity	Type tested, 0% to 95% at 40°C, non-condensing

Operating Temperature and Accuracy Enhancement

Because the dimensions of critical components may vary over temperature, certain electrical characteristics may change as well. Thus, the operating temperature is a critical factor in its performance, and must be stable before use. In addition, excessive air flow can prevent the ECal module from warming up properly.

Measurement calibration, performance verification, and actual device measurements must be made within ±1 °C of the error-corrected operating temperature range specification of the network analyzer. If the ambient operating temperature drift of the network analyzer exceeds the allowable error-corrected temperature range, a new measurement calibration must be performed to ensure optimum accuracy.

NOTE

Avoid prolonged handling of the module, connectors, and cables. Your fingers are a heat source that can increase the temperature of these devices.

Barometric Pressure and Relative Humidity

Barometric pressure and relative humidity also affect module performance. The dielectric constant of the air between the inner and outer conductors of the module changes as the air pressure and humidity change.

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Characteristic Performance

Characteristic performance for RF and microwave ECal modules are provided in the following tables, which describe non-warranted performance that most units exhibit.

8509x Series

Table 5-3 Characteristic Performance for 85091C (7 mm)[a]

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 9 GHz
Directivity (dB)	45	52	52	50	45
Source Match (dB)	36	45	44	41	34
Reflection Tracking (±dB)	0.1	0.04	0.04	0.07	0.1
Transmission Tracking (±dB)[b]	0.08	0.05	0.05	0.07	0.15
Load Match (dB)[b]	40	46	45	43	38

a. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.

Table 5-4 Characteristic Performance for 85092C (Type-N 50Ω)[a]

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 9 GHz
Directivity (dB)	45	52	52	49	45
Source Match (dB)	36	45	44	41	36
Reflection Tracking (±dB)	0.1	0.04	0.04	0.06	0.07
Transmission Tracking (±dB)[b]	0.12	0.05	0.06	0.11	0.17
Load Match (dB)[b]	36	41	45	40	37

a. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.

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Table 5-5 Characteristic Performance for 85093C (3.5 mm)[a]

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 9 GHz
Directivity (dB)	45	52	52	50	47
Source Match (dB)	36	44	44	39	34
Reflection Tracking (±dB)	0.1	0.03	0.04	0.05	0.07
Transmission Tracking (±dB)[b]	0.13	0.05	0.05	0.10	0.16
Load Match (dB)[b]	36	42	45	42	39

a. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.

Table 5-6 Characteristic Performance for 85096C (Type-N 75Ω)[a]

Parameter	Frequency Range			
	300 kHz to 10 MHz	10 MHz to 300 MHz	300 MHz to 1.3 GHz	1.3 GHz to 3 GHz
Directivity (dB)	45	50	48	43
Source Match (dB)	36	48	45	38
Reflection Tracking (±dB)	0.1	0.03	0.06	0.10
Transmission Tracking (±dB)[b]	0.13	0.05	0.06	0.10
Load Match (dB)[b]	36	42	41	37

a. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer E5061B Option 237.

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Table 5-7 Characteristic Performance for 85098C (7-16)[a]

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 7.5 GHz
Directivity (dB)	45	47	47	46	45
Source Match (dB)	36	43	43	38	37
Reflection Tracking (±dB)	0.10	0.03	0.03	0.05	0.06
Transmission Tracking (±dB)[b]	0.13	0.06	0.07	0.12	0.14
Load Match (dB)[b]	36	40	38	36	34

a. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.

Table 5-8 Characteristic Performance for 85099C (Type-F)[a], [b]

Parameter	Frequency Range			
	300 kHz to 10 MHz	10 MHz to 300 MHz	300 MHz to 1.3 GHz	1.3 GHz to 3 GHz
Directivity (dB)	45	50	48	43
Source Match (dB)	36	48	45	38
Reflection Tracking (±dB)	0.10	0.03	0.07	0.15
Transmission Tracking (±dB)[c]	0.14	0.05	0.07	0.11
Load Match (dB)[c]	36	42	41	36

a. When mated with male connectors with a 0.77 mm (.030 in) to 0.86 (0.34) pin diameter
b. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
c. Values based on using the network analyzer E5061B Option 237.

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N4431B (3.5 mm)

The characteristic performance in the following table applies to N4431B Option 010 (3.5 mm female connectors on all ports). The data describes performance when measuring “thru path” A-B, C-D, A-D and B-C.

Table 5-9 Characteristic Performance for N4431B Option 010[a]

Parameter	Frequency Range						
	9 kHz[b] to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 8 GHz	8 GHz to 9 GHz	9 GHz to 13.5 GHz
Directivity (dB)	45	53	52	48	46	44	40
Source Match (dB)	36	50	47	45	44	43	32
Reflection Tracking (±dB)	0.10	0.03	0.03	0.04	0.04	0.05	0.10
Transmission Tracking (±dB)[c]	0.10	0.04	0.06	0.12	0.16	0.17	0.44
Load Match (dB)[c]	39	45	45	40	38	36	32

a. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
b. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
c. Values based on using the network analyzer N5231A Option 400.

The characteristic performance in the following table applies to N4431B Option 010 (3.5 mm female connectors on all ports). The data describes performance when measuring “thru path” A-C and B-D.

Table 5-10 Characteristic Performance for N4431B Option 010[a]

Parameter	Frequency Range						
	9 kHz[b] to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHZ to 6 GHz	6 GHz to 8 GHz	8 GHz to 9 GHz	9 GHz to 13.5 GHz
Directivity (dB)	45	53	52	48	46	44	40
Source Match (dB)	36	50	47	45	44	43	32
Reflection Tracking (±dB)	0.10	0.03	0.03	0.04	0.04	0.05	0.10
Transmission Tracking (±dB)[c]	0.10	0.04	0.06	0.11	0.14	0.15	0.30
Load Match (dB)[c]	38	45	45	40	38	36	32

a. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
b. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
c. Values based on using the network analyzer N5231A Option 400.

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N4431B (Type-N 50 Ω)

The characteristic performance in the following table applies to N4431B Option 020 (type-N female connectors on all ports). The data describes performance when measuring “thru path” A-B, C-D, A-D and B-C.

Table 5-11 Characteristic Performance for N4431B Option 020[a]

Parameter	Frequency Range						
	9 kHz[b] to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 8 GHz	8 GHz to 9 GHz	9 GHz to 13.5 GHz
Directivity (dB)	45	53	52	46	44	42	38
Source Match (dB)	36	47	43	42	40	39	31
Reflection Tracking (±dB)	0.10	0.03	0.04	0.04	0.05	0.06	0.11
Transmission Tracking (±dB)[c]	0.10	0.04	0.07	0.12	0.16	0.18	0.45
Load Match (dB)[c]	39	45	44	39	37	35	31

a. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
b. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
c. Values based on using the network analyzer N5231A Option 400.

The characteristic performance in the following table applies to N4431B Option 020 (type-N female connectors on all ports). The data describes performance when measuring “thru path” A-C and B-D.

Table 5-12 Characteristic Performance for N4431B Option 020[a]

Parameter	Frequency Range						
	9 kHz[b] to 10 MHz	10 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 6 GHz	6 GHz to 8 GHz	8 GHz to 9 GHz	9 GHz to 13.5 GHz
Directivity (dB)	45	53	52	46	44	42	38
Source Match (dB)	36	47	43	42	40	39	31
Reflection Tracking (±dB)	0.10	0.03	0.04	0.04	0.05	0.06	0.11
Transmission Tracking (±dB)[c]	0.10	0.04	0.06	0.11	0.14	0.15	0.31
Load Match (dB)[c]	38	45	44	39	37	35	31

a. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
b. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
c. Values based on using the network analyzer N5231A Option 400.

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N4432A (Type-N 50 Ω)

The characteristic performance in the following table applies to N4432A Option 020 (type-N female connectors on all ports).

