



Accredited Laboratory

A2LA has accredited

EXCALIBUR ENGINEERING, INC.

Irvine, CA

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the requirements of ANSI/NCSLI Z540-1-1994 and any additional program requirements in the field of calibration. 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 8 January 2009).



Presented this 12th day of February 2016.

A handwritten signature in blue ink, appearing to read "J. C. Bennett".

Senior Director of Quality & Communications
For the Accreditation Council
Certificate Number 2374.01
Valid to September 30, 2017

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



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005
& ANSI/NCSL Z540-1-1994

EXCALIBUR ENGINEERING, INC.⁷
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Irvine, CA 92618
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CALIBRATION

Valid To: September 30, 2017

Certificate Number: 2374.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory at the location listed above, *as well as the satellite laboratory location listed below*, to perform the following calibrations¹:

I. Dimensional

Parameter/Equipment	Range	CMC ² (±)	Comments
Calipers	Up to 6 in Up to 12 in	490 μin 990 μin	Gage blocks
Micrometers	Up to 4 in Up to 6 in	16 μin 52 μin	Gage blocks

II. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
DC Voltage ³ – Generate	(0 to 330) mV (0 to 3.3) V (0 to 33) V (30 to 330) V (100 to 1020) V	7.6 μV 38 μV 0.42 mV 5.9 mV 20 mV	Fluke 5522A

Parameter/Equipment	Range	CMC ^{2, 4, 5} (\pm)	Comments
DC Voltage ³ – Measure	100 mV 1 V 10 V 100 V 1000 V	0.8 μ V 4.2 μ V 44 μ V 0.62 mV 6.0 mV	Agilent 3458A
DC Current ³ – Generate	(0 to 330) μ A (0 to 3.3) mA (0 to 33) mA (0 to 330) mA (0 to 1.1) A (1.1 to 3) A (0 to 11) A (11 to 20.5) A	68 nA 0.37 μ A 3.6 μ A 36 μ A 0.26 mA 1.2 mA 6.1 mA 22 mA	Fluke 5522A
DC Current ³ – Measure, Fixed Points	1 μ A 10 μ A 100 μ A 1 mA 10 mA 100 mA 1 A 20 A 100 A 1000 A	0.24 nA 0.35 nA 2.8 nA 25 nA 0.25 μ A 4.0 μ A 0.12 mA 6.9 mA 6.9 mA 0.31 A	Agilent 3458A Agilent 3458A, Fluke Y5020 Agilent 3458A, Honeywell 1166 Agilent 3458A, Guideline 9230A-1000
Resistance ³ – Measure	10 Ω 100 Ω 1 k Ω 10 k Ω 100 k Ω 1 M Ω 10 M Ω 100 M Ω	0.22 m Ω 1.9 m Ω 13 m Ω 0.13 Ω 1.3 Ω 19 Ω 0.61 k Ω 55 k Ω	Agilent 3458A

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Resistance ³ – Generate	(0 to 11) Ω (11 to 33) Ω (33 to 110) Ω (110 to 330) Ω 330 Ω to 1.1 kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 33) kΩ (33 to 110) kΩ (110 to 330) kΩ 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	0.48 mΩ 1.7 mΩ 3.2 mΩ 9.2 mΩ 31 mΩ 94 mΩ 0.32 Ω 0.93 Ω 3.1 Ω 11 Ω 36 Ω 0.20 kΩ 1.4 kΩ 8.5 kΩ 59 kΩ 0.97 MΩ 16 MΩ	Fluke 5522A (Applies to 4-wire compensation only)

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Voltage ³ – Generate			
(1.0 to 33) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	49 μV 11 μV 13 μV 38 μV 0.13 mV 0.31 mV	Fluke 5522A
(33 to 330) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.11 mV 55 μV 60 μV 0.12 mV 0.29 mV 0.72 mV	
(0.33 to 3.3) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	1.0 mV 0.55 mV 0.68 mV 1.0 mV 2.4 mV 8.4 mV	

