



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: August 31, 2023

Certificate Number: 2044.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations^{1, 10}:

I. Dimensional

Parameter/Equipment	Range	CMC ^{2, 4} (±)	Comments
Dial Indicators ³	Up to 1 in	60 µin	Comparison to gage blocks or Bench micrometer
Micrometers ³	Up to 36 in	(4 + 8L + 0.6R) µin	Comparison to gage blocks
Calipers ³	Up to 36 in	(4 + 8L + 0.6R) µin	Comparison to gage blocks
Go/No-Go Gauges ³	Up to 1 in	22 µin	High resolution micrometer, compared to gage blocks

II. Electrical – DC/ Low Frequency

Parameter/Equipment	Range	CMC ^{2, 5, 6} (\pm)	Comments
DC Voltage ³ – Measure	(0 to 200) mV 200 mV to 2 V (2 to 20) V (20 to 200) V (200 to 1000) V	4.5 μ V/V + 0.11 μ V 3 μ V/V + 0.41 μ V 3 μ V/V + 5 μ V 4.5 μ V/V + 41 μ V 4.5 μ V/V + 500 μ V	Long scale multimeter
Fixed Points	10 V Reference	8.4 μ V	Standard cell inter-comparison to standard reference voltage cell
DC Voltage ³ – Generate	(0 to 220) mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	7.5 μ V/V + 0.4 μ V 5 μ V/V + 0.7 μ V 3.5 μ V/V + 2.5 μ V 3.5 μ V/V + 4 μ V 5 μ V/V + 40 μ V 6.5 μ V/V + 400 μ V	Precision multi-function calibrator
DC Voltage – Generate & Measure, Fixed Points	0.1 V 1 V 10 V 19 V 100 V 1000 V	3.5 μ V/V 2.1 μ V/V 2.1 μ V/V 2.1 μ V/V 2.1 μ V/V 2.1 μ V/V	Ratiometric measurement techniques performed utilizing standard reference voltage cell and standard divider
DC High Voltage ^{3, 9} – Measure and Generate	(1 to 100) kV (100 to 200) kV 150 kV 200 kV	0.02 % 0.08 % 0.06 % 0.06 %	Precision high voltage divider with long scale multimeter
DC Linearity ^{3, 9}	(200 to 450) kV	0.6 %	Precision current meter and high voltage DC resistor
DC Current ³ – Measure	(0 to 200) μ A 200 μ A to 2 mA (2 to 20) mA (20 to 200) mA 200 mA to 2 A (2 to 20) A	12 μ A/A + 0.4 nA 12 μ A/A + 4 nA 13 μ A/A + 41 nA 36 μ A/A + 800 nA 0.017 % + 17 μ A 0.039 % + 500 μ A	Long scale multimeter

Parameter/Equipment	Range	CMC ^{2,5,6} (\pm)	Comments
DC Current ³ – Generate	(0 to 220) μ A 220 μ A to 2.2 mA (2.2 to 22) mA (22 to 220) mA 220 mA to 2.2 A (2.2 to 11) A (11 to 20) A	40 μ A/A + 6 nA 35 μ A/A + 7 nA 35 μ A/A + 40 nA 45 μ A/A + 0.7 μ A 80 μ A/A + 12 μ A 0.036 % + 480 μ A 0.1 % + 750 μ A	Precision multi-function calibrator with precision amplifier (>100 to 220) mA, add 200 ² μ A/A to the CMC. <i>I</i> = current (>1 to 2.2) A, add 10 ² μ A/A to the CMC <i>I</i> = current
DC Current ⁸ – Generate & Measure	(0 to 1) μ A (1 to 10) μ A (10 to 100) μ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 10) A (10 to 20) A	0.043 nA 0.011 % 15 μ A/A 11 μ A/A 5 μ A/A 7 μ A/A 8.5 μ A/A 35 μ A/A 89 μ A/A	Standard resistors & long scale voltmeter
Resistance – Generate & Measure	(0.01 to 0.1) Ω (0.1 to 1) Ω (1 to 10) Ω (10 to 100) Ω (100 to 1000) Ω (1 to 10) k Ω (10 to 100) k Ω (100 to 1000) k Ω (1 to 10) M Ω (10 to 100) M Ω (>100 to 200) M Ω 200 M Ω to 2 G Ω (2 to 20) G Ω (20 to 200) G Ω 200 G Ω to 2 T Ω (2 to 20) T Ω (20 to 200) T Ω	0.85 $\mu\Omega/\Omega$ 0.8 $\mu\Omega/\Omega$ 0.85 $\mu\Omega/\Omega$ 0.9 $\mu\Omega/\Omega$ 0.95 $\mu\Omega/\Omega$ 0.95 $\mu\Omega/\Omega$ 0.75 $\mu\Omega/\Omega$ 1 $\mu\Omega/\Omega$ 3 $\mu\Omega/\Omega$ 20 $\mu\Omega/\Omega$ 60 $\mu\Omega/\Omega$ + 1 k Ω 0.015 % 0.04 % 0.06 % 0.1 % 0.25 % 0.4 %	Primary resistance bridge & working standard resistors Primary resistance bridge & working standard resistors Long scale multimeter Precision high resistance meter
Fixed Point	1 G Ω	0.011 %	Precision high resistance standard, long scale multimeter & precision multi-function calibrator

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
Resistance ³ – Generate, Variable (cont)	330 kΩ to 1.1 MΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ (110 to 330) MΩ (330 to 1100) MΩ	32 μΩ/Ω + 2 Ω 60 μΩ/Ω + 30 Ω 0.013 % + 50 Ω 0.025 % + 2.5 kΩ 0.05 % + 3 kΩ 0.3 % + 100 kΩ 1.5 % + 500 kΩ	Precision multi-function calibrator

