



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017,
ANSI/NCSL Z540-1-1994 & ANSI/NCSL Z540.3-2006

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CALIBRATION

Valid To: May 31, 2024

Certificate Number: 1022.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations^{1, 8}:

I. Acoustics

Parameter/Equipment	Range	CMC ^{2, 5} (±)	Comments
Acoustics – Measure Sound Level Calibrators	(74 to 114) dB 20 Hz to 8 kHz	0.29 dB	Reference microphone, standard pistonphone, precision attenuator
Acoustics – Measuring Equipment ³			
Sound Pressure Level - Microphones	124 dB @ 250 Hz 94 dB @ at 1 kHz (104, 114) dB @ 1 kHz	0.27 dB 0.26 dB 0.28 dB	Standard pistonphone 4226 acoustical calibrator
Frequency Response – Microphones	20 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.25 dB 0.34 dB 0.64 dB	Electrostatic actuator, sine generator, amplifier, multimeter
Sound Pressure Level – Sound Level Meters	(64 to 124) dB, 1 kHz	0.26 dB	Sine generator, attenuator, calibrator
Frequency Response – Sound Level Meters	94 dB, 100 Hz to 16 kHz	0.1 dB	Sine generator, reference microphone
Microphone Sensitivity	124 dB, re 1 V/Pa, 250 Hz	0.27 dB	Standard pistonphone

II. Chemical

Parameter/Equipment	Range	CMC ^{2, 5} ($\pm$)	Comments
pH – Measuring Equipment ³	4 pH 7 pH 10 pH	0.012 pH 0.015 pH 0.021 pH	Buffer solutions
Electrolytic Conductivity – Measuring Equipment ³	10 μ S/cm 100 μ S/cm 1000 μ S/cm 10 000 μ S/cm	0.35 μ S/cm 1.4 μ S/cm 12 μ S/cm 110 μ S/cm	Conductivity solutions

III. Dimensional

Parameter/Equipment	Range	CMC ^{2, 5, 6} ($\pm$)	Comments
Angle – Measuring Equipment ³	Up to 360° Up to 60° 90° $\pm$ 3'	4.7 arc-sec 5.4 arc-sec 2.4 arc-sec	Angle encoder Gage blocks w/ sine bar Cylinder square
Angle – Measure ³	Up to 60°	5.4 arc-sec	Gage blocks, sine bar
Flatness – Measure ³	Up to 4 in diameter	3.2 μ in	Optical flats
Gage Blocks	Up to 0.05 in (0.05 to 20) in	2.2 μ in 2.4 μ in + 1.5 μ in/in	Master gage blocks & laser interferometer
Length Standards, Foils, Shims & Feeler/Thickness Gauges	Up to 12 in (12 to 48) in	5.8 μ in + 1.5 μ in/in 14 μ in + 0.8 μ in/in	Master gage blocks & laser interferometer Master gage blocks, gage amplifier
Bore Gages	(0.2 to 4.0) in	120 μ in	Ring gages

Parameter/Equipment	Range	CMC ^{2, 5, 6} ($\pm$)	Comments
Hand Tools ³ – Calipers Outside Step, Depth Inside Digital & Dial Indicators Micrometers Spindle Linearity Anvil Flatness Parallelism Height Gages	 Up to 72 in Up to 72 in 1.4 in Up to 6 in Up to 72 in 50 μ in 50 μ in Up to 72 in	 31 μ in + 4.9 μ in/in 10 μ in + 4.9 μ in/in 42 μ in 30 μ in + 3 μ in/in 6.5 μ in + 5.3 μ in/in 3.2 μ in 5.6 μ in 31 μ in + 4.9 μ in/in	 Gage blocks Master ring Gage blocks Gage blocks Optical flat Gage blocks
Coating Thickness – Measuring Equipment	(0.5 to 150) mils (0.01 to 5.7) mm	0.061 mils + 0.012 mils/mils 0.74 μ m + 6.9 μ m/mm	Thickness foil sets
Linear Displacement ³ – Measuring Equipment (String Potentiometers, LVDT's, etc)	Up to 6 in Up to 24 in (24 to 72) in	3 μ in + 13 μ in/in 350 μ in + 5.6 μ in/in 0.0058 in + 1.4 μ in/in	Gage blocks Height gage, 34401A Linear encoder, 34401A
Optical Comparators ³ – Linear Travel (X & Y) Magnification Rotational Accuracy Squareness (X to Y)	Up to 30 in 10x to 100x (Up to 360)° Up to 10 in	83 μ in + 6.2 μ in/in 0.014 % 0.43 arc-sec + 0.055 arc-sec/arc-sec 280 μ in	Glass scales Magnification checker, spheres Angle blocks Precision square
Plain Diameter – Internal (Plain Rings)	Up to 12 in	5.8 μ in + 1.5 μ in/in	Master gage blocks & laser interferometer

Parameter/Equipment	Range	CMC ^{2, 4, 5} ($\pm$)	Comments
Plain Diameter – External (Plug Gages, Pin Gages)	Up to 12 in	5.7 μin + 1.5 $\mu\text{in/in}$	Master gage blocks & laser interferometer
Steel Tapes ³	(1 to 100) ft	0.0029 in	Steel tape, jeweler's loupe
Surface Plate ³ – Flatness	Up to 16 ft diagonal	$\sqrt{D} \times 9.2 \mu\text{in}$	Electronic leveling system
Local Area Flatness	Up to 0.001 in	31 μin	Repeat-o-meter
Threaded Plug Gages – Pitch Diameter (Imperial)	Up to 12 in, (2.5 to 80) TPI	76 μin + 0.3 $\mu\text{in/in}$	Gage blocks, thread wires & laser interferometer
Pitch Diameter (Metric)	Up to 300 mm, (0.2 to 10) mm pitch	3 μm + 34 $\mu\text{m/m}$	
Gage Amplifier & Probe(s) Single Probe	Up to 0.025 in	8.3 μin + 0.8 $\mu\text{in/in}$	Gage blocks
Dual Probe	Up to 0.002 in	8.3 μin + 1.1 $\mu\text{in/in}$	
Thread Measure Wires – Imperial	Up to 0.25 in	5.8 μin + 8.6 $\mu\text{in/in}$	Master gage blocks & laser interferometer
Metric	Up to 6 mm	0.15 μm + 39 $\mu\text{m/m}$	
Length 1D – Measure Length	Up to 10 in	160 μin + 46 $\mu\text{in/in}$	Optical comparator
Angle	Up to 360°	5.9 arc-min	

IV. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} (±)	Comments
DC Voltage – Generate ³	(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	0.4 μV + 7.5 μV/V 0.71 μV + 5 μV/V 2.6 μV + 3.5 μV/V 4.1 μV + 3.5 μV/V 41 μV + 5 μV/V 0.41 mV + 6.5 μV/V	Fluke 5730A
DC Voltage – Measure	Up to 200 mV 200 mV to 20 V (20 to 200) V (200 to 1000) V 1 V 1.018 V 10 V	2.8 μV/V 0.76 μV/V 0.98 μV/V 1.5 μV/V 1 μV/V 1 μV/V 0.53 μV/V	Fluke 732B w/ 720A & 8508A Fluke 732B w/ 720A Fluke 732B
DC Voltage – Measure ³	(0 to 1) mV (1 to 10) mV (7 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	25 nV + 52 μV/V 0.41 μV + 53 μV/V 0.33 μV + 11 μV/V 0.52 μV + 2.6 μV/V 1.6 μV + 2.1 μV/V 35 μV + 4.3 μV/V 1.2 mV + 5 μV/V	Agilent 34420A Agilent 3458A Opt HFL
DC Ratio – Generate (0.0 to 1.0) (0.0 to 1.9) (0.0 to 1.0) (0.0 to 1.9)	Up to 200 mV (0.2 to 20) V (20 to 200) V (200 to 1000) V	2.7 μV/V 0.52 μV/V 0.81 μV/V 1.4 μV/V	Fluke 8508A (ratio mode)
DC High Voltage – Generate Measure	(1 to 10) kV (10 to 35) kV (35 to 40) kV (1 to 10) kV (10 to 35) kV (35 to 100) kV	0.04 % 0.042 % 0.062 % 0.04 % 0.042 % 0.063 %	Vitretek 4700 w/ HVL-100 & HVP-35

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
DC Current – Generate ³	(1 to 10) pA	0.092 %	Fluke 5730A, Keithley resistors
	(10 to 100) pA	0.092 %	
	(0.1 to 1) μ A	0.048 %	
	(1 to 10) μ A	0.034 %	
	(20 to 220) μ A	6 nA + 40 μ A/A	Fluke 5730A w/ 5725A
	(0.22 to 2.2) mA	11 nA + 33 μ A/A	
	(2.2 to 22) mA	67 nA + 34 μ A/A	
	(22 to 220) mA	0.93 μ A + 50 μ A/A	
	(0.22 to 2.2) A	12 μ A + 0.13 mA/A	
	(2.2 to 11) A	0.49 mA + 0.36 mA/A	
Generate & Measure	(11 to 20.5) A	9.1 mA + 0.78 mA/A	Fluke 5520A
Measure	(10 to 100) A	0.0028 %	Agilent 3458A w/ Honeywell 1168
	(100 to 300) A	0.0037 %	
Generate	(100 to 500) A	0.0042 %	Ohm-Labs CS-500
	(300 to 1500) A	0.0081 %	Ohm-Labs CS-1500
	(100 to 1200) A	0.0081 %	CS-1500, power supply
	(10 to 16.5 A	50 mA + 6.5 mA/A	Fluke 5520A w/ 5500A/coil
	(16.5 to 150) A	0.18 A + 3.4 mA/A	
	(150 to 1025) A	0.83 A + 3.3 mA/A	
DC Resistance – Generate, Fixed Points to Calibrate Thermometer Digital Readouts	1 Ω	0.93 $\mu\Omega$	IET SRL-1
	25 Ω	23 $\mu\Omega$	IET SRL-25
	200 Ω	0.19 m Ω	IET SRL-200
	400 Ω	0.38 m Ω	IET SRL-400