Parameter/Range	Frequency	CMC ^{2,4,5} (±)	Comments
AC Voltage ³ – Generate (cont)			
(3.3 to 33) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	10 mV 5.5 mV 8.4 mV 12 mV 31 mV	Fluke 5522A
(33 to 330) V	45 Hz to 1 kHz (1 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	64 mV 71 mV 87 mV 0.1 V 0.7 V	
(330 to 1020) V	45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.31 V 0.26 V 0.31 V	
AC Voltage ³ – Measure			
(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	59 µV 31 µV 41 µV 0.11 mV 36 mV 3.9 mV	Agilent 3458A
100 mV 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	1.3 mV 1.0 mV 1.7 mV 3.4 mV 8.2 mV 6.4 mV	
(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	25 mV 23 mV 23 mV 39 mV 0.12 mV	
(100 to 1000) V	40 Hz to 1 kHz (1 to 20) kHz	0.42 mV 0.61 mV	

Parameter/Range	Frequency	CMC ^{2, 4, 5} (±)	Comments
AC Current ³ – Measure			
(0 to 100) µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 1 kHz	0.42 µA 0.18 µA 94 nA 94 nA	Agilent 3458A
(1 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	0.41 mA 0.17 mA 81 µA 54 µA 82 µA	
100 mA to 1 A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	4.1 mA 1.8 mA 8.0 mA 1.2 mA 3.1 mA	
(1.1 to 20) A	60 Hz	1.4 mA	Agilent 3458A, Fluke Y5020
(20 to 100) A	60 Hz	6.9 mA	Agilent 3458A, Honeywell 1166
AC Current ³ – Generate			
(29 to 330) µA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.75 µA 0.58 µA 0.5 µA 1.1 µA 2.7 µA 5.4 µA	Fluke 5522A
(0.33 to 3.3) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	6.9 µA 4.2 µA 3.4 µA 6.6 µA 16 µA 33 µA	

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Current ³ – Generate (cont)			
(3.3 to 33) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	59 µA 31 µA 16 µA 30 µA 67 µA 0.13 mA	Fluke 5522A
(33 to 330) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.59 mA 0.31 mA 0.15 mA 0.35 mA 0.70 mA 1.4 mA	
(0.33 to 1.1) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	2.2 mA 0.65 mA 7.5 mA 32 mA	
(1.1 to 3) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	5.5 mA 1.9 mA 19 mA 78 mA	
(3 to 11) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	8.6 mA 13 mA 0.33 A	
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	29 mA 35 mA 0.61 A	
Capacitance ³ – Generate			
(0.04 to 1.1) nF (1.1 to 3.3) nF (3.3 to 110) nF (110 to 330) nF	10 Hz to 10 kHz 10 Hz to 3 kHz 10 Hz to 10 kHz 10 Hz to 10 kHz	16 pF 26 pF 0.29 nF 0.86 nF	Fluke 5522A

