



# CERTIFICATE OF ACCREDITATION

**The ANSI National Accreditation Board**

Hereby attests that

**Keysight Technologies Singapore (Sales) Pte Ltd**  
**1 Yishun Avenue 7**  
**Singapore 768923**

Fulfils the requirements of

**ISO/IEC 17025:2017**

and national standards

**ANSI/NCSL Z540-1-1994 (R2002) AND**  
**ANSI/NCSL Z540.3-2006 (R2013)**

In the field of

**CALIBRATION**

This certificate is valid only when accompanied by a current scope of accreditation document.  
The current scope of accreditation can be verified at [www.anab.org](http://www.anab.org).

Jason Stine, Vice President

Expiry Date: 05 December 2024

Certificate Number: AC-3156



This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017.  
This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory  
quality management system (refer to joint ISO-ILAC-IAF Communiqué dated April 2017).



## SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

AND

**ANSI/NCSL Z540-1-1994 (R2002)**  
**ANSI/NCSL Z540.3-2006 (R2013)**

### **Keysight Technologies Singapore (Sales) Pte Ltd**

1 Yishun Avenue 7  
Singapore 768923

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### **CALIBRATION**

Valid to: **December 5, 2024**

Certificate Number: **AC-3156**

#### **Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	(0 to 220) mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 µV/V + 0.39 µV 4.7 µV/V + 0.62 µV 3.1 µV/V + 2.3 µV 3.1 µV/V + 4.2 µV 4.7 µV/V + 39 µV 6.2 µV/V + 0.39 mV	Fluke 57x0A Multi Product Calibrator
DC Voltage – Source Fixed Values <sup>1</sup>	100 mV 1 V 10 V 100 V 1 000 V	0.27 µV 1.5 µV 11 µV 0.15 mV 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure <sup>1</sup>	(0 to 100) mV (0.1 to 1) V (1 to 12) V (12 to 120) V (120 to 1 050) V	6.4 µV/V + 0.41 µV 5.9 µV/V + 0.41 µV 5.3 µV/V + 0.91 µV 7.5 µV/V + 41 µV 7.5 µV/V + 0.14 mV	Keysight 3458A Multimeter
DC Voltage – Measure Differential <sup>1</sup>	(0.01 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.54 µV/V + 0.054 µV 0.32 µV/V + 0.11 µV 0.054 µV/V + 0.54 µV 0.54 µV/V + 0.011 mV 1.6 µV/V + 0.054 mV	Keysight 3458A Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup>	Up to 2.2 mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (2.2 to 22) mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (22 to 220) mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (0.22 to 2.2) V (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	230 µV/V + 3.9 µV 89 µV/V + 3.9 µV 77 µV/V + 3.9 µV 190 µV/V + 3.9 µV 460 µV/V + 4.7 µV 1 mV/V + 9.3 µV 1.3 mV/V + 19 µV 2.6 mV/V + 19 µV  230 µV/V + 3.9 µV 89 µV/V + 3.9 µV 77 µV/V + 3.9 µV 190 µV/V + 3.9 µV 470 µV/V + 4.7 µV 1 mV/V + 9.3 µV 1.3 mV/V + 19 µV 2.6 mV/V + 19 µV  230 µV/V + 12 µV 89 µV/V + 6.2 µV 54 µV/V + 6.2 µV 120 µV/V + 6.2 µV 310 µV/V + 16 µV 620 µV/V + 19 µV 1.3 mV/V + 23 µV 2.6 mV/V + 47 µV  230 µV/V + 39 µV 85 µV/V + 16 µV 37 µV/V + 7.8 µV 62 µV/V + 9.3 µV 78 µV/V + 31 µV 310 µV/V + 78 µV 930 µV/V + 190 µV 1.6 mV/V + 310 µV	Fluke 5730A Multi Product Calibrator and Fluke 5725A Amplifier

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup>	(2.2 to 22) V (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (22 to 220) V (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (22 to 220) V (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (220 to 250) V (15 to 40) Hz (220 to 1 100) V (40 to 50) Hz 50 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	230 $\mu$ V/V + 390 $\mu$ V 85 $\mu$ V/V + 160 $\mu$ V 37 $\mu$ V/V + 54 $\mu$ V 62 $\mu$ V/V + 93 $\mu$ V 78 $\mu$ V/V + 190 $\mu$ V 230 $\mu$ V/V + 620 $\mu$ V 930 $\mu$ V/V + 1.9 mV 1.4 mV/V + 3.1 mV  230 $\mu$ V/V + 3.9 mV 85 $\mu$ V/V + 1.6 mV 50 $\mu$ V/V + 0.54 mV 78 $\mu$ V/V + 0.93 mV 140 $\mu$ V/V + 2.3 mV  850 $\mu$ V/V + 16 mV 4.2 mV/V + 39 mV 7.8 mV/V + 78 mV  280 $\mu$ V/V + 16 mV  70 $\mu$ V/V + 3.1 mV 66 $\mu$ V/V + 3.1 mV 130 $\mu$ V/V + 4.7 mV 470 $\mu$ V/V + 8.5 mV  470 $\mu$ V/V + 8.5 mV 1.8 mV/V + 35 mV	Fluke 5730A Multi Product Calibrator and Fluke 5725A Amplifier
AC Voltage - Source Fixed Values, Fixed Frequencies <sup>1</sup>	0.01 V  1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz	0.87 $\mu$ V 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 0.14 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment															
AC Voltage - Source Fixed Values, Fixed Frequencies <sup>1</sup>	<table border="1"> <tr><td>0.1 V</td><td>1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz</td><td>4.6 µV 6.9 µV 36 µV 52 µV 0.17 mV 0.67 mV 0.69 mV 2.3 mV</td><td></td></tr> <tr><td>1 V</td><td>1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz</td><td>26 µV 32 µV 59 µV 0.17 mV 0.41 µV 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV</td><td></td></tr> <tr><td>3V</td><td>100 kHz (2, 4, 8) MHz 10 MHz</td><td>0.42 mV 21 mV 75 mV</td><td>Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter</td></tr> <tr><td>10 V</td><td>10 Hz 20 Hz 40 Hz 200 Hz 500 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz</td><td>0.48 mV 0.27 mV 0.23 mV 0.46 mV 0.45 mV 0.26 mV 0.27 mV 0.32 mV 0.53 mV 1.1 mV 2.6 mV 6.3 mV 12 mV</td><td></td></tr> </table>	0.1 V	1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	4.6 µV 6.9 µV 36 µV 52 µV 0.17 mV 0.67 mV 0.69 mV 2.3 mV		1 V	1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz	26 µV 32 µV 59 µV 0.17 mV 0.41 µV 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV		3V	100 kHz (2, 4, 8) MHz 10 MHz	0.42 mV 21 mV 75 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter	10 V	10 Hz 20 Hz 40 Hz 200 Hz 500 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz	0.48 mV 0.27 mV 0.23 mV 0.46 mV 0.45 mV 0.26 mV 0.27 mV 0.32 mV 0.53 mV 1.1 mV 2.6 mV 6.3 mV 12 mV		
0.1 V	1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	4.6 µV 6.9 µV 36 µV 52 µV 0.17 mV 0.67 mV 0.69 mV 2.3 mV																
1 V	1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz	26 µV 32 µV 59 µV 0.17 mV 0.41 µV 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV																
3V	100 kHz (2, 4, 8) MHz 10 MHz	0.42 mV 21 mV 75 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter															
10 V	10 Hz 20 Hz 40 Hz 200 Hz 500 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz	0.48 mV 0.27 mV 0.23 mV 0.46 mV 0.45 mV 0.26 mV 0.27 mV 0.32 mV 0.53 mV 1.1 mV 2.6 mV 6.3 mV 12 mV																

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source Fixed Values, Fixed Frequencies <sup>1</sup>	100 V 1 kHz 20 kHz 50 kHz 100 kHz  700 V 1 kHz	4 mV 8.8 mV 7.9 mV 16 mV  75 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
AC Voltage - Measure <sup>1</sup>	Up to 10 mV (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 4) MHz (4 to 8) MHz (10 to 120) mV (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz (0.12 to 1.2) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz	0.35 mV/V + 3.4 µV 0.23 mV/V + 1.3 µV 0.34 mV/V + 1.3 µV 1.1 mV/V + 1.3 µV 5.7 mV/V + 1.2 µV 46 mV/V + 2.3 µV 14 mV/V + 5.8 µV 81 mV/V + 8.1 µV 230 mV/V + 9.2 µV  83 µV/V + 4.6 µV 83 µV/V + 2.3 µV 0.16 mV/V + 2.3 µV 0.34 mV/V + 2.3 µV 0.92 mV/V + 2.3 µV 3.4 mV/V + 12 µV 11 mV/V + 12 µV 17 mV/V + 12 µV 46 mV/V + 81 µV 46 mV/V + 92 µV 170 mV/V + 120 µV  83 µV/V + 46 µV 83 µV/V + 23 µV 0.16 mV/V + 23 µV 0.34 mV/V + 23 µV 0.92 mV/V + 23 µV 3.4 mV/V + 0.11 mV 11 mV/V + 0.12 mV 17 mV/V + 0.12 mV 46 mV/V + 0.81 mV 46 mV/V + 0.92 mV 170 mV/V + 1.2 mV	Keysight 3458A Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure <sup>1</sup>	(1.2 to 12) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz  (12 to 120) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz  (120 to 700) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	83 µV/V + 0.46 mV 83 µV/V + 0.23 mV 0.16 mV/V + 0.23 mV 0.34 mV/V + 0.23 mV 0.92 mV/V + 0.23 mV 3.4 mV/V + 1.2 mV 11 mV/V + 1.2 mV 17 mV/V + 1.2 mV 46 mV/V + 8.1 mV 46 mV/V + 9.2 mV 170 mV/V + 12 mV  0.23 mV/V + 4.6 mV 0.23 mV/V + 2.3 mV 0.23 mV/V + 2.3 mV 0.4 mV/V + 2.3 mV 1.4 mV/V + 2.3 mV 4.6 mV/V + 11 mV 17 mV/V + 11 mV  0.46 mV/V + 46 mV 0.46 mV/V + 23 mV 0.7 mV/V + 23 mV 1.4 mV/V + 23 mV 3.5 mV/V + 23 mV	Keysight 3458A Multimeter
DC Current - Source <sup>1</sup>	(0 to 220) µA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 100) mA (100 to 220) mA (0.22 to 1) A (1 to 2.2) A (2.2 to 11) A	39 µA/A + 5.4 nA 31 µA/A + 6.3 nA 31 µA/A + 39 nA 39 µA/A + 0.62 µA 52 µA/A - 0.74 µA 70 µA/A + 12 µA 150 µA/A - 92 µA 280 µA/A +370 µA	Fluke 5730A Multi Product Calibrator and Fluke 5725A Amplifier
DC Current – Source Fixed <sup>1</sup>	100 µA 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 µA 36 µA	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Measure-Differential <sup>1</sup>	(10 to 100) µA 100 µA to 1 mA (1 to 10) mA (10 to 100) mA	22 µA/A + 0.86 nA 22 µA/A + 5.4 nA 22 µA/A + 0.054 µA 38 µA/A + 0.54 µA	Keysight 3458A Multimeter
DC Current – Measure-Differential <sup>1</sup>	100 mA to 1.0 A (1 to 10) A (10 to 15) A (15 to 100) A (100 to 300) A	0.54 µA/A + 0.54 µA 0.32 µA/A + 1.1 µA 0.054 µA/A + 5.4 µA 0.32 µA/A + 11 µA 0.32 µA/A + 0.11 mA	Keysight 3458A Multimeter Guildline 9230/9230A Current Shunt
AC Current - Source <sup>1</sup>	Up to 220 µA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 µA/A + 16 nA 160 µA/A + 9.3 nA 93 µA/A + 7.8 nA 270 µA/A + 12 nA 1 mA/A + 62 nA	Fluke 57x0A Multi Product Calibrator
AC Current - Source <sup>1</sup>	(0.22 to 2.2) mA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 22) mA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (22 to 220) mA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 µA/A + 39 nA 160 µA/A + 31 nA 93 µA/A + 31 nA 190 µA/A + 100 nA 1 mA/A + 620 nA  230 µA/A + 390 nA 160 µA/A + 310 nA 93 µA/A + 310 nA 190 µA/A + 540 nA 1 mA/A + 4.7 µA  230 µA/A + 3.9 µA 160 µA/A + 3.1 µA 93 µA/A + 2.3 µA 190 µA/A + 3.1 µA 1 mA/A + 9.3 µA  230 µA/A + 31 µA 390 µA/A + 78 µA 6.2 mA/A + 160 µA  360 µA/A + 130 µA 740 µA/A + 290 µA 2.8 mA/A + 580 µA	Fluke 57x0A Multi Product Calibrator