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} (±)	Comments
DC Current ³ – Measure	(1 to 10) pA	0.63 %	Fluke 5730A, Keithley resistors
	(10 to 100) pA	0.094 %	
	(0.1 to 1) nA	0.093 %	
	(1 to 10) nA	0.092 %	
	(10 to 100) nA	0.092 %	
	(0.1 to 1) µA	0.048 %	
	(1 to 10) µA	0.033 %	
	Up to 1 nA	0.0029 %	Agilent 3458A, Fluke 742A resistors
	(1 to 10) nA	0.0015 %	
	(10 to 100) nA	0.0014 %	
	(0.1 to 1) µA	0.0015 %	
	(1 to 10) µA	0.0014 %	
	(10 to 100) µA	0.0014 %	
	(0.1 to 1) mA	0.0014 %	
	(1 to 10) mA	0.0014 %	
	(10 to 100) mA	0.0014 %	
	(100 to 200) mA	0.0014 %	
	(200 to 500) mA	0.0017 %	Agilent 3458A, A40B shunts
	(0.5 to 1) A	0.0015 %	
	(1 to 2) A	0.0015 %	
	(2 to 5) A	0.0016 %	
	(5 to 10) A	0.0016 %	
	(10 to 20) A	0.0017 %	
	(20 to 50) A	0.0019 %	
	(50 to 100) A	0.002 %	
	Up to 2 nA	0.51 pA + 3 mA/A	Keithley 487
	(2 to 20) nA	7.1 pA + 2.1 mA/A	
	(20 to 200) nA	51 pA + 1.6 mA/A	
	(0.2 to 2) µA	0.51 nA + 1.6 mA/A	
	(2 to 20) µA	4.1 nA + 1.1 mA/A	
	(20 to 200) µA	41 nA + 1 mA/A	
	(0.2 to 2) mA	0.41 µA + 1 mA/A	
	(1 to 100) nA	41 pA + 89 µA/A	Agilent 3458A Opt HFL
	(0.1 to 1) µA	70 pA + 18 µA/A	
	(1 to 10) µA	0.7 nA + 14 µA/A	
	(10 to 100) µA	5.8 nA + 6.9 µA/A	
	(0.1 to 1) mA	58 nA + 7.4 µA/A	
	(1 to 10) mA	0.58 µA + 59 µA/A	
	(10 to 100) mA	5.8 µA + 14 µA/A	
	(0.1 to 1) A	59 µA + 72 µA/A	Fluke 8508A
	(1 to 2) A	12 µA + 0.18 mA/A	
	(2 to 20) A	0.33 mA + 0.39 mA/A	Fluke 8588A
	(20 to 30) A	4.4 mA + 0.49 mA/A	

Parameter/Equipment	Range	CMC ^{2, 6, 7} ($\pm$)	Comments
DC Resistance ³ – Generate, Fixed Points	0 Ω	0.1 m Ω	Fluke 5450A
	1 Ω	0.11 m Ω	
	1.9 Ω	0.19 m Ω	
	10 Ω	0.35 m Ω	
	19 Ω	0.6 m Ω	
	100 Ω	1.8 m Ω	
	190 Ω	3 m Ω	
	1 k Ω	14 m Ω	
	1.9 k Ω	25 m Ω	
	10 k Ω	0.13 Ω	
	19 k Ω	0.24 Ω	
	100 k Ω	1.5 Ω	
	190 k Ω	2.6 Ω	
	1 M Ω	20 Ω	
	1.9 M Ω	37 Ω	
	10 M Ω	0.53 k Ω	
	19 M Ω	1.1 k Ω	
	100 M Ω	20 k Ω	
	1 G Ω	40 k Ω	Fluke 8508A-7000K
	1 Ω	21 $\mu\Omega$	L&N shunts
	10 Ω	0.11 m Ω	
	1 k Ω	9.1 m Ω	
	10 k Ω	99 m Ω	
	100 k Ω	1.2 Ω	
	1 M Ω	11 Ω	
	1 Ω	0.93 $\mu\Omega$	Fluke 742A resistors
	10 Ω	9.5 $\mu\Omega$	
	100 Ω	94 $\mu\Omega$	
	1 k Ω	0.81 m Ω	
	10 k Ω	7.5 m Ω	
	100 k Ω	87 m Ω	
	1 M Ω	0.93 Ω	
	10 M Ω	41 Ω	
	19 M Ω	0.14 k Ω	
	0 Ω	41 $\mu\Omega$	Fluke 5730A
	1 Ω	95 $\mu\Omega$	
	1.9 Ω	0.18 m Ω	
	10 Ω	0.23 m Ω	
	19 Ω	0.44 m Ω	
	100 Ω	1 m Ω	
	190 Ω	1.9 m Ω	
	1 k Ω	6.5 m Ω	
	1.9 k Ω	12 m Ω	
	10 k Ω	65 m Ω	
	19 k Ω	0.12 Ω	
	100 k Ω	0.85 Ω	
	190 k Ω	1.6 Ω	
	1 M Ω	13 Ω	
	1.9 M Ω	34 Ω	
	10 M Ω	400 Ω	
	19 M Ω	900 Ω	
	100 M Ω	50 k Ω	

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
Resistance – Measure			
Up to 2 Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	7.3 $\mu\Omega/\Omega$ 8.5 $\mu\Omega/\Omega$ 43 $\mu\Omega/\Omega$	Resistance transfer w/ 8508A
(2 to 20) Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	2.8 $\mu\Omega/\Omega$ 3.2 $\mu\Omega/\Omega$ 15 $\mu\Omega/\Omega$	
(20 to 200) Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	0.83 $\mu\Omega/\Omega$ 0.91 $\mu\Omega/\Omega$ 3.3 $\mu\Omega/\Omega$	
(0.2 to 2) k Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	0.86 $\mu\Omega/\Omega$ 0.93 $\mu\Omega/\Omega$ 3.3 $\mu\Omega/\Omega$	
(2 to 20) k Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	0.76 $\mu\Omega/\Omega$ 0.84 $\mu\Omega/\Omega$ 3.2 $\mu\Omega/\Omega$	
(20 to 200) k Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	0.8 $\mu\Omega/\Omega$ 0.88 $\mu\Omega/\Omega$ 3.3 $\mu\Omega/\Omega$	
(0.2 to 2) M Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	2.2 $\mu\Omega/\Omega$ 2.4 $\mu\Omega/\Omega$ 11 $\mu\Omega/\Omega$	
(2 to 20) M Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	15 $\mu\Omega/\Omega$ 18 $\mu\Omega/\Omega$ 0.1 m Ω/Ω	
(20 to 200) M Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	0.18 m Ω/Ω 0.18 m Ω/Ω 1 m Ω/Ω	
200 M Ω to 2 G Ω	Rs/Rx Ratio 1:1.9 Rs/Rx Ratio 1:1 Rs/Rx Ratio 10:1	1.7 m Ω/Ω 1.7 m Ω/Ω 10 m Ω/Ω	
	(2 to 20) G Ω 20 G Ω to 1 T Ω	0.28 % 0.35 %	Keithley 487, Fluke 5730A

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
AC Voltage – Generate ³			
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	4 μ V + 0.24 mV/V 4 μ V + 90 μ V/V 4 μ V + 80 μ V/V 4 μ V + 0.2 mV/V 5 μ V + 0.5 mV/V 10 μ V + 1.1 mV/V 20 μ V + 1.4 mV/V 20 μ V + 2.7 mV/V	Fluke 5730A
(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	4.6 μ V + 0.24 mV/V 4.2 μ V + 90 μ V/V 4.2 μ V + 80 μ V/V 4.5 μ V + 0.2 mV/V 6.2 μ V + 0.5 mV/V 12 μ V + 1.1 mV/V 23 μ V + 1.4 mV/V 26 μ V + 2.7 mV/V	
(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	18 μ V + 0.24 mV/V 9.2 μ V + 90 μ V/V 8.4 μ V + 57 μ V/V 10 μ V + 0.12 mV/V 24 μ V + 0.31 mV/V 36 μ V + 0.66 mV/V 58 μ V + 1.4 mV/V 0.11 mV + 2.7 mV/V	
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	96 μ V + 0.25 mV/V 37 μ V + 91 μ V/V 18 μ V + 42 μ V/V 26 μ V + 68 μ V/V 50 μ V + 85 μ V/V 0.16 mV + 0.35 mV/V 0.43 mV + 1 mV/V 0.69 mV + 1.7 mV/V	
(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	0.97 mV + 0.25 mV/V 0.36 mV + 92 μ V/V 0.16 mV + 42 μ V/V 0.26 mV + 68 μ V/V 0.4 mV + 84 μ V/V 1.2 mV + 0.27 mV/V 4.3 mV + 1 mV/V 6.6 mV + 1.5 mV/V	
(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	9.6 mV + 0.25 mV/V 3.6 mV + 92 μ V/V 1.8 mV + 52 μ V/V 2.9 mV + 81 μ V/V 5.9 mV + 0.15 mV/V 36 mV + 0.91 mV/V 0.14 V + 4.4 mV/V 0.26 V + 8 mV/V	* 220 V range subject to 2.2E7 V-Hz limitation w/5725A