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
Capacitance ³ – Generate (cont)			Fluke 5522A
(0.33 to 1.1) μF	(10 to 600) Hz	2.9 nF	
(1.1 to 3.3) μF	(10 to 300) Hz	8.6 nF	
(3.3 to 11) μF	(10 to 150) Hz	29 nF	
(11 to 33) μF	(10 to 120) Hz	0.16 μF	
(33 to 110) μF	(10 to 80) Hz	0.6 μF	
(110 to 330) μF	(0 to 50) Hz	1.8 μF	
0.33 μF to 1.1 mF	(0 to 20) Hz	5.9 μF	
(1.1 to 3.3) mF	(0 to 6) Hz	18 μF	
(3.3 to 11) mF	(0 to 2) Hz	59 μF	
(11 to 33) mF	(0 to 0.6) Hz	0.27 mF	
(33 to 110) mF	(0 to 0.2) Hz	1.3 mF	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ – Measure and Generate			Fluke 5522A
Type K	(-200 to -100) °C	0.34 °C	
	(-100 to -25) °C	0.20 °C	
	(-25 to 120) °C	0.19 °C	
	(120 to 1000) °C	0.28 °C	
	(1000 to 1372) °C	0.93 °C	
Type T	(-250 to -150) °C	0.63 °C	
	(-150 to 0) °C	0.26 °C	
	(0 to 120) °C	0.19 °C	
	(120 to 400) °C	0.17 °C	
Type J	(-210 to -100) °C	0.28 °C	
	(-100 to -30) °C	0.19 °C	
	(-30 to 150) °C	0.17 °C	
	(150 to 760) °C	0.20 °C	
	(760 to 1200) °C	0.62 °C	
Type N	(-200 to -100) °C	0.41 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.20 °C	
	(410 to 1300) °C	0.63 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ – Measure and Generate (cont)			
Type E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.50 °C 0.19 °C 0.17 °C 0.19 °C 0.23 °C	Fluke 5522A
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.57 °C 0.36 °C 0.34 °C 0.39 °C	
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.47 °C 0.37 °C 0.68 °C 0.73 °C	
Type B	(600 to 800) °C (800 to 1000) °C (1000 to 1550) °C (1550 to 1820) °C	0.44 °C 0.35 °C 0.64 °C 0.66 °C	
Type C	(0 to 150) °C (150 to 650) °C (650 to 1000) °C (1000 to 1800) °C (1800 to 2316) °C	0.31 °C 0.28 °C 0.31 °C 0.75 °C 1.0 °C	
Type L	(-200 to -100) °C (-100 to 800) °C (800 to 900) °C	0.38 °C 0.28 °C 0.20 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.56 °C 0.28 °C	

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Oscilloscopes ³ –			
DC Voltage: 50 Ω 1 MΩ	(0 to ± 6.6) V (0 to ± 130) V	27 mV 64 mV	Fluke 5522A/SC1100
AC Voltage (Square wave): 50 Ω 1 MΩ	±1 mV _{pk-pk} to ±6.6 V _{pk-pk} ±1 mV _{pk-pk} to ±130 V _{pk-pk}	20 mV _{pk-pk} 0.13 V _{pk-pk}	
Leveled Sine Wave (Amplitude)	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz 600 MHz to 1.1 GHz	0.19 V 0.22 V 0.32 V 0.24 V	
Time Markers	5 s to 50 ms 20 ms to 100 ns (50 to 20) ns 10 ns (5 to 2) ns	25 ms 49 ns 0.12 ps 25 fs 12 fs	
Wave Generator: 50 Ω 1 MΩ	1.8 mV _{pk-pk} to 2.5 V _{pk-pk} 1.8 mV _{pk-pk} to 55 V _{pk-pk}	74 mV _{pk-pk} 1.6 V _{pk-pk}	
Pulse Generator: (4 to 500) ns width	10 mV to 2.5 V	0.29 μs	
Fast Edge: 50 Ω < 300 ps rise time	4 mV _{pk-pk} to 2.5 V _{pk-pk}	0.34 ns	

III. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC ^{2,6} (±)	Comments
RF Power – Measure 30 MHz to 50 GHz	(0 to 70) dB (71 to 120) dB	0.98 dB 1.1 dB	Agilent E4448A with N5532A opt. 550

