

Schedule

Issue date: 15 May 2023
Valid until: 11 August 2028



NO: SAMM 048

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LABORATORY LOCATION:
(PERMANENT LABORATORY)



CALTECH LABORATORY SDN. BHD.
NO. 51-GRD., LEBUH BUKIT KECIL 2
TAMAN SRI NIBONG
11900 BAYAN LEPAS, PULAU PINANG
MALAYSIA

FIELDS OF CALIBRATION: ELECTRICAL & TEMPERATURE

This laboratory has demonstrated its technical competence to operate in accordance with MS ISO/IEC 17025:2017 (ISO/IEC 17025:2017).

This laboratory's fulfillment of the requirements of ISO/IEC 17025 means the laboratory meets both the technical competence requirements and management system requirements that are necessary for it to consistently deliver technically valid test results and calibrations. The management system requirements in ISO/IEC 17025 are written in language relevant to laboratory operations and operate generally in accordance with the principles of ISO 9001 (see Joint ISO-ILAC-IAF Communiqué dated April 2017).

* The uncertainty covered by the CMC is expressed as the expanded uncertainty corresponding to a coverage probability of approximately 95 % and have a coverage factor of k=2 unless stated otherwise.

SCOPE OF CALIBRATION: ELECTRICAL

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
1. Measuring Instruments (a) DC Voltage	0 to 220 mV 220 mV to 2.2 V 2.2 V to 11 V 11 V to 22 V 22 V to 220 V 220 V to 1100 V 1 kV to 2 kV 2 kV to 20 kV	8.1 μV/V + 0.61 μV 7.1 μV/V + 1.0 μV 7.1 μV/V + 3.6 μV 7.1 μV/V + 6.6 μV 8.1 μV/V + 0.081 mV 9.1 μV/V + 0.51 mV 0.41 mV/V + 0.67 V 0.46 mV/V + 4.6 V	Generation using calibrator model Fluke 5700A, Vitrek 4620B,
(b) DC Current	0 to 2 pA 2 pA to 20 pA 20 pA to 200 pA 200 pA to 2 nA 2 nA to 20 nA 20 nA to 200 nA 200 nA to 2 μA 2 μA to 20 μA 20 μA to 220 μA 220 μA to 2.2 mA 2.2 mA to 22 mA 22 mA to 220 mA 220 mA to 2.2 A 2.2 A to 11 A 11 A to 20.5 A	4.9 mA/A + 0.012 pA 4.3 mA/A + 0.012 pA 2.9 mA/A + 0.034 pA 0.74 mA/A + 0.12 pA 0.74 mA/A + 1.2 pA 0.40 mA/A + 0.012 nA 0.29 mA/A + 0.12 nA 0.29 mA/A + 1.2 nA 0.051 mA/A + 8.1 nA 0.051 mA/A + 8.1 nA 0.051 mA/A + 0.081 μA 0.061 mA/A + 0.81 μA 0.081 mA/A + 0.026 mA 0.37 mA/A + 0.49 mA 0.76 mA/A + 0.57 mA	Generation using calibrator model Fluke 5700A, 5725A, 5520A, Keithley 263

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
(b) DC Current (Cont')	10 A to 16.5 A 16.5 A to 150 A 150 A to 550 A 550 A to 1025 A	1.9 mA/A + 1.5 mA 1.9 mA/A + 0.011 A 1.9 mA/A + 0.040 A 2.0 mA/A + 0.046 A	Fluke 5520A with 50 Turn Coil
c) AC Voltage	0 V to 1100 V	See Matrix A	Generating using calibrator model Fluke 5700A
d) AC Current	0 to 20.5 A	See Matrix B	Generation using calibrator model Fluke 5700A, 5725A, 5520A
	10 A to 1025 A	See Matrix B	Fluke 5520A with 50 Turn Coil
(e) (i) DC Resistance	Fixed Value		Generation using calibrator model Fluke 5700A
	0 Ω	51 $\mu\Omega$	
	1 Ω	96 $\mu\Omega$	
	1.9 Ω	0.19 m Ω	
	10 Ω	0.29 m Ω	
	19 Ω	0.52 m Ω	
	100 Ω	1.8 m Ω	
	190 Ω	3.3 m Ω	
	1 k Ω	14 m Ω	
	1.9 k Ω	25 m Ω	
	10 k Ω	0.12 Ω	
	19 k Ω	0.23 Ω	
	100 k Ω	1.5 Ω	
	190 k Ω	2.7 Ω	
	1 M Ω	21 Ω	
	1.9 M Ω	41 Ω	
	10 M Ω	0.41 k Ω	
	19 M Ω	0.90 k Ω	
	100 M Ω	11 k Ω	
	1 G Ω	1.2 M Ω	
	10 G Ω	26 M Ω	
	100 G Ω	0.46 G Ω	Keithley 263
	Decade Value		Decade Resistor Model Genrad 1433T & 1433Z, Yokogawa- 2793-03
0.01 Ω to 0.1 Ω	23 m Ω/Ω + 50 n Ω		
0.1 Ω to 1 Ω	4.6 m Ω/Ω + 25 n Ω		
1 Ω to 10 Ω	1.2 m Ω/Ω + 1.0 $\mu\Omega$		
10 Ω to 100 Ω	0.46 m Ω/Ω + 0.25 $\mu\Omega$		
100 Ω to 1000 Ω	0.12 m Ω/Ω + 8.6 $\mu\Omega$		
1 k Ω to 10 k Ω	0.12 m Ω/Ω + 0.10 m Ω		
10 k Ω to 100 k Ω	0.12 m Ω/Ω + 1.0 m Ω		
100 k Ω to 1000 k Ω	0.12 m Ω/Ω + 10 m Ω		
1 M Ω to 10 M Ω	0.12 m Ω/Ω + 0.10 m Ω		
10 M Ω to 100 M Ω	2.3 m Ω/Ω + 0.50 m Ω		

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(e) (ii) DC Resistance (Insulation Tester)	100 Ω to 100 k Ω 100 k Ω to 1 M Ω 1 M Ω to 10 M Ω 10 M Ω to 100 M Ω Fixed Value 200 M Ω 500 M Ω 1000 M Ω 2000 M Ω 5000 M Ω 10 G Ω 100 G Ω	0.57 m Ω / Ω + 57 m Ω 0.57 m Ω / Ω + 59 m Ω 2.3 m Ω / Ω + 5.0 m Ω 2.3 m Ω / Ω + 0.50 m Ω 3.4 M Ω 5.8 M Ω 12 M Ω 23 M Ω 58 M Ω 0.13 G Ω 1.2 G Ω	Decade Resistor/Standard Resistor model Yokogawa 2793-03 ChenHwa 9001-200 M Ω Zentech 9001-1000 M Ω Zentech 9001-2000 M Ω (Max Voltage = 1 kV) Insulation Resistance Standard (Max Voltage= 7.5 kV)
(e) (iii) DC Resistance (Ground Bond / Continuity Tester)	100 m Ω 500 m Ω	0.57 m Ω 0.57 m Ω	Standard Resistor model CGS HSC200 Max. Current 40 A
(e) (iv) DC Resistance (Multiple ranges)	0 to 10.9999 Ω 11 Ω to 32.9999 Ω 33 Ω to 109.9999 Ω 110 Ω to 329.9999 Ω 330 Ω to 1.099999 k Ω 1.1 k Ω to 3.299999 k Ω 3.3 k Ω to 10.99999 k Ω 11 k Ω to 32.99999 k Ω 33 k Ω to 109.9999 k Ω 110 k Ω to 329.9999 k Ω 330 k Ω to 1.099999 M Ω 1.1 M Ω to 3.299999 M Ω 3.3 M Ω to 10.99999 M Ω 11 M Ω to 32.99999 M Ω 33 M Ω to 109.9999 M Ω 110 M Ω to 329.9999 M Ω 330 M Ω to 1100 M Ω	27 $\mu\Omega$ / Ω + 35 $\mu\Omega$ 23 $\mu\Omega$ / Ω + 7.1 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 2.5 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 0.76 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 28 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 7.6 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 0.28 m Ω 22 $\mu\Omega$ / Ω + 76 $\mu\Omega$ 22 $\mu\Omega$ / Ω + 2.5 m Ω 25 $\mu\Omega$ / Ω + 0.67 m Ω 25 $\mu\Omega$ / Ω + 22 m Ω 46 $\mu\Omega$ / Ω + 3.6 m Ω 0.10 m Ω / Ω + 53 m Ω 0.20 m Ω / Ω + 8.5 m Ω 0.39 m Ω / Ω + 0.14 Ω 2.3 m Ω / Ω + 0.74 Ω 12 m Ω / Ω + 4.4 Ω	Fluke 5520A
(e) (v) DC / AC Resistance	<u>1 mΩ</u> DC to 1 kHz <u>10 mΩ</u> DC to 1 kHz <u>100 mΩ</u> DC to 1 kHz <u>1 Ω</u> DC to 1 kHz	0.0012 m Ω 0.012 m Ω 0.12 m Ω 0.0012 Ω	Agilent 42030A

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(continued)	<u>10 Ω</u>		Agilent 42030A
	DC to 1 kHz	0.0035 Ω	
	1 MHz	0.014 Ω	
	2 MHz	0.017 Ω	
	3 MHz	0.023 Ω	
	4 MHz	0.029 Ω	
	5 MHz	0.046 Ω	
	10 MHz	0.12 Ω	
	13 MHz	0.17 Ω	
	<u>100 Ω</u>		
	DC to 1 kHz	0.023 Ω	
	1 MHz	0.14 Ω	
	2 MHz	0.14 Ω	
	3 MHz	0.17 Ω	
	4 MHz	0.17 Ω	
	5 MHz	0.23 Ω	
	10 MHz	0.58 Ω	
	13 MHz	0.81 Ω	
	<u>1 kΩ</u>		
	DC to 1 kHz	0.00023 k Ω	
	100 kHz	0.0014 k Ω	
	1 MHz	0.00093 k Ω	
	2 MHz	0.0012 k Ω	
	3 MHz	0.0012 k Ω	
	4 MHz	0.0017 k Ω	
	5 MHz	0.0017 k Ω	
	10 MHz	0.0046 k Ω	
	13 MHz	0.0069 k Ω	
	<u>10 kΩ</u>		
	DC to 1 kHz	0.0023 k Ω	
	100 kHz	0.0093 k Ω	
	1 MHz	0.0093 k Ω	
	<u>100 kΩ</u>		
	DC to 1 kHz	0.023 k Ω	
	100 kHz	0.093 k Ω	
	1 MHz	0.14 k Ω	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
(f) RF Power	0 dBm, 50 MHz (Ref.)	0.051 dB	HP 8902A and 11722A
	-20 dBm to +30 dBm at 100 kHz to 2.6 GHz	0.021 dB	
	<u>at Frequency:</u> 2.5 MHz to 1.3 GHz	Ref.	HP 8902A and 11722A
	0 dB	0.14 dB	
	-10 dB	0.14 dB	
	-20 dB	0.18 dB	
	-30 dB	0.18 dB	
	-40 dB	0.19 dB	
	-50 dB	0.20 dB	
	-60 dB	0.21 dB	
-70 dB	0.22 dB		
-80 dB	0.22 dB		
-90 dB	0.23 dB		
-100 dB	0.41 dB		
-110 dB	0.42 dB		
-120 dB	0.42 dB		
-127 dB	0.42 dB		
<u>-70 dBm to -20 dBm</u> 10 MHz to 30 MHz	0.054 dB	Agilent EPM- 441A and HP 8481D	
30 MHz to 4 GHz	0.031 dB		
4 GHz to 10 GHz	0.035 dB		
10 GHz to 15 GHz	0.045 dB		
15 GHz to 18 GHz	0.050 dB		
<u>-30 dBm to 20 dBm</u> 100 kHz to 300 kHz	0.072 dB	Agilent EPM- 441A, HP 8481A, 8482A	
300 kHz to 1 MHz	0.035 dB		
1 MHz to 2 GHz	0.027 dB		
2 GHz to 12.4 GHz	0.034 dB		
12.4 GHz to 18 GHz	0.043 dB		
(g) Amplitude Modulation	<u>Carrier Frequency:</u> 150 kHz to 4000 MHz	See Matrix C	HP 8902A and 11722A Agilent 8648D
(h) Frequency Modulation	<u>Carrier Frequency:</u> 150 kHz to 4000 MHz	See Matrix D	
(i) Phase Modulation	<u>Carrier Frequency:</u> 150 kHz to 4000 MHz	See Matrix E	
(j) Audio Distortion	10 Hz to 110 kHz -83.7 dBm to 16.2 dBm	0.17 dB	Agilent 33250A, SRS DS360

