

Electricity and Magnetism, Malaysia, NML-SIRIM (National Metrology Laboratory, SIRIM Berhad)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty							
Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty matrix	Comments	NMI Service Identifier
DC voltage sources: single values	Zener references, standard cells	Voltage difference	1	1	V	Temperature	23 °C	0.2	µV	2	95%	No		Approved on 18 October 2004	1
DC voltage sources: single values	Zener references, standard cells	Voltage difference	1.018	1.018	V	Temperature	23 °C	0.2	µV	2	95%	No		Approved on 18 October 2004	1a
DC voltage sources: single values	Zener references	Voltage difference	10	10	V	Temperature	23 °C	0.4	µV	2	95%	No		Approved on 18 October 2004	2
DC voltage sources: low value ranges <= 10 V	DC voltage source, multifunction calibrator	Voltage divider	0.1	1	V	Temperature	23 °C	4	µV/V	2	95%	Yes		Approved on 18 October 2004	3
DC voltage sources: low value ranges <= 10 V	DC voltage source, multifunction calibrator	Voltage divider	1	10	V	Temperature	23 °C	2	µV/V	2	95%	Yes		Approved on 18 October 2004	4
DC voltage sources: value ranges > 10 V to 1100 V	DC voltage source, multifunction calibrator	Voltage divider	10	1000	V	Temperature	23 °C	2	µV/V	2	95%	Yes		Approved on 18 October 2004	5
DC resistance sources: lower than 1 Ω	Standard resistor	DCC bridge with current extender	0.001	0.001	Ω	Oil bath temperature	25 °C	5	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	6
DC resistance sources: lower than 1 Ω	Standard resistor	DCC bridge with current extender	0.01	0.01	Ω	Oil bath temperature	25 °C	5	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	7
DC resistance sources: lower than 1 Ω	Standard resistor	DCC bridge with current extender	0.1	0.1	Ω	Oil bath temperature	25 °C	4	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	8

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DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge	1	1	Ω	Oil bath temperature	25 °C	0.3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	9
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	10	10	Ω	Oil bath temperature	25 °C	0.3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	10
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	100	100	Ω	Oil bath temperature	25 °C	0.3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	11
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	1	1	kΩ	Oil bath temperature	25 °C	3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	12
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	10	10	kΩ	Oil bath temperature	25 °C	3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	13
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	100	100	kΩ	Oil bath temperature	25 °C	3	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	14
DC resistance sources: from 1 Ω to 1 MΩ	Standard resistor	DCC bridge and Hamon devices	1	1	MΩ	Oil bath temperature	25 °C	4	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	15
DC resistance sources: higher than 1 MΩ	Standard resistor	DCC bridge and Hamon devices	10	10	MΩ	Room temperature	23 °C	5	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	16
DC resistance sources: higher than 1 MΩ	Standard resistor	Modified Wheatstone bridge	100	100	MΩ	Maximum voltage	100 V	9	µΩ/Ω	2	95%	Yes		Approved on 18 October 2004	17

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Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty matrix	Comments	NMI Service Identifier
DC resistance sources: higher than 1 MΩ	Standard resistor	Modified Wheatstone bridge	1	1	GΩ	Maximum voltage	100 V	17	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	18
DC resistance sources: higher than 1 MΩ	Standard resistor	Modified Wheatstone bridge	10	10	GΩ	Maximum voltage	100 V	25	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	19
DC resistance sources: higher than 1 MΩ	Standard resistor	Modified Wheatstone bridge	100	100	GΩ	Maximum voltage	100 V	36	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	20
DC resistance sources: higher than 1 MΩ	Standard resistor	Modified Wheatstone bridge	1	1	TΩ	Maximum voltage	100 V	585	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	21
DC resistance sources: standards for high current	DC shunt	DCC bridge	0.001	0.1	Ω	Room temperature	23 °C	4 to 5	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	22
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	1	1	Ω	Room temperature	23 °C	1	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	23
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	10	10	Ω	Room temperature	23 °C	10	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	24
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	100	100	Ω	Room temperature	23 °C	7	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	25

