



# CERTIFICATE OF ACCREDITATION

**The ANSI National Accreditation Board**

Hereby attests that

**Keysight Technologies, Inc. Service Center**  
**10090 Foothills Blvd.**  
**Roseville, CA 95747**  
**(and satellite sites as listed on the scope)**

Fulfills 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: 16 November 2026  
Certificate Number: AC-1498



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

**Keysight Technologies, Inc. Service Center**

10090 Foothills Blvd.  
Roseville, CA 95747  
Chris Cox 916-788-5594  
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**CALIBRATION**

Valid to: November 16, 2026

Certificate Number: AC-1498

**Satellite locations in:**

[Roseville, CA Primary Standards Laboratory](#)

[El Segundo, CA \(AC-1498.01\)](#)

[Colorado Springs, CO \(AC-1498.02\)](#)

[Richardson, TX \(AC-1498.04\)](#)

[Tempe, AZ \(AC-1498.05\)](#)

[West Valley City, UT \(AC-1498.06\)](#)

[Fort Wayne, IN \(AC-1498.08\)](#)

[Nashua, NH \(AC-1498.10\)](#)

[Montreal, QC Canada \(AC-1498.11\)](#)

[Tlaquepaque, JL Mexico \(AC-1498.13\)](#)

[Barueri, SP Brazil \(AC-1498.14\)](#)

[Plantation, FL \(AC-1498.16\)](#)

[Redmond, WA \(AC-1498.17\)](#)

[Greensboro, NC \(AC-1498.18\)](#)

[Calgary, AB Canada \(AC-1498.19\)](#)

[Kimballton, IA \(AC-1498.20\)](#)

[Elk Horn, IA \(AC-1498.20\)](#)

[Ottawa, ON Canada \(AC-1498.21\)](#)



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## Services performed at Main Site laboratory

10090 Foothills Blvd.

Roseville, CA 95747

Chris Cox 916-788-5594

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[www.keysight.com](http://www.keysight.com)

### Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	0 V 100 mV 1 V 10 V 100 V 1000 V	54 nV 91 nV 320 nV 2.5 μV 38 μV 0.65 mV	Multifunction Calibrator Keysight 3458A Multimeter
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 to 1100) V	7.2 μV/V + 0.5 μV 5.1 μV/V + 0.8 μV 3.5 μV/V + 0.4 μV 3.6 μV/V + 4.5 μV 5.3 μV/V + 23 μV 7.1 μV/V + 0.3 mV	Multifunction Calibrator
DC Voltage – Measure <sup>1</sup>	(>0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	4.1 μV/V + 0.36 μV 3.7 μV/V + 0.35 μV 3.1 μV/V + 0.59 μV 5.3 μV/V + 36 μV 5.3 μV/V + 0.12 mV	Keysight 3458A Multimeter
DC Voltage – Measure <sup>1</sup>	1500 V 2000 V	0.016 V 0.029 V	Keysight 3458A Voltage Divider
DC Current – Source <sup>1</sup>	0 A 100 μA 1 mA 10 mA 100 mA 1 A	42 pA 150 pA 1.5 nA 16 nA 460 nA 9.5 μA	Multifunction Calibrator Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) μA (0.22 μA to 22) mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A (2.2 to 11) A	35 μA/A 29 μA/A 37 μA/A 50 μA/A - 1.2 μA 59 μA/A + 12 μA 120 μA/A - 42 μA 280 μA/A + 41 μA	Multifunction Calibrator Amplifier



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	(11 to 20) A	0.67 mA/A	Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Multiproduct Calibrator Current Coil
DC Current – Measure <sup>1</sup>	(>0 to 100) nA (0.1 to 1) μA (1 to 10) μA (10 to 100) μA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 μA/A + 50 pA 21 μA/A + 50 pA 25 μA/A + 0.11 nA 25 μA/A + 0.85 nA 22 μA/A + 6.4 nA 23 μA/A + 59 nA 41 μA/A + 0.6 μA 125 μA/A + 12 μA	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A (15 A to 100) A (100 A to 300) A (300 A to 1 000) A	76 μA/A 75.5 μA/A 130 μA/A 325 μA/A	Current Shunt Keysight 3458A Multimeter
AC Voltage – Source <sup>1</sup>	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	0.6 μV 0.3 μV 0.3 μV 0.7 μV 5 μV 28 μV 1.2 μV 1.3 μV 9 μV 3.4 μV 13 μV 100 μV 180 μV 270 μV	Multifunction Calibrator Keysight 3458A Multimeter

Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	1 V		Multifunction Calibrator Keysight 3458A Multimeter
	1 kHz	6 $\mu$ V	
	20 kHz	11 $\mu$ V	
	50 kHz	11 $\mu$ V	
	100 kHz	14 $\mu$ V	
	300 kHz	23 $\mu$ V	
	500 kHz	38 $\mu$ V	
	1 MHz	270 $\mu$ V	
	4 MHz	1 mV	
	8 MHz	1.7 mV	
	10 MHz	2.2 mV	
	3 V		
	100 kHz	38 $\mu$ V	
	2 MHz	2.3 mV	
	4 MHz	3.4 mV	
	8 MHz	5.2 mV	
	10 MHz	6.8 mV	
	10 V		
	10 Hz	130 $\mu$ V	
	20 Hz	138 $\mu$ V	
	40 Hz	150 $\mu$ V	
	200 Hz	65 $\mu$ V	
	500 Hz	63 $\mu$ V	
	1 kHz	56 $\mu$ V	
	10 kHz	86 $\mu$ V	
	20 kHz	95 $\mu$ V	
	50 kHz	0.11 mV	
	100 kHz	0.11 mV	
	300 kHz	0.2 mV	
	500 kHz	0.34 mV	
1 MHz	1.1 mV		
100 V			
1 kHz	0.99 mV		
20 kHz	1.3 mV		
50 kHz	1.9 mV		
100 kHz	2.5 mV		
700 V			
1 kHz	14 mV		



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Multifunction Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	(0.5 to 1) MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	(0.5 to 1) MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	(0.5 to 1) MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
220 mV to 2.2 V			
(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$		
(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$		
(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$		
(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$		
(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$		
(0.5 to 1) MHz	2.8 mV/V + 300 $\mu\text{V}$		



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Multifunction Calibrator
	(10 to 20) Hz	251 $\mu$ V/V + 390 $\mu$ V	
	(20 to 40) Hz	93 $\mu$ V/V + 156 $\mu$ V	
	40 Hz to 20 kHz	47 $\mu$ V/V + 48 $\mu$ V	
	(20 to 50) kHz	78 $\mu$ V/V + 107 $\mu$ V	
	(50 to 100) kHz	113 $\mu$ V/V + 42 $\mu$ V	
	(100 to 300) kHz	432 $\mu$ V/V + 97 $\mu$ V	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	(0.5 to 1) MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu$ V/V + 4.2 mV	
	(20 to 40) Hz	94 $\mu$ V/V + 1.6 mV	
	40 Hz to 20 kHz	54 $\mu$ V/V + 0.68 mV	
	(20 to 50) kHz	83 $\mu$ V/V + 1.1 mV	
(50 to 100) kHz	156 $\mu$ V/V + 2.6 mV		
(100 to 300) kHz	941 $\mu$ V/V + 16 mV		
(300 to 500) kHz	4.6 mV/V + 42 mV		
(0.5 to 1) MHz	8.3 mV/V + 83 mV		
(220 to 1100) V			
40 Hz to 20 kHz	313 $\mu$ V/V + 17 mV		
(20 to 50) kHz	73 $\mu$ V/V + 3.7 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1100) V		Multifunction Calibrator Amplifier
	40 Hz to 1 kHz	80 $\mu$ V/V + 18 mV	
	(1 to 20) kHz	173 $\mu$ V/V + 5.3 mV	
	(20 to 30) kHz	625 $\mu$ V/V + 12 mV	
	(220 to 750) V		
(30 to 50) kHz	634 $\mu$ V/V + 5.5 mV		
(50 to 100) kHz	2.4 mV/V + 28 mV		
AC Voltage – Source <sup>1</sup>	0.01 V		Multifunction Calibrator Keysight 3458A Multimeter
	1 kHz	870 nV	
	20 kHz	1.2 $\mu$ V	
	100 kHz	4.5 $\mu$ V	
	300 kHz	33 $\mu$ V	
	1 MHz	21 $\mu$ V	
4 MHz	140 $\mu$ V		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Voltage – Source <sup>1</sup>	0.1 V		Multifunction Calibrator Keysight 3458A Multimeter	
	1 kHz	4.6 $\mu$ V		
	20 kHz	6.9 $\mu$ V		
	100 kHz	36 $\mu$ V		
	300 kHz	52 $\mu$ V		
	1 MHz	170 $\mu$ V		
	4 MHz	670 $\mu$ V		
	8 MHz	690 $\mu$ V		
	10 MHz	2.3 mV		
	1 V			
	1 kHz	26 $\mu$ V		
	20 kHz	32 $\mu$ V		
	50 kHz	59 $\mu$ V		
	100 kHz	170 $\mu$ V		
	300 kHz	410 $\mu$ V		
	500 kHz	0.97 mV		
	1 MHz	1.7 mV		
	4 MHz	6.7 mV		
	8 MHz	6.9 mV		
	10 MHz	25 mV		
	3 V			
	100 kHz	420 $\mu$ V		
	(2, 4, 8) MHz	21 mV		
	10 MHz	75 mV		
	10 V			
	10 Hz	480 $\mu$ V		
	20 Hz	270 $\mu$ V		
	40 Hz	230 $\mu$ V		
	200 Hz	460 $\mu$ V		
	500 Hz	450 $\mu$ V		
	1 kHz	260 $\mu$ V		
	10 kHz	270 $\mu$ V		
	20 kHz	320 $\mu$ V		
	50 kHz	0.53 mV		
	100 kHz	1.1 mV		
	300 kHz	2.6 mV		
500 kHz	6.3 mV			
1 MHz	12 mV			



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	100 V 1 kHz 20 kHz 50 kHz 100 kHz	4 mV 7.9 mV 7.5 mV 16 mV	Multifunction Calibrator Keysight 3458A Multimeter
	700 V 1 kHz	60 mV	
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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter
	(10 to 100) 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 100 mV to 1 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	70 μV/V + 4.1 μV 70 μV/V + 2.1 μV 0.14 mV/V + 2.3 μV 0.3 mV/V + 2.6 μV 0.8 mV/V + 2.3 μV 3 mV/V + 15 μV 10 mV/V + 28 μV 15 mV/V + 20 μV 40 mV/V + 74 μV 40 mV/V + 83 μV 0.15 V/V + 0.11 mV 70 μV/V + 41 μV 70 μV/V + 21 μV 0.14 mV/V + 22 μV 0.3 mV/V + 22 μV 0.8 mV/V + 22 μV 3 mV/V + 0.12 mV 10 mV/V + 0.3 mV 15 mV/V + 0.21 mV 40 mV/V + 0.73 mV 40 mV/V + 0.83 mV 0.15 V/V + 1 mV	

**Electrical – DC/Low Frequency**

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(1 to 10) 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 (10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	70 $\mu$ V/V + 0.42 mV 70 $\mu$ V/V + 0.22 mV 0.14 mV/V + 0.24 mV 0.3 mV/V + 0.25 mV 0.8 mV/V + 0.22 mV 3 mV/V + 1.1 mV 10 mV/V + 1.1 mV 15 mV/V + 1.1 mV 40 mV/V + 7.1 mV 40 mV/V + 8.1 mV 0.15 mV/V + 11 mV 0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Current – Source <sup>1</sup>	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	3 nA 2.5 nA 32 nA 330 nA 3.3 $\mu$ A 38 $\mu$ A	Multifunction Calibrator Keysight 3458A Multimeter
AC Current – Source <sup>1</sup>	(0 to 220) $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA	Multifunction calibrator

**Electrical – DC/Low Frequency**

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source <sup>1</sup>	220 µA to 2.2 mA		Multifunction calibrator
	(10 to 20) Hz	233 µA/A + 42 nA	
	(20 to 40) Hz	150 µA/A + 34 nA	
	40 Hz to 1 kHz	108 µA/A + 34 nA	
	(1 to 5) kHz	183 µA/A + 109 nA	
	(5 to 10) kHz	915 µA/A + 655 nA	
	(2.2 to 22) mA		
	(10 to 20) Hz	233 µA/A + 422 nA	
	(20 to 40) Hz	149 µA/A + 342 nA	
	40 Hz to 1 kHz	108 µA/A + 343 nA	
	(1 to 5) kHz	183 µA/A + 588 nA	
	(5 to 10) kHz	915 µA/A + 5 µA	
	(22 to 220) mA		
	(10 to 20) Hz	233 µA/A + 4.2 µA	
	(20 to 40) Hz	149 µA/A + 3.4 µA	
	40 Hz to 1 kHz	108 µA/A + 2.6 µA	
	(1 to 5) kHz	183 µA/A + 3.4 µA	
	(5 to 10) kHz	915 µA/A + 10 µA	
(0.22 to 2.2) A			
20 Hz to 1 kHz	249 µA/A + 34 µA		
(1 to 5) kHz	383 µA/A + 83 µA		
(5 to 10) kHz	5.8 mA/A + 166 µA		
(2.2 to 11) A			
20 Hz to 1 kHz	332 µA/A + 149 µA		
(1 to 5) kHz	707 µA/A + 320 µA		
(5 to 10) kHz	2.8 mA/A + 600 µA		
AC Current Source <sup>1</sup>	(0 to 0.33) mA		Multiproduct Calibrator
	10 to 30 kHz	10 mA/A + 330 nA	
	(0.33 to 3.3) mA		
	10 to 30 kHz	6.6 mA/A + 550 nA	
	(3.3 to 33) mA		
	10 to 30 kHz	2.7 mA/A + 2.7 µA	
	(33 to 330) mA		
	10 to 30 kHz	2.7 mA/A + 160 µA	
	(2.2 to 20.5) A		
	45 to 100 Hz	830 mA/A + 4.2 mA	
100 Hz to 1 kHz	1.1 mA/A + 3.9 mA		
1 to 5 kHz	21 mA/A + 1 mA		



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source <sup>1</sup>	(10 to 20) A		Multiproduct Calibrator Current Coil
	(45 to 65) Hz	0.3 % of reading + 3.7 mA	
	(65 to 100) Hz	0.31 % of reading + 24 mA	
	(100 to 440) Hz	0.33 % of reading + 50 mA	
	(20 to 100) A		
	(45 to 65) Hz	0.85 % of reading + 3.6 mA	
AC Current – Measure <sup>1</sup>	(65 to 100) Hz	0.85 % of reading + 29 mA	Current Transducer
	(100 to 440) Hz	0.85 % of reading + 100 mA	
	(100 to 1 000) A		
Resistance – Source <sup>1</sup>	(45 to 100) Hz	0.85 % of reading + 3.6 mA	Standard Resistors
	(5 to 20) A	0.85 % of reading + 28 mA	
	(20 to 60) A	1 % of reading + 0.25 A	
	(60 to 85) A		
	(85 to 170) A		
	1 mΩ	0.07 % of reading	
	10 mΩ	0.11 % of reading	
	100 mΩ	0.66 % of reading	
	1 Ω	63 μΩ/Ω	
	10 Ω	38 μΩ/Ω	
	100 Ω	30 μΩ/Ω	
	1 kΩ	29 μΩ/Ω	
10 kΩ	29 μΩ/Ω		
100 kΩ	2.1 μΩ/Ω		
1 MΩ	8 μΩ/Ω		
10 MΩ	16 μΩ/Ω		
100 MΩ	96 μΩ/Ω		
1 GΩ	240 μΩ/Ω		
10 GΩ	590 μΩ/Ω		
100 GΩ	560 μΩ/Ω		
Resistance – Source <sup>1</sup>	0 Ω	7.6 μΩ	Multifunction Calibrator Keysight 3458A Multimeter
	10 Ω	12 μΩ	
	100 Ω	76 μΩ	
	1 kΩ	0.4 mΩ	
	10 kΩ	4.5 mΩ	
	100 kΩ	42 mΩ	
	1 MΩ	0.8 Ω	
	10 MΩ	21 Ω	
100 MΩ	1.2 kΩ		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	0 Ω	0.25 mΩ	Multifunction Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 kΩ	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
10 MΩ	0.40 kΩ		
19 MΩ	1.5 kΩ		
100 MΩ	12 kΩ		
Resistance – Source <sup>1</sup>	(0 to 11) Ω	33 μΩ/Ω + 8.3 mΩ	Multiproduct Calibrator
	(11 to 110) Ω	25 μΩ/Ω + 12.5 mΩ	
	110 Ω to 1.1 kΩ	23 μΩ/Ω + 17 mΩ	
	(1.1 to 3.3) kΩ	23 μΩ/Ω + 170 mΩ	
	(3.3 to 11) kΩ	23 μΩ/Ω + 84 mΩ	
	(11 to 110) kΩ	23 μΩ/Ω + 0.84 Ω	
	110 kΩ to 1.1 MΩ	27 μΩ/Ω + 8 Ω	
	(1.1 to 3.3) MΩ	50 μΩ/Ω + 125 Ω	
	(3.3 to 11) MΩ	0.11 mΩ/Ω + 0.2 kΩ	
	(11 to 33) MΩ	0.21 mΩ/Ω + 2 kΩ	
(33 to 110) MΩ	0.41 mΩ/Ω + 2.8 kΩ		
(110 to 330) MΩ	2.5 mΩ/Ω + 83 kΩ		
(330 to 1100) MΩ	13 mΩ/Ω + 0.4 MΩ		
Resistance – Measure <sup>1</sup>	(0 to 12) Ω	18 μΩ/Ω + 20 μΩ	Keysight 3458A Multimeter
	(10 to 120) Ω	12 μΩ/Ω + 0.6 mΩ	
	(0.1 to 1.2) kΩ	9.6 μΩ/Ω + 0.6 mΩ	
	(1 to 12) kΩ	9.6 μΩ/Ω + 6 mΩ	
	(10 to 120) kΩ	9.6 μΩ/Ω + 60 mΩ	
	(0.1 to 1.2) MΩ	15 μΩ/Ω + 2.4 Ω	
	(1 to 12) MΩ	60 μΩ/Ω + 120 Ω	
	(10 to 120) MΩ	0.6 mΩ/Ω + 1.2 kΩ	
(0.1 to 1.2) GΩ	6 mΩ/Ω + 12 kΩ		



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Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Measure <sup>1</sup>	(100 to 200) pF (200 to 400) pF 400 pF to 1 nF (1 to 20) nF 20 nF to 4 μF (4 to 10) μF (10 to 50) μF (50 to 100) μF (100 to 200) μF	0.097 % of reading + 0.13 pF 0.098 % of reading + 0.12 pF 0.092 % of reading + 0.15 pF 0.093 % of reading + 0.15 pF 0.09 % of reading 0.094 % of reading + 40 pF 0.11 % of reading - 1.8 nF 0.16 % of reading 0.28 % of reading - 60 nF	E4980A LCR Meter
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF (3.3 to 10.99) nF (11 to 109.99) nF (110 to 329.99) nF (0.33 to 1.099) μF (1.1 to 3.299) μF (3.3 to 10.99) μF (11 to 32.99) μF (33 to 109.99) μF (110 to 329.99) μF (0.33 to 1.099) mF (1.1 to 3.299) mF (3.3 to 10.00) mF (11 to 32.99) mF (33 to 110) mF	3.1 mF/F + 7.7 pF 1.4 mF/F + 8.2 pF 1.4 mF/F + 80 pF 1.5 mF/F + 0.24 nF 1.4 mF/F + 0.82 nF 1.5 mF/F + 2.4 nF 1.4 mF/F + 8.1 nF 2.4 mF/F + 24 nF 2.6 mF/F + 83 nF 2.7 mF/F + 0.24 μF 2.6 mF/F + 0.82 μF 2.7 mF/F + 2.4 μF 3.3 mF/F + 5.2 μF 5.5 mF/F + 24 μF 7.9 mF/F + 79 μF	Multiproduct Calibrator
Capacitance – Source <sup>1</sup>	1 pF 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 10 pF 1 kHz to 5 MHz (5 to 10) MHz (10 to 13) MHz	0.24 fF 0.19 fF 0.31 fF 0.49 fF 0.68 fF 0.9 fF 2.5 fF 3.8 fF 1.5 fF 2 fF 2.2 fF	Reference Capacitors

**Electrical – DC/Low Frequency**

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>1</sup>	100 pF		Reference Capacitors
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
	(4 to 5) MHz	20 fF	
	(5 to 10) MHz	37 fF	
	(10 to 13) MHz	53 fF	
	1 000 pF		
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
120 Hz to 100 kHz	1.5 pF		
100 nF			
120 Hz to 100 kHz	15 pF		
1 μF			
120 Hz to 1 kHz	0.52 nF		
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
10 μF			
20 Hz to 1 kHz	1.6 nF		
(1 to 20) kHz	2.2 nF		
Dissipation Factor – Source <sup>1,2</sup>	>0 to 1 (dimensionless)		Reference Capacitors
	1 pF		
	1 kHz	0.0019	
	1 kHz to 4 MHz	0.00015	
	(4 to 5) MHz	0.00021	
	(5 to 10) MHz	0.00057	
	(10 to 13) MHz	0.00084	
	10 pF		
	1 kHz	0.000036	
	1 kHz to 1 MHz	0.000025	
	(1 to 4) MHz	0.00005	
	(4 to 5) MHz	0.000073	
	(5 to 10) MHz	0.000075	
(10 to 13) MHz	0.000095		

Electrical – DC/Low Frequency

Roseville, CA Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source <sup>1,2</sup>	>0 to 1 (dimensionless)		Reference Capacitors
	100 pF	0.000023	
	1 kHz	0.000021	
	1 kHz to 1 MHz	0.000052	
	(1 to 2) MHz	0.000048	
	(2 to 3) MHz	0.000062	
	(3 to 4) MHz	0.000071	
	(4 to 5) MHz	0.00016	
	(5 to 10) MHz	0.00024	
	(10 to 13) MHz		
	1 000 pF	0.00002	
	20 Hz to 1 kHz	0.000031	
	1 kHz to 1 MHz	0.000073	
	(1 to 2) MHz	0.0001	
	(2 to 3) MHz	0.0015	
	(3 to 4) MHz	0.00021	
	(4 to 5) MHz	0.00058	
	(5 to 10) MHz	0.00086	
	(10 to 13) MHz		
	10 nF	0.000024	
	120 Hz to 1 kHz	0.000021	
	(1 to 100) kHz		
100 nF	0.00004		
120 Hz to 1 kHz	0.000021		
(1 to 100) kHz			
1 μF	0.000041		
120 Hz to 1 kHz	0.000035		
(1 to 10) kHz	0.00011		
(10 to 100) kHz			
10 μF	0.00004		
(20 to 120) Hz	0.00003		
120 Hz to 10 kHz	0.00076		
(10 to 100) kHz			



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Electrical - RF/Microwave

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 1 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.037 % Depth 0.038 % Depth	Keysight Signal Analyzer
	4.3 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth	
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 10 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth	Keysight Signal Analyzer
	100 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.028 % Depth 0.036 % Depth	
	3 MHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.036 % Depth 0.084 % Depth	
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading	Keysight Signal Analyzer
	(3.6 to 8.4) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.7 % of reading + 0.2 %M 2 % of reading	
	(8.4 to 17.1) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.7 % of reading + 0.3 %M 2.5 % of reading	
	(17.1 to 34.5) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.8 % of reading + 0.3 %M 3 % of reading	
	(34.5 to 50) GHz Modulation Index (0.2 to 100) (100 to 2 000)	1.4 % of reading + 0.5 %M 4 % of reading	



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Electrical - RF/Microwave

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading  0.015° 0.12°	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	Keysight Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	Keysight Signal Analyzer



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Electrical - RF/Microwave

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	Keysight Signal Analyzer
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.002 5 rad 0.1 % of reading + 0.004 9 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.003 5 rad 0.058 % of reading + 0.005 8 rad	Keysight Signal Analyzer
Distortion Measure <sup>1</sup>	(-80 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference	1 mW, 50 MHz	0.22 % of reading	Agilent 478A Power Meter
RF Power Sensors - Calibration Factors <sup>2</sup>	DC to 9 kHz	0.4 %	Keysight 3458A Multimeter
RF Power Sensors - Calibration Factors <sup>2</sup>	(0.1 to 50) MHz (50 to 100) MHz (0.1 to 4) GHz (4 to 8) GHz (8 to 12.4) GHz (12.4 to 15) GHz (15 to 16) GHz (16 to 17) GHz (17 to 18) GHz (18 to 26) GHz (26 to 31) GHz (31 to 37) GHz (37 to 38) GHz (38 to 40) GHz (40 to 45) GHz (45 to 50) GHz	0.57 % 0.21 % 0.33 % 0.39 % 0.48 % 0.51 % 0.54 % 0.59 % 0.67 % 0.81 % 0.86 % 0.84 % 0.93 % 0.83 % 1.4 % 1.7 %	Reference Power Sensor

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.13 dB 0.14 dB 0.14 dB 0.16 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source
Phase Noise – Source <sup>1</sup>	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise – Measure <sup>1</sup>	Phase Noise $\geq$ -187 dBc/Hz Carrier: 50 kHz < f $\leq$ 54 GHz Offset Frequency $\leq$ 1 Hz $\leq$ 10 Hz $\leq$ 1 MHz $\leq$ 100 MHz	2.3 dB 2.2 dB 1.9 dB 3.8 dB	Keysight N5511A Phase Noise Test System

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise - Measure	(5 to 22) dB		Reference Noise Source
	0.01 GHz	0.1 dB	
	0.1 GHz	0.09 dB	
	1 GHz	0.09 dB	
	2 GHz	0.09 dB	
	3 GHz	0.08 dB	
	4 GHz	0.06 dB	
	5 GHz	0.11 dB	
	6 GHz	0.11 dB	
	7 GHz	0.09 dB	
	8 GHz	0.07 dB	
	9 GHz	0.04 dB	
	10 GHz	0.04 dB	
	11 GHz	0.07 dB	
	12 GHz	0.07 dB	
	13 GHz	0.07 dB	
	14 GHz	0.08 dB	
	15 GHz	0.1 dB	
	16 GHz	0.06 dB	
	17 GHz	0.07 dB	
	18 GHz	0.1 dB	
	19 GHz	0.08 dB	
	20 GHz	0.09 dB	
	21 GHz	0.1 dB	
	22 GHz	0.1 dB	
	23 GHz	0.1 dB	
	24 GHz	0.09 dB	
	25 GHz	0.07 dB	
	26 GHz	0.09 dB	
	26.5 GHz	0.1 dB	
	27 GHz	0.1 dB	
28 GHz	0.08 dB		
29 GHz	0.09 dB		
30 GHz	0.1 dB		
31 GHz	0.11 dB		

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Thermal Noise - Measure	(5 to 22) dB		Reference Noise Source	
	32 GHz	0.1 dB		
	33 GHz	0.08 dB		
	34 GHz	0.09 dB		
	35 GHz	0.1 dB		
	36 GHz	0.12 dB		
	37 GHz	0.12 dB		
	38 GHz	0.1 dB		
	39 GHz	0.1 dB		
	40 GHz	0.1 dB		
	41 GHz	0.13 dB		
	42 GHz	0.15 dB		
	43 GHz	0.17 dB		
	44 GHz	0.19 dB		
	44.5 GHz	0.18 dB		
	45 GHz	0.18 dB		
46 GHz	0.1 dB			
47 GHz	0.11 dB			
48 GHz	0.11 dB			
49 GHz	0.12 dB			
50 GHz	0.16 dB			
Excess Noise Ratio Cold Source Method	(5 to 21) dB		Keysight PNA-X Network Analyzer	
	(0.5 to 6) GHz	0.1 dB		
	(6 to 18) GHz	0.11 dB		
	(18 to 26.5) GHz	0.13 dB		
	(26.5 to 33) GHz	0.14 dB		
	(33 to 36) GHz	0.15 dB		
	(36 to 39) GHz	0.16 dB		
	(39 to 40) GHz	0.17 dB		
(40 to 48) GHz	0.2 dB			
(48 to 50) GHz	0.21 dB			
CISPR 16 Pulse Response Quasi-Peak Detector Response			IGUU 2916 Pulse Generator	
	Band A	(1 to 100) Hz		0.23 dB
	Band B	(1 to 20) Hz		0.23 dB
	Band C	(1 to 20) Hz		0.3 dB
	Band D	(1 to 20) Hz		0.3 dB

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
CISPR 16 Pulse Response Quasi-Peak to Peak Detector Relative Response Ratio Band A Bands B, C, D Quasi-Peak to Average Detector Relative Response Ratio Band A Band B Band C, D Quasi-Peak	25 Hz 100 Hz  25 Hz 500 Hz 5 kHz	0.21 dB 0.21 dB  0.21 dB 0.21 dB 0.21 dB	IGUU 2916 Pulse Generator
CISPR 16 Pulse Response Absolute Amplitude Band A Band B Band C Quasi-Peak to RMS Relative Band A Band B, C, D	25 Hz 100 Hz 100 Hz  25Hz 100Hz	0.35 dB 0.35 dB 0.51 dB  0.21 dB 0.21 dB	Keysight E4419B Power Meter and E9304A Power Sensor
RF Power Measure <sup>1</sup> – Fixed Points	Power Level: -26 dBm 80 GHz 100 GHz 110 GHz	0.35 dB 0.41 dB 0.41 dB	U8489A Power Sensor
Reflection Coefficient – Magnitude <sup>2</sup>	(0.000 01 to 0.4) DC to 2 GHz (2 to 20) GHz (20 to 33) GHz (33 to 40) GHz (40 to 50) GHz (50 to 67) GHz (67 to 120) GHz	0.000 17 0.000 57 0.000 9 0.001 0.001 4 0.003 8 0.028	Keysight vector network analyzer and calibration kit
Reflection Coefficient - Phase	(0 to 180)° DC to 2 GHz (2 to 8) GHz (8 to 20) GHz (20 to 40) GHz (40 to 50) GHz (50 to 67) GHz (67 to 120) GHz	0.013° 0.026° 0.065° 0.13° 0.26° 0.57° 2.6°	Keysight vector network analyzer and calibration kit

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Transmission Coefficient - Magnitude	(-100 to 10) dB		Keysight vector network analyzer and calibration kit
	DC to 10 MHz	0.001 dB	
	10 MHz to 2 GHz	0.004 dB	
	(2 to 8) GHz	0.005 dB	
	(8 to 20) GHz	0.008 dB	
	(20 to 26.5) GHz	0.010 dB	
	(26.5 to 33) GHz	0.014 dB	
	(33 to 50) GHz	0.02 dB	
	(50 to 60) GHz	0.028 dB	
	(60 to 67) GHz	0.034 dB	
(67 to 120) GHz	0.035 dB		
Transmission Coefficient - Phase	(0 to 180)°		Keysight vector network analyzer and calibration kit
	DC to 10 MHz	0.009°	
	10 MHz to 2 GHz	0.028°	
	(2 to 8) GHz	0.067°	
	(8 to 20) GHz	0.078°	
	(20 to 26.5) GHz	0.16°	
	(26.5 to 33) GHz	0.2°	
	(33 to 40) GHz	0.23°	
	(40 to 45) GHz	0.29°	
	(45 to 50) GHz	0.31°	
(50 to 60) GHz	0.37°		
(60 to 67) GHz	0.43°		
(67 to 120) GHz	2.4°		
Attenuation - Measure	(1 to 40) dB		Keysight vector network analyzer and calibration kit
	300 kHz to 500 MHz	0.003 4 dB	
	500 MHz to 2 GHz	0.004 7 dB	
	(2 to 10) GHz	0.005 1 dB	
	(10 to 18) GHz	0.006 dB	
	(18 to 40) GHz	0.008 9 dB	
	(40 to 50) GHz	0.012 dB	
	(50 to 80) dB		
	300 kHz to 8 GHz	0.025 dB	
	(8 to 18) GHz	0.029 dB	
	(18 to 40) GHz	0.034 dB	
	(40 to 50) GHz	0.037 dB	
	(80 to 100) dB		
300 kHz to 8 GHz	0.048 dB		
(8 to 18) GHz	0.056 dB		
(18 to 40) GHz	0.059 dB		
(40 to 50) GHz	0.065 dB		

**Electrical - RF/Microwave**

Roseville, CA - Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Attenuation - Measure	(100 to 120) dB 300 kHz to 8 GHz (8 to 18) GHz (18 to 40) GHz (40 to 50) GHz	0.072 dB 0.08 dB 0.084 dB 0.094 dB	Keysight vector network analyzer and calibration kit

**Electrical – RF/Microwave**

Roseville, CA – Main Site

Parameter/Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Roseville, CA – Main Site

Parameter/ Equipment	Attenuation – Source <sup>1</sup>											
Reference Standard, Method, and/or Equipment	8496H Attenuator											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2	
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18	
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19	
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24	
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24	
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37	
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Roseville, CA – Main Site

Parameter/ Equipment	RF Power Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors											
Range	Expanded Uncertainty of Measurement (+/-)											
Power Range	Frequency Ranges (uncertainties in dB)											
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz	
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093	
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084	

**Electrical – RF/Microwave**

Roseville, CA – Main Site

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.11	0.10	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.10	0.10	0.12

**Mass and Mass Related**

Roseville, CA – Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Torque	4 lbf·in 8 lbf·in 12 lbf·in	0.08 lbf·in 0.1 lbf·in 0.17 lbf·in	Torque Analyzer
Pressure	(70 to 110) kPa	0.02 kPa	Reference Pressure Monitor

**Photometry and Radiometry**

Roseville, CA – Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Laser Optical Power – Measure (488 to 788) nm	(80 to 1 000) $\mu$ W	0.046 $\mu$ W/W + 0.09 $\mu$ W	Photodiode Power Sensor
Laser Wavelength - Measure	633 nm	0.000 0045 nm	Keysight HP 5517B Laser Head

**Thermodynamic**

Roseville, CA – Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Temperature	(-1 to 41) $^{\circ}$ C	0.01 $^{\circ}$ C	Precision Reference Thermometer
Humidity	(10 to 90) %RH	0.8 %RH	Humidity Generator

**Time and Frequency**

Roseville, CA – Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency – Source <sup>1</sup>	10 MHz	$6.5 \times 10^{-11}$ Hz	Rubidium Frequency Standard
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter
Period – Measure <sup>1</sup>	$20 \text{ ps} \leq t < 66 \text{ ps}$ $66 \text{ ps} \leq t < 100 \text{ ms}$ $100 \text{ ms} \leq t < 1 \text{ s}$ $1 \text{ s} \leq t \leq 10 \text{ s}$	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	$20 \text{ ps} \leq t \leq 100 \text{ ps}$ $100 \text{ ps} < t \leq 700 \text{ ps}$ $700 \text{ ps} < t \leq 3.8 \text{ ns}$ $3.8 \text{ ns} < t \leq 250 \text{ ns}$ $250 \text{ ns} < t \leq 1 \text{ ms}$	1.3 ps 1.1% of reading + 0.9 ps 8.5 ps 0.105% of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	$1 \text{ ms} < t \leq 100 \text{ ms}$ $100 \text{ ms} < t \leq 1 \text{ s}$ $1 \text{ s} < t \leq 10 \text{ s}$	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module

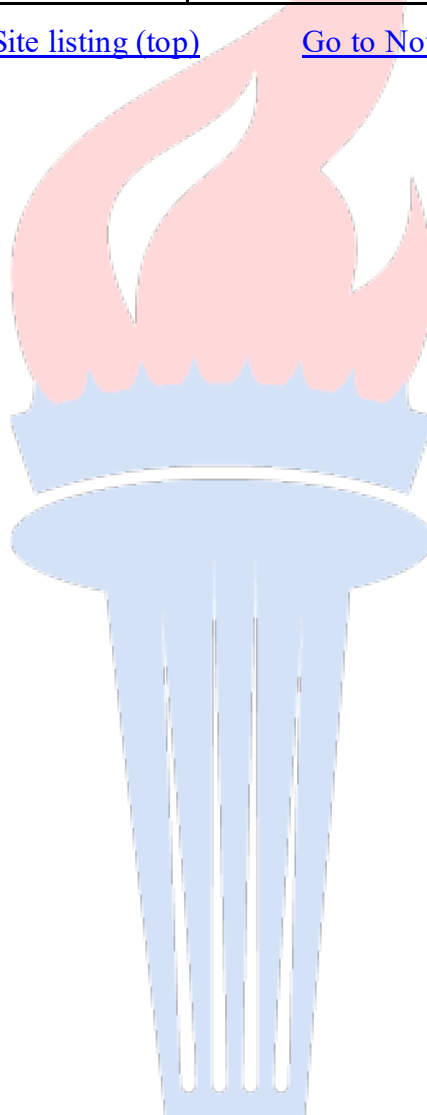
**Time and Frequency**

Roseville, CA – Main Site

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pulse Amplitude – Measure 1	$25 \text{ mV} \leq V < 100 \text{ mV}$ $100 \text{ mV} \leq V < 200 \text{ mV}$ $200 \text{ mV} \leq V < 400 \text{ mV}$ $400 \text{ mV} \leq V \leq 750 \text{ mV}$ $750 \text{ mV} < V \leq 10 \text{ V}$ $10 \text{ V} < V \leq 70 \text{ V}$	3.2 mV 4 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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## Services performed at Primary Standards laboratory

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### Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Measure <sup>5</sup>	Up to 10 V	5.5 nV	Programmable Josephson voltage standard
DC Voltage – Source <sup>5</sup>	Up to 10 V	1.1 nV	Programmable Josephson voltage standard
DC Ratio <sup>2,5</sup>	Up to 10	$1.7 \cdot 10^{-8}$ (dimensionless)	DC Voltage Standard
DC Voltage – Source & Measure	0 V (> 0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	20 nV 0.24 $\mu$ V/V 0.057 $\mu$ V/V 0.027 $\mu$ V/V 0.14 $\mu$ V/V 0.16 $\mu$ V/V	DC Voltage Standard Reference Resistors Keysight 3458A Multimeter
DC Current – Source & Measure	100 nA 1 $\mu$ A 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A (1 to 10) A	1.2 $\mu$ A/A 1.1 $\mu$ A/A 1.2 $\mu$ A/A 0.2 $\mu$ A/A 0.26 $\mu$ A/A 0.23 $\mu$ A/A 0.2 $\mu$ A/A 1 $\mu$ A/A 3.5 $\mu$ A/A	Reference Resistors Keysight 3458A Multimeter
AC Voltage – Source & Measure	1 mV 10 Hz to 1 kHz (1 to 20) kHz (20 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.11 mV/V 0.17 mV/V 0.25 mV/V 0.34 mV/V 0.53 mV/V 1.1 mV/V	AC Measurement Standard AC Divider Multifunction Calibrator

**Electrical – DC/Low Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source & Measure	3 mV		AC Measurement Standard AC Divider Multifunction Calibrator
	10 Hz to 1 kHz	36 $\mu$ V/V	
	(1 to 20) kHz	52 $\mu$ V/V	
	(20 to 100) kHz	0.11 mV/V	
	(100 to 300) kHz	0.16 mV/V	
	(300 to 500) kHz	0.26 mV/V	
	500 kHz to 1 MHz	0.52 mV/V	
	10 mV		
	10 Hz to 1 kHz	22 $\mu$ V/V	
	(1 to 20) kHz	33 $\mu$ V/V	
	(20 to 100) kHz	53 $\mu$ V/V	
	(100 to 300) kHz	0.11 mV/V	
	(300 to 500) kHz	0.21 mV/V	
	500 kHz to 1 MHz	0.42 mV/V	
	4 MHz	10.2 $\mu$ V	
	30 mV		
	10 Hz to 100 kHz	30 $\mu$ V/V	
	(100 to 300) kHz	56 $\mu$ V/V	
(300 to 500) kHz	0.11 mV/V		
500 kHz to 1 MHz	0.22 mV/V		
100 mV			
10 Hz to 100 kHz	27 $\mu$ V/V		
(100 to 300) kHz	35 $\mu$ V/V		
(300 to 500) kHz	61 $\mu$ V/V		
500 kHz to 1 MHz	0.12 mV/V		
4 MHz	102 $\mu$ V		
8 MHz	160 $\mu$ V		
10 MHz	180 $\mu$ V		
AC Voltage – Source & Measure	300 mV		Thermal Voltage Converter AC Measurement Standard
	(10 to 20) Hz	18 $\mu$ V/V	
	(20 to 100) Hz	14 $\mu$ V/V	
	100 Hz to 100 kHz	12 $\mu$ V/V	
	(100 to 500) kHz	30 $\mu$ V/V	
	500 kHz to 1 MHz	44 $\mu$ V/V	
500 mV			
1 kHz	7.2 $\mu$ V/V		

**Electrical – DC/Low Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source & Measure	1 V		Thermal Voltage Converter AC Measurement Standard
	(10 to 40) Hz	9.6 $\mu$ V/V	
	40 Hz to 30 kHz	4.8 $\mu$ V/V	
	(30 to 200) kHz	9.1 $\mu$ V/V	
	(200 to 500) kHz	17 $\mu$ V/V	
	500 kHz to 1 MHz	30 $\mu$ V/V	
	4 MHz	1 mV	
	8 MHz	1.6 mV	
	10 MHz	1.8 mV	
	3 V		
	1 kHz	4.8 $\mu$ V/V	
	(1 to 100) kHz	4.9 $\mu$ V/V	
	100 kHz to 1 MHz	0.22 mV/V	
	2 MHz	2.1 mV	
	4 MHz	3.2 mV	
	8 MHz	4.8 mV	
	10 MHz	5.5 mV	
	6 V		
	1 kHz	3.8 $\mu$ V/V	
	10 V		
	(10 to 20) Hz	7.7 $\mu$ V/V	
	20 Hz to 1 kHz	4.1 $\mu$ V/V	
	(1 to 20) kHz	3.5 $\mu$ V/V	
	(20 to 100) kHz	6.1 $\mu$ V/V	
	(100 to 300) kHz	8.5 $\mu$ V/V	
	(300 to 500) kHz	13 $\mu$ V/V	
	500 kHz to 1 MHz	22 $\mu$ V/V	
	70 V		
300 kHz	13 $\mu$ V/V		
100 V			
10 Hz to 30 kHz	7.8 $\mu$ V/V		
(30 to 50) kHz	12 $\mu$ V/V		
(50 to 200) kHz	24 $\mu$ V/V		
300 V			
(40 to 100) Hz	8.8 $\mu$ V/V		
100 Hz to 50 kHz	11 $\mu$ V/V		
(50 to 100) kHz	15 $\mu$ V/V		
500 V			
40 Hz to 50 kHz	15 $\mu$ V/V		
(50 to 100) kHz	29 $\mu$ V/V		

**Electrical – DC/Low Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source & Measure	700 V 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	11 $\mu$ V/V 13 $\mu$ V/V 19 $\mu$ V/V 55 $\mu$ V/V	Thermal Voltage Converter AC Measurement Standard
	1 000 V (40 to 100) Hz 100 Hz to 10 kHz (10 to 20) kHz (20 to 30) kHz	12 $\mu$ V/V 17 $\mu$ V/V 20 $\mu$ V/V 32 $\mu$ V/V	
AC DC Difference	300 mV (10 to 20) Hz (20 to 100) Hz 100 Hz to 100 kHz (100 to 500) kHz (0.5 to 1) MHz	18 $\mu$ V/V 14 $\mu$ V/V 12 $\mu$ V/V 30 $\mu$ V/V 44 $\mu$ V/V	Thermal Voltage Converter Nanovoltmeter
	500 mV 1 kHz	7.2 $\mu$ V/V	
	1 V (10 to 20) Hz 20 Hz to 30 kHz (30 to 200) kHz (200 to 500) kHz 500 kHz to 1 MHz	9.6 $\mu$ V/V 4.8 $\mu$ V/V 9.1 $\mu$ V/V 17 $\mu$ V/V 30 $\mu$ V/V	
	3 V 1 kHz 100 kHz to 100 kHz	4.8 $\mu$ V/V 4.9 $\mu$ V/V	
	6 V 1 kHz	3.8 $\mu$ V/V	
	10 V (10 to 20) Hz 20 Hz to 1 kHz (1 to 20) kHz (20 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	7.7 $\mu$ V/V 4.1 $\mu$ V/V 3.5 $\mu$ V/V 6.1 $\mu$ V/V 8.5 $\mu$ V/V 13 $\mu$ V/V 22 $\mu$ V/V	



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Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC DC Difference	70 V		Thermal Voltage Converter Nanovoltmeter
	300 kHz	13 $\mu$ V/V	
	100 V		
	10 Hz to 30 kHz	7.8 $\mu$ V/V	
	(30 to 50) kHz	12 $\mu$ V/V	
	(50 to 200) kHz	24 $\mu$ V/V	
	300 V		
	(40 to 100) Hz	8.8 $\mu$ V/V	
	100 Hz to 50 kHz	11 $\mu$ V/V	
	(50 to 100) kHz	15 $\mu$ V/V	
	500 V		
	40 Hz to 50 kHz	15 $\mu$ V/V	
	(50 to 100) kHz	29 $\mu$ V/V	
	700 V		
40 Hz to 1 kHz	11 $\mu$ V/V		
(1 to 20) kHz	13 $\mu$ V/V		
(20 to 50) kHz	19 $\mu$ V/V		
(50 to 100) kHz	55 $\mu$ V/V		
1 000 V			
(40 to 100) Hz	12 $\mu$ V/V		
100 Hz to 10 kHz	17 $\mu$ V/V		
(10 to 20) kHz	20 $\mu$ V/V		
(20 to 30) kHz	32 $\mu$ V/V		
AC Voltage Flatness	1 mV		Thermal Voltage Converter AC Measurement Standard
	(10 to 50) Hz	0.014 % of reading	
	50 Hz to 100 kHz	0.0096 % of reading	
	100 kHz to 1 MHz	0.014 % of reading	
	(1 to 3) MHz	0.035 % of reading	
	(3 to 4) MHz	0.049 % of reading	
	(4 to 8) MHz	0.079 % of reading	
(8 to 10) MHz	0.096 % of reading		
(10 to 30) MHz	0.13 % of reading		



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Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness	3 mV		Thermal Voltage Converter AC Measurement Standard
	(10 to 100) Hz	0.0098 % of reading	
	100 Hz to 100 kHz	0.0057 % of reading	
	(100 to 300) kHz	0.0071 % of reading	
	300 kHz to 1 MHz	0.013 % of reading	
	(1 to 3) MHz	0.033 % of reading	
	(3 to 4) MHz	0.047 % of reading	
	(4 to 8) MHz	0.075 % of reading	
	(8 to 20) MHz	0.11 % of reading	
	(20 to 30) MHz	0.12 % of reading	
	10 mV		
	(10 to 50) Hz	0.0088 % of reading	
	50 Hz to 300 kHz	0.0069 % of reading	
	300 kHz to 1 MHz	0.011 % of reading	
	(1 to 3) MHz	0.028 % of reading	
	(3 to 10) MHz	0.069 % of reading	
	(10 to 20) MHz	0.084 % of reading	
	(20 to 30) MHz	0.11 % of reading	
	30 mV		
	(10 to 50) Hz	0.0082 % of reading	
	50 Hz to 100 kHz	0.0058 % of reading	
	(100 to 300) kHz	0.0069 % of reading	
	300 kHz to 1 MHz	0.011 % of reading	
	(1 to 3) MHz	0.026 % of reading	
(3 to 10) MHz	0.062 % of reading		
(10 to 20) MHz	0.08 % of reading		
(20 to 30) MHz	0.099 % of reading		
100 mV			
(10 to 50) Hz	0.0082 % of reading		
50 Hz to 50 kHz	0.005 % of reading		
(50 to 300) kHz	0.0068 % of reading		
300 kHz to 1 MHz	0.0098 % of reading		
(1 to 3) MHz	0.025 % of reading		
(3 to 10) MHz	0.056 % of reading		
(10 to 20) MHz	0.073 % of reading		
(20 to 30) MHz	0.094 % of reading		



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Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness	300 mV		Thermal Voltage Converter AC Measurement Standard
	(10 to 50) Hz	0.008 % of reading	
	50 Hz to 50 kHz	0.0051 % of reading	
	(50 to 300) kHz	0.0066 % of reading	
	300 kHz to 1 MHz	0.0089 % of reading	
	(1 to 3) MHz	0.023 % of reading	
	(3 to 10) MHz	0.046 % of reading	
	(10 to 20) MHz	0.067 % of reading	
	(20 to 30) MHz	0.088 % of reading	
	1 V		
	(10 to 50) Hz	0.0079 % of reading	
	50 Hz to 50 kHz	0.0047 % of reading	
	(50 to 300) kHz	0.0065 % of reading	
	300 kHz to 1 MHz	0.0086 % of reading	
	(1 to 3) MHz	0.021 % of reading	
	(3 to 10) MHz	0.036 % of reading	
	(10 to 20) MHz	0.061 % of reading	
	(20 to 30) MHz	0.084 % of reading	
	3 V		
	(10 to 50) Hz	0.0077 % of reading	
	50 Hz to 50 kHz	0.005 % of reading	
(50 to 300) kHz	0.0067 % of reading		
300 kHz to 1 MHz	0.009 % of reading		
(1 to 3) MHz	0.022 % of reading		
(3 to 10) MHz	0.037 % of reading		
(10 to 20) MHz	0.061 % of reading		
(20 to 30) MHz	0.084 % of reading		
Thermal Voltage Converters	0.5 V		Thermal Voltage Converter Nanovoltmeter
	10 Hz	15 $\mu$ V/V	
	20 Hz	12 $\mu$ V/V	
	40 Hz	11 $\mu$ V/V	
	100 Hz	12 $\mu$ V/V	
	1 kHz	4.6 $\mu$ V/V	
	10 kHz	6.0 $\mu$ V/V	
	20 kHz	7.4 $\mu$ V/V	
	30 kHz	8.5 $\mu$ V/V	
	50 kHz	8.2 $\mu$ V/V	
	100 kHz	9.4 $\mu$ V/V	
	(200, 300) kHz	21 $\mu$ V/V	
	500 kHz	25 $\mu$ V/V	
1 MHz	34 $\mu$ V/V		

Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Voltage Converters	1 V		Thermal Voltage Converter Nanovoltmeter
	10 Hz	6.3 $\mu$ V/V	
	20 Hz	4.5 $\mu$ V/V	
	40 Hz	3.8 $\mu$ V/V	
	100 Hz	2.7 $\mu$ V/V	
	1 kHz	3.1 $\mu$ V/V	
	(10, 20) kHz	3.5 $\mu$ V/V	
	30 kHz	3.1 $\mu$ V/V	
	50 kHz	4.3 $\mu$ V/V	
	100 kHz	4.6 $\mu$ V/V	
	200 kHz	7.9 $\mu$ V/V	
	300 kHz	7.7 $\mu$ V/V	
	500 kHz	11 $\mu$ V/V	
	1 MHz	19 $\mu$ V/V	
	3 V		
	10 Hz	8.2 $\mu$ V/V	
	100 Hz	3.1 $\mu$ V/V	
	1 kHz	3.1 $\mu$ V/V	
	(10, 20) kHz	3.5 $\mu$ V/V	
	30 kHz	4.5 $\mu$ V/V	
	100 kHz	4.7 $\mu$ V/V	
	300 kHz	7.5 $\mu$ V/V	
	1 MHz	17 $\mu$ V/V	
	6V		
	1 kHz	2.9 $\mu$ V/V	
	10 V		
	10 Hz	8.2 $\mu$ V/V	
	20 Hz	5.1 $\mu$ V/V	
	40 Hz	3.9 $\mu$ V/V	
	100 Hz	3.1 $\mu$ V/V	
	1 kHz	3.4 $\mu$ V/V	
	10 kHz	3 $\mu$ V/V	
	20 kHz	2.7 $\mu$ V/V	
	30 kHz	2.7 $\mu$ V/V	
	50 kHz	4 $\mu$ V/V	
	100 kHz	5.2 $\mu$ V/V	
	200 kHz	7.6 $\mu$ V/V	
300 kHz	7.6 $\mu$ V/V		
500 kHz	11 $\mu$ V/V		
1 MHz	19 $\mu$ V/V		
20 V			
1 kHz	3.5 $\mu$ V/V		

Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Thermal Voltage Converters	100 V		Thermal Voltage Converter Nanovoltmeter	
	10 Hz	6.9 $\mu\text{V/V}$		
	20 Hz	7.6 $\mu\text{V/V}$		
	40 Hz	6.3 $\mu\text{V/V}$		
	100 Hz	6.8 $\mu\text{V/V}$		
	1 kHz	4 $\mu\text{V/V}$		
	10 kHz	4.3 $\mu\text{V/V}$		
	20 kHz	3.7 $\mu\text{V/V}$		
	30 kHz	3.9 $\mu\text{V/V}$		
	50 kHz	6.7 $\mu\text{V/V}$		
	100 kHz	7.3 $\mu\text{V/V}$		
	200 kHz	13 $\mu\text{V/V}$		
	300 V			
	40 Hz	6.3 $\mu\text{V/V}$		
	100 Hz	6.4 $\mu\text{V/V}$		
	1 kHz	6.6 $\mu\text{V/V}$		
	10 kHz	6.9 $\mu\text{V/V}$		
	20 kHz	5.6 $\mu\text{V/V}$		
	30 kHz	7.3 $\mu\text{V/V}$		
	50 kHz	8.7 $\mu\text{V/V}$		
	100 kHz	15 $\mu\text{V/V}$		
	500 V			
	(40, 100) Hz	9.2 $\mu\text{V/V}$		
	1 kHz	9.2 $\mu\text{V/V}$		
	10 kHz	9.4 $\mu\text{V/V}$		
	20 kHz	10 $\mu\text{V/V}$		
	30 kHz	11 $\mu\text{V/V}$		
	50 kHz	15 $\mu\text{V/V}$		
	100 kHz	26 $\mu\text{V/V}$		
	700 V			
	40 Hz	10 $\mu\text{V/V}$		
	100 Hz	9.3 $\mu\text{V/V}$		
(1, 10, 20) kHz	10 $\mu\text{V/V}$			
30 kHz	12 $\mu\text{V/V}$			
50 kHz	16 $\mu\text{V/V}$			
100 kHz	24 $\mu\text{V/V}$			
1000 V				
40 Hz	11 $\mu\text{V/V}$			
100 Hz	10 $\mu\text{V/V}$			
(1, 10, 20) kHz	11 $\mu\text{V/V}$			
30 kHz	12 $\mu\text{V/V}$			

**Electrical – DC/Low Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Voltage Converters	(0.5 to 3) V 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.02 % of reading 0.03 % of reading 0.04 % of reading 0.06 % of reading 0.08 % of reading 0.17 % of reading 0.29 % of reading 0.31 % of reading 0.37 % of reading	Ballantine 1395A Thermal Voltage Converter
Thermal Voltage Converters	6 V 10 Hz 100 Hz 10 kHz 30 kHz 100 kHz 300 kHz 1 MHz	0.007 % of reading 0.004 % of reading 0.004 % of reading 0.004 % of reading 0.005 % of reading 0.006 % of reading 0.01 % of reading	Holt 11 Thermal Voltage Converter
AC Ratio <sup>2,5</sup>	(0.001 to 1) Ratio 400 Hz to 1 kHz	4 x 10 <sup>-6</sup>	Decade Ratio Transformer
AC Current – Measure	20 μA (1, 10) kHz 200 μA 10 Hz 20 Hz (0.04, 1, 5, 10) kHz 2 mA 10 Hz 20 Hz (0.04, 1, 5, 10) kHz 20 mA 10 Hz 20 Hz (0.04, 1, 5, 10) kHz 200 mA 10 Hz 20 Hz (0.04, 1, 5, 10) kHz	2.8 nA 31 nA 23 nA 21 nA 270 nA 180 nA 150 nA 2.6 μA 1.6 μA 1.3 μA 26 μA 16 μA 13 μA	AC Measurement Standard AC Shunt Resistors Multifunction Calibrator

Electrical – DC/Low Frequency

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Current – Measure	2 A 20 Hz (1, 5) kHz 10 kHz	190 $\mu$ A 170 $\mu$ A 590 $\mu$ A	AC Measurement Standard AC Shunt Resistors Multifunction Calibrator	
	3 A 40 Hz (1, 5) kHz 10 kHz	64 $\mu$ A 93 $\mu$ A 200 $\mu$ A		
	10 A 40 Hz 1 kHz 5 kHz 10 kHz	0.36 mV 0.39 mV 0.79 mV 8 mV		
AC Current – Measure	10 $\mu$ A (0 to 10) Hz (10 to 20) Hz (20 to 50) Hz 50 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	51 $\mu$ A/A 72 $\mu$ A/A 49 $\mu$ A/A 45 $\mu$ A/A 53 $\mu$ A/A 55 $\mu$ A/A	Current Shunt AC Measurement Standard Multifunction Calibrator Keysight 3458A Multimeter	
	100 $\mu$ A (0 to 10) Hz (10 to 50) Hz 50 Hz to 1 kHz (1 to 10) kHz	47 $\mu$ A/A 46 $\mu$ A/A 46 $\mu$ A/A 47 $\mu$ A/A		
	1 mA (0 to 50) Hz 50 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	40 $\mu$ A/A 40 $\mu$ A/A 41 $\mu$ A/A 39 $\mu$ A/A		
	10 mA (>0 to 10) Hz (10 to 20) Hz (20 to 50) Hz 50 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	26 $\mu$ A/A 25 $\mu$ A/A 25 $\mu$ A/A 25 $\mu$ A/A 26 $\mu$ A/A 26 $\mu$ A/A		
AC Current – Measure	10 mA (>0 to 10) Hz (10 to 20) Hz (20 to 50) Hz 50 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	26 $\mu$ A/A 25 $\mu$ A/A 25 $\mu$ A/A 25 $\mu$ A/A 26 $\mu$ A/A 26 $\mu$ A/A	Current Shunt Multifunction Calibrator Nanovoltmeter	

**Electrical – DC/Low Frequency**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure	100 mA		Current Shunt Multifunction Calibrator Nanovoltmeter
	(>0 to 10) Hz	48 $\mu$ A/A	
	(10 to 20) Hz	48 $\mu$ A/A	
	(20 to 50) Hz	48 $\mu$ A/A	
	50 Hz to 1 kHz	48 $\mu$ A/A	
	(1 to 5) kHz	48 $\mu$ A/A	
	(5 to 10) kHz	44 $\mu$ A/A	
	1 A		
	(>0 to 10) Hz	37 $\mu$ A/A	
	(10 to 20) Hz	37 $\mu$ A/A	
	(20 to 50) Hz	37 $\mu$ A/A	
	50 Hz to 1 kHz	37 $\mu$ A/A	
	(1 to 5) kHz	38 $\mu$ A/A	
	(5 to 10) kHz	42 $\mu$ A/A	
	10 A		
40 Hz to 1 kHz	53 $\mu$ A/A		
(1 to 5) kHz	73 $\mu$ A/A		
(5 to 10) kHz	53 $\mu$ A/A		
Resistance – Source and Measure	0.001 $\Omega$		Current Shunt Reference Resistor AC Measurement Standard
	> 0 Hz to 10 kHz	0.029 % of reading	
	0.004 $\Omega$		
	(> 0 to 40) Hz	0.013 % of reading	
	(40 to 400) Hz	0.012 % of reading	
	400 Hz to 1 kHz	0.011 % of reading	
	40 Hz to 3 kHz	0.012 % of reading	
	(1 to 3) kHz	0.012 % of reading	
	(3 to 5) kHz	0.011 % of reading	
	(5 to 10) kHz	0.011 % of reading	
	0.01 $\Omega$		
	(> 0 to 40) Hz	0.014 % of reading	
	(40 to 400) Hz	0.012 % of reading	
	400 Hz to 1 kHz	0.01 % of reading	
	(1 to 10) kHz	0.009 % of reading	

Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source and Measure	0.1 $\Omega$		Current Shunt Reference Resistor AC Measurement Standard
	10 Hz	46 $\mu\Omega/\Omega$	
	20 Hz	30 $\mu\Omega/\Omega$	
	30 Hz	34 $\mu\Omega/\Omega$	
	50 Hz	34 $\mu\Omega/\Omega$	
	100 Hz	34 $\mu\Omega/\Omega$	
	300 Hz	30 $\mu\Omega/\Omega$	
	1 kHz	29 $\mu\Omega/\Omega$	
	3 kHz	30 $\mu\Omega/\Omega$	
	5 kHz	29 $\mu\Omega/\Omega$	
	10 kHz	33 $\mu\Omega/\Omega$	
	1 $\Omega$		
	10 Hz	29 $\mu\Omega/\Omega$	
	20 Hz	30 $\mu\Omega/\Omega$	
	30 Hz	29 $\mu\Omega/\Omega$	
	50 Hz	27 $\mu\Omega/\Omega$	
	100 Hz	28 $\mu\Omega/\Omega$	
	300 Hz	26 $\mu\Omega/\Omega$	
	1 kHz	26 $\mu\Omega/\Omega$	
	3 kHz	29 $\mu\Omega/\Omega$	
	5 kHz	29 $\mu\Omega/\Omega$	
	10 kHz	30 $\mu\Omega/\Omega$	
	10 $\Omega$		
	10 Hz	31 $\mu\Omega/\Omega$	
	20 Hz	26 $\mu\Omega/\Omega$	
	30 Hz	27 $\mu\Omega/\Omega$	
	50 Hz	28 $\mu\Omega/\Omega$	
	100 Hz	26 $\mu\Omega/\Omega$	
	300 Hz	28 $\mu\Omega/\Omega$	
	1 kHz	28 $\mu\Omega/\Omega$	
3 kHz	27 $\mu\Omega/\Omega$		
5 kHz	28 $\mu\Omega/\Omega$		
10 kHz	28 $\mu\Omega/\Omega$		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source and Measure	100 Ω		Current Shunt Reference Resistor AC Measurement Standard
	10 Hz	54 μΩ/Ω	
	20 Hz	43 μΩ/Ω	
	30 Hz	38 μΩ/Ω	
	50 Hz	38 μΩ/Ω	
	100 Hz	37 μΩ/Ω	
	300 Hz	38 μΩ/Ω	
	1 kHz	35 μΩ/Ω	
	3 kHz	36 μΩ/Ω	
	5 kHz	38 μΩ/Ω	
	10 kHz	37 μΩ/Ω	
	1 000 Ω		
	10 Hz	72 μΩ/Ω	
	20 Hz	55 μΩ/Ω	
	30 Hz	52 μΩ/Ω	
	50 Hz	51 μΩ/Ω	
	100 Hz	51 μΩ/Ω	
	300 Hz	52 μΩ/Ω	
	1 kHz	46 μΩ/Ω	
	3 kHz	47 μΩ/Ω	
5 kHz	50 μΩ/Ω		
10 kHz	50 μΩ/Ω		
Resistance – Measure 4 Terminal Pair	10 Ω		LCR Meter RL Standard Capacitor Set
	1 MHz	0.3 mΩ/Ω	
	2 MHz	0.5 mΩ/Ω	
	3 MHz	0.6 mΩ/Ω	
	4 MHz	0.7 mΩ/Ω	
	5 MHz	1 mΩ/Ω	
	10 MHz	4 mΩ/Ω	
	13 MHz	6 mΩ/Ω	
	100 Ω		
	1 MHz	0.3 mΩ/Ω	
	2 MHz	0.4 mΩ/Ω	
	(3, 4, 5) MHz	0.5 mΩ/Ω	
	10 MHz	2 mΩ/Ω	
	13 MHz	3 mΩ/Ω	

**Electrical – DC/Low Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Measure 4 Terminal Pair	1 kΩ		LCR Meter RL Standard Capacitor Set
	100 kHz	0.3 mΩ/Ω	
	(1, 2, 3) MHz	0.3 mΩ/Ω	
	4 MHz	0.4 mΩ/Ω	
	5 MHz	0.5 mΩ/Ω	
	10 MHz	2 mΩ/Ω	
	13 MHz	3 mΩ/Ω	
	10 kΩ		
	100 kHz	0.2 mΩ/Ω	
	1 MHz	0.3 mΩ/Ω	
DC Resistance – Source and Measure <sup>5</sup>	100 kΩ		Resistance Bridge Reference Resistors
	100 kHz	0.3 mΩ/Ω	
	1 MHz	0.3 mΩ/Ω	
	Short	0.02 μΩ	
	1 mΩ to 1 Ω	0.064 μΩ/Ω	
	(1 to 100) Ω	0.065 μΩ/Ω	
	100 Ω to 1 kΩ	0.082 μΩ/Ω	
	(1 to 10) kΩ	0.10 μΩ/Ω	
10 kΩ	0.095 μΩ/Ω		
DC Resistance – Source and Measure <sup>5</sup>	(10 to 100) kΩ	0.17 μΩ/Ω	High Resistance Meter Reference Resistors
	100 kΩ to 1 MΩ	0.35 μΩ/Ω	
	(1 to 10) MΩ	0.69 μΩ/Ω	
	(10 to 100) MΩ	4.1 μΩ/Ω	
Capacitance – Source	1 GΩ	41 μΩ/Ω	Reference Capacitors
	10 GΩ	46 μΩ/Ω	
	100 GΩ	52 μΩ/Ω	
	1 pF		
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
(10 to 13) MHz	2.2 fF		

**Electrical – DC/Low Frequency**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Capacitance – Source	100 pF		Reference Capacitors	
	1 kHz to 3 MHz	14 fF		
	(3 to 4) MHz	17 fF		
	(4 to 5) MHz	20 fF		
	(5 to 10) MHz	37 fF		
	(10 to 13) MHz	53 fF		
	1 000 pF			
	20 Hz to 1 MHz	0.14 pF		
	(1 to 2) MHz	0.21 pF		
	(2 to 3) MHz	0.31 pF		
	(3 to 4) MHz	0.47 pF		
	(4 to 5) MHz	0.64 pF		
	(5 to 10) MHz	2 pF		
(10 to 13) MHz	3 pF			
10 nF		Reference Capacitors		
120 Hz to 100 kHz	1.5 pF			
100 nF				
120 Hz to 100 kHz	15 pF			
1 μF				
120 Hz to 1 kHz	0.52 nF			
(1 to 10) kHz	0.43 nF			
(10 to 100) kHz	0.72 nF			
10 μF				
20 Hz to 1 kHz	1.6 nF			
(1 to 20) kHz	2.2 nF			
Capacitance – Source	1 kHz			Capacitance Standard Ratio Transformer
	1 pF		11 μF/F	
	10 pF	5.4 μF/F		
	100 pF	1.9 μF/F		
	1 nF	8.8 μF/F		
	10 nF	27 μF/F		
	100 nF	34 μF/F		
1 μF	43 μF/F			
Capacitance - Measure	1 kHz		Capacitance Bridge	
	1 pF to 40 nF	3 μF/F		
	(40 to 100) nF	4 μF/F		
	(100 to 400) nF	5 μF/F		
	400 nF to 1.2 μF	8 μF/F		

Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Measure <sup>2</sup>	>0 to 1		Capacitance Bridge
	1 kHz		
	1 pF to 1 nF	0.000 003	
	(1 to 10) nF	0.000 005	
	(10 to 40) nF	0.000 010	
	(40 to 70) nF	0.000 015	
	(70 to 100) nF	0.000 020	
	(100 to 200) nF	0.000 040	
	(200 to 300) nF	0.000 055	
	(300 to 400) nF	0.000 075	
	(400 to 500) nF	0.000 095	
	(500 to 600) nF	0.000 11	
	(600 to 700) nF	0.000 13	
	(700 to 800) nF	0.000 15	
(800 to 900) nF	0.000 16		
900 nF to 1 μF	0.000 18		
(1 to 1.2) μF	0.000 21		
Dissipation Factor – Measure <sup>2</sup>	>0 to 1		Capacitance Bridge Network Analyzer Calibration Kit
	1 pF		
	1 kHz	0.000 02	
	1 MHz	0.000 03	
	2 MHz	0.000 06	
	3 MHz	0.000 09	
	4 MHz	0.000 14	
	5 MHz	0.000 2	
	10 MHz	0.000 57	
	13 MHz	0.000 83	
	10 pF		
	1 kHz	0.000 02	
	(1, 2, 3, 4) MHz	0.000 02	
	5 MHz	0.000 03	
	10 MHz	0.000 07	
	13 MHz	0.000 09	

Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Measure <sup>2</sup>	>0 to 1		Capacitance Bridge Network Analyzer Calibration Kit
	100 pF		
	1 kHz	0.000 02	
	(1, 2) MHz	0.000 02	
	3 MHz	0.000 03	
	4 MHz	0.000 05	
	5 MHz	0.000 06	
	10 MHz	0.000 16	
	13 MHz	0.000 24	
	1 000 pF		
	1 kHz	0.000 02	
	1 MHz	0.000 03	
	2 MHz	0.000 06	
	3 MHz	0.000 10	
	4 MHz	0.000 15	
	5 MHz	0.000 21	
	10 MHz	0.000 58	
	13 MHz	0.000 85	
	0.01 μF		
	120 Hz,	0.000 02	
	(1, 10, 100) kHz	0.000 02	
	0.1 μF		
	120 Hz	0.000 03	
	(1, 10) kHz	0.000 02	
	100 kHz	0.000 03	
	1 μF		
	120 Hz	0.000 04	
	1 kHz	0.000 02	
	10 kHz	0.000 03	
	100 kHz	0.000 04	
10 μF			
120 Hz	0.000 04		
1 kHz	0.000 03		
10 kHz	0.000 28		
100 kHz	0.000 7		
1 pF			
1 kHz	0.001 9		
1 kHz to 4 MHz	0.000 15		
(4 to 5) MHz	0.000 21		
(5 to 10) MHz	0.000 57		
(10 to 13) MHz	0.000 84		

Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Measure <sup>2</sup>	>0 to 1		Capacitance Bridge Network Analyzer Calibration Kit
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
(1 to 2) MHz	0.000 073		
(2 to 3) MHz	0.000 1		
(3 to 4) MHz	0.001 5		
(4 to 5) MHz	0.000 21		
(5 to 10) MHz	0.000 58		
(10 to 13) MHz	0.000 86		
10 nF			
120 Hz to 1 kHz	0.000 024		
(1 to 100) kHz	0.000 021		
Dissipation Factor – Source <sup>2</sup>	>0 to 1		Reference Capacitors
	100 nF		
	120 Hz to 1 kHz	0.000 04	
	(1 to 100) kHz	0.000 021	
	1 μF		
	120 Hz to 1 kHz	0.000 041	
	(1 to 10) kHz	0.000 035	
	(10 to 100) kHz	0.000 11	
	10 μF		
	(20 to 120) Hz	0.000 04	
120 Hz to 10 kHz	0.000 03		
(10 to 100) kHz	0.000 76		

**Electrical – DC/Low Frequency**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Inductance – Measure	1 MHz		LCR Meter Reference RL Standard
	1 nH 0.2 nH 1 nH	1 nH 0.3 nH 1 nH	
Reactance – Measure	20 nH	7 nH	LCR Meter RL Standard Reference Capacitors
	10 Ω		
	1 MHz	4 mΩ	
	(2, 3) MHz	5 mΩ	
	4 MHz	6 mΩ	
	5 MHz	7 mΩ	
	10 MHz	20 mΩ	
	13 MHz	40 mΩ	
	100 Ω		
	(1, 2, 3, 4, 5) MHz	40 mΩ	
10 MHz	80 mΩ		
13 MHz	90 mΩ		
Susceptance – Measure	1 kΩ		LCR Meter Reference Capacitors
	100 kHz	0.4 μS	
	(1, 2, 3, 4, 5) MHz	0.4 μS	
	(10, 13) MHz	0.7 μS	
	10 kΩ		
(0.1, 1) MHz	0.04 μS		
100 kΩ			
(0.1, 1) MHz	4 nS		

**Electrical – RF/Microwave**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power - Power Meter Reference	1 mW, 50 MHz	0.22 % of reading	Coaxial Thermistor Mount Power Meter