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments
AC Voltage – Generate ³ (cont)			
(220 to 1100) V	(15 to 50) Hz** 50 Hz to 1 kHz	84 mV + 0.31 mV/V 20 mV + 69 µV/V	Fluke 5730A
	40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	25 mV + 90 µV/V 43 mV + 0.17 mV/V 0.14 V + 0.17 mV/V	w/5725A ** Maximum output limited to 250 V
(220 to 750) V	(30 to 50) kHz (50 to 100) kHz	0.15 V + 0.6 mV/V 0.55 V + 2.3 mV/V	
AC Voltage – Measure			
(0.7 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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	1.1 µV + 1.3 mV/V 1.1 µV + 0.56 mV/V 1.1 µV + 0.32 mV/V 1.6 µV + 0.62 mV/V 2 µV + 0.92 mV/V 3.1 µV + 1.8 mV/V 6.2 µV + 1.9 mV/V 6.2 µV + 2.7 mV/V 29 µV + 29 µV/V 29 µV + 0.12 mV/V 29 µV + 0.32 mV/V 29 µV + 1.6 mV/V 6.2 µV + 7.8 mV/V	Fluke 5790B
(2.2 to 7) 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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	2.3 µV + 0.66 mV/V 1.6 µV + 0.29 mV/V 1.3 µV + 0.16 mV/V 2.2 µV + 0.31 mV/V 2.9 µV + 0.47 mV/V 5 µV + 0.93 mV/V 8.2 µV + 1 mV/V 9.8 µV + 1.8 mV/V 18 µV + 93 µV/V 19 µV + 0.17 mV/V 19 µV + 0.44 mV/V 19 µV + 1.7 mV/V 8.5 µV + 3.9 mV/V	
(7 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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	2.4 µV + 0.23 mV/V 1.9 µV + 0.15 mV/V 1.5 µV + 85 µV/V 2.5 µV + 0.16 mV/V 3.4 µV + 0.24 mV/V 6.9 µV + 0.63 mV/V 10 µV + 0.69 mV/V 14 µV + 1.3 mV/V 19 µV + 0.2 mV/V 19 µV + 0.38 mV/V 20 µV + 0.89 mV/V 25 µV + 2.5 mV/V 28 µV + 4.7 mV/V	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
AC Voltage – Measure (cont)			
(22 to 70) mV	(9.5 to 10) Hz (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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	17 μ V + 0.78 mV/V 4.9 μ V + 0.19 mV/V 3 μ V + 93 μ V/V 2.2 μ V + 50 μ V/V 3.6 μ V + 0.1 mV/V 6 μ V + 0.2 mV/V 11 μ V + 0.4 mV/V 17 μ V + 0.52 mV/V 23 μ V + 0.85 mV/V 31 μ V + 0.19 mV/V 34 μ V + 0.56 mV/V 38 μ V + 0.98 mV/V 62 μ V + 2.6 mV/V 93 μ V + 4.7 mV/V	Fluke 5790B
(70 to 220) mV	(9.5 to 10) Hz (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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	48 μ V + 0.78 mV/V 11 μ V + 0.16 mV/V 5.1 μ V + 66 μ V/V 2.9 μ V + 30 μ V/V 4.8 μ V + 54 μ V/V 9.4 μ V + 0.12 mV/V 15 μ V + 0.19 mV/V 24 μ V + 0.3 mV/V 53 μ V + 0.78 mV/V 27 μ V + 0.37 mV/V 49 μ V + 0.77 mV/V 71 μ V + 1.2 mV/V 0.16 mV + 2.7 mV/V 0.28 mV + 4.7 mV/V	
(220 to 700) mV	(9.5 to 10) Hz (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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	0.16 mV + 0.78 mV/V 34 μ V + 0.16 mV/V 13 μ V + 60 μ V/V 6.3 μ V + 30 μ V/V 9.5 μ V + 40 μ V/V 14 μ V + 60 μ V/V 31 μ V + 0.14 mV/V 53 μ V + 0.23 mV/V 0.16 mV + 0.75 mV/V 79 μ V + 0.39 mV/V 0.15 mV + 0.78 mV/V 0.23 mV + 1.2 mV/V 0.54 mV + 2.7 mV/V 0.93 mV + 4.7 mV/V	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
AC Voltage – Measure (cont)			
700 mV to 2.2 V	(9.5 to 10) Hz (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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	0.47 mV + 0.78 mV/V 94 μ V + 0.16 mV/V 33 μ V + 51 μ V/V 17 μ V + 16 μ V/V 25 μ V + 34 μ V/V 36 μ V + 54 μ V/V 76 μ V + 0.12 mV/V 0.12 mV + 0.2 mV/V 0.42 mV + 0.7 mV/V 11 mV + 19 μ V/V 11 mV + 74 μ V/V 11 mV + 0.17 mV/V 11 mV + 0.86 mV/V 2.8 mV + 4.7 mV/V	Fluke 5790B
(2.2 to 7) V	(9.5 to 10) Hz (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 (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz (30 to 50) MHz	1.5 mV + 0.78 mV/V 0.31 mV + 0.16 mV/V 0.11 mV + 52 μ V/V 39 μ V + 18 μ V/V 76 μ V + 37 μ V/V 0.13 mV + 63 μ V/V 0.3 mV + 0.15 mV/V 0.62 mV + 0.31 mV/V 1.9 mV + 0.93 mV/V 11 mV + 59 μ V/V 11 mV + 0.23 mV/V 12 mV + 0.48 mV/V 13 mV + 1.9 mV/V 9.3 mV + 4.7 mV/V	
(7 to 22) V	(9.5 to 10) Hz (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 (0.5 to 1) MHz	4.7 mV + 0.78 mV/V 0.93 mV + 0.16 mV/V 0.31 mV + 52 μ V/V 0.13 mV + 21 μ V/V 0.22 mV + 37 μ V/V 0.38 mV + 63 μ V/V 0.89 mV + 0.15 mV/V 1.9 mV + 0.31 mV/V 5.6 mV + 0.93 mV/V	
(22 to 70) V	(9.5 to 10) Hz (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 (0.5 to 1) MHz	15 mV + 0.78 mV/V 3.1 mV + 0.16 mV/V 1.1 mV + 53 μ V/V 0.51 mV + 25 μ V/V 0.89 mV + 44 μ V/V 1.5 mV + 73 μ V/V 3.1 mV + 0.16 mV/V 6.4 mV + 0.32 mV/V 19 mV + 0.93 mV/V	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
AC Voltage ³ – Measure (cont)			
(70 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	9.3 mV + 0.16 mV/V 3.2 mV + 53 μ V/V 1.4 mV + 24 μ V/V 3.2 mV + 54 μ V/V 4.6 mV + 76 μ V/V 9.8 mV + 0.16 mV/V 23 mV + 0.39 mV/V	Fluke 5790B
(220 to 700) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	31 mV + 0.16 mV/V 15 mV + 77 μ V/V 6.4 mV + 32 μ V/V 20 mV + 0.1 mV/V 78 mV + 0.39 mV/V	
(700 to 1000) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	93 mV + 0.16 mV/V 16 mV + 80 μ V/V 18 mV + 30 μ V/V 61 mV + 0.1 mV/V 0.23 V + 0.39 mV/V	
(0.1 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	3.3 μ V + 0.3 mV/V 1.3 μ V + 0.2 mV/V 1.4 μ V + 0.3 mV/V 2.1 μ V + 1 mV/V 6.1 μ V + 5 mV/V 42 μ V + 40 mV/V	Agilent 3458A
(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 (0.3 to 1) MHz (1 to 2) MHz	4.7 μ V + 70 μ V/V 2.7 μ V + 70 μ V/V 3.4 μ V + 0.14 mV/V 5 μ V + 0.3 mV/V 10 μ V + 0.8 mV/V 40 μ V + 3 mV/V 0.11 mV + 10 mV/V 0.16 mV + 15 mV/V	

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} (±)	Comments
AC Voltage ³ – Measure (cont)			
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 (0.3 to 1) MHz (1 to 2) MHz	47 µV + 70 µV/V 27 µV + 70 µV/V 35 µV + 0.14 mV/V 50 µV + 0.3 mV/V 0.1 mV + 0.8 mV/V 0.4 mV + 3 mV/V 1.1 mV + 10 mV/V 1.6 mV + 15 mV/V	Agilent 3458A
(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 (0.3 to 1) MHz (1 to 2) MHz	0.47 mV + 70 µV/V 0.27 mV + 70 µV/V 0.34 mV + 0.14 mV/V 0.5 mV + 0.3 mV/V 1 mV + 0.8 mV/V 4 mV + 3 mV/V 11 mV + 10 mV/V 16 mV + 15 mV/V	
(10 to 100) 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 (0.3 to 1) MHz	6 mV + 0.2 mV/V 4 mV + 0.2 mV/V 4 mV + 0.2 mV/V 5.5 mV + 0.35 mV/V 14 mV + 1.2 mV/V 50 mV + 4 mV/V 0.16 V + 15 mV/V	
(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	56 mV + 0.4 mV/V 42 mV + 0.4 mV/V 56 mV + 0.6 mV/V 98 mV + 1.2 mV/V 0.22 V + 3 mV/V	
AC High Voltage ³			
Generate (1 to 10) kV (10 to 20) kV	60 Hz 60 Hz	0.16 % 0.12 %	Vitrek 4700 w/ HVL-100 & HVP- 35
Measure (1 to 10) kV (10 to 35) kV (35 to 70) kV	50/60 Hz 50/60 Hz 50/60 Hz	0.16 % 0.12 % 0.12 %	
AC Ratio – Generate			
0.0 to 0.1	400 Hz & 1 kHz	$1.2 \times 10^{-6} + 4 \times 10^{-6}/0.000\ 001\ \text{step}$	DT72A, 1232-A
0.1 to 1.111111	400 Hz & 1 kHz	1.6×10^{-6}	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
AC Current ³ – Generate			
(9 to 220) μ A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	20 nA + 0.25 mA/A 13 nA + 0.16 mA/A 11 nA + 98 μ A/A 16 nA + 0.28 mA/A 77 nA + 1.1 mA/A	Fluke 5730A
(29 to 330) μ A	(10 to 30) kHz	0.67 nA + 12 mA/A	Fluke 5520A
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.1 μ A + 0.25 mA/A 79 nA + 0.16 mA/A 68 nA + 99 μ A/A 0.16 μ A + 0.2 mA/A 0.89 μ A + 1.1 mA/A	Fluke 5730A
(0.33 to 3.3) mA	(10 to 30) kHz	3.3 μ A + 7.7 mA/A	Fluke 5520A
(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	1 μ A + 0.25 μ A/A 0.76 μ A + 0.16 μ A/A 0.65 μ A + 0.1 mA/A 1 μ A + 0.2 μ A/A 7.4 μ A + 1.1 mA/A	Fluke 5730A
(3.3 to 33) mA	(10 to 30) kHz	13 μ A + 3.1 mA/A	Fluke 5520A
(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	9.5 μ A + 0.25 mA/A 7.1 μ A + 0.16 mA/A 4.8 μ A + 0.1 mA/A 8 μ A + 0.2 mA/A 34 μ A + 1.1 mA/A	Fluke 5730A
(33 to 330) mA	(10 to 30) kHz	0.26 mA + 3.1 mA/A	Fluke 5520A
(0.22 to 2.2) A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	90 μ A + 0.24 mA/A 0.18 mA + 0.45 mA/A 1.7 mA + 7 mA/A	Fluke 5730A
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	1.2 mA + 0.46 mA/A 2.5 mA + 0.95 mA/A 8.7 mA + 3.6 mA/A	Fluke 5730A w/ 5725A
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	14 mA + 0.9 mA/A 17 mA + 1.2 mA/A 0.26 A + 23 mA/A	Fluke 5520A

