

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

WORLD CAL, INC.
 2012 High Street
 Elk Horn, IA 51531
 Michael W. Howard Phone: 712 764 2197
 Email: mhoward@liberty-labs.com
 Web: <https://www.world-cal.com>

CALIBRATION

Valid until: September 30, 2009

Certificate Number: 1818.01

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	Best Uncertainty ^{2,4} (±)	Comments
DC Voltage – Measure	(0 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	9 μV/V + 0.3 μV 8 μV/V + 0.3 μV 8 μV/V + 0.5 μV 10 μV/V + 30 μV 22 μV/V + 0.1 mV	HP 3458A, Option 002
DC Current – Measure	(10 to 100) nA 100 nA to 1 μA (1 to 10) μA (10 to 100) μA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	37 μA/A + 0.04 nA 27 μA/A + 0.04 nA 27 μA/A + 0.1 nA 27 μA/A + 0.8 nA 27 μA/A + 5 nA 27 μA/A + 50 nA 42 μA/A + 0.5 μA 0.012 % + 10 μA	HP 3458A, Option 002

Parameter/Equipment	Range	Best Uncertainty ^{2,3,4} (\pm)	Comments
Resistance – Measure	(0 to 10) Ω (10 to 100) Ω (0.1 to 1) k Ω (1 to 10) k Ω (10 to 100) k Ω (0.1 to 1) M Ω (1 to 10) M Ω (10 to 100) M Ω 100 M Ω to 1 G Ω	20 $\mu\Omega/\Omega$ + 50 $\mu\Omega$ 17 $\mu\Omega/\Omega$ + 0.5 m Ω 15 $\mu\Omega/\Omega$ + 0.5 m Ω 15 $\mu\Omega/\Omega$ + 5 m Ω 15 $\mu\Omega/\Omega$ + 50 m Ω 20 $\mu\Omega/\Omega$ + 2 Ω 55 $\mu\Omega/\Omega$ + 100 Ω 0.051 % + 1 k Ω 0.5 % + 10 k Ω	HP 3458A, Option 002
DC Voltage – Generate	Up to 0.22 V (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	10 $\mu\text{V}/\text{V}$ + 0.6 μV 9 $\mu\text{V}/\text{V}$ + 1.0 μV 9 $\mu\text{V}/\text{V}$ + 3.5 μV 9 $\mu\text{V}/\text{V}$ + 6.5 μV 10 $\mu\text{V}/\text{V}$ + 80 μV 11 $\mu\text{V}/\text{V}$ + 500 μV	Fluke 5700A
DC Current – Generate	Up to 220 μA 220 μA 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	52 $\mu\text{A}/\text{A}$ + 8 nA 52 $\mu\text{A}/\text{A}$ + 8 nA 52 $\mu\text{A}/\text{A}$ + 80 nA 62 $\mu\text{A}/\text{A}$ + 0.8 μA 82 $\mu\text{A}/\text{A}$ + 25 μA 500 $\mu\text{A}/\text{A}$ + 500 μA 0.1 % + 750 μA	Fluke 5700A Fluke 5520A
Resistance – Generate Fixed Points	(1, 1.9) Ω 10 Ω 19 Ω (100, 190) Ω (1, 1.9) k Ω (10, 19) k Ω (100, 190) k Ω 1 M Ω 1.9 M Ω 10 M Ω 19 M Ω 100 M Ω	0.013 % 39 parts in 10^6 38 parts in 10^6 24 parts in 10^6 18 parts in 10^6 17 parts in 10^6 19 parts in 10^6 27 parts in 10^6 29 parts in 10^6 54 parts in 10^6 65 parts in 10^6 0.016 %	Fluke 5700A

Parameter/Equipment	Range	Best Uncertainty ^{2,3} (\pm)	Comments
Resistance – Generate	(0 to 11) Ω (11 to 33) Ω (33 to 110) Ω (110 to 330) Ω 330 Ω to 1.1 k Ω (1.1 to 3.3) k Ω (3.3 to 11) k Ω (11 to 33) k Ω (3 to 110) k Ω (110 to 330) k Ω 330 k Ω to 1.1 M Ω (1.1 to 3.3) M Ω (3.3 to 11) M Ω (11 to 33) M Ω (33 to 110) M Ω (110 to 330) M Ω 330 M Ω to 1.1 G Ω	42 $\mu\Omega/\Omega$ + 0.001 Ω 32 $\mu\Omega/\Omega$ + 0.0015 Ω 30 $\mu\Omega/\Omega$ + 0.0014 Ω 30 $\mu\Omega/\Omega$ + 0.002 Ω 30 $\mu\Omega/\Omega$ + 0.002 Ω 30 $\mu\Omega/\Omega$ + 0.02 Ω 30 $\mu\Omega/\Omega$ + 0.02 Ω 30 $\mu\Omega/\Omega$ + 0.2 Ω 30 $\mu\Omega/\Omega$ + 0.2 Ω 34 $\mu\Omega/\Omega$ + 2 Ω 34 $\mu\Omega/\Omega$ + 2 Ω 62 $\mu\Omega/\Omega$ + 30 Ω 0.014 % + 50 Ω 0.026 % + 2.5 k Ω 0.051 % + 3.0 k Ω 0.3 % + 100 k Ω 1.5 % + 500 k Ω	Fluke 5520A