Parameter/Range	Frequency	CMC ^{2,5,6} (±)	Comments
AC Resistance ³ – Measure			
(0.1 to 1) Ω	1 kHz	0.64 %	Precision impedance meter
(1 to 10) Ω	1 kHz	0.074 %	
10 Ω to 100 kΩ	1 kHz	0.021 %	
100 kΩ to 1 MΩ	1 kHz	0.036 %	
(1 to 10) MΩ	1 kHz	0.29 %	
(0.1 to 1) Ω	250 Hz to 2.5 kHz	1.3 %	
(1 to 10) Ω	(12 to 50) Hz	0.53 %	
	(50 to 250) Hz	0.27 %	
	250 Hz to 2.5 kHz	0.14 %	
	(2.5 to 5) kHz	0.21 %	
	(5 to 10) kHz	0.27 %	
10 Ω to 10 kΩ	(10 to 50) kHz	1.1 %	
	(12 to 50) Hz	0.091 %	
	(50 to 250) Hz	0.051 %	
	250 Hz to 2.5 kHz	0.031 %	
	(2.5 to 10) kHz	0.051 %	
(10 to 100) kΩ	(10 to 50) kHz	0.18 %	
	(50 to 100) kHz	0.33 %	
	(12 to 50) Hz	0.091 %	
	(50 to 250) Hz	0.051 %	
	250 Hz to 1 kHz	0.031 %	
100 kΩ to 1 MΩ	(1 to 2.5) kHz	0.041 %	
	(2.5 to 5) kHz	0.081 %	
	(5 to 10) kHz	0.18 %	
	(12 to 50) Hz	0.21 %	
100 kΩ to 1 MΩ	(50 to 100) Hz	0.11 %	
	(100 to 250) Hz	0.084 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Resistance ³ – Measure (cont)			
100 kΩ to 1 MΩ	250 Hz to 1 kHz (1 to 2.5) kHz (2.5 to 5) kHz (5 to 10) kHz	0.06 % 0.089 % 0.21 % 0.48 %	Precision impedance meter
(1 to 10) MΩ	(50 to 100) Hz (100 to 250) Hz 250 Hz to 1 kHz (1 to 2.5) kHz	1 % 0.75 % 0.54 % 0.97 %	

Parameter/Equipment	Range	CMC ^{2, 6} (±)	Comments
Impulse, Lightning Impulse ³ –	(50 to 500) kV	1.3 %	Direct comparison with high voltage divider and precision data acquisition system
Voltage	(500 to 2500) kV	1.7 %	
Linearity	(50 to 2500) kV	0.85 %	DC charge ratio comparison
Time Parameters Front Time (T1) Time to half value (T2)	1.2 μs 60 μs	4.3 % 4.3 %	Direct comparison with high voltage divider and precision data acquisition system
Impulse, Switching Impulse ³ –			
Voltage	(50 to 500) kV (500 to 1000) kV	1.3 % 1.7 %	Direct comparison with high voltage divider and precision data acquisition system
Linearity	(50 to 1000) kV	0.85 %	
Time Parameters Front Time (T1) Time to Peak (Tp)	250 μs 2500 μs	4.3 % 4.3 %	Direct comparison with high voltage divider and precision data acquisition system