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} (±)	Comments
AC Current ³ – Generate (cont)			
(20 to 100) A	(25 to 500) Hz	0.22 %	Agilent 3458A, 461CT & 1620A TCA
Clamp-On Only ³			
Toroidal			
(10 to 16.5) A (16.5 to 150) A (150 to 1025) A	(45 to 65) Hz	26 mA + 2.1 mA/A 50 mA + 1.9 mA/A 0.34 A + 1.9 mA/A	Fluke 5520A, 5500A/coil
(10 to 16.5) A (16.5 to 150) A (150 to 1025) A	(65 to 440) Hz	60 mA + 6 mA/A 0.11 A + 5.3 mA/A 0.86 A + 5.3 mA/A	
Non-Toroidal			
(10 to 16.5) A (16.5 to 150) A (150 to 1025) A	(45 to 65) Hz	60 mA + 3.8 mA/A 0.23 A + 3.7 mA/A 1.2 A + 3.7 mA/A	
(10 to 16.5) A (16.5 to 150) A (150 to 1025) A	(65 to 440) Hz	90 mA + 7.2 mA/A 0.28 A + 6.7 mA/A 1.6 + 6.7 mA/A	

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} (±)	Comments
AC Current ³ – Measure			
(5 to 100) µA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	55 nA + 4 mA/A 43 nA + 1.5 mA/A 38 nA + 0.64 mA/A	Agilent 3458A
(0.1 to 1) 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	0.41 µA + 4.1 mA/A 0.28 µA + 1.6 mA/A 0.24 µA + 0.67 mA/A 0.22 µA + 0.37 mA/A 0.24 µA + 0.67 mA/A 0.61 µA + 4.1 mA/A 1.8 µA + 5.6 mA/A	
(1 to 10) 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	2.2 µA + 4.1 mA/A 2.1 µA + 1.6 mA/A 2 µA + 0.67 mA/A 2 µA + 0.37 mA/A 2 µA + 0.67 mA/A 4.2 µA + 4.1 mA/A 15 µA + 5.6 mA/A	
(10 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	40 µA + 4.1 mA/A 27 µA + 1.5 mA/A 23 µA + 0.6 mA/A 21 µA + 0.3 mA/A 23 µA + 0.6 mA/A 60 µA + 4 mA/A 0.18 mA + 5.5 mA/A	
(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	0.4 mA + 4.1 mA/A 0.28 mA + 1.7 mA/A 0.24 mA + 0.9 mA/A 0.25 mA + 1.1 mA/A 0.35 mA + 3.1 mA/A 0.9 mA + 10 mA/A	
(1 to 20) A	Up to 1 kHz (1 to 5) kHz	0.026 % 0.039 %	Y5020, 3458A
(0 to 20) A	1 Hz to 2 kHz (2 to 10) kHz	0.66 mA + 0.8 mA/A 0.64 mA + 0.8 mA/A	Fluke 8588A
(0 to 30) A	1 Hz to 2 kHz (2 to 10) kHz	12 mA + 0.8 mA/A 12 mA + 1.2 mA/A	
(20 to 800) A	(25 to 500) Hz	0.23 %	Agilent 3458A, 461CT

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} (±)	Comments
AC Current ³ – Measure (cont)			
(0.1 to 1) mA	(10 to 20) Hz	0.0076 %	Fluke 5790B with A40B current shunts
	(20 to 40) Hz	0.0032 %	
	(40 to 400) Hz	0.0024 %	
	400 Hz to 3 kHz	0.0028 %	
	(3 to 20) kHz	0.003 %	
	(20 to 50) kHz	0.0038 %	
	(50 to 100) kHz	0.0055 %	
(1 to 10) mA	(10 to 20) Hz	0.0079 %	
	(20 to 40) Hz	0.0034 %	
	40 Hz to 20 kHz	0.002 %	
	(20 to 50) kHz	0.0026 %	
	(50 to 100) kHz	0.0047 %	
(10 to 20) mA	(10 to 20) Hz	0.0077 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.002 %	
	(20 to 50) kHz	0.0027 %	
	(50 to 100) kHz	0.0046 %	
(20 to 50) mA	(10 to 20) Hz	0.0077 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.0021 %	
	(20 to 50) kHz	0.0026 %	
	(50 to 100) kHz	0.0045 %	
(50 to 100) mA	(10 to 20) Hz	0.0076 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.0019 %	
	(20 to 50) kHz	0.0026 %	
	(50 to 100) kHz	0.0047 %	
(100 to 200) mA	(10 to 20) Hz	0.0076 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.0019 %	
	(20 to 50) kHz	0.0025 %	
	(50 to 100) kHz	0.0047 %	
(200 to 500) mA	(10 to 20) Hz	0.0076 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.0019 %	
	(20 to 50) kHz	0.0025 %	
	(50 to 100) kHz	0.0044 %	
500 mA to 1 A	(10 to 20) Hz	0.0076 %	
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.002 %	
	(20 to 50) kHz	0.0028 %	
	(50 to 100) kHz	0.0046 %	

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} (±)	Comments
AC Current ³ – Measure (cont)			
(1 to 2) A	(10 to 20) Hz	0.0076 %	Fluke 5790B with A40B current shunts
	(20 to 40) Hz	0.0031 %	
	40 Hz to 20 kHz	0.0022 %	
	(20 to 50) kHz	0.0034 %	
	(50 to 100) kHz	0.006 %	
(2 to 5) A	(10 to 20) Hz	0.0078 %	
	(20 to 40) Hz	0.0036 %	
	40 Hz to 20 kHz	0.0029 %	
	(20 to 50) kHz	0.0045 %	
	(50 to 100) kHz	0.0076 %	
(5 to 10) A	(10 to 20) Hz	0.008 %	
	(20 to 40) Hz	0.004 %	
	40 Hz to 20 kHz	0.0038 %	
	(20 to 50) kHz	0.0068 %	
	(50 to 100) kHz	0.011 %	
(10 to 20) A	(10 to 20) Hz	0.0085 %	
	(20 to 40) Hz	0.0048 %	
	40 Hz to 5 kHz	0.0041 %	
	(5 to 20) kHz	0.0059 %	
	(20 to 50) kHz	0.0089 %	
(20 to 50) A	(50 to 100) kHz	0.017 %	
	(10 to 20) Hz	0.0085 %	
	(20 to 40) Hz	0.0056 %	
	40 Hz to 5 kHz	0.0055 %	
	(5 to 20) kHz	0.0077 %	
	(20 to 33) kHz	0.0096 %	
	(33 to 50) kHz	0.011 %	
(50 to 100) A	(50 to 70) kHz	0.013 %	
	(70 to 100) kHz	0.019 %	
	(10 to 20) Hz	0.0085 %	
	(20 to 40) Hz	0.0066 %	
	(40 to 500) Hz	0.006 %	
	500 Hz to 5 kHz	0.0073 %	
	(5 to 20) kHz	0.011 %	
	(20 to 33) kHz	0.013 %	
	(33 to 50) kHz	0.016 %	
	(50 to 70) kHz	0.02 %	
	(70 to 100) kHz	0.025 %	

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
AC Impedance ³ – Generate, Fixed Points			
0 Ω	1 kHz	3.2 m Ω	Agilent 16074A AC resistance standards
100 m Ω	1 kHz	0.13 m Ω	
1 Ω	1 kHz	0.2 m Ω	
10 Ω	1 kHz	1.3 m Ω	
100 Ω	1 kHz	1.9 m Ω	
1 k Ω	1 kHz	19 m Ω	
10 k Ω	1 kHz	0.18 Ω	
100 k Ω	1 kHz	3 Ω	
AC Impedance – Measure			
100 m Ω	(50 to 300) Hz 300 to 10 kHz (10 to 100) kHz	10 % 1 % 10 %	PM6304C LCR meter
1 Ω	(50 to 300) Hz 300 to 10 kHz (10 to 100) kHz	1 % 0.14 % 1 %	
10 Ω	(50 to 300) Hz 300 to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.1 % 0.05 % 0.1 % 0.41 %	
100 Ω	50 to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.05 % 0.1 % 0.41 %	
1 k Ω	50 to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.05 % 0.1 % 0.41 %	
10 k Ω	(50 to 150) Hz 150 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.1 % 0.05 % 0.1 % 0.41 %	
100 k Ω	50 Hz to 20 kHz (20 to 100) kHz	0.1 % 0.4 %	
1 M Ω	(50 to 150) Hz 150 Hz to 20 kHz (20 to 100) kHz	1 % 0.1 % 0.4 %	
10 M Ω	(50 to 150) Hz 150 Hz to 20 kHz (20 to 100) kHz	10 % 1 % 10 %	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
Capacitance ³ – Generate			
(0.19 to 0.3999) nF	10 Hz to 10 kHz	8.5 pF + 3.8 pF/nF	Fluke 5520A
(0.4 to 1.0999) nF	10 Hz to 10 kHz	9.4 pF + 3.9 pF/nF	
(1.1 to 3.2999) nF	10 Hz to 3 kHz	12 pF + 3.9 pF/nF	
(0.33 to 10.999) nF	(10 to 1000) Hz	15 pF + 1.9 pF/nF	
(11 to 32.9999) nF	(10 to 1000) Hz	99 pF + 1.9 pF/nF	
(33 to 109.999) nF	(10 to 1000) Hz	0.14 nF + 1.9 pF/nF	
(110 to 329.99) nF	(10 to 1000) Hz	0.45 nF + 1.9 pF/nF	
(0.33 to 1.0999) μ F	(10 to 600) Hz	1.4 nF + 1.9 nF/ μ F	
(1.1 to 3.2999) μ F	(10 to 300) Hz	4.5 nF + 1.9 nF/ μ F	
(3.3 to 10.999) μ F	(10 to 150) Hz	14 nF + 1.9 nF/ μ F	
(11 to 32.999) μ F	(10 to 120) Hz	58 nF + 3.1 nF/ μ F	
(33 to 109.99) μ F	(10 to 80) Hz	0.19 μ F + 3.5 nF/ μ F	
(110 to 329.99) μ F	Up to 50 Hz	0.62 μ F + 3.5 nF/ μ F	
(0.33 to 1.0999) mF	Up to 20 Hz	1.9 μ F + 3.5 μ F/mF	
(1.1 to 3.2999) mF	Up to 6 Hz	6.8 μ F + 3.4 μ F/mF	
(3.3 to 10.999) mF	Up to 2 Hz	38 μ F + 2.4 μ F/mF	
(11 to 32.999) mF	Up to 0.6 Hz	87 μ F + 5.8 μ F/mF	
(33 to 110) mF	Up to 0.2 Hz	0.36 mF + 8.5 μ F/mF	
(1 to 10) pF	10 Hz to 1 MHz	0.073 fF + 0.027 fF/pF	General Radio 1413
(10 to 100) pF	10 Hz to 1 MHz	0.36 fF + 0.031 fF/pF	
(100 to 1000) pF	10 Hz to 500 kHz	0.63 fF + 0.031 fF/pF	
(1 to 10) nF	10 Hz to 500 kHz	5.2 pF + 16 pF/nF	
(10 to 100 nF	10 Hz to 50 kHz	0.15 nF + 38 pF/nF	
(100 to 1000) nF	10 Hz to 10 kHz	3.6 nF + 82 pF/nF	
Capacitance ³ – Generate, Fixed Points			
1 pF	1 kHz	0.05 fF	Agilent 16380A
	1 MHz	0.09 fF	
	2 MHz	0.23 fF	
	3 MHz	0.41 fF	
	4 MHz	0.63 fF	
	5 MHz	0.9 fF	
	10 MHz	2.5 fF	
	13 MHz	3.7 fF	
10 pF	1 kHz	0.1 fF	
	1 MHz	0.41 fF	
	2 MHz	0.42 fF	
	3 MHz	0.4 fF	
	4 MHz	0.5 fF	
	5 MHz	0.6 fF	
	10 MHz	1.2 fF	
	13 MHz	1.6 fF	

