



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005
& ANSI/NCSL Z540.3-2006

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CALIBRATION

Valid To: June 30, 2019

Certificate Number: 2562.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations¹:

I. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2, 3, 8, 10} (±)	Comments
DC Voltage – Generate and Measure	Fixed Points		
	10 V	0.70 µV/V	Zener voltage standard
	0 V	0.01 µV	Low thermal short
	0.1 V	1.8 µV/V	Zener, 752A ratio divider
	1 V	0.73 µV/V	
	10 V	0.73 µV/V	
	100 V	0.73 µV/V	
	1000 V	0.73 µV/V	
Generate	(0 to 220) mV	3.7 µV/V + 0.41 µV	
	(0.22 to 2.2) V	2.6 µV/V + 0.90 µV	
	(2.2 to 11) V	1.1 µV/V + 6.5 µV	
	(11 to 22) V	1.3 µV/V + 5.8 µV	
	(22 to 60) V	2.4 µV/V + 69 µV	
	(60 to 220) V	2.6 µV/V + 56 µV	
	(220 to 1000) V	3.6 µV/V + 62 µV	
Measure	(0 to 120) mV	2.9 µV/V + 0.29 µV	AT 3458A
	(0.12 to 1.2) V	1.7 µV/V + 1.9 µV	
	(1.2 to 12) V	1.7 µV/V + 18 µV	
	(12 to 120) V	3.1 µV/V + 180 µV	
	(120 to 1100) V	2.9 µV/V + 1.7 mV	

Parameter/Equipment	Range	CMC ^{2, 10, 11, 12} (\pm)	Comments
DC Voltage – Generate and Measure (cont)			
Measure	(0 to 200) mV (0.2 to 2) V (2 to 20) V (20 to 200) V (200 to 1050) V	1.8 μ V/V + 0.31 μ V 2.3 μ V/V + 0.56 μ V 2.4 μ V/V + 3.3 μ V 4.4 μ V/V + 91 μ V 4.2 μ V/V + 0.66 mV	Fluke 8508A
	(2 to 10) kV (10 to 100) kV	0.03 % 570 μ V/V + 0.6R	Divider DMM

Parameter/Range ¹³	Frequency	CMC ^{2, 8} (\pm)	Comments
AC Voltage – Generate and Measure			
1 mV	(10 to 30) Hz (30 to 1000) Hz (1 to 120) kHz (120 to 500) kHz (500 to 1000) kHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.22 % 0.19 % 0.19 % 0.20 % 0.20 % 0.20 % 0.28 % 0.28 % 0.28 % 0.40 % 0.84 %	Fluke 5790A/03, 5720A
2 mV	(10 to 30) Hz (30 to 1000) Hz (1 to 120) kHz (120 to 500) kHz (500 to 1000) kHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.22 % 0.19 % 0.19 % 0.20 % 0.20 % 0.14 % 0.24 % 0.24 % 0.24 % 0.37 % 0.83 %	
10 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz	0.04 % 0.033 % 0.02 % 0.032 %	



Parameter/Range ¹³	Frequency	CMC ^{2,8} (±)	Comments
AC Voltage – Generate and Measure (cont)			
10 mV	(50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.045 % 0.097 % 0.14 % 0.09 % 0.09 % 0.13 % 0.13 % 0.13 % 0.21 % 0.44 %	Fluke 5790A, 5720A
20 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 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.03 % 0.019 % 0.014 % 0.025 % 0.034 % 0.080 % 0.11 % 0.093 % 0.093 % 0.13 % 0.13 % 0.13 % 0.21 % 0.44 %	
100 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	0.023 % 0.10 % 46 μV/V 70 μV/V 0.015 % 0.023 % 0.037 %	
70 mV	(0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.067 % 0.063 % 0.12 % 0.12 % 0.12 % 0.18 % 0.41 %	
200 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz	0.019 % 83 μV/V 33 μV/V 49 μV/V	



Parameter/Range ¹³	Frequency	CMC ^{2,8} (±)	Comments
AC Voltage – Generate and Measure (cont)			
200 mV	(50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.0072 % 0.016 % 0.027 % 0.061 % 0.063 % 0.13 % 0.13 % 0.13 % 0.19 % 0.42 %	Fluke 5790A, 5720A
1 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 (0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.017 % 61 µV/V 22 µV/V 37 µV/V 56 µV/V 0.013 % 0.021 % 0.066 % 0.068 % 0.13 % 0.13 % 0.13 % 0.19 % 0.42 %	
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 (0.5 to 1) MHz	0.017 % 60 µV/V 21 µV/V 37 µV/V 56 µV/V 0.013 % 0.021 % 0.070 %	
3 V	(0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.076 % 0.080 % 0.14 % 0.15 % 0.15 % 0.26 % 0.55 %	



