German Accreditation Body

Annex to the Accreditation Certificate D-K-15019-01-01
In accordance with DIN EN ISO/IEC 17025:2018

Valid from: **18.08.2026**

Date of issue: 18.08.2026

This annex is a part of the accreditation certificate D-K-15019-01-00.

Holder of the accreditation certificate:

esz AG calibration & metrology
Max-Planck-Straße 16, 82223 Eichenau

with the locations

esz AG calibration & metrology
Max-Planck-Straße 16, 82223 Eichenau

esz AG calibration & metrology
Richard-Willstätter-Str. 14, 12489 Berlin

esz AG calibration & metrology
Donaustraße 68, 68199 Mannheim

esz AG calibration & metrology
Nordostpark 12, 90411 Nuremberg

esz AG calibration & metrology
Webereistraße 3, 48565 Steinfurt

esz AG calibration & metrology
Lemböckgasse 49, A-1230 Vienna, AUSTRIA

This certificate annex is only valid together with the written accreditation certificate and reflects the status as indicated by the date of issue. The current status of any given scope of accreditation can be found in the directory of accredited bodies maintained by Deutsche Akkreditierungsstelle GmbH at https://www.dakks.de.

The calibration laboratory meets the requirements of DIN EN ISO/IEC 17025:2018 to carry out the conformity assessment activities listed in this annex. The calibration laboratory meets additional legal and normative requirements, if applicable, including those in relevant sectoral schemes, provided that these are explicitly confirmed below.

The management system requirements of DIN EN ISO/IEC 17025 are written in the language relevant to the operations of calibration laboratories and they conform to the principles of DIN EN ISO 9001.

Calibrations in the fields of:

Electrical measurement quantities

Direct current and low frequency

- **Voltage** [a)]
- **Current** [a)]
- **Voltage ratio** [a)]
- **High voltage measurement quantities** [a)]
- **Resistance** [a)]
- **Charge** [a)]
- **Phase angle** [a)]
- **Electric power** [a)]
- **Power factor** [a)]
- **Electric energy** [a)]
- **Inductance** [a)]
- **Capacitance** [a)]

Time and frequency

- **Time interval** [a)]
- **Frequency and rotational frequency** [a)]

Dimensional measurement quantities

Length

- **Diameter** [a)]
- **Thread** [a)]
- **Parallel end dimensions**
- **Length measuring instruments** [a)]
- **Line scales, distances** [a)]

Angle

- **Inclination**

High-frequency and radiation measurement quantities

High frequency measurement quantities

- **RF attenuation** [a)]
- **RF impedance (reflection coefficient)** [a)]
- **RF power** [a)]
- **RF voltage** [a)]
- **RF current** [a)]
- **RF noise**
- **Pulse-shaped measurement quantities** [a)]
- **Oscilloscope measurement quantities** [a)]
- **Rise time** [a)]
- **Bandwidth** [a)]

Optical measurement quantities

- **Radiometry** [a)]
- **Photometry** [a)]

[a)] **also on-site calibrations**

For the measurement quantities/calibration objects marked with *, the calibration laboratory is permitted to apply the standards/calibration guidelines listed here in different editions without the need for prior notification to and approval by DAkkS.
The calibration laboratory maintains an up-to-date list of all standards/calibration guidelines within the flexible scope of accreditation.

Electrical measurement quantities – DC power and low frequency

DC and AC voltage

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage	0 V		35 nV	Short-circuit bridge
	0 V to 200 mV		14 nV	Calibration of voltage sources
	> 200 mV to 2 V		0.10 µV	
	> 2 V to 10 V		0.16 µV	
	0 mV to < 200 mV		12 nV	Calibration of the non-linearity of voltmeters
	200 mV to < 2 V		40 nV	
	2 V to 10 V		0.25 µV	
	> 0 mV to < 2 V		0.12 µV	Calibration of voltmeter deviation
	2 V to 10 V		0.27 µV	
	> 10 V to 100 V		$0.28 \cdot 10^{-6} \cdot U$ - 0.34 µV	U = measured value
	> 100 V to 1050 V		$0.24 \cdot 10^{-6} \cdot U$ + 64 µV	
High voltage	1 kV to 10 kV		$7.9 \cdot 10^{-6} \cdot U$ + 17 mV	
	> 10 kV to 60 kV		$46 \cdot 10^{-6} \cdot U$ + 0.95 V	
AC voltage	2 mV to 10 mV	10 Hz; 12.5 Hz	$26 \cdot 10^{-6} \cdot U$ + 0.11 µV	U = measured value
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$28 \cdot 10^{-6} \cdot U$ + 23 nV	When calibrating measuring instruments, the influence of load impedance and repeatability must be taken into account
		48 Hz; 60 Hz; 62.5 Hz	$19 \cdot 10^{-6} \cdot U$ + 0.11 µV	
		625 Hz; 937.5 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot U$ + 0.12 µV	
	> 10 mV to 60 mV	10 Hz; 12.5 Hz	$13 \cdot 10^{-6} \cdot U$ + 0.19 µV	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$8.6 \cdot 10^{-6} \cdot U$ + 0.16 µV	
		48 Hz; 60 Hz; 62.5 Hz	$10 \cdot 10^{-6} \cdot U$ + 0.16 µV	
		625 Hz; 937.5 Hz; 1 kHz	$9.1 \cdot 10^{-6} \cdot U$ + 0.16 µV	
	60 mV to 7.2 V	10 Hz; 12.5 Hz	$10 \cdot 10^{-6} \cdot U$ + 0.14 µV	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$2.2 \cdot 10^{-6} \cdot U$ + 0.16 µV	
		48 Hz; 60 Hz; 62.5 Hz	$4.2 \cdot 10^{-6} \cdot U$ + 0.14 µV	
		625 Hz; 937.5 Hz; 1 kHz	$1.4 \cdot 10^{-6} \cdot U$ + 0.16 µV	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Ranges	2 mV to 22 V 2 mV	10 Hz to 1 MHz 10 Hz; 20 Hz; 40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz; 300 kHz	$0.29 \cdot 10^{-3} \cdot U$	U = measured value When calibrating measuring instruments, the influence of the load/connection impedance and repeatability must be taken into account
		500 kHz	$0.32 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.43 \cdot 10^{-3} \cdot U$	
	6 mV	10 Hz	$0.16 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.14 \cdot 10^{-3} \cdot U$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$0.13 \cdot 10^{-3} \cdot U$	Intermediate values increase the measurement uncertainty
		300 kHz	$0.15 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.17 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.22 \cdot 10^{-3} \cdot U$	
	10 mV	10 Hz	$0.13 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.12 \cdot 10^{-3} \cdot U$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$0.10 \cdot 10^{-3} \cdot U$	
		300 kHz	$0.12 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.16 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.21 \cdot 10^{-3} \cdot U$	
	20 mV	10 Hz	$0.12 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.11 \cdot 10^{-3} \cdot U$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$86 \cdot 10^{-6} \cdot U$	
		300 kHz	$0.11 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.13 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.17 \cdot 10^{-3} \cdot U$	
	60 mV	10 Hz	$54 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$32 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$46 \cdot 10^{-6} \cdot U$	
		500 kHz	$60 \cdot 10^{-6} \cdot U$	
		1 MHz	$95 \cdot 10^{-6} \cdot U$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Ranges	100 mV	10 Hz	$22 \cdot 10^{-6} \cdot U$	U = measured value. When calibrating measuring instruments, the influence of the load/connection impedance and repeatability must be taken into account Intermediate values increase the measurement uncertainty
		20 Hz; 40 Hz	$20 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$17 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$15 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$25 \cdot 10^{-6} \cdot U$	
		500 kHz	$34 \cdot 10^{-6} \cdot U$	
		1 MHz	$53 \cdot 10^{-6} \cdot U$	
	200 mV	10 Hz	$37 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$18 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$15 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$12 \cdot 10^{-6} \cdot U$	
		100 kHz	$13 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$23 \cdot 10^{-6} \cdot U$	
		500 kHz	$33 \cdot 10^{-6} \cdot U$	
		1 MHz	$49 \cdot 10^{-6} \cdot U$	
	600 mV	10 Hz	$31 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$13 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$10 \cdot 10^{-6} \cdot U$	
		100 kHz	$11 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$21 \cdot 10^{-6} \cdot U$	
		500 kHz	$33 \cdot 10^{-6} \cdot U$	
		1 MHz	$50 \cdot 10^{-6} \cdot U$	
	1 V	10 Hz	$17 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$11 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$7 \cdot 10^{-6} \cdot U$	
		100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$13 \cdot 10^{-6} \cdot U$	
		500 kHz	$17 \cdot 10^{-6} \cdot U$	
		1 MHz	$30 \cdot 10^{-6} \cdot U$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Ranges	2 V	10 Hz	$38 \cdot 10^{-6} \cdot U$	U = measured value When calibrating measuring instruments, the influence of the load/connection impedance and repeatability must be taken into account Intermediate values increase the measurement uncertainty
		20 Hz; 40 Hz	$12 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$7 \cdot 10^{-6} \cdot U$	
		100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$11 \cdot 10^{-6} \cdot U$	
		500 kHz	$16 \cdot 10^{-6} \cdot U$	
		1 MHz	$29 \cdot 10^{-6} \cdot U$	
	4 V; 6 V	10 Hz	$32 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$13 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$21 \cdot 10^{-6} \cdot U$	
		500 kHz	$32 \cdot 10^{-6} \cdot U$	
		1 MHz	$35 \cdot 10^{-6} \cdot U$	
	8 V; 10 V	10 Hz	$19 \cdot 10^{-6} \cdot U$	
		20 Hz	$13 \cdot 10^{-6} \cdot U$	
		40 Hz	$10 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$8 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$15 \cdot 10^{-6} \cdot U$	
		500 kHz	$30 \cdot 10^{-6} \cdot U$	
		1 MHz	$47 \cdot 10^{-6} \cdot U$	
	20 V	10 Hz	$29 \cdot 10^{-6} \cdot U$	
		20 Hz	$14 \cdot 10^{-6} \cdot U$	
		40 Hz	$11 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$9 \cdot 10^{-6} \cdot U$	
		100 kHz	$10 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$16 \cdot 10^{-6} \cdot U$	
		500 kHz	$32 \cdot 10^{-6} \cdot U$	
		1 MHz	$49 \cdot 10^{-6} \cdot U$	
	12 V; 15 V; 19 V	1 kHz; 10 kHz; 100 kHz	$10 \cdot 10^{-6} \cdot U$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Ranges	> 22 V to 70 V 60 V	10 Hz to 300 kHz 10 Hz	$23 \cdot 10^{-6} \cdot U$	U = measured value. When calibrating measuring instruments, the influence of the load/connection impedance and repeatability must be taken into account Intermediate values increase the measurement uncertainty
		20 Hz; 40 Hz	$15 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$13 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz	$9 \cdot 10^{-6} \cdot U$	
		70 kHz	$10 \cdot 10^{-6} \cdot U$	
		100 kHz	$14 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$22 \cdot 10^{-6} \cdot U$	
	> 70 V to 110 V 100 V	10 Hz to 200 kHz 10 Hz; 20 Hz	$19 \cdot 10^{-6} \cdot U$	
		40 Hz	$15 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz	$13 \cdot 10^{-6} \cdot U$	
		70 kHz	$20 \cdot 10^{-6} \cdot U$	
		100 kHz	$32 \cdot 10^{-6} \cdot U$	
		200 kHz	$37 \cdot 10^{-6} \cdot U$	
	> 110 V to 700 V 200 V	10 Hz to 100 kHz 10 Hz	$27 \cdot 10^{-6} \cdot U$	
		20 Hz	$21 \cdot 10^{-6} \cdot U$	
		40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$15 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz;	$13 \cdot 10^{-6} \cdot U$	
		10 kHz; 20 kHz; 50 kHz	$17 \cdot 10^{-6} \cdot U$	
		70 kHz	$20 \cdot 10^{-6} \cdot U$	
		100 kHz	$31 \cdot 10^{-6} \cdot U$	
	600 V	40 Hz	$17 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$14 \cdot 10^{-6} \cdot U$	
		1 kHz; 10 kHz; 20 kHz; 50 kHz	$16 \cdot 10^{-6} \cdot U$	
		70 kHz	$25 \cdot 10^{-6} \cdot U$	
		100 kHz	$37 \cdot 10^{-6} \cdot U$	
	> 700 V to 1000 V 1000 V	10 Hz to 100 kHz 40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz	$14 \cdot 10^{-6} \cdot U$	
		50 kHz	$25 \cdot 10^{-6} \cdot U$	
		70 kHz	$32 \cdot 10^{-6} \cdot U$	
		100 kHz	$42 \cdot 10^{-6} \cdot U$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
High voltage Sources	1 kV to 10 kV	10 Hz to 20 kHz > 20 kHz to 50 kHz > 50 kHz to 100 kHz	$50 \cdot 10^{-6} \cdot U + 2$ V $0.34 \cdot 10^{-3} \cdot U + 1.6$ V $1.6 \cdot 10^{-3} \cdot U + 0.9$ V	U = measured value
	> 10 kV to 40 kV	10 Hz to 20 kHz > 20 kHz to 50 kHz > 50 kHz to 100 kHz	$0.10 \cdot 10^{-3} \cdot U + 3.7$ V $0.43 \cdot 10^{-3} \cdot U + 2.1$ V $1.7 \cdot 10^{-3} \cdot U + 0.7$ V	
Measuring instruments	1 kV to 10 kV	45 Hz to 65 Hz	$50 \cdot 10^{-6} \cdot U + 2$ V	
	10 kV to 30 kV		$0.10 \cdot 10^{-3} \cdot U + 3.7$ V	
Square-wave voltage	5 mV to 220 mV	1 Hz to 10 kHz	$10 \cdot 10^{-6} \cdot U + 0.36$ µV $+ 6.4 \cdot 10^{-9}$ V/Hz · f	Sampling method at 10 MΩ load range Range in voltage peak-to-peak U = peak value of the voltage f = frequency The additional influence of deviating load conditions (such as 50 Ω or 1 MΩ) must be taken into account
	> 220 mV to 2.2 V		$9.3 \cdot 10^{-6} \cdot U + 0.35$ µV $+ 7.0 \cdot 10^{-9}$ V/Hz · f	
	> 2.2 V to 22 V		$9.3 \cdot 10^{-6} \cdot U + 0.58$ µV $+ 14 \cdot 10^{-9}$ V/Hz · f	
	> 22 V to 220 V		$12 \cdot 10^{-6} \cdot U + 35$ µV $+ 75 \cdot 10^{-9}$ V/Hz · f	
AC voltage Amplitude parameters	5 mV to 5 V	DC to 10 MHz > 10 MHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 1 GHz	$25 \cdot 10^{-3} \cdot U + 0.2$ µV $37 \cdot 10^{-3} \cdot U + 0.5$ µV $44 \cdot 10^{-3} \cdot U + 0.4$ µV $70 \cdot 10^{-3} \cdot U$	Oscilloscope as standard U = measured value
	> 5 V to 50 V	DC to 2 kHz > 2 kHz to 10 MHz	$12 \cdot 10^{-3} \cdot U + 0.7$ µV $25 \cdot 10^{-3} \cdot U + 0.7$ µV	

DC and AC current
Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments	100 µA to 2 A	10 Hz to 1 kHz	2.2 nA to 61 µA	*I* = measured value *f* = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
	100 µA; 200 µA; 500 µA	10 Hz; 12.5 Hz; 20 Hz	$62 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$22 \cdot 10^{-6} \cdot I$	
	1 mA	10 Hz; 12.5 Hz	$25 \cdot 10^{-6} \cdot I$	
		20 Hz	$22 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$18 \cdot 10^{-6} \cdot I$	
	2 mA	10 Hz; 12.5 Hz	$23 \cdot 10^{-6} \cdot I$	
		20 Hz	$20 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$15 \cdot 10^{-6} \cdot I$	
	5 mA; 10 mA; 20 mA	10 Hz; 12.5 Hz	$22 \cdot 10^{-6} \cdot I$	
		20 Hz	$20 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$14 \cdot 10^{-6} \cdot I$	
	50 mA	10 Hz; 12.5 Hz	$23 \cdot 10^{-6} \cdot I$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz	$21 \cdot 10^{-6} \cdot I$	
		48 Hz; 60 Hz; 62.5 Hz	$16 \cdot 10^{-6} \cdot I$	
		75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$15 \cdot 10^{-6} \cdot I$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments	100 mA; 200 mA	10 Hz; 12.5 Hz	$25 \cdot 10^{-6} \cdot I$	I = measured value f = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz	$21 \cdot 10^{-6} \cdot I$	
		48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$16 \cdot 10^{-6} \cdot I$	
	500 mA; 1 A	10 Hz; 12.5 Hz	$30 \cdot 10^{-6} \cdot I$	
		20 Hz	$28 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$23 \cdot 10^{-6} \cdot I$	
		48 Hz; 60 Hz; 62.5 Hz	$24 \cdot 10^{-6} \cdot I$	
	2 A	10 Hz; 12.5 Hz; 20 Hz	$50 \cdot 10^{-6} \cdot I$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$45 \cdot 10^{-6} \cdot I$	
AC current	100 µA to 100 A	10 Hz to 10 kHz	4.4 nA to 6.5 mA	
	100 µA	10 Hz; 20 Hz	$76 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$44 \cdot 10^{-6} \cdot I$	
		10 kHz	$47 \cdot 10^{-6} \cdot I$	
	200 µA	10 Hz; 20 Hz	$68 \cdot 10^{-6} \cdot I$	
		40 Hz	$39 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$36 \cdot 10^{-6} \cdot I$	
		10 kHz	$39 \cdot 10^{-6} \cdot I$	
	0.5 mA	10 Hz; 20 Hz	$64 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz	$28 \cdot 10^{-6} \cdot I$	
		400 Hz; 500 Hz; 1 kHz	$27 \cdot 10^{-6} \cdot I$	
		10 kHz	$32 \cdot 10^{-6} \cdot I$	
	1 mA	10 Hz	$33 \cdot 10^{-6} \cdot I$	
		20 Hz	$30 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz	$26 \cdot 10^{-6} \cdot I$	
		120 Hz; 400 Hz; 500 Hz; 1 kHz	$25 \cdot 10^{-6} \cdot I$	
		10 kHz	$27 \cdot 10^{-6} \cdot I$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current	2 mA	10 Hz	$32 \cdot 10^{-6} \cdot I$	I = measured value f = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
		20 Hz	$29 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$24 \cdot 10^{-6} \cdot I$	
	5 mA	10 Hz	$32 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$29 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$24 \cdot 10^{-6} \cdot I$	
	10 mA	10 Hz	$26 \cdot 10^{-6} \cdot I$	
		20 Hz	$24 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$19 \cdot 10^{-6} \cdot I$	
		10 kHz	$22 \cdot 10^{-6} \cdot I$	
	20 mA	10 Hz	$25 \cdot 10^{-6} \cdot I$	
		20 Hz	$23 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot I$	
		10 kHz	$19 \cdot 10^{-6} \cdot I$	
	50 mA	10 Hz	$25 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$23 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot I$	
		10 kHz	$19 \cdot 10^{-6} \cdot I$	
	100 mA	10 Hz	$26 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$24 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$18 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$20 \cdot 10^{-6} \cdot I$	
	200 mA	10 Hz	$27 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$24 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$18 \cdot 10^{-6} \cdot I$	
		10 kHz	$20 \cdot 10^{-6} \cdot I$	
	500 mA	10 Hz	$36 \cdot 10^{-6} \cdot I$	
		20 Hz	$34 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$31 \cdot 10^{-6} \cdot I$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current	1 A	10 Hz	$32 \cdot 10^{-6} \cdot I$	I = measured value f = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
		20 Hz	$29 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$25 \cdot 10^{-6} \cdot I$	
	2 A	10 Hz; 20 Hz	$40 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$34 \cdot 10^{-6} \cdot I$	
	5 A; 10 A	10 Hz	$39 \cdot 10^{-6} \cdot I$	
		20 Hz	$37 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$32 \cdot 10^{-6} \cdot I$	
	20 A	10 Hz; 20 Hz	$57 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$53 \cdot 10^{-6} \cdot I$	
	50 A	10 Hz; 20 Hz	$64 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$59 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$68 \cdot 10^{-6} \cdot I$	
	100 A	10 Hz; 20 Hz	$75 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$65 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$75 \cdot 10^{-6} \cdot I$	
	100 A to 200 A		12 mA to 24 mA	
		10 Hz to 10 kHz	$0.13 \cdot 10^{-3} \cdot I$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	200 A to 300 A	10 Hz to 1 kHz	$0.30 \cdot 10^{-3} \cdot I$ - 0.53 mA	I = measured value f = frequency
	300 A to 495 A	10 Hz to 65 Hz	$0.48 \cdot 10^{-3} \cdot I$ + 11 mA	
		65 Hz to 100 Hz	$0.49 \cdot 10^{-3} \cdot I$ + 11 mA	
		100 Hz to 400 Hz	$0.74 \cdot 10^{-3} \cdot I$ + 7.7 mA	
		400 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I$ + 4.0 mA	
AC current Current clamps and current clamp transformers	10 µA to 2400 A	1 to N windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot I$ but not less than $90 \cdot 10^{-6} \cdot I$ or 8 nA	W_{in} is the relative uncertainty of the current of the single winding. W_{DUT} is the relative uncertainty of the object under test in the stray field of the current-carrying conductor
Equivalent leakage current I	0.2 µA to 200 mA	at R_N to 1 GΩ	$10 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix M.1	Total uncertainty U depends on the relative uncertainty $U(R_N)/R_N$ of the calibration resistor R_N