Parameter/Range	Frequency	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
Capacitance ³ – Generate, Fixed Points (cont)			
100 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	1 fF 4 fF 5 fF 6.7 fF 9 fF 13 fF 33 fF 49 fF	Agilent 16380A
1000 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	43 fF 65 fF 0.15 pF 0.28 pF 0.44 pF 0.62 pF 1.9 pF 2.8 pF	
10 nF 100 nF 1 μ F	120 Hz to 100 kHz 120 Hz to 120 kHz 120 Hz (1 to 10) kHz 100 kHz	0.51 pF 5.1 pF 65 pF 57 pF 81 pF	Agilent 16380C
100 pF	1 kHz	0.2 fF	Andeen-Hagerling AH1100
Capacitance ³ – Measure			
(0.001 to 0.01) pF	1 kHz 2 kHz 5 kHz	0.018 fF 0.024 fF 0.083 fF	Andeen-Hagerling AH2700A
(0.01 to 0.1) pF	400 Hz 1 kHz 2 kHz 5 kHz	0.038 fF 0.019 fF 0.027 fF 0.091 fF	
(0.1 to 1) pF	50 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	0.99 fF 92 fF 74 fF 87 fF 0.11 fF 0.18 fF 0.51 fF	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
Capacitance ³ – Measure (cont)			
(1 to 10) pF	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	2.4 fF 0.87 fF 0.7 fF 0.64 fF 0.7 fF 0.79 fF 1.1 fF 2.1 fF	Andeen-Hagerling AH2700A
(10 to 100) pF	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	17 fF 8.2 fF 6.8 fF 6.3 fF 6.7 fF 7.2 fF 8.7 fF 14 fF	
(0.1 to 1) nF	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	0.17 pF 82 fF 68 fF 63 fF 67 fF 72 fF 88 fF 0.14 pF	
(1 to 10) nF	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	13 pF 3.8 pF 2.3 pF 1.8 pF 2.1 pF 2.7 pF 4.1 pF 8.3 pF	
(10 to 100) nF	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz 10 kHz	0.37 nF 98 pF 57 pF 41 pF 52 pF 70 pF 0.12 nF 0.31 nF	
(0.1 to 1.5) μ F	50 Hz 200 Hz 400 Hz 1 kHz 2 kHz 3 kHz 5 kHz	11 nF 2.9 nF 2 nF 1.2 nF 1.9 nF 3 nF 7.7 nF	

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
Capacitance ³ – Measure (cont)			
Up to 1 pF	(1 to 20) kHz (20 to 100) kHz	0.1 pF 10 fF	Fluke PM6304C
(1 to 10) pF	200 Hz to 1 kHz (1 to 20) kHz (20 to 100) kHz	1 pF 0.1 pF 40 nF	
(10 to 100) pF	(50 to 300) Hz 300 Hz to 1 kHz (1 to 20) kHz (20 to 100) kHz	10 pF 1 pF 0.11 pF 0.4 pF	
(0.1 to 1) nF	(50 to 200) Hz 200 Hz to 20 kHz (20 to 100) kHz	10 pF 1.1 pF 4 pF	
(1 to 10) nF	(50 to 500) Hz 500 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	11 pF 6.5 pF 11 pF 40 pF	
(10 to 100) nF	(50 to 200) Hz 200 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.11 nF 64 pF 0.11 nF 0.4 nF	
(0.1 to 1) μ F	50 Hz to 1.5 kHz (1.5 to 20) kHz (20 to 100) kHz	0.64 nF 1.1 nF 4 nF	
(1 to 10) μ F	50 Hz to 1.5 kHz (1.5 to 15) kHz (15 to 20) kHz (20 to 100) kHz	6.4 nF 11 nF 0.1 μ F 1 μ F	
(10 to 100) μ F	50 Hz to 1.5 kHz (1.5 to 15) kHz (15 to 50) kHz	0.11 μ F 1 μ F 10 μ F	
(0.1 to 1) mF	50 Hz to 1.5 kHz (1.5 to 15) kHz	10 μ F 0.1 mF	

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
Oscilloscopes ³ –			
Voltage			
DC Into 50 Ω	$\pm$ (0 to 6.6) V	44 μ V + 2.5 mV/V	Fluke 5820A
DC Into 1 M Ω	$\pm$ (0 to 130) V	31 μ V + 0.25 mV/V	
Squarewave Into 50 Ω	1 mV to 6.6 V _{p-p}	44 μ V + 2.5 mV/V	
Squarewave Into 1 M Ω	1 mV to 130 V _{p-p}	17 μ V + 0.5 mV/V	
Fast Edge Into 50 Ω	$\leq$ 150 ps	25 ps	
Leveled Sine Wave	50 kHz Reference	0.41 mV + 20 mV/V	
	50 kHz to 100 MHz	0.51 mV + 38 mV/V	
	(100 to 300) MHz	0.54 mV + 45 mV/V	
	(300 to 500) MHz	0.64 mV + 65 mV/V	
	(500 to 600) MHz	0.67 mV + 72 mV/V	
	10 MHz Reference	0.41 mV + 20 mV/V	
	(600 to 1100) MHz	0.74 mV + 86 mV/V	
	(1.1 to 1.6) GHz	0.74 mV + 86 mV/V	
	(1.6 to 2.1) GHz	0.81 mV + 0.1 V/V	
Bandwidth	(2.1 to 4.2) GHz	3.6 %	8482A
	(4.2 to 18) GHz	3.7 %	8481A
	(18 to 26.5) GHz	4.7 %	8485A
Time Marker	5 s to 50 ms	5 ns + 0.0003 %	Fluke 5820A
	20 ms to 500 ps	0.000 033 %	

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} ($\pm$)	Comments
Oscilloscopes ³ –			
Voltage			
DC Into 1 M Ω	± 1 mV to 200 V	28 μ V + 0.25 mV/V	Fluke 9500B
DC Into 50 Ω	± 1 mV to 5 V	29 μ V + 0.25 mV/V	
Squarewave Into 1 M Ω	40 μ V + 200 V _{p-p}	12 μ V + 1 mV/V	
Squarewave Into 50 Ω	40 μ V to 5 V _{p-p}	12 μ V + 1 mV/V	
Risetime – Generate	500 ps 10 Hz to 2 MHz	62 ps	w/9510 active head
	150 ps 10 Hz to 2 MHz	28 ps	w/9530 active head
	70 ps 10 Hz to 1 MHz	17 ps	w/9560 active head
	15 ps 10 Hz to 1 MHz	8.4 ps	Tektronix 067-1338-00 step generator
Risetime – Measure	(0 to 50) GHz	11 ps	Tektronix 80E04
Time Marker	9 ns to 83 μ s 83 μ s to 55 s	0.000 047 % 0.000 35 %	Fluke 9500B
Level Sine Wave	50 kHz to 300 MHz (300 to 550) MHz (0.55 to 1.1) GHz (1.1 to 3.2) GHz (3.2 to 6) GHz	3.3 % 3.4 % 4 % 4.4 % 5.8 %	Fluke 9500B w/ active heads
AC Flatness – Measure	10 Hz 100 Hz 10 kHz 30 kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz	0.05 % 0.049 % 0.049 % 0.049 % 0.05 % 0.05 % 0.051 % 0.058 % 0.062 % 0.067 % 0.078 % 0.1 % 0.28 %	Ballantine 3 V TVC, 3458A