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC Voltage ³ – Measure			
(1 to 12) mV	(1 to 10) Hz	0.03 % + 3 μV	Long scale multimeter
(12 to 120) mV	(1 to 10) Hz	72 μV/V + 4 μV	
120 mV to 1.2 V	(1 to 10) Hz	72 μV/V + 40 μV	
(1.2 to 12) V	(1 to 10) Hz	72 μV/V + 0.4 mV	
(12 to 120) V	(1 to 10) Hz	0.02 % + 4 mV	
(120 to 700) V	(1 to 10) Hz	0.04 % + 40 mV	
600 μV 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	0.17 % + 1.3 μV 0.074 % + 1.3 μV 0.042 % + 1.3 μV 0.081 % + 2 μV 0.12 % + 2.5 μV 0.23 % + 4 μV 0.24 % + 8 μV 0.35 % + 8 μV	Precision AC/DC transfer standard
(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 500 kHz to 1 MHz	0.085 % + 1.3 μV 0.037 % + 1.3 μV 0.021 % + 1.3 μV 0.04 % + 2 μV 0.06 % + 2.5 μV 0.12 % + 4 μV 0.13 % + 8 μV 0.23 % + 8 μV	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Voltage ³ – Measure (cont)			
(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 500 kHz to 1 MHz	0.029 % + 1.3 μV 0.019 % + 1.3 μV 0.011 % + 1.3 μV 0.021 % + 2 μV 0.031 % + 2.5 μV 0.081 % + 4 μV 0.089 % + 8 μV 0.17 % + 8 μV	Precision AC/DC transfer standard
(22 to 70) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 1.5 μV 0.012 % + 1.5 μV 65 μV/V + 1.5 μV 0.013 % + 2 μV 0.026 % + 2.5 μV 0.051 % + 4 μV 0.067 % + 8 μV 0.11 % + 8 μV	
(70 to 220) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 1.5 μV 85 μV/V + 1.5 μV 38 μV/V + 1.5 μV 69 μV/V + 2 μV 0.016 % + 2.5 μV 0.025 % + 4 μV 0.038 % + 8 μV 0.1 % + 8 μV	
(220 to 700) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 1.5 μV 76 μV/V + 1.5 μV 33 μV/V + 1.5 μV 51 μV/V + 2 μV 79 μV/V + 2.5 μV 0.018 % + 4 μV 0.03 % + 8 μV 0.096 % + 8 μV	
700 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	0.02 % 66 μV/V 24 μV/V 46 μV/V 71 μV/V 0.016 % 0.026 % 0.09 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Voltage ³ – Measure (cont)			
(2.2 to 7) 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	0.02 % 67 μV/V 24 μV/V 48 μV/V 81 μV/V 0.019 % 0.04 % 0.12 %	Precision AC/DC transfer standard
(7 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	0.02 % 67 μV/V 27 μV/V 48 μV/V 81 μV/V 0.019 % 0.04 % 0.12 %	
(22 to 70) 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	0.02 % 68 μV/V 32 μV/V 57 μV/V 94 μV/V 0.02 % 0.041 % 0.12 %	
(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	0.02 % 68 μV/V 31 μV/V 69 μV/V 98 μV/V 0.021 % 0.05 %	
(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	0.02 % 99 μV/V 41 μV/V 0.013 % 0.05 %	
(700 to 1000) V	(20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	99 μV/V 38 μV/V 0.013 % 0.05 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Voltage ³ – Measure (cont)			
Flatness – (Relative to 1 kHz)			
600 µV to 2.2 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.05 % 0.05 % 0.05 % 0.07 % + 1 µV 0.07 % + 1 µV 0.07 % + 1 µV 0.17 % + 1 µV 0.3 % + 1 µV 0.7 % + 2 µV	Precision AC/DC transfer standard
(2.2 to 7) mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.05 % 0.05 % 0.05 % 0.07 % + 1 µV 0.07 % + 1 µV 0.07 % + 1 µV 0.1 % + 1 µV 0.17 % + 1 µV 0.37 % + 1 µV	
(7 to 22) mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.05 % 0.05 % 0.05 % 0.07 % 0.07 % 0.07 % 0.1 % 0.17 % 0.37 %	
(22 to 70) mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.05 % 0.05 % 0.05 % 0.05 % 0.05 % 0.05 % 0.1 % 0.15 % 0.35 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Voltage ³ – Measure (cont)			
Flatness – (Relative to 1 kHz)			
(70 to 220) mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.04 % 0.04 % 0.04 % 0.04 % 0.05 % 0.05 % 0.1 % 0.15 % 0.35 %	Precision AC/DC transfer standard
(220 to 700) mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.03 % 0.03 % 0.03 % 0.03 % 0.05 % 0.05 % 0.1 % 0.15 % 0.35 %	
700 mV to 2.2 V	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.03 % 0.03 % 0.03 % 0.03 % 0.05 % 0.05 % 0.1 % 0.15 % 0.35 %	
(2.2 to 7) V	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (1.2 to 120) kHz (120 to 500) kHz 500 kHz to 1.2 MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % 0.03 % 0.03 % 0.03 % 0.03 % 0.05 % 0.05 % 0.1 % 0.15 % 0.35 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC High Voltage ^{3, 11} – Generate & Measure			
50, 60 Hz	(1 to 100) kV _{RMS}	0.14 %	Precision high voltage divider with long scale multimeter
50, 60 Hz	(100 to 200) kV _{RMS}	0.18 %	
50, 60 Hz	150 kV _{RMS}	0.14 %	
50, 60 Hz	200 kV _{RMS}	0.18 %	
50, 60 Hz	(1 to 100) kV _{pK ±√2}	0.14 %	Note: measurements made at RMS and peak/√2 voltages
50, 60 Hz	(100 to 200) kV _{pK ±√2}	0.18 %	
50, 60 Hz	150 kV _{pK ±√2}	0.14 %	
50, 60 Hz	200 kV _{pK ±√2}	0.18 %	
AC Linearity ^{3, 11} (@ 50, 60 Hz)	(200 to 800) kV	0.5 %	Peak AC meter and field probe
AC Voltage ³ – Generate			
(0.22 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	0.024 % + 4 μV 90 μV/V + 4 μV 80 μV/V + 4 μV 0.02 % + 4.1 μV 0.05 % + 5.2 μV 0.11 % + 10 μV 0.14 % + 20 μV 0.27 % + 22 μV	Precision multi- function calibrator
(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	0.024 % + 4 μV 90 μV/V + 4 μV 80 μV/V + 4 μV 0.02 % + 4 μV 0.05 % + 5 μV 0.11 % + 10 μV 0.14 % + 20 μV 0.27 % + 20 μV	
(22 to 220) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 12 μV 90 μV/V + 7 μV 57 μV/V + 7 μV 0.012 % + 7 μV 0.031 % + 18 μV 0.066 % + 22 μV 0.14 % + 25 μV 0.27 % + 45 μV	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC Voltage ³ – Generate (cont)			
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	0.024 % + 40 µV 90 µV/V + 15 µV 42 µV/V + 8 µV 67 µV/V + 11 µV 85 µV/V + 30 µV 0.034 % + 80 µV 0.1 % + 200 µV 0.17 % + 300 µV	Precision multi-function calibrator
(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	0.024 % + 400 µV 90 µV/V + 150 µV 42 µV/V + 60 µV 67 µV/V + 100 µV 83 µV/V + 200 µV 0.02 % + 600 µV 0.1 % + 2 mV 0.15 % + 3.2 mV	
(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	0.024 % + 4 mV 90 µV/V + 1.5 mV 52 µV/V + 0.7 mV 80 µV/V + 1.5 mV 0.015 % + 2.5 mV 0.09 % + 16 mV 0.44 % + 40 mV 0.8 % + 80 mV	Voltage limited to 2.2 x 10 ⁷ Volt-Hertz
(220 to 250) V	(15 to 50) Hz	0.03 % + 16 mV	
(220 to 1100) V	50 Hz to 1 kHz 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	70 µV/V + 3.5 mV 90 µV/V + 4 mV 0.017 % + 6 mV 0.06 % + 11 mV	With precision amplifier
(220 to 750) V	(30 to 50) kHz (50 to 100) kHz	0.06 % + 11 mV 0.23 % + 45 mV	
AC Current ³ – Generate & Measure			
(0.02 to 0.1) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.021 % + 1.9 nA 0.017 % + 1.4 nA 90 µA/A + 1.4 nA 97 µA/A + 1.4 nA	Precision multi-function calibrators, precision AC/DC transfer standard & precision AC current shunts

