



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017  
& ANSI/NCSL Z540-1-1994

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CALIBRATION

Valid To: March 31, 2022

Certificate Number: 2147.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations<sup>1, 11</sup>:

I. Acoustical Quantities

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Sound Level – Measuring Equipment, Fixed Points <sup>3</sup>	94 dB 114 dB	0.28 dB 0.28 dB	Bruel & Kjaer 4231

II. Chemical

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
pH Meters, Fixed Points <sup>3</sup>	4 pH 7 pH 10 pH	0.017 pH 0.012 pH 0.019 pH	Standard pH solutions
Conductivity Meters <sup>3</sup>	≈10 μS/cm ≈1413 μS/cm ≈10 mS/cm ≈100.9 mS/cm	4.4 μS/cm 9.8 μS/cm 0.15 mS/cm 2.2 mS/cm	Standard conductivity solutions

III. Dimensional

Parameter/Equipment	Range	CMC <sup>2, 6</sup> ( $\pm$ )	Comments
Bore Gauges <sup>3</sup>	Up to 6 in	$(47 + 26L) \mu\text{in}$	Master rings
Calipers <sup>3</sup> – Dial, Digital, Vernier –  Length  Parallelism	Up to 18 in (18 to 48) in  Up to 2 in	$(290 + 7.3L) \mu\text{in}$ $(240 + 4.9L) \mu\text{in}$  30 $\mu\text{in}$	Gage blocks
Depth Gauge <sup>3</sup> – Dial, Digital, Vernier	(0.001 to 48) in	$(59 + 7.2L) \mu\text{in}$	Gage blocks, surface plate
Gage Blocks –  Flatness	Up to 10 in  Up to 2 in	$(3.2 + 0.9L) \mu\text{in}$  2.5 $\mu\text{in}$	Pratt & Whitney Labmaster™ LMU-175, gauge blocks, optical flat
Height Gauges <sup>3</sup>	Up to 18 in (18 to 36) in	$(30 + 6.5L) \mu\text{in}$ $(16 + 7.3L) \mu\text{in}$	Gage blocks
Indicators – Dial & Digital <sup>3</sup>	(0.000 01 to 2) in	$(11 + 8.9L) \mu\text{in}$	Gage blocks, surface plate
Length Standards <sup>3</sup>	Up to 10 in (10 to 20) in (20 to 96) in	$(3.2 + 1.0L) \mu\text{in}$ $(7.8 + 15L) \mu\text{in}$ $(45 + 17L) \mu\text{in}$	Pratt & Whitney Labmaster™ LMU-175, micrometer head, gage blocks, P&W PC25
Measuring Rule & Tapes <sup>3</sup>	Up to 300 in	$(300 + 4.0L) \mu\text{in}$	Hexagon Optiv Classic 321
Micrometers <sup>3</sup> –  OD ID  Flatness Parallelism	Up to 48 in Up to 24 in  Up to 2 in Up to 2 in	$(30 + 13L) \mu\text{in}$ $(30 + 13L) \mu\text{in}$  2.5 $\mu\text{in}$ 2.5 $\mu\text{in}$	Gage blocks  Optical flat

Parameter/Equipment	Range	CMC <sup>2,6</sup> ( $\pm$ )	Comments
Optical Comparators <sup>3</sup> – Angularity Linearity X-Y Magnification	(0 to 180) $^{\circ}$ Up to 12 in Up to 50X	0.79 arc sec 160 $\mu$ in 0.13 % of Magnification	Sine bar, gage blocks Glass scale Magnification master, pin gauge
Plain Gage <sup>3</sup> – Pins & Plugs Rings	Up to 1 in (1 to 10) in (10 to 20) in  Up to 1 in (1 to 10) in	(7.8 + 9.1L) $\mu$ in (2.9 + 14L) $\mu$ in (11 + 13L) $\mu$ in  (6.3 + 12L) $\mu$ in (2.4 + 16L) $\mu$ in	Pratt & Whitney Labmaster <sup>TM</sup> LMU-175, gage blocks, P&W PC25
Protractors <sup>3</sup>	Up to 90 $^{\circ}$	0.060 $^{\circ}$	Surface plate, sine bar, gage blocks
Sine Bars – Length Flatness	(5 to 10) in  (5 to 10) in	(76 + 4.6L) $\mu$ in  29 $\mu$ in	Hexagon Optiv Classic 321, Hexagon Global S Chrome  Electronic gauge head
Surface Plates <sup>3</sup> – Flatness Repeatability	Up to 170 in diagonal  (-0.002 to 0.002) in	(7.1 $\sqrt{D}$ ) $\mu$ in  28 $\mu$ in	Mahr Federal EMD-832-W3 electronic level  Rahn Repeat-O-Meter
Thickness Gauge <sup>3</sup> (Feeler Type)	(0.001 to 1) in	(8.6 + 30L) $\mu$ in	Pratt & Whitney Labmaster <sup>TM</sup> LMU-175
Thickness Gauge <sup>3</sup> (Ultrasonic)	(0.001 to 8) in	590 $\mu$ in	Gage Blocks

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Thread Gauges – Thread Ring, Adjustable <sup>3</sup> Thread Plugs <sup>3</sup> Major Diameter Pitch Diameter	Up to 4 in  Up to 3 in Up to 3 in  (80 to 6) TPI	Thread Plug tolerance (W)  79 µin 120 µin	Set using master plug gages. ASME/ANSI B1.2- 1983 & ASME/ANSI B1.3- 2007  Pratt & Whitney Labmaster™ LMU-175, gauge blocks, thread wires
Thread Wires	(80 to 6) TPI	9.0 µin	Labmaster™ LMU-175, gauge blocks
Vision System <sup>3</sup> – Linearity	Up to 100 mm	0.0020 mm	Standard glass scale

#### IV. Dimensional Testing/Calibration<sup>10</sup>

Parameter/Equipment	Range	CMC <sup>2,6</sup> (±)	Comments
Dimensional Inspection – Linear (1D)  Volumetric 3D Fixtures & Artifacts	Up to 10) mm (10 to 100) mm (100 to 300) mm  (300 x 200 x 150) mm  (24 x 32 x 22) in	0.0017 mm 0.0021 mm 0.0030 mm  0.0042 mm  (65 + 2.8L) µin	Hexagon Optiv Classic 321  Hexagon Global S Chrome