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source Fixed Values <sup>1</sup>	1 kHz 10 µA 100 µA 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 µA 8.7 µA 0.2 mA	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
AC Current - Measure <sup>1</sup>	Up to 120 µA 10 Hz to 20 Hz 20 Hz to 45 Hz 45 Hz to 5 kHz	4.6 mA/A + 34 nA 1.7 mA/A + 34 nA 0.69 mA/A + 34 nA	Keysight 3458A Multimeter
AC Current - Measure <sup>1</sup>	(0.12 to 1.2) mA 10 Hz to 20 Hz 20 Hz to 45 Hz 45 Hz to 100 Hz 100 Hz to 5 kHz (1.2 to 12) mA 10 Hz to 20 Hz 20 Hz to 45 Hz 45 Hz to 100 Hz 100 Hz to 5 kHz (12 to 120) mA 10 Hz to 20 Hz 20 Hz to 45 Hz 45 Hz to 100 Hz 100 Hz to 5 kHz (0.12 to 1.05) A 10 Hz to 20 Hz 20 Hz to 45 Hz 45 Hz to 100 Hz 100 Hz to 5 kHz	4.6 mA/A + 0.23 µA 1.7 mA/A + 0.23 µA 0.69 mA/A + 0.23 µA 0.35 mA/A + 0.23 µA  4.6 mA/A + 2.3 µA 1.7 mA/A + 2.3 µA 0.69 mA/A + 2.3 µA 0.35 mA/A + 2.3 µA  4.6 mA/A + 23 µA 1.7 mA/A + 23 µA 0.69 mA/A + 23 µA 0.35 mA/A + 23 µA  4.6 mA/A + 0.23 mA 1.8 mA/A + 0.23 mA 0.93 mA/A + 0.23 mA 1.1 mA/A + 0.23 mA	Keysight 3458A Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Resistance - Source <sup>1</sup>	1 Ω 1.9 Ω 10 Ω 19 Ω 100 Ω 190 Ω 1 kΩ 1.9 kΩ 10 kΩ 19 kΩ 100 kΩ 190 kΩ 1 MΩ 1.9 MΩ 10 MΩ 19 MΩ 100 MΩ	86 μΩ/Ω 85 μΩ/Ω 21 μΩ/Ω 21 μΩ/Ω 9.3 μΩ/Ω 9.3 μΩ/Ω 6.2 μΩ/Ω 6.2 μΩ/Ω 6.2 μΩ/Ω 7.8 μΩ/Ω 9.3 μΩ/Ω 12 μΩ/Ω 16 μΩ/Ω 36 μΩ/Ω 43 μΩ/Ω 93 μΩ/Ω	Fluke 5730A Multi Product Calibrator
Resistance – Source Fixed Points <sup>1</sup>	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 0.42 mΩ 1.8 mΩ 17 mΩ 0.19 Ω 4.6 Ω 0.18 kΩ 19 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
Resistance – Source <sup>1</sup>	1 Ω 10 kΩ	12 μΩ 2.4 μΩ	Fluke742A 10K Ohm standard Resistor & 9330 Guildline 1 Ohm Resistor
DC Resistance - Measure <sup>1</sup>	(0 to 12) Ω (12 to 100) Ω (0.1 to 1.2) kΩ (1.2 to 12) kΩ (12 to 120) kΩ (0.12 to 1.2) MΩ (1.2 to 12) MΩ (12 to 120) MΩ (0.12 to 1.2) GΩ	20 μΩ/Ω + 79 μΩ 15 μΩ/Ω + 0.79 mΩ 13 μΩ/Ω + 0.79 mΩ 13 μΩ/Ω + 7.8 mΩ 13 μΩ/Ω + 78 mΩ 17 μΩ/Ω + 2.6 Ω 61 μΩ/Ω + 0.12 kΩ 0.58 mΩ/Ω + 3.6 kΩ 5.7 mΩ/Ω + 0.26 MΩ	Keysight 3458A Multimeter

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current - Measure <sup>1</sup>	0 to 100) nA (0.1 to 1.2) $\mu$ A (1.2 to 12) $\mu$ A (12 to 120) $\mu$ A (0.12 to 1.2) mA (1.2 to 12) mA (12 to 120) mA (0.12 to 1.05) A	41 $\mu$ A/A + 63 pA 23 $\mu$ A/A + 63 pA 23 $\mu$ A/A + 0.13 nA 23 $\mu$ A/A + 1.1 nA 23 $\mu$ A/A + 7.4 nA 23 $\mu$ A/A + 74 nA 40 $\mu$ A/A + 0.74 $\mu$ A 0.12 mA/A + 13 $\mu$ A	Keysight 3458A Multimeter
DC Current - Measure <sup>1</sup>	(0.10 to 1.0) A (1 to < 30) A (30 to < 120) A (120 to 300) A	72 $\mu$ A/A + 1.3 $\mu$ A 73 $\mu$ A/A + 0.5 $\mu$ A 47 $\mu$ A/A + 0.1 mA 70 $\mu$ A/A - 2.8 mA	Keysight 3458A Multimeter with Guildline shunt 9230
DC Current - Measure <sup>1</sup>	(1 to 11.5) $\mu$ A (0.1 to 1.15) $\mu$ A 10 nA to 115 nA 1 nA to 11.5 nA 1 nA to 11.5 nA 0.1 nA to 1.15 nA 10 pA to 115 pA 1 pA to 115 pA 0.1 pA to 1.15 pA	13 $\mu$ A/A + 28 pA 20 $\mu$ A/A + 1.7 pA 51 $\mu$ A/A + 0.54 pA 26 $\mu$ A/A + 0.25 pA 0.14 mA/A + 0.11 pA 0.24 mA/A + 21 fA 0.24 mA/A + 1.4 fA 0.92 mA/A + 0.38 fA 0.83 mA/A + 0.59 fA	Keysight 16353A, 16353H Shunt+ Keysight 3458A Multimeter
DC Current - Measure <sup>1</sup>	(1-3) A (3-20) A	0.017 mA/A + 0.12 mA 0.22 mA/A + 0.29 mA	Keysight 16353J Shunt+ Keysight 3458A Multimeter
4 Terminal Pair Capacitance - Source <sup>1</sup>	1 pF 1.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz	0.26 % of reading 0.033 % of reading 0.038 % of reading 0.055 % of reading 0.073 % of reading 0.093 % of reading 0.25 % of reading 0.37 % of reading	Keysight 16380A/C Standard Capacitor

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Capacitance Source <sup>1</sup>	10 pF 1.0 kHz 12.5 kHz 48.0 kHz 96.0 kHz 100.0 kHz 300.0 kHz 500.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz  100 pF 125.0 Hz 1.0 kHz 12.5 kHz 48.0 kHz 96.0 kHz 100.0 kHz 300.0 kHz 500.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz	0.02 % of reading 0.019 % of reading 0.018 % of reading 0.022 % of reading 0.022 % of reading 0.018 % of reading 0.025 % of reading 0.027 % of reading  0.11 % of reading 0.015 % of reading 0.014 % of reading 0.020 % of reading 0.021 % of reading 0.021 % of reading 0.036 % of reading 0.051 % of reading	Keysight 16380A/C Standard Capacitor

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
	1 000 pF	0.084 % of reading	
	20.0 Hz	0.018 % of reading	
	125.0 Hz	0.014 % of reading	
	1.0 kHz	0.020 % of reading	
	10.0 kHz	0.014 % of reading	
	12.5 kHz	0.014 % of reading	
	48.0 kHz	0.014 % of reading	
	96.0 kHz	0.014 % of reading	
	100.0 kHz	0.020 % of reading	
	300.0 kHz	0.016 % of reading	
	500.0 kHz	0.019 % of reading	
	1.0 MHz	0.015 % of reading	
	2.0 MHz	0.020 % of reading	
	3.0 MHz	0.034 % of reading	
	4.0 MHz	0.048 % of reading	
	5.0 MHz	0.065 % of reading	
	10.0 MHz	0.19 % of reading	
	13.0 MHz	0.28 % of reading	
4 Terminal Pair Capacitance - Source <sup>1</sup>	0.01 µF	0.021 % of reading	Keysight 16380A/C Standard Capacitor
	100.0 Hz	0.021 % of reading	
	120.0 Hz	0.015 % of reading	
	1.0 kHz	0.017 % of reading	
	10.0 kHz	0.021 % of reading	
	100.0 kHz	0.015 % of reading	
	0.1 µF	0.015 % of reading	
	120.0 Hz	0.015 % of reading	
	1.0 kHz	0.016 % of reading	
	10.0 kHz	0.015 % of reading	
1 µF	100.0 kHz	0.021 % of reading	
	120.0 Hz	0.015 % of reading	
	1.0 kHz	0.021 % of reading	
	10.0 kHz	0.022 % of reading	
	100.0 kHz	0.017 % of reading	
	20.0 Hz	0.016 % of reading	
	120.0 Hz	0.016 % of reading	
	1.0 kHz	0.016 % of reading	
	10.0 kHz	0.023 % of reading	
	100.0 kHz	0.073 % of reading	

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Capacitance - Source <sup>1</sup>	1 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 10 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 100 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 1000 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 10 $\mu$ F (20 to 120) Hz	7.7 % of reading 5.2 % of reading 0.26 % of reading 5.8 % of reading 0.53 % of reading 0.026 % of reading 0.85 % of reading 0.045 % of reading 0.019 % of reading 0.084 % of reading 0.077 % of reading 0.075 % of reading 0.022 % of reading	Keysight 16380A/C Standard Capacitor
4 Terminal Pair Dissipation Factor – Source <sup>1,3</sup>	0 < Df < 1 1pF 1.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz	0.002 4 0.000 069 0.000 095 0.000 41 0.000 42 0.000 23 0.000 58 0.000 84	Keysight 16380A/C Standard Capacitor

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Dissipation Factor – Source <sup>1,3</sup>	0 < Df < 1 10 pF 1.0 kHz      0.000 071 12.5 kHz     0.000 061 48.0 kHz     0.000 061 96.0 kHz     0.000 061 100.0 kHz    0.000 061 300.0 kHz    0.000 061 500.0 kHz    0.000 061 1.0 MHz      0.000 061 2.0 MHz      0.000 061 3.0 MHz      0.000 11 4.0 MHz      0.000 11 5.0 MHz      0.000 067 10.0 MHz     0.000 12 13.0 MHz     0.000 13  100 pF 125.0 Hz     0.000 72 1.0 kHz      0.000 061 12.5 kHz     0.000 061 48.0 kHz     0.000 061 96.0 kHz     0.000 061 100.0 kHz    0.000 061 300.0 kHz    0.000 061 500.0 kHz    0.000 061 1.0 MHz      0.000 061 2.0 MHz      0.000 061 3.0 MHz      0.000 089 4.0 MHz      0.000 097 5.0 MHz      0.000 087 10.0 MHz     0.000 18 13.0 MHz     0.000 25	Keysight 16380A/C Standard Capacitor	