Matrix M.1 Equivalent leakage current

Standard resistance R_N	1 kΩ		10 kΩ		100 kΩ		1 MΩ		10 MΩ		100 MΩ		1 GΩ	
Nominal voltage	**Current | Expanded measurement uncertainty U in µA/A**										**Current | U in mA/A**			
60 V	60 mA	10	6 mA	10	600 µA	13	60 µA	19	6 µA	70	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Sources, measuring instruments	0 pA to 10 nA 0 pA 1 pA 10 pA 100 pA 1 nA 10 nA		0.85 fA to 51 fA 12 fA $0.85 \cdot 10^{-3} \cdot I$ $0.53 \cdot 10^{-3} \cdot I$ $75 \cdot 10^{-6} \cdot I$ $10 \cdot 10^{-6} \cdot I$ $5.1 \cdot 10^{-6} \cdot I$	I = measured value Intermediate values increase the measurement uncertainty
	> 10 nA to 100 nA		$4.1 \cdot 10^{-6} \cdot I + 10$ fA	I = measured value
	> 100 nA to < 1 µA		$1.4 \cdot 10^{-6} \cdot I + 0.21$ pA	
	1 µA to 10 µA		$1.4 \cdot 10^{-6} \cdot I + 0.19$ pA	
	> 10 µA to 100 µA		$1.4 \cdot 10^{-6} \cdot I + 1.8$ pA	
	> 100 µA to 500 µA		$1.1 \cdot 10^{-6} \cdot I + 72$ pA	
	20 µA to 200 µA		$1.4 \cdot 10^{-6} \cdot I + 14$ pA	
	200 µA to 2 mA		$0.54 \cdot 10^{-6} \cdot I + 0.23$ nA	
	2 mA to 10 mA		$1.1 \cdot 10^{-6} \cdot I + 2.4$ nA	
	10 mA to 50 mA		$0.90 \cdot 10^{-6} \cdot I + 25$ nA	
	50 mA to 200 mA		$0.33 \cdot 10^{-6} \cdot I + 0.26$ µA	
	200 mA to 1 A		$12 \cdot 10^{-6} \cdot I$	
	1 A to 10 A		$16 \cdot 10^{-6} \cdot I$	
	10 A to 100 A		$28 \cdot 10^{-6} \cdot I$	
	100 A to 300 A		$37 \cdot 10^{-6} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measuring function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Sources	300 A to 700 A		$27 \cdot 10^{-6} \cdot I + 2.3$ mA	
DC current Measuring instruments	20 µA to 2 mA		$0.48 \cdot 10^{-6} \cdot I + 19$ pA	
	2 mA to 20 mA		$1.1 \cdot 10^{-6} \cdot I + 1.0$ nA	
	20 mA to 200 mA		$0.26 \cdot 10^{-6} \cdot I + 24$ nA	
	200 mA to 2 A		$12 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	0 A to 3000 A	1 to N windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot I$ but not less than $8 \cdot 10^{-6} \cdot I$ or 6 nA	W_{in} is the relative uncertainty of the current of the single winding. W_{DUT} is the relative uncertainty of the object under test in the stray field of the current-carrying conductor

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Charge Q	20 pC to 200 pC		$0.50 \cdot 10^{-3} \cdot Q + 0.025$ pC	Rectangular current pulses ≥ 1 s, duration t and rise times ≤ 10 µs as a product $Q = I \cdot t$ Total uncertainty calculated from the relative uncertainty W(Iin) of the calibration current
	> 200 pC to 2 nC		$0.33 \cdot 10^{-3} \cdot Q + 0.05$ pC	
	> 2 nC to 11 C		$60 \cdot 10^{-3} \cdot Q + 0.5$ pC	
AC voltage Harmonics Sources and measuring instruments	RMS value of the 1st harmonic			U_1 = RMS value of the 1st harmonic U_n = RMS value of the nth harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic
	100 mV to 500 V	45 Hz ≤ f_1 ≤ 65 Hz 1 mV ≤ U_n ≤ 200 V 1% ≤ (U_n / U_1) ≤ 40% 2 ≤ n ≤ 100 f_n ≤ 6 kHz	$20 \cdot 10^{-6} \cdot U_1$ to $39 \cdot 10^{-6} \cdot U_1$	
	100 mV		$26 \cdot 10^{-6} \cdot U_1$	
	200 mV		$25 \cdot 10^{-6} \cdot U_1$	
	1.2 V		$20 \cdot 10^{-6} \cdot U_1$	
	8 V		$25 \cdot 10^{-6} \cdot U_1$	
	16 V		$30 \cdot 10^{-6} \cdot U_1$	
	30 V		$20 \cdot 10^{-6} \cdot U_1$	
	60 V		$20 \cdot 10^{-6} \cdot U_1$	
	120 V		$30 \cdot 10^{-6} \cdot U_1$	
	240 V		$39 \cdot 10^{-6} \cdot U_1$	
	460 V		$39 \cdot 10^{-6} \cdot U_1$	
	RMS value of the higher harmonic			U_1 = RMS value of the 1st harmonic U_n = RMS value of the nth harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic
	1 mV to 200 V	45 Hz ≤ f_1 ≤ 65 Hz 100 mV ≤ U_1 ≤ 500 V 1% ≤ (U_n / U_1) ≤ 40% 2 ≤ n ≤ 100 f_n ≤ 6 kHz	$0.13 \cdot 10^{-3} \cdot U_n$ to $1.1 \cdot 10^{-3} \cdot U_n$ See matrix M.15	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Harmonics Sources and measuring instruments	RMS value of the 1st harmonic			I_1 = RMS value of the 1st harmonic I_n = RMS value of the nth harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic I_s = peak value of the current signal The measurement uncertainty may increase for measuring instruments with a connected (clamp) current transformer The measuring range is extended to $I_1 \leq$ 600 A Current transformers are calibrated in conjunction with the display device for the secondary signal
	100 mA to 60 A	45 Hz ≤ f_1 ≤ 65 Hz 2 ≤ n ≤ 100 I_s ≤ 113 A	$32 \cdot 10^{-6} \cdot I_1$ to $71 \cdot 10^{-6} \cdot I_1$	
	100 mA	1 mA ≤ I_n ≤ 4.8 A f_n ≤ 6 kHz 1% ≤ (I_n / I_1) ≤ 30%	$32 \cdot 10^{-6} \cdot I_1$	
	200 mA		$47 \cdot 10^{-6} \cdot I_1$	
	400 mA		$47 \cdot 10^{-6} \cdot I_1$	
	800 mA		$47 \cdot 10^{-6} \cdot I_1$	
	1.6 A		$45 \cdot 10^{-6} \cdot I_1$	
	4 A		$57 \cdot 10^{-6} \cdot I_1$	
	5 A		$57 \cdot 10^{-6} \cdot I_1$	
	16 A		$55 \cdot 10^{-6} \cdot I_1$	
	30 A	160 mA ≤ I_n ≤ 18 A f_n ≤ 3 kHz 1% ≤ (I_n / I_1) ≤ 30%	$71 \cdot 10^{-6} \cdot I_1$	
	60 A		$71 \cdot 10^{-6} \cdot I_1$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Harmonics Sources and measuring instruments	RMS value of the higher harmonic	45 Hz ≤ f_1 ≤ 65 Hz 2 ≤ n ≤ 100 I_s ≤ 113 A		I_1 = RMS value of the 1st harmonic I_n = RMS value of the nth harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1
	1 mA to 4.8 A	100 mA ≤ I_1 ≤ 16 A f_n ≤ 6 kHz 1% ≤ I_n / I_1 ≤ 30%	$0.22 \cdot 10^{-3} \cdot I_n$ to $0.46 \cdot 10^{-3} \cdot I_n$ see matrix M.16	
	160 mA to 18 A	16 A ≤ I_1 ≤ 60 A f_n ≤ 3 kHz 1% ≤ (I_n / I_1) ≤ 30%	$0.22 \cdot 10^{-3} \cdot I_n$ to $0.46 \cdot 10^{-3} \cdot I_n$ see matrix M.16	The number of higher harmonics is limited to one higher harmonic I_s = peak value of the current signal The measurement uncertainty may increase for measuring instruments with a connected (clamp) current transformer The measuring range is extended to I_n ≤ 200 A Current transformers are calibrated in conjunction with the display device for the secondary signal

Matrix M.15 – Relative measurement uncertainty of the effective value U_n of the higher harmonic at the frequency $f_1 = 50\ \mathrm{Hz}$ in mV/V

		n													
U_1 / V	U_n / V	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0.10	**0.001**	1.1	1.1	0.57	0.57	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.48	0.48	0.48
0.10	**0.01**	0.17	0.17	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.20	**0.025**	0.17	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1.2	**0.15**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
8.0	**1.0**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
16	**4.5**	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
30	**9.0**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
60	**18**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
120	**36**	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
240	**72**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
460	**130**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Matrix M.16 – Relative measurement uncertainty of the effective value I_n of the higher harmonic at the frequency $f_1 = 50\ \mathrm{Hz}$ in mA/A

		n													
I_1 / A	I_n / A	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0.1	**0.01**	0.24	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.2	**0.025**	0.24	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.4	**0.05**	0.24	0.24	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.8	**0.1**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
1.6	**0.016**	0.46	0.46	0.46	0.46	0.32	0.28	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22
1.6	**0.2**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
4	**0.5**	0.25	0.25	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
8	**1**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
16	**2**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
30	**8**	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	-	-	-	-
60	**15**	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	-	-	-	-

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Flicker modulation depth Sources	0.407% to 4.837%	1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V rectangular modulation		*ΔU/U* = modulation depth *U* = RMS value of the modulated AC voltage signal *f* = frequency of the modulated AC voltage signal *CPM* = changes per minute The combinations of *ΔU/U* and *CPM* defined in DIN EN 61000-4-15:2011, Table 5 apply
		1 min^{-1} ≤ *CPM* ≤ 39 min^{-1} *f* = 50 Hz; *f* = 60 Hz	1.0 · 10^{-3}%	
		CPM = 110 min^{-1} *f* = 50 Hz; *f* = 60 Hz	3.7 · 10^{-3}%	
		CPM = 1620 min^{-1} *f* = 50 Hz; *f* = 60 Hz	12 · 10^{-3}%	
		CPM = 4000 min^{-1}; *CPM* = 4800 min^{-1} *f* = 51 Hz; *f* = 61 Hz	12 · 10^{-3}%	
Flicker modulation depth Measuring instruments	0.407% to 4.837%	1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V rectangular modulation		*ΔU/U* = RMS depth *U* = effective value of the modulated AC voltage signal *f* = frequency of the modulated AC voltage signal *CPM* = changes per minute The combinations of *ΔU/U* and *CPM* defined in DIN EN 61000-4-15:2011, Table 5 apply
		1 min^{-1} ≤ *CPM* ≤ 39 min^{-1} *f* = 50 Hz; *f* = 60 Hz	1.0 · 10^{-3}%	
		CPM = 110 min^{-1} *f* = 50 Hz; *f* = 60 Hz	3.7 · 10^{-3}%	
		CPM = 1620 min^{-1} *f* = 50 Hz; *f* = 60 Hz	12 · 10^{-3}%	
		CPM = 4000 min^{-1}; *CPM* = 4800 min^{-1} *f* = 50 Hz; *f* = 60 Hz	28 · 10^{-3}%	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Flicker frequency Sources and measuring instruments	8.3 mHz to 40 Hz	0.407% ≤ (*ΔU/U*) ≤ 4.837% 1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V *f* = 50 Hz; *f* = 60 Hz Rectangular modulation	$1.0 \cdot 10^{-6} \cdot f_{Flicker}$	*ΔU/U* = modulation depth *U* = RMS value of the modulated AC voltage signal *f* = frequency of the modulated AC voltage signal *CPM* = changes per minute $f_{Flicker}$ = *CPM* / 120 The combinations of *ΔU/U* and *CPM* defined in DIN EN 61000-4-15:2011, Table 5 apply
P_{st} value	only P_{st} = 1		$2.5 \cdot 10^{-3}$	Value at *ΔU/U* expressed in *ΔU/U* rectangular flicker
AC voltage Distortion factor *k*	0% to 30%	45 Hz to 5 kHz > 5 kHz to 30 kHz	$0.5 \cdot 10^{-3} \cdot k + 0.012\%$ $0.8 \cdot 10^{-3} \cdot k + 0.012\%$	Values expressed in % distortion