V. Electrical DC/Low Frequency

Parameter/Equipment	Range	CMC <sup>2, 7</sup> (±)	Comments
DC Voltage <sup>3</sup> –			
Fixed – Generate	10 V	0.5 µV/V	Fluke 732B
Measure	0 V Short	0.62 µV/V	Copper short
	(0 to 100) mV	2.7 µV/V + 0.84 µV	HP 3458A Opt. 002 digital multimeter
	(0.1 to 1) V	2.0 µV/V + 5.7 µV	
	(1 to 10) V	4.4 µV/V + 88 µV	
	(10 to 100) V	1.5 µV/V + 2.0 mV	
	(100 to 1000) V	5.3 µV/V + 2.0 mV	
	(1 to 10) kV	0.35 mV/V + 35 mV	Vitretek 4700 high voltage multimeter, Vitrek HVL-100 high voltage probe
	(10 to 100) kV	0.58 mV/V + 0.50 V	
DC Voltage <sup>3</sup> –			
Generate	(0 to 220) mV	9.6 µV/V + 0.63 µV	Fluke 5700A
	(0.22 to 2.2) V	4.3 µV/V + 4.4 µV	
	(2.2 to 11) V	4.0 µV/V + 4.5 µV	
	(11 to 22) V	4.1 µV/V + 4.9 µV	
	(22 to 220) V	5.7 µV/V + 98 µV	
	(220 to 1100) V	7.8 µV/V + 661 µV	
Transfer	(0 to 100) mV	0.98 µV	Wavetek 4950
	(0.1 to 1) V	6.0 µV	
	(1 to 10) V	0.037 mV	
	(10 to 100) V	0.77 mV	
	(100 to 1000) V	7.7 mV	

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
DC Current <sup>3</sup> –  Measure	(0 to 100) µA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 10) A (10 to 2000) A  (2000 to 2800) A  10 µA 100 µA 1 mA 10 mA 20 mA 100 mA 200 mA 1 A 1.9 A	20 µA/A + 1.4 nA 21 µA/A + 7.9 nA 21 µA/A + 81 nA 39 µA/A + 0.78 µA 1.1 mA/A + 36 µA 1.1 mA/A + 4.8 mA 6.1 mA/A + 19 µA  18 mA/A + 12 mA  7.9 nA 3.3 nA 0.012 µA 0.18 µA 0.15 µA 1.8 µA 1.8 µA 24 µA 26 µA	HP 3458A opt. 002 digital multimeter          Agilent 34461A current shunt, HP 3458A opt. 002 digital multimeter LEM PR2000 current clamp, HP 3458A opt. 002 digital multimeter HP 3458A opt. 002, Fluke A40B series current shunts
Generate	(0 to 220) µA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A  (1.1 to 3) A (1.2 (3 to 11) A (11 to 20.5) A	10 nA/A + 7.1 nA 8.7 nA/A + 13 nA 8.7 nA/A + 49 nA 1.1 nA/A + 0.84 µA 2.0 nA/A + 31 µA  402 µA/A + 1.5 mA 1 mA/A + 2.4 mA 1.1 mA/A + 2.4 mA	Fluke 5700A     Fluke 5520A
Toroidal Non-Toroidal	(20.5 to 1000) A (20.5 to 1000) A	3.1 mA/A + 0.60 A 6.0 mA/A + 0.60 A	Fluke 5520A w/ coil
DC Current <sup>3</sup> – Transfer	(0 to 100) µA (1.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	2.7 nA 0.020 µA 0.21 µA 2.4 µA 0.035 mA	Wavetek 4950

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
Resistance <sup>3</sup> – Measure  Fixed	10 mΩ	0.89 mΩ	Leeds & Northrop 4222 Resistor
	100 mΩ	0.89 mΩ	Guidline 9330 series resistors
	1 Ω	0.89 mΩ	
	10 kΩ	7.4 mΩ	
	10 MΩ	0.32 kΩ	
	1 GΩ	0.56 MΩ	
	10 GΩ	0.61 MΩ	
	100 GΩ	0.12 GΩ	
	1 TΩ	2.6 GΩ	
	0 Ω	47 μΩ	Fluke 5720A
	1 Ω	110 μΩ	
	1.9 Ω	110 μΩ	
	10 Ω	35 μΩ	
	19 Ω	43 μΩ	
	100 Ω	0.15 mΩ	
	190 Ω	0.28 mΩ	
	1 kΩ	1.6 mΩ	
	1.9 kΩ	2.9 mΩ	
	10 kΩ	15 mΩ	
	19 kΩ	29 mΩ	
	100 kΩ	0.18 Ω	
	190 kΩ	0.30 Ω	
	1 MΩ	17 Ω	
	1.9 MΩ	19 Ω	
	10 MΩ	71 Ω	
	19 MΩ	250 Ω	
	100 MΩ	4.2 kΩ	
(0 to 10) Ω	29 μΩ/Ω + 0.58 mΩ	HP 3458A Opt. 002, digital multimeter	
(10 to 100) Ω	12 μΩ/Ω + 0.58 mΩ		
(100 to 1000) Ω	12 μΩ/Ω + 5.8 mΩ		
(1 to 10) kΩ	12 μΩ/Ω + 58 mΩ		
(10 to 100) kΩ	18 μΩ/Ω + 2.3 Ω		
100 kΩ to 1 MΩ	58 μΩ/Ω + 0.12 kΩ		
(1 to 100) MΩ	5.8 mΩ/Ω + 12 kΩ		
100 MΩ to 1 GΩ	5.8 mΩ/Ω + 12 kΩ		

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
Resistance <sup>3</sup> – Generate	(0 to 1) Ω (1 to 1.9) Ω (1.9 to 10) Ω (10 to 19) Ω (19-100) Ω (100 to 190) Ω (190 to 1000) Ω (1000 to 1900) Ω (1.9 to 10) kΩ (10 to 19) kΩ (19 to 100) kΩ (100 to 190) kΩ (0.19 to 1) MΩ (1 to 1.9) MΩ (1.9 to 100) MΩ	46 μΩ/Ω + 1.2 mΩ 46 μΩ/Ω + 1.2 mΩ 46 μΩ/Ω + 1.2 mΩ 34 μΩ/Ω + 1.8 mΩ 28 μΩ/Ω + 3.5 mΩ 28 μΩ/Ω + 3.5 mΩ 29 μΩ/Ω + 6.3 mΩ 27 μΩ/Ω + 4.0 mΩ 26 μΩ/Ω + 100 mΩ 27 μΩ/Ω + 40 mΩ 26 μΩ/Ω + 1 Ω 33 μΩ/Ω + 3.4 Ω 30 μΩ/Ω + 11 Ω 63 μΩ/Ω + 0.05 kΩ 0.52 mΩ/Ω + 10 kΩ	Fluke 5520A
Resistance <sup>3</sup> – Current Shunt	Up to 80 mΩ (80 to 800) mΩ (0.8 to 1000) Ω	320 μΩ/Ω + 1.3 nΩ 140 μΩ/Ω + 4.7 nΩ 81 μΩ/Ω + 16 μΩ	Fluke 5520A, HP 3458A Opt.002 digital multimeter
Resistance <sup>3</sup> – Transfer	Up to 1 Ω (1 to 10) Ω (0.01 to 190) kΩ (0.19 to 1.9) MΩ (1.9 to 19) MΩ (19 to 100) MΩ	73 μΩ/Ω 110 μΩ/Ω 11 μΩ/Ω 18 μΩ/Ω 26 μΩ/Ω 0.032 %	Wavetek 4950