**Electrical – DC/Low Frequency**

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
	0 <Df <1		
	1 000 pF		
	20.0 Hz	0.000 31	
	125.0 Hz	0.000 077	
	1.0 kHz	0.000 061	
	10.0 kHz	0.000 065	
	12.5 kHz	0.000 065	
	48.0 kHz	0.000 065	
	96.0 kHz	0.000 065	
	100.0 kHz	0.000 065	
	300.0 kHz	0.000 065	
	500.0 kHz	0.000 065	
	1.0 MHz	0.000 065	
	2.0 MHz	0.000 083	
	3.0 MHz	0.000 13	
	4.0 MHz	0.000 17	
	5.0 MHz	0.000 22	
	10.0 MHz	0.000 59	
	13.0 MHz	0.000 85	
4 Terminal Pair Dissipation Factor – Source <sup>1,3</sup>	0.01 μF		Keysight 16380A/C Standard Capacitor
	100 Hz	0.000 062	
	120.0 Hz	0.000 062	
	1.0 kHz	0.000 061	
	10.0 kHz	0.000 061	
	100.0 kHz	0.000 061	
	0.1 μF		
	120.0 Hz	0.000 065	
	1.0 kHz	0.000 061	
	10.0 kHz	0.000 061	
	100.0 kHz	0.000 065	
	1 μF		
	120.0 Hz	0.000 071	
	1.0 kHz	0.000 061	
	10.0 kHz	0.000 065	
	100.0 kHz	0.000 08	
	10 μF		
	20.0 Hz	0.000 073	
	120.0 Hz	0.000 070	
	1.0 kHz	0.000 065	
	10.0 kHz	0.000 29	
	100.0 kHz	0.000 7	

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Dissipation Factor – Source <sup>1,3</sup>	0 < Df < 1 1 pF 100 Hz to 1 kHz 1 kHz to 1 MHz 10 pF 100 Hz to 1 kHz 1 kHz to 1 MHz 100 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 1000 pF (20 to 100) Hz 100 Hz to 1 kHz 1 kHz to 1 MHz 10 µF (20 to 120) Hz	0.025 0.002 4 0.003 9 0.000 24 0.003 0.000 43 0.000 086 0.000 54 0.000 46 0.000 085 0.000 078	Keysight 16380A/C Standard Capacitor
4 Terminal Pair Resistance – Source <sup>1</sup>	10 mΩ 1.0 kHz 100 mΩ 100.0 Hz 1.0 kHz 1 Ω 120 Hz 1.0 kHz 10 Ω 120 Hz 1.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz	0.37 % of reading 0.03 % of reading 0.03 % of reading 0.014 % of reading 0.007 8 % of reading 0.004 5 % of reading 0.004 5 % of reading 0.096 % of reading 0.094 % of reading 0.1 % of reading 0.1 % of reading 0.12 % of reading 0.4 % of reading 0.6 % of reading	Keysight 42030A Standard Resistor

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Resistance – Source <sup>1</sup>	100 Ω 20.0 Hz 125.0 Hz 1.0 kHz 12.5 kHz 48.0 kHz 96.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz  1 kΩ 20.0 Hz 125.0 Hz 1.0 kHz 12.5 kHz 48.0 kHz 96.0 kHz 100.0 kHz 1.0 MHz 2.0 MHz 3.0 MHz 4.0 MHz 5.0 MHz 10.0 MHz 13.0 MHz  10 kΩ 100.0 kHz 1.0 MHz  100 kΩ 100.0 kHz 1.0 MHz  10 Ω (20 to 100) Hz 100 Hz to 1 MHz  100 Ω (20 to 100) Hz 100 Hz to 1 MHz	0.004 5 % of reading 0.004 3 % of reading 0.004 4 % of reading 0.004 3 % of reading 0.004 7 % of reading 0.005 5 % of reading 0.005 % of reading 0.04 % of reading 0.05 % of reading 0.05 % of reading 0.2 % of reading 0.3 % of reading  0.005 % of reading 0.004 9 % of reading 0.004 4 % of reading 0.004 4 % of reading 0.004 7 % of reading 0.005 3 % of reading 0.031 % of reading 0.0045 % of reading 0.031 % of reading 0.031% of reading 0.041 % of reading 0.05 % of reading 0.2 % of reading 0.3 % of reading  0.021 % of reading 0.031 % of reading  0.0067 % of reading 0.0068 % of reading  0.036 % of reading 0.094 % of reading  0.044 % of reading 0.043 % of reading	Keysight 42030A Standard Resistor

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
4 Terminal Pair Resistance – Source <sup>1</sup>	1 kΩ (20 to 100) Hz 100 Hz to 100 kHz 100 kHz to 1 MHz 10 kΩ 20 Hz to 100 kHz 100 kHz to 1 MHz 100 kΩ 20 Hz to 100 kHz 100 kHz to 1 MHz	0.049 % of reading 0.033 % of reading 0.033 % of reading 0.024 % of reading 0.032 % of reading 0.096 % of reading 0.096 % of reading	Keysight 42030A Standard Resistor
Noise Voltage (peak-to-peak) - Measure <sup>1</sup>	Bandwidth (20 MHz or 1 GHz) Up to 2 mV 2 mV to 2 V	0.07 mV 1.9 % of reading	LeCroy DA1855A Differential Amplifier with Rohde & Schwarz URE 2 RMS/Peak Voltmeter or Keysight DSO8104A Oscilloscope
Noise Voltage (rms) - Measure <sup>1</sup>	Bandwidth (20 MHz) Up to 0.5 mV (0.5 to 1) mV 1 mV to 1 V	21 % of reading 6.6 % of reading 1.9 % of reading	LeCroy DA1855A Differential Amplifier with Rohde & Schwarz URE 2 RMS/Peak Voltmeter or Keysight DSO8104A Oscilloscope
Noise Current(rms) – Measure <sup>1</sup>	Bandwidth (20 MHz) Up to 10 µA (10 to 100) µA (0.1 to 250) mA	33 mA/A + 5.7 µA 0.11 A/A + 4.2 µA 0.15 A/A	Keysight DSOS104A or N9030A/B with Tektronix Current Probe (TCP312A or TCP305A) and Current Probe Amplifier (TCPA300)
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type J (-210 to -100) °C (-100 to -30) °C (-30 to +150) °C (150 to 760) °C (760 to 1 200) °C Type K (-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1 000) °C (1 000 to 1 372) °C	0.22 °C 0.14 °C 0.12 °C 0.14 °C 0.19 °C 0.26 °C 0.15 °C 0.14 °C 0.21 °C 0.32 °C	Fluke 552xA multifunction calibrator

## Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of RTD Indicating Devices <sup>1</sup>	Pt 385, 100 Ω (-200 to -80) °C	0.039 °C	Fluke 552xA multifunction calibrator
	(-80 to 0) °C	0.039 °C	
	(0 to 100) °C	0.055 °C	
	(100 to 300) °C	0.07 °C	
	(300 to 400) °C	0.078 °C	
	(400 to 630) °C	0.093 °C	
	(630 to 800) °C	0.18 °C	
	Pt 3926, 100 Ω (-200 to -80) °C	0.039 °C	
	(-80 to 0°C)	0.039 °C	
	(0 to 100) °C	0.055 °C	
	(100 to 300) °C	0.07 °C	
	(300 to 400) °C	0.078 °C	
	(400 to 630) °C	0.093 °C	
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.1 mF/F + 7.7 pF	Fluke 552xA multifunction calibrator
	(3.3 to 10.99) nF	1.4 mF/F + 8.2 pF	
	(11 to 109.99) nF	1.4 mF/F + 80 pF	
	(110 to 329.99) nF	1.5 mF/F + 0.24 nF	
	(0.33 to 1.099) μF	1.4 mF/F + 0.82 nF	
	(1.1 to 3.299) μF	1.5 mF/F + 2.4 nF	
	(3.3 to 10.99) μF	1.4 mF/F + 8.1 nF	
	(11 to 32.99) μF	2.4 mF/F + 24 nF	
	(33 to 109.99) μF	2.6 mF/F + 82 nF	
	(110 to 329.99) μF	2.7 mF/F + 0.24 μF	
	(0.33 to 1.099) mF	2.6 mF/F + 0.82 μF	
	(1.1 to 3.299) mF	2.7 mF/F + 2.4 μF	
	(3.3 to 10.99) mF	3.3 mF/F + 5.2 μF	
	(11 to 32.99) mF	5.5 mF/F + 24 μF	
	(33 to 110) mF	7.9 mF/F + 79 μF	

### Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance- Source <sup>1</sup>	(0 to 11) Ω	31 μΩ/Ω + 0.78 mΩ	Fluke 552xA multifunction calibrator
	(11 to 33) Ω	23 μΩ/Ω + 1.2 mΩ	
	(33 to 110) Ω	22 μΩ/Ω + 1.1 mΩ	
	110 Ω to 1.1 kΩ	22 μΩ/Ω + 1.6 mΩ	
	(1.1 to 11) kΩ	22 μΩ/Ω + 16 mΩ	
	(11 to 110) kΩ	22 μΩ/Ω + 0.16 Ω	
	110 kΩ to 1.1 MΩ	25 μΩ/Ω + 1.6 Ω	
	(1.1 to 3.3) MΩ	47 μΩ/Ω + 23 Ω	
	(3.3 to 11) MΩ	0.1 mΩ/Ω + 39 Ω	
	(11 to 33) MΩ	0.19 mΩ/Ω + 1.9 kΩ	
	(33 to 110) MΩ	0.39 mΩ/Ω + 2.3 kΩ	
	(110 to 330) MΩ	2.3 mΩ/Ω + 78 kΩ	
	330 MΩ to 1.1 GΩ	12 mΩ/Ω + 0.39 MΩ	

### Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Jitter Source <sup>1</sup>	(0.01 to 25) ps	0.12 ps	E8257D Keysight Signal Generator
	2.0 GHz	44 fs	
	2.5 GHz	65 fs	
	2.75 GHz	0.13 ps	
	3.0 GHz	0.13 ps	
	3.2 GHz	0.1 ps	
	5.0 GHz	52 fs	
	8.0 GHz	31 fs	
	10.0 GHz	50 fs	
	12.0 GHz	50 fs	
	13.0 GHz	0.1 ps	
	14.0 GHz	50 fs	
	15.0 GHz	42 fs	
	28.0 GHz	37 fs	
	32.0 GHz		
Jitter Measure <sup>1</sup>	(0.1 to 130) ps 200 kHz to 15 GHz	1.9 ps	Keysight 86100x or N1000A with 86112/7A

**Electrical – RF/Microwave**

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Function Gen - Amplitude Flatness <sup>1</sup>	0.3 V to 8 V 100 kHz to 10 MHz 10 MHz to <50 MHz 50 MHz >50 MHz to 80 MHz  0.3 V to 5 V 80 MHz to 250 MHz	0.025 dB 0.028 dB 0.018 dB 0.023 dB  0.023 dB	Keysight 3458A Multimeter, Keysight E9304A Power Sensor (OptH84), Keysight E4419B/N191xA Power Meter, Keysight 8491B Fixed Attenuator (Opt 010, H87)
RF Power Sensor - Calibration Factors (9 kHz to 50 GHz) <sup>1,3</sup>	(0.009 to < 0.03) MHz (0.03 to < 1) MHz (1 to < 3) MHz (3 to < 5) MHz (5 to < 10) MHz (10 to < 50) MHz (50 to < 100) MHz 100 MHz to < 3GHz (3 to < 4) GHz (4 to < 5) GHz (5 to < 7) GHz (7 to < 9) GHz (9 to < 10) GHz (10 to < 11) GHz (11 to < 12) GHz (12 to < 13) GHz (13 to < 14) GHz (14 to < 17) GHz (17 to < 18) GHz (18 to < 19) GHz (19 to < 24) GHz (24 to < 25) GHz (25 to < 27) GHz (27 to < 28) GHz (28 to < 32) GHz (32 to < 33) GHz (33 to < 34) GHz (34 to < 34.5) GHz (34.5 to < 35) GHz (34.5 to < 35) GHz (35 to < 36) GHz (36 to < 39) GHz	0.56 % of reading 0.48 % of reading 0.52 % of reading 0.53 % of reading 0.56 % of reading 0.6 % of reading 0.59 % of reading 0.39 % of reading 0.47 % of reading 0.41 % of reading 0.49 % of reading 0.51 % of reading 0.5 % of reading 0.59 % of reading 0.51 % of reading 0.6 % of reading 0.59 % of reading 0.68 % of reading 0.79 % of reading 0.8 % of reading 1.6 % of reading 1.7 % of reading 1.6 % of reading 1.9 % of reading 2 % of reading 1.9 % of reading 2 % of reading 2.1 % of reading 2.2 % of reading 2.1 % of reading 2.2 % of reading 2.6 % of reading	Keysight N5245B opt 423 Network Analyzer, Keysight E9304A Opt H84, and N848xA Power Sensors