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 5 GHz	5 GHz to 9 GHz	9 GHz to 13.5 GHz	13.5 GHz to 18 GHz
Directivity (dB)	45	50	47	41	40
Source Match (dB)	35	41	37	34	34
Reflection Tracking (±dB)	0.10	0.06	0.10	0.15	0.14
Transmission Tracking (±dB)[a]	0.18	0.05	0.10	0.17	0.21
Load Match (dB)[a]	35	42	39	35	33

a. Values based on using the network analyzer N5232A Option 400.

N4433A (3.5 mm)

The characteristic performance in the following table applies to N4433A Option 010 (3.5 mm female connectors on all ports).

Parameter	Frequency Range				
	300 kHz to 10 MHz	10 MHz to 5 GHz	5 GHz to 9 GHz	9 GHz to 13.5 GHz	13.5 to 20 GHz
Directivity (dB)	45	50	47	45	40
Source Match (dB)	36	42	39	37	31
Reflection Tracking (±dB)	0.10	0.06	0.09	0.10	0.18
Transmission Tracking (±dB)[a]	0.18	0.05	0.09	0.12	0.23
Load Match (dB)[a]	35	42	39	38	32

a. Values based on using the network analyzer N5232A Option 400.

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N469xA/B/C Series

Table 5-13 Characteristic Performance for N4690B and N4690C (Type-N 50 Ω)[a]

Parameter	Frequency Range					
	300 kHz to 2 MHz	2 MHz to 10 MHz	10 MHz to 500 MHz	500 MHz to 2 GHz	2 GHz to 10 GHz	10 GHz to 18 GHz
Directivity (dB)	30	40	45	48	44	42
Source Match (dB)	28	35	40	43	40	35
Reflection Tracking (±dB)	0.12	0.07	0.05	0.03	0.03	0.05
Transmission Tracking (±dB)	0.37[b]	0.08[b]	0.10[c]	0.04[c]	0.05[c]	0.08[c]
Load Match w/ ECal Thru (dB)	26[b]	37[b]	33[c]	42[c]	39[c]	34[c]

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.
c. Values based on using the network analyzer N5222A Option 200.

Table 5-14 Characteristic Performance for N4691B (3.5 mm)[a]

Parameter	Frequency Range						
	300 kHz to 2 MHz	2 MHz to 10 MHz	10 MHz to 500 MHz	500 MHz to 2 GHz	2 GHz to 10 GHz	10 GHz to 20 GHz	20 GHz to 26.5 GHz
Directivity (dB)	31	41	46	52	48	46	44
Source Match (dB)	29	36	41	47	45	42	40
Reflection Tracking (±dB)	0.11	0.06	0.05	0.02	0.03	0.04	0.05
Transmission Tracking (±dB)	0.37[b]	0.08[b]	0.09[c]	0.03[c]	0.04[c]	0.06[c]	0.08[c]
Load Match w/ ECal Thru (dB)	27[b]	37[b]	34[c]	46[c]	43[c]	40[c]	38[c]

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.
c. Values based on using the network analyzer N5222A Option 200.

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Table 5-15 Characteristic Performance for N4692A (2.92 mm)[a]

Parameter	Frequency Range					
	10 MHz to 45 MHz[b]	**45 MHz to 200 MHz**	**200 MHz to 2 GHz**	**2 GHz to 20 GHz**	**20 GHz to 30 GHz**	**30 GHz to 40 GHz**
Directivity (dB)	35	41	45	42	39	38
Source Match (dB)	30	36	36	35	30	29
Reflection Tracking (±dB)	0.10	0.08	0.08	0.08	0.10	0.10
Transmission Tracking (±dB)[c]	0.15	0.11	0.09	0.11	0.14	0.15
Load Match (dB)[c]	29	34	35	33	28	27

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Based on typical performance.
c. Values based on using the network analyzer N5224A Option 200.

Table 5-16 Characteristic Performance for N4693A (2.4 mm)[a]

Parameter	Frequency Range						
	10 MHz to 45 MHz[b]	**45 MHz to 200 MHz**	**200 MHz to 2 GHz**	**2 GHz to 10 GHz**	**10 GHz to 20 GHz**	**20 GHz to 40 GHz**	**40 GHz to 50 GHz**
Directivity (dB)	32	42	51	49	45	41	36
Source Match (dB)	25	44	46	42	37	35	32
Reflection Tracking (±dB)	0.05	0.03	0.03	0.04	0.05	0.06	0.08
Transmission Tracking (±dB)[c]	0.12	0.06	0.04	0.05	0.07	0.10	0.14
Load Match (dB)[c]	24	42	45	40	35	33	30

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Based on typical performance.
c. Values based on using the network analyzer N5225A Option 200.

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Table 5-17 Characteristic Performance for N4694A (1.85 mm)[a]

Parameter	Frequency Range								
	10 MHz to 45 MHz[b]	45 MHz to 200 MHz	200 MHz to 2 GHz	2 GHz to 20 GHz	20 GHz to 30 GHz	30 GHz to 40 GHz	40 GHz to 50 GHz	50 GHz to 60 GHz	60 GHz to 67 GHz
Directivity (dB)	33	41	46	47	46	44	42	41	38
Source Match (dB)	25	38	38	39	35	34	33	30	27
Reflection Tracking (±dB)	0.05	0.04	0.04	0.04	0.05	0.06	0.07	0.08	0.09
Transmission Tracking (±dB)[c]	0.15	0.08	0.06	0.06	0.08	0.09	0.11	0.12	0.15
Load Match (dB)[c]	24	36	36	37	33	32	31	28	26

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Based on typical performance.
c. Values based on using the network analyzer N5227A Option 200.

Table 5-18 Characteristic Performance for N4696B (7 mm)[a]

Parameter	Frequency Range					
	300 kHz to 2 MHz	2 MHz to 10 MHz	10 MHz to 500 MHz	500 MHz to 2 GHz	2 GHz to 10 GHz	10 GHz to 18 GHz
Directivity (dB)	30	40	46	45	47	42
Source Match (dB)	28	35	40	40	42	36
Reflection Tracking (±dB)	0.12	0.07	0.05	0.03	0.03	0.05
Transmission Tracking (±dB)	0.37[b]	0.07[a]	0.10[c]	0.04[c]	0.04[c]	0.08[c]
Load Match w/ ECal Thru (dB)	26[a]	37[a]	33[c]	39[c]	41[c]	34[c]

a. When applied power exceeds -5 dBm, calibration results will be degraded from the performance indicated in this table.
b. Values based on using the network analyzer N5231A Option 200.
c. Values based on using the network analyzer N5222A Option 200.

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Mechanical Characteristics

Mechanical characteristics, such as center conductor protrusion and pin depth, are not warranted performance specifications. They are, however, important supplemental characteristics related to the electrical performance of devices. Keysight Technologies verifies the mechanical characteristics of the devices with special gaging processes and electrical testing. These processes ensure that the device connectors do not exhibit any excess center conductor protrusion or improper pin depth when the module leaves the factory.

"Gaging Connectors" on page 9 explains how to use pin-depth gages. Refer to "Typical Pin Depth Values" on page 15 for typical and observed pin depth limits.