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Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty matrix	Comments	NMI Service Identifier
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	1	1	kΩ	Room temperature	23 °C	5	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	26
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	10	10	kΩ	Room temperature	23 °C	5	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	27
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	100	100	kΩ	Room temperature	23 °C	8	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	28
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	1	1	MΩ	Room temperature	23 °C	14	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	29
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	10	10	MΩ	Room temperature	23 °C	24	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	30
DC resistance sources: multiple ranges	Multifunction calibrator	Transfer via Multifunction Transfer Standard (MTS)	100	100	MΩ	Room temperature	23 °C	198	μΩ/Ω	2	95%	Yes		Approved on 18 October 2004	31
DC current sources: low values < 0.1 mA	Multifunction calibrator	Voltage drop across a resistor	0.01	0.1	mA	Temperature	23 °C	11	μA/A	2	95%	Yes		Approved on 18 October 2004	32

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Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty matrix	Comments	NMI Service Identifier
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	0.1	1	mA	Temperature	23 °C	11	µA/A	2	95%	Yes		Approved on 18 October 2004	33
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	1	10	mA	Temperature	23 °C	11	µA/A	2	95%	Yes		Approved on 18 October 2004	34
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	10	100	mA	Temperature	23 °C	11	µA/A	2	95%	Yes		Approved on 18 October 2004	35
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	100	1000	mA	Temperature	23 °C	20	µA/A	2	95%	Yes		Approved on 18 October 2004	36
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	1	10	A	Temperature	23 °C	21	µA/A	2	95%	Yes		Approved on 18 October 2004	37
DC current sources: intermediate values > 0.1 mA to 20 A	Multifunction calibrator	Voltage drop across a resistor	10	20	A	Temperature	23 °C	100	µA/A	2	95%	Yes		Approved on 18 October 2004	38
DC current sources: high values > 20 A to 100 A	Current generator	Voltage drop across a resistor	20	50	A	Temperature	23 °C	100	µA/A	2	95%	Yes		Approved on 18 October 2004	39
DC current sources: high values > 20 A to 100 A	Current generator	Voltage drop across a resistor	50	100	A	Temperature	23 °C	100	µA/A	2	95%	Yes		Approved on 18 October 2004	40
Capacitance: low loss capacitor	Standard capacitor (sealed, dry-nitrogen or fused silica dielectric)	Capacitance bridge, substitution method	1	1000	pF	Frequency	1 kHz	5	µF/F	2	95%	Yes		Approved on 18 October 2004	41