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(k) Frequency	1 µHz to 10 µHz 10 µHz to 100 µHz 100 µHz to 1 mHz 1 mHz to 10 mHz 10 mHz to 100 mHz 100 mHz to 1 Hz 1 Hz to 10 Hz 10 Hz to 100 Hz 100 Hz to 1 kHz 1 kHz to 10 kHz 10 kHz to 100 kHz 100 kHz to 1 MHz 1 MHz to 10 MHz 10 MHz to 100 MHz 100 MHz to 1 GHz 1 GHz to 4 GHz 4 GHz to 10 GHz 10 GHz to 26 GHz	37 pHz/Hz + 0.50 fHz 37 pHz/Hz + 5.0 fHz 37 pHz/Hz + 50 fHz 37 pHz/Hz + 0.50 pHz 37 pHz/Hz + 5.0 pHz 37 pHz/Hz + 50 pHz 37 pHz/Hz + 0.50 nHz 37 pHz/Hz + 5.0 nHz 37 pHz/Hz + 50 nHz 37 pHz/Hz + 0.50 µHz 37 pHz/Hz + 5.0 µHz 37 pHz/Hz + 50 µHz 37 pHz/Hz + 0.50 mHz 37 pHz/Hz + 5.0 mHz 37 pHz/Hz + 50 mHz 22 pHz/Hz + 0.54 Hz 48 pHz/Hz + 0.43 Hz 16 pHz/Hz + 5.5 Hz	Novatech 2960AR, Agilent 8648D, Agilent 33250A, HP 8673D
(l) LCR Meter (1) Inductance	<u>100 µH</u> 100 Hz 120 Hz 1 kHz 10 kHz <u>1 mH</u> 100 Hz 120 Hz 1 kHz 10 kHz <u>10 mH</u> 100 Hz 120 Hz 1 kHz 10 kHz <u>100 mH</u> 100 Hz 120 Hz 1 kHz 10 kHz <u>1 H</u> 100 Hz 120 Hz 1 kHz 10 kHz <u>10 H</u> 100 Hz 120 Hz 1 kHz	0.13 µH 0.13 µH 0.061 µH 0.13 µH 0.0017 mH 0.0017 mH 0.00015 mH 0.0012 mH 0.017 mH 0.017 mH 0.0012 mH 0.012 mH 0.13 mH 0.12 mH 0.015 mH 0.13 mH 0.0013 H 0.0013 H 0.00015 H 0.0018 H 0.012 H 0.014 H 0.0070 H	Genrad 1482-B Genrad 1482-T Genrad 1482-L Genrad 1482-E Genrad 1482-H Genrad 1482-P

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(I2) Capacitance	100 pF to 190 pF at 10 Hz to 10 kHz	5.7 mF/F + 5.7 pF	Fluke 5520A, Genrad 1423A
	0.19 nF to 1.0999 nF at 10 Hz to 10 kHz	3.9 mF/F + 7.7 pF	
	1.1 nF to 3.2999 nF at 10 Hz to 3 kHz	3.9 mF/F + 7.7 pF	
	3.3 nF to 10.9999 nF at 10 Hz to 1 kHz	2.0 mF/F + 7.7 pF	
	11 nF to 109.999 nF at 10 Hz to 1 kHz	2.0 mF/F + 77 pF	
	110 nF to 329.999 nF at 10 Hz to 1 kHz	2.0 mF/F + 0.23 nF	
	0.33 μ F to 1.09999 μ F at 10 Hz to 600 Hz	2.0 mF/F + 0.77 nF	
	1.1 μ F to 3.29999 μ F at 10 Hz to 300 Hz	2.0 mF/F + 2.3 nF	Fluke 5520A
	3.3 μ F to 10.9999 μ F at 10 Hz to 150 Hz	2.0 mF/F + 7.7 nF	
	11 μ F to 32.9999 μ F at 10 Hz to 120 Hz	3.1 mF/F + 23 nF	
	33 μ F to 109.999 μ F at 10 Hz to 80 Hz	3.5 mF/F + 77 nF	
	110 μ F to 329.999 μ F at 0 Hz to 50 Hz	3.5 mF/F + 0.23 μ F	
	0.33 mF to 1.09999 mF at 0 Hz to 20 Hz	3.5 mF/F + 0.77 μ F	
	1.1 mF to 3.29999 mF at 0 Hz to 6 Hz	3.5 mF/F + 2.3 μ F	
	3.3 mF to 10.9999 mF at 0 Hz to 2 Hz	3.5 mF/F + 7.7 μ F	
11 mF to 32.9999 mF at 0 Hz to 0.6 Hz	5.8 mF/F + 23 μ F		
33 mF to 110 mF at 0 Hz to 0.2 Hz	8.4 mF/F + 77 μ F		

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(m1) AC Power at Power Factor = 1	0.1089 mW to 2.97 mW 33 mV to 330 mV / 3.3 mA to 9 mA at 45 Hz to 1 kHz	0.76 mW/W + 5.3 nW	Fluke 5520A P=VI Whereby its equivalent with VA and VAR when Power Factor = 1
	0.297 mW to 10.89 mW 33 mV to 330 mV / 9 mA to 33 mA at 45 Hz to 1 kHz	0.45 mW/W + 28 nW	
	1.089 mW to 29.7 mW 33 mV to 330 mV / 33 mA to 90 mA at 45 Hz to 1 kHz	0.76 mW/W + 53 nW	
	2.97 mW to 108.9 mW 33 mV to 330 mV / 90 mA to 330 mA at 45 Hz to 1 kHz	0.45 mW/W + 0.28 μ W	
	10.89 mW to 297 mW 33 mV to 330 mV / 0.33 A to 0.9 A at 45 Hz to 1 kHz	0.60 mW/W + 0.65 μ W	
	29.7 mW to 726 mW 33 mV to 330 mV / 0.9 A to 2.2 A at 45 Hz to 1 kHz	0.44 mW/W + 2.8 μ W	
	72.6 mW to 1.485 W 33 mV to 330 mV / 2.2 A to 4.5 A at 45 Hz to 1 kHz	0.49 mW/W + 4.9 μ W	
	0.1485 W to 6.765 W 33 mV to 330 mV / 4.5 A to 20.5 A <u>at Frequency:</u> 45 Hz to 100 Hz 100 Hz to 1 kHz	0.78 mW/W + 7.6 μ W 1.0 mW/W + 5.6 μ W	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(continued) at Power Factor = 1	1.089 mW to 9.18 W 330 mV to 1020 V / 3.3 mA to 9 mA at 45 Hz to 1 kHz	0.76 mW/W + 10 nW	Fluke 5520A
	2.97 mW to 33.66 W 330 mV to 1020 V / 9 mA to 33 mA at 45 Hz to 1 kHz	0.47 mW/W + 51 nW	P=VI Whereby its equivalent with VA and VAR when Power Factor = 1
	10.89 mW to 91.8 W 330 mV to 1020 V / 33 mA to 90 mA at 45 Hz to 1 kHz	0.76 mW/W + 0.10 μ W	
	29.7 mW to 336.6 W 330 mV to 1020 V / 90 mA to 330 mA at 45 Hz to 1 kHz	0.47 mW/W + 0.51 μ W	
	0.1089 W to 918 W 330 mV to 1020 V / 0.33 A to 0.9 A at 45 Hz to 1 kHz	0.61 mW/W + 1.3 μ W	
	297 mW to 2244 W 330 mV to 1020 V / 0.9 A to 2.2 A at 45 Hz to 1 kHz	0.47 mW/W + 5.2 μ W	
	726 mW to 4590 W 330 mV to 1020 V / 2.2 A to 4.5 A at 45 Hz to 1 kHz	0.49 mW/W + 9.9 μ W	
	1.485 W to 20.91 kW 330 mV to 1020 V / 4.5 A to 20.5 A at Frequency: 45 Hz to 100 Hz 100 Hz to 1 kHz	0.79 mW/W + 14 μ W 1.1 mW/W + 10 μ W	

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(m2) DC Power	0.01089 mW to 336.6 W 33 mV to 1020 V / 0.33 mA to 330 mA	0.12 mW/W + 0.57 nW	Fluke 5520A P=VI Whereby its equivalent with VA and VAR when Power Factor = 1
	0.01089 W to 3.06 kW 33 mV to 1020 V / 0.33 A to 3 A	0.24 mW/W + 29 nW	
	0.099 W to 20.91 kW 33 mV to 1020 V / 3 A to 20.5 A	0.46 mW/W + 0.14 μ W	
n) Phase	<u>0 ° to \pm180 °</u>		Fluke 5520A
	10 Hz to 65 Hz	0.076 °	
	65 Hz to 500 Hz	0.19 °	
	500 Hz to 1 kHz	0.38 °	
	1 kHz to 5 kHz	1.9 °	
	5 kHz to 10 kHz 10 kHz to 30 kHz	3.8 ° 7.6 °	
2. Generating Instrument / Source (a) DC Voltage	0 to 100 mV	5.7 μ V/V + 0.34 μ V	HP 3458A, Vitrek 4620B
	100 mV to 1 V	4.6 μ V/V + 0.34 μ V	
	1 V to 10 V	4.6 μ V/V + 0.57 μ V	
	10 V to 100 V	6.8 μ V/V + 0.034 mV	
	100 V to 1000 V	6.8 μ V/V + 0.12 mV	
	1 kV to 2 kV	0.46 mV/V + 0.46 V	
	2 kV to 20 kV	0.46 mV/V + 4.6 V	
(b) AC Voltage	0 to 1000 V	See Matrix F	Fluke 5790A
	1 kV to 2 kV <u>at Frequency (Hz):</u> 20 to 100 100 to 400	0.80 mV/V + 2.3 V 4.6 mV/V + 4.6 V	Vitrek 4620B
	2 kV to 20 kV <u>at Frequency (Hz):</u> 20 to 100	2.3 mV/V + 23 V	