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Measure  (0 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.43 mV/V + 1.5 μV 0.25 mV/V + 1.5 μV 0.25 mV/V + 1.5 μV 0.46 mV/V + 2.3 μV 0.69 mV/V + 2.9 μV 1.4 mV/V + 4.6 μV 1.5 mV/V + 9.2 μV 2.7 mV/V + 9.2 μV	Fluke 5790A



Parameter/Range	Frequency	CMC <sup>2,7</sup> ( $\pm$ )	Comments
AC Voltage <sup>3</sup> – Measure (cont)			
(2.2 to 7) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.22 mV/V + 1.5 $\mu$ V 0.13 mV/V + 1.5 $\mu$ V 0.13 mV/V + 1.5 $\mu$ V 0.24 mV/V + 2.3 $\mu$ V 0.36 mV/V + 2.9 $\mu$ V 0.95 mV/V + 4.6 $\mu$ V 1.0 $\mu$ V/V + 9.2 $\mu$ V 2.0 mV/V + 9.2 $\mu$ V	Fluke 5790A
(7 to 22) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.15 mV/V + 1.8 $\mu$ V 78 $\mu$ V/V + 1.8 $\mu$ V 78 $\mu$ V/V + 1.8 $\mu$ V 0.14 mV/V + 3.1 $\mu$ V 0.24 mV/V + 5.9 $\mu$ V 0.63 mV/V + 4.7 $\mu$ V 0.82 mV/V + 9.3 $\mu$ V 1.3 mV/V + 9.3 $\mu$ V	
(22 to 70) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	99 $\mu$ V/V + 1.9 $\mu$ V 45 $\mu$ V/V + 1.9 $\mu$ V 45 $\mu$ V/V + 1.9 $\mu$ V 70 $\mu$ V/V + 4.1 $\mu$ V 0.14 mV/V + 9.8 $\mu$ V 0.31 mV/V + 5.0 $\mu$ V 0.45 mV/V + 9.5 $\mu$ V 1.2 mV/V + 9.6 $\mu$ V	
(70 to 220) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	15 $\mu$ V/V + 77 $\mu$ V 3.6 $\mu$ V/V + 65 $\mu$ V 3.6 $\mu$ V/V + 65 $\mu$ V 6.6 $\mu$ V/V + 85 $\mu$ V 7.8 $\mu$ V/V + 0.15 mV 24 $\mu$ V/V + 0.28 mV 59 $\mu$ V/V + 0.28 mV 0.44 mV/V + 0.28 mV	

Parameter/Range	Frequency	CMC <sup>2, 7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Measure (cont)			
(220 to 700) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	12 μV/V + 0.17 mV 3.4 μV/V + 83 μV 3.4 μV/V + 84 μV 24 μV/V + 36 μV 39 μV/V + 49 μV 44 μV/V + 0.34 mV 92 μV/V + 0.35 mV 0.68 μV/V + 0.36 mV	Fluke 5790A
(0.7 to 2.2) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	28 μV/V + 0.22 mV 15 μV/V + 45 μV 15 μV/V + 45 μV 52 μV/V + 16 μV 83 μV/V + 26 μV 0.22 mV/V + 50 μV 0.13 mV/V + 1.7 mV 0.89 mV/V + 1.5 mV	
(2.2 to 7) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	70 μV/V + 80 μV 25 μV/V + 59 μV 25 μV/V + 59 μV 49 μV/V + 59 μV 87 μV/V + 52 μV 0.23 mV/V + 40 μV 0.45 mV/V + 0.19 mV 1.3 mV/V + 0.43 mV	
(7 to 22) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	76 μV/V + 0.12 mV 34 μV/V + 0.10 mV 34 μV/V + 0.10 mV 62 μV/V + 0.10 mV 100 μV/V + 0.30 mV 0.20 mV/V + 0.86 mV 0.45 mV/V + 0.75 mV 1.4 mV/V + 0.58 mV	
(22 to 70) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	75 μV/V + 0.51 mV 30 μV/V + 0.64 mV 30 μV/V + 0.64 mV 74 μV/V + 0.51 mV 100 μV/V + 1.1 mV 0.21 mV/V + 2.8 mV 0.57 mV/V + 1.0 mV	

Parameter/Range	Frequency	CMC <sup>2, 7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Measure (cont)			
(70 to 220) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	80 μV/V + 0.51 mV 35 μV/V + 0.64 mV 35 μV/V + 0.64 mV 78 μV/V + 0.51 mV 0.11 mV/V + 1.1 mV 0.23 mV/V + 2.8 mV 0.58 mV/V + 1.0 mV	Fluke 5790A
(220 to 700) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.11 mV/V + 4.2 mV 43 μV/V + 3.4 mV 43 μV/V + 3.4 mV 90 μV/V + 64 mV 0.31 mV/V + 0.27 V	
(700 to 1000) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.11 mV/V + 4.2 mV 44 μV/V + 3.4 mV 44 μV/V + 3.4 mV 0.11 mV/V + 64 mV 0.37 mV/V + 0.27 V	
(1 to 10) kV	(0.01 to 600) Hz	1.4 mV/V + 0.12 V	Vitrek 4700 high voltage multimeter
(10 to 75) kV	(0.01 to 600) Hz	1.2 mV/V + 0.77 V	Vitrek HVL-100 high voltage probe