DC and AC resistance

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Sources, measuring instruments	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value
		4-wire short circuit	0.35 µΩ	
	10 µΩ to < 1 GΩ	I = 100 A	1.6 nΩ to 49 Ω	Calibration of measuring instruments at the nominal values of the standards Intermediate values and deviating measurement conditions increase the measurement uncertainty
	10 µΩ 100 µΩ 1 mΩ 10 mΩ 100 mΩ 1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ	I = 50 A I = 10 A	$0.16 \cdot 10^{-3} \cdot R$ $34 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $5.6 \cdot 10^{-6} \cdot R$ $0.32 \cdot 10^{-6} \cdot R$ $1.0 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-6} \cdot R$ $0.56 \cdot 10^{-6} \cdot R$ $1.4 \cdot 10^{-6} \cdot R$ $4.1 \cdot 10^{-6} \cdot R$ $4.9 \cdot 10^{-6} \cdot R$	
	1 GΩ to 1 TΩ	Measuring voltage 100 V; 1000 V	67 kΩ to 72 MΩ	
	1 GΩ; 10 GΩ; 100 GΩ; 1 TΩ		$67 \cdot 10^{-6} \cdot R$ $72 \cdot 10^{-6} \cdot R$	
	> 1 TΩ to 120 TΩ	Measuring voltage 1000 V	0.13 GΩ to 23 GΩ	
	10 TΩ; 100 TΩ		$0.13 \cdot 10^{-3} \cdot R$ $0.23 \cdot 10^{-3} \cdot R$	
	100 mΩ to 2 Ω	3 µA ≤ I ≤ 50 mA	$0.39 \cdot 10^{-6} \cdot R$ + 0.25 µΩ	R = measured value
	2 Ω to 10 Ω		$0.43 \cdot 10^{-6} \cdot R$ + 1.0 µΩ	
	10 Ω to 100 Ω		$1.2 \cdot 10^{-6} \cdot R$ - 0.50 µΩ	
	100 Ω to 500 Ω		$0.52 \cdot 10^{-6} \cdot R$ - 2.5 µΩ	
	500 Ω to 10 kΩ		$0.47 \cdot 10^{-6} \cdot R$ + 20 µΩ	
	10 kΩ to 100 kΩ		$0.73 \cdot 10^{-6} \cdot$ R - 0.13 mΩ	
	100 kΩ to 1.9 MΩ		$0.83 \cdot 10^{-6} \cdot R$ + 90 µΩ	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (absolute value of impedance)	1 Ω to 10 kΩ	10 µA ≤ *I* ≤ 50 mA 10 Hz to 1 kHz	20 µΩ to 0.77 Ω	*R* = measured value *I* = current *f* = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
	1 Ω	10 Hz; 12.5 Hz	$30 \cdot 10^{-6} \cdot R$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz	$24 \cdot 10^{-6} \cdot R$	
		48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$21 \cdot 10^{-6} \cdot R$	
	2 Ω	10 Hz; 12.5 Hz	$26 \cdot 10^{-6} \cdot R$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz	$21 \cdot 10^{-6} \cdot R$	
		48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$16 \cdot 10^{-6} \cdot R$	
	5 Ω	10 Hz; 12.5 Hz	$25 \cdot 10^{-6} \cdot R$	
		20 Hz	$20 \cdot 10^{-6} \cdot R$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$15 \cdot 10^{-6} \cdot R$	
	10 Ω	10 Hz; 12.5 Hz	$24 \cdot 10^{-6} \cdot R$	
		20 Hz	$19 \cdot 10^{-6} \cdot R$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$14 \cdot 10^{-6} \cdot R$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (absolute value of impedance)	20 Ω; 50 Ω; 100 Ω	10 Hz; 12.5 Hz	$59 \cdot 10^{-6} \cdot R$	R = measured value I = current f = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
		20 Hz	$19 \cdot 10^{-6} \cdot R$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$14 \cdot 10^{-6} \cdot R$	
		625 Hz; 937.5 Hz; 1 kHz	$12 \cdot 10^{-6} \cdot R$	
	1 kΩ	10 Hz; 12.5 Hz; 20 Hz	$59 \cdot 10^{-6} \cdot R$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$56 \cdot 10^{-6} \cdot R$	
	10 kΩ	10 Hz; 12.5 Hz; 20 Hz	$81 \cdot 10^{-6} \cdot R$	
		25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 48 Hz; 60 Hz; 62.5 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz; 625 Hz; 937.5 Hz; 1 kHz	$78 \cdot 10^{-6} \cdot R$	
	100 µΩ to 100 Ω	100 µA ≤ I ≤ 100 A	13 nΩ to 1.7 mΩ	
		10 Hz to 10 kHz		
	100 µΩ	10 Hz; 20 Hz	$0.17 \cdot 10^{-3} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$0.14 \cdot 10^{-3} \cdot R$	
		1 kHz; 10 kHz	$0.15 \cdot 10^{-3} \cdot R$	
	1 mΩ	10 Hz	$65 \cdot 10^{-6} \cdot R$	
		20 Hz	$63 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$58 \cdot 10^{-6} \cdot R$	
		1 kHz	$61 \cdot 10^{-6} \cdot R$	
		10 kHz	$64 \cdot 10^{-6} \cdot R$	
	10 mΩ	10 Hz	$46 \cdot 10^{-6} \cdot R$	
		20 Hz	$43 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$37 \cdot 10^{-6} \cdot R$	
		1 kHz; 10 kHz	$35 \cdot 10^{-6} \cdot R$	
	20 mΩ	10 Hz	$45 \cdot 10^{-6} \cdot R$	
		20 Hz	$42 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$36 \cdot 10^{-6} \cdot R$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (absolute value of impedance)	50 mΩ	10 Hz	$45 \cdot 10^{-6} \cdot R$	R = measured value I = current f = frequency Intermediate values and deviating measurement conditions increase the measurement uncertainty
		20 Hz	$42 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$36 \cdot 10^{-6} \cdot R$	
	100 mΩ; 200 mΩ	10 Hz	$39 \cdot 10^{-6} \cdot R$	
		20 Hz	$35 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$30 \cdot 10^{-6} \cdot R$	
	0.5 Ω	10 Hz	$36 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$31 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$26 \cdot 10^{-6} \cdot R$	
	1 Ω	10 Hz	$34 \cdot 10^{-6} \cdot R$	
		20 Hz	$30 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$25 \cdot 10^{-6} \cdot R$	
	2 Ω; 5 Ω	10 Hz	$31 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$26 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$20 \cdot 10^{-6} \cdot R$	
		10 kHz	$23 \cdot 10^{-6} \cdot R$	
	10 Ω	10 Hz	$30 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$26 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$21 \cdot 10^{-6} \cdot R$	
		10 kHz	$23 \cdot 10^{-6} \cdot R$	
	20 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$25 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$19 \cdot 10^{-6} \cdot R$	
		10 kHz	$22 \cdot 10^{-6} \cdot R$	
	50 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	
		20 Hz	$25 \cdot 10^{-6} \cdot R$	
		40 Hz	$20 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$19 \cdot 10^{-6} \cdot R$	
		1 kHz	$21 \cdot 10^{-6} \cdot R$	
		10 kHz	$25 \cdot 10^{-6} \cdot R$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (absolute value of impedance)	100 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	
		20 Hz	$25 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz	$19 \cdot 10^{-6} \cdot R$	
		120 Hz; 400 Hz	$18 \cdot 10^{-6} \cdot R$	
		500 Hz	$20 \cdot 10^{-6} \cdot R$	
		1 kHz	$31 \cdot 10^{-6} \cdot R$	
		10 kHz	$75 \cdot 10^{-6} \cdot R$	
	100 µΩ to 10 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$	U_I is the relative uncertainty of the calibration current U_U is the relative uncertainty of the measured voltage at resistor R
	0 Ω to 10 kΩ	20 Hz to 50 Hz	$2.5 \cdot 10^{-3} \cdot R + 3.1$ mΩ	R = measured value Direct measurement method
	> 10 kΩ to 110 MΩ		$2.3 \cdot 10^{-9} \cdot R^2/\Omega + 2.5 \cdot 10^{-3} \cdot R$	
	0 Ω to 20 kΩ	> 50 Hz to 100 Hz	$1.0 \cdot 10^{-3} \cdot R + 2.6$ mΩ	
	> 20 kΩ to 110 MΩ		$2.3 \cdot 10^{-9} \cdot R^2/\Omega + 1.3 \cdot 10^{-3} \cdot R$	
	0 Ω to 50 kΩ	> 100 Hz to 1 kHz	$0.5 \cdot 10^{-3} \cdot R + 1.3$ mΩ	
	> 50 kΩ to 110 MΩ		$1.1 \cdot 10^{-9} \cdot R^2/\Omega + 1.2 \cdot 10^{-3} \cdot R$	
	0 Ω to < 50 Ω	> 1 kHz to 30 kHz	$1.1 \cdot 10^{-3} \cdot R + 1.2$ mΩ	
	50 Ω to 20 kΩ		$0.5 \cdot 10^{-3} \cdot R$	
	> 20 kΩ to 110 MΩ		$1.1 \cdot 10^{-9} \cdot R^2/\Omega + 0.79 \cdot 10^{-3} \cdot R$	
	0 Ω to 20 Ω	> 30 kHz to 100 kHz	$1.1 \cdot 10^{-3} \cdot R + 1.2$ mΩ	
	> 20 Ω to 20 kΩ		$0.5 \cdot 10^{-3} \cdot R$	
	> 20 kΩ to 110 MΩ		$1.3 \cdot 10^{-9} \cdot R^2/\Omega + 1.0 \cdot 10^{-3} \cdot R$	
	0 Ω to 100 Ω	> 100 kHz to 300 kHz	$1.1 \cdot 10^{-3} \cdot R + 2.2$ mΩ	
	> 100 Ω to 2 kΩ		$0.5 \cdot 10^{-3} \cdot R$	
	> 2 kΩ to 110 MΩ		$4.5 \cdot 10^{-9} \cdot R^2/\Omega + 0.9 \cdot 10^{-3} \cdot R$	
	0 Ω to 50 Ω	> 300 kHz to 1 MHz	$1.3 \cdot 10^{-3} \cdot R + 3.2$ mΩ	
	> 50 Ω to 2 kΩ		$0.7 \cdot 10^{-3} \cdot R$	
	> 2 kΩ to 22 MΩ		$15 \cdot 10^{-9} \cdot R^2/\Omega + 1.1 \cdot 10^{-3} \cdot R$	

Electrical power

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power	0 W to 110 kW	0 mV to 1100 V 0 µA to 100 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ but not less than $44 \cdot 10^{-6} \cdot P + 5$ fW	P = measured value
Power factor Sources, measuring instruments	0 to 1	10 Hz ≤ f ≤ 10 kHz [i] 1 mV ≤ U ≤ 1 kV [i] 1 mA ≤ I ≤ 100 A	$6.8 \cdot 10^{-12}$ to $2.1 \cdot 10^{-3}$	$PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = effective value of the AC voltage I = effective value of the AC current The measurement uncertainties apply to sinusoidal signals See also matrices M.21 to M.25
		For a measuring instrument with a current clamp / current transformer the upper current limit is extended to 1 kA in the range 10 Hz ≤ f ≤ 100 Hz	$7.8 \cdot 10^{-9}$ to $1.5 \cdot 10^{-4}$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC active power Sources, measuring instruments	0 W to 100 kW	10 Hz ≤ f ≤ 10 kHz [i] 1 mV ≤ U ≤ 1 kV [i] 1 mA ≤ I ≤ 100 A 0 ≤ PF ≤ 1	7.5 pW to 210 W	$P(U;I;PF) = U \cdot I \cdot PF$ = AC active power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = RMS value of AC voltage I = RMS value of AC current The measurement uncertainties apply to sinusoidal signals See also matrices M.26 to M.35
	0 W to 1 MW	Additional range for measuring instruments with current clamp / current transformer: 10 Hz ≤f ≤ 100 Hz [i] 1 mV ≤U ≤ 1 kV [i] 100 A <I ≤ 1 kA 0 ≤ PF ≤ 1	Current transformers: $3.8 \cdot 10^{-4} \cdot P$ not less than 2 µW Current clamps: $4.6 \cdot 10^{-3} \cdot P$ not less than 2 µW	
AC reactive power Sources, measuring instruments	-100 kvar to 100 kvar	10 Hz ≤ f ≤ 10 kHz [i] 1 mV ≤ U ≤ 1 kV [i] 1 mA ≤ I ≤ 100 A 0 ≤ PF ≤ 1	7.5 pvar to 210 var	$Q = U \cdot I \cdot \sin(\Delta\varphi)$ $= U \cdot I \cdot \sqrt{1 - PF^2}$ AC reactive power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I$ = phase angle U = RMS value of AC voltage I = RMS value of AC current The measurement uncertainties apply to sinusoidal signals See also matrices M.26 to M.35
	-1 Mvar to 1 Mvar	Additional range for measuring instruments with current clamp / current transformer: 10 Hz ≤ f ≤ 100 Hz [i] 1 mV ≤ U ≤ 1 kV [i] 100 A < I ≤ 1 kA 0 ≤ PF ≤ 1	Current transformers: $3.8 \cdot 10^{-4} \cdot Q$ not less than 2 µvar Current clamps: $4.6 \cdot 10^{-3} \cdot Q$ not less than 2 µvar	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC apparent power Sources, measuring instruments	0 VA to 100 kVA	10 Hz ≤ f ≤ 10 kHz [i)] 1 mV ≤ U ≤ 1 kV [i)] 1 mA ≤ I ≤ 100 A	59 pVA to 7.6 VA	$S = U \cdot I$ $= P(U; I; PF = 1)$ = AC apparent power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = RMS value of AC voltage I = RMS value of AC current P = AC active power The measurement uncertainties apply to sinusoidal signals See also matrices M.26 to M.35 for $PF = 1$
	0 VA to 1 MVA	Additional range for measuring instruments with current clamps / current transformers: 1 mV ≤U ≤ 1 kV [i)] 10 Hz ≤f ≤ 100 Hz [i)]: I ≤ 1 kA	Current transformers: $3.8 \cdot 10^{-4} \cdot S$ Current clamps: $4.6 \cdot 10^{-3} \cdot S$	
Energy E Defibrillator tester	5 J to 150 J		$2.3 \cdot 10^{-3} \cdot E + 49$ mJ	E = energy Monophasic or biphasic
	> 150 J to 360 J		$1.1 \cdot 10^{-3} \cdot E + 0.27$ J	
Voltage ratio Bridge standards and measuring instruments	0 mV/V to 100 mV/V	DC voltage Bridge voltage: 1 V to 10 V	0.1 µV/V to 1.6 µV/V see matrix M.2	

Matrix M.2: Voltage ratio

Bridge voltage / Measured value	10 V	5 V	2 V	1 V
0 mV/V	0.10 µV/V	0.10 µV/V	0.17 µV/V	0.35 µV/V
± 2 mV/V	0.10 µV/V	0.11 µV/V	0.26 µV/V	0.51 µV/V
± 5 mV/V	0.10 µV/V	0.13 µV/V	0.27 µV/V	0.52 µV/V
± 10 mV/V	0.10 µV/V	0.16 µV/V	0.31 µV/V	0.56 µV/V
± 20 mV/V	0.16 µV/V	0.20 µV/V	0.38 µV/V	0.66 µV/V
± 50 mV/V	0.35 µV/V	0.39 µV/V	0.58 µV/V	1 µV/V
± 100 mV/V	0.65 µV/V	0.73 µV/V	1.0 µV/V	1.6 µV/V

Matrix M.21: Absolute measurement uncertainty of the **power factor** PF
for the calibration of **sources** in the range **2 A < I ≤ 20 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.1 \cdot 10^{-6}$	$3.0 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.5 \cdot 10^{-6}$	$1.9 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$6.8 \cdot 10^{-12}$
45	$9.8 \cdot 10^{-6}$	$9.6 \cdot 10^{-6}$	$9.0 \cdot 10^{-6}$	$7.9 \cdot 10^{-6}$	$5.9 \cdot 10^{-6}$	$4.3 \cdot 10^{-6}$	$6.8 \cdot 10^{-11}$
111	$1.9 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.8 \cdot 10^{-5}$	$1.5 \cdot 10^{-6}$	$1.2 \cdot 10^{-5}$	$8.4 \cdot 10^{-6}$	$2.6 \cdot 10^{-10}$
1000	$1.6 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$9.7 \cdot 10^{-5}$	$7.1 \cdot 10^{-5}$	$1.9 \cdot 10^{-8}$
10000	$1.6 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$	$9.7 \cdot 10^{-4}$	$7.1 \cdot 10^{-4}$	$1.6 \cdot 10^{-6}$

Matrix M.22: Absolute measurement uncertainty of the **power factor** PF
for the calibration of **sources** in the range **20 A < I ≤ 100 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.4 \cdot 10^{-6}$	$3.4 \cdot 10^{-6}$	$3.2 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.1 \cdot 10^{-6}$	$1.5 \cdot 10^{-6}$	$8.4 \cdot 10^{-12}$
45	$1.1 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$9.1 \cdot 10^{-6}$	$6.8 \cdot 10^{-6}$	$5.0 \cdot 10^{-6}$	$9.2 \cdot 10^{-11}$
111	$2.4 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.2 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.4 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$4.0 \cdot 10^{-10}$
1000	$2.0 \cdot 10^{-4}$	$2.0 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$8.8 \cdot 10^{-5}$	$2.9 \cdot 10^{-8}$
10000	$2.0 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$8.8 \cdot 10^{-4}$	$2.9 \cdot 10^{-6}$

Matrix M.23: Absolute measurement uncertainty of the **power factor** PF
for the calibration of **measuring instruments** in the range **2 A < I ≤ 20 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.2 \cdot 10^{-6}$	$3.2 \cdot 10^{-6}$	$2.9 \cdot 10^{-6}$	$2.6 \cdot 10^{-6}$	$1.9 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$7.3 \cdot 10^{-12}$
45	$1.0 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$9.5 \cdot 10^{-6}$	$8.3 \cdot 10^{-6}$	$6.2 \cdot 10^{-6}$	$4.5 \cdot 10^{-6}$	$7.6 \cdot 10^{-11}$
111	$2.1 \cdot 10^{-5}$	$2.0 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.6 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$9.0 \cdot 10^{-6}$	$3.0 \cdot 10^{-10}$
1000	$1.7 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$	$7.6 \cdot 10^{-5}$	$2.1 \cdot 10^{-8}$
10000	$1.7 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$	$1.0 \cdot 10^{-3}$	$7.6 \cdot 10^{-4}$	$2.1 \cdot 10^{-6}$

Matrix M.24: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **measuring instruments** in the range **20 A < I ≤ 100 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.6 \cdot 10^{-6}$	$3.5 \cdot 10^{-6}$	$3.3 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.1 \cdot 10^{-6}$	$1.5 \cdot 10^{-6}$	$8.9 \cdot 10^{-12}$
45	$1.2 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$9.5 \cdot 10^{-6}$	$7.1 \cdot 10^{-6}$	$5.2 \cdot 10^{-6}$	$1.0 \cdot 10^{-10}$
111	$2.5 \cdot 10^{-5}$	$2.4 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.0 \cdot 10^{-5}$	$1.5 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$4.4 \cdot 10^{-10}$
1000	$2.1 \cdot 10^{-4}$	$2.1 \cdot 10^{-4}$	$2.0 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$9.3 \cdot 10^{-5}$	$3.3 \cdot 10^{-8}$
10000	$2.1 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$	$9.3 \cdot 10^{-4}$	$3.3 \cdot 10^{-6}$

Matrix M.25: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **measuring instruments with current clamps / current transformers**
in the range **100 A < I ≤ 1 kA & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10 Hz to 100 Hz	$1.5 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$8.9 \cdot 10^{-5}$	$6.5 \cdot 10^{-5}$	$7.8 \cdot 10^{-9}$

Matrix M.26: Absolute measurement uncertainty of the **AC active power $P = U \cdot I \cdot \cos(\varphi)$** (see values for PF), the **AC reactive power $Q = U \cdot I \cdot \sin(\varphi)$** (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power $S = U \cdot I$** (see values for $PF = 1$)
for the calibration of **sources** with **U = 2 mV and I = 100 µA**

	$\cos(\varphi) = PF$ | $\sin(\varphi) = \pm\sqrt{1 - PF^2}$					
f (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
10	48 pW	54 pW	60 pW	68 pW	72 pW	77 pW
1000	34 pW	39 pW	44 pW	51 pW	55 pW	59 pW
10000	340 pW	310 pW	270 pW	210 pW	160 pW	59 pW

Matrix M.27: Absolute measurement uncertainty of the **AC active power $P = U \cdot I \cdot \cos(\varphi)$** (see values for PF), the **AC reactive power $Q = U \cdot I \cdot \sin(\varphi)$** (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power $S = U \cdot I$** (see values for $PF = 1$) for the calibration of **measuring instruments** with **U = 2 mV and I = 1 mA**

	$\cos(\varphi) = PF$ | $\sin(\varphi) = \pm\sqrt{1 - PF^2}$					
f (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.0 nW	1.0 nW	1.1 nW	1.1 nW	1.1 nW	1.2 nW
1000	230 pW	320 pW	400 pW	490 pW	530 pW	580 pW
10000	2.3 nW	2.1 nW	1.9 nW	1.5 nW	1.1 nW	580 pW

Matrix M.28: Absolute measurement uncertainty of the **AC active power $P = U \cdot I \cdot \cos(\varphi)$** (see values for PF), the **AC reactive power $Q = U \cdot I \cdot \sin(\varphi)$** (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power $S = U \cdot I$** (see values for $PF = 1$) for the calibration of **sources** with **U = 20 mV and I = 100 µA**

	$\cos(\varphi) = PF$ | $\sin(\varphi) = \pm\sqrt{1 - PF^2}$					
f (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
10	7.5 pW	110 pW	170 pW	230 pW	260 pW	280 pW
1000	340 pW	320 pW	290 pW	250 pW	230 pW	190 pW
10000	3.4 nW	3.1 nW	2.7 nW	2.0 nW	1.5 nW	200 pW

Matrix M.29: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 mV and** $\boldsymbol{I}$ **= 1 mA**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	150 pW	730 pW	1.1 nW	1.4 nW	1.6 nW	1.8 nW
1000	2.3 nW	2.3 nW	2.2 nW	2.0 nW	1.9 nW	1.8 nW
10000	23 nW	21 nW	19 nW	14 nW	10 nW	1.8 nW

Matrix M.30: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 1 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	140 µW	250 µW	350 µW	440 µW	500 µW	550 µW
1000	2.1 mW	1.9 mW	1.7 mW	1.3 mW	1.0 mW	530 µW
10000	21 mW	19 mW	17 mW	13 mW	9.1 mW	530 µW

Matrix M.31: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 1 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	150 µW	260 µW	350 µW	450 µW	500 µW	550 µW
1000	2.3 mW	2.1 mW	1.9 mW	1.5 mW	1.1 mW	530 µW
10000	23 mW	21 mW	19 mW	14 mW	10 mW	530 µW

Matrix M.32: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 20 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	3.5 mW	9.2 mW	13 mW	17 mW	20 mW	22 mW
1000	65 mW	60 mW	53 mW	43 mW	34 mW	22 mW
10000	650 mW	590 mW	520 mW	390 mW	280 mW	22 mW

Matrix M.33: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 20 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	3.7 mW	9.3 mW	13 mW	17 mW	20 mW	22 mW
1000	70 mW	65 mW	58 mW	46 mW	36 mW	22 mW
10000	700 mW	650 mW	560 mW	420 mW	310 mW	22 mW

Matrix M.34: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 1 kV and** $\boldsymbol{I}$ **= 100 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.0 W	2.8 W	4.1 W	5.4 W	6.0 W	6.7 W
1000	20 W	19 W	17 W	14 W	11 W	7.6 W
10000	200 W	190 W	160 W	120 W	89 W	7.6 W

Matrix M.35: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 1 kV and** $\boldsymbol{I}$ **= 100 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.1 W	2.8 W	4.1 W	5.4 W	6.0 W	6.7 W
1000	21 W	20 W	18 W	14 W	12 W	7.6 W
10000	210 W	200 W	170 W	130 W	93 W	7.6 W

[i] The specified range applies only when the maximum volt-hertz product is maintained as shown in Figure A of the Operator's Manual Multi-Function Calibrator 5700A/5720A Series II May 1996 Rev. 2, 3/05.