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(c) DC Current	0 to 100 nA	0.034 mA/A + 0.046 nA	HP 3458A, HP 34401A, Shunt		
	100 nA to 1 µA	0.023 mA/A + 0.046 nA			
	1 µA to 10 µA	0.023 mA/A + 0.12 nA			
	10 µA to 100 µA	0.023 mA/A + 0.91 nA			
	100 µA to 1 mA	0.023 mA/A + 5.7 nA			
	1 mA to 10 mA	0.023 mA/A + 0.057 µA			
	10 mA to 100 mA	0.040 mA/A + 0.57 µA			
	100 mA to 1 A	0.13 mA/A + 0.012 mA			
	1 A to 10 A	0.12 mA/A + 5.2 µA			
	10 A to 20 A	0.12 mA/A + 2.1 µA			
	20 A to 100 A	0.14 mA/A + 0.034 mA			
	(d) AC Current	0 to 20 A		See Matrix G	
		20 A to 100 A at DC to 1 kHz		0.16 mA/A + 1.6 mA	
(e) DC Resistance	0 to 10 Ω	0.017 mΩ/Ω + 0.057 mΩ	HP 3458A		
	10 Ω to 100 Ω	0.014 mΩ/Ω + 0.57 mΩ			
	100 Ω to 1 kΩ	0.012 mΩ/Ω + 0.57 mΩ			
	1 kΩ to 10 kΩ	0.012 mΩ/Ω + 5.7 mΩ			
	10 kΩ to 100 kΩ	0.012 mΩ/Ω + 0.057 Ω			
	100 kΩ to 1 MΩ	0.017 mΩ/Ω + 2.3 Ω			
	1 MΩ to 10 MΩ	0.057 mΩ/Ω + 0.12 kΩ			
	10 MΩ to 100 MΩ	0.57 mΩ/Ω + 1.2 kΩ			
	100 MΩ to 1 GΩ	5.7 mΩ/Ω + 0.012 MΩ			
(f) Frequency	100 mHz to 1 Hz	37 pHz/Hz + 50 pHz	Novatech 2960AR, Fluke PM6680B, EIP 548A		
	1 Hz to 10 Hz	37 pHz/Hz + 0.50 nHz			
	10 Hz to 100 Hz	37 pHz/Hz + 5.0 nHz			
	100 Hz to 1 kHz	37 pHz/Hz + 50 nHz			
	1 kHz to 10 kHz	37 pHz/Hz + 0.50 µHz			
	10 kHz to 100 kHz	37 pHz/Hz + 5.0 µHz			
	100 kHz to 1 MHz	37 pHz/Hz + 50 µHz			
	1 MHz to 10 MHz	37 pHz/Hz + 0.50 mHz			
	10 MHz to 100 MHz	37 pHz/Hz + 5.0 mHz			
	100 MHz to 1 GHz	37 pHz/Hz + 50 mHz			
	1 GHz to 2.7 GHz	22 pHz/Hz + 0.54 Hz			
2.7 GHz to 26.5 GHz	61 pHz/Hz + 0.33 Hz				
(g) RF Power	0 dBm, 50 MHz (Ref.)	0.051 dB	HP 8902A and 11722A		
	-20 dBm to +30 dBm at 100 kHz to 2.6 GHz	0.021 dB			

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)* (of reading)	Remarks
(continued)	<u>at Frequency:</u> 2.5 MHz to 1.3 GHz 0 dB -10 dB -20 dB -30 dB -40 dB -50 dB -60 dB -70 dB -80 dB -90 dB -100 dB -110 dB -120 dB -127 dB	Ref. 0.14 dB 0.14 dB 0.18 dB 0.18 dB 0.19 dB 0.20 dB 0.21 dB 0.22 dB 0.22 dB 0.23 dB 0.41 dB 0.42 dB 0.42 dB	HP 8902A and 11722A
(h) Amplitude Modulation	<u>Carrier Frequency:</u> 150 kHz to 9000 MHz	See Matrix H	HP 8902A and 11722A
(i) Frequency Modulation	<u>Carrier Frequency:</u> 150 kHz to 9000 MHz	See Matrix I	
(j) Phase Modulation	<u>Carrier Frequency:</u> 150 kHz to 9000 MHz	See Matrix J	
(k) (i) Amplitude Modulation Distortion	fc: 150 kHz to 10 MHz fm: 20 Hz to 10 kHz Depth: 5 % to 50 % Depth: 50 % to 99 % fc: 10 MHz to 1300 MHz fm: 20 Hz to 100 kHz Depth: 5 % to 50 % Depth: 50 % to 99 % fc: 1300 MHz to 9000 MHz fd: 150 kHz to 10 MHz fm: 20 Hz to 10 kHz Depth: 5 % to 50 % Depth: 50 % to 99 % fc: 1300 MHz to 9000 MHz fd: 10 MHz to 1300 MHz fm: 20 Hz to 100 kHz Depth: 5 % to 50 % Depth: 50 % to 99 %	0.028 %/% + 0.34 % 0.014 %/% + 0.69 % 0.028 %/% + 0.34 % 0.014 %/% + 0.69 % 0.028 %/% + 0.34 % 0.014 %/% + 0.69 % 0.028 %/% + 0.34 % 0.014 %/% + 0.69 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency HP 8902A, Panasonic VP7722A, Mixer fc = Carrier Frequency fd = Downconverted Frequency fm = Modulation Frequency

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(k) (ii) Frequency Modulation Distortion	fc: 250 kHz to 10 MHz fm: 20 Hz to 10 kHz Δf : < 40 kHz	0.069 %/% + 0.11 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency Δf = Deviation
	fc: 10 MHz to 1300 MHz fm: 20 Hz to 200 kHz Δf : < 400 kHz	0.069 %/% + 0.11 %	
	fc: 1300 MHz to 9000 MHz fd: 250 kHz to 10 MHz fm: 20 Hz to 10 kHz Δf : < 40 kHz	0.069 %/% + 0.11 %	
	fc: 1300 MHz to 9000 MHz fd: 10 MHz to 1300 MHz fm: 20 Hz to 200 kHz Δf : < 400 kHz	0.069 %/% + 0.11 %	
(k) (iii) Phase Modulation Distortion	fc: 150 kHz to 10 MHz fm: 200 Hz to 10 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency Δf = Deviation
	fc: 10 MHz to 1300 MHz fm: 200 Hz to 20 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	
	fc: 1300 MHz to 9000 MHz fd: 150 kHz to 10 MHz fm: 200 Hz to 10 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	
	fc: 1300 MHz to 9000 MHz fd: 10 MHz to 1300 MHz fm: 200 Hz to 20 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	
(k) (iv) Audio Distortion	10 Hz to 15.99 kHz	0.14 %/%	Panasonic VP7722A
	16 kHz to 110 kHz	0.48 %/%	
(l) Capacitor / Decade Capacitor	0 pF to 31.8 F at DC to 100 kHz	1.2 mF/F	Fluke PM6304C
(m) Inductor / Decade Inductor	0 μ H to 637 kH at 0 to 20 kHz	1.2 mH/H	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)* (of reading)	Remarks
3. Oscilloscope (a) (i) DC Signal (in 1, 2, 5 sequence)	<u>50 Ω load:</u> 0 V to 2.1999 V 2.2 V to 6.6 V <u>1 MΩ load:</u> 0 V to 2.1999 V 2.2 V to 10.999 V 11 V to 130 V	1.9 mV/V + 0.043 mV 1.9 mV/V + 0.074 mV 0.38 mV/V + 0.048 mV 0.37 mV/V + 0.19 mV 0.37 mV/V + 2.0 mV	Fluke 5520A (SC600)
(a) (ii) Square Wave Signal (in 1, 2, 5 sequence)	<u>50 Ω load</u> at 10 Hz to 10 kHz 1 mV to 24.999 mV 25 mV to 109.99 mV 110 mV to 2.1999 V 2.2 V to 6.6 V <u>1 MΩ load</u> at 10 Hz to 10 kHz 1 mV to 24.999 mV 25 mV to 109.99 mV 110 mV to 2.1999 V 2.2 V to 10.999 V 11 V to 130 V	2.0 mV/V + 0.031 mV 2.0 mV/V + 0.031 mV 2.0 mV/V + 0.034 mV 2.0 mV/V + 0.074 mV 0.77 mV/V + 0.031 mV 0.77 mV/V + 0.031 mV 0.76 mV/V + 0.038 mV 0.76 mV/V + 0.12 mV 0.76 mV/V + 1.2 mV	
(b) Bandwidth	<u>Frequency (Hz):</u> 50 k to 1000 k 1 M to 600 M 600 M to 1050 M 1050 M to 4 G 4 G to 26 G	0.31 μHz/Hz + 5.7 Hz 0.20 μHz/Hz + 5.7 kHz 0.77 pHz/Hz + 5.7 Hz 2.3 pHz/Hz + 5.7 Hz 51 fHz/Hz + 0.57 kHz	Fluke 5520A (SC600), Agilent 8648D, HP 8673D, Novatech 2960AR
(c) Time Base	2 ns to 1000 ns 1 μs to 1000 μs 1 ms to 1000 ms 1 s to 5 s	2.3 μs/s + 0.31 ps 2.3 μs/s + 0.31 ns 2.3 μs/s + 0.31 μs 0.032 μs/s + 0.57 ms	Fluke 5520A (SC600)
4. (a) DC Cutoff Current (Hipot)	0 to 30 mA 30 mA to 100 mA 100 mA to 10 A	0.38 mA/A + 2.4 μA 0.38 mA/A + 17 μA 1.6 mA/A + 3.9 mA	Fluke 45

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks		
(b) AC Cutoff Current (Hipot)	0 mA to 30 mA <u>at Frequency (Hz):</u> 20 to 50 50 to 10 k 10 k to 20 k	16 mA/A + 7.7 µA 3.9 mA/A + 7.7 µA 16 mA/A + 16 µA	Fluke 45		
	30 mA to 100 mA <u>at Frequency (Hz):</u> 20 to 50 50 to 10 k 10 k to 20 k	16 mA/A + 77 µA 3.9 mA/A + 77 µA 16 mA/A + 0.16 mA			
	100 mA to 10 A <u>at Frequency (Hz):</u> 20 to 50 50 to 2 k	16 mA/A + 7.7 mA 7.7 mA/A + 7.7 mA			
	5. Impedance Analyzer (a) Capacitance	<u>1 pF</u> 1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz		0.000048 pF 0.000093 pF 0.00023 pF 0.00042 pF 0.00064 pF 0.00090 pF 0.0026 pF 0.0040 pF	HP 16380A, HP 16380C
		<u>10 pF</u> 1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz		0.00055 pF 0.00055 pF 0.00056 pF 0.00057 pF 0.00059 pF 0.00064 pF 0.0012 pF 0.0016 pF	
		<u>100 pF</u> 1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz		0.0039 pF 0.0041 pF 0.0049 pF 0.0067 pF 0.0091 pF 0.013 pF 0.033 pF 0.049 pF	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
(Continued)	<u>1 nF</u> 1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz <u>10 nF</u> 120 Hz 1 kHz 10 kHz 100 kHz <u>100 nF</u> 120 Hz 1 kHz 10 kHz 100 kHz <u>1 μF</u> 120 Hz 1 kHz 10 kHz 100 kHz	0.000048 nF 0.000069 nF 0.00015 nF 0.00028 nF 0.00044 nF 0.00063 nF 0.0020 nF 0.0030 nF 0.00040 nF 0.00040 nF 0.00041 nF 0.00043 nF 0.0083 nF 0.0040 nF 0.0040 nF 0.0050 nF 0.00010 μ F 0.000050 μ F 0.000050 μ F 0.000094 μ F	HP 16380A, HP 16380C
6. Stop Watch	1 s to 1500 s 1500 s to 7200 s	0.10 s 0.12 s	Totalizing Method with reference to frequency standard
7. Timer	1 s to 3600 s	0.16 s	Stop Watch
8. Electrostatic Instrument – Electrostatic Voltage	0 to \pm 1000 V 1000 V to 19000 V	(of reading) 5.1 mV/V + 0.80 V 0.018 V/V + 7.0 V	BS 7506 Fluke 5520A, Vitrek 4620B,

Signatories:

1. **Poh Soo Leng**
2. **Tiong Tark Hoe**
3. **Poh Soo Beng**
4. **Kho Hup Ann**
5. **Tan Soon Leng (Except RF parameters)**