Parameter/Range	Frequency	CMC ^{2, 6} (±)	Comments
Audio Distortion – Measure 20 Hz to 250 kHz	(0.01 to 100) %	0.064 %	Agilent E4448A
Amplitude Modulation – Measure AM Depth:			Agilent E4448A
100 kHz to 10 MHz	50 Hz to 10 kHz, 5 % to 99 %	0.84 %	
10 MHz to 3 GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	0.57 % 0.86 %	
(3 to 26.5) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	1.0 % 1.7 %	
(26.5 to 31.15) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	1.5 % 2.2 %	
(31.15 to 50) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	5.9 % 6.7 %	
AM Distortion:			
100 kHz to 10 GHz	20 Hz to 1 kHz > 1 % > 3 %	0.91 % 0.34 %	
10 MHz to 26.5 GHz	20 Hz to 1 kHz > 1 % > 3 %	1.1 % 0.45 %	
(26.5 to 50) GHz	20 Hz to 1 kHz > 1 % > 3 % > 5 %	7.0 % 2.3 % 1.7 %	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments
Frequency Modulation – Measure			
FM Deviation:			
250 kHz to 10 MHz	20 Hz to 10 kHz Dev/Rate > 0.2 Dev/Rate > 1.2	1.7 % 1.1 %	Agilent E4448A
10 MHz to 6.6 GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 0.45	1.7 % 1.1 %	
(6.6 to 13.2) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 8	2.8 % 1.1 %	
(13.2 to 31.15) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 16	4.3 % 1.1 %	
(31.5 to 50) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 32	9.6 % 1.1 %	
FM Distortion:			
1 MHz to 6.6 GHz	20 Hz to 1 kHz Dev 500 Hz to 2 kHz Dev ≥ 2.0 kHz	0.34 % 0.11 %	
(6.6 to 13.2) GHz	20 Hz to 1 kHz Dev > 2.3 kHz Dev ≥ 4.5 kHz	0.34 % 0.11 %	
(13.2 to 31.15) GHz	20 Hz to 1 kHz Dev > 2.7 kHz Dev ≥ 6.0 kHz	0.34 % 0.11 %	
(31.15 to 50) GHz	20 Hz to 1 kHz Dev > 4.0 kHz Dev ≥ 12.0 kHz	0.34 % 0.11 %	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments	
Phase Modulation – Measure				
PM Deviation:				
100 kHz to 6.6 GHz	> 0.3 rad	3.4 %	Agilent E4448A	
	>0.7 rad	1.1 %		
(6.6 to 13.2) GHz	> 0.6 rad	3.4 %		
	> 2.0 rad	1.1 %		
(13.2 to 26.5) GHz	> 1.2 rad	3.4 %		
	> 4.0 rad	1.1 %		
(26.5 to 31.15) GHz	> 1.3 rad	3.4 %		
	> 4.0 rad	1.1 %		
(31.15 to 50) GHz	> 2.4 rad	3.4 %		
	> 8.0 rad	1.1 %		
PM Distortion:				
1 MHz to 6.6 GHz	(20 to 500) Hz			
	> 0.8 rad	3.4 %		
	≥ 2.5 rad	1.1 %		
	500 Hz to 1 kHz			
	> 0.4 rad	3.4 %		
	≥ 1.0 rad	1.1 %		
(6.6 to 13.2) GHz	(20 to 500) Hz			
	> 1.8 rad	3.4 %		
	≥ 5.5 rad	1.1 %		
	500 Hz to 1 kHz			
	≥ 0.8 rad	3.4 %		
	≥ 2.5 rad	1.1 %		
(13.2 to 31.15) GHz	(20 to 500) Hz			
	> 3.5 rad	3.4 %		
	≥ 10.0 rad	1.1 %		
	500 Hz to 1 kHz			
	> 1.2 rad	3.4 %		
	≥ 4 rad	1.1 %		
(31.15 to 50) GHz	(20 to 500) Hz			
	> 7.5 rad	3.4 %		
	≥ 19.0 rad	1.1 %		
	500 Hz to 1 kHz			
	> 3.0 rad	3.4 %		
	≥ 8.0 rad	1.1 %		

IV. Time & Frequency

Parameter/Range	Frequency	CMC ² (±)	Comments
Frequency – Measuring Equipment	10 MHz	5.7 X 10 ⁻¹² Hz/Hz	Fluke 910R
Frequency Accuracy – Measure	0.001 Hz to 50 GHz	5.7 X 10 ⁻¹² f	Frequency counter f= frequency

¹ This laboratory offers commercial 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 and this laboratory meets A2LA R104 - *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the 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 The measurements stated are generated with the Fluke 5522A series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.

⁵ The measurands stated are measured with the Agilent 3458A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a combination of the fraction of the reading/output plus a range specification.