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power Sensor - Calibration Factors (9 kHz to 50 GHz) <sup>1,3</sup>	(39 to < 40) GHz (45 to < 47) GHz (47 to < 48) GHz (48 to < 49) GHz (49 to < 50) GHz 50 GHz	2.7 % of reading 2.8 % of reading 2.6 % of reading 2.7 % of reading 2.8 % of reading 2.7 % of reading	Keysight N5245B opt 423 Network Analyzer, Keysight E9304A Opt H84, and N848xA Power Sensors
RF Power Sensor - Linearity (50MHz) <sup>1</sup>	30 dBm (29 to 26) dBm (25 to 21) dBm 20 dBm (19 to 14) dBm (13 to 9) dBm (9 to 7) dBm (6 to -1) dBm <sup>4</sup> 0 dBm -1 dBm (-2 to -6) dBm (-7 to -10) dBm (-11 to -14) dBm (-14 to -21) dBm (-21 to -25) dBm (-26 to -29) dBm -29 dBm -30 dBm (-31 to -37) dBm	0.35 % 0.34 % 0.33 % 0.22 % 0.21 % 0.2 % 0.15 % 0.14 % Reference 0.21 % 0.24 % 0.29 % 0.26 % 0.3 % 0.34 % 0.33 % 0.38 % 0.4 % 0.39 %	Keysight N5245B opt 423
RF Power – Measure <sup>1</sup>	1 mW 50 MHz	2.3 μW	Keysight N8482A or 8482A Power Sensor and E4419B NPL power Meter
Signal Sources Amplitude Modulation Distortion <sup>1</sup>	fc: 500 kHz to 50 GHz Distortion: (0.01 to 0.1) % Distortion: (>0.1 to <0.3) % Distortion: 0.3%to 15 %	0.52 % of reading + 0.001 1 % 1 % of reading + 0.000 63 % 1.2% of measured distortion	Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement
Signal Sources Frequency Modulation Distortion <sup>1</sup>	fc: 1 MHz to 50 GHz (0.01 to 15) % distortion	2.3 % of measured distortion	Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Signal Sources Phase Modulation <sup>1</sup>	(0.2 to 1) rad fm 50 Hz to 50 kHz fc 100 kHz to 3.6 GHz fc 3.6 GHz to 17.1 GHz fc 17.1 GHz to 34.5 GHz fc 34.5 GHz to 50 GHz	0.001 rad/rad + 0.001 rad 0.001 rad/rad + 0.002 rad 0.001 rad/rad + 0.002 5 rad 0.001 rad/rad + 0.004 9 rad	Keysight Signal Analyzer N9030B fc = Carrier Frequency fm = Modulation Rate Direct measurement
Signal Sources Phase Modulation <sup>1</sup>	(1 to 10) rad fm 50 Hz to 50 kHz fc 100 kHz to 3.6 GHz fc 3.6 GHz to 17.1 GHz fc 17.1 GHz to 34.5 GHz fc 34.5 GHz to 50 GHz	81 $\mu$ rad/rad + 0.002 rad 150 $\mu$ rad/rad + 0.003 rad 200 $\mu$ rad/rad + 0.003 5 rad 580 $\mu$ rad/rad + 0.005 8 rad	Keysight Signal Analyzer N9030B fc = Carrier Frequency fm = Modulation Rate Direct measurement
Signal Sources Phase Modulation Distortion <sup>1</sup>	fc: 1 MHz to 50 GHz Distortion: (0.01 to 15) %	2.3 % of measured distortion	Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement
Signal Sources Frequency Modulation <sup>1,2</sup>	fc: 2 MHz to 3.6 GHz fm: 20 Hz to 50 kHz Deviation: 200 Hz to 100 kHz Modulation Index: (0.2 to 100) Modulation Index: (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading	Keysight Signal analyzer N9030A fc = Carrier Frequency fm = Modulation Rate Direct measurement
Phase Noise – Measure <sup>1</sup>	LREF - LDUT) $\geq$ 10dB  Offset Frequency ≤ 100 kHz ≤ 100 kHz ≤ 1 MHz ≤ 10 MHz < 100 MHz	2.3 dB 2.3 dB 2.3 dB 4.6 dB 4.6 dB	
	10dB > (LREF - LDUT) $\geq$ 5dB  Offset Frequency ≤ 100 kHz ≤ 100 kHz ≤ 1 MHz ≤ 10 MHz < 100 MHz	2.8 dB 2.9 dB 2.9 dB 5.2 dB 5.3 dB	Keysight E5505A Phase Noise System

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Noise – Measure <sup>1</sup>	5dB > (LREF - LDUT) ≥ 3dB ≤ 100 kHz ≤ 100 kHz ≤ 1 MHz ≤ 10 MHz < 100 MHz	3.2 dB 3.3 dB 3.3 dB 5.4 dB 5.5 dB	Keysight E5505A Phase Noise System
	100 MHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz	3.3 dB 3.3 dB 5.4 dB 5.5 dB	
	3dB > (LREF - LDUT) ≥ 0dB ≤ 100 kHz ≤ 100 kHz ≤ 1 MHz ≤ 10 MHz < 100 MHz	4.3 dB 4.3 dB 4.3 dB 6.1 dB 6.2 dB	
	100 MHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz 50 kHz < f ≤ 26.5 GHz	4.3 dB 4.3 dB 4.3 dB 6.1 dB 6.2 dB	
	Carrier frequency: 1 GHz Offset frequency: 100 Hz > 100 Hz to 30 kHz > 30 kHz to 10 MHz	0.45 dB 0.35 dB 0.37 dB	Signal Source 500-13483D Source phase noise: -107 to -167 dBc/Hz Direct measurement
	(0 to 1.5) % error EDGE: residual EVM (rms) (0 to 1) ° GSM: rms residual phase error (0 to 3) ° GSM: peak residual phase error	0.015 % error 0.013° 0.12°	
	CDMA2000, IS95, 1xEV-DO Residual EVM (0 to 2) % error fc: (800 to 2 100) MHz	0.023 % error	
	W-CDMA Residual EVM (0 to 1.5) % error fc: (800 to 2 200) MHz	0.025 % error	
	BPSK: Residual EVM (0 to 2.5) % error fc: ≤ 3 GHz fc: > 3 to 32 GHz fc: > 32 to 44 GHz	0.02 % error 0.055 % error 0.07 % error	
Signal Sources - Digital Modulation RF Quality <sup>1</sup>			Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Signal Sources - Digital Modulation RF Quality <sup>1</sup>	QPSK Residual EVM (0 to 2.5) % error fc: Up to 1 GHz fc: (1 to 2) GHz fc: (2 to 3) GHz fc: (3 to 4) GHz fc: (4 to 5) GHz fc: (5 to 6) GHz fc: (6 to 32) GHz fc: (32 to 44) GHz	0.01 % error 0.015 % error 0.025 % error 0.03 % error 0.035 % error 0.045 % error 0.05 % error 0.065 % error	
	$\pi/4$ DQPSK Residual EVM (0 to 2.5) % error fc: Up to 1 GHz fc: (1 to 2) GHz fc: (2 to 3) GHz fc: (3 to 4) GHz fc: (4 to 5) GHz fc: (5 to 6) GHz	0.025 % error 0.046 % error 0.059 % error 0.11 % error 0.059 % error 0.059 % error	
	16, 64, 256 QAM Residual EVM (0 to 2.5) % error fc: Up to 3 GHz fc: (3 to 6) GHz fc: (6 to 32) GHz fc: (32 to 44) GHz	0.015 % error 0.02 % error 0.03 % error 0.045 % error	Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement
	2FSK (Including DECT) Shift Error or (0 to 4.0) % error fc: 1 MHz to 50 GHz Up to 3 GHz 3 to 6 GHz	0.049 % error 0.048 % error	
	Frequency Deviation (0 to 10) kHz DECT - kHz	0.12 kHz	
	NADC Residual EVM (0 to 2) % error fc: (750 to 950) MHz	0.042 % error	
	PDC Residual EVM (0 to 2) % error fc: (810 to 1501) MHz	0.055 % error	

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Signal Sources - Digital Modulation RF Quality <sup>1</sup>	PHS Residual EVM (0 to 2) % error fc: (1800 to 2000) MHz	0.035 % error	Keysight Signal analyzer N9030A fc = Carrier Frequency Direct measurement
	TETRA Residual EVM (0 to 2) % error fc: (350 to 1000) MHz	0.044 % error	
Step Attenuator Measure <sup>1,2</sup>	1 dB to 40 dB (Type-N, 3.5 mm, and 2.4 mm) 300 kHz to 500 MHz >500 MHz to 2 GHz >2 GHz to 18 GHz >18 GHz to 40 GHz >40 GHz to 50 GHz	0.003 4 dB 0.004 7 dB (0.011% *f + 0.004 9) dB 0.008 9 dB 0.012 dB	Keysight Network Analyzes + Keysight Calibration Kits
Step Attenuator Measure <sup>1,2</sup>	50 dB to 80 dB (Type-N) 50 dB and 60 dB (3.5 mm) 50 dB (2.4 mm) 300 kHz to 8 GHz 8 GHz to 18 GHz >8 GHz to 40 GHz >40 GHz to 50 GHz 70 dB to 100 dB (Type-N) 70 dB or 80 dB (3.5 mm) 300 kHz to 18 GHz >18 GHz to 20 GHz >20 GHz to 40 GHz >40 GHz to 50 GHz 110 dB or 120 dB (Type-N) 90 dB (3.5 mm) 65 dB or 90 dB (2.4 mm) 300 kHz to 18 GHz >18 GHz to 20 GHz >20 GHz to 40 GHz >40 GHz to 50 GHz	0.025 dB 0.029 dB 0.034 dB 0.037 dB 0.048 dB 0.056 dB 0.059 dB 0.065 dB 0.072 dB 0.08 dB 0.084 dB 0.094 dB	Keysight Network Analyzes + Keysight Calibration Kits