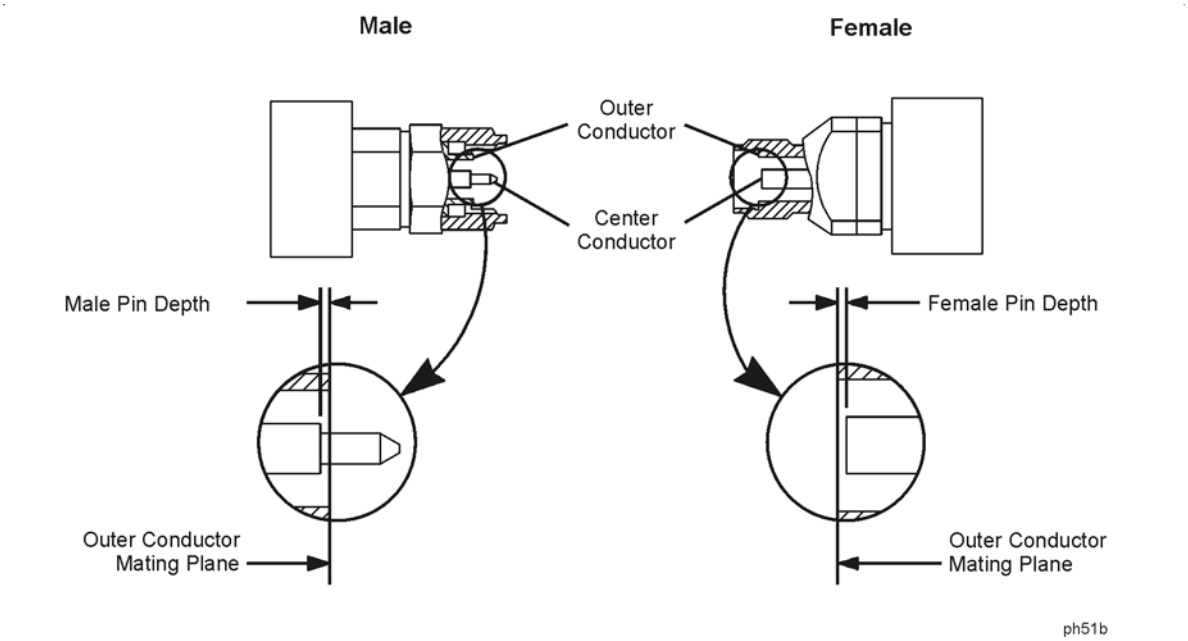
Pin Depth

Pin depth is the distance the center conductor mating plane differs from being flush with the outer connector mating plane. The pin depth of a connector can be in one of two states: protrusion or recession. The pin depth for a 3.5 mm connector is shown in Figure 5-1, although the description also applies to 2.92 mm, 2.4 mm, or 1.85 mm connectors. Typical pin depths for ECal connectors are listed in "Typical Pin Depth Values" on page 15.

Protrusion occurs when the center conductor extends beyond the outer conductor mating plane. It reads as a positive value on the connector gage.

Recession occurs when the center conductor is set back from the outer conductor mating plane. It reads as a negative value on the gage.

Figure 5-1 Pin Depth for a 3.5 mm Connectors



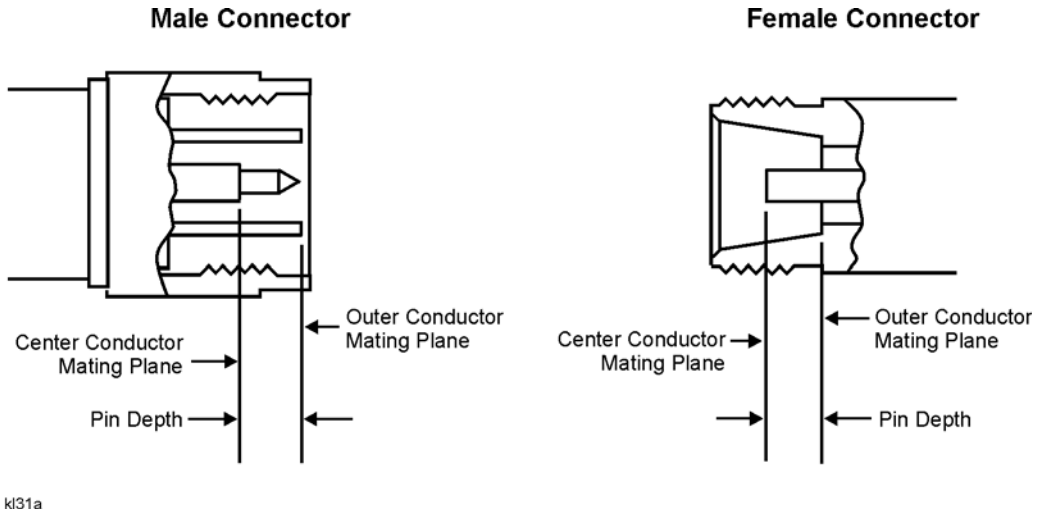
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Type-N Characteristics

With type-N and 7-16 connectors, the shoulder position of the male contact pin (not the position of the tip) defines the position of the center conductor. The male contact pin slides into the female contact fingers; the inside surfaces of the tip of the female contact fingers on the sides of the male contact pin provide electrical contact.

Type-N connectors differ from most connector types in that the outer conductor mating plane is offset from the mating plane of the center conductor (see Figure 5-2). The outer conductor in the male connector extends in front of the shoulder of the male contact pin. When you make a connection, this outer conductor fits into a recess in the female outer conductor behind the plane defined by the tip of the female contact fingers.

Figure 5-2 Pin Depth for Type-N Connectors



Critical Type-N Mechanical Characteristics

CAUTION

Never use a type-N connector if the possibility of interference between the shoulder of the male contact pin and the tip of the female contact fingers exists.

Irreparable damage will occur if a male 50 Ω type-N connector is mated to a female 75 Ω type-N connector. If you use both 75 Ω and 50 Ω type-N connectors, mark the 75 Ω connectors so that they are never accidentally mated with 50 Ω connectors. The diameter of the center conductor, male contact pin, and female contact hole are smaller on 75 Ω connectors.

- *Minimum* **protrusion** of the female center conductor in front of the outer conductor mating plane is 5.182 mm or 0.204 inches.
- *Maximum* **protrusion** of the female center conductor in front of the outer conductor mating plane is 5.258 mm or 0.207 inches.
- *Minimum* **recession** of the shoulder of the male contact pin behind the outer conductor mating plane is 5.258 mm or 0.207 inches.

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– *Maximum* **recession** of the shoulder of the male contact pin behind the outer conductor mating plane is 5.334 mm or 0.210 inches.

In the Keysight precision specification for type-N connectors, the minimum allowable recession for the male contact pin shoulder is 0.001 inches less than in the MIL-C-39012, Class II specification. Keysight Technologies type-N pin depth gages set “zero” on the gage to be equal to a nominal 5.258 mm (0.207 inches) offset.

As type-N connectors wear, the protrusion of the female contact-fingers generally increases. This is due to the wear of the outer conductor mating plane inside the female connector. It is necessary to check this periodically as it decreases the total center conductor contact separation.

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Typical Pin Depth Values

The pin depth value of each device is not specified, but is an important mechanical parameter. The electrical performance of the device depends, to some extent, on its pin depth. The electrical specifications for each module takes into account the effect of pin depth on the device's performance. The following tables list the typical pin depths and measurement uncertainties, and provides observed pin depth limits for the devices. If the pin depth of a device does not measure within the observed pin depth limits, it may be an indication that the device fails to meet electrical specification. Refer to Figure 5-1 and Figure 5-2 for a visual representation of proper pin depth (slightly recessed).

NOTE

Keysight Technologies does not supply pin depth gages for 7-16 connectors. The 7-16 module adapter pin depth is set at 0 to –0.0381 millimeters recessed from the nominal 1.77 mm offset between inner conductor and outer conductor mating planes.