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Voltage – Wideband Measure			
(0 to 2.2) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	7.9 mV/V + 1.9 μV 7.5 mV/V + 1.9 μV 7.5 mV/V + 1.9 μV 7.5 mV/V + 1.9 μV 7.7 mV/V + 3.0 μV	Fluke 5790A w/ wideband opt.
(2.2 to 7) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	7.7 mV/V + 2.6 μV 7.2 mV/V + 2.6 μV 7.2 mV/V + 2.6 μV 7.2 mV/V + 2.6 μV 7.4 mV/V + 3.7 μV	
(7 to 22) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	7.4 mV/V + 4.9 μV 6.9 mV/V + 4.9 μV 6.9 mV/V + 4.9 μV 6.9 mV/V + 4.9 μV 7.0 mV/V + 6.6 μV	
(22 to 70) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	7.4 mV/V + 6.1 μV 6.8 mV/V + 6.1 μV 6.8 mV/V + 6.1 μV 6.8 mV/V + 6.1 μV 6.7 mV/V + 6.1 μV	
(70 to 220) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	7.0 mV/V + 35 μV 6.4 mV/V + 35 μV 6.4 mV/V + 35 μV 6.4 mV/V + 35 μV 6.4 mV/V + 35 μV	
(220 to 700) mV	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	5.8 mV/V + 93 μV 5.1 mV/V + 93 μV 5.1 mV/V + 93 μV 5.1 mV/V + 93 μV 5.1 mV/V + 93 μV	
(0.7 to 2.2) V	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	5.7 mV/V + 0.35 mV 5.0 mV/V + 0.35 mV 5.0 mV/V + 0.35 mV 5.0 mV/V + 0.35 mV 5.0 mV/V + 0.35 mV	
(2.2 to 7) V	(10 to 30) Hz (30 to 120) Hz (0.12 to 1.2) kHz (1.2 to 120) kHz (120 to 500) kHz	5.2 mV/V + 0.49 mV 4.4 mV/V + 0.49 mV 4.4 mV/V + 0.49 mV 4.4 mV/V + 0.49 mV 4.4 mV/V + 0.49 mV	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Generate			
(0.005 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.022 % + 5.2 μV 0.011 % + 5.2 μV 0.011 % + 5.2 μV 0.038 % + 5.2 μV 0.087 % + 8.1 μV 0.12 % + 15 μV 0.17 % + 29 μV 0.36 % + 29 μV	Fluke 5700A
(2.2 to 220) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.022 % + 9.5 μV 0.011 % + 9.6 μV 0.011 % + 9.4 μV 0.018 % + 62 μV 0.058 % + 130 μV 0.11 % + 37 μV 0.18 % + 41 μV 0.37 % + 93 μV	
(0.22 to 2.2) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.016 % + 48 μV 0.074 % + 14 μV 0.075 % + 11 μV 29 μV/V + 0.70 mV 0.016 % + 0.38 mV 0.046 % + 0.15 mV 0.11 % + 0.42 mV 0.22 % + 1.0 mV	
(2.2 to 22) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.016 % + 0.38 mV 73 μV/V + 0.15 mV 75 μV/V + 0.12 mV 0.011 % + 0.82 mV 0.024 % + 0.47 mV 0.053 % + 1.7 mV 0.14 % + 5.0 mV 0.29 % + 1.0 mV	Fluke 5700A
(22 to 220) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.16 % + 3.9 mV 80 μV/V + 1.5 mV 82 μV/V + 1.2 mV 0.022 % + 4.2 mV 0.53 % + 9.5 mV 0.16 % + 0.1 V 0.53 % + 0.1 V 1.3 % + 0.2 V	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Generate			
(220 to 750) V	(15 to 50) Hz (0.05 to 1) kHz	0.042 % + 19 mV 78 μV/V + 9.2 mV	Wavetek 4808
(750 to 1000) V	(10 to 31) Hz (32 to 330) Hz (0.3 to 10) kHz (10 to 33) kHz (30 to 100) kHz (100 to 330) kHz (0.3 to 1000) MHz	110 μV/V + 340 μV 66 μV/V + 210 μV 56 μV/V + 110 μV 65 μV/V + 210 μV 110 μV/V + 340 μV 620 μV/V + 3.5 mV 8.9 mV/V + 14 mV	
(1000 to 1100) V	(10 to 330) Hz (0.3 to 10) kHz (10 to 33) kHz	160 μV/V + 2.3 mV 120 μV/V + 2.2 mV 160 μV/V + 2.3 mV	Fluke 5520A
(1 to 33) mV	(10 to 45) Hz (0.045 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	99 μV/V + 19 μV 99 μV/V + 19 μV 9.3 μV/V + 250 μV 48 μV/V + 140 μV 0.045 % + 100 μV 0.22 % + 87 μV	
(33 to 330) mV	(10 to 45) Hz (0.045 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.012 % + 0.12 mV 0.012 % + 0.12 mV 13 μV/V + 1.8 mV 35 μV/V + 1.1 mV 0.045 % + 0.43 mV 0.26 % + 0.80 mV	
(0.33 to 3.3) V	(10 to 45) Hz (0.045 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.017 % + 0.71 mV 0.017 % + 0.71 mV 0.027 % + 0.72 mV 0.040 % + 0.74 mV 0.10 % + 1.9 mV 0.28 % + 0.80 mV	
(3.3 to 33) V	(10 to 45) Hz (0.045 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.021 % + 3.0 mV 0.022 % + 7.8 mV 0.024 % + 10 mV 0.019 % + 20 mV 0.22 % + 62 mV	
(330 to 1020) V	(0.045 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.034 % + 19 mV 0.028 % + 20 mV 0.033 % + 32 mV	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Voltage <sup>3</sup> – Transfer			
1 mV	10 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz 300 kHz to 1 MHz	3.0 μV 3.0 μV 3.1 μV 5.0 μV	Wavetek 4950
10 mV	10 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz 300 kHz to 1 MHz	3.4 μV 4.5 μV 5.9 μV 0.016 mV	
100 mV	10 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz (300 to 500) kHz 500 kHz to 1 MHz	7.0 μV 0.014 mV 0.016 mV 0.074 mV 0.082 mV	
1 V	(10 to 40) Hz 40 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz 300 kHz to 1 MHz	0.021 mV 0.021 mV 0.050 mV 0.059 mV 0.43 mV	
10 V	(10 to 40) Hz 40 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz 300 kHz to 1 MHz	0.21 mV 0.21 mV 0.50 mV 0.59 mV 4.8 mV	
19 V	1 kHz	0.51 mV	
100 V	(10 to 40) Hz 40 Hz to 30 kHz (30 to 50) kHz (50 to 100) kHz (100 to 200) kHz	2.4 mV 2.4 mV 5.5 mV 5.5 mV 16 mV	
1000 V	(55 to 300) Hz 300 Hz to 1 kHz	0.035 V 0.032 V	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Current <sup>3</sup> – Measure			
Up to 100 µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 1) kHz	1.9 mA/A + 0.56 µA 0.37 mA/A + 0.58 µA 91 µA/A + 0.58 µA 84 µA/A + 0.57 µA	HP 3458 opt. 002 digital multimeter
(1 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	4.7 mA/A + 24 µA 1.8 mA/A + 24 µA 0.70 mA/A + 24 µA 0.35 mA/A + 24 µA 0.70 mA/A + 24 µA 4.7 mA/A + 47 µA 6.4 mA/A + 174 µA	
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz (5 to 20) kHz (20 to 50) kHz	4.7 mA/A + 0.24 mA 1.9 mA/A + 0.24 mA 0.92 mA/A + 0.25 mA 1.2 mA/A + 0.25 mA 3.5 mA/A + 0.24 mA 12 mA/A + 0.47 mA	
(1 to 3) A	10 Hz to 3 kHz (3 to 5) kHz	1.7 mA/A + 5.8 mA 32 mA/A + 13 mA	Keithley 2015
(3 to 10) A	3 Hz to 10 kHz	33 mA/A + 13 mA	Agilent 34461A
(10 to 2800) A	1 Hz to 10 kHz	0.22 mA/A + 1.3 A	LEM PR2000 current clamp, HP 3458A opt. 002 digital multimeter
AC Current <sup>3</sup> – Measure (cont)			
1 kHz	10 µA 100 µA 1 mA 10 mA 20 mA 100 mA 200 mA 1 A 1.9 A	0.78 nA 4.4 nA 0.053 µA 0.49 µA 0.43 µA 2.1 µA 2.4 µA 0.032 mA 0.047 mA	Fluke A40B series shunts, HP 3458A opt. 002 digital multimeter



Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Current <sup>3</sup> – Generate			
(0.02 to 220) µA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	35 µA/A + 0.50 µA 170 µA/A + 0.048 µA 170 µA/A + 0.048 µA 220 µA/A + 0.22 µA 0.14 % + 1.0 µA	Fluke 5700A
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	210 µA/A + 0.63 µA 170 µA/A + 0.48 µA 170 µA/A + 0.48 µA 130 µA/A + 2.4 µA 0.15 % + 7.2 µA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	94 µA/A + 17 µA 170 µA/A + 3.6 µA 170 µA/A + 3.6 µA 130 µA/A + 16 µA 0.057 % + 77 µA	
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.016 % + 0.20 mA 0.037 % + 0.12 mA 0.037 % + 0.12 mA 0.044 % + 0.32 mA 0.77 % + 0.73 mA	Fluke 5520A
(0.22 to 2.2) A	(0.02 to 1) kHz (1 to 5) kHz (5 to 10) kHz	110 µA/A + 3.9 mA 0.034 % + 5.1 mA 0.17 % + 12 mA	
(1.1 to 3) A	(10 to 45) Hz (0.045 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.045 % + 4.5 mA 0.038 % + 5.6 mA 0.69 % + 1.2 mA 2.9 % + 5.8 mA	
(3 to 11) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.16 % + 7.7 mA 0.16 % + 7.7 mA 3.4 % + 14 mA	Fluke 5520A, 5500A/coil
(11 to 20.5) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.17 % + 7.7 mA 0.17 % + 7.7 mA 3.4 % + 14 mA	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
AC Current <sup>3</sup> – Generate (cont)			
(20.5 to 150) A Toroidal	(45 to 65) Hz (65 to 440) Hz	5.8 mA/A + 0.53 A 11 mA/A + 0.47 A	Fluke 5520A, 5500A/coil
Non-Toroidal	(45 to 65) Hz (65 to 440) Hz	7.8 mA/A + 0.56 A 12 mA/A + 0.51 A	
(150 to 1000) A Toroidal	(45 to 65) Hz (65 to 440) Hz	7.0 mA/A + 0.59 A 12 mA/A + 0.59 A	
Non-Toroidal	(45 to 65) Hz (65 to 440) Hz	8.6 mA/A + 0.59 A 13 mA/A + 0.59 A	
AC Current <sup>3</sup> – Transfer			
Up to 100 µA	10 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.017 µA 0.026 µA 0.049 µA	Wavetek 4950
100 µA to 1 mA	10 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.16 µA 0.21 µA 0.53 µA	
(1 to 10) mA	10 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	1.6 µA 2.4 µA 6.8 µA	
(10 to 100) mA	(10 to 55) Hz (55 to 300) Hz 300 Hz to 1 kHz	0.016 mA 0.018 mA 0.017 mA	
	(1 to 5) kHz (5 to 10) kHz	0.024 mA 0.068 mA	
100 mA to 1 A	10 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.19 mA 0.30 mA 1.1 mA	

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
Phase Angle <sup>3</sup> –  Measure (0 to 359.9999) °  Generate (0 to 999.999) °	10 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 200) kHz  1 Hz to 1 kHz (1 to 50) kHz (50 to 200) kHz	0.012° 0.017° 0.051° 0.11°  0.028° 0.056° 0.068°	North Atlantic PAV 2250A  Clarke Hess 5000
Inductance <sup>3</sup> –  Fixed  Measure  Generate	20 mH 100 mH 200 mH 2 H  (0.1 to 10) μH (0.01 to 10) mH 0.01 to 100) mH (0.1 to 10) kH (10 to 100) kH  (1 to 10) mH (10 to 100) mH (0.1 to 1) H (1 to 10) H	0.012 mH 0.054 mH 0.12 mH 1.3 mH  0.022 μH 0.21 μH 0.02 H 6.4 H 0.61 kH  9.5 μH 0.81 mH 0.011 H 0.2 H	General radio 1482 series inductors  HP 4284A  General radio 1490D
Capacitance <sup>3</sup> – Fixed	1 nF 2 nF 10 nF 100 nF 200 nF 1 μF	0.50 pF 1.1 pF 5.4 pF 7.4 pF 0.10 nF 0.19 nF	General radio 1409 series standard capacitors