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power – Relative <sup>1</sup> (Specific Frequency)	99.6 MHz  (-60.0 to < -59.0) dBm (-59.0 >= to < -58.0) dBm (-58.0 >= to < -57.0) dBm (-57.0 >= to < -56.0) dBm (-56.0 >= to < -52.0) dBm (-52.0 >= to < -47.0) dBm (-47.0 >= to < -46.0) dBm (-46.0 >= to < -41.0) dBm (-41.0 >= to < -37.0) dBm (-37.0 >= to < -32.0) dBm (-32.0 >= to < -31.0) dBm (-31.0 >= to < -27.0) dBm (-27.0 >= to < -26.0) dBm (-26.0 >= to < -21.0) dBm (-21.0 >= to < -18.5) dBm (-18.5 >= to < -13.5) dBm (-13.5 >= to < -12.5) dBm (-12.5 >= to < -8.5) dBm (-8.5 >= to < -7.5) dBm (-7.5 >= to < -2.5) dBm (-2.5 >= to < 0.5) dBm (0.5 >= to < 1.5) dBm (1.5 >= to 5.0) dBm (2.5 >= to 5.0) dBm	0.009 5 dB 0.008 6 dB 0.007 9 dB 0.006 9 dB 0.006 3 dB 0.005 9 dB 0.005 7 dB 0.005 3 dB 0.004 8 dB 0.004 dB 0.003 6 dB 0.003 4 dB 0.003 1 dB 0.002 3 dB 0.001 2 dB 0.002 3 dB 0.003 1 dB 0.003 4 dB 0.003 6 dB 0.004 dB 0.004 8 dB 0.005 1 dB 0.005 4 dB 0.005 5 dB	Keysight Function Generator (33250A)
RF Power – Relative <sup>1</sup> (Specific Frequency)	1.195 GHz  (-80 to < -79) dBm (-79 >= to < -78) dBm (-78 >= to < -77) dBm (-77 >= to < -76) dBm (-76 >= to < -75) dBm (-75 >= to < -74) dBm (-74 >= to < -73) dBm (-73 >= to < -72) dBm (-72 >= to < -70) dBm (-70 >= to < -69) dBm (-69 >= to < -67) dBm (-67 >= to < -65) dBm (-65 >= to < -60) dBm (-60 >= to < -58) dBm (-58 >= to < -54) dBm (-54 >= to < -50) dBm	0.041 dB 0.037 dB 0.035 dB 0.032 dB 0.03 dB 0.029 dB 0.028 dB 0.027 dB 0.026 dB 0.022 dB 0.021 dB 0.02 dB 0.019 dB 0.016 dB 0.015 dB 0.014 dB	Keysight Power Meter(E4419B), Keysight Power Sensor (N8482A, 8482A), Keysight Dynamic Accuracy Test Set (Z5623A)

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power – Relative <sup>1</sup> (Specific Frequency)	1.195 GHz (-50 >= to < -49) dBm (-49 >= to < -45) dBm (-45 >= to < -40) dBm (-40 >= to < -39) dBm (-39 >= to < -38) dBm (-38 >= to < -37) dBm (-37 >= to < -35) dBm (-35 >= to < -31) dBm (-31 >= to < -30) dBm (-30 >= to < -29) dBm (-29 >= to < -28) dBm (-28 >= to < -27) dBm (-27 >= to < -26) dBm (-26 >= to < -24) dBm (-24 >= to < -21) dBm (-21 >= to < 1) dBm (1 >= to 10) dBm	0.013 dB 0.012 dB 0.011 dB 0.009 7 dB 0.009 1 dB 0.008 7 dB 0.008 2 dB 0.007 9 dB 0.007 8 dB 0.006 6 dB 0.005 7 dB 0.005 1 dB 0.004 6 dB 0.004 1 dB 0.003 8 dB 0.003 7 dB 0.005 3 dB	Keysight Power Meter(E4419B), Keysight Power Sensor (N8482A, 8482A), Keysight Dynamic Accuracy Test Set (Z5623A)
RF Power – Relative <sup>1</sup> (Specific Frequency)	1.998 77 GHz (5 to < 1) dBm (1 >= to < -4) dBm (-4 >= to < -9) dBm (-9 >= to < -14) dBm (-14 >= to < -19) dBm (-19 >= to < -22) dBm (-22 >= to < -23) dBm (-23 >= to < -25) dBm (-25 >= to < -26) dBm (-26 >= to < -27) dBm (-27 >= to < -29) dBm (-29 >= to < -31) dBm (-31 >= to < -33) dBm (-33 >= to < -35) dBm (-35 >= to < -37) dBm (-37 >= to < -39) dBm (-39 >= to < -41) dBm (-41 >= to < -42) dBm (-42 >= to < -44) dBm	0.005 7 dB 0.004 7 dB 0.003 9 dB 0.003 3 dB 0.002 3 dB 0.001 dB 0.001 6 dB 0.001 9 dB 0.002 3 dB 0.002 5 dB 0.002 7 dB 0.003 dB 0.003 2 dB 0.003 5 dB 0.003 8 dB 0.004 1 dB 0.004 5 dB 0.004 8 dB 0.005 dB	Keysight Power Meter(E4419B), Keysight Power Sensor (N8482A, 8482A), Keysight Dynamic Accuracy Test Set (U3020AD01)

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power – Relative <sup>1</sup> (Specific Frequency)	1.998 77 GHz (-44 >= to < -46) dBm (-46 >= to < -47) dBm (-47 >= to < -49) dBm (-49 >= to < -52) dBm (-52 >= to < -57) dBm (-57 >= to -60) dBm	0.005 4 dB 0.005 8 dB 0.006 dB 0.006 3 dB 0.006 7 dB 0.007 1 dB	Keysight Power Meter(E4419B), Keysight Power Sensor (N8482A, 8482A), Keysight Dynamic Accuracy Test Set (U3020AD01)
Attenuation - Source <sup>1</sup>	1 dB to 11 dB in 1 dB steps 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz 10 dB to 20 dB 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz 30 dB 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz 40 to 60 dB 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz 70 to 90 dB 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz 100 dB to 110 dB 1 kHz to 50 MHz > 50 MHz to 1 GHz > 1 GHz to 2 GHz	0.002 8 dB 0.005 3 dB 0.006 3 dB 0.003 6 dB + 0.000 4 dB/10 dB step 0.005 4 dB + 0.002 1 dB/10 dB step 0.01 dB + 0.002 dB/10 dB step 0.007 5 dB 0.015 dB 0.02 dB 0.000 6 dB + 0.0018 dB/10 dB step 0.001 2 dB + 0.0035 dB/10 dB step 0.005 dB/10 dB step -0.005 dB + 0.003 dB/10 dB step -0.017 dB + 0.007 dB/10 dB step -0.002 dB + 0.009 dB/10 dB step -0.038 dB + 0.007 dB/10 dB step -0.025 dB + 0.009 dB/10 dB step -0.16 dB + 0.025 dB/10 dB step	Step Attenuators Keysight 8494G/H Keysight 8496G/H

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Admittance Open Magnitude - Measure <sup>1</sup>	3 $\mu$ S to 15 mS 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 2 800 MHz 3 000 MHz	0.18 $\mu$ S 0.21 $\mu$ S 2.1 $\mu$ S 6.9 $\mu$ S 10 $\mu$ S 17 $\mu$ S 20 $\mu$ S 27 $\mu$ S 33 $\mu$ S 43 $\mu$ S 59 $\mu$ S 68 $\mu$ S 85 $\mu$ S 95 $\mu$ S 110 $\mu$ S 130 $\mu$ S 140 $\mu$ S 160 $\mu$ S	Keysight 16190B Performance Test Kit
Impedance Short Magnitude - Measure <sup>1</sup>	0 $\Omega$ 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 2 800 MHz 3 000 MHz	2.5 m $\Omega$ 3.5 m $\Omega$ 14 m $\Omega$ 25 m $\Omega$ 30 m $\Omega$ 40 m $\Omega$ 40 m $\Omega$ 50 m $\Omega$ 50 m $\Omega$ 100 m $\Omega$ 100 m $\Omega$ 100 m $\Omega$ 200 m $\Omega$ 200 m $\Omega$ 200 m $\Omega$ 200 m $\Omega$ 200 m $\Omega$ 200 m $\Omega$	Keysight 16190B Performance Test Kit

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Impedance Load Magnitude - Measure <sup>1</sup>	50 Ω 1 kHz 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 2 800 MHz 3 000 MHz	0.05 Ω 0.08 Ω 0.079 Ω 0.077 Ω 0.12 Ω 0.12 Ω 0.16 Ω 0.21 Ω 0.22 Ω 0.25 Ω 0.3 Ω 0.35 Ω 0.36 Ω 0.5 Ω 0.49 Ω 0.47 Ω 0.43 Ω 0.41 Ω 0.42 Ω	Keysight 16190B Performance Test Kit
Impedance Load Phase - Measure <sup>1</sup>	(-1.0 to 1.0)° 1 kHz 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 2 800 MHz 3 000 MHz	0.095 mrad 1.6 mrad 1.6 mrad 1.5 mrad 2.3 mrad 2.3 mrad 3.2 mrad 4.2 mrad 4.5 mrad 5 mrad 6 mrad 7 mrad 7.3 mrad 10 mrad 9.8 mrad 9.3 mrad 8.7 mrad 8.2 mrad 8.4 mrad	Keysight 16190B Performance Test Kit

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Impedance Airline + Short Magnitude - Measure <sup>1</sup>	(0 to 25) Ω 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 400 MHz 2 600 MHz 2 800 MHz	0.000 23 Ω 0.002 2 Ω 0.023 Ω 0.053 Ω 0.087 Ω 0.29 Ω 0.72 Ω 0.45 Ω 0.14 Ω 0.092 Ω 0.28 Ω 0.92 Ω 1.7 Ω 0.58 Ω 0.23 Ω	Keysight 16190B Performance Test Kit
Impedance Airline + Short Phase - Measure <sup>1</sup>	(-100 to 100) <sup>o</sup> 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 1 000 MHz 1 300 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 400 MHz 2 600 MHz 2 800 MHz	2.1 mrad 2.1 mrad 2.2 mrad 2.4 mrad 2.4 mrad 3.4 mrad 4.6 mrad 5.3 mrad 6.3 mrad 8.4 mrad 7.5 mrad 10 mrad 11 mrad 11 mrad 11 mrad	Keysight 16190B Performance Test Kit

## Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Impedance Airline + Open Magnitude - Measure <sup>1</sup>	50 Ω to 25 kΩ 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 3 000 MHz	39 Ω 3.9 Ω 0.38 Ω 0.22 Ω 0.13 Ω 0.072 Ω 0.053 Ω 0.077 Ω 0.24 Ω 0.62 Ω 0.25 Ω 0.08 Ω 0.18 Ω 0.53 Ω 2.1 Ω 1.1 Ω	Keysight 16190B Performance Test Kit
Impedance Airline + Open Phase - Measure <sup>1</sup>	(-100 to 100)° 1 MHz 10 MHz 100 MHz 200 MHz 300 MHz 500 MHz 600 MHz 800 MHz 1 000 MHz 1 600 MHz 1 800 MHz 2 000 MHz 2 200 MHz 2 400 MHz 2 600 MHz 3 000 MHz	1.8 mrad 1.8 mrad 1.8 mrad 2.2 mrad 2.2 mrad 3.2 mrad 5.4 mrad 5.6 mrad 5.4 mrad 7.2 mrad 7.5 mrad 12 mrad 11 mrad 10 mrad 14 mrad 15 mrad	Keysight 16190B Performance Test Kit