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Matrix A

Measurement Instrument - AC Voltage

Range	Frequency							
	Hz		kHz					MHz
	10 to 20	20 to 40	0.04 to 20	20 to 50	50 to 100	100 to 300	300 to 500	0.5 to 1
0 to 2.2 mV	0.56 + 0.0046	0.22 + 0.0046	0.11 + 0.0046	0.38 +0.0046	0.86 + 0.0071	1.1 + 0.014	1.8 + 0.026	3.5 + 0.026
2.2 mV to 22 mV	0.56 + 0.0051	0.22 + 0.0051	0.11 + 0.0051	0.38 + 0.0051	0.86 + 0.0071	1.1 + 0.013	1.8 + 0.026	3.5 + 0.026
22 mV to 220 mV	0.56 + 0.014	0.22 + 0.0081	0.11 + 0.0081	0.33 + 0.0081	0.86 + 0.026	1.1 + 0.026	1.8 + 0.036	3.5 + 0.081
220 mV to 2.2 V	0.51 + 0.081	0.17 + 0.026	0.076 + 0.0061	0.13 + 0.017	0.26 + 0.071	0.44 + 0.14	1.1 + 0.36	2.3 + 0.86
2.2 V to 22 V	0.51 + 0.81	0.17 + 0.26	0.076 + 0.061	0.13 + 0.17	0.26 + 0.36	0.51 + 1.6	1.3 + 4.4	2.8 + 8.6
22 V to 220 V	0.51 + 8.1	0.17 + 2.6	0.081 + 0.81	0.23 + 3.6	0.51 + 8.1	1.6 + 91	4.8 + 91	12 + 200
	Frequency (kHz)							
	0.04 to 1	1 to 20	20 to 30	30 to 50	50 to 100			
220 V to 1100 V	0.091 + 4.1	0.17 + 6.1	0.61 + 11	-	-			
220 V to 750 V	-	-	-	0.61 + 11	2.4 + 46			

The expanded uncertainties given in above table are expressed in mV/V + mV

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Matrix B

Measurement Instrument - AC Current

Range	Frequency				
	Hz		kHz		
	10 to 20	20 to 40	0.04 to 1	1 to 5	5 to 10
0 to 220 μ A	0.71 + 0.000026	0.36 + 0.000021	0.15 + 0.000017	0.61 + 0.000041	1.7 + 0.000081
220 μ A to 2.2 mA	0.71 + 0.000041	0.36 + 0.000036	0.15 + 0.000036	0.61 + 0.00041	1.7 + 0.00081
2.2 mA to 22 mA	0.71 + 0.00041	0.36 + 0.00036	0.15 + 0.00036	0.61 + 0.0041	1.7 + 0.0081
22 mA to 220 mA	0.71 + 0.0041	0.36 + 0.0036	0.15 + 0.0036	0.61 + 0.041	1.7 + 0.081
220 mA to 2.2 A	-	-	0.66 + 0.036	0.76 + 0.081	8.6 + 0.17
2.2 A to 11 A	-	-	0.47 + 0.18	0.96 + 0.39	3.7 + 0.76
	Frequency (Hz)				
	45 to 100	100 to 1 k	1 k to 5 k		
11 A to 20.5 A	0.91 + 3.8	1.1 + 3.8	22 + 3.8		
	Frequency (Hz)				
	45 to 65	65 to 440			
10 A to 16.5 A	2.2 + 2.5	6.0 + 2.4			
16.5 A to 150 A	2.2 + 22	6.0 + 22			
150 A to 550 A	2.1 + 88	6.0 + 87			
550 A to 1025 A	2.3 + 140	6.0 + 110			

The expanded uncertainties given in above table are expressed in mA/A + mA

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Matrix C

Measurement Instrument - Amplitude Modulation

Carrier Frequency	Depth	Modulation Frequency			
		20 Hz to 50 Hz	50 Hz to 10 kHz	50 Hz to 50 kHz	50 kHz to 100 kHz
150 kHz to 10 MHz	1 % to 39.99 %	0.034 + 0.012	-	-	-
	5 % to 39.99 %	-	0.023 + 0.012	-	-
	40 % to 99 %	0.034 + 0.12	0.023 + 0.12	-	-
10 MHz to 1300 MHz	1 % to 39.99 %	-	-	0.012 + 0.012	-
	5 % to 39.99 %	0.034 + 0.012	-	-	0.034 + 0.012
	40 % to 99 %	0.034 + 0.12	-	0.012 + 0.12	0.034 + 0.12

Carrier Frequency: 1300 MHz to 4000 MHz

Downconverted Frequency	Depth	Modulation Frequency			
		20 Hz to 50 Hz	50 Hz to 10 kHz	50 Hz to 50 kHz	50 kHz to 100 kHz
150 kHz to 10 MHz	1 % to 39.99 %	0.034 + 0.012	-	-	-
	5 % to 39.99 %	-	0.023 + 0.012	-	-
	40 % to 99 %	0.034 + 0.12	0.023 + 0.12	-	-
10 MHz to 1300 MHz	1 % to 39.99 %	-	-	0.012 + 0.012	-
	5 % to 39.99 %	0.034 + 0.012	-	-	0.034 + 0.012
	40 % to 99 %	0.034 + 0.12	-	0.012 + 0.12	0.034 + 0.12

The expanded uncertainties given in above table are expressed in %/% + %

Matrix D

Measurement Instrument - Frequency Modulation

Carrier Frequency	Deviation	Modulation Frequency						
		20 Hz to 50 Hz	20 Hz to 3.999 kHz	50 Hz to 3.999 kHz	4 kHz to 10 kHz	4 kHz to 39.99 kHz	40 kHz to 100 kHz	100 kHz to 200 kHz
250 kHz to 10 MHz	0 to 40 kHz	-	0.023 + 1.2	-	0.023 + 12	-	-	-
10 MHz to 1300 MHz	0 to 400 kHz	0.056 + 1.3	-	0.012 + 1.2	-	0.012 + 12	0.012 + 120	0.057 + 120

Down converted Frequency	Deviation	Modulation Frequency						
		20 Hz to 50 Hz	20 Hz to 3.999 kHz	50 Hz to 3.999 kHz	4 kHz to 10 kHz	4 kHz to 39.99 kHz	40 kHz to 100 kHz	100 kHz to 200 kHz
250 kHz to 10 MHz	0 to 40 kHz	-	0.023 + 1.2	-	0.023 + 12	-	-	-
10 MHz to 1300 MHz	0 to 400 kHz	0.056 + 1.3	-	0.012 + 1.2	-	0.012 + 12	0.012 + 120	0.057 + 120

The expanded uncertainties given in above table are expressed in Hz/Hz + Hz

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Matrix E

Measurement Instrument - Phase Modulation

Carrier Frequency	Deviation	Modulation Frequency	
		200 Hz to 10 kHz	200 Hz to 20 kHz
150 kHz to 10 MHz	0.1 rad. to 4 rad.	0.046 + 0.0012	-
	4.01 rad. to 40 rad.	0.046 + 0.012	-
10 MHz to 1300 MHz	0.1 rad. to 4 rad.	-	0.034 + 0.0012
	4.01 rad. to 40 rad.	-	0.034 + 0.012
	40.1 rad. to 400 rad.	-	0.034 + 0.12
Carrier Frequency: 1300 MHz to 4000 MHz			
Downconverted Frequency	Deviation	Modulation Frequency	
		200 Hz to 10 kHz	200 Hz to 20 kHz
150 kHz to 10 MHz	0.1 rad. to 4 rad.	0.046 + 0.0012	-
	4.01 rad. to 40 rad.	0.046 + 0.012	-
10 MHz to 1300 MHz	0.1 rad. to 4 rad.	-	0.034 + 0.0012
	4.01 rad. to 40 rad.	-	0.034 + 0.012
	40.1 rad. to 400 rad.	-	0.034 + 0.12

The expanded uncertainties given in above table are expressed in rad./rad. + rad.

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Matrix F

Generating Instrument / Source - AC Voltage

Range	Frequency						
	Hz		kHz				
	10 to 20	20 to 40	0.04 to 20	20 to 50	50 to 100	100 to 300	300 to 500
0 mV to 2.2 mV	1.3 + 0.00099	0.57 + 0.00099	0.32 + 0.00099	0.62 + 0.0016	0.92 + 0.0019	1.8 + 0.0031	1.9 + 0.0061
2.2 mV to 7 mV	0.65 + 0.00099	0.29 + 0.00099	0.16 + 0.00099	0.31 + 0.0016	0.46 + 0.0019	0.92 + 0.0031	0.99 + 0.0061
7 mV to 22 mV	0.22 + 0.00099	0.15 + 0.00099	0.084 + 0.00099	0.16 + 0.0016	0.24 + 0.0019	0.62 + 0.0031	0.68 + 0.0061
22 mV to 70 mV	0.19 + 0.0012	0.092 + 0.0012	0.05 + 0.0012	0.10 + 0.0016	0.20 + 0.002	0.39 + 0.0031	0.51 + 0.0061
70 mV to 220 mV	0.16 + 0.0012	0.065 + 0.0012	0.029 + 0.0012	0.053 + 0.0016	0.13 + 0.0019	0.19 + 0.0031	0.29 + 0.0061
220 mV to 700 mV	0.16 + 0.0012	0.058 + 0.0012	0.025 + 0.0012	0.039 + 0.0016	0.06 + 0.002	0.14 + 0.0031	0.23 + 0.0061
0.7 V to 2.2 V	0.16 + 0.0000019	0.051 + 0.0000057	0.019 + 0.000016	0.035 + 0.000081	0.054 + 0.000053	0.13 + 0.000024	0.20 + 0.000015
2.2 V to 7 V	0.16 + 0.000059	0.051 + 0.00018	0.019 + 0.00049	0.037 + 0.00025	0.062 + 0.00015	0.15 + 0.000062	0.31 + 0.000030
7 V to 22 V	0.16 + 0.000019	0.051 + 0.000056	0.021 + 0.00014	0.037 + 0.000078	0.062 + 0.000046	0.15 + 0.000020	0.31 + 0.000093
22 V to 70 V	0.16 + 0.00059	0.052 + 0.0018	0.025 + 0.0037	0.044 + 0.0021	0.072 + 0.0013	0.16 + 0.00059	0.32 + 0.00029
70 V to 220 V	0.16 + 0.00019	0.052 + 0.00055	0.024 + 0.0012	0.053 + 0.00054	0.075 + 0.00038	0.16 + 0.00018	0.38 + 0.000075
220 V to 700 V	0.16 + 0.0059	0.076 + 0.012	0.032 + 0.029	0.099 + 0.0091	0.38 + 0.0024		
700 V to 1000 V	0.16 + 0.0027	0.076 + 0.0054	0.029 + 0.014	0.099 + 0.0041	0.38 + 0.0011		

Range	Frequency				
	MHz				
	0.5 to 1	1.2 to 2	2 to 10	10 to 20	20 to 30
0 mV to 2.2 mV	2.7 + 0.0061	0.60 + 0.0013	1.3 + 0.0012	2.2 + 0.0012	5.3 + 0.0018
2.2 mV to 7 mV	1.80 + 0.0061	0.55 + 0.0012	0.77 + 0.0011	1.3 + 0.0010	2.9 + 0.0009
7 mV to 22 mV	1.30 + 0.0061	0.54 + 0.0003	0.77 + 0.00022	1.3 + 0.00013	2.9 + 0.000059
22 mV to 70 mV	0.84 + 0.0061	0.39 + 0.00024	0.77 + 0.00012	1.2 + 0.00008	2.7 + 0.00004
70 mV to 220 mV	0.76 + 0.0061	0.39 + 0.00013	0.76 + 0.000062	1.2 + 0.000041	2.7 + 0.000018
220 mV to 700 mV	0.73 + 0.0061	0.39 + 0.000076	0.76 + 0.000038	1.2 + 0.000026	2.7 + 0.000011
0.7 V to 2.2 V	0.69 + 0.00000042	0.38 + 0.000075	0.76 + 0.000038	1.2 + 0.000025	2.7 + 0.000011
2.2 V to 7 V	0.92 + 0.0000099	0.38 + 0.000024	0.76 + 0.000012	1.2 + 0.0000079	2.7 + 0.0000034
7 V to 22 V	0.92 + 0.0000031				
22 V to 70 V	0.92 + 0.000099				
70 V to 220 V					
220 V to 700 V					
700 V to 1000 V					