**Electrical – RF/Microwave**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Power Sensors - Calibration Factors <sup>2</sup>	50 to 110%		Coaxial Thermistor Mount Power Meter
	9 kHz to 50 MHz	0.35 %	
	(50 to 100) MHz	0.21 %	
	(0.1 to 4) GHz	0.33 %	
	(4 to 8) GHz	0.39 %	
	(8 to 12.4) GHz	0.48 %	
	(12.4 to 15) GHz	0.51 %	
	(15 to 16) GHz	0.54 %	
	(16 to 17) GHz	0.59 %	
	(17 to 18) GHz	0.67 %	
	(18 to 26) GHz	0.81 %	
	(26 to 31) GHz	0.86 %	
	(31 to 37) GHz	0.84 %	
(37 to 38) GHz	0.93 %		
(38 to 40) GHz	0.83 %		
(40 to 45) GHz	1.4 %		
(45 to 50) GHz	1.7 %		
Attenuation – Measure	20 Hz to 50 MHz (1 to 12) dB	0.002 4 dB	Precision Ratio Transformer Network Analyzer Calibration Kit
	50 MHz to 1 GHz (1 to 12) dB	0.004 8 dB	
	1 GHz to 2 GHz (1 to 12) dB	0.005 8 dB	
	2 GHz to 4 GHz (1 to 12) dB	0.007 5 dB	
Attenuation - Measure	20 Hz to 50 MHz		Precision Ratio Transformer Network Analyzer Calibration Kit
	10 dB	0.0025 dB	
	20 dB	0.0035 dB	
	30 dB	0.0044 dB	
	40 dB	0.0067 dB	
	50 dB	0.0085 dB	
	60 dB	0.0100 dB	
	70 dB	0.014 dB	
	80 dB	0.017 dB	
	90 dB	0.020 dB	
100 dB	0.030 dB		
110 dB	0.037 dB		

**Electrical – RF/Microwave**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Attenuation - Measure	50 MHz to 1 GHz		Precision Ratio Transformer Network Analyzer Calibration Kit
	10 dB	0.0052 dB	
	20 dB	0.0074 dB	
	30 dB	0.0091 dB	
	40 dB	0.014 dB	
	50 dB	0.017 dB	
	60 dB	0.020 dB	
	70 dB	0.029 dB	
	80 dB	0.036 dB	
	90 dB	0.042 dB	
	100 dB	0.060 dB	
	110 dB	0.074 dB	
	(1 to 2) GHz		
	10 dB	0.0066 dB	
	20 dB	0.010 dB	
	30 dB	0.012 dB	
	40 dB	0.019 dB	
	50 dB	0.024 dB	
	60 dB	0.028 dB	
	70 dB	0.040 dB	
	80 dB	0.049 dB	
	90 dB	0.057 dB	
	100 dB	0.081 dB	
	110 dB	0.100 dB	
	(2 to 4) GHz		
	10 dB	0.0068 dB	
	20 dB	0.011 dB	
	30 dB	0.015 dB	
	40 dB	0.025 dB	
	50 dB	0.031 dB	
60 dB	0.037 dB		
70 dB	0.053 dB		
80 dB	0.066 dB		
90 dB	0.077 dB		
100 dB	0.11 dB		
110 dB	0.13 dB		
Excess Noise Ratio – Measure	(5, 15, 21) dB		Reference Noise Source
	10 MHz to 18 GHz	0.052 dB	
	18 to 26.5 GHz	0.056 dB	



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Electrical - RF Microwave

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Parameter/Equipment		Voltage Reflection Coefficient S11/S22 - Magnitude (Linear)								
Reference Standard, Method, and/or Equipment		Keysight Microwave Network analyzer								
Expanded Uncertainty of Measurement (+/-)										
Frequency	≤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
900 Hz to 10 MHz	0.000 17	0.000 23	0.000 3	0.000 37	0.000 41	0.000 45	0.000 48	0.000 51	0.000 53	0.000 22
10 MHz to 2 GHz	0.000 18	0.000 23	0.000 31	0.000 38	0.000 43	0.000 47	0.000 5	0.000 52	0.000 53	0.000 22
(2.0 to 8.0) GHz	0.000 57	0.000 61	0.000 72	0.000 76	0.000 75	0.000 72	0.000 66	0.000 59	0.000 55	0.000 23
(8.0 to 20) GHz	0.000 57	0.000 62	0.000 71	0.000 81	0.000 91	0.001	0.000 97	0.000 94	0.000 94	0.000 89
(20 to 26.5) GHz	0.000 91	0.000 96	0.001 1	0.001 2	0.001 4	0.001 6	0.001 5	0.001 4	0.001 4	0.001 4
(26.5 to 33) GHz	0.000 9	0.000 99	0.001 2	0.001 5	0.001 8	0.001 8	0.001 6	0.001 5	0.001 4	0.001 4
(33 to 40) GHz	0.001	0.001	0.001 2	0.001 6	0.002	0.002 1	0.001 8	0.001 6	0.001 5	0.001 5
(40 to 45) GHz	0.001 4	0.001 5	0.001 8	0.002 2	0.002 7	0.002 5	0.002 3	0.002 1	0.002 1	0.002 1
(45 to 50) GHz	0.001 4	0.001 5	0.001 7	0.002	0.002 2	0.002 6	0.002 5	0.002 3	0.002 1	0.002 1
(50 to 60) GHz	0.003 8	0.003 8	0.003 9	0.003 9	0.003 9	0.004	0.004 1	0.004 4	0.004 8	0.005 4
(60 to 67) GHz	0.003 9	0.003 9	0.004	0.004	0.004 2	0.004 4	0.004 7	0.005 1	0.005 7	0.006 4

Electrical - RF Microwave

Roseville, CA Primary Standards Laboratory

Parameter/Equipment		Voltage Reflection Coefficient S11/S22 - Phase (Degrees)								
Reference Standard, Method, and/or Equipment		Keysight Microwave Network analyzer								
Expanded Uncertainty of Measurement (+/-)										
Frequency	≤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
900 Hz to 10 MHz	0.13 °	0.086 °	0.070 °	0.059 °	0.052 °	0.046 °	0.041 °	0.038 °	0.035 °	0.013 °
10 MHz to 2 GHz	0.13 °	0.089 °	0.073 °	0.062 °	0.054 °	0.048 °	0.043 °	0.038 °	0.035 °	0.013 °
(2.0 to 8.0) GHz	0.37 °	0.23 °	0.16 °	0.12 °	0.094 °	0.076 °	0.063 °	0.050 °	0.042 °	0.026 °
(8.0 to 20) GHz	0.39 °	0.26 °	0.21 °	0.16 °	0.13 °	0.11 °	0.092 °	0.081 °	0.071 °	0.065 °
(20 to 26.5) GHz	0.59 °	0.41 °	0.37 °	0.29 °	0.23 °	0.20 °	0.17 °	0.16 °	0.15 °	0.15 °
(26.5 to 33) GHz	0.63 °	0.45 °	0.40 °	0.36 °	0.29 °	0.23 °	0.19 °	0.16 °	0.14 °	0.14 °
(33 to 40) GHz	0.63 °	0.46 °	0.42 °	0.37 °	0.29 °	0.24 °	0.19 °	0.16 °	0.14 °	0.13 °
(40 to 45) GHz	0.93 °	0.63 °	0.55 °	0.51 °	0.42 °	0.35 °	0.31 °	0.27 °	0.26 °	0.26 °
(45 to 50) GHz	0.96 °	0.69 °	0.61 °	0.54 °	0.43 °	0.36 °	0.31 °	0.28 °	0.26 °	0.26 °
(50 to 60) GHz	2.2 °	1.2 °	0.8 °	0.69 °	0.61 °	0.57 °	0.55 °	0.55 °	0.55 °	0.57 °
(60 to 67) GHz	2.3 °	1.2 °	0.8 °	0.70 °	0.64 °	0.61 °	0.59 °	0.59 °	0.60 °	0.58 °



ANSI National Accreditation Board

**Electrical - RF Microwave**

Roseville, CA Roseville, CA Primary Standards Laboratory

Parameter/Equipment		Transmission S12/S21 - Magnitude (dB)						
Reference Standard, Method, and/or Equipment		Keysight Microwave Network analyzer						
Expanded Uncertainty of Measurement (+/-)								
Frequency	(0 to 3) dB	(3 to 6) dB	(6 to 10) dB	(10 to 20) dB	(20 to 30) dB	(30 to 40) dB	(40 to 50) dB	(50 to 60) dB
900 Hz to 10 MHz	0.001 2 dB	0.005 9 dB	0.007 3 dB	0.009 3 dB	0.013 dB	0.017 dB	0.02 dB	0.026 dB
10 MHz to 2 GHz	0.004 dB	0.007 1 dB	0.008 1 dB	0.009 dB	0.011 dB	0.014 dB	0.017 dB	0.021 dB
(2.0 to 8.0) GHz	0.005 4 dB	0.007 5 dB	0.008 1 dB	0.009 dB	0.011 dB	0.014 dB	0.017 dB	0.021 dB
(8.0 to 20) GHz	0.008 2 dB	0.009 6 dB	0.01 dB	0.011 dB	0.013 dB	0.016 dB	0.018 dB	0.021 dB
(20 to 26.5) GHz	0.01 dB	0.011 dB	0.012 dB	0.012 dB	0.014 dB	0.017 dB	0.019 dB	0.022 dB
(26.5 to 33) GHz	0.015 dB	0.016 dB	0.016 dB	0.016 dB	0.018 dB	0.02 dB	0.022 dB	0.028 dB
(33 to 40) GHz	0.020 dB	0.028 dB	0.028 dB	0.028 dB	0.029 dB	0.03 dB	0.032 dB	0.036 dB
(40 to 45) GHz	0.022 dB	0.033 dB	0.033 dB	0.033 dB	0.034 dB	0.035 dB	0.037 dB	0.044 dB
(45 to 50) GHz	0.023 dB	0.035 dB	0.035 dB	0.035 dB	0.036 dB	0.037 dB	0.039 dB	0.045 dB
(50 to 60) GHz	0.028 dB	0.028 dB	0.029 dB	0.029 dB	0.03 dB	0.031 dB	0.033 dB	0.042 dB
(60 to 67) GHz	0.034 dB	0.034 dB	0.034 dB	0.035 dB	0.035 dB	0.037 dB	0.039 dB	0.048 dB

**Electrical - RF Microwave**

Roseville, CA Roseville, CA Primary Standards Laboratory

Parameter/Equipment		Transmission S12/S21 - Phase (degrees)						
Reference Standard, Method, and/or Equipment		Keysight Microwave Network analyzer						
Expanded Uncertainty of Measurement (+/-)								
Frequency	(0 to 3) dB	(3 to 6) dB	(6 to 10) dB	(10 to 20) dB	(20 to 30) dB	(30 to 40) dB	(40 to 50) dB	(50 to 60) dB
900 Hz to 10 MHz	0.0090 °	0.040 °	0.049 °	0.062 °	0.087 °	0.11 °	0.14 °	0.17 °
10 MHz to 2 GHz	0.028 °	0.048 °	0.056 °	0.067 °	0.088 °	0.11 °	0.13 °	0.15 °
(2.0 to 8.0) GHz	0.069 °	0.077 °	0.080 °	0.084 °	0.096 °	0.11 °	0.13 °	0.15 °
(8.0 to 20) GHz	0.078 °	0.085 °	0.088 °	0.091 °	0.10 °	0.12 °	0.13 °	0.15 °
(20 to 26.5) GHz	0.17 °	0.17 °	0.17 °	0.17 °	0.18 °	0.19 °	0.20 °	0.21 °
(26.5 to 33) GHz	0.20 °	0.21 °	0.21 °	0.21 °	0.21 °	0.22 °	0.23 °	0.26 °
(33 to 40) GHz	0.23 °	0.24 °	0.24 °	0.24 °	0.24 °	0.25 °	0.26 °	0.28 °
(40 to 45) GHz	0.30 °	0.30 °	0.30 °	0.30 °	0.30 °	0.31 °	0.32 °	0.35 °
(45 to 50) GHz	0.31 °	0.31 °	0.31 °	0.31 °	0.32 °	0.32 °	0.33 °	0.37 °
(50 to 60) GHz	0.38 °	0.38 °	0.38 °	0.38 °	0.38 °	0.39 °	0.4 °	0.43 °
(60 to 67) GHz	0.43 °	0.43 °	0.44 °	0.44 °	0.44 °	0.44 °	0.45 °	0.49 °

**Mass and Mass Related**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Torque	4 lbf·in 8 lbf·in 12 lbf·in	0.08 lbf·in 0.1 lbf·in 0.17 lbf·in	Torque Analyzer

**Time/Frequency**

Roseville, CA Primary Standards Laboratory

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Source	1 Hz 1 kHz 10 MHz	12 $\mu$ Hz/Hz 0.15 $\mu$ Hz/Hz 0.01 $\mu$ Hz/Hz	Frequency Reference Standard Function Generator

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**Services performed at satellite laboratory  
(AC-1498.01)**

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**Acoustics and Vibration**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Accelerometers 0.1 mV to 10 V/G or pc/g	Sinusoidal (2 to 4) Hz 5 Hz to 2 kHz (2 to 10) kHz	2.5 % of reading 1.5 % of reading 2.5 % of reading	Bouche Vibration System; Endevco 2270M8 Standard Accelerometer (Reference & Check Standard)
	Shock (20 to 10 000) g	2 % of reading	Shock System & Standard Shock Accelerometer

**Electrical – DC/Low Frequency**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	(2 to 60) kV	40 $\mu$ V/V	PTB Voltage Divider
DC Voltage – Source Fixed Points	1 mV 10 mV	15 $\mu$ V 110 nV	Fluke 57x0A Calibrator Fluke 742A Resistors
DC Voltage – Source <sup>1</sup> Fixed Points	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage Measure	0V	12 $\mu$ V	Keysight 34420A



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu\text{V}/\text{V}$ + 0.36 $\mu\text{V}$ 3.7 $\mu\text{V}/\text{V}$ + 0.35 $\mu\text{V}$ 3.1 $\mu\text{V}/\text{V}$ + 0.59 $\mu\text{V}$ 5.3 $\mu\text{V}$ + 36 $\mu\text{V}$ 5.3 $\mu\text{V}/\text{V}$ + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu\text{V}/\text{V}$ + 62 nV 0.37 $\mu\text{V}/\text{V}$ + 124 nV 62 nV/V + 0.62 $\mu\text{V}$ 0.62 $\mu\text{V}/\text{V}$ + 12 $\mu\text{V}$ 1.9 $\mu\text{V}/\text{V}$ + 63 $\mu\text{V}$	Keysight 3458A Multimeter
Resistance – Source <sup>1</sup>	(0.1 to 0.2) m $\Omega$ (0.2 to 0.3) m $\Omega$ (0.3 to 0.4) m $\Omega$ (0.4 to 1) m $\Omega$ (1 to 2) m $\Omega$ (3 to 5) m $\Omega$ (6 to 9) m $\Omega$ (10 to 20) m $\Omega$ (3 to 5) m $\Omega$ (6 to 9) m $\Omega$ (0.3 to 0.5) $\Omega$ (0.6 to 0.9) $\Omega$ (1 to 13) $\Omega$ 14 $\Omega$ to 1 k $\Omega$ (1.1 to 9) k $\Omega$ (11 to 100) k $\Omega$ 200 k $\Omega$ to 1 M $\Omega$ (2 to 10) M $\Omega$ (11 to 100) M $\Omega$ (200 to 900) M $\Omega$	7.2 $\mu\Omega/\Omega$ 4.3 $\mu\Omega/\Omega$ 3.3 $\mu\Omega/\Omega$ 2.9 $\mu\Omega/\Omega$ 1.4 $\mu\Omega/\Omega$ 3.4 $\mu\Omega/\Omega$ 2.4 $\mu\Omega/\Omega$ 1.5 $\mu\Omega/\Omega$ 3.4 $\mu\Omega/\Omega$ 2.4 $\mu\Omega/\Omega$ 1.4 $\mu\Omega/\Omega$ 1 $\mu\Omega/\Omega$ 0.17 $\mu\Omega/\Omega$ 0.38 $\mu\Omega/\Omega$ 0.4 $\mu\Omega/\Omega$ 0.45 $\mu\Omega/\Omega$ 0.84 $\mu\Omega/\Omega$ 1.8 $\mu\Omega/\Omega$ 4.1 $\mu\Omega/\Omega$ 12 $\mu\Omega/\Omega$	Guildline 6675A Bridge, 6623 Extender, L&N Standard Resistors, ESIU SR 1010, SR 1050, Hart 7009 Oil Bath, MI 9300 Air Bath
Resistance – Source Fixed Points <sup>1</sup>	0.1 $\Omega$ 0.2 $\Omega$ 1 $\Omega$ 10 $\Omega$ 100 $\Omega$ 1 k $\Omega$ 10 k $\Omega$ 1 G $\Omega$	0.62 $\mu\Omega/\Omega$ 0.64 $\mu\Omega/\Omega$ 0.17 $\mu\Omega/\Omega$ 0.17 $\mu\Omega/\Omega$ 0.38 $\mu\Omega/\Omega$ 0.38 $\mu\Omega/\Omega$ 0.25 $\mu\Omega/\Omega$ 12 $\mu\Omega/\Omega$	Guildline 6675Av Bridge, 6623 Extender, L&N Standard Resistors, ESIU SR 1010, SR 1050, Hart 7009 Oil Bath, MI 9300 Air Bath



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 14.5 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
High Resistance - Measure	(1 to 10) GΩ (10 to 100) GΩ 100 GΩ to 1 TΩ (1 to 10) TΩ (10 to 100) TΩ 100 TΩ to 1 PΩ (1 to 10) PΩ	0.8 mΩ/Ω 1.2 mΩ/Ω 2.3 mΩ/Ω 3.5 mΩ/Ω 5.8 mΩ/Ω 12 mΩ/Ω 0.12 Ω/Ω	Guildline 6500A Terohmmeter
Capacitance – Measure <sup>1</sup> 50 Hz to 20 kHz	(1 to 2) pF (2 to 4) pF (4 to 9) pF (10, 20, 30) pF (40 to 100) pF (300 to 400) pF (500 to 600) pF (700 to 800) pf 0.9 pF to 1 nF (1 to 4) nF (4 to 10) nF (10 to 40) nF (40 to 100) nF (100 to 400) nF (400 to 1200) nF	4.1 μF/F 3.7 μF/F 3.6 μF/F 3.6 μF/F 3.5 μF/F 3.5 μF/F 3.6 μF/F 3.5 μF/F 3.6 μF/F 3.6 μF/F 3.7 μF/F 3.9 μF/F 4.7 μF/F 7.4 μF/F 15 μF/F	Andeen Hagerling 2500A Capacitance Bridge, Andeen Hagerling 2700A Capacitance Bridge
Capacitance – Measure <sup>1</sup> 50 Hz to 20 kHz Fixed Points	1 pF 2 pF 0.2 nF	4.1 μF/F 3.8 μF/F 3.6 μF/F	Andeen Hagerling AH1100 – 10 PFD & 100 PFD Standard Capacitors, GR 1404A 1 000 PFD Standard Capacitor



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Measure	200 $\mu$ F	48 nF	E4980A Precision LCR Meter
	300 $\mu$ F	59 nF	
	330 $\mu$ F	61 nF	
	700 $\mu$ F	110 nF	
	1.09 mF	160 nF	
	1.1 mF	160 nF	
	2 mF	290 nF	
	3 mF	430 nF	
	10.9 mF	1.6 $\mu$ F	
	20 mF	2.7 $\mu$ F	
	30 mF	4.1 $\mu$ F	
	33 mF	4.5 $\mu$ F	
	110 mF	16 $\mu$ F	
	Capacitance – Source <sup>1</sup> Fixed Points	10 pF	
50 Hz		3.4 $\mu$ F/F	
0.1 kHz		1.6 $\mu$ F/F	
0.4 kHz		0.48 $\mu$ F/F	
0.8 kHz		0.35 $\mu$ F/F	
1 kHz		0.33 $\mu$ F/F	
2 kHz		0.32 $\mu$ F/F	
6 kHz		0.55 $\mu$ F/F	
8 kHz		0.75 $\mu$ F/F	
10 kHz		1.1 $\mu$ F/F	
16 kHz		2.3 $\mu$ F/F	
20 kHz		3.5 $\mu$ F/F	
100 pF			
50 Hz		1.9 $\mu$ F/F	
0.1 kHz		1 $\mu$ F/F	
0.4 kHz		0.54 $\mu$ F/F	
0.8 kHz		0.46 $\mu$ F/F	
1 kHz		0.29 $\mu$ F/F	
2 kHz		0.28 $\mu$ F/F	
6 kHz		0.45 $\mu$ F/F	
8 kHz		0.81 $\mu$ F/F	
10 kHz		0.94 $\mu$ F/F	
16 kHz		2.1 $\mu$ F/F	
20 kHz		2.7 $\mu$ F/F	
1 000 pF			
0.1 kHz		3.7 $\mu$ F/F	
0.4 kHz		2.7 $\mu$ F/F	
1 kHz		2.3 $\mu$ F/F	



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>1</sup> Fixed Points	1 pF		Standard Capacitors
	1 kHz 30 μF/F 10 kHz 33 μF/F 50 kHz 55 μF/F 100 kHz 83 μF/F 500 kHz 0.35 mF/F 1 MHz 0.71 mF/F 2 MHz 1.6 mF/F 3 MHz 2.8 mF/F 4 MHz 3.8 mF/F 5 MHz 5.1 mF/F 6 MHz 6.6 mF/F 7 MHz 8.2 mF/F 8 MHz 10 mF/F 9 MHz 12 mF/F 10 MHz 14 mF/F		
	10 pF		
	1 kHz 29 μF/F 10 kHz 33 μF/F 50 kHz 33 μF/F 100 kHz 33 μF/F 500 kHz 33 μF/F 1 MHz 33 μF/F 2 MHz 54 μF/F 3 MHz 0.1 mF/F 4 MHz 0.17 mF/F 5 MHz 0.27 mF/F 6 MHz 0.39 mF/F 7 MHz 0.53 mF/F 8 MHz 0.7 mF/F 9 MHz 0.9 mF/F 10 MHz 1.1 mF/F		
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B (600 to 800) °C (800 to 1 000) °C (1 000 to 1 550) °C (1 550 to 1 820) °C	0.47 °C 0.36 °C 0.32 °C 0.35 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type C		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1 800) °C	0.53 °C	
	(1 800 to 2316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		
Type N			
(-200 to -100) °C	0.42 °C		
(-100 to -25) °C	0.24 °C		
(-25 to 120) °C	0.21 °C		
(120 to 410) °C	0.2 °C		
(410 to 1 300) °C	0.29 °C		
Type R			
(0 to 250) °C	0.6 °C		
(250 to 400) °C	0.37 °C		
(400 to 1 000) °C	0.35 °C		
(1 000 to 1 767) °C	0.42 °C		



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment		
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type S (0 to 250) °C	0.5 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator		
	(250 to 1 000) °C	0.38 °C			
	(1 000 to 1 400) °C	0.39 °C			
	(1 400 to 1 767) °C	0.49 °C			
	Type T (-250 to -150) °C	0.66 °C			
	(-150 to 0) °C	0.26 °C			
	(0 to 120) °C	0.18 °C			
	(120 to 400) °C	0.16 °C			
	Type U (-200 to 0) °C	0.59 °C			
	(0 to 600) °C	0.29 °C			
	DC Current – Source and Measure <sup>1</sup>	1 µA to 30 mA		4 µA/A	Stable DC Source, Standard Resistor, Voltmeter
		(30 to 100) mA		5 µA/A	
(100 to 300) mA		6 µA/A			
(300 to 400) mA		13 µA/A			
(500 to 800) mA		11 µA/A			
(800 to 900) mA		9 µA/A			
900 mA to 15 A		8 µA/A			
(16 to 50) A		13 µA/A			
(50 to 70) A		18 µA/A			
(70 to 100) A		24 µA/A			
(100 to 400) A		30 µA/A			
Inductance – Fixed Points		100 µH		Quadtech 7600 Plus LCR Meter, GR 1482B,E,L,P,T Standard Inductors	
	100 Hz	0.15 mH/H			
	1 kHz	80 µH/H			
	10 kHz	0.15 mH/H			
	1 mH				
	100 Hz	0.1 mH/H			
	1 kHz	70 µH/H			
	10 kHz	0.15 mH/H			
	10 mH				
	1 kHz	70 µH/H			
	10 kHz	0.13 mH/H			
	100 mH				
100 Hz	90 µH/H				
1 kHz	70 µH/H				
10 kHz	0.2 mH/H				



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Inductance – Fixed Points	1 H 100, 400 Hz 1 kHz	80 $\mu$ H/H 70 $\mu$ H/H	Quadtech 7600 Plus LCR Meter, GR 1482B,E,L,P,T Standard Inductors
	10 H 100, 400 Hz 1 kHz	90 $\mu$ H/H 80 $\mu$ H/H	
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A Multimeter
AC Voltage – Measure	( $\geq$ 3 to <33) mV $\leq$ 10Hz	0.006 8 mV	5790A/B AC Measurement Standard
	>10 Hz to $\leq$ 10kHz	0.001 5 mV	
	(>10 to $\leq$ 20kHz)	0.002 7 mV	
	50 kHz	0.004 6 mV	
	100 kHz	0.008 mV	
	450 kHz	0.022 mV	
	$\geq$ 33 mV to <3.3 V $\leq$ 10 Hz	0.05 mV	
	>10 Hz to $\leq$ 10 kHz	0.002 9 mV	
	(>10 to $\leq$ 20) kHz	0.009 mV	
	50 kHz	0.014 mV	
	100 kHz	0.021 mV	
	450 kHz	0.076 mV	
	( $\geq$ 3.3 to <33) V $\leq$ 10 Hz	0.47 mV	
	>10 Hz to $\leq$ 10 kHz	0.012 mV	
	(>10 to $\leq$ 20) kHz	0.056 mV	
50 kHz	0.11 mV		
100 kHz	0.19 mV		
450 kHz	0.93 mV		
( $\geq$ 3.3 to <33) V $\leq$ 10Hz	4.7 mV		
>10 Hz to $\leq$ 10 kHz	0.11 mV		
(>10 to $\leq$ 20 kHz)	0.75 mV		
50 kHz	1.3 mV		
90 kHz	2.2 mV		



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Electrical – DC/Low Frequency

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure	(≥33 to <330) V >10 Hz to ≤ 10 kHz (>10 to ≤ 20) kHz 50kHz (≥330 to <1 020) V >10 Hz to ≤10 kHz	1.1 mV 9.6 mV 5.4 mV 11 mV	5790A/B AC Measurement Standard
AC Voltage - Measure Relative <sup>1</sup>	1.9445 V (50 to 600) MHz 1.202 V 50 MHz to 1.1 GHz 459.6 mV 50 MHz to 1.1 GHz 424.3 mV 50 MHz to 1.1 GHz 120.2 mV 50 MHz to 1.1 GHz 35 mV 50 MHz to 1.1 GHz 12 mV 50 MHz to 1.1 GHz 3.45 mV 50 MHz to 1.1 GHz	0.88 % of reading 0.81 % of reading 0.81 % of reading 0.81 % of reading 0.75 % of reading 0.78 % of reading 0.95 % of reading 0.79 % of reading	Fluke 5790A, Power Sensors
AC Voltage – Measure, Source <sup>1</sup>	1 V 10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 800 kHz 1 MHz	14 μV/V 9 μV/V 9 μV/V 7 μV/V 11 μV/V 12 μV/V 13 μV/V 9 μV/V 8 μV/V 12 μV/V 15 μV/V 20 μV/V 27 μV/V	Fluke 792A AC/DC Thermal Transfer Standard



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Voltage – Measure, Source <sup>1</sup>	2 V		Fluke 792A AC/DC Thermal Transfer Standard	
	10 Hz	13 $\mu$ V/V		
	20 Hz	7 $\mu$ V/V		
	40 Hz	7 $\mu$ V/V		
	100 Hz	7 $\mu$ V/V		
	1 kHz	7 $\mu$ V/V		
	10 kHz	7 $\mu$ V/V		
	20 kHz	7 $\mu$ V/V		
	50 kHz	8 $\mu$ V/V		
	100 kHz	8 $\mu$ V/V		
	300 kHz	13 $\mu$ V/V		
	500 kHz	21 $\mu$ V/V		
	800 kHz	27 $\mu$ V/V		
	1 MHz	31 $\mu$ V/V		
	6 V			
	10 Hz	12 $\mu$ V/V		
	20 Hz	7 $\mu$ V/V		
	40 Hz	7 $\mu$ V/V		
	100 Hz	7 $\mu$ V/V		
	1 kHz	8 $\mu$ V/V		
	10 kHz	8 $\mu$ V/V		
	20 kHz	8 $\mu$ V/V		
	50 kHz	8 $\mu$ V/V		
	100 kHz	9 $\mu$ V/V		
	300 kHz	11 $\mu$ V/V		
	500 kHz	16 $\mu$ V/V		
	800 kHz	19 $\mu$ V/V		
	1 MHz	25 $\mu$ V/V		
	10 V			
	10 Hz	16 $\mu$ V/V		
	20 Hz	9 $\mu$ V/V		
	40 Hz	8 $\mu$ V/V		
	100 Hz	8 $\mu$ V/V		
	1 kHz	9 $\mu$ V/V		
	10 kHz	9 $\mu$ V/V		
	20 kHz	10 $\mu$ V/V		
50 kHz	11 $\mu$ V/V			
100 kHz	11 $\mu$ V/V			
300 kHz	12 $\mu$ V/V			
500 kHz	18 $\mu$ V/V			
800 kHz	20 $\mu$ V/V			
1 MHz	26 $\mu$ V/V			



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure, Source <sup>1</sup>	20 V		Fluke 792A AC/DC Thermal Transfer Standard
	10 Hz	13 $\mu$ V/V	
	20 Hz	8 $\mu$ V/V	
	40 Hz	7 $\mu$ V/V	
	100 Hz	7 $\mu$ V/V	
	1 kHz	8 $\mu$ V/V	
	10 kHz	8 $\mu$ V/V	
	20 kHz	9 $\mu$ V/V	
	50 kHz	10 $\mu$ V/V	
	100 kHz	10 $\mu$ V/V	
	300 kHz	11 $\mu$ V/V	
	500 kHz	15 $\mu$ V/V	
	800 kHz	19 $\mu$ V/V	
	1 MHz	25 $\mu$ V/V	
	60 V		
	10 Hz	14 $\mu$ V/V	
	20 Hz	10 $\mu$ V/V	
	40 Hz	9 $\mu$ V/V	
	100 Hz	9 $\mu$ V/V	
	1 kHz	9 $\mu$ V/V	
	10 kHz	9 $\mu$ V/V	
	20 kHz	10 $\mu$ V/V	
	50 kHz	11 $\mu$ V/V	
	100 kHz	14 $\mu$ V/V	
	300 kHz	19 $\mu$ V/V	
	200 V		
	10 Hz	23 $\mu$ V/V	
	20 Hz	13 $\mu$ V/V	
	40 Hz	11 $\mu$ V/V	
	100 Hz	10 $\mu$ V/V	
1 kHz	10 $\mu$ V/V		
10 kHz	11 $\mu$ V/V		
20 kHz	10 $\mu$ V/V		
50 kHz	13 $\mu$ V/V		
100 kHz	15 $\mu$ V/V		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure, Source <sup>1</sup>	600 V	21 $\mu\text{V/V}$	Fluke 792A AC/DC Thermal Transfer Standard
	10 Hz	12 $\mu\text{V/V}$	
	20 Hz	12 $\mu\text{V/V}$	
	40 Hz	10 $\mu\text{V/V}$	
	100 Hz	10 $\mu\text{V/V}$	
	1 kHz	10 $\mu\text{V/V}$	
	10 kHz	10 $\mu\text{V/V}$	
	20 kHz	10 $\mu\text{V/V}$	
	50 kHz	11 $\mu\text{V/V}$	
	100 kHz	15 $\mu\text{V/V}$	
	1 000 V	17 $\mu\text{V/V}$	
	10 Hz	12 $\mu\text{V/V}$	
	20 Hz	11 $\mu\text{V/V}$	
	40 Hz	11 $\mu\text{V/V}$	
	100 Hz	12 $\mu\text{V/V}$	
	1 kHz	12 $\mu\text{V/V}$	
	10 kHz	12 $\mu\text{V/V}$	
	20 kHz	13 $\mu\text{V/V}$	
	50 kHz	24 $\mu\text{V/V}$	
100 kHz			
AC High Voltage – Measure	(1 to 80) kV 60 Hz	0.19 % of reading	Ross Voltage Divider, Agilent 3458A
AC Current – Measure, Source <sup>1</sup>	10 mA	31 $\mu\text{A/A}$	Holt HCS-1 AC Shunts, Fluke 5720A Multi Product Calibrator / 5725A Amplifier, HP 3458A DMM, Wavetek 4920 Voltmeter Standard, Fluke 792A Thermal Transfer Standard
	20 Hz	18 $\mu\text{A/A}$	
	400 Hz	18 $\mu\text{A/A}$	
	1 kHz	18 $\mu\text{A/A}$	
	5 kHz	18 $\mu\text{A/A}$	
	20 kHz	18 $\mu\text{A/A}$	
	50 kHz	29 $\mu\text{A/A}$	
	20 mA	31 $\mu\text{A/A}$	
	20 Hz	18 $\mu\text{A/A}$	
	400 Hz	18 $\mu\text{A/A}$	
	1 kHz	18 $\mu\text{A/A}$	
	5 kHz	18 $\mu\text{A/A}$	
	50 mA	31 $\mu\text{A/A}$	
	20 Hz	18 $\mu\text{A/A}$	
	400 Hz	18 $\mu\text{A/A}$	
1 kHz	18 $\mu\text{A/A}$		
5 kHz	18 $\mu\text{A/A}$		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure, Source <sup>1</sup>	100 mA		Holt HCS-1 AC Shunts, Fluke 5720A Multi Product Calibrator / 5725A Amplifier, HP 3458A DMM, Wavetek 4920 Voltmeter Standard, Fluke 792A Thermal Transfer Standard
	20 Hz	32 $\mu$ A/A	
	400 Hz	21 $\mu$ A/A	
	1 kHz	21 $\mu$ A/A	
	5 kHz	21 $\mu$ A/A	
	20 kHz	21 $\mu$ A/A	
	50 kHz	41 $\mu$ A/A	
	200 mA		
	20 Hz	34 $\mu$ A/A	
	400 Hz	22 $\mu$ A/A	
	1 kHz	22 $\mu$ A/A	
	5 kHz	22 $\mu$ A/A	
	500 mA		
	20 Hz	36 $\mu$ A/A	
	400 Hz	23 $\mu$ A/A	
	1 kHz	23 $\mu$ A/A	
	5 kHz	23 $\mu$ A/A	
	1A		
	20 Hz	38 $\mu$ A/A	
	400 Hz	25 $\mu$ A/A	
1 kHz	25 $\mu$ A/A		
5 kHz	25 $\mu$ A/A		
2A			
20 kHz	25 $\mu$ A/A		
50 kHz	55 $\mu$ A/A		
20 Hz	42 $\mu$ A/A		
400 Hz	27 $\mu$ A/A		
1 kHz	27 $\mu$ A/A		
5 kHz	27 $\mu$ A/A		
AC Current - Measure	33 $\mu$ A		Fluke 5790B, Current Shunts
	1 kHz	3.9 nA	
	5 kHz	9.5 nA	
	10 kHz	5 nA	
	190 $\mu$ A		
	45 Hz	9.6 nA	
	1 kHz	9.5 nA	
	5 kHz	9.5 nA	
10 kHz	9.5 nA		
30 kHz	14 nA		

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	329 $\mu$ A		Fluke 5790B, Current Shunts
	10 Hz	56 nA	
	45 Hz	15 nA	
	1 kHz	5 nA	
	5 kHz	5 nA	
	10 kHz	5 nA	
	30 kHz	19 nA	
	330 $\mu$ A		
	1 kHz	20 nA	
	5 kHz	19 nA	
	30 kHz	21 nA	
	1.9 mA		
	1 kHz	87 nA	
	5 kHz	88 nA	
	10 kHz	88 nA	
	30 kHz	130 nA	
	3.29 mA		
	10 Hz	560 nA	
	45 Hz	130 nA	
	1 kHz	130 nA	
	5 kHz	130 nA	
	10 kHz	130 nA	
	30 kHz	170 nA	
	3.3 mA		
	1 kHz	150 nA	
	5 kHz	150 nA	
	30 kHz	230 nA	
	19 mA		
1 kHz	600 nA		
10 kHz	610 nA		
30 kHz	850 nA		
32.9 mA			
10 Hz	5.6 $\mu$ A		
45 Hz	1.3 $\mu$ A		
1 kHz	1.3 $\mu$ A		
5 kHz	1.3 $\mu$ A		
10 kHz	1.3 $\mu$ A		
10 kHz	1.8 $\mu$ A		
33 mA			
1 kHz	1.4 $\mu$ A		
5 kHz	1.4 $\mu$ A		
30 kHz	2 $\mu$ A		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	190 mA		Fluke 5790B, Current Shunts
	1 kHz	6.4 $\mu$ A	
	10 kHz	6.4 $\mu$ A	
	30 kHz	8.8 $\mu$ A	
	329 mA		
	10 Hz	57 $\mu$ A	
	45 Hz	17 $\mu$ A	
	1 kHz	17 $\mu$ A	
	5 kHz	17 $\mu$ A	
	10 kHz	17 $\mu$ A	
	30 kHz	20 $\mu$ A	
	330 mA		
	1 kHz	17 $\mu$ A	
	5 kHz	17 $\mu$ A	
	10 kHz	17 $\mu$ A	
	1.09 A		
	10 Hz	0.17 mA	
	45 Hz	39 $\mu$ A	
	1 kHz	39 $\mu$ A	
	5 kHz	39 $\mu$ A	
	10 kHz	39 $\mu$ A	
	2.19 A		
	10 Hz	0.11 mA	
	1 kHz	0.11 mA	
	5 kHz	0.12 mA	
	2.2 A		
	500 Hz	0.12 mA	
	1 kHz	0.12 mA	
	2.99 A		
	10 Hz	0.51 mA	
45 Hz	0.15 mA		
1 kHz	0.15 mA		
5 kHz	0.15 mA		
10 kHz	0.15 mA		
3.3 A			
500 Hz	0.23 mA		
1 kHz	0.23 mA		
5 kHz	0.18 mA		
10.9 A			
45 Hz	1 mA		
65 Hz	0.89 mA		
500 Hz	0.9 mA		
1 kHz	0.9 mA		
5 kHz	0.9 mA		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	11 A 45 Hz 65 Hz 500 Hz 1 kHz 5 kHz	0.98 mA 0.9 mA 0.9 mA 0.9 mA 0.94 mA	Fluke 5790B, Current Shunts
	20 A 45 Hz 65 Hz 500 Hz 1 kHz 5 kHz	1.4 mA 0.93 mA 0.97 mA 0.96 mA 1.1 mA	
AC Power – Measure	3.3 mA 65 Hz	12 mA	AC Shunts
	33 mA 500 Hz 1 kHz 5 kHz 7 kHz 10 kHz	1.2 mA 1.1 mA 1.1 mA 1.1 mA 1.1 mA	
Ratio Transformer <sup>2</sup>	400 & 1 000 Hz	0.000 051 % of Input	Gertsch 1011 Ratio Standard
Phase Angle – Source  @ 5V Equal Input  @50 mV to 100V  @100V to 120V	(0 to 360)° 1 Hz to 6.25 kHz (6.25 to 50) kHz (50 to 200) kHz	0.005 8° 0.012° 0.047°	Clark-Hess 5500-2 Phase Standard
	(0 to 360)° 1 Hz to 1kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz	0.006° 0.012° 0.018° 0.047°	
	(0 to 360)° 1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz	0.01 ° 0.02 ° 0.035° 0.093°	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Angle – Measure @10 mV to 350V	(0 to 360)°		Clark-Hess 6000A Phase Meter
	(5 to 10) Hz	0.23°	
	10 Hz to 50 kHz	0.06°	
	(50 to 57) kHz	0.12°	
	(57 to 66) kHz	0.13°	
	(66 to 75) kHz	0.14°	
	(75 to 83) kHz	0.15°	
	(83 to 92) kHz	0.16°	
	(92 to 100) kHz	0.17°	
	101 kHz	0.57°	
	110 kHz	0.62°	
	115 kHz	0.64°	
	120 kHz	0.67°	
	125 kHz	0.69°	
	130 kHz	0.72°	
	135 kHz	0.74°	
	140 kHz	0.77°	
145 kHz	0.79°		
150 kHz	0.82°		
200 kHz	1.1°		
250 kHz	1.4°		
300 kHz	1.6°		
350 kHz	1.9°		
400 kHz	2.1°		
450 kHz	2.4°		
500 kHz	2.6°		

Electrical – RF/Microwave

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	(>0 to 99) % Depth		Agilent 8902A Measuring Receiver
	(0.15 to 10) MHz	2.1 % Depth	
	(0.01 to 1.3) GHz	1.1 % Depth	
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(1.3 to 26.5) GHz	1.6 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
	(>0 to 99) % Depth		
	(0.1 to 10) MHz	0.8 % Depth	
	(0.01 to 3) GHz	0.5 % Depth	
	(3 to 26.5) GHz	1.5 % Depth	
(26.5 to 31.15) GHz	1.9 % Depth		
(31.5 to 50) GHz	6.1 % Depth		



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Electrical – RF/Microwave

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 100) kHz	(0.25 to 10) MHz (0.01 to 26.5) GHz	2.2 % Deviation 1.2 % Deviation	HP 8902A Measuring Receiver
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	(0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude <sup>1,2</sup> (EVM)	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.43 % 0.48 % 0.82 %	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error <sup>1</sup>	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.17 ° rms 0.34 ° rms 0.57 ° rms	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error <sup>1</sup>	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho) <sup>1</sup>	Mod Frequency Span: f ≤ 100 kHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	8.6E <sup>-5</sup> ρ 0.000 43 ρ 0.000 68 ρ 0.000 84 ρ 0.001 2 ρ 0.001 6 ρ	HP 89441A Vector Signal Analyzer

**Electrical – RF/Microwave**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy (Rho) <sup>1</sup>	Mod Frequency Span: $100 \text{ kHz} \leq f \leq 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $f > 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$9.6E^{-5} \rho$ $0.00048 \rho$ $0.00076 \rho$ $0.00094 \rho$ $0.0014 \rho$ $0.0018 \rho$ $1.6E^{-4} \rho$ $0.00082 \rho$ $0.0013 \rho$ $0.0016 \rho$ $0.0024 \rho$ $0.003 \rho$	<p style="text-align: center;">HP 89441A Vector Signal Analyzer</p>
Phase Modulation – Measure <sup>1</sup>	$(0.15 \text{ to } 10) \text{ MHz}$ Rate: $(0.02 \text{ to } 10) \text{ kHz}$ $(0.01 \text{ to } 26.5) \text{ GHz}$ Rate: $(0.2 \text{ to } 20) \text{ kHz}$	$4.1 \% \text{ Deviation}$  $3.1 \% \text{ Deviation}$	<p style="text-align: center;">HP 8902A Measuring Receiver</p>
Phase Modulation – Measure <sup>1</sup>	$100 \text{ kHz to } 6.6 \text{ GHz}$ Deviations: $(0.3 \text{ to } 7) \text{ rad}$ Deviations: $> 7 \text{ rad}$ $(6.6 \text{ to } 13.2) \text{ GHz}$ Deviations: $(0.6 \text{ to } 2) \text{ rad}$ $(13.2 \text{ to } 26.5) \text{ GHz}$ Deviations: $> 2 \text{ rad}$ Deviations: $(1.2 \text{ to } 4) \text{ rad}$ $(26.5 \text{ to } 31.5) \text{ GHz}$ Deviations: $> 4 \text{ rad}$ Deviations: $(1.3 \text{ to } 4) \text{ rad}$ $(31.5 \text{ to } 50) \text{ GHz}$ Deviations: $> 4 \text{ rad}$ Deviations $(2.4 \text{ to } 8) \text{ rad}$ Deviations: $> 8 \text{ rad}$	$3.1 \% \text{ Deviation}$ $1 \% \text{ Deviation}$  $3.1 \% \text{ Deviation}$  $1 \% \text{ Deviation}$ $3.1 \% \text{ Deviation}$  $1 \% \text{ Deviation}$ $3.1 \% \text{ Deviation}$  $1 \% \text{ Deviation}$ $3.1 \% \text{ Deviation}$ $1 \% \text{ Deviation}$	<p style="text-align: center;">Keysight E444xA with Opt. 233 Spectrum Analyzer</p>
Distortion Measure <sup>1</sup>	$20 \text{ Hz to } 20 \text{ kHz}$ $(20 \text{ to } 100) \text{ kHz}$	$1.2 \text{ dB}$ $2.4 \text{ dB}$	<p style="text-align: center;">HP 8903A/B Audio Analyzer</p>
RF Power - Power Meter Reference	$1 \text{ mW}$  $50 \text{ MHz}$	$0.23 \% \text{ of reading}$	<p style="text-align: center;">Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor</p>



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Power Sensors Cal Factors <sup>1</sup>	9 kHz to 10 MHz	0.69 % of reading	E9304A Power Sensor
RF Power Sensors Cal Factors <sup>1</sup>	30 MHz 50 MHz 100 MHz 300 MHz to 3 GHz 4 GHz 5 GHz (6 to 7) GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 12.4 GHz 10 MHz	0.58 % of reading 0.54 % of reading 0.41 % of reading 0.51 % of reading 0.6 % of reading 0.61 % of reading 0.67 % of reading 0.68 % of reading 0.7 % of reading 0.79 % of reading 0.82 % of reading 0.79 % of reading 0.76 % of reading 0.8 % of reading	Keysight PNA-X Network Analyzer, 2.4, 3.5 mm Calibration Kits, Reference Power Sensors



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power Sensors Cal Factors <sup>1</sup>	(13 to 15) GHz 16 GHz 17 GHz 18 GHz (19 to 26) GHz 26.5 GHz 27 GHz (28 to 29) GHz 30 GHz (31 to 32) GHz 33 GHz (34 to 40) GHz 41 GHz (42 to 44) GHz (45 to 47) GHz (48 to 50) GHz	0.79 % of reading 0.87 % of reading 0.91 % of reading 0.97 % of reading 1.5 % of reading 1.6 % of reading 1.7 % of reading 1.8 % of reading 1.7 % of reading 1.8 % of reading 1.7 % of reading 1.8 % of reading 2.4 % of reading 2.5 % of reading 2.6 % of reading 2.5 % of reading	Keysight PNA-X Network Analyzer, 2.4, 3.5 mm Calibration Kits Reference Power Sensors
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	Offset (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System
Antenna Gain  On Axis Gain, Antenna factor  Dish Antenna	(5 to 25) dB (0.2 to 26.5) GHz (26.5 to 40) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz (140 to 220) GHz  (5 to 45) dB (12.4 to 110) GHz	0.15 dB 0.2 dB 0.2 dB 0.25 dB 0.3 dB 0.5 dB  0.31 dB	Agilent 8510C Network Analyzer, 8530A Receiver, 8517B S-Parameter Test Set, V85104A, W85104A Modules Scientific Atlanta 12-2.9, 12-5.8, 12-8.2, 12-12, 12-18, 12-26, 12-33 Narda 642, 643, 645 TRG 861B/383, Ab90 FXR M638A Hughes 45826H-1020 TRG/Custom Microwave Wr-5 Gain Horns, X, Ku, K, Ka, Q, V, W Probes Leica LT300 Laser Tracker



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Directional/ SWR Bridge <sup>1</sup> Reflections/ Directivity	(0 to 60) dB 5 Hz to 110 GHz	0.03 $\Gamma$ 1 dB	Agilent/HP 8757D Network Analyzer, 355C/D Step Attenuators, 85054B Calibration Kit, 8481D Opt H70, 8487A, VA8486A, W8486 Power Sensors, E8361C Network Analyzer, V85104A, W85104A Modules
Insertion Loss/Linearity	(0 to 60) dB 5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.1 dB	
Directional Coupler <sup>1</sup> Main Line Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	Agilent/HP E8361A Network Analyzer, 8510C Network Analyzer, 8517B S-Parameter Test Set V85104A, W85104A Modules, E8361C Network Analyzer, 85054B Calibration Kit, TRL Calibration Kit
Coupling Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	
Reflection Directivity	5 Hz to 110 GHz 5 Hz to 110 GHz	0.03 $\Gamma$ 1 dB	
Gaussian Noise <sup>1</sup> Noise Output Power	(-100 to +20) dBm 100 kHz to 18 GHz (18 to 40) GHz	0.05 dB 0.11 dB	Agilent/HP 8482A/D, 8481A/D, 8485A/D, 8487 A/D Power Sensors
Signal Path Response	(-60 to +20) dB 9 kHz to 3 GHz (3 to 22) GHz (22 to 50) GHz	1 dB 2.6 dB 3.5 dB	Agilent/HP 8565E Spectrum Analyzer
Gaussian Noise Attenuation	(0 to 10) dB (10 to 30) dB (40 to 50) dB	0.1 dB 0.2 dB 0.3 dB	Agilent E4448A Spectrum Analyzer
Harmonic Mixer Conversion Loss	(0 to 50) dB (18 to 26.5) GHz (26.5 to 40) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz	1.8 dB 1.8 dB 1.8 dB 1.8 dB 1.8 dB	Agilent/HP 8563E Spectrum Analyzer, 8485A, 8487A, V8486A, W8486A Power Sensors Hughes/HP/Millitech Thermistor mounts
RF Power – Absolute <sup>1</sup> WR-42 WR-28 WR-22 WR-15 WR-10	(-30 to +20) dBm (18 to 26.5) GHz (26.5 to 40) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz	1.1 % of reading 1.1 % of reading 1.5 % of reading 2.0 % of reading 2.5 % of reading	Hughes/Millitech/ Agilent/HP Thermistor Mounts, V8486A, W8486A, E4419B



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Power Sensor Characterization <sup>1</sup> Waveguide			
S Band	(2.6 to 3.95) GHz	0.9 dB	Waveguide Thermistor/ Thermocouple or Diode Power Sensors
G Band	(3.95 to 5.85) GHz	0.9 dB	
H Band	(7.05 to 10) GHz	0.9 dB	
X Band	(8.2 to 12.4) GHz	1.1 dB	
Ku band	(12.4 to 18) GHz	1.1 dB	
K Band	(18 to 26.5) GHz	1.2 dB	
Ka Band	(26.5 to 40) GHz	1.1 % of reading	
Q Band	(33 to 50) GHz	1.8 % of reading	
Power Sensor Characterization <sup>1</sup> V Band			
(50 to 52) GHz		2.5 % of reading	Waveguide Thermistor/ Thermocouple or Diode Power Sensors
(52 to 56) GHz		2.4 % of reading	
(56 to 64) GHz		2.7 % of reading	
(65 to 75) GHz		2.4 % of reading	
Power Sensor Characterization <sup>1</sup> W Band			
(75 to 76) GHz		3.2 % of reading	Waveguide Thermistor/ Thermocouple or Diode Power Sensors
(76 to 77) GHz		3.0 % of reading	
(77 to 80) GHz		2.9 % of reading	
(80 to 81) GHz		4.6 % of reading	
(81 to 110) GHz		3.1 % of reading	
Power Sensor Characterization <sup>1</sup> (75 Ω)			
100 kHz to 2 GHz		1.3 % of reading	Tegam F1119, Tegam 1804 Power Standards, NIST CN Mount, Agilent 11852B
(2 to 4.2) GHz		1.5 % of reading	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Scattering Parameters Reflection: S11 and S22 Reflection Coefficient <sup>1,2</sup>  Coaxial (50/75) Ω	(0.005 to 30) kHz (0 to 1) lin (-180 to 180)°	0.001 0.1°	Agilent/HP3577A Network Analyzer, 87512A Transmission/Reflection Test Set, 8753ES, 8510C Network Analyzers, 8517B S-Parameter Test Set, E8361A Network Analyzer, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B, 85059A Calibration Kits Type N S-Parameter Ref Standards 7mm S-Parameter Standards 3.5mm S-Parameter Ref Standards 2.92mm S-Parameter Ref Standards 1.85mm S-Parameter Ref Standards	
	(0.03 to 45) MHz (0 to 1) lin (-180 to 180)°	0.002 0.1°		
	(0.045 to 0.3) GHz (0 to 1) lin (-180 to 180)°	0.002 0.1°		
	(0.3 to 17) GHz (0 to 1) lin (-180 to 180)°	0.004 0.2°		
	(17 to 18) GHz (0 to 1) lin (-180 to 180)°	0.005 0.3°		
	(18 to 40) GHz (0 to 1) lin (-180 to 180)°	0.015 0.8°		
	(41 to 50) GHz (0 to 1) lin (-180 to 180)°	0.018 1.1°		
	(50 to 67) GHz (0 to 1) lin (-180 to 180)°	0.23 1.3°		
	Scattering Parameters Waveguide Reflection: S11 and S22 Reflection Coefficient <sup>1,2</sup>	(2.6 to 12.4) GHz (0 to 1) lin (-180 to 180)°		0.009 0.5°
		(12.4 to 26.5) GHz (0 to 1) lin (-180 to 180)°		0.01 0.5°
(26.5 to 50) GHz (0 to 1) lin (-180 to 180)°		0.006 0.3°		
(50 to 75) GHz (0 to 1) lin (-180 to 180)°		0.018 1.1°		
(75 to 110) GHz (0 to 1) lin (-180 to 180)°		0.024 1.4°		
(140 to 220) GHz (0 to 1) lin (-180 to 180)°		0.048 10°		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment		
Scattering Parameters <sup>1</sup> Transmission: S21 and S12 Coaxial – (50/75) Ω	(0.005 to <30) kHz (0 to 70) dB (-180 to 180)°	0.01 dB 0.2°	Agilent/HP 3577A Network Analyzer, 87512A, 8753ES, 8510C Network Analyzer, 8517B S-Parameter Test Set, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B Calibration Kits, E8361A Network Analyzer, 85058E Type N S-Parameter Ref Standards 7mm S-Parameter Standards 3.5mm S-Parameter Ref Standards 2.92mm S-Parameter Ref Standards 1.85mm S-Parameter Ref Standards		
	(0.03 to 45) MHz (0 to 70) dB (-180 to 180)°	0.01 dB 0.02°			
	(0.045 to 67) GHz (0 to 10) dB (-180 to 180)°	0.01 dB 0.2°			
	(10 to 20) dB (-180 to 180)°	0.02 dB 0.2°			
	(20 to 30) dB (-180 to 180)°	0.03 dB 0.21°			
	(30 to 50) dB (-180 to 180)°	0.11 dB 0.57°			
	(50 to 70) dB (-180 to 180)°	0.2 dB 1.3°			
	Scattering Parameters Waveguide <sup>1</sup>	(2.6 to 12.4) GHz (0 to 30) dB (-180 to 180)°		0.02 dB 0.6°	Agilent/HP 8510C Network Analyzer, 8517B S-Parameter Test Set, E8361A Network Analyzer, V85104A, W85104A Modules, PSNA TRL Calibration Kit, Oleson V05 VNA1-T/R WR28 S-Parameter Ref Standards WR22 S-Parameter Ref Standards WR15 S-Parameter Ref Standards WR10 S-Parameter Ref Standards
		(30 to 50) dB (-180 to 180)°		0.08 dB 0.7°	
		(0 to 30) dB (-180 to 180)°		0.02 dB 0.7°	
		(12.4 to 18) GHz (30 to 50) dB (-180 to 180)°		0.09 dB 0.7°	
		(0 to 30) dB (-180 to 180)°		0.05 dB 1.8°	
(18 to 26.5) GHz (30 to 50) dB (-180 to 180)°		0.08 dB 1.8°			
(0 to 30) dB (-180 to 180)°		0.03 dB 1.2°			
(26.5 to 40) GHz (30 to 50) dB (-180 to 180)°		0.09 dB 1.4°			
(0 to 30) dB (-180 to 180)°		0.03 dB 1.8°			



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Scattering Parameters Waveguide <sup>1</sup>	(40.0 to 50.0) GHz		Agilent/HP 8510C Network Analyzer, 8517B S-Parameter Test Set, E8361A Network Analyzer, V85104A, W85104A Modules, PSNA TRL Calibration Kit, Oleson V05 VNA1-T/R WR28 S-Parameter Ref Standards WR22 S-Parameter Ref Standards WR15 S-Parameter Ref Standards WR10 S-Parameter Ref Standards
	(30 to 50) dB	0.09 dB	
	(-180 to 180)°	2.1°	
	(0 to 30) dB	0.05 dB	
	(-180 to 180)°	3.3°	
	(50 to 75.0) GHz		
	(30 to 50) dB	0.1 dB	
	(-180 to 180)°	3.4°	
	(0 to 30) dB	0.06 dB	
	(-180 to 180)°	4.6°	
	(75 to 110) GHz		
	(30 to 50) dB	0.11 dB	
(-180 to 180)°	5.4°		
(0 to 30) dB	0.07 dB		
(-180 to 180)°	9.3°		
(140 to 220) GHz			
(30 to 40) dB	1 dB		
(-180 to 180)°	14°		
Thermal Noise <sup>1</sup> Coaxial (0.01 to 50) GHz	(5 to 40) dB ENR		Agilent 8970B, 8971B, N8975A, 6A, 346B, 346C Noise Sources, 8510C Network Analyzer, 8517B S-Parameter Test Set, Clare TN162 (WR-28), TN172 (WR-22) Noise Sources
	(0.1 to 1.0) GHz	0.08 dB	
	(1.0 to 11) GHz	0.09 dB	
	(11 to 18) GHz	0.13 dB	
	(18 to 26.5) GHz	0.07 dB	
	(26.5 to 35) GHz	0.15 dB	
(35 to 50) GHz	0.16 dB		
Thermal Noise <sup>1</sup> Waveguide (26.5 to 50) GHz	(5 to 30) dB ENR		Agilent 8970B, 8971C, N8975A, 346C Noise Source, 8510C Network Analyzer, 8517B S-Parameter Test Set, Clare TN162 (WR-28), TN 172 (WR-22), TN164 (WR-15), TN165 (WR-10) Noise Sources
	(26.5 to 27) GHz	0.07 dB	
	(27 to 31) GHz	0.06 dB	
	(31 to 39) GHz	0.08 dB	
	40 GHz	0.1 dB	
(40 to 50) GHz	0.13 dB		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise <sup>1</sup> Waveguide (50 to 75) GHz	(5 to 30) dB ENR		Agilent 8970B, 8971C, N8975A, 346C Noise Sources, 8510C Network Analyzer, 8517B S-Parameter Test Set, Clare TN162 (WR-28), TN 172 (WR-22), TN164 (WR-15), TN165 (WR-10) Noise Sources
	(50 to 54) GHz	0.15 dB	
	55 GHz	0.14 dB	
	(55 to 63) GHz	0.16 dB	
	(63 to 65) GHz	0.19 dB	
	66 GHz	0.21 dB	
	67 GHz	0.23 dB	
	68 GHz	0.25 dB	
	69 GHz	0.26 dB	
	70 GHz	0.28 dB	
	71 GHz	0.31 dB	
	72 GHz	0.33 dB	
Thermal Noise <sup>1</sup> Waveguide (75 to 110) GHz	(75 to 77) GHz	0.3 dB	Agilent 8970B, N8975A, Clare TN164 (WR-15), TN 165 (WR-10) Noise Sources
	(77 to 80) GHz	0.31 dB	
	(80 to 89) GHz	0.44 dB	
	(89 to 94) GHz	0.31 dB	
	(94 to 100) GHz	0.43 dB	
	101 GHz	0.78 dB	
	102 GHz	0.77 dB	
	103 GHz	0.77 dB	
	104 GHz	0.76 dB	
	105 GHz	0.75 dB	
	106 GHz	0.94 dB	
	107 GHz	1.1 dB	
	108 GHz	1.3 dB	
	109 GHz	1.5 dB	
110 GHz	1.7 dB		

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Parameter/ Equipment	Attenuation - Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

Electrical – RF/Microwave

El Segundo, CA

Parameter/ Equipment	Attenuation - Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8496H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation - Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

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<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

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<b>Parameter/ Equipment</b>	RF Power Measure <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084

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Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.11	0.10	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.10	0.10	0.12

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Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	67 GHz to 80 GHz	80 GHz to 95 GHz	95 GHz to 110 GHz
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	-	-	-

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Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	67 GHz to 80 GHz	80 GHz to 95 GHz	95 GHz to 110 GHz
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	-	-	-
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	-	-	-
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	-	-	-
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	-	-	-
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	-	-	-
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	0.63	0.644	0.639
0 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	-	-	-
2 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	-	-	-
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	-	-	-
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	-	-	-

**Length – Dimensional Metrology**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Calipers <sup>3</sup>	(0 to 12) in (>12 to 60) in	(310 + 2L) μin (310 + 4L) μin	Gage Blocks, Ring Gage
Connector Gage Masters	Up to 0.35 in	31 μin	Optical Flat
Cylindrical Plug Gages <sup>3</sup>	Up to 4 in	(26 + 6D) μin	Gage Blocks
Cylindrical Ring Gages <sup>3</sup>	Up to 6 in	(6 + 12L) μin	Gage Blocks, Internal Comparison

**Length – Dimensional Metrology**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dial and Digital Indicators <sup>1</sup>			
Digital Indicators	(0 to 1) in (>1 to 2) in (>2 to 6) in	35 μin 38 μin 80 μin	Grade 0 Gage Blocks + Accessories, Surface Plate
Dial Indicators	(0 to 1) in (>1 to 6) in	64 μin 621 μin	
Electronic Gage Amplifiers	Up to 0.1 in	10 μin	Gage Blocks
Gage Blocks <sup>3</sup>	(0.01 to 4) in	(2 + 1L) μin	Electromechanical Comparison
Height Gages <sup>3</sup>	(0 to 48) in	(310 + 4L) μin	Grade 0 Gage Blocks, Surface Plate
Length – Non-Contact Measurement <sup>3</sup>	Up to 12 in (12 to 60) in	(10 + 10L) μin (150 + 12L) μin	Laser Interferometer
Outside Micrometer Length <sup>1,3</sup>	(0 to 12) in (>12 to 48) in	(30 + 6L) μin (30 + 7L) μin	Grade 0 & 1 Gage Blocks
Outside Micrometer Anvil Flatness <sup>1,3</sup>	(0 to 48) μin	6 μin	Optical Flats and Monochromatic Light
Inside Micrometer Length <sup>1</sup>	(0 to 12) in	(30 + 6L) μin	Grade 0 & 1 Gage Blocks
Depth Micrometer Length <sup>1</sup>	(0 to 12) in	(30 + 6L) μin	Grade 0 & 1 Gage Blocks
Thread Measuring Wires	(4 to 80) TPI	15 μin	Mechanical Comparison
Torque Moment Arms and Wheels <sup>3</sup>	Up to 48 in	(150 + 50L) μin	Gage Blocks, Electronic Amplifier
Alignment Collimator	2 ft to Infinity Focus	1 arcsec	Optical Wedge
Autocollimators	Up to 1 000 arcsec (1 000 to 1 800) arcsec	0.3 % of reading + 0.4 arc s 0.1 % of reading + 0.2 arc s	Laser Interferometer
Angle Generator	(0.05 to 1 000) arcsec	0.27 % of reading	Laser Interferometer
Angle Gage Blocks	1 arcsec to 45 °	1 arcsec	Angle Gage Blocks; Autocollimator
Electronic Levels	Up to 200 arcsec Up to 1 000 arcsec	0.8 arcsec 2.9 arcsec	Laser Interferometer
Bubble Levels <sup>3</sup>	Up to 15 in	0.65R μin	Surface Plate, Grade 0 Gage Blocks

**Length – Dimensional Metrology**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Sine Bars & Plates Angle Parallelism	Up to 45 ° 0.10 in	2.3 arc s 33 μin	Angle Gage Blocks, Gaging Amplifier
Square s and Angle Plates	90 °	6.5 arc s	Cylindrical Square
Protractor	Up to 90 °	53 arc sec	Sine Bar, Grade 0 Gage Blocks, Surface Plate, Right Angle, Precision Level
Optical Wedge	Up to 30 arc s	0.29 arc s	Laser Interferometer
Theodolite/Transmit/ Alignment Telescope Collimation	Infinity Focus	1.1 arc s	Alignment Collimator
Line of Sight	2 ft to Infinity focus	1.6 arc s	
Trunnion Axis	(60 to 135) °	1.2 arc s	
V-Blocks Parallelism	Up to 6 in	37 μin	Gaging Amplifier
Perpendicularity	Up to 6 in	6.5 arc s	Cylindrical Square
Surface Plate <sup>1,3</sup>	(60 x 96) in	12 √D μin	Electronic Level
Thread Plug Gages Pitch Diameter	Up to 1 in	60 μin	3 Wire Method
Major Diameter	Up to 1 in	50 μin	Gage Blocks
Thread Ring Gages Pitch Diameter	Up to 1 in	160 μin	Thread Setting Plug

**Mass and Mass Related**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Gas Flow <sup>1</sup>	10 sccm to 30 slpm (30 to 100) slpm	0.5 % of reading 0.7 % of reading	Nitrogen, Air, Argon Mass Flow Standards
Helium Leak Rate	(10 <sup>-09</sup> to 10 <sup>-03</sup> ) sccs	10 % of reading	Standard Comparison
Force <sup>1</sup>	(0.00044 to 50 000) lbf (50 000 to 100 000) lbf	0.05 % of reading 0.22% of reading	Dead Weight, Load Cell



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Mass and Mass Related

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Mass Standards	(1 to 500) mg 500 mg to 2 g (2 to 5) g (5 to 10) g (10 to 20) g (20 to 50) g (50 to 100) g (100 to 200) g (200 to 500) g 500 g to 1 kg (1 to 2) kg (2 to 5) kg 10 kg  1 lb 2 lb 5 lb 10 lb 20 lb 25 lb 50 lb	0.012 mg 0.04 mg 0.043 mg 0.075 mg 0.12 mg 0.23 mg 0.46 mg 0.91 mg 2.3 mg 5.2 mg 26 mg 33 mg 0.25 g  4.7 e-6 lb 1.1 e-5 lb 5 e-5 lb 6.3 e-5 lb 5.5 e-4 lb 5.4 e-4 lb 5.9 e-4 lb	Class 1 Weights and Electronic Balances
Pressure <sup>1</sup>	(0.2 to 100) psia (100 to 1 000) psia	0.003 6 % of reading 0.004 % of reading	Ruska 2465 Deadweight Tester, Heise PTE-1 Calibrator
Pressure <sup>1</sup>	(1 000 to 15 000) psig (15 000 to 20 000) psig	0.004 4 % of reading 0.006 2 % of reading	Ruska 2475, 2485 Deadweight Testers Heise PTE-1 Calibrator
Scales and Balances <sup>1,4</sup>	(5 to 500) mg (0.5 to 5) g (5 to 10) g (10 to 20) g (20 to 50) g (50 to 100) g (100 to 200) g (200 to 500) g (500 to 1000) g (1 to 2) kg (2 to 5) kg (5 to 20) kg	0.012 mg 0.044 mg 0.064 mg 0.093 mg 0.14 mg 0.3 mg 0.59 mg 1.5 mg 3.2 mg 13 mg 19 mg 0.1 g	Class 1 Weights
Scales and Balances <sup>1,4</sup>	(50 to 2 000) lb (2 000 to 5 000) lb	0.025 % of reading 0.06 % of reading	Class F Weights



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**Mass and Mass Related**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Vacuum Ionization Gages, Inverted Magnetron Gages, Cold Cathode Gages, Residual Drag Gages	2.0 x 10 <sup>-7</sup> torr 5.0 x 10 <sup>-7</sup> torr 9.0 x 10 <sup>-7</sup> torr	8.3 % of reading 5 % of reading 4.4 % of reading	Ionization Gage
Vacuum Ionization Gages, Inverted Magnetron Gages, Cold Cathode Gages, Residual Drag Gages	2.0 x 10 <sup>-6</sup> torr 5.0 x 10 <sup>-6</sup> torr 9.0 x 10 <sup>-6</sup> torr 2.0 x 10 <sup>-5</sup> torr 5.0 x 10 <sup>-5</sup> torr 9.0 x 10 <sup>-5</sup> torr 2.0 x 10 <sup>-4</sup> torr 5.0 x 10 <sup>-4</sup> torr 9.0 x 10 <sup>-4</sup> torr	6.3 % of reading 3.5 % of reading 2.8 % of reading 6.3 % of reading 3.4 % of reading 2.7 % of reading 6.3 % of reading 3.4 % of reading 2.7 % of reading	Spinning Rotor Gage
Thermocouple Vacuum Gage/Capacitance Manometer	(0.01 to 0.1) torr (0.1 to 10) torr (10 to 1 000) torr	0.6 % of reading + 0.2 mtorr 0.6 % of reading + 1 mtorr 0.006 6 % of reading	Capacitance Diaphragm Gage Ruska 2465 Deadweight Tester
Torque Transducers	10 ozf·in to 2 000 lbf·ft	0.03 % of reading	Standard Weights, Torque Moment Arms
Torque Wrench and Torque Screwdriver	20 ozf·in to 2 000 lbf·ft	0.7 % of reading	AKO TSD011-1016-S2 and TSD6500-6 Torque Testers

**Photometry and Radiometry**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Fiber Optic Attenuation Single Mode	(1 310, 1 550) nm (0 to 60) dB	0.021 dB	EXFO 1502 Power Meter
Multi Mode	(850, 1 300) nm (0 to 60) dB	0.021 dB	
Fiber Optic Power Single Mode	(1 310, 1 550) nm (-60 to 5) dBm	0.047 dB	EXFO 1502 Power Meter
Multi Mode	(850, 1 300) nm (-60 to 5) dBm	0.047 dB	
Fiber Optic Wavelength Wavelength Meter	(1 528 to 1 563) nm	0.001 4 nm	NIST SRM 2519

**Photometry and Radiometry**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Fiber Optic Wavelength Measure (Single Mode)	(700 to 1 700) nm	2 pm	Burleigh WA-1650 Wavelength Meter
Fiber Optic Wavelength Measure (Multi Mode)	(550 to 2 000) nm	2.9 nm	Newport 77250 Monochromator
Luminous Intensity	(20 to 500) fc	0.8 % of reading	NIST Luminous Intensity Lamp

**Thermodynamic**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dewpoint / Frostpoint Indicators	(-80 to 10) °C	0.35 °C	Thunder Scientific 3900 Low Humidity Generator
Relative Humidity <sup>1</sup>	(10 to 90) %RH	0.8 %RH	Thunder Scientific 2500ST Humidity Generator
Infrared Thermometers	(-15 to 0) °C (0 to 100) °C (100 to 200) °C (200 to 350) °C (350 to 500) °C	1.3 °C 1.2 °C 1.4 °C 1.9 °C 2.4 °C	Infrared Calibrator $\epsilon = 0.95, \lambda = (8 \text{ to } 14) \mu\text{m}$
Resistance Thermometry, Fixed Points	-195.5 °C	0.002 3 °C	DCC Resistance Bridge, Standard Resistors, NIST SPRT LN2 Comparator
	-38.8344 °C	0.001 4 °C	DCC Resistance Bridge, Standard Resistors, NIST SPRT, TP Mercury Cell
	0.01 °C	0.000 4 °C	DCC Resistance Bridge, Standard Resistors, NIST SPRT, TPW Cell
	231.9280 °C	0.002 5 °C	DCC Resistance Bridge, Standard Resistors, NIST SPRT, FP Tin Cell
Resistance Thermometry, Fixed Points	419.527 °C	0.002 8 °C	DCC Resistance Bridge, Standard Resistors, NIST SPRT, FP Zinc Cell