**Electrical – RF/Microwave**

Parameter/ Equipment		RF Power Measure <sup>1</sup>																					
Reference Standard, Method, and/or Equipment		Direct measurement, Power Sensor, Power Meter, PSA, PXA																					
Range	Expanded Uncertainty of Measurement (+/-)																						
Frequency Range	Step Attenuation Level in dB																						
	(-140 to -130) dBm	(-130 to -110) dBm	(-110 to -90) dBm	(-90 to -30) dBm	(-30 to -20) dBm	(-20 to -10) dBm	(-10 to -3) dBm	(-3 to 3) dBm	(3 to 10) dBm	(10 to 15) dBm	(15 to 20) dBm	(20 to 30) dBm											
9 kHz to < 100 kHz	0.17	0.17	0.16	0.16	0.16	0.13	0.13	0.037	0.063	0.010	0.11	0.16											
100 kHz to < 10 MHz	0.075	0.069	0.053	0.045	0.044	0.043	0.043	0.035	0.037	0.042	0.049	0.16											
10 MHz to < 50 MHz	0.072	0.064	0.049	0.04	0.039	0.038	0.038	0.029	0.031	0.037	0.045	0.16											
50 MHz	0.071	0.062	0.047	0.037	0.036	0.035	0.035	0.024	0.028	0.033	0.043	0.16											
> 50 to 100 MHz	0.072	0.063	0.048	0.039	0.037	0.037	0.037	0.027	0.030	0.036	0.044	0.16											
> 0.1 to 2 GHz	0.071	0.063	0.048	0.038	0.037	0.036	0.036	0.026	0.032	0.038	0.044	0.16											
> 2 to 4.2 GHz	0.072	0.066	0.049	0.039	0.038	0.037	0.037	0.027	0.033	0.040	0.044	0.16											
> 4.2 to 6 GHz	0.076	0.069	0.052	0.042	0.041	0.041	0.041	0.032	0.037	0.042	0.047	0.16											
> 6 to 8 GHz	0.08	0.073	0.058	0.049	0.048	0.047	0.047	0.039	0.041	0.045	0.06	0.16											
> 8 to 12.4 GHz	0.079	0.073	0.058	0.049	0.049	0.047	0.047	0.040	0.042	0.046	0.065	0.16											
> 12.4 to 14 GHz	0.078	0.072	0.058	0.049	0.048	0.047	0.047	0.039	0.041	0.045	0.066	0.17											
> 14 to 18 GHz	0.08	0.074	0.059	0.051	0.05	0.049	0.049	0.042	0.043	0.047	0.069	0.17											
> 18 to 24.0 GHz	0.1	0.095	0.082	0.076	0.075	0.075	0.075	0.071	0.073	0.076	0.079	0.19											
> 24 to 26.5 GHz	0.1	0.095	0.083	0.077	0.076	0.076	0.076	0.071	0.074	0.078	0.079	-											
> 26.5 to 33 GHz	0.11	0.11	0.095	0.090	0.089	0.089	0.089	0.085	0.086	0.088	0.092	-											
> 33 to 40 GHz	0.12	0.11	0.099	0.093	0.093	0.092	0.092	0.089	0.090	0.092	0.11	-											
> 40 to 50 GHz	0.15	0.14	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	-											
> 50 to 60 GHz	-	-	-	-	0.18	0.15	0.15	0.14	0.14	0.15	0.17	-											
> 60 to 67 GHz	-	-	-	-	0.20	0.16	0.16	0.15	0.16	0.16	0.18	-											

### Electrical – RF/Microwave

Parameter/ Equipment		S11/S22 - Reflection Magnitude <sup>1,3</sup>																									
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits																									
Range	Expanded Uncertainty of Measurement (+/-)																										
Frequency	Measured Magnitude (Linear)																										
	≤ 0.01	> 0.01 to ≤ 0.03	> 0.03 to ≤ 0.06	> 0.06 to ≤ 0.1	> 0.1 to ≤ 0.2	> 0.2 to ≤ 0.3	> 0.3 to ≤ 0.4	> 0.4 to ≤ 0.5	> 0.5 to ≤ 0.6	> 0.6 to ≤ 0.7	> 0.7 to ≤ 0.8	> 0.8 to ≤ 0.9	> 0.9 to ≤ 1.0														
0.9 kHz to 0.3 MHz	0.0012	0.0012	0.0012	0.0013	0.0014	0.0016	0.0017	0.0019	0.002	0.0022	0.0024	0.0026	0.0029														
0.3 MHz to 1.0 GHz	0.0012	0.0012	0.0013	0.0013	0.0015	0.0017	0.0019	0.0021	0.0023	0.0026	0.0029	0.0032	0.0036														
(1.0 to 2.0) GHz	0.0017	0.0018	0.0019	0.002	0.0023	0.0026	0.0029	0.0032	0.0035	0.0039	0.0043	0.0047	0.0052														
(2.0 to 3.0) GHz	0.002	0.002	0.0021	0.0022	0.0025	0.0029	0.0032	0.0035	0.0039	0.0043	0.0048	0.0052	0.0058														
(3.0 to 10.0) GHz	0.0026	0.0027	0.0029	0.003	0.0039	0.0045	0.0051	0.0058	0.0065	0.0073	0.0082	0.0092	0.01														
(10.0 to 20.0) GHz	0.0037	0.0038	0.004	0.0041	0.005	0.0058	0.0067	0.0076	0.0087	0.0098	0.011	0.012	0.014														
(20.0 to 26.5) GHz	0.0049	0.005	0.0051	0.0052	0.0063	0.0075	0.0087	0.0099	0.011	0.013	0.014	0.016	0.018														
(26.5 to 36.0) GHz	0.0064	0.0065	0.0067	0.0069	0.0081	0.0093	0.011	0.012	0.014	0.016	0.019	0.021	0.024														
(36.0 to 40.0) GHz	0.0065	0.0066	0.0068	0.0071	0.0084	0.0097	0.011	0.013	0.015	0.017	0.02	0.022	0.025														
(40.0 to 50.0) GHz	0.0091	0.0093	0.0095	0.0098	0.012	0.013	0.015	0.017	0.02	0.023	0.026	0.029	0.033														

### Electrical – RF/Microwave

Parameter/ Equipment		S11/S22 - Reflection Phase <sup>1</sup>										
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits										
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency	Measured Magnitude (Degrees)											
	≤ 0.008	> 0.008 to ≤ 0.009	> 0.009 to ≤ 0.01	> 0.01 to ≤ 0.02	> 0.02 to ≤ 0.03	> 0.03 to ≤ 0.04	> 0.04 to ≤ 0.05	> 0.05 to ≤ 0.06	> 0.06 to ≤ 0.07	> 0.07 to ≤ 0.08		
0.9 kHz to 0.3 MHz	8.5°	7.6°	6.8°	3.5°	2.3°	1.8°	1.4°	1.2°	1°	0.93°		
0.3 MHz to 1.0 GHz	8.6°	7.7°	6.9°	3.5°	2.4°	1.8°	1.5°	1.2°	1.1°	0.94°		
(1.0 to 2.0) GHz	13°	11°	10°	5.2°	3.5°	2.7°	2.2°	1.9°	1.6°	1.5°		
(2.0 to 3.0) GHz	15°	13°	12°	5.8°	3.9°	3°	2.4°	2°	1.8°	1.6°		



*ANSI National Accreditation Board*

### Electrical – RF/Microwave

Parameter/ Equipment		S11/S22 - Reflection Phase <sup>1</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzes + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude (Degrees)																				
	≤ 0.008	> 0.008 to ≤ 0.009	> 0.009 to ≤ 0.01	> 0.01 to ≤ 0.02	> 0.02 to ≤ 0.03	> 0.03 to ≤ 0.04	> 0.04 to ≤ 0.05	> 0.05 to ≤ 0.06	> 0.06 to ≤ 0.07	> 0.07 to ≤ 0.08											
(3.0 to 10.0) GHz	20°	17°	16°	7.9°	5.4°	4.1°	3.3°	2.8°	2.5°	2.2°											
(10.0 to 20.0) GHz	28°	20°	22°	11°	7.5°	5.7°	4.6°	3.9°	3.4°	3°											
(20.0 to 26.5) GHz	38°	33°	29°	14°	9.6°	7.3°	5.9°	4.9°	4.3°	3.8°											
(26.5 to 36.0) GHz	53°	40 °	40°	19°	13°	9.6°	7.7°	6.5°	5.6°	5°											
(36.0 to 40.0) GHz	55°	47°	41°	19°	13°	9.8°	7.9°	6.7°	5.8°	5.1°											
(40.0 to 50.0) GHz	180°	180°	66°	28°	18°	14°	11°	9.3	8°	7.1°											

### Electrical – RF/Microwave

Parameter/ Equipment		S11/S22 - Reflection Phase <sup>1</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzes + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude (Degrees)																				
	> 0.08 to ≤ 0.09	> 0.09 to ≤ 0.1	> 0.1 to ≤ 0.2	> 0.2 to ≤ 0.3	> 0.3 to ≤ 0.4	> 0.4 to ≤ 0.5	> 0.5 to ≤ 0.6	> 0.6 to ≤ 0.7	> 0.7 to ≤ 0.8	> 0.8 to ≤ 1.0											
0.9 kHz to 0.3 MHz	0.83°	0.76°	0.41°	0.3°	0.25°	0.21°	0.19°	0.18°	0.17°	0.16°											
0.3 MHz to 1.0 GHz	0.85°	0.77°	0.43°	0.32°	0.27°	0.24°	0.22°	0.21°	0.21°	0.2°											
(1.0 to 2.0) GHz	1.3°	1.2°	0.67°	0.5°	0.41°	0.37°	0.34°	0.32°	0.31°	0.3°											
(2.0 to 3.0) GHz	1.4°	1.3°	0.73°	0.55°	0.45°	0.4°	0.37°	0.35°	0.34°	0.33°											
(3.0 to 10.0) GHz	2°	1.8°	1.1°	0.85°	0.73°	0.66°	0.62°	0.6°	0.59°	0.58°											
(10.0 to 20.0) GHz	2.7°	2.5°	1.4°	1.1°	0.96°	0.87°	0.83°	0.8°	0.79°	0.79°											
(20.0 to 26.5) GHz	3.4°	3.1°	1.8°	1.4°	1.2°	1. °	1.1°	1°	1°	1°											
(26.5 to 36.0) GHz	4.5°	4.1°	2.3°	1.8°	1.5°	1. °	1.4°	1.3°	1.3°	1.3°											

### Electrical – RF/Microwave

Parameter/ Equipment		S11/S22 - Reflection Phase <sup>1</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude (Degrees)																				
	> 0.08 to ≤ 0.09	> 0.09 to ≤ 0.1	> 0.1 to ≤ 0.2	> 0.2 to ≤ 0.3	> 0.3 to ≤ 0.4	> 0.4 to ≤ 0.5	> 0.5 to ≤ 0.6	> 0.6 to ≤ 0.7	> 0.7 to ≤ 0.8	> 0.8 to ≤ 1.0											
(36.0 to 40.0) GHz	4.6°	4.2°	2.4°	1.9°	1.6°	1.°	1.4°	1.4°	1.4°	1.4°											
(40.0 to 50.0) GHz	6.4°	5.8°	3.3°	2.5°	2.2°	2°	1.9°	1.9°	1.8°	1.9°											

### Electrical – RF/Microwave

Parameter/ Equipment		S21/S12 - Transmission Magnitude <sup>1,2</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude in dB																				
	(0.0 to ≤ 2.0) dB	(2.0 > to ≤ 5.0) dB	(5.0 > to ≤ 9.0) dB	(9.0 > to ≤ 11.0) dB	(11.0 > to ≤ 20.0) dB	(20.0 > to ≤ 30.0) dB	(30.0 > to ≤ 40.0) dB	(40.0 > to ≤ 50.0) dB	(50.0 > to ≤ 60.0) dB	(60.0 > to ≤ 70.0) dB											
(0.9 to 9.0) kHz	0.026	0.027	0.029	0.03	0.034	0.038	0.043	0.063	0.15	0.44											
9.0 kHz to 0.9 MHz	0.019	0.02	0.021	0.023	0.026	0.03	0.033	0.038	0.046	0.083											
(0.9 to 40.0) MHz	0.025	0.027	0.028	0.03	0.033	0.037	0.04	0.044	0.052	0.084											
40.0 MHz to 0.5 GHz	0.021	0.023	0.024	0.025	0.028	0.03	0.034	0.039	0.047	0.085											
(0.5 to 1.0) GHz	0.024	0.027	0.029	0.031	0.033	0.036	0.039	0.042	0.048	0.071											
(1.0 to 2.0) GHz	0.025	0.027	0.029	0.031	0.034	0.036	0.039	0.042	0.047	0.066											
(2.0 to 3.0) GHz	0.026	0.028	0.03	0.033	0.036	0.038	0.041	0.044	0.048	0.067											
(3.0 to 6.0) GHz	0.035	0.037	0.039	0.041	0.044	0.046	0.049	0.052	0.056	0.074											
(6.0 to 10.0) GHz	0.039	0.04	0.042	0.044	0.047	0.049	0.052	0.055	0.06	0.078											
(10.0 to 20.0) GHz	0.045	0.047	0.049	0.051	0.053	0.056	0.059	0.062	0.066	0.081											
(20.0 to 26.5) GHz	0.07	0.072	0.075	0.076	0.079	0.082	0.084	0.087	0.091	0.1											
(26.5 to 30.0) GHz	0.08	0.079	0.079	0.08	0.082	0.084	0.087	0.09	0.097	0.12											