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Current ³ – Generate & Measure (cont)			
(0.03 to 0.1) mA	(10 to 30) kHz	0.013 % + 1.6 nA	Precision multi-function calibrators, precision AC/DC transfer standard & precision AC current shunts
(0.1 to 0.3) mA	(10 to 20) Hz	0.017 % + 2.9 nA	
	(20 to 40) Hz	86 µA/A + 1.2 nA	
	40 Hz to 1 kHz	62 µA/A + 0.9 nA	
	(1 to 10) kHz	82 µA/A + 0.6 nA	
	(10 to 30) kHz	98 µA/A + 1.3 nA	
(0.3 to 0.9) mA	(10 to 20) Hz	0.017 % + 2.9 nA	
	(20 to 40) Hz	81 µA/A + 1 nA	
	40 Hz to 1 kHz	61 µA/A + 0.6 nA	
	(1 to 10) kHz	79 µA/A + 0.7 nA	
	(10 to 30) kHz	140 µA/A + 0.9 nA	
(0.9 to 1) mA	(10 to 20) Hz	0.017 %	
	(20 to 40) Hz	76 µA/A	
	40 Hz to 1 kHz	59 µA/A	
	(1 to 10) kHz	78 µA/A	
	(10 to 30) kHz	84 µA/A	
(1 to 3) mA	(10 to 20) Hz	0.017 % + 10 nA	
	(20 to 40) Hz	72 µA/A + 13 nA	
	40 Hz to 1 kHz	39 µA/A + 13 nA	
	(1 to 10) kHz	39 µA/A + 13 nA	
	(10 to 30) kHz	59 µA/A + 19 nA	
(3 to 9) mA	(10 to 20) Hz	0.017 % + 1.5 nA	
	(20 to 40) Hz	66 µA/A + 12 nA	
	40 Hz to 1 kHz	39 µA/A + 10 nA	
	(1 to 10) kHz	38 µA/A + 10 nA	
	(10 to 30) kHz	47 µA/A + 20 nA	
(9 to 10) mA	(10 to 20) Hz	0.016 %	
	(20 to 40) Hz	58 µA/A	
	40 Hz to 1 kHz	33 µA/A	
	(1 to 10) kHz	33 µA/A	
	(10 to 30) kHz	46 µA/A	
(10 to 18) mA	(10 to 20) Hz	0.017 % + 1 nA	
	(20 to 40) Hz	65 µA/A + 24 nA	
	40 Hz to 1 kHz	37 µA/A + 19 nA	
	(1 to 10) kHz	37 µA/A + 19 nA	
	(10 to 30) kHz	47 µA/A + 39 nA	

Parameter/Range	Frequency	CMC ^{2,5,6} (±)	Comments
AC Current ³ – Generate & Measure (cont)			
(18 to 20) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.016 % 58 µA/A 33 µA/A 33 µA/A 45 µA/A	Precision multi-function calibrators, precision AC/DC transfer standard & precision AC current shunts
(20 to 44) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.017 % 63 µA/A + 80 nA 35 µA/A + 49 nA 35 µA/A + 49 nA 47 µA/A + 83 nA	
(44 to 50) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.016 % 57 µA/A 30 µA/A 30 µA/A 46 µA/A	
(50 to 88) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.017 % 64 µA/A + 130 nA 36 µA/A + 120 nA 36 µA/A + 120 nA 48 µA/A + 200 nA	
(88 to 100) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.016 % 59 µA/A 33 µA/A 39 µA/A 46 µA/A	
(100 to 180) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.017 % + 10 nA 64 µA/A + 350 nA 38 µA/A + 200 nA 37 µA/A + 200 nA 49 µA/A + 390 nA	
(180 to 200) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.016 % 59 µA/A 37 µA/A 36 µA/A 45 µA/A	