Parameter/Range	Frequency	CMC ^{2, 6, 7} ($\pm$)	Comments
Inductance ³ – Generate			
100 μ H	100 Hz	0.018 μ H	General Radio 1482 Series
	200 Hz	0.018 μ H	
	400 Hz	0.018 μ H	
	1 kHz	0.012 μ H	
	10 kHz	0.018 μ H	
200 μ H	100 Hz	1 μ H	
	200 Hz	0.98 μ H	
	400 Hz	0.72 μ H	
	1 kHz	0.46 μ H	
	10 kHz	0.64 μ H	
500 μ H	100 Hz	0.097 μ H	
	200 Hz	0.6 μ H	
	400 Hz	0.39 μ H	
	1 kHz	0.31 μ H	
	10 kHz	0.6 μ H	
1 mH	100 Hz	0.14 μ H	
	200 Hz	0.14 μ H	
	400 Hz	0.14 μ H	
	1 kHz	0.13 μ H	
	10 kHz	0.18 μ H	
5 mH	100 Hz	12 μ H	
	200 Hz	3.7 μ H	
	400 Hz	7 μ H	
	1 kHz	6 μ H	
	10 kHz	2.4 μ H	
10 mH	100 Hz	1.4 μ H	
	200 Hz	1.4 μ H	
	400 Hz	1.4 μ H	
	1 kHz	1.1 μ H	
	10 kHz	1.6 μ H	
100 mH	100 Hz	13 μ H	
	200 Hz	13 μ H	
	400 Hz	13 μ H	
	1 kHz	11 μ H	
	10 kHz	21 μ H	
500 mH	100 Hz	0.36 mH	
	200 Hz	0.36 mH	
	400 Hz	2.8 mH	
	1 kHz	0.27 mH	
1 H	100 Hz	0.12 mH	
	200 Hz	0.12 mH	
	400 Hz	0.12 mH	
	1 kHz	0.12 mH	

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments
Inductance ³ – Generate (cont)			
5 H	100 Hz 200 Hz 400 Hz 1 kHz	1.6 mH 3.6 mH 1.3 mH 1.5 mH	General Radio 1482 Series
10 H	100 Hz 200 Hz 400 Hz 1 kHz	1.3 mH 1.3 mH 1.3 mH 1.2 mH	
Inductance ³ – Measure			
100 µH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	0.021 µH 0.021 µH 0.021 µH 0.017 µH 0.021 µH	Transfer method using PM6304C & General Radio 1482 series
200 µH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	1 µH 0.98 µH 0.72 µH 0.46 µH 0.64 µH	
500 µH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	0.11 µH 0.6 µH 0.39 µH 0.31 µH 0.6 µH	
1 mH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	0.6 µH 0.6 µH 0.6 µH 0.6 µH 0.62 µH	
5 mH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	12 µH 3.8 µH 7.1 µH 6.1 µH 2.5 µH	
10 mH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	1.8 µH 1.8 µH 1.8 µH 1.6 µH 2 µH	

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments
Inductance ³ – Measure (cont)			
100 mH	100 Hz 200 Hz 400 Hz 1 kHz 10 kHz	17 µH 17 µH 17 µH 16 µH 24 µH	Transfer method using PM6304C and General Radio 1482 Series
500 mH	100 Hz 200 Hz 400 Hz 1 kHz	0.37 mH 0.37 mH 2.8 mH 0.28 mH	
1 H	100 Hz 200 Hz 400 Hz 1 kHz	0.17 mH 0.17 mH 0.17 mH 0.17 mH	
5 H	100 Hz 200 Hz 400 Hz 1 kHz	1.7 mH 3.6 mH 1.4 mH 1.6 mH	
10 H	100 Hz 200 Hz 400 Hz 1 kHz	1.7 mH 1.7 mH 1.7 mH 1.7 mH	
Inductance ³ – Measure			
1 µH	(1.5 to 75) kHz (75 to 100) kHz	0.1 µH 10 nH	Fluke PM6304C
10 µH	250 Hz to 1.5 kHz (1.5 to 20) kHz (20 to 100) kHz	1 µH 0.1 µH 40 nH	
100 µH	(75 to 250) Hz 250 Hz to 1.5 kHz (1.5 to 20) kHz (20 to 100) kHz	10 µH 1 µH 0.1 µH 0.4 µH	
1 mH	(50 to 75) Hz (75 to 250) Hz 250 Hz to 20 kHz (20 to 100) kHz	0.1 mH 10 µH 1 µH 4 µH	

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments
Inductance ³ – Measure (cont)			
10 mH	(50 to 75) Hz (75 to 200) Hz 200 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.1 mH 10 µH 5.7 µH 10 µH 40 µH	Fluke PM6304C
100 mH	(50 to 75) Hz 75 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	1 mH 57 µH 0.1 mH 0.4 mH	
1 H	50 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.57 mH 1 mH 4 mH	
10 H	(50 to 300) Hz 300 Hz to 15 kHz (15 to 100) kHz	5.7 mH 10 mH 0.1 H	
100 H	50 Hz to 3 kHz (3 to 15) kHz (15 to 75) kHz	0.1 H 1 H 10 H	
1000 H	(50 to 300) Hz 300 Hz to 3 kHz (3 to 15) kHz	1 H 10 H 100 H	
Electrical Calibration of RTDs ³ – Measure			
Pt 385, 100 Ω	(-200 to 80) °C (-80 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 800) °C	0.019 °C 0.023 °C 0.027 °C 0.031 °C 0.038 °C 0.048 °C	Fluke 7526A
Pt 3926, 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	0.018 °C 0.018 °C 0.02 °C 0.024 °C 0.029 °C 0.038 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of RTDs ³ – Measure (cont)			
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.017 °C 0.018 °C 0.019 °C 0.019 °C 0.025 °C 0.03 °C 0.036 °C 0.043 °C	Fluke 7526A
Pt 385, 200 Ω	(-200 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 630) °C	0.054 °C 0.057 °C 0.061 °C 0.061 °C 0.071 °C 0.073 °C 0.09 °C	
Pt 385, 500 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.029 °C 0.029 °C 0.036 °C 0.041 °C 0.049 °C	
Pt 385, 1000 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.02 °C 0.02 °C 0.027 °C 0.03 °C 0.038 °C	
Ni 120, 120 Ω	(-80 to 260) °C	0.0097 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.11 °C	
YSI 400	(15 to 50) °C	0.0071 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of RTDs ³ – Generate			
PT 385, 100 Ω	(-200 to 800) °C	0.052 °C	Fluke 7526A
PT 3926, 100 Ω	(-200 to 630) °C	0.052 °C	
PT 3916, 100 Ω	(-200 to 630) °C	0.052 °C	
PT 385, 200 Ω	(-200 to 400) °C (400 to 630) °C	0.4 °C 0.5 °C	
PT 385, 500 Ω	(-200 to 630) °C	0.17 °C	
PT 385, 1000 Ω	(-200 to 630) °C	0.091 °C	
Ni 120, 120 Ω	(-80 to 260) °C	0.021 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.38 °C	
YSI 400	(15 to 50) °C	0.009 °C	
Thermocouple ³ – Indicating Systems & Measure			
Type B	(600 to 800) °C (800 to 1550) °C (1550 to 1820) °C	0.35 °C 0.28 °C 0.23 °C	Fluke 7526A
Type C	(0 to 1000) °C (1000 to 1800) °C (1800 to 2000) °C (2000 to 2316) °C	0.16 °C 0.23 °C 0.27 °C 0.36 °C	
Type E	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 600) °C (600 to 1000) °C	0.25 °C 0.12 °C 0.091 °C 0.082 °C 0.1 °C	
Type J	(-210 to -100) °C (-100 to 800) °C (800 to 1200) °C	0.14 °C 0.091 °C 0.11 °C	
Type K	(-250 to -200) °C (-200 to -100) °C (-100 to 500) °C (500 to 800) °C (800 to 1372) °C	0.46 °C 0.16 °C 0.1 °C 0.1 °C 0.14 °C	
Type L	(-200 to -100) °C (-100 to 900) °C	0.1 °C 0.092 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Thermocouple ³ – Indicating Systems & Measure (cont)			
Type N	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 100) °C (100 to 800) °C (800 to 1300) °C	0.73 °C 0.23 °C 0.12 °C 0.11 °C 0.1 °C 0.13 °C	Fluke 7526A
Type R	(-50 to -25) °C (-25 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 600) °C (600 to 1000) °C (1000 to 1600) °C (1600 to 1767) °C	0.55 °C 0.45 °C 0.39 °C 0.28 °C 0.22 °C 0.21 °C 0.2 °C 0.24 °C	
Type S	(-50 to -25) °C (-25 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 600) °C (600 to 1000) °C (1000 to 1600) °C (1600 to 1767) °C	0.51 °C 0.43 °C 0.38 °C 0.29 °C 0.23 °C 0.22 °C 0.22 °C 0.27 °C	
Type T	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 200) °C (200 to 400) °C	0.35 °C 0.16 °C 0.14 °C 0.12 °C 0.12 °C	
Type U	(-200 to 0) °C (0 to 200) °C (200 to 600) °C	0.23 °C 0.1 °C 0.1 °C	

V. Electrical – RF/Microwave

Parameter/Equipment	Range	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Power Meter ³ –			
Power Reference @ 1 mW	50 MHz	0.49 %	N432A w/ 478A, 3458A
Power Accuracy	3 μ W to 100 mW	0.29 %	Range calibrator

Parameter/Range	Frequency	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Power Sensor Calibration Factor ³	9 kHz to 50 MHz 50 MHz to 2 GHz (2 to 6) GHz	1.5 % 1.4 % 1.5 %	437B, E9304
@ 1 mW	100 kHz 200 kHz 300 kHz 455 kHz to 2 GHz (2 to 3.6) GHz (3.6 to 4.6) GHz (4.6 to 10) GHz (10 to 11.8) GHz (11.8 to 17.25) GHz (17.25 to 18) GHz (18 to 22) GHz (22 to 26.5) GHz	0.89 % 0.83 % 0.81 % 0.8 % 0.81 % 0.83 % 0.86 % 0.9 % 0.96 % 1.1 % 2.5 % 3 %	Power sensor calibration system with Tegam F1130B and 1135B
@ 1 μ W	100 kHz to 10 GHz (10 to 17.25) GHz (17.25 to 18) GHz (18 to 22) GHz (22 to 26.5) GHz	1.5 % 1.6 % 1.7 % 2.8 % 3.3 %	
Amplitude Modulation ³ – Measure			
(5 to 99) % Depth	100 kHz to 10 MHz	0.86 % of depth	Agilent E4440A
(5 to 20) % Depth (20 to 99) % Depth	10 MHz to 3 GHz	2.6 % of depth 0.78 % of depth	
(5 to 20) % Depth (20 top 99) % Depth	(3 to 26.5) GHz	4.6 % of depth 1.7 % of depth	