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### Electrical – RF/Microwave

Parameter/ Equipment		S21/S12 - Transmission Magnitude <sup>1,2</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude in dB																				
(0.0 to ≤ 2.0) dB	(2.0 > to ≤ 5.0) dB	(5.0 > to ≤ 9.0) dB	(9.0 > to ≤ 11.0) dB	(11.0 > to ≤ 20.0) dB	(20.0 > to ≤ 30.0) dB	(30.0 > to ≤ 40.0) dB	(40.0 > to ≤ 50.0) dB	(50.0 > to ≤ 60.0) dB	(60.0 > to ≤ 70.0) dB												
(30.0 to 40.0) GHz	0.082	0.084	0.086	0.087	0.09	0.092	0.095	0.098	0.1	0.12											
(40.0 to 50.0) GHz	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.15											

### Electrical – RF/Microwave

Parameter/ Equipment		S21/S12 - Transmission Phase <sup>1</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzers + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude (Degrees)																				
(0.0 to ≤ 0.0) dB	(0.0 > to ≤ 1.0) dB	(1.0 > to ≤ 4.0) dB	(4.0 > to ≤ 8.0) dB	(8.0 > to ≤ 11.0) dB	(11.0 > to ≤ 20.0) dB	(20.0 > to ≤ 30.0) dB	(30.0 > to ≤ 40.0) dB	(40.0 > to ≤ 50.0) dB	(50.0 > to ≤ 60.0) dB	(60.0 > to ≤ 70.0) dB											
(0.9 to 9.0) kHz	0.17°	0.17°	0.18°	0.19°	0.2°	0.22°	0.25°	0.29°	0.42°	0.98°	3°										
9.0 kHz to 0.9 MHz	0.13°	0.13°	0.13°	0.14°	0.15°	0.17°	0.2°	0.22°	0.25°	0.31°	0.55°										
(0.9 to 40.0) MHz	0.17°	0.17°	0.17°	0.18°	0.19°	0.22°	0.24°	0.27°	0.29°	0.34°	0.55°										
40.0 MHz to 0.5 GHz	0.14°	0.14°	0.15°	0.15°	0.16°	0.18°	0.2°	0.22°	0.26°	0.31°	0.56°										
(0.5 to 1.0) GHz	0.16°	0.17°	0.17°	0.18°	0.2°	0.22°	0.24°	0.26°	0.28°	0.32°	0.47°										
(1.0 to 2.0) GHz	0.16°	0.17°	0.17°	0.19°	0.2°	0.22°	0.24°	0.26°	0.28°	0.31°	0.44°										
(2.0 to 3.0) GHz	0.17°	0.18°	0.18°	0.2°	0.21°	0.23°	0.25°	0.27°	0.29°	0.32°	0.45°										
(3.0 to 6.0) GHz	0.23°	0.23°	0.24°	0.25°	0.27°	0.29°	0.31°	0.32°	0.34°	0.37°	0.49°										
(6.0 to 10.0) GHz	0.25°	0.26°	0.26°	0.28°	0.29°	0.31°	0.33°	0.35°	0.36°	0.39°	0.51°										
(10.0 to 20.0) GHz	0.3°	0.3°	0.31°	0.32°	0.33°	0.35°	0.37°	0.39°	0.41°	0.44°	0.53°										
(20.0 to 26.5) GHz	0.47°	0.47°	0.48°	0.49°	0.5°	0.52°	0.54°	0.56°	0.58°	0.6°	0.67°										
(26.5 to 30.0) GHz	0.54°	0.53°	0.53°	0.53°	0.53°	0.54°	0.56°	0.58°	0.6°	0.64°	0.79°										

### Electrical – RF/Microwave

Parameter/ Equipment		S21/S12 - Transmission Phase <sup>1</sup>										
Reference Standard, Method, and/or Equipment		Keysight Network Analyzes + Keysight Calibration Kits										
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency	Measured Magnitude (Degrees)											
(0.0 to ≤ 0.0) dB	(0.0 > to ≤ 1.0) dB	(1.0 > to ≤ 4.0) dB	(4.0 > to ≤ 8.0) dB	(8.0 > to ≤ 11.0) dB	(11.0 > to ≤ 20.0) dB	(20.0 > to ≤ 30.0) dB	(30.0 > to ≤ 40.0) dB	(40.0 > to ≤ 50.0) dB	(50.0 > to ≤ 60.0) dB	(60.0 > to ≤ 70.0) dB		
(30.0 to 40.0) GHz	0.55°	0.55°	0.55°	0.57°	0.58°	0.59°	0.61°	0.63°	0.65°	0.68°	0.8°	
(40.0 to 50.0) GHz	0.79°	0.78°	0.76°	0.75°	0.75°	0.76°	0.78°	0.79°	0.81°	0.86°	1°	

### Electrical – RF/Microwave

Parameter/ Equipment		S21S12 - Transmission Gain Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment		Keysight Network Analyzes + Keysight Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency	Measured Magnitude in dB										
(0.0 to ≤ 2.0) dB	(2.0 > to ≤ 4.0) dB	(4.0 > to ≤ 6.0) dB	(6.0 > to ≤ 8.0) dB	(8.0 > to ≤ 10.0) dB	(10.0 > to ≤ 12.0) dB	(12.0 > to ≤ 14.0) dB	(14.0 > to ≤ 16.0) dB	(16.0 > to ≤ 18.0) dB	(18.0 > to ≤ 20.0) dB		
(0.9 to 9.0) kHz	0.029 dB	0.031 dB	0.031 dB	0.032 dB	0.033 dB	0.033 dB	0.034 dB	0.035 dB	0.036 dB	0.037 dB	
9.0 kHz to 0.1 MHz	0.024 dB	0.025 dB	0.026 dB	0.027 dB	0.027 dB	0.028 dB	0.029 dB	0.03 dB	0.031 dB	0.032 dB	
(0.1 to 0.3) MHz	0.021 dB	0.022 dB	0.023 dB	0.024 dB	0.024 dB	0.025 dB	0.026 dB	0.027 dB	0.028 dB	0.029 dB	
(0.3 to 0.9) MHz	0.022 dB	0.023 dB	0.024 dB	0.025 dB	0.025 dB	0.026 dB	0.027 dB	0.028 dB	0.03 dB	0.031 dB	
(0.9 to 4.0) MHz	0.026 dB	0.027 dB	0.028 dB	0.029 dB	0.03 dB	0.031 dB	0.032 dB	0.033 dB	0.034 dB	0.036 dB	
(4.0 to 20.0) MHz	0.029 dB	0.03 dB	0.031 dB	0.032 dB	0.032 dB	0.033 dB	0.034 dB	0.035 dB	0.037 dB	0.038 dB	
(20.0 to 40.0) MHz	0.029 dB	0.03 dB	0.031 dB	0.032 dB	0.033 dB	0.033 dB	0.034 dB	0.035 dB	0.037 dB	0.038 dB	
40.0 MHz to 0.3 GHz	0.024 dB	0.025 dB	0.026 dB	0.026 dB	0.027 dB	0.028 dB	0.029 dB	0.03 dB	0.031 dB	0.032 dB	
(0.3 to 0.5) GHz	0.024 dB	0.025 dB	0.026 dB	0.026 dB	0.027 dB	0.028 dB	0.029 dB	0.029 dB	0.031 dB	0.032 dB	
(0.5 to 1.0) GHz	0.025 dB	0.026 dB	0.027 dB	0.027 dB	0.028 dB	0.029 dB	0.029 dB	0.03 dB	0.032 dB	0.033 dB	
(1.0 to 3.0) GHz	0.027 dB	0.028 dB	0.029 dB	0.029 dB	0.03 dB	0.031 dB	0.032 dB	0.033 dB	0.035 dB	0.037 dB	
(3.0 to 6.0) GHz	0.037 dB	0.038 dB	0.039 dB	0.04 dB	0.041 dB	0.043 dB	0.045 dB	0.049 dB	0.054 dB	0.062 dB	

### Electrical – RF/Microwave

Parameter/ Equipment	S21S12 - Transmission Gain Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	Keysight Network Analyzes + Keysight Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude in dB									
(0.0 to ≤ 2.0) dB	(2.0 > to ≤ 4.0) dB	(4.0 > to ≤ 6.0) dB	(6.0 > to ≤ 8.0) dB	(8.0 > to ≤ 10.0) dB	(10.0 > to ≤ 12.0) dB	(12.0 > to ≤ 14.0) dB	(14.0 > to ≤ 16.0) dB	(16.0 > to ≤ 18.0) dB	(18.0 > to ≤ 20.0) dB	
(6.0 to 10.0) GHz	0.042 dB	0.044 dB	0.045 dB	0.047 dB	0.05 dB	0.053 dB	0.055 dB	0.057 dB	0.06 dB	0.065 dB
(10.0 to 20.0) GHz	0.049 dB	0.051 dB	0.052 dB	0.054 dB	0.057 dB	0.061 dB	0.067 dB	0.072 dB	0.079 dB	0.089 dB
(20.0 to 26.5) GHz	0.074 dB	0.076 dB	0.077 dB	0.079 dB	0.082 dB	0.086 dB	0.091 dB	0.1 dB	0.11 dB	0.14 dB
(26.5 to 40.0) GHz	0.087 dB	0.09 dB	0.093 dB	0.096 dB	0.1 dB	0.11 dB	0.12 dB	0.14 dB	0.17 dB	0.22 dB
(40.0 to 50.0) GHz	0.13 dB	0.13 dB	0.13 dB	0.14 dB	0.15 dB	0.16 dB	0.18 dB	0.22 dB	0.27 dB	0.35 dB

### Electrical – RF/Microwave

Parameter/ Equipment	S21S12 - Transmission Gain Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	Keysight Network Analyzes + Keysight Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude in dB									
(20.0 > to ≤ 22.0) dB	(22.0 > to ≤ 24.0) dB	(24.0 > to ≤ 26.0) dB	(26.0 > to ≤ 28.0) dB	(28.0 > to ≤ 30.0) dB	(30.0 > to ≤ 32.0) dB	(32.0 > to ≤ 34.0) dB	(34.0 > to ≤ 36.0) dB	(36.0 > to ≤ 38.0) dB	(38.0 > to ≤ 40.0) dB	
(0.9 to 9.0) kHz	0.039 dB	0.041 dB	0.044 dB	0.048 dB	0.055 dB	0.065 dB	0.081 dB	0.11 dB	0.14 dB	0.21 dB
9.0 kHz to 0.1 MHz	0.033 dB	0.035 dB	0.038 dB	0.043 dB	0.049 dB	0.059 dB	0.075 dB	0.1 dB	0.14 dB	0.2 dB
(0.1 to 0.3) MHz	0.031 dB	0.033 dB	0.036 dB	0.041 dB	0.048 dB	0.058 dB	0.074 dB	0.099 dB	0.14 dB	0.2 dB
(0.3 to 0.9) MHz	0.034 dB	0.037 dB	0.041 dB	0.048 dB	0.058 dB	0.074 dB	0.099 dB	0.14 dB	0.2 dB	0.29 dB
(0.9 to 4.0) MHz	0.038 dB	0.041 dB	0.046 dB	0.052 dB	0.063 dB	0.079 dB	0.1 dB	0.14 dB	0.21 dB	0.3 dB
(4.0 to 20.0) MHz	0.041 dB	0.044 dB	0.048 dB	0.055 dB	0.066 dB	0.081 dB	0.1 dB	0.14 dB	0.2 dB	0.29 dB
(20.0 to 40.0) MHz	0.04 dB	0.043 dB	0.047 dB	0.054 dB	0.064 dB	0.08 dB	0.1 dB	0.14 dB	0.2 dB	0.3 dB
40.0 MHz to 0.3 GHz	0.034 dB	0.037 dB	0.042 dB	0.049 dB	0.059 dB	0.075 dB	0.1 dB	0.14 dB	0.2 dB	0.3 dB
(0.3 to 0.5) GHz	0.034 dB	0.037 dB	0.042 dB	0.05 dB	0.061 dB	0.078 dB	0.1 dB	0.14 dB	0.21 dB	0.31 dB