⁶ In the statement of CMC, percentages are to be read as percent of reading unless otherwise noted.

⁷ This accreditation covers calibrations performed at the main laboratory listed above, and the calibrations listed below, performed at the satellite facility laboratory listed below:

EXCALIBUR ENGINEERING, INC.
 14 Inverness Drive east, Suite B106
 Englewood, Colorado 80112
 Andy Watson Phone: 949 454 6603

I. Dimensional

Parameter/Equipment	Range	CMC ² (±)	Comments
Calipers	Up to 6 in Up to 12 in	490 µin 990 µin	Gage blocks
Micrometers	Up to 4 in Up to 6 in	16 µin 52 µin	Gage blocks

II. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
DC Voltage ³ – Generate	(0 to 330) mV (0 to 3.3) V (0 to 33) V (30 to 330) V (100 to 1020) V	7.6 µV 38 µV 0.42 mV 5.9 mV 20 mV	Fluke 5522A

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
DC Voltage ³ – Measure	100 mV 1 V 10 V 100 V 1000 V	0.8 µV 4.2 µV 44 µV 0.62 mV 6.0 mV	Agilent 3458A

Parameter/Equipment	Range	CMC ^{2, 4, 5} (\pm)	Comments
DC Current ³ – Generate	(0 to 330) μ A (0 to 3.3) mA (0 to 33) mA (0 to 330) mA (0 to 1.1) A (1.1 to 3) A (0 to 11) A (11 to 20.5) A	68 nA 0.37 μ A 3.6 μ A 36 μ A 0.26 mA 1.2 mA 6.1 mA 22 mA	Fluke 5522A
DC Current ³ – Measure, Fixed Points	1 μ A 10 μ A 100 μ A 1 mA 10 mA 100 mA 1 A 20 A 100 A 1000 A	0.24 nA 0.35 nA 2.8 nA 25 nA 0.25 μ A 4.0 μ A 0.12 mA 6.9 mA 6.9 mA 0.31 A	Agilent 3458A Agilent 3458A, Fluke Y5020 Agilent 3458A, Honeywell 1166 Agilent 3458A, Guideline 9230A- 1000
Resistance ³ – Measure	10 Ω 100 Ω 1 k Ω 10 k Ω 100 k Ω 1 M Ω 10 M Ω 100 M Ω	0.22 m Ω 1.9 m Ω 13 m Ω 0.13 Ω 1.3 Ω 19 Ω 0.61 k Ω 55 k Ω	Agilent 3458A

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Resistance ³ – Generate	(0 to 11) Ω (11 to 33) Ω (33 to 110) Ω (110 to 330) Ω 330 Ω to 1.1 kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 33) kΩ (33 to 110) kΩ (110 to 330) kΩ 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	0.48 mΩ 1.7 mΩ 3.2 mΩ 9.2 mΩ 31 mΩ 94 mΩ 0.32 Ω 0.93 Ω 3.1 Ω 11 Ω 36 Ω 0.20 kΩ 1.4 kΩ 8.5 kΩ 59 kΩ 0.97 MΩ 16 MΩ	Fluke 5522A (Applies to 4-wire compensation only)

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Voltage ³ – Generate			
(1.0 to 33) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	49 μV 11 μV 13 μV 38 μV 0.13 mV 0.31 mV	Fluke 5522A
(33 to 330) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.11 mV 55 μV 60 μV 0.12 mV 0.29 mV 0.72 mV	
(0.33 to 3.3) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	1.0 mV 0.55 mV 0.68 mV 1.0 mV 2.4 mV 8.4 mV	