Parameter/Range	Frequency	Best Uncertainty ² (\pm)	Comments
AC Voltage Flatness – Measure (0.5, 1 or 3) V	10 Hz to 10 MHz (10 to 30) MHz (30 to 60) MHz (60 to 100) MHz	0.13 % of reading 0.25 % of reading 0.50 % of reading 1.5 % of reading	HP 11049A, 11050A Precision Measurements EL 1300

Parameter/Range	Frequency	Best Uncertainty ^{2,3} (\pm)	Comments
AC Voltage – Generate ⁶			
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	0.056 % + 4.5 μ V 0.022 % + 4.5 μ V 0.011 % + 4.5 μ V 0.038 % + 4.5 μ V 0.086 % + 7 μ V 0.11 % + 13 μ V 0.17 % + 25 μ V 0.34 % + 25 μ V	Fluke 5700A
(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	0.056 % + 5 μ V 0.022 % + 5 μ V 0.011 % + 5 μ V 0.038 % + 5 μ V 0.086 % + 7 μ V 0.11 % + 12 μ V 0.17 % + 25 μ V 0.34 % + 25 μ 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	0.056 % + 13 μ V 0.022 % + 8 μ V 0.011 % + 8 μ V 0.033 % + 8 μ V 0.086 % + 25 μ V 0.11 % + 25 μ V 0.17 % + 35 μ V 0.34 % + 80 μ 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	0.051 % + 80 μ V 0.017 % + 25 μ V 0.008 % + 6 μ V 0.013 % + 16 μ V 0.026 % + 70 μ V 0.044 % + 130 μ V 0.11 % + 0.35 mV 0.23 % + 0.85 mV	
(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	0.051 % + 800 μ V 0.017 % + 250 μ V 0.008 % + 60 μ V 0.013 % + 160 μ V 0.026 % + 350 μ V 0.051 % + 1.5 mV 0.13 % + 4.3 mV 0.27 % + 8.5 mV	

Parameter/Range	Frequency	Best Uncertainty ^{2,3} (±)	Comments
AC Current – Generate ⁶			
Up to 220 µA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.03 % + 20 nA 0.02 % + 12 nA 0.014 % + 10 nA 0.035 % + 15 nA 0.13 % + 80 nA	Fluke 5700A
220 µA 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	0.03 % + 50 nA 0.02 % + 40 nA 0.014 % + 40 nA 0.024 % + 130 nA 1.3 % + 0.8 µA	
(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	0.03 % + 0.5 µA 0.02 % + 0.4 µA 0.014 % + 0.4 µA 0.024 % + 0.7 µA 1.3 % + 6 µA	
(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	0.03 % + 5 µA 0.02 % + 4 µA 0.014 % + 3 µA 0.024 % + 4 µA 1.3 % + 12 µA	
220 mA to 2.2 A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.032 % + 40 µA 0.05 % + 100 µA 0.8 % + 200 µA	
(2.2 to 3) A	(10 to 100) Hz (100 to 440) Hz	0.12 % + 200 µA 0.3 % + 1 mA	
(3 to 20) A	(10 to 100) Hz 100 Hz to 1 kHz	0.12 % + 2 mA 1 % + 5 mA	

Parameter/Range	Frequency	Best Uncertainty ^{2,4} (±)	Comments
AC Voltage ⁶ – Measure			
(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	0.03 % + 3 μV 0.02 % + 1.1 μV 0.03 % + 1.1 μV 0.1 % + 1.1 μV 0.5 % + 1.1 μV 4 % + 2 μV	HP 3458A, Option 002
(10 to 100) mV	(1 Hz 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	72 μV/V + 4 μV 72 μV/V + 2 μV 0.015 % + 2 μV 0.03 % + 2 μV 0.08 % + 2 μV 0.3 % + 1 μV 1.0 % + 1 μV 1.5 % + 1 μV	
100 mV to 1 V	(1 Hz 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	72 μV/V + 40 μV 72 μV/V + 20 μV 0.015 % + 20 μV 0.03 % + 20 μV 0.080 % + 20 μV 0.3 % + 10 μV 1.0 % + 10 μV 1.5 % + 10 μV	
(1 to 10) V	(1 Hz 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	72 μV/V + 400 μV 72 μV/V + 200 μV 0.015 % + 200 μV 0.03 % + 200 μV 0.08 % + 200 μV 0.3 % + 100 μV 1.0 % + 100 μV 1.5 % + 100 μV	
(10 to 100) V	(1 Hz 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	0.02 % + 4 mV 0.02 % + 2 mV 0.02 % + 2 mV 0.035 % + 2 mV 0.12 % + 2 mV 0.4 % + 1 mV 1.5 % + 1 mV	
(100 to 1000) V	(1 Hz to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.04 % + 40 mV 0.04 % + 20 mV 0.06 % + 20 mV 1.2 % + 20 mV 3 % + 20 mV	

Parameter/Range	Frequency	Best Uncertainty ^{2,4} (±)	Comments
AC Current ⁶ – Measure			
(5 to 100) μA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.4 % + 30 nA 0.15 % + 30 nA 0.06 % + 30 nA 0.06 % + 30 nA	HP 3458A, Option 002
100 μA to 1 mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.4 % + 200 nA 0.15 % + 200 nA 0.06 % + 200 nA 0.03 % + 200 nA 0.06 % + 200 nA 0.4 % + 400 nA 0.55 % + 1.5 μA	
(1 to 10) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.4 % + 0.2 μA 0.15 % + 0.2 μA 0.06 % + 0.2 μA 0.03 % + 0.2 μA 0.06 % + 0.2 μA 0.4 % + 0.4 μA 0.55 % + 15 μA	
(10 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.4 % + 2 μA 0.15 % + 2 μA 0.06 % + 2 μA 0.03 % + 2 μA 0.06 % + 2 μA 0.4 % + 4 μA 0.55 % + 150 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 (20 to 50) kHz	0.4 % + 20 μA 0.16 % + 20 μA 0.08 % + 20 μA 0.1 % + 20 μA 0.3 % + 20 μA 1 % + 40 μA	