ANSI National Accreditation Board

**Thermodynamic**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Temperature <sup>1</sup>	(-80 to 0) °C	0.005 °C	Super Thermometer, SPRT, TPW Cell, Oil Bath, LN <sub>2</sub> Nanovoltmeter, Type S Thermocouple, Furnace
	(1 to 125) °C	0.003 °C	
	(126 to 300) °C	0.005 °C	
	(301 to 660) °C	0.3 °C	
	(661 to 1 000) °C	0.3 °C	
Optical Pyrometer	(800 to 849) °C	3.3 °C	NIST Tungsten Strip Lamp
	(850 to 949) °C	3 °C	
	(950 to 1 049) °C	2.6 °C	
	(1 050 to 1 149) °C	3.1 °C	
	(1 150 to 1 249) °C	2.4 °C	
	(1 250 to 1 349) °C	2.5 °C	
	(1 350 to 1 449) °C	2.8 °C	
	(1 450 to 1 549) °C	2.8 °C	
	(1 550 to 1 649) °C	3.1 °C	
	(1 650 to 1 749) °C	2.9 °C	
	(1 750 to 1 849) °C	3.1 °C	
	(1 850 to 1 949) °C	3.2 °C	
	(1 950 to 2 049) °C	4.1 °C	
	(2 050 to 2 149) °C	5 °C	
(2 150 to 2 249) °C	4.5 °C		
(2 250 to 2 300) °C	3.8 °C		

**Time and Frequency**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	HP 53132A Counter
	50 MHz to 26.5 GHz	30 pHz/Hz + 3.75 Hz	
Frequency Measure Frequency Offset Frequency Stability	(1, 5, 10) MHz (1, 5, 10) MHz	5.8 parts in 10 <sup>14</sup> Hz 5.8 parts in 10 <sup>14</sup> Hz	NIST TMAS System
Allan Variance	(1, 5, 10) MHz	7.8 x 10 <sup>-14</sup> Hz	HP 5370B Counter, Symmetricon 5120A Opt 001 Phase Noise Test Set
Stop Watches – Timers With Human Interaction	24 hrs	0.6 s/24 hours	HP 5326A Counter, NIST TMAS System

**Time and Frequency**

El Segundo, CA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Stop Watches – Timers Without Human Interaction	24 hrs	0.23 s/24 hours	Agilent 53131A Counter
Pulse - Source Width <sup>1</sup>	150 ps to 10 ns (10 to 100) ns 100 μs to 10 ms (10 to 100) ms (100 to 0.99) ms	0.13 ns (0.013* Width) + 1.2 ns (0.013*Width) +0.14 μs (0.012 * Width) + 2 ns (0.012*Width) +0.19 μs	HP 8161A Pulse Generator
Pulse - Source RMS Jitter - Period, Delay and Width <sup>1</sup>	33 MHz to 3 GHz	10 ps	HP 8133A Pulse Generator
Pulse Width – Measure	2 μs 10 μs 20 ms	37 ps 1.8 ps 3.7 ns	MSOS 804A Oscilloscope
Rise Time Measure <sup>1</sup>	10 Hz to 1 GHz 300 ps to 1 μs	8.1 ps	DSO9104A Oscilloscope
Rise Time – Measure	25 mVpp 1 ns 250 mVpp 300 ps 350 ps 400 ps 1 ns 500 mVpp 300 ps 350 ps 400 ps	0.11 ns 3.5 ps 4 ps 4.6 ps 11 ps 3.9 ps 4.5 ps 5.1 ps	MSOS 804A Oscilloscope
Rise Time – Measure	1 Vpp 300 ps 350 ps 400 ps 2.5 Vpp 300 ps 350 ps 400 ps 1 ns	4.1 ps 7.3 ps 5.3 ps 3.5 ps 4 ps 4.5 ps 11 ps	MSOS 804A Oscilloscope
Rise/ Fall Time (10 to 90) %	(20 to 50) ps	1.6 ps	Wavetek 9550 pulse head

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**Services performed at satellite laboratory  
(AC-1498.02)**

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**Electrical - DC/Low Frequency**

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	Up to 100 mV 100 mV to 1 V (1 to 10) V (10 to 100) V 100 V to 1 kV	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	Up to 220 $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A – 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical - DC/Low Frequency**

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(15 A to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
DC Current - Measure <sup>1</sup>	(100 A to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source Fixed Points <sup>1</sup>	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$	Fluke 5720A Multiproduct Calibrator



ANSI National Accreditation Board

Electrical - DC/Low Frequency

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source Fixed Points <sup>1</sup>	100 kΩ	1.2 Ω	Fluke 5720A Multiproduct Calibrator
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
	10 MΩ	0.4 kΩ	
	19 MΩ	1.5 kΩ	
	100 MΩ	12 kΩ	
Resistance – Source Fixed Points <sup>1</sup>	0 Ω	21 μΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
Resistance – Source <sup>1</sup>	(0 to 11) Ω	33 μΩ/Ω + 8.3 mΩ	Fluke 5520A Multiproduct Calibrator
	(11 to 110) Ω	25 μΩ/Ω + 12.5 mΩ	
	110 Ω to 1.1 kΩ	23 μΩ/Ω + 17 mΩ	
	(1.1 to 3.3) kΩ	23 μΩ/Ω + 170 mΩ	
	(3.3 to 11) kΩ	23 μΩ/Ω + 84 mΩ	
	(11 to 110) kΩ	23 μΩ/Ω + 0.84 Ω	
	110 kΩ to 1.1 MΩ	27 μΩ/Ω + 8 Ω	
	(1.1 to 3.3) MΩ	50 μΩ/Ω + 125 Ω	
	(3.3 to 11) MΩ	0.11 mΩ/Ω + 0.2 kΩ	
	(11 to 33) MΩ	0.21 mΩ/Ω + 2 kΩ	
Resistance – Source <sup>1</sup>	(33 to 110) MΩ	0.41 mΩ/Ω + 2.8 kΩ	Fluke 5520A Multiproduct Calibrator
	(110 to 330) MΩ	2.5 mΩ/Ω + 83 kΩ	
	(330 to 1 100) MΩ	13 mΩ/Ω + 0.4 MΩ	
Resistance – Measure <sup>1</sup>	(0 to 12) Ω	18 μΩ/ Ω + 20 μΩ	Keysight 3458A Multimeter
	(10 to 120) Ω	12 μΩ/Ω + 0.6 mΩ	
	100 Ω to 1.2 kΩ	9.6 μΩ/Ω + 0.6 mΩ	
	(1 to 12) kΩ	9.6 μΩ/Ω + 6 mΩ	
	(10 to 120) kΩ	9.6 μΩ/Ω + 60 mΩ	
	100 kΩ to 1.2 MΩ	14.5 μΩ/Ω + 2.4 Ω	
	(1 to 12) MΩ	60 μΩ/Ω + 120 Ω	
	(10 to 120) MΩ	0.6 mΩ/Ω + 1.2 kΩ	
100 Ω to 1.2 GΩ	6 mΩ/Ω + 1.2 kΩ		



ANSI National Accreditation Board

Electrical - DC/Low Frequency

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$		
(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$		
220 mV to 2.2 V			
(10 to 20) Hz	251 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V/V} + 9 \mu\text{V}$		
(50 to 100) kHz	103 $\mu\text{V/V} + 204 \mu\text{V}$		
(100 to 300) kHz	287 $\mu\text{V/V} + 611 \mu\text{V}$		
(300 to 500) kHz	1 mV/V + 2.1 mV		
500 kHz to 1 MHz	1.6 mV/V + 3.3 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	251 $\mu\text{V/V}$ + 390 $\mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V}$ + 156 $\mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V}$ + 48 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V}$ + 107 $\mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V}$ + 42 $\mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V}$ + 97 $\mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu\text{V/V}$ + 4.2 mV	
	(20 to 40) Hz	94 $\mu\text{V/V}$ + 1.6 mV	
	40 Hz to 20 kHz	54 $\mu\text{V/V}$ + 0.68 mV	
	(20 to 50) kHz	83 $\mu\text{V/V}$ + 1.1 mV	
	(50 to 100) kHz	156 $\mu\text{V/V}$ + 2.6 mV	
(100 to 300) kHz	941 $\mu\text{V/V}$ + 16 mV		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	40 Hz to 1 kHz	80 $\mu\text{V/V}$ + 18 mV	
	(1 to 20) kHz	173 $\mu\text{V/V}$ + 5.3 mV	
	(20 to 30) kHz	625 $\mu\text{V/V}$ + 12 mV	
AC Voltage – Source <sup>1</sup>	(220 to 750) V		Fluke 5730A Multiproduct Calibrator
	(30 to 50) kHz	634 $\mu\text{V/V}$ + 5.5 mV	
	(50 to 100) kHz	2.4 mV/V + 28 mV	
	Up to 2.2 mV		
AC Voltage – Source <sup>1</sup>	(10 to 20) Hz	250 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	Fluke 5730A Multiproduct Calibrator
	(20 to 40) Hz	94 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$		

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(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	250 $\mu$ V/V + 4.1 $\mu$ V 94 $\mu$ V/V + 4.1 $\mu$ V 83 $\mu$ V/V + 4.1 $\mu$ V 210 $\mu$ V/V + 4.1 $\mu$ V 520 $\mu$ V/V + 4.1 $\mu$ V 1.1 mV/V + 4.1 $\mu$ V 1.4 mV/V + 4.1 $\mu$ V 2.8 mV/V + 4.1 $\mu$ V	Fluke 5730A Multiproduct Calibrator
	(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	250 $\mu$ V/V + 39 $\mu$ V 94 $\mu$ V/V + 16 $\mu$ V 60 $\mu$ V/V + 7 $\mu$ V 120 $\mu$ V/V + 8 $\mu$ V 320 $\mu$ V/V + 18 $\mu$ V 680 $\mu$ V/V + 20 $\mu$ V 1.5 mV/V + 20 $\mu$ V 2.8 mV/V + 50 $\mu$ V	
AC Voltage – Source <sup>1</sup>	220 mV 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	250 mV/V + 39 $\mu$ V 94 $\mu$ V/V + 16 $\mu$ V 43 $\mu$ V/V + 8.8 $\mu$ V 70 $\mu$ V/V + 10 $\mu$ V 89 $\mu$ V/V + 30 $\mu$ V 350 $\mu$ V/V + 83 $\mu$ V 1.1 mV/V + 190 $\mu$ V 1.8 mV/V + 300 $\mu$ V	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	220 V to 1.1 kV 15 Hz to 50 Hz 50 Hz to 1 kHz 750 V to 1.1 kV 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (30 to 50) kHz (50 to 100) kHz	0.3 mV/V + 20 $\mu$ V 70 $\mu$ V/V + 90 $\mu$ V 80 $\mu$ V/V + 16 mV 0.2 mV/V – 0.8 mV 0.6 mV/V + 10 $\mu$ V 0.6 mV/V – 5.6 mV 2.4 mV/V – 20 mV	



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AC Voltage – Source Fixed Values, Fixed Frequencies <sup>1</sup>	0.01 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	870 nV	
	20 kHz	1.2 μV	
	100 kHz	4.5 μV	
	300 kHz	33 μV	
	1 MHz	21 μV	
	4 MHz	140 μV	
	0.1 V		
	1 kHz	4.6 μV	
	20 kHz	6.9 μV	
	100 kHz	36 μV	
	300 kHz	52 μV	
	1 MHz	170 μV	
	4 MHz	670 μV	
	8 MHz	690 μV	
	10 MHz	2.3 mV	
	1 V		
	1 kHz	26 μV	
	20 kHz	32 μV	
	50 kHz	59 μV	
	100 kHz	170 μV	
	300 kHz	410 μV	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
100 kHz	420 μV		
(2, 4, 8) MHz	21 mV		
10 MHz	75 mV		

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source Fixed Values, Fixed Frequencies <sup>1</sup>	10 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	10 Hz	480 μV	
	20 Hz	270 μV	
	40 Hz	230 μV	
	200 Hz	460 μV	
	500 Hz	450 μV	
	1 kHz	260 μV	
	10 kHz	270 μV	
	20 kHz	320 μV	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
AC Voltage - Source Fixed Values, Fixed Frequencies <sup>1</sup>	100 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	4 mV	
	20 kHz	7.9 mV	
	50 kHz	7.5 mV	
	100 kHz	16 mV	
AC Voltage – Source <sup>1</sup>	700 V		Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	1 kHz	60 mV	
AC Voltage – Source <sup>1</sup>	220 V to 1.1 kV		Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	15 Hz to 50 Hz	0.3 mV/V + 20 μV	
	50 Hz to 1 kHz	70 μV/V + 90 μV	
	750 V to 1.1 kV		
	40 Hz to 1 kHz	80 μV/V + 16 mV	
	(1 to 20) kHz	0.2 mV/V – 0.8 mV	
	(20 to 30) kHz	0.6 mV/V + 10 μV	
(30 to 50) kHz	0.6 mV/V – 5.6 mV		
(50 to 100) kHz	2.4 mV/V – 20 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A, Agilent 8491B Power Sensors, Agilent 3458A 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	0.3 mV/V + 3.1 $\mu$ V 0.2 mV/V + 1.2 $\mu$ V 0.3 mV/V + 1.7 $\mu$ V 1 mV/V + 1.6 $\mu$ V 5 mV/V + 1.3 $\mu$ V 40 mV/V + 2.1 $\mu$ V 12 mV/V + 6.6 $\mu$ V 70 mV/V + 7.5 $\mu$ V 20 mV/V + 8.2 $\mu$ V	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage - Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	3 % of reading	DSO 8104A Oscilloscope
AC Current Source <sup>1</sup>	(0 to 220) μA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz 220 μA 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	230 μA/A + 17 nA 150 μA/A + 10 nA 108 μA/A + 8.4 nA 266 μA/A + 12.5 nA 915 μA/A + 66 nA 233 μA/A + 42 nA 150 μA/A + 34 nA 108 μA/A + 34 nA 183 μA/A + 109 nA 915 μA/A + 655 nA 233 μA/A + 422 nA 149 μA/A + 342 nA 108 μA/A + 343 nA 183 μA/A + 588 nA 915 μA/A + 5 μA 233 μA/A + 4.2 μA 149 μA/A + 3.4 μA 108 μA/A + 2.6 μA 183 μA/A + 3.4 μA 915 μA/A + 10 μA	Fluke 5720A or 5730A Multiproduct Calibrator

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current Source <sup>1</sup>	(0 to 0.33) mA 10 Hz to 30 kHz (0.33 to 3.3) mA 10 Hz to 30 kHz (3.3 to 33) mA 10 Hz to 30 kHz (33 to 330) mA 10 Hz to 30 kHz (2.2 to 20.5) A (45 to 100 Hz 100 Hz to 1 kHz (1 to 5) kHz	10 mA/A + 330 nA 6.6 mA/A + 550 nA 2.7 mA/A + 2.7 $\mu$ A 2.7 mA/A + 160 $\mu$ A 830 mA/A + 4.2 mA 1.1 mA/A + 3.9 mA 21 mA/A + 1 mA	Fluke 552xA Multiproduct Calibrator
AC Current - Source Fixed Values <sup>1</sup> @ 1 kHz	10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	Up to 100 $\mu$ A (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 10) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	4 mA/A + 31 nA 1.5 mA/A + 31 nA 0.6 mA/A + 31 nA 4 mA/A + 0.31 $\mu$ A 0.15 mA/A + 0.21 $\mu$ A 0.6 mA/A + 0.21 $\mu$ A 4 mA/A + 3.1 $\mu$ A 1.5 mA/A + 2.1 $\mu$ A 0.6 mA/A + 2.1 $\mu$ A	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(10 to 100) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz 100 mA to 1.05 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	4 mA/A + 31 $\mu$ A 1.5 mA/A + 21 $\mu$ A 0.6 mA/A + 21 $\mu$ A  4 mA/A + 0.22 mA 1.6 mA/A + 0.22 mA 0.8 mA/A + 0.22 mA 1 mA/A + 0.22 mA	Keysight 3458A Multimeter
Resistance - Source	1 m $\Omega$ 10 m $\Omega$ 100 m $\Omega$ 1 $\Omega$ 10 $\Omega$ 100 $\Omega$ 1 k $\Omega$ 10 k $\Omega$ 100 k $\Omega$ 1 M $\Omega$ 10 M $\Omega$ 100 M $\Omega$ 1 G $\Omega$ 10 G $\Omega$ 100 G $\Omega$	0.75 % of reading 1.1 % of reading 7 % of reading 63 $\mu\Omega/\Omega$ 38 $\mu\Omega/\Omega$ 30 $\mu\Omega/\Omega$ 29 $\mu\Omega/\Omega$ 29 $\mu\Omega/\Omega$ 2.1 $\mu\Omega/\Omega$ 8 $\mu\Omega/\Omega$ 16 $\mu\Omega/\Omega$ 96 $\mu\Omega/\Omega$ 240 $\mu\Omega/\Omega$ 590 $\mu\Omega/\Omega$ 560 $\mu\Omega/\Omega$	Standard Resistor Sets 16074A, 42030A, 16340A 16353A
Capacitance – Source Fixed Points <sup>1</sup>	1 pF 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 10 pF 1 kHz to 5 MHz (5 to 10) MHz (10 to 13) MHz	0.24 fF 0.19 fF 0.31 fF 0.49 fF 0.68 fF 0.9 fF 2.5 fF 3.8 fF  1.5 fF 2 fF 2.2 fF	Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source Fixed Points <sup>1</sup>	100 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
	(4 to 5) MHz	20 fF	
	(5 to 10) MHz	37 fF	
	(10 to 13) MHz	53 fF	
	1 000 pF		
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
	120 Hz to 100 kHz	1.5 pF	
100 nF			
120 Hz to 100 kHz	15 pF		
1 μF			
120 Hz to 1 kHz	0.52 nF		
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
10 μF			
20 Hz to 1 kHz	1.6 nF		
(1 to 20) kHz	2.2 nF		
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.1 mF/F + 7.7 pF	Fluke 5520A or 5522A Multiproduct 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 + 83 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 10.00) 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		



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Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
(4 to 5) MHz	0.000 21		
(5 to 10) MHz	0.000 58		
(10 to 13) MHz	0.000 86		
10 nF			
120 Hz to 1 kHz	0.000 024		
(1 to 100) kHz	0.000 021		
100 nF			
120 Hz to 1 kHz	0.000 04		
(1 to 100) kHz	0.000 021		

**Electrical - DC/Low Frequency**

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 $\mu$ F		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	120 Hz to 1 kHz	0.000 041	
	(1 to 10) kHz	0.000 035	
	(10 to 100) kHz	0.000 11	
	10 $\mu$ F		
	(20 to 120) Hz	0.000 04	
	120 Hz to 10 kHz	0.000 03	
	(10 to 100) kHz	0.000 76	
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1 800) °C	0.53 °C	
	(1 800 to 2 316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1 000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
(120 to 1 000) °C	0.28 °C		
(1 000 to 1 372) °C	0.42 °C		
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		

**Electrical - DC/Low Frequency**

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type N		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
	Type S		
	(0 to 250) °C	0.5 °C	
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
	(1 400 to 1 767) °C	0.49 °C	
Type T			
(-250 to -150) °C	0.66 °C		
(-150 to 0) °C	0.26 °C		
(0 to 120) °C	0.18 °C		
(120 to 400) °C	0.16 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		

**Electrical - RF/Microwave**

Parameter/ Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 1 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 4.3 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 10 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 100 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 3 MHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.037 % Depth 0.038 % Depth 0.026 % Depth 0.03 % Depth 0.026 % Depth 0.03 % Depth 0.028 % Depth 0.036 % Depth 0.036 % Depth 0.084 % Depth	N9030A or N9030B Signal Analyzer
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz Modulation Index (0.2 to 100) (100 to 2 000) (3.6 to 8.4) GHz Modulation Index (0.2 to 100) (100 to 2 000) (8.4 to 17.1) GHz Modulation Index (0.2 to 100) (100 to 2 000) (17.1 to 34.5) GHz Modulation Index (0.2 to 100) (100 to 2 000) (34.5 to 50) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading 0.7 % of reading + 0.2 %M 2 % of reading 0.7 % of reading + 0.3 %M 2.5 % of reading 0.8 % of reading + 0.3 %M 3 % of reading 1.4 % of reading + 0.5 %M 4 % of reading	N9030A with Opt. TES or N9030B Signal Analyzer

**Electrical - RF/Microwave**

Parameter/ Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading  0.015° 0.12°	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer



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**Electrical - RF/Microwave**

Parameter/ Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.002 5 rad 0.1 % of reading + 0.004 9 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.003 5 rad 0.058 % of reading + 0.005 8 rad	N9030B Signal Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Electrical - RF/Microwave

Parameter/ Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz 10 MHz ≤ f ≤ 50 MHz 50 MHz ≤ f ≤ 80 MHz V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz 10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz 40 Hz ≤ f ≤ 1 kHz 1 kHz < f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz 100 mV < V ≤ 1 V 20 Hz ≤ f ≤ 1 kHz 1 kHz < f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.05 mV 0.38 mV 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Electrical - RF/Microwave

Parameter/ Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power Source <sup>1</sup>	$1\text{ V} < V \leq 3.5\text{ V}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$	2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power Source <sup>1</sup>	$7\text{ dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	0.49 dB 0.58 dB 0.69 dB 0.79 dB 0.49 dB 0.59 dB 0.69 dB 0.8 dB	Signal Source PSG, ESG
RF Absolute Power Source <sup>1</sup>	$-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	0.5 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	$(-167\text{ to } -89)\text{ dBc/Hz}$ Offsets $(10\text{ to } 100)\text{ Hz}$ $(0.1\text{ to } 100)\text{ kHz}$ $(0.1\text{ to } 1)\text{ MHz}$ $(1\text{ to } 10)\text{ MHz}$	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	$\geq -150\text{ dBc/Hz}$ Offsets $1\text{ Hz to } 100\text{ kHz}$	2.1 dB	Keysight E5500 Phase Noise System

Electrical – RF/Microwave

Colorado Springs, CO

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

Electrical – RF/Microwave

Colorado Springs, CO

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37

**Electrical – RF/Microwave**

Colorado Springs, CO

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
$8 \text{ GHz} \leq f < 10 \text{ GHz}$	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	
$10 \text{ GHz} \leq f < 12 \text{ GHz}$	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
$12 \text{ GHz} \leq f < 14 \text{ GHz}$	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
$14 \text{ GHz} \leq f < 18 \text{ GHz}$	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Colorado Springs, CO

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
$10 \text{ MHz} \leq f < 300 \text{ MHz}$	0.028	0.029	0.029	0.03	0.031	0.031	0.03	0.033	0.034	0.034	0.035	0.036
$300 \text{ MHz} \leq f < 2 \text{ GHz}$	0.028	0.029	0.031	0.032	0.033	0.032	0.032	0.035	0.036	0.036	0.037	0.038
$2 \text{ GHz} \leq f < 8 \text{ GHz}$	0.046	0.048	0.049	0.05	0.051	0.051	0.052	0.053	0.054	0.054	0.055	0.056
$8 \text{ GHz} \leq f < 12 \text{ GHz}$	0.052	0.052	0.054	0.055	0.056	0.056	0.057	0.055	0.059	0.059	0.059	0.061
$12 \text{ GHz} \leq f < 18 \text{ GHz}$	0.058	0.06	0.061	0.062	0.063	0.064	0.064	0.067	0.067	0.066	0.067	0.069
$18 \text{ GHz} \leq f < 20 \text{ GHz}$	-	-	-	0.062	-	-	0.064	-	-	-	0.067	-
$20 \text{ GHz} \leq f < 30 \text{ GHz}$	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
$30 \text{ GHz} \leq f < 40 \text{ GHz}$	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
$40 \text{ GHz} \leq f < 50 \text{ GHz}$	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.091	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.05	0.062	0.082	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.061	0.084	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.07	0.078	0.1	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.076	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.066	0.082	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.097	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

**Electrical – RF/Microwave**

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Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
-1 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

Electrical – RF/Microwave

City, ST

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, N8481B, N8482B, E9300A, E9304A, N8487A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 2 GHz	2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.073	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.060	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 10 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
10 dBm ≤ P < 15 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	0.096	0.081	0.081	0.081	0.083	0.091	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	0.090	0.087	0.0874	0.087	0.095	0.1	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	0.090	0.087	0.0874	0.087	0.095	0.095	0.1	0.1	0.1	0.12

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, N8481B, N8482B, E9300A, E9304A, N8485A, N8487A, N8488A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>										
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency	Measured Magnitude (Linear)										
	≤ 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	
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7	

Electrical – RF/Microwave

Colorado Springs, CO

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

Electrical – RF/Microwave

Colorado Springs, CO

Parameter/ Equipment	S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Colorado Springs, CO

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

**Electrical – RF/Microwave**

Colorado Springs, CO

<b>Parameter/ Equipment</b>	S21 - Transmission Phase <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	<b>Measured Magnitude (Degrees)</b>								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Colorado Springs, CO

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Frequency - Source <sup>1</sup>	5 MHz, 10 MHz	50 pHz/Hz	Datum 8040 Rubidium Standard
Frequency - Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter
Rise Time Source <sup>1</sup>	2 kHz to 2 MHz (200 to 300) ps (2 to 10) MHz (200 to 350) ps	37 ps 37 ps	Fluke 55xxA + SC600/1100 Multifunction Calibrator
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 0.64 ns/s 0.64 ns/s 0.74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1% of reading + 0.9 ps 8.5 ps 0.105% of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module



**ANSI National Accreditation Board**

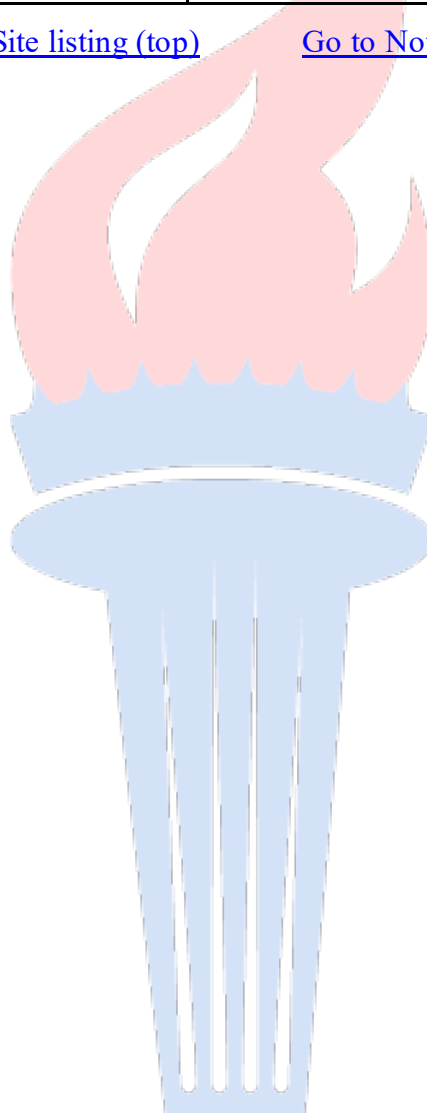
**Time and Frequency**

Colorado Springs, CO

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pulse Amplitude – Measure 1	$25 \text{ mV} \leq V < 100 \text{ mV}$ $100 \text{ mV} \leq V < 200 \text{ mV}$ $200 \text{ mV} \leq V < 400 \text{ mV}$ $400 \text{ mV} \leq V \leq 750 \text{ mV}$ $750 \text{ mV} < V \leq 10 \text{ V}$ $10 \text{ V} < V \leq 70 \text{ V}$	3.2 mV 4 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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**Services performed at satellite laboratory  
(AC-1498.04)**

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**Electrical - DC/Low Frequency**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical - DC/Low Frequency**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A	1.3 nA	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
	1 mA	9.5 nA	
	10 mA	93 nA	
	100 mA	2.2 $\mu$ A	
	1 A	36 $\mu$ A	
DC Current – Source <sup>1</sup>	(10 to 20) A	0.57 % of reading + 21 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
	(20 to 200) A	0.57 % of reading + 145 mA	
	(200 to 1 000) A	0.57 % of reading + 510 mA	
DC Current – Measure <sup>1</sup>	(0 to 100) nA	42 $\mu$ A/A + 50 pA	Keysight 3458A Multimeter
	(0.1 to 1) $\mu$ A	21 $\mu$ A/A + 50 pA	
	(1 to 10) $\mu$ A	25 $\mu$ A/A + 0.11 nA	
	(10 to 100) $\mu$ A	25 $\mu$ A/A + 0.85 nA	
	(0.1 to 1) mA	22 $\mu$ A/A + 6.4 nA	
	(1 to 10) mA	23 $\mu$ A/A + 59 nA	
	(10 to 100) mA	41 $\mu$ A/A + 0.6 $\mu$ A	
(0.1 to 1) A	125 $\mu$ A/A + 12 $\mu$ A		
	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(15 to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup> Fixed Points	0 $\Omega$	0.25 m $\Omega$	Fluke 5720A Multiproduct Calibrator
	1 $\Omega$	0.27 m $\Omega$	
	1.9 $\Omega$	0.31 m $\Omega$	
	10 $\Omega$	0.34 m $\Omega$	
	19 $\Omega$	2.5 m $\Omega$	
	100 $\Omega$	2.7 m $\Omega$	
	190 $\Omega$	3.3 m $\Omega$	
	1 k $\Omega$	9.3 m $\Omega$	
	1.9 k $\Omega$	31 m $\Omega$	
	10 k $\Omega$	93 m $\Omega$	
	19 k $\Omega$	0.19 $\Omega$	
	100 k $\Omega$	1.2 $\Omega$	



ANSI National Accreditation Board

Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	190 kΩ	2.2 Ω	Fluke 5720A Multiproduct Calibrator
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
	10 MΩ	0.4 kΩ	
	19 MΩ	1.5 kΩ	
	100 MΩ	12 kΩ	
Resistance – Source <sup>1</sup> Fixed Points	0 Ω	21 μΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
	10 MΩ	140 Ω	
Resistance – Source <sup>1</sup>	(0 to 11) Ω	33 μΩ/Ω + 8.3 mΩ	Fluke 5520A Multiproduct Calibrator
	(11 to 110) Ω	25 μΩ/Ω + 12.5 mΩ	
	110 Ω to 1.1 kΩ	23 μΩ/Ω + 17 mΩ	
	(1.1 to 3.3) kΩ	23 μΩ/Ω + 170 mΩ	
	(3.3 to 11) kΩ	23 μΩ/Ω + 84 mΩ	
	(11 to 110) kΩ	23 μΩ/Ω + 0.84 Ω	
	110 kΩ to 1.1 MΩ	27 μΩ/Ω + 8 Ω	
	(1.1 to 3.3) MΩ	50 μΩ/Ω + 125 Ω	
	(3.3 to 11) MΩ	0.11 mΩ/Ω + 0.2 kΩ	
	(11 to 33) MΩ	0.21 mΩ/Ω + 2 kΩ	
	(33 to 110) MΩ	0.41 mΩ/Ω + 2.8 kΩ	
(110 to 330) MΩ	2.5 mΩ/Ω + 83 kΩ		
(330 to 1 100) MΩ	13 mΩ/Ω + 0.4 MΩ		
Resistance – Measure <sup>1</sup>	(0 to 12) Ω	18 μΩ/ Ω + 20 μΩ	Keysight 3458A Multimeter
	(10 to 120) Ω	12 μΩ/Ω + 0.6 mΩ	
	100 Ω to 1.2 kΩ	9.6 μΩ/Ω + 0.6 mΩ	
	(1 to 12) kΩ	9.6 μΩ/Ω + 6 mΩ	
	(10 to 120) kΩ	9.6 μΩ/Ω + 60 mΩ	
	100 k Ω to 1.2 MΩ	15 μΩ/Ω + 2.4 Ω	
	(1 to 12) MΩ	60 μΩ/Ω + 120 Ω	
	(10 to 120) MΩ	0.6 mΩ/Ω + 1.2 kΩ	
100 MΩ to 1.2 GΩ	6 mΩ/Ω + 12 kΩ		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 20 kHz	83 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 50) kHz	210 $\mu$ V/V + 4.1 $\mu$ V	
	(50 to 100) kHz	520 $\mu$ V/V + 4.1 $\mu$ V	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu$ V	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu$ V	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu$ V	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 20 kHz	83 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 50) kHz	210 $\mu$ V/V + 4.1 $\mu$ V	
	(50 to 100) kHz	520 $\mu$ V/V + 4.1 $\mu$ V	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu$ V	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu$ V	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu$ V	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu$ V/V + 39 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 16 $\mu$ V	
	40 Hz to 20 kHz	83 $\mu$ V/V + 8.7 $\mu$ V	
	(20 to 50) kHz	200 $\mu$ V/V + 10 $\mu$ V	
	(50 to 100) kHz	470 $\mu$ V/V + 210 $\mu$ V	
(100 to 300) kHz	930 $\mu$ V/V + 600 $\mu$ V		
(300 to 500) kHz	1.5 mV/V + 190 $\mu$ V		
500 kHz to 1 MHz	2.8 mV/V + 300 $\mu$ V		
220 mV to 2.2 V			
(10 to 20) Hz	250 $\mu$ V/V + 39 $\mu$ V		
(20 to 40) Hz	94 $\mu$ V/V + 16 $\mu$ V		
40 Hz to 20 kHz	46 $\mu$ V/V + 9 $\mu$ V		
(20 to 50) kHz	78 $\mu$ V/V + 10 $\mu$ V		
(50 to 100) kHz	100 $\mu$ V/V + 70 $\mu$ V		
(100 to 300) kHz	290 $\mu$ V/V + 80 $\mu$ V		
(300 to 500) kHz	1.1 mV/V + 200 $\mu$ V		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu$ V		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	251 $\mu\text{V/V}$ + 390 $\mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V}$ + 156 $\mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V}$ + 48 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V}$ + 107 $\mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V}$ + 42 $\mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V}$ + 97 $\mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu\text{V/V}$ + 4.17 mV	
	(20 to 40) Hz	94 $\mu\text{V/V}$ + 1.6 mV	
	40 Hz to 20 kHz	549 $\mu\text{V/V}$ + 0.68 mV	
	(20 to 50) kHz	83 $\mu\text{V/V}$ + 1.1 mV	
(50 to 100) kHz	156 $\mu\text{V/V}$ + 2.6 mV		
(100 to 300) kHz	941 $\mu\text{V/V}$ + 16 mV		
(300 to 500) kHz	4.6 mV/V + 41.7 mV		
500 kHz to 1 MHz	8.3 mV/V + 834 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	(15 to 50) Hz	313 $\mu\text{V/V}$ + 17 mV	
	50 Hz to 1 MHz	73 $\mu\text{V/V}$ + 3.7 mV	
	(220 to 1 100) V		
AC Voltage – Source <sup>1</sup>	40 Hz to 1 kHz	80 $\mu\text{V/V}$ + 18 mV	Fluke 5730A Multiproduct Calibrator
	(1 to 20) kHz	173 $\mu\text{V/V}$ + 5.3 mV	
	(20 to 30) kHz	625 $\mu\text{V/V}$ + 12 mV	
	(220 to 750) V		
	(30 to 50) kHz	634 $\mu\text{V/V}$ + 5.5 mV	
AC Voltage – Source <sup>1</sup>	(50 to 100) kHz	2.4 mV/V + 28 mV	Fluke 5730A Multiproduct Calibrator
	Up to 2.2 mV		
	(10 to 20) Hz	250 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V}$ + 4.1 $\mu\text{V}$	
(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$		
(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$		
500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 20 kHz	83 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 50) kHz	210 $\mu$ V/V + 4.1 $\mu$ V	
	(50 to 100) kHz	520 $\mu$ V/V + 4.1 $\mu$ V	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu$ V	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu$ V	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu$ V	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu$ V/V + 39 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 16 $\mu$ V	
	40 Hz to 20 kHz	60 $\mu$ V/V + 7 $\mu$ V	
	(20 to 50) kHz	120 $\mu$ V/V + 8 $\mu$ V	
	(50 to 100) kHz	320 $\mu$ V/V + 18 $\mu$ V	
	(100 to 300) kHz	680 $\mu$ V/V + 20 $\mu$ V	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu$ V	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu$ V	
	220 mV to 2.2 V		
	(10 to 20) Hz	250 $\mu$ V/V + 39 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 16 $\mu$ V	
	40 Hz to 20 kHz	43 $\mu$ V/V + 8.8 $\mu$ V	
	(20 to 50) kHz	70 $\mu$ V/V + 10 $\mu$ V	
	(50 to 100) kHz	89 $\mu$ V/V + 30 $\mu$ V	
	(100 to 300) kHz	350 $\mu$ V/V + 83 $\mu$ V	
	(300 to 500) kHz	1.1 mV/V + 190 $\mu$ V	
	500 kHz to 1 MHz	1.8 mV/V + 300 $\mu$ V	
(2.2 to 22) V			
(10 to 20) Hz	251 $\mu$ V/V + 392 $\mu$ V		
(20 to 40) Hz	93.8 $\mu$ V/V + 15.6 $\mu$ V		
40 Hz to 20 kHz	43.9 $\mu$ V/V + 48.3 $\mu$ V		
(20 to 50) kHz	69.7 $\mu$ V/V + 107 $\mu$ V		
(50 to 100) kHz	86.3 $\mu$ V/V + 213 $\mu$ V		
(100 to 300) kHz	265 $\mu$ V/V + 623 $\mu$ V		
(300 to 500) kHz	10.4 mV/V + 2.08 mV		
500 kHz to 1 MHz	1.56 mV/V + 3.33 mV		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(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 (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	250 $\mu\text{V}/\text{V} + 4.17 \mu\text{V}$ 93.8 $\mu\text{V}/\text{V} + 15.6 \text{ mV}$ 53.9 $\mu\text{V}/\text{V} + 0.68 \text{ mV}$ 83.3 $\mu\text{V}/\text{V} + 1.05 \text{ mV}$ 156 $\mu\text{V}/\text{V} + 2.62 \text{ mV}$ 941 $\mu\text{V}/\text{V} + 16 \text{ mV}$ 4.58 $\text{mV}/\text{V} + 41.7 \text{ mV}$ 8.33 $\text{mV}/\text{V} + 83.4 \text{ mV}$	Fluke 5730A Multiproduct Calibrator
AC Voltage – Source <sup>1</sup>	220 V to 1.1 kV 15 Hz to 50 Hz 50 Hz to 1 kHz 220 V to 1.1 kV 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	313 $\mu\text{V}/\text{V} + 17 \mu\text{V}$ 72.9 $\mu\text{V}/\text{V} + 3.7 \text{ mV}$ 79.6 $\mu\text{V}/\text{V} + 18 \text{ mV}$ 173 $\mu\text{V}/\text{V} + 5.3 \text{ mV}$ 625 $\mu\text{V}/\text{V} + 12 \text{ mV}$ 634 $\mu\text{V}/\text{V} + 5.5 \text{ mV}$ 2.4 $\text{mV}/\text{V} + 28 \text{ mV}$	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	870 nV 1.2 $\mu\text{V}$ 4.5 $\mu\text{V}$ 33 $\mu\text{V}$ 21 $\mu\text{V}$ 140 $\mu\text{V}$ 4.6 $\mu\text{V}$ 6.9 $\mu\text{V}$ 36 $\mu\text{V}$ 52 $\mu\text{V}$ 170 $\mu\text{V}$ 670 $\mu\text{V}$ 690 $\mu\text{V}$ 2.3 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter

**Electrical - DC/Low Frequency**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	1 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	480 $\mu$ V	
	20 Hz	270 $\mu$ V	
	40 Hz	230 $\mu$ V	
	200 Hz	460 $\mu$ V	
	500 Hz	450 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	6.3 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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	0.3 mV/V + 3.1 $\mu$ V 0.2 mV/V + 1.2 $\mu$ V 0.3 mV/V + 1.7 $\mu$ V 1 mV/V + 1.6 $\mu$ V 5 mV/V + 1.3 $\mu$ V 40 mV/V + 2.1 $\mu$ V 12 mV/V + 6.6 $\mu$ V 70 mV/V + 7.5 $\mu$ V 20 mV/V + 8.2 $\mu$ V	Keysight 3458A Multimeter



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20Hz to 20 MHz	3 % of reading	Keysight DSO8104A Oscilloscope
AC Current Source <sup>1</sup>	(0 to 220) $\mu$ A 10 to 20 Hz 20 to 40 Hz 40 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz 220 $\mu$ A 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	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA 233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA 233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A 233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator

**Electrical - DC/Low Frequency**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz (2.2 to 11) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(0 to 0.33) mA 10 to 30 kHz (0.33 to 3.3) mA 10 to 30 kHz (3.3 to 33) mA 10 to 30 kHz (33 to 330) mA 10 to 30 kHz (2.2 to 20.5) A 45 to 100 Hz 100 Hz to 1 kHz 1 to 5 kHz	10 mA/A + 330 nA 6.6 mA/A + 550 nA 2.7 mA/A + 2.7 $\mu$ A 2.7 mA/A + 160 $\mu$ A 830 mA/A + 4.2 mA 1.1 mA/A + 3.9 mA 21 mA/A + 1 mA	Fluke 552xA Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A 45 Hz to 65 Hz (65 to 100) Hz (100 to 440) Hz (20 to 100) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz (100 to 1 000) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.3 % of reading + 3.7 mA 0.31 % of reading + 24 mA 0.33 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 552xA Multiproduct Calibrator, Fluke Current Coil
AC Current - Source Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 0.039 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.040 $\mu$ A	
	(45 to 100) Hz	0.065 % of reading + 0.040 $\mu$ A	
	100 Hz to 5 kHz	0.67 % of reading + 0.040 $\mu$ A	
	100 $\mu$ A to 1 mA		
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A	
	(1 to 10) mA		
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.30 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
(1 to 3) A			
(3 to 10) Hz	1.3 % of reading + 2.1 mA		
(10 to 40) Hz	0.39 % of reading + 2.2 mA		
40 Hz to 300 kHz	0.17 % of reading + 2.1 mA		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	1 mΩ	0.75 % of reading	Standard Resistor Sets 16074A 42030A 16340A 16353A
	10 mΩ	1.1 % of reading	
	100 mΩ	7 % of reading	
	1 Ω	63 μΩ/Ω	
	10 Ω	38 μΩ/Ω	
	100 Ω	30 μΩ/Ω	
	1 kΩ	29 μΩ/Ω	
	10 kΩ	29 μΩ/Ω	
	100 kΩ	2.1 μΩ/Ω	
	1 MΩ	8 μΩ/Ω	
	10 MΩ	16 μΩ/Ω	
	100 MΩ	96 μΩ/Ω	
	1 GΩ	240 μΩ/Ω	
	10 GΩ	590 μΩ/Ω	
100 GΩ	560 μΩ/Ω		
Capacitance – Source <sup>1</sup> Fixed Points	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
	(10 to 13) MHz	2.2 fF	
	100 pF		
1 kHz to 3 MHz	14 fF		
(3 to 4) MHz	17 fF		
(4 to 5) MHz	20 fF		
(5 to 10) MHz	37 fF		
(10 to 13) MHz	53 fF		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source Fixed Points <sup>1</sup>	1 000 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
	120 Hz to 100 kHz	1.5 pF	
	100 nF		
	120 Hz to 100 kHz	15 pF	
	1 μF		
	120 Hz to 1 kHz	0.52 nF	
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
Capacitance – Source <sup>1</sup>	10 μF		Fluke 5520A or 5522A Multiproduct Calibrator
	20 Hz to 1 kHz	1.6 nF	
	(1 to 20) kHz	2.2 nF	
	0.19 to 3.29 nF	3.1 mF/F + 7.7 pF	
	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 + 83 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 10.00 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		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source <sup>1,2</sup> Fixed Points	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 58	
(10 to 13) MHz	0.000 86		
10 nF			
120 Hz to 1 kHz	0.000 024		
(1 to 100) kHz	0.000 021		
100 nF			
120 Hz to 1 kHz	0.000 04		
(1 to 100) kHz	0.000 021		
1 μF			
120 Hz to 1 kHz	0.000 041		
(1 to 10) kHz	0.000 035		
(10 to 100) kHz	0.000 11		



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Electrical - DC/Low Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source <sup>1,2</sup> Fixed Points	10 $\mu$ F		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	(20 to 120) Hz	0.000 04	
	120 Hz to 10 kHz	0.000 03	
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	(10 to 100) kHz	0.000 76	Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	Type B		
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1800) °C	0.53 °C	
	(1 800 to 2316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 1000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
Type K			
(-200 to -100) °C	0.35 °C		
(-100 to -25) °C	0.2 °C		
(-25 to 120) °C	0.18 °C		
(120 to 1 000) °C	0.28 °C		
(1 000 to 1 372) °C	0.42 °C		
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		

**Electrical - DC/Low Frequency**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type N		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
	Type S		
	(0 to 250) °C	0.5 °C	
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
	(1 400 to 1 767) °C	0.49 °C	
Type T			
(-250 to -150) °C	0.66 °C		
(-150 to 0) °C	0.26 °C		
(0 to 120) °C	0.18 °C		
(120 to 400) °C	0.16 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		

**Electrical - RF/Microwave**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth		N9030A or N9030B Signal Analyzer
	1 kHz Resolution Band Width		
	2 MHz to 6 GHz (6 to 50) GHz	0.037 % Depth 0.038 % Depth	
	4.3 kHz Resolution Band Width		
	2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth	
	10 kHz Resolution Band Width		
	2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth	
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	100 kHz Resolution Band Width		N9030A with Opt. TES or N9030B Signal Analyzer
	2 MHz to 6 GHz (6 to 50) GHz	0.028 % Depth 0.036 % Depth	
	3 MHz Resolution Band Width		
	2 MHz to 6 GHz (6 to 50) GHz	0.036 % Depth 0.084 % Depth	
	2 MHz to 3.6 GHz		
	Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading	
	(3.6 to 8.4) GHz		
Modulation Index (0.2 to 100) (100 to 2 000)	0.7 % of reading + 0.2 %M 2 % of reading		
(8.4 to 17.1) GHz			
Modulation Index (0.2 to 100) (100 to 2 000)	0.7 % of reading + 0.3 %M 2.5 % of reading		
(17.1 to 34.5) GHz			
Modulation Index (0.2 to 100) (100 to 2 000)	0.8 % of reading + 0.3 %M 3 % of reading		
(34.5 to 50) GHz			
Modulation Index (0.2 to 100) (100 to 2 000)	1.4 % of reading + 0.5 %M 4 % of reading		

**Electrical - RF/Microwave**

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading  0.015° 0.12°	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer



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Electrical - RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.002 5 rad 0.1 % of reading + 0.004 9 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.003 5 rad 0.058 % of reading + 0.005 8 rad	N9030B Signal Analyzer
Distortion Measure <sup>1</sup>	(-80 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Electrical - RF/Microwave

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power – Source <sup>1</sup> 50 MHz	(-11 to -1) dB (-30 to -10) dB (-50 to -40) dB -60 dB (-90 to -70) dB -100 dB -110 dB	0.025 dB 0.025 dB 0.027 dB 0.028 dB 0.033 dB 0.04 dB 0.048 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
RF Absolute Power – Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz 10 MHz ≤ f ≤ 50 MHz 50 MHz ≤ f ≤ 80 MHz V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz 10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz 40 Hz ≤ f ≤ 1 kHz 1 kHz < f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.05 mV 0.38 mV 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Electrical - RF/Microwave

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	$100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $1 \text{ V} < V \leq 3.5 \text{ V}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV  2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power – Source <sup>1</sup>	$7 \text{ dBm} \geq P \geq 0 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $0 \text{ dBm} > P \geq -25 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-25 \text{ dBm} > P \geq -70 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-70 \text{ dBm} > P \geq -95 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-95 \text{ dBm} > P \geq -125 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB  0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG



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Electrical - RF/Microwave

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.13 dB 0.14 dB 0.14 dB 0.16 dB 0.17 dB 0.14 dB 0.13 dB 0.15 dB 0.15 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Power Sensor										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Attenuation Level	Frequency Ranges (uncertainties in dB)										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Power Sensor										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Attenuation Level	Frequency Ranges (uncertainties in dB)										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kits											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Frequency Ranges (uncertainties in dB)											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Frequency Ranges (uncertainties in dB)									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-



ANSI National Accreditation Board

Electrical – RF/Microwave

Richardson, TX

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 2 GHz	2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

Electrical – RF/Microwave

Richardson, TX

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (uncertainties in dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05



ANSI National Accreditation Board

Electrical – RF/Microwave

Richardson, TX

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (uncertainties in dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

Electrical – RF/Microwave

Richardson, TX

Parameter/ Equipment	RF Power Measure <sup>1</sup>					
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors					
Range	Expanded Uncertainty of Measurement (+/-)					
Power Range	Frequencies / Frequency Ranges (uncertainties in dB)					
	f = 62 GHz	63 GHz ≤ f ≤ 64 GHz		f = 65 GHz	f = 66 GHz	f = 67 GHz
-30 dBm ≤ P < -20 dBm	0.34	0.33		0.29	0.35	0.36
-20 dBm ≤ P < -10 dBm	0.34	0.33		0.29	0.35	0.36
-10 dBm ≤ P < 0 dBm	0.34	0.33		0.29	0.35	0.36
-1 dBm ≤ P < 2 dBm	0.34	0.33		0.29	0.35	0.36
2 dBm ≤ P < 10 dBm	0.34	0.33		0.29	0.35	0.36
10 dBm ≤ P < 15 dBm	0.34	0.34		0.2	0.36	0.36
15 dBm ≤ P < 20 dBm	0.34	0.34		0.2	0.36	0.36

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	(S11 - Reflection) Magnitude Uncertainty <sup>1,2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (+/- Linear)									
	≤ 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
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015

**Electrical – RF/Microwave**

Richardson, TX

<b>Parameter/ Equipment</b>	(S11 - Reflection) Phase Uncertainty									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (+/- Degrees)									
	≤ 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
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2

Electrical – RF/Microwave

Richardson, TX

<b>Parameter/ Equipment</b>	(S21 - Transmission) Magnitude Uncertainty <sup>1,2</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (+/- Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051

Electrical – RF/Microwave

Richardson, TX

<b>Parameter/ Equipment</b>	(S21 - Transmission) Phase Uncertainty <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (+/- Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4



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Time and Frequency

Richardson, TX

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency – Source <sup>1</sup>	10 MHz	6.5 pHz/Hz	Symmetricon 8040C GPS Disciplined
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1% of reading + 0.9 ps 8.5 ps 0.105% of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4.0 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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**Services performed at satellite laboratory  
(AC-1498.05)**

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**Electrical – DC/Low Frequency**

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage - Source	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage - Source Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure	Up to 100 mV 100 mV to 1 V (1 to 10) V (10 to 100) V 100 V to 1 kV	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current - Source	Up to 220 $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current - Source	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current - Source	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
DC Current - Measure	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current - Measure	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Dissipated Power - 300 mA to Full Power	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 A to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$ 10 M $\Omega$ 19 M $\Omega$ 100 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$ 42 $\Omega$ 0.4 k $\Omega$ 1.5 k $\Omega$ 12 k $\Omega$	Fluke 5720A Multiproduct Calibrator



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 kΩ to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 14.5 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
AC Voltage - Source	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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV 250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.4 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V}$ + 8.7 $\mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V}/\text{V}$ + 210 $\mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V}/\text{V}$ + 600 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$	
	40 Hz to 20 kHz	46 $\mu\text{V}/\text{V}$ + 9 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$	
	(50 to 100) kHz	100 $\mu\text{V}/\text{V}$ + 70 $\mu\text{V}$	
	(100 to 300) kHz	290 $\mu\text{V}/\text{V}$ + 80 $\mu\text{V}$	
	(300 to 500) kHz	1.1 mV/V + 200 $\mu\text{V}$	
	500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$	
	(2.2 to 22) V		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 390 $\mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V}/\text{V}$ + 160 $\mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V}/\text{V}$ + 48 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V}/\text{V}$ + 100 $\mu\text{V}$	
	(50 to 100) kHz	110 $\mu\text{V}/\text{V}$ + 70 $\mu\text{V}$	
(100 to 300) kHz	430 $\mu\text{V}/\text{V}$ + 97 $\mu\text{V}$		
(300 to 500) kHz	1 mV/V + 2.1 mV		
500 kHz to 1 MHz	1.6 mV/V + 3.3 mV		
(22 to 220) V			
40 Hz to 20 kHz	54 $\mu\text{V}/\text{V}$ + 65 $\mu\text{V}$		
(20 to 50) kHz	83 $\mu\text{V}/\text{V}$ + 34 $\mu\text{V}$		
(50 to 100) kHz	155 $\mu\text{V}/\text{V}$ + 2.9 $\mu\text{V}$		
(100 to 300) kHz	940 $\mu\text{V}/\text{V}$ + 180 $\mu\text{V}$		
(300 to 500) kHz	4.6 mV/V + 40 $\mu\text{V}$		
500 kHz to 1 MHz	8.3 mV/V + 8.4 $\mu\text{V}$		
(220 to 1 100) V			
40 Hz to 20 kHz	310 $\mu\text{V}/\text{V}$ + 20 $\mu\text{V}$		
(20 to 50) kHz	73 $\mu\text{V}/\text{V}$		



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(220 to 1 100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	78 $\mu$ V/V + 14 mV 170 $\mu$ V/V 620 $\mu$ V/V 620 $\mu$ V/V 2.4 mV/V	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage - Source Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz 1 V 1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz 3V 100 kHz (2, 4, 8) MHz 10 MHz	890 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V 4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV 26 $\mu$ V 32 $\mu$ V 59 $\mu$ V 170 $\mu$ V 410 $\mu$ V 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV 420 $\mu$ V 21 mV 75 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source Fixed Values, Fixed Frequencies	10 V		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	0.63 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		
AC Voltage Flatness - Source	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz	4.6 mV/V	
	(10 to 20) MHz	6.2 mV/V	
	(20 to 30) MHz	8 mV/V	
	24 mV/V		
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz	2.2 mV/V	
	(10 to 20) MHz	3.7 mV/V	
	(20 to 30) MHz	5.5 mV/V	
	14 mV/V		
	3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz	1.2 mV/V	
	(10 to 20) MHz	2.1 mV/V	
	(20 to 30) MHz	3.8 mV/V	
	8.6 mV/V		



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Measure <sup>1</sup>	9 kHz to 2 GHz (-60 to 25) dBm	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A, Agilent 8491B Power Sensors, Agilent 3458A Multimeter
AC Voltage - Measure	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 100) 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 100 mV to 1 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV 70 μV/V + 4.1 μV 70 μV/V + 2.1 μV 0.14 mV/V + 2.3 μV 0.3 mV/V + 2.6 μV 0.8 mV/V + 2.3 μV 3 mV/V + 15 μV 10 mV/V + 28 μV 15 mV/V + 20 μV 40 mV/V + 74 μV 40 mV/V + 83 μV 0.15 V/V + 0.11 mV 70 μV/V + 41 μV 70 μV/V + 21 μV 0.14 mV/V + 22 μV 0.3 mV/V + 22 μV 0.8 mV/V + 22 μV 3 mV/V + 0.12 mV 10 mV/V + 0.30 mV 15 mV/V + 0.21 mV 40 mV/V + 0.73 mV 40 mV/V + 0.83 mV 0.15 V/V + 1 mV	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(1 to 10) V		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
	(2 to 4) MHz	40 mV/V + 7.1 mV	
	(4 to 8) MHz	40 mV/V + 8.1 mV	
	(8 to 10) MHz	0.15 mV/V + 11 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.2 mV/V + 4.1 mV	
	40 Hz to 20 kHz	0.2 mV/V + 2.6 mV	
(20 to 50) kHz	0.35 mV/V + 2.4 mV		
(50 to 100) kHz	1.2 mV/V + 2.1 mV		
(100 to 300) kHz	4 mV/V + 11 mV		
300 kHz to 1 MHz	15 mV/V + 50 mV		
(100 to 750) V			
(1 to 40) Hz	0.4 mV/V + 31 mV		
40 Hz to 1 kHz	0.4 mV/V + 16 mV		
(1 to 20) kHz	0.6 mV/V + 16 mV		
(20 to 50) kHz	1.2 mV/V + 16 mV		
(50 to 100) kHz	3 mV/V + 15 mV		
AC Voltage - Measure	1 mV to 8 V 10 Hz to 20 MHz	4.6 % of reading	DSO 9104A Oscilloscope
AC Current - Source	(0 to 220) $\mu$ A		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	230 $\mu$ A/A + 17 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 10 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 8.4 nA	
	(1 to 5) kHz	266 $\mu$ A/A + 12.5 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 66 nA	
	220 $\mu$ A to 2.2 mA		
	(10 to 20) Hz	233 $\mu$ A/A + 42 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 34 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 34 nA	
(1 to 5) kHz	183 $\mu$ A/A + 109 nA		
(5 to 10) kHz	915 $\mu$ A/A + 655 nA		



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Electrical – DC/Low Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Source	(2.2 to 22) mA		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	233 $\mu$ A/A + 422 nA	
	(20 to 40) Hz	149 $\mu$ A/A + 342 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 343 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 588 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 5 $\mu$ A	
	(22 to 220) mA		
	(10 to 20) Hz	233 $\mu$ A/A + 4.2 $\mu$ A	
	(20 to 40) Hz	149 $\mu$ A/A + 3.4 $\mu$ A	
	40 Hz to 1 kHz	108 $\mu$ A/A + 2.6 $\mu$ A	
	(1 to 5) kHz	183 $\mu$ A/A + 3.4 $\mu$ A	
	(5 to 10) kHz	915 $\mu$ A/A + 10 $\mu$ A	
	(0.22 to 2.2) A		
	20 Hz to 1 kHz	249 $\mu$ A/A + 34 $\mu$ A	
(1 to 5) kHz	383 $\mu$ A/A + 83 $\mu$ A		
(5 to 10) kHz	5.8 mA/A + 166 $\mu$ A		
AC Current - Source Fixed Values	1 kHz		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 $\mu$ A	7.3 nA	
	100 $\mu$ A	14 nA	
	1 mA	85 nA	
AC Current - Measure	10 mA	0.87 $\mu$ A	Keysight 3458A Multimeter
	100 mA	8.7 $\mu$ A	
	1 A	200 $\mu$ A	
	Up to 100 $\mu$ A		
	(10 to 20) Hz	4 mA/A + 31 nA	
	(20 to 45) Hz	1.5 mA/A + 31 nA	
	45 Hz to 1 kHz	0.6 mA/A + 31 nA	
	100 $\mu$ A to 1 mA		
	(10 to 20) Hz	4 mA/A + 0.31 $\mu$ A	
	(20 to 45) Hz	0.15 mA/A + 0.21 $\mu$ A	
	45 Hz to 1 kHz	0.6 mA/A + 0.21 $\mu$ A	
	(1 to 10) mA		
(10 to 20) Hz	4 mA/A + 3.1 $\mu$ A		
(20 to 45) Hz	1.5 mA/A + 2.1 $\mu$ A		
45 Hz to 1 kHz	0.6 mA/A + 2.1 $\mu$ A		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	(10 to 100) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	4 mA/A + 31 $\mu$ A 1.5 mA/A + 21 $\mu$ A 0.6 mA/A + 21 $\mu$ A	Keysight 3458A Multimeter
	100 mA to 1.05 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	4 mA/A + 0.22 mA 1.6 mA/A + 0.22 mA 0.80 mA/A + 0.22 mA 1 mA/A + 0.22 mA	
Resistance - Source	1 m $\Omega$	0.75 % of reading	Standard Resistor Sets 42030A
	10 m $\Omega$	1.1 % of reading	
	100 m $\Omega$	7 % of reading	
	1 $\Omega$	63 $\mu\Omega/\Omega$	
	10 $\Omega$	38 $\mu\Omega/\Omega$	
	100 $\Omega$	30 $\mu\Omega/\Omega$	
	1 k $\Omega$	29 $\mu\Omega/\Omega$	
	10 k $\Omega$	29 $\mu\Omega/\Omega$	
	100 k $\Omega$	2.1 $\mu\Omega/\Omega$	
	1 M $\Omega$	8 $\mu\Omega/\Omega$	
	10 M $\Omega$	16 $\mu\Omega/\Omega$	
	100 M $\Omega$	96 $\mu\Omega/\Omega$	
	1 G $\Omega$	240 $\mu\Omega/\Omega$	
10 G $\Omega$	590 $\mu\Omega/\Omega$		
100 G $\Omega$	560 $\mu\Omega/\Omega$		



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Electromagnetic - RF/Microwave

Tempe, AZ

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth		N9030A or N9030B Signal Analyzer
	1 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.037 % Depth	
	(6 to 50) GHz	0.038 % Depth	
	4.3 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.026 % Depth	
	(6 to 50) GHz	0.03 % Depth	
	10 kHz Resolution Band Width		
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz		N9030A with Opt. TES or N9030B Signal Analyzer
	Modulation Index (0.2 to 100)	0.35 % of reading + 0.2 %M	
	(100 to 2 000)	0.8 % of reading	
	(3.6 to 8.4) GHz		
	Modulation Index (0.2 to 100)	0.7 % of reading + 0.2 %M	
	(100 to 2 000)	2 % of reading	
	(8.4 to 17.1) GHz		
	Modulation Index (0.2 to 100)	0.7 % of reading + 0.3 %M	
(100 to 2 000)	2.5 % of reading		
	(17.1 to 34.5) GHz		
	Modulation Index (0.2 to 100)	0.8 % of reading + 0.3 %M	
	(100 to 2 000)	3 % of reading	
	(34.5 to 50) GHz		
	Modulation Index (0.2 to 100)	1.4 % of reading + 0.5 %M	
	(100 to 2 000)	4 % of reading	



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Electromagnetic - RF/Microwave

Tempe, AZ

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1) <sup>o</sup> (0 to 3) <sup>o</sup>	0.015 % of reading  0.015 <sup>o</sup> 0.12 <sup>o</sup>	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV- DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer



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**Electromagnetic - RF/Microwave**

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Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.002 5 rad 0.1 % of reading + 0.004 9 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.003 5 rad 0.058 % of reading + 0.005 8 rad	N9030B Signal Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Electromagnetic - RF/Microwave

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Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Tuned RF Power - Relative – Measure  2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Power Sensors - Calibration Factors	9 kHz to 100 kHz	0.69 % of reading	E9304A Power Sensor
RF Power Sensors Cal Factors <sup>1</sup>	10 MHz 30 MHz 50 MHz 100 MHz 300 MHz to 3 GHz 4 GHz 5 GHz (6 to 7) GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 12.4 GHz (13 to 15) GHz 16 GHz 17 GHz 18 GHz (19 to 26) GHz 26.5 GHz 27 GHz (28 to 29) GHz 30 GHz (31 to 32) GHz 33 GHz (34 to 40) GHz	0.58 % of reading 0.54 % of reading 0.41 % of reading 0.51 % of reading 0.6 % of reading 0.61 % of reading 0.67 % of reading 0.68 % of reading 0.7 % of reading 0.79 % of reading 0.82 % of reading 0.79 % of reading 0.76 % of reading 0.8 % of reading 0.79 % of reading 0.87 % of reading 0.91 % of reading 0.97 % of reading 1.5 % of reading 1.6 % of reading 1.7 % of reading 1.8 % of reading 1.7 % of reading 1.8 % of reading 1.7 % of reading 1.8 % of reading	Keysight PNA-X Network Analyzer, 2.4, 3.5 mm Calibration Kits, Reference Power Sensors



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Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
RF Power Sensors Cal Factors <sup>1</sup>	41 GHz (42 to 44) GHz (45 to 47) GHz (48 to 50) GHz	2.4 % of reading 2.5 % of reading 2.6 % of reading 2.5 % of reading	Keysight PNA-X Network Analyzer, 2.4, 3.5 mm Calibration Kits, Reference Power Sensors
RF Absolute Power - Source	$0.02 \text{ V} \leq V < 7 \text{ V}$ $f < 10 \text{ MHz}$ $10 \text{ MHz} \leq f \leq 50 \text{ MHz}$ $50 \text{ MHz} \leq f \leq 80 \text{ MHz}$ $V \leq 10 \text{ mV}$ $20 \text{ Hz} \leq f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.082 dB 0.16 dB 0.4 dB  0.017 mV 0.021 mV 0.050 mV 0.38 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power - Source	$10 \text{ mV} < V \leq 100 \text{ mV}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV  0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power - Source	$1 \text{ V} < V \leq 3.5 \text{ V}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Electromagnetic - RF/Microwave

Tempe, AZ

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty (±)]	Reference Standard or Equipment
RF Absolute Power - Source	$7\text{dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
RF Absolute Power - Source	$-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz	 0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source



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**Electromagnetic - RF/Microwave**

Tempe, AZ

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty (±)]	Reference Standard or Equipment
Thermal Noise – Source ENR <sup>1</sup>	14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.13 dB 0.14 dB 0.14 dB 0.16 dB 0.17 dB 0.14 dB 0.13 dB 0.15 dB 0.15 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074

**Electrical – RF/Microwave**

Tempe, AZ

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Tempe, AZ

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	20	30	40	50	60	70	80	90	100	110	
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19	
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16	
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14	
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25	

Electrical – RF/Microwave

Tempe, AZ

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

Electrical – RF/Microwave

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, V8486A, N8481B, N8482B, N9030A, E9300A, E9304A, N8485A, Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, V8486A, N8481B, N8482B, N9030A, E9300A, E9304A, N8485A, Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.09	0.087	0.087	0.087	0.095	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	-	0.09	0.087	0.087	0.087	0.095	0.1	0.1	0.1	0.12

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E9300A, E9304A, N8481A, N8482A, N8485A, N8487A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 2 GHz	2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.073	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.060	0.06	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E9300A, E9304A, N8481A, N8482A, N8485A, N8487A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 2 GHz	2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-20 dBm ≤ P < -10 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 10 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
10 dBm ≤ P < 15 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	0.096	0.081	0.081	0.081	0.083	0.091	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	0.09	0.087	0.087	0.087	0.095	0.1	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.087	0.087	0.087	0.095	0.095	0.1	0.1	0.1	0.12

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E9300A, E9304A, N8481A, N8482A, N8485A, N8487A, N8488A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequency Ranges (uncertainties in dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment	E9300A, E9304A, N8481A, N8482A, N8485A, N8487A, N8488A Power Sensors							
Range	Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequency Ranges (uncertainties in dB)							
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
5 Hz to 9 kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4
(1 to 100) kHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 5	0.003 7	0.003 9	0.004 2	0.004 6	0.005
(0.1 to 20) MHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 7	0.004 2	0.004 8	0.005 6	0.006 6	0.007 7
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
5 Hz to 9 kHz	1.9	1	0.77	0.65	0.58	0.53	0.5	0.48	0.47	0.47
(1 to 100) kHz	1.8	1	0.77	0.62	0.49	0.42	0.37	0.34	0.32	0.31
(0.1 to 20) MHz	1.8	1.04	0.78	0.64	0.52	0.47	0.45	0.45	0.46	0.49
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Tempe, AZ

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
5 Hz to 9 kHz	0.058	0.058	0.063	0.067	0.074	0.088	0.104	0.126	0.175	
(9 to 100) kHz	0.028	0.029	0.031	0.034	0.038	0.049	0.082	0.123	0.159	
(0.1 to 130) MHz	0.028	0.029	0.031	0.034	0.038	0.047	0.069	0.09	0.128	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78	

**Electrical – RF/Microwave**

Tempe, AZ

<b>Parameter/ Equipment</b>		S21 - Transmission Magnitude <sup>1,2</sup>							
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	>-6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(67 to 120) GHz	-	-	0.68	0.68	0.68	-	-	-	-

**Electrical – RF/Microwave**

Tempe, AZ

<b>Parameter/ Equipment</b>		S21 - Transmission Phase <sup>1</sup>							
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.38	0.38	0.42	0.45	0.49	0.58	0.69	0.83	1.17
(9 to 100) kHz	0.19	0.19	0.21	0.22	0.25	0.32	0.54	0.82	1.06
(0.1 to 130) MHz	0.19	0.19	0.2	0.22	0.25	0.31	0.46	0.61	0.85
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5



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Time and Frequency

Tempe, AZ

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ps 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 0.64 ns/s 0.64 ns/s 0.74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module
Frequency - Source	10 MHz	6.5 x 10 <sup>-11</sup> Hz	Datum 8040 Rubidium Standard
Frequency - Measure	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	HP 53132A Counter
Frequency - Measure	50 MHz to 26.5 GHz	30 pHz/Hz + 3.75 Hz	HP 53152A Counter

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(AC-1498.06)**

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**Electrical – DC/Low Frequency**

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage - Source	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current - Source	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current – Source	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier



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Electrical – DC/Low Frequency

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current - Source	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Measure	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current - Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
DC Current - Measure <sup>1</sup>	(15 to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
DC Current - Measure <sup>1</sup>	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points	1.9 MΩ 10 MΩ 19 MΩ 100 MΩ	42 Ω 0.40 kΩ 1.5 kΩ 12 kΩ	Fluke 5720A Multiproduct Calibrator
Resistance - Source Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Measure	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
AC Voltage - Source	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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV 250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.4 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V}$ + 8.7 $\mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V}/\text{V}$ + 210 $\mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V}/\text{V}$ + 600 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	251 $\mu\text{V}/\text{V}$ + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$	
	40 Hz to 20 kHz	46 $\mu\text{V}/\text{V}$ + 9 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$	
	(50 to 100) kHz	103 $\mu\text{V}/\text{V}$ + 204 $\mu\text{V}$	
	(100 to 300) kHz	287 $\mu\text{V}/\text{V}$ + 611 $\mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(2.2 to 22) V		
	(10 to 20) Hz	251 $\mu\text{V}/\text{V}$ + 390 $\mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V}/\text{V}$ + 156 $\mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V}/\text{V}$ + 48 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V}/\text{V}$ + 107 $\mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V}/\text{V}$ + 42 $\mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V}/\text{V}$ + 97 $\mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 4.2 mV		
(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 1.6 mV		
40 Hz to 20 kHz	54 $\mu\text{V}/\text{V}$ + 0.68 mV		
(20 to 50) kHz	83 $\mu\text{V}/\text{V}$ + 1.1 mV		
(50 to 100) kHz	156 $\mu\text{V}/\text{V}$ + 2.6 mV		
(100 to 300) kHz	941 $\mu\text{V}/\text{V}$ + 16 mV		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
(220 to 1 100) V			
40 Hz to 20 kHz	313 $\mu\text{V}/\text{V}$ + 17 mV		
(20 to 50) kHz	73 $\mu\text{V}/\text{V}$ + 3.7 mV		



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Electrical – DC/Low Frequency

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(220 to 1 100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	80 $\mu$ V/V + 18 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 12 mV 634 $\mu$ V/V + 5.5 mV 2.4 mV/V + 28 mV	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage - Source Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz 1 V 1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz 3V 100 kHz (2, 4, 8) MHz 10 MHz	890 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V 4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV 26 $\mu$ V 32 $\mu$ V 59 $\mu$ V 170 $\mu$ V 410 $\mu$ V 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV 420 $\mu$ V 21 mV 75 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

West Valley City, UT

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source Fixed Values, Fixed Frequencies	10 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	0.63 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		
AC Voltage – Source	(22 to 220) V		Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	40 Hz to 20 kHz	50 $\mu$ V/V + 80 $\mu$ V	
	(20 to 50) kHz	80 $\mu$ V/V + 30 $\mu$ V	
	(50 to 100) kHz	0.2 mV/V + 3 $\mu$ V	
	(100 to 300) kHz	0.9 mV/V – 0.2 mV	
	(300 to 500) kHz	4.6 mV/V + 40 $\mu$ V	
	500 kHz to 1 MHz	8.3 mV/V + 80 $\mu$ V	
	220 V to 1.1 kV		
	15 Hz to 50 Hz	0.3 mV/V + 20 $\mu$ V	
	50 Hz to 1 kHz	70 $\mu$ V/V + 90 $\mu$ V	
	750 V to 1.1 kV		
	40 Hz to 1 kHz	80 $\mu$ V/V + 16 mV	
	(1 to 20) kHz	0.2 mV/V – 0.8 mV	
	(20 to 30) kHz	0.6 mV/V + 10 $\mu$ V	
	(30 to 50) kHz	0.6 mV/V – 5.6 mV	
(50 to 100) kHz	2.4 mV/V – 20 mV		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Voltage Flatness - Source	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)	
	30 Hz to 120 kHz	1.4 mV/V		
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz	4.6 mV/V		
	(2 to 10) MHz	6.2 mV/V		
	(10 to 20) MHz	8 mV/V		
	(20 to 30) MHz	24 mV/V		
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz	2.2 mV/V		
	(2 to 10) MHz	3.7 mV/V		
	(10 to 20) MHz	5.5 mV/V		
	(20 to 30) MHz	14 mV/V		
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A Multimeter	
	AC Voltage - Measure	Up to 10 mV (1 to 40) Hz	0.3 mV/V + 3.1 $\mu$ V	Keysight 3458A Multimeter
		40 Hz to 1 kHz	0.2 mV/V + 1.2 $\mu$ V	
		(1 to 20) kHz	0.3 mV/V + 1.7 $\mu$ V	
(20 to 50) kHz		1 mV/V + 1.6 $\mu$ V		
(50 to 100) kHz		5 mV/V + 1.3 $\mu$ V		
(100 to 300) kHz		40 mV/V + 2.1 $\mu$ V		
300 kHz to 1 MHz	12 mV/V + 6.6 $\mu$ V			
(1 to 4) MHz	70 mV/V + 7.5 $\mu$ V			
(4 to 8) MHz	20 mV/V + 8.2 $\mu$ V			