Table 5-19 Type-N 50 Ω Connector Pin Depth Characteristics

Device	Typical Pin Depth[a] in Millimeters (10^{-4} inches)	Measurement Uncertainty[b] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
Type-N 50 Ω ECal Module (85092C, N4431B Opt. 020, N4432A Opt. 020)	–0.0254 to –0.0508 (–10.0 to –20.0)	+0.0038 to –0.0038 (+1.5 to –1.5)	–0.0216 to –0.0546 (–8.5 to –21.5)
Type-N 50 Ω ECal Module (N4690B/C)	–0.0051 to –0.0152 (–2.0 to –6.0)	+0.0038 to –0.0038 (+1.5 to –1.5)	–0.0013 to –0.0190 (–0.5 to –7.5)
Type-N 50 Ω Adapter	0 to –0.0127 (0 to –5.0)	+0.0038 to –0.0038 (+1.5 to –1.5)	+0.0038 to –0.0165 (+1.5 to –6.5)

a. Measured from a 5.258 mm (0.207 inches) nominal offset.
b. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

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Table 5-20 3.5 mm Connector Pin Depth Characteristics

Device	Typical Pin Depth in Millimeters (10^{-4} inches)	Measurement Uncertainty[a] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
3.5 mm ECal Module (85093C, N4433A, N4431B Opt. 010)	–0.0254 to –0.0508 (–10.0 to –20.0)	+0.0041 to –0.0041 (+1.6 to –1.6)	–0.0213 to –0.0549 (–8.4 to –21.6)
3.5 mm ECal Module (N4691B)	–0.0025 to –0.0152 (–1.0 to –6.0)	+0.0041 to –0.0041 (+1.6 to –1.6)	+0.0016 to –0.0193 (+0.6 to –7.6)
3.5 mm Adapter	0 to –0.0254 (0 to –10)	+0.0041 to –0.0041 (+1.6 to –1.6)	+0.0041 to –0.0295 (+1.6 to –11.6)

a. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

Table 5-21 7 mm Connector Pin Depth Characteristics

Device	Typical Pin Depth in Millimeters (10^{-4} inches)	Measurement Uncertainty[a] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
7 mm ECal Module (85091C, N4432A)	–0.0254 to –0.0508 (–10.0 to –20.0)	+0.0038 to –0.0038 (+1.5 to –1.5)	–0.0216 to –0.0546 (–8.5 to –21.5)
7 mm ECal Module (N4696B)	–0.0025 to –0.0152 (–1.0 to –6.0)	+0.0038 to –0.0038 (+1.5 to –1.5)	+0.0013 to –0.0190 (+0.5 to –7.5)

a. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

Table 5-22 2.92 mm Connector Pin Depth Characteristics

Device	Typical Pin Depth in Millimeters (10^{-4} inches)	Measurement Uncertainty[a] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
2.92 mm ECal Module	–0.0025 to –0.0152 (–1.0 to –6.0)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0005 to –0.0182 (+0.2 to –7.2)
2.92 mm Adapter	0 to –0.0381 (0 to –15)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0030 to –0.0411 (+1.2 to –16.2)

a. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

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Table 5-23 2.4 mm Connector Pin Depth Characteristics

Device	Typical Pin Depth in Millimeters (10^{-4} inches)	Measurement Uncertainty[a] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
2.4 mm ECal Module	–0.0025 to –0.0152 (–1.0 to –6.0)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0005 to –0.0182 (+0.2 to –7.2)
2.4 mm Adapter	0 to –0.0381 (0 to –15)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0030 to –0.0411 (+1.2 to –16.2)

a. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

Table 5-24 1.85 mm Connector Pin Depth Characteristics

Device	Typical Pin Depth in Millimeters (10^{-4} inches)	Measurement Uncertainty[a] in Millimeters (10^{-4} inches)	Observed Pin Depth Limits in Millimeters (10^{-4} inches)
1.85 mm ECal Module	–0.0025 to –0.0152 (–1.0 to –6.0)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0005 to –0.0182 (+0.2 to –7.2)
1.85 mm Adapter	0 to –0.0381 (0 to –15)	+0.0030 to –0.0030 (+1.2 to –1.2)	+0.0030 to –0.0411 (+1.2 to –16.2)

a. Approximately +2 sigma to –2 sigma of gage uncertainty based on studies performed at the factory using precision digital gages according to recommended procedures.

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Supplemental Mechanical Characteristics

Table 5-25 8509x Series Mechanical Characteristics

Characteristic	Limits
Net weight with case	
Standard	2.7 kilograms (5.9 lbs)
Shipping weight	
Standard	4.3 kilograms (9.5 lbs)
Shipping dimensions	
Length	45.7 cm (17.82 inches)
Width	26.2 cm (10.22 inches)
Height	13.3 cm (5.19 inches)

Table 5-26 N4431B Series Mechanical Characteristics

Characteristic	Limits
Net weight with case	
Standard	2.9 kilograms (6.3 lbs)
Shipping weight	
Standard	4.5 kilograms (9.9 lbs)
Shipping dimensions	
Length	45.7cm (17.82 inches)
Width	26.2 cm (10.22 inches)
Height	13.3 cm (5.19 inches)

Table 5-27 N469xA/B/C Series Mechanical Characteristics

Characteristic	Limits
Net weight with case	
Standard	2.7 kilograms (5.9 lbs)
Shipping weight	
Standard	4.3 kilograms (9.5 lbs)
Shipping dimensions	
Length	45.7 cm (17.82 inches)
Width	26.2 cm (10.22 inches)
Height	13.3 cm (5.19 inches)

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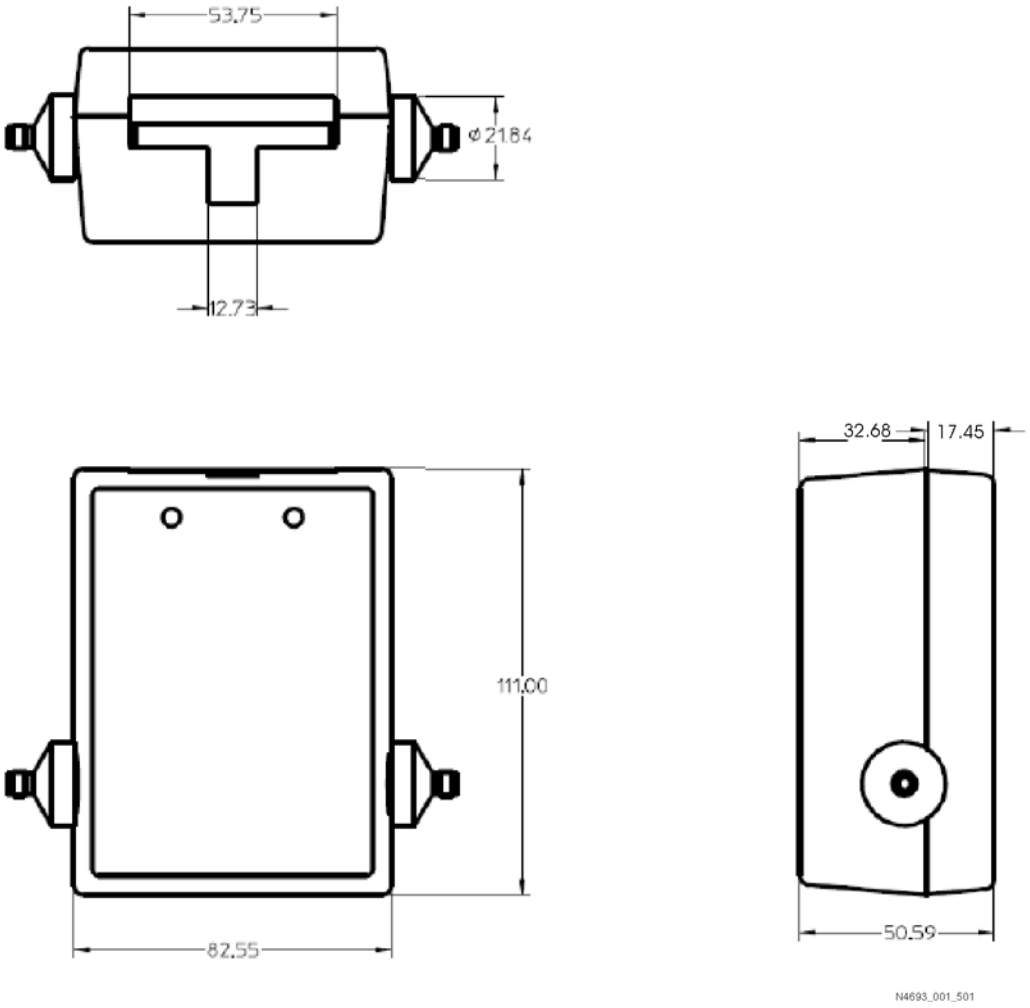
Table 5-28 N443xA Series Mechanical Characteristics