Parameter/Range	Frequency	CMC ^{2,4,5} (±)	Comments
AC Voltage ³ – Generate (cont)			
(3.3 to 33) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	10 mV 5.5 mV 8.4 mV 12 mV 31 mV	Fluke 5522A
(33 to 330) V	45 Hz to 1 kHz (1 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	64 mV 71 mV 87 mV 0.1 V 0.7 V	
(330 to 1020) V	45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.31 V 0.26 V 0.31 V	
AC Voltage ³ – Measure			
(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	59 µV 31 µV 41 µV 0.11 mV 36 mV 3.9 mV	Agilent 3458A
100 mV 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	1.3 mV 1.0 mV 1.7 mV 3.4 mV 8.2 mV 6.4 mV	
(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	25 mV 23 mV 23 mV 39 mV 0.12 mV	
(100 to 1000) V	40 Hz to 1 kHz (1 to 20) kHz	0.42 mV 0.61 mV	

Parameter/Range	Frequency	CMC ^{2, 4, 5} (±)	Comments
AC Current ³ – Measure			
(0 to 100) µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 1 kHz	0.42 µA 0.18 µA 94 nA 94 nA	Agilent 3458A
(1 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	0.41 mA 0.17 mA 81 µA 54 µA 82 µA	
100 mA to 1 A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	4.1 mA 1.8 mA 8.0 mA 1.2 mA 3.1 mA	
(1.1 to 20) A	60 Hz	1.4 mA	Agilent 3458A, Fluke Y5020
(20 to 100) A	60 Hz	6.9 mA	Agilent 3458A, Honeywell 1166
AC Current ³ – Generate			
(29 to 330) µA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.75 µA 0.58 µA 0.5 µA 1.1 µA 2.7 µA 5.4 µA	Fluke 5522A
(0.33 to 3.3) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	6.9 µA 4.2 µA 3.4 µA 6.6 µA 16 µA 33 µA	

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Current ³ – Generate (cont)			
(3.3 to 33) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	59 µA 31 µA 16 µA 30 µA 67 µA 0.13 mA	Fluke 5522A
(33 to 330) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.59 mA 0.31 mA 0.15 mA 0.35 mA 0.7 mA 1.4 mA	
(0.33 to 1.1) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	2.2 mA 0.65 mA 7.5 mA 32 mA	
(1.1 to 3) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	5.5 mA 1.9 mA 19 mA 78 mA	
(3 to 11) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	8.6 mA 13 mA 0.33 A	
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	29 mA 35 mA 0.61 A	
Capacitance ³ – Generate			
(0.04 to 1.1) nF (1.1 to 3.3) nF (3.3 to 110) nF (110 to 330) nF	10 Hz to 10 kHz 10 Hz to 3 kHz 10 Hz to 10 kHz 10 Hz to 10 kHz	16 pF 26 pF 0.29 nF 0.86 nF	Fluke 5522A

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
Capacitance ³ – Generate (cont)			Fluke 5522A
(0.33 to 1.1) μF	(10 to 600) Hz	2.9 nF	
(1.1 to 3.3) μF	(10 to 300) Hz	8.6 nF	
(3.3 to 11) μF	(10 to 150) Hz	29 nF	
(11 to 33) μF	(10 to 120) Hz	0.16 μF	
(33 to 110) μF	(10 to 80) Hz	0.6 μF	
(110 to 330) μF	(0 to 50) Hz	1.8 μF	
0.33 μF to 1.1 mF	(0 to 20) Hz	5.9 μF	
(1.1 to 3.3) mF	(0 to 6) Hz	18 μF	
(3.3 to 11) mF	(0 to 2) Hz	59 μF	
(11 to 33) mF	(0 to 0.6) Hz	0.27 mF	
(33 to 110) mF	(0 to 0.2) Hz	1.3 mF	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ – Measure and Generate			Fluke 5522A
Type K	(-200 to -100) °C	0.34 °C	
	(-100 to -25) °C	0.20 °C	
	(-25 to 120) °C	0.19 °C	
	(120 to 1000) °C	0.28 °C	
	(1000 to 1372) °C	0.93 °C	
Type T	(-250 to -150) °C	0.63 °C	
	(-150 to 0) °C	0.26 °C	
	(0 to 120) °C	0.19 °C	
	(120 to 400) °C	0.17 °C	
Type J	(-210 to -100) °C	0.28 °C	
	(-100 to -30) °C	0.19 °C	
	(-30 to 150) °C	0.17 °C	
	(150 to 760) °C	0.20 °C	
	(760 to 1200) °C	0.62 °C	
Type N	(-200 to -100) °C	0.41 °C	
	(-100 to -25) °C	0.24 °C	
	(-25 to 120) °C	0.21 °C	
	(120 to 410) °C	0.20 °C	
	(410 to 1300) °C	0.63 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ – Measure and Generate (cont)			
Type E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.50 °C 0.19 °C 0.17 °C 0.19 °C 0.23 °C	Fluke 5522A
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.57 °C 0.36 °C 0.34 °C 0.39 °C	
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.47 °C 0.37 °C 0.68 °C 0.73 °C	
Type B	(600 to 800) °C (800 to 1000) °C (1000 to 1550) °C (1550 to 1820) °C	0.44 °C 0.35 °C 0.64 °C 0.66 °C	
Type C	(0 to 150) °C (150 to 650) °C (650 to 1000) °C (1000 to 1800) °C (1800 to 2316) °C	0.31 °C 0.28 °C 0.31 °C 0.75 °C 1.0 °C	
Type L	(-200 to -100) °C (-100 to 800) °C (800 to 900) °C	0.38 °C 0.28 °C 0.20 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.56 °C 0.28 °C	