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Matrix G

Generating Instrument / Source - AC Current

Range	Frequency						
	Hz			kHz			
	10 to 20	20 to 45	45 to 100	0.1 to 1			
0 to 100 μ A	4.6 + 0.000034	1.7 + 0.000034	0.68 + 0.000034	0.68 + 0.000034			
Range	Frequency (Hz)			Frequency (kHz)			
	10 to 20	20 to 45	45 to 100	0.1 to 5	5 to 20	20 to 50	50 to 100
100 μ A to 1 mA	4.6 + 0.00023	1.7 + 0.00023	0.68 + 0.00023	0.34 + 0.00023	0.68 + 0.00023	4.6 + 0.00046	6.3 + 0.0017
1 mA to 10 mA	4.6 + 0.0023	1.7 + 0.0023	0.68 + 0.0023	0.34 + 0.0023	0.68 + 0.0023	4.6 + 0.0046	6.3 + 0.017
10 mA to 100 mA	4.6 + 0.023	1.7 + 0.023	0.68 + 0.023	0.34 + 0.023	0.68 + 0.023	4.6 + 0.046	6.3 + 0.17
100 mA to 1 A	4.6 + 0.23	1.9 + 0.23	0.91 + 0.23	1.2 + 0.23	3.4 + 0.23	12 + 0.46	
Range	Frequency						
	Hz		kHz				
	3 to 5	5 to 10	0.01 to 5				
1 A to 3 A	13 + 2.1	4.0 + 2.1	1.7 + 2.1				
Range	Frequency (kHz)						
	0.001 to 1	1 to 5					
3 A to 10 A	0.24 + 0.27	0.38 + 1.9					
10 A to 20 A	0.25 + 0.21	0.42 + 1.5					

The expanded uncertainties given in above table are expressed in mA/A + mA

Matrix H

Generating Instrument / Source - Amplitude Modulation

Carrier Frequency	Depth	Modulation Frequency			
		20 Hz to 50 Hz	50 Hz to 10 kHz	50 Hz to 50 kHz	50 kHz to 100 kHz
150 kHz to 10 MHz	1 % to 39.99 %	0.034 + 0.012	-	-	-
	5 % to 39.99 %	-	0.023 + 0.012	-	-
	40 % to 99 %	0.034 + 0.12	0.023 + 0.12	-	-
10 MHz to 1300 MHz	1 % to 39.99 %	-	-	0.012 + 0.012	-
	5 % to 39.99 %	0.034 + 0.012	-	-	0.034 + 0.012
	40 % to 99 %	0.034 + 0.12	-	0.012 + 0.12	0.034 + 0.12
Carrier Frequency: 1300 MHz to 9000 MHz					
Downconverted Frequency	Depth	Modulation Frequency			
		20 Hz to 50 Hz	50 Hz to 10 kHz	50 Hz to 50 kHz	50 kHz to 100 kHz
150 kHz to 10 MHz	1 % to 39.99 %	0.034 + 0.012	-	-	-
	5 % to 39.99 %	-	0.023 + 0.012	-	-
	40 % to 99 %	0.034 + 0.12	0.023 + 0.12	-	-
10 MHz to 1300 MHz	1 % to 39.99 %	-	-	0.012 + 0.012	-
	5 % to 39.99 %	0.034 + 0.012	-	-	0.034 + 0.012
	40 % to 99 %	0.034 + 0.12	-	0.012 + 0.12	0.034 + 0.12

The expanded uncertainties given in above table are expressed in %/% + %

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SCOPE OF CALIBRATION: ELECTRICAL

Matrix I

Generating Instrument / Source - Frequency Modulation

Carrier Frequency	Deviation	Modulation Frequency						
		20 Hz to 50 Hz	20 Hz to 3.999 kHz	50 Hz to 3.999 kHz	4 kHz to 10 kHz	4 kHz to 39.99 kHz	40 kHz to 100 kHz	100 kHz to 200 kHz
250 kHz to 10 MHz	0 to 40 kHz	-	0.023 + 1.2	-	0.023 + 12	-	-	-
10 MHz to 1300 MHz	0 to 400 kHz	0.056 + 1.3	-	0.012 + 1.2	-	0.012 + 12	0.012 + 120	0.057 + 120
Carrier Frequency: 1300 MHz to 9000 MHz								
Downconverted Frequency	Deviation	Modulation Frequency						
		20 Hz to 50 Hz	20 Hz to 3.999 kHz	50 Hz to 3.999 kHz	4 kHz to 10 kHz	4 kHz to 39.99 kHz	40 kHz to 100 kHz	100 kHz to 200 kHz
250 kHz to 10 MHz	0 to 40 kHz	-	0.023 + 1.2	-	0.023 + 12	-	-	-
10 MHz to 1300 MHz	0 to 400 kHz	0.056 + 1.3	-	0.012 + 1.2	-	0.012 + 12	0.012 + 120	0.057 + 120

The expanded uncertainties given in above table are expressed in Hz/Hz + Hz

Matrix J

Generating Instrument / Source - Phase Modulation

Carrier Frequency	Deviation	Modulation Frequency	
		200 Hz to 10 kHz	200 Hz to 20 kHz
150 kHz to 10 MHz	0.1 rad. to 4 rad.	0.046 + 0.0012	-
	4.01 rad. to 40 rad.	0.046 + 0.012	-
10 MHz to 1300 MHz	0.1 rad. to 4 rad.	-	0.034 + 0.0012
	4.01 rad. to 40 rad.	-	0.034 + 0.012
	40.1 rad. to 400 rad.	-	0.034 + 0.12
Carrier Frequency: 1300 MHz to 9000 MHz			
Downconverted Frequency	Deviation	Modulation Frequency	
		200 Hz to 10 kHz	200 Hz to 20 kHz
150 kHz to 10 MHz	0.1 rad. to 4 rad.	0.046 + 0.0012	-
	4.01 rad. to 40 rad.	0.046 + 0.012	-
10 MHz to 1300 MHz	0.1 rad. to 4 rad.	-	0.034 + 0.0012
	4.01 rad. to 40 rad.	-	0.034 + 0.012
	40.1 rad. to 400 rad.	-	0.034 + 0.12

The expanded uncertainties given in above table are expressed in rad./rad. + rad.

Signatories:

1. Poh Soo Leng
2. Tiong Tark Hoe
3. Poh Soo Beng
4. Kho Hup Ann
5. Tan Soon Leng (Except RF parameters)

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SCOPE OF CALIBRATION: TEMPERATURE

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
1. Temperature recorder / indicator			
B – TYPE	600 °C to 800 °C 800 °C to 1000 °C 1000 °C to 1550 °C 1550 °C to 1820 °C	0.34 °C 0.26 °C 0.23 °C 0.26 °C	By electrical simulation using Fluke calibrator model 5500A
E – TYPE	-250 °C to -100 °C -100 °C to -25 °C -25 °C to 350 °C 350 °C to 650 °C 650 °C to 1000 °C	0.39 °C 0.13 °C 0.11 °C 0.13 °C 0.17 °C	
J – TYPE	-210 °C to -100 °C -100 °C to -30 °C -30 °C to 150 °C 150 °C to 760 °C 760 °C to 1200 °C	0.21 °C 0.13 °C 0.11 °C 0.13 °C 0.18 °C	
K – TYPE	-200 °C to -100 °C -100 °C to -25 °C -25 °C to 120 °C 120 °C to 1000 °C 1000 °C to 1372 °C	0.26 °C 0.14 °C 0.13 °C 0.20 °C 0.31 °C	
N – TYPE	-200 °C to -100 °C -100 °C to -25 °C -25 °C to 120 °C 120 °C to 410 °C 410 °C to 1300 °C	0.31 °C 0.17 °C 0.15 °C 0.14 °C 0.21 °C	
R – TYPE	0 °C to 250 °C 250 °C to 400 °C 400 °C to 1000 °C 1000 °C to 1767 °C	0.44 °C 0.27 °C 0.26 °C 0.31 °C	
S – TYPE	0 °C to 250 °C 250 °C to 1000 °C 1000 °C to 1400 °C 1400 °C to 1767 °C	0.36 °C 0.28 °C 0.29 °C 0.35 °C	
T – TYPE	-250 °C to -150 °C -150 °C to 0 °C 0 °C to 120 °C 120 °C to 400 °C	0.48 °C 0.19 °C 0.13 °C 0.11 °C	

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SCOPE OF CALIBRATION: TEMPERATURE

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
1. Temperature recorder / indicator			
Pt 100 (385)	-200 °C to -80 °C	0.039 °C	By electrical measurement using Fluke calibrator model 5500A
	-80 °C to 0 °C	0.039 °C	
	0 °C to 100 °C	0.054 °C	
	100 °C to 300 °C	0.069 °C	
	300 °C to 400 °C	0.077 °C	
	400 °C to 630 °C	0.092 °C	
	630 °C to 800 °C	0.18 °C	
Pt 100 (3916)	-200 °C to -190 °C	0.20 °C	
	-190 °C to -80 °C	0.031 °C	
	-80 °C to 0 °C	0.039 °C	
	0 °C to 100 °C	0.046 °C	
	100 °C to 260 °C	0.054 °C	
	260 °C to 300 °C	0.062 °C	
	300 °C to 400 °C	0.069 °C	
	400 °C to 600 °C	0.077 °C	
Pt 100 (3926)	-200 °C to -80 °C	0.039 °C	
	-80 °C to 0 °C	0.039 °C	
	0 °C to 100 °C	0.054 °C	
	100 °C to 300 °C	0.069 °C	
	300 °C to 400 °C	0.077 °C	
2. Temperature calibrator / simulator			
B – TYPE	600 °C to 800 °C	0.34 °C	
	800 °C to 1000 °C	0.26 °C	
	1000 °C to 1550 °C	0.23 °C	
	1550 °C to 1820 °C	0.26 °C	
E – TYPE	-250 °C to -100 °C	0.39 °C	
	-100 °C to -25 °C	0.13 °C	
	-25 °C to 350 °C	0.11 °C	
	350 °C to 650 °C	0.13 °C	
	650 °C to 1000 °C	0.17 °C	
J – TYPE	-210 °C to -100 °C	0.21 °C	
	-100 °C to -30 °C	0.13 °C	
	-30 °C to 150 °C	0.11 °C	
	150 °C to 760 °C	0.13 °C	
	760 °C to 1200 °C	0.18 °C	
K – TYPE	-200 °C to -100 °C	0.26 °C	
	-100 °C to -25 °C	0.14 °C	
	-25 °C to 120 °C	0.13 °C	
	120 °C to 1000 °C	0.20 °C	
	1000 °C to 1372 °C	0.31 °C	

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SCOPE OF CALIBRATION: TEMPERATURE

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
2. Temperature calibrator / simulator			
N – TYPE	-200 °C to -100 °C -100 °C to -25 °C -25 °C to 120 °C 120 °C to 410 °C 410 °C to 1300 °C	0.31 °C 0.17 °C 0.15 °C 0.14 °C 0.21 °C	By electrical measurement using Fluke calibrator model 5500A
R – TYPE	0 °C to 250 °C 250 °C to 400 °C 400 °C to 1000 °C 1000 °C to 1767 °C	0.44 °C 0.27 °C 0.26 °C 0.31 °C	
S – TYPE	0 °C to 250 °C 250 °C to 1000 °C 1000 °C to 1400 °C 1400 °C to 1767°C	0.36 °C 0.28 °C 0.29 °C 0.35 °C	
T – TYPE	-250 °C to -150 °C -150 °C to 0 °C 0 °C to 120 °C 120 °C to 400 °C	0.48 °C 0.19 °C 0.13 °C 0.11 °C	
Pt 100	-200 °C to 800 °C	0.042 °C	