Parameter/Range	Frequency	CMC ^{2,5,6} (±)	Comments
AC Current ³ – Generate & Measure (cont)			
(200 to 440) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz (10 to 30) kHz	0.017 % + 120 nA 65 µA/A + 860 nA 37 µA/A + 970 nA 37 µA/A + 970 nA 52 µA/A + 1.1 µA	Precision multi-function calibrators, precision AC/DC transfer standard & precision AC current shunts
(440 to 500) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.016 % 58 µA/A 33 µA/A 33 µA/A	
(0.5 to 0.88) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.017 % 71 µA/A 45 µA/A 46 µA/A	
(0.88 to 1) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.016 % 59 µA/A 37 µA/A 37 µA/A	
(1 to 1.8) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.017 % 71 µA/A 45 µA/A 47 µA/A	
(1.8 to 2) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.016 % 59 µA/A 35 µA/A 38 µA/A	
(2 to 4.4) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 10) kHz	0.018 % 76 µA/A 52 µA/A 52 µA/A	
(4.4 to 5) A	40 Hz to 1 kHz (1 to 10) kHz	37 µA/A 38 µA/A	
(5 to 8.8) A	40 Hz to 1 kHz (1 to 10) kHz	48 µA/A + 130 µA 68 µA/A + 97 µA	
(8.8 to 10) A	40 Hz to 1 kHz (1 to 10) kHz	45 µA/A 65 µA/A	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Current ³ – Generate & Measure (cont)			
(10 to 18) A	45 Hz to 1 kHz (1 to 5) kHz	55 µA/A + 310 µA 58 µA/A + 300 µA	Precision multi-function calibrators, precision AC/DC transfer standard & precision AC current shunts
(18 to 20) A	45 Hz to 1 kHz (1 to 5) kHz	51 µA/A 59 µA/A	
(20 to 5000) A	60 Hz	0.08 %	
AC Current ³ – Measure			
(2 to 200) µA	10 Hz to 10 kHz	0.048 % + 20 nA	Long scale multimeter
200 µA to 2 mA	10 Hz to 10 kHz	0.028 % + 220 nA	
(2 to 20) mA	10 Hz to 10 kHz	0.028 % + 2.2 µA	
(20 to 200) mA	10 Hz to 10 kHz	0.025 % + 21 µA	
200 mA to 2 A	10 Hz to 2 kHz (2 to 10) kHz	0.06 % + 200 µA 0.071 % + 210 µA	
(2 to 20) A	10 Hz to 2 kHz (2 to 10) kHz	0.08 % + 2 mA 0.25 % + 2 mA	
AC Current ³ – Measure			
(20 to 5000) A	60 Hz	0.08 %	Current transformer and current meter
AC Current ³ – Generate			
(10 to 220) µA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 18 nA 0.016 % + 10 nA 0.01 % + 9 nA 0.028 % + 12 nA 0.11 % + 65 nA	Precision multi-function calibrator

Parameter/Range	Frequency	CMC ^{2, 5, 6} (\pm)	Comments	
AC Current ³ – Generate (cont)				
(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	0.025 % + 60 nA 0.016 % + 35 nA 0.01 % + 35 nA 0.02 % + 110 nA 0.11 % + 650 nA	Precision multi-function calibrator	
(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	0.026 % + 600 nA 0.016 % + 350 nA 0.01 % + 350 nA 0.02 % + 550 nA 0.11 % + 5 μ A		
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 5 μ A 0.016 % + 3.5 μ A 0.01 % + 2.5 μ A 0.02 % + 3.5 μ A 0.11 % + 10 μ A		
(0.22 to 2.2) A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.024 % + 40 μ A 0.045 % + 80 μ A 0.70 % + 160 μ A		
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.046 % + 170 μ A 0.095 % + 380 μ A 0.36 % + 750 μ A		With precision amplifier
(29 to 330) μ A	(10 to 30) kHz	1.6 % + 0.4 μ A		Precision multi-function calibrator
(0.33 to 3.3) mA	(10 to 30) kHz	1 % + 0.6 μ A		
(3.3 to 33) mA	(10 to 30) kHz	0.4 % + 4 μ A		
(33 to 330) mA	(10 to 30) kHz	0.4 % + 200 μ A		
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.12 % + 5 mA 0.15 % + 5 mA 3 % + 5 mA		
Impulse – Exponential Current ³				
Current	(4 to 100) kA	1.4 %	Direct comparison with current shunt and precision data acquisition system	
Time Parameters				
Front (T1) Time to half-value (T2)	(1 to 8) μ s (10 to 20) μ s	2.0 % 1.9 %		

Parameter/Range	Frequency	CMC ^{2,6} (±)	Comments
Capacitance ³ – Measure			
(10 to 100) pF	1 kHz	0.42 %	Precision impedance meter
(100 to 1000) pF	1 kHz	0.051 %	
1 nF to 10 μF	1 kHz	0.021 %	
(10 to 100) μF	1 kHz	0.052 %	
100 μF to 1 mF	1 kHz	0.82 %	
(10 to 100) pF	750 Hz to 1 kHz	1.1 %	
	(1 to 5) kHz	0.58 %	
	(5 to 10) kHz	0.87 %	
100 pF to 1 nF	(250 to 500) Hz	0.34 %	
	500 Hz to 10 kHz	0.18 %	
(1 to 10) nF	(50 to 250) Hz	0.34 %	
	250 Hz to 2.5 kHz	0.043 %	
	(2.5 to 7.5) kHz	0.081 %	
	(7.5 to 10) kHz	0.051 %	
	(10 to 50) kHz	0.18 %	
	(50 to 100) kHz	0.33 %	
(10 to 100) nF	(12 to 50) Hz	0.28 %	
	(50 to 100) Hz	0.052 %	
	(100 to 250) Hz	0.041 %	
	250 Hz to 2.5 kHz	0.032 %	
	(2.5 to 5) kHz	0.041 %	
	(5 to 10) kHz	0.051 %	
	(10 to 50) kHz	0.18 %	
	(50 to 100) kHz	0.33 %	
100 nF to 1 μF	(12 to 50) Hz	0.091 %	
	(50 to 100) Hz	0.051 %	
	(100 to 250) Hz	0.041 %	
	250 Hz to 2.5 kHz	0.032 %	
	(2.5 to 5) kHz	0.041 %	
	(5 to 10) kHz	0.052 %	
	(10 to 25) kHz	0.18 %	
	(25 to 50) kHz	0.37 %	
(1 to 10) μF	(12 to 50) Hz	0.11 %	
	(50 to 100) Hz	0.052 %	
	(100 to 250) Hz	0.041 %	
	250 Hz to 2.5 kHz	0.032 %	
	(2.5 to 5) kHz	0.074 %	
	(5 to 7.5) kHz	0.14 %	
	(7.5 to 10) kHz	0.19 %	