Phase angle

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal voltage signals multichannel sources, measuring instruments	-360° to 360°	10 Hz ≤ f ≤ 1 MHz 1 mV ≤ $U_{\mathrm{eff,i}}$ ≤ 1 kV	$360° \cdot f \cdot 17\ \mathrm{ns}$	$\Delta\varphi = \varphi_2 - \varphi_1 =$ phase angle $U_{\mathrm{i}}(t) = \sqrt{2}U_{\mathrm{eff,i}} \sin(2\pi f t + \varphi_{\mathrm{i}})$ with $i \in \{1; 2\}$ f = frequency $U_{\mathrm{eff,i}}$ = RMS value of AC voltage Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as measurements at f = (50 ± 5) Hz, can increase the measurement uncertainty

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal output voltage and sinusoidal input current Resistance standard		10 mA ≤ $I_{\text{eff.}}$ ≤ 100 A for f ≤ 10 kHz 10 mA ≤ $I_{\text{eff.}}$ ≤ 50 mA For f ≤ 100 kHz		$\Delta\varphi = \varphi_{\text{U}} - \varphi_{\text{I}} =$ phase angle $I(t) = \sqrt{2} I_{\text{eff.}} \sin(2\pi f t + \varphi_{\text{I}})$ $U(t) = \sqrt{2} I_{\text{eff.}} \lvert Z \rvert \sin(2\pi f t + \varphi_{\text{U}})$ f = frequency R = DC resistance $I_{\text{eff.}}$ = RMS value of AC current Z = impedance of the resistance standard Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as deviating measurement conditions, can increase the measurement uncertainty
	-90° to 90°	10 Hz ≤ f ≤ 100 kHz 10 mΩ ≤ R < 50 mΩ		The specified measurement uncertainties apply to resistors of the SIQ MU series, Fluke A40B or similar designs with coaxial connection sockets The measurement uncertainty may increase for resistors of other designs
		f = 10 Hz	0.18 m°	
		f = 45 Hz	0.60 m°	
		f = 111 Hz	1.2 m°	
		1 kHz ≤ f ≤ 100 kHz	$360° \cdot f \cdot 28\ \text{ns}$	
		10 Hz ≤ f ≤ 100 kHz 50 mΩ ≤ R ≤ 100 Ω		
		f = 40 Hz	0.43 m°	
		f = 100 Hz	0.79 m°	
		1 kHz ≤ f ≤ 100 kHz	$360° \cdot f \cdot 20\ \text{ns}$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal output signal and sinusoidal input current Current transformer		10 Hz ≤ f ≤ 10 kHz		$\Delta\varphi = \varphi_Y - \varphi_I =$ Phase angle $I(t) = \sqrt{2} I_{\text{eff.}} \sin(2\pi f t + \varphi_I)$ $Y(t) = \sqrt{2} Y_{\text{eff.}} \sin(2\pi f t + \varphi_Y)$ f = frequency $I_{\text{eff.}}$ = RMS value of AC current $Y_{\text{eff.}}$ = RMS value of output signal of the current transformer (current or voltage)
	-90° to 90°	1 A < $I_{\text{eff.}}$ ≤ 2 A		The specified uncertainties apply in cases where the output signal of the current transformer is a voltage Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, deviating measurement conditions, as well as the case where the output signal of the current transformer is a current, increase the measurement uncertainty
		f = 40 Hz	0.43 m°	
		f = 100 Hz	0.79 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 20\ \text{ns}$	
		2 A < $I_{\text{eff.}}$ ≤ 20 A		
		f = 10 Hz	0.18 m°	
		f = 45 Hz	0.60 m°	
		f = 111 Hz	1.2 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 28\ \text{ns}$	
		20 A < $I_{\text{eff.}}$ ≤ 100 A		
		f = 10 Hz	0.21 m°	
		f = 45 Hz	0.68 m°	
		f = 111 Hz	1.4 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 35\ \text{ns}$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal voltage signal and sinusoidal current signal Sources	-180° to 180°	10 Hz ≤ f ≤ 10 kHz 1 mV ≤ $U_{\text{eff.}}$ ≤ 1 kV		$\Delta\varphi = \varphi_U - \varphi_I =$ phase angle $I(t) = \sqrt{2} I_{\text{eff.}} \sin(2\pi f t + \varphi_I)$ $U(t) = \sqrt{2} U_{\text{eff.}} \sin(2\pi f t + \varphi_U)$ f = frequency $I_{\text{eff.}}$ = RMS value of AC current $U_{\text{eff.}}$ = RMS value of AC voltage Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as deviating measurement conditions, can increase the measurement uncertainty
		100 µA ≤ $I_{\text{eff.}}$ ≤ 10 mA		
		f = 10 Hz	0.21 m°	
		f = 45 Hz	0.57 m°	
		f = 111 Hz	1.1 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 27\ \text{ns}$	
		10 mA < $I_{\text{eff.}}$ ≤ 200 mA		
		f = 40 Hz	0.37 m°	
		f = 100 Hz	0.72 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 18\ \text{ns}$	
		200 mA < $I_{\text{eff.}}$ ≤ 2 A		
		f = 40 Hz	0.40 m°	
		f = 100 Hz	0.68 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 17\ \text{ns}$	
		2 A < $I_{\text{eff.}}$ ≤ 20 A		
		f = 10 Hz	0.18 m°	
		f = 45 Hz	0.57 m°	
		f = 111 Hz	1.1 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 26\ \text{ns}$	
		20 A < $I_{\text{eff.}}$ ≤ 100 A		
		f = 10 Hz	0.20 m°	
		f = 45 Hz	0.65 m°	
		f = 111 Hz	1.4 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 32\ \text{ns}$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal voltage signal and sinusoidal current signal Measuring instruments	-180° to 180°	10 Hz ≤ f ≤ 10 kHz 1 mV ≤ $U_{\mathrm{eff.}}$ ≤ 1 kV		$\Delta\varphi = \varphi_{\mathrm{U}} - \varphi_{\mathrm{I}} =$ phase angle $I(t) = \sqrt{2} I_{\mathrm{eff.}} \sin(2\pi f t + \varphi_{\mathrm{I}})$ $U(t) = \sqrt{2} U_{\mathrm{eff.}} \sin(2\pi f t + \varphi_{\mathrm{U}})$ f = frequency $I_{\mathrm{eff.}}$ = RMS value of AC current $U_{\mathrm{eff.}}$ = RMS value of AC voltage Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as deviating measurement conditions, can increase the measurement uncertainty
		1 mA ≤ $I_{\mathrm{eff.}}$ ≤ 2 A		
		f = 40 Hz	0.42 m°	
		f = 100 Hz	0.76 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 19\ \mathrm{ns}$	
		2 A < $I_{\mathrm{eff.}}$ ≤ 20 A		
		f = 10 Hz	0.18 m°	
		f = 45 Hz	0.60 m°	
		f = 111 Hz	1.2 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 28\ \mathrm{ns}$	
		20 A < $I_{\mathrm{eff.}}$ ≤ 100 A		
		f = 10 Hz	0.21 m°	
		f = 45 Hz	0.68 m°	
		f = 111 Hz	1.4 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 34\ \mathrm{ns}$	

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle Between the 1st harmonic and the n^{th} harmonic of a voltage signal Measuring instruments	-180° to 180°	$1 \le n \le 100$ 45 Hz ≤ f_1 ≤ 65 Hz f_n ≤ 6 kHz U_1 ≥ 100 mV U_n ≥ 10 mV U_S ≤ 1050 V	$360° \cdot f_n \cdot 225\ \text{ns}$	$\Delta\varphi = \varphi_n - n\varphi_1 =$ phase angle $U(t) = \sum_{n=1}^{100} \sqrt{2} U_n \sin(2\pi f_n t + \varphi_n)$ f_1 = frequency of the 1st harmonic f_n = frequency of the n^{th} harmonic U_1 = RMS value of the 1st harmonic U_n = RMS value of n^{th} harmonic U_S = peak value of the voltage signal The range limits and other specifications in the Fluke 6100B/6105A user manual (September 2009 Rev. 1, 6/10) apply

Permanent laboratory

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between the 1st harmonic and the n^{th} harmonic of a current signal Measuring instruments	-180° to 180°	$1 \le n \le 100$ 45 Hz ≤ f_1 ≤ 65 Hz I_S ≤ 29.7 A: f_n ≤ 6 kHz or I_S > 29.7 A: f_n ≤ 3 kHz I_1 ≥ 100 mA I_n ≥ 10 mA I_S ≤ 113 A	$360° \cdot f_n \cdot 228\ \text{ns}$	$\Delta\varphi = \varphi_n - n\varphi_1 =$ phase angle $I(t) = \sum_{n=1}^{100} \sqrt{2} I_n \sin(2\pi f_n t + \varphi_n)$ f_1 = frequency of the 1st harmonic f_n = frequency of the n^{th} harmonic I_1 = RMS value of the 1st harmonic I_n = RMS value of the n^{th} harmonic I_S = peak value of the current signal The range limits and other specifications in the Fluke 6100B/6105A user manual (September 2009 Rev. 1, 6/10) apply

Inductance and capacitance

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance	0 µH		0.03 µH	2-wire short circuit
	0 H to 1.1 H			L = measured value
	100 µH	100 Hz	$0.63 \cdot 10^{-3} \cdot L$	
		1 kHz	$0.17 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.22 \cdot 10^{-3} \cdot L$	Absolute value of impedance
	1 mH	100 Hz	$0.14 \cdot 10^{-3} \cdot L$	50 mΩ ≤ $\|Z\|$ ≤ 11 kΩ
		1 kHz	$0.12 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.17 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz; 1 kHz	$0.11 \cdot 10^{-3} \cdot L$	Smallest specified fixed measurement uncertainties for direct measurement or substitution at GR 1482 or identical construction
		10 kHz	$0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz	$0.11 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.25 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.13 \cdot 10^{-3} \cdot L$	
Capacitance	0 pF		0.2 pF	No load
	0 pF to 10 µF			C = measured value
	1 pF	1 kHz	$0.21 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.31 \cdot 10^{-3} \cdot C$	Absolute value of impedance
	10 pF	1 kHz	$19 \cdot 10^{-6} \cdot C$	1 Ω ≤ $\|Z\|$ ≤ 110 MΩ
		10 kHz; 100 kHz	$62 \cdot 10^{-6} \cdot C$	Smallest specified fixed measurement uncertainties for direct measurement or substitution at GR 1403 / 1404 / 1409 or identical
		1 MHz	$0.10 \cdot 10^{-3} \cdot C$	
	100 pF	1 kHz	$26 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz	$31 \cdot 10^{-6} \cdot C$	
		100 kHz	$0.10 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz	$0.20 \cdot 10^{-3} \cdot C$	
		1 kHz	$0.12 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.11 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz; 1 kHz; 10 kHz	$0.15 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz	$0.10 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.20 \cdot 10^{-3} \cdot C$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Capacitance	10 µF to 1 mF			C = capacitance
	10 µF	100 Hz	$71 \cdot 10^{-5} \cdot C$	Intermediate values & varying measurement conditions increase the measurement uncertainty f_R = charge-discharge rate I = current Varying measurement conditions increase the measurement uncertainty
		1 kHz	$69 \cdot 10^{-5} \cdot C$	
	100 µF	100 Hz	$39 \cdot 10^{-5} \cdot C$	
		1 kHz	$66 \cdot 10^{-5} \cdot C$	
	1 mF	100 Hz	$11 \cdot 10^{-4} \cdot C$	
	0.12 mF to 120 mF			
	0.12 mF to < 2 mF	f_R = 13.2 Hz; I = 10 mA	$30 \cdot 10^{-5} \cdot C$	
	2 mF to < 20 mF	f_R = 2.3 Hz; I = 10 mA	$16 \cdot 10^{-5} \cdot C$	
	20 mF to 120 mF	f_R = 0.25 Hz; I = 10 mA	$16 \cdot 10^{-5} \cdot C$	

Electrical measurement quantities – time and frequency

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f	1 MHz to 10 MHz in steps of 1 MHz	Phase difference time measurements over measurement times > 1 h	$2.0 \cdot 10^{-12} \cdot f$	f = measured value U_{Tf} = trigger uncertainty
	0.01 Hz to 350 MHz > 350 MHz to 26.5 GHz > 26.5 GHz to 40 GHz		$2.6 \cdot 10^{-12} \cdot f + U_{Tf}$ $11 \cdot 10^{-12} \cdot f + U_{Tf}$ 0.6 Hz + U_{Tf}	
Time interval Δt	0 ns to 0.7 ms 0 ns to 200 s 1 µs to 100 h 1 s to 100 h		1.3 ns $1.5 \cdot 10^{-6} \cdot \Delta t$ + 50 ps $10 \cdot 10^{-9} \cdot \Delta t$ + 1 µs $13 \cdot 10^{-6} \cdot \Delta t$ + 0.82 s	
Clock drift	0 s/d to 100 s/d		$1.3 \cdot 10^{-7}$ = 0.011 s/d	Electronic or mechanical clocks
Rotational frequency	0.02 s^{-1} to 3500 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	f = measured value

High-frequency and radiation measurement quantities – High-frequency measurement quantities

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Oscilloscopes vertical	1 mV to 5 V 5 mV to 200 V	DC to 10 kHz	$1.2 \cdot 10^{-3} \cdot U + 12\ \mu V$	U = measured value 50 Ω 1 MΩ
Oscilloscope horizontal	25 ps to 40 s		$0.12 \cdot 10^{-6} \cdot T + 0.1$ ps	T = measured value
Bandwidth f (frequency response)	40 Hz to 6 GHz		$6.3 \cdot 10^{-3} \cdot f^2/\text{GHz} + 20 \cdot 10^{-3} \cdot f$	f = measured value
	> 6 GHz to 40 GHz		$75 \cdot 10^{-3} \cdot f$	
Rise time	30 ps to 45 ps > 45 ps to 1 ms	0.1 V to 3 V	5 ps $10 \cdot 10^{-3} \cdot T + 3$ ps	
	70 ps to 85 ps > 85 ps to 310 ps > 310 ps to 650 ps > 650 ps to 1 ms	0.1 V to 3 V	$78 \cdot 10^{-3} \cdot T$ $67 \cdot 10^{-3} \cdot T$ $58 \cdot 10^{-3} \cdot T$ $56 \cdot 10^{-3} \cdot T$	Calculated from 3 dB bandwidth T = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Pulse measurements Rise time (e.g. oscilloscope calibrator)	15 ps to 10 ns	0.1 V to 40 V in 50 Ω	$10 \cdot 10^{-3} \cdot T + 3$ ps	External trigger signal required
	160 ps to 10 ms	0.1 V to 2 V in 50 Ω	$30 \cdot 10^{-3} \cdot T + 30$ ps	
Burst generator Output voltage Peak value U_s	100 V to 4 kV	under 50 Ω or 1 kΩ load	$48 \cdot 10^{-3} \cdot U_s$	
Rise time and pulse duration T_r	3 ns to 1 µs		$41 \cdot 10^{-3} \cdot T_r$	
Burst duration and burst period T	10 µs to 1 s		$5 \cdot 10^{-3} \cdot T$	
Pulse frequency f	100 Hz to 500 kHz		$1 \cdot 10^{-3} \cdot f$	
ESD generator Rise time t_r of peak current	300 ps to 3 ns		3% · t_r + 15 ps	
Discharge current I	1.5 A to 35 A		4.3% · I + 0.15 A	Measuring range relative to peak current I_P
Surge voltage generator Front time $t_{r,Us}$ of the open-circuit voltage	15 ns to 100 ms		3% · $t_{r,Us}$ + 1 ns	
Front time $t_{r,Is}$ of the short-circuit current	100 ns to 100 ms		3% · $t_{r,Is}$ + 2 ns	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Rear half-life t_H of the waveform	0.5 µs to 100 ms		5% · t_H	
Peak value of open-circuit voltage U_S	0.1 kV to 7 kV		3.3% · U_S	
Peak value of short-circuit current I_S	10 A to 5 kA		3.5% · I_S	
	> 5 kA to 10 kA		3.8% · I_S	
Pulse-shaped measurement quantities *		EN 55016-1-1:2015		
Measuring receiver				
Display behavior with pulses Amplitude relationship (absolute calibration)	9 kHz to 150 kHz		0.35 dB	Band A
	> 150 kHz to 30 MHz			Band B
	> 30 MHz to 300 MHz		0.40 dB	Band C
	> 300 MHz to 1 GHz			Band D
Change in display with the pulse frequency (relative calibration)	Pulse repetition frequency			
	0.1 Hz to 2 kHz		0.30 dB	Band A
	0.1 Hz to 50 kHz		0.35 dB	Band B
	0.1 Hz to 1 MHz			Band C and D