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Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty matrix	Comments	NMI Service Identifier
Inductance: self inductance < 1 mH	Fixed inductor, variable inductor, inductance box	Inductance meter, substitution method	100	100	µH	Frequency	1 kHz	300	µH/H	2	95%	Yes		Approved on 18 October 2004	42
Inductance: self inductance 1 mH to 1 H	Fixed inductor, variable inductor, inductance box	Inductance meter, substitution method	1	1000	mH	Frequency	1 kHz	200	µH/H	2	95%	Yes		Approved on 18 October 2004	43
Inductance: self inductance > 1 H	Fixed inductor, variable inductor, inductance box	Inductance meter, substitution method	10	10	H	Frequency	1 kHz	200	µH/H	2	95%	Yes		Approved on 18 October 2004	44
AC/DC voltage transfer: AC/DC transfer difference at medium voltages	Thermal converter (directly connected), AC/DC transfer standard	AC/DC difference	1	4	V	Frequency	10 Hz to 1 MHz	5 to 38	µV/V	2	95%	Yes	Matrix 1	Approved on 18 October 2004	45
AC/DC voltage transfer: AC/DC transfer difference at higher voltages	Thermal converter (directly connected), AC/DC transfer standard	AC/DC difference	6	12	V	Frequency	10 Hz to 1 MHz	7 to 49	µV/V	2	95%	Yes	Matrix 1	Approved on 18 October 2004	46
AC/DC voltage transfer: AC/DC transfer difference at higher voltages	Thermal converter (directly connected), AC/DC transfer standard	AC/DC difference	20	30	V	Frequency	10 Hz to 500 kHz	8 to 35	µV/V	2	95%	Yes	Matrix 1	Approved on 18 October 2004	47
AC/DC voltage transfer: AC/DC transfer difference at higher voltages	Thermal converter with range extender, AC/DC transfer standard	AC/DC difference	40	40	V	Frequency	10 Hz to 300 kHz	8 to 29	µV/V	2	95%	Yes	Matrix 1	Approved on 18 October 2004	48
AC/DC voltage transfer: AC/DC transfer difference at higher voltages	Thermal converter with range extender, AC/DC transfer standard	AC/DC difference	60	1000	V	Frequency	10 Hz to 100 kHz	9 to 45	µV/V	2	95%	Yes	Matrix 1	Approved on 18 October 2004	49
AC voltage up to 1000 V: sources	Multifunction calibrator	AC/DC transfer	0.5	1000	V	Frequency	10 Hz to 1 MHz	7 to 53	µV/V	2	95%	Yes	Matrix 2	Approved on 18 October 2004	50

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AC voltage up to 1000 V: meters	Digital multimeter	AC/DC transfer	2	10	mV	Frequency	10 Hz to 1 MHz	345	µV/V	2	95%	Yes		Approved on 18 October 2004	51
AC voltage up to 1000 V: meters	Digital multimeter	AC/DC transfer	20	100	mV	Frequency	10 Hz to 1 MHz	169	µV/V	2	95%	Yes		Approved on 18 October 2004	52
AC voltage up to 1000 V: meters	Digital multimeter	AC/DC transfer	200	200	mV	Frequency	10 Hz to 1 MHz	161	µV/V	2	95%	Yes		Approved on 18 October 2004	53
AC current up to 100 A: sources	Multifunction calibrator, transconductance amplifier	AC/DC transfer	0.01	20	A	Frequency	40 Hz to 10 kHz	20 to 132	µA/A	2	95%	Yes	Matrix 3	Approved on 18 October 2004	54
AC power and energy: single phase power at frequencies <= 400 Hz	Power meter, energy meter, power converter, wattmeter	Direct comparison	60	1200	W	Frequency	50 Hz	300	µW/W	2	95%	Yes		Approved on 18 October 2004	55
						Power factor	0.5 to 1								
						Voltage	120 V, 240 V								
						Current	1 A, 5 A								
AC power and energy: three phase	Energy meter	Direct comparison	60	1200	Wh	Frequency	50 Hz	800	µWh/Wh	2	95%	Yes		Approved on 18 October 2004	56
						Power factor	0.5								
						Voltage	120 V, 240 V								
						Current	1 A, 5 A								
						Test time	1 hour								

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AC power and energy: three phase	Energy meter	Direct comparison	60	1200	Wh	Frequency	50 Hz	700	µWh/ Wh	2	95%	Yes		Approved on 18 October 2004	56a
						Power factor	1								
						Voltage	120 V, 240 V								
						Current	1 A, 5 A								
						Test time	1 hour								
AC high voltage: ratio error	High voltage transformer	Ratio test set	-2	+2	%	Frequency	50 Hz	0.04	%	2	95%	Yes		Approved on 18 October 2004	57
						Voltage	11 kV maximum								
AC high voltage: phase displacement	High voltage transformer	Ratio test set	-80	+80	'	Frequency	50 Hz	0.7	'	2	95%	No		Approved on 18 October 2004	58
						Voltage	11 kV maximum								
AC high current: ratio error	Current transformer	Ratio test set	-2	+2	%	Frequency	50 Hz	0.04	%	2	95%	Yes		Approved on 18 October 2004	59
						Current	2000 A maximum								
AC high current: phase displacement	Current transformer	Ratio test set	-80	+80	'	Frequency	50 Hz	0.7	'	2	95%	No		Approved on 18 October 2004	60
						Current	2000 A maximum								