Parameter/Range ¹³	Frequency	CMC ^{2, 8, 11, 12} (\pm)	Comments
AC Voltage – Generate and Measure (cont)			
10 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 (0.5 to 1) MHz	0.016 % 59 μ V/V 22 μ V/V 38 μ V/V 63 μ V/V 0.015 % 0.032 % 0.094 %	Fluke 5790A, 5720A
20 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 (0.5 to 1) MHz	0.016 % 59 μ V/V 22 μ V/V 38 μ V/V 63 μ V/V 0.015 % 0.032 % 0.094 %	
44 V	(300 to 500) kHz	0.032 %	
60 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	0.016 % 60 μ V/V 26 μ V/V 45 μ V/V 73 μ V/V 0.016 %	
100 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.017 % 62 μ V/V 25 μ V/V 54 μ V/V 77 μ V/V	
200 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.017 % 63 μ V/V 25 μ V/V 54 μ V/V 76 μ V/V	
300 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.016 % 77 μ V/V 33 μ V/V 0.011 % 0.039 %	



Parameter/Range ¹³	Frequency	CMC ^{2, 8, 12} (\pm)	Comments
AC Voltage – Generate and Measure (cont)			
600 V	50 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	33 μ V/V 0.011 % 0.039 %	Fluke 5790A, 5720A
1000 V	50 Hz to 1 kHz	33 μ V/V	
AC Voltage – Measure			
(10 to 100) kV (2 to 10) kV	60 Hz	0.25 % + 18 V 0.4 % + 3 V	Divider DMM

Parameter/Equipment	Range	CMC ^{2, 12} (\pm)	Comments
DC Current – Generate and Measure			
Fixed Points	100 μ A 1 mA 10 mA 20 mA 100 mA 200 mA 1 A 10 A 20A (10 to 100) A (100 to 300) A (300 to 500) A	1.9 nA 14 nA 0.14 μ A 0.28 μ A 1.4 μ A 2.8 μ A 20 μ A 550 μ A 1.1 mA 0.048 % + 2.3 mA 0.15 % + 1.5 mA 0.028 % + 21 mA	Guildline 9334A ⁴ Guildline 9330 ⁴ Fluke Y5020 ⁴ Guildline 9211A CS 9230 shunt
Generate	(0 to 220) μ A (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA 220 mA to 2.2 A	40 μ A/A + 5.5 nA 32 μ A/A + 6.2 nA 32 μ A/A + 39 nA 39 μ A/A + 0.62 μ A 70 μ A/A + 12 μ A	Fluke 5700A/EP
Measure	(10 to 100) μ A (1 to 10) mA (10 to 100) mA 100 mA to 1 A	53 μ A/A + 0.2 nA 52 μ A/A + 0.1 μ A 0.012 % + 1 μ A 0.014 % + 15 μ A	AT 3458A AT 3458A GDI-9230



Parameter/Range ¹³	Frequency	CMC ^{2, 8} (±)	Comments
AC Current – Measure			
1 mA	60 Hz	0.47 µA	DMM
10 mA	60 Hz	4.3 µA	
10 mA	10 Hz 20 Hz 40 Hz (1, 5, 10) kHz	0.50 µA 0.39 µA 1.7 µA 1.6 µA	5790A with A40 shunts
20 mA	10 Hz 20 Hz 40 Hz to 10 kHz	0.098 µA 0.90 µA 0.75 µA	
100 mA	10 Hz 20 Hz 40 Hz to 5 kHz 10 kHz	5.1 µA 4.8 µA 4.1 µA 4.4 µA	
200 mA	10 Hz 20 Hz 40 Hz to 5 kHz 10 kHz	11 µA 9.9 µA 7.6 µA 11 µA	
1 A	40 Hz to 5 kHz 10 kHz	48 µA 58 µA	
2 A	40 Hz to 5 kHz 10 kHz	89 µA 330 µA	
10 A	40 Hz to 5 kHz (1, 5, 10) kHz	1.0 mA 2.0 mA	
11 A	(45, 500, 1000) Hz	1.3 mA	Y5020A
20 A	(45, 500, 1000) Hz	2.2 mA	



Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
AC Current – Generate			
(0 to 220) µA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 0.022 µA 0.016 % + 0.015 µA 0.011 % + 0.013 µA 0.027 % + 0.034 µA 0.10 % + 0.081 µA	Fluke 5700A/EP
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 0.15 µA 0.016 % + 0.10 µA 0.011 % + 0.095 µA 0.019 % + 0.17 µA 0.10 % + 0.64 µA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 2.4 µA 0.016 % + 1.3 µA 0.011 % + 0.95 µA 0.019 % + 1.4 µA 0.10 % + 5.0 µA	
(22 to 220) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 24 µA 0.016 % + 12 µA 0.011 % + 93 µA 0.019 % + 13 µA 0.1 % + 47 µA	
(0.22 to 2.2) A	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.025 % + 140 µA 0.025 % + 140 µA 0.025 % + 140 µA 0.039 % + 160 µA 0.62 % + 890 µA	
(3 to 10.9999) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.42 mA/A + 0.84 mA 0.74 mA/A + 0.59 mA 23 mA/A + 22 µA	5520A
(11 to 20.5) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.91 mA/A + 1.1 mA 1.1 mA/A + 0.87 mA 25 mA/A + 42 µA	
(8 to 32) A	(16 to 450) Hz	21 mA/A + 1.2 mA	6100A
(32 to 80) A	(16 to 450) Hz	22 mA/A + 0.44 mA	
(100 to 1000) A*	(45 to 65) Hz	0.24 % + 0.02 A	*Coil ampere turns



Parameter/Range	Frequency	CMC ^{2, 8} (±)	Comments
Phase – Measure			
Sinewave Voltage to Voltage –			
20 mV to 350 V	(0.010 to 5) kHz (5 to 50) kHz (50 to 75) kHz (75 to 100) kHz	0.053 deg 0.056 deg 0.10 deg 0.15 deg	Clarke Hess 6000
Sinewave Voltage to Current –			
20 mV to 350 V	(0.010 to 5) kHz (5 to 50) kHz (50 to 75) kHz (75 to 100) kHz	0.056 deg 0.60 deg 0.11 deg 0.15 deg	Clarke Hess 6000, Current transformer
Phase – Generate			
Sinewave Voltage to Voltage	(10 to 65) Hz (65 to 500) Hz (0.5 to 1) kHz (1 to 5) kHz	0.67 deg 0.17 deg 0.33 deg 1.7 deg	Fluke 5520A
Sinewave Voltage to Current –			
(0.25 to 5) A	(16 to 69) Hz (69 to 180) Hz (180 to 450) Hz (450 to 850) Hz (0.850 to 3) kHz (3 to 6) kHz	13 mdeg 10 mdeg 17 mdeg 31 mdeg 0.15 deg 0.30 deg	Fluke 6100A
(5 to 21) A	(16 to 69) Hz (69 to 180) Hz (180 to 450) Hz (450 to 850) Hz (0.850 to 3) kHz (3 to 6) kHz	13 mdeg 11 mdeg 22 mdeg 41 mdeg 0.20 deg 0.40 deg	
(20 to 80) A	(16 to 69) Hz (69 to 180) Hz (180 to 450) Hz (450 to 850) Hz (0.850 to 3) kHz	13 mdeg 12 mdeg 0.27 deg 0.51 deg 0.20 deg	