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure			Expanded measurement uncertainty	Remarks
RF power Input power And calibration factor of RF power meters	10 fW to < 100 fW	DC	to	2 GHz	$21 \cdot 10^{-3} \cdot P$	PC Type N *) up to 18 GHz PC-3.5 mm *) up to 33 GHz PC-2.92 mm *) up to 40 GHz *) Other connectors increase the measurement uncertainty P = measured value (W)
		> 2 GHz	to	< 5 GHz	$26 \cdot 10^{-3} \cdot P$	
		5 GHz	to	< 9 GHz	$34 \cdot 10^{-3} \cdot P$	
		9 GHz	to	< 12 GHz	$40 \cdot 10^{-3} \cdot P$	
		12 GHz	to	15 GHz	$48 \cdot 10^{-3} \cdot P$	
		> 15 GHz	to	18 GHz	$54 \cdot 10^{-3} \cdot P$	
	100 fW to 1 pW	DC	to	100 MHz	$18 \cdot 10^{-3} \cdot P$	
		> 100 MHz	to	2 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 2 GHz	to	8 GHz	$22 \cdot 10^{-3} \cdot P$	
		> 8 GHz	to	12 GHz	$24 \cdot 10^{-3} \cdot P$	
		> 12 GHz	to	40 GHz	$29 \cdot 10^{-3} \cdot P$	
	> 1 pW to 10 pW	DC	to	100 MHz	$13 \cdot 10^{-3} \cdot P$	
		> 100 MHz	to	2 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 2 GHz	to	8 GHz	$18 \cdot 10^{-3} \cdot P$	
		> 8 GHz	to	12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz	to	26.5 GHz	$26 \cdot 10^{-3} \cdot P$	
		> 26.5 GHz	to	40 GHz	$29 \cdot 10^{-3} \cdot P$	
	> 10 pW to 1 nW	DC	to	100 MHz	$12 \cdot 10^{-3} \cdot P$	
		> 100 MHz	to	2 GHz	$14 \cdot 10^{-3} \cdot P$	
		> 2 GHz	to	8 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 8 GHz	to	12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz	to	40 GHz	$22 \cdot 10^{-3} \cdot P$	
	> 1 nW to 100 nW	DC	to	2 GHz	$10 \cdot 10^{-3} \cdot P$	
		> 2 GHz	to	8 GHz	$12 \cdot 10^{-3} \cdot P$	
		> 8 GHz	to	12 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 12 GHz	to	40 GHz	$15 \cdot 10^{-3} \cdot P$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF power Input power and calibration factor of RF power meters	> 100 nW to 10 µW	DC to 100 MHz	$7.1 \cdot 10^{-3} \cdot P$	PC Type N *) up to 18 GHz PC-3.5 mm *) up to 33 GHz PC-2.92 mm *) up to 40 GHz *) Other connectors increase measurement uncertainty P = measured value (W)
		> 100 MHz to 2 GHz	$9.4 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$15 \cdot 10^{-3} \cdot P$	
	> 10 µW To 100 mW	DC to 100 MHz	$6.1 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$7.9 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$9.3 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$13 \cdot 10^{-3} \cdot P$	
	2 W to 160 W	QMH chapter XIII.2.A Version 1.0 300 kHz 500 kHz 1 MHz to 10 MHz	$20 \cdot 10^{-3} \cdot P$	$\lvert\Gamma_{DUT}\rvert \leq 0.01$ *) *) Higher reflectance factors increase the measurement uncertainty P = measured value (W) $\lvert\Gamma_{DUT}\rvert$ = magnitude of the reflectance factor of the calibration object
RF power Output power and calibration factor of RF sources	1 mW	50 MHz	$5 \cdot 10^{-3} \cdot P$	Substitution
	0.1 pW To < 10 pW	50 MHz	$27 \cdot 10^{-3} \cdot P$	PC Type N *) up to 18 GHz PC-3.5 mm *) up to 33 GHz PC-2.92 mm *) up to 40 GHz *) Other connectors increase measurement uncertainty $f \leq 5$ GHz: $\lvert\Gamma_G\rvert \leq 0.025$ 5 GHz < $f \leq 20$ GHz: $\lvert\Gamma_G\rvert \leq 0.1$
		10 MHz to 2 GHz	$30 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 3 GHz	$35 \cdot 10^{-3} \cdot P$	
	10 pW To < 1 nW	50 MHz	$21 \cdot 10^{-3} \cdot P$	
		10 MHz to 2 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 3 GHz	$31 \cdot 10^{-3} \cdot P$	
	1 nW To < 100 nW	50 MHz	$17 \cdot 10^{-3} \cdot P$	
		10 MHz to 2 GHz	$21 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 4 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 12 GHz	$38 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 18 GHz	$71 \cdot 10^{-3} \cdot P$	
		> 18 GHz to 26.5 GHz	$93 \cdot 10^{-3} \cdot P$	
	100 nW To < 1 µW	8 kHz to < 10 MHz	$28 \cdot 10^{-3} \cdot P$	
		10 MHz to 50 MHz	$13 \cdot 10^{-3} \cdot P$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
		> 50 MHz to 4 GHz	$14 \cdot 10^{-3} \cdot P$	20 GHz < f ≤ 33 GHz: $\lvert\Gamma_G\rvert$ ≤ 0.15 33 GHz < f ≤ 40 GHz: $\lvert\Gamma_G\rvert$ ≤ 0.3 f = frequency (Hz) P = measured value (W) $\lvert\Gamma_G\rvert$ = reflection factor of the calibration object
		> 4 GHz to 5 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 5 GHz to 12 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 20 GHz	$28 \cdot 10^{-3} \cdot P$	
		> 20 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF power Output power and calibration factor of RF sources	1 µW to < 10 µW	8 kHz to < 10 MHz	$18 \cdot 10^{-3} \cdot P$	PC Type N *) up to 18 GHz PC-3.5 mm *) up to 33 GHz PC-2.92 mm *) up to 40 GHz *) Other connectors increase measurement uncertainty $f \leq 5$ GHz: $\lvert\Gamma_G\rvert \leq 0.025$ 5 GHz < $f \leq$ 20 GHz: $\lvert\Gamma_G\rvert \leq 0.1$ 20 GHz < $f \leq$ 33 GHz: $\lvert\Gamma_G\rvert \leq 0.15$ 33 GHz < $f \leq$ 40 GHz: $\lvert\Gamma_G\rvert \leq 0.3$ f = frequency (Hz) P = measured value (W) $\lvert\Gamma_G\rvert$ = reflection factor of the calibration object
		10 MHz to 50 MHz	$13 \cdot 10^{-3} \cdot P$	
		> 50 MHz to 4 GHz	$14 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 5 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 5 GHz to 12 GHz	$21 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 20 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 20 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	
	10 µW to < 100 µW	DC to < 10 MHz	$9.0 \cdot 10^{-3} \cdot P$	
		10 MHz to 100 MHz	$10 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$12 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 10 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 10 GHz to 12 GHz	$16 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 30 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 30 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	
	100 µW to 0.1 W	DC to < 10 MHz	$5.6 \cdot 10^{-3} \cdot P$	
		10 MHz to 100 MHz	$7.5 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$10 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 10 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 10 GHz to 12 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 30 GHz	$19 \cdot 10^{-3} \cdot P$	
		> 30 GHz to 33 GHz	$39 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$53 \cdot 10^{-3} \cdot P$	
	> 0.1 W to 1 W	DC to 50 MHz	$11 \cdot 10^{-3} \cdot P$	
		> 50 MHz to 2 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 4 GHz	$16 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 18 GHz	$30 \cdot 10^{-3} \cdot P$	
	> 1 W to 70 W	DC to 3 GHz	$38 \cdot 10^{-3} \cdot P$	
	> 70 W to 250 W	DC to 500 MHz	$37 \cdot 10^{-3} \cdot P$	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	2.2 µV to 220 µV	DC to 3 GHz	$W(U_{RF}) = \frac{W(P)}{2}$	$W(P)$ = relative uncertainty of the Measured power at Z_0 = 50 Ω
	220 µV to 7 V	DC to 18 GHz		**)
	2.2 µV to 220 µV	DC to 3 GHz		***)
	2.2 mV to 2 V	DC to 40 GHz		
RF voltage U_{RF} Measuring instruments and receivers with RF voltage display relative to 50 Ω	0.7 µV to 2 V	DC to 18 GHz	$W(U_{RF}) = \frac{W(P_{inc})}{2}$	$W(P_{inc})$ = relative uncertainty of the irradiated power relative to Z_0 = 50 Ω **)
	2.2 mV to 2 V	DC to 40 GHz		***)
RF power Noise display of receivers	DC to 40 GHz		1.6 dB	Power > -170 dB (1 mW) relative to 1 Hz bandwidth
Signal level difference	0 dBc to 100 dBc	100 Hz to 26.5 GHz 100 Hz to 40 GHz	1.3 dB 2.7 dB	SNR ≥ 12 dB
Bandwidth filter	1 Hz to 10 MHz		0.5%	Signal-to-noise ratio SNR ≥ 70 dB
Form factor	> 1:1 to 5:1 > 5:1 to 10:1 > 10:1 to 20:1		3% 6% 12%	Signal-to-noise ratio SNR ≥ 15 dB
Switching deviation			0.02 dB	
Phase noise RF sources	≥ -186 dBc/Hz See matrix M.36	QMH XIII.7 Version 1.0 5 MHz ≤ f_C ≤ 40 GHz 10 MHz ≤ f_O ≤ 30 GHz	+1.3 dB to +2.9 dB and -1.9 dB to -14 dB [See matrix M.37]	f_C = carrier frequency f_O = offset frequency $\lvert\Gamma_G\rvert$ = magnitude of the reflection factor of the RF source The measurement uncertainties were calculated for $\lvert\Gamma_G\rvert$ < 0.12 Higher reflection factors increase the measurement uncertainty

Matrix M.36: Exemplary values for the lower threshold of the measurement range in dBc/Hz as a function of carrier and offset frequency. The figures are based on a carrier power PT = 13 dBm. Differing carrier powers will alter the measurement range.

	Offset frequency							
Carrier frequency	**10 Hz**	**100 Hz**	**1 kHz**	**10 kHz**	**100 kHz**	**1 MHz**	**10 MHz**	**30 MHz**
5 MHz	-141	-158	-170	-170	-170	-170	-	-
10 MHz	-138	-153	-170	-170	-170	-170	-	-
100 MHz	-123	-151	-179	-181	-183	-184	-184	-186
1 GHz	-103	-131	-163	-177	-183	-184	-184	-186
3 GHz	-93	-121	-153	-171	-173	-180	-183	-185
7 GHz	-86	-141	-146	-164	-165	-172	-182	-184
10 GHz	-83	-111	-146	-160	-160	-165	-181	-183
16 GHz	-79	-107	-142	-155	-155	-163	-180	-181
26 GHz	-75	-103	-138	-145	-145	-157	-174	-175
40 GHz	-68	-96	-121	-128	-128	-142	-165	-166

Matrix M.36: Example values for the expanded measurement uncertainty in dB as a function of carrier and offset frequency

		Distance from the inherent noise contributions of the measurement system								
Carrier frequency	**Offset frequency**	**2 dB**	**3 dB**	**4 dB**	**5 dB**	**6 dB**	**7 dB**	**8 dB**	**9 dB**	**10 dB**
5 MHz ≤ f_C ≤ 10 GHz	**10 Hz ≤ f_O ≤ 1 kHz**	-9.5; +2.8	-6.8; +2.5	-5.6; +2.4	-3.8; +2.0	-3.4; +1.9	-3.2; +1.8	-2.5; +1.6	-2.4; +1.5	-2.4; +1.5
	1 kHz ≤ f_O ≤ 1 MHz	-9.0; +2.7	-6.5; +2.5	-5.3; +2.3	-3.5; +1.9	-3.2; +1.8	-2.9; +1.7	-2.3; +1.5	-2.2; +1.4	-2.1; +1.4
	1 MHz ≤ f_O ≤ 10 MHz	-8.6; +2.7	-6.3; +2.5	-5.1; +2.3	3.4; +1.9	-3.0; +1.8	-2.8; +1.7	-2.2; +1.4	-2.0; +1.4	-2.0; +1.3
	10 MHz ≤ f_O ≤ 30 MHz	-14; +2.9	-8.9; +2.7	-7.1; +2.6	-4.9; +2.3	-4.5; +2.2	-4.2; +2.1	-3.6; +1.9	-3.5; +1.9	-3.4; +1.9
10 GHz ≤ f_C ≤ 40 GHz	**10 Hz ≤ f_O ≤ 1 kHz**	-10.0; +2,8	-7.2; +2.6	-5.9; +2.4	-4.0; +2.1	-3.6; +1.9	-3.4; +1.9	-2.8; +1.7	-2.6; +1.6	-2.6; +1.6
	1 kHz ≤ f_O ≤ 1 MHz	-9.0; +2.7	-6.5; +2.5	-5.3; +2.3	-3.6; +1.9	-3.2; +1.8	-2.9; +1.7	-2.3; +1.5	-2.2; +1.5	-2.1; +1.4
	1 MHz ≤ f_O ≤ 10 MHz	-8.5; +2,7	-6.2; +2.5	-5.1; +2.3	-3.4; +1.9	-3.0; +1.8	-2.7; +1.7	-2.1; +1.4	-2.0; +1.4	-1.9; +1.3
	10 MHz ≤ f_O ≤ 30 MHz	-14.0; +2.9	-8.9; +2.7	-7.1; +2.6	-5.0; +2.3	-4.5; +2.2	-4.2; +2.1	-3.6; +1.9	-3.5; +1.9	-3.4; +1.9

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Display linearity	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB > 80 dB to 100 dB > 100 dB to 110 dB	100 kHz to 500 MHz	0.06 dB 0.07 dB 0.09 dB 0.1 dB 0.2 dB	SNR ≥ 50 dB $\lvert\Gamma_{L,DUT}\rvert \leq 0.05$ $f \leq 500$ MHz
Input attenuator or IF amplifier	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB > 80 dB to 100 dB > 100 dB to 110 dB	100 kHz to 500 MHz	0.06 dB 0.07 dB 0.09 dB 0.1 dB 0.2 dB	Comparison with external attenuator $\lvert\Gamma_{L,DUT}\rvert \leq 0.05$ $f \leq 500$ MHz
	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB	100 kHz to 500 MHz	0.04 dB 0.06 dB 0.08 dB	Stepwise display comparison SNR ≥ 50 dB, receiver linearity < (0.01 dB + 0.005 dB/10 dB)
RF amplification Amplifier	0 dB to 70 dB	DC to 100 MHz > 100 MHz to 2 GHz > 2 GHz to 4 GHz > 4 GHz to 18 GHz	0.19 dB 0.26 dB 0.3 dB 0.5 dB	BNC connector to max. 2 GHz N connector and BNC connector, 50 Ω, other connectors increase measurement uncertainty
	0 dB to 70 dB	DC to 100 MHz > 100 MHz to 4 GHz > 4 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.21 dB 0.3 dB 0.6 dB 0.7 dB	2.92 mm compatible connector, 50 Ω, other connectors increase measurement uncertainty
Non-linearity of RF power meters	10 nW to 1 W	50 MHz	$5.5 \cdot 10^{-3}$ (0.024 dB)	R&S NRVC-B2 60 dB max.

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF current Current clamps	100 µA to 50 mA	40 Hz to 10 MHz > 10 MHz to 30 MHz > 30 MHz to 65 MHz	$14 \cdot 10^{-3} \cdot I$ $18 \cdot 10^{-3} \cdot I$ $20 \cdot 10^{-6} f^2 \cdot I$	Tektronix 015-0601-50 in combination with oscilloscope I = measured value f = frequency in MHz
RF current	50 mA to 1.8 A	QMH chapter XIII.2.B Version 1.0 10 kHz to 10 MHz	$10 \cdot 10^{-3} \cdot I$ to $21 \cdot 10^{-3} \cdot I$	I = measured value (A)
	50 mA to < 95 mA	10 kHz	$11 \cdot 10^{-3} \cdot I$	
		100 kHz	$13 \cdot 10^{-3} \cdot I$	
		500 kHz	$12 \cdot 10^{-3} \cdot I$	
		1 MHz	$12 \cdot 10^{-3} \cdot I$	
		2 MHz	$12 \cdot 10^{-3} \cdot I$	
		3 MHz	$16 \cdot 10^{-3} \cdot I$	
		4 MHz	$14 \cdot 10^{-3} \cdot I$	
		5 MHz	$13 \cdot 10^{-3} \cdot I$	
		6 MHz	$12 \cdot 10^{-3} \cdot I$	
		7 MHz	$14 \cdot 10^{-3} \cdot I$	
		10 MHz	$21 \cdot 10^{-3} \cdot I$	
	95 mA to 1.8 A	10 kHz	$10 \cdot 10^{-3} \cdot I$	
		100 kHz	$12 \cdot 10^{-3} \cdot I$	
		500 kHz	$11 \cdot 10^{-3} \cdot I$	
		1 MHz	$11 \cdot 10^{-3} \cdot I$	
		2 MHz	$11 \cdot 10^{-3} \cdot I$	
		3 MHz	$15 \cdot 10^{-3} \cdot I$	
		4 MHz	$13 \cdot 10^{-3} \cdot I$	
		5 MHz	$12 \cdot 10^{-3} \cdot I$	
		6 MHz	$11 \cdot 10^{-3} \cdot I$	
		7 MHz	$13 \cdot 10^{-3} \cdot I$	
		10 MHz	$20 \cdot 10^{-3} \cdot I$	

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF reflection coefficient * Magnitude $\|\Gamma\|$	0 to 1	9 kHz to 18 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.003 to 0.013 See matrix M.3	N connector, 50 Ω, other connectors increase measurement uncertainty Measurement uncertainty in units of reflection factor
	0 to 1	9 kHz to 33 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.003 to 0.016 See matrix M.4	3.5 mm connector Measurement uncertainty in units of reflection factor
	0 to 1	45 MHz to 45 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.004 to 0.017 See matrix M.5	2.92 mm connector Measurement uncertainty in units of reflection factor
RF reflection coefficient * Phase angle φ	-180° to +180°	9 kHz to 18 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.2° to 4.7° See matrix M.6	N connector, 50 Ω, other connectors increase measurement uncertainty
	-180° to +180°	9 kHz to 33 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.3° to 5.8° See matrix M.7	3.5 mm connector
	-180° to +180°	45 MHz to 45 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.3° to 6.3° See matrix M.8	2.92 mm connector
RF attenuation Attenuators	0 dB to 30 dB	100 kHz to 10 GHz > 10 GHz to 18 GHz > 18 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.03 dB 0.05 dB 0.09 dB 0.10 dB	L is the measured attenuation, ****) $\|\Gamma_{DUT}\| \leq 0.01$ $f \leq 500$ MHz $\|\Gamma_{L,DUT}\| \leq 0.05$ 500 MHz < $f \leq$ 10 GHz $\|\Gamma_{L,DUT}\| \leq 0.08$ 10 GHz < $f \leq$ 18 GHz $\|\Gamma_{L,DUT}\| \leq 0.1$ 18 GHz < $f \leq$ 40 GHz
	> 30 dB to 60 dB	100 kHz to 10 GHz > 10 GHz to 18 GHz > 18 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.001 dB/dB · L 0.02 dB + 0.001 dB/dB · L 0.10 dB + 0.001 dB/dB · L 0.11 dB + 0.001 dB/dB · L	