Characteristic	Limits
Net weight with case	
Standard	2.8 kilograms (6.2 lbs)
Shipping weight	
Standard	4.4 kilograms (9.7 lbs)
Shipping container dimensions	
Length	45.7 cm (17.82 inches)
Width	26.2 cm (10.22 inches)
Height	13.3 cm (5.19 inches)

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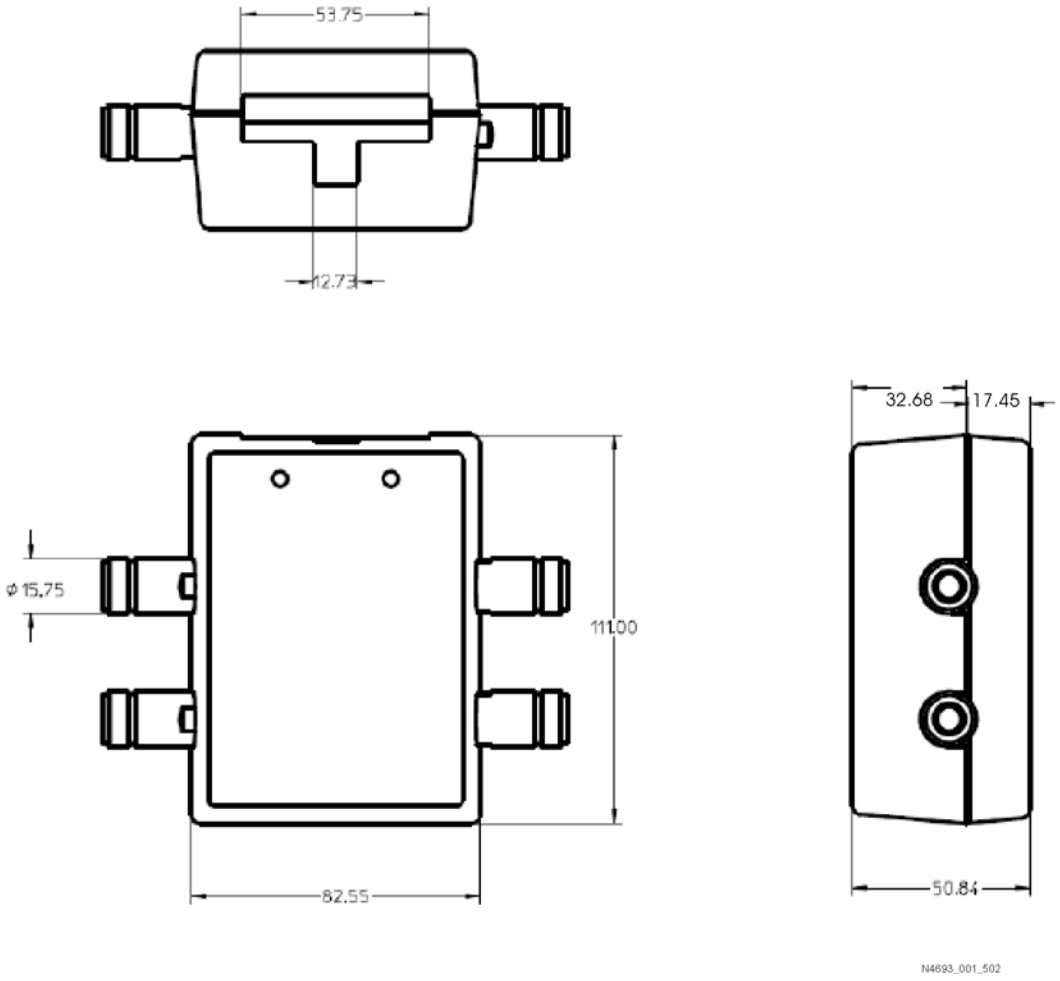
Mechanical Dimensions of the Modules

Figure 5-3 8509x Modules (RF 2-Port)



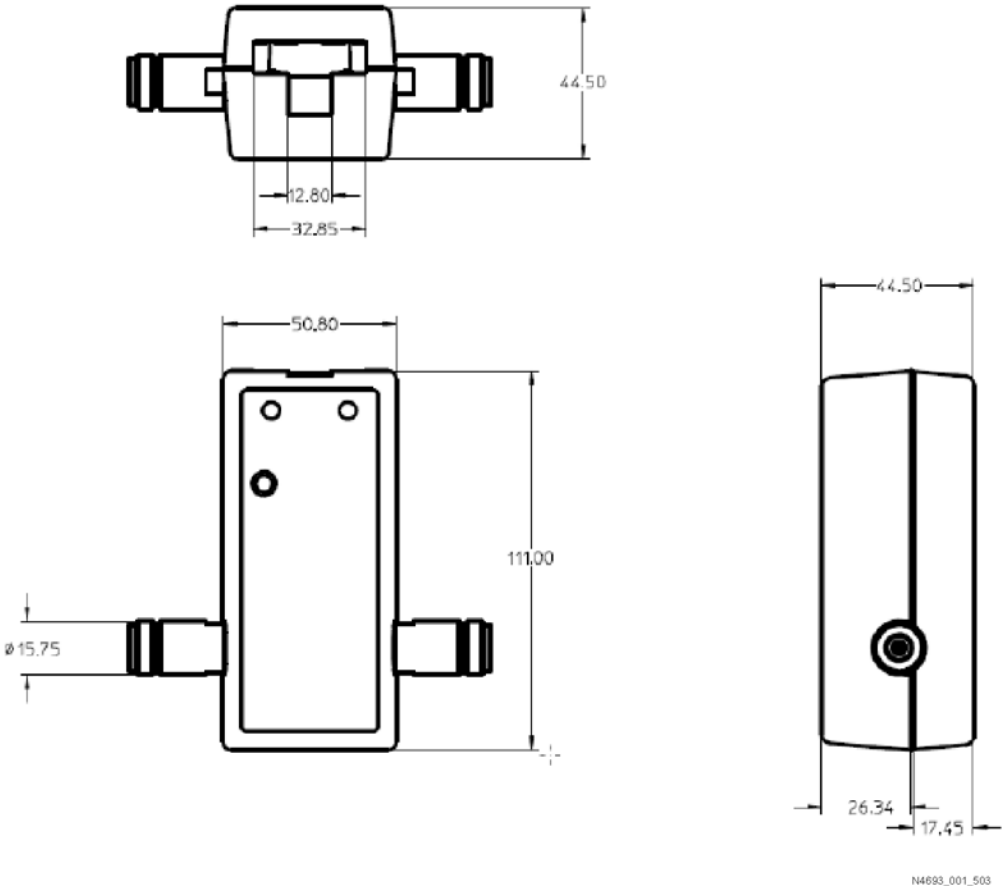
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Figure 5-4 N4431B Module (RF 4-Port)