Parameter/Equipment	Frequency	Best Uncertainty ^{2,3} (±)	Comments
<p>Capacitance – Measure</p> <p>20 pF to 100 μF (0.1 to 200) mF</p> <p>1 pF to 10 μF (0.01 to 20) mF</p> <p>0.1 pF to 1 μF (1 to 500) μ</p>	<p>100 Hz; 120 Hz</p> <p>1 kHz</p> <p>10 kHz</p>	<p>0.1 % of reading + 2 pF (0.1 + Reading/20 mF) %</p> <p>0.1 % of reading + 1 pF (0.1 + Reading/2 mF) %</p> <p>0.1 % of reading + 0.1 pF (0.1 + Reading/50 μF) %</p>	<p>GenRad 1659 RLC Digibridge</p>
<p>Capacitance – Generate</p> <p>(0.2 to 0.4) nF</p> <p>(0.4 to 1.1) nF</p> <p>(1.1 to 3.3) nF</p> <p>(3.3 to 11) nF</p> <p>(11 to 33) nF</p> <p>(33 to 110) nF</p> <p>(110 to 330) nF</p> <p>330 nF to 1.1 μF</p> <p>(1.1 to 3.3) μF</p> <p>(3.3 to 11) μF</p> <p>(11 to 33) μF</p> <p>(33 to 110) μF</p> <p>(110 to 330) μF</p> <p>330 μF to 1.1 mF</p> <p>(1.1 to 3.3) mF</p> <p>(3.3 to 11) mF</p> <p>(11 to 33) mF</p> <p>(33 to 110) mF</p>	<p>10 Hz to 10 kHz</p> <p>10 Hz to 10 kHz</p> <p>10 Hz to 3 kHz</p> <p>10 Hz to 1 kHz</p> <p>10 Hz to 1 kHz</p> <p>10 Hz to 1 kHz</p> <p>10 Hz to 1 kHz</p> <p>10 Hz to 1 kHz</p> <p>(10 to 600) Hz</p> <p>(10 to 300) Hz</p> <p>(10 to 150) Hz</p> <p>(10 to 120) Hz</p> <p>(10 to 80) Hz</p> <p>(0 to 50) Hz</p> <p>(0 to 20) Hz</p> <p>(0 to 6) Hz</p> <p>(0 to 2) Hz</p> <p>(0 to 0.6) Hz</p> <p>(0 to 0.2) Hz</p>	<p>0.5 % + 0.01 nF</p> <p>0.5 % + 0.01 nF</p> <p>0.5 % + 0.01 nF</p> <p>0.25 % + 0.01 nF</p> <p>0.25 % + 0.1 nF</p> <p>0.25 % + 0.1 nF</p> <p>0.25 % + 0.3 nF</p> <p>0.25 % + 1 nF</p> <p>0.25 % + 3 nF</p> <p>0.25 % + 10 nF</p> <p>0.40 % + 30 nF</p> <p>0.45 % + 100 nF</p> <p>0.45 % + 300 nF</p> <p>0.45 % + 1 μF</p> <p>0.45 % + 3 μF</p> <p>0.45 % + 10 μF</p> <p>0.75 % + 30 μF</p> <p>1.1 % + 100 μF</p>	<p>Fluke 5520A</p>

Parameter/Equipment	Frequency	Best Uncertainty ² (±)	Comments
Oscilloscope Calibration – source			
Voltage			
DC – 1 MΩ	1 mV to 200 V	0.03 % + 25 μV	Fluke 9500B with 9530, 9550 and 9560 heads.
DC – 50 Ω	1 mV to 5 V	0.03 % + 25 μV	
Square – Wave – 50 Ω	(0.04 to 1) mV	1.5 % + 10 μV	All best uncertainties shall be read as “percent of reading”.
	1 mV to 5 V	0.12 % + 10 μV	
Rise – Time	150 ps @ 5 mV to 3V	27 ps	
	70 ps @ 25 mV to 2 V	20 ps	
	25 ps @ (425 to 575) mV	8 ps	
Timing	Narrow Triangle	3.4 μs/s	
	900.91 ns to 55 s		
Leveled Sine – wave Amplitude	5 mV to 5 V	1.5 %	
Single	0.1 Hz to 300 MHz	2 %	
	(300 to 550) MHz	2.5 %	
	550 MHz to 3.0 GHz	3.5 %	
	(3.0 to 6.0) GHz	5 %	
Dual	With respect to Reference Frequency		
	0.1 Hz to 1 GHz	10 %	
	(1 to 3.2) GHz	25 %	
Pulse Width	(1 to 100) ns	5 % + 200 ps	