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage - Measure	1 mV to 8 V 20 Hz to 20 MHz	4.6 % of reading	Keysight DSO 9104A Oscilloscope
AC Current Source	(0 to 220) $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz 220 $\mu$ A 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	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA 233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current Source	(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	233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A 233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source	(0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Current - Source Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current - Measure	(5 to 100) $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz (1 to 10) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.46 % of reading + 0.039 $\mu$ A 0.17 % of reading + 0.04 $\mu$ A 0.065 % of reading + 0.04 $\mu$ A 0.67 % of reading + 0.04 $\mu$ A 0.46 % of reading + 0.25 $\mu$ A 0.17 % of reading + 0.26 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.033 % of reading + 0.27 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.46 % of reading + 0.48 $\mu$ A 0.63 % of reading + 1.7 $\mu$ A 0.46 % of reading + 2.5 $\mu$ A 0.17 % of reading + 2.5 $\mu$ A 0.067 % of reading + 2.7 $\mu$ A 0.033 % of reading + 2.7 $\mu$ A 0.067 % of reading + 2.6 $\mu$ A 0.46 % of reading + 4.7 $\mu$ A 0.63 % of reading + 17 $\mu$ A	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	(10 to 100) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
	(10 to 20) Hz	0.46 % of reading + 0.29 mA	
	(20 to 45) Hz	0.18 % of reading + 0.32 mA	
	(45 to 100) Hz	0.085 % of reading + 0.34 mA	
	100 Hz to 5 kHz	0.11 % of reading + 0.34 mA	
	(5 to 20) kHz	0.34 % of reading + 0.3 mA	
(20 to 50) kHz	1.1 % of reading + 0.49 mA		

Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(> 0 to 99) % Depth (0.1 to 10) MHz (0.01 to 3) GHz (3 to 26.5) GHz (26.5 to 31.15) GHz (31.5 to 50) GHz	0.8 % Depth 0.5 % Depth 1.5 % Depth 1.9 % Depth 6.1 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
Frequency Modulation – Measure Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	$\leq$ 400 kHz <sup>Peak</sup> (0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude <sup>2</sup> (EVM)	Mod Frequency Span: $f \leq$ 100 kHz $100 \text{ kHz} \leq f \leq$ 1 MHz $f >$ 1 MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180 ° rms Mod Frequency Span: $f \leq$ 100 kHz $100 \text{ kHz} \leq f \leq$ 1 MHz $f >$ 1 MHz	0.17 ° 0.34 ° 0.57 °	

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $f \leq 100$ kHz 0.999 9 $\leq \rho \leq 1$ 0.997 5 $\leq \rho < 0.999 9$ 0.993 6 $\leq \rho < 0.997 5$ 0.99 $\leq \rho < 0.993 6$ 0.978 $\leq \rho < 0.99$ 0.96 $\leq \rho < 0.978$ 100 kHz $\leq f \leq 1$ MHz 0.999 9 $\leq \rho \leq 1$ 0.997 5 $\leq \rho < 0.999 9$ 0.993 6 $\leq \rho < 0.997 5$ 0.99 $\leq \rho < 0.993 6$ 0.978 $\leq \rho < 0.99$ 0.96 $\leq \rho < 0.978$ $f > 1$ MHz 0.999 9 $\leq \rho \leq 1$ 0.997 5 $\leq \rho < 0.999 9$ 0.993 6 $\leq \rho < 0.997 5$ 0.99 $\leq \rho < 0.993 6$ 0.978 $\leq \rho < 0.99$ 0.96 $\leq \rho < 0.978$	8.6 E-5 $\rho$ 0.000 43 $\rho$ 0.000 68 $\rho$ 0.000 84 $\rho$ 0.001 2 $\rho$ 0.001 6 $\rho$ 9.6 E-5 $\rho$ 0.000 48 $\rho$ 0.000 76 $\rho$ 0.000 94 $\rho$ 0.001 4 $\rho$ 0.001 8 $\rho$ 1.6 E-4 $\rho$ 0.000 82 $\rho$ 0.001 3 $\rho$ 0.001 6 $\rho$ 0.002 4 $\rho$ 0.003 $\rho$	HP 89441A Vector Signal Analyzer
Phase Modulation – Measure	(0.15 to 10) MHz Rate: (0.02 to 10) kHz < 40 Radians Deviation (0.01 to 26.5) GHz Rate: (0.2 to 20) kHz < 40 Radians Deviation	4.1 % Deviation 3.1 % Deviation	HP 8902A Measuring Receiver
Phase Modulation – Measure	100 kHz to 6.6 GHz Deviations: (0.3 to 7) rad Deviations: > 7 rad	3.1 % Deviation 1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure	(6.6 to 13.2) GHz Deviations: (0.6 to 2) rad (13.2 to 26.5) GHz Deviations: > 2 rad Deviations: (1.2 to 4) rad (26.5 to 31.5) GHz Deviations: > 4 rad Deviations: (1.3 to 4) rad (31.5 to 50) GHz Deviations: > 4 rad Deviations (2.4 to 8) rad Deviations: > 8 rad	3.1 % Deviation  1 % Deviation 3.1 % Deviation  1 % Deviation 3.1 % Deviation  1 % Deviation 3.1 % Deviation 1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure  2.5 MHz to 26.5 GHz	(+2 to +10) dBm	0.08 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-12 to +2) dBm	0.07 dB	
	(-22 to -12) dBm	0.08 dB	
	(-31 to -22) dBm	0.09 dB	
	(-40 to -31) dBm	0.1 dB	
	(-50 to -40) dBm	0.12 dB	
	(-61 to -50) dBm	0.15 dB	
	(-71 to -61) dBm	0.16 dB	
	(-80 to -71) dBm	0.17 dB	
	(-90 to -80) dBm	0.19 dB	
	(-100 to -90) dBm	0.22 dB	
	(-110 to -100) dBm	0.23 dB	
	(-120 to -110) dBm	0.27 dB	
(-127 to -120) dBm	0.3 dB		
RF Absolute Power - Source	0.02 V ≤ V < 7 V f < 10 MHz	0.082 dB	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	10 MHz ≤ f ≤ 50 MHz	0.16 dB	
	50 MHz ≤ f ≤ 80 MHz	0.4 dB	
	V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz	0.017 mV	
	20 kHz < f ≤ 50 kHz	0.021 mV	
	50 kHz < f ≤ 100 kHz	0.05 mV	
	100 kHz < f ≤ 300 kHz	0.38 mV	
	10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz	0.029 mV	
	40 Hz ≤ f ≤ 1 kHz	0.028 mV	
	1 kHz < f ≤ 20 kHz	0.032 mV	
	20 kHz < f ≤ 50 kHz	0.045 mV	
	50 kHz < f ≤ 100 kHz	0.08 mV	
	100 kHz < f ≤ 300 kHz	0.3 mV	
	100 mV < V ≤ 1 V 20 Hz ≤ f ≤ 1 kHz	0.7 mV	
	1 kHz < f ≤ 20 kHz	0.72 mV	
	20 kHz < f ≤ 50 kHz	0.79 mV	
	50 kHz < f ≤ 100 kHz	1.3 mV	
	100 kHz < f ≤ 300 kHz	3.7 mV	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source	$1\text{ V} < V \leq 3.5\text{ V}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$	2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power - Source	$7\text{ dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	0.49 dB 0.58 dB 0.69 dB 0.79 dB 0.49 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	$(-167\text{ to }-89)\text{ dBc/Hz}$ Offsets: $(10\text{ to }100)\text{ Hz}$ $(0.1\text{ to }100)\text{ kHz}$ $(0.1\text{ to }1)\text{ MHz}$ $(1\text{ to }10)\text{ MHz}$	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	$\geq -150\text{ dBc/Hz}$ Offsets $1\text{ Hz to }100\text{ kHz}$	2.1 dB	Keysight E5500 Phase Noise System

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	1	2	3	4	5	6	7	8	9	10	11	
$20 \text{ Hz} \leq f < 300 \text{ kHz}$	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.002 8	0.003 3
$300 \text{ kHz} \leq f < 80 \text{ MHz}$	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 7	0.003 8
$80 \text{ MHz} \leq f < 1 \text{ GHz}$	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 4	0.005 9	0.005 3
$1 \text{ GHz} \leq f < 4 \text{ GHz}$	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074	0.074
$4 \text{ GHz} \leq f < 10 \text{ GHz}$	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11	0.11
$10 \text{ GHz} \leq f < 14 \text{ GHz}$	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14	0.14
$14 \text{ GHz} \leq f \leq 18 \text{ GHz}$	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.19	0.2

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
$1 \text{ kHz} \leq f < 100 \text{ MHz}$	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
$100 \text{ MHz} \leq f < 300 \text{ MHz}$	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
$300 \text{ MHz} \leq f < 500 \text{ MHz}$	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
$500 \text{ MHz} \leq f < 1 \text{ GHz}$	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
$1 \text{ GHz} \leq f < 4 \text{ GHz}$	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
$4 \text{ GHz} \leq f < 8 \text{ GHz}$	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
$8 \text{ GHz} \leq f < 10 \text{ GHz}$	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

West Valley City, UT

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.11	0.10	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.10	0.10	0.12

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, N8481A, 8482A, 8485A, 8487A, E9300A, E9304A, N8488A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.10	0.10	0.10	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, N8481A, 8482A, 8485A, 8487A, E9300A, E9304A, N8488A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	S11 - Reflection Magnitude <sup>2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
5 Hz to 9 kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4
(1 to 100) kHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 5	0.003 7	0.003 9	0.004 2	0.004 6	0.005
(0.1 to 20) MHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 7	0.004 2	0.004 8	0.005 6	0.006 6	0.007 7

Electrical – RF/Microwave

West Valley City, UT

Parameter/ Equipment		S11 - Reflection Magnitude <sup>2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

Electrical – RF/Microwave

West Valley City, UT

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
5 Hz to 9 kHz	1.87	1.03	0.77	0.65	0.58	0.53	0.5	0.48	0.47	0.47
(1 to 100) kHz	1.81	1.03	0.77	0.62	0.49	0.42	0.37	0.34	0.32	0.31
(0.1 to 20) MHz	1.81	1.04	0.78	0.64	0.52	0.47	0.45	0.45	0.46	0.49
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

West Valley City, UT

Parameter/ Equipment	S21 - Transmission Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
5 Hz to 9 kHz	0.058	0.058	0.063	0.067	0.074	0.088	0.104	0.126	0.175	
(9 to 100) kHz	0.028	0.029	0.031	0.034	0.038	0.049	0.082	0.123	0.159	
(0.1 to 130) MHz	0.028	0.029	0.031	0.034	0.038	0.047	0.069	0.09	0.128	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	

**Electrical – RF/Microwave**

West Valley City, UT

<b>Parameter/ Equipment</b>	S21 - Transmission Magnitude <sup>1,2</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

West Valley City, UT

<b>Parameter/ Equipment</b>	S21 - Transmission Phase <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.38	0.38	0.42	0.45	0.49	0.58	0.69	0.83	1.17
(9 to 100) kHz	0.19	0.19	0.21	0.22	0.25	0.32	0.54	0.82	1.06
(0.1 to 130) MHz	0.19	0.19	0.2	0.22	0.25	0.31	0.46	0.61	0.85
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5



ANSI National Accreditation Board

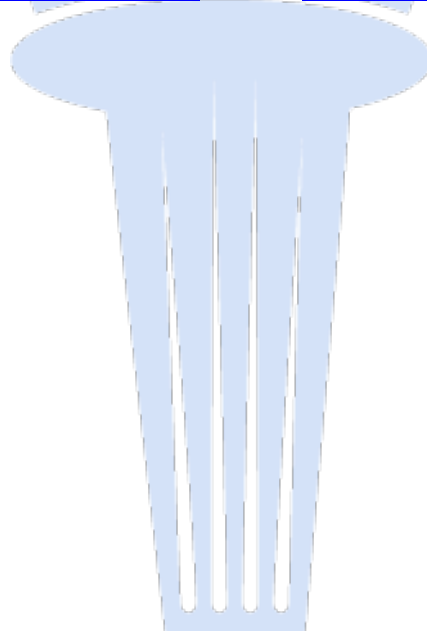
**Time and Frequency**

West Valley City, UT

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Frequency - Source <sup>1</sup>	10 MHz	65 pHz/Hz	Symmetricom 8040 Frequency Standard
Frequency - Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	HP 53132A Counter + Frequency Reference Standard
	50 MHz to 26.5 GHz	30 pHz/Hz + 3.8 Hz	HP 53151A Counter + Frequency Reference Standard
Rise Time Measure <sup>1</sup>	10 Hz to 1 GHz 300 ps to 1 $\mu$ s	8.1 ps	DSO9104A Oscilloscope
Pulse - Source RMS Jitter - Period, Delay and Width <sup>1</sup>	33 MHz to 3 GHz	10 ps	HP 81134A Pulse Generator
Pulse - Source Width	150 ps to 10 ns (10 to 100) ns 100 $\mu$ s to 10 ms (10 to 100) ms 100 ms to 0.99) ms	0.13 ns (0.013* Width) + 1.2 ns (0.013*Width) +0.14 $\mu$ s (0.012 * Width) + 2 ns (0.012*Width) +0.19 $\mu$ s	HP 8161A Pulse Generator

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**Services performed at satellite laboratory  
(AC-1498.08)**

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**Electrical – DC/Low Frequency**

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(15 to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup> Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$ 42 $\Omega$	Fluke 5720A Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	10 MΩ 19 MΩ 100 MΩ	0.4 kΩ 1.5 kΩ 12 kΩ	Fluke 5720A Multiproduct Calibrator
Resistance – Source <sup>1</sup> Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Source <sup>1</sup>	(0 to 11) Ω (11 to 110) Ω 110 Ω to 1.1 kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 110) kΩ 110 kΩ to 1.1 MΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ (110 to 330) MΩ (330 to 1 100) MΩ	33 μΩ/Ω + 8.3 mΩ 25 μΩ/Ω + 12.5 mΩ 23 μΩ/Ω + 17 mΩ 23 μΩ/Ω + 170 mΩ 23 μΩ/Ω + 84 mΩ 23 μΩ/Ω + 0.84 Ω 27 μΩ/Ω + 8 Ω 50 μΩ/Ω + 125 Ω 0.11 mΩ/Ω + 0.2 kΩ 0.21 mΩ/Ω + 2 kΩ 0.41 mΩ/Ω + 2.8 kΩ 2.5 mΩ/Ω + 83 kΩ 13 mΩ/Ω + 0.4 MΩ	Fluke 5520A Multiproduct Calibrator
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter



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AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
(10 to 20) Hz	251 $\mu\text{V/V} + 39 \mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V/V} + 10 \mu\text{V}$		
(50 to 100) kHz	103 $\mu\text{V/V} + 204 \mu\text{V}$		
(100 to 300) kHz	287 $\mu\text{V/V} + 611 \mu\text{V}$		
(300 to 500) kHz	1.0 mV/V + 2.1 mV		
500 kHz to 1 MHz	1.6 mV/V + 3.3 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	251 $\mu$ V/V + 390 $\mu$ V	
	(20 to 40) Hz	93 $\mu$ V/V + 156 $\mu$ V	
	40 Hz to 20 kHz	47 $\mu$ V/V + 48 $\mu$ V	
	(20 to 50) kHz	78 $\mu$ V/V + 107 $\mu$ V	
	(50 to 100) kHz	113 $\mu$ V/V + 42 $\mu$ V	
	(100 to 300) kHz	432 $\mu$ V/V + 97 $\mu$ V	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu$ V/V + 4.17 mV	
	(20 to 40) Hz	93.8 $\mu$ V/V + 1.56 mV	
	40 Hz to 20 kHz	53.9 $\mu$ V/V + 0.68 mV	
	(20 to 50) kHz	83.3 $\mu$ V/V + 1.05 mV	
	(50 to 100) kHz	156 $\mu$ V/V + 2.62 mV	
(100 to 300) kHz	941 $\mu$ V/V + 16 mV		
(300 to 500) kHz	4.58 mV/V + 41.7 mV		
500 kHz to 1 MHz	8.33 mV/V + 83.4 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	40 Hz to 1 kHz	79.6 $\mu$ V/V + 18.3 mV	
	(1 to 20) kHz	173 $\mu$ V/V + 5.3 mV	
	(20 to 30) kHz	625 $\mu$ V/V + 11.5 mV	
	(220 to 750) V		
(30 to 50) kHz	634 $\mu$ V/V + 5.45 mV		
(50 to 100) kHz	2.42 mV/V + 28 mV		
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 40) Hz	94 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 20 kHz	83 $\mu$ V/V + 4.1 $\mu$ V	
	(20 to 50) kHz	210 $\mu$ V/V + 4.1 $\mu$ V	
	(50 to 100) kHz	520 $\mu$ V/V + 4.1 $\mu$ V	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu$ V	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu$ V	
500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu$ V		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V/V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V/V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V/V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V/V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
220 mV to 2.2 V			
(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	43 $\mu\text{V/V} + 8.8 \mu\text{V}$		
(20 to 50) kHz	70 $\mu\text{V/V} + 10 \mu\text{V}$		
(50 to 100) kHz	89 $\mu\text{V/V} + 30 \mu\text{V}$		
(100 to 300) kHz	350 $\mu\text{V/V} + 83 \mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.01 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	890 nV	
	20 kHz	1.2 $\mu\text{V}$	
	100 kHz	4.5 $\mu\text{V}$	
	300 kHz	33 $\mu\text{V}$	
	1 MHz	21 $\mu\text{V}$	
4 MHz	140 $\mu\text{V}$		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.1 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter	
	1 kHz	4.6 $\mu$ V		
	20 kHz	6.9 $\mu$ V		
		100 kHz		36 $\mu$ V
		300 kHz		52 $\mu$ V
		1 MHz		170 $\mu$ V
		4 MHz		670 $\mu$ V
		8 MHz		690 $\mu$ V
		10 MHz		2.3 mV
		1 V		
		1 kHz		26 $\mu$ V
		20 kHz		32 $\mu$ V
		50 kHz		59 $\mu$ V
		100 kHz		170 $\mu$ V
		300 kHz		410 $\mu$ V
		500 kHz		0.97 mV
		1 MHz		1.7 mV
		4 MHz		6.7 mV
		8 MHz		6.9 mV
		10 MHz		25 mV
		3V		
		100 kHz		420 $\mu$ V
		(2, 4, 8) MHz		21 mV
		10 MHz		75 mV
		10 V		
		10 Hz		550 $\mu$ V
		20 Hz		380 $\mu$ V
		40 Hz		310 $\mu$ V
		200 Hz		504 $\mu$ V
		500 Hz		495 $\mu$ V
		1 kHz		260 $\mu$ V
		10 kHz		270 $\mu$ V
		20 kHz		320 $\mu$ V
	50 kHz	0.53 mV		
	100 kHz	1.1 mV		
	300 kHz	2.6 mV		
	500 kHz	0.63 mV		
	1 MHz	12 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	100 V 1 kHz 20 kHz 50 kHz 100 kHz 700 V 1 kHz	4 mV 7.9 mV 7.5 mV 16 mV 60 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Voltage Flatness – Source <sup>1</sup>	300 μV to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 μV to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 μV to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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AC Voltage – Measure <sup>1</sup>	(10 to 100) V		Keysight 3458A Multimeter
	(1 to 40) Hz	0.2 mV/V + 4.1 mV	
	40 Hz to 20 kHz	0.2 mV/V + 2.6 mV	
	(20 to 50) kHz	0.35 mV/V + 2.4 mV	
	(50 to 100) kHz	1.2 mV/V + 2.1 mV	
	(100 to 300) kHz	4 mV/V + 11 mV	
	300 kHz to 1 MHz	15 mV/V + 50 mV	
	(100 to 750) V		
	(1 to 40) Hz	0.4 mV/V + 31 mV	
	40 Hz to 1 kHz	0.4 mV/V + 16 mV	
(1 to 20) kHz	0.6 mV/V + 16 mV	URE3 Voltmeter	
(20 to 50) kHz	1.2 mV/V + 16 mV		
(50 to 100) kHz	3 mV/V + 15 mV		
AC Voltage – Measure <sup>1</sup>	20 Hz to 20 MHz		4.8 % of reading
AC Current – Source <sup>1</sup>	0 to 220 $\mu$ A		
	10 to 20 Hz	230 $\mu$ A/A + 17 nA	
	20 to 40 Hz	150 $\mu$ A/A + 10 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 8.4 nA	
	1 to 5 kHz	266 $\mu$ A/A + 12.5 nA	
	5 to 10 kHz	915 $\mu$ A/A + 66 nA	
	220 $\mu$ A to 2.2 mA		
	10 to 20 Hz	233 $\mu$ A/A + 42 nA	
	20 to 40 Hz	150 $\mu$ A/A + 34 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 34 nA	
	1 to 5 kHz	183 $\mu$ A/A + 109 nA	
	5 to 10 kHz	915 $\mu$ A/A + 655 nA	
	(2.2 to 22) mA		
	10 to 20 Hz	233 $\mu$ A/A + 422 nA	
	20 to 40 Hz	149 $\mu$ A/A + 342 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 343 nA	
	1 to 5 kHz	183 $\mu$ A/A + 588 nA	
	5 to 10 kHz	915 $\mu$ A/A + 5 $\mu$ A	
	(22 to 220) mA		
	10 to 20 Hz	233 $\mu$ A/A + 4.2 $\mu$ A	
20 to 40 Hz	149 $\mu$ A/A + 3.4 $\mu$ A		
40 Hz to 1 kHz	108 $\mu$ A/A + 2.6 $\mu$ A		
1 to 5 kHz	183 $\mu$ A/A + 3.4 $\mu$ A		
5 to 10 kHz	915 $\mu$ A/A + 10 $\mu$ A		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz (2.2 to 11) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current Source <sup>1</sup>	(0 to 0.33) mA 10 to 30 kHz (0.33 to 3.3) mA 10 to 30 kHz (3.3 to 33) mA 10 to 30 kHz (33 to 330) mA 10 to 30 kHz (2.2 to 20.5) A 45 to 100 Hz 100 Hz to 1 kHz 1 to 5 kHz	10 mA/A + 330 nA 6.6 mA/A + 550 nA 2.7 mA/A + 2.7 $\mu$ A 2.7 mA/A + 160 $\mu$ A 830 mA/A + 4.2 mA 1.1 mA/A + 3.9 mA 21 mA/A + 1 mA	Fluke 552xA Multiproduct Calibrator
AC Current – Source <sup>1</sup> Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 $\mu$ A to 1mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.46 % of reading + 0.039 $\mu$ A 0.17 % of reading + 0.040 $\mu$ A 0.065 % of reading + 0.040 $\mu$ A 0.67 % of reading + 0.040 $\mu$ A 0.46 % of reading + 0.25 $\mu$ A 0.17 % of reading + 0.26 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.033 % of reading + 0.27 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.46 % of reading + 0.48 $\mu$ A 0.63 % of reading + 1.7 $\mu$ A	Keysight 3458A Multimeter

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(1 to 10) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz (10 to 100) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz 100 mA to 1 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz	0.46 % of reading + 2.5 $\mu$ A 0.17 % of reading + 2.5 $\mu$ A 0.067 % of reading + 2.7 $\mu$ A 0.033 % of reading + 2.7 $\mu$ A 0.067 % of reading + 2.6 $\mu$ A 0.46 % of reading + 4.7 $\mu$ A 0.63 % of reading + 17 $\mu$ A 0.46 % of reading + 25 $\mu$ A 0.17 % of reading + 26 $\mu$ A 0.067 % of reading + 26 $\mu$ A 0.033 % of reading + 27 $\mu$ A 0.067 % of reading + 26 $\mu$ A 0.46 % of reading + 47 $\mu$ A 0.63 % of reading + 0.17 mA 0.46 % of reading + 0.29 mA 0.18 % of reading + 0.32 mA 0.085 % of reading + 0.34 mA 0.11 % of reading + 0.34 mA 0.34 % of reading + 0.30 mA 1.1 % of reading + 0.49 mA	Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(1 to 3) A (3 to 10) Hz (10 to 40) Hz 40 Hz to 300 kHz	1.3 % of reading + 2.1 mA 0.39 % of reading + 2.2 mA 0.17 % of reading + 2.1 mA	Agilent 34401A Multimeter
Capacitance – Source Fixed Points <sup>1</sup>	1 pF 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 10 pF 1 kHz to 5 MHz (5 to 10) MHz (10 to 13) MHz	0.24 fF 0.19 fF 0.31 fF 0.49 fF 0.68 fF 0.9 fF 2.5 fF 3.8 fF 1.5 fF 2 fF 2.2 fF	Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair



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Electrical – DC/Low Frequency

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source Fixed Points <sup>1</sup>	100 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
	(4 to 5) MHz	20 fF	
	(5 to 10) MHz	37 fF	
	(10 to 13) MHz	53 fF	
	1 000 pF		
	1 kHz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
120 Hz to 100 kHz	1.5 pF		
100 nF			
120 Hz to 100 kHz	15 pF		
1 μF			
120 Hz to 1 kHz	0.52 nF		
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
10 μF			
20 Hz to 1 kHz	1.6 nF		
(1 to 20) kHz	2.2 nF		
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	100 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 58	
	(10 to 13) MHz	0.000 86	
	10 nF		
	120 Hz to 1 kHz	0.000 024	
(1 to 100) kHz	0.000 021		
100 nF			
120 Hz to 1 kHz	0.000 04		
(1 to 100) kHz	0.000 021		
1 μF			
120 Hz to 1 kHz	0.000 041		
(1 to 10) kHz	0.000 035		
(10 to 100) kHz	0.000 11		
10 μF			
(20 to 120) Hz	0.000 04		
120 Hz to 10 kHz	0.000 03		
(10 to 100) kHz	0.000 76		
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B (600 to 800) °C (800 to 1 000) °C (1 000 to 1 550) °C (1 550 to 1 820) °C	0.47 °C 0.36 °C 0.32 °C 0.35 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type C		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1800) °C	0.53 °C	
	(1 800 to 2316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		
Type N			
(-200 to -100) °C	0.42 °C		
(-100 to -25) °C	0.24 °C		
(-25 to 120) °C	0.21 °C		
(120 to 410) °C	0.2 °C		
(410 to 1 300) °C	0.29 °C		
Type R			
(0 to 250) °C	0.6 °C		
(250 to 400) °C	0.37 °C		
(400 to 1 000) °C	0.35 °C		
(1 000 to 1 767) °C	0.42 °C		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type S (0 to 250) °C	0.5 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
	(1 400 to 1 767) °C	0.49 °C	
	Type T (-250 to -150) °C	0.66 °C	
	(-150 to 0) °C	0.26 °C	
	(0 to 120) °C	0.18 °C	
	(120 to 400) °C	0.16 °C	
	Type U (-200 to 0) °C	0.59 °C	
	(0 to 600) °C	0.29 °C	
Pulse Amplitude – Measure	25 mV ≤ V < 100 mV	3.2 mV	86100C/D Oscilloscope with 86117A Sampling Module
	100 mV ≤ V < 200 mV	4 mV	
	200 mV ≤ V < 400 mV	5.4 mV	
	400 mV ≤ V ≤ 750 mV	7.8 mV	
	750 mV < V ≤ 10 V	1.5 % of reading	
	10 V < V ≤ 70 V	1.5 % of reading	

Electrical – RF/Microwave

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	(> 0 to 99) % Depth		Agilent 8902A Measuring Receiver
	(0.15 to 10) MHz	2.1 % Depth	
	(0.01 to 1.3) GHz	1.1 % Depth	
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(1.3 to 26.5) GHz	1.6 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
	(> 0 to 99) % Depth	0.8 % Depth	
	(0.1 to 10) MHz	0.5 % Depth	
	(0.01 to 3) GHz	1.5 % Depth	
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 100) kHz	(3 to 26.5) GHz	1.9 % Depth	HP 8902A Measuring Receiver
	(26.5 to 31.15) GHz	6.1 % Depth	
	(31.5 to 50) GHz		
	≤ 40 kHz Peak (0.25 to 10) MHz	2.2 % Deviation	
	≤ 400 kHz Peak (0.01 to 26.5) GHz	1.2 % Deviation	



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Electrical – RF/Microwave

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	≤ 400 kHz <sub>Peak</sub> (0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude <sup>2</sup> (EVM)	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180° rms Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.17° 0.34° 0.57°	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: f ≤ 100 kHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978 100 kHz ≤ f ≤ 1 MHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	8.6 E-5 ρ 0.000 43 ρ 0.000 68 ρ 0.000 84 ρ 0.001 2 ρ 0.001 6 ρ 9.6 E-5 ρ 0.000 48 ρ 0.000 76 ρ 0.000 94 ρ 0.001 4 ρ 0.001 8 ρ	HP 89441A Vector Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: f > 1 MHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	1.6 E-4 ρ 0.000 82 ρ 0.001 3 ρ 0.001 6 ρ 0.002 4 ρ 0.003 ρ	HP 89441A Vector Signal Analyzer
Phase Modulation – Measure <sup>1</sup>	(0.15 to 10) MHz Rate: (0.02 to 10) kHz < 40 Radians Deviation (0.01 to 26.5) GHz Rate: (0.2 to 20) kHz < 40 Radians Deviation	4.1 % Deviation 3.1 % Deviation	HP 8902A Measuring Receiver
Phase Modulation – Measure <sup>1</sup>	100 kHz to 6.6 GHz Deviations: (0.3 to 7) rad Deviations: > 7 rad (6.6 to 13.2) GHz Deviations: (0.6 to 2) rad (13.2 to 26.5) GHz Deviations: > 2 rad Deviations: (1.2 to 4) rad (26.5 to 31.5) GHz Deviations: > 4 rad Deviations: (1.3 to 4) rad (31.5 to 50) GHz Deviations: > 4 rad Deviations (2.4 to 8) rad Deviations: > 8 rad	3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power – Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz 10 MHz ≤ f ≤ 50 MHz 50 MHz ≤ f ≤ 80 MHz V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.05 mV 0.38 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter





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Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	-70 dBm > P ≥ -95 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -95 dBm > P ≥ -125 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz	0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.06 dB 0.07 dB 0.13 dB 0.14 dB 0.14 dB 0.16 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.17 dB 0.14 dB 0.13 dB 0.15 dB 0.15 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2	
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18	
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19	
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24	
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24	
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37	
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Fort Wayne, IN

<b>Parameter/ Equipment</b>	RF Power Measure <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/ Equipment		RF Power Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment		E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors									
Range		Expanded Uncertainty of Measurement (+/-)									
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.09	0.087	0.087	0.087	0.095	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	-	0.09	0.087	0.087	0.087	0.095	0.1	0.1	0.1	0.12

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/ Equipment		RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment		E444xA Spectrum Analyzer, N9030A Signal Analyzer, E9300A, E9304A, N8481A, N8482A, N8485A, N8487A, N8488A Power Sensors							
Range		Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.10	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)										
	≤ 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	
5 Hz to 9 kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4	
(1 to 100) kHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 5	0.003 7	0.003 9	0.004 2	0.004 6	0.005	
(0.1 to 20) MHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 7	0.004 2	0.004 8	0.005 6	0.006 6	0.007 7	
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7	
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9	
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6	
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1	
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012	
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015	
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)										
	≤ 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	
5 Hz to 9 kHz	1.87	1.03	0.77	0.65	0.58	0.53	0.5	0.48	0.47	0.47	
(1 to 100) kHz	1.81	1.03	0.77	0.62	0.49	0.42	0.37	0.34	0.32	0.31	
(0.1 to 20) MHz	1.81	1.04	0.78	0.64	0.52	0.47	0.45	0.45	0.46	0.49	

Electrical – RF/Microwave

Fort Wayne, IN

Parameter/ Equipment	S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

Electrical – RF/Microwave

Fort Wayne, IN

Parameter/ Equipment	S21 - Transmission Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
5 Hz to 9 kHz	0.058	0.058	0.063	0.067	0.074	0.088	0.104	0.126	0.175	
(9 to 100) kHz	0.028	0.029	0.031	0.034	0.038	0.049	0.082	0.123	0.159	
(0.1 to 130) MHz	0.028	0.029	0.031	0.034	0.038	0.047	0.069	0.09	0.128	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	

**Electrical – RF/Microwave**

Fort Wayne, IN

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

City, ST

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.38	0.38	0.42	0.45	0.49	0.58	0.69	0.83	1.17
(9 to 100) kHz	0.19	0.19	0.21	0.22	0.25	0.32	0.54	0.82	1.06
(0.1 to 130) MHz	0.19	0.19	0.2	0.22	0.25	0.31	0.46	0.61	0.85
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4



ANSI National Accreditation Board

Electrical – RF/Microwave

City, ST

<b>Parameter/ Equipment</b>	S21 - Transmission Phase <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Degrees)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5	

Time and Frequency

Fort Wayne, IN

<b>Parameter/ Equipment</b>	<b>Range</b>	<b>Calibration and Measurement Capability [Expressed as Uncertainty (±)]</b>	<b>Reference Standard or Equipment</b>
Frequency – Source <sup>1</sup>	10 MHz	65 pHz/Hz	Rubidium Frequency Standard
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	Agilent 53132A Counter, Rubidium Frequency Standard
	(12.4 to 26.5) GHz	30 pHz/Hz + 3.75 Hz	Agilent 53151A Counter, Rubidium Frequency Standard
Time Interval – Measure	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Period – Measure	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 0.64 ns/s 0.64 ns/s 0.74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module

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ANSI National Accreditation Board

**Services performed at satellite laboratory  
(AC-1498.10)**

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**Electrical - DC/Low Frequency**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multifunction Calibrator with Fluke 5725A Amplifier
DC Voltage – Source Fixed Values	1 mV 10 mV	15 $\mu$ V 110 nV	Fluke 57x0A Calibrator Fluke 742A Resistors
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multifunction Calibrator disciplined with Keysight 3458A/100 NPLC Option 002
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V/V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12.4 $\mu$ V 1.85 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A – 42 $\mu$ A	Fluke 5720A or 5730A Multifunction Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5725A Amplifier

**Electrical - DC/Low Frequency**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multifunction Calibrator disciplined with Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup>	(0 to 11) $\Omega$ (11 to 110) $\Omega$ (0.11 to 1.1) k $\Omega$ (1.1 to 3.3) k $\Omega$ (3.3 to 11) k $\Omega$ (11 to 110) k $\Omega$ (0.11 to 1.1) M $\Omega$ (1.1 to 3.3) M $\Omega$ (3.3 to 11) M $\Omega$ (11 to 33) M $\Omega$ (33 to 110) M $\Omega$ (110 to 330) M $\Omega$ (330 to 1 100) M $\Omega$	33 $\mu\Omega/\Omega$ + 8.3 m $\Omega$ 25 $\mu\Omega/\Omega$ + 12.5 m $\Omega$ 23 $\mu\Omega/\Omega$ + 17 m $\Omega$ 23 $\mu\Omega/\Omega$ + 170 m $\Omega$ 23 $\mu\Omega/\Omega$ + 84 m $\Omega$ 23 $\mu\Omega/\Omega$ + 0.84 $\Omega$ 27 $\mu\Omega/\Omega$ + 8 $\Omega$ 50 $\mu\Omega/\Omega$ + 125 $\Omega$ 110 $\mu\Omega/\Omega$ + 0.2 k $\Omega$ 210 $\mu\Omega/\Omega$ + 2 k $\Omega$ 410 $\mu\Omega/\Omega$ + 2.8 k $\Omega$ 2.5 m $\Omega/\Omega$ + 83 k $\Omega$ 12.5 m $\Omega/\Omega$ + 0.4 M $\Omega$	Fluke 552X A Multifunction Calibrator



ANSI National Accreditation Board

Electrical - DC/Low Frequency

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	0 Ω	21 μΩ	Fluke 57X0A Multifunction Calibrator disciplined with Keysight 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
	10 MΩ	140 Ω	
	100 MΩ	18 kΩ	
Resistance – Source <sup>1</sup> Fixed Points	0 Ω	0.25 mΩ	Fluke 57X0A Multifunction Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 k Ω	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
	10 MΩ	0.4 kΩ	
19 MΩ	1.5 kΩ		
100 MΩ	12 kΩ		
Resistance – Measure <sup>1</sup>	(0 to 12) Ω	18 μΩ/ Ω + 20 μΩ	Keysight 3458A Multimeter
	(10 to 120) Ω	12 μΩ/Ω + 0.6 mΩ	
	100 Ω to 1.2 kΩ	9.6 μΩ/Ω + 0.6 mΩ	
	(1 to 12) kΩ	9.6 μΩ/Ω + 6 mΩ	
	(10 to 120) kΩ	9.6 μΩ/Ω + 60 mΩ	
	100 k Ω to 1.2 MΩ	15 μΩ/Ω + 2.4 Ω	
	(1 to 12) MΩ	60 μΩ/Ω + 120 Ω	
	(10 to 120) MΩ	0.6 mΩ/Ω + 1.2 kΩ	
100 Ω to 1.2 GΩ	6 mΩ/Ω + 12 kΩ		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 57X0A Multifunction Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	2.2 to 22 mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V}$ + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V}$ + 8.7 $\mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V}/\text{V}$ + 210 $\mu\text{V}$	
(100 to 300) kHz	930 $\mu\text{V}/\text{V}$ + 600 $\mu\text{V}$		
(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$		
220 mV to 2.2 V			
(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V}/\text{V}$ + 16 $\mu\text{V}$		
40 Hz to 20 kHz	46 $\mu\text{V}/\text{V}$ + 9 $\mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V}/\text{V}$ + 10 $\mu\text{V}$		
(50 to 100) kHz	100 $\mu\text{V}/\text{V}$ + 70 $\mu\text{V}$		
(100 to 300) kHz	290 $\mu\text{V}/\text{V}$ + 80 $\mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 200 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 57X0A Multifunction Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V}$ + 390 $\mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V}$ + 160 $\mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V}$ + 48 $\mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V}$ + 100 $\mu\text{V}$	
	(50 to 100) kHz	110 $\mu\text{V/V}$ + 70 $\mu\text{V}$	
	(100 to 300) kHz	430 $\mu\text{V/V}$ + 97 $\mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	40 Hz to 20 kHz	54 $\mu\text{V/V}$ + 65 $\mu\text{V}$	
	(20 to 50) kHz	83 $\mu\text{V/V}$ + 34 $\mu\text{V}$	
	(50 to 100) kHz	155 $\mu\text{V/V}$ + 2.9 $\mu\text{V}$	
	(100 to 300) kHz	940 $\mu\text{V/V}$ + 180 $\mu\text{V}$	
(300 to 500) kHz	4.6 mV/V + 40 $\mu\text{V}$		
500 kHz to 1 MHz	8.3 mV/V + 8.4 $\mu\text{V}$		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 57X0A Multifunction Calibrator with Fluke 5725A Amplifier
	40 Hz to 1 kHz	80 $\mu\text{V/V}$ + 18.3 mV	
	(1 to 20) kHz	173 $\mu\text{V/V}$ + 5.3 mV	
	(20 to 30) kHz	625 $\mu\text{V/V}$ + 11.5 mV	
	(220 to 750) V		
(30 to 50) kHz	634 $\mu\text{V/V}$ + 5.45 mV		
(50 to 100) kHz	2.42 mV/V + 28 mV		
AC Voltage - Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.01 V		Fluke 57X0A Multifunction Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	890 nV	
	20 kHz	1.2 $\mu\text{V}$	
	100 kHz	4.5 $\mu\text{V}$	
	300 kHz	33 $\mu\text{V}$	
	1 MHz	21 $\mu\text{V}$	
4 MHz	140 $\mu\text{V}$		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
AC Voltage - Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.1 V		Fluke 57X0A Multifunction Calibrator disciplined with Keysight 3458A Multimeter	
	1 kHz	4.6 $\mu$ V		
	20 kHz	6.9 $\mu$ V		
	100 kHz	36 $\mu$ V		
	300 kHz	52 $\mu$ V		
	1 MHz	170 $\mu$ V		
	4 MHz	670 $\mu$ V		
	8 MHz	690 $\mu$ V		
	10 MHz	2.3 mV		
	1 V			
	1 kHz	26 $\mu$ V		
	20 kHz	32 $\mu$ V		
	50 kHz	59 $\mu$ V		
	100 kHz	170 $\mu$ V		
	300 kHz	410 $\mu$ V		
	500 kHz	0.97 mV		
	1 MHz	1.7 mV		
	4 MHz	6.7 mV		
	8 MHz	6.9 mV		
	10 MHz	25 mV		
	3V			
	100 kHz	420 $\mu$ V		
	(2, 4, 8) MHz	21 mV		
	10 MHz	75 mV		
	10 V			
	10 Hz	550 $\mu$ V		
	20 Hz	380 $\mu$ V		
	40 Hz	310 $\mu$ V		
	200 Hz	504 $\mu$ V		
	500 Hz	495 $\mu$ V		
	1 kHz	260 $\mu$ V		
	10 kHz	270 $\mu$ V		
	20 kHz	320 $\mu$ V		
	50 kHz	0.53 mV		
	100 kHz	1.1 mV		
	300 kHz	2.6 mV		
500 kHz	0.63 mV			
1 MHz	12 mV			

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup> Fixed Values, Fixed Frequencies	100 V 1 kHz 20 kHz 50 kHz 100 kHz 700 V 1 kHz	4 mV 7.9 mV 7.5 mV 16 mV 60 mV	Fluke 57X0A Multifunction Calibrator disciplined with Keysight 3458A Multimeter
AC Voltage Flatness – Source <sup>1</sup>	300 μV to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 μV to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 μV to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 57X0A Multifunction Calibrator, (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu\text{V}/\text{V}$ + 4.1 $\mu\text{V}$	
	40 Hz to 1 kHz	70 $\mu\text{V}/\text{V}$ + 2.1 $\mu\text{V}$	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu\text{V}$	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu\text{V}$	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu\text{V}$	
	(100 to 300) kHz	3 mV/V + 15 $\mu\text{V}$	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu\text{V}$	
	(1 to 2) MHz	15 mV/V + 20 $\mu\text{V}$	
	(2 to 4) MHz	40 mV/V + 74 $\mu\text{V}$	
	(4 to 8) MHz	40 mV/V + 83 $\mu\text{V}$	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	(0.1 to 1) V		
	(1 to 40) Hz	70 $\mu\text{V}/\text{V}$ + 41 $\mu\text{V}$	
	40 Hz to 1 kHz	70 $\mu\text{V}/\text{V}$ + 21 $\mu\text{V}$	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu\text{V}$	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu\text{V}$	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu\text{V}$	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.30 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu\text{V}/\text{V}$ + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu\text{V}/\text{V}$ + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	4.6 % of reading	Keysight DSO 9104A Oscilloscope
AC Current Source <sup>1</sup>	0 to 220 μA 10 to 20 Hz 20 to 40 Hz 40 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz 220 μA 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	230 μA/A + 17 nA 150 μA/A + 10 nA 108 μA/A + 8.4 nA 266 μA/A + 13 nA 915 μA/A + 66 nA 233 μA/A + 42 nA 150 μA/A + 34 nA 108 μA/A + 34 nA 183 μA/A + 109 nA 915 μA/A + 655 nA	Fluke 5720A or 5730A Multifunction Calibrator
AC Current Source <sup>1</sup>	(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	233 μA/A + 422 nA 149 μA/A + 342 nA 108 μA/A + 343 nA 183 μA/A + 588 nA 915 μA/A + 5 μA 233 μA/A + 4.2 μA 149 μA/A + 3.4 μA 108 μA/A + 2.6 μA 183 μA/A + 3.4 μA 915 μA/A + 10 μA	Fluke 5720A or 5730A Multifunction Calibrator

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz (2.2 to 11) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multifunction Calibrator
AC Current Source <sup>1</sup>	(10 to 20) A 45 Hz to 65 Hz 65 Hz to 440 Hz (20 to 100) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz (100 to 1 000) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.3 % of reading + 27 mA 0.33 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
AC Current – Source <sup>1</sup> Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 57X0A Multifunction Calibrator disciplined with Keysight 3458A
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.46 % of reading + 0.039 $\mu$ A 0.17 % of reading + 0.04 $\mu$ A 0.065 % of reading + 0.04 $\mu$ A 0.67 % of reading + 0.04 $\mu$ A 0.46 % of reading + 0.25 $\mu$ A 0.17 % of reading + 0.26 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.033 % of reading + 0.27 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.46 % of reading + 0.48 $\mu$ A 0.63 % of reading + 1.7 $\mu$ A	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(1 to 10) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
	(10 to 20) Hz	0.46 % of reading + 0.29 mA	
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
Resistance - Source	1 m $\Omega$	0.07 % of reading	Standard Resistor Sets 16074A 42030A 16340A 16353A
	10 m $\Omega$	0.11 % of reading	
	100 m $\Omega$	0.66 % of reading	
	1 $\Omega$	63 $\mu\Omega/\Omega$	
	10 $\Omega$	38 $\mu\Omega/\Omega$	
	100 $\Omega$	30 $\mu\Omega/\Omega$	
	1 k $\Omega$	29 $\mu\Omega/\Omega$	
	10 k $\Omega$	29 $\mu\Omega/\Omega$	
	100 k $\Omega$	2.1 $\mu\Omega/\Omega$	
	1 M $\Omega$	8 $\mu\Omega/\Omega$	
	10 M $\Omega$	16 $\mu\Omega/\Omega$	
	100 M $\Omega$	96 $\mu\Omega/\Omega$	
	1 G $\Omega$	240 $\mu\Omega/\Omega$	
	10 G $\Omega$	590 $\mu\Omega/\Omega$	
100 G $\Omega$	560 $\mu\Omega/\Omega$		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>-1</sup> Fixed Points	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
	(10 to 13) MHz	2.2 fF	
	100 pF		
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
	(4 to 5) MHz	20 fF	
	(5 to 10) MHz	37 fF	
	(10 to 13) MHz	53 fF	
	1 000 pF		
20 Hz to 1 MHz	0.14 pF		
(1 to 2) MHz	0.21 pF		
(2 to 3) MHz	0.31 pF		
(3 to 4) MHz	0.47 pF		
(4 to 5) MHz	0.64 pF		
(5 to 10) MHz	2 pF		
(10 to 13) MHz	3 pF		
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.2 mF/F + 8.3 pF	Fluke 5520A or 5522A Multifunction Calibrator
	(3.3 to 10.99) nF	1.6 mF/F + 8.3 pF	
	(11 to 109.99) nF	1.6 mF/F + 83 pF	
	(110 to 329.99) nF	1.6 mF/F + 0.25 nF	
	(0.33 to 1.099) μF	1.6 mF/F + 0.83 nF	
	(1.1 to 3.299) μF	1.6 mF/F + 2.5 nF	
	(3.3 to 10.99) μF	1.6 mF/F + 8.3 nF	
	(11 to 32.99) μF	2.5 mF/F + 25 nF	
	(33 to 109.99) μF	2.8 mF/F + 84 nF	
	(110 to 329.99) μF	2.8 mF/F + 0.25 μF	
	(0.33 to 1.099) mF	4 mF/F + 1.2 μF	
	(1.1 to 3.299) mF	4 mF/F + 3.6 μF	

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>1</sup>	(3.3 to 10.00) mF (11 to 32.99) mF (33 to 110) mF	4 mF/F + 12 μF 8.3 mF/F + 36 μF 12 mF/F + 0.11 mF	Fluke 5520A or 5522A Multifunction Calibrator
Dissipation Factor – Source <sup>1,2</sup> Fixed Points	0 < DF < 1 1 pF 1 kHz 1 kHz to 4 MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz	0.001 9 0.000 15 0.000 21 0.000 57 0.000 84	Agilent 16380A, Agilent 16380C Capacitance Standards
	10 pF 1 kHz 1 kHz to 1 MHz (1 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz	0.000 036 0.000 025 0.000 05 0.000 073 0.000 075 0.000 095	
Dissipation Factor – Source <sup>1,2</sup> Fixed Points	0 < DF < 1 100 pF 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz	0.000 023 0.000 021 0.000 052 0.000 048 0.000 062 0.000 071 0.000 16 0.000 24	Agilent 16380A, Agilent 16380C Capacitance Standards
	1 000 pF 20 Hz to 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 10 nF 120 Hz to 1 kHz (1 to 100) kHz	0.000 02 0.000 031 0.000 073 0.000 1 0.001 5 0.000 21 0.000 58 0.000 86 0.000 024 0.000 021	

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Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source <sup>1,2</sup> Fixed Points	0 < DF < 1		Agilent 16380A, Agilent 16380C Capacitance Standards
	100 nF		
	120 Hz to 1 kHz (1 to 100) kHz	0.000 04 0.000 021	
	1 μF		
	120 Hz to 1 kHz (1 to 10) kHz (10 to 100) kHz	0.000 041 0.000 035 0.000 11	
	10 μF		
	(20 to 120) Hz 120 Hz to 10 kHz (10 to 100) kHz	0.000 04 0.000 03 0.000 76	
High Voltage Measure <sup>1</sup> DC Voltage	(1 to 90) kV	1.8 mV/V	Ross Engineering VD90
High Voltage Measure <sup>1</sup> AC Voltage	(1 to 64) kV (50 to 60) Hz 60 Hz to 1 MHz	6.2 mV/V 36 mV/V	Voltage Divider, Keysight 34401A Multimeter
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B		Fluke 5520A, Fluke 5522A Multifunction Calibrator
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1 800) °C	0.53 °C	
	(1 800 to 2 316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1 000) °C	0.23 °C	
	Type J		
(-210 to -100) °C	0.29 °C		
(-100 to -30) °C	0.18 °C		
(-30 to 150) °C	0.16 °C		
(150 to 760) °C	0.19 °C		
(760 to 1 200) °C	0.25 °C		



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Electrical - DC/Low Frequency

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type K		Fluke 552XA Multifunction Calibrator
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
	Type L		
	(-200 to -100) °C	0.39 °C	
	(-100 to 800) °C	0.28 °C	
	(800 to 900) °C	0.19 °C	
	Type N		
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
Type S			
(0 to 250) °C	0.5 °C		
(250 to 1 000) °C	0.38 °C		
(1 000 to 1 400) °C	0.39 °C		
(1 400 to 1 767) °C	0.49 °C		
Type T			
(-250 to -150) °C	0.26 °C		
(-150 to 0) °C	0.18 °C		
(0 to 120) °C	0.16 °C		
(120 to 400) °C	0.66 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		

**Electrical - RF/Microwave**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 1 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 4.3 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 10 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 100 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 3 MHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.037 % Depth 0.038 % Depth 0.026 % Depth 0.030 % Depth 0.026 % Depth 0.030 % Depth 0.028 % Depth 0.036 % Depth 0.036 % Depth 0.084 % Depth	N9030A or N9030B Signal Analyzer
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz Modulation Index (0.2 to 100) (100 to 2 000) (3.6 to 8.4) GHz Modulation Index (0.2 to 100) (100 to 2 000) (8.4 to 17.1) GHz Modulation Index (0.2 to 100) (100 to 2 000) (17.1 to 34.5) GHz Modulation Index (0.2 to 100) (100 to 2 000) (34.5 to 50) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading 0.7 % of reading + 0.2 %M 2 % of reading 0.7 % of reading + 0.3 %M 2.5 % of reading 0.8 % of reading + 0.3 %M 3.0 % of reading 1.4 % of reading + 0.5 %M 4 % of reading	N9030A with Opt. TES or N9030B Signal Analyzer

**Electrical - RF/Microwave**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading  0.015° 0.12°	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer



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Electrical - RF/Microwave

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 10) rad 2 MHz to 3.6 GHz (3.6 to 13.6) GHz (13.6 to 17.1) GHz (17.1 to 26.5) GHz (26.5 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.002 rad 0.1 % of reading + 0.003 rad 0.1 % of reading + 0.004 rad 0.1 % of reading + 0.006 rad 0.1 % of reading + 0.009 rad 0.1 % of reading + 0.01 rad	N9030A with Opt. TES Signal Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Power Sensors Cal Factors <sup>1,2</sup>	9 kHz to 10 MHz	0.69 %	E9304A Power Sensor



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Electrical - RF/Microwave

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power Sensors Cal Factors <sup>1,2</sup>	10 MHz	0.58 %	Keysight PNA-X Network Analyzer 2.4, 3.5 mm Calibration Kits Reference Power Sensors
	30 MHz	0.54 %	
	50 MHz	0.41 %	
	100 MHz	0.51 %	
	300 MHz to 3 GHz	0.6 %	
	4 GHz	0.61 %	
	5 GHz	0.67 %	
	(6 to 7) GHz	0.68 %	
	8 GHz	0.7 %	
	9 GHz	0.79 %	
	10 GHz	0.82 %	
	11 GHz	0.79 %	
	12 GHz	0.76 %	
	12.4 GHz	0.8 %	
	(13 to 15) GHz	0.79 %	
	16 GHz	0.87 %	
	17 GHz	0.91 %	
	18 GHz	0.97 %	
	(19 to 26) GHz	1.5 %	
	26.5 GHz	1.6 %	
27 GHz	1.7 %		
(28 to 29) GHz	1.8 %		
30 GHz	1.7 %		
(31 to 32) GHz	1.8 %		
33 GHz	1.7 %		
(34 to 40) GHz	1.8 %		
41 GHz	2.4 %		
(42 to 44) GHz	2.5 %		
(45 to 47) GHz	2.6 %		
(48 to 50) GHz	2.5 %		
RF Absolute Power - Source <sup>1</sup> 50 MHz	(-11 to -1) dB	0.025 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
	(-30 to -10) dB	0.025 dB	
	(-50 to -40) dB	0.027 dB	
	-60 dB	0.028 dB	
	(-90 to -70) dB	0.033 dB	
	-100 dB	0.04 dB	
	-110 dB	0.048 dB	



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Electrical - RF/Microwave

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	0.02 V ≤ V < 7 V		Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A
	f < 10 MHz	0.082 dB	
	10 MHz ≤ f ≤ 50 MHz	0.16 dB	
	50 MHz ≤ f ≤ 80 MHz	0.4 dB	
	V ≤ 10mV		
	20 Hz ≤ f ≤ 20 kHz	0.017 mV	
	20 kHz < f ≤ 50 kHz	0.021 mV	
	50 kHz < f ≤ 100 kHz	0.05 mV	
	100 kHz < f ≤ 300 kHz	0.38 mV	
	10 mV < V ≤ 100 mV		
	20 Hz ≤ f ≤ 40 Hz	0.029 mV	
	40 Hz ≤ f ≤ 1 kHz	0.028 mV	
	1 kHz < f ≤ 20 kHz	0.032 mV	
	20 kHz < f ≤ 50 kHz	0.045 mV	
	50 kHz < f ≤ 100 kHz	0.08 mV	
	100 kHz < f ≤ 300 kHz	0.3 mV	
	100 mV < V ≤ 1 V		
	20 Hz ≤ f ≤ 1 kHz	0.7 mV	
	1 kHz < f ≤ 20 kHz	0.72 mV	
	20 kHz < f ≤ 50 kHz	0.79 mV	
50 kHz < f ≤ 100 kHz	1.3 mV		
100 kHz < f ≤ 300 kHz	3.7 mV		
1 V < V ≤ 3.5 V			
20 Hz ≤ f ≤ 40 Hz	2.2 mV		
40 Hz ≤ f ≤ 1 kHz	2.1 mV		
1 kHz < f ≤ 20 kHz	2.2 mV		
20 kHz < f ≤ 50 kHz	2.5 mV		
50 kHz < f ≤ 100 kHz	4 mV		
100 kHz < f ≤ 300 kHz	13 mV		
RF Absolute Power – Source <sup>1</sup>	7dBm ≥ P ≥ 0 dBm		Signal Source PSG, ESG, E4438C, E4428C
	0.3 MHz ≤ f ≤ 1.1 GHz	0.49 dB	
	1.1 GHz ≤ f ≤ 2.985 GHz	0.58 dB	
	2.985 GHz < f ≤ 4 GHz	0.69 dB	
	4 GHz < f ≤ 6 GHz	0.79 dB	
	0 dBm > P ≥ -25 dBm		
	0.3 MHz ≤ f ≤ 1.1 GHz	0.49 dB	
	1.1 GHz ≤ f ≤ 2.985 GHz	0.59 dB	
	2.985 GHz < f ≤ 4 GHz	0.69 dB	
	4 GHz < f ≤ 6 GHz	0.8 dB	

**Electrical - RF/Microwave**

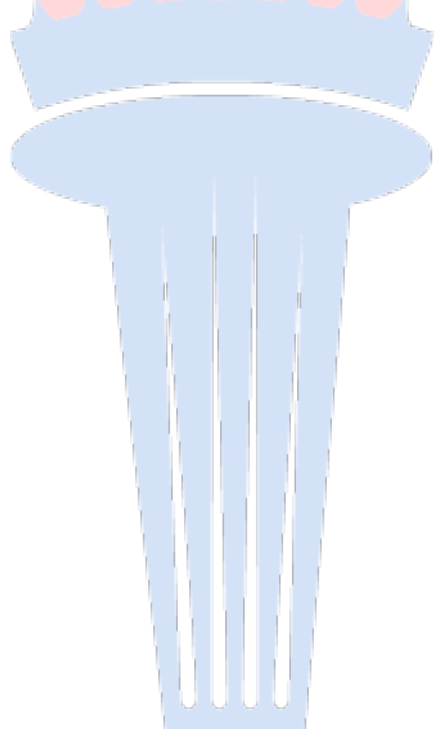
Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	-25 dBm > P ≥ -70 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -70 dBm > P ≥ -95 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -95 dBm > P ≥ -125 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz	0.5 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG, E4438C, E4428C
Thermal Noise – Source ENR	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.13 dB 0.14 dB	HP 346B opt. 002 346B/N4001A opt. 001 346B opt. 004 346C/N4002A Noise Source

**Electrical - RF/Microwave**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise – Source ENR	5 dB, 15 dB, or 21 dB 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.14 dB 0.16 dB 0.17 dB 0.14 dB 0.13 dB 0.15 dB 0.15 dB	HP 346B opt. 002 346B/N4001A opt. 001 346B opt. 004 346C/N4002A Noise Source
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System



**Electrical - RF/Microwave**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz Offsets: 100 kHz	Phase Noise Measurement dBc/Hz		Wenzel 500-13438C Oscillator
	-102 ≥ PN ≤ -131	0.55 dB	
-131 < PN ≤ -132	0.56 dB		
-132 < PN ≤ -136	0.58 dB		
-136 < PN ≤ -139	0.64 dB		
-139 < PN ≤ -142	0.81 dB		
-142 < PN ≤ -145	1.3 dB		
-145 < PN ≤ -146	1.5 dB		
-146 < PN ≤ -149	2.1 dB		
1 MHz	-120 ≥ PN ≤ -139	0.55 dB	
	-139 < PN ≤ -142	0.56 dB	
	-142 < PN ≤ -145	0.58 dB	
	-143 < PN ≤ -148	0.64 dB	
	-148 < PN ≤ -150	0.74 dB	
	-150 < PN ≤ -152	0.93 dB	
9.9 and 10 MHz	-152 < PN ≤ -155	1.5 dB	
	-155 < PN ≤ -158	2.1 dB	
	-131 ≥ PN ≤ -136	0.69 dB	
	-136 < PN ≤ -156	0.79 dB	
	-156 < PN ≤ -158	0.91 dB	
	-158 < PN ≤ -159	1 dB	
	-159 < PN ≤ -162	1.5 dB	
	-162 < PN ≤ -165	2.1 dB	

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
-1 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	RF Power Measure <sup>1</sup>				
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors				
Range	Expanded Uncertainty of Measurement (+/-)				
Frequency Range	Frequencies / Frequency Ranges (dB)				
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	RF Power Measure <sup>1</sup>				
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors				
Range	Expanded Uncertainty of Measurement (+/-)				
Frequency Range	Frequencies / Frequency Ranges (dB)				
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz
-130 dBm ≤ P < -110 dBm	0.1	0.09	0.09	0.09	0.09
-110 dBm ≤ P < -90 dBm	0.08	0.08	0.08	0.08	0.08
-90 dBm ≤ P < -30 dBm	0.07	0.06	0.06	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.07	0.05	0.05	0.06	0.06
-20 dBm ≤ P < -10 dBm	0.07	0.05	0.05	0.06	0.06
-10 dBm ≤ P < 0 dBm	0.07	0.06	0.06	0.06	0.06
-1 dBm ≤ P < 2 dBm	0.07	0.05	0.05	0.06	0.06
2 dBm ≤ P < 10 dBm	0.13	0.15	0.15	0.21	0.23
10 dBm ≤ P < 15 dBm	0.07	0.06	0.06	0.06	0.06
15 dBm ≤ P < 20 dBm	0.08	0.07	0.07	0.07	0.07
20 dBm ≤ P < 30 dBm	0.172	-	-	-	-

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
300 kHz to 20 MHz	0.002 4	0.002 6	0.002 9	0.002 8	0.003 1	0.003 5	0.003 9	0.004 3	0.004 6	0.004 9
20 MHz to 2 GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)										
	≤ 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	
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9	
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6	
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.0031	
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012	
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015	

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)										
	≤ 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	
300 kHz to 20 MHz	0.91	0.55	0.43	0.38	0.34	0.32	0.3	0.29	0.28	0.27	
20 MHz to 2 GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1	
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11	
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13	
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17	
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99	
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2	

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
300 kHz to 45 MHz	0.018	0.021	0.023	0.027	0.026	0.027	0.029	0.032	0.065
(45 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13
130 MHz to 1.25 GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051

**Electrical – RF/Microwave**

Nashua, NH

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
300 kHz to 45 MHz	0.62	0.62	0.62	0.62	0.23	0.23	0.23	0.23	0.58
(45 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
130 MHz to 1.25 GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53

**Electrical – RF/Microwave**

Nashua, NH

<b>Parameter/ Equipment</b>	S21 - Transmission Phase <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4

**Length - Dimensional Metrology**

Nashua, NH

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Calipers – Length <sup>3</sup>	(0 to 12) in (>12 to 60) in	(310 + 2L) μin (310 + 4L) μin	Grade 0 & 1 Gage Blocks
Calipers – Jaw Parallelism	≤ 1 inch	372 μin	Grade ZZ Pin Gages
Outside Diameter Micrometer Length <sup>3</sup>	(0 to 12) in (>12 to 48) in	(30 + 6L) μin (30 + 7L) μin	Grade 0 & 1 Gage Blocks
Inside Diameter Micrometer	(0 to 12) in	(30 + 6L) μin	Optical Flats and Monochromatic Light
Depth Micrometer	(0 to 12) in	(30 + 6L) μin	
Anvil Flatness	Up to 1 in	6 μin	
Dial and Digital Indicators			
Digital Indicators	(0 to 1) in (>1 to 2) in (>2 to 6) in	35 μin 38 μin 80 μin	Grade 0 Gage Blocks + Accessories, Surface Plate
Dial Indicators	(0 to 1) in (>1 to 6) in	64 μin 621 μin	
Height Gages	(0 to 48) in.	(310 + 4L) μin	Grade 0 Gage Blocks, Surface Plate
Plug and Pin Gages <sup>3</sup>	Up to 4 inches	(5 + 4D) μin	Labmaster, Grade 00 Gage Blocks

**Length - Dimensional Metrology**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Plain Rings <sup>3</sup>	Up to 4 in	$(7 + 4D) \mu\text{in}$	Grade 00 Gage Blocks, Labmaster
Bubble Levels <sup>3</sup>	Up to 15 in	$0.65R \mu\text{in}$	Surface Plate, Grade 0 Gage Blocks
Level Base Flatness	0.002 in	$37 \mu\text{in}$	Surface Plate, Amplifier Gage/Electronic Height Gage
Protractors	Up to 90°	53 arc sec.	Sine Bar, Grade 0 Gage Blocks, Surface Plate, Right Angle, Precision Level

**Mass and Mass Related**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Torque Wrenches/Screwdrivers	(5 to 16) ozf-in	0.4 ozf-in	Dillon 49754-0245 Torque Tester
	1 lbf-in to 1 000 lbf-ft	0.4 % of reading	AWS QCMI-XX and QCMF-XX Torque Tester
Pneumatic Pressure Absolute / Gage	(-14.6 to 100) psi	0.02 psi	Ruska 7010 Pressure Controller and Terranova 906A Pressure Controller
	(>100 to 200) psi	0.014 % of reading	
	(>200 to 350) psi	0.01 % of reading	
	(>350 to 500) psi	0.008 % of reading	
Scales and Balances <sup>4</sup>	(5 to 500) mg	0.099 mg	Class 1, F1 Weights
	(> 0.5 to 5) g	0.025 mg	
	(> 5 to 10) g	0.039 mg	
	(> 10 to 20) g	0.065 mg	
	(> 20 to 50) g	0.15 mg	
	(> 50 to 100) g	0.277 mg	
	(> 100 to 200) g	0.548 mg	
	(> 200 to 300) g	0.83 mg	
	(> 300 to 500) g	3.4 mg	
	> 500 g to 1 kg	6.6 mg	
	(> 1 to 2) kg	16 mg	
(> 2 to 5) kg	35 mg		
(> 5 to 10) kg	67 mg		

**Thermodynamic**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Temperature Measure	(-196 to ≤ 0) °C (> 0 to ≤ 200) °C (> 200 to ≤ 420) °C (> 420 to ≤ 660) °C	0.01 °C 0.018 °C 0.028 °C 0.039 °C	Fluke 5628 PRT/1502A Indicator
Temperature Source	(-68 to < -30) °C (≥ -30 to ≤ 200) °C (> 200 to ≤ 500) °C (> 500 to 660) °C	0.097 °C 0.074 °C 0.095 °C 0.12 °C	Fluke 9011 Drywell
Humidity – Source	(10 to 90) %RH	0.8 %RH	Thunder Scientific 2500 Chamber

**Time and Frequency**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Time Interval – Measure <sup>1</sup>	10 ns to 10 s	2.9 ns	HP 5334B Counter connected to Time base (HP 5071A or Datum 8040) Frequency Standard
Frequency – Source <sup>1</sup>	10 MHz	6.5 <sup>-11</sup> Hz	8040C Frequency Standard
Frequency – Measure <sup>1</sup>	1 to 100 Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.015 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	Agilent 53132A Counter and 8040C Frequency Standard
	(12.4 to 46) GHz	30 pHz/Hz + 3.7 Hz	Agilent 53151A Counter and 8040C Frequency Standard
Rise Time – Generate <sup>1</sup>	2 kHz to 2 MHz (200 to 300) ps (2 to 10) MHz (200 to 350) ps	37 ps 37 ps	Fluke 55xxA + SC600/1100 Multifunction Calibrator
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module

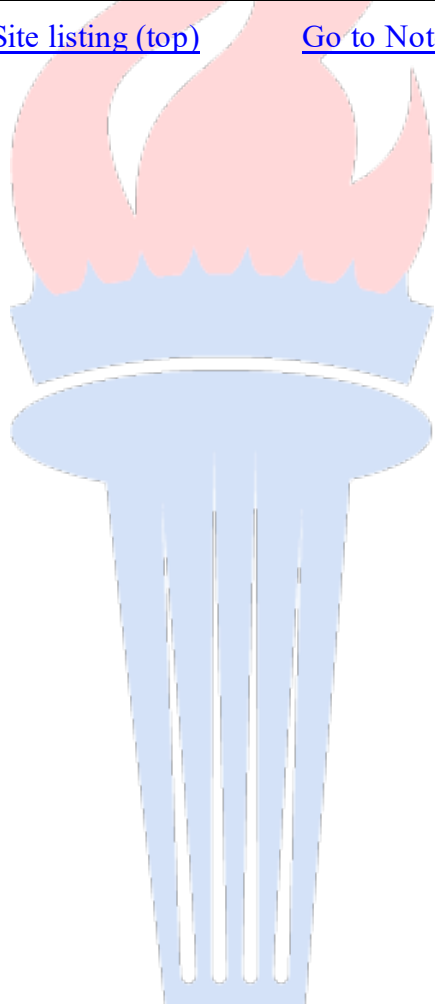
**Time and Frequency**

Nashua, NH

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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**Electrical – DC/Low Frequency**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (0.22 to 1.1) kV	7 $\mu\text{V/V}$ + 0.54 $\mu\text{V}$ 5 $\mu\text{V/V}$ + 0.8 $\mu\text{V}$ 3.5 $\mu\text{V/V}$ + 0.4 $\mu\text{V}$ 3.6 $\mu\text{V/V}$ + 4.5 $\mu\text{V}$ 5.3 $\mu\text{V/V}$ + 23 $\mu\text{V}$ 7.1 $\mu\text{V/V}$ + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu\text{V}$ 11 $\mu\text{V}$ 150 $\mu\text{V}$ 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu\text{V/V}$ + 0.36 $\mu\text{V}$ 3.7 $\mu\text{V/V}$ + 0.35 $\mu\text{V}$ 3.1 $\mu\text{V/V}$ + 0.59 $\mu\text{V}$ 5.3 $\mu\text{V/V}$ + 36 $\mu\text{V}$ 5.3 $\mu\text{V/V}$ + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu\text{V/V}$ + 62 nV 0.37 $\mu\text{V/V}$ + 124 nV 62 nV/V + 0.62 $\mu\text{V}$ 0.62 $\mu\text{V/V}$ + 12.4 $\mu\text{V}$ 1.85 $\mu\text{V/V}$ + 63 $\mu\text{V}$	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(0 to 220) $\mu\text{A}$ 220 $\mu\text{A}$ to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu\text{A/A}$ 29 $\mu\text{A/A}$ 37 $\mu\text{A/A}$ 50 $\mu\text{A/A}$ - 1.2 $\mu\text{A}$ 59 $\mu\text{A/A}$ + 12 $\mu\text{A}$ 120 $\mu\text{A/A}$ - 42 $\mu\text{A}$	Fluke 5720A or 5730A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu\text{A/A}$ + 41 $\mu\text{A}$	Fluke 5725A Amplifier