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Oscilloscopes ³ –			
DC Voltage: 50 Ω 1 MΩ	(0 to ± 6.6) V (0 to ± 130) V	27 mV 64 mV	Fluke 5522A/SC1100
AC Voltage (Square wave): 50 Ω 1 MΩ	±1 mV _{pk-pk} to ±6.6 V _{pk-pk} ±1 mV _{pk-pk} to ±130 V _{pk-pk}	20 mV _{pk-pk} 0.13 V _{pk-pk}	
Leveled Sine Wave (Amplitude)	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz 600 MHz to 1.1 GHz	0.19 V 0.22 V 0.32 V 0.24 V	
Time Markers	5 s to 50 ms 20 ms to 100 ns (50 to 20) ns 10 ns (5 to 2) ns	25 ms 49 ns 0.12 ps 25 fs 12 fs	
Wave Generator: 50 Ω 1 MΩ	1.8 mV _{pk-pk} to 2.5 V _{pk-pk} 1.8 mV _{pk-pk} to 55 V _{pk-pk}	74 mV _{pk-pk} 1.6 V _{pk-pk}	
Pulse Generator: (4 to 500) ns width	10 mV to 2.5 V	0.29 μs	
Fast Edge: 50 Ω < 300 ps rise time	4 mV _{pk-pk} to 2.5 V _{pk-pk}	0.34 ns	

III. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC ^{2,6} (±)	Comments
RF Power – Measure 30 MHz to 50 GHz	(0 to 70) dB (71 to 120) dB	0.98 dB 1.1 dB	Agilent E4448A with N5532A opt. 550