II. Electrical – RF/Microwave

Parameter/Range	Frequency	Best Uncertainty ^{2, 5, 7, 8} (\pm)	Comments
RF Power Sensor Transfer – 10 μ W to 25 mW	10 MHz to 10 GHz (10 to 18) GHz 100 kHz to 4,2 GHz	$M + 1.4 \%$ $M + 1.4 \%$ $M + 1.4 \%$	Tegam 1803A w/1805B Tegam F1119 w/1805B
RF Absolute Power – Measure ⁶ (+20 to -60) dBm (+20 to -30) dBm (-30 to -70) dBm	9 kHz to 6 GHz (1 to 6) GHz 10 MHz to 1 GHz (1 to 2) GHz (2 to 4) GHz (4 to 6) GHz (6 to 8) GHz (8 to 10) GHz (10 to 12) GHz (12 to 14) GHz (14 to 16) GHz (16 to 18) GHz 18 GHz 10 MHz to 1 GHz (1 to 2) GHz (2 to 4) GHz (4 to 6) GHz (6 to 8) GHz (8 to 10) GHz (10 to 12) GHz (12 to 14) GHz (14 to 16) GHz (16 to 18) GHz 18 GHz	1.1 % + M 1.7 % + M 1.4 % + M 1.6 % + M 1.4 % + M 1.5 % + M 1.5 % + M 1.7 % + M 1.9 % + M 2.1 % + M 2.6 % + M 2.9 % + M 3.2 % + M 1.4 % + M 1.9 % + M 1.8 % + M 1.8 % + M 1.8 % + M 2.0 % + M 2.2 % + M 2.8 % + M 3.2 % + M 3.4 % + M 3.7 % + M	All best uncertainties shall be read as “percent of reading” Agilent E9304A Agilent 8481A Agilent 8481D

Parameter/Range	Frequency	Best Uncertainty ^{2, 5, 6, 7, 8} (\pm)	Comments
RF Absolute Power – Measure (cont)			
(+20 to -30) dBm	50 MHz to 1 GHz	1.3 % + <i>M</i>	HP 8487D All best uncertainties shall be read as “percent of reading”
	(1 to 2) GHz	1.6 % + <i>M</i>	
	(2 to 4) GHz	1.6 % + <i>M</i>	
	(4 to 6) GHz	1.6 % + <i>M</i>	
	(6 to 8) GHz	1.7 % + <i>M</i>	
	(8 to 10) GHz	1.8 % + <i>M</i>	
	(10 to 12) GHz	1.8 % + <i>M</i>	
	(12 to 14) GHz	1.9 % + <i>M</i>	
	(14 to 16) GHz	2.1 % + <i>M</i>	
	(16 to 18) GHz	2.2 % + <i>M</i>	
	(18 to 22) GHz	2.3 % + <i>M</i>	
	(22 to 26.5) GHz	1.8 % + <i>M</i>	
	(26.5 to 28) GHz	2.1 % + <i>M</i>	
	(28 to 30) GHz	2.3 % + <i>M</i>	
	(30 to 33) GHz	2.1 % + <i>M</i>	
	(33 to 34.5) GHz	2.3 % + <i>M</i>	
	(34.5 to 37) GHz	2.1 % + <i>M</i>	
	(37 to 40) GHz	2.3 % + <i>M</i>	
	(40 to 42) GHz	2.6 % + <i>M</i>	
	(42 to 44) GHz	3.2 % + <i>M</i>	
(44 to 46) GHz	3.6 % + <i>M</i>		
(46 to 48) GHz	4.1 % + <i>M</i>		
(48 to 50) GHz	4.5 % + <i>M</i>		
(-30 to -70) dBm	50 MHz to 1 GHz	1.7 % + <i>M</i>	
	(1 to 2) GHz	2.0 % + <i>M</i>	
	(2 to 4) GHz	2.0 % + <i>M</i>	
	(4 to 6) GHz	2.0 % + <i>M</i>	
	(6 to 8) GHz	2.3 % + <i>M</i>	
	(8 to 10) GHz	2.3 % + <i>M</i>	
	(10 to 12) GHz	2.3 % + <i>M</i>	
	(12 to 14) GHz	2.8 % + <i>M</i>	
	(14 to 16) GHz	2.8 % + <i>M</i>	
	(16 to 18) GHz	2.8 % + <i>M</i>	
	(18 to 22) GHz	2.8 % + <i>M</i>	
	(22 to 26.5) GHz	2.8 % + <i>M</i>	
	(26.5 to 28) GHz	3.0 % + <i>M</i>	

Parameter/Range	Frequency	Best Uncertainty ^{2, 5, 6, 7, 8} (\pm)	Comments
RF Absolute Power – Measure (cont) (-30 to -70) dBm (cont)	(28 to 30) GHz (30 to 33) GHz (33 to 34.5) GHz (34.5 to 37) GHz (37 to 40) GHz (40 to 42) GHz (42 to 44) GHz (44 to 46) GHz (46 to 48) GHz (48 to 50) GHz 50 GHz	3.0 % + <i>M</i> 3.0 % + <i>M</i> 3.0 % + <i>M</i> 3.0 % + <i>M</i> 3.0 % + <i>M</i> 3.0 % + <i>M</i> 2.9 % + <i>M</i> 2.9 % + <i>M</i> 3.1 % + <i>M</i> 4.5 % + <i>M</i> 4.5 % + <i>M</i>	HP 8487D All best uncertainties shall be read as “percent of reading”
RF Power – Generate (+23 to 0) dBm (+24 to -130) dBm (+14 to -130) dBm (+10 to -110) dBm (+5 to -110) dBm (+2.5 to -110) dBm	1 μ Hz to 80 MHz 10 Hz to 12.5 MHz 12.5 MHz to 4 GHz 10 MHz to 26.5 GHz (26.5 to 40) GHz (40 to 50) GHz	0.1 dB + <i>M</i> 0.05 dB + <i>M</i> 0.06 dB + <i>M</i> 0.6 dB + <i>M</i> 0.8 dB + <i>M</i> 1.5 dB + <i>M</i>	Agilent 33250A Fluke 9640A Agilent 83650B
Tuned RF Power Relative – Measure (0 to -3) dBm (-3 to -10) dBm (-10 to -40) dBm (-40 to -50) dBm (-50 to -80) dBm (-80 to -90) dBm (-90 to -110) dBm	2.5 MHz to 26.5 GHz	0.02 dB 0.02 dB 0.08 dB 0.14 dB 0.20 dB 0.26 dB 0.30 dB	HP 8902A HP 11722A HP 11792A HP 11793A