Parameter/Range	Frequency	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Frequency Modulation ³ – Measure Modulation rate: 20 Hz to 10 kHz Deviation: 200 Hz to 40 kHz Modulation rate: 50 Hz to 200 kHz Deviation: 250 Hz to 400 kHz	250 kHz to 10 MHz 10 MHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 26.5) GHz	1.5 % 1.5 % 2.5 % 3.8 %	Agilent E4440A
Phase Modulation ³ – Measure (0.3 to $\leq$ 0.7) rad > 0.7 rad (0.6 to $\leq$ 2.0) rad 2.0 rad (1.2 to $\leq$ 4.0) rad > 4.0 rad	100 kHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 26.5) GHz	3 % 1.1 % 3 % 1.1 % 3 % 1.1 %	Agilent E4440A
Relative Power ³ – Measure (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to -70) dB (-70 to -80) dB (-80 to -90) dB (-90 to -100) dB (-100 to -110) dB (-110 to -120) dB (-120 to -130) dB	100 kHz to 26.5 GHz	0.031 dB 0.035 dB 0.039 dB 0.058 dB 0.06 dB 0.064 dB 0.077 dB 0.082 dB 0.086 dB 0.096 dB 0.1 dB 0.11 dB 0.12 dB	Agilent E4440A

Parameter/Range	Frequency	CMC ^{2, 4, 5, 6} (±)	Comments
Attenuation – Measure ³ (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to -70) dB (-70 to -80) dB (-80 to -90) dB (-90 to -100) dB (-100 to -110) dB (-110 to -120) dB (-120 to -127) dB	10 MHz to 26.5 GHz	0.039 dB 0.042 dB 0.045 dB 0.062 dB 0.064 dB 0.068 dB 0.081 dB 0.085 dB 0.089 dB 0.099 dB 0.11 dB 0.11 dB 0.13 dB	Agilent E4440A
Attenuation – Generate ³ (1 to 20) dB (21 to 60) dB (61 to 100) dB (101 to 121) dB (1 to 60) dB (61 to 121) dB	DC to 6 GHz (6 to 18) GHz	0.21 dB 0.22 dB 0.23 dB 0.24 dB 0.51 dB 0.52 dB	Keysight J7211B
Displayed Average Noise Level (-165 to -50) dBm	45 MHz to 2 GHz (2 to 26.5) GHz	0.091 dB 0.17 dB	50 Ω termination
Absolute Power ³ – Measure (-30 to +20) dBm (-70 to -20) dBm	100 kHz to 4.2 GHz (4.2 to 18) GHz (18 to 26.5) GHz (10 to 50) MHz 50 MHz to 9 GHz (9 to 18) GHz (18 to 26.5) GHz	3.6 % 3.7 % 4.7 % 3.8 % 2.8 % 2.9 % 4.1 %	437B Power meter with: 8482A 8481A 8485A 8484A 8485D

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
LISN			
Insertion Loss, (-5 to 0) dB	(10 to 300) kHz 300 kHz to 10 MHz (10 to 400) MHz	0.035 dB 0.024 dB 0.027 dB	Agilent E5071C, cal/ver kit
Phase Angle, (-10 to 90) °	10 to 10 MHz (10 to 400) MHz	1.4° 1.7°	CISPR 16, CISPR 25, IEC61000-4, MIL-STD-461F, ISO 7637, ANSI C63.4
Impedance, (0.5 to 100) Ω	10 kHz to 10 MHz (10 to 400) MHz	0.54 Ω 0.75 Ω	
Isolation, (0 to 60) dB	(10 to 300) kHz 300 kHz to 10 MHz (10 to 400) MHz	0.035 dB 0.024 dB 0.027 dB	
Reflection ³ S ₁₁ /S ₂₂ – Measure			
Magnitude, 1 to ∞	(9 to 30) kHz 30 kHz to 10 MHz 10 MHz to 3 GHz 3 to 4.38) GHz (4.38 to 6) GHz (6 to 8.5) GHz	0.0054 lin 0.0054 lin 0.0075 lin 0.013 lin 0.013 lin 0.017 lin	E5071C, cal/ver kit
Phase, (0 to 180)°	(9 to 30) kHz (30 to 300) kHz 300 kHz to 10 MHz 10 MHz to 3 GHz (3 to 4.38) GHz (4.38 to 6) GHz (6 to 8.5) GHz	1.1° 1.1° 1° 1° 1.9° 1.9° 2.1°	
Reflection ³ S ₁₁ /S ₂₂ – Measure			
Magnitude, 1 to ∞	45 MHz to 2 GHz (2 to 10) GHz (10 to 20) GHz (20 to 40) GHz (40 to 50) GHz	0.006 lin 0.010 lin 0.011 lin 0.012 lin 0.013 lin	E8364A, cal/ver kit
Phase, (0 to 180) °	(45 MHz to 2 GHz (2 to 10) GHz (10 to 20) GHz (20 to 40) GHz (40 to 50) GHz	1.7° 2.1° 2.1° 3.7° 4.2°	

Parameter/Range	Frequency	CMC ^{2, 6} (±)	Comments
Transmission ³ S ₁₂ /S ₂₁ – Measure			
Magnitude, (0 to 60) dB	(9 to 30) kHz (30 to 300) kHz 300 kHz to 10 MHz 10 MHz to 3 GHz (3 to 4.38) GHz (4.38 to 6) GHz (6 to 8.5) GHz	0.035 dB 0.035 dB 0.024 dB 0.027 dB 0.068 dB 0.068 dB 0.113 dB	E5071C, cal/ver kit
Phase, (0 to 180)°	9 kHz to 10 MHz 10 MHz to 3 GHz (3 to 4.38) GHz (4.38 to 6) GHz (6 to 8.5) GHz	1.4° 1.7° 2.8° 2.8° 3.4°	
Transmission ³ S ₁₂ /S ₂₁ – Measure			
Magnitude, (0 to 60) dB	45 MHz to 2 GHz (2 to 10) GHz (10 to 20) GHz (20 to 40) GHz (40 to 50) GHz	0.044 dB 0.052 dB 0.07 dB 0.16 dB 0.28 dB	E8364A, cal/ver kit
Phase, (0 to 180)°	(45 MHz to 2 GHz (2 to 10) GHz (10 to 20) GHz (20 to 40) GHz (40 to 50) GHz	1.2° 1.3° 1.3° 1.6° 2.4°	
Single Side-Band Phase Noise ³ – Measure			
Carrier: 1 MHz to 26.5 GHz	At offsets:		
System Noise Floor Limits	10 Hz	2.7 dB	
Measurements Below:	100 Hz	2.7 dB	
(1 to 10) MHz: -150 dBm	1 kHz	2.5 dB	
10 MHz to 1.2 GHz: -154 dBm	10 kHz	2.4 dB	
(1.2 to 2.1) GHz: -153 dBm	20 kHz	2.4 dB	
(2.1 to 6.6) GHz: -153 dBm	100 kHz	2.4 dB	
(6.6 to 13.2) GHz: -152 dBm	1 MHz	2.4 dB	
(13.2 to 20) GHz: -147 dBm	10 MHz	2.4 dB	
(20 to 26.5) GHz: -143 dBm			
			Agilent E4440A option 226

Parameter/Equipment		Range		CMC ^{2, 6} (±)		Comments	
Low Phase Noise RF Signal – Generate		1 Hz offset 10 Hz offset 100 Hz offset 1 kHz offset 10 kHz offset 100 kHz offset		3 dB 3 dB 2.8 dB 2.5 dB 2.6 dB 2.4 dB		E8257D Opt UNY	
Carrier Frequency	Offset from Carrier Frequency <i>(values below are in dBc/Hz which represents the noise floor at the specific offset from the Carrier Frequency signal as decibels from carrier (dBc) in a 1-Hz bandwidth. CMCs stated above are valid down to these levels for the applicable offset being tested at a specific Carrier Frequency.)</i>						
	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	
250 kHz to 250 MHz		-64	-92	-115	-123	-138	-141
(250 to 500) MHz		-67	-93	-111	-125	-138	-142
500 MHz to 1 GHz		-62	-91	-105	-121	-138	-138
(1 to 2) GHz		-57	-86	-100	-115	-133	-133
(2 to 3.2) GHz		-52	-81	-96	-111	-128	-128
(3.2 to 10) GHz		-43	-72	-85	-101	-120	-120
(10 to 20) GHz		-37	-66	-79	-95	-114	-114
(20 to 40) GHz		-31	-60	-73	-89	-108	-108

VI. Fluid Quantities

Parameter/Equipment	Range	CMC ^{2, 4, 5, 6} (±)	Comments
Hydrometers ³	(0.7 to 1.0) sp. gr. (1.0 to 2.0) sp. gr.	0.0012 sp. gr. 0.0024 sp. gr.	Comparison to reference hydrometer using ASTM E126
Gas Flow – Measure	(1 to 1000) sccm (1000 to 10 000) sccm (10 000 to 50 000) sccm	0.58 % 0.73 % 0.8 %	Sierra Instruments cal-bench system
Viscosity ³ – Ford, Dip & Other Viscosity Cups	Cup Nos. 1 through 5	3.3 %	Viscosity cups, stopwatch, thermometer using ASTM D1200, D4212, ISO-2431

Parameter/Equipment	Range	CMC ^{2, 6} ($\pm$)	Comments
Volume ³ – Volumetric Glassware & Apparatus	Up to 500 μ L (0.5 to 1) mL (1 to 2) mL (2 to 3) mL (3 to 5) mL (5 to 10) mL (10 to 20) mL (20 to 30) mL (30 to 50) mL (100 to 200) mL (200 to 500) mL (0.5 to 1) L (1 to 2) L (2 to 3) L (3 to 5) L (5 to 10) L (10 to 20) L (20 to 30) L	0.027 μ L 0.048 μ L 0.052 μ L 0.056 μ L 0.069 μ L 0.12 μ L 0.22 μ L 0.32 μ L 0.52 μ L 2.2 μ L 5.3 μ L 11 μ L 21 μ L 32 μ L 53 μ L 110 μ L 210 μ L 320 μ L	Gravimetric method using electronic balances