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 552xA Multiproduct Calibrator with 50 turn coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup>	(0 to 11) $\Omega$ (11 to 110) $\Omega$ (0.11 to 1.1) k $\Omega$ (1.1 to 3.3) k $\Omega$ (3.3 to 11) k $\Omega$ (11 to 110) k $\Omega$	33 $\mu\Omega/\Omega$ + 8.3 m $\Omega$ 25 $\mu\Omega/\Omega$ + 12.5 m $\Omega$ 23 $\mu\Omega/\Omega$ + 17 m $\Omega$ 23 $\mu\Omega/\Omega$ + 170 m $\Omega$ 23 $\mu\Omega/\Omega$ + 84 m $\Omega$ 23 $\mu\Omega/\Omega$ + 0.84 $\Omega$	Fluke 552xA Multiproduct Calibrator
Resistance – Source <sup>1</sup>	(0.11 to 1.1) M $\Omega$ (1.1 to 3.3) M $\Omega$ (3.3 to 11) M $\Omega$ (11 to 33) M $\Omega$ (33 to 110) M $\Omega$ (110 to 330) M $\Omega$ (330 to 1 100) M $\Omega$	27 $\mu\Omega/\Omega$ + 8 $\Omega$ 50 $\mu\Omega/\Omega$ + 125 $\Omega$ 110 $\mu\Omega/\Omega$ + 0.2 k $\Omega$ 210 $\mu\Omega/\Omega$ + 2 k $\Omega$ 410 $\mu\Omega/\Omega$ + 2.8 k $\Omega$ 2.5 m $\Omega/\Omega$ + 83 k $\Omega$ 12.5 m $\Omega/\Omega$ + 0.4 M $\Omega$	Fluke 552xA Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	0 Ω	21 μΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
	10 MΩ	140 Ω	
	100 MΩ	18 kΩ	
Resistance – Source <sup>1</sup> Fixed Points	0 Ω	0.25 mΩ	Fluke 5720A Multiproduct Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 k Ω	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
	10 MΩ	0.4 kΩ	
19 MΩ	1.5 kΩ		
100 MΩ	12 kΩ		
Resistance – Measure <sup>1</sup>	(0 to 10) Ω	22 μΩ/Ω + 90 μΩ	Keysight 3458A Multimeter
	(10 to 100) Ω	19 μΩ/Ω + 0.88 mΩ	
	(0.1 to 1) kΩ	16 μΩ/Ω + 0.95 mΩ	
	(1 to 10) kΩ	16 μΩ/Ω + 9.5 mΩ	
	(10 to 100) kΩ	16 μΩ/Ω + 95 mΩ	
	(0.1 to 1) MΩ	22 μΩ/Ω + 3 Ω	
	(1 to 10) MΩ	65 μΩ/Ω + 132 Ω	
	(10 to 100) MΩ	624 μΩ/Ω + 4.5 kΩ	
	(0.1 to 1) GΩ	6.2 mΩ/Ω + 0.35 MΩ	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	2.2 to 22 mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V/V} + 10 \mu\text{V}$		
(50 to 100) kHz	100 $\mu\text{V/V} + 70 \mu\text{V}$		
(100 to 300) kHz	290 $\mu\text{V/V} + 80 \mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 200 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu$ V/V + 390 $\mu$ V	
	(20 to 40) Hz	93 $\mu$ V/V + 160 $\mu$ V	
	40 Hz to 20 kHz	47 $\mu$ V/V + 48 $\mu$ V	
	(20 to 50) kHz	78 $\mu$ V/V + 100 $\mu$ V	
	(50 to 100) kHz	110 $\mu$ V/V + 70 $\mu$ V	
	(100 to 300) kHz	430 $\mu$ V/V + 97 $\mu$ V	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu$ V/V + 4.2 mV	
	(20 to 40) Hz	94 $\mu$ V/V + 1.6 mV	
	40 Hz to 20 kHz	54 $\mu$ V/V + 0.68 mV	
	(20 to 50) kHz	83 $\mu$ V/V + 1.1 mV	
(50 to 100) kHz	156 $\mu$ V/V + 2.6 mV		
(100 to 300) kHz	941 $\mu$ V/V + 16 mV		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	40 Hz to 1 kHz	80 $\mu$ V/V + 18 mV	
	(1 to 20) kHz	173 $\mu$ V/V + 5.3 mV	
	(20 to 30) kHz	625 $\mu$ V/V + 12 mV	
	(220 to 750) V		
(30 to 50) kHz	634 $\mu$ V/V + 5.5 mV		
(50 to 100) kHz	2.4 mV/V + 28 mV		
AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	0.01 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	890 nV	
	20 kHz	1.2 $\mu$ V	
	100 kHz	4.5 $\mu$ V	
	300 kHz	33 $\mu$ V	
	1 MHz	21 $\mu$ V	
4 MHz	140 $\mu$ V		



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AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	0.1 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter	
	1 kHz	4.6 $\mu$ V		
	20 kHz	6.9 $\mu$ V		
		100 kHz		36 $\mu$ V
		300 kHz		52 $\mu$ V
		1 MHz		170 $\mu$ V
		4 MHz		670 $\mu$ V
		8 MHz		690 $\mu$ V
		10 MHz		2.3 mV
		1 V		
		1 kHz		26 $\mu$ V
		20 kHz		32 $\mu$ V
		50 kHz		59 $\mu$ V
		100 kHz		170 $\mu$ V
		300 kHz		410 $\mu$ V
		500 kHz		0.97 mV
		1 MHz		1.7 mV
		4 MHz		6.7 mV
		8 MHz		6.9 mV
		10 MHz		25 mV
		3V		
		100 kHz		420 $\mu$ V
		(2, 4, 8) MHz		21 mV
		10 MHz		75 mV
		10 V		
		10 Hz		550 $\mu$ V
		20 Hz		380 $\mu$ V
		40 Hz		310 $\mu$ V
		200 Hz		504 $\mu$ V
		500 Hz		495 $\mu$ V
		1 kHz		260 $\mu$ V
		10 kHz		270 $\mu$ V
		20 kHz		320 $\mu$ V
	50 kHz	0.53 mV		
	100 kHz	1.1 mV		
	300 kHz	2.6 mV		
	500 kHz	0.63 mV		
	1 MHz	12 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	100 V 1 kHz 20 kHz 50 kHz 100 kHz 700 V 1 kHz	4 mV 7.9 mV 7.5 mV 16 mV  60 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Voltage Flatness – Source <sup>1</sup>	300 μV to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 μV to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 μV to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 57x0A Multiproduct Calibrator, (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	(0.1 to 1) V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.30 mV/V + 0.25 mV	
	(50 to 100) kHz	0.80 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.20 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV	Keysight 3458A Multimeter
	(100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.40 mV/V + 31 mV 0.40 mV/V + 16 mV 0.60 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	
AC Voltage – Measure <sup>1</sup>	20 Hz to 20 MHz	4.6% of reading	Keysight DSO 9104A Oscilloscope
AC Current Source <sup>1</sup>	(0 to 220) $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA	Fluke 5720A or 5730A Multiproduct Calibrator
	220 $\mu$ A 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	233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA	
	(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	233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A	
	(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	233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A 45 Hz to 65 Hz 65 Hz to 440 Hz (20 to 100) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz (100 to 1 000) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.3 % of reading + 27 mA 0.33 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 552xA Multiproduct Calibrator with 50 turn coil
AC Current – Source <sup>1</sup> Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.46 % of reading + 0.039 $\mu$ A 0.17 % of reading + 0.04 $\mu$ A 0.065 % of reading + 0.04 $\mu$ A 0.67 % of reading + 0.04 $\mu$ A 0.46 % of reading + 0.25 $\mu$ A 0.17 % of reading + 0.26 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.033 % of reading + 0.27 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.46 % of reading + 0.48 $\mu$ A 0.63 % of reading + 1.7 $\mu$ A	Keysight 3458A Multimeter



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AC Current – Measure <sup>1</sup>	(1 to 10) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
Resistance – Source <sup>1</sup>	1 m $\Omega$	0.07 % of reading	Agilent 16074A RL Standard
	10 m $\Omega$	0.11 % of reading	
	100 m $\Omega$	0.66 % of reading	
	1 $\Omega$	63 $\mu\Omega/\Omega$	
	10 $\Omega$	38 $\mu\Omega/\Omega$	
	100 $\Omega$	30 $\mu\Omega/\Omega$	
	1 k $\Omega$	29 $\mu\Omega/\Omega$	
	10 k $\Omega$	29 $\mu\Omega/\Omega$	
	100 k $\Omega$	2.1 $\mu\Omega/\Omega$	
	1 M $\Omega$	8 $\mu\Omega/\Omega$	
	10 M $\Omega$	16 $\mu\Omega/\Omega$	
	100 M $\Omega$	96 $\mu\Omega/\Omega$	
	1 G $\Omega$	240 $\mu\Omega/\Omega$	
	10 G $\Omega$	590 $\mu\Omega/\Omega$	
100 G $\Omega$	560 $\mu\Omega/\Omega$		



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Capacitance – Source <sup>1</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
	(10 to 13) MHz	2.2 fF	
	100 pF		
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
	(4 to 5) MHz	20 fF	
	(5 to 10) MHz	37 fF	
	(10 to 13) MHz	53 fF	
	1 000 pF		
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
10 nF			
120 Hz to 100 kHz	1.5 pF		
100 nF			
120 Hz to 100 kHz	15 pF		
1 μF			
120 Hz to 1 kHz	0.52 nF		
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
10 μF			
20 Hz to 1 kHz	1.6 nF		
(1 to 20) kHz	2.2 nF		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF (3.3 to 10.99) nF (11 to 109.99) nF (110 to 329.99) nF (0.33 to 1.099) μF (1.1 to 3.299) μF (3.3 to 10.99) μF (11 to 32.99) μF (33 to 109.99) μF (110 to 329.99) μF (0.33 to 1.099) mF (1.1 to 3.299) mF (3.3 to 10.00) mF (11 to 32.99) mF (33 to 110) mF	3.2 mF/F + 8.3 pF 1.6 mF/F + 8.3 pF 1.6 mF/F + 83 pF 1.6 mF/F + 0.25 nF 1.6 mF/F + 0.83 nF 1.6 mF/F + 2.5 nF 1.6 mF/F + 8.3 nF 2.5 mF/F + 25 nF 2.8 mF/F + 84 nF 2.8 mF/F + 0.25 μF 4 mF/F + 1.2 μF 4 mF/F + 3.6 μF 4 mF/F + 12 μF 8.3 mF/F + 36 μF 12 mF/F + 0.11 mF	Fluke 5520A or 5522A Multiproduct Calibrator
Dissipation Factor – Source <sup>1,2</sup>	0 < DF < 1 1 pF 1 kHz 1 kHz to 4 MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 10 pF 1 kHz 1 kHz to 1 MHz (1 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz 100 pF 1 kHz 1 kHz to 1 MHz (1 to 2) MHz (2 to 3) MHz (3 to 4) MHz (4 to 5) MHz (5 to 10) MHz (10 to 13) MHz	  0.001 9 0.000 15 0.000 21 0.000 57 0.000 84  0.000 036 0.000 025 0.000 05 0.000 073 0.000 075 0.000 095  0.000 023 0.000 021 0.000 052 0.000 048 0.000 062 0.000 071 0.000 16 0.000 24	Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair

**Electrical – DC/Low Frequency**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Dissipation Factor – Source <sup>1,2</sup>	0 < DF < 1		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair	
	1 000 pF			
	20 Hz to 1 kHz	0.000 02		
	1 kHz to 1 MHz	0.000 031		
	(1 to 2) MHz	0.000 073		
	(2 to 3) MHz	0.000 1		
	(3 to 4) MHz	0.001 5		
	(4 to 5) MHz	0.000 21		
	(5 to 10) MHz	0.000 58		
	(10 to 13) MHz	0.000 86		
	10 nF			
	120 Hz to 1 kHz	0.000 024		
	(1 to 100) kHz	0.000 021		
	100 nF			
	120 Hz to 1 kHz	0.000 04		
	(1 to 100) kHz	0.000 021		
	1 μF			
	120 Hz to 1 kHz	0.000 041		
(1 to 10) kHz	0.000 035			
(10 to 100) kHz	0.000 11			
10 μF				
(20 to 120) Hz	0.000 04			
120 Hz to 10 kHz	0.000 03			
(10 to 100) kHz	0.000 76			
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B		Fluke 5520A, Fluke 5522A Multiproduct Calibrator	
	(600 to 800) °C	0.47 °C		
	(800 to 1 000) °C	0.36 °C		
	(1 000 to 1 550) °C	0.32 °C		
	(1 550 to 1 820) °C	0.35 °C		
	Type C			
	(0 to 150) °C	0.32 °C		
	(150 to 650) °C	0.28 °C		
	(650 to 1 000) °C	0.33 °C		
	(1 000 to 1 800) °C	0.53 °C		
	(1 800 to 2 316) °C	0.88 °C		
	Type E			
	(-250 to -100) °C	0.53 °C		
	(-100 to -25) °C	0.18 °C		
	(-25 to 350) °C	0.16 °C		
(350 to 650) °C	0.18 °C			
(650 to 1 000) °C	0.23 °C			



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Electrical – DC/Low Frequency

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type J		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
	Type L		
	(-200 to -100) °C	0.39 °C	
	(-100 to 800) °C	0.28 °C	
	(800 to 900) °C	0.19 °C	
	Type N		
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
(250 to 400) °C	0.37 °C		
(400 to 1 000) °C	0.35 °C		
(1 000 to 1 767) °C	0.42 °C		
Type S			
(0 to 250) °C	0.5 °C		
(250 to 1 000) °C	0.38 °C		
(1 000 to 1 400) °C	0.39 °C		
(1 400 to 1 767) °C	0.49 °C		
Type T			
(-250 to -150) °C	0.26 °C		
(-150 to 0) °C	0.18 °C		
(0 to 120) °C	0.16 °C		
(120 to 400) °C	0.66 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		



ANSI National Accreditation Board

Electrical – RF/Microwave

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	(> 0 to 99) % Depth (0.15 to 10) MHz (0.01 to 1.3) GHz (1.3 to 26.5) GHz	2.1 % Depth 1.1 % Depth 1.6 % Depth	Agilent 8902A Measuring Receiver
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(> 0 to 99) % Depth (0.1 to 10) MHz (0.01 to 3) GHz (3 to 26.5) GHz (26.5 to 31.15) GHz (31.5 to 50) GHz	0.8 % Depth 0.5 % Depth 1.5 % Depth 1.9 % Depth 6.1 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 100) kHz	≤ 40 kHz Peak (0.25 to 10) MHz ≤ 400 kHz Peak (0.01 to 26.5) GHz	2.2 % Deviation 1.2 % Deviation	HP 8902A Measuring Receiver
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	≤ 400 kHz Peak (0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude (EVM)	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180 ° rms Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.17 ° 0.34 ° 0.57 °	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer



ANSI National Accreditation Board

Electrical – RF/Microwave

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $f \leq 100 \text{ kHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $100 \text{ kHz} \leq f \leq 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $f > 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$8.6 \text{ E-5 } \rho$ $0.00043 \rho$ $0.00068 \rho$ $0.00084 \rho$ $0.0012 \rho$ $0.0016 \rho$ $9.6 \text{ E-5 } \rho$ $0.00048 \rho$ $0.00076 \rho$ $0.00094 \rho$ $0.0014 \rho$ $0.0018 \rho$ $1.6 \text{ E-4 } \rho$ $0.00082 \rho$ $0.0013 \rho$ $0.0016 \rho$ $0.0024 \rho$ $0.003 \rho$	HP 89441A Vector Signal Analyzer
Phase Modulation – Measure <sup>1</sup>	$(0.15 \text{ to } 10) \text{ MHz}$ Rate: $(0.02 \text{ to } 10) \text{ kHz}$ $< 40 \text{ Radians Deviation}$ $(0.01 \text{ to } 26.5) \text{ GHz}$ Rate: $(0.2 \text{ to } 20) \text{ kHz}$ $< 40 \text{ Radians Deviation}$	$4.1 \% \text{ Deviation}$ $3.1 \% \text{ Deviation}$	HP 8902A Measuring Receiver
Phase Modulation – Measure <sup>1</sup>	$100 \text{ kHz to } 6.6 \text{ GHz}$ Deviations: $(0.3 \text{ to } 7) \text{ rad}$ Deviations: $> 7 \text{ rad}$ $(6.6 \text{ to } 13.2) \text{ GHz}$ Deviations: $(0.6 \text{ to } 2) \text{ rad}$	$3.1 \% \text{ Deviation}$ $1 \% \text{ Deviation}$ $3.1 \% \text{ Deviation}$	Keysight E444xA with Opt. 233 Spectrum Analyzer

**Electrical – RF/Microwave**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure <sup>1</sup>	(13.2 to 26.5) GHz Deviations: > 2 rad	1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
	Deviations: (1.2 to 4) rad	3.1 % Deviation	
	(26.5 to 31.5) GHz Deviations: > 4 rad	1 % Deviation	
	Deviations: (1.3 to 4) rad	3.1 % Deviation	
	(31.5 to 50) GHz Deviations: > 4 rad	1 % Deviation	
	Deviations (2.4 to 8) rad Deviations: > 8 rad	3.1 % Deviation 1 % Deviation	
Distortion Measure <sup>1</sup>	(-99 to 0) dB		HP 8903A/B Audio Analyzer
	20 Hz to 20 kHz	1.2 dB	
	(20 to 100) kHz	2.4 dB	
RF Power - Power Meter Reference <sup>1</sup>	1 mW  50 MHz	  0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(-22 to +10) dBm	0.17 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-42 to -22) dBm	0.18 dB	
	(-50 to -42) dBm	0.2 dB	
	(-60 to -50) dBm	0.21 dB	
	(-72 to -60) dBm	0.22 dB	
	(-80 to -72) dBm	0.23 dB	
	(-92 to -80) dBm	0.24 dB	
	(-102 to -92) dBm	0.27 dB	
	(-110 to -102) dBm	0.28 dB	
	(-120 to -110) dBm	0.31 dB	
(-127 to -120) dBm	0.34 dB		

**Electrical – RF/Microwave**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power – Source <sup>1</sup> 50 MHz	-1 dB to -11 dB -10 dB to -30 dB -40 dB to -50 dB -60 dB -70 dB to -90 dB -100 dB -110 dB	0.025 dB 0.025 dB 0.027 dB 0.028 dB 0.033 dB 0.04 dB 0.048 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
RF Absolute Power – Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz 10 MHz ≤ f ≤ 50 MHz 50 MHz ≤ f ≤ 80 MHz V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz 10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz 40 Hz ≤ f ≤ 1 kHz 1 kHz < f ≤ 20 kHz 20 kHz < f ≤ 50 kHz 50 kHz < f ≤ 100 kHz 100 kHz < f ≤ 300 kHz	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.05 mV 0.38 mV 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Electrical – RF/Microwave

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source	$100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $1 \text{ V} < V \leq 3.5 \text{ V}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV  2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power – Source	$7 \text{ dBm} \geq P \geq 0 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $0 \text{ dBm} > P \geq -25 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-25 \text{ dBm} > P \geq -70 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-70 \text{ dBm} > P \geq -95 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-95 \text{ dBm} > P \geq -125 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB  0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG, E4438C, E4428C

**Electrical – RF/Microwave**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System

**Electrical – RF/Microwave**

Montreal, QC

Parameter/Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.0034	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.0051	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Montreal, QC

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2	
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18	
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19	
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24	
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24	
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37	
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Montreal, QC

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-

Electrical – RF/Microwave

Montreal, QC

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

Electrical – RF/Microwave

Montreal, QC

<b>Parameter/ Equipment</b>	S11 - Reflection Magnitude <sup>1,2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency	Measured Magnitude (Linear)									
	≤ 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
300 kHz to 20 MHz	0.002 4	0.002 6	0.002 9	0.002 8	0.003 1	0.003 5	0.003 9	0.004 3	0.004 6	0.004 9
20 MHz to 2 GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment	S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
300 kHz to 20 MHz	0.91	0.55	0.43	0.38	0.34	0.32	0.3	0.29	0.28	0.27
20 MHz to 2 GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment	S21 - Transmission Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
300 kHz to 45 MHz	0.018	0.021	0.023	0.027	0.026	0.027	0.029	0.032	0.065	
(45 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13	
130 MHz to 1.25 GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
300 kHz to 45 MHz	0.62	0.62	0.62	0.62	0.23	0.23	0.23	0.23	0.58
(45 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
130 MHz to 1.25 GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5



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Electrical – RF/Microwave

Montreal, QC

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.11	0.10	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.10	0.10	0.12

**Electrical – RF/Microwave**

Montreal, QC

Parameter/ Equipment	RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors							
Range	Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequencies / Frequency Ranges (dB)							
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
0 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
2 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-

**Time and Frequency**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Rise Time - Source <sup>1</sup>	1 kHz to 2 MHz (200 to 300) ps (2 to 10) MHz (200 to 350) ps	37 ps 37 ps	Fluke 55xxA + SC600/1100 Multifunction Calibrator
Frequency - Source <sup>1</sup>	10 MHz	6.5 e-11 Hz	Datum 8040 Frequency Standard
Frequency - Measure <sup>1</sup>	(10 to 100) Hz (100 to 1000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	Keysight 53132A Counter, 8040C Frequency Standard

**Time and Frequency**

Montreal, QC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Measure <sup>1</sup>	12.4 GHz to 26.5 GHz	30 pHz/Hz + 3.75 Hz	Keysight 53151A Counter, 8040C Frequency Standard
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4.0 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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**Electrical – DC/Low Frequency**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V/V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) $\mu$ A 220 $\mu$ A to 2.2 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) mA (10 to 100) mA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 A to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 A to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points <sup>1</sup>	0 $\Omega$ 10 $\Omega$ 100 $\Omega$ 1 k $\Omega$ 10 k $\Omega$ 100 k $\Omega$ 1 M $\Omega$ 10 M $\Omega$ 100 M $\Omega$	21 $\mu\Omega$ 49 $\mu\Omega$ 420 $\mu\Omega$ 1.8 m $\Omega$ 17 m $\Omega$ 190 m $\Omega$ 4.6 $\Omega$ 140 $\Omega$ 18 k $\Omega$	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points <sup>1</sup>	0 Ω	0.25 mΩ	Fluke 5720A Multiproduct Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 kΩ	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
	10 MΩ	0.4 kΩ	
19 MΩ	1.5 kΩ		
100 MΩ	12 kΩ		
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 μV/V + 4.1 μV	
	(20 to 40) Hz	94 μV/V + 4.1 μV	
	40 Hz to 20 kHz	83 μV/V + 4.1 μV	
	(20 to 50) kHz	210 μV/V + 4.1 μV	
	(50 to 100) kHz	520 μV/V + 4.1 μV	
	(100 to 300) kHz	1.1 mV/V + 4.1 μV	
	(300 to 500) kHz	1.5 mV/V + 4.1 μV	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 μV	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 μV/V + 4.1 μV	
	(20 to 40) Hz	94 μV/V + 4.1 μV	
	40 Hz to 20 kHz	83 μV/V + 4.1 μV	
	(20 to 50) kHz	210 μV/V + 4.1 μV	
	(50 to 100) kHz	520 μV/V + 4.1 μV	
	(100 to 300) kHz	1.1 mV/V + 4.1 μV	
	(300 to 500) kHz	1.4 mV/V + 4.1 μV	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 μV	



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	(220 mV to 2.2 V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	103 $\mu\text{V/V} + 204 \mu\text{V}$	
	(100 to 300) kHz	287 $\mu\text{V/V} + 611 \mu\text{V}$	
	(300 to 500) kHz	1.0 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(2.2 to 22) V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 390 \mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V} + 156 \mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V} + 48 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 107 \mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V} + 42 \mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V} + 97 \mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
(10 to 20) Hz	250 $\mu\text{V/V} + 4.2 \text{ mV}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 1.6 \text{ mV}$		
40 Hz to 20 kHz	54 $\mu\text{V/V} + 0.68 \text{ mV}$		
(20 to 50) kHz	83 $\mu\text{V/V} + 1.1 \text{ mV}$		
(50 to 100) kHz	156 $\mu\text{V/V} + 2.6 \text{ mV}$		
(100 to 300) kHz	941 $\mu\text{V/V} + 16 \text{ mV}$		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
(220 to 1 100) V			
40 Hz to 20 kHz	313 $\mu\text{V/V} + 17 \text{ mV}$		
(20 to 50) kHz	73 $\mu\text{V/V} + 3.7 \text{ mV}$		

**Electrical – DC/Low Frequency**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	80 $\mu$ V/V + 18 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 12 mV 634 $\mu$ V/V + 5.5 mV 2.4 mV/V + 28 mV	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz 1 V 1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz 3V 100 kHz (2, 4, 8) MHz 10 MHz	870 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V 4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV 26 $\mu$ V 32 $\mu$ V 59 $\mu$ V 170 $\mu$ V 410 $\mu$ V 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV 420 $\mu$ V 21 mV 75 mV	Fluke 5700A or Fluke 5720A disciplined with HP 3458A



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup> Fixed Values, Fixed Frequencies	10 V		Fluke 5700A or Fluke 5720A disciplined with HP 3458A
	10 Hz	480 $\mu$ V	
	20 Hz	270 $\mu$ V	
	40 Hz	230 $\mu$ V	
	200 Hz	460 $\mu$ V	
	500 Hz	450 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	6.3 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz	4.6 mV/V	
	(2 to 10) MHz	6.2 mV/V	
	(10 to 20) MHz	8 mV/V	
	(20 to 30) MHz	24 mV/V	
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz	2.2 mV/V	
	(2 to 10) MHz	3.7 mV/V	
	(10 to 20) MHz	5.5 mV/V	
	(20 to 30) MHz	14 mV/V	
	3 mV to 3.5 V 120 kHz to 2 MHz	1.2 mV/V	
	(2 to 10) MHz	2.1 mV/V	
	(10 to 20) MHz	3.8 mV/V	
	(20 to 30) MHz	8.6 mV/V	



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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 100) 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 100 mV to 1 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV 70 μV/V + 4.1 μV 70 μV/V + 2.1 μV 0.14 mV/V + 2.3 μV 0.3 V/V + 2.6 μV 0.80 mV/V + 2.3 μV 3 mV/V + 15 μV 10 mV/V + 28 μV 15 mV/V + 20 μV 40 mV/V + 74 μV 40 mV/V + 83 μV 0.15 V/V + 0.11 mV 70 μV/V + 41 μV 70 μV/V + 21 μV 0.14 mV/V + 22 μV 0.3 mV/V + 22 μV 0.8 mV/V + 22 μV 3 mV/V + 0.12 mV 10 mV/V + 0.3 mV 15 mV/V + 0.21 mV 40 mV/V + 0.73 mV 40 mV/V + 0.83 mV 0.15 V/V + 1 mV	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure 1	(1 to 10) V		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
	(2 to 4) MHz	40 mV/V + 7.1 mV	
	(4 to 8) MHz	40 mV/V + 8.1 mV	
	(8 to 10) MHz	0.15 mV/V + 11 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.2 mV/V + 4.1 mV	
	40 Hz to 20 kHz	0.2 mV/V + 2.6 mV	
(20 to 50) kHz	0.35 mV/V + 2.4 mV		
(50 to 100) kHz	1.2 mV/V + 2.1 mV		
(100 to 300) kHz	4 mV/V + 11 mV		
300 kHz to 1 MHz	15 mV/V + 50 mV		
(100 to 750) V			
(1 to 40) Hz	0.4 mV/V + 31 mV		
40 Hz to 1 kHz	0.4 mV/V + 16 mV		
(1 to 20) kHz	0.6 mV/V + 16 mV		
(20 to 50) kHz	1.2 mV/V + 16 mV		
(50 to 100) kHz	3 mV/V + 15 mV		
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	5.4 % of reading	3400B Multimeter
AC Current – Source <sup>1</sup>	0 to 220 $\mu$ A		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	230 $\mu$ A/A + 17 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 10 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 8.4 nA	
	(1 to 5) kHz	266 $\mu$ A/A + 12.5 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 66 nA	
	220 $\mu$ A to 2.2 mA		
	(10 to 20) Hz	233 $\mu$ A/A + 42 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 34 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 34 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 109 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 655 nA	



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source <sup>1</sup>	(2.2 to 22) mA		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	233 $\mu$ A/A + 422 nA	
	(20 to 40) Hz	149 $\mu$ A/A + 342 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 343 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 588 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 5 $\mu$ A	
	(22 to 220) mA		
	(10 to 20) Hz	233 $\mu$ A/A + 4.2 $\mu$ A	
	(20 to 40) Hz	149 $\mu$ A/A + 3.4 $\mu$ A	
	40 Hz to 1 kHz	108 $\mu$ A/A + 2.6 $\mu$ A	
	(1 to 5) kHz	183 $\mu$ A/A + 3.4 $\mu$ A	
	(5 to 10) kHz	915 $\mu$ A/A + 10 $\mu$ A	
	(0.22 to 2.2) A		
	20 Hz to 1 kHz	249 $\mu$ A/A + 34 $\mu$ A	
(1 to 5) kHz	383 $\mu$ A/A + 83 $\mu$ A		
(5 to 10) kHz	5.8 mA/A + 166 $\mu$ A		
AC Current - Source Fixed Values <sup>1</sup>	1 kHz		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 $\mu$ A	7.3 nA	
	100 $\mu$ A	14 nA	
	1 mA	85 nA	
AC Current – Source <sup>1</sup>	10 mA	0.87 $\mu$ A	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
	100 mA	8.7 $\mu$ A	
	1 A	200 $\mu$ A	
	(10 to 20) A		
	(45 to 65) Hz	0.3 % of reading + 3.7 mA	
	(65 to 100) Hz	0.31 % of reading + 24 mA	
	(100 to 440) Hz	0.33 % of reading + 50 mA	
	(20 to 100) A		
	(45 to 65) Hz	0.85 % of reading + 3.6 mA	
	(65 to 100) Hz	0.85 % of reading + 29 mA	
	(100 to 440) Hz	0.85 % of reading + 100 mA	
	(100 to 1 000) A		
(45 to 65) Hz	0.85 % of reading + 3.6 mA		
(65 to 100) Hz	0.85 % of reading + 28 mA		
(100 to 440) Hz	1 % of reading + 0.25 A		



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 0.039 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.04 $\mu$ A	
	(45 to 100) Hz	0.065 % of reading + 0.04 $\mu$ A	
	100 Hz to 5 kHz	0.67 % of reading + 0.04 $\mu$ A	
	100 $\mu$ A to 1 mA		
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A	
	(1 to 10) mA		
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A		
100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A		
(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A		
(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A		
(50 to 100) kHz	0.63 % of reading + 0.17 mA		
100 mA to 1 A			
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
AC Current – Measure <sup>1</sup>	(1 to 3) A		Keysight 34401A Multimeter
	(3 to 10) Hz	1.3 % of reading + 2.1 mA	
	(10 to 40) Hz	0.39 % of reading + 2.2 mA	
	40 Hz to 300 kHz	0.17 % of reading + 2.1 mA	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	1 mΩ	0.07 % of reading	Standard Resistor Sets 16074A 42030A 16340A 16353A
	10 mΩ	0.11 % of reading	
	100 mΩ	0.66 % of reading	
	1 Ω	63 μΩ/Ω	
	10 Ω	38 μΩ/Ω	
	100 Ω	30 μΩ/Ω	
	1 kΩ	29 μΩ/Ω	
	10 kΩ	29 μΩ/Ω	
	100 kΩ	2.1 μΩ/Ω	
	1 MΩ	8 μΩ/Ω	
	10 MΩ	16 μΩ/Ω	
	100 MΩ	96 μΩ/Ω	
	1 GΩ	240 μΩ/Ω	
	10 GΩ	590 μΩ/Ω	
100 GΩ	560 μΩ/Ω		
Capacitance - Source Fixed Points <sup>1</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
	(10 to 13) MHz	2.2 fF	
	100 pF		
1 kHz to 3 MHz	14 fF		
(3 to 4) MHz	17 fF		
(4 to 5) MHz	20 fF		
(5 to 10) MHz	37 fF		
(10 to 13) MHz	53 fF		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance - Source Fixed Points <sup>1</sup>	1 000 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
	120 Hz to 100 kHz	1.5 pF	
100 nF	120 Hz to 100 kHz	15 pF	
1 μF	120 Hz to 1 kHz	0.52 nF	
	(1 to 10) kHz	0.43 nF	
	(10 to 100) kHz	0.72 nF	
Capacitance - Source Fixed Points <sup>1</sup>	10 μF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 kHz	1.6 nF	
	(1 to 20) kHz	2.2 nF	
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.1 mF/F + 7.7 pF	Fluke 5520A or 5522A Multiproduct 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 + 83 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 10.00) 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	



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Electrical – DC/Low Frequency

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 58	
	(10 to 13) MHz	0.000 86	
	10 nF		
	120 Hz to 1 kHz	0.000 024	
(1 to 100) kHz	0.000 021		
100 nF			
120 Hz to 1 kHz	0.000 04		
(1 to 100) kHz	0.000 021		
1 μF			
120 Hz to 1 kHz	0.000 041		
(1 to 10) kHz	0.000 035		
(10 to 100) kHz	0.000 11		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	10 $\mu$ F		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	(20 to 120) Hz	0.000 04	
	120 Hz to 10 kHz (10 to 100) kHz	0.000 03 0.000 76	

Electrical – RF/Microwave

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power - Power Meter Reference <sup>1</sup>	1 mW, 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(-22 to +10) dBm	0.17 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-42 to -22) dBm	0.18 dB	
	(-50 to -42) dBm	0.2 dB	
	(-60 to -50) dBm	0.21 dB	
	(-72 to -60) dBm	0.22 dB	
	(-80 to -72) dBm	0.23 dB	
	(-92 to -80) dBm	0.24 dB	
	(-102 to -92) dBm	0.27 dB	
	(-110 to -102) dBm	0.28 dB	
Tuned RF Power - Relative – Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(-120 to -110) dBm	0.31 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-127 to -120) dBm	0.34 dB	
	(+2 to +10) dBm	0.08 dB	
	(-12 to +2) dBm	0.07 dB	
	(-22 to -12) dBm	0.08 dB	
	(-31 to -22) dBm	0.09 dB	
	(-40 to -30) dBm	0.1 dB	
	(-50 to -40) dBm	0.12 dB	
	(-61 to -50) dBm	0.15 dB	
	(-71 to -61) dBm	0.16 dB	
	(-80 to -71) dBm	0.17 dB	
(-90 to -80) dBm	0.19 dB		
(-100 to -90) dBm	0.22 dB		
(-110 to -100) dBm	0.23 dB		
(-120 to -110) dBm	0.27 dB		
(-127 to -120) dBm	0.3 dB		



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Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz	0.082 dB	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	0.02 V ≤ V < 7 V 10 MHz ≤ f ≤ 50 MHz	0.16 dB	
	0.02 V ≤ V < 7 V 50 MHz ≤ f ≤ 80 MHz	0.4 dB	
	V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz	0.017 mV	
	20 kHz < f ≤ 50 kHz	0.021 mV	
	50 kHz < f ≤ 100 kHz	0.05 mV	
	100 kHz < f ≤ 300 kHz	0.38 mV	
RF Absolute Power - Source <sup>1</sup>	10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz	0.029 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	40 Hz ≤ f ≤ 1 kHz	0.028 mV	
	1 kHz < f ≤ 20 kHz	0.032 mV	
	20 kHz < f ≤ 50 kHz	0.045 mV	
	50 kHz < f ≤ 100 kHz	0.08 mV	
	100 kHz < f ≤ 300 kHz	0.3 mV	
	100 mV < V ≤ 1 V 20 Hz ≤ f ≤ 1 kHz	0.7 mV	
	1 kHz < f ≤ 20 kHz	0.72 mV	
	20 kHz < f ≤ 50 kHz	0.79 mV	
	50 kHz < f ≤ 100 kHz	1.3 mV	
	100 kHz < f ≤ 300 kHz	3.7 mV	
	1 V < V ≤ 3.5 V 20 Hz ≤ f ≤ 40 Hz	2.2 mV	
	40 Hz ≤ f ≤ 1 kHz	2.1 mV	
	1 kHz < f ≤ 20 kHz	2.2 mV	
20 kHz < f ≤ 50 kHz	2.5 mV		
50 kHz < f ≤ 100 kHz	4 mV		
100 kHz < f ≤ 300 kHz	13 mV		



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Electrical – RF/Microwave

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source <sup>1</sup>	-7 dBm ≥ P ≥ 0 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz 0 dBm > P ≥ -25 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -25 dBm > P ≥ -70 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -70 dBm > P ≥ -95 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -95 dBm > P ≥ -125 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz	0.49 dB 0.58 dB 0.69 dB 0.79 dB 0.49 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.59 dB 0.69 dB 0.8 dB 0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
Amplitude Modulation – Measure <sup>1</sup> (0.15 to 10) MHz (0.01 to 1.3) GHz (1.3 to 26.5) GHz	(> 0 to 99) % Depth Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	2.1 % Depth 1.1 % Depth 1.6 % Depth	Agilent 8902A Measuring Receiver
Amplitude Modulation – Measure <sup>1</sup> (0.1 to 10) MHz (0.01 to 3) GHz (3 to 26.5) GHz (26.5 to 31.15) GHz (31.5 to 50) GHz	(> 0 to 99) % Depth Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	0.8 % Depth 0.5 % Depth 1.5 % Depth 1.9 % Depth 6.1 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency Modulation – Measure <sup>1</sup> (0.25 to 10) MHz (0.01 to 26.5) GHz	≤40 kHz Peak Rate: (0.02 to 10) kHz ≤400 kHz Peak Rate: (0.05 to 100) kHz	2.2 % Deviation  1.2 % Deviation	Agilent 8902A Measuring Receiver
Frequency Modulation – Measure <sup>1</sup> (0.25 to 10) MHz (0.01 to 50) GHz	≤400 kHz Peak Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	1.1 % Deviation 1.1 % Deviation	Agilent E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude (EVM)	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180 ° rms Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.17 ° 0.34 ° 0.57 °	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: f ≤ 100 kHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	8.6 E-5 ρ 0.000 43 ρ 0.000 68 ρ 0.000 84 ρ 0.001 2 ρ 0.001 6 ρ	HP 89441A Vector Signal Analyzer

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $100 \text{ kHz} \leq f \leq 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $f > 1 \text{ MHz}$ $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$9.6 \text{ E-5 } \rho$ $0.00048 \rho$ $0.00076 \rho$ $0.00094 \rho$ $0.0014 \rho$ $0.0018 \rho$ $1.6 \text{ E-4 } \rho$ $0.00082 \rho$ $0.0013 \rho$ $0.0016 \rho$ $0.0024 \rho$ $0.003 \rho$	<p style="text-align: center;">HP 89441A Vector Signal Analyzer</p>
Phase Modulation – Measure <sup>1</sup>	$(0.15 \text{ to } 10) \text{ MHz}$ Rate: $(0.02 \text{ to } 10) \text{ kHz}$ , $< 40 \text{ Radians Deviation}$ $(0.01 \text{ to } 26.5) \text{ GHz}$ Rate: $(0.2 \text{ to } 20) \text{ kHz}$ $< 40 \text{ Radians Deviation}$	<p style="text-align: center;"><math>4.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p>	<p style="text-align: center;">HP 8902A Measuring Receiver</p>
Phase Modulation – Measure <sup>1</sup>	$100 \text{ kHz to } 6.6 \text{ GHz}$ Deviations: $(0.3 \text{ to } 7) \text{ rad}$ Deviations: $> 7 \text{ rad}$ $(6.6 \text{ to } 13.2) \text{ GHz}$ Deviations: $(0.6 \text{ to } 2) \text{ rad}$ Deviations: $> 2 \text{ rad}$ Deviations: $(1.2 \text{ to } 4) \text{ rad}$ Deviations: $(26.5 \text{ to } 31.5) \text{ GHz}$ Deviations: $> 4 \text{ rad}$ Deviations: $(1.3 \text{ to } 4) \text{ rad}$ Deviations: $(31.5 \text{ to } 50) \text{ GHz}$ Deviations: $> 4 \text{ rad}$ Deviations $(2.4 \text{ to } 8) \text{ rad}$ Deviations: $> 8 \text{ rad}$	<p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>3.1 \% \text{ Deviation}</math></p> <p style="text-align: center;"><math>1 \% \text{ Deviation}</math></p>	<p style="text-align: center;">Keysight E444xA with Opt. 233 Spectrum Analyzer</p>

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Noise for Signal Analyzers Carrier 1 GHz Offsets: 100 kHz	(-167 to -89) dBc/Hz Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System
Distortion Measure <sup>1</sup>	(-99.99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	Attenuation – Source <sup>1</sup>											
Reference Standard, Method, and/or Equipment	8496H Attenuator											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2	
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18	
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19	
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24	
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24	
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37	
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	20	30	40	50	60	70	80	90	100	110	
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19	
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16	
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14	
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25	
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33	
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47	
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-	
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-	

Electrical – RF/Microwave

Tlaquepaque, JL

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

Electrical – RF/Microwave

Tlaquepaque, JL

<b>Parameter/ Equipment</b>	RF Power Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Power Range	Frequency Ranges (uncertainties in dB)											
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz	
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
-1 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1	
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, V8486A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	-	-	-
-130 dBm ≤ P < -110 dBm	0.1	0.09	0.09	0.09	0.09	-	-	-	-	-	-
-110 dBm ≤ P < -90 dBm	0.08	0.08	0.08	0.08	0.08	-	-	-	-	-	-
-90 dBm ≤ P < -30 dBm	0.07	0.06	0.06	0.06	0.06	-	-	-	-	-	-
-30 dBm ≤ P < -20 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-20 dBm ≤ P < -10 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-10 dBm ≤ P < 0 dBm	0.07	0.06	0.06	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-1 dBm ≤ P < 2 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, V8486A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
2 dBm ≤ P < 10 dBm	0.13	0.15	0.15	0.21	0.23	0.34	0.33	0.29	0.34	0.3	0.34
10 dBm ≤ P < 15 dBm	0.07	0.06	0.06	0.06	0.06	0.34	0.34	0.3	0.34	0.3	0.35
15 dBm ≤ P < 20 dBm	0.08	0.07	0.07	0.07	0.07	0.34	0.34	0.3	0.34	0.3	0.35
20 dBm ≤ P < 30 dBm	0.172	-	-	-	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment	RF Power Measure <sup>1</sup>				
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, V8486A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors				
Range	Expanded Uncertainty of Measurement (+/-)				
Power Range	Frequencies / Frequency Ranges (dB)				
	f = 62 GHz	63 GHz ≤ f ≤ 64 GHz	f = 65 GHz	f = 66 GHz	f = 67 GHz
-30 dBm ≤ P < -20 dBm	0.34	0.33	0.29	0.35	0.36
-20 dBm ≤ P < -10 dBm	0.34	0.33	0.29	0.35	0.36
-10 dBm ≤ P < 0 dBm	0.34	0.33	0.29	0.35	0.36
-1 dBm ≤ P < 2 dBm	0.34	0.33	0.29	0.35	0.36
2 dBm ≤ P < 10 dBm	0.34	0.33	0.29	0.35	0.36
10 dBm ≤ P < 15 dBm	0.34	0.34	0.2	0.36	0.36
15 dBm ≤ P < 20 dBm	0.34	0.34	0.2	0.36	0.36

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.0025	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2

**Electrical – RF/Microwave**

Tlaquepaque, JL

<b>Parameter/ Equipment</b>	S11 - Reflection Phase <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Degrees)									
	≤ 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
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Tlaquepaque, JL

<b>Parameter/ Equipment</b>	S21 - Transmission Magnitude <sup>1,2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
(20 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78	

**Electrical – RF/Microwave**

Tlaquepaque, JL

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Tlaquepaque, JL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Source <sup>1</sup>	10 MHz	6.5 x 10 <sup>-11</sup> Hz	Symmetricon 8040C GPS Disciplined
Frequency - Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter
Pulse - Measure <sup>1</sup> RMS Jitter - Period, Delay and Width	33 MHz to 3 GHz	6.6 ps	HP 54124T or HP 86100

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**Services performed at satellite laboratory  
(AC-1498.14)**

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**Electrical - DC/Low Frequency**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV 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 + 0.54 µV 5 µV/V + 0.8 µV 3.5 µV/V + 0.4 µV 3.6 µV/V + 4.5 µV 5.3 µV/V + 23 µV 7.1 µV/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source Fixed Points	1 mV 10 mV	15 µV 110 nV	Fluke 57x0A Calibrator Fluke 742A Resistors
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 µV 11 µV 150 µV 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	Up to 100 mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 µV/V + 0.36 µV 3.7 µV/V + 0.35 µV 3.1 µV/V + 0.59 µV 5.3 µV/V + 36 µV 5.3 µV/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 µV/V + 62 nV 0.37 µV/V + 124 nV 62 nV/V + 0.62 µV 0.62 µV/V + 12 µV 1.9 µV/V + 63 µV	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(0 to 220) µA 220 µA to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A 1 A to 2.2 A	35 µA/A 29 µA/A 37 µA/A 50 µA/A - 1.2 µA 59 µA/A + 12 µA 120 µA/A - 42 µA	Fluke 57x0A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 µA/A + 41 µA	Fluke 5725A Amplifier

**Electrical - DC/Low Frequency**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup> Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$	Fluke 5720A Multiproduct Calibrator

**Electrical - DC/Low Frequency**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	190 kΩ 1 MΩ 1.9 MΩ 10 MΩ 19 MΩ 10 MΩ 100 MΩ	2.2 Ω 20 Ω 42 Ω 0.4 kΩ 1.5 kΩ 0.4 kΩ 12 kΩ	Fluke 5720A Multiproduct Calibrator
Resistance - Source <sup>1</sup> Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Source <sup>1</sup>	(0 to 11) Ω (11 to 110) Ω (0.11 to 1.1) kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 110) kΩ (0.11 to 1.1) MΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ	33 μΩ/Ω + 8.3 mΩ 25 μΩ/Ω + 12.5 mΩ 23 μΩ/Ω + 17 mΩ 23 μΩ/Ω + 170 mΩ 23 μΩ/Ω + 84 mΩ 23 μΩ/Ω + 0.84 Ω 27 μΩ/Ω + 8 Ω 50 μΩ/Ω + 125 Ω 110 μΩ/Ω + 0.2 kΩ 210 μΩ/Ω + 2 kΩ 410 μΩ/Ω + 2.8 kΩ	Fluke 5520A Multiproduct Calibrator
Resistance – Source <sup>1</sup>	(110 to 330) MΩ (330 to 1 100) MΩ	2.5 mΩ/Ω + 83 kΩ 13 mΩ/Ω + 0.4 MΩ	Fluke 5520A Multiproduct Calibrator
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 MΩ to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter



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Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V}/\text{V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V}/\text{V} + 210 \mu\text{V}$	
(100 to 300) kHz	930 $\mu\text{V}/\text{V} + 600 \mu\text{V}$		
(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$		
220 mV to 2.2 V			
(10 to 20) Hz	251 $\mu\text{V}/\text{V} + 39 \mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	46 $\mu\text{V}/\text{V} + 9 \mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V}/\text{V} + 10 \mu\text{V}$		
(50 to 100) kHz	103 $\mu\text{V}/\text{V} + 204 \mu\text{V}$		
(100 to 300) kHz	287 $\mu\text{V}/\text{V} + 611 \mu\text{V}$		
(300 to 500) kHz	1.0 mV/V + 2.1 mV		
500 kHz to 1 MHz	1.6 mV/V + 3.3 mV		



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Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) V		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	251 $\mu\text{V/V} + 390 \mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V} + 156 \mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V} + 48 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 107 \mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V} + 42 \mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V} + 97 \mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.2 \text{ mV}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 1.6 \text{ mV}$	
	40 Hz to 20 kHz	54 $\mu\text{V/V} + 0.68 \text{ mV}$	
	(20 to 50) kHz	83 $\mu\text{V/V} + 1 \text{ mV}$	
	(50 to 100) kHz	156 $\mu\text{V/V} + 2.6 \text{ mV}$	
(100 to 300) kHz	941 $\mu\text{V/V} + 16 \text{ mV}$		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V		Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
	40 Hz to 1 kHz	79.6 $\mu\text{V/V} + 18.3 \text{ mV}$	
	(1 to 20) kHz	173 $\mu\text{V/V} + 5.3 \text{ mV}$	
	(20 to 30) kHz	625 $\mu\text{V/V} + 11.5 \text{ mV}$	
	(220 to 750) V		
(30 to 50) kHz	634 $\mu\text{V/V} + 5.45 \text{ mV}$		
(50 to 100) kHz	2.42 mV/V + 28 mV		
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$		
500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$		



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Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(2.2 to 22) mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V/V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V/V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V/V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V/V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	43 $\mu\text{V/V} + 8.8 \mu\text{V}$	
	(20 to 50) kHz	70 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	89 $\mu\text{V/V} + 30 \mu\text{V}$	
	(100 to 300) kHz	350 $\mu\text{V/V} + 83 \mu\text{V}$	
	(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$	
2.2 V to 22 V			
(10 to 20) Hz	251 $\mu\text{V/V} + 392 \mu\text{V}$		
(20 to 40) Hz	93.8 $\mu\text{V/V} + 156 \mu\text{V}$		
40 Hz to 20 kHz	43.9 $\mu\text{V/V} + 48.36 \mu\text{V}$		
(20 to 50) kHz	69.7 $\mu\text{V/V} + 107 \mu\text{V}$		
(50 to 100) kHz	86.3 $\mu\text{V/V} + 213 \mu\text{V}$		
(100 to 300) kHz	265 $\mu\text{V/V} + 623 \mu\text{V}$		
(300 to 500) kHz	1.04 mV/V + 2.08 mV		
500 kHz to 1 MHz	1.56 mV/V + 3.33 mV		



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Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	22 V to 220 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	250 $\mu$ V/V + 4.17 mV 93.8 $\mu$ V/V + 15.6 mV 53.9 $\mu$ V/V + 0.68 mV 83.3 $\mu$ V/V + 1.05 mV 156 $\mu$ V/V + 2.62 mV 941 $\mu$ V/V + 16 mV 4.58 mV/V + 41.7 mV 8.33 mV/V + 83.4 mV	Fluke 5730A Multiproduct Calibrator
	220 V to 1100 V (15 to 50) Hz 50 Hz to 1 kHz	313 $\mu$ V/V + 16.6 mV 72.9 $\mu$ V/V + 3.65 mV	
AC Voltage – Source <sup>1</sup>	220 V to 1100 V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	79.6 $\mu$ V/V + 18.3 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 11.5 mV	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	220 to 750 V (30 to 50) kHz (50 to 100) kHz	634 $\mu$ V/V + 5.45 mV 2.42 mV/V + 28 mV	
AC Voltage - Source Fixed Values at Fixed Frequencies <sup>1</sup>	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz	870 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V	Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV	

Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source Fixed Values at Fixed Frequencies <sup>1</sup>	1 V		Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	480 $\mu$ V	
	20 Hz	270 $\mu$ V	
	40 Hz	230 $\mu$ V	
	200 Hz	460 $\mu$ V	
	500 Hz	450 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	6.3 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz		4.6 mV/V	
		6.2 mV/V	
		8 mV/V	
		24 mV/V	
1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz		2.2 mV/V	
		3.7 mV/V	
		5.5 mV/V	
		14 mV/V	
AC Voltage Flatness – Source <sup>1</sup>	3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	9 kHz to 2 GHz (-60 to 25) dBm	0.026 dB	Agilent E9304A, Agilent N1914A, Agilent 8491B, Agilent 3458A
AC Voltage - Measure	Up to 10 mV (1 to 40) Hz	0.3 mV/V + 3.1 $\mu$ V	Keysight 3458A Multimeter
	40 Hz to 1 kHz	0.2 mV/V + 1.2 $\mu$ V	
	(1 to 20) kHz	0.3 mV/V + 1.7 $\mu$ V	
	(20 to 50) kHz	1 mV/V + 1.6 $\mu$ V	
	(50 to 100) kHz	5 mV/V + 1.3 $\mu$ V	
	(100 to 300) kHz	40 mV/V + 2.1 $\mu$ V	
	300 kHz to 1 MHz	12 mV/V + 6.6 $\mu$ V	
	(1 to 4) MHz	70 mV/V + 7.5 $\mu$ V	
(4 to 8) MHz	20 mV/V + 8.2 $\mu$ V		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	(0.1 to 1) V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.30 mV/V + 0.25 mV	
	(50 to 100) kHz	0.80 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Electrical - DC/Low Frequency

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV	Keysight 3458A Multimeter
	(100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	3 % of reading	Keysight DSO 8104A Oscilloscope
AC Current Source <sup>1</sup>	(0 to 220) $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA	Fluke 5720A or 5730A Multiproduct Calibrator
	220 $\mu$ A 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	233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA	
	(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	233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A	
	(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	233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(0 to 0.33) mA (10 to 30) kHz (0.33 to 3.3) mA (10 to 30) kHz (3.3 to 33) mA (10 to 30) kHz (33 to 330) mA (10 to 30) kHz (2.2 to 20.5) A (45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	10 mA/A + 330 nA 6.6 mA/A + 550 nA 2.7 mA/A + 2.7 $\mu$ A 2.7 mA/A + 160 $\mu$ A 830 mA/A + 4.2 mA 1.1 mA/A + 3.9 mA 21 mA/A + 1 mA	Fluke 552xA Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A 45 Hz to 65 Hz 65 Hz to 440 Hz (20 to 100) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.3 % of reading + 27 mA 0.88 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
AC Current – Source <sup>1</sup>	(100 to 1 000) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
AC Current – Source <sup>1</sup> Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter



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Electrical - DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 0.039 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.04 $\mu$ A	
	(45 to 100) Hz	0.065 % of reading + 0.04 $\mu$ A	
	100 Hz to 5 kHz	0.67 % of reading + 0.04 $\mu$ A	
	100 $\mu$ A to 1mA		
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A	
	(1 to 10) mA		
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A		
100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A		
(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A		
(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A		
(50 to 100) kHz	0.63 % of reading + 0.17 mA		
100 mA to 1 A			
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
AC Current – Measure <sup>1</sup>	(1 to 3) A		Keysight 34401 Multimeter
	(3 to 10) Hz	1.3 % of reading + 2.1 mA	
	(10 to 40) Hz	0.39 % of reading + 2.2 mA	
	40 Hz to 300 kHz	0.17 % of reading + 2.1 mA	

Electrical - DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	1 mΩ	0.75 % of reading	Standard Resistor Sets 16074A, 42030A 16340A, 16353A
	10 mΩ	1.1 % of reading	
	100 mΩ	7 % of reading	
	1 Ω	63 μΩ/Ω	
	10 Ω	38 μΩ/Ω	
	100 Ω	30 μΩ/Ω	
	1 kΩ	29 μΩ/Ω	
	10 kΩ	29 μΩ/Ω	
	100 kΩ	2.1 μΩ/Ω	
	1 MΩ	8 μΩ/Ω	
	10 MΩ	16 μΩ/Ω	
	100 MΩ	96 μΩ/Ω	
	1 GΩ	240 μΩ/Ω	
	10 GΩ	590 μΩ/Ω	
100 GΩ	560 μΩ/Ω		
Capacitance – Source Fixed Points <sup>1</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	(1 to 2) MHz	0.31 fF	
	(2 to 3) MHz	0.49 fF	
	(3 to 4) MHz	0.68 fF	
	(4 to 5) MHz	0.9 fF	
	(5 to 10) MHz	2.5 fF	
	(10 to 13) MHz	3.8 fF	
	10 pF		
	1 kHz to 5 MHz	1.5 fF	
	(5 to 10) MHz	2 fF	
	(10 to 13) MHz	2.2 fF	
	100 pF		
	1 kHz to 3 MHz	14 fF	
	(3 to 4) MHz	17 fF	
(4 to 5) MHz	20 fF		
(5 to 10) MHz	37 fF		
(10 to 13) MHz	53 fF		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source Fixed Points <sup>1</sup>	1 000 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
	120 Hz to 100 kHz	1.5 pF	
100 nF	120 Hz to 100 kHz	15 pF	
	1 μF		
120 Hz to 1 kHz	(1 to 10) kHz	0.52 nF	
	(10 to 100) kHz	0.43 nF	
		0.72 nF	
10 μF	20 Hz to 1 kHz	1.6 nF	
	(1 to 20) kHz	2.2 nF	
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.2 mF/F + 8.3 pF	Fluke 5520A, Fluke 5522A Multiproduct Calibrators
	(3.3 to 10.99) nF	1.6 mF/F + 8.3 pF	
	(11 to 109.99) nF	1.6 mF/F + 83 pF	
	(110 to 329.99) nF	1.6 mF/F + 0.25 nF	
	(0.33 to 1.099) μF	1.6 mF/F + 0.83 nF	
	(1.1 to 3.299) μF	1.6 mF/F + 2.5 nF	
	(3.3 to 10.99) μF	1.6 mF/F + 8.3 nF	
	(11 to 32.99) μF	2.5 mF/F + 25 nF	
	(33 to 109.99) μF	2.8 mF/F + 84 nF	
	(110 to 329.99) μF	2.8 mF/F + 0.25 μF	
	(0.33 to 1.099) mF	4 mF/F + 1.2 μF	
	(1.1 to 3.299) mF	4 mF/F + 3.6 μF	
	(3.3 to 10.00) mF	4 mF/F + 12 μF	
	(11 to 32.99) mF	8.3 mF/F + 36 μF	
(33 to 110) mF	12 mF/F + 0.11 mF		
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	10 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
	(10 to 13) MHz	0.000 24	
	1 000 pF		
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 58	
	(10 to 13) MHz	0.000 86	
	10 nF		
	120 Hz to 1 kHz	0.000 024	
	(1 to 100) kHz	0.000 021	
	100 nF		
	120 Hz to 1 kHz	0.000 04	
(1 to 100) kHz	0.000 021		
1 μF			
120 Hz to 1 kHz	0.000 041		
(1 to 10) kHz	0.000 035		
(10 to 100) kHz	0.000 11		
10 μF			
(20 to 120) Hz	0.000 04		
120 Hz to 10 kHz	0.000 03		
(10 to 100) kHz	0.000 76		

Electrical - DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1 800) °C	0.53 °C	
	(1 800 to 2 316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1 000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
(-200 to -100) °C	0.35 °C		
(-100 to -25) °C	0.2 °C		
(-25 to 120) °C	0.18 °C		
(120 to 1 000) °C	0.28 °C		
(1 000 to 1 372) °C	0.42 °C		
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		
Type N			
(-200 to -100) °C	0.42 °C		
(-100 to -25) °C	0.24 °C		
(-25 to 120) °C	0.21 °C		
(120 to 410) °C	0.2 °C		
(410 to 1 300) °C	0.29 °C		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type R		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(0 to 250) °C	0.6 °C	
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
	Type S		
	(0 to 250) °C	0.5 °C	
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
	(1 400 to 1 767) °C	0.49 °C	
	Type T		
	(-250 to -150) °C	0.66 °C	
	(-150 to 0) °C	0.26 °C	
(0 to 120) °C	0.18 °C		
(120 to 400) °C	0.16 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		

Electrical - RF/Microwave

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth		N9030A or N9030B Signal Analyzer
	1 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.037 % Depth	
	(6 to 50) GHz	0.038 % Depth	
	4.3 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.026 % Depth	
(6 to 50) GHz	0.03 % Depth		

**Electrical - RF/Microwave**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 10 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 100 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 3 MHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth 0.028 % Depth 0.036 % Depth 0.036 % Depth 0.084 % Depth	N9030A or N9030B Signal Analyzer
Frequency Modulation – Measure <sup>1,3</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz Modulation Index (0.2 to 100) (100 to 2 000) (3.6 to 8.4) GHz Modulation Index (0.2 to 100) (100 to 2 000) (8.4 to 17.1) GHz Modulation Index (0.2 to 100) (100 to 2 000) (17.1 to 34.5) GHz Modulation Index (0.2 to 100) (100 to 2 000) (34.5 to 50) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading 0.7 % of reading + 0.2 %M 2 % of reading 0.7 % of reading + 0.3 %M 2.5 % of reading 0.8 % of reading + 0.3 %M 3 % of reading 1.4 % of reading + 0.5 %M 4 % of reading	N9030A with Opt. TES or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15)% GSM rms residual phase error (0 to 1)° GSM peak residual phase error (0 to 3)°	0.015 % of reading 0.015° 0.12°	N9030A or N9030B Signal Analyzer

**Electrical - RF/Microwave**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2)% (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5)% (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5)% (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5)% (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5)% (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2)%	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2)%	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2)%	0.035 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2)%	0.044 % of reading	N9030A or N9030B Signal Analyzer
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 10) rad 2 MHz to 3.6 GHz (3.6 to 13.6) GHz (13.6 to 17.1) GHz (17.1 to 26.5) GHz (26.5 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.002 rad 0.1 % of reading + 0.003 rad 0.1 % of reading + 0.004 rad 0.1 % of reading + 0.006 rad 0.1 % of reading + 0.009 rad 0.1 % of reading + 0.01 rad	N9030A with Opt. TES Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Distortion Measure <sup>1</sup>	(-99.99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power – Source <sup>1</sup>	0.02 V ≤ V < 7 V f < 10 MHz 10 MHz ≤ f ≤ 50 MHz 50 MHz ≤ f ≤ 80 MHz	0.082 dB 0.16 dB 0.4 dB	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	$V \leq 10 \text{ mV}$		Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	$20 \text{ Hz} \leq f \leq 20 \text{ kHz}$	0.017 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.021 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	0.05 mV	
	$100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.38 mV	
	$10 \text{ mV} < V \leq 100 \text{ mV}$		
	$20 \text{ Hz} \leq f \leq 40 \text{ Hz}$	0.029 mV	
	$40 \text{ Hz} \leq f \leq 1 \text{ kHz}$	0.028 mV	
	$1 \text{ kHz} < f \leq 20 \text{ kHz}$	0.032 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.045 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	0.08 mV	
	$100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.3 mV	
	$100 \text{ mV} < V \leq 1 \text{ V}$		
	$20 \text{ Hz} \leq f \leq 1 \text{ kHz}$	0.7 mV	
	$1 \text{ kHz} < f \leq 20 \text{ kHz}$	0.72 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.79 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	1.3 mV	
$100 \text{ kHz} < f \leq 300 \text{ kHz}$	3.7 mV		
$1 \text{ V} < V \leq 3.5 \text{ V}$			
$20 \text{ Hz} \leq f \leq 40 \text{ Hz}$	2.2 mV		
$40 \text{ Hz} \leq f \leq 1 \text{ kHz}$	2.1 mV		
$1 \text{ kHz} < f \leq 20 \text{ kHz}$	2.2 mV		
$20 \text{ kHz} < f \leq 50 \text{ kHz}$	2.5 mV		
$50 \text{ kHz} < f \leq 100 \text{ kHz}$	4 mV		
$100 \text{ kHz} < f \leq 300 \text{ kHz}$	13 mV		
RF Absolute Power – Source <sup>1</sup>	$7 \text{ dBm} \geq P \geq 0 \text{ dBm}$		Signal Source PSG, ESG, E4438C, E4428C
	$0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$	0.49 dB	
	$1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$	0.58 dB	
	$2.985 \text{ GHz} < f \leq 4 \text{ GHz}$	0.69 dB	
	$4 \text{ GHz} < f \leq 6 \text{ GHz}$	0.79 dB	
	$0 \text{ dBm} > P \geq -25 \text{ dBm}$		
	$0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$	0.49 dB	
	$1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$	0.59 dB	
	$2.985 \text{ GHz} < f \leq 4 \text{ GHz}$	0.69 dB	
	$4 \text{ GHz} < f \leq 6 \text{ GHz}$	0.8 dB	
	$-25 \text{ dBm} > P \geq -70 \text{ dBm}$		
	$0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$	0.5 dB	
	$1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$	0.59 dB	
$2.985 \text{ GHz} < f \leq 4 \text{ GHz}$	0.69 dB		
$4 \text{ GHz} < f \leq 6 \text{ GHz}$	0.8 dB		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	-70 dBm > P ≥ -95 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz -95 dBm > P ≥ -125 dBm 0.3 MHz ≤ f ≤ 1.1 GHz 1.1 GHz ≤ f ≤ 2.985 GHz 2.985 GHz < f ≤ 4 GHz 4 GHz < f ≤ 6 GHz	0.5 dB 0.6 dB 0.7 dB 0.8 dB 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG, E4438C, E4428C
Pulse – Source Width <sup>1</sup>	150 ps to 10 ns (10 to 100) ns 100 μs to 10 ms (10 to 100) ms (100 to 0.99) ms	0.13 ns (0.013 * Width) + 1.2 ns (0.013 * Width) + 0.14 μs (0.012 * Width) + 2 ns (0.012 * Width) + 0.19 μs	HP 8133A Pulse Generator
RMS Jitter - Period, Delay and Width <sup>1</sup>	33 MHz to 3 GHz	10 ps	
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C Oscillator
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System
Thermal Noise – ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB	HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source

**Electrical - RF/Microwave**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermal Noise – ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB		HP 346B opt. 002 346B/N4001A opt. 001, 346B opt. 004 346C/N4002A Noise Source
	6 GHz	0.06 dB	
	7 GHz	0.06 dB	
	8 GHz	0.07 dB	
	9 GHz	0.06 dB	
	10 GHz	0.09 dB	
	11 GHz	0.07 dB	
	12 GHz	0.07 dB	
	13 GHz	0.07 dB	
	14 GHz	0.06 dB	
	15 GHz	0.06 dB	
	16 GHz	0.06 dB	
	17 GHz	0.07 dB	
	18 GHz	0.06 dB	
	19 GHz	0.13 dB	
	20 GHz	0.14 dB	
	21 GHz	0.14 dB	
	22 GHz	0.16 dB	
	23 GHz	0.17 dB	
24 GHz	0.14 dB		
25 GHz	0.13 dB		
26 GHz	0.15 dB		
26.5 GHz	0.15 dB		

**Electrical – RF/Microwave**

Barueri, SP

Parameter/Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074

**Electrical – RF/Microwave**

Barueri, SP

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Barueri, SP

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.073	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.060	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-10 dBm ≤ P < 0 dBm	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-1 dBm ≤ P < 2 dBm	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 10 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
10 dBm ≤ P < 15 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	0.096	0.081	0.081	0.081	0.083	0.091	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	0.090	0.087	0.0874	0.087	0.095	0.1	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	0.090	0.087	0.0874	0.087	0.095	0.095	0.1	0.1	0.1	0.012

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.10	0.10	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors							
Range	Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequencies / Frequency Ranges (dB)							
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(30 to 300) kHz	0.005 3	0.0057	0.006 5	0.007 9	0.009 6	0.012	0.014	0.017	0.021	0.025
300 kHz to 20 MHz	0.002 4	0.002 6	0.002 9	0.002 8	0.003 1	0.003 5	0.003 9	0.004 3	0.004 6	0.004 9
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Linear)									
	≤ 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
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(30 to 300) kHz	42	42	42	42	42	42	42	42	42	42
300 kHz to 20 MHz	0.91	0.55	0.43	0.38	0.34	0.32	0.3	0.29	0.28	0.27
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(30 to 300) kHz	0.047	0.047	0.047	0.047	0.026	0.027	0.029	0.032	0.065
300 kHz to 45 MHz	0.018	0.021	0.023	0.027	0.026	0.027	0.029	0.032	0.065
(45 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(30 to 300) kHz	0.46	0.46	0.46	0.46	0.23	0.23	0.23	0.23	0.58
300 kHz to 45 MHz	0.62	0.62	0.62	0.62	0.23	0.23	0.23	0.23	0.58
(45 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92

**Electrical – RF/Microwave**

Barueri, SP

Parameter/ Equipment	S21 - Transmission Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Time Interval – Measure <sup>1</sup>	10 ns to 10 s	2.9 ns	HP 5334B Counter connected to Time base (HP 5071A or Datum 8040)
Frequency – Source <sup>1</sup>	10 MHz	$6.5 \times 10^{-11}$ Hz	SRS FS7525 Frequency Standard
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	HP 53132A Counter + Frequency Reference Standard
Frequency – Measure <sup>1</sup>	50 MHz to 26.5 GHz	30 pHz/Hz + 3.8 Hz	HP 53151A + Frequency Reference Standard
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module

**Time and Frequency**

Barueri, SP

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4.0 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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**Electrical – DC/Low Frequency**

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage - Source	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage - Source Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V/V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current - Source	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 57x0A Multiproduct Calibrator with Fluke 5725A Amplifier



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current - Source	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
DC Current - Measure	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current - Measure	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 A to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$ 10 M $\Omega$ 19 M $\Omega$ 100 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$ 42 $\Omega$ 0.40 k $\Omega$ 1.5 k $\Omega$ 12 k $\Omega$	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
AC Voltage - Source	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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV 250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.4 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5720A Multiproduct Calibrator



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	103 $\mu\text{V/V} + 204 \mu\text{V}$	
	(100 to 300) kHz	287 $\mu\text{V/V} + 611 \mu\text{V}$	
	(300 to 500) kHz	1.0 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(2.2 to 22) V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 390 \mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V} + 156 \mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V} + 48 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 107 \mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V} + 42 \mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V} + 97 \mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
(22 to 220) V			
(10 to 20) Hz	250 $\mu\text{V/V} + 4.2 \text{ mV}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 1.6 \text{ mV}$		
40 Hz to 20 kHz	54 $\mu\text{V/V} + 0.68 \text{ mV}$		
(20 to 50) kHz	83 $\mu\text{V/V} + 1.1 \text{ mV}$		
(50 to 100) kHz	156 $\mu\text{V/V} + 2.6 \text{ mV}$		
(100 to 300) kHz	941 $\mu\text{V/V} + 16 \text{ mV}$		
(300 to 500) kHz	4.6 mV/V + 42 mV		
500 kHz to 1 MHz	8.3 mV/V + 83 mV		
(220 to 1 100) V			
40 Hz to 20 kHz	313 $\mu\text{V/V} + 17 \text{ mV}$		
(20 to 50) kHz	73 $\mu\text{V/V} + 3.7 \text{ mV}$		



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(100 to 220) 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	0.24 mV/V + 3.9 mV 0.10 mV/V + 1.5 mV 69 μV/V + 0.43 mV 0.17 mV/V + 0.56 mV 0.21 mV/V + 1.9 mV 0.87 mV/V + 16 mV 0.43 mV/V + 39 mV 7.9 mV/V + 79 mV	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage - Source	(220 to 1 100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	80 μV/V + 18 mV 173 μV/V + 5.3 mV 625 μV/V + 12 mV 634 μV/V + 5.5 mV 2.4 mV/V + 28 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
AC Voltage - Source	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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV 250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.4 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5730A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(22 to 220) mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V}/\text{V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V}/\text{V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V}/\text{V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V}/\text{V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	43 $\mu\text{V}/\text{V} + 8.8 \mu\text{V}$	
	(20 to 50) kHz	70 $\mu\text{V}/\text{V} + 10 \mu\text{V}$	
(50 to 100) kHz	89 $\mu\text{V}/\text{V} + 30 \mu\text{V}$		
(100 to 300) kHz	350 $\mu\text{V}/\text{V} + 83 \mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		
AC Voltage - Source Fixed Values, Fixed Frequencies	0.01 V		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	1 kHz	890 nV	
	20 kHz	1.2 $\mu\text{V}$	
	100 kHz	4.5 $\mu\text{V}$	
	300 kHz	33 $\mu\text{V}$	
	1 MHz	21 $\mu\text{V}$	
	4 MHz	140 $\mu\text{V}$	
	0.1 V		
	1 kHz	4.6 $\mu\text{V}$	
	20 kHz	6.9 $\mu\text{V}$	
	100 kHz	36 $\mu\text{V}$	
	300 kHz	52 $\mu\text{V}$	
	1 MHz	170 $\mu\text{V}$	
	4 MHz	670 $\mu\text{V}$	
8 MHz	690 $\mu\text{V}$		
10 MHz	2.3 mV		



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source Fixed Values, Fixed Frequencies	1 V		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	0.63 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness - Source	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV	4.6 mV/V	
	120 kHz to 2 MHz	6.2 mV/V	
	(2 to 10) MHz	8 mV/V	
	(10 to 20) MHz (20 to 30) MHz	24 mV/V	
AC Voltage Flatness - Source	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz	2.2 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	(2 to 10) MHz	3.7 mV/V	
	(10 to 20) MHz	5.5 mV/V	
	(20 to 30) MHz	14 mV/V	
	3 mV to 3.5 V 120 kHz to 2 MHz	1.2 mV/V	
	(2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.1 mV/V 3.8 mV/V 8.6 mV/V	
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A Multimeter
AC Voltage Flatness - Measure	Up to 3 V 10 Hz 100 Hz (10, 30) kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.20 mV/V + 6.9 $\mu$ V 80 $\mu$ V/V + 5.5 $\mu$ V 80 $\mu$ V/V + 3.2 $\mu$ V 0.1 mV/V + 8 $\mu$ V 0.1 mV/V + 5.2 $\mu$ V 0.1 mV/V + 6.5 $\mu$ V 1.3 mV/V + 59 $\mu$ V 1.3 mV/V + 0.11 mV 1.3 mV/V + 91 $\mu$ V 2.5 mV/V + 0.21 mV 2.5 mV/V + 0.24 mV 6.1 mV/V + 0.34 mV 9 mV/V + 0.24 mV 11 mV/V + 0.79 mV 13 mV/V + 0.94 mV	Agilent 11049A, Agilent 11050A, Agilent 11051A Thermal Voltage Converters