Parameter/Range	Frequency	Best Uncertainty ^{2, 6, 7, 8} (\pm)	Comments
Amplitude Modulation – Generate Frequency 250 kHz to 40 GHz Rates (0 to 100) kHz	Modulation Depths: 0 % to 100 %	6 % of setting + 1 % of reading 6 % of setting + 1 % of reading	Agilent E8257C
Sine Wave Distortion– Measure 400 Hz and 1000 Hz modulation	Modulation Depths: 0 % to 90 %	0.84 % of reading	HP8903B
Amplitude Modulation – Measure Rate: 50 Hz to 10 kHz Depth: 5 % to 99 % Rate: 20 Hz to 10 kHz Depth: 0 % to 99 % Rate: 50 Hz to 50 kHz Depth: 5 % to 99 % Rate: 20 Hz to 100 kHz Depth: 0 % to 99 % Rate: 50 Hz to 50 kHz Depth: 5 % to 99 % Rate: 30 Hz to 1 MHz	150 kHz to 10 MHz 150 kHz to 10 MHz (10 to 1300) MHz (10 to 1300) MHz (1.3 to 26.5) GHz (26.5 to 50) GHz	2.5 % of reading 3.6 % of reading 1.6 % of reading 3.6 % of reading 2.1 % of reading 1.4 % of reading	HP 8902A HP 8902A with HP 11793A, HP 11792A, Agilent 8565E, Option 001

Parameter/Range	Frequency	Best Uncertainty ^{2, 6, 7, 8} (±)	Comments
Phase Modulation – Measure Rate: 200 Hz to 10 kHz 200 Hz to 20 kHz	(10 to 1300) MHz (10 MHz to 26.5 GHz)	3.6 % of reading 4.7 % of reading	HP 8902A with HP 11973A, HP 11972A
Pulse Repetition Frequency – Measure	3 Hz to 26.5 GHz 30 Hz to 50 GHz	150 Hz 150 Hz	Agilent E4440A Agilent 8565E
Frequency Modulation – Generate 250 kHz to 40 GHz 10 MHz to 50 GHz	For 400 and 1000 Hz internal modulation 1 MHz rate, 1 MHz deviation	3.5 % of reading + 20 Hz 10 % of reading	Agilent E8257C HP 83650B
Frequency Modulation – Measure Rate: 20 Hz to 10 kHz Dev.: ≤ 40 kHz peak Rate: 50 Hz to 100 kHz Dev.: ≤ 400 kHz peak Rate: (20 to 200) kHz Dev.: ≤ 400 kHz peak 30 Hz to 1 MHz	250 kHz to 10 MHz (10 to 1300) MHz (0.10 to 26.5) GHz (26.5 to 50) GHz	2.4 % of reading 1.3 % of reading 5.8 % of reading 150 Hz	HP 8902A With HP 11793A, HP11792A Agilent 8565E, Option 001
VSWR – Measure	5 Hz to 500 MHz 100 kHz to 50 GHz	0.93% of reading 1.1 % of Indicated Value	HP 8751A HP 8757D with HP 8721A HP 85027C HP 85027E HP 85027D

III. Time and Frequency

Parameter/Equipment	Frequency	Best Uncertainty ^{2,6,7,8} (\pm)	Comments
Frequency – Generate	1 μ Hz to 80 MHz 10 Hz to 4 GHz 10 MHz to 50 GHz	5 parts in 10^{11}	With GPS conditioning Agilent 33250 Fluke 9640 Agilent 83650B
Frequency – Measure	0 Hz to 50 GHz	5 parts in 10^{11}	With GPS conditioning HP 5335A Agilent 53152A Agilent 53151A Agilent 8565E
Time Interval – Measure	500 ps to 500 ms	0.3 sample interval + 15 ppm of reading	Tektronix TDS 7104 Oscilloscope
10 MHz Source (Rubidium)	10 MHz	1.2 Hz	Rubidium frequency standard referenced to GPS
Measurement of 10 MHz	10 MHz	1.2 Hz	HP 53132A
Frequency Stability	10 MHz	1 part in 10^{11}	Rubidium frequency standard referenced to GPS

IV. Device Specific Parameters

EMI receivers (CISPR 16-1), EFT/Burst Generators (EN 61000-4-4), ESD Guns and Targets (IEC 61000-4-2, ANSI C63.16, SAE J1113-13), Surge Generators (EN 61000-4-5), Generators for Voltage Dips, Short Interrupts and Voltage Variations (EN 61000-4-11), Ring Wave Generators (ANSI C62.41), Network Analyzers, Impulse Generators (CISPR 16-1), Oscilloscopes, Power Meters, Power Sensors, Signal Generators, Spectrum Analyzers, 50 Ω Terminators