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Magnetic fields below 50 kHz: DC magnetic flux density and applied magnetic field strength	Magnetic flux density meter, magnetic field strength meter	NMR	1E-04	2	T	Frequency	4 kHz to 100 MHz	5	µT/T	2	95%	Yes		Approved on 18 October 2004	61
Magnetic fields below 50 kHz: DC magnetic flux density and applied magnetic field strength	Magnetic flux density meter, magnetic field strength meter	Helmholtz coil	0.1	25	mT	DC current	0.2 mA to 4 A	0.8	µT/mT	2	95%	Yes		Approved on 18 October 2004	62
Magnetic fields below 50 kHz: DC magnetic flux density and applied magnetic field strength	Magnetic flux density meter, magnetic field strength meter	NMR and electromagnet	0.1	1.6	T	DC current	1 A to 70 A	0.3	mT/T	2	95%	Yes		Approved on 18 October 2004	63
RF power: calibration factor and effective efficiency on coaxial lines	Thermistor mount 50 Ω, Type-N	DC substitution	0.9	1		Frequency	10 MHz to 18 GHz	1.8	%	2	95%	Yes		Approved on 18 October 2004	64
RF power: calibration factor and effective efficiency on coaxial lines	Thermistor mount 50 Ω, APC7	DC substitution	0.9	1		Frequency	1 GHz to 18 GHz	1.8	%	2	95%	Yes		Approved on 18 October 2004	65
Scalar RF reflection coefficient and attenuation: attenuation on coaxials	Passive device	Direct substitution	0	50	dB	Frequency	50 MHz to 18 GHz	0.8	dB	2	95%	No		Approved on 18 October 2004	66

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Scattering parameters: reflection coefficient on coaxial lines: magnitude	Passive device: 50 Ω, type-N	Vector network analyzer	0	0.1		Frequency	50 MHz to 18 GHz	0.015		2	95%	No		Approved on 18 October 2004	67

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Uncertainty table: Matrix 1

AC/DC voltage transfer: AC/DC transfer difference at medium voltages, NML-SIRIM Internal Identifier: 45

AC/DC voltage transfer: AC/DC transfer difference at higher voltages, NML-SIRIM Internal Identifier: 46, 47, 48, and 49

	10 Hz	20 Hz	30 Hz	40 Hz	57 Hz	100 Hz	400 Hz	1 kHz	5 kHz	10 kHz	20 kHz	30 kHz	50 kHz	100 kHz	200 kHz	300 kHz	500 kHz	1 MHz
1 V	10	8	7	7	7	7	7	7	7	7	8	8	11	15	19	24	38	
2 V	13	8	5	6	5	5	5	5	5	6	6	6	8	10	14	18	28	
3 V	10	7	6	5	5	5	5	5	5	6	6	6	7	8	11	14	19	29
4 V	11	8	7	6	6	6	6	6	6	6	7	8	10	13	17	22	34	
6 V	12	8	7	7	7	7	7	7	7	7	8	8	11	16	21	27	45	
10 V	11	8	7	7	7	7	7	7	7	7	8	8	11	16	21	27	45	
12 V	11	8	7	7	7	7	7	7	7	7	8	8	9	12	17	22	29	49
20 V	13	9	8	8	8	8	8	8	8	8	8	9	9	13	19	26	34	-
30 V	12	9	8	8	8	8	8	8	9	9	9	10	11	15	20	27	35	-
40 V	12	9	9	8	8	8	8	8	9	9	9	10	11	16	21	29	-	-
60 V	13	10	9	9	9	9	9	9	10	10	10	11	12	17	-	-	-	-
100 V	12	10	9	9	9	9	9	9	10	10	10	11	13	17	-	-	-	-
120 V	13	11	10	10	10	10	10	10	10	10	11	11	14	18	-	-	-	-
200 V	14	11	11	10	10	10	10	10	11	11	11	12	14	20	-	-	-	-
300 V	15	12	12	11	11	11	11	11	11	11	12	13	16	23	-	-	-	-
400 V	15	13	12	12	12	12	12	12	12	12	13	15	19	27	-	-	-	-
600 V	16	14	14	14	14	14	14	14	15	15	17	19	26	36	-	-	-	-
1000 V	16	15	15	15	15	15	15	15	17	17	19	23	32	45	-	-	-	-