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	Up to 10 mV		Keysight 3458A Multimeter
	(1 to 40) Hz	0.3 mV/V + 3.1 $\mu$ V	
	40 Hz to 1 kHz	0.2 mV/V + 1.2 $\mu$ V	
	(1 to 20) kHz	0.3 mV/V + 1.7 $\mu$ V	
	(20 to 50) kHz	1 mV/V + 1.6 $\mu$ V	
	(50 to 100) kHz	5 mV/V + 1.3 $\mu$ V	
	(100 to 300) kHz	40 mV/V + 2.1 $\mu$ V	
	300 kHz to 1 MHz	12 mV/V + 6.6 $\mu$ V	
	(1 to 4) MHz	70 mV/V + 7.5 $\mu$ V	
	(4 to 8) MHz	20 mV/V + 8.2 $\mu$ V	
	(10 to 100) mV		
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V		
(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V		
(20 to 50) kHz	0.30 mV/V + 22 $\mu$ V		
(50 to 100) kHz	0.80 mV/V + 22 $\mu$ V		
(100 to 300) kHz	3 mV/V + 0.12 mV		
300 kHz to 1 MHz	10 mV/V + 0.30 mV		
(1 to 2) MHz	15 mV/V + 0.21 mV		
(2 to 4) MHz	40 mV/V + 0.73 mV		
(4 to 8) MHz	40 mV/V + 0.83 mV		
(8 to 10) MHz	0.15 V/V + 1 mV		



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(1 to 10) V		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.30 mV/V + 0.25 mV	
	(50 to 100) kHz	0.80 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
	(2 to 4) MHz	40 mV/V + 7.1 mV	
	(4 to 8) MHz	40 mV/V + 8.1 mV	
	(8 to 10) MHz	0.15 mV/V + 11 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.20 mV/V + 4.1 mV	
40 Hz to 20 kHz	0.20 mV/V + 2.6 mV		
(20 to 50) kHz	0.35 mV/V + 2.4 mV		
(50 to 100) kHz	1.2 mV/V + 2.1 mV		
(100 to 300) kHz	4 mV/V + 11 mV		
300 kHz to 1 MHz	15 mV/V + 50 mV		
AC Voltage - Measure	(100 to 750) V		Keysight 3458A Multimeter
	(1 to 40) Hz	0.40 mV/V + 31 mV	
	40 Hz to 1 kHz	0.40 mV/V + 16 mV	
	(1 to 20) kHz	0.60 mV/V + 16 mV	
	(20 to 50) kHz	1.2 mV/V + 16 mV	
(50 to 100) kHz	3 mV/V + 15 mV		
AC Voltage - Measure	1 mV to 8 V 20 Hz to 20 MHz	3 % of reading	DSO 8104A Oscilloscope
AC Current - Source	(0 to 220) $\mu$ A		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	230 $\mu$ A/A + 17 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 10 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 8.4 nA	
	(1 to 5) kHz	266 $\mu$ A/A + 12.5 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 66 nA	
	220 $\mu$ A to 2.2 mA		
	(10 to 20) Hz	233 $\mu$ A/A + 42 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 34 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 34 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 109 nA	
(5 to 10) kHz	915 $\mu$ A/A + 655 nA		



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Electrical – DC/Low Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Source	(2.2 to 22) mA		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	233 $\mu$ A/A + 422 nA	
	(20 to 40) Hz	149 $\mu$ A/A + 342 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 343 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 588 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 5 $\mu$ A	
	(22 to 220) mA		
	(10 to 20) Hz	233 $\mu$ A/A + 4.2 $\mu$ A	
	(20 to 40) Hz	149 $\mu$ A/A + 3.4 $\mu$ A	
	40 Hz to 1 kHz	108 $\mu$ A/A + 2.6 $\mu$ A	
	(1 to 5) kHz	183 $\mu$ A/A + 3.4 $\mu$ A	
	(5 to 10) kHz	915 $\mu$ A/A + 10 $\mu$ A	
	(0.22 to 2.2) A		
	20 Hz to 1 kHz	249 $\mu$ A/A + 34 $\mu$ A	
(1 to 5) kHz	383 $\mu$ A/A + 83 $\mu$ A		
(5 to 10) kHz	5.8 mA/A + 166 $\mu$ A		
AC Current - Source Fixed Values	1 kHz		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 $\mu$ A	7.3 nA	
	100 $\mu$ A	14 nA	
	1 mA	85 nA	
	10 mA	0.87 $\mu$ A	
AC Current - Measure	100 mA	8.7 $\mu$ A	Keysight 3458A Multimeter
	1 A	200 $\mu$ A	
	100 $\mu$ A to 1 mA		
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A		
(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A		
(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A		

**Electrical – DC/Low Frequency**

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	(1 to 10) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 2.5 uA	
	(20 to 45) Hz	0.17 % of reading + 2.5 uA	
	(45 to 100) Hz	0.067 % of reading + 2.7 uA	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 uA	
	(5 to 20) kHz	0.067 % of reading + 2.6 uA	
	(20 to 50) kHz	0.46 % of reading + 4.7 uA	
	(50 to 100) kHz	0.63 % of reading + 17 uA	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 uA	
	(20 to 45) Hz	0.17 % of reading + 26 uA	
	(45 to 100) Hz	0.067 % of reading + 26 uA	
	100 Hz to 5 kHz	0.033 % of reading + 27 uA	
	(5 to 20) kHz	0.067 % of reading + 26 uA	
	(20 to 50) kHz	0.46 % of reading + 47 uA	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1.05 A		
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		

**Electromagnetic - RF/Microwave**

Plantation, FL

Parameter/Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(>0 to 99) % Depth (0.1 to 10) MHz (0.01 to 3) GHz (3 to 26.5) GHz (26.5 to 31.15) GHz (31.5 to 50) GHz	0.8 % Depth 0.5 % Depth 1.5 % Depth 1.9 % Depth 6.1 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	$\leq$ 400 kHz <sub>peak</sub> (0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer

**Electromagnetic - RF/Microwave**

Plantation, FL

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Digital Modulation RF Quality Error Vector Magnitude (EVM)	Mod Frequency Span: $f \leq 100\text{kHz}$ $100\text{kHz} \leq f \leq 1\text{MHz}$ $f > 1\text{MHz}$	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180 ° rms Mod Frequency Span: $f \leq 100\text{kHz}$ $100\text{kHz} \leq f \leq 1\text{MHz}$ $f > 1\text{MHz}$	0.17 ° 0.34 ° 0.57 °	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $f \leq 100\text{ kHz}$ $0.999\ 9 \leq \rho \leq 1$ $0.997\ 5 \leq \rho < 0.999\ 9$ $0.993\ 6 \leq \rho < 0.997\ 5$ $0.99 \leq \rho < 0.993\ 6$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$8.6\ \text{E}^{-5}\ \rho$ 0.000 43 $\rho$ 0.000 68 $\rho$ 0.000 84 $\rho$ 0.001 2 $\rho$ 0.001 6 $\rho$	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $100\text{ kHz} \leq f \leq 1\text{ MHz}$ $0.999\ 9 \leq \rho \leq 1$ $0.997\ 5 \leq \rho < 0.999\ 9$ $0.993\ 6 \leq \rho < 0.997\ 5$ $0.99 \leq \rho < 0.993\ 6$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $f > 1\text{ MHz}$ $0.999\ 9 \leq \rho \leq 1$ $0.997\ 5 \leq \rho < 0.999\ 9$ $0.993\ 6 \leq \rho < 0.997\ 5$ $0.99 \leq \rho < 0.993\ 6$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$9.6\ \text{E}^{-5}\ \rho$ 0.000 48 $\rho$ 0.000 76 $\rho$ 0.000 94 $\rho$ 0.001 4 $\rho$ 0.001 8 $\rho$ $1.6\ \text{E}^{-4}\ \rho$ 0.000 82 $\rho$ 0.001 3 $\rho$ 0.001 6 $\rho$ 0.002 4 $\rho$ 0.003 0 $\rho$	HP 89441A Vector Signal Analyzer



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Electromagnetic - RF/Microwave

Plantation, FL

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Phase Modulation – Measure <sup>1</sup>	100 kHz to 6.6 GHz Deviations: (0.3 to 7) rad Deviations: > 7 rad (6.6 to 13.2) GHz Deviations: (0.6 to 2) rad (13.2 to 26.5) GHz Deviations: > 2 rad Deviations: (1.2 to 4) rad (26.5 to 31.5) GHz Deviations: > 4 rad Deviations: (1.3 to 4) rad (31.5 to 50) GHz Deviations: > 4 rad Deviations (2.4 to 8) rad Deviations: > 8 rad	3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure <sup>1</sup>	(-99.99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute - Measure 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
Tuned RF Power - Relative – Measure  2.5 MHz to 26.5 GHz	(+2 to +10) dBm	0.08 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-12 to +2) dBm	0.07 dB	
	(-22 to -12) dBm	0.08 dB	
	(-31 to -22) dBm	0.09 dB	
	(-40 to -31) dBm	0.1 dB	
	(-50 to -40) dBm	0.12 dB	
	(-61 to -50) dBm	0.15 dB	
	(-71 to -61) dBm	0.16 dB	
	(-80 to -71) dBm	0.17 dB	
	(-90 to -80) dBm	0.19 dB	
	(-100 to -90) dBm	0.22 dB	
	(-110 to -100) dBm	0.23 dB	
	(-120 to -110) dBm	0.27 dB	
RF Absolute Power - Source	$0.02 \text{ V} \leq V < 7 \text{ V}$ $f < 10 \text{ MHz}$	0.082 dB	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	$10 \text{ MHz} \leq f \leq 50 \text{ MHz}$	0.16 dB	
	$50 \text{ MHz} \leq f \leq 80 \text{ MHz}$	0.4 dB	
	$V \leq 10 \text{ mV}$ $20 \text{ Hz} \leq f \leq 20 \text{ kHz}$	0.017 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.021 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	0.05 mV	
	$100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.38 mV	
	$10 \text{ mV} < V \leq 100 \text{ mV}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$	0.029 mV	
	$40 \text{ Hz} \leq f \leq 1 \text{ kHz}$	0.028 mV	
	$1 \text{ kHz} < f \leq 20 \text{ kHz}$	0.032 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.045 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	0.08 mV	
	$100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.3 mV	
	$100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$	0.7 mV	
	$1 \text{ kHz} < f \leq 20 \text{ kHz}$	0.72 mV	
	$20 \text{ kHz} < f \leq 50 \text{ kHz}$	0.79 mV	
	$50 \text{ kHz} < f \leq 100 \text{ kHz}$	1.3 mV	
	$100 \text{ kHz} < f \leq 300 \text{ kHz}$	3.7 mV	



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Plantation, FL

Parameter/ Equipment	Range	Calibration and Measurement Capability [Expressed as Uncertainty ( $\pm$ )]	Reference Standard or Equipment
RF Absolute Power - Source	$1\text{ V} < V \leq 3.5\text{ V}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$	 2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power - Source	$7\text{dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.50 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB  0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment		RF Power Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment		E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors									
Range		Expanded Uncertainty of Measurement (+/-)									
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
-30 dBm ≤ P < -20 dBm	0.11	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-20 dBm ≤ P < -10 dBm	0.11	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
-10 dBm ≤ P < 0 dBm	0.11	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
-1 dBm ≤ P < 2 dBm	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
2 dBm ≤ P < 10 dBm	0.1	0.08	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.1
10 dBm ≤ P < 15 dBm	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
15 dBm ≤ P < 20 dBm	0.1	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
20 dBm ≤ P < 30 dBm	0.16	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.12
30 dBm ≤ P < 35 dBm	-	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.11	0.12	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.11

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment		RF Power Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment		E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors									
Range		Expanded Uncertainty of Measurement (+/-)									
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	-	-	-

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequencies / Frequency Ranges (dB)										
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	f = 51 GHz	52 GHz ≤ f ≤ 54 GHz	f = 55 GHz	56 GHz ≤ f ≤ 59 GHz	f = 60 GHz	f = 61 GHz
-130 dBm ≤ P < -110 dBm	0.1	0.09	0.09	0.09	0.09	-	-	-	-	-	-
-110 dBm ≤ P < -90 dBm	0.08	0.08	0.08	0.08	0.08	-	-	-	-	-	-
-90 dBm ≤ P < -30 dBm	0.07	0.06	0.06	0.06	0.06	-	-	-	-	-	-
-30 dBm ≤ P < -20 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-20 dBm ≤ P < -10 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-10 dBm ≤ P < 0 dBm	0.07	0.06	0.06	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
-1 dBm ≤ P < 2 dBm	0.07	0.05	0.05	0.06	0.06	0.34	0.33	0.29	0.34	0.3	0.34
2 dBm ≤ P < 10 dBm	0.13	0.15	0.15	0.21	0.23	0.34	0.33	0.29	0.34	0.3	0.34
10 dBm ≤ P < 15 dBm	0.07	0.06	0.06	0.06	0.06	0.34	0.34	0.3	0.34	0.3	0.35
15 dBm ≤ P < 20 dBm	0.08	0.07	0.07	0.07	0.07	0.34	0.34	0.3	0.34	0.3	0.35
20 dBm ≤ P < 30 dBm	0.172	-	-	-	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	RF Power Measure <sup>1</sup>				
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors				
Range	Expanded Uncertainty of Measurement (+/-)				
Power Range	Frequencies / Frequency Ranges (dB)				
	f = 62 GHz	63 GHz ≤ f ≤ 64 GHz	f = 65 GHz	f = 66 GHz	f = 67 GHz
-30 dBm ≤ P < -20 dBm	0.34	0.33	0.29	0.35	0.36
-20 dBm ≤ P < -10 dBm	0.34	0.33	0.29	0.35	0.36

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	RF Power Measure <sup>1</sup>				
<b>Reference Standard, Method, and/or Equipment</b>	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, V8486A Power Sensors				
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>				
Power Range	Frequencies / Frequency Ranges (dB)				
	f = 62 GHz	63 GHz ≤ f ≤ 64 GHz	f = 65 GHz	f = 66 GHz	f = 67 GHz
-10 dBm ≤ P < 0 dBm	0.34	0.33	0.29	0.35	0.36
-1 dBm ≤ P < 2 dBm	0.34	0.33	0.29	0.35	0.36
2 dBm ≤ P < 10 dBm	0.34	0.33	0.29	0.35	0.36
10 dBm ≤ P < 15 dBm	0.34	0.34	0.2	0.36	0.36
15 dBm ≤ P < 20 dBm	0.34	0.34	0.2	0.36	0.36

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>	S11 - Reflection Magnitude <sup>1,2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Linear)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
20 MHz to 2 GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
20 MHz to 2 GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Plantation, FL

Parameter/ Equipment	S21 - Transmission Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	0	3	6	10	20	30	40	50	60	
(20 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13	
130 MHz to 1.25 GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>		S21 - Transmission Magnitude <sup>1,2</sup>							
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Linear)								
	0	3	6	10	20	30	40	50	60
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Plantation, FL

<b>Parameter/ Equipment</b>		S21 - Transmission Phase <sup>1</sup>							
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	Measured Magnitude (Degrees)								
	0	3	6	10	20	30	40	50	60
(20 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
130 MHz to 1.25 GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Plantation, FL

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Pulse - Measure RMS Jitter - Period, Delay and Width	33 MHz to 3 GHz	6.6 ps	HP 54124T or HP 86100 with 86107A



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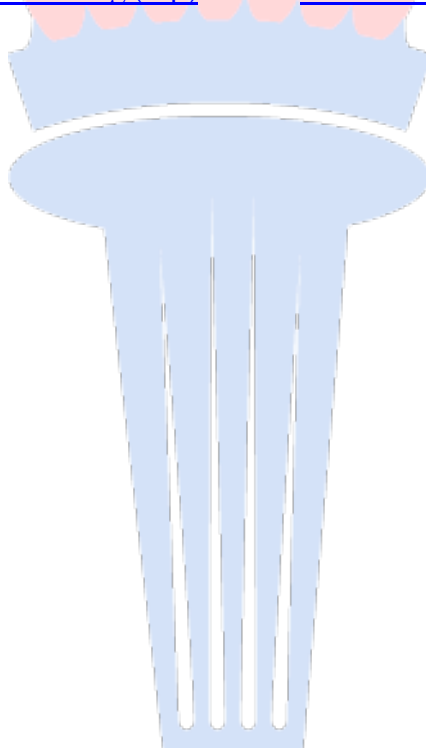
Time and Frequency

Plantation, FL

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pulse - Source Transition Time	<100 ps	0.13 ns	HP 8133A Pulse Generator
Width	150 ps to 10 ns (10 to 100) ns 100 μs to 10 ms (10 to 100) ms (100 to 0.99) ms	0.13 ns (0.013 * Width) + 1.2 ns (0.013 * Width) + 0.14 μs (0.012 * Width) + 2 ns (0.012 * Width) + 0.19 μs	HP 8161A Pulse Generator
RMS Jitter - Period, Delay and Width	33 MHz to 3 GHz	10 ps	HP 8133A Pulse Generator
Frequency - Source	10 MHz	$6.5 \times 10^{-11}$ Hz	Symmetricon 8040C GPS Disciplined
Frequency - Measure	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter

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**Services performed at satellite laboratory  
(AC-1498.17)**

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**Electrical – DC/Low Frequency**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage - Source	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage - Source Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current - Source	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A Multiproduct Calibrator
DC Current - Source	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current - Source	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current - Measure	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current - Measure	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$ 10 M $\Omega$ 19 M $\Omega$ 100 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$ 42 $\Omega$ 0.4 k $\Omega$ 1.5 k $\Omega$ 12 k $\Omega$	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Measure	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 MΩ to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
AC Voltage - Source	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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV 250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.4 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5720A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 8.7 \mu\text{V}$	
	(20 to 50) kHz	200 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	470 $\mu\text{V/V} + 210 \mu\text{V}$	
	(100 to 300) kHz	930 $\mu\text{V/V} + 600 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 300 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	46 $\mu\text{V/V} + 9 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	103 $\mu\text{V/V} + 204 \mu\text{V}$	
	(100 to 300) kHz	287 $\mu\text{V/V} + 611 \mu\text{V}$	
	(300 to 500) kHz	1.0 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(2.2 to 22) V		
	(10 to 20) Hz	251 $\mu\text{V/V} + 390 \mu\text{V}$	
	(20 to 40) Hz	93 $\mu\text{V/V} + 156 \mu\text{V}$	
	40 Hz to 20 kHz	47 $\mu\text{V/V} + 48 \mu\text{V}$	
	(20 to 50) kHz	78 $\mu\text{V/V} + 107 \mu\text{V}$	
	(50 to 100) kHz	113 $\mu\text{V/V} + 42 \mu\text{V}$	
	(100 to 300) kHz	432 $\mu\text{V/V} + 97 \mu\text{V}$	
	(300 to 500) kHz	1 mV/V + 2.1 mV	
	500 kHz to 1 MHz	1.6 mV/V + 3.3 mV	
	(22 to 220) V		
(10 to 20) Hz	250 $\mu\text{V/V} + 4.17 \text{ mV}$		
(20 to 40) Hz	93.8 $\mu\text{V/V} + 1.56 \text{ mV}$		
40 Hz to 20 kHz	53.9 $\mu\text{V/V} + 0.68 \text{ mV}$		
(20 to 50) kHz	83.3 $\mu\text{V/V} + 1.05 \text{ mV}$		
(50 to 100) kHz	156 $\mu\text{V/V} + 2.62 \text{ mV}$		
(100 to 300) kHz	941 $\mu\text{V/V} + 16 \text{ mV}$		
(300 to 500) kHz	4.58 mV/V + 41.7 mV		
500 kHz to 1 MHz	8.33 mV/V + 83.4 mV		
(220 to 1 100) V			
40 Hz to 20 kHz	313 $\mu\text{V/V} + 16.6 \text{ mV}$		
(20 to 50) kHz	73 $\mu\text{V/V} + 3.65 \text{ mV}$		

Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	220 V to 1 100 V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz 220 V to 750 V (30 to 50) kHz (50 to 100) kHz	79.6 $\mu$ V/V + 18.3 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 11.5 mV 634 $\mu$ V/V + 5.45 mV 2.42 mV/V + 28 mV	Fluke 5720A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage – Source, Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz 1 V 1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz 3V 100 kHz (2, 4, 8) MHz 10 MHz	890 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V 4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV 26 $\mu$ V 32 $\mu$ V 59 $\mu$ V 170 $\mu$ V 410 $\mu$ V 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV 420 $\mu$ V 21 mV 75 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source, Fixed Values, Fixed Frequencies	10 V		Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	0.63 mV	
	1 MHz	12 mV	
	100 V	1 kHz	
20 kHz		7.9 mV	
50 kHz		7.5 mV	
100 kHz		16 mV	
700 V	1 kHz	60 mV	
AC Voltage Flatness - Source	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz	4.6 mV/V	
	(10 to 20) MHz	6.2 mV/V	
	(20 to 30) MHz	8 mV/V	
	24 mV/V		
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz	2.2 mV/V	
	(10 to 20) MHz	3.7 mV/V	
	(20 to 30) MHz	5.5 mV/V	
	14 mV/V		
	3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz	1.2 mV/V	
	(10 to 20) MHz	2.1 mV/V	
	(20 to 30) MHz	3.8 mV/V	
	8.6 mV/V		



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Measure	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A Multimeter
AC Voltage - Measure	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 100) 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 100 mV to 1 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV 70 μV/V + 4.1 μV 70 μV/V + 2.1 μV 0.14 mV/V + 2.3 μV 0.3 mV/V + 2.6 μV 0.8 mV/V + 2.3 μV 3 mV/V + 15 μV 10 mV/V + 28 μV 15 mV/V + 20 μV 40 mV/V + 74 μV 40 mV/V + 83 μV 0.15 V/V + 0.11 mV 70 μV/V + 41 μV 70 μV/V + 21 μV 0.14 mV/V + 22 μV 0.3 mV/V + 22 μV 0.8 mV/V + 22 μV 3 mV/V + 0.12 mV 10 mV/V + 0.3 mV 15 mV/V + 0.21 mV 40 mV/V + 0.73 mV 40 mV/V + 0.83 mV 0.15 V/V + 1 mV	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(1 to 10) V		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
	(2 to 4) MHz	40 mV/V + 7.1 mV	
	(4 to 8) MHz	40 mV/V + 8.1 mV	
	(8 to 10) MHz	0.15 mV/V + 11 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.2 mV/V + 4.1 mV	
	40 Hz to 20 kHz	0.2 mV/V + 2.6 mV	
(20 to 50) kHz	0.35 mV/V + 2.4 mV		
(50 to 100) kHz	1.2 mV/V + 2.1 mV		
(100 to 300) kHz	4 mV/V + 11 mV		
300 kHz to 1 MHz	15 mV/V + 50 mV		
(100 to 750) V			
(1 to 40) Hz	0.4 mV/V + 31 mV		
40 Hz to 1 kHz	0.4 mV/V + 16 mV		
(1 to 20) kHz	0.6 mV/V + 16 mV		
(20 to 50) kHz	1.2 mV/V + 16 mV		
(50 to 100) kHz	3 mV/V + 15 mV		
AC Voltage – Measure	1 mV to 8 V 20 Hz to 20 MHz	3 % of reading	DSO 8104A Oscilloscope
AC Current Source	(0 to 220) $\mu$ A		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	230 $\mu$ A/A + 17 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 10 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 8.4 nA	
	(1 to 5) kHz	266 $\mu$ A/A + 12.5 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 66 nA	
	220 $\mu$ A to 2.2 mA		
	(10 to 20) Hz	233 $\mu$ A/A + 42 nA	
	(20 to 40) Hz	150 $\mu$ A/A + 34 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 34 nA	
(1 to 5) kHz	183 $\mu$ A/A + 109 nA		
(5 to 10) kHz	915 $\mu$ A/A + 655 nA		



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Electrical – DC/Low Frequency

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source	(2.2 to 22) mA		Fluke 5720A or 5730A Multiproduct Calibrator
	(10 to 20) Hz	233 $\mu$ A/A + 422 nA	
	(20 to 40) Hz	149 $\mu$ A/A + 342 nA	
	40 Hz to 1 kHz	108 $\mu$ A/A + 343 nA	
	(1 to 5) kHz	183 $\mu$ A/A + 588 nA	
	(5 to 10) kHz	915 $\mu$ A/A + 5 $\mu$ A	
	(22 to 220) mA		
	(10 to 20) Hz	233 $\mu$ A/A + 4.2 $\mu$ A	
	(20 to 40) Hz	149 $\mu$ A/A + 3.4 $\mu$ A	
	40 Hz to 1 kHz	108 $\mu$ A/A + 2.6 $\mu$ A	
	(1 to 5) kHz	183 $\mu$ A/A + 3.4 $\mu$ A	
	(5 to 10) kHz	915 $\mu$ A/A + 10 $\mu$ A	
	(0.22 to 2.2) A		
	20 Hz to 1 kHz	249 $\mu$ A/A + 34 $\mu$ A	
	(1 to 5) kHz	383 $\mu$ A/A + 83 $\mu$ A	
(5 to 10) kHz	5.8 mA/A + 166 $\mu$ A		
AC Current – Source Fixed Values	1 kHz		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	10 $\mu$ A	7.3 nA	
	100 $\mu$ A	14 nA	
	1 mA	85 nA	
	10 mA	0.87 $\mu$ A	
AC Current - Measure	100 mA	8.7 $\mu$ A	Keysight 3458A Multimeter
	1 A	200 $\mu$ A	
	(5 to 100) $\mu$ A		
	(10 to 20) Hz	0.46 % of reading + 0.039 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.04 $\mu$ A	
	(45 to 100) Hz	0.065 % of reading + 0.04 $\mu$ A	
	100 Hz to 5 kHz	0.67 % of reading + 0.04 $\mu$ A	
	100 $\mu$ A to 1mA		
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A	

**Electrical – DC/Low Frequency**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Measure	(1 to 10) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
	(10 to 20) Hz	0.46 % of reading + 0.29 mA	
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11% of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		

**Electrical – RF/Microwave**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(> 0 to 99) % Depth		Agilent E444xA with Opt. 233 Spectrum Analyzer
	(0.1 to 10) MHz	0.8 % Depth	
	(0.01 to 3) GHz	0.5 % Depth	
	(3 to 26.5) GHz	1.5 % Depth	
	(26.5 to 31.15) GHz	1.9 % Depth	
	(31.5 to 50) GHz	6.1 % Depth	
Frequency Modulation – Measure Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	$\leq$ 400 kHz <sub>Peak</sub>		Agilent E444xA with Opt. 233 Spectrum Analyzer
	(0.25 to 10) MHz	1.1 % Deviation	
	(0.01 to 50) GHz	1.1 % Deviation	



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Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure	100 kHz to 6.6 GHz Deviations: (0.3 to 7) rad Deviations: > 7 rad (6.6 to 13.2) GHz Deviations: (0.6 to 2) rad (13.2 to 26.5) GHz Deviations: > 2 rad Deviations: (1.2 to 4) rad (26.5 to 31.5) GHz Deviations: > 4 rad Deviations: (1.3 to 4) rad (31.5 to 50) GHz Deviations: > 4 rad Deviations (2.4 to 8) rad Deviations: > 8 rad	3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation	Agilent E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
Digital Modulation RF Quality Error Vector Magnitude (EVM)	Mod Frequency Span: $f \leq 100\text{kHz}$ $100\text{kHz} \leq f \leq 1\text{MHz}$ $f > 1\text{MHz}$	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error	Up to 180 ° rms Mod Frequency Span: $f \leq 100\text{kHz}$ $100\text{kHz} \leq f \leq 1\text{MHz}$ $f > 1\text{MHz}$	0.17 ° rms 0.34 ° rms 0.57 ° rms	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy (Rho)	Mod Frequency Span: $f \leq 100$ kHz		HP 89441A Vector Signal Analyzer
	$0.9999 \leq \rho \leq 1$	8.6 E-5 $\rho$	
	$0.9975 \leq \rho < 0.9999$	0.00043 $\rho$	
	$0.9936 \leq \rho < 0.9975$	0.00068 $\rho$	
	$0.99 \leq \rho < 0.9936$	0.00084 $\rho$	
	$0.978 \leq \rho < 0.99$	0.0012 $\rho$	
	$0.96 \leq \rho < 0.978$	0.0016 $\rho$	
	100 kHz $\leq f \leq 1$ MHz		
	$0.9999 \leq \rho \leq 1$	9.6 E-5 $\rho$	
	$0.9975 \leq \rho < 0.9999$	0.00048 $\rho$	
	$0.9936 \leq \rho < 0.9975$	0.00076 $\rho$	
	$0.99 \leq \rho < 0.9936$	0.00094 $\rho$	
	$0.978 \leq \rho < 0.99$	0.0014 $\rho$	
	$0.96 \leq \rho < 0.978$	0.0018 $\rho$	
	$f > 1$ MHz		
	$0.9999 \leq \rho \leq 1$	1.6 E-4 $\rho$	
$0.9975 \leq \rho < 0.9999$	0.00082 $\rho$		
$0.9936 \leq \rho < 0.9975$	0.0013 $\rho$		
$0.99 \leq \rho < 0.9936$	0.0016 $\rho$		
$0.978 \leq \rho < 0.99$	0.0024 $\rho$		
$0.96 \leq \rho < 0.978$	0.003 $\rho$		
Tuned RF Power - Absolute - Measure  2.5 MHz to 26.5 GHz	(-22 to +10) dBm	0.17 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-42 to -22) dBm	0.18 dB	
	(-50 to -42) dBm	0.2 dB	
	(-60 to -50) dBm	0.21 dB	
	(-72 to -60) dBm	0.22 dB	
	(-80 to -72) dBm	0.23 dB	
	(-92 to -80) dBm	0.24 dB	
	(-102 to -92) dBm	0.27 dB	
	(-110 to -102) dBm	0.28 dB	
	(-120 to -110) dBm	0.31 dB	
(-127 to -120) dBm	0.34 dB		



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Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure  2.5 MHz to 26.5 GHz	(2 to 10) dBm	0.08 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-12 to +2) dBm	0.07 dB	
	(-22 to -12) dBm	0.08 dB	
	(-31 to -22) dBm	0.09 dB	
	(-40 to -31) dBm	0.1 dB	
	(-50 to -40) dBm	0.12 dB	
	(-61 to -50) dBm	0.15 dB	
	(-71 to -61) dBm	0.16 dB	
	(-80 to -71) dBm	0.17 dB	
	(-90 to -80) dBm	0.19 dB	
	(-100 to -90) dBm	0.22 dB	
	(-110 to -100) dBm	0.23 dB	
	(-120 to -110) dBm	0.27 dB	
(-127 to -120) dBm	0.3 dB		
RF Absolute Power - Source	0.02 V ≤ V < 7 V f < 10 MHz	0.082 dB	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
	10 MHz ≤ f ≤ 50 MHz	0.16 dB	
	50 MHz ≤ f ≤ 80 MHz	0.4 dB	
	V ≤ 10mV 20 Hz ≤ f ≤ 20 kHz	0.017 mV	
	20 kHz < f ≤ 50 kHz	0.021 mV	
	50 kHz < f ≤ 100 kHz	0.05 mV	
	100 kHz < f ≤ 300 kHz	0.38 mV	
	10 mV < V ≤ 100 mV 20 Hz ≤ f ≤ 40 Hz	0.029 mV	
	40 Hz ≤ f ≤ 1 kHz	0.028 mV	
	1 kHz < f ≤ 20 kHz	0.032 mV	
	20 kHz < f ≤ 50 kHz	0.045 mV	
	50 kHz < f ≤ 100 kHz	0.08 mV	
	100 kHz < f ≤ 300 kHz	0.3 mV	
	100 mV < V ≤ 1 V 20 Hz ≤ f ≤ 1 kHz	0.7 mV	
	1 kHz < f ≤ 20 kHz	0.72 mV	
	20 kHz < f ≤ 50 kHz	0.79 mV	
	50 kHz < f ≤ 100 kHz	1.3 mV	
	100 kHz < f ≤ 300 kHz	3.7 mV	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source	$1\text{ V} < V \leq 3.5\text{ V}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$	 2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power - Source	$7\text{ dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$ $-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB  0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	Attenuation – Source										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	Attenuation – Source										
Reference Standard, Method, and/or Equipment	8496H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45

**Electrical – RF/Microwave**

Redmond, WA

<b>Parameter/ Equipment</b>	Attenuation – Source											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Redmond, WA

<b>Parameter/ Equipment</b>	Attenuation – Measure											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	Attenuation – Measure									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	RF Power Measure									
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors									
Range	Expanded Uncertainty of Measurement (+/-)									
Power Range	Frequency Ranges (uncertainties in dB)									
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	RF Power Measure									
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A Power Sensors									
Range	Expanded Uncertainty of Measurement (+/-)									
Power Range	Frequency Ranges (uncertainties in dB)									
	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	0.090	0.087	0.087	0.087	0.095	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	0.090	0.087	0.087	0.087	0.095	0.1	0.1	0.1	0.12

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	RF Power Measure								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	RF Power Measure								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
0 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
2 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	S11 - Reflection Magnitude <sup>2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(30 to 300) kHz	0.005 3	0.005 7	0.006 5	0.007 9	0.009 6	0.012	0.014	0.017	0.021	0.025
300 kHz to 20 MHz	0.002 4	0.002 6	0.002 9	0.002 8	0.003 1	0.003 5	0.003 9	0.004 3	0.004 6	0.004 9
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.0008 1	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment		S11 - Reflection Magnitude <sup>2</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)										
	≤ 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	
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6	
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1	
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012	
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015	
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment		S11 - Reflection Phase									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)										
	≤ 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	
(30 to 300) kHz	42	42	42	42	42	42	42	42	42	42	
300 kHz to 20 MHz	0.91	0.55	0.43	0.38	0.34	0.32	0.3	0.29	0.28	0.27	
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1	
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11	
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13	
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17	
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99	
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2	

**Electrical – RF/Microwave**

Redmond, WA

<b>Parameter/ Equipment</b>	S11 - Reflection Phase									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Degrees)									
	≤ 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
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Redmond, WA

<b>Parameter/ Equipment</b>	S21 - Transmission Magnitude <sup>2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
(30 to 300) kHz	0.047	0.047	0.047	0.047	0.026	0.027	0.029	0.032	0.065	
300 kHz to 45 MHz	0.018	0.021	0.023	0.027	0.026	0.027	0.029	0.032	0.065	
(45 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78	

**Electrical – RF/Microwave**

Redmond, WA

Parameter/ Equipment	S21 - Transmission Phase								
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(30 to 300) kHz	0.46	0.46	0.46	0.46	0.23	0.23	0.23	0.23	0.58
300 kHz to 45 MHz	0.62	0.62	0.62	0.62	0.23	0.23	0.23	0.23	0.58
(45 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Thermodynamic**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Temperature – Measure	(-50 to <0) °C (≥0 to ≤60) °C (>60 to 120) °C	0.5 °C 0.35 °C 0.52 °C	Vaisala HM70 Thermohygrometer

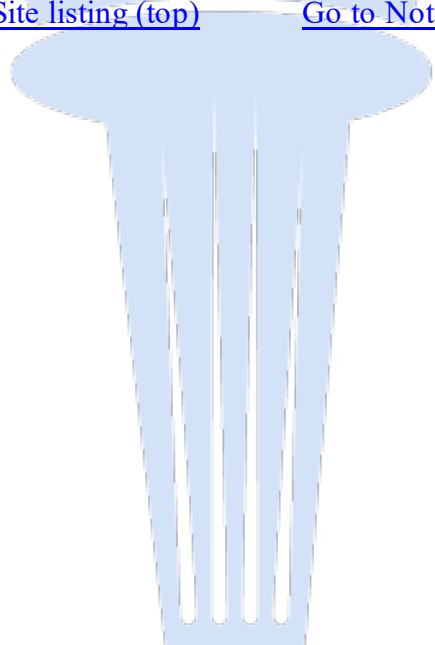
**Time and Frequency**

Redmond, WA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Rise Time Source	2 kHz to 2 MHz (200 to 300) ps (2 to 10) MHz (200 to 350) ps	37 ps 37 ps	Fluke 55xxA + SC600/1100 Multifunction Calibrator
Pulse - Source Width	150 ps to 10 ns	0.13 ns	HP 8133A Pulse Generator
Pulse - Source Width	(10 to 100) ns 100 μs to 10 ms (10 to 100) ms (100 to 0.99) ms	(0.013 * Width) + 1.2 ns (0.013 * Width) + 0.14 μs (0.012 * Width) + 2 ns (0.012 * Width) + 0.19 μs	HP 8161A Pulse Generator
RMS Jitter - Period, Delay and Width	33 MHz to 3 GHz	10 ps	HP 8133A Pulse Generator
Frequency - Source	10 MHz	6.5 x 10 <sup>-11</sup> Hz	Symmetricon 8040 Rubidium Standard
Frequency - Measure	(10 to 100) Hz (100 to 1,000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter, Symmetricon 8040 Rubidium Standard

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**Services performed at satellite laboratory  
(AC-1498.18)**

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**Electrical – DC/Low Frequency**

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage - Source	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage - Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V/V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 PLC Option 002 Multimeter
DC Voltage Transfer – Measure	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
DC Current – Source	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5700A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current - Measure	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Dissipated Power - 300 mA to Full Power	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
	(100 to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
	(300 to 1 000) A	325 $\mu$ A/A	Guildline 9230-1000, Keysight 3458A, Electronic Load
Resistance - Source Fixed Points	0 $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$	0.25 m $\Omega$ 0.27 m $\Omega$ 0.31 m $\Omega$ 0.34 m $\Omega$ 2.5 m $\Omega$ 2.7 m $\Omega$ 3.3 m $\Omega$ 9.3 m $\Omega$ 31 m $\Omega$ 93 m $\Omega$ 0.19 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 20 $\Omega$ 42 $\Omega$	Fluke 5720A or 5730A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance - Source Fixed Points	10 MΩ 19 MΩ 100 MΩ	0.4 kΩ 1.5 kΩ 12 kΩ	Fluke 5720A or 5730A Multiproduct Calibrator
Resistance – Source Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
Resistance – Source	0 to 11 Ω 11 to 110 Ω 110 Ω to 1.1 kΩ 1.1 to 3.3 kΩ 3.3 to 11 kΩ 11 to 110 kΩ 110 kΩ to 1.1 MΩ 1.1 to 3.3 MΩ 3.3 to 11 MΩ 11 to 33 MΩ	33 μΩ/Ω + 8.3 mΩ 25 μΩ/Ω + 12.5 mΩ 23 μΩ/Ω + 17 mΩ 23 μΩ/Ω + 170 mΩ 23 μΩ/Ω + 84 mΩ 23 μΩ/Ω + 0.84 Ω 27 μΩ/Ω + 8 Ω 50 μΩ/Ω + 125 Ω 0.11 mΩ/Ω + 0.2 kΩ 0.21 mΩ/Ω + 2 kΩ	Fluke 552xA Multiproduct Calibrator
Resistance – Source	33 to 110 MΩ 110 to 330 MΩ 330 to 1100 MΩ	0.41 mΩ/Ω + 2.8 kΩ 2.5 mΩ/Ω + 83 kΩ 13 mΩ/Ω + 0.4 MΩ	Fluke 552xA Multiproduct Calibrator
Resistance – Measure	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 k Ω to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 MΩ to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	Up to 22 mV		Fluke 5700A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V}/\text{V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V}/\text{V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V}/\text{V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V}/\text{V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V}/\text{V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V}/\text{V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
	220 mV to 2.2 V		
(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V}/\text{V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	43 $\mu\text{V}/\text{V} + 8.8 \mu\text{V}$		
(20 to 50) kHz	70 $\mu\text{V}/\text{V} + 10 \mu\text{V}$		
(50 to 100) kHz	89 $\mu\text{V}/\text{V} + 30 \mu\text{V}$		
(100 to 300) kHz	350 $\mu\text{V}/\text{V} + 83 \mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		



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Electrical – DC/Low Frequency

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source	(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 (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	251 $\mu\text{V/V} + 39 \mu\text{V}$ 94 $\mu\text{V/V} + 16 \mu\text{V}$ 44 $\mu\text{V/V} + 48 \mu\text{V}$ 70 $\mu\text{V/V} + 107 \mu\text{V}$ 86.3 $\mu\text{V/V} + 213 \mu\text{V}$ 265 $\mu\text{V/V} + 623 \mu\text{V}$ 1 $\text{mV/V} + 2.1 \text{mV}$ 1.6 $\text{mV/V} + 3.3 \text{mV}$ 250 $\mu\text{V/V} + 4.17 \text{mV}$ 94 $\mu\text{V/V} + 16 \text{mV}$ 54 $\mu\text{V/V} + 0.68 \text{mV}$ 83 $\mu\text{V/V} + 1.1 \text{mV}$ 156 $\mu\text{V/V} + 2.6 \text{mV}$ 941 $\mu\text{V/V} + 16 \text{mV}$ 4.6 $\text{mV/V} + 42 \text{mV}$ 8.3 $\text{mV/V} + 83 \text{mV}$	Fluke 5730A Multiproduct Calibrator
AC Voltage - Source	220 V to 1100 V (15 to 50) Hz 50 Hz to 1 kHz	313 $\mu\text{V/V} + 17 \text{mV}$ 73 $\mu\text{V/V} + 3.7 \text{mV}$	Fluke 5730A Multiproduct Calibrator
AC Voltage - Source	220 V to 1100 V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz 220 to 750 V (30 to 50) kHz (50 to 100) kHz	80 $\mu\text{V/V} + 18 \text{mV}$ 173 $\mu\text{V/V} + 5.3 \text{mV}$ 625 $\mu\text{V/V} + 12 \text{mV}$ 634 $\mu\text{V/V} + 5.5 \text{mV}$ 2.4 $\text{mV/V} + 28 \text{mV}$	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage – Source Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz	890 nV 1.2 $\mu\text{V}$ 4.5 $\mu\text{V}$ 33 $\mu\text{V}$ 21 $\mu\text{V}$ 140 $\mu\text{V}$	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source Fixed Values, Fixed Frequencies	0.1 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	4.6 $\mu$ V	
	20 kHz	6.9 $\mu$ V	
	100 kHz	36 $\mu$ V	
	300 kHz	52 $\mu$ V	
	1 MHz	170 $\mu$ V	
	4 MHz	670 $\mu$ V	
	8 MHz	690 $\mu$ V	
	10 MHz	2.3 mV	
	1 V		
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
50 kHz	0.53 mV		
100 kHz	1.1 mV		
300 kHz	2.6 mV		
500 kHz	0.63 mV		
1 MHz	12 mV		



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Electrical – DC/Low Frequency

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source Fixed Values, Fixed Frequencies	100 V 1 kHz 20 kHz 50 kHz 100 kHz	4 mV 7.9 mV 7.5 mV 16 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	700 V 1 kHz	60 mV	
AC Voltage Flatness - Source	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 57x0A Multiproduct Calibrator
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz	4.6 mV/V	
	(2 to 10) MHz	6.2 mV/V	
	(10 to 20) MHz	8 mV/V	
	(20 to 30) MHz	24 mV/V	
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz	2.2 mV/V	
	(2 to 10) MHz	3.7 mV/V	
3 mV to 3.5 V	120 kHz to 2 MHz	1.2 mV/V	
	(2 to 10) MHz	2.1 mV/V	
	(10 to 20) MHz	3.8 mV/V	
	(20 to 30) MHz	8.6 mV/V	
AC Voltage Flatness - Measure	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A Multimeter
AC Voltage - Measure	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	0.3 mV/V + 3.1 $\mu$ V 0.2 mV/V + 1.2 $\mu$ V 0.3 mV/V + 1.7 $\mu$ V 1 mV/V + 1.6 $\mu$ V 5 mV/V + 1.3 $\mu$ V 40 mV/V + 2.1 $\mu$ V 12 mV/V + 6.6 $\mu$ V 70 mV/V + 7.5 $\mu$ V 20 mV/V + 8.2 $\mu$ V	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Measure	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV	Keysight 3458A Multimeter
	(100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	
AC Voltage – Measure	1 mV to 8V 20 Hz to 20 MHz	3 % of reading	DSO 8104A
AC Current - Source	(0 to 220) $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA	Fluke 5720A or 5730A Multiproduct Calibrator
	220 $\mu$ A 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	233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA	
	(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	233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A	
	(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	233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current - Source	(0.22 to 2.2) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current – Source Fixed Values	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current - Measure	Up to 100 $\mu$ A (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 10) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (10 to 100) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz 100 mA to 1.05 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	4 mA/A + 31 nA 1.5 mA/A + 31 nA 0.6 mA/A + 31 nA 4 mA/A + 0.31 $\mu$ A 0.15 mA/A + 0.21 $\mu$ A 0.6 mA/A + 0.21 $\mu$ A 4 mA/A + 3.1 $\mu$ A 1.5 mA/A + 2.1 $\mu$ A 0.6 mA/A + 2.1 $\mu$ A 4 mA/A + 31 $\mu$ A 1.5 mA/A + 21 $\mu$ A 0.6 mA/A + 21 $\mu$ A 4 mA/A + 0.22 mA 1.6 mA/A + 0.22 mA 0.8 mA/A + 0.22 mA 1 mA/A + 0.22 mA	Keysight 3458A
AC Current - Measure	(1 to 3) A (3 to 10) Hz (10 to 40) Hz 40 Hz to 300 kHz	1.3% + 2.1 mA 0.39% + 2.2 mA 0.17% + 2.1 mA	Agilent 34401A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B		Fluke 552xA Multiproduct Calibrator
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
	(0 to 150) °C	0.32 °C	
	(150 to 650) °C	0.28 °C	
	(650 to 1 000) °C	0.33 °C	
	(1 000 to 1800) °C	0.53 °C	
	(1 800 to 2316) °C	0.88 °C	
	Type E		
	(-250 to -100) °C	0.53 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to 350) °C	0.16 °C	
	(350 to 650) °C	0.18 °C	
	(650 to 1 000) °C	0.23 °C	
	Type J		
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
(1 000 to 1 372) °C	0.42 °C		
Type L			
(-200 to -100) °C	0.39 °C		
(-100 to 800) °C	0.28 °C		
(800 to 900) °C	0.19 °C		
Type N			
(-200 to -100) °C	0.42 °C		
(-100 to -25) °C	0.24 °C		
(-25 to 120) °C	0.21 °C		
(120 to 410) °C	0.2 °C		
(410 to 1 300) °C	0.29 °C		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type R (0 to 250) °C	0.6 °C	Fluke 552xA Multiproduct Calibrator
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
	Type S (0 to 250) °C	0.5 °C	
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
	(1 400 to 1 767) °C	0.49 °C	
	Type T (-250 to -150) °C	0.66 °C	
	(-150 to 0) °C	0.26 °C	
	(0 to 120) °C	0.18 °C	
	(120 to 400) °C	0.16 °C	
	Type U (-200 to 0) °C	0.59 °C	
(0 to 600) °C	0.29 °C		

Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure Rate: 10 Hz to 100 kHz	(5 to 80) % Depth		N9030A or N9030B Signal Analyzer
	1 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.037 % Depth	
	(6 to 50) GHz	0.038 % Depth	
	4.3 kHz Resolution Band Width		
	2 MHz to 6 GHz	0.026 % Depth	
(6 to 50) GHz	0.03 % Depth		

**Electrical – RF/Microwave**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure Rate: 10 Hz to 100 kHz	(5 to 80) % Depth 10 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 100 kHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz 3 MHz Resolution Band Width 2 MHz to 6 GHz (6 to 50) GHz	0.026 % Depth 0.03 % Depth 0.028 % Depth 0.036 % Depth 0.036 % Depth 0.084 % Depth	N9030A or N9030B Signal Analyzer
Frequency Modulation – Measure <sup>1,4</sup>  FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz Modulation Index (0.2 to 100) (100 to 2 000) (3.6 to 8.4) GHz Modulation Index (0.2 to 100) (100 to 2 000) (8.4 to 17.1) GHz Modulation Index (0.2 to 100) (100 to 2 000) (17.1 to 34.5) GHz Modulation Index (0.2 to 100) (100 to 2 000) (34.5 to 50) GHz Modulation Index (0.2 to 100) (100 to 2 000)	0.35 % of reading + 0.2 %M 0.8 % of reading 0.7 % of reading + 0.2 %M 2 % of reading 0.7 % of reading + 0.3 %M 2.5 % of reading 0.8 % of reading + 0.3 %M 3 % of reading 1.4 % of reading + 0.5 %M 4 % of reading	N9030A with Opt. TES or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading 0.015° 0.12°	N9030A or N9030B Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.0025 rad 0.1 % of reading + 0.0049 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.0035 rad 0.058 % of reading + 0.0058 rad	N9030B Signal Analyzer
Tuned RF Power - Absolute - Measure  2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure  2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power - Source 50 MHz	(-11 to -1) dB (-30 to -11) dB (-50 to -40) dB -60 dB (-90 to -70) dB -100 dB -110 dB	0.025 dB 0.025 dB 0.027 dB 0.028 dB 0.033 dB 0.04 dB 0.048 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source	$0.02 \text{ V} \leq V < 7 \text{ V}$ $f < 10 \text{ MHz}$ $10 \text{ MHz} \leq f \leq 50 \text{ MHz}$ $50 \text{ MHz} \leq f \leq 80 \text{ MHz}$ $V \leq 10 \text{ mV}$ $20 \text{ Hz} \leq f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.050 mV 0.38 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A
RF Absolute Power - Source	$10 \text{ mV} < V \leq 100 \text{ mV}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $1 \text{ V} < V \leq 3.5 \text{ V}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.30 mV 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV 2.2 mV 2.1 mV 2.2 mV 2.5 mV 4.0 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A
RF Absolute Power - Source	$7 \text{ dBm} \geq P \geq 0 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $0 \text{ dBm} > P \geq -25 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$	0.49 dB 0.58 dB 0.69 dB 0.79 dB 0.49 dB 0.59 dB 0.69 dB 0.8 dB	Signal Source PSG, ESG



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power - Source	-25 dBm > P ≥ -70 dBm		Signal Source PSG, ESG
	0.3 MHz ≤ f ≤ 1.1 GHz	0.5 dB	
	1.1 GHz ≤ f ≤ 2.985 GHz	0.59 dB	
	2.985 GHz < f ≤ 4 GHz	0.69 dB	
	4 GHz < f ≤ 6 GHz	0.8 dB	
	-70 dBm > P ≥ -95 dBm		
	0.3 MHz ≤ f ≤ 1.1 GHz	0.5 dB	
	1.1 GHz ≤ f ≤ 2.985 GHz	0.6 dB	
	2.985 GHz < f ≤ 4 GHz	0.7 dB	
	4 GHz < f ≤ 6 GHz	0.8 dB	
	-95 dBm > P ≥ -125 dBm		
	0.3 MHz ≤ f ≤ 1.1 GHz	0.51 dB	
1.1 GHz ≤ f ≤ 2.985 GHz	0.6 dB		
2.985 GHz < f ≤ 4 GHz	0.7 dB		
4 GHz < f ≤ 6 GHz	1.5 dB		
Phase Noise for Signal Analyzers Carrier 1 GHz Offsets: 100 kHz	(-167 to -89) dBc/Hz Offsets:		Wenzel 500-13438C/D Oscillator
	(10 to 100) Hz	0.5 dB	
	(0.1 to 100) kHz	0.36 dB	
	(0.1 to 1) MHz	0.48 dB	
	(1 to 10) MHz	0.53 dB	
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets	2.1 dB	Keysight E5500 Phase Noise System
	1 Hz to 100 kHz		

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Parameter/ Equipment	Attenuation – Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5

**Electrical – RF/Microwave**

Greensboro, NC

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

Greensboro, NC

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

Electrical – RF/Microwave

Greensboro, NC

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

Electrical – RF/Microwave

Greensboro, NC

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-140 dBm ≤ P < -130 dBm	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093
-130 dBm ≤ P < -110 dBm	0.13	0.13	0.073	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment	RF Power Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors											
Range	Expanded Uncertainty of Measurement (+/-)											
Power Range	Frequency Ranges (uncertainties in dB)											
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz	
-110 dBm ≤ P < -90 dBm	0.12	0.12	0.060	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066	
-90 dBm ≤ P < -30 dBm	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-1 dBm ≤ P < 2 dBm	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 10 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
10 dBm ≤ P < 15 dBm	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	0.096	0.081	0.081	0.081	0.083	0.091	0.091	0.097	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	0.09	0.087	0.0874	0.087	0.095	0.1	0.1	0.11	0.1	0.1	0.12
35 dBm ≤ P < 44 dBm	-	0.09	0.087	0.0874	0.087	0.095	0.095	0.1	0.1	0.1	0.1	0.012

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	66 GHz ≤ f ≤ 67 GHz	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
-1 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
2 dBm ≤ P < 10 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
10 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13	
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-	

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(30 to 300) kHz	0.005 3	0.005 7	0.006 5	0.007 9	0.009 6	0.012	0.014	0.017	0.021	0.025
300 kHz to 20 MHz	0.002 4	0.002 6	0.002 9	0.002 8	0.003 1	0.003 5	0.003 9	0.004 3	0.004 6	0.004 9

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(30 to 300) kHz	42	42	42	42	42	42	42	42	42	42
300 kHz to 20 MHz	0.91	0.55	0.43	0.38	0.34	0.32	0.3	0.29	0.28	0.27
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17

**Electrical – RF/Microwave**

Greensboro, NC

<b>Parameter/ Equipment</b>	S11 - Reflection Phase <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Degrees)									
	≤ 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
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Greensboro, NC

<b>Parameter/ Equipment</b>	S21 - Transmission Magnitude <sup>1,2</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (Linear)									
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60	
(30 to 300) kHz	0.047	0.047	0.047	0.047	0.026	0.027	0.029	0.032	0.065	
300 kHz to 45 MHz	0.018	0.021	0.023	0.027	0.026	0.027	0.029	0.032	0.065	
(45 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13	
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093	
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044	
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045	
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038	
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048	
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051	
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78	

**Electrical – RF/Microwave**

Greensboro, NC

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(30 to 300) kHz	0.46	0.46	0.46	0.46	0.23	0.23	0.23	0.23	0.58
300 kHz to 45 MHz	0.62	0.62	0.62	0.62	0.23	0.23	0.23	0.23	0.58
(45 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Greensboro, NC

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Source	10 MHz	6.5 x 10 <sup>-11</sup> Hz	Datum 8040 Rubidium Standard
Frequency - Measure	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz 50 MHz to 26.5 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz 30 pHz/Hz + 3.75 Hz	HP 53132A Counter, 8040C Frequency Standard

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**Electrical – DC/Low Frequency**

Calgary, AB

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	4 μV/V + 2.6 μV 7.2 μV/V + 1.7 μV 6.7 μV/V + 4.6 μV 6 μV/V + 37 μV 8.5 μV/V + 53 μV 9.4 μV/V + 0.57 mV	Fluke 5700A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source <sup>1</sup> Fixed Values	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 μV 11 μV 150 μV 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	Up to 100 mV (0.1 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	4.1 μV/V + 0.36 μV 3.7 μV/V + 0.35 μV 3.1 μV/V + 0.59 μV 5.3 μV/V + 36 μV 5.3 μV/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 μV/V + 62 nV 0.37 μV/V + 124 nV 62 nV/V + 0.62 μV 0.62 μV/V + 12.4 μV 1.85 μV/V + 63 μV	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	Up to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A	42 mA/A 50 mA/A 62 mA/A - 1.1 mA 66 mA/A - 1.1 mA	Fluke 5700A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(1 to 2.2) A (2.2 to 11) A	120 μA/A - 23 μA 280 μA/A + 41 μA	Fluke 5700A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Current – Source <sup>1</sup>	(11 to 20) A	0.67 mA/A	Fluke 552xA Multiproduct Calibrator

Electrical – DC/Low Frequency

Calgary, AB

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 552xA Multiproduct Calibrator with 50 turn coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
	(15 to 100) A	75.5 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup>	(0 to 11) $\Omega$ (11 to 110) $\Omega$ (0.11 to 1.1) k $\Omega$ (1.1 to 3.3) k $\Omega$ (3.3 to 11) k $\Omega$ (11 to 110) k $\Omega$ (0.11 to 1.1) M $\Omega$ (1.1 to 3.3) M $\Omega$ (3.3 to 11) M $\Omega$ (11 to 33) M $\Omega$ (33 to 110) M $\Omega$ (110 to 330) M $\Omega$ (330 to 1 100) M $\Omega$	33 $\mu\Omega/\Omega$ + 8.3 m $\Omega$ 25 $\mu\Omega/\Omega$ + 12.5 m $\Omega$ 23 $\mu\Omega/\Omega$ + 17 m $\Omega$ 23 $\mu\Omega/\Omega$ + 170 m $\Omega$ 23 $\mu\Omega/\Omega$ + 84 m $\Omega$ 23 $\mu\Omega/\Omega$ + 0.84 $\Omega$ 27 $\mu\Omega/\Omega$ + 8 $\Omega$ 50 $\mu\Omega/\Omega$ + 125 $\Omega$ 110 $\mu\Omega/\Omega$ + 0.2 k $\Omega$ 210 $\mu\Omega/\Omega$ + 2 k $\Omega$ 410 $\mu\Omega/\Omega$ + 2.8 k $\Omega$ 2.5 m $\Omega/\Omega$ + 83 k $\Omega$ 12.5 m $\Omega/\Omega$ + 0.4 M $\Omega$	Fluke 552xA Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup> Fixed Points	0 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ	21 μΩ 49 μΩ 420 μΩ 1.8 mΩ 17 mΩ 190 mΩ 4.6 Ω 140 Ω 18 kΩ	Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
Resistance – Source <sup>1</sup> Fixed Points	0 Ω 1 Ω 1.9 Ω 10 Ω 19 Ω 100 Ω 190 Ω 1 kΩ 1.9 k Ω 10 kΩ 19 kΩ 100 kΩ 190 kΩ 1 MΩ 1.9 MΩ	0.25 mΩ 0.27 mΩ 0.31 mΩ 0.37 mΩ 2.6 mΩ 3 mΩ 4.1 mΩ 13 mΩ 36 mΩ 0.13 Ω 0.25 Ω 1.4 Ω 2.7 Ω 20 Ω 42 Ω	Fluke 5700A Multiproduct Calibrator
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 kΩ to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 MΩ to 1.2 GΩ	18 μΩ/ Ω + 20 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 15 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 22 mV		Fluke 5700A Multiproduct Calibrator
	(10 to 20) Hz	0.55 mV/V + 4.5 μV	
	(20 to 40) Hz	0.25 mV/V + 4.7 μV	
	40 Hz to 20 kHz	0.17 mV/V + 4.6 μV	
	(20 to 50) kHz	0.42 mV/V + 4.7 μV	
	(50 to 100) kHz	0.82 mV/V + 6.9 μV	
	(100 to 300) kHz	1.1 mV/V + 13 μV	
	(300 to 500) kHz	1.8 mV/V + 27 μV	
	500 kHz to 1 MHz	4.1 mV/V + 35 μV	
	(22 to 220) mV		
	(10 to 20) Hz	0.51 mV/V + 14 μV	
	(20 to 40) Hz	0.21 mV/V + 8.5 μV	
	40 Hz to 20 kHz	90 μV/V + 9.3 μV	
	(20 to 50) kHz	0.30 mV/V + 10 μV	
	(50 to 100) kHz	0.76 mV/V + 26 μV	
	(100 to 300) kHz	0.93 mV/V + 26 mV	
	(300 to 500) kHz	1.6 mV/V + 39 mV	
	500 kHz to 1 MHz	3 mV/V + 88 mV	
	220 mV to 2.2 V		
	(10 to 20) Hz	0.51 mV/V + 83 μV	
	(20 to 40) Hz	0.16 mV/V + 24 μV	
	40 Hz to 20 kHz	88 μV/V + 4.4 μV	
	(20 to 50) kHz	0.13 mV/V + 14 μV	
	(50 to 100) kHz	0.24 mV/V + 66 μV	
(100 to 300) kHz	0.41 mV/V + 0.13 mV		
(300 to 500) kHz	1 mV/V + 0.35 mV		
500 kHz to 1 MHz	2 mV/V + 0.85 mV		
(2.2 to 22) V			
(10 to 20) Hz	0.51 mV/V + 0.83 mV		
(20 to 40) Hz	0.1 mV/V + 0.17 mV		
40 Hz to 20 kHz	87 μV/V + 51 μV		
(20 to 50) kHz	0.13 mV/V + 0.16 mV		
(50 to 100) kHz	0.25 mV/V + 0.33 mV		
(100 to 300) kHz	0.50 mV/V + 1.5 mV		
(300 to 500) kHz	1.2 mV/V + 4.2 mV		
500 kHz to 1 MHz	2.5 mV/V + 7.6 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(22 to 100) V		Fluke 5700A Multiproduct Calibrator
	(10 to 20) Hz	0.51 mV/V + 8.4 mV	
	(20 to 40) Hz	0.16 mV/V + 2.4 mV	
	40 Hz to 20 kHz	90 μV/V + 0.74 mV	
	(20 to 50) kHz	0.22 mV/V + 3 mV	
	(50 to 100) kHz	0.51 mV/V + 8.4 mV	
	(100 to 300) kHz	1.3 mV/V + 95 mV	
	(300 to 500) kHz	4.5 mV/V + 93 mV	
	500 kHz to 1 MHz	1.1 mV/V + 0.18 V	
	(100 to 220) V		
	(10 to 20) Hz	0.51 mV/V + 8.4 mV	
	(20 to 40) Hz	0.16 mV/V + 2.4 mV	
	40 Hz to 20 kHz	90 μV/V + 0.74 mV	
	(20 to 50) kHz	0.25 mV/V + 3.5 mV	
	(50 to 100) kHz	0.52 mV/V + 8.7 mV	
	(100 to 300) kHz	1.3 mV/V + 95 mV	
	(300 to 500) kHz	4.5 mV/V + 93 mV	
	500 kHz to 1 MHz	1.1 mV/V + 0.18 V	
AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	0.01 V		Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	890 nV	
	20 kHz	1.2 μV	
	100 kHz	4.5 μV	
	300 kHz	33 μV	
	1 MHz	21 μV	
4 MHz	140 μV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	0.1 V		Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	4.6 $\mu$ V	
	20 kHz	6.9 $\mu$ V	
	100 kHz	36 $\mu$ V	
	300 kHz	52 $\mu$ V	
	1 MHz	170 $\mu$ V	
	4 MHz	670 $\mu$ V	
	8 MHz	690 $\mu$ V	
	10 MHz	2.3 mV	
	1 V		
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	550 $\mu$ V	
	20 Hz	380 $\mu$ V	
	40 Hz	310 $\mu$ V	
	200 Hz	504 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
50 kHz	0.53 mV		
100 kHz	1.1 mV		
300 kHz	2.6 mV		
500 kHz	0.63 mV		
1 MHz	12 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup>  Fixed Values, Fixed Frequencies	100 V 1 kHz 20 kHz 50 kHz 100 kHz  700 V 1 kHz	4 mV 7.9 mV 7.5 mV 16 mV  60 mV	Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Voltage Flatness – Source <sup>1</sup>	300 μV to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 μV to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 μV to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.2 mV/V 2.1 mV/V 3.8 mV/V 8.6 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	(-60 to 25) dBm 9 kHz to 2 GHz	0.026 dB	Agilent E4419B Power Meter, Agilent E9304A, Agilent 8491B Power Sensors, Agilent 3458A 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	(0.1 to 1) V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.30 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.30 mV/V + 0.25 mV	
	(50 to 100) kHz	0.80 mV/V + 0.22 mV	
(100 to 300) kHz	3 mV/V + 1.1 mV		
300 kHz to 1 MHz	10 mV/V + 1.1 mV		
(1 to 2) MHz	15 mV/V + 1.1 mV		
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	3 % of reading	Keysight MSO 9104A Oscilloscope
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 220 µA 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	0.54 mA/A + 0.64 µA 0.25 mA/A + 0.64 µA 80 µA/A + 0.64 µA 0.59 mA/A + 0.42 µA 1.4 mA/A + 0.10 µA 0.68 mA/A + 51 nA 0.37 mA/A + 47 nA 0.17 mA/A + 52 nA 0.6 mA/A + 0.42 µA 1.5 mA/A + 0.84 µA 0.68 mA/A + 0.51 µA 0.37 mA/A + 0.47 µA 0.17 mA/A + 0.51 µA 0.6 mA/A + 4.2 µA 1.5 mA + 8.5 µA 0.68 mA/A + 4.2 µA 0.37 mA/A + 3.2 µA 0.2 mA/A + 3 µA 0.6 mA/A + 42 µA 1.5 mA/A + 80 µA	Fluke 5700A Multiproduct Calibrator

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	220 mA to 1 A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (1 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	0.64 mA/A + 35 µA 0.72 mA/A + 87 µA 0.84 mA/A + 76 µA 0.67 mA/A + 30 µA 0.87 mA/A + 76 µA 8.4 mA/A + 76 µA 0.44 mA/A + 0.13 mA 0.88 mA/A + 0.3 mA 3.1 mA/A + 0.63 mA	Fluke 5700A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A (45 to 65) Hz (65 to 440) Hz (20 to 100) A (45 to 65) Hz (65 to 100) Hz (100 to 440) Hz (100 to 1 000) A (45 to 65) Hz (65 to 100) Hz (100 to 440) Hz	0.3 % of reading + 27 mA 0.88 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 552xA Multiproduct Calibrator with 50 turn coil
AC Current – Source <sup>1</sup> Fixed Values	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 200 µA	Fluke 57X0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(5 to 100) µA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.46 % of reading + 0.039 µA 0.17 % of reading + 0.04 µA 0.065 % of reading + 0.04 µA 0.67 % of reading + 0.04 µA	Keysight 3458A Multimeter



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	100 $\mu$ A to 1mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 0.25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 0.26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 0.26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 0.27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 0.26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 0.48 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 1.7 $\mu$ A	
	(1 to 10) mA		
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A		
(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A		
(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A		
(50 to 100) kHz	0.63 % of reading + 0.17 mA		
100 mA to 1 A			
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.3 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
Resistance – Source <sup>1</sup>	1 m $\Omega$	0.75 % of reading	Standard Resistor Sets 16074A, 42030A 16340A, 16353A
	10 m $\Omega$	1.1 % of reading	
	100 m $\Omega$	7 % of reading	
	1 $\Omega$	63 $\mu\Omega/\Omega$	
	10 $\Omega$	38 $\mu\Omega/\Omega$	
	100 $\Omega$	30 $\mu\Omega/\Omega$	
	1 k $\Omega$	29 $\mu\Omega/\Omega$	
	10 k $\Omega$	29 $\mu\Omega/\Omega$	
	100 k $\Omega$	2.1 $\mu\Omega/\Omega$	



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Resistance – Source <sup>1</sup>	1 MΩ 10 MΩ 100 MΩ 1 GΩ 10 GΩ 100 GΩ	8 μΩ/Ω 16 μΩ/Ω 96 μΩ/Ω 240 μΩ/Ω 590 μΩ/Ω 560 μΩ/Ω	Standard Resistor Sets 16074A, 42030A 16340A, 16353A
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF (3.3 to 10.99) nF (11 to 109.99) nF (110 to 329.99) nF (0.33 to 1.099) μF (1.1 to 3.299) μF (3.3 to 10.99) μF (11 to 32.99) μF (33 to 109.99) μF (110 to 329.99) μF (0.33 to 1.099) mF (1.1 to 3.299) mF (3.3 to 10.00) mF (11 to 32.99) mF (33 to 110) mF	3.2 mF/F + 8.3 pF 1.6 mF/F + 8.3 pF 1.6 mF/F + 83 pF 1.6 mF/F + 0.25 nF 1.6 mF/F + 0.83 nF 1.6 mF/F + 2.5 nF 1.6 mF/F + 8.3 nF 2.5 mF/F + 25 nF 2.8 mF/F + 84 nF 2.8 mF/F + 0.25 μF 4 mF/F + 1.2 μF 4 mF/F + 3.6 μF 4 mF/F + 12 μF 8.3 mF/F + 36 μF 12 mF/F + 0.11 mF	Fluke 5520A or 5522A Multiproduct Calibrator
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B (600 to 800) °C (800 to 1 000) °C (1 000 to 1 550) °C (1 550 to 1 820) °C Type C (0 to 150) °C (150 to 650) °C (650 to 1 000) °C (1 000 to 1 800) °C (1 800 to 2 316) °C Type E (-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 1 000) °C	0.47 °C 0.36 °C 0.32 °C 0.35 °C 0.32 °C 0.28 °C 0.33 °C 0.53 °C 0.88 °C 0.53 °C 0.18 °C 0.16 °C 0.18 °C 0.23 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type J		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.20 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
	Type L		
	(-200 to -100) °C	0.39 °C	
	(-100 to 800) °C	0.28 °C	
	(800 to 900) °C	0.19 °C	
	Type N		
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
(250 to 400) °C	0.37 °C		
(400 to 1 000) °C	0.35 °C		
(1 000 to 1 767) °C	0.42 °C		
Type S			
(0 to 250) °C	0.5 °C		
(250 to 1 000) °C	0.38 °C		
(1 000 to 1 400) °C	0.39 °C		
(1 400 to 1 767) °C	0.49 °C		
Type T			
(-250 to -150) °C	0.26 °C		
(-150 to 0) °C	0.18 °C		
(0 to 120) °C	0.16 °C		
(120 to 400) °C	0.66 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		