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (\pm)	Comments
Single Sideband Phase Noise (SSB)	(10 to 1300) MHz	1 dB	HP 8902A w/ Option 036/037
Frequency Accuracy –	(1.5, 4, 9, 16, 21) GHz (21, 26.5, 40) GHz	3 kHz	HP 8902A
	50 GHz	5 kHz	HP 8565E
Span Accuracy – (at 1500 MHz)	5 MHz span and 30 kHz RBW	0.18 GHz	HP 3335A HP 86350A
Residual FM – (at 500 MHz)	5 kHz span and 1 kHz RBW	0.24 kHz	HP 3335A HP 86350A
Cal Output Port Check	300 MHz -20 dBm	1.2 Hz 0.44 dB	Agilent 53132A HP E9304A & HP 8482A (based on HP 8593E)
Average Noise	9 kHz to 50 GHz	0.31 dB	50 Ω load
Residuals	20 Hz to 50 GHz	0.31 dB	50 Ω load
Reference Level –			HP 11792 with:
Log Scale	50 MHz	0.14 dB	HP 3335A
Linear Scale	50 MHz	0.32 dB	HP 83650B (based on HP 8593E)
Attenuator Check	50 MHz	0.15 dB	HP 8593E

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Log Fidelity	50 MHz 50 MHz	1.1 dB 1.1 dB	HP 3335A HP 83650B (based on HP 8593E)
Linear Fidelity	50 MHz 50 MHz	1.0 dB 1.0 dB	HP 3335A HP 83650B (based on HP 8593E)
BW Accuracy	20 Hz to 50 GHz	550 Hz	HP 83650B (based on HP 8565E)
BW Switching	20 Hz to 50 GHz	1.1 dB	HP 83650B (based on HP 8565E)
2 nd Harmonic Distortion	30 Hz to 50 GHz 200 Hz to 80 MHz (10 to 50) GHz	1.4 dB 1.4 dB 1.4 dB	Agilent 8565E HP 3335A HP 83650B (based on HP 8565E)
3 rd Order Intermodulation	200 Hz to 80 MHz (10 to 50) GHz	0.5 dB 0.5 dB	HP 3335A HP 83650B (based on HP8565E)
Noise Sidebands	200 Hz to 80 MHz (10 to 50) GHz	0.7 dB 0.8 dB	HP 3335A HP 83650B (based on HP 8565E)
System Sidebands	200 Hz to 80 MHz (10 to 50) GHz	0.48 dB 0.52 dB	HP 3335A HP 83650B (based on HP 8565E)
Sweep Time	10 MHz to 50 GHz	6.1 % of reading	HP 83650B (based on HP 8565E)
Harmonic Measurements	30 Hz to 50 GHz 200 Hz to 80 MHz (10 to 50) GHz	0.5 dB 0.6 dB 0.8 dB	Agilent 8565E HP 3335A HP 83650B (based on HP 8565E)
Tracking Generator Non-Harmonics	9 kHz to 2.9 GHz	0.59 dB	Agilent 8565E

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Tracking Generator Feedthrough	9 kHz to 2.9 GHz	0.63 dB	50 Ω load, 909F
Tracking Absolute Amplitude Output	9 kHz to 2.9 GHz	0.61 dB	Agilent E9304A HP E4418B
Frequency Response	9 kHz to 40 GHz 50 MHz to 50 GHz	1.1 dB 1.3 dB	HP 8902A HP 8487A (based on HP 8565E)
Gain Compression	200 Hz to 80 MHz (10 to 50) GHz	1.5 dB 1.5 dB	HP 3335A HP 83650B (based on HP 8565E)
General RF Insertion Loss/Gain	9 kHz to 6 GHz 10 MHz to 18 GHz (18 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.42 dB 0.42 dB 0.6 dB 0.8 dB 1.1 dB	Agilent E9304A, HP E4418B Agilent E4412A, HP E4418B HP E4418B, HP 8487A
Impedance – Measure, 50 Ω Terminations	30 kHz to 6 GHz 10 MHz to 18 GHz (18 to 50) GHz	0.93 % of reading 0.95 % of reading 1 % of reading	HP 8753D, HP 85032B cal kit, S11 – 1 port calibration Agilent E8364B, N4690A cal kit, S11 – 1 port calibration Agilent E8364B, N4693A cal kit, S11 – 1 port calibration
Type N Calibration Kits – Pin Depth	± 0.02 in 10 kHz to 18GHz	560 μin	HP 85054B
Impedance – Measure ⁵ 50 Ω devices	30 kHz to 6 GHz	<i>M</i> + 2.9 % of reading	HP 8753D, HP 85032B cal kit, S11 – 1 port calibration

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Attenuation Measurements – (0 to 100) dB (0 to 80) dB	100 kHz to 18 GHz (18 to 40) GHz	0.24 dB 0.31 dB	HP 8902A, HP 11792A, and HP11722A Agilent E8364B, N4693A cal kit
SWR of Power Sensor	100 kHz to 50 GHz	0.25 dB	HP 8757D
Source Errors for CISPR Bands A and B for Impulse Spectral Amplitude	Band A (10 to 150 kHz) Band B (0.15 to 30 MHz)	0.82 dB 0.82 dB	IGUU 2916
Source Errors for CISPR Bands C and D for Impulse Spectral Amplitude	Band C and D (30 to 1000 MHz)	1.1 dB	IGUU 2916
Pulse Generator – Level Change	Band A through D	0.50 dB	E4418B and E9304A
Source Errors for Sinewave Output for CISPR Checks (@ 60 dB/μV)	100 kHz (1, 10, and 100) MHz	0.26 dB 0.26 dB	IGUU 2916
Peak & Average Detector Response	Band A through D	1.3 dB	IGUU 2916
Source Errors for Frequency Response	Band A Band B Band C Band D	0.53 dB 0.62 dB 0.57 dB 0.69 dB	HP 8565E
Impulse BW Measurement	Above 1 GHz	3.7 kHz	HP 83630B, Agilent 33250A