Parameter/Equipment	Range	CMC ^{2, 12} (\pm)	Comments		
Resistance – Generate and Measure	Fixed Points ⁴	1 Ω	7.0 $\mu\Omega/\Omega$	Guildline 9334A	
		10 Ω	4.1 $\mu\Omega/\Omega$		
		100 Ω	5.4 $\mu\Omega/\Omega$		
		1 k Ω	5.6 $\mu\Omega/\Omega$		
		10 k Ω	4.3 $\mu\Omega/\Omega$		
	Measure Only ⁵	100 k Ω 1 M Ω 10 M Ω 100 M Ω	100 k Ω	5.7 $\mu\Omega/\Omega$	Guildline 9334A
			1 M Ω	7.1 $\mu\Omega/\Omega$	
			10 M Ω	21 $\mu\Omega/\Omega$	
		(100 to 1000) M Ω (1 to 10) G Ω (10 to 1000) G Ω	(100 to 1000) M Ω	0.73 %	IET-HRRS-B-9-1K-10KV
			(1 to 10) G Ω	0.98 %	
(10 to 1000) G Ω			1.3 %		
Measure Only ⁵		(0.01 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 (0.01 to 1.9999) Ω (0.1 to 19.999) Ω (1 to 199.99) Ω (10 to 19999) Ω (0.1 to 19.999) k Ω (1 to 199.99) k Ω (10 to 19999) k Ω (0.1 to 19.999) M Ω (1 to 199.99) M Ω (10 to 1999.9) M Ω	(0.01 to 1) Ω	14 $\mu\Omega/\Omega$ + 84 $\mu\Omega$	Agilent 3458A
			(1 to 10) Ω	14 $\mu\Omega/\Omega$ + 84 $\mu\Omega$	
			(10 to 100) Ω	12 $\mu\Omega/\Omega$ + 800 $\mu\Omega$	
			(100 to 1000) Ω	11 $\mu\Omega/\Omega$ + 2.5 m Ω	
	(1 to 10) k Ω		11 $\mu\Omega/\Omega$ + 25 m Ω		
	(10 to 100) k Ω		11 $\mu\Omega/\Omega$ + 250 m Ω		
	(100 to 1000) k Ω		11 $\mu\Omega/\Omega$ + 7 Ω		
	(1 to 10) M Ω		44 $\mu\Omega/\Omega$ + 150 Ω		
	(10 to 100) M Ω		0.036 % + 1.5 k Ω		
	(0.01 to 1.9999) Ω		4.3 $\mu\Omega/\Omega$ + 9.5 $\mu\Omega$	Fluke 8508A (8.5digits @ 23°C \pm 1°C)	
	(0.1 to 19.999) Ω		4.1 $\mu\Omega/\Omega$ + 31 $\mu\Omega$		
	(1 to 199.99) Ω		4.4 $\mu\Omega/\Omega$ + 230 $\mu\Omega$		
	(10 to 19999) Ω		4.6 $\mu\Omega/\Omega$ + 1.8 m Ω		
	(0.1 to 19.999) k Ω		4.8 $\mu\Omega/\Omega$ + 14 m Ω		
	(1 to 199.99) k Ω		4.3 $\mu\Omega/\Omega$ + 240 m Ω		
(10 to 19999) k Ω	3.7 $\mu\Omega/\Omega$ + 4.3 Ω				
(0.1 to 19.999) M Ω	3.3 $\mu\Omega/\Omega$ + 120 Ω				
(1 to 199.99) M Ω	6.5 $\mu\Omega/\Omega$ + 7.8 k Ω				
(10 to 1999.9) M Ω	0.016 % + 840 k Ω				



Parameter/Equipment	Range	CMC ^{2, 12} (±)	Comments
Oscilloscope –			
Generate Amplitude Volt	0 V (0.9 to 80) mV (0.08 to 2) V (2 to 20) V (20 to 200) V (200 to 230) V	25 μV 0.045 % + 25 μV 0.056 % + 16 μV 0.055 % + 0.2 mV 0.055 % + 1.6 μV 0.047 % + 32 mV	9500B
Measure Resistance	50 Ω 1 MΩ	1.4 mΩ 19 Ω	Agilent 3458A
AC Voltage Bandwidth – Generate and Measure	50 kHz to 550 MHz 50 kHz to 3.2 GHz 50 MHz to 33 GHz	4.5 % 5.5 % 3.5 %	9500B 9500B 9560
Pulse – Generate & Measure			
Transition Time	20 ps 20 ns	6 ps + 0.03*T rdg	9500B SD24/11801C T = transition time
Generate Only			
Transition Time	< 20 ps	5.3 ps	Tek 067-1338-00

II. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC ^{2, 12} (±)	Comments
Milliwatt Reference –			
Power Measure – 1 mW @ 50 Ω	50 MHz	0.21 %	432A w/478AH76, 3458A
Power Source – 1 mW @ 50 Ω	50 MHz	2.1 μW	E44xX series