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
Capacitance <sup>3</sup> –			
Measure	(0 to 1) nF (0.001 to 10) µF (0.001 to 10) mF (0.01 to 110) mF	1.1 pF 5.4 nF 0.011 mF 0.28 mF	HP 4284A
Generate	(0.19 to 0.4) nF (0.4 to 1.1) nF (1.1 to 3.3) nF (3.3 to 11) nF (11 to 33) nF (33 to 110) nF (110 to 330) nF (0.33 to 1.1) µF (1.1 to 3.3) µF (3.3 to 11) µF (11 to 33) µF (33 to 110) µF (110 to 330) µF (0.33 to 1.1) mF (1.1 to 3.3) mF (3.3 to 11) mF (11 to 33) mF (33 to 100) mF	0.26 % + 13 pF 0.56 % + 12 pF 0.27 % + 13 pF 0.29 % + 120 pF 0.27 % + 140 pF 0.27 % + 390 pF 0.27 % + 1.3 nF 0.27 % + 3.9 nF 0.25 % + 15 nF 0.26 % + 42 nF 0.38 % + 170 nF 0.45 % + 480 nF 0.50 % + 1.4 µF 0.44 % + 4.9 µF 0.26 % + 36 µF 0.78 % + 49 µF 0.83 % + 360 µF 1.1 % + 360 µF	Fluke 5520A
Thermocouple Simulation <sup>3</sup> –			
Type E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.58 °C 0.20 °C 0.18 °C 0.20 °C 0.26 °C	Fluke 5520A
Type J	(-210 to -30) °C (-30 to 50) °C (50 to 500) °C (500 to 1200) °C	0.30 °C 0.29 °C 0.16 °C 0.23 °C	
Type K	(-200 to -100) °C (-100 to -30) °C (-30 to 120) °C (120 to 1050) °C (1050 to 1371.1) °C	0.35 °C 0.19 °C 0.17 °C 0.15 °C 0.23 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments	
Thermocouple Simulation <sup>3</sup> –				
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.42 °C 0.24 °C 0.21 °C 0.20 °C 0.28 °C	Fluke 5520A	
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.62 °C 0.41 °C 0.37 °C 0.43 °C		
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.53 °C 0.41 °C 0.41 °C 0.49 °C		
Type T	(-250 to -150) °C (-250 to -100) °C (-100 to 0) °C  (0 to 400) °C	0.64 °C 0.26 °C 0.18 °C  0.15 °C		
RTD Simulation <sup>3</sup> –				
Cu427	100 to 260°C	0.34°C		Fluke 5520A
Ni120	(-80 to 0) °C (0 to 100) °C (100 to 260) °C	0.085 °C 0.084 °C 0.15 °C		
Pt 385, 100 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C (630 to 800) °C	0.090 °C 0.093 °C 0.11 °C 0.13 °C 0.14 °C 0.15 °C 0.25 °C		

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
RTD Simulation <sup>3</sup> –			
Pt 385, 200 Ω	(-200 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.046 °C 0.055 °C 0.13 °C 0.14 °C 0.15 °C 0.17 °C	Fluke 5520A
Pt 385, 500 Ω	(-200 to -80) °C (-80 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.042 °C 0.051 °C 0.061 °C 0.081 °C 0.092 °C 0.12 °C	
Pt 385, 1000 Ω	(-200 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 600) °C (600 to 630) °C	0.031 °C 0.041 °C 0.052 °C 0.062 °C 0.072 °C 0.23 °C	
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.28 °C 0.058 °C 0.067 °C 0.075 °C 0.093 °C 0.11 °C 0.11 °C 0.12 °C 0.24 °C	
Pt 3926, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.066 °C 0.083 °C 0.11 °C 0.12 °C 0.14 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Oscilloscopes – Amplitude – DC Signal <sup>3</sup> 50 Ω Load 1 MΩ Load  Amplitude – Square Wave 50 Ω Load  1 MΩ Load	(0 to 6) V (0 to 130) V  1 mV <sub>p-p</sub> to 6.6 V <sub>p-p</sub> ; 10 Hz to 10 kHz  1 mV <sub>p-p</sub> to 130 V <sub>p-p</sub> ; 10 Hz to 10 kHz	29 mV/V + 0.58 mV 590 μV/V + 75 μV  29 mV <sub>p-p</sub> /V <sub>p-p</sub> + 75 μV <sub>p-p</sub>  280 μV <sub>p-p</sub> /V <sub>p-p</sub> + 75 μV <sub>p-p</sub>	5520A-SC100 multifunction calibrator w/ oscilloscope opt
Oscilloscopes – Edge Functions <sup>3</sup>	(200 to 300) ps	120 ps	5520A-SC100 multifunction calibrator w/ oscilloscope opt
Oscilloscopes – Bandwidth <sup>3</sup>  5 mV to 5.5 V <sub>p-p</sub>  4 mV to 3.5 V <sub>p-p</sub>  Leveled Sine Wave – Frequency <sup>3</sup>  Time Marker	50 kHz 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz  (600 to 1100) MHz  50 kHz to 1.1 GHz  2 ns to 20 ms 50 ms to 5 s	58 mV <sub>p-p</sub> /V <sub>p-p</sub> + 470 μV <sub>p-p</sub> 58 mV <sub>p-p</sub> /V <sub>p-p</sub> + 470 μV <sub>p-p</sub> 70 mV <sub>p-p</sub> /V <sub>p-p</sub> + 470 μV <sub>p-p</sub> 120 mV <sub>p-p</sub> /V <sub>p-p</sub> + 470 μV <sub>p-p</sub>  140 mV <sub>p-p</sub> /V <sub>p-p</sub> + 470 μV <sub>p-p</sub>  0.58 kHz  2.9 μs/s + 0.15 ps 1.2 ms/s + 58 μs	5520A-SC100 multifunction calibrator w/ oscilloscope opt

Parameter/Equipment	Range	CMC <sup>2</sup> ( $\pm$ )	Comments
Oscilloscopes – Wave Functions - Square, Sine, & Triangle <sup>3</sup>			
50 $\Omega$ Load	1.8 mV <sub>p-p</sub> to 2.5 V <sub>p-p</sub> ; 10 Hz to 10 kHz	35 mV <sub>p-p</sub> /V <sub>p-p</sub> + 120 $\mu$ V <sub>p-p</sub>	5520A-SC100 multifunction calibrator w/ oscilloscope opt
1 M $\Omega$ Load	1.8 mV <sub>p-p</sub> to 55 V <sub>p-p</sub> ; 10 Hz to 10 kHz	35 mV <sub>p-p</sub> /V <sub>p-p</sub> + 120 $\mu$ V <sub>p-p</sub>	
Pulse Characteristics <sup>3</sup> –			
Pulse Width	(4 to 500) ns	2.6 ns	
Pulse Period	200 ns to 20 ms	150 ps	
Rise Time – Generate	1 kHz to 2 MHz (200 to 300) ps	120 ps	
	2 to 10 MHz (200 to 350) ps	120 ps	