Signatories:

1. Poh Soo Leng
2. Tiong Tark Hoe
3. Tan Soon Leng

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SCOPE OF CALIBRATION: TEMPERATURE

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
3. Temperature and Humidity Indicator or Recorder	10 °C to 80 °C (At 50 %RH)	0.65 °C	Comparison with dry bulb thermometer in humidity chamber.
	30 %RH to 90 %RH (At 25 °C)	3.5 %RH	Comparison with wet and dry bulb thermometer in humidity chamber.
4. Radiation Thermometer	35 °C to 100 °C	0.46 °C	Using IR Calibrator with reference to ASTM E 2847- 2014
	100 °C to 200 °C	0.67 °C	
	200 °C to 350 °C	1.1 °C	
	350 °C to 500 °C	1.5 °C	

Signatories:

1. **Tiong Tark Hoe**
2. **Tan Soon Leng**

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**SCOPE OF CALIBRATION: ELECTRICAL
SITE CALIBRATION: CATEGORY I**

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)* (of reading)	Remarks
1. Measuring Instruments (a) DC Voltage	0 to 329.9999 mV 330 mV to 3.299999 V 3.3 V to 32.99999 V 33 V to 329.9999 V 330 V to 1020 V	16 µV/V + 0.77 µV 8.4 µV/V + 1.6 µV 9.2 µV/V + 12 µV 14 µV/V + 0.12 mV 14 µV/V + 1.2 mV	Generation using calibrator model Fluke 5520A
(b) DC Current	0 to 329.999 µA 330 µA to 3.29999 mA 3.3 mA to 32.9999 mA 33 mA to 329.999 mA 330 mA to 1.09999 A 1.1 A to 2.99999 A 3 A to 10.9999 A 11 A to 20.5 A	0.12 mA/A + 16 nA 77 µA/A + 24 nA 77 µA/A + 0.16 µA 77 µA/A + 1.6 µA 0.16 mA/A + 31 µA 0.29 mA/A + 31 µA 0.39 mA/A + 0.26 mA 0.77 mA/A + 0.58 mA	
(c) AC Voltage	1.0 mV to 1020 V	See Matrix K	
(d) AC Current	29 µA to 20.5 A	See Matrix L	
(e) (i) DC Resistance	0 to 10.9999 Ω	27 µΩ/Ω + 35 µΩ	
	11 Ω to 32.9999 Ω	23 µΩ/Ω + 7.1 µΩ	
	33 Ω to 109.9999 Ω	22 µΩ/Ω + 2.5 µΩ	
	110 Ω to 329.9999 Ω	22 µΩ/Ω + 0.76 µΩ	
	330 Ω to 1.099999 kΩ	22 µΩ/Ω + 28 µΩ	
	1.1 kΩ to 3.299999 kΩ	22 µΩ/Ω + 7.6 µΩ	
	3.3 kΩ to 10.99999 kΩ	22 µΩ/Ω + 0.28 mΩ	
	11 kΩ to 32.99999 kΩ	22 µΩ/Ω + 76 µΩ	
	33 kΩ to 109.9999 kΩ	22 µΩ/Ω + 2.5 mΩ	
	110 kΩ to 329.9999 kΩ	25 µΩ/Ω + 0.67 mΩ	
	330 kΩ to 1.099999 MΩ	25 µΩ/Ω + 22 mΩ	
	1.1 MΩ to 3.299999 MΩ	46 µΩ/Ω + 3.6 mΩ	
	3.3 MΩ to 10.99999 MΩ	0.10 mΩ/Ω + 53 mΩ	
	11 MΩ to 32.99999 MΩ	0.20 mΩ/Ω + 8.5 mΩ	
	33 MΩ to 109.9999 MΩ	0.39 mΩ/Ω + 0.14 Ω	
110 MΩ to 329.9999 MΩ	2.3 mΩ/Ω + 0.74 Ω		
330 MΩ to 1100 MΩ	12 mΩ/Ω + 4.4 Ω		
<u>Decade Value</u>			Decade Resistor model Genrad 1433T & Genrad 1433Z, Yokogawa 2793-03
0.01 Ω to 0.1 Ω	23 mΩ/Ω + 50 nΩ		
0.1 Ω to 1 Ω	4.6 mΩ/Ω + 25 nΩ		
1 Ω to 10 Ω	1.2 mΩ/Ω + 1.0 µΩ		
10 Ω to 100 Ω	0.46 mΩ/Ω + 0.25 µΩ		
100 Ω to 1000 Ω	0.12 mΩ/Ω + 8.6 µΩ		
1 kΩ to 10 kΩ	0.12 mΩ/Ω + 0.10 mΩ		
10 kΩ to 100 kΩ	0.12 mΩ/Ω + 1.0 mΩ		
100 kΩ to 1000 kΩ	0.12 mΩ/Ω + 10 mΩ		
1 MΩ to 10 MΩ	0.12 mΩ/Ω + 0.10 mΩ		
10 MΩ to 100 MΩ	2.3 mΩ / Ω + 0.50 mΩ		

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(e) (ii) DC Resistance (Insulation Tester)	100 Ω to 100 k Ω	0.57 m Ω / Ω + 57 m Ω	Decade Resistor/Standard Resistor model Yokogawa 2793-03 ChenHwa 9001-200 M Ω Zentech 9001-1000 M Ω Zentech 9001-2000 M Ω (Max Voltage = 1 kV) Insulation Resistance Standard (Max Voltage= 7.5 kV)
	100 k Ω to 1 M Ω	0.57 m Ω / Ω + 59 m Ω	
	1 M Ω to 10 M Ω	2.3 m Ω / Ω + 5.0 m Ω	
	10 M Ω to 100 M Ω	2.3 m Ω / Ω + 0.50 m Ω	
	<u>Fixed Value</u>		
	200 M Ω	3.4 M Ω	
	500 M Ω	5.8 M Ω	
	1000 M Ω	12 M Ω	
	2000 M Ω	23 M Ω	
	5000 M Ω	58 M Ω	
	10 G Ω	0.13 G Ω	
	100 G Ω	1.2 G Ω	
	(e) (iii) DC Resistance (Ground Bond / Continuity Tester)	100 m Ω	
500 m Ω		0.57 m Ω	
(f) DC / AC Resistance	<u>1 mΩ</u> DC to 1 kHz	0.0012 m Ω	Agilent 42030A
	<u>10 mΩ</u> DC to 1 kHz	0.012 m Ω	
	<u>100 mΩ</u> DC to 1 kHz	0.12 m Ω	
	<u>1 Ω</u> DC to 1 kHz	0.0012 Ω	
	<u>10 Ω</u> DC to 1 kHz	0.0035 Ω	
	1 MHz	0.014 Ω	
	2 MHz	0.017 Ω	
	3 MHz	0.023 Ω	
	4 MHz	0.029 Ω	
	5 MHz	0.046 Ω	
	10 MHz	0.12 Ω	
13 MHz	0.17 Ω		

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
(Continued)	<u>100 Ω</u> DC to 1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.023 Ω 0.14 Ω 0.14 Ω 0.17 Ω 0.17 Ω 0.23 Ω 0.58 Ω 0.81 Ω	Agilent 42030A
	<u>1 kΩ</u> DC to 1 kHz 100 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.00023 k Ω 0.0014 k Ω 0.00093 k Ω 0.0012 k Ω 0.0012 k Ω 0.0017 k Ω 0.0017 k Ω 0.0046 k Ω 0.0069 k Ω	
	<u>10 kΩ</u> DC to 1 kHz 100 kHz 1 MHz	0.0023 k Ω 0.0093 k Ω 0.0093 k Ω	
	<u>100 kΩ</u> DC to 1 kHz 100 kHz 1 MHz	0.023 k Ω 0.093 k Ω 0.14 k Ω	
(f) Frequency	1 μ Hz to 10 μ Hz 10 μ Hz to 100 μ Hz 100 μ Hz to 1 mHz 1 mHz to 10 mHz 10 mHz to 100 mHz 100 mHz to 1 Hz 1 Hz to 10 Hz 10 Hz to 100 Hz 100 Hz to 1 kHz 1 kHz to 10 kHz 10 kHz to 100 kHz 100 kHz to 1 MHz 1 MHz to 10 MHz 10 MHz to 100 MHz 100 MHz to 1 GHz 1 GHz to 4 GHz	(of reading) 8.5 nHz/Hz + 0.014 fHz 8.5 nHz/Hz + 0.14 fHz 8.5 nHz/Hz + 1.4 fHz 8.5 nHz/Hz + 14 fHz 8.5 nHz/Hz + 0.14 pHz 8.5 nHz/Hz + 1.4 pHz 8.5 nHz/Hz + 14 pHz 8.5 nHz/Hz + 0.14 nHz 8.5 nHz/Hz + 1.4 nHz 8.5 nHz/Hz + 14 nHz 8.5 nHz/Hz + 0.14 μ Hz 8.5 nHz/Hz + 1.4 μ Hz 8.5 nHz/Hz + 14 μ Hz 8.5 nHz/Hz + 0.14 mHz 8.5 nHz/Hz 1.4 mHz 5.8 nHz/Hz + 14 Hz	Agilent 33250A, Agilent 8648D, Philips PM9691

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
(g) Capacitance	0.19 nF to 1.0999 nF at 10 Hz to 10 kHz	3.9 mF/F + 7.7 pF	Generation using calibrator model Fluke 5520A
	1.1 nF to 3.2999 nF at 10 Hz to 3 kHz	3.9 mF/F + 7.7 pF	
	3.3 nF to 10.9999 nF at 10 Hz to 1 kHz	2.0 mF/F + 7.7 pF	
	11 nF to 109.999 nF at 10 Hz to 1 kHz	2.0 mF/F + 77 pF	
	110 nF to 329.999 nF at 10 Hz to 1 kHz	2.0 mF/F + 0.23 nF	
	0.33 µF to 1.09999 µF at 10 Hz to 600 Hz	2.0 mF/F + 0.77 nF	
	1.1 µF to 3.29999 µF at 10 Hz to 300 Hz	2.0 mF/F + 2.3 nF	
	3.3 µF to 10.9999 µF at 10 Hz to 150 Hz	2.0 mF/F + 7.7 nF	
	11 µF to 32.9999 µF at 10 Hz to 120 Hz	3.1 mF/F + 23 nF	
	33 µF to 109.999 µF at 10 Hz to 80 Hz	3.5 mF/F + 77 nF	
	110 µF to 329.999 µF at 0 Hz to 50 Hz	3.5 mF/F + 0.23 µF	
	0.33 mF to 1.09999 mF at 0 Hz to 20 Hz	3.5 mF/F + 0.77 µF	
	1.1 mF to 3.29999 mF at 0 Hz to 6 Hz	3.5 mF/F + 2.3 µF	
	3.3 mF to 10.9999 mF at 0 Hz to 2 Hz	3.5 mF/F + 7.7 µF	
	11 mF to 32.9999 mF at 0 Hz to 0.6 Hz	5.8 mF/F + 23 µF	
33 mF to 110 mF at 0 Hz to 0.2 Hz	8.4 mF/F + 77 µF		