Parameter/Equipment	Frequency	CMC ² (±)	Comments
Power Measure ⁹ –			
(-10 to 20) dBm	(9 to 100) kHz	0.10 dB	Agilent E9304A-H19 with E4419B
(-20 to -10) dBm	(9 to 100) kHz	0.26 dB	
(20 to 30) dBm	9 kHz to 20 GHz SWR < 1.2	0.16 dB	E9304A-H19 E9300A-H25
(10 to 20) dBm	(100 to 300) kHz SWR < 1.6:1	0.14 dB	Agilent 8482A-H84 with E4419B
	300 kHz to 1 MHz SWR < 1.2:1	0.13 dB	
	1 MHz to 2 GHz SWR < 1.1:1	0.13 dB	
	(2 to 4.2) GHz SWR < 1.3:1	0.14 dB	
(-20 to 10) dBm	(100 to 300) kHz SWR < 1.6:1	0.057 dB	Agilent 8487A-H84 with E4419B
	300 kHz to 1 MHz SWR < 1.2:1	0.052 dB	
	1 MHz to 2 GHz SWR < 1.1:1	0.054 dB	
	(2 to 4.2) GHz SWR < 1.3:1	0.055 dB	
(10 to 20) dBm	(50 to 100) MHz SWR < 1.15:1	0.15 dB	Agilent 8487A-H84 with E4419B
	(0.1 to 2) GHz SWR < 1.1:1	0.15 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.15 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.15 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.16 dB	



Parameter/Range	Frequency	CMC ² (±)	Comments
Power Measure ⁹ (cont) – (10 to 20) dBm	(26.5 to 40) GHz SWR < 1.4:1	0.16 dB	Agilent 8487D with E4419B
	(40 to 50) GHz SWR < 1.5:1	0.2 dB	
(-20 to 10) dBm	(50 to 100) MHz SWR < 1.15:1	0.076 dB	
	(0.1 to 2) GHz SWR < 1.1:1	0.077 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.081 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.082 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.09 dB	
(-60 to -20) dBm	(26.5 to 40) GHz SWR < 1.4:1	0.11 dB	
	(40 to 50) GHz SWR < 1.5:1	0.16 dB	
	(50 to 100) MHz SWR < 1.15:1	0.18 dB	
	(0.1 to 2) GHz SWR < 1.1:1	0.18 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.19 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.19 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.19 dB	
	(26.5 to 40) GHz SWR < 1.4:1	0.20 dB	
	(40 to 50) GHz SWR < 1.5:1	0.23 dB	



Parameter/Range	Frequency	CMC ² (±)	Comments
Power Measure ⁹ (cont) – (-20 to 10) dBm	(50 to 67) GHz	0.23 dB	KT-V8486A E4419B
(10 to 20) dBm SWR < 1.2:1	(0.01 to 2) GHz (2 to 26.5) GHz (26.5 to 50) GHz (50 to 67) GHz	0.21 dB 0.21 dB 0.21 dB 0.21 dB	KT-N8488A E4419B
(-20 to 10) dBm SWR < 1.2:1	(0.01 to 2) GHz (2 to 26.5) GHz (26.5 to 50) GHz (50 to 67) GHz	0.21 dB 0.21 dB 0.21 dB 0.21 dB	
(-30 to -20) dBm SWR < 1.2:1	(0.01 to 2) GHz (2 to 26.5) GHz (26.5 to 50) GHz (50 to 67) GHz	0.34 dB 0.34 dB 0.34 dB 0.34 dB	
Power Generate – (Includes DUT Mismatch 1.4 VSWR)			
(-10 to 20) dBm	(9 to 100) kHz	0.10 dB	Measure transfer 33250A, E4419B, E9304H19
(-20 to -10) dBm	(9 to 100) kHz	0.26 dB	
(10 to 20) dBm	(100 to 300) kHz	0.14 dB	33250A, E4419B, 8482A-H84
	300 kHz to 1 MHz	0.13 dB	E8257D, E4419B, 8482A-H84
	1 MHz to 2 GHz	0.21 dB	
	(2 to 4.2) GHz	0.35 dB	
(-20 to 10) dBm	(100 to 300) kHz	0.05 dB	
	300 kHz to 1 MHz	0.06 dB	
	1 MHz to 2 GHz	0.18 dB	
	(2 to 4.2) GHz	0.33 dB	