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF attenuation Attenuators	> 60 dB to 70 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.07 dB 0.10 dB	$\lvert\Gamma_{L,DUT}\rvert \leq 0.01$ $f \leq 500$ MHz $\lvert\Gamma_{L,DUT}\rvert \leq 0.05$ 500 MHz < $f \leq 3$ GHz
	> 70 dB to 80 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.08 dB 0.2 dB	
	> 80 dB to 100 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.1 dB 0.3 dB	
RF attenuation *	0 dB to 60 dB	9 kHz to 18 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.01 dB to 0.09 dB See matrix M.9	N connector, 50 Ω, other connectors increase measurement uncertainty
	0 dB to 60 dB	9 kHz to 33 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.01 dB to 0.22 dB See matrix M.10	3.5 mm connector
	0 dB to 60 dB	45 MHz to 45 GHz EURAMET Calibration Guide No. 12 Version 3.0	0.01 dB to 0.32 dB See matrix M.11	2.92 mm connector
RF attenuation * Phase angle φ	-180° to +180°	9 kHz to 18 GHz 0 dB to 60 dB EURAMET Calibration Guide No. 12 Version 3.0	0.2° to 0.8° See matrix M.12	N connector, 50 Ω, other connectors increase measurement uncertainty
	-180° to +180°	9 kHz to 33 GHz 0 dB to 60 dB EURAMET Calibration Guide No. 12 Version 3.0	0.2° to 1.8° See matrix M.13	3.5 mm connector
	-180° to +180°	45 MHz to 45 GHz 0 dB to 60 dB EURAMET Calibration Guide No. 12 Version 3.0	0.2° to 2.5° See matrix M.14	2.92 mm connector

Matrix M.3 RF reflection coefficient, magnitude |Γ|; N connector 50 Ω

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude |Γ|	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0	0.003 to 0.004	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.1	0.003 to 0.005	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0	0.003 to 0.005	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.3	0.003 to 0.006	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.4	0.003 to 0.005	0.004	0.003 to 0.008	0.008 to 0.009
0.5	0.003 to 0.006	0.004	0.004 to 0.009	0.008 to 0.009
0.6	0.004 to 0.006	0.004 to 0.005	0.004 to 0.009	0.009
0.7	0.004 to 0.006	0.005	0.005 to 0.010	0.009 to 0.010
0.8	0.004 to 0.006	0.005 to 0.006	0.005 to 0.010	0.010
0.9	0.004 to 0.007	0.006	0.005 to 0.011	0.011 to 0.012
1	0.003 to 0.006	0.004 to 0.006	0.004 to 0.012	0.011 to 0.013

Matrix M.4 RF reflection coefficient, magnitude |Γ|; 3.5 mm connector

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude |Γ|	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0	0.003 to 0.004	0	0.003 to 0.004	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.1	0.003 to 0.005	0.003	0.003 to 0.004	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.2	0.003 to 0.006	0.003 to 0.004	0.004 to 0.005	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.3	0.003 to 0.006	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.011
0.4	0.004 to 0.005	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.011
0.5	0.004 to 0.006	0.004 to 0.005	0.004 to 0.005	0.005 to 0.006	0.005 to 0.008	0.008 to 0.011
0.6	0.004 to 0.006	0.005	0.005 to 0.006	0.006	0.006 to 0.009	0.009 to 0.012
0.7	0.004 to 0.006	0.005 to 0.006	0.005 to 0.006	0.006 to 0.007	0.006 to 0.010	0.009 to 0.013
0.8	0.004 to 0.007	0.005 to 0.006	0.005 to 0.007	0.006 to 0.007	0.006 to 0.010	0.010 to 0.014
0.9	0.004 to 0.007	0.006 to 0.007	0.006 to 0.008	0.007 to 0.008	0.007 to 0.011	0.011 to 0.015
1	0.004 to 0.006	0.005 to 0.006	0.005 to 0.008	0.006 to 0.009	0.007 to 0.012	0.011 to 0.016

Matrix M.5 RF reflection coefficient, magnitude $|\Gamma|$; 2.92 mm connector

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude $\|\Gamma\|$	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.1	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.2	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.3	0.004	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.4	0.004	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.5	0.004 to 0.005	0.005	0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.012
0.6	0.005	0.005	0.005 to 0.006	0.005 to 0.006	0.005 to 0.009	0.008 to 0.011	0.010 to 0.011	0.010 to 0.012
0.7	0.005 to 0.006	0.005	0.005 to 0.006	0.006	0.006 to 0.009	0.009 to 0.012	0.011 to 0.012	0.011 to 0.013
0.8	0.005 to 0.006	0.006	0.006 to 0.007	0.006 to 0.007	0.006 to 0.010	0.009 to 0.013	0.012 to 0.013	0.012 to 0.014
0.9	0.005 to 0.007	0.006 to 0.007	0.006 to 0.008	0.007 to 0.008	0.007 to 0.011	0.010 to 0.014	0.013 to 0.014	0.013 to 0.015
1	0.005 to 0.007	0.005 to 0.006	0.005 to 0.008	0.007 to 0.008	0.006 to 0.012	0.011 to 0.015	0.014 to 0.015	0.014 to 0.017

Matrix M.6 RF reflection coefficient, phase angle φ; N connector 50 Ω

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0.1	1.4° to 2.2°	1.5° to 1.9°	1.5° to 4.5°	4.4° to 4.7°
0.2	0.7° to 1.4°	0.8° to 1.0°	0.8° to 2.3°	2.2° to 2.4°
0.3	0.5° to 1.0°	0.6° to 0.7°	0.6° to 1.5°	1.5° to 1.6°
0.4	0.4° to 0.7°	0.5° to 0.6°	0.5° to 1.2°	1.2°
0.5	0.4° to 0.6°	0.4° to 0.5°	0.4° to 1.0°	1.0°
0.6	0.4° to 0.5°	0.4° to 0.5°	0.4° to 0.9°	0.9°
0.7	0.3° to 0.5°	0.4°	0.4° to 0.8°	0.8°
0.8	0.3° to 0.5°	0.4°	0.4° to 0.8°	0.7° to 0.8°
0.9	0.3° to 0.4°	0.4°	0.4° to 0.8°	0.7° to 0.8°
1	0.2° to 0.4°	0.3° to 0.4°	0.3° to 0.7°	0.7° to 0.8°

Matrix M.7 RF reflection coefficient, phase angle φ; 3.5 mm connector

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0.1	1.5° to 2.6°	1.6° to 1.7°	1.7° to 2.3°	2.3° to 2.6°	2.4° to 4.2°	4.1° to 5.8°
0.2	0.8° to 1.5°	0.9°	0.9° to 1.2°	1.2° to 1.4°	1.3° to 2.2°	2.2° to 3.0°
0.3	0.6° to 1.1°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.0°	1.0° to 1.6°	1.6° to 2.1°
0.4	0.5° to 0.8°	0.5° to 0.6°	0.6° to 0.8°	0.7° to 0.9°	0.8° to 1.3°	1.3° to 1.7°
0.5	0.5° to 0.7°	0.5°	0.5° to 0.7°	0.7° to 0.8°	0.8° to 1.2°	1.1° to 1.5°
0.6	0.4° to 0.6°	0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.1°	1.1° to 1.4°
0.7	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
0.8	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
0.9	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
1	0.3° to 0.4°	0.3° to 0.4°	0.3° to 0.5°	0.5° to 0.7°	0.7° to 1.0°	0.9° to 1.2°

Matrix M.8 RF reflection factor, phase angle φ; 2.92 mm connector

Magnitude $\lvert\Gamma\rvert$	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0.1	2.0° to 2.1°	2.0°	2.0° to 2.3°	2.2° to 2.3°	2.2° to 4.2°	4.2° to 5.3°	5.3° to 5.4°	5.3° to 6.3°
0.2	1.0° to 1.1°	1.0° to 1.1°	1.0° to 1.2°	1.2°	1.2° to 2.2°	2.1° to 2.7°	2.7°	2.7° to 3.2°
0.3	0.7° to 0.8°	0.7°	0.7° to 0.9°	0.8° to 0.9°	0.8° to 1.5°	1.5° to 1.9°	1.9°	1.9° to 2.2°
0.4	0.6°	0.6°	0.6° to 0.7°	0.7°	0.7° to 1.2°	1.1° to 1.5°	1.5°	1.5° to 1.7°
0.5	0.5° to 0.6°	0.5°	0.5° to 0.6°	0.6°	0.6° to 1.0°	1.0° to 1.3°	1.2° to 1.3°	1.3° to 1.5°
0.6	0.4° to 0.5°	0.5°	0.5° to 0.6°	0.5° to 0.6°	0.6° to 0.9°	0.9° to 1.1°	1.1° to 1.2°	1.1° to 1.3°
0.7	0.4° to 0.5°	0.5°	0.5° to 0.6°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.1°	1.0° to 1.1°	1.1° to 1.2°
0.8	0.4° to 0.5°	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.0°	1.0°	1.0° to 1.2°
0.9	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.0°	1.0°	1.0° to 1.2°
1	0.3° to 0.4°	0.3° to 0.4°	0.3° to 0.5°	0.5°	0.5° to 0.8°	0.7° to 1.0°	0.9° to 1.0°	0.9° to 1.2°

Matrix M.9 RF attenuation; N connector 50 Ω

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB
3 dB	0.04 dB to 0.05 dB	0.05 dB	0.05 dB	0.05 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB
10 dB	0.05 dB	0.05 dB	0.06 dB	0.05 dB to 0.06 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
40 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB to 0.07 dB
50 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB
60 dB	0.05 dB to 0.09 dB	0.08 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB

Matrix M.10 RF attenuation; 3.5 mm connector

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB	0.02 dB	0.02 dB
3 dB	0.04 dB to 0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB
10 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB
40 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.07 dB
50 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.09 dB	0.08 dB to 0.10 dB
60 dB	0.05 dB to 0.09 dB	0.07 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB	0.08 dB to 0.19 dB	0.15 dB to 0.22 dB

Matrix M.11 RF attenuation; 2.92 mm connector

Absolute attenuation	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB	0.02 dB	0.02 dB	0.02 dB to 0.04 dB	0.03 dB
3 dB	0.04 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB
10 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB	0.07 dB to 0.08 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB	0.07 dB	0.07 dB to 0.08 dB
40 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.07 dB	0.07 dB to 0.08 dB	0.08 dB to 0.09 dB
50 dB	0.05 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.09 dB	0.08 dB to 0.10 dB	0.09 dB to 0.10 dB	0.10 dB to 0.13 dB
60 dB	0.06 dB	0.08 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB	0.08 dB to 0.18 dB	0.15 dB to 0.22 dB	0.17 dB to 0.22 dB	0.20 dB to 0.32 dB

Matrix M.12 RF attenuation; phase angle φ; N connector 50 Ω

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
50 dB	0.4°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°
60 dB	0.4° to 0.6°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°

Matrix M.13 RF attenuation; phase angle φ; 3.5 mm connector

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°	0.6° to 0.9°	0.9° to 1.0°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°
50 dB	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°
60 dB	0.4° to 0.6°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°	0.8° to 1.5°	1.3° to 1.8°

Matrix M.14 RF attenuation; phase angle φ; 2.92 mm connector

Absolute attenuation	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°	0.6° to 0.9°	0.9° to 1.0°	1.0° to 1.2°	1.2° to 1.4°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°	1.2° to 1.3°	1.3° to 1.5°
50 dB	0.4°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°	1.2° to 1.4°	1.4° to 1.7°
60 dB	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°	0.8° to 1.5°	1.3° to 1.8°	1.6° to 1.9°	1.8° to 2.5°

High-frequency and radiation measurement quantities – Optical measurement quantities

Radiometry

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Optical radiation power Fiber optic power meters	1 µW to 0.5 mW	1310 nm, 1550 nm	1.3%	Connector FC, ST, SC, SMA, HMS-10 or adaptable Other wavelengths (780 nm, 635 nm, 1625 nm) interpolated
		850 nm 654 nm	2.2% 2.2%	
Nonlinearity of fiber optic radiation receivers	10 nW to 160 µW	1310 nm, 1550 nm, 850 nm	$1.8 \cdot 10^{-3}$ (0.008 dB)	Addition method
	0.1 nW to < 0.32 nW		$20 \cdot 10^{-3}$ (0.085 dB)	Comparison method
	0.32 nW to < 3.2 nW		$7.1 \cdot 10^{-3}$ (0.031 dB)	
	3.2 nW to 0.5 µW		$6.0 \cdot 10^{-3}$ (0.026 dB)	
Attenuation or amplification of fiber optic components	0 dB to 50 dB	Wavelengths: 1310 nm, 1550 nm, 850 nm Reference power: approx. 0.5 mW	$6.0 \cdot 10^{-3}$ (0.026 dB)	
	> 50 dB to 60 dB		$7.1 \cdot 10^{-3}$ (0.031 dB)	
	> 60 dB to 70 dB		$20 \cdot 10^{-3}$ (0.085 dB)	
Central wavelength λ	350 nm to < 700 nm		0.5 nm	
	700 nm to < 1250 nm		2.5 pm	
	1250 nm to 1700 nm		2 pm	

Photometry

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Transmission filter		QMH chapter XXXIV v4.0 Nominal values in the turbidity values of the standard		
Transmission *T*	16% to 60%		0.65%	
	> 60% to 76%		0.70%	
	> 76% to < 100%		0.80%	
Turbidity level *N*	> 0% to < 24%		0.80%	
	24% to < 40%		0.70%	
	40% to 84%		0.65%	
Turbidity coefficient *k*	Measuring chamber length 0.43 m > 0 m^{-1} to 4.3 m^{-1}		0.020 m^{-1} to 0.050 m^{-1}	Turbidity coefficient *k* calculated from the degree of turbidity *N* Uncertainty interval *U(k)* calculated from the uncertainty interval of the turbidity degree *U(N)* Other measuring chamber lengths increase the measurement uncertainty
Illuminance *E*	0 lx	QMH XXXI	0.01 lx	Reference zero
	900 lx to 2000 lx		1.7% · *E*	Standard light
	≥ 5 lx to < 10 klx		1.9% · *E*	LED light
	≥ 10 klx to 110 klx		$9.0 \cdot 10^{-8} \cdot E^2$/lx + 0.02 · *E* - 13 lx	

Dimensional measurement quantities

Length and angle

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Calipers for external, internal, and depth measurements *	> 0 mm to 1000 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	20 µm + 15 · 10^{-6} · l	l = measured value
Bow micrometers *	to 300 mm > 300 mm to 1000 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	2 µm + 6 · 10^{-6} · l 0.30 µm + 12 · 10^{-6} · l	
Dial gauges with scale display *	to 100 mm	VDI/VDE/DGQ 2618 Sheet 11.1:2014	1.5 µm + 10 · 10^{-6} · l	
Dial gauges with digital display *	to 100 mm	VDI/VDE/DGQ/DKD 2618 Sheet 11.4:2020	1.5 µm + 10 · 10^{-6} · l	
Fine pointer *	to 3 mm	VDI/VDE/DGQ 2618 Sheet 11.2:2002	0.9 µm	
Probe lever gauges *	to 1.6 mm	VDI/VDE/DGQ 2618 Sheet 11.3:2002		
Parallel gauges made of steel or ceramic according to DIN ISO 3650 *	0.5 mm to 100 mm	VDI/VDE/DGQ 2618 Sheet 3.1:2004 Measurement of the deviation l_c from the nominal dimension l_n by difference measurement	0.1 µm + 0.8 · 10^{-6} · l	
	> 100 mm to 175 mm		0.47 µm	
	in the nominal dimensions of the standard	Measurement of deviations f_o and f_u from the center dimension using 5-point differential measurement	0.08 µm	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Cylindrical standard Rings * Diameter	3 mm to 125 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.7 µm + 0.8 · 10^{-6} · *d*	*d* = measured diameter
	> 125 mm to 300 mm		0.6 µm + 2.1 · 10^{-6} · *d*	
Plug Gauge * Diameter	1 mm to 125 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.5 µm + 1.2 · 10^{-6} · *d*	
	> 125 mm to 300 mm		0.3 µm + 2.8 · 10^{-6} · *d*	
Test pins * Diameter	1 mm to 20 mm	VDI/VDE/DGQ 2618 Sheet 4.2:2006 Option 1	0.5 µm + 1.2 · 10^{-6} · *d*	
Thread gauges * (single and multiple thread cylindrical external and internal threads with straight flanks, symmetrical profile, nominal pitch, and nominal profile angle) External threads Simple flank diameter	1 mm to 125 mm	VDI/VDE/DGQ 2618 Sheet 4.8:2006 Option 1 Three-wire method (perpendicular to thread axis)	2.8 µm + 0.2 · 10^{-6} · *d*	*d* = measured flank diameter
	> 125 mm to 500 mm		2.7 µm + 1.0 · 10^{-6} · *d*	
Internal threads Simple flank diameter	3 mm to 125 mm	VDI/VDE/DGQ 2618 Sheet 4.9:2006 Option 1 Two-ball method (perpendicular to thread axis)	2.5 µm + 0.3 · 10^{-6} · *d*	
Lever systems for force transmission on brake test benches	to 600 mm	Work instruction AA0364 Version 8.0	52 µm	
	600 mm to 2500 mm		23 · 10^{-6} · *l* + 0.12 mm	*l* = measured value

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Levelling rods for interval measurements		to	100 mm	QMH-L.VIII.2 Section 4 Version 1.0	40 µm	Measuring range based on the interval between any two graduation marks on the scale
Tape measures	0.1 m	to	25 m	QMH-L.VIII.2 Section 2 Version 1.0	2.4 mm + 45 · 10^{-6} · l	l = measured length Tape measures for characterizing headlight adjustment test systems
Circumference measuring tapes made of steel Diameter	150 mm	to	300 mm	QMH-L.VIII.2 Section 3 Version 1.0	0.62 mm	Calibration at the nominal values of the standards
	> 300 mm	to	400 mm		0.94 mm	
Circumference	470 mm	to	950 mm		0.19 mm	
	> 950 mm	to	1257 mm		0.297 mm	
Electronic inclinometers	-55°	to	-30°	QMH-L.VIII.1 Version 1.0	42 · 10^{-6} · |α| + 0.00034°	Max. base length 100 mm α = angle in °
	-30°	to	30°		0.0016°	
	30°	to	55°		42 · 10^{-6} · |α| + 0.00034°	
Point and line lasers Tilt deviation horizontal vertical	0 mm/m	to	2 mm/m	AA0356 Version 9.0	0.080 mm/m 0.10 mm/m	
Position sensitive detector / PSD diodes X and Y axis deviation		to	5 mm	AA0356 Version 9.0	18 µm	