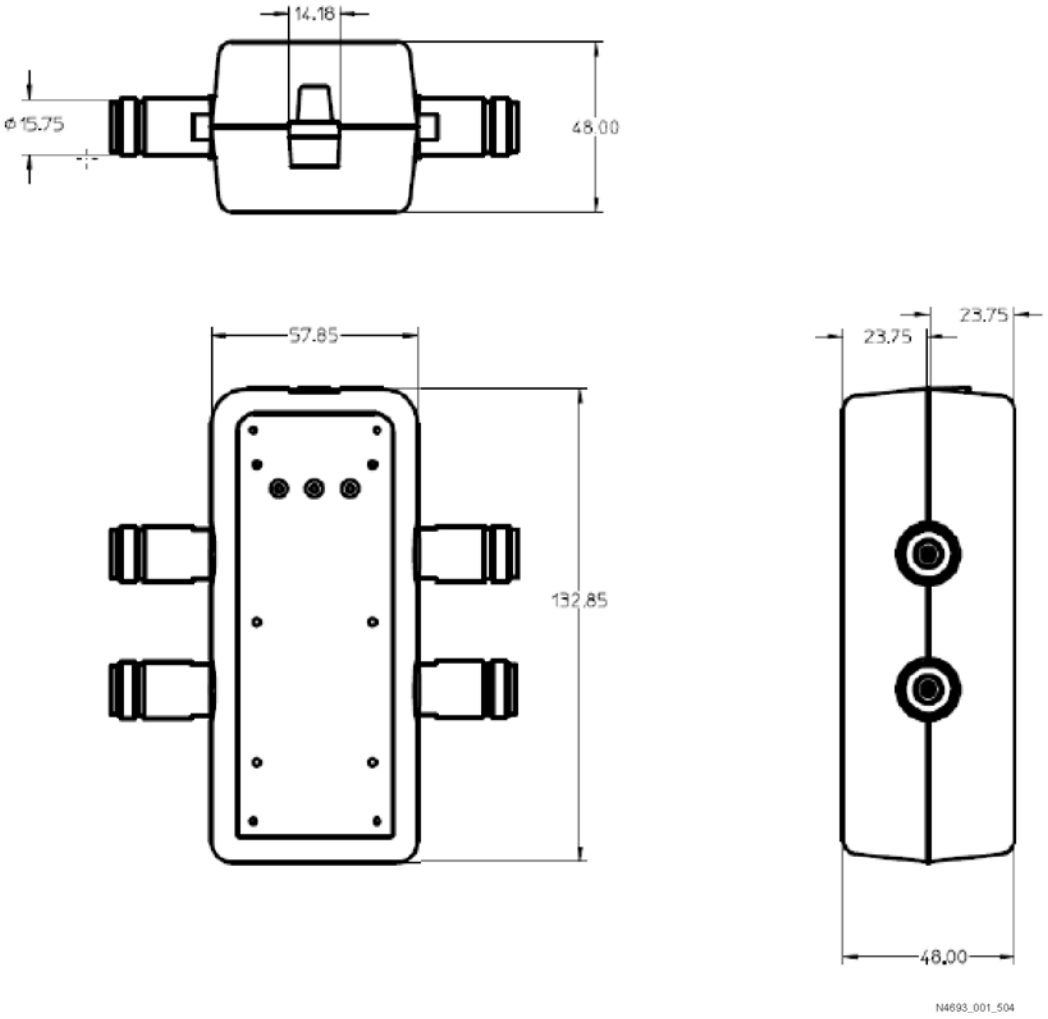
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Figure 5-5 N469xA/B/C Modules (Microwave 2-Port)



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Figure 5-6 N4432A and N4433A Modules (Microwave 4-Port)



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Measurement Uncertainty Calculator

This section provides information about determining the uncertainty of the measurements on your network analyzer.

Download the Vector Network Analyzer Uncertainty Calculator

You can download a program from Keysight that provides the measurement uncertainty associated with your vector network analyzer measurement and ECal module. Go to www.keysight.com/find/na_calculator and follow the instructions on the Web site to download the program.

The program uses your Keysight network analyzer model number, your ECal module model number, and electrical limits to calculate specific uncertainty charts for your network analyzer. The program is Microsoft Windows based and uses a Microsoft Excel spreadsheet to calculate, graph, and display uncertainty curves.

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6 Replaceable Parts

Description of This Chapter

The following tables contain the replaceable part numbers for ECal options and accessories. Refer to "Inspecting the ECal Kit" on page 1 for the contents of each kit. To order a part, note the description, Keysight part number, and the quantity desired. Telephone or send your order to Keysight Technologies. See "Contacting Keysight" on page 14.

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7 mm Modules and Accessories

Table 6-1

Description[a]	Qty	Part Number
Wrenches		
3/4 in, 135 N-cm (12 in-lb) torque wrench (supplied with 7 mm kits) 1/2 in to 9/16 in open-ended wrench (supplied with N4696B)	1 1	8710-1766 8710-1770
Protective End Caps		
DB25 multi-pin connector cap 7 mm connector cap 36-pin connector cap, ESD protected	as required as required as required	1252-1935 1401-0249 N4693-40002
Gages and Accessories		
7 mm pin depth gage and master	1	85050-80012
Other		
Electronic calibration module reference manual USB cable, 1.8 meter Storage box for the ECal module and accessories	1 1 1	N4693-90001 8121-0506 N4693-60042

a. See "Clarifying the Terminology of a Connector Interface" on page 1.

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Type-N (50 ohm) Modules and Accessories

Table 6-2

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
Type-N (50 Ω) -f- to -f- adapter Type-N (50 Ω) -m- to -m- adapter	1 1	85054-60037 85054-60038
Wrenches		
3/4 in, 135 N-cm (12 in-lb) torque wrench (supplied with type-N kits) 1/2 in to 9/16 in open-ended wrench (supplied with N4690B/C)	1 1	8710-1766 8710-1770
Protective End Caps		
DB-25 multi-pin connector cap Type-N -f- connector cap Type-N -m- connector cap 36-pin connector cap, ESD protected	as required as required as required as required	1252-1935 1401-0225 1401-0214 N4693-40002
Gages and Accessories		
Type-N pin depth gages (-m- and -f- gages and masters)	1 set	85054-60049
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable A to B 1.8 meter Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See “Clarifying the Terminology of a Connector Interface” on page 1.

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3.5 mm Modules and Accessories

Table 6-3

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
3.5 mm -f- to -f- adapter 3.5 mm -m- to -m- adapter	1 1	85052-60012 85052-60014
Wrenches		
20 mm, 90 N-cm (8 in-lb) torque wrench (supplied with all 3.5 mm kits) 5/16 in, 90 N-cm (8 in-lb) torque wrench (supplied with N4691B, N443xA/B, 85093C kits) Spanner wrench (supplied with N4691B) 1/2 in to 9/16 in open-ended wrench (supplied with N4691B)	1 1 1 1	8710-1764 8710-1765 08513-20014 8710-1770
Protective End Caps		
DB-25 multi-pin connector cap 3.5 mm connector cap (for module) 3.5 mm -f- connector cap (for adapter) 3.5 mm -m- connector cap (for adapter) 36-pin connector cap, ESD protected	as required as required as required as required as required	1252-1935 1401-0214 1401-0202 1401-0208 N4693-40002
Gages and Accessories		
3.5 mm -f- pin-depth gage[b] 3.5 mm -m- pin-depth gage[b]	1 1	11752-60105 11752-60106
Other		
Electronic calibration module reference guide Connector care quick reference card (part of reference manual) USB cable, 1.8 meter Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See "Clarifying the Terminology of a Connector Interface" on page 1.
b. A 3.5 mm gage is capable of measuring 3.5 mm and 2.92 mm connectors.

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7-16 Modules and Accessories

Table 6-4

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
7-16 -f- to -f- adapter 7-16 -m- to -m- adapter	1 1	11906-80016 11906-80015
Wrenches		
1-1/16 in, 226 N-cm (20 in-lb) torque wrench (supplied with kit) 15/16 in open-ended wrench (supplied with kit)	1 1	8710-2175 8710-2174
Protective End Caps		
DB-25 multi-pin connector cap 7-16 -m- connector cap 7-16 -f- connector cap	as required as required as required	1252-1935 1401-0417 1401-0418
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB Cable, 1.8 meter Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See "Clarifying the Terminology of a Connector Interface" on page 1.

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2.92 mm Modules and Accessories

Table 6-5

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
2.92 mm female to female adapter 2.92 mm male to male adapter	1 1	N4692-60022 N4692-60021
Wrenches		
20 mm, 90 N-cm (8 in-lb) torque wrench (supplied with kit) 5/16 in, 90 N-cm (8 in-lb) torque wrench (supplied with kit) Spanner wrench (supplied with kit) 1/2 in to 9/16 in open-ended wrench (supplied with kit)	1 1 1 1	8710-1764 8710-1765 08513-20014 8710-1770
Protective End Caps		
2.92 mm connector cap (for module) 2.92 mm female connector cap (for adapter) 2.92 mm male connector cap (for adapter) 36-pin connector cap, ESD protected	as required as required as required as required	1401-0214 1401-0202 1401-0208 N4693-40002
Gages		
3.5 mm female pin-depth gage[b] 3.5 mm male pin-depth gage[b]	1 1	11752-60105 11752-60106
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable, 1.8 meters Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See “Clarifying the Terminology of a Connector Interface” on page 1.
b. A 3.5 mm gage is capable of measuring 3.5 mm and 2.92 mm connectors.