#### IV. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC <sup>2,7</sup> ( $\pm$ )	Comments
RF Power <sup>3</sup> – Measure			
(-67 to +20) dB	10 MHz to 40 GHz	0.82 dB	Anritsu MA2444D
(-35 to +20) dB	DC to 100 MHz	0.061 dB	Rohde & Schwarz NRP-Z55
	100 MHz to 4 GHz	0.077 dB	
	(4 to 8) GHz	0.091 dB	
	(8 to 12.4) GHz	0.11 dB	
	(12.4 to 18) GHz	0.13 dB	
	(18 to 26.5) GHz	0.11 dB	
	(26.5 to 30) GHz	0.13 dB	
	(30 to 35) GHz	0.14 dB	
	(35 to 40) GHz	0.14 dB	
(-30 to +20) dB	50 MHz to 50 GHz	0.11 dB	HP 8487A, Agilent E4418B



Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
RF Power – Generate			
(-100 to +24) dB	1 mHz to 4.024 GHz	0.60 dB	Fluke 96270A leveled microwave output
(-100 to +20) dB	(1.4 to 20) GHz	1.2 dB	
(-100 to +18) dB	(20 to 26.5) GHz	1.2 dB	
Leveled Sine Wave – Generate			
(-130 to -94) dBm	(10 to 128) MHz 128 MHz to 3 GHz	0.74 dB 1.6 dB	Fluke 96270A
(-94 to -84) dBm	100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz	0.52 dB 0.35 dB 0.51 dB	
	300 MHz to 3 GHz	1.1 dB	
(-84 to -74) dBm	100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 4) GHz	0.51 dB 0.13 dB 0.33 dB 0.54 dB 1.1 dB	
(-74 to -48) dBm	100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 4) GHz	0.21 dB 0.11 dB 0.11 dB 0.43 dB 0.58 dB	
(-48 to -17) dBm	(10 to 100) kHz 100 kHz to 128 MHz (128 to 300) MHz 300 MHz to 1.4 GHz	0.032 dB 0.062 dB 0.079 dB 0.22 dB	
	(1.4 to 3) GHz (3 to 4) GHz	0.38 dB 0.53 dB	
(-17 to +14) dBm	(10 to 100) kHz 100 kHz to 128 MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 4) GHz	0.031 dB 0.059 dB 0.079 dB 0.22 dB 0.33 dB	

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
RF Power <sup>3</sup> – Leveled Sine Wave – Generate (cont)  (+14 to +20) dBm  (+20 to +24) dBm	(10 to 100) kHz 100 kHz to 128 MHz (128 to 300) MHz 300 MHz to 1.4 GHz  (10 to 100) kHz 100 kHz to 128 MHz	0.051 dB 0.058 dB 0.11 dB 0.26 dB  0.031 dB 0.059 dB	Fluke 96270A
Attenuation <sup>3,5</sup> – Measure  10 Hz to 128 MHz	(0 to 55) dB (55 to 64) dB (64 to 100) dB (100 to 116) dB	0.044 dB 0.057 dB 0.17 dB 0.23 dB	Fluke 96270A, Rohde & Schwarz FSP
Amplitude Modulation <sup>3</sup> – Measure  Carrier: 150 kHz to 10 MHz Rate: 50 Hz to 10 kHz Rate: 20 Hz to 10 kHz  Carrier: 10 MHz to 1.3 GHz Rate: 50 Hz to 50 kHz Rate: 20 Hz to 100 kHz	Depth: (5 to 99) % Depth: (5 to 99) %  Depth: (5 to 99) % Depth: (5 to 99) %	2.7 % 3.8 %  1.9 % 3.8 %	HP 8901B
Amplitude Modulation <sup>3</sup> – Generate  Carrier: 50 kHz to 4 GHz Rate: 1 Hz to 100 kHz	Depth: (5 to 10) % Depth: (10 to 99) %	1.6 % 3.9 %	Fluke 96270A

Parameter/Range	Frequency	CMC <sup>2,7</sup> (±)	Comments
<p>Frequency Modulation<sup>3</sup> – Measure</p> <p>Carrier: 150 kHz to 10 MHz Rate: 20 Hz to 10 kHz</p> <p>Carrier: 10 MHz to 1.3 GHz Rate: 50 Hz to 100 kHz</p> <p>Carrier: 10 MHz to 1.3 GHz Rate: 20 Hz to 200 kHz</p>	<p>Deviation: Up to 40 kHz</p> <p>Deviation: Up to 400 kHz</p> <p>Deviation: Up to 400 kHz</p>	<p>26 mHz/Hz + 310 mHz</p> <p>15 mHz/Hz + 320 mHz</p> <p>59 mHz/Hz + 290 mHz</p>	HP 8901B
<p>Frequency Modulation<sup>3</sup> – Generate</p> <p>Carrier: 9 MHz to 31.25 MHz Rate: 1 Hz to 50 kHz Rate: 50 Hz to 300 kHz</p> <p>Carrier: 31.25 MHz to 125 MHz Rate: 1 Hz to 50 kHz Rate: 50 Hz to 300 kHz</p> <p>Carrier: 125 MHz to 4 GHz Rate: 1 Hz to 50 kHz Rate: 50 Hz to 300 kHz</p>	<p>Deviation: 10 Hz to 300 kHz</p> <p>Deviation: 10 Hz to 750 kHz</p> <p>Deviation: 10 Hz to 4.8 MHz</p>	<p>11 mHz/Hz 60 mHz/Hz</p> <p>11 mHz/Hz 36 mHz/Hz</p> <p>11 mHz/Hz 36 mHz/Hz</p>	Fluke 96270A
<p>Phase Modulation<sup>3</sup> – Measure</p> <p>Carrier: 150 kHz to 10 MHz Rate: 200 Hz to 10 kHz</p> <p>Carrier: 10 MHz to 1.3 GHz Rate: 200 Hz to 20 kHz</p>	<p>Deviation: Up to 420 rad</p> <p>Deviation: Up to 420 rad</p>	<p>0.050 rad/rad + 0.067 rad</p> <p>0.040 rad/rad + 0.067 rad</p>	HP 8901B
<p>Amplitude Modulation<sup>3</sup> – Sine Distortion</p> <p>(10.0 to 89.0) %</p>	50 kHz to 125 MHz	-40 dBc	Fluke 9640A