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Range to Range Calibration Uncertainty	(3, 10, 30, 100, 300) μW (1, 3, 10, 30, 100) mW	0.49 % of reading 0.49 % of reading	HP 11683A
RF Power Sensor Transfer ⁵ 10 μW to 25 mW	10 MHz to 10 GHz (10 to 18) GHz 100 kHz to 4.2 GHz	<i>M</i> + 1.4 % of reading <i>M</i> + 1.4 % of reading <i>M</i> + 1.4 % of reading	Tegam 1803A w/1805B Tegam F1119 w/1805B
Power Meter Accuracy Check	(0.1 to 10) mW (0.01 to 0.03) mW	1.4 % of reading 1.5 % of reading	HP 432A
Time Base Accuracy for Oscilloscope Measurement	Up to 10 μs	0.34 % of reading	Tegam CG5011
Bandwidth Measurement	1 MHz to 2.5 GHz	0.10 % of reading	Tegam CG5050
Square Wave Measuring Equipment	50 kHz to 2.5 GHz	0.3 % of reading + 1 μV	Tegam CG5050
Level Sine Flatness Measurement	50 kHz to 250 MHz 250 MHz to 2.5 GHz	1.7 % of reading 4.6 % of reading	Tegam CG5050
Time Marker Output Measuring Equipment	50 kHz to 2.5 GHz	0.004 % of reading	Tegam CG5011
Non-Sweep Linearity Test (NA)	(-90 to +20) dBm	0.24 dB	HP438A, E4418B, HP8481D
Frequency Accuracy Test (NA)	10 Hz to 26.5 GHz	12 Hz	HP53151A rubidium frequency standard

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Source Level Accuracy/Flatness Test (NA)	10 Hz to 50 GHz	0.14 dB	HP438A, E4418B, HP8482A, HP8487A, HP34401A
Power Sweep Linearity Test (NA)	(0 to 20) dB	0.23 dB	HP438A, E4418B, HP8481D
Harmonics/Non-Harmonic Test (NA)	(-30 to -120) dBc	0.46 dB	HP8563E
Receiver Noise Level Test (NA)	(-30 to -120) dBm	0.31 dB	HP909C, opt 012
Input Crosstalk Test (NA)	(-30 to -120) dB	0.23 dB	HP909C, opt 012
Input Impedance Test (NA)	(0 to 110) dB	0.37 dB	HP8753D/E
Absolute Amplitude Accuracy Test (NA)	(0 to -60) dBm	0.13 dB	HP438A, E4418B, HP8482A
Magnitude Ratio/Phase Dynamic Accuracy Test (NA) –			HP11667A, P8496A/G N4693A
Magnitude Ratio Dynamic	(0 to -100) dB	0.37 dB	
Phase Dynamic	(0 to -100) dB	0.06°	
Receiver Trace Noise (NA)	300 kHz to 50 GHz	0.33 dB	HP11850C

Parameter/Equipment	Range/Frequency	Best Uncertainty ² (±)	Comments
Magnitude Ratio/Phase Frequency Response Test (NA) – Magnitude Ratio Accuracy Phase Frequency Response	100 kHz to 50 GHz 100 kHz to 50 GHz	0.37 dB 0.6°	HP1167A, P8496A/G N4693A
Receiver Input Impedance (NA)	(0 to 120) dB Return Loss	0.37 dB	HP85032B, N4693A
Receiver Magnitude Accuracy (NA)	300 kHz to 50 GHz	0.1 dB	HP438A, E4418B, HP8482A, HP8487A
Receiver Phase Compression (NA)	300 kHz to 50 GHz	0.1 dB	HP438A, E4418B, HP8482A, HP8487A
Port Match (NA)	300 kHz to 50 GHz	0.1 dB	HP85032B, HP85044A N4693A
Switch Repeatability (NA)	300 kHz to 50 GHz	0.1 dB	Associated Network Analyzer used with S parameter test set
Effective Source Match (NA)	300 kHz to 50 GHz	0.1 dB	HP85031B, N4693A
Directivity	300 kHz to 50 GHz	0.1 dB	HP85031B, N4693A