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Electrical – RF/Microwave

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	(> 0 to 99) % Depth (0.15 to 10) MHz (0.01 to 1.3) GHz (1.3 to 26.5) GHz	2.1 % Depth 1.1 % Depth 1.6 % Depth	Agilent 8902A Measuring Receiver
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 100) kHz	(> 0 to 99) % Depth (0.1 to 10) MHz (0.01 to 3) GHz (3 to 26.5) GHz (26.5 to 31.15) GHz (31.5 to 50) GHz	0.8 % Depth 0.5 % Depth 1.5 % Depth 1.9 % Depth 6.1 % Depth	Agilent E444xA with Opt. 233 Spectrum Analyzer
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 100) kHz	≤ 40 kHz <sub>Peak</sub> (0.25 to 10) MHz ≤ 400 kHz <sub>Peak</sub> (0.01 to 26.5) GHz	2.2 % Deviation 1.2 % Deviation	HP 8902A Measuring Receiver
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 200) kHz	≤ 400 kHz <sub>Peak</sub> (0.25 to 10) MHz (0.01 to 50) GHz	1.1 % Deviation 1.1 % Deviation	E444xA with Opt. 233 Spectrum Analyzer
Digital Modulation RF Quality Error Vector Magnitude <sup>1,2</sup> (EVM)	Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error <sup>1</sup>	Up to 180° rms Mod Frequency Span: f ≤ 100kHz 100kHz ≤ f ≤ 1MHz f > 1MHz	0.17° 0.34° 0.57°	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error <sup>1</sup>	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation RF Quality Modulation Accuracy <sup>1</sup> (Rho)	Mod Frequency Span: f ≤ 100 kHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	8.6 E-5 ρ 0.00043 ρ 0.00068 ρ 0.00084 ρ 0.0012 ρ 0.0016 ρ	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy <sup>1</sup> (Rho)	Mod Frequency Span: 100 kHz ≤ f ≤ 1 MHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978 f > 1 MHz 0.999 9 ≤ ρ ≤ 1 0.997 5 ≤ ρ < 0.999 9 0.993 6 ≤ ρ < 0.997 5 0.99 ≤ ρ < 0.993 6 0.978 ≤ ρ < 0.99 0.96 ≤ ρ < 0.978	9.6 E-5 ρ 0.00048 ρ 0.00076 ρ 0.00094 ρ 0.0014 ρ 0.0018 ρ 1.6 E-4 ρ 0.00082 ρ 0.0013 ρ 0.0016 ρ 0.0024 ρ 0.0030 ρ	HP 89441A Vector Signal Analyzer
Phase Modulation – Measure <sup>1</sup>	< 40 Radians Deviation (0.15 to 10) MHz Rate: (0.02 to 10) kHz (0.01 to 26.5) GHz Rate: (0.2 to 20) kHz	4.1 % Deviation 3.1 % Deviation	HP 8902A Measuring Receiver
Phase Modulation – Measure <sup>1</sup>	100 kHz to 6.6 GHz Deviations: (0.3 to 7) rad Deviations: > 7 rad (6.6 to 13.2) GHz Deviations: (0.6 to 2) rad (13.2 to 26.5) GHz Deviations: > 2 rad Deviations: (1.2 to 4) rad	3.1 % Deviation 1 % Deviation 3.1 % Deviation 1 % Deviation 3.1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure <sup>1</sup>	(26.5 to 31.5) GHz Deviations: > 4 rad Deviations: (1.3 to 4) rad (31.5 to 50) GHz Deviations: > 4 rad Deviations (2.4 to 8) rad Deviations: > 8 rad	1 % Deviation  3.1 % Deviation  1 % Deviation  3.1 % Deviation  1 % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source 1 50 MHz	(-11 dB to -1) dB (-30 dB to -10) dB (-50 dB to -40) dB -60 dB (-90 dB to -70) dB -100 dB -110 dB	0.025 dB 0.025 dB 0.027 dB 0.028 dB 0.033 dB 0.04 dB 0.048 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H
RF Absolute Power – Source 1	$0.02\text{ V} \leq V < 7\text{ V}$ $f < 10\text{ MHz}$ $10\text{ MHz} \leq f \leq 50\text{ MHz}$ $50\text{ MHz} \leq f \leq 80\text{ MHz}$ $V \leq 10\text{ mV}$ $20\text{ Hz} \leq f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$ $10\text{ mV} < V \leq 100\text{ mV}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$ $100\text{ mV} < V \leq 1\text{ V}$ $20\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$ $1\text{ V} < V \leq 3.5\text{ V}$ $20\text{ Hz} \leq f \leq 40\text{ Hz}$ $40\text{ Hz} \leq f \leq 1\text{ kHz}$ $1\text{ kHz} < f \leq 20\text{ kHz}$ $20\text{ kHz} < f \leq 50\text{ kHz}$ $50\text{ kHz} < f \leq 100\text{ kHz}$ $100\text{ kHz} < f \leq 300\text{ kHz}$	0.082 dB 0.16 dB 0.4 dB 0.017 mV 0.021 mV 0.05 mV 0.38 mV 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV 2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	$7\text{dBm} \geq P \geq 0\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB	Signal Source PSG, ESG, E4438C, E4428C
RF Absolute Power – Source <sup>1</sup>	$0\text{ dBm} > P \geq -25\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.49 dB 0.59 dB 0.69 dB 0.8 dB	Signal Source PSG, ESG, E4438C, E4428C
RF Absolute Power – Source <sup>1</sup>	$-25\text{ dBm} > P \geq -70\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.50 dB 0.59 dB 0.69 dB 0.80 dB	Signal Source PSG, ESG, E4438C, E4428C
RF Absolute Power – Source <sup>1</sup>	$-70\text{ dBm} > P \geq -95\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.5 dB 0.6 dB 0.7 dB 0.8 dB	Signal Source PSG, ESG, E4438C, E4428C
RF Absolute Power – Source <sup>1</sup>	$-95\text{ dBm} > P \geq -125\text{ dBm}$ $0.3\text{ MHz} \leq f \leq 1.1\text{ GHz}$ $1.1\text{ GHz} \leq f \leq 2.985\text{ GHz}$ $2.985\text{ GHz} < f \leq 4\text{ GHz}$ $4\text{ GHz} < f \leq 6\text{ GHz}$	 0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG, E4438C, E4428C
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	$(-167\text{ to }-89)\text{ dBc/Hz}$ Offsets: (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	 0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator
Phase Noise for Signal Sources <sup>1</sup>	$\geq -150\text{ dBc/Hz}$ Offsets 1 Hz to 100 kHz	 2.1 dB	Keysight E5500 Phase Noise System

**Electrical – RF/Microwave**

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Parameter/ Equipment	Attenuation – Source <sup>1</sup>											
Reference Standard, Method, and/or Equipment	8494H Attenuator											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	1	2	3	4	5	6	7	8	9	10	11	
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.19	0.2

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Parameter/ Equipment	Attenuation – Source <sup>1</sup>											
Reference Standard, Method, and/or Equipment	8496H Attenuator											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19	0.19
500 MHz ≤ f < 1 GHz	0.00 73	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45	0.45

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	10	20	30	40	50	60	70	80	90	100	110	
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46	
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51	
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5	
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58	

**Electrical – RF/Microwave**

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<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5230A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

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Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

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Parameter/ Equipment	RF Power Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, N8488A Power Sensors											
Range	Expanded Uncertainty of Measurement (+/-)											
Power Range	Frequency Ranges (uncertainties in dB)											
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz	
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093	
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084	

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Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.060	0.060	0.060	0.060	0.06	0.066	0.066	0.066
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.11	0.10	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.10	0.10	0.10	0.12

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Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	

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Parameter/ Equipment	RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors							
Range	Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequencies / Frequency Ranges (dB)							
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
0 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
2 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-

**Electrical – RF/Microwave**

Calgary, AB

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (Linear)									
	≤ 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
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1

**Electrical – RF/Microwave**

Calgary, AB

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Linear)									
	≤ 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
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Calgary, AB

Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>								
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
Range		Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (Degrees)									
	≤ 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
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Calgary, AB

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1,2</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Linear)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.016	0.015	0.015	0.017	0.02	0.03	0.052	0.074	0.13
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Calgary, AB

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(20 to 130) MHz	0.16	0.16	0.16	0.17	0.19	0.26	0.66	0.6	0.92
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

**Electrical – RF/Microwave**

Calgary, AB

<b>Parameter/ Equipment</b>	S21 - Transmission Phase <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>								
<b>Frequency</b>	<b>Measured Magnitude (Degrees)</b>								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Time and Frequency**

Calgary, AB

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Frequency – Source <sup>1</sup>	10 MHz	65 pHz/Hz	Symmetricom 8040 Time base
Time Interval – Measure <sup>1</sup>	10 ns to 10 s	2.9 ns	HP 5334B Counter connected to Time base (HP 5071A or Symmetricom 8040)
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	Agilent 53132A, Counter Symmetricom 8040C Time base
	12.4 GHz to 26.5 GHz	30 pHz/Hz + 3.72 Hz	Agilent 53151A, Counter Symmetricom 8040C Time base
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 64 ns/s 64 ns/s 74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1 % of reading + 0.9 ps 8.5 ps 0.11 % of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module

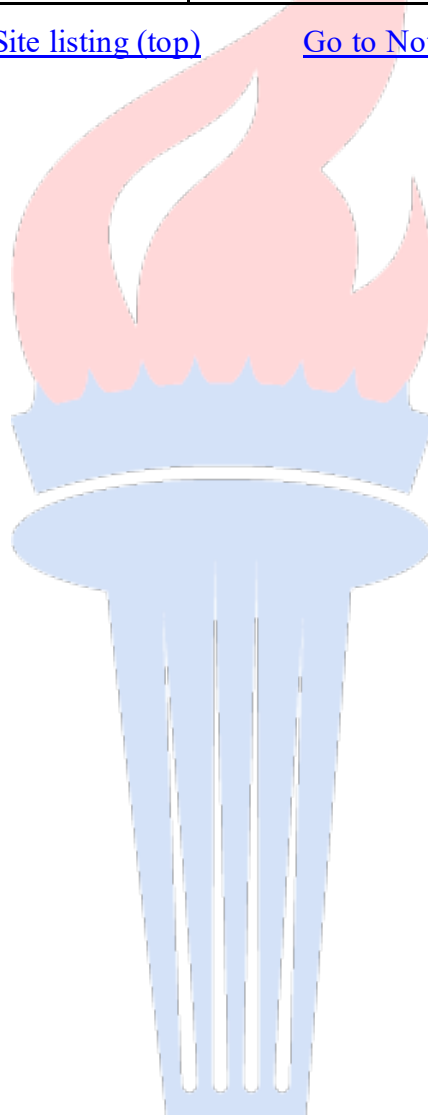
**Time and Frequency**

Calgary, AB

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pulse Amplitude – Measure 1	$25 \text{ mV} \leq V < 100 \text{ mV}$ $100 \text{ mV} \leq V < 200 \text{ mV}$ $200 \text{ mV} \leq V < 400 \text{ mV}$ $400 \text{ mV} \leq V \leq 750 \text{ mV}$ $750 \text{ mV} < V \leq 10 \text{ V}$ $10 \text{ V} < V \leq 70 \text{ V}$	3.2 mV 40 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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ANSI National Accreditation Board

**Services performed at satellite laboratory  
(AC-1498.20)**

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**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
ISN <sup>1</sup> – Phase	(0 to 360) °	3 °	CISPR 22, CISPR 32, CISPR 16-1-2 E5061B, E5071C Network Analyzers
Insertion Loss	150 kHz to 80 MHz (0 to 110) dB	0.36 dB	
Impedance	150 kHz to 80 MHz (0 to 5000) Ω	2.4 Ω	
Longitudinal Conversion Loss	150 kHz to 80 MHz (0 to 110) dB	0.88 dB	
Decoupling Attenuation	150 kHz to 80 MHz (0 to 110) dB	0.36 dB	
LISN <sup>1</sup> Insertion Loss	(0 to 110) dB 9 kHz to 108 MHz (108 to 400) MHz	0.66 dB 0.86 dB	ANSI C63.4, CISPR 25 & CISPR 16-1-2, ISO 7637-2, MIL-STD-461, RTCA DO-160
Impedance – Magnitude	(0 to 110) dB 150 kHz to 100 MHz	0.38 dB	
	(100 to 200) MHz	0.61 dB	
	(200 to 400) MHz	1.4 dB	
	(400 to 600) MHz	1.3 dB	
	(600 to 800) MHz	1.4 dB	
	800 MHz to 1 GHz	2.3 dB	
(0 to 5 000) Ω			
	9 kHz to 100 MHz	0.2 Ω	
	(100 to 200) MHz	0.7 Ω	
	(200 to 400) MHz	1.2 Ω	

**Electrical – RF/Microwave**

Kimballton, IA

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
LISN <sup>1</sup> Impedance – Magnitude	(0 to 5 000) $\Omega$ 150 kHz to 100 MHz	0.35 $\Omega$	ANSI C63.4, CISPR 25 & CISPR 16-1-2, ISO 7637-2, MIL-STD-461, RTCA DO-160
	(100 to 200) MHz	1.3 $\Omega$	
	(200 to 400) MHz	2.3 $\Omega$	
	(400 to 600) MHz	2.2 $\Omega$	
	(600 to 800) MHz	1.9 $\Omega$	
	800 MHz to 1 GHz	2.2 $\Omega$	
Impedance – Phase	(0 to 360) $^{\circ}$ 9 kHz to 100 MHz	3.6 $^{\circ}$	
	(100 to 200) MHz	3.4 $^{\circ}$	
	(200 to 400) MHz	3.2 $^{\circ}$	
Isolation	(0 to 110) dB 9 kHz to 100 MHz	0.36 dB	
	(100 to 200) MHz	1.1 dB	
	(200 to 400) MHz	1.6 dB	
	400 MHz to 1.0 GHz	1.6 dB	
Current Probes <sup>1</sup> & Bulk Current Injection Probes <sup>1</sup> Insertion Loss	(0 to 110) dB 5 Hz to 500 MHz	0.77 dB	CISPR 16-1-2, IEC/EN 61000-4-6 E5061B, E5071C Network Analyzers, BNC & Type “N” calibration standards
	500 MHz to 2.4 GHz	1.1 dB	
Transfer Impedance	(0 to 110) dB 5 Hz to 500 MHz	0.77 dB	
	500 MHz to 2.4 GHz	1.1 dB	
CDN’s & Adapters <sup>1</sup> (50 to 150) $\Omega$ Adapter Insertion Loss	(0 to 110) dB 10 kHz to 230 MHz	1.2 dB	IEC/EN 61000-4-6 CISPR 16-1-2 E5061B, E5071C Network Analyzers, BNC and Type “N” calibration standards
Coupling Factor	(0 to 110) dB 10 kHz to 230 MHz	1.1 dB	
Impedance	(0 to 5000) $\Omega$ 10 kHz to 230 MHz	3.5 $\Omega$	
CDN’s & Adapters <sup>1</sup> – (50 to 150) $\Omega$ Voltage Division Factor	(0 to 110) dB 10 kHz to 230 MHz	0.25 dB	IEC/EN 61000-4-6 CISPR 16-1-2 Agilent E5061B ENA Network Analyzer

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Absorbing Clamps	(0 to 110) dB 30 MHz to 1 GHz 30 MHz to 1 GHz	0.32 dB 2.4 dB	CISPR 16-1-3 Annex B, Agilent E5061B Network Analyzer, original calibration method, OATS/CALTS CISPR 16-1-3 Annex C, Agilent E5061B
Injection Clamps <sup>1</sup>	(0 to 110) dB (0.01 to 1.0) MHz (1.0 to 1 000) MHz	0.3 dB 0.35 dB	IEC/EN 61000-4-6 E5061B
NSA/CALTS Measurements <sup>1</sup>	(0 to 110) dB (30 to 1 000) MHz	0.1 dB	ANSI C63.5, ANSI C63.4, EN 50147-2 (1997) CISPR 16-1-4, CISPR 16-1-5 Agilent E5061B & E5071C HP 8753D, Agilent E8364C, Keysight N5225A Network Analyzers
Site VSWR Measurements <sup>1</sup>	(0 to 110) dB (1 to 3) GHz (3 to 18) GHz	0.66 dB 0.84 dB	CISPR 16-1-4, CISPR 16-1-5 Agilent E8364C, Keysight N5225A Network Analyzers
Field Uniformity <sup>1</sup>	(0 to 110) dB 26 MHz to 18 GHz	1.2 dB	IEC/EN 61000-4-3
ESD Targets <sup>1</sup> Frequency Response	(0 to 110) dB DC to 4.0 GHz	0.26 dB	IEC 61000-4-2, ISO 10605 Agilent ENA E5071C Network Analyzer, Fluke 123 Scopemeter, HP 3478A Multimeter, Solar 7144-1.0 Decade Resistor
Low Frequency Transfer Function	(0 to 30) A	0.32 % of reading	
Insertion Loss	(0 to 110) dB Up to 300 kHz (0.30 to 10) MHz (0.010 to 3.0) GHz (3.0 to 4.0) GHz	0.072 dB 0.076 dB 0.08 dB 0.092 dB	

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
ESD Simulators <sup>1</sup> –			
Contact Voltage (Positive & Negative)	(0 to 2) kV (2 to 8) kV (8 to 15) kV (15 to 30) kV (30 to 40) kV	2.6 % of reading 0.7 % of reading 0.6 % of reading 0.54 % of reading 0.72 % of reading	IEC/EN 61000-4-2; ISO 10605; SAE J1113-13, GR1089 TEK TDS 7404 Oscilloscope IEC ESD target applied kilovolt 149-3 High Voltage Meter
Rise Time	(0 to 2) ns	61 ps	
Peak Current	(0 to 40) A	5 % of reading	
30 ns Current	(0 to 40) A	5.6 % of reading	
60 ns Current	(0 to 40) A	6.1 % of reading	
Air Discharge Voltage (Positive & Negative)	(0 to 2) kV (2 to 20) kV (20 to 40) kV	0.15 % of reading 0.61 % of reading 1.2 % of reading	
Rise Time – RC Time Constant  (at ± 15 kV) 330 pF probe 150 pF probe	(0 to 2) ns  600 ns ± 130 ns 300 ns ± 60 ns	61 ps  7.2 ns 6 ns	
Magnetic Field Strength Meters –			Reference Magnets Standard Field using Helmholtz coil
DC	(50 to 2 000) G	2 % of reading	IEEE 291 Agilent E5061B, E5071C Agilent E8364C, Keysight N5225A Network Analyzer
AC	0.20 mG to 20 G	0.33 % +1.2 mG	
RF Pre-Amplifiers, Amplifiers <sup>1</sup> – Gain	(0 to 110) dB 5 Hz to 18 GHz (18 to 50) GHz	0.97 dB 1 dB	

**Electrical – RF/Microwave**

Kimballton, IA

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>											
<b>Reference Standard, Method, and/or Equipment</b>	N5225A/C Network Analyzer and Calibration Kit											
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.03	0.031	0.03	0.032	0.033	0.032	0.034	0.035	0.035	0.035	0.037
300 MHz ≤ f < 2 GHz	0.028	0.03	0.032	0.032	0.033	0.034	0.034	0.036	0.037	0.037	0.037	0.039
2 GHz ≤ f < 8 GHz	0.047	0.048	0.049	0.049	0.051	0.052	0.052	0.054	0.055	0.055	0.054	0.057
8 GHz ≤ f < 12 GHz	0.052	0.053	0.055	0.054	0.056	0.057	0.056	0.059	0.06	0.06	0.059	0.062
12 GHz ≤ f < 18 GHz	0.059	0.061	0.062	0.061	0.064	0.065	0.064	0.067	0.067	0.068	0.067	0.07
18 GHz ≤ f < 20 GHz	-	-	-	0.061	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

**Electrical – RF/Microwave**

Kimballton, IA

<b>Parameter/ Equipment</b>	Attenuation – Measure <sup>1</sup>									
<b>Reference Standard, Method, and/or Equipment</b>	N5225A/C Network Analyzer and Calibration Kit									
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.089	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.053	0.063	0.095	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.06	0.085	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.051	0.078	0.11	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.068	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5225A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
12 GHz ≤ f < 18 GHz	0.074	0.074	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.096	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (+/- Linear)									
	≤ 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
5 Hz to 9 kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4
(9 to 100) kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4
(0.1 to 20 MHz)	0.003 1	0.003 3	0.003 6	0.004 1	0.004 7	0.005 4	0.006 2	0.007 2	0.008	0.009 5
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.001 4	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.004 1	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012

Electrical – RF/Microwave

Kimballton, IA

Parameter/ Equipment		S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency		Measured Magnitude (+/- Linear)									
		≤ 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
(40 to 50) GHz		0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015
(50 to 67) GHz		0.014	0.014	0.014	0.014	0.014	0.014	0.015	0.015	0.015	0.016

Electrical – RF/Microwave

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Parameter/ Equipment		S11 - Reflection Phase <sup>1</sup>									
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range		Expanded Uncertainty of Measurement (+/-)									
Frequency		Measured Magnitude (+/- Degrees)									
		≤ 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
5 Hz to 9 kHz		1.9	1	0.77	0.65	0.58	0.53	0.50	0.48	0.47	0.47
(9 to 100) kHz		1.9	1	0.77	0.65	0.58	0.53	0.50	0.48	0.47	0.47
(0.1 to 20 MHz		1.9	1	0.78	0.67	0.61	0.59	0.58	0.58	0.6	0.6
(0.02 to 2) GHz		0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz		0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz		0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz		1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz		2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz		3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67 GHz)		8.1	4.1	2.7	2.0	1.6	1.4	1.2	1.1	1	0.95

**Electrical – RF/Microwave**

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Parameter/ Equipment		S21 - Transmission Magnitude <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (dB)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.058	0.058	0.063	0.067	0.074	0.088	0.104	0.126	0.175
(9 to 100) kHz	0.028	0.029	0.031	0.034	0.038	0.049	0.082	0.123	0.159
(0.1 to 130) MHz	0.028	0.029	0.031	0.034	0.038	0.047	0.069	0.09	0.128
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13

**Electrical – RF/Microwave**

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Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (+/- Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.38	0.38	0.42	0.45	0.49	0.58	0.69	0.83	1.2
(9 to 100) kHz	0.19	0.19	0.21	0.22	0.25	0.32	0.54	0.82	1.1
(0.1 to 130) MHz	0.19	0.19	0.2	0.22	0.25	0.31	0.46	0.61	0.85

**Electrical – RF/Microwave**

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Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (+/- Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.79	0.79	0.79	0.79	0.8	0.81	0.83	0.86	0.89

**Electrical – RF/Microwave**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Isotropic E-Field Probe  Field Strengths up to 1200 V/m	(0 to 15) dB 5 kHz to 800 MHz Frequency Response Linearity Isotropic Response	0.73 dB 0.91 dB 0.92 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution, Calculated using TEM Cell
	(0 to 15) dB 10 kHz to 1 000 MHz Frequency Response Linearity Isotropic Response	0.86 dB 1.1 dB 1.2 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution, Calculated Tri-plate
	(0 to 15) dB 10 kHz to 1 000 MHz Frequency Response Linearity Isotropic Response	0.79 dB 0.94 dB 0.97 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution using GTEM Cell



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Isotropic E-Field Probe  Field Strengths up to 1200 V/m	(0 to 15) dB 450 MHz to 18 GHz Frequency Response Linearity Isotropic Response	0.91 dB 1.1 dB 1.1 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution, Calculated using Anechoic chamber
	18 to 40 GHz Frequency Response Linearity Isotropic Response	1.1 dB 1.7 dB 1.7 dB	
	(0 to 15) dB 40 to 60 GHz Frequency Response Linearity Isotropic Response	1.7 dB 0.54 dB 0.47 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution using Anechoic chamber
Electronic E-Field Probes	(0 to 15) dB 10 kHz to 5 GHz Frequency Response Linearity Channel Match Factor	1.3 dB 0.83 dB 1 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution using FP 5000 type probe
	(0 to 15) dB 10 kHz to 5 GHz Isotropic Response	0.83 dB	
	(0 to 15) dB 80 MHz to 18 GHz Frequency Response Linearity	1.9 dB 0.84 dB	
Electronic E-Field Probes	(0 to 15) dB (18 to 40) GHz Frequency Response Linearity	2.3 dB 1.3 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution using FP 2080 type probe
	(0 to 5) dB 80 MHz to 40 GHz Isotropic Response	1.2 dB	
	(0 to 5) dB 80 MHz to 18 GHz Channel Match Factor	1 dB	

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electronic E-Field Probes	(0 to 5) dB (18 to 40) GHz Channel Match Factor	1.3 dB	IEEE 1309, IEC/EN 61000-4-3 Substitution using FP 2080 type probe
Dipole Antennae 3 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.5 dB 0.48 dB 0.55 dB 0.6 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/ Vertical Polarization
Dipole Antennae 3 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.52 dB 0.55 dB 0.60 dB 0.62 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Reference Antenna Method, Horizontal/ Vertical Polarization
Dipole Antennae 3 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.45 dB 0.52 dB 0.45 dB 0.58 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6, SAE ARP: Identical Antenna Method, Horizontal/Vertical Polarization

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dipole Antennae 3 meter distance	(0 to 110) dB (30 to 1 000) MHz	0.59 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/Vertical Polarization
Dipole Antennae 3 meter distance	(0 to 110) dB (30 to 1 000) MHz	0.4 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization
Dipole Antennae 10 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.41 dB 0.45 dB 0.51 dB 0.55 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dipole Antennae 10 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.35 dB 0.4 dB 0.45 dB 0.51 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Reference Antenna Method, Horizontal/Vertical Polarization
Dipole Antennae 10 meter distance	(0 to 110) dB (30 to 60) MHz (50 to 150) MHz (140 to 400) MHz (400 to 1 000) MHz	0.41 dB 0.38 dB 0.45 dB 0.5 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, Horizontal/Vertical Polarization
Dipole Antennae 10 meter distance	(0 to 110) dB (30 to 1 000) MHz	0.63 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/ Vertical Polarization

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dipole Antennae 10 meter distance	(0 to 110) dB (30 to 1 000) MHz	0.41 dB	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6, SAE ARP 958: Three Antenna Method, Horizontal/Vertical Polarization
Horn Antennae Log Periodic Antennas Dipole Antennas 1 meter distance	(0 to 110) dB 700 MHz to 50 GHz	0.45 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers SAE ARP 958: Identical
Horn Antennae Log Periodic Antennas Dipole Antennas 3 meter distance	(0 to 110) dB 700 MHz to 50 GHz	0.45 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers SAE ARP: Appendix C
Horn Antennae Log Periodic Antennas Dipole Antennas 1 and 3 meter distance Far Field	(0 to 110) dB 700 MHz to 18 GHz (18 to 26.5) GHz (26.5 to 50) GHz	0.37 dB 0.42 dB 0.47 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers SAE ARP 958: Combo of Identical and Appendix C, Horizontal/Vertical Polarization
Horn Antennae Log Periodic Antennas Dipole Antennas 1 and 3 meter distance Far Field	(0 to 110) dB 700 MHz to 18 GHz (18 to 26.5) GHz (26.5 to 50) GHz (50 to 67) GHz	0.37 dB 0.42 dB 0.47 dB 0.21 dB	Fully Anechoic Room (FAR), Keysight N5225A, N5291A, E8364B Network Analyzers CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization

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<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Horn Antennae Log Periodic Antennas Dipole Antennas 1 and 3 meter distance Far Field	(0 to 110) dB 700 MHz to 18 GHz (18 to 26.5) GHz (26.5 to 50) GHz	0.37 dB 0.42 dB 0.47 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers ANSI C63.5: Standard Site Method, Horizontal/Vertical Polarization
Horn Antennae Log Periodic Antennas Dipole Antennas	(0 to 110) dB 700 MHz to 50 GHz Far Field Near Field	0.44 dB 0.5 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers ANSI C63.5: Identical Antenna Method, Three Antenna Method, Horizontal/Vertical Polarization
Horn Antennae Log Periodic Antennas Dipole Antennas	(0 to 110) dB 700 MHz to 50 GHz Time Domain	0.46 dB	Fully Anechoic Room (FAR), Keysight N5225A, E8364B Network Analyzers ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, Three Antenna Method Horizontal/Vertical Polarization
Lens Antennas 1 and 3 meter distance Far Field	(1 to 110) dB (20 to 46) GHz	0.24 dB	Fully Anechoic Room (FAR), Keysight N5225A Network Analyzer CISPR 16-1-6: Three Antenna Method



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Parameter/Equipment	Biconical Antennas		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Frequency Range	Expanded Uncertainty of Measurement (+/-)
SAE ARP 958	1 Meter	(0 to 110) dB (20 to 70) MHz (70 to 200) MHz (200 to 300) MHz	0.33 dB 0.34 dB 0.37 dB
SAE ARP 958: Appendix C	3 Meter	(0 to 110) dB (20 to 70) MHz (70 to 200) MHz (200 to 300) MHz	0.37 dB 0.48 dB 0.37 dB
ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (20 to 70) MHz (70 to 200) MHz (200 to 300) MHz	0.93 dB 0.54 dB 0.25 dB
ANSI C63.5, CISPR 16-1-6: Reference Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (20 to 72.5) MHz (72.5 to 115) MHz (115 to 157.5) MHz (157.5 to 200) MHz (200 to 300) MHz	0.95 dB 0.55 dB 0.41 dB 0.5 dB 0.6 dB
ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, horizontal/vertical	3 Meter	(0 to 110) dB (20 to 72.5) MHz (72.5 to 115) MHz (115 to 157.5) MHz (157.5 to 200) MHz (200 to 300) MHz	0.96 dB 0.6 dB 0.39 dB 0.47 dB 0.52 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (20 to 300) MHz	0.5 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (20 to 300) MHz	0.4 dB
ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 72.5) MHz (72.5 to 115) MHz (115 to 157.5) MHz (157.5 to 200) MHz (200 to 300) MHz	0.93 dB 0.52 dB 0.24 dB 0.2 dB 0.25 dB

**Electrical – RF/Microwave**

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Parameter/Equipment	Biconical Antennas		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Frequency Range	Expanded Uncertainty of Measurement (+/-)
ANSI C63.5, CISPR 16-1-6 Reference Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 72.5) MHz (72.5 to 115) MHz (115 to 157.5) MHz (157.5 to 200) MHz (200 to 300) MHz	0.97 dB 0.62 dB 0.41 dB 0.3 dB 0.31 dB
ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 72.5) MHz (72.5 to 115) MHz (115 to 157.5) MHz (157.5 to 200) MHz (200 to 300) MHz	0.96 dB 0.6 dB 0.38 dB 0.46 dB 0.52 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 300) MHz	0.52 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 300) MHz	0.43 dB

**Electrical – RF/Microwave**

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Parameter/Equipment	Log-Periodic Antennas - Horns		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Range	Expanded Uncertainty of Measurement (+/-)
SAE ARP 958	1 Meter	(0 to 110) dB (140 to 400) MHz (400 to 1 000) MHz (1 000 to 5 000) MHz	0.32 dB 0.38 dB 0.52 dB
SAE ARP 958: Appendix C	3 Meter	(0 to 110) dB (140 to 400) MHz (400 to 1 000) MHz (1 000 to 5 000) MHz	0.38 dB 0.45 dB 0.58 dB

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Log-Periodic Antennas - Horns		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Range	Expanded Uncertainty of Measurement (+/-)
ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (140 to 300) MHz (300 to 400) MHz (400 to 500) MHz (500 to 600) MHz (600 to 700) MHz (700 to 800) MHz (800 to 900) MHz (900 to 1 000) MHz (1 000 to 5 000) MHz	0.3 dB 0.3 dB 0.4 dB 0.4 dB 0.4 dB 0.5 dB 0.5 dB 0.6 dB 0.7 dB
ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (140 to 300) MHz (300 to 400) MHz (400 to 500) MHz (500 to 600) MHz (600 to 700) MHz (700 to 800) MHz (800 to 900) MHz (900 to 1 000) MHz (1 000 to 5 000) MHz	0.2 dB 0.2 dB 0.2 dB 0.25 dB 0.35 dB 0.45 dB 0.45 dB 0.5 dB 0.6 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (140 to 5 000) MHz	0.65 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization	3 Meter	(0 to 110) dB (140 to 5 000) MHz	0.46 dB
ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (140 to 300) MHz (300 to 400) MHz (400 to 500) MHz (500 to 600) MHz (600 to 700) MHz (700 to 800) MHz (800 to 900) MHz (900 to 1 000) MHz (1 000 to 5 000) MHz	0.3 dB 0.3 dB 0.4 dB 0.4 dB 0.4 dB 0.5 dB 0.5 dB 0.6 dB 0.7 dB

**Electrical – RF/Microwave**

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Parameter/Equipment	Log-Periodic Antennas - Horns		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Range	Expanded Uncertainty of Measurement (+/-)
ANSI C63.5, CISPR 16-1-6: Identical Antenna Method	10 Meter	(0 to 110) dB (140 to 300) MHz (300 to 400) MHz (400 to 500) MHz (500 to 600) MHz (600 to 700) MHz (700 to 800) MHz (800 to 900) MHz (900 to 1 000) MHz (1 000 to 5 000) MHz	0.3 dB 0.3 dB 0.3 dB 0.3 dB 0.45 dB 0.45 dB 0.55 dB 0.6 dB 0.7 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (140 to 5 000) MHz	0.69 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (140 to 5 000) MHz	0.5 dB

**Electrical – RF/Microwave**

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Parameter/Equipment	Hybrid Antennas		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/ Domain	Range	Expanded Uncertainty of Measurement (+/-)
SAE ARP 958	1 Meter	(0 to 110) dB (20 to 70) MHz (70 to 200) MHz (200 to 400) MHz (400 to 1 000) MHz (1 000 to 6 000) MHz	0.5 dB 0.76 dB 0.91 dB 0.74 dB 0.75 dB
SAE ARP958: Appendix C	3 Meter	(0 to 110) dB (20 to 70) MHz (70 to 200) MHz (200 to 400) MHz (400 to 1 000) MHz (1 000 to 6 000) MHz	0.11 dB 0.11 dB 0.19 dB 0.26 dB 0.41 dB



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Parameter/Equipment	Hybrid Antennas		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/Domain	Range	Expanded Uncertainty of Measurement (+/-)
ANSI C63.5, CISPR 16-1-6: Standard Site Method	3 Meter	(0 to 110) dB (20 to 1000) MHz (1 000 to 6 000) MHz	0.58 dB 0.75 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method	3 Meter	(0 to 110) dB (20 to 6 000) MHz	0.74 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method	3 Meter	(0 to 110) dB (20 to 6 000) MHz	0.46 dB
ANSI C63.5, CISPR 16-1-6: Standard Site Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 1 000) MHz (1 000 to 6 000) MHz	0.58 dB 0.75 dB
ANSI C63.5, CISPR 16-1-6: Identical Antenna Method, Horizontal/Vertical Polarization	10 Meter	(0 to 110) dB (20 to 1 000) MHz (1 000 to 6 000) MHz	0.68 dB 0.89 dB
ANSI C63.5, CISPR 16-1-6: Standard Antenna Method	10 Meter	(0 to 110) dB (20 to 6 000) MHz	0.77 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method	10 Meter	(0 to 110) dB (20 to 6 000) MHz	0.5 dB

Electrical – RF/Microwave

Kimballton, IA

Parameter/Equipment	Conical Log Spiral Antennas		
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Keysight E5071C, N5225A, E8364B Network Analyzers		
Method	Distance/Domain	Frequency Range	Expanded Uncertainty of Measurement (+/-)
SAE ARP 958	1 Meter	(0 to 110) dB (200 to 400) MHz (400 to 1 000) MHz (1 000 to 10 000) MHz	2.2 dB 0.88 dB 1.7 dB



ANSI National Accreditation Board

Electrical – RF/Microwave

Kimballton, IA

Parameter/Equipment	Loop Antennas	
Reference Standard	Electromagnetic Shielded Enclosure, Keysight E4445A Spectrum Analyzer	
Method	Range	Expanded Uncertainty of Measurement (+/-)
Standard field using Vacuo junction	(0 to 110) dB 5 Hz to 30 MHz	0.32 dB
ANSI C63.5, CISPR 16-1-6: Three Antenna Method	(0 to 110) dB 5 Hz to 30 MHz	0.5 dB
Standard field using loop current measurement	(0 to 110) dB 5 Hz to 30 MHz	0.34 dB
Substitution method using reference antenna	(0 to 110) dB 5 Hz to 30 MHz	0.44 dB

Electrical – RF/Microwave

Kimballton, IA

Parameter/Equipment	Rod Antennas	
Reference Standard	Keysight E5061B, E5071C Network Analyzers	
Method	Range	Expanded Uncertainty of Measurement (+/-)
CISPR 25, ANSI C63.5, SAE ARP 958, CISPR 16-1-4, CISPR 16-1-6: Equivalent Capacitance Substitution Method (ECSM)	(0 to 110) dB 10 Hz to 60 MHz	0.23 dB

Electrical – RF/Microwave

Kimballton, IA

Parameter/Equipment	Additional Antenna Parameters	
Reference Standard	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Open Ended Anechoic Room, Keysight E5071C, N5225A, E8364B Network Analyzers	
Method	Range	Expanded Uncertainty of Measurement (+/-)
ANSI C63.5 4.4, CISPR 16-1-6: Symmetry	(0 to 110) dB 300 kHz to 1 GHz 10 MHz to 18 GHz (18 to 40) GHz	0.07 dB 0.05 dB 0.084 dB
CISPR 16-1-4, CISPR 16-1-6: Balance	(0 to 110) dB 20 MHz to 40 GHz	0.09 dB
CISPR 16-1-4, CISPR 16-1-6: Electric Field Discrimination	(0 to 110) dB 5 Hz to 30 MHz	0.13 dB
CISPR 16-1-4, CISPR 16-1-6: Cross-Polar Response	(0 to 110) dB 20 MHz to 40 GHz	0.5 dB

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Additional Antenna Parameters	
<b>Reference Standard</b>	Calibration Test Site (CALTS) / Open Area Test Site (OATS), Fully Anechoic Room (FAR), Open Ended Anechoic Room, Keysight E5071C, N5225A, E8364B Network Analyzers	
<b>Method</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>
ANSI C63.4, CISPR 16-1-4, CISPR 16-1-6, IEEE 149-1979: VSWR	(0 to 110) dB (20 to 2000) MHz (1 to 40) GHz	0.6 dB 0.9 dB
CISPR 16-1-6: Pattern Measurements	(0 to 110) dB 1 MHz to 40 GHz	0.25 dB

**Electrical – RF/Microwave**

Kimballton, IA

Parameter/Equipment	Antenna Site Parameters <sup>1</sup>	
<b>Reference Standard</b>	Keysight E5071C, N5225A, E8364B Network Analyzers	
<b>Method</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>
ANSI C63.4, CISPR 16-1-4, CISPR 16-1-5, EN 50147-2: Normalized Site Attenuation (NSA)	(0 to 110) dB (30 to 1000) MHz	0.1 dB
ANSI C63.4, CISPR 16-1-4, CISPR 16-1-5: Site VSWR	(0 to 110) dB (1 to 6) GHz (6 to 18) GHz	0.66 dB 0.84 dB

**Length – Dimensional metrology**

Kimballton, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pin Depth <sup>1</sup>	(0.18 to 0.23) in	34 µin	Maury Microwave A020D

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**Services performed at satellite laboratory  
(AC-1498.20 continued)**

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**Electrical – DC/Low Frequency**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage – Source Fixed Values	1 mV 10 mV	15 $\mu$ V 110 nV	Fluke 57x0A Calibrator Fluke 742A Resistors
DC Voltage – Source Fixed Values <sup>1</sup>	100 mV 1 V 10 V 100 V 1 000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	(2.2 to 11) A	0.28 mA/A + 41 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(0.10 to 1.0) A (1.0 to 3.0) A (3.0 to 10) A	22 $\mu$ A/A + 61 $\mu$ A 38 $\mu$ A/A + 0.80 mA 0.02 % of reading + 1.9 mA	Keysight 34470A Multimeter
DC Current – Measure <sup>1</sup>	(1.0 to 2.0) A (2.0 to 10) A (10 to 20) A (20 to 50) A	0.016 % of reading - 0.032 mA 90 $\mu$ A/A + 1.0 mA 0.047 % of reading - 2.7 mA 0.048 % of reading - 2.7 mA	PA2201A
DC Current – Measure <sup>1</sup>	(20 to 500) A	0.09 % of reading	500 A shunts



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source Fixed Points <sup>1</sup>	0 Ω	0.25 mΩ	Fluke 5730A Multiproduct Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 kΩ	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
1.9 MΩ	42 Ω		
Resistance – Source Fixed Points <sup>1</sup>	10 MΩ	0.4 kΩ	Fluke 5730A Multiproduct Calibrator
	19 MΩ	1.5 kΩ	
	100 MΩ	12 kΩ	
Resistance - Source Fixed Points <sup>1</sup>	0 Ω	21 μΩ	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
	10 MΩ	140 Ω	
Resistance – Source <sup>1</sup>	(0 to 11) Ω	33 μΩ/Ω + 8.3 mΩ	Fluke 5520A Multiproduct Calibrator
	(11 to 110) Ω	25 μΩ/Ω + 12.5 mΩ	
	110 Ω to 1.1 kΩ	23 μΩ/Ω + 17 mΩ	
	(1.1 to 3.3) kΩ	23 μΩ/Ω + 170 mΩ	
	(3.3 to 11) kΩ	23 μΩ/Ω + 84 mΩ	
	(11 to 110) kΩ	23 μΩ/Ω + 0.84 Ω	
	110 kΩ to 1.1 MΩ	27 μΩ/Ω + 8 Ω	
	(1.1 to 3.3) MΩ	50 μΩ/Ω + 125 Ω	
	(3.3 to 11) MΩ	0.11 mΩ/Ω + 0.2 kΩ	
	(11 to 33) MΩ	0.21 mΩ/Ω + 2 kΩ	
	(33 to 110) MΩ	0.41 mΩ/Ω + 2.8 kΩ	
	(110 to 330) MΩ	2.5 mΩ/Ω + 83 kΩ	
	(330 to 1 100) MΩ	13 mΩ/Ω + 0.4 MΩ	



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	(1 to 10) GΩ (10 to 100) GΩ	1.2 % of reading + 56 kΩ 1.2 % of reading + 0.56 MΩ	IET HRRS-F-6, 2177 Decade Resistor
Resistance – Measure <sup>1</sup>	(0 to 12) Ω (10 to 120) Ω 100 Ω to 1.2 kΩ (1 to 12) kΩ (10 to 120) kΩ 100 kΩ to 1.2 MΩ (1 to 12) MΩ (10 to 120) MΩ 100 Ω to 1.2 GΩ	18 μΩ/ Ω + 60 μΩ 12 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 0.6 mΩ 9.6 μΩ/Ω + 6 mΩ 9.6 μΩ/Ω + 60 mΩ 14.5 μΩ/Ω + 2.4 Ω 60 μΩ/Ω + 120 Ω 0.6 mΩ/Ω + 1.2 kΩ 6 mΩ/Ω + 12 kΩ	Keysight 3458A Multimeter
Resistance – Measure Fixed Points <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	12 μΩ 13 μΩ 47 μΩ 0.098 mΩ 0.32 mΩ 0.55 mΩ 2.8 mΩ 3.9 mΩ 19 mΩ 57 mΩ 0.29 Ω 0.7 Ω 4.2 Ω 9.4 Ω 50 Ω 0.24 kΩ 2.3 kΩ	Keysight 3458A Multimeter
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	250 μV/V + 4.1 μV 94 μV/V + 4.1 μV 83 μV/V + 4.1 μV 210 μV/V + 4.1 μV 520 μV/V + 4.1 μV 1.1 mV/V + 4.1 μV 1.5 mV/V + 4.1 μV 2.8 mV/V + 4.1 μV	Fluke 5730A Multiproduct Calibrator



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 22 mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V/V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V/V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V/V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V/V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
	220 mV to 2.2 V		
	(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	43 $\mu\text{V/V} + 8.8 \mu\text{V}$	
	(20 to 50) kHz	70 $\mu\text{V/V} + 10 \mu\text{V}$	
	(50 to 100) kHz	89 $\mu\text{V/V} + 30 \mu\text{V}$	
	(100 to 300) kHz	350 $\mu\text{V/V} + 83 \mu\text{V}$	
	(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$	
	500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$	
(2.2 to 22) V			
(10 to 20) Hz	251 $\mu\text{V/V} + 390 \mu\text{V}$		
(20 to 40) Hz	93 $\mu\text{V/V} + 156 \mu\text{V}$		
40 Hz to 20 kHz	47 $\mu\text{V/V} + 48 \mu\text{V}$		
(20 to 50) kHz	78 $\mu\text{V/V} + 107 \mu\text{V}$		
(50 to 100) kHz	113 $\mu\text{V/V} + 42 \mu\text{V}$		
(100 to 300) kHz	432 $\mu\text{V/V} + 97 \mu\text{V}$		
(300 to 500) kHz	1 mV/V + 2.1 mV		
500 kHz to 1 MHz	1.6 mV/V + 3.3 mV		



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(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 (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	250 $\mu$ V/V + 4.2 mV 94 $\mu$ V/V + 1.6 mV 54 $\mu$ V/V + 0.68 mV 83 $\mu$ V/V + 1.1 mV 156 $\mu$ V/V + 2.6 mV 941 $\mu$ V/V + 16 mV 4.6 mV/V + 42 mV 8.3 mV/V + 83 mV	Fluke 5730A Multiproduct Calibrator
	(220 to 1 100) V (15 to 50) Hz 50 Hz to 1 kHz	313 $\mu$ V/V + 17 mV 73 $\mu$ V/V + 3.7 mV	
AC Voltage – Source <sup>1</sup>	(220 to 1100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	80 $\mu$ V/V + 18 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 12 mV	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
	(250 to 750) V (30 to 50) kHz (50 to 100) kHz	634 $\mu$ V/V + 5.5 mV 2.4 mV/V + 28 mV	
Fixed Values, Fixed Frequencies <sup>1</sup>	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz	870 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz	4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV	



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Fixed Values, Fixed Frequencies <sup>1</sup>	1 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	1 kHz	26 $\mu$ V	
	20 kHz	32 $\mu$ V	
	50 kHz	59 $\mu$ V	
	100 kHz	170 $\mu$ V	
	300 kHz	410 $\mu$ V	
	500 kHz	0.97 mV	
	1 MHz	1.7 mV	
	4 MHz	6.7 mV	
	8 MHz	6.9 mV	
	10 MHz	25 mV	
	3V		
	100 kHz	420 $\mu$ V	
	(2, 4, 8) MHz	21 mV	
	10 MHz	75 mV	
	10 V		
	10 Hz	480 $\mu$ V	
	20 Hz	270 $\mu$ V	
	40 Hz	230 $\mu$ V	
	200 Hz	460 $\mu$ V	
	500 Hz	495 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	6.3 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.5 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz 30 Hz to 120 kHz 300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz 3 mV to 3.5 V 120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2.7 mV/V 1.4 mV/V 4.6 mV/V 6.2 mV/V 8 mV/V 24 mV/V 2.2 mV/V 3.7 mV/V 5.5 mV/V 14 mV/V 1.3 mV/V 2.1 mV/V 3.9 mV/V 8.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
AC Voltage Flatness – Measure <sup>1</sup>	Up to 3 V 10 Hz 100 Hz (10, 30) kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.2 mV/V + 6.9 $\mu$ V 80 $\mu$ V/V + 5.5 $\mu$ V 80 $\mu$ V/V + 3.2 $\mu$ V 0.1 mV/V + 8 $\mu$ V 0.1 mV/V + 5.2 $\mu$ V 0.1 mV/V + 6.5 $\mu$ V 1.3 mV/V + 59 $\mu$ V 1.3 mV/V + 0.11 mV 1.3 mV/V + 91 $\mu$ V 2.5 mV/V + 0.21 mV 2.5 mV/V + 0.24 mV 6.1 mV/V + 0.34 mV 9 mV/V + 0.24 mV 11 mV/V + 0.79 mV 13 mV/V + 0.94 mV	Agilent 11049A, Agilent 11050A, Agilent 11051A Thermal Voltage Converters
AC Voltage Flatness – Measure <sup>1</sup>	9 kHz to 2 GHz (-60 to 25) dBm	0.026 dB	Agilent N1914A Power Meter, Agilent E9304A, Agilent 8491B Power Sensors, Agilent 3458A Multimeter



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	Up to 10 mV		Keysight 3458A Multimeter
	(1 to 40) Hz	0.3 mV/V + 3.1 μV	
	40 Hz to 1 kHz	0.2 mV/V + 1.2 μV	
	(1 to 20) kHz	0.3 mV/V + 1.7 μV	
	(20 to 50) kHz	1 mV/V + 1.6 μV	
	(50 to 100) kHz	5 mV/V + 1.3 μV	
	(100 to 300) kHz	40 mV/V + 2.1 μV	
	300 kHz to 1 MHz	12 mV/V + 6.6 μV	
	(1 to 4) MHz	70 mV/V + 7.5 μV	
	(4 to 8) MHz	20 mV/V + 8.2 μV	
	(10 to 100) mV		
	(1 to 40) Hz	70 μV/V + 4.1 μV	
	40 Hz to 1 kHz	70 μV/V + 2.1 μV	
	(1 to 20) kHz	0.14 mV/V + 2.3 μV	
	(20 to 50) kHz	0.3 V/V + 2.6 μV	
	(50 to 100) kHz	0.8 mV/V + 2.3 μV	
	(100 to 300) kHz	3 mV/V + 15 μV	
	300 kHz to 1 MHz	10 mV/V + 28 μV	
	(1 to 2) MHz	15 mV/V + 20 μV	
	(2 to 4) MHz	40 mV/V + 74 μV	
	(4 to 8) MHz	40 mV/V + 83 μV	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	100 mV to 1 V		
	(1 to 40) Hz	70 μV/V + 41 μV	
40 Hz to 1 kHz	70 μV/V + 21 μV		
(1 to 20) kHz	0.14 mV/V + 22 μV		
(20 to 50) kHz	0.3 mV/V + 22 μV		
(50 to 100) kHz	0.8 mV/V + 22 μV		
(100 to 300) kHz	3 mV/V + 0.12 mV		
300 kHz to 1 MHz	10 mV/V + 0.3 mV		
(1 to 2) MHz	15 mV/V + 0.21 mV		
(2 to 4) MHz	40 mV/V + 0.73 mV		
(4 to 8) MHz	40 mV/V + 0.83 mV		
(8 to 10) MHz	0.15 V/V + 1 mV		



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Electrical – DC/Low Frequency

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(1 to 10) V		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
	(2 to 4) MHz	40 mV/V + 7.1 mV	
	(4 to 8) MHz	40 mV/V + 8.1 mV	
	(8 to 10) MHz	0.15 mV/V + 11 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.2 mV/V + 4.1 mV	
	40 Hz to 20 kHz	0.2 mV/V + 2.6 mV	
	(20 to 50) kHz	0.35 mV/V + 2.4 mV	
	(50 to 100) kHz	1.2 mV/V + 2.1 mV	
	(100 to 300) kHz	4 mV/V + 11 mV	
300 kHz to 1 MHz	15 mV/V + 50 mV		
AC Voltage – Measure <sup>1</sup>	(100 to 750) V		Keysight-PA2201A Power Analyzer
	(1 to 40) Hz	0.4 mV/V + 31 mV	
	40 Hz to 1 kHz	0.4 mV/V + 16 mV	
	(1 to 20) kHz	0.6 mV/V + 16 mV	
	(20 to 50) kHz	1.2 mV/V + 16 mV	
	(50 to 100) kHz	3 mV/V + 15 mV	

**Electrical – DC/Low Frequency**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	Up to 220 $\mu$ A (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz 220 $\mu$ A 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 220 mA 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 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA 233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA 233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A 233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A 249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current Source <sup>1</sup>	(0 to 0.33) mA (10 to 30) kHz (0.33 to 3.3) mA (10 to 30) kHz (3.3 to 33) mA (10 to 30) kHz (33 to 330) mA (10 to 30) kHz	10 mA/A + 330 nA 6.6 mA/A + 550 nA 2.7 mA/A + 2.7 $\mu$ A 2.7 mA/A + 160 $\mu$ A	Fluke 552xA Multiproduct Calibrator

**Electrical – DC/Low Frequency**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(2.2 to 20.5) A (45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	830 $\mu$ A/A + 4.2 mA 1.1 mA/A + 3.9 mA 21 mA/A + 1 mA	Fluke 552xA Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A (45 to 65) Hz (65 to 440) Hz (20 to 100) A (45 to 65) Hz (65 to 100) Hz (100 to 440) Hz (100 to 1 000) A (45 to 65) Hz (65 to 100) Hz (100 to 440) Hz	0.3 % of reading + 27 mA 0.33 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 5520A Multiproduct Calibrator, Fluke Current Coil
AC Current – Source Fixed Values <sup>1</sup> @ 1 kHz	10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	Up to 100 $\mu$ A (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz 100 $\mu$ A to 1 mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 10) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (10 to 100) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	4 mA/A + 31 nA 1.5 mA/A + 31 nA 0.6 mA/A + 31 nA 4 mA/A + 0.31 $\mu$ A 0.15 mA/A + 0.21 $\mu$ A 0.6 mA/A + 0.21 $\mu$ A 4 mA/A + 3.1 $\mu$ A 1.5 mA/A + 2.1 $\mu$ A 0.6 mA/A + 2.1 $\mu$ A 4 mA/A + 31 $\mu$ A 1.5 mA/A + 21 $\mu$ A 0.6 mA/A + 21 $\mu$ A	Keysight 3458A Multimeter

**Electrical – DC/Low Frequency**

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	100 mA to 1.05 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	4 mA/A + 0.22 mA 1.6 mA/A + 0.22 mA 0.8 mA/A + 0.22 mA 1 mA/A + 0.22 mA	Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(1 to 3) A 3.0 Hz to 5.0 kHz (5.0 to 10) kHz (3 to 10) A 3.0 Hz to 5.0 kHz (5.0 to 10) kHz	0.028 % of reading + 0.19 mA 0.044 % of reading + 0.37 mA 0.035 % of reading + 0.58 mA 0.076 % of reading + 0.63 mA	Keysight 34470A Multimeter
AC Current – Measure <sup>1</sup>	(1.0 to 2.0) A (1.0 to 100) Hz (0.10 to 1.0) kHz (1.0 to 10) kHz (10 to 100) kHz (2.0 to 50) A (1.0 to 100) Hz (0.10 to 1.0) kHz (1.0 to 10) kHz (10 to 100) kHz	0.01 % of reading + 73 $\mu$ A 0.021 % of reading + 8.0 $\mu$ A 0.11 % of reading + 19 $\mu$ A 0.11 % of reading + 20 $\mu$ A 0.044 % of reading + 1.9 mA 0.045 % of reading + 1.6 mA 0.046 % of reading + 2.3 mA 0.043 % of reading + 3.7 mA	Keysight-PA2201A Power Analyzer
Oscilloscope Calibration <sup>1</sup> – Generate Voltage – DC to 1 M $\Omega$ DC to 50 $\Omega$  Square Wave – 50 $\Omega$  Rise Time  Timing	1 mV to 200 V 1 mV to 5 V  (0.04 to 1) mV 1 mV to 5 V  150 ps @ 5 mV to 3 V 70 ps @ 25 mV to 2 V 25 ps @ (425 to 575) mV  Narrow Triangle 900.91 ns to 55 s	0.03 % of reading + 25 $\mu$ V 0.03 % of reading + 25 $\mu$ V  1.5 % of reading + 10 $\mu$ V 0.12 % of reading + 10 $\mu$ V  27 ps 20 ps 8.1 ps  3.4 $\mu$ s/s	Fluke 9500 oscilloscope calibration system Fluke 9500B with 9530, 9550 and 9560 heads



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Oscilloscope Calibration <sup>1</sup> – Leveled Sine Wave – Amplitude	4.44 mV to 5.56 V	1.5 % of reading	Fluke 9500 oscilloscope calibration system Fluke 9500B with 9530, 9550 and 9560 heads
Single	Flatness 0.1 Hz to 300 MHz (300 to 550) MHz 550 MHz to 3.0 GHz (3.0 to 6.0) GHz	2 % of reading 2.5 % of reading 3.5 % of reading 5 % of reading	
Dual	Flatness wrt Reference Frequency: 0.1 Hz to 1 GHz (1 to 3.2) GHz	10 % of reading 25 % of reading	
Pulse Width	(1 to 100) ns	5 % of reading + 200 ps	
Time Marker Output – Measuring Equipment <sup>1</sup>	50 kHz to 2.5 GHz	0.004 % of reading	
Bandwidth Measurement <sup>1</sup>	1 MHz to 2.5 GHz	2.3 % of reading	
Inductance – Measure <sup>1</sup>	10 μH to 100 H (100, 120) Hz	0.1 % of reading + 1 μH	GenRad 1659 Digibridge Impedance Bridge
	1 μH to 10 H 1 kHz	0.1 % of reading + 0.1 μH	
	0.1 μH to 1 H 10 kHz	0.1 % of reading + 0.02 μH	
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.1 mF/F + 7.7 pF	Fluke 5520A or 5522A Multiproduct 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	



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Capacitance – Source <sup>1</sup>	(1.1 to 3.299) $\mu$ F (3.3 to 10.99) $\mu$ F (11 to 32.99) $\mu$ F (33 to 109.99) $\mu$ F (110 to 329.99) $\mu$ F (0.33 to 1.099) mF (1.1 to 3.299) mF (3.3 to 10.00) mF (11 to 32.99) mF (33 to 110) mF	1.5 mF/F + 2.4 nF 1.4 mF/F + 8.1 nF 2.4 mF/F + 24 nF 2.6 mF/F + 83 nF 2.7 mF/F + 0.24 $\mu$ F 2.6 mF/F + 0.82 $\mu$ F 2.7 mF/F + 2.4 $\mu$ F 3.3 mF/F + 5.2 $\mu$ F 5.5 mF/F + 24 $\mu$ F 7.9 mF/F + 79 $\mu$ F	Fluke 5520A or 5522A Multiproduct Calibrator
Capacitance – Measure <sup>1</sup>	(10 to 100) pF (0.10 to 1.0) nF (1.0 to 100) nF (0.10 to 1.0) $\mu$ F (1.0 to 100) $\mu$ F (100 to 1 000) $\mu$ F (1.0 to 10) mF (10 to 100) mF	0.029 % of reading + 0.000 11 pF 0.026 % of reading + 0.029 pF 0.029 % of reading + 0.006 1 pF 0.015 % of reading + 0.000 31 nF 0.022 % of reading + 0.008 9 nF 0.029 % of reading + 0.000 55 $\mu$ F 0.029 % of reading + 0.005 4 $\mu$ F 0.029 % of reading + 0.054 $\mu$ F	Keysight Technologies E4980A
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type B (600 to 800) $^{\circ}$ C (800 to 1 000) $^{\circ}$ C (1 000 to 1 550) $^{\circ}$ C (1 550 to 1 820) $^{\circ}$ C Type C (0 to 150) $^{\circ}$ C (150 to 650) $^{\circ}$ C (650 to 1 000) $^{\circ}$ C (1 000 to 1 800) $^{\circ}$ C (1 800 to 2 316) $^{\circ}$ C Type E (-250 to -100) $^{\circ}$ C (-100 to -25) $^{\circ}$ C (-25 to 350) $^{\circ}$ C (350 to 650) $^{\circ}$ C (650 ) $^{\circ}$ C Type J (-210 to -100) $^{\circ}$ C (-100 to -30) $^{\circ}$ C (-30 to 150) $^{\circ}$ C (150 to 760) $^{\circ}$ C (760 to 1 200) $^{\circ}$ C	0.47 $^{\circ}$ C 0.36 $^{\circ}$ C 0.32 $^{\circ}$ C 0.35 $^{\circ}$ C 0.32 $^{\circ}$ C 0.28 $^{\circ}$ C 0.33 $^{\circ}$ C 0.53 $^{\circ}$ C 0.88 $^{\circ}$ C 0.53 $^{\circ}$ C 0.18 $^{\circ}$ C 0.16 $^{\circ}$ C 0.18 $^{\circ}$ C 0.23 $^{\circ}$ C 0.29 $^{\circ}$ C 0.18 $^{\circ}$ C 0.16 $^{\circ}$ C 0.19 $^{\circ}$ C 0.25 $^{\circ}$ C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type K (-200 to -100) °C	0.35 °C	Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
	Type L (-200 to -100) °C	0.39 °C	
	(-100 to 800) °C	0.28 °C	
	(800 to 900) °C	0.19 °C	
	Type N (-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R (0 to 250) °C	0.6 °C	
	(250 to 400) °C	0.37 °C	
	(400 to 1 000) °C	0.35 °C	
	(1 000 to 1 767) °C	0.42 °C	
	Type S (0 to 250) °C	0.5 °C	
	(250 to 1 000) °C	0.38 °C	
	(1 000 to 1 400) °C	0.39 °C	
(1 400 to 1 767) °C	0.49 °C		
Type T (-250 to -150) °C	0.66 °C		
(-150 to 0) °C	0.26 °C		
(0 to 120) °C	0.18 °C		
(120 to 400) °C	0.16 °C		
Type U (-200 to 0) °C	0.59 °C		
(2 (0 to 600) °C	0.29 °C		
DC High Voltage – Measure and Source <sup>1</sup>	(1.0 to 10) kV	44 μV/V + 0.42 V	Vitrek 4700 Precision High Voltage Meter
DC High Voltage – Measure and Source <sup>1</sup>	(10 to 35) kV	20 μV/V + 5.5 V	Vitrek 4700 Precision High Voltage Meter and Probe Vitrek 4700 & HVP-35 Vitrek 4700 & HVL-70 Vitrek 4700 & HVL-70
	(35 to 50) kV	34 μV/V + 11 V	
	(50 to 70) kV	47 μV/V + 30 V	



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC High Voltage – Measure and Source <sup>1</sup>	(DC to 1 kHz) (1.0 to 10) kV	0.013 % of reading + 2.6 V	Vitrek 4700 Precision High Voltage Meter
AC High Voltage – Measure and Source <sup>1</sup>	(DC to 1 kHz) (10 to 30) kV (30 to 50) kV	0.016 % of reading + 1.6 V 66µV/V + 13 V	Vitrek 4700 Precision High Voltage Meter and Probe Vitrek 4700 & HVP-35 Vitrek 4700 & HVL-70

Electrical – RF/Microwave

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: (0.05 to 10) kHz Rate: (0.05 to 50) kHz Rate: (0.05 to 10) kHz	Up to 99% Depth (0.15 to 10) MHz (0.01 to 1.3) GHz (1.3 to 26.5) GHz	2.1 % Depth 1.1 % Depth 1.6 % Depth	Agilent 8902A Measuring Receiver
Frequency Modulation – Measure <sup>1</sup> Rate: (0.02 to 10) kHz Rate: (0.05 to 100) kHz	≤ 40 kHz <sub>peak</sub> (0.25 to 10) MHz ≤ 400 kHz <sub>peak</sub> (0.01 to 26.5) GHz	2.2 % Deviation 1.2 % Deviation	HP 8902A Measuring Receiver
Digital Modulation RF Quality Error Vector Magnitude <sup>1</sup> (EVM)	Mod Frequency Span: f ≤ 100 kHz 100 kHz ≤ f ≤ 1 MHz f > 1 MHz	0.43 % of reading 0.48 % of reading 0.82 % of reading	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Phase Error <sup>1</sup>	Up to 180 ° Mod Frequency Span: f ≤ 100 kHz 100kHz ≤ f ≤ 1MHz f > 1 MHz	0.17 ° rms 0.34 ° rms 0.57 ° rms	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Frequency Error <sup>1</sup>	(0 to 5) % error Mod Frequency 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz	0.063 % error 0.068 % error 0.079 % error 0.099 % error 0.33 % error 0.39 % error	HP 89441A Vector Signal Analyzer



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Digital Modulation RF Quality Modulation Accuracy (Rho) <sup>1</sup>	Mod Frequency Span: $f \leq 100$ kHz $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$ $100$ kHz $\leq f \leq 1$ MHz $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$8.6E^{-5} \rho$ $0.00043 \rho$ $0.00068 \rho$ $0.00084 \rho$ $0.0012 \rho$ $0.0016 \rho$ $9.6E^{-5} \rho$ $0.00048 \rho$ $0.00076 \rho$ $0.00094 \rho$ $0.0014 \rho$ $0.0018 \rho$	HP 89441A Vector Signal Analyzer
Digital Modulation RF Quality Modulation Accuracy (Rho) <sup>1</sup>	Mod Frequency Span: $f > 1$ MHz $0.9999 \leq \rho \leq 1$ $0.9975 \leq \rho < 0.9999$ $0.9936 \leq \rho < 0.9975$ $0.99 \leq \rho < 0.9936$ $0.978 \leq \rho < 0.99$ $0.96 \leq \rho < 0.978$	$1.6E^{-4} \rho$ $0.00082 \rho$ $0.0013 \rho$ $0.0016 \rho$ $0.0024 \rho$ $0.003 \rho$	HP 89441A Vector Signal Analyzer
Phase Modulation – Measure <sup>1</sup>	$(0.15$ to $10)$ MHz Rate: $(0.02$ to $10)$ kHz $<40$ Radians Deviation $(0.01$ to $26.5)$ GHz Rate: $(0.2$ to $20)$ kHz $<400$ Radians Deviation	$4.1$ % Deviation $3.1$ % Deviation	HP 8902A Measuring Receiver
Phase Modulation – Measure <sup>1</sup>	$100$ kHz to $6.6$ GHz Deviations: $(0.3$ to $7)$ rad Deviations: $> 7$ rad $(6.6$ to $13.2)$ GHz Deviations: $(0.6$ to $2)$ rad $(13.2$ to $26.5)$ GHz Deviations: $> 2$ rad Deviations: $(1.2$ to $4)$ rad	$3.1$ % Deviation $1$ % Deviation $3.1$ % Deviation $1$ % Deviation $3.1$ % Deviation	Keysight E444xA with Opt. 233 Spectrum Analyzer
Distortion Measure <sup>1</sup>	$(-99.99$ to $0)$ dB $20$ Hz to $20$ kHz $(20$ to $100)$ kHz	$1.2$ dB $2.4$ dB	HP 8903A/B Audio Analyzer



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RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
Tuned RF Power - Relative – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(+2 to +10) dBm (-12 to +2) dBm (-22 to -12) dBm (-31 to -22) dBm (-40 to -31) dBm (-50 to -40) dBm (-61 to -50) dBm (-71 to -61) dBm (-80 to -71) dBm (-90 to -80) dBm (-100 to -90) dBm (-110 to -100) dBm (-120 to -110) dBm (-127 to -120) dBm	0.08 dB 0.07 dB 0.08 dB 0.09 dB 0.1 dB 0.12 dB 0.15 dB 0.16 dB 0.17 dB 0.19 dB 0.22 dB 0.23 dB 0.27 dB 0.3 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
RF Absolute Power - Source 50 MHz <sup>1</sup>	(-11 to -1) dB (-30 to -10) dB (-50 to -40) dB -60 dB (-90 to -70) dB -100 dB -110 dB	0.025 dB 0.025 dB 0.027 dB 0.028 dB 0.033 dB 0.04 dB 0.048 dB	Signal Source and Step Attenuators PSG, ESG, 8496G/H and 8494G/H



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RF Absolute Power – Source 1	$0.02 \text{ V} \leq V < 7 \text{ V}$ $f < 10 \text{ MHz}$ $10 \text{ MHz} \leq f \leq 50 \text{ MHz}$ $50 \text{ MHz} \leq f \leq 80 \text{ MHz}$ $V \leq 10 \text{ mV}$ $20 \text{ Hz} \leq f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.082 dB 0.16 dB 0.4 dB  0.017 mV 0.021 mV 0.05 mV 0.38 mV	Function Generator and DVM Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power – Source 1	$10 \text{ mV} < V \leq 100 \text{ mV}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.029 mV 0.028 mV 0.032 mV 0.045 mV 0.08 mV 0.3 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter
RF Absolute Power – Source 1	$100 \text{ mV} < V \leq 1 \text{ V}$ $20 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$ $1 \text{ V} < V \leq 3.5 \text{ V}$ $20 \text{ Hz} \leq f \leq 40 \text{ Hz}$ $40 \text{ Hz} \leq f \leq 1 \text{ kHz}$ $1 \text{ kHz} < f \leq 20 \text{ kHz}$ $20 \text{ kHz} < f \leq 50 \text{ kHz}$ $50 \text{ kHz} < f \leq 100 \text{ kHz}$ $100 \text{ kHz} < f \leq 300 \text{ kHz}$	 0.7 mV 0.72 mV 0.79 mV 1.3 mV 3.7 mV  2.2 mV 2.1 mV 2.2 mV 2.5 mV 4 mV 13 mV	Function Generator and DVM, Agilent 33250A, Agilent 33120A, Agilent 3458A Multimeter



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Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Absolute Power – Source <sup>1</sup>	$7 \text{ dBm} \geq P \geq 0 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $0 \text{ dBm} > P \geq -25 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-25 \text{ dBm} > P \geq -70 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-70 \text{ dBm} > P \geq -95 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$ $-95 \text{ dBm} > P \geq -125 \text{ dBm}$ $0.3 \text{ MHz} \leq f \leq 1.1 \text{ GHz}$ $1.1 \text{ GHz} \leq f \leq 2.985 \text{ GHz}$ $2.985 \text{ GHz} < f \leq 4 \text{ GHz}$ $4 \text{ GHz} < f \leq 6 \text{ GHz}$	 0.49 dB 0.58 dB 0.69 dB 0.79 dB  0.49 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.59 dB 0.69 dB 0.8 dB  0.5 dB 0.6 dB 0.7 dB 0.8 dB  0.51 dB 0.6 dB 0.7 dB 1.5 dB	Signal Source PSG, ESG
Harmonic Measurements <sup>1</sup>	(0 to 90) dB 30 Hz to 25 GHz 200 Hz to 80 MHz (10 to 25) GHz	 0.5 dB 1.2 dB 0.8 dB	Agilent 8565E Spectrum Analyzer Agilent 3335A Agilent 83650B (based on Agilent 8565E) Signal Generators
Source Errors for CISPR Impulse Spectral Amplitude <sup>1</sup>	(-20 to 45) dB Band A (9.0 to 150) kHz Band B (0.15 to 30) MHz Band C and D (30 to 1 000) MHz	 0.17 dB 0.22 dB  0.22 dB	CISPR 16-1-1 IGUU 2916 IGUU 2918 Pulse Generators
Source Errors for CISPR Impulse Spectral Amplitude <sup>1</sup>	(-30 to 20) dB Band E (1.0 to 18) GHz	0.27 dB	Agilent 83650B, Agilent 33250A Signal Generators

**Electrical – RF/Microwave**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Source Errors for Sinewave Output <sup>1</sup>	(40 to 80) dB Band A Band B Band C/D	0.17 dB 0.22 dB 0.22 dB	CISPR 16-1-1 IGUU 2916 IGUU 2918 Pulse Generators
Source Errors for Sinewave Output <sup>1</sup>	(40 to 80) dB Band E	0.27 dB	Agilent 83650B, Agilent 33250A Signal Generators
Relative Pulse Response <sup>1</sup>	(0 to 40) dB Band A Band B Band C/D	0.17 dB 0.22 dB 0.22 dB	CISPR 16-1-1 IGUU 2916 IGUU 2918 Pulse Generators
Relative Pulse Response <sup>1</sup>	(0 to 40) dB Band E	0.27 dB	Agilent 83650B, Agilent 33250A Signal Generators
Impulse Flatness of Spectral Amplitude <sup>1</sup>	(0 to 5) dB Band A Band B Band C/D	0.14 dB 0.13 dB 0.13 dB	CISPR 16-1-1 Agilent E4440 Spectrum Analyzer
EFT/Burst Generator <sup>1</sup> – Voltage	10 V to 6 kV	0.7 % of reading	EN 61000-4-4; IEC 61000-4-4, IEC 61000-4-4(2004, 2011); GR 1089 CORE ISO 7637-2 Tektronix TDS 5104B Oscilloscope
Rise Time	5 ns	0.067 ns	
Impulse Duration	150 ns	0.095 ns	
Burst Duration	15 ms 0.75 ms	1.4 μs 0.033 μs	
Burst Period	300 ms	0.016 ms	
Repetition Rate	5.0 kHz 100 kHz	0.23 Hz 5 Hz	



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Electrical – RF/Microwave

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Surge Generator <sup>1</sup> – Ring/ Impulse/ PQF Front Time Open Short	(0.1 to 50) $\mu$ s	0.004 % of reading + 0.2 ns	IEC/EN61000-4-5; IEC/EN 61000-4-8; IEC/EN 61000-4-9; IEC/EN 61000-4-10; IEC/EN 61000-4-11; IEC/EN 61000-4-12 UL 864; UL 1449; ISO 7637-2
Rise Time Open Circuit Short Circuit	(0.1 to 50) $\mu$ s	0.004 % of reading + 0.2 ns	
Time to Half-Value Impulse Duration	(20 to 1 500) $\mu$ s	0.004 % of reading + 0.2 ns	
Surge Generator <sup>1</sup> – Ring/ Impulse/ PQF Voltage	10 V to 6.0 kV (6.0 to 18) kV	0.7 % of reading 1.1 % of reading	ITU Rec K.17, K.20, ITU Rec K.21; SBC-TP-76200; GR1089CORE
Current	(0.001 to 5) kA	1.1 % of reading	
Surge Generator <sup>1</sup> – Ring/ Impulse/ PQF Phase Synchronization	50 Hz 60 Hz 400 Hz	0.11 ° 0.095 ° 0.21 °	IEC/EN 61000-4-18 Tektronix TDS 5104B Oscilloscope PDP8000, P6015A,110 Voltage Probes ANSI C62.41
Mains Harmonic Emissions <sup>1</sup>	(100 to 280) V (0.1 to 20) A (20 to 60) A (0.5 to 179.5)°	0.07 % of reading + 270 mV 0.2 % of reading 0.1 A 0.1°	IEC/EN 61000-3-2; IEC/EN 61000-4-7; IEC/EN 61000-4-13; IEC/EN 61000-4-14
Voltage Fluctuations <sup>1</sup> (Flicker)	(100 to 280) V (0.1 to 20) A (20 to 60) A	0.1 % of reading + 370 mV 0.2 % of reading 0.1 A	IEC/EN 61000-3-3 IEC/EN 61000-3-12 IEC/EN 61000-4-15