Permanent laboratory – Location Eichenau

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length measuring instrument Gauges	0 mm to 75 mm	QMH-L.VIII.3 Section 2.1 Version 1.0 External measurement	31 µm	Assumed temperature range: 20 °C ± 1 K Assumed thermal expansion coefficient: $\alpha = 11.5 \cdot 10^{-6}\ K^{-1}$ Different environmental conditions and materials of the test gauges to be calibrated increase the measurement uncertainty
	> 75 mm to 150 mm		37 µm	
	0 mm to 150 mm	QMH-L.VIII.3 Section 2.2 Version 1.0 Internal measurement	36 µm	
	0 mm to 150 mm	QMH-L.VIII.3 Section 2.3 Version 1.0 Depth measurement	39 µm	
	0 to 75 mm	QMH-L.VIII.3 Section 2.4 Version 1.0 Step measurement	55 µm	
	> 75 mm to 150 mm		76 µm	

Electrical measurement quantities

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage Sources	0 V				120 nV	Short-circuit bridge
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	U = measured value
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	
	> 1050 V	to	10 kV		$0.17 \cdot 10^{-3} \cdot U$	
DC voltage Measuring instruments	0 V	to	220 mV		$6 \cdot 10^{-6} \cdot U + 0.6\ \mu V$	U = measured value
	> 220 mV	to	2.2 V		$5 \cdot 10^{-6} \cdot U + 1\ \mu V$	
	> 2.2 V	to	11 V		$4 \cdot 10^{-6} \cdot U + 3.5\ \mu V$	
	> 11 V	to	22 V		$4 \cdot 10^{-6} \cdot U + 6.5\ \mu V$	
	> 22 V	to	220 V		$5 \cdot 10^{-6} \cdot U + 80\ \mu V$	
	> 220 V	to	1050 V		$7 \cdot 10^{-6} \cdot U + 0.5\ mV$	
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Sources, measuring instruments	2 mV to 1000 V	10 Hz to 1 MHz	4.1 µV to 0.48 V	U = measured value
	2 mV to 10 mV	10 Hz to 40 Hz	$0.36 \cdot 10^{-3} \cdot U + 3.4$ µV	
		> 40 Hz to 1 kHz	$0.24 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 1 kHz to 20 kHz	$0.36 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 20 kHz to 50 kHz	$1.2 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 50 kHz to 100 kHz	$5.8 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 100 kHz to 300 kHz	$46 \cdot 10^{-3} \cdot U + 2.3$ µV	
	> 10 mV to 100 mV	10 Hz to 40 Hz	$86 \cdot 10^{-6} \cdot U + 4.6$ µV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 2.3$ µV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 50 kHz to 100 kHz	$0.93 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 12$ µV	
	> 100 mV to 1 V	10 Hz to 40 Hz	$83 \cdot 10^{-6} \cdot U + 46$ µV	
		> 40 Hz to 1 kHz	$82 \cdot 10^{-6} \cdot U + 23$ µV	
		> 1 kHz to 20 kHz	$0.16 \cdot 10^{-3} \cdot U + 23$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 23$ µV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 23$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 0.12$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 0.12$ mV	
	> 1 V to 10 V	10 Hz to 40 Hz	$85 \cdot 10^{-6} \cdot U + 0.46$ mV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 0.23$ mV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 1.2$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 1.2$ mV	
	> 10 V to 100 V	10 Hz to 40 Hz	$0.23 \cdot 10^{-3} \cdot U + 4.6$ mV	
		> 40 Hz to 1 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 1 kHz to 20 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 20 kHz to 50 kHz	$0.41 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 50 kHz to 100 kHz	$1.4 \cdot 10^{-3} \cdot U + 2.3$ mV	
	> 100 V to 1000 V	50 Hz to 1 kHz	$0.46 \cdot 10^{-3} \cdot U + 16$ mV	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	1 mV to 1100 V	10 Hz to 1 MHz	5 µV to 81 mV	*U* = measured value
	1 mV to 2.2 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 4.5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 13$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 2.2 mV to 22 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 22 mV to 220 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 13$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 8$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 8$ µV	
		> 20 kHz to 50 kHz	$0.28 \cdot 10^{-3} \cdot U + 8$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 25$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 25$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 35$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 80$ µV	
	> 220 mV to 2.2 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 80$ µV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 25$ µV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 6$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 16$ µV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 70$ µV	
		> 100 kHz to 300 kHz	$0.39 \cdot 10^{-3} \cdot U + 0.13$ mV	
		> 300 kHz to 500 kHz	$0.95 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 500 kHz to 1 MHz	$1.9 \cdot 10^{-3} \cdot U + 0.85$ mV	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	> 2.2 V to 22 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 0.8$ mV	U = measured value
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 0.25$ mV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 60$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 0.16$ mV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 100 kHz to 300 kHz	$0.45 \cdot 10^{-3} \cdot U + 1.5$ mV	
		> 300 kHz to 500 kHz	$1.2 \cdot 10^{-3} \cdot U + 4.3$ mV	
		> 500 kHz to 1 MHz	$2.5 \cdot 10^{-3} \cdot U + 8.5$ mV	
	> 22 V to 220 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 2.5$ mV	
		> 40 Hz to 20 kHz	$70 \cdot 10^{-6} \cdot U + 0.8$ mV	
		> 20 kHz to 50 kHz	$0.19 \cdot 10^{-3} \cdot U + 3.5$ mV	
		> 50 kHz to 100 kHz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
	> 220 V to 1100 V	15 Hz to 50 Hz	$0.36 \cdot 10^{-3} \cdot U + 16$ mV	
		> 50 Hz to 1 kHz	$70 \cdot 10^{-6} \cdot U + 3.5$ mV	
	1 mV to 220 V	1 Hz to 10 kHz Rectangular tension	0.38 µV to 3.2 mV See matrix BM.1	
Sources	1100 V to 10 kV	45 Hz to 55 Hz	$0.46 \cdot 10^{-3} \cdot U$	U = measured value

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Measuring instruments, sources	0 mA to 220 µA		$40 \cdot 10^{-6} \cdot I + 8$ nA	I = measured value
	> 220 µA to 2.2 mA		$40 \cdot 10^{-6} \cdot I + 8$ nA	
	> 2.2 mA to 22 mA		$40 \cdot 10^{-6} \cdot I + 80$ nA	
	> 22 mA to 100 mA		$50 \cdot 10^{-6} \cdot I + 0.8$ µA	
	> 100 mA to 220 mA		$50 \cdot 10^{-6} \cdot I + 200 \cdot 10^{-6} \cdot I^2 + 0.8$ µA	
	> 220 mA to 1 A		$65 \cdot 10^{-6} \cdot I + 25$ µA	
	> 1 A to 2.2 A		$65 \cdot 10^{-6} \cdot I + 10 \cdot 10^{-6} \cdot I^2 + 25$ µA	
	> 2.2 A to 3 A		$0.38 \cdot 10^{-3} \cdot I + 40$ µA	
	> 3 A to 10.1 A		$0.5 \cdot 10^{-3} \cdot I + 0.5$ mA	
	> 10.1 A to 20.5 A		$1 \cdot 10^{-3} \cdot I + 0.75$ mA	
	0 pA to 1 pA		1 pA	
	> 1 pA to 100 nA		$35 \cdot 10^{-6} \cdot I + 46$ pA	
	> 100 nA to 1 µA		$23 \cdot 10^{-6} \cdot I + 46$ pA	
	> 1 µA to 10 µA		$23 \cdot 10^{-6} \cdot I + 0.12$ nA	
	> 10 µA to 100 µA		$23 \cdot 10^{-6} \cdot I + 0.92$ nA	
	> 100 µA to 1 mA		$23 \cdot 10^{-6} \cdot I + 6$ nA	
	> 1 mA to 10 mA		$23 \cdot 10^{-6} \cdot I + 58$ nA	
	> 10 mA to 100 mA		$41 \cdot 10^{-6} \cdot I + 580$ nA	
	> 100 mA to 1 A		$0.13 \cdot 10^{-3} \cdot I + 12$ µA	
	1 A to 400 A		$0.21 \cdot 10^{-3} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings	$3 \cdot 10^{-3} \cdot I$	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments, sources	10 µA to 20.5 A	10 Hz to 10 kHz	25 nA to 0.62 A	*I* = measured value
	0.01 mA to 0.22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 25$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 16$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ nA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ nA	
	> 0.22 mA to 2.2 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 40$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-4} \cdot I + 35$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 0.8$ µA	
	> 2.2 mA to 22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 0.35$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 8$ µA	
	> 22 mA to 220 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 3.5$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ µA	
	> 220 mA to 2.2 A	20 Hz to 1 kHz	$0.55 \cdot 10^{-3} \cdot I + 35$ µA	
		> 1 kHz to 5 kHz	$0.65 \cdot 10^{-3} \cdot I + 80$ µA	
		> 5 kHz to 10 kHz	$0.75 \cdot 10^{-3} \cdot I + 0.16$ mA	
	> 2.2 A to 3 A	10 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.1$ mA	
		> 45 Hz to 1 kHz	$0.6 \cdot 10^{-3} \cdot I + 0.1$ mA	
	> 3 A to 11 A	45 Hz to 100 Hz	$0.6 \cdot 10^{-3} \cdot I + 2$ mA	
		> 100 Hz to 1 kHz	$1.0 \cdot 10^{-3} \cdot I + 2$ mA	
	> 11 A to 20.5 A	45 Hz to 100 Hz	$1.2 \cdot 10^{-3} \cdot I + 5$ mA	
		> 100 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 5$ mA	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	5 µA to 1 A	20 Hz to 5 kHz	35 nA to 13 mA	I = measured value
	5 µA to 100 µA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 35$ nA	
		> 45 Hz to 1 kHz	$0.76 \cdot 10^{-3} \cdot I + 34$ nA	
	> 100 µA to 1 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 0.2$ µA	
	> 1 mA to 10 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 2$ µA	
	> 10 mA to 100 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 20$ µA	
	> 100 mA to 1 A	20 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.23$ mA	
		> 45 Hz to 100 Hz	$0.83 \cdot 10^{-3} \cdot I + 0.33$ mA	
		> 100 Hz to 5 kHz	$1.6 \cdot 10^{-3} \cdot I + 0.21$ mA	
AC current Sources, measuring instruments	10 mA to 500 A		3 µA to 0.2 A	I = measured value
	10 mA to 1 A	40 Hz to 1 kHz	$0.32 \cdot 10^{-3} \cdot I$	
	> 1 A to 100 A		$0.69 \cdot 10^{-3} \cdot I$	
	> 100 A to 450 A		$0.9 \cdot 10^{-3} \cdot I$	
Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$4 \cdot 10^{-3} \cdot I$	I = measured value
Equivalent leakage current	0.2 µA to 200 mA	at R_N to 1 GΩ DC to 60 Hz	$17 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix BM.2	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Fixed values	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value Intermediate values increase the measurement uncertainty
		4-wire short circuit	0.35 µΩ	
	100 µΩ 1 mΩ 10 mΩ 100 mΩ		$0.45 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.10 \cdot 10^{-3} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ;		$40 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $14 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $9.5 \cdot 10^{-6} \cdot R$ $11 \cdot 10^{-6} \cdot R$ $15 \cdot 10^{-6} \cdot R$ $31 \cdot 10^{-6} \cdot R$ $100 \cdot 10^{-6} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ; 1 GΩ		$76 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $17 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $13 \cdot 10^{-6} \cdot R$ $19 \cdot 10^{-6} \cdot R$ $70 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-3} \cdot R$ $5.9 \cdot 10^{-3} \cdot R$	
Measuring instruments	0 to < 11 Ω 11 Ω to < 110 Ω 110 Ω to < 110 kΩ 110 kΩ to < 1.1 MΩ 1.1 MΩ to < 3.3 MΩ 3.3 MΩ to < 11 MΩ 11 MΩ to < 33 MΩ 33 MΩ to < 110 MΩ 110 MΩ to < 330 MΩ 330 MΩ to < 1.1 GΩ		$40 \cdot 10^{-6} \cdot R$ $35 \cdot 10^{-6} \cdot R$ $28 \cdot 10^{-6} \cdot R$ $32 \cdot 10^{-6} \cdot R$ $60 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.25 \cdot 10^{-3} \cdot R$ $0.5 \cdot 10^{-3} \cdot R$ $3 \cdot 10^{-3} \cdot R$ $15 \cdot 10^{-3} \cdot R$	
AC resistance (absolute value of impedance)	500 µΩ to 45 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ to $1.7 \cdot 10^{-3} \cdot R$ See matrix BM.3	R = measured value U_I is the relative uncertainty of the calibration current U_U is the relative uncertainty of the measured voltage at the resistor

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance Fixed values	0 µH	2-wire short circuit	0.03 µH	
	100 µH	100 Hz	$0.54 \cdot 10^{-3} \cdot L$	L = measured value Absolut value of impedance 50 mΩ ≤ |Z| ≤ 11 kΩ
		1 kHz	$0.28 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.29 \cdot 10^{-3} \cdot L$	
	1 mH	100 Hz	$0.14 \cdot 10^{-3} \cdot L$	
		1 kHz	$0.14 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.24 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz;	$0.13 \cdot 10^{-3} \cdot L$	
		1 kHz; 10 kHz	$0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz	$0.13 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.28 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance	0 pF		0.2 pF	No load
Fixed values	1 pF	1 kHz	$0.63 \cdot 10^{-3} \cdot C$	C = measured value Absolute value of impedance 1 Ω ≤ |Z| ≤ 110 MΩ
		10 kHz	$0.31 \cdot 10^{-3} \cdot C$	
	10 pF	1 kHz	$42 \cdot 10^{-6} \cdot C$	
		10 kHz;	$53 \cdot 10^{-6} \cdot C$	
		100 kHz	$88 \cdot 10^{-6} \cdot C$	
		1 MHz	$0.24 \cdot 10^{-3} \cdot C$	
	100 pF	1 kHz	$39 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz	$71 \cdot 10^{-6} \cdot C$	
		100 kHz	$0.13 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz	$0.49 \cdot 10^{-3} \cdot C$	
		1 kHz	$0.21 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.23 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz;	$0.21 \cdot 10^{-3} \cdot C$	
		1 kHz;	$0.20 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.17 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz	$0.29 \cdot 10^{-3} \cdot C$	
			$0.13 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.29 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance F = frequency Different measurement conditions increase the measurement uncertainty
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power Measuring instruments	0 W to 21 kW	0 mV to 1020 V 0 µA to 20.5 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ $0.21 \cdot 10^{-3} \cdot P$ to $0.70 \cdot 10^{-3} \cdot P$	P = measured value
via current clamp	0 W to 300 kW	0 V to 330 V 0 mA to 1000 A	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.2 \cdot 10^{-3} \cdot P$	W_{in} is the relative uncertainty of the active power of the single winding
AC active power Measuring instruments	0.11 mW to 21 kW	PF = 1; 45 Hz to 65 Hz 33 mV to 1020 V 3.3 mA to 20 A	$0.7 \cdot 10^{-3} \cdot P$ to $1.4 \cdot 10^{-3} \cdot P$	P = measured value PF = power factor (capacitive or inductive)
	15 W; 60 W; 100 W; 400 W; 500 W; 1 kW; 2 kW; 4 kW	PF = 1; 45 Hz to 65 Hz 50 V; 200 V 0.3 A; 2 A; 10 A; 20 A	$0.16 \cdot 10^{-3} \cdot P$	
	1.5 W; 6 W	30 mA;	$0.26 \cdot 10^{-3} \cdot P$	
	2.3 W to 20.6 kW	45 Hz to 65 Hz; PF = 1 23 V to 1020 V 30 mA to 20.5 A	$0.32 \cdot 10^{-3} \cdot P$ to $0.48 \cdot 10^{-3} \cdot P$	
	220 W	45 Hz to 65 Hz 220 V; 1 A PF = 1	$0.16 \cdot 10^{-3} \cdot P$	
	198 W	PF = 0.9	$0.18 \cdot 10^{-3} \cdot P$	
	110 W	PF = 0.5	$0.29 \cdot 10^{-3} \cdot P$	
	22 W	PF = 0.1	$1.4 \cdot 10^{-3} \cdot P$	
	11 W	PF = 0.05	$2.7 \cdot 10^{-3} \cdot P$	
	10 W to 1 kW	33 V to 330 V 330 mA to < 3 A 45 Hz to 65 Hz $0.05 \le PF < 1$ Inductive, capacitive	0.22 W	
via current clamp	0.5 W to 218 kW	33 V to 330 V 10 mA to 660 A 45 Hz to 65 Hz $0.05 \le PF \le 1$ 1 to 60 windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.4 \cdot 10^{-3} \cdot P$	W_{in} is the relative uncertainty of the active power of the single winding The relative uncertainty of the object under test W_{DUT} in the measuring circuit and in the stray field of the current-carrying conductor must be taken into account
Power factor	0 to 0.4	33 V to 330 V 330 mA to 2.2 A 45 Hz to 65 Hz	$0.15 \cdot 10^{-3}$	
	> 0.4 to < 1		$-60 \cdot 10^{-6} \cdot P + 0.16 \cdot 10^{-3}$	
	1		$89 \cdot 10^{-6}$	
AC reactive power Measuring instruments	0 var to 1 kvar	45 Hz to 65 Hz	$U_P \cdot$ var/W	U_P = uncertainty of the active power