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
2. Generating Instrument / Source			
(a1) DC Voltage	0 to 100 mV 100 mV to 1 V 1 V to 10 V 10 V to 100 V	5.7 µV/V + 0.34 µV 4.6 µV/V + 0.34 µV 4.6 µV/V + 0.57 µV 6.8 µV/V + 0.034 mV	HP 3458A, Vitrek 4620B
(a2) DC Voltage (Hipot)	100 V to 1000 V 1 kV to 2 kV 2 kV to 20 kV	6.8 µV/V + 0.12 mV 0.46 mV/V + 0.46 V 0.46 mV/V + 4.6 V	
(b1) AC Voltage	0 to 1000 V	See Matrix M	Fluke 5790A
(b2) AC Voltage (Hipot)	1 kV to 2 kV <u>at Frequency (Hz):</u> 20 to 100 100 to 400 2 kV to 20 kV <u>at Frequency (Hz):</u> 20 to 100	0.80 mV/V + 2.3 V 4.6 mV/V + 4.6 V 2.3 mV/V + 23 V	Vitrek 4620B
(c) DC Current	0 to 100 nA 100 nA to 1 µA 1 µA to 10 µA 10 µA to 100 µA 100 µA to 1 mA 1 mA to 10 mA 10 mA to 100 mA 100 mA to 1 A 1 A to 10 A 10 A to 20 A 20 A to 100 A	0.034 mA/A + 0.046 nA 0.023 mA/A + 0.046 nA 0.023 mA/A + 0.12 nA 0.023 mA/A + 0.91 nA 0.023 mA/A + 5.7 nA 0.023 mA/A + 0.057 µA 0.040 mA/A + 0.57 µA 0.13 mA/A + 0.012 mA 0.12 mA/A + 5.2 µA 0.12 mA/A + 2.1 µA 0.14 mA/A + 0.034 mA	HP 3458A, HP 34401A, Shunt
(d) AC Current	0 to 20 A 20 A to 100 A at DC to 1 kHz	See Matrix N 0.16 mA/A + 1.6 mA	
(e) DC Resistance	0 to 10 Ω 10 Ω to 100 Ω 100 Ω to 1 kΩ 1 kΩ to 10 kΩ 10 kΩ to 100 kΩ 100 kΩ to 1 MΩ 1 MΩ to 10 MΩ 10 MΩ to 100 MΩ 100 MΩ to 1 GΩ	0.017 mΩ/Ω + 0.057 mΩ 0.014 mΩ/Ω + 0.57 mΩ 0.012 mΩ/Ω + 0.57 mΩ 0.012 mΩ/Ω + 5.7 mΩ 0.012 mΩ/Ω + 0.057 Ω 0.017 mΩ/Ω + 2.3 Ω 0.057 mΩ/Ω + 0.12 kΩ 0.57 mΩ/Ω + 1.2 kΩ 5.7 mΩ/Ω + 0.012 MΩ	HP 3458A

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
(f) RF Power	0 dBm, 50 MHz (Ref.) -20 dBm to +30 dBm <u>At Frequency:</u> 100 kHz to 2.6 GHz <u>at Frequency:</u> 2.5 MHz to 1.3 GHz 0 dB -10 dB -20 dB -30 dB -40 dB -50 dB -60 dB -70 dB -80 dB -90 dB -100 dB -110 dB -120 dB -127 dB	0.051 dB 0.021 dB Ref. 0.14 dB 0.14 dB 0.18 dB 0.18 dB 0.19 dB 0.20 dB 0.21 dB 0.22 dB 0.22 dB 0.23 dB 0.41 dB 0.42 dB 0.42 dB	HP 8902A and 11722A
(g) Amplitude Modulation	<u>Carrier Frequency:</u> 150 kHz to 1300 MHz	See Matrix O	HP 8902A and 11722A
(h) Frequency Modulation	<u>Carrier Frequency:</u> 150 kHz to 1300 MHz	See Matrix P	
(i) Phase Modulation	<u>Carrier Frequency:</u> 150 kHz to 1300 MHz	See Matrix Q	
(j) (i) Amplitude Modulation Distortion	fc: 150 kHz to 10 MHz fm: 20 Hz to 10 kHz Depth: 5 % to 50 % Depth: 50 % to 99 % fc: 10 MHz to 1300 MHz fm: 20 Hz to 100 kHz Depth: 5 % to 50 % Depth: 50 % to 99 %	(of reading) 0.028 %/% + 0.34 % 0.014 %/% + 0.69 % 0.028 %/% + 0.34 % 0.014 %/% + 0.69 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency
(j) (ii) Frequency Modulation Distortion	fc: 250 kHz to 10 MHz fm: 20 Hz to 10 kHz Δf: < 40 kHz fc: 10 MHz to 1300 MHz fm: 20 Hz to 200 kHz Δf: < 400 kHz	0.069 %/% + 0.11 % 0.069 %/% + 0.11 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency Δf = Deviation

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)* (of reading)	Remarks
(j) (iii) Phase Modulation Distortion	fc: 150 kHz to 10 MHz fm: 200 Hz to 10 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	HP 8902A, Panasonic VP7722A fc = Carrier Frequency fm = Modulation Frequency Δf = Deviation
	fc: 10 MHz to 1300 MHz fm: 200 Hz to 20 kHz Δf : < 400 rad	0.069 %/% + 0.11 %	
(j) (iv) Audio Distortion	10 Hz to 15.99 kHz	0.14 %/%	Panasonic VP7722A
	16 kHz to 110 kHz	0.48 %/%	
(k) Frequency	100 mHz to 1 Hz	8.5 nHz/Hz + 1.4 pHz	Philips PM9691, Fluke PM6680B
	1 Hz to 10 Hz	8.5 nHz/Hz + 14 pHz	
	10 Hz to 100 Hz	8.5 nHz/Hz + 0.14 nHz	
	100 Hz to 1 kHz	8.5 nHz/Hz + 1.4 nHz	
	1 kHz to 10 kHz	8.5 nHz/Hz + 14 nHz	
	10 kHz to 100 kHz	8.5 nHz/Hz + 0.14 μ Hz	
	100 kHz to 1 MHz	8.5 nHz/Hz + 1.4 μ Hz	
	1 MHz to 10 MHz	8.5 nHz/Hz + 14 μ Hz	
	10 MHz to 100 MHz	8.5 nHz/Hz + 0.14 mHz	
	100 MHz to 1 GHz	8.5 nHz/Hz + 1.4 mHz	
	1 GHz to 2.7 GHz	8.5 nHz/Hz + 22 mHz	
(l) Timer	1 s to 3600 s	0.16 s	Stopwatch
3.(a) DC Cutoff Current (Hipot)	0 to 30 mA	0.38 mA/A + 2.4 μ A	Fluke 45
	30 mA to 100 mA	0.38 mA/A + 17 μ A	
	100 mA to 10 A	1.6 mA/A + 3.9 mA	
(b) AC Cutoff Current (Hipot)	0 mA to 30 mA <u>at Frequency (Hz):</u>		
	20 to 50	16 mA/A + 7.7 μ A	
	50 to 10 k	3.9 mA/A + 7.7 μ A	
	10 k to 20 k	16 mA/A + 16 μ A	
	30 mA to 100 mA <u>at Frequency (Hz):</u>		
	20 to 50	16 mA/A + 77 μ A	
	50 to 10 k	3.9 mA/A + 77 μ A	
	10 k to 20 k	16 mA/A + 0.16 mA	
	100 mA to 10 A <u>at Frequency (Hz):</u>		
	20 to 50	16 mA/A + 7.7 mA	
	50 to 2 k	7.7 mA/A + 7.7 mA	

Schedule

Issue date: 15 May 2023
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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)* (of reading)	Remarks
4. Oscilloscope (a) (i) DC Signal (in 1, 2, 5 sequence)	<u>50 Ω load:</u> 0 V to 2.1999 V 2.2 V to 6.6 V <u>1 MΩ load:</u> 0 V to 2.1999 V 2.2 V to 10.999 V 11 V to 130 V	1.9 mV/V + 0.043 mV 1.9 mV/V + 0.074 mV 0.38 mV/V + 0.048 mV 0.37 mV/V + 0.19 mV 0.37 mV/V + 2.0 mV	Fluke 5520A (SC600)
(a) (ii) Square Wave Signal (in 1, 2, 5 sequence)	<u>50 Ω load</u> at 10 Hz to 10 kHz 1 mV to 24.999 mV 25 mV to 109.99 mV 110 mV to 2.1999 V 2.2 V to 6.6 V <u>1 MΩ load</u> at 10 Hz to 10 kHz 1 mV to 24.999 mV 25 mV to 109.99 mV 110 mV to 2.1999 V 2.2 V to 10.999 V 11 V to 130 V	2.0 mV/V + 0.031 mV 2.0 mV/V + 0.031 mV 2.0 mV/V + 0.034 mV 2.0 mV/V + 0.074 mV 0.77 mV/V + 0.031 mV 0.77 mV/V + 0.031 mV 0.76 mV/V + 0.038 mV 0.76 mV/V + 0.12 mV 0.76 mV/V + 1.2 mV	
(b) Bandwidth	<u>Frequency (Hz):</u> 50 k to 1000 k 1 M to 600 M 600 M to 1050 M 1050 M to 4 G 4 G to 26 G	0.31 μHz/Hz + 5.7 Hz 0.20 μHz/Hz + 5.7 kHz 0.77 pHz/Hz + 5.7 Hz 2.3 pHz/Hz + 5.7 Hz 51 fHz/Hz + 0.57 kHz	Fluke 5520A (SC600), Agilent 8648D, HP 8673D, Novatech 2960AR
(c) Time Base	2 ns to 1000 ns 1 μs to 1000 μs 1 ms to 1000 ms 1 s to 5 s	2.3 μs/s + 0.31 ps 2.3 μs/s + 0.31 ns 2.3 μs/s + 0.31 μs 0.032 μs/s + 0.57 ms	Fluke 5520A (SC600)

Signatories:

1. **Poh Soo Leng**
2. **Tiong Tark Hoe**
3. **Kho Hup Ann**
4. **Tan Soon Leng (Except RF Parameters)**

Schedule

Issue date: 15 May 2023
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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Matrix K

Measuring Instrument - AC Voltage

Range	Frequency					
	Hz		kHz			
	10 to 45	0.045 to 10	10 to 20	20 to 50	50 to 100	100 to 500
1.0 mV to 32.999 mV	0.61 + 0.0046	0.12 + 0.0047	0.16 + 0.0047	0.77 + 0.0046	2.7 + 0.0092	6.2 + 0.039
33 mV to 329.999 mV	0.23 + 0.0062	0.10 + 0.0062	0.12 + 0.0062	0.27 + 0.0062	0.62 + 0.025	1.6 + 0.054
0.33 V to 3.29999 V	0.23 + 0.039	0.092 + 0.020	0.15 + 0.039	0.23 + 0.039	0.54 + 0.096	1.9 + 0.46
3.3 V to 32.9999 V	0.23 + 0.50	0.12 + 0.16	0.19 + 0.46	0.27 + 0.46	0.69 + 1.3	
	Frequency (kHz)					
	0.045 to 1	1 to 10	10 to 20	20 to 50	50 to 100	
33 V to 329.999 V	0.15 + 1.6	0.16 + 4.6	0.20 + 4.6	0.23 + 4.6	1.6 + 39	
	Frequency (kHz)					
	0.045 to 1	1 to 5	5 to 10			
330 V to 1020 V	0.23 + 7.9	0.20 + 7.9	0.23 + 7.9			