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2.4 mm Modules and Accessories

Table 6-6

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
2.4 mm female to female adapter 2.4 mm male to male adapter	1 1	85056-60006 85056-60005
Wrenches		
20 mm, 90 N-cm (8 in-lb) torque wrench (supplied with kit) 5/16 in, 90 N-cm (8 in-lb) torque wrench (supplied with kit) 1/2 in to 9/16 in open-ended wrench (supplied with kit) Spanner wrench (supplied with kit)	1 1 1 1	8710-1764 8710-1765 8710-1770 08513-20014
Protective End Caps		
2.4 mm connector cap (for module) 2.4 mm female connector cap (for adapter) 2.4 mm male connector cap (for adapter) 36-pin connector cap, ESD protected	as required as required as required as required	1401-0214 1401-0095 1401-0208 N4693-40002
Gages		
2.4 mm female pin-depth gage[b] 2.4 mm male pin-depth gage[b]	1 1	11752-60107 11752-60108
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable, 1.8 meters Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See “Clarifying the Terminology of a Connector Interface” on page 1.
b. A 2.4 mm gage is capable of measuring 2.4 mm and 1.85 mm connectors.

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1.85 mm Modules and Accessories

Table 6-7

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
1.85 mm female to female adapter 1.85 mm male to male adapter	1 1	85058-60114 85058-60113
Wrenches		
20 mm, 90 N-cm (8 in-lb) torque wrench (supplied with kit) 5/16 in, 90 N-cm (8 in-lb) torque wrench (supplied with kit) Spanner wrench (supplied with kit) 1/2 in to 9/16 in open-ended wrench (supplied with kit)	1 1 1 1	8710-1764 8710-1765 08513-20014 8710-1770
Protective End Caps		
1.85 mm connector cap (for module) 1.85 mm female connector cap (for adapter) 1.85 mm male connector cap (for adapter) 36-pin connector cap, ESD protected	as required as required as required as required	1401-0214 1401-0202 1401-0208 N4693-40002
Gages		
2.4 mm female pin-depth gage [b] 2.4 mm male pin-depth gage[b]	1 1	11752-60107 11752-60108
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable, 1.8 meters Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See "Clarifying the Terminology of a Connector Interface" on page 1.
b. A 2.4 mm gage is capable of measuring 2.4 mm and 1.85 mm connectors.

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Type-N (75 ohm) Modules and Accessories

Table 6-8

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
Type-N (75 Ω) female to female adapter Type-N (75 Ω) male to male adapter	1 1	85036-60014 85036-60013
Wrenches		
3/4 in, 135 N-cm (12 in-lb) torque wrench 1/2 in to 9/16 in open-ended wrench	1 1	8710-1766 8710-1770
Protective End Caps		
DB-25 multi-pin connector cap Type-N male connector cap Type-N female connector cap	as required as required as required	1252-1935 1401-0248 1401-0247
Gages		
Type-N (75 ohm) mm pin depth gages (male and female gages and masters)	1 set	85036B Option K01
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable, 1.8 meters Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See “Clarifying the Terminology of a Connector Interface” on page 1.

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Type-F Modules and Accessories

Table 6-9

Description[a]	Qty	Part Number
Adapters (added with Option 00A)		
Type-F female to female adapter Type-F male to male adapter	1 1	85039-60002 85039-60006
Wrenches		
Type-F wrench (supplied with kit)	1	8710-1841
Protective End Caps		
DB-25 multi-pin connector cap Type-F male connector cap Type-F female connector cap	as required as required as required	1252-1935 1401-0297 1401-0296
Other		
Electronic calibration module reference manual Connector care quick reference card (part of reference manual) USB cable, 1.8 meters Storage box for the ECal module and accessories	1 1 1 1	N4693-90001 08510-90360 8121-0506 N4693-60042

a. See “Clarifying the Terminology of a Connector Interface” on page 1.

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Other ECal Accessories

Table 6-10

Description	Qty	Part Number
Cleaning Supplies		
Compressed air (235 ml)	1	8500-6659
Anhydrous isopropyl alcohol (>92% pure)[a]	--	--
Cleaning swabs	100	9301-1243
Lint-free cleaning cloth	150	9310-4242
ESD Supplies		
Grounding wrist strap	1	9300-1367
5 ft Wrist-strap to table-mat grounding cord	1	9300-0980
2 x 4 ft conductive table mat with 15 ft ground wire	1	9300-0797
ESD heel strap	1	9300-1308
USB Accessories		
USB 4-port hub	1	N4689A
Module Accessories		
Rubber foot	1	85060-40001
Storage box for the ECal module and accessories	1	N4693-60042

a. Keysight can no longer safely ship isopropyl alcohol, so customers should purchase it locally.

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Index

Numerics

85060A (discontinued)
  connector type, 10
  frequency range, 10
85060B (discontinued)
  connector type, 10
  frequency range, 10
85062A (discontinued)
  connector type, 10
  frequency range, 10
85062B (discontinued)
  connector type, 10
  frequency range, 10
85064A (discontinued)
  connector type, 10
  frequency range, 10
85064B (discontinued)
  connector type, 10
  frequency range, 10
85091A (discontinued)
  connector type, 10
  frequency range, 10
85091B (discontinued)
  connector type, 10
  frequency range, 10
85091C
  characteristic performance, 3
  connector type, 4
  frequency range, 4
  replaceable parts, 2
85092A (discontinued)
  connector type, 10
  frequency range, 10
85092B (discontinued)
  connector type, 10
  frequency range, 10
85092C
  characteristic performance, 3
  connector type, 4
  frequency range, 4
  replaceable parts, 3
85093A (discontinued)
  connector type, 10
  frequency range, 10
85093B (discontinued)
  connector type, 10
  frequency range, 10
85093C
  characteristic performance, 3
  connector type, 4
  frequency range, 4
  replaceable parts, 4
85096A (discontinued)
  connector type, 10
  frequency range, 10
85096B (discontinued)
  connector type, 10
  frequency range, 10
85096C
  characteristic performance, 3
  connector type, 4
  frequency range, 4
  replaceable parts, 9
85098A (discontinued)
  connector type, 10
  frequency range, 10
85098B (discontinued)
  connector type, 10
  frequency range, 10
85098C
  characteristic performance, 4
  connector type, 4
  frequency range, 4
  replaceable parts, 5
85099A (discontinued)
  connector type, 10
  frequency range, 10
85099B (discontinued)
  connector type, 10
  frequency range, 10
85099C
  characteristic performance, 5
  connector type, 4
  frequency range, 4
  replaceable parts, 10

A

accuracy of ECal vs. mechanical cal, 2
adapter cable
  connection to module, 14
  part number, 11
adapter removal calibration, 4
alcohol, cleaning connectors, 6

B

barometric pressure, 2
box, ECal storage, 22

C

calibration
  adapter removal, 4
  adjustments, 1
  advanced settings, 2
  frequency, 3
  isolation, 2
  non-insertable device, 4
  perform a calibration, 6
  setting up, 1
  types available, 2
  unknown thru, 4
  user-characterization, 4
  when to perform, 3
  why validate accuracy, 7
center conductor
  pin depth, 12
characteristic performance
  85091C, 3
  85092C, 3
  85093C, 3
  85096C, 3
  85098C, 4
  85099C, 5
  N4431B, 6, 7
  N4432A, 8
  N4433A, 8
  N4690B/C, 9
  N4691B, 9
  N4692A, 10
  N4693A, 10
  N4694A, 11
  N4696B, 11
characteristics
  connector, type-N, 13
  mechanical, 12
cleaning
  connectors, 6
cleaning supplies, 11
collet, 8
compatible network analyzers, 13
compressed air or nitrogen, 6
confidence check, 7