Parameter/Range	Frequency	CMC <sup>2, 6, 7</sup> (±)	Comments
Phase Modulation <sup>3</sup> – Generate  Carrier: 9 MHz to 4 GHz Rate: 1 Hz to 50 kHz Rate: 50 kHz to 300 kHz	Deviation: Up to 1000 rad	0.011 rad/rad 0.036 rad/rad	Fluke 96270A
Total Harmonic Distortion	47 Hz to 100 kHz	1.7 %	North Atlantic PAV 2250A

## VI. Mechanical

Parameter/Equipment	Range	CMC <sup>2, 6</sup> (±)	Comments
Accelerometers <sup>3</sup>	50 Hz to 2 kHz (2 to 10) kHz	3.4 % 5.0 %	Modal shop 9100D shaker, HP 3458A opt. 002 digital multimeter, Endeveco BF11 signal conditioner
Scales & Balances <sup>3</sup>	(1 to 50) mg (50 to 500) mg (0.5 to 1) g (1 to 5) g (5 to 50) g (50 to 100) g (100 to 200) g (200 to 2000) g (2000 to 6000) g	0.017 mg 0.027 mg 0.055 mg 0.055 mg 0.16 mg 0.64 mg 0.77 mg 6.9 mg 0.14 g	Class 1 weights

Parameter/Equipment	Range	CMC <sup>2, 6, 8</sup> (±)	Comments
Force – Measuring Equipment <sup>3</sup>	Up to 100 lb	0.052 %	Rice Lake RL20000I-100
	(50 to 500) lb	0.090 %	Rice Lake RL2000I-T10-500
	(0.5 to 5) klb	0.16 %	Interface RL9000TWM-5K
	(10 to 100) klb	0.049 %	Omega LCW-100K
Pneumatic Pressure – Measuring Equipment <sup>3</sup>	(-15 to 0) psig	0.0019 PSI	Fluke 700PD7, Fluke 744
	Up to 25 psig (25 to 100) psig	0.004 % + 0.0017 PSI 0.0057 % + 0.0041 PSI	Fluke 7252i dual channel pressure controller
	Up to 625 psig (625 to 2500) psig	0.057 PSI 0.70 PSI	
	Up to 3000 psig (3000 to 10 000) psig	0.33 PSI 1.1 PSI	Wika CPG 2500
Tachometers <sup>3</sup> – Optical	(5 to 250 000) rpm	12 μRPM/RPM + 0.6R	Starrett 7793
Torque – Measure <sup>3</sup>	(1 to 9) in·lbf	2.1 %	Delta Regis DRBT-10
	(5 to 50) in·lbf	0.64 %	Sturtevant Richmond
	(50 to 300) in·lbf	0.38 %	system 8 w/ transducers
	(10 to 150) ft·lbf	0.35 %	
	(150 to 600) ft·lbf	0.31 %	

V. Thermodynamics

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Humidity <sup>3</sup> – Measuring Equipment	(5 to 95) % RH	0.84 % RH	Rotronic HF53W-ID, Rotronic HC2A probe
Temperature <sup>3</sup> – Measuring Equipment			
Thermometers	(-20 to 375) °C (375 to 600) °C	0.088 °C 0.32 °C	WIKA CTP5000-450 probe
Infrared	(-15 to 0) °C (0 to 50) °C (50 to 100) °C (100 to 120) °C	0.96 °C 0.99 °C 1.0 °C 1.2 °C	Fluke 4180 wavelength (8 to 14) μm emissivity 0.95
	(35 to 100) °C (100 to 200) °C (200 to 350) °C (350 to 500) °C	0.82 °C 1.4 °C 2.0 °C 3.0 °C	Fluke 4181 wavelength (8 to 14) μm emissivity 0.95
Temperature – Measure	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 420) °C	0.084 °C 0.034 °C 0.037 °C 0.085 °C	Fluke 5616-12 probe, Fluke 1524 reference thermometer

VI. Time & Frequency

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Frequency <sup>3</sup> –			
Measure	Up to 20 GHz	0.085 μHz/Hz	Agilent 53140
Generate	Up to 10 kHz 10 kHz to 4 GHz (4 to 26) GHz	0.091 μHz/Hz 0.060 μHz/Hz 0.058 μHz/Hz	Fluke 96270A
GPS Clock	10 MHz	0.12 mHz	Trimble Thunderbolt E
Timers/Stopwatches <sup>3</sup>	Up to 24 hr	0.065 s/day	Timometer 4500

- <sup>1</sup> This laboratory offers commercial calibration service and field calibration service.
- <sup>2</sup> Calibration and Measurement Capability Uncertainty (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. CMCs represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.
- <sup>3</sup> Field calibration service is available for this calibration and this laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.
- <sup>4</sup> Specifications are typical below 10 MHz.
- <sup>5</sup> Relative to +16 dBm output.
- <sup>6</sup> In the statement of CMC,  $L$  is the numerical value of the nominal length of the device measured in inches;  $R$  is instrument resolution;  $D$  is diagonal length; percentages are percentage of reading, unless otherwise indicated.
- <sup>7</sup> The measurands stated are generated using the indicated instrument (see Comments). This capability is suitable for the calibration of the devices intended to measure the measurand in the ranges indicated. CMC are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.
- <sup>8</sup> The type of instrument or material being calibrated is defined by the parameter. This indicates the laboratory is capable of calibrating instruments that measure or generate the values in the ranges indicated for the listed measurement parameter.
- <sup>9</sup> Adjustable thread rings are set to applicable specifications using calibrated master set plug gages.
- <sup>10</sup> This laboratory meets R205 – Specific Requirements: Calibration Laboratory Accreditation Program for the types of dimensional tests listed above and is considered equivalent to that of a calibration.
- <sup>11</sup> This scope meets A2LA's *P112 Flexible Scope Policy*.



## Accredited Laboratory

A2LA has accredited

**ENI LABS**

*Fort Wayne, IN*

for technical competence in the field of

**Calibration**

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the requirements of ANSI/NCSL Z540-1-1994 and R205 – Specific Requirements: Calibration Laboratory Accreditation Program. 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).



Presented this 21<sup>st</sup> day of September 2020.

A blue ink signature of the Vice President of Accreditation Services.

Vice President, Accreditation Services  
For the Accreditation Council  
Certificate Number 2147.01  
Valid to March 31, 2022

*For the calibrations to which this accreditation applies, please refer to the laboratory's Calibration Scope of Accreditation.*