Parameter/Equipment	Range/Frequency	Best Uncertainty ^{2, 4, 3, 6} (±)	Comments
Current Monitor Conversion Factors	(0.001 to 1) V/A	0.05 %	Fluke 5700A, HP3458A
ESD Simulators –			EN 61000-4-2;
Contact Voltage (positive and negative)	(2 to 8) kV	1.9 % of reading	TEK TDS 540 with 6015A probe; HP 54845A with IEC ESD target
Rise Time	(0.7 to 1) ns	61 ps	
Peak Current	(6.8 to 33) A	2.6 % of reading	
30 ns current	(2.8 to 20.8) A	3.5 % of reading	
60 ns current	(1.4 to 10.4) A	9 % of reading	
Air Discharge Voltage (positive and negative)	(0 to 25) kV	1.9 % of reading	TEK TDS 540 TEK 6015A probe IEC ESD target
Rise Time	(0.7 to 1) ns	61 ps	
RC Time Constant	600 ns ± 130 ns	61 ps	
(at ± 15 kV)	(for 330 pF probe) 300 ns ± 60 ns (for 150 pF probe)	61 ps	
Indicated Voltage	(2 to 25) kV	1.9 % of reading	SAE J1113-13 with 54845A and target
EFT/Burst Generator			EN 61000-4-4; IEC 61000-4-6; GR 1089 CORE
Voltage (±)	10 V to 6 kV	2.8 % of reading	Tektronix TDS 5104B
Rise Time	5 ns ± 30 %	0.74 ns	
Impulse Duration	50 ns ± 30 %	0.74 ns	
Burst Duration	15 ms ± 20 %	0.74 ns	
Burst Period	300 ms ± 20 %	0.74 ns	
Repetition Rate			
0.125 kV	5 kHz ± 20 %	23 Hz (freq)	2.8 % (volt) of reading
0.25 kV	5 kHz ± 20 %		
0.5 kV	5 kHz ± 20 %		
1.0 kV	5 kHz ± 20 %		
2.0 kV	2.5 kHz ± 20 %		

Parameter/Equipment	Range/Frequency	Best Uncertainty ^{2, 4, 3, 6} (±)	Comments
Surge Generator –			
Front Time (±)	(1.2 to 50) µs	0.74 ns	EN61000-4-5; IEC61000-4-8; IEC61000-4-9; , IEC61000-4-10; IEC61000-4-11; IEC6100-4-12
Rise Time Open circuit (±) Short circuit (±)	(1.2 to 50) µs	1.2 ns	UL 864; UL 1449; ISO 7637-2; ISO 17069
Time to Half-Value (±)	(20 to 700) µs	0.74 ns	ITU Rec K.17, K.20, ITU Rec K.21; SBC-TP-76200;
Open Circuit Voltage (±)	10 V to 12 kV	2.8 % of reading	
Short Circuit Current (±)	(0.125 to 3) kA	2.8 % of reading	
Ring Wave Voltage	1 kV ± 10 %	2.8 % of reading	
Ring Wave Rise Time	1.5 µs ± 0.5 µs	0.74 ns	
Ring Wave Frequency	5 kHz ± 1 kHz	23 Hz (freq) 2.9 % (volt) of reading	GR1089CORE Tektronix TDS 5104B ANSI 62.41, 1991
Mains Harmonic Emissions	(0 to 2 kHz)	6.1 % of reading	IEC 61000-3-2; IEC 61000-4-7; IEC 61000-4-13; IEC 61000-4-14; IEC 61000-4-15;
Voltage Fluctuations (Flicker)	(100 to 280) Volts	6.6 % of reading	IEC 61000-3-3;
Rise/Fall Time – Measure	(200 ps to 1000 s)/div	2 % of reading + 50 ps	TDS 5104B
Voltage – Measure	(1 mV to 10 V)/div	2 % of reading	TDS 5104B

¹ This laboratory offers commercial and on-site calibration service.

² “Best Uncertainty” 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 of nearly ideal measuring equipment. Best uncertainties represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of $k = 2$. The best uncertainty of a specific calibration performed by the laboratory may be greater than the best uncertainty due to the behavior of the customer’s device and to influences from the circumstances of the specific calibration.

- ³ The measurands stated are generated with the Fluke 5000A series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. Best measurement uncertainties are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.
- ⁴ The measurands stated are measured with the HP 3458A or the HP 8487A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. Best measurement uncertainties 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.
- ⁵ In the statement of Best Uncertainty, M is the mismatch uncertainty for the unit under test. Mismatch uncertainties, due to the reflection coefficient of the device to be calibrated, are to be included in the overall measurement uncertainty. The approach of determining expanded uncertainties, expressed at approximately the 95 % level of confidence, (using a coverage factor of $k = 2$) is to be applied for this calculation as well.
- ⁶ On-site calibration service is available for this calibration. The uncertainties achievable on a customer's site can normally be expected to be larger than the Best Measurement Capabilities (BMC) that the accredited laboratory has been assigned as Best Uncertainty 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 calibration uncertainty being larger than the BMC.
- ⁷ Instruments are calibrated against manufacturer's specifications. These calibrations may also, at customer request, be based on conformance to the calibration requirements of various standards such as CISPR 16-1-1, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-11, EN 61000-4-5, IEC 61000-4-2, IEC 61000-3-2, IEC 61000-4-7, IEC 61000-4-8, IEC 61000-4-9, IEC 61000-4-10, IEC 61000-4-11, IEC 61000-4-12, IEC 61000-4-13, IEC 61000-4-14, IEC 61000-4-15, ANSI 62.41:1991, ANSI C63.16, ANSI C62-41, UL 864, UL 1449, ISO 7637-2, ISO 17069, ITU Rec K.17, ITU Rec K.20, ITU Rec K.21, SBC-TP-76200, GR1089CORE and SAE J1113-13. Other standards may apply and the customer should contact the lab for further information.
- ⁸ Some of the types of instruments calibrated under these parameters are EMI Receivers, EFT/Burst Generators, ESD Guns and Targets, Surge Generators, Generators for Voltage Dips, Short Interrupts and Variations, Ring Wave Generators, Network Analyzers, Click Analyzers, Impulse Generators, Power Meters, Power Sensors, Signal Generators, Spectrum Analyzers, Attenuators and Terminations.