### Electrical – RF/Microwave

Parameter/ Equipment		S21S12 - Transmission Gain Magnitude <sup>1,2</sup>																			
Reference Standard, Method, and/or Equipment		Keysight Network Analyzes + Keysight Calibration Kits																			
Range	Expanded Uncertainty of Measurement (+/-)																				
Frequency	Measured Magnitude in dB																				
(20.0 > to ≤ 22.0) dB	(22.0 > to ≤ 24.0) dB	(24.0 > to ≤ 26.0) dB	(26.0 > to ≤ 28.0) dB	(28.0 > to ≤ 30.0) dB	(30.0 > to ≤ 32.0) dB	(32.0 > to ≤ 34.0) dB	(34.0 > to ≤ 36.0) dB	(36.0 > to ≤ 38.0) dB	(38.0 > to ≤ 40.0) dB												
(0.5 to 1.0) GHz	0.035 dB	0.039 dB	0.044 dB	0.051 dB	0.062 dB	0.079 dB	0.1 dB	0.14 dB	0.2 dB	0.3 dB											
(1.0 to 3.0) GHz	0.041 dB	0.047 dB	0.056 dB	0.069 dB	0.089 dB	0.12 dB	0.17 dB	0.24 dB	0.36 dB	0.54 dB											
(3.0 to 6.0) GHz	0.072 dB	0.084 dB	0.1 dB	0.13 dB	0.17 dB	0.24 dB	0.35 dB	0.51 dB	0.76 dB	1.1 dB											
(6.0 to 10.0) GHz	0.072 dB	0.084 dB	0.1 dB	0.13 dB	0.17 dB	0.24 dB	0.35 dB	0.51 dB	0.76 dB	1.1 dB											
(10.0 to 20.0) GHz	0.1 dB	0.13 dB	0.17 dB	0.23 dB	0.32 dB	0.47 dB	0.69 dB	1.0 dB	1.6 dB	2.3 dB											
(20.0 to 26.5) GHz	0.17 dB	0.22 dB	0.31 dB	0.44 dB	0.64 dB	0.95 dB	1.4 dB	2.1 dB	3.1 dB	-											
(26.5 to 40.0) GHz	0.29 dB	0.41 dB	0.59 dB	0.87 dB	1.3 dB	1.9 dB	2.8 dB	-	-	-											
(40.0 to 50.0) GHz	0.48 dB	0.68 dB	0.99 dB	1.5 dB	2.2 dB	3.1 dB	-	-	-	-											

### Electrical – RF/Microwave

Parameter/ Equipment		Frequency Modulation Deviation <sup>1</sup>				
Reference Standard, Method, and/or Equipment		N9030B Network Analyzer				
Frequencies	Deviation Range	Modulation Rate	Modulation index	Expanded Uncertainty of Measurement (+/-)		
100 kHz ≤ fc ≤ 3.6 GHz	20 Hz < FM Dev < 2 MHz	10 Hz ≤ fm < 500 kHz	β ≥ 0.5	0.2 % of reading		
100 kHz ≤ fc ≤ 3.6 GHz	10 Hz ≤ FM Dev < 10 MHz	20 Hz < fm ≤ 1 MHz	β ≥ 0.2	0.7 % of reading		
100 kHz ≤ fc ≤ 3.6 GHz	10 Hz ≤ FM Dev ≤ 16 MHz	50 Hz < fm ≤ 1 MHz	β ≥ 0.05	2 % of reading		
100 kHz ≤ fc ≤ 3.6 GHz	10 Hz < FM Dev < 50 kHz	100 Hz < fm ≤ 1 MHz	β ≥ 0.025	5.2 % of reading		
100 kHz ≤ fc ≤ 3.6 GHz	10 Hz ≤ FM Dev < 40 kHz	100 Hz < fm ≤ 1 MHz	β ≥ 0.020	10 % of reading		
100 kHz ≤ fc ≤ 3.6 GHz	10 Hz ≤ FM Dev < 20 kHz	500 Hz < fm ≤ 1 MHz	β ≥ 0.010	20 % of reading		
3.5 GHz ≤ fc ≤ 8.4 GHz	20 Hz < FM Dev < 1 MHz	10 Hz ≤ fm < 500 kHz	β ≥ 0.5	0.21 % of reading		
3.5 GHz ≤ fc ≤ 8.4 GHz	10 Hz ≤ FM Dev < 5 MHz	20 Hz < fm ≤ 1 MHz	β ≥ 0.2	0.7 % of reading		
3.5 GHz ≤ fc ≤ 8.4 GHz	10 Hz ≤ FM Dev < 16 MHz	50 Hz < fm ≤ 1 MHz	β ≥ 0.05	2.2 % of reading		
3.5 GHz ≤ fc ≤ 8.4 GHz	10 Hz < FM Dev ≤ 16 MHz	100 Hz < fm ≤ 1 MHz	β ≥ 0.025	5.2 % of reading		

**Electrical – RF/Microwave**

<b>Parameter/ Equipment</b>	Frequency Modulation Deviation <sup>1</sup>			
<b>Reference Standard, Method, and/or Equipment</b>	N9030B Network Analyzer			
<b>Frequencies</b>	<b>Deviation Range</b>	<b>Modulation Rate</b>	<b>Modulation index</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>
3.5 GHz ≤ fc ≤ 8.4 GHz	10 Hz ≤ FM Dev < 40 kHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	10 % of reading
3.5 GHz ≤ fc ≤ 8.4 GHz	10 Hz ≤ FM Dev < 20 kHz	500 Hz < fm ≤ 1 MHz	$\beta \geq 0.010$	20 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	20 Hz < FM Dev < 2 MHz	10 Hz ≤ fm < 500 kHz	$\beta \geq 0.5$	0.21 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	10 Hz < FM Dev < 10 MHz	50 Hz < fm ≤ 1 MHz	$\beta \geq 0.2$	0.7 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	10 Hz ≤ FM Dev ≤ 16 MHz	50 Hz < fm ≤ 1 MHz	$\beta \geq 0.05$	2.2 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	10 Hz < FM Dev < 500 kHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.025$	5.2 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	10 Hz ≤ FM Dev < 40 kHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	10 % of reading
8.3 GHz ≤ fc ≤ 13.6 GHz	10 Hz ≤ FM Dev < 20 kHz	500 Hz < fm ≤ 1 MHz	$\beta \geq 0.010$	20 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	20 Hz < FM Dev < 1 MHz	10 Hz ≤ fm < 200 kHz	$\beta \geq 0.5$	0.21 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	10 Hz ≤ FM Dev < 5 MHz	20 Hz < fm ≤ 1 MHz	$\beta \geq 0.2$	0.7 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	10 Hz ≤ FM Dev < 16 MHz	50 Hz < fm ≤ 1 MHz	$\beta \geq 0.05$	2.2 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	10 Hz < FM Dev ≤ 16 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.025$	5.2 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	10 Hz ≤ FM Dev ≤ 40 kHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	10 % of reading
13.5 GHz ≤ fc ≤ 17.1 GHz	10 Hz ≤ FM Dev ≤ 20 kHz	500 Hz < fm ≤ 1 MHz	$\beta \geq 0.010$	20 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	50 Hz < FM Dev < 400 kHz	10 Hz ≤ fm < 50 kHz	$\beta \geq 0.8$	0.31 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	20 Hz < FM Dev < 5 MHz	10 Hz < fm ≤ 1 MHz	$\beta \geq 0.2$	0.9 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	20 Hz < FM Dev < 10 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.08$	3.3 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	10 Hz < FM Dev ≤ 16 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.04$	6.3 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	10 Hz ≤ FM Dev ≤ 40 kHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	12 % of reading
17.0 GHz ≤ fc ≤ 26.5 GHz	10 Hz ≤ FM Dev ≤ 1 kHz	500 Hz < fm ≤ 100 kHz	$\beta \geq 0.010$	30 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	50 Hz < FM Dev < 400 kHz	10 Hz ≤ fm < 50 kHz	$\beta \geq 0.8$	0.31 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	20 Hz < FM Dev < 5 MHz	10 Hz < fm < 1 MHz	$\beta \geq 0.2$	0.9 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	20 Hz < FM Dev < 10 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.08$	3.3 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	10 Hz < FM Dev < 16 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.04$	6.3 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	10 Hz ≤ FM Dev ≤ 16 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	12 % of reading
26.4 GHz ≤ fc ≤ 34.5 GHz	10 Hz ≤ FM Dev ≤ 1 kHz	500 Hz < fm ≤ 100 kHz	$\beta \geq 0.010$	30 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	50 Hz < FM Dev < 100 kHz	10 Hz ≤ fm < 20 kHz	$\beta \geq 0.8$	0.32 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	20 Hz < FM Dev < 500 kHz	10 Hz ≤ fm < 200 kHz	$\beta \geq 0.2$	0.9 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	20 Hz < FM Dev < 2 MHz	20 Hz < fm ≤ 1 MHz	$\beta \geq 0.08$	3.3 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	10 Hz < FM Dev < 5 MHz	50 Hz < fm ≤ 1 MHz	$\beta \geq 0.04$	6.4 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	10 Hz ≤ FM Dev < 16 MHz	100 Hz < fm ≤ 1 MHz	$\beta \geq 0.020$	12 % of reading
34.4 GHz ≤ fc ≤ 50 GHz	10 Hz ≤ FM Dev ≤ 16 MHz	500 Hz < fm ≤ 200 kHz	$\beta \geq 0.010$	30 % of reading

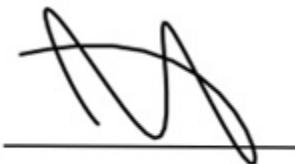
## Time and Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Source <sup>1</sup>	10 MHz	20 pHz/Hz	HP 5071A GPS Disciplined
Frequency – Source <sup>1</sup>	(0.1 to 1) Hz 1 Hz to 250 kHz 250 kHz to 1 MHz 1 MHz to 40 GHz	2 µHz/Hz + 0.43 µHz 2.4 µHz/Hz 5.2 nHz/Hz + 0.14 mHz 5.3 nHz/Hz	Hp 5071A Frequency Standard + Keysight 33250A Function Generator / Keysight E8257D Signal Source
Frequency – Measure <sup>1</sup>	(0.1 to 1) Hz (1 to 10) Hz (10 to 100) Hz 100 Hz to 12.4 GHz (12.4 to 40) GHz	67 pHz 0.88 nHz 4.7 nHz 24 pHz/Hz 23 pHz/Hz +1.2 Hz	HP5071A Standard + Keysight 53132A Counter (Opt 124) / HP 5361B
Time Interval – Measure <sup>1,2</sup>	0.8 ns to 1 µs 1 µs to 10 ms 10 ms to 1 s (1 to 10) s (10 to 100) s	1.2 <sup>E-3</sup> *TI (ns) + 0.009 5 ns 2.1 ns 2.3 ns 7.9 ns 6.9 <sup>E-12</sup> *TI (s) + 7.8 ns	Keysight DCA 86100C+86117A/ Keysight Frequency counter 53132A

Calibration and Measurement Capability (CMC) is expressed in terms of the measurement parameter, measurement range, expanded uncertainty of measurement and reference standard, method, and/or equipment. The expanded uncertainty of measurement is expressed as the standard uncertainty of the measurement multiplied by a coverage factor of 2 ( $k=2$ ), corresponding to a confidence level of approximately 95%.

Notes:

1. On-site calibration service is available for this parameter, since on-site conditions are typically more variable than those in the laboratory, larger measurement uncertainties are expected on-site than what is reported on the accredited scope.
2.  $f$  = frequency,  $M$  = modulation rate,  $TI$  = time interval.
3. Unitless linear measure.
4. Excluding 0 dBm.
5. This scope is formatted as part of a single document including Certificate of Accreditation No. AC-3156.



Jason Stine, Vice President