Parameter/Range	Frequency	CMC ² (±)	Comments
Power Generate – (Includes DUT Mismatch 1.4 VSWR) (cont) –			
(10 to 20) dBm	(50 to 100) MHz (0.1 to 2) GHz (2 to 12.4) GHz (12.4 to 18) GHz (18 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.22 dB 0.22 dB 0.35 dB 0.35 dB 0.44 dB 0.60 dB 0.61 dB	E8257D, E4419B, 8487A-H84
(-20 to 10) dBm	(50 to 100) MHz (0.1 to 2) GHz (2 to 12.4) GHz (12.4 to 18) GHz (18 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.18 dB 0.19 dB 0.33 dB 0.33 dB 0.43 dB 0.59 dB 0.60 dB	
(-60 to -20) dBm	(50 to 100) MHz (0.1 to 2) GHz (2 to 12.4) GHz (12.4 to 18) GHz (18 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.24 dB 0.24 dB 0.37 dB 0.37 dB 0.46 dB 0.61 dB 0.62 dB	E8257D, E4419B, 8487D-H84
(-20 to 10) dBm	(50 to 67) GHz	0.23 dB + <i>M</i>	<i>M</i> = Mismatch error E8257D, KT-E8361A V8486A



Parameter/Equipment	Frequency	CMC ² (±)	Comments
Power Generate – (-20 to 10) dBm Ratio Steps (-1 to -11) dB (-10 to -50) dB (-50 to -110) dB	50 MHz	0.054 dB + R 0.012 dB + 0.00031 dB/dB + R 0.011 dB + 0.00062 dB/dB + R 0.015 dB + 0.00098 dB/dB + R	Substitution/transfer using CMC measurement to set initial reference on UUT as limited by R Characterized Step Attenuators <i>Footnote: CMC shown at 50MHz Type N, other frequency and connectors will be greater magnitude; R is contribution of resolution of measuring equipment typically 0.6 times actual resolution</i>
Network Analyzer Dynamic Accuracy Test – dB Steps	5 dBm change (0 to 5) dB (-1 to -10) dB (-11 to -19) dB (-21 to -30) dB (-31 to -40) dB (-41 to -50) dB (-51 to -60) dB	0.002 lin (0.0012 to 0.0014) lin (0.0011 to 0.00078) lin (0.00069 to 0.000095) lin (0.000091 to 0.00071) lin (0.00075 to 0.0011) lin (0.0011 to 0.0015) lin (0.0015 to 0.0018) lin	KT 8482A 4419B Two CW signals offset and phase locked (in dB steps)



Parameter/Equipment	Frequency	CMC ² (±)	Comments
Network Analyzer Dynamic Accuracy Test – (cont) Network Analyzer Calibration Comparison 3.5mm Rho 0.999 Rho 0.001	 10 MHz (0.125 to 2) GHz (2.125 to 8) GHz (8.125 to 20) GHz (20.125 to 26.5) GHz 10 MHz (0.125 to 2) GHz (2.125 to 8) GHz (8.125 to 20) GHz (20.125 to 26.5) GHz	 0.0060 lin 0.0045 lin 0.0061 lin (0.012 + 6.7 × 10 ⁻⁶ *f) lin (0.015 - 5.6 × 10 ⁻⁶ *f) lin 0.00099 lin 0.00090 lin 0.0011 lin (0.0019 + 2.9 × 10 ⁻⁶ *f) lin (0.0025 + 4.5 × 10 ⁻⁶ *f) lin	 E8361A with data based SOL cal kit <i>f</i> = frequency Note: <i>f</i> in GHz
Phase Noise for Analyzers – (Offset Frequency) 10 Hz 100 Hz 1 kHz 10 kHz 30 kHz 100 kHz 1000 kHz 3000 kHz 6000 kHz 9990 kHz	1 GHz	± 2.6 dB @ 89 dbc/Hz ± 2.6 dB @ 115 dbc/Hz ± 1.3 dB @ 135 dbc/Hz ± 1.0 dB @ 147 dbc/Hz ± 1.0 dB @ 149 dbc/Hz ± 1.0 dB @ 151 dbc/Hz ± 1.0 dB @ 160 dbc/Hz ± 1.0 dB @ 160 dbc/Hz ± 1.0 dB @ 165 dbc/Hz ± 1.0 dB @ 167 dbc/Hz	Low noise oscillator



Parameter/Equipment	Frequency	CMC ² (±)	Comments
Phase Noise for Signal Sources – (Offset Frequency)			
≤ 100 kHz	≤ 100 MHz	± 2.3 dB	(LREF - LDUT) ≥ 10dB, f = frequency
≤ 100 kHz	0.1 GHz < f ≤ 26.5GHz	± 2.3 dB	
≤ 1 MHz	50 kHz < f ≤ 26.5 GHz	± 2.3 dB	
Cal Factor & Effective Efficiency ⁶ @ 50 Ω – Nominal 1 μW, 1 mW	(0.1 to 4200) MHz (4.2 to 12.4) GHz (12.4 to 15) GHz (15 to 26) GHz (26 to 40) GHz (40 to 50) GHz	1.3 % cal factor 1.8 % cal factor 2 % cal factor 3 % cal factor 3 % cal factor 5 % cal factor	RF power transfer & DC substitution

Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters – S ₁₁₍₂₂₎ Measure – @ 50 Ω 2.4 mm 45 MHz to 2 GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.019 to 0.028) lin (0.017 to 0.018) lin 0.017 lin	E8361A, 85056A
	(0.3 to 1) lin (0.01 to 0.3) lin	(3.5 to 1.6) deg (180 to 3.5) deg	
(2 to 20) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.023 to 0.034) lin (0.018 to 0.023) lin 0.018 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(5 to 2) deg (180 to 5) deg	



Parameter/Equipment	Range	CMC ² (\pm)	Comments
S-Parameters – S ₁₁₍₂₂₎ Measure – @ 50 Ω (cont) – 2.4 mm (20 to 40) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.037 to 0.056) lin (0.03 to 0.037) lin 0.03 lin	E8361A, 85056A
(40 to 50) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(9 to 3.2) deg (180 to 9) deg (0.044 to 0.07) lin (0.034 to 0.044) lin 0.034 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(11 to 4) deg (180 to 11) deg	
S ₁₂₍₂₁₎ Measure – 2.4 mm 45 MHz to 50 GHz	(0 to -60) dB	(0.08 to 0.6) dB (0.5 to 5.8) deg	
S ₁₁₍₂₂₎ Measure – @ 50 Ω 3.5 mm 45 MHz to 2 GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.01 to 0.022) lin (0.009 to 0.01) lin 0.009 lin	E8361A, 85052C
(2 to 20) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(2 to 1.3) deg (54 to 2) deg (0.012 to 0.015) lin (0.008 to 0.013) lin 0.008 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(2.6 to 0.82) deg (0.0045 to 2.6) deg	



Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters – S ₁₁₍₂₂₎ Measure – @ 50 Ω 3.5 mm (cont) – (20 to 26) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.013 to 0.017) lin (0.008 to 0.014) lin 0.009 lin	E8361A, 85052C
(26 to 33) GHz	(0.3 to 1) lin (0.01 to 0.3) lin	(2.8 to 1) deg (53 to 2.8) deg	
S ₁₂₍₂₁₎ Measure – 3.5 mm 45 MHz to 26 GHz	(0 to -60) dB	(0.05 to 0.27) dB; (0.3 to 1.9) deg	
S ₁₁₍₂₂₎ Measure – @ 50 Ω 7 mm, Type N ⁶ 1 MHz to 2 GHz	(0.01 to 1) lin (0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.003 to 0.01) lin (1 to 0.6) deg (6 to 1) deg (16 to 6) deg	E8361A, 85050C
(2 to 18) GHz	(0.01 to 1) lin (0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.002 to 0.007) lin (1.6 to 0.4) deg (5 to 1.6) deg (11 to 5) deg	
S ₁₂₍₂₁₎ Measure – 7 mm, Type N ⁶ 1 MHz to 18 GHz	(0 to -60) dB	(0.05 to 0.27) dB; (0.3 to 1.9) deg	



Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters (cont) – S ₁₁₍₂₂₎ Measure @ 50 Ω 1.85 mm (1 to 67) GHz	(0.1 to 1) lin S _(ij)	(0.016, 0.016) lin S _(ij) to (0.034, 0.034) lin S _(ij)	E8361A, 85050C E8361A 85058B
S ₁₂₍₂₁₎ Measure @ 50 Ω 1.85 mm (1 to 67) GHz	(0.001 to 0.1) lin S _(ij) 0 to -60 dB	(0.004, 0.004) lin S _(ij) to (0.015, 0.015) lin S _(ij) (0.09 to 0.37 dB (0.45 to 4.5) deg	

Parameter/Equipment	Range	CMC ² (±)	Comments
RF Power – Measure Relative Level Insertion Loss	100 kHz to 50 GHz 100 kHz to 50 GHz	0.013 dB + 0.004 dB/10 dB 0.026 dB + 0.004 dB/10 dB + <i>M</i>	E4448A/233 <i>M</i> = mismatch error
Amplitude Modulation – Measure 200 MHz to 3 GHz 0.010 kHz to 50 GHz	(30 to 90) % ratio; 1 kHz rate 5 % ratio; 50 Hz to 5 kHz rate 30 % ratio; 50 Hz to 5 kHz rate 99 % ratio; 50 Hz to 5 kHz rate 5 % ratio; (5 to 100) kHz rate	0.43 % AM 2.4 % AM 1.2 % AM 0.42 % AM 2.4 % AM	E4448A/233