Parameter/Range	Frequency	CMC ^{2,6} (±)	Comments
Capacitance ³ – Measure (cont)			
(10 to 100) μF	(12 to 50) Hz (50 to 100) Hz (100 to 250) Hz 250 Hz to 1 kHz (1 to 2.5) kHz	0.12 % 0.059 % 0.041 % 0.071 % 0.22 %	Precision impedance meter
100 μF to 1 mF	(12 to 50) Hz (50 to 100) Hz (100 to 250) Hz (250 to 500) Hz 500 Hz to 1 kHz	0.13 % 0.18 % 0.32 % 0.62 % 0.92 %	
(1 to 10) mF	(12 to 50) Hz	0.47 %	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments
Capacitance – Measure on Fluke 55xx Series Calibrators	200 μF 300 μF 0.33 mF 0.7 mF 1.09 mF 1.1 mF 2 mF 3 mF 3.3 mF 10.9 mF 20 mF 30 mF 33 mF 110 mF	0.021 % 0.018 % 0.018 % 0.015 % 0.015 % 0.016 % 0.014 % 0.014 % 0.015 % 0.015 % 0.014 % 0.014 % 0.015 % 0.016 %	Charge technique using a precision DC current source & long scale voltmeter

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
Capacitance ³ – Generate	(0.19 to 0.3999) nF (0.4 to 1.0999) nF (1.1 to 3.2999) nF (3.3 to 10.9999) nF (11 to 32.9999) nF (33 to 109.999) nF (110 to 329.999) nF (0.33 to 1.099 99) μF (1.1 to 3.299 99) μF (3.3 to 10.9999) μF (11 to 32.9999) μF (33 to 109.9999) μF (110 to 329.9999) μF (0.33 to 1.099 99) mF (1.1 to 3.2999) m (3.3 to 10.9999) mF (11 to 32.9999) mF (33 to 110) mF	0.5 % + 0.01 nF 0.5 % + 0.01 nF 0.5 % + 0.01 nF 0.25 % + 0.01 nF 0.25 % + 0.1 nF 0.25 % + 0.1 nF 0.25 % + 0.3 nF 0.25 % + 1 nF 0.25 % + 3 nF 0.25 % + 10 nF 0.4 % + 30 nF 0.45 % + 100 nF 0.45 % + 300 nF 0.45 % + 1 μF 0.45 % + 3 μF 0.45 % + 10 μF 0.75 % + 30 μF 1.1 % + 100 μF	Precision multi-function calibrator with capacitance generation

Parameter/Range	Frequency	CMC ^{2,5,6} (±)	Comments
Inductance ³ – Measure			
200 μH to 1 mH	1 kHz	0.071 %	Precision impedance meter
1 mH to 10 H	1 kHz	0.021 %	
200 μH to 1 mH	500 Hz to 1 kHz	0.29 %	
	(1 to 10) kHz	0.071 %	
	(10 to 50) kHz	0.18 %	
	(50 to 100) kHz	0.33 %	
(1 to 10) mH	(50 to 100) Hz	1.1 %	
	(100 to 250) Hz	0.36 %	
	(250 to 500) Hz	0.096 %	
	500 Hz to 10 kHz	0.052 %	
	(10 to 25) kHz	0.18 %	
(10 to 100) mH	(12 to 50) Hz	1.1 %	
	(50 to 100) Hz	0.11 %	
	(100 to 250) Hz	0.043 %	
	250 Hz to 2.5 kHz	0.031 %	
	(2.5 to 10) kHz	0.051 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (\pm)	Comments
Inductance ³ – Measure (cont)			
100 mH to 10 H	(12 to 50) Hz (50 to 100) Hz (100 to 250) Hz 250 Hz to 1 kHz	0.14 % 0.056 % 0.043 % 0.031 %	Precision impedance meter
Phase ³ – Measure			
(0.01 to 0.032) V	20 Hz to 10 kHz (10 to 50) kHz	0.2° 0.35°	Precision phase meter
(0.032 to 100) V	20 Hz to 50 kHz	0.05°	
(100 to 320) V	20 Hz to 5 kHz	0.1°	
Voltage to Current	(20 to 500) Hz	0.05°	Precision phase meter with voltage to current capability
Phase ³ – Generate			
Equal V @ 0°	10 Hz to 250 KHz 250 KHz to 10 MHz	0.005° ($f(\text{Hz}) \times 2.5E^{-8}$)°	Single source with equal length cables <i>f</i> is frequency
5 V/@ Equal V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz	0.0058° 0.0057° 0.012° 0.022°	Precision phase generator
50 mV to 10 V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz	0.019° 0.016° 0.016° 0.041°	
(10 to 100) V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz	0.016° 0.016° 0.023° 0.042°	
(100 to 120) V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz	0.015° 0.022° 0.032° 0.080°	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
Phase ³ – Generate (cont)			
Voltage & Current	(10 to 65) Hz	0.1°	Precision multi-function calibrator with phase generation
Phase	(65 to 500) Hz	0.25°	
	500 Hz to 1 kHz	0.5°	
	(1 to 5) kHz	2.5°	
	(5 to 10) kHz	5°	
	(10 to 30) kHz	10°	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Devices ³ –			
Type B	(600 to 800) °C	0.44 °C	Precision multi-function calibrator with temperature generation
	(800 to 1000) °C	0.34 °C	
	(1000 to 1550) °C	0.3 °C	
	(1550 to 1820) °C	0.33 °C	
Type C	(0 to 150) °C	0.3 °C	
	(150 to 650) °C	0.26 °C	
	(650 to 1000) °C	0.31 °C	
	(1000 to 1800) °C	0.5 °C	
	(1800 to 2316) °C	0.84 °C	
Type E	(-250 to -100) °C	0.5 °C	
	(-100 to -25) °C	0.16 °C	
	(-25 to 350) °C	0.14 °C	
	(350 to 650) °C	0.16 °C	
	(650 to 1000) °C	0.21 °C	
Type J	(-210 to -100) °C	0.27 °C	
	(-100 to -30) °C	0.16 °C	
	(-30 to 150) °C	0.14 °C	
	(150 to 760) °C	0.17 °C	
	(760 to 1200) °C	0.23 °C	
Type K	(-200 to -100) °C	0.33 °C	
	(-100 to -30) °C	0.18 °C	
	(-25 to 120) °C	0.16 °C	
	(120 to 1000) °C	0.26 °C	
	(1000 to 1372) °C	0.4 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Devices ³ – (cont)			
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.4 °C 0.22 °C 0.19 °C 0.18 °C 0.27 °C	Precision multi-function calibrator with temperature generation
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.57 °C 0.35 °C 0.33 °C 0.4 °C	
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.47 °C 0.36 °C 0.37 °C 0.46 °C	
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.63 °C 0.24 °C 0.16 °C 0.14 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.56 °C 0.27 °C	
Oscilloscope ³ –			
50 Ω Load	(0 to 6.6) V	0.25 % of output + 40 μV	Precision multi-function calibrator with waveform generation
1 MΩ Load	(0 to 130) V	0.05 % of output + 40 μV	
Squarewave Signal			
50 Ω at 1 kHz	1.8 mV to 2.2 V _{pk-pk}	0.25 % of output + 40 μV	
1 MΩ 10 Hz to 1 kHz	1.8 mV to 105 V _{pk-pk}	0.1 % of output + 40 μV	
1 MΩ (1 to 10) kHz	1.8 mV to 105 V _{pk-pk}	0.25 % of output + 40 μV	