The expanded uncertainties given in this table are expressed in $\mu\text{V}/\text{V}$.

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Uncertainty table: Matrix 2

AC voltage up to 1000 V: sources, NML-SIRIM Internal Identifier: 50

	10 Hz	20 Hz	30 Hz	40 Hz	57 Hz	100 Hz	400 Hz	1 kHz	5 kHz	10 kHz	20 kHz	30 kHz	50 kHz	100 kHz	200 kHz	300 kHz	500 kHz	1 MHz
1 V	18	12	10	10	13	10	10	9	9	9	11	13	23	37	27	28	38	49
2 V	17	12	10	9	9	10	9	7	9	11	10	8	11	14	14	18	22	32
3 V	15	9	12	8	10	11	11	8	8	14	18	16	23	23	22	23	27	38
4 V	18	14	13	12	81	13	11	10	11	12	10	12	13	16	19	21	25	39
6 V	18	12	13	13	12	13	12	11	14	12	13	13	14	15	19	24	32	51
10 V	21	22	19	19	19	16	17	18	20	21	22	17	24	22	24	30	34	53
12 V	16	13	12	12	11	13	12	12	11	12	13	13	14	16	20	26	34	-
20 V	19	14	12	14	12	12	11	12	15	13	12	13	14	18	25	30	39	-
30 V	25	19	17	13	17	18	16	14	13	13	13	14	25	24	29	36	-	-
40 V	19	13	14	13	13	14	13	13	14	14	14	15	14	21	27	-	-	-
60 V	19	15	15	14	15	15	14	14	16	15	14	17	17	21	-	-	-	-
100 V	21	25	18	21	18	20	20	16	23	21	19	19	20	28	-	-	-	-
120 V	17	13	13	13	13	12	13	13	13	12	15	13	16	21	-	-	-	-
200 V	17	13	13	12	12	12	12	12	13	13	13	14	17	24	-	-	-	-
300 V	-	-	-	14	14	18	14	15	14	14	15	16	-	-	-	-	-	-
400 V	-	-	-	15	14	14	14	14	14	14	15	17	-	-	-	-	-	-
600 V	-	-	-	16	16	16	16	16	17	17	19	22	-	-	-	-	-	-
1000 V	-	-	-	17	18	17	17	18	19	19	19	20	26	-	-	-	-	-

The expanded uncertainties given in this table are expressed in $\mu\text{V/V}$.

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Uncertainty table: Matrix 3

AC current up to 100 A: sources, NML-SIRIM Internal Identifier: 54

	40 Hz	57 Hz	400 Hz	1 kHz	2 kHz	5 kHz	10 kHz
10 mA	21	21	21	21	21	21	22
25 mA	23	20	20	23	24	24	25
50 mA	23	23	23	23	24	24	25
100 mA	26	26	26	26	26	27	27
250 mA	33	33	33	33	33	33	34
1 A	37	37	37	37	37	46	65
2.5 A	37	37	37	37	37	51	70
5 A	37	37	37	37	37	51	74
10 A	37	37	37	37	37	52	81
20 A	105	105	105	105	106	112	132

The expanded uncertainties given in this table are expressed in $\mu\text{A/A}$.