Parameter/Equipment	Range	CMC ² (±)	Comments
Amplitude Modulation – Measure (cont) – 0.010 kHz to 50 GHz 0.010 kHz to 50 GHz	30 % ratio; (5 to 100) kHz rate 99 % ratio; (5 to 100) kHz rate	0.88 % AM 0.32 % AM	E4448A/233
Angular (Frequency) Modulation – Measure 200 MHz to 20 GHz	(100 to 240) kHz peak deviation modulation index > 1	0.8 kHz	AT-E4448A AT-33250A AT-34401A Rubidium oscillator
Angular (Phase) Modulation – Measure 200 MHz to 20 GHz	(1 to 10) radian modulation index	0.77 % radian + 0.0025 radian	AT-E4448A Rubidium oscillator
Angular and Amplitude Modulation (Digital Signal) – Measure 16 QAM 256 QAM 64 QAM, B PSK QPSK	(0.5 to 44) GHz	0.83 % EVM 0.83 % EVM 0.83 % EVM 0.83 % EVM 0.83 % EVM	AT 89441A



III. Thermodynamics

Parameter/Equipment	Range	CMC ^{2, 11} (±)	Comments
Temperature – Measure & Measuring Equipment	20 °C to 30 °C 20 °C to 30 °C	0.07 °C 0.07 °C + 0.6R	Hart 5628/1502 comparison
Relative Humidity – Measuring Equipment Measure	(10 to 90) % RH (10 to 90) % RH	0.59 % + 0.0022 % per % RH 3.5 % RH 2.3 % RH 3.5 % RH	Fluke 5121 (TS2500) Veriteq SP 2000

IV. Time & Frequency

Parameter/Range	Range	CMC ² (±)	Comments
Frequency – Measure	5, 10 MHz 1 Hz to 120 MHz 250 kHz to 50 GHz	2.5 pHz/Hz 10 pHz/Hz 10 nHz/Hz + 0.1 Hz	NIST FMAS, GPS receiver (1 Hz Steps) E4448A/233 ext lock
Frequency – Measuring Equipment	10 MHz distribution 1 Hz to 10 MHz 250 kHz to 67 GHz	10 pHz/Hz 2 μHz/Hz 10 nHz/Hz + 1.2 mHz	Rubidium, 58503B distribution amplifiers AT 33250 E8257D-550 ext lock
Time Interval – Measuring Equipment and Measure	1 ns to 10 s	0.92 ns + $TI \cdot 0.04 \mu\text{s/s}$	33250A/ 53132A/12 $TI =$ Time interval in seconds



¹ This laboratory does not normally offer commercial calibration services.

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 Agilent 3458A with Option 2, settings DCV, 100PLC, ACAL within prior 24 Hrs, 1 year cal cycle.

⁴ Transfer using Agilent 3458A

⁵ Agilent 3458A four wire ohms, ACAL within prior 24 Hrs, NPLC 100 < 100E6 Ohm > NPLC 10

⁶ Calibration Factor 100 kHz to 10 MHz is effective efficiency only.

⁷ Measure and Generate is limited to below 5 kHz; Measure only above 5 kHz.

⁸ The measurands stated are generated with the Fluke 5700, 5720 and/or 5790 series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMC is expressed as either a specific value that covers the full range either as a fraction or as a percentage of the reading plus a fixed floor specification.

⁹ The statement of CMC does not include the effects of mismatch error.

¹⁰ Add $(12 \mu\text{V}/\text{V}) * (V_{\text{input}} / 1000)^2$ for voltage > 100 V unless used as a characterized transfer.

¹¹ R = resolution contribution from unit under test.

¹² In the statement of CMC, the value is defined as the percentage of reading unless otherwise noted.

¹³ Points identified in the Parameter/Range reflect the reference standard range for which the CMC applies.



Accredited Laboratory

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Van Nuys, CA

for technical competence in the field of

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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 Z540.3-2006 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 8 January 2009*).



Presented this 8th day of June 2017.

A handwritten signature in black ink, written over a horizontal line.

President and CEO
For the Accreditation Council
Certificate Number 2562.01
Valid to June 30, 2019

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