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connecting ECal module, 12
connection
  ENA analyzer, 12
  to interface, 14
  to USB port, 12
  VNA analyzer, 14
connections, 16, 17, 20
  1.85 mm, 16
  2.4 mm, 16
  2.92 mm, 16
  3.5 mm, 16
  7 mm, 16
  type-F, 16
  type-N, 16
connector
  cleaning, 6
    fixed connectors, 8
    precision 7 mm, 8
  gaging, 9, 10, 15
  pin depth
    1.85 mm, 17
    2.4 mm, 17
    2.92 mm, 16
    3.5 mm, 16
    7 mm, 15, 16
  slotted, 5
  visual inspection, 3
  wear, 3
connector gage
  accuracy, 9
  handling, 15
  master, 15
  zeroing, 14
connector wear
  causes, 3
contacting Keysight, 14
container for storage, 21

D

damaged connectors, 3
declaration of conformity, 19
defective connectors, 3
definitions
  specifications, 1
depth gage
  7mm part number, 2
  Type-N part number, 3
device
  connecting, 16
  disconnecting, 20
  gaging, 15
  handling and storage, 21
  specifications
    traceability, 15
  visual inspection, 3
dimensions, modules, 20
discontinued models, 10

E

ECal
  adapter removal, 4
  confidence check, 4
  connecting and
    disconnecting, 12
  ENA compatibility, 13
  ENA connections, 12
  factory characterization, 4
  inspecting kit, 1
  network analyzer
    compatibility, 13
  network analyzer
    connections, 12
  perform a calibration, 6
  PNA compatibility, 13
  PNA connections, 12
  setting up, 12
  storage box, 21
  unknown thru, 4
  user-characterization, 4
  VNA compatibility, 13
  VNA connections, 12
ECal kit serial number, 1
ECal kit storage box, 22
ECal module
  overview, 1
ECal serial number, 1
ECal vs. mechanical cal, 2
electrostatic discharge
    (ESD), 1
ENA analyzer
  connection to module, 12
environmental specifications, 2
ESD protection, 1
ESD supplies, 11

F

female connectors
  inspection of, 5
frequency of calibration, 3

G

gage
  handling, 15
  zeroing, 14
gage master, using, 9
gaging
  connectors, 9, 10
  procedure, 14

H

handling
  of devices, 21
how often to calibrate, 3
humidity, 2

I

input power limits, 11
inspecting ECal on arrival, 1
inspection
  damage, 3
  defects, 3
  female connectors, 5
  mating plane, 3
  visual, 3
instrument markings, 18
interface kit, 11
isopropyl alcohol, cleaning, 6

K

Keysight Technologies
  contacting, 14
  returning an ECal, 14
Keysight, contacting, 14
kit contents
  85091C, 4
  85092C, 4
  85093C, 4
  85096C, 4
  85098C, 4
  85099C, 4
  microwave four-port, 8
  microwave two-port, 6
  N4431B Opt. 010, 5
  N4431B Opt. 020, 5
  N4432A Opt. 020, 8
  N4433A Opt. 010, 8
  N4691B, 6
  N4692A, 6
  N4693A, 6
  N4694A, 6
  N4696B, 6
  RF four-port, 5
  RF two-port, 4
kit serial number, 1
kit storage box, 22

L

line drawings of modules, 20

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M

maintenance, 1
making connections, 16
manual overview, 1
markings, instrument, 18
mating plane surfaces
  inspection, 3
measurements, modules, 20
mechanical cal vs. ECal, 2
mechanical characteristics, 12, 18
  center conductor protrusion, 12
  microwave, 18
  RF, 18
  type-N, critical, 13
mechanical dimensions
  8509x modules, 20
  N4431B module, 21
  N4432A & N4433A modules, 23
  N469xA/B modules, 22
models
  discontinued, 10
module serial number, 1
modules
  mechanical dimensions, 20
  microwave 2-port, 7
  microwave 4-port, 9
  performance verification, 14
  RF 2-port, 4
  RF 4-port, 6
modules, dimensions, 20

N

N4431A (discontinued)
  connector type, 10
  frequency range, 10
N4431B
  characteristic performance, 6, 7
  connector type, 6
  frequency range, 6
  mixed connector options, 6
  replaceable parts, 3, 4
N4432A/3A
  characteristic performance, 8
  connector type, 9
  frequency range, 9
  mixed connector options, 9
N4690A (discontinued)
  connector type, 10
  frequency range, 10
N4690B/C
  characteristic performance, 9
  connector type, 8
  frequency range, 8, 6
  replaceable parts, 3
N4691A (discontinued)
  connector type, 10
  frequency range, 10
N4691B
  characteristic performance, 9
  connector type, 7
  frequency range, 7
  replaceable parts, 4
N4692A
  characteristic performance, 10
  connector type, 7
  frequency range, 7
  replaceable parts, 6
N4693A
  characteristic performance, 10
  connector type, 7
  frequency range, 7
  replaceable parts, 7
N4694A
  characteristic performance, 11
  connector type, 7
  frequency range, 7
  replaceable parts, 8
N4696B, 9
  characteristic performance, 11
  connector type, 7
  frequency range, 7
  replaceable parts, 2
National Institute of Standards and Technology (NIST), 15
nitrogen, cleaning connectors, 6
non-insertable calibration, 4

O

on arrival
  inspecting, 1
  recording serial numbers, 1
operating
  connector care, 9
  ESD precautions, 9
  handling, 11
  input level, 11
  operating temperature, 11
  precautions, 9
operating temperature
  accuracy enhancement, 2
option 150, 22
overview
  ECal module, 1

P

physical dimensions of modules, 20
pin depth characteristics
  1.85 mm, 17
  2.4 mm, 17
  2.92 mm, 16
  3.5 mm, 16
  7 mm, 16
  type-N, 15
pin depth information, 12
PNA analyzer
  connection to module, 12
prerequisite knowledge, 10
procedure, gaging, 14
protrusion definition, 12

R

reading connector gage, 10
recertification
  how often, 15
  how to order, 15
  verification, 14
  where to send, 15
recession definition, 12
recording serial numbers, 1
relative humidity, 2
replaceable parts
  1.85 mm, 8
  2.4 mm, 7
  2.92 mm, 6
  3.5 mm, 4
  7 mm, 2
  7 mm depth gage, 2
  7-16, 5
  85091C, 2
  85092C, 3
  85093C, 4
  85096C, 9
  85098C, 5
  85099C, 10
  N4431B, 3, 4
  N4690B/C, 3
  N4691B, 4
  N4692A, 6
  N4693A, 7
  N4694A, 8
  N4696B, 2
  Type-F, 10

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Type-N 50 ohm, 3
Type-N 75 ohm, 9
Type-N depth gage, 3
returning an ECal to Keysight, 14
rubber foot, 11

S

safety and regulatory information, 17
separating connections, 20
serial numbers, 1
service
recertification, 14
setting up calibration, 1
7 mm depth gage
part number, 2
specifications
download descriptions, 24
environmental, 2
terminology and definitions, 1
torque wrench, 17
traceability, 15
specifications and characteristics
accuracy-enhanced temperature range, 2
connector pin depth values, 1
error-corrected temperature range, 1
measurement calibration, 1
operating temperature range, 1
standards
National Institute of Standards and Technology (NIST), 15
static discharge, 1
storage
box, 22
of devices, 21
supplemental characteristics
mechanical, 18

T

temperature
operating, 2
terminology
specifications, 1
torque wrench
connector types, 20
part numbers, 20
selection, 20
settings, 20
torque wrench connections
microwave, 17
RF, 17
traceability
of device specifications, 15
type-N depth gage
part number, 3

U

uncertainty calculator
web address to download, 24
unknown thru, calibration, 4
USB Hub, 11
user-characterization, 4

V

validate accuracy, 7
verification
confidence check, 7
measure known standards, 7
visual inspection, 3
VNA analyzer
connection to module, 14

W

web address
download uncertainty calculator, 24
when to calibrate, 3

Z

zeroing, connector gage, 14

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