The expanded uncertainties given in above table are expressed in mV/V + mV

Matrix L

Measuring Instrument - AC Current

Range	Frequency					
	Hz		kHz			
	10 to 20	20 to 45	0.045 to 1	1 to 5	5 to 10	10 to 30
29 μ A to 329.99 μ A	1.6 + 0.000077	1.2 + 0.000077	0.96 + 0.000077	2.3 + 0.00012	6.2 + 0.00016	13 + 0.00031
0.33 mA to 3.2999 mA	1.6 + 0.00012	0.96 + 0.00012	0.77 + 0.00012	1.6 + 0.00016	3.9 + 0.00023	7.7 + 0.00046
3.3 mA to 32.999 mA	1.4 + 0.0016	0.69 + 0.0016	0.31 + 0.0016	0.62 + 0.0016	1.6 + 0.0023	3.1 + 0.0031
33 mA to 329.99 mA	1.4 + 0.016	0.69 + 0.016	0.31 + 0.016	0.77 + 0.039	1.6 + 0.077	3.1 + 0.16
	Frequency (Hz)	Frequency (kHz)				
	10 to 45	0.045 to 1	1 to 5	5 to 10		
0.33 A to 1.09999 A	1.4 + 0.077	0.39 + 0.077	4.6 + 0.77	20 + 3.9		
1.1 A to 2.99999 A	1.4 + 0.077	0.46 + 0.077	4.6 + 0.77	20 + 3.9		
	Frequency (Hz)	Frequency (kHz)				
	45 to 100	0.1 to 1	1 to 5			
3 A to 10.9999 A	0.46 + 1.6	0.77 + 1.6	23 + 1.6			
11 A to 20.5 A	0.92 + 3.9	1.2 + 3.9	23 + 3.9			

The expanded uncertainties given in above table are expressed in mA/A + m

Schedule

Issue date: 15 May 2023
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SCOPE OF CALIBRATION: ELECTRICAL SITE CALIBRATION: CATEGORY I

Matrix M

Generating Instrument / Source - AC Voltage

Range	Frequency						
	Hz		kHz				
	10 to 20	20 to 40	0.04 to 20	20 to 50	50 to 100	100 to 300	300 to 500
0 mV to 2.2 mV	1.3 + 0.00099	0.57 + 0.00099	0.32 + 0.00099	0.62 + 0.0016	0.92 + 0.0019	1.8 + 0.0031	1.9 + 0.0061
2.2 mV to 7 mV	0.65 + 0.00099	0.29 + 0.00099	0.16 + 0.00099	0.31 + 0.0016	0.46 + 0.0019	0.92 + 0.0031	0.99 + 0.0061
7 mV to 22 mV	0.22 + 0.00099	0.15 + 0.00099	0.084 + 0.00099	0.16 + 0.0016	0.24 + 0.0019	0.62 + 0.0031	0.68 + 0.0061
22 mV to 70 mV	0.19 + 0.0012	0.092 + 0.0012	0.05 + 0.0012	0.10 + 0.0016	0.20 + 0.002	0.39 + 0.0031	0.51 + 0.0061
70 mV to 220 mV	0.16 + 0.0012	0.065 + 0.0012	0.029 + 0.0012	0.053 + 0.0016	0.13 + 0.0019	0.19 + 0.0031	0.29 + 0.0061
220 mV to 700 mV	0.16 + 0.0012	0.058 + 0.0012	0.025 + 0.0012	0.039 + 0.0016	0.06 + 0.002	0.14 + 0.0031	0.23 + 0.0061
0.7 V to 2.2 V	0.16 + 0.0000019	0.051 + 0.0000057	0.019 + 0.000016	0.035 + 0.000081	0.054 + 0.000053	0.13 + 0.000024	0.20 + 0.000015
2.2 V to 7 V	0.16 + 0.000059	0.051 + 0.00018	0.019 + 0.00049	0.037 + 0.00025	0.062 + 0.00015	0.15 + 0.000062	0.31 + 0.000030
7 V to 22 V	0.16 + 0.000019	0.051 + 0.000056	0.021 + 0.00014	0.037 + 0.000078	0.062 + 0.000046	0.15 + 0.000020	0.31 + 0.000093
22 V to 70 V	0.16 + 0.00059	0.052 + 0.0018	0.025 + 0.0037	0.044 + 0.0021	0.072 + 0.0013	0.16 + 0.00059	0.32 + 0.00029
70 V to 220 V	0.16 + 0.00019	0.052 + 0.00055	0.024 + 0.0012	0.053 + 0.00054	0.075 + 0.00038	0.16 + 0.00018	0.38 + 0.000075
220 V to 700 V	0.16 + 0.0059	0.076 + 0.012	0.032 + 0.029	0.099 + 0.0091	0.38 + 0.0024		
700 V to 1000 V	0.16 + 0.0027	0.076 + 0.0054	0.029 + 0.014	0.099 + 0.0041	0.38 + 0.0011		

Range	Frequency				
	MHz				
	0.5 to 1	1.2 to 2	2 to 10	10 to 20	20 to 30
0 mV to 2.2 mV	2.7 + 0.0061	0.60 + 0.0013	1.3 + 0.0012	2.2 + 0.0012	5.3 + 0.0018
2.2 mV to 7 mV	1.80 + 0.0061	0.55 + 0.0012	0.77 + 0.0011	1.3 + 0.0010	2.9 + 0.0009
7 mV to 22 mV	1.30 + 0.0061	0.54 + 0.0003	0.77 + 0.00022	1.3 + 0.00013	2.9 + 0.000059
22 mV to 70 mV	0.84 + 0.0061	0.39 + 0.00024	0.77 + 0.00012	1.2 + 0.00008	2.7 + 0.00004
70 mV to 220 mV	0.76 + 0.0061	0.39 + 0.00013	0.76 + 0.000062	1.2 + 0.000041	2.7 + 0.000018
220 mV to 700 mV	0.73 + 0.0061	0.39 + 0.000076	0.76 + 0.000038	1.2 + 0.000026	2.7 + 0.000011
0.7 V to 2.2 V	0.69 + 0.00000042	0.38 + 0.000075	0.76 + 0.000038	1.2 + 0.000025	2.7 + 0.000011
2.2 V to 7 V	0.92 + 0.0000099	0.38 + 0.000024	0.76 + 0.000012	1.2 + 0.0000079	2.7 + 0.0000034
7 V to 22 V	0.92 + 0.0000031				
22 V to 70 V	0.92 + 0.000099				
70 V to 220 V					
220 V to 700 V					
700 V to 1000 V					

Schedule

Issue date: 15 May 2023
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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Matrix N

Generating Instrument / Source - AC Current

Range	Frequency						
	Hz			kHz			
	10 to 20	20 to 45	45 to 100	0.1 to 1			
0 to 100 μ A	4.6 + 0.000034	1.7 + 0.000034	0.68 + 0.000034	0.68 + 0.000034			
Range	Frequency (Hz)			Frequency (kHz)			
	10 to 20	20 to 45	45 to 100	0.1 to 5	5 to 20	20 to 50	50 to 100
100 μ A to 1 mA	4.6 + 0.00023	1.7 + 0.00023	0.68 + 0.00023	0.34 + 0.00023	0.68 + 0.00023	4.6 + 0.00046	6.3 + 0.0017
1 mA to 10 mA	4.6 + 0.0023	1.7 + 0.0023	0.68 + 0.0023	0.34 + 0.0023	0.68 + 0.0023	4.6 + 0.0046	6.3 + 0.017
10 mA to 100 mA	4.6 + 0.023	1.7 + 0.023	0.68 + 0.023	0.34 + 0.023	0.68 + 0.023	4.6 + 0.046	6.3 + 0.17
100 mA to 1 A	4.6 + 0.23	1.9 + 0.23	0.91 + 0.23	1.2 + 0.23	3.4 + 0.23	12 + 0.46	
Range	Frequency						
	Hz		kHz				
	3 to 5	5 to 10	0.01 to 5				
1 A to 3 A	13 + 2.1	4.0 + 2.1	1.7 + 2.1				
Range	Frequency (kHz)						
	0.001 to 1	1 to 5					
3 A to 10 A	0.24 + 0.27	0.38 + 1.9					
10 A to 20 A	0.25 + 0.21	0.42 + 1.5					

The expanded uncertainties given in above table are expressed in mA/A + mA

Schedule

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SCOPE OF CALIBRATION: ELECTRICAL

SITE CALIBRATION: CATEGORY I

Matrix O

Generating Instrument / Source - Amplitude Modulation

Carrier Frequency	Depth	Modulation Frequency			
		20 Hz to 50 Hz	50 Hz to 10 kHz	50 Hz to 50 kHz	50 kHz to 100 kHz
150 kHz to 10 MHz	1 % to 39.99 %	0.034 + 0.012	-	-	-
	5 % to 39.99 %	-	0.023 + 0.012	-	-
	40 % to 99 %	0.034 + 0.12	0.023 + 0.12	-	-
10 MHz to 1300 MHz	1 % to 39.99 %	-	-	0.012 + 0.012	-
	5 % to 39.99 %	0.034 + 0.012	-	-	0.034 + 0.012
	40 % to 99 %	0.034 + 0.12	-	0.012 + 0.12	0.034 + 0.12

The expanded uncertainties given in above table are expressed in %/% + %

Matrix P

Generating Instrument / Source - Frequency Modulation

Carrier Frequency	Deviation	Modulation Frequency						
		20 Hz to 50 Hz	20 Hz to 3.999 kHz	50 Hz to 3.999 kHz	4 kHz to 10 kHz	4 kHz to 39.99 kHz	40 kHz to 100 kHz	100 kHz to 200 kHz
250 kHz to 10 MHz	0 to 40 kHz	-	0.023 + 1.2	-	0.023 + 12	-	-	-
10 MHz to 1300 MHz	0 to 400 kHz	0.056 + 1.3	-	0.012 + 1.2	-	0.012 + 12	0.012 + 120	0.057 + 120

The expanded uncertainties given in above table are expressed in Hz/Hz + Hz

Matrix Q

Generating Instrument / Source - Phase Modulation

Carrier Frequency	Deviation	Modulation Frequency	
		200 Hz to 10 kHz	200 Hz to 20 kHz
150 kHz to 10 MHz	0.1 rad. to 4 rad.	0.046 + 0.0012	-
	4.01 rad. to 40 rad.	0.046 + 0.012	-
10 MHz to 1300 MHz	0.1 rad. to 4 rad.	-	0.034 + 0.0012
	4.01 rad. to 40 rad.	-	0.034 + 0.012
	40.1 rad. to 400 rad.	-	0.034 + 0.12

The expanded uncertainties given in above table are expressed in rad./rad. + rad.

Signatories:

1. Poh Soo Leng
2. Tiong Tark Hoe
3. Kho Hup Ann
4. Tan Soon Leng (Except RF Parameters)

Schedule

Issue date: 15 May 2023
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SCOPE OF CALIBRATION: TEMPERATURE

SITE CALIBRATION: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks	
1. Temperature Recorders / Indicators / Controllers			By electrical simulation using Fluke portable calibrator model 744	
J – TYPE	-210 °C to -100 °C -100 °C to 800 °C 800 °C to 1200 °C	0.31 °C 0.26 °C 0.26 °C		
K – TYPE	-200 °C to -100 °C -100 °C to 400 °C 400 °C to 1200 °C 1200 °C to 1372 °C	0.37 °C 0.31 °C 0.31 °C 0.31 °C		
T – TYPE	-250 °C to -200 °C -200 °C to 0 °C 0 °C to 400 °C	0.72 °C 0.37 °C 0.31 °C		
Pt 100 (385)	-200 °C to 0 °C 0 °C to 400 °C 400 °C to 800 °C	0.15 °C 0.20 °C 0.34 °C		
Pt 100 (3916)	-200 °C to -190 °C -190 °C to 0 °C 0 °C to 360 °C	0.27 °C 0.15 °C 0.20 °C		
Pt 100 (3926)	-200 °C to 0 °C 0 °C to 630 °C	0.15 °C 0.20 °C		
2. Temperature Controlled Enclosures	50 °C to 100 °C 150 °C to 300 °C 350 °C to 500 °C	0.26 °C 0.30 °C 0.59 °C		Using thermocouple sensor and based on AS 2853-1986

Signatories:

1. **Tiong Tark Hoe**
2. **Tan Soon Leng**