Parameter/Range	Frequency	CMC ^{2, 6} (±)	Comments
Audio Distortion – Measure 20 Hz to 250 kHz	(0.01 to 100) %	0.064 %	Agilent E4448A
Amplitude Modulation – Measure AM Depth:			
100 kHz to 10 MHz	50 Hz to 10 kHz, 5 % to 99 %	0.84 %	Agilent E4448A
10 MHz to 3 GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	0.57 % 0.86 %	
(3 to 26.5) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	1.0 % 1.7 %	
(26.5 to 31.15) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	1.5 % 2.2 %	
(31.15 to 50) GHz	50 Hz to 100 kHz, 5 % to 20 % 20 % to 99 %	5.9 % 6.7 %	
AM Distortion:			
100 kHz to 10 GHz	20 Hz to 1 kHz > 1 % > 3 %	0.91 % 0.34 %	
10 MHz to 26.5 GHz	20 Hz to 1 kHz > 1 % > 3 %	1.1 % 0.45 %	
(26.5 to 50) GHz	20 Hz to 1 kHz > 1 % > 3 % > 5 %	7.0 % 2.3 % 1.7 %	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments
Frequency Modulation – Measure			
FM Deviation:			
250 kHz to 10 MHz	20 Hz to 10 kHz Dev/Rate > 0.2 Dev/Rate > 1.2	1.7 % 1.1 %	Agilent E4448A
10 MHz to 6.6 GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 0.45	1.7 % 1.1 %	
(6.6 to 13.2) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 8	2.8 % 1.1 %	
(13.2 to 31.15) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 16	4.3 % 1.1 %	
(31.5 to 50) GHz	50 Hz to 200 kHz Dev/Rate > 0.2 Dev/Rate > 32	9.6 % 1.1 %	
FM Distortion:			
1 MHz to 6.6 GHz	20 Hz to 1 kHz Dev 500 Hz to 2 kHz Dev ≥ 2.0 kHz	0.34 % 0.11 %	
(6.6 to 13.2) GHz	20 Hz to 1 kHz Dev > 2.3 kHz Dev ≥ 4.5 kHz	0.34 % 0.11 %	
(13.2 to 31.15) GHz	20 Hz to 1 kHz Dev > 2.7 kHz Dev ≥ 6.0 kHz	0.34 % 0.11 %	
(31.15 to 50) GHz	20 Hz to 1 kHz Dev > 4.0 kHz Dev ≥ 12.0 kHz	0.34 % 0.11 %	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments	
Phase Modulation – Measure				
PM Deviation:				
100 kHz to 6.6 GHz	> 0.3 rad	3.4 %	Agilent E4448A	
	>0.7 rad	1.1 %		
(6.6 to 13.2) GHz	> 0.6 rad	3.4 %		
	> 2.0 rad	1.1 %		
(13.2 to 26.5) GHz	> 1.2 rad	3.4 %		
	> 4.0 rad	1.1 %		
(26.5 to 31.15) GHz	> 1.3 rad	3.4 %		
	> 4.0 rad	1.1 %		
(31.15 to 50) GHz	> 2.4 rad	3.4 %		
	> 8.0 rad	1.1 %		
PM Distortion:				
1 MHz to 6.6 GHz	(20 to 500) Hz			
	> 0.8 rad	3.4 %		
	≥ 2.5 rad	1.1 %		
	500 Hz to 1 kHz			
	> 0.4 rad	3.4 %		
	≥ 1.0 rad	1.1 %		
(6.6 to 13.2) GHz	(20 to 500) Hz			
	> 1.8 rad	3.4 %		
	≥ 5.5 rad	1.1 %		
	500 Hz to 1 kHz			
	≥ 0.8 rad	3.4 %		
	≥ 2.5 rad	1.1 %		
(13.2 to 31.15) GHz	(20 to 500) Hz			
	> 3.5 rad	3.4 %		
	≥ 10.0 rad	1.1 %		
	500 Hz to 1 kHz			
	> 1.2 rad	3.4 %		
	≥ 4 rad	1.1 %		
(31.15 to 50) GHz	(20 to 500) Hz			
	> 7.5 rad	3.4 %		
	≥ 19.0 rad	1.1 %		
	500 Hz to 1 kHz			
	> 3.0 rad	3.4 %		
	≥ 8.0 rad	1.1 %		

IV. Time & Frequency

Parameter/Range	Frequency	CMC ² (±)	Comments
Frequency – Measuring Equipment	10 MHz	5.7 X 10 ⁻¹² Hz/Hz	Fluke 910R
Frequency Accuracy – Measure	0.001 Hz to 50 GHz	5.7 X 10 ⁻¹² f	Frequency counter f= frequency

¹ This laboratory offers commercial 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 and this laboratory meets A2LA R104 - *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the 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 The measurements stated are generated with the Fluke 5522A series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.

⁵ The measurands stated are measured with the Agilent 3458A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a combination of the fraction of the reading/output plus a range specification.

⁶ In the statement of CMC, percentages are to be read as percent of reading unless otherwise noted.