**Electrical – RF/Microwave**

Elk Horn, IA

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

**Electrical – RF/Microwave**

Elk Horn, IA

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.0037	0.0071	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.0042	0.0092	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.0073	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.0073	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.0096	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45

**Electrical – RF/Microwave**

Elk Horn, IA

<b>Parameter/ Equipment</b>	Attenuation – Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58

**Electrical – RF/Microwave**

Elk Horn, IA

<b>Parameter/ Equipment</b>	RF Power Measure <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8487A, 8487D, E9304A-H18 Power Sensors										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Power Range	Frequency Ranges (uncertainties in dB)										
	9 kHz To 50 MHz	50 MHz to 500 MHz	500 MHz to 1.2 GHz	1.2 GHz to 6.0 GHz	6.0 GHz to 14 GHz	14 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz	45 GHz to 50 GHz
-70 to -60 dBm	-	0.819	0.819	0.82	0.821	0.822	0.823	0.824	0.830	0.841	0.843
-60 to -50 dBm	1.789	0.257	0.257	0.258	0.266	0.269	0.28	0.284	0.313	0.360	0.369
-50 to -40 dBm	0.257	0.092	0.093	0.096	0.117	0.125	0.146	0.155	0.205	0.273	0.285
-40 to -30 dBm	0.145	0.094	0.094	0.97	0.118	0.126	0.147	0.156	0.206	0.274	0.286
-30 to -20 dBm	0.108	0.111	0.111	0.113	0.125	0.131	0.175	0.183	0.226	0.275	0.301
-20 to -10 dBm	0.108	0.086	0.080	0.087	0.092	0.101	0.123	0.140	0.145	0.198	0.218
-10 to 0 dBm	0.108	0.087	0.080	0.088	0.093	0.103	0.127	0.145	0.150	0.207	0.228
0 to 10 dBm	0.099	0.087	0.080	0.088	0.093	0.103	0.127	0.145	0.150	0.207	0.228
10 to 20 dBm	0.096	0.100	0.100	0.097	0.109	0.122	0.160	0.170	0.173	0.252	0.270

**Mass and Mass Related**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Barometers	(22 to 34) inHg (750 to 1 150) mBar	0.011 inHg 0.39 mBar	DPI 740 Barometer

**Thermodynamic**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Relative Humidity <sup>1</sup>	(0 to 90) %RH (90 to 100) %RH	1.3 %RH 2.4 %RH	Vaisala hygrometer
Relative Humidity	(5 to 90) %RH (90 to 95) %RH	0.81 %RH 1 %RH	Rotronic HG2-S101 Humidity Generator and Rotronic H290D sensor
Temperature <sup>1</sup>	(5 to 60) °C	0.14 °C	Rotronics HG2-S101 Humidity Generator and Rotronics H290D sensor
Temperature <sup>1</sup>	(-200 to 0) °C (0 to 200) °C (200 to 660) °C	0.021 °C 0.022 °C 0.027 °C	Fluke 5618B, 5628B RTD Probes and 1523 Temperature Indicator
Temperature	(-70 to 0) °C (0 to 180) °C	0.021 °C 0.022 °C	Fluke 5628B RTD Probe and 1523 Temperature Indicator, comparison to reference thermometer, in temperature chambers

**Time and Frequency**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency – Measuring Equipment <sup>1</sup>	1 mHz to 80 MHz	2.5 μHz/Hz + 1 μHz	With GPS conditioning: Agilent 33250 Signal Generator with GPS conditioning
Frequency – Measuring Equipment <sup>1</sup>	10 Hz to 4 GHz	0.03 nHz/Hz + 0.6 mHz	Fluke 9640 Reference Source with GPS conditioning
Frequency – Measuring Equipment <sup>1</sup>	10 MHz to 50 GHz	0.03 nHz/Hz + 0.6 Hz	Agilent 83650B w/ option 008 Signal Generator with GPS conditioning

**Time and Frequency**

Elk Horn, IA

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency – Measuring Equipment <sup>1</sup> 10 MHz Source (Rubidium)	10 MHz	0.03 nHz/Hz	Rubidium frequency standard referenced to GPS
Frequency – Measure 1	1 Hz to 225 MHz 225 MHz to 50 GHz	0.06 nHz/Hz + 25 pHz 0.04 nHz/Hz + 2 Hz	With GPS conditioning: Agilent 5335A, 53132A, Agilent 53151A, 53132A Counters, 8565E Spectrum Analyzer
Frequency – Measure 1	10 MHz	0.003 nHz/Hz	Agilent 53132A Counter referenced to GPS
Time Interval – Measure <sup>1</sup>	120 ps to 400 s	19 μs/s + 24 ps	Tektronix TDS 7404B oscilloscope
Time Interval – Measure <sup>1</sup>	(1 to 3 600) s	0.008 8 s	Agilent 33250A Signal Generator, with photo comparison

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(AC-1498.21)**

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**Electrical – DC/Low Frequency**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source <sup>1</sup>	Up to 220 mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	7 $\mu$ V/V + 0.54 $\mu$ V 5 $\mu$ V/V + 0.8 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.6 $\mu$ V/V + 4.5 $\mu$ V 5.3 $\mu$ V/V + 23 $\mu$ V 7.1 $\mu$ V/V + 0.3 mV	Fluke 5720A or 5730A Multiproduct Calibrator with Fluke 5725A Amplifier
DC Voltage - Source Fixed Values <sup>1</sup>	100 mV 1 V 10 V 100 V 1000 V	270 nV 1.5 $\mu$ V 11 $\mu$ V 150 $\mu$ V 5.3 mV	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Voltage – Measure <sup>1</sup>	Up to 100 mV (0.1 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	4.1 $\mu$ V/V + 0.36 $\mu$ V 3.7 $\mu$ V/V + 0.35 $\mu$ V 3.1 $\mu$ V/V + 0.59 $\mu$ V 5.3 $\mu$ V + 36 $\mu$ V 5.3 $\mu$ V/V + 0.12 mV	Keysight 3458A/100 NPLC Option 002 Multimeter
DC Voltage Transfer – Measure <sup>1</sup>	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1 000) V	0.62 $\mu$ V/V + 62 nV 0.37 $\mu$ V/V + 124 nV 62 nV/V + 0.62 $\mu$ V 0.62 $\mu$ V/V + 12.4 $\mu$ V 1.9 $\mu$ V/V + 63 $\mu$ V	Keysight 3458A Multimeter
DC Current – Source <sup>1</sup>	(>0 to 220) $\mu$ A 220 $\mu$ A to 22 mA (22 to 100) mA (100 to 220) mA 220 mA to 1 A (1 to 2.2) A	35 $\mu$ A/A 29 $\mu$ A/A 37 $\mu$ A/A 50 $\mu$ A/A - 1.2 $\mu$ A 59 $\mu$ A/A + 12 $\mu$ A 120 $\mu$ A/A - 42 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	280 $\mu$ A/A + 41 $\mu$ A	Fluke 5730A Multiproduct Calibrator with Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source <sup>1</sup>	100 $\mu$ A 1 mA 10 mA 100 mA 1 A	1.3 nA 9.5 nA 93 nA 2.2 $\mu$ A 36 $\mu$ A	Fluke 57x0A Multiproduct Calibrator disciplined with HP 3458A/100 NPLC Option 002 Multimeter
DC Current – Source <sup>1</sup>	(10 to 20) A (20 to 200) A (200 to 1 000) A	0.57 % of reading + 21 mA 0.57 % of reading + 145 mA 0.57 % of reading + 510 mA	Fluke 552xA Multiproduct Calibrator with 50 turn coil
DC Current – Measure <sup>1</sup>	(0 to 100) nA (0.1 to 1) $\mu$ A (1 to 10) $\mu$ A (10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	42 $\mu$ A/A + 50 pA 21 $\mu$ A/A + 50 pA 25 $\mu$ A/A + 0.11 nA 25 $\mu$ A/A + 0.85 nA 22 $\mu$ A/A + 6.4 nA 23 $\mu$ A/A + 59 nA 41 $\mu$ A/A + 0.6 $\mu$ A 125 $\mu$ A/A + 12 $\mu$ A	Keysight 3458A Multimeter
DC Current – Measure <sup>1</sup>	(1 to 3) A	1.4 mA/A + 0.74 mA	Keysight 34401A Multimeter
DC Current – Measure <sup>1</sup>	(0.01 to 15) A	76 $\mu$ A/A	Guildline 9230-15, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(15 A to 100) A	76 $\mu$ A/A	Guildline 9230-100, Keysight 3458A, Electronic Load
DC Current – Measure <sup>1</sup>	(100 A to 300) A	130 $\mu$ A/A	Guildline 9230-300, Keysight 3458A, Electronic Load
Resistance – Source <sup>1</sup>	(0 to 11) $\Omega$ (11 to 110) $\Omega$ (0.11 to 1.1) k $\Omega$ (1.1 to 3.3) k $\Omega$ (3.3 to 11) k $\Omega$ (11 to 110) k $\Omega$ (0.11 to 1.1) M $\Omega$ (1.1 to 3.3) M $\Omega$	33 $\mu\Omega/\Omega$ + 8.3 m $\Omega$ 25 $\mu\Omega/\Omega$ + 12.5 m $\Omega$ 23 $\mu\Omega/\Omega$ + 17 m $\Omega$ 23 $\mu\Omega/\Omega$ + 170 m $\Omega$ 23 $\mu\Omega/\Omega$ + 84 m $\Omega$ 23 $\mu\Omega/\Omega$ + 0.84 $\Omega$ 27 $\mu\Omega/\Omega$ + 8 $\Omega$ 50 $\mu\Omega/\Omega$ + 125 $\Omega$	Fluke 552xA Multiproduct Calibrator
Resistance – Source <sup>1</sup>	(3.3 to 11) M $\Omega$ (11 to 33) M $\Omega$ (33 to 110) M $\Omega$ (110 to 330) M $\Omega$ (330 to 1 100) M $\Omega$	110 $\mu\Omega/\Omega$ + 0.2 k $\Omega$ 210 $\mu\Omega/\Omega$ + 2 k $\Omega$ 410 $\mu\Omega/\Omega$ + 2.8 k $\Omega$ 2.5 m $\Omega/\Omega$ + 83 k $\Omega$ 13 m $\Omega/\Omega$ + 0.4 M $\Omega$	Fluke 552xA Multiproduct Calibrator



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source Fixed Points <sup>1</sup>	0 Ω	0.25 mΩ	Fluke 5720A/5730A Multiproduct Calibrator
	1 Ω	0.27 mΩ	
	1.9 Ω	0.31 mΩ	
	10 Ω	0.34 mΩ	
	19 Ω	2.5 mΩ	
	100 Ω	2.7 mΩ	
	190 Ω	3.3 mΩ	
	1 kΩ	9.3 mΩ	
	1.9 kΩ	31 mΩ	
	10 kΩ	93 mΩ	
	19 kΩ	0.19 Ω	
	100 kΩ	1.2 Ω	
	190 kΩ	2.2 Ω	
	1 MΩ	20 Ω	
	1.9 MΩ	42 Ω	
10 MΩ	0.40 kΩ		
19 MΩ	1.5 kΩ		
100 MΩ	12 kΩ		
Resistance – Source Fixed Points <sup>1</sup>	0 Ω	21 μΩ	Fluke 57x0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	10 Ω	49 μΩ	
	100 Ω	420 μΩ	
	1 kΩ	1.8 mΩ	
	10 kΩ	17 mΩ	
	100 kΩ	190 mΩ	
	1 MΩ	4.6 Ω	
	10 MΩ	140 Ω	
100 MΩ	18 kΩ		
Resistance – Measure <sup>1</sup>	(0 to 12) Ω	18 μΩ/Ω + 20 μΩ	Keysight 3458A Multimeter
	(10 to 120) Ω	12 μΩ/Ω + 0.6 mΩ	
	100 Ω to 1.2 kΩ	9.6 μΩ/Ω + 0.6 mΩ	
	(1 to 12) kΩ	9.6 μΩ/Ω + 6 mΩ	
	(10 to 120) kΩ	9.6 μΩ/Ω + 60 mΩ	
	100 kΩ to 1.2 MΩ	15 μΩ/Ω + 2.4 Ω	
	(1 to 12) MΩ	60 μΩ/Ω + 120 Ω	
(10 to 120) MΩ	0.6 mΩ/Ω + 1.2 kΩ		
100 MΩ to 1.2 GΩ	6 mΩ/Ω + 12 kΩ		
Resistance – Measure <sup>1</sup>	(10 to 100) MΩ	624 μΩ/Ω + 4.5 kΩ	Keysight 3458A Multimeter
	(0.1 to 1) GΩ	6.2 mΩ/Ω + 0.35 MΩ	



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	Up to 2.2 mV		Fluke 5730A Multiproduct Calibrator
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(2.2 to 22) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	40 Hz to 20 kHz	83 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(20 to 50) kHz	210 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(50 to 100) kHz	520 $\mu\text{V/V} + 4.1 \mu\text{V}$	
	(100 to 300) kHz	1.1 mV/V + 4.1 $\mu\text{V}$	
	(300 to 500) kHz	1.4 mV/V + 4.1 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 4.1 $\mu\text{V}$	
	(22 to 220) mV		
	(10 to 20) Hz	250 $\mu\text{V/V} + 39 \mu\text{V}$	
	(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$	
	40 Hz to 20 kHz	60 $\mu\text{V/V} + 7 \mu\text{V}$	
	(20 to 50) kHz	120 $\mu\text{V/V} + 8 \mu\text{V}$	
	(50 to 100) kHz	320 $\mu\text{V/V} + 18 \mu\text{V}$	
	(100 to 300) kHz	680 $\mu\text{V/V} + 20 \mu\text{V}$	
	(300 to 500) kHz	1.5 mV/V + 20 $\mu\text{V}$	
	500 kHz to 1 MHz	2.8 mV/V + 50 $\mu\text{V}$	
220 mV to 2.2 V			
(10 to 20) Hz	250 mV/V + 39 $\mu\text{V}$		
(20 to 40) Hz	94 $\mu\text{V/V} + 16 \mu\text{V}$		
40 Hz to 20 kHz	43 $\mu\text{V/V} + 8.8 \mu\text{V}$		
(20 to 50) kHz	70 $\mu\text{V/V} + 10 \mu\text{V}$		
(50 to 100) kHz	89 $\mu\text{V/V} + 30 \mu\text{V}$		
(100 to 300) kHz	350 $\mu\text{V/V} + 83 \mu\text{V}$		
(300 to 500) kHz	1.1 mV/V + 190 $\mu\text{V}$		
500 kHz to 1 MHz	1.8 mV/V + 300 $\mu\text{V}$		

**Electrical – DC/Low Frequency**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(220 to 1 100) V 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (220 to 750) V (30 to 50) kHz (50 to 100) kHz	80 $\mu$ V/V + 18 mV 173 $\mu$ V/V + 5.3 mV 625 $\mu$ V/V + 12 mV 634 $\mu$ V/V + 5.5 mV 2.4 mV/V + 28 mV	Fluke 5720A/5730A Multiproduct Calibrator with Fluke 5725A Amplifier
AC Voltage - Source <sup>1</sup> Fixed Values, Fixed Frequencies	0.01 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 0.1 V 1 kHz 20 kHz 100 kHz 300 kHz 1 MHz 4 MHz 8 MHz 10 MHz 1 V 1 kHz 20 kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz 4 MHz 8 MHz 10 MHz 3V 100 kHz (2, 4, 8) MHz 10 MHz	870 nV 1.2 $\mu$ V 4.5 $\mu$ V 33 $\mu$ V 21 $\mu$ V 140 $\mu$ V 4.6 $\mu$ V 6.9 $\mu$ V 36 $\mu$ V 52 $\mu$ V 170 $\mu$ V 670 $\mu$ V 690 $\mu$ V 2.3 mV 26 $\mu$ V 32 $\mu$ V 59 $\mu$ V 170 $\mu$ V 410 $\mu$ V 0.97 mV 1.7 mV 6.7 mV 6.9 mV 25 mV 420 $\mu$ V 21 mV 75 mV	Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage - Source <sup>1</sup> Fixed Values, Fixed Frequencies	10 V		Fluke 5700A or Fluke 5720A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
	10 Hz	480 $\mu$ V	
	20 Hz	270 $\mu$ V	
	40 Hz	230 $\mu$ V	
	200 Hz	460 $\mu$ V	
	500 Hz	450 $\mu$ V	
	1 kHz	260 $\mu$ V	
	10 kHz	270 $\mu$ V	
	20 kHz	320 $\mu$ V	
	50 kHz	0.53 mV	
	100 kHz	1.1 mV	
	300 kHz	2.6 mV	
	500 kHz	6.3 mV	
	1 MHz	12 mV	
	100 V		
1 kHz	4 mV		
20 kHz	7.9 mV		
50 kHz	7.9 mV		
100 kHz	16 mV		
700 V			
1 kHz	60 mV		
AC Voltage Flatness – Source <sup>1</sup>	300 $\mu$ V to 3.5 V (10 to 30) Hz	2.7 mV/V	Fluke 5720A, Fluke 5700A, or Fluke 5700A-03 Multiproduct Calibrator (referenced to 1 kHz)
	30 Hz to 120 kHz	1.4 mV/V	
	300 $\mu$ V to 1.1 mV 120 kHz to 2 MHz	4.6 mV/V	
	(2 to 10) MHz	6.2 mV/V	
	(10 to 20) MHz	8 mV/V	
	(20 to 30) MHz	24 mV/V	
	1.1 $\mu$ V to 3 mV 120 kHz to 2 MHz	2.2 mV/V	
	(2 to 10) MHz	3.7 mV/V	
	(10 to 20) MHz	5.5 mV/V	
	(20 to 30) MHz	14 mV/V	
	3 mV to 3.5 V 120 kHz to 2 MHz	1.2 mV/V	
	(2 to 10) MHz	2.1 mV/V	
(10 to 20) MHz	3.8 mV/V		
(20 to 30) MHz	8.6 mV/V		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage Flatness – Measure <sup>1</sup>	Up to 3 V 10 Hz 100 Hz (10, 30) kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.2 mV/V + 6.9 μV 80 μV/V + 5.5 μV 80 μV/V + 3.2 μV 0.1 mV/V + 8 μV 0.1 mV/V + 5.2 μV 0.1 mV/V + 6.5 μV 1.3 mV/V + 59 μV 1.3 mV/V + 0.11 mV 1.3 mV/V + 91 μV 2.5 mV/V + 0.21 mV 2.5 mV/V + 0.24 mV 6.1 mV/V + 0.34 mV 9 mV/V + 0.24 mV 11 mV/V + 0.79 mV 13 mV/V + 0.94 mV	Agilent 11049A, Agilent 11050A, Agilent 11051A Thermal Voltage Converters 3458A Multimeter
AC Voltage Flatness – Measure <sup>1</sup> (Relative to 1 kHz)	9 kHz to 2 GHz (-60 to 24) dBm	0.026 dB	Agilent E9304A Power Sensor, Agilent 8491B Attenuator, Agilent 3458A 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	0.3 mV/V + 3.1 μV 0.2 mV/V + 1.2 μV 0.3 mV/V + 1.7 μV 1 mV/V + 1.6 μV 5 mV/V + 1.3 μV 40 mV/V + 2.1 μV 12 mV/V + 6.6 μV 70 mV/V + 7.5 μV 20 mV/V + 8.2 μV	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) mV		Keysight 3458A Multimeter
	(1 to 40) Hz	70 $\mu$ V/V + 4.1 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 2.1 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 2.3 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 2.6 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 2.3 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 15 $\mu$ V	
	300 kHz to 1 MHz	10 mV/V + 28 $\mu$ V	
	(1 to 2) MHz	15 mV/V + 20 $\mu$ V	
	(2 to 4) MHz	40 mV/V + 74 $\mu$ V	
	(4 to 8) MHz	40 mV/V + 83 $\mu$ V	
	(8 to 10) MHz	0.15 V/V + 0.11 mV	
	(0.1 to 1) V		
	(1 to 40) Hz	70 $\mu$ V/V + 41 $\mu$ V	
	40 Hz to 1 kHz	70 $\mu$ V/V + 21 $\mu$ V	
	(1 to 20) kHz	0.14 mV/V + 22 $\mu$ V	
	(20 to 50) kHz	0.3 mV/V + 22 $\mu$ V	
	(50 to 100) kHz	0.8 mV/V + 22 $\mu$ V	
	(100 to 300) kHz	3 mV/V + 0.12 mV	
	300 kHz to 1 MHz	10 mV/V + 0.3 mV	
	(1 to 2) MHz	15 mV/V + 0.21 mV	
	(2 to 4) MHz	40 mV/V + 0.73 mV	
	(4 to 8) MHz	40 mV/V + 0.83 mV	
	(8 to 10) MHz	0.15 V/V + 1 mV	
	(1 to 10) V		
	(1 to 40) Hz	70 $\mu$ V/V + 0.42 mV	
	40 Hz to 1 kHz	70 $\mu$ V/V + 0.22 mV	
	(1 to 20) kHz	0.14 mV/V + 0.24 mV	
	(20 to 50) kHz	0.3 mV/V + 0.25 mV	
	(50 to 100) kHz	0.8 mV/V + 0.22 mV	
	(100 to 300) kHz	3 mV/V + 1.1 mV	
	300 kHz to 1 MHz	10 mV/V + 1.1 mV	
	(1 to 2) MHz	15 mV/V + 1.1 mV	
(2 to 4) MHz	40 mV/V + 7.1 mV		
(4 to 8) MHz	40 mV/V + 8.1 mV		
(8 to 10) MHz	0.15 mV/V + 11 mV		



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V (1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 750) V (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.2 mV/V + 4.1 mV 0.2 mV/V + 2.6 mV 0.35 mV/V + 2.4 mV 1.2 mV/V + 2.1 mV 4 mV/V + 11 mV 15 mV/V + 50 mV 0.4 mV/V + 31 mV 0.4 mV/V + 16 mV 0.6 mV/V + 16 mV 1.2 mV/V + 16 mV 3 mV/V + 15 mV	Keysight 3458A Multimeter
AC Voltage – Measure <sup>1</sup>	1 mV to 8 V 20 Hz to 20 MHz	4.6 % of reading	Keysight DSO9104A Oscilloscope
AC Current Source <sup>1</sup>	0 to 220 $\mu$ A 10 to 20 Hz 20 to 40 Hz 40 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz 220 $\mu$ A 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	230 $\mu$ A/A + 17 nA 150 $\mu$ A/A + 10 nA 108 $\mu$ A/A + 8.4 nA 266 $\mu$ A/A + 12.5 nA 915 $\mu$ A/A + 66 nA 233 $\mu$ A/A + 42 nA 150 $\mu$ A/A + 34 nA 108 $\mu$ A/A + 34 nA 183 $\mu$ A/A + 109 nA 915 $\mu$ A/A + 655 nA 233 $\mu$ A/A + 422 nA 149 $\mu$ A/A + 342 nA 108 $\mu$ A/A + 343 nA 183 $\mu$ A/A + 588 nA 915 $\mu$ A/A + 5 $\mu$ A 233 $\mu$ A/A + 4.2 $\mu$ A 149 $\mu$ A/A + 3.4 $\mu$ A 108 $\mu$ A/A + 2.6 $\mu$ A 183 $\mu$ A/A + 3.4 $\mu$ A 915 $\mu$ A/A + 10 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator

**Electrical – DC/Low Frequency**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current Source <sup>1</sup>	(0.22 to 2.2) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz (2.2 to 11) A 20 Hz to 1 kHz 1 to 5 kHz 5 to 10 kHz	249 $\mu$ A/A + 34 $\mu$ A 383 $\mu$ A/A + 83 $\mu$ A 5.8 mA/A + 166 $\mu$ A 332 $\mu$ A/A + 149 $\mu$ A 707 $\mu$ A/A + 320 $\mu$ A 2.8 mA/A + 600 $\mu$ A	Fluke 5720A or 5730A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(10 to 20) A 45 Hz to 65 Hz 65 Hz to 440 Hz (20 to 100) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz (100 to 1 000) A 45 Hz to 65 Hz 65 Hz to 100 Hz 100 Hz to 440 Hz	0.3 % of reading + 27 mA 0.33 % of reading + 50 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 29 mA 0.85 % of reading + 100 mA 0.85 % of reading + 3.6 mA 0.85 % of reading + 28 mA 1 % of reading + 0.25 A	Fluke 552xA Multiproduct Calibrator with 50 turn coil
AC Current - Source Fixed Values <sup>1</sup>	1 kHz 10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A	7.3 nA 14 nA 85 nA 0.87 $\mu$ A 8.7 $\mu$ A 200 $\mu$ A	Fluke 57X0A Multiproduct Calibrator disciplined with Keysight 3458A Multimeter
AC Current – Measure <sup>1</sup>	(5 to 100) $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 $\mu$ A to 1mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.46 % of reading + 0.039 $\mu$ A 0.17 % of reading + 0.040 $\mu$ A 0.065 % of reading + 0.040 $\mu$ A 0.67 % of reading + 0.040 $\mu$ A 0.46 % of reading + 0.25 $\mu$ A 0.17 % of reading + 0.26 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.033 % of reading + 0.27 $\mu$ A 0.067 % of reading + 0.26 $\mu$ A 0.46 % of reading + 0.48 $\mu$ A 0.63 % of reading + 1.7 $\mu$ A	Keysight 3458A Multimeter



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(1 to 10) mA		Keysight 3458A Multimeter
	(10 to 20) Hz	0.46 % of reading + 2.5 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 2.5 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 2.7 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 2.7 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 2.6 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 4.7 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 17 $\mu$ A	
	(10 to 100) mA		
	(10 to 20) Hz	0.46 % of reading + 25 $\mu$ A	
	(20 to 45) Hz	0.17 % of reading + 26 $\mu$ A	
	(45 to 100) Hz	0.067 % of reading + 26 $\mu$ A	
	100 Hz to 5 kHz	0.033 % of reading + 27 $\mu$ A	
	(5 to 20) kHz	0.067 % of reading + 26 $\mu$ A	
	(20 to 50) kHz	0.46 % of reading + 47 $\mu$ A	
	(50 to 100) kHz	0.63 % of reading + 0.17 mA	
	100 mA to 1 A		
(10 to 20) Hz	0.46 % of reading + 0.29 mA		
(20 to 45) Hz	0.18 % of reading + 0.32 mA		
(45 to 100) Hz	0.085 % of reading + 0.34 mA		
100 Hz to 5 kHz	0.11 % of reading + 0.34 mA		
(5 to 20) kHz	0.34 % of reading + 0.30 mA		
(20 to 50) kHz	1.1 % of reading + 0.49 mA		
Capacitance – Source <sup>1</sup>	(0.19 to 3.29) nF	3.1 mF/F + 7.7 pF	Fluke 5520A or 5522A Multiproduct 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) $\mu$ F	1.4 mF/F + 0.82 nF	
	(1.1 to 3.299) $\mu$ F	1.5 mF/F + 2.4 nF	
	(3.3 to 10.99) $\mu$ F	1.4 mF/F + 8.1 nF	
	(11 to 32.99) $\mu$ F	2.4 mF/F + 24 nF	
	(33 to 109.99) $\mu$ F	2.6 mF/F + 83 nF	
	(110 to 329.99) $\mu$ F	2.7 mF/F + 0.24 $\mu$ F	
	(0.33 to 1.099) mF	2.6 mF/F + 0.82 $\mu$ F	
	(1.1 to 3.299) mF	2.7 mF/F + 2.4 $\mu$ F	
	(3.3 to 10.00) mF	3.3 mF/F + 5.2 $\mu$ F	
(11 to 32.99) mF	5.5 mF/F + 24 $\mu$ F		
(33 to 110) mF	7.9 mF/F + 79 $\mu$ F		



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source <sup>1</sup>	1 mΩ	0.7 % of reading	Standard Resistor Sets 16074A 42030A 16340A 16353A
	10 mΩ	0.11 % of reading	
	100 mΩ	0.66 % of reading	
	1 Ω	63 μΩ/Ω	
	10 Ω	38 μΩ/Ω	
	100 Ω	30 μΩ/Ω	
	1 kΩ	29 μΩ/Ω	
	10 kΩ	29 μΩ/Ω	
	100 kΩ	2.1 μΩ/Ω	
	1 MΩ	8 μΩ/Ω	
	10 MΩ	16 μΩ/Ω	
	100 MΩ	96 μΩ/Ω	
	1 GΩ	240 μΩ/Ω	
	10 GΩ	590 μΩ/Ω	
100 GΩ	560 μΩ/Ω		
Capacitance – Source Fixed Points <sup>1</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.24 fF	
	1 kHz to 1 MHz	0.19 fF	
	2 MHz	0.31 fF	
	3 MHz	0.49 fF	
	4 MHz	0.68 fF	
	5 MHz	0.9 fF	
	10 MHz	2.5 fF	
	13 MHz	3.7 fF	
	10 pF		
	1 kHz	2 fF	
	(1 to 10) MHz	1.5 fF	
	10 MHz	2 fF	
	13 MHz	2.2 fF	
	100 pF		
	1 kHz to 3 MHz	14 fF	
4 MHz	17 fF		
5 MHz	20 fF		
10 MHz	37 fF		
13 MHz	53 fF		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source Fixed Points <sup>1</sup>	1 000 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 MHz	0.14 pF	
	(1 to 2) MHz	0.21 pF	
	(2 to 3) MHz	0.31 pF	
	(3 to 4) MHz	0.47 pF	
	(4 to 5) MHz	0.64 pF	
	(5 to 10) MHz	2 pF	
	(10 to 13) MHz	3 pF	
	10 nF		
	120 Hz to 100 kHz	1.5 pF	
	100 nF		
	120 Hz to 100 kHz	15 pF	
1 µF			
120 Hz to 1 kHz	0.52 nF		
(1 to 10) kHz	0.43 nF		
(10 to 100) kHz	0.72 nF		
10 µF			
20 Hz to 1 kHz	1.6 nF		
(1 to 20) kHz	2.2 nF		
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	1 kHz	0.001 9	
	1 kHz to 4 MHz	0.000 15	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 57	
	(10 to 13) MHz	0.000 84	
	10 pF		
	1 kHz	0.000 036	
	1 kHz to 1 MHz	0.000 025	
	(1 to 4) MHz	0.000 05	
	(4 to 5) MHz	0.000 073	
	(5 to 10) MHz	0.000 075	
	(10 to 13) MHz	0.000 095	
	100 pF		
	1 kHz	0.000 023	
	1 kHz to 1 MHz	0.000 021	
	(1 to 2) MHz	0.000 052	
	(2 to 3) MHz	0.000 048	
	(3 to 4) MHz	0.000 062	
	(4 to 5) MHz	0.000 071	
	(5 to 10) MHz	0.000 16	
(10 to 13) MHz	0.000 24		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dissipation Factor – Source Fixed Points <sup>1,2</sup>	1 000 pF		Agilent 16380A, Agilent 16380C Standard Air Capacitor Set, BNC 4 Terminal Pair
	20 Hz to 1 kHz	0.000 02	
	1 kHz to 1 MHz	0.000 031	
	(1 to 2) MHz	0.000 073	
	(2 to 3) MHz	0.000 1	
	(3 to 4) MHz	0.001 5	
	(4 to 5) MHz	0.000 21	
	(5 to 10) MHz	0.000 58	
	(10 to 13) MHz	0.000 86	
	10 nF		
	120 Hz to 1 kHz	0.000 024	
	(1 to 100) kHz	0.000 021	
	100 nF		
	120 Hz to 1 kHz	0.000 04	
(1 to 100) kHz	0.000 021		
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	1 μF		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	120 Hz to 1 kHz	0.000 041	
	(1 to 10) kHz	0.000 035	
	(10 to 100) kHz	0.000 11	
	Type B		
	(600 to 800) °C	0.47 °C	
	(800 to 1 000) °C	0.36 °C	
	(1 000 to 1 550) °C	0.32 °C	
	(1 550 to 1 820) °C	0.35 °C	
	Type C		
(0 to 150) °C	0.32 °C		
(150 to 650) °C	0.28 °C		
(650 to 1 000) °C	0.33 °C		
(1 000 to 1 800) °C	0.53 °C		
(1 800 to 2 316) °C	0.88 °C		
Type E			
(-250 to -100) °C	0.53 °C		
(-100 to -25) °C	0.18 °C		
(-25 to 350) °C	0.16 °C		
(350 to 650) °C	0.18 °C		
(650 to 1 000) °C	0.23 °C		



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Electrical – DC/Low Frequency

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices <sup>1</sup>	Type J		Fluke 5520A, Fluke 5522A Multiproduct Calibrator
	(-210 to -100) °C	0.29 °C	
	(-100 to -30) °C	0.18 °C	
	(-30 to 150) °C	0.16 °C	
	(150 to 760) °C	0.19 °C	
	(760 to 1 200) °C	0.25 °C	
	Type K		
	(-200 to -100) °C	0.35 °C	
	(-100 to -25) °C	0.2 °C	
	(-25 to 120) °C	0.18 °C	
	(120 to 1 000) °C	0.28 °C	
	(1 000 to 1 372) °C	0.42 °C	
	Type L		
	(-200 to -100) °C	0.39 °C	
	(-100 to 800) °C	0.28 °C	
	(800 to 900) °C	0.19 °C	
	Type N		
	(-200 to -100) °C	0.42 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.2 °C	
	(410 to 1 300) °C	0.29 °C	
	Type R		
	(0 to 250) °C	0.6 °C	
(250 to 400) °C	0.37 °C		
(400 to 1 000) °C	0.35 °C		
(1 000 to 1 767) °C	0.42 °C		
Type S			
(0 to 250) °C	0.5 °C		
(250 to 1 000) °C	0.38 °C		
(1 000 to 1 400) °C	0.39 °C		
(1 400 to 1 767) °C	0.49 °C		
Type T			
(-250 to -150) °C	0.66 °C		
(-150 to 0) °C	0.26 °C		
(0 to 120) °C	0.18 °C		
(120 to 400) °C	0.16 °C		
Type U			
(-200 to 0) °C	0.59 °C		
(0 to 600) °C	0.29 °C		



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Electrical – RF/Microwave

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Amplitude Modulation – Measure <sup>1</sup> Rate: 10 Hz to 100 kHz	(5 to 80) % Depth		N9030A or N9030B Signal Analyzer
	1 kHz Resolution Band Width	0.037 % Depth	
	2 MHz to 6 GHz (6 to 50) GHz	0.038 % Depth	
	4.3 kHz Resolution Band Width	0.026 % Depth	
	2 MHz to 6 GHz (6 to 50) GHz	0.03 % Depth	
	10 kHz Resolution Band Width	0.026 % Depth	
	2 MHz to 6 GHz (6 to 50) GHz	0.03 % Depth	
	100 kHz Resolution Band Width	0.028 % Depth	
	2 MHz to 6 GHz (6 to 50) GHz	0.036 % Depth	
	3 MHz Resolution Band Width	0.036 % Depth	
2 MHz to 6 GHz (6 to 50) GHz	0.084 % Depth		
Frequency Modulation – Measure <sup>1,4</sup> FM Deviation: 200 Hz to 100 kHz	2 MHz to 3.6 GHz		N9030A with Opt. TES or N9030B Signal Analyzer
	Modulation Index (0.2 to 100)	0.35 % of reading + 0.2 %M	
	(100 to 2 000)	0.8 % of reading	
	(3.6 to 8.4) GHz		
	Modulation Index (0.2 to 100)	0.7 % of reading + 0.2 %M	
	(100 to 2 000)	2 % of reading	
	(8.4 to 17.1) GHz		
	Modulation Index (0.2 to 100)	0.7 % of reading + 0.3 %M	
	(100 to 2 000)	2.5 % of reading	
	(17.1 to 34.5) GHz		
Modulation Index (0.2 to 100)	0.8 % of reading + 0.3 %M		
(100 to 2 000)	3 % of reading		
(34.5 to 50) GHz			
Modulation Index (0.2 to 100)	1.4 % of reading + 0.5 %M		
(100 to 2 000)	4 % of reading		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Digital Modulation – Measure <sup>1</sup> GSM EDGE	(0.8 to 1.9) GHz EDGE residual EVM (0 to 15) % GSM rms residual phase error (0 to 1)° (0 to 3)°	0.015 % of reading  0.015° 0.12°	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> CDMA2000 IS95, 1xEV-DO	Residual EVM (0 to 2) % (0.8 to 2.1) GHz	0.023 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> W-CDMA	Residual EVM (0 to 1.5) % (1.8 to 2.2) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> QPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz (6 to 32) GHz (32 to 44) GHz	0.01 % of reading 0.05 % of reading 0.065 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> $\pi/4$ DQPSK	Residual EVM (0 to 2.5) % (1 to 6) GHz	0.025 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 16, 64 and 256 QAM	Residual EVM (0 to 2.5) % (1 to 6) GHz (16 to 32) GHz (32 to 44) GHz	0.015 % of reading 0.03 % of reading 0.045 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> 2FSK (including DECT)	(1 to 6) GHz (0 to 2) % Shift Error or Frequency Deviation	0.048 % of deviation	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> NADC	(750 to 950) MHz Residual EVM (0 to 2) %	0.042 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PDC	(810 to 1501) MHz Residual EVM (0 to 2) %	0.055 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> PHS	(1.8 to 2) GHz Residual EVM (0 to 2) %	0.035 % of reading	N9030A or N9030B Signal Analyzer
Digital Modulation – Measure <sup>1</sup> TETRA	350 MHz to 1 GHz Residual EVM (0 to 2) %	0.044 % of reading	N9030A or N9030B Signal Analyzer



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Modulation – Measure <sup>1</sup> Modulation Rate: 50 Hz to 50 kHz	(0.2 to 1) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz (1 to 10) rad 100 kHz to 3.6 GHz (3.6 to 17.1) GHz (17.1 to 34.5) GHz (34.5 to 50) GHz	0.1 % of reading + 0.001 rad 0.1 % of reading + 0.002 rad 0.1 % of reading + 0.002 5 rad 0.1 % of reading + 0.004 9 rad 0.008 1 % of reading + 0.002 rad 0.015 % of reading + 0.003 rad 0.02 % of reading + 0.003 5 rad 0.058 % of reading + 0.005 8 rad	N9030B Signal Analyzer
Distortion Measure <sup>1</sup>	(-99 to 0) dB 20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	HP 8903A/B Audio Analyzer
RF Power - Power Meter Reference <sup>1</sup>	1 mW 50 MHz	0.23 % of reading	Keysight N1914A or E4419A/B Power Meter and N8482A or 8482A Power Sensor
Tuned RF Power - Absolute – Measure <sup>1</sup> 2.5 MHz to 26.5 GHz	(-22 to +10) dBm (-42 to -22) dBm (-50 to -42) dBm (-60 to -50) dBm (-72 to -60) dBm (-80 to -72) dBm (-92 to -80) dBm (-102 to -92) dBm (-110 to -102) dBm (-120 to -110) dBm (-127 to -120) dBm	0.17 dB 0.18 dB 0.2 dB 0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.27 dB 0.28 dB 0.31 dB 0.34 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tuned RF Power - Relative – Measure <sup>1</sup>  2.5 MHz to 26.5 GHz	(+2 to +10) dBm	0.08 dB	HP 8902A Measuring Receiver with HP 11722A or with HP 11792A and HP 11793A Power Sensor
	(-12 to +2) dBm	0.07 dB	
	(-22 to -12) dBm	0.08 dB	
	(-31 to -22) dBm	0.09 dB	
	(-40 to -31) dBm	0.1 dB	
	(-50 to -40) dBm	0.12 dB	
	(-61 to -50) dBm	0.15 dB	
	(-71 to -61) dBm	0.16 dB	
	(-80 to -71) dBm	0.17 dB	
	(-90 to -80) dBm	0.19 dB	
	(-100 to -90) dBm	0.22 dB	
	(-110 to -100) dBm	0.23 dB	
	(-120 to -110) dBm	0.27 dB	
(-127 to -120) dBm	0.3 dB		
RF Power Sensors Cal Factors <sup>1</sup>	9 kHz to 10 MHz	0.69 % of reading	E9304A Power Sensor
RF Power Sensors Cal Factors <sup>1</sup>	10 MHz	0.58 % of reading	Keysight PNA-X Network Analyzer 2.4, 3.5 mm Calibration Kits Reference Power Sensors
	30 MHz	0.54 % of reading	
	50 MHz	0.41 % of reading	
	100 MHz	0.51 % of reading	
	300 MHz to 3 GHz	0.6 % of reading	
	4 GHz	0.61 % of reading	
	5 GHz	0.67 % of reading	
	(6 to 7) GHz	0.68 % of reading	
	8 GHz	0.7 % of reading	
	9 GHz	0.79 % of reading	
	10 GHz	0.82 % of reading	
	11 GHz	0.79 % of reading	
	12 GHz	0.76 % of reading	
	12.4 GHz	0.8 % of reading	
	(13 to 15) GHz	0.79 % of reading	
	16 GHz	0.87 % of reading	
	17 GHz	0.91 % of reading	
	18 GHz	0.97 % of reading	
	(19 to 26) GHz	1.5 % of reading	
	26.5 GHz	1.6 % of reading	
27 GHz	1.7 % of reading		
(28 to 29) GHz	1.8 % of reading		
30 GHz	1.7 % of reading		
(31 to 32) GHz	1.8 % of reading		
33 GHz	1.7 % of reading		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power Sensors Cal Factors <sup>1</sup>	(34 to 40) GHz 41 GHz (42 to 44) GHz (45 to 47) GHz (48 to 50) GHz	1.8 % of reading 2.4 % of reading 2.5 % of reading 2.6 % of reading 2.5 % of reading	Keysight PNA-X Network Analyzer 2.4, 3.5 mm Calibration Kits Reference Power Sensors
Thermal Noise – Source ENR <sup>1</sup>	5 dB, 15 dB, or 21 dB 0.01 GHz 0.1 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.06 dB 0.06 dB 0.11 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.09 dB 0.07 dB 0.07 dB 0.07 dB 0.06 dB 0.06 dB 0.06 dB 0.07 dB 0.06 dB 0.13 dB 0.14 dB 0.14 dB 0.16 dB 0.17 dB 0.14 dB 0.13 dB 0.15 dB 0.15 dB	HP 346B opt. 002 346B/N4001A opt. 001 346B opt. 004 346C/N4002A Noise Source
Phase Noise for Signal Analyzers <sup>1</sup> Carrier 1 GHz	(-167 to -89) dBc/Hz Offsets (10 to 100) Hz (0.1 to 100) kHz (0.1 to 1) MHz (1 to 10) MHz	0.5 dB 0.36 dB 0.48 dB 0.53 dB	Wenzel 500-13438C/D Oscillator



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Phase Noise for Signal Sources <sup>1</sup>	≥ -150 dBc/Hz Offsets 1 Hz to 100 kHz	2.1 dB	Keysight E5500 Phase Noise System
Rod Antennas (ECISM) Antenna Factor	(0 to 110) dB 9 kHz to 60 MHz	0.32 dB	CISPR 25, ANSI C63.5, SAE ARP 958, CISPR 16-1-4 E5061B Network Analyzer Transmission/Reflection Test Set, BNC calibration standards
Current Probes & Bulk Current Injection Probes <sup>1</sup> –  Insertion Loss  Transfer Impedance	(0 to 110) dB 5 Hz to 2.4 GHz 10 MHz to 2.4 GHz (0 to 110) dB 5 Hz to 2.4 GHz 50 MHz to 2.4 GHz	 0.75 dB 1.0 dB  0.75 dB 1.0 dB	CISPR 16-1-2, IEC/EN 61000-4-6; E5061B Network Analyzer Transmission/Reflection Test Set, BNC & Type “N” calibration standards
CDN’s & Adapters <sup>1</sup> – (50 to 150) Ω  Voltage Division Factor  Adapter Insertion Loss  Coupling Factor  Impedance	  10 kHz to 230 MHz  10 kHz to 230 MHz  10 kHz to 230 MHz  10 kHz to 230 MHz	  0.25 dB  0.86 dB  0.82 dB  2.3 Ω	IEC/EN 61000-4-6 CISPR 16-1-2 E5061B Network Analyzer Transmission/Reflection Test Set, BNC & Type “N” calibration standards
LISN <sup>1</sup> –  Insertion Loss	(0 to 110) dB 9 kHz to 108 MHz (108 to 400) MHz (0 to 110) dB 150 kHz to 100 MHz (100 to 200) MHz (200 to 400) MHz (400 to 600) MHz (600 to 800) MHz 800 MHz to 1 GHz	 0.57 dB 0.68 dB  0.18 dB 0.55 dB 1.33 dB 1.2 dB 1.3 dB 2.2 dB	ANSI C63.4, CISPR: 25 & 16-1-2; E5061B Network Analyzer Transmission/Reflection Test Set, BNC Type “N” calibration standards

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
LISN <sup>1</sup> – Impedance – Magnitude	(0 to 5000) $\Omega$ 9 kHz to 100 MHz (100 to 200) MHz (200 to 400) MHz	0.68 $\Omega$ 0.77 $\Omega$ 0.91 $\Omega$	ANSI C63.4, CISPR: 25 & 16-1-2; E5061B Network Analyzer Transmission/Reflection Test Set, BNC Type “N” calibration standards	
Impedance – Phase	(0 to 5000) $\Omega$ 150 kHz to 100 MHz (100 to 200) MHz (200 to 400) MHz (400 to 600) MHz (600 to 800) MHz 800 MHz to 1 GHz	0.35 $\Omega$ 1.2 $\Omega$ 2.2 $\Omega$ 2 $\Omega$ 1.8 $\Omega$ 2.2 $\Omega$		
Isolation	(0 to 360) $^{\circ}$ 9 kHz to 100 MHz (100 to 200) MHz (200 to 400) MHz	3.1 $^{\circ}$ 2.8 $^{\circ}$ 2.7 $^{\circ}$		
	(0 to 110) dB 9 kHz to 100 MHz (100 to 200) MHz (200 to 400) MHz	0.36 dB 1.1 dB 1.6 dB		
ISN <sup>1</sup> – Phase	150 kHz to 80 MHz	2.3 $^{\circ}$		CISPR: 22 & 16-1-2, E5061B Network Analyzer Transmission/Reflection Test Set
Insertion Loss	150 kHz to 80 MHz	0.36 dB		
Impedance	150 kHz to 80 MHz	2.2 $\Omega$		
Longitudinal Conversion Loss	150 kHz to 80 MHz	0.88 dB		
Decoupling Attenuation	150 kHz to 80 MHz	0.36 dB		
EFT/Burst Generator <sup>1</sup> – Voltage	10 V to 6 kV	0.7 % of reading		EN 61000-4-4; IEC 61000-4-4, IEC 61000-4-4(2004, 2011); GR 1089 CORE ISO 7637-2 Tektronix TDS 5104B Oscilloscope
Rise Time	5 ns	0.067 ns		
Impulse Duration	50 ns	0.095 ns		
Burst Duration	15 ms 0.75 ms	1.4 $\mu$ s 0.033 $\mu$ s		
Burst Period	300 ms	0.016 ms		
Repetition Rate	5.0 kHz 100 kHz	0.23 Hz 5 Hz		



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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Mains Harmonic Emissions <sup>1</sup>	(100 to 280) V (0.1 to 20) A (20 to 60) A (0.5 to 179.5) °	0.07 % of reading + 270 mV 0.2 % of reading 0.1 A 0.1 °	IEC 61000-3-2; IEC 61000-4-7; IEC 61000-4-13; IEC 61000-4-14; IEC 61000-4-15; 61000-3-11
Voltage Fluctuations (Flicker) <sup>1</sup>	(100 to 280) V (0.1 to 20) A (20 to 60) A	0.1 % of reading + 370 mV 0.2 % of reading 0.1 A	IEC 61000-3-3 61000-3-12
RF Pre-Amplifiers, Amplifiers <sup>1</sup> – Gain	(0 to 110) dB 5 Hz to 3 GHz (20 to 50) GHz	0.71 dB 1 dB	IEEE 291 E5061B Vector Network Analyzer N5230C Signal Generator
Surge Generator <sup>1</sup> Voltage  Current	10 V to 6.0 kV (6.0 to 18) kV  (0.001 to 5) kA	0.72 % of reading 1.1 % of reading  1.1 % of reading	ITU Rec K.17, K.20, ITU Rec K.21; SBC-TP-76200; GR1089CORE
Surge Generator <sup>1</sup> Ring/ Impulse/ PQF Phase Synchronization	(0 to 360) ° 50 Hz 60 Hz 400 Hz	0.11 ° 0.095 ° 0.21 °	IEC/EN 61000-4-18 Tektronix TDS 5104B Oscilloscope PDP8000, P6015A,110 High Voltage Probes ANSI C62.41
Surge Generator <sup>1</sup> – Ring/ Impulse/ PQF  Front Time Open Short  Rise Time Open Circuit Short Circuit  Time to Half-Value Impulse Duration	  (0.1 to 50) µs  (0.1 to 50) µs  (20 to 1500) µs	  0.004 % of reading +0.2 ns  0.004 % of reading +0.2 ns  0.004 % of reading +0.2 ns	IEC/EN61000-4-5; IEC/EN 61000-4-8; IEC/EN 61000-4-9; IEC/EN 61000-4-10; IEC/EN 61000-4-11; IEC/EN 61000-4-12 UL 864; UL 1449; ISO 7637-2

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Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
ESD Simulators –			
Contact Voltage (Positive & Negative)	(0.5 to 2) kV (2 to 8) kV (8 to 15) kV (15 to 30) kV	2.6 % of reading 0.7 % of reading 0.6 % of reading 0.54 % of reading	IEC/EN 61000-4-2; ISO 10605; SAE J1113-13 TEK TDS 740B Oscilloscope IEC ESD Target Applied Kilovolt 149-3 Power Supply
Rise Time	(0 to 2) ns	61 ps	
Peak Current	(0 to 40) A	5 % of reading	
30 ns Current	(0 to 40) A	5.6 % of reading	
60 ns Current	(0 to 40) A	6.1 % of reading	
Air Discharge Voltage (Positive & Negative)	(0 to 2) kV (2 to 20) kV (20 to 40) kV	0.15 % of reading 0.61 % of reading 1.2 % of reading	
Rise Time	(0.7 to 1) ns	61 ps	
RC Time Constant (at ± 15 kV) (for 330 pF probe) (for 150 pF probe)	600 ns ± 130 ns 300 ns ± 60 ns	7.2 ns 6 ns	

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Parameter/Equipment	Attenuation - Source <sup>1</sup>										
Reference Standard, Method, and/or Equipment	8494H Attenuator										
Range	Expanded Uncertainty of Measurement (+/-)										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
20 Hz ≤ f < 300 kHz	0.002 8	0.002 7	0.002 7	0.002 8	0.002 9	0.002 8	0.002 9	0.002 8	0.002 8	0.002 8	0.003 3
300 kHz ≤ f < 80 MHz	0.002 9	0.002 8	0.002 8	0.003	0.003	0.003	0.003	0.003 4	0.003 7	0.003 7	0.003 8
80 MHz ≤ f < 1 GHz	0.005 4	0.005 4	0.005 4	0.005 3	0.005 4	0.005 4	0.005 1	0.005 4	0.005 4	0.005 9	0.005 3
1 GHz ≤ f < 4 GHz	0.066	0.068	0.068	0.069	0.071	0.071	0.072	0.073	0.073	0.074	0.074
4 GHz ≤ f < 10 GHz	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11

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<b>Parameter/ Equipment</b>	Attenuation - Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8494H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	1	2	3	4	5	6	7	8	9	10	11
10 GHz ≤ f < 14 GHz	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.15	0.15	0.14	0.14
14 GHz ≤ f ≤ 18 GHz	0.19	0.18	0.19	0.17	0.2	0.19	0.19	0.19	0.18	0.19	0.2

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<b>Parameter/ Equipment</b>	Attenuation - Source <sup>1</sup>										
<b>Reference Standard, Method, and/or Equipment</b>	8496H Attenuator										
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>										
Frequency Ranges	Step Attenuation Level in dB										
	10	20	30	40	50	60	70	80	90	100	110
1 kHz ≤ f < 100 MHz	0.003 7	0.007 1	0.052	0.064	0.049	0.089	0.083	0.12	0.14	0.16	0.2
100 MHz ≤ f < 300 MHz	0.004 2	0.009 2	0.058	0.071	0.055	0.089	0.083	0.12	0.14	0.17	0.18
300 MHz ≤ f < 500 MHz	0.007 3	0.014	0.065	0.079	0.062	0.096	0.088	0.13	0.14	0.18	0.19
500 MHz ≤ f < 1 GHz	0.007 3	0.016	0.082	0.086	0.071	0.1	0.094	0.13	0.15	0.22	0.24
1 GHz ≤ f < 4 GHz	0.009 6	0.02	0.097	0.1	0.086	0.11	0.1	0.15	0.16	0.22	0.24
4 GHz ≤ f < 8 GHz	0.011	0.023	0.1	0.11	0.089	0.15	0.14	0.19	0.21	0.36	0.37
8 GHz ≤ f < 10 GHz	0.016	0.032	0.12	0.13	0.11	0.19	0.18	0.27	0.28	0.42	0.45
10 GHz ≤ f < 12 GHz	0.019	0.039	0.12	0.12	0.1	0.16	0.15	0.2	0.23	0.38	0.46
12 GHz ≤ f < 14 GHz	0.022	0.045	0.14	0.14	0.12	0.2	0.19	0.27	0.29	0.43	0.51
14 GHz ≤ f < 18 GHz	0.032	0.063	0.14	0.14	0.12	0.21	0.2	0.27	0.29	0.36	0.5
18 GHz	0.039	0.075	0.16	0.17	0.14	0.26	0.24	0.34	0.36	0.56	0.58

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Parameter/ Equipment	Attenuation - Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit											
Range	Expanded Uncertainty of Measurement (+/-)											
Frequency Ranges	Step Attenuation Level in dB											
	0	1	2	3	4	5	6	7	8	9	10	11
10 MHz ≤ f < 300 MHz	0.028	0.029	0.029	0.03	0.031	0.031	0.03	0.033	0.034	0.034	0.035	0.036
300 MHz ≤ f < 2 GHz	0.028	0.029	0.031	0.032	0.033	0.032	0.031	0.035	0.036	0.036	0.037	0.038
2 GHz ≤ f < 8 GHz	0.046	0.048	0.049	0.05	0.051	0.051	0.052	0.053	0.054	0.054	0.055	0.056
8 GHz ≤ f < 12 GHz	0.052	0.052	0.054	0.055	0.056	0.056	0.057	0.058	0.059	0.059	0.059	0.061
12 GHz ≤ f < 18 GHz	0.058	0.06	0.061	0.062	0.063	0.064	0.064	0.066	0.067	0.066	0.067	0.069
18 GHz ≤ f < 20 GHz	-	-	-	0.062	-	-	0.064	-	-	-	0.067	-
20 GHz ≤ f < 30 GHz	-	-	-	0.11	-	-	0.11	-	-	-	0.12	-
30 GHz ≤ f < 40 GHz	-	-	-	0.12	-	-	0.13	-	-	-	0.13	-
40 GHz ≤ f < 50 GHz	-	-	-	0.18	-	-	0.19	-	-	-	0.2	-

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Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
10 MHz ≤ f < 50 MHz	0.042	0.053	0.091	0.17	0.12	0.14	0.17	0.18	0.18	0.19
50 MHz ≤ f < 500 MHz	0.042	0.05	0.062	0.082	0.097	0.11	0.12	0.14	0.14	0.16
500 MHz ≤ f < 2 GHz	0.044	0.051	0.061	0.084	0.1	0.11	0.1	0.11	0.12	0.14
2 GHz ≤ f < 8 GHz	0.061	0.07	0.078	0.1	0.14	0.19	0.15	0.2	0.2	0.25
8 GHz ≤ f < 12 GHz	0.066	0.076	0.089	0.15	0.19	0.25	0.21	0.26	0.29	0.33

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Parameter/ Equipment	Attenuation – Measure <sup>1</sup>									
Reference Standard, Method, and/or Equipment	N5230A/C Network Analyzer and Calibration Kit									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency Ranges	Step Attenuation Level in dB									
	20	30	40	50	60	70	80	90	100	110
12 GHz ≤ f < 18 GHz	0.074	0.082	0.096	0.16	0.34	0.39	0.35	0.4	0.41	0.47
18 GHz ≤ f < 20 GHz	0.074	0.082	0.097	-	-	-	-	-	-	-
20 GHz ≤ f < 26.5 GHz	0.12	0.12	0.12	-	-	-	-	-	-	-
26.5 GHz ≤ f < 30 GHz	0.13	0.13	0.15	-	-	-	-	-	-	-
30 GHz ≤ f < 40 GHz	0.14	0.15	0.17	-	-	-	-	-	-	-
40 GHz ≤ f < 50 GHz	0.2	0.21	0.24	-	-	-	-	-	-	-

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Parameter/ Equipment	RF Power Measure <sup>1</sup>											
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, N8488A Power Sensors											
Range	Expanded Uncertainty of Measurement (+/-)											
Power Range	Frequency Ranges (uncertainties in dB)											
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz	
-140 dBm ≤ P < -130 dBm	-	0.15	0.15	0.088	0.088	0.088	0.088	0.088	0.088	0.093	0.093	
-130 dBm ≤ P < -110 dBm	-	0.13	0.13	0.079	0.079	0.079	0.079	0.079	0.079	0.084	0.084	
-110 dBm ≤ P < -90 dBm	-	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.066	0.066	0.066	
-90 dBm ≤ P < -30 dBm	-	0.12	0.12	0.049	0.049	0.049	0.049	0.049	0.049	0.057	0.057	
-30 dBm ≤ P < -20 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048	
-20 dBm ≤ P < -10 dBm	-	0.13	0.13	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048	
-10 dBm ≤ P < 0 dBm	-	0.099	0.099	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048	



ANSI National Accreditation Board

Electrical – RF/Microwave

Ottawa, ON

Parameter/ Equipment	RF Power Measure <sup>1</sup>										
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, N8488A Power Sensors										
Range	Expanded Uncertainty of Measurement (+/-)										
Power Range	Frequency Ranges (uncertainties in dB)										
	1 kHz to 9 kHz	9 kHz ≤ f < 100 kHz	100 kHz ≤ f < 10 MHz	10 MHz ≤ f < 30 MHz	30 MHz ≤ f < 500 MHz	500 MHz ≤ f < 1.2 GHz	1.2 GHz ≤ f < 6 GHz	6 GHz ≤ f < 8 GHz	8 GHz ≤ f < 12.4 GHz	12.4 GHz ≤ f < 14 GHz	14 GHz ≤ f < 18 GHz
0 dBm ≤ P < 2 dBm	-	0.039	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
2 dBm ≤ P < 15 dBm	0.14	0.096	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.048	0.048
15 dBm ≤ P < 20 dBm	-	0.096	0.096	0.054	0.054	0.054	0.054	0.054	0.054	0.061	0.061
20 dBm ≤ P < 30 dBm	-	0.096	0.081	0.081	0.081	0.083	0.091	0.097	0.097	0.097	0.11
30 dBm ≤ P < 35 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.1	0.11	0.1	0.12
35 dBm ≤ P < 44 dBm	-	-	0.090	0.087	0.087	0.087	0.095	0.1	0.1	0.1	0.12

Electrical – RF/Microwave

Ottawa, ON

Parameter/ Equipment	RF Power Measure <sup>1</sup>								
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors								
Range	Expanded Uncertainty of Measurement (+/-)								
Power Range	Frequencies / Frequency Ranges (dB)								
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz	
-140 dBm ≤ P < -130 dBm	0.1	0.1	0.1	0.12	0.12	-	-	-	
-130 dBm ≤ P < -110 dBm	0.097	0.087	0.087	0.088	0.088	-	-	-	
-110 dBm ≤ P < -90 dBm	0.082	0.078	0.078	0.078	0.078	-	-	-	
-90 dBm ≤ P < -30 dBm	0.075	0.062	0.062	0.063	0.063	-	-	-	
-30 dBm ≤ P < -20 dBm	0.068	0.055	0.055	0.056	0.056	-	-	-	
-20 dBm ≤ P < -10 dBm	0.068	0.055	0.055	0.055	0.055	0.18	0.16	0.13	
-10 dBm ≤ P < 0 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13	

Electrical – RF/Microwave

Ottawa, ON

Parameter/ Equipment	RF Power Measure <sup>1</sup>							
Reference Standard, Method, and/or Equipment	E444xA Spectrum Analyzer, N9030A Signal Analyzer, 8482A, 8485A, 8487A, N8481B, N8482B, E9300A, E9304A, N8485A, U8489A Power Sensors							
Range	Expanded Uncertainty of Measurement (+/-)							
Power Range	Frequencies / Frequency Ranges (dB)							
	18 GHz ≤ f ≤ 26.5 GHz	26.5 GHz ≤ f ≤ 33 GHz	33 GHz ≤ f < 40 GHz	40 GHz ≤ f < 45 GHz	45 GHz ≤ f ≤ 50 GHz	51 GHz ≤ f ≤ 55 GHz	56 GHz ≤ f ≤ 65 GHz	65 GHz ≤ f ≤ 67 GHz
0 dBm ≤ P < 2 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
2 dBm ≤ P < 15 dBm	0.068	0.055	0.055	0.056	0.056	0.18	0.16	0.13
15 dBm ≤ P < 20 dBm	0.078	0.067	0.067	0.068	0.068	0.18	0.16	0.13
20 dBm ≤ P < 30 dBm	0.11	0.12	0.13	0.16	0.17	-	-	-

Electrical – RF/Microwave

Ottawa, ON

Parameter/ Equipment	S11 - Reflection Magnitude <sup>1,2</sup>									
Reference Standard, Method, and/or Equipment	85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits									
Range	Expanded Uncertainty of Measurement (+/-)									
Frequency	Measured Magnitude (+/- Linear)									
	≤ 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
5 Hz to 9 kHz	0.003 1	0.003 3	0.003 6	0.004 1	0.004 5	0.005 1	0.005 6	0.006 2	0.006 8	0.007 4
(1 to 100) kHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 5	0.003 7	0.003 9	0.004 2	0.004 6	0.005
(0.1 to 20) MHz	0.003 1	0.003 1	0.003 2	0.003 4	0.003 7	0.004 2	0.004 8	0.005 6	0.006 6	0.007 7
(0.02 to 2) GHz	0.000 54	0.000 62	0.000 7	0.000 81	0.000 93	0.001 1	0.001 2	0.0014	0.001 6	0.001 7
(2 to 8) GHz	0.000 78	0.000 82	0.000 89	0.000 98	0.001 1	0.001 2	0.001 4	0.001 5	0.001 7	0.001 9
(8 to 20) GHz	0.001 4	0.001 4	0.001 5	0.001 5	0.001 6	0.001 7	0.001 8	0.002	0.002 3	0.002 6
(20 to 26.5) GHz	0.001 9	0.001 9	0.001 9	0.002	0.002	0.002 1	0.002 3	0.002 5	0.002 7	0.003 1
(26.5 to 40) GHz	0.003 9	0.0041	0.004 4	0.004 9	0.005 6	0.006 6	0.007 7	0.009 1	0.011	0.012
(40 to 50) GHz	0.005 2	0.005 4	0.005 8	0.006 3	0.007	0.008 1	0.009 5	0.011	0.013	0.015

**Electrical – RF/Microwave**

Ottawa, ON

<b>Parameter/ Equipment</b>		S11 - Reflection Magnitude <sup>1,2</sup>								
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (+/- Linear)									
	≤ 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
(50 to 67) GHz	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019

**Electrical – RF/Microwave**

Ottawa, ON

<b>Parameter/ Equipment</b>		S11 - Reflection Phase <sup>1</sup>								
<b>Reference Standard, Method, and/or Equipment</b>		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits								
<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>									
<b>Frequency</b>	Measured Magnitude (+/- Degrees)									
	≤ 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
5 Hz to 9 kHz	1.87	1.03	0.77	0.65	0.58	0.53	0.5	0.48	0.47	0.47
(1 to 100) kHz	1.81	1.03	0.77	0.62	0.49	0.42	0.37	0.34	0.32	0.31
(0.1 to 20) MHz	1.81	1.04	0.78	0.64	0.52	0.47	0.45	0.45	0.46	0.49
(0.02 to 2) GHz	0.31	0.17	0.13	0.11	0.1	0.1	0.098	0.098	0.1	0.1
(2 to 8) GHz	0.45	0.24	0.17	0.14	0.12	0.12	0.11	0.11	0.11	0.11
(8 to 20) GHz	0.81	0.42	0.29	0.23	0.19	0.16	0.15	0.14	0.13	0.13
(20 to 26.5) GHz	1.1	0.55	0.38	0.29	0.24	0.2	0.18	0.17	0.17	0.17
(26.5 to 40) GHz	2.3	1.3	1	0.93	0.9	0.91	0.93	0.94	0.96	0.99
(40 to 50) GHz	3.1	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2
(50 to 67) GHz	7.7	3.8	2.6	1.9	1.6	1.3	1.2	1	0.95	0.88

**Electrical – RF/Microwave**

Ottawa, ON

Parameter/ Equipment		S21 - Transmission Magnitude <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B, 85059B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (dB)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> -6 to ≤ 10	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.058	0.058	0.063	0.067	0.074	0.088	0.104	0.126	0.175
(9 to 100) kHz	0.028	0.029	0.031	0.034	0.038	0.049	0.082	0.123	0.159
(0.1 to 130) MHz	0.028	0.029	0.031	0.034	0.038	0.047	0.069	0.09	0.128
(0.13 to 1.25) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.035	0.044	0.093
(1.25 to 4) GHz	0.031	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.044
(4 to 5) GHz	0.032	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.045
(5 to 26.5) GHz	0.034	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.038
(26.5 to 40) GHz	0.037	0.039	0.039	0.039	0.039	0.039	0.04	0.04	0.048
(40 to 50) GHz	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.044	0.051
(50 to 67) GHz	0.094	0.094	0.095	0.096	0.099	0.11	0.14	0.28	0.78

**Electrical – RF/Microwave**

Ottawa, ON

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range		Expanded Uncertainty of Measurement (+/-)							
Frequency	Measured Magnitude (+/- Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
5 Hz to 9 kHz	0.38	0.38	0.42	0.45	0.49	0.58	0.69	0.83	1.17
(9 to 100) kHz	0.19	0.19	0.21	0.22	0.25	0.32	0.54	0.82	1.06
(0.1 to 130) MHz	0.19	0.19	0.2	0.22	0.25	0.31	0.46	0.61	0.85

**Electrical – RF/Microwave**

Ottawa, ON

Parameter/ Equipment		S21 - Transmission Phase <sup>1</sup>							
Reference Standard, Method, and/or Equipment		85054B, 85031B, ET33700, 85056A, 85058B Calibration Kits							
Range	Expanded Uncertainty of Measurement (+/-)								
Frequency	Measured Magnitude (+/- Degrees)								
	10 to ≤ 0	> 0 to ≤ 3	> 3 to ≤ 6	> 6 to ≤ -0	> 10 to ≤ 20	> 20 to ≤ 30	> 30 to ≤ 40	> 40 to ≤ 50	> 50 to ≤ 60
(0.13 to 1.25) GHz	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.41	0.68
(1.25 to 4) GHz	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.46
(4.0 to 5) GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.53
(5 to 26.5) GHz	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
(26.5 to 40) GHz	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
(40 to 50) GHz	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
(50 to 67) GHz	0.63	0.63	0.64	0.66	0.67	0.76	0.97	1.9	5.5

**Thermodynamic**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Temperature – Measuring Equipment	(5 to 60) °C	0.14 °C	Rotronics HG2-S101 Humidity Generator & Rotronics H290D sensor
Temperature – Measure	(-70 to 0) °C (0 to 200) °C (200 to 420) °C	0.03 °C 0.055 °C 0.038 °C	Fluke 5618B PRT & 1523 Thermometer
Relative Humidity – Measure	(0 to 90) % RH (90 to 100) % RH	1.3 % RH 2.4 % RH	Vaisala HMI41 Humidity Indicator, HMP46 Probe
Relative Humidity – Generate	(5 to 90) % RH (90 to 95) % RH	0.81 % RH 1 % RH	Rotronics HG2-S101 & Humidity Generator & Rotronics H290D sensor

**Time and Frequency**

Ottawa, ON

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Time Interval – Measure <sup>1</sup>	10 ns to 10 s	2.9 ns	HP 5334B Counter connected to Time base (HP 5071A or Datum 8040)
Frequency – Source <sup>1</sup>	10 MHz	65 pHz/Hz	Symmetricom 8040 Frequency Standard
Frequency – Measure <sup>1</sup>	(10 to 100) Hz (100 to 1 000) Hz 1 kHz to 12.4 GHz	71 pHz/Hz + 0.15 nHz 68 pHz/Hz + 0.5 nHz 67 pHz/Hz	Agilent 53132A Counter Symmetricom 8040C Frequency Standard
Frequency – Measure <sup>1</sup>	(12.4 to 26.5) GHz	30 pHz/Hz + 3.7 Hz	Agilent 53151A Counter, Symmetricom 8040C Frequency Standard
Rise Time – Source <sup>1</sup>	1 kHz to 2 MHz (200 to 300) ps (2 to 10) MHz (200 to 350) ps	37 ps 37 ps	Fluke 55xxA + SC600/1100 Multiproduct Calibrator
Rise Time – Measure <sup>1</sup>	300 μs to 1 ps Up to 1 GHz	8.1 ps	DSO 9104A Oscilloscope
Period – Measure <sup>1</sup>	20 ps ≤ t < 66 ps 66 ps ≤ t < 100 ms 100 ms ≤ t < 1 s 1 s ≤ t ≤ 10 s	1.3 ps 0.64 ns/s 0.64 ns/s 0.74 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Time Interval – Measure <sup>1</sup>	20 ps ≤ t ≤ 100 ps 100 ps < t ≤ 700 ps 700 ps < t ≤ 3.8 ns 3.8 ns < t ≤ 250 ns 250 ns < t ≤ 1 ms	1.3 ps 1.1% of reading + 0.9 ps 8.5 ps 0.105% of reading + 8.5 ps 0.27 ns	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Width – Measure <sup>1</sup>	1 ms < t ≤ 100 ms 100 ms < t ≤ 1 s 1 s < t ≤ 10 s	0.27 ns 0.5 ns/s + 0.18 ns 0.63 ns/s	86100C/D Oscilloscope with 86117A Sampling Module
Pulse Amplitude – Measure <sup>1</sup>	25 mV ≤ V < 100 mV 100 mV ≤ V < 200 mV 200 mV ≤ V < 400 mV 400 mV ≤ V ≤ 750 mV 750 mV < V ≤ 10 V 10 V < V ≤ 70 V	3.2 mV 4 mV 5.4 mV 7.8 mV 1.5 % of reading 1.5 % of reading	86100C/D Oscilloscope with 86117A Sampling Module

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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. Unitless linear measure.
3.  $D$  = diameter in inches,  $f$  = frequency,  $L$  = length in inches,  $M$  = modulation rate,  $P$  = power applied,  $R$  = resolution of device under test, " $\rho$ " = modulation accuracy or rho,  $S$  = step(dB).
4. The CMC for scales and balances is highly dependent upon the resolution of the unit under test. The uncertainties presented here do not include the resolution of the unit under test. The resolution will be included in the reported measurement uncertainty at the time of calibration.
5. The CMC expanded uncertainty of measurement excludes the repeatability of the DUT.
6. This scope is formatted as part of a single document including Certificate of Accreditation No. AC-1498. Site specific sections are identified by city and suffix (AC-1498.xx) for convenience.
7. The satellite sites in Bethlehem, PA, Arlington Heights, IL and Mississauga, ON have been voluntarily withdrawn as of September 20, 2024.



Jason Stine, Vice President