VII. Mechanical

Parameter/Equipment	Range	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Balances ³			
When $R = 0.0001$ g	≤ 500 mg > 500 mg to 10 g > 10 g to 7.4 kg	0.82R 0.91R 1.2R	Class 1 & Class 3 weights
0.001 g	≤ 50 g $(> 50$ to 100) g $(> 100$ to 200) g > 200 g to 7.4 kg	0.83R 0.87R 1.0R 1.2R	
0.01 g	≤ 500 g 500 g to 7.4 kg	0.83R 0.87R	
0.1 g	≤ 2 kg $(> 2$ to 7.4) kg	0.82R 1.0R	
1 g & 10 g	≤ 7.4 kg	0.82R	

Parameter/Equipment	Range	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Mass – Measure	1 mg 2 mg 3 mg 5 mg 10 mg 20 mg 30 mg 50 mg 100 mg 200 mg 300 mg 500 mg 1 g 2 g 3 g 5 g 10 g 20 g 30 g 50 g 100 g 200 g 300 g 500 g 1 kg 2 kg 3 kg 5 kg 10 kg 20 kg 30 kg 32 kg	18 μ g 18 μ g 18 μ g 18 μ g 17 μ g 17 μ g 18 μ g 17 μ g 17 μ g 17 μ g 17 μ g 18 μ g 24 μ g 19 μ g 20 μ g 21 μ g 29 μ g 35 μ g 43 μ g 85 μ g 88 μ g 0.6 mg 1.1 mg 1.2 mg 5.9 mg 5.9 mg 15 mg 15 mg 15 mg 15 mg 16 mg 16 mg	Mass comparator, Class 1 weight set, substitution method
Scales – For Unit Under Test Resolutions From (0.0001 to 10) g	Up to 1500 lbf	0.83R	Class F & 6 weights
Scales – Substitution Testing	(1500 to 3000) lbf (3000 to 4500) lbf	1.1R 1.4R	Test loads using EURAMET CG-18
Force, Compression & Tension – Measure ³	Up to 1500 lbf	0.012 %	Deadweight using Class F & 6 weights

Parameter/Equipment	Range	CMC ^{2, 4, 5} (±)	Comments
Force – Compression & Tension ³ (Incl. Wheel Load Scales & Dynamometers)	(50 to 2000) lbf (100 to 5000) lbf (200 to 10 000) lbf (500 to 25 000) lbf (1000 to 50 000) lbf	0.023 % 0.012 % 0.015 % 0.015 % 0.13 %	Standard load cells
Torque – Measure	(0.5 to 42.5) ozf·in (20 to 200) ozf·in (5 to 50) lbf·in (40 to 400) lbf·in (100 to 1000) lbf·in (25 to 250) lbf·ft (60 to 600) lbf·ft (100 to 1000) lbf·ft (200 to 2000) lbf·ft (60 to 600) lbf·in (200 to 3000) lbf·in (50 to 500) lbf·ft (100 to 1000) lbf·ft	0.42 % 0.31 % 0.3 % 0.3 % 0.31 % 0.3 % 0.31 % 0.31 % 0.3 % 0.72 lbf·in 3.6 lbf·in 0.61 lbf·ft 1.2 lbf·ft	Waters 6500-T4 CDI torque system Norbar torque analyzer
Torque – Measuring Equipment	2 ozf·in to 150 lbf·in 150 lbf·in to 250 lbf·ft (250 to 5000) lbf·ft	0.037 % 0.061 % 0.071 %	Torque arms, Class 6 weights
Pressure – Measure & Generate	 Hydraulic (0.2 to 600) psi (6 to 2400) psi (2400 to 12 000) psi Differential ± 1 inH ₂ O ± 10 inH ₂ O Pneumatic (2 to 100) psi (14 to 1000) psi (0.9 to < 7) psi (7 to 23) psi (-15 to 15) psi (15 to 50) psi (50 to 330) psi	 0.0014 % 0.0022 % 0.0029 % 0.0017 inH ₂ O 0.016 inH ₂ O 0.023 psi 0.0086 % 0.0077 % 0.011 % 0.0035 psi 0.0046 psi 0.0092 %	 Ruska 2465 DWT Ruska 2400HL DWT Additel 761-LLP Fluke PPC3-7M DHI RPM4 CPC6050

Parameter/Equipment	Range	CMC ^{2, 4, 5} (±)	Comments
Direct Verification of Durometers ³ – A, B, C, D, DO, O, OO, OOO			Using ASTM D2240
Indenter Shape & Extension			
Orifice Diameter	(0.047 to 011) in	170 µin	Optical comparator
Extension Length	(0.049 to 0.198) in	170 µin	
Tip Radius, Indentor Thickness	(0.004 to 0.0468) in	190 µin	
Cone Angle	Up to 60°	0.11°	
Spring Force	Up to 100 pts	0.71 pts	Durocalibrator, Class 1 weight set
Accelerometers –			
Voltage Sensitivity, (98 to 102) mV/g	100 Hz (ref) 159 Hz (ref)	1.4 % 1.4 %	Vibration transducer calibration system
Frequency Response (1 to 10) g	(0.5 to < 1) Hz (1 to < 2) Hz (2 to < 5) Hz (5 to < 10) Hz (10 to < 100) Hz 100 Hz (> 100 to 920) Hz > 920 to 2 kHz (> 2 to 5) kHz (> 5 to 7) kHz (> 7 to 10) kHz	3.2 % 2.4 % 2.2 % 2.1 % 2 % 1.3 % 1.5 % 1.8 % 2.9 % 3.2 % 3.3 %	
Accelerometers – Amplitude Response	(1 to 1000) g	0.61 %	Centrifugal acceleration calibration system
Indirect Verification of Rockwell Hardness Testers ³	HRC: Low Middle High	0.45 HRC 0.48 HRC 0.37 HRC	ASTM E18 w/ traceable blocks

VIII. Optical Quantities

Parameter/Equipment	Range	CMC ^{2, 5} ($\pm$)	Comments
Gloss – Measure	(85 to 100) GU 20° 60° 85°	0.94 GU 0.8 GU 0.82 GU	Reference gloss standard

IX. Thermodynamics

Parameter/Equipment	Range	CMC ^{2, 4, 5, 6} ($\pm$)	Comments
Temperature ³ – Measure	(-196 to 0) °C (0 to 660) °C	0.011 °C 0.011 °C + 0.000 042 °C/ °C	Fluke 5628 & 1502A
Temperature ³ – Measuring Equipment	-78.5 °C (-45 to -40) °C (-40 to 30) °C (30 to 300) °C (300 to 600) °C	0.072 °C 0.021 °C 0.015 °C 0.016 °C + 0.000 04 °C / °C 0.029 °C + 0.000 096 °C/ °C	Fluke 5628 & 1502A, dry ice bath Fluke 5628 & 1502A, calibration bath/well
Infrared Temperature – Measuring Equipment ³	(-15 to -12) °C ($\geq$ -12 to -9) °C ($\geq$ -9 to -6) °C ($\geq$ -6 to -2) °C ($\geq$ -2 to 0) °C ($\geq$ 0 to 120) °C (35 to 500) °C	1.2 °C 1.1 °C 1 °C 0.9 °C 0.8 °C 0.87 °C + 0.01 °C/ °C 0.62 °C + 0.017 °C/ °C	Hart 4180 Hart 4181
Relative Humidity – Measuring Equipment	(10 to 95) % RH	0.63 % RH	Thunder Scientific 2500
Relative Humidity ³ – Measuring Equipment	(10 to 80) % RH ($>$ 80 to 95) % RH	1.4 % RH 2.1 % RH	Kaymont 2000
Relative Humidity ³ – Measure	(10 to 90) % RH (90 to 95) % RH	1.4 % RH 2.1 % RH	Vaisala MI70 w/ HMP77/HMP76

X. Time & Frequency

Parameter/Equipment	Range	CMC ^{2, 5, 6} ($\pm$)	Comments
Frequency ³ – Measure	1 mHz to 12.4 GHz (12.4 to 26.5) GHz	58 pHz + 12 pHz/Hz 0.12 Hz	GPS w/ counter
Frequency ³ – Measuring Equipment	1 μ Hz to 80 MHz 80 MHz to 26.5 GHz	0.58 μ Hz + 0.67 pHz/Hz 0.58 mHz + 0.66 pHz/Hz	GPS w/ generator
Frequency – Measure	10 MHz	6.7 μ Hz	GPS
Stopwatches & Timers	Up to 24 hours (0 to 19.99) sec/day	32 ms 0.037 sec/day	Using NIST 960-12 GPS, function generator & counter Timometer
Tachometers – Optical	(1 to 100 000) rpm	0.000 54 rpm + 0.000 038 rpm/rpm	Function generator & LED

¹ This laboratory offers commercial calibration service and field calibration service.

² 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.

³ Field calibration service is available for this calibration. 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.

⁴ In the statement of CMC, L is the numerical value of the nominal length of the device measured in inches; D is the numerical value of the nominal diameter of the device measured in inches; D_i is the numerical value of the nominal diagonal of the plate measured in feet; R is the numerical value of the resolution of the device in its respective units; F is the applied frequency in kHz; and percentages are percentage of reading unless otherwise indicated.

⁵ 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.

⁶ CMC components that can be reasonably attributed to the Unit Under Test have not been utilized in the calculation of the CMC value for this measurement parameter.

⁷ The stated measured values are determined using the indicated instrument (see Comments). This capability is suitable for the calibration of the devices intended to measure or generate the measured value in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a percent or fraction of the reading plus a fixed floor specification.

⁸ This scope meets A2LA's *P112 Flexible Scope Policy*.



Accredited Laboratory

A2LA has accredited

TRESCAL, INC.

Hartland, MI

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, ANSI/NCSL Z540.3-2006, 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 13th day of December 2022.

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

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 1022.01
Valid to May 31, 2024

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