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
Oscilloscope ³ – (cont)			
Level Sine Wave			
Amplitude (50 kHz Reference)	50 kHz 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz	2 % + 300 μV 3.5 % + 300 μV 4 % + 300 μV 6 % + 300 μV	Precision multi- function calibrator with waveform generation
Flatness (50 kHz Reference)	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz	1.5 % + 100 μV 2 % + 100 μV 4 % + 100 μV	
Time Markers – Generate & Period into a 50 Ω load	5 s to 50 ms 20 ms to 2 ns	(25 + 1000t) parts in 10 ⁶ 2.5 parts in 10 ⁶	t is the time in seconds
Rise Time –			
≤2 MHz	(24 to 300) ps	+0 ps / -100 ps	
>2 MHz	(24 to 350) ps	+0 ps / -100 ps	
Wave Generator			
Amplitude			
1 MΩ	1.8 mV to 55 V _{pk-pk}	3 % of output + 100 μV	
50 Ω	1.8 mV to 2.5 V _{pk-pk}	3 % of output + 100 μV	
Frequency	10 Hz to 100 kHz	25 parts in 10 ⁶ + 15 mHz	
Time Interval – Measure	100 ps to 100 μs	0.1 % Δt + 10 ps	Precision high sampling oscilloscope Δt is the nominal time interval

III. Electrical – RF/ Microwave

Parameter/Equipment	Range	CMC ^{2, 5, 6} (±)	Comments
Power – Measure ^{3, 7}			
1 mW, 50 Ω	(10 to 30) MHz	0.41 %	Precision power meter with reference mount & long scale multimeter
(-60 to -30) dBm, 50 Ω	(10 to 30) MHz SWR ≤ 1.4:1	0.13 dB	Precision power meter with precision power sensor
	30 MHz to 4 GHz SWR ≤ 1.15:1	0.13 dB	
	(4 to 10) GHz SWR ≤ 1.2:1	0.13 dB	
(-30 to +20) dBm, 50 Ω	(10 to 15) GHz SWR ≤ 1.3:1	0.13 dB	
	(15 to 18) GHz SWR ≤ 1.35:1	0.14 dB	
	(100 to 300) kHz SWR ≤ 1.6:1	0.13 dB	
	300 kHz to 1 MHz SWR ≤ 1.2:1	0.081 dB	
	1 MHz to 2 GHz SWR ≤ 1.1:1	0.078 dB	
	(2 to 4.2) GHz SWR ≤ 1.3:1	0.1 dB	
	(10 to 30) MHz SWR ≤ 1.4:1	0.069 dB	
	(30 to 50) MHz SWR ≤ 1.18:1	0.069 dB	
	50 MHz to 2 GHz SWR ≤ 1.1:1	0.071 dB	
	(2 to 12.4) GHz SWR ≤ 1.18:1	0.078 dB	
	(12.4 to 18) GHz SWR ≤ 1.28:1	0.097 dB	

IV. Mechanical

Parameter/Equipment	Range	CMC ^{2, 6, 10} (±)	Comments
Torque Wrenches ³	(0.4 to 6500) lbf·ft	0.63 %	Precision torque transducer system
Torque Transducers	(5 to 50) lbf·in (10 to 100) lbf·ft (100 to 1000) lbf·ft (650 to 6500) lbf·ft	0.057 % 0.077 % 0.077 % 0.18 %	Class F weights mounted on a precision torque arm
Mass – Measure	2 mg to 10 g (10 to 50) g (50 to 100) g (100 to 210) g (210 to 6200) g (6200 to 32 000) g	0.12 mg 0.14 mg 0.20 mg 0.30 mg 14 mg 130 mg	Comparison to Class 1 standard weights using a balance
Gauge Pressure – Measure & Measuring Equipment	(1 to 50) psig (30 to 1000) psig	13 parts in 10 ⁶ 20 parts in 10 ⁶	Primary deadweight tester
Absolute Pressure – Measure & Measuring Equipment	(0 to 50) psia (0 to 1000) psia	13 parts in 10 ⁶ 19 parts in 10 ⁶	Primary deadweight tester
Differential Pressure – Measure & Measuring Equipment	(15 to 100) kPa absolute (2.2 to 15) psia	17 parts in 10 ⁶	Primary deadweight tester
Gas Flow – Calibration of Gas Flow Measurement & Control Equipment	(0.02 to 30) slpm (30 to 100) slpm	0.37 % 0.63 %	Primary air flow measurement system
Force – Compression & Tension	(100 to 2000) lbf (2000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 25 000) lbf (25 000 to 50 000) lbf (50 000 to 100 000) lbf	1.6 lbf 2.8 lbf 7.5 lbf 15 lbf 43 lbf 74 lbf	Primary load cell system

Parameter/Equipment	Range	CMC ² (±)	Comments
Scales & Balances ³	2 mg to 10 g (10 to 100) g (100 to 210) g (210 to 6200) g (6200 to 32 000) g	0.068 mg 0.17 mg 0.28 mg 8.7 mg 71 mg	Class 1 weights

V. Thermodynamics

Parameter/Equipment	Range	CMC ^{2, 10} (±)	Comments
Temperature – Measuring Equipment	(-60 to 232) °C (232 to 500) °C	0.03 °C 0.035 °C	Precision thermometer with reference SPRT, precision temperature baths
Temperature – Measure	(-200 to 100) °C (100 to 420) °C	0.03 °C 0.034 °C	Precision thermometer with PRT
Infrared Temperature – Measuring Equipment	(-15 to 0) °C (0 to 120) °C (120 to 200) °C (200 to 350) °C (350 to 500) °C	0.8 °C 0.71 °C 0.97 °C 1.8 °C 2.2 °C	Primary infrared temperature blackbody sources $\epsilon = 0.9$ to 1.0 $\lambda = (8$ to $14) \mu\text{m}$
Relative Humidity – Measuring Equipment	(10 to 95) % RH	0.51 % RH	Primary 2 pressure humidity generator
Electrical Calibration of Thermocouple Reference Junction	(22 to 25) °C	0.067 °C	Precision temperature indicator and PRT and reference thermocouple

VI. Time & Frequency

Parameter/Equipment	Frequency	CMC ^{2,10} (±)	Comments
Frequency ³ – Measuring Equipment	0.01 Hz to 2 MHz	2.5 µHz/Hz + 5 µHz	Precision multi-function calibrator
Fixed Point	10 MHz	1.0 nHz/Hz	Rubidium standard
Frequency – Measure	(1 to 100) Hz 100 Hz to 1 kHz (1 to 10) kHz (10 to 100) kHz 100 kHz to 1 MHz (1 to 10) MHz (10 to 100) MHz (100 to 225) MHz 100 MHz to 1 GHz (1 to 5) GHz (5 to 12.4) GHz	1.8 µHz 1 µHz 10 µHz 100 µHz 1 mHz 10 mHz 100 mHz 230 mHz 1 Hz 5 Hz 12 Hz	Signal generators & precision frequency counter referenced to GPS receiver

SATELLITE FACILITY

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I. Electrical – DC/ Low Frequency

Parameter/Equipment	Range	CMC ^{2, 5, 6} (±)	Comments
DC High Voltage ^{3, 7} – Measure and Generate	(1 to 100) kV (100 to 200) kV 150 kV 200 kV	0.02 % 0.08 % 0.06 % 0.06 %	Precision high voltage divider with long scale multimeter
AC High Voltage ^{3, 7} – Generate and Measure			
50, 60 Hz	(1 to 100) kV _{RMS}	0.14 %	Precision high voltage divider with long scale multimeter Note: measurements made at RMS and peak/ $\sqrt{2}$ voltages
50, 60 Hz	(100 to 200) kV _{RMS}	0.18 %	
50, 60 Hz	150 kV _{RMS}	0.14 %	
50, 60 Hz	200 kV _{RMS}	0.18 %	
50, 60 Hz	(1 to 100) kV _{pK ±√2}	0.14 %	
50, 60 Hz	(100 to 200) kV _{pK ±√2}	0.18 %	
50, 60 Hz	150 kV _{pK ±√2}	0.14 %	
50, 60 Hz	200 kV _{pK ±√2}	0.18 %	
Partial Discharge – Measure ³	(-10 000 to -100) pC (-100 to 100) pC (100 to 10 000) pC	1.0 % 1.5 % 1.0 %	($\Delta T/R$) * ΣV_i technique using long scale multimeter and digital oscilloscope ΔT is the time interval R is the resistance value ΣV_i is the sum of the voltage measurements taken at each time interval

¹ This laboratory offers commercial 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 laboratory. 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, R is the resolution of the device under test.
- ⁵ 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.
- ⁶ In the statement of CMC, percentages are percentage of reading, unless otherwise indicated.
- ⁷ The CMC associated with RF Power measurement does not include mismatch.
- ⁸ The CMC claim is smaller than that of the expanded uncertainty claim for NIST as listed in the BIPM Key Comparison Database. A2LA has evaluated the laboratory's CMC claim and has verified this information to be correct and appropriate.
- ⁹ This scope meets A2LA's *P112 Flexible Scope Policy*.
- ¹⁰ 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.
- ¹¹ High Voltage calibrations are performed to internal procedures written to requirements contained within IEEE STD 4, IEC 60060-2, and IEC 60270.



Accredited Laboratory

A2LA has accredited

EXELON POWERLABS, LLC

Coatesville, PA

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, the requirements of 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 27th day of January 2022

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

Vice President Accreditation Services
For the Accreditation Council
Certificate Number 2044.01
Valid to August 31, 2023

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