Permanent laboratory – Location Berlin

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 18 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms 2 ns to 100 s 1 s to 100 h		1.2 ns $1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps $14 \cdot 10^{-6} \cdot \Delta t + U_{Tf}$	
Rotational frequency	0.02 s^{-1} to 18000 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	
Oscilloscope Vertical	0 V to 5 V 5 V to 130 V	DC to 10 kHz	$1.1 \cdot 10^{-3} \cdot U + 66$ µV $1.2 \cdot 10^{-3} \cdot U + 44$ µV	U = measured value
Oscilloscope Horizontal	1 ns to < 100 ns 100 ns to 20 ms > 20 ms to 5 s		$0.6 \cdot 10^{-6} \cdot T + 60$ fs $3.1 \cdot 10^{-6} \cdot T + 11$ fs $1.2 \cdot 10^{-3} \cdot T^2 + 29 \cdot 10^{-6} \cdot T$	T = measured value
Oscilloscopes Bandwidth f (frequency response)	50 kHz > 50 kHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 600 MHz > 600 MHz to 1.1 GHz > 1.1 GHz to 2 GHz > 2 GHz to 4 GHz		$3.3 \cdot 10^{-2} \cdot f$ $2.5 \cdot 10^{-2} \cdot f$ $3.1 \cdot 10^{-2} \cdot f$ $5.5 \cdot 10^{-2} \cdot f$ $6.5 \cdot 10^{-2} \cdot f$ $6.8 \cdot 10^{-2} \cdot f$ $9.5 \cdot 10^{-2} \cdot f$	f = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Rise time Oscilloscopes	50 ps to 1 ms 1 ns to 1 ms	0.05 V to 1.2 V 0.1 to 3 V	4 ps + $5.7 \cdot 10^{-3} \cdot T$ 2.5 ps + $5.8 \cdot 10^{-3} \cdot T$	
Rise time Generators, pulses	0.5 ns to < 2.5 ns 2.5 ns to 5 ms		28 ps + $14 \cdot 10^{-3} \cdot T$ 13 ps + $28 \cdot 10^{-3} \cdot T$	
RF power Output power and calibration factor of RF sources	10 µW to 80 mW	DC to 50 MHz 50 MHz to 4 GHz 4 GHz to 12 GHz 12 GHz to 18 GHz	$9.5 \cdot 10^{-3} \cdot P$ $14 \cdot 10^{-3} \cdot P$ $22 \cdot 10^{-3} \cdot P$ $36 \cdot 10^{-3} \cdot P$	N connector, 50 Ω $\lvert\Gamma_G\rvert \le 0.035$ $f \le 4$ GHz $\lvert\Gamma_G\rvert \le 0.056$ $f \le 12$ GHz $\lvert\Gamma_G\rvert \le 0.075$ $f \le 18$ GHz Other connectors and reflection factors increase the measurement uncertainty
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	22 mV to 2 V	DC to 18 MHz	$W(U_{HF}) = \frac{W(P)}{2}$	$W(P)$ is the relative uncertainty of the measured power at $Z_0 = 50$ Ω

Permanent laboratory – Location Berlin

Matrix BM.1 Square-wave voltage

Square-wave voltage [V] / Frequency [Hz]	0.001	0.01	0.1	0.1	0.5	1	5	10	50	100
10	3.8E-07	512.2E-9	2.44E-06	2.37E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
100	7.4E-07	814.6E-9	2.52E-06	2.46E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
1000	6.4E-06	6.4E-6	6.99E-06	6.97E-06	1.34E-05	2.4E-05	111.6E-6	251.5E-6	1.2E-3	2.3E-3
10000	6.3E-05	63.7E-6	6.56E-05	6.56E-05	7.47E-05	8.7E-05	200.5E-6	369.5E-6	1.6E-3	3.2E-3

Matrix BM.2 Equivalent leakage current

Normal resistance R_N	**1 kΩ**		**10 kΩ**		**100 kΩ**		**1 MΩ**		**10 MΩ**		**100 MΩ**		**1 GΩ**	
Nominal voltage	**Current | Expanded measurement uncertainty *U* in µA/A**										**Current | *U* in mA/A**			
60 V	60 mA	12	6 mA	12	600 µA	12	60 µA	20	6 µA	71	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Matrix BM.3 AC resistance

Voltage [V] / Current [A]	0.001 V	0.010 V	0.010 V	0.100 V	0.100 V	1.000 V	1.000 V	10.000 V	10.000 V	100.000 V
$2.2 \cdot 10^{-3}$ A	1.57E-03	4.66E-04	4.66E-04	3.00E-04	3.00E-04	2.98E-04	2.98E-04	3.00E-04	3.00E-04	3.78E-04
$22 \cdot 10^{-3}$ A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
0.22 A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
2.2 A	1.64E-03	6.78E-04	6.78E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	6.21E-04

Dimensional measurement quantities

Permanent laboratory – Location Berlin

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length				*l* = measured value
Caliper gauge for external, internal, and depth dimensions *	0 mm to 500 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	$20\ \mu m + 15 \cdot 10^{-6} \cdot l$	
Bow micrometers *	0 mm to 300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	$2\ \mu m + 6 \cdot 10^{-6} \cdot l$	

Electrical measurement quantitites

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage Sources	0 V				120 nV	Short-circuit bridge
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	U = measured value
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	
	> 1050 V	to	10 kV		$0.17 \cdot 10^{-3} \cdot U$	
DC voltage Measuring instruments	0	to	220 mV		$6 \cdot 10^{-6} \cdot U + 0.6\ \mu V$	U = measured value
	> 220 mV	to	2.2 V		$5 \cdot 10^{-6} \cdot U + 1\ \mu V$	
	> 2.2 V	to	11 V		$4 \cdot 10^{-6} \cdot U + 3.5\ \mu V$	
	> 11 V	to	22 V		$4 \cdot 10^{-6} \cdot U + 6.5\ \mu V$	
	> 22 V	to	220 V		$5 \cdot 10^{-6} \cdot U + 80\ \mu V$	
	> 220 V	to	1050 V		$7 \cdot 10^{-6} \cdot U + 0.5\ mV$	
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Sources, measuring instruments	2 mV to 1000 V	10 Hz to 1 MHz	4.1 µV to 0.48 V	*U* = measured value
	2 mV to 10 mV	10 Hz to 40 Hz	$0.36 \cdot 10^{-3} \cdot U + 3.4$ µV	
		> 40 Hz to 1 kHz	$0.24 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 1 kHz to 20 kHz	$0.36 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 20 kHz to 50 kHz	$1.2 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 50 kHz to 100 kHz	$5.8 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 100 kHz to 300 kHz	$46 \cdot 10^{-3} \cdot U + 2.3$ µV	
	> 10 mV to 100 mV	10 Hz to 40 Hz	$86 \cdot 10^{-6} \cdot U + 4.6$ µV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 2.3$ µV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 50 kHz to 100 kHz	$0.93 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 12$ µV	
	> 100 mV to 1 V	10 Hz to 40 Hz	$83 \cdot 10^{-6} \cdot U + 46$ µV	
		> 40 Hz to 1 kHz	$82 \cdot 10^{-6} \cdot U + 23$ µV	
		> 1 kHz to 20 kHz	$0.16 \cdot 10^{-3} \cdot U + 23$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 23$ µV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 23$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 0.12$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 0.12$ mV	
	> 1 V to 10 V	10 Hz to 40 Hz	$85 \cdot 10^{-6} \cdot U + 0.46$ mV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 0.23$ mV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 1.2$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 1.2$ mV	
	> 10 V to 100 V	10 Hz to 40 Hz	$0.23 \cdot 10^{-3} \cdot U + 4.6$ mV	
		> 40 Hz to 1 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 1 kHz to 20 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 20 kHz to 50 kHz	$0.41 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 50 kHz to 100 kHz	$1.4 \cdot 10^{-3} \cdot U + 2.3$ mV	
	> 100 V to 1000 V	50 Hz to 1 kHz	$0.46 \cdot 10^{-3} \cdot U + 16$ mV	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	1 mV to 1100 V	10 Hz to 1 MHz	5 µV to 81 mV	U = measured value
	1 mV to 2.2 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 4.5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 13$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 2.2 mV to 22 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 22 mV to 220 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 13$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 8$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 8$ µV	
		> 20 kHz to 50 kHz	$0.28 \cdot 10^{-3} \cdot U + 8$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 25$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 25$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 35$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 80$ µV	
	> 220 mV to 2.2 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 80$ µV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 25$ µV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 6$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 16$ µV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 70$ µV	
		> 100 kHz to 300 kHz	$0.39 \cdot 10^{-3} \cdot U + 0.13$ mV	
		> 300 kHz to 500 kHz	$0.95 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 500 kHz to 1 MHz	$1.9 \cdot 10^{-3} \cdot U + 0.85$ mV	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	> 2.2 V to 22 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 0.8$ mV	U = measured value
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 0.25$ mV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 60$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 0.16$ mV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 100 kHz to 300 kHz	$0.45 \cdot 10^{-3} \cdot U + 1.5$ mV	
		> 300 kHz to 500 kHz	$1.2 \cdot 10^{-3} \cdot U + 4.3$ mV	
		> 500 kHz to 1 MHz	$2.5 \cdot 10^{-3} \cdot U + 8.5$ mV	
	> 22 V to 220 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 2.5$ mV	
		> 40 Hz to 20 kHz	$70 \cdot 10^{-6} \cdot U + 0.8$ mV	
		> 20 kHz to 50 kHz	$0.19 \cdot 10^{-3} \cdot U + 3.5$ mV	
		> 50 kHz to 100 kHz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
	> 220 V to 1100 V	15 Hz to 50 Hz	$0.36 \cdot 10^{-3} \cdot U + 16$ mV	
		> 50 Hz to 1 kHz	$70 \cdot 10^{-6} \cdot U + 3.5$ mV	
	1 mV to 220 V	1 Hz to 10 kHz Square-wave voltage	0.38 µV to 3.2 mV See matrix MM.1	
Sources	1100 V to 10 kV	45 Hz to 55 Hz	$0.46 \cdot 10^{-3} \cdot U$	U = measured value

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Measuring instruments, sources	0 mA to 220 µA		$40 \cdot 10^{-6} \cdot I + 8$ nA	I = measured value
	> 220 µA to 2.2 mA		$40 \cdot 10^{-6} \cdot I + 8$ nA	
	> 2.2 mA to 22 mA		$40 \cdot 10^{-6} \cdot I + 80$ nA	
	> 22 mA to 100 mA		$50 \cdot 10^{-6} \cdot I + 0.8$ µA	
	> 100 mA to 220 mA		$50 \cdot 10^{-6} \cdot I + 200 \cdot 10^{-6} \cdot I^2 + 0.8$ µA	
	> 220 mA to 1 A		$65 \cdot 10^{-6} \cdot I + 25$ µA	
	> 1 A to 2.2 A		$65 \cdot 10^{-6} \cdot I + 10 \cdot 10^{-6} \cdot I^2 + 25$ µA	
	> 2.2 A to 3 A		$0.38 \cdot 10^{-3} \cdot I + 40$ µA	
	> 3 A to 10.1 A		$0.5 \cdot 10^{-3} \cdot I + 0.5$ mA	
	> 10.1 A to 20.5 A		$1 \cdot 10^{-3} \cdot I + 0.75$ mA	
	0 pA to 1 pA		1 pA	
	> 1 pA to 100 nA		$35 \cdot 10^{-6} \cdot I + 46$ pA	
	> 100 nA to 1 µA		$23 \cdot 10^{-6} \cdot I + 46$ pA	
	> 1 µA to 10 µA		$23 \cdot 10^{-6} \cdot I + 0.12$ nA	
	> 10 µA to 100 µA		$23 \cdot 10^{-6} \cdot I + 0.92$ nA	
	> 100 µA to 1 mA		$23 \cdot 10^{-6} \cdot I + 6$ nA	
	> 1 mA to 10 mA		$23 \cdot 10^{-6} \cdot I + 58$ nA	
	> 10 mA to 100 mA		$41 \cdot 10^{-6} \cdot I + 580$ nA	
	> 100 mA to 1 A		$0.13 \cdot 10^{-3} \cdot I + 12$ µA	
	1 A to 400 A		$0.21 \cdot 10^{-3} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings	$3 \cdot 10^{-3} \cdot I$	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments, sources	10 µA to 20.5 A	10 Hz to 10 kHz	25 nA to 0.62 A	*I* = measured value
	0.01 mA to 0.22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 25$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 16$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ nA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ nA	
	> 0.22 mA to 2.2 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 40$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-4} \cdot I + 35$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 0.8$ µA	
	> 2.2 mA to 22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 0.35$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 8$ µA	
	> 22 mA to 220 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 3.5$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ µA	
	> 220 mA to 2.2 A	20 Hz to 1 kHz	$0.55 \cdot 10^{-3} \cdot I + 35$ µA	
		> 1 kHz to 5 kHz	$0.65 \cdot 10^{-3} \cdot I + 80$ µA	
		> 5 kHz to 10 kHz	$0.75 \cdot 10^{-3} \cdot I + 0.16$ mA	
	> 2.2 A to 3 A	10 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.1$ mA	
		> 45 Hz to 1 kHz	$0.6 \cdot 10^{-3} \cdot I + 0.1$ mA	
	> 3 A to 11 A	45 Hz to 100 Hz	$0.6 \cdot 10^{-3} \cdot I + 2$ mA	
		> 100 Hz to 1 kHz	$1.0 \cdot 10^{-3} \cdot I + 2$ mA	
	> 11 A to 20.5 A	45 Hz to 100 Hz	$1.2 \cdot 10^{-3} \cdot I + 5$ mA	
		> 100 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 5$ mA	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	5 µA to 1 A	20 Hz to 5 kHz	35 nA to 13 mA	*I* = measured value
	5 µA to 100 µA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 35$ nA	
		> 45 Hz to 1 kHz	$0.76 \cdot 10^{-3} \cdot I + 34$ nA	
	> 100 µA to 1 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 0.2$ µA	
	> 1 mA to 10 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 2$ µA	
	> 10 mA to 100 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 20$ µA	
	> 100 mA to 1 A	20 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.23$ mA	
		> 45 Hz to 100 Hz	$0.83 \cdot 10^{-3} \cdot I + 0.33$ mA	
		> 100 Hz to 5 kHz	$1.6 \cdot 10^{-3} \cdot I + 0.21$ mA	
AC current Sources, measuring instruments	10 mA to 500 A		3 µA to 0.2 A	*I* = measured value
	10 mA to 1 A	40 Hz to 1 kHz	$0.32 \cdot 10^{-3} \cdot I$	
	> 1 A to 100 A		$0.69 \cdot 10^{-3} \cdot I$	
	> 100 A to 450 A		$0.9 \cdot 10^{-3} \cdot I$	
Current clamps and current clamp transformers	1 mA to 1100 A	1 to *N* windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$4 \cdot 10^{-3} \cdot I$	*I* = measured value
Equivalent leakage current	0.2 µA to 200 mA	at R_N to 1 GΩ DC to 60 Hz	$17 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix MM.2	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Fixed values	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value
		4-wire short circuit	0.35 µΩ	
	100 µΩ		$0.45 \cdot 10^{-3} \cdot R$	
	1 mΩ		$0.17 \cdot 10^{-3} \cdot R$	
	10 mΩ		$0.17 \cdot 10^{-3} \cdot R$	
	100 mΩ		$0.10 \cdot 10^{-3} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ;		$40 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $14 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $9.5 \cdot 10^{-6} \cdot R$ $11 \cdot 10^{-6} \cdot R$ $15 \cdot 10^{-6} \cdot R$ $31 \cdot 10^{-6} \cdot R$ $100 \cdot 10^{-6} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ; 1 GΩ		$76 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $17 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $13 \cdot 10^{-6} \cdot R$ $19 \cdot 10^{-6} \cdot R$ $70 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-3} \cdot R$ $5.9 \cdot 10^{-3} \cdot R$	
	0 to < 11 Ω 11 Ω to < 110 Ω 110 Ω to < 110 kΩ 110 kΩ to < 1.1 MΩ 1.1 MΩ to < 3.3 MΩ 3.3 MΩ to < 11 MΩ 11 MΩ to < 33 MΩ 33 MΩ to < 110 MΩ 110 MΩ to < 330 MΩ 330 MΩ to < 1.1 GΩ		$40 \cdot 10^{-6} \cdot R$ $35 \cdot 10^{-6} \cdot R$ $28 \cdot 10^{-6} \cdot R$ $32 \cdot 10^{-6} \cdot R$ $60 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.25 \cdot 10^{-3} \cdot R$ $0.5 \cdot 10^{-3} \cdot R$ $3 \cdot 10^{-3} \cdot R$ $15 \cdot 10^{-3} \cdot R$	
AC resistance (amount of impedance)	500 µΩ to 45 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ to $1.7 \cdot 10^{-3} \cdot R$ See matrix MM.3	R = measured value U_I is the relative uncertainty of the calibration current U_U is the relative uncertainty of the measured voltage at the resistor

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance Fixed values	0 µH	2-wire short circuit	0.03 µH	
	100 µH	100 Hz 1 kHz 10 kHz	$0.54 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$ $0.29 \cdot 10^{-3} \cdot L$	L = measured value
	1 mH	100 Hz 1 kHz 10 kHz	$0.14 \cdot 10^{-3} \cdot L$ $0.14 \cdot 10^{-3} \cdot L$ $0.24 \cdot 10^{-3} \cdot L$	Amount of impedance 50 mΩ ≤ |Z| ≤ 11 kΩ
	10 mH	100 Hz; 1 kHz; 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance Fixed values	0 pF		0.2 pF	No load
	1 pF	1 kHz 10 kHz	$0.63 \cdot 10^{-3} \cdot C$ $0.31 \cdot 10^{-3} \cdot C$	
	10 pF	1 kHz 10 kHz; 100 kHz 1 MHz	$42 \cdot 10^{-6} \cdot C$ $53 \cdot 10^{-6} \cdot C$ $88 \cdot 10^{-6} \cdot C$ $0.24 \cdot 10^{-3} \cdot C$	C = measured value
	100 pF	1 kHz	$39 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz 100 kHz	$71 \cdot 10^{-6} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$	Amount of impedance 1 Ω ≤ |Z| ≤ 110 MΩ
	10 nF	100 Hz 1 kHz 10 kHz	$0.49 \cdot 10^{-3} \cdot C$ $0.21 \cdot 10^{-3} \cdot C$ $0.23 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz; 1 kHz; 10 kHz	$0.21 \cdot 10^{-3} \cdot C$ $0.20 \cdot 10^{-3} \cdot C$ $0.17 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz 10 kHz	$0.29 \cdot 10^{-3} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$ $0.29 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance f = frequency Different measurement conditions increase the measurement uncertainty
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power Measuring instruments	0 W to 21 kW	0 mV to 1020 V 0 µA to 20.5 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ $0.21 \cdot 10^{-3} \cdot P$ to $0.70 \cdot 10^{-3} \cdot P$	P = measured value
with clamp connection	0 W to 300 kW	0 V to 330 V 0 mA to 1000 A	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.2 \cdot 10^{-3} \cdot P$	W_{in} is the relative uncertainty of the active power of the single winding
AC active power Measuring instruments	0.11 mW to 21 kW	PF = 1; 45 Hz to 65 Hz 33 mV to 1020 V 3.3 mA to 20 A	$0.7 \cdot 10^{-3} \cdot P$ to $1.4 \cdot 10^{-3} \cdot P$	P = measured value PF = power factor (capacitive or inductive)
	15 W; 60 W; 100 W; 400 W; 500 W; 1 kW; 2 kW; 4 kW	PF = 1; 45 Hz to 65 Hz 50 V; 200 V 0.3 A; 2 A; 10 A; 20 A	$0.16 \cdot 10^{-3} \cdot P$	
	1.5 W; 6 W	30 mA	$0.26 \cdot 10^{-3} \cdot P$	
	2.3 W to 20.6 kW	45 Hz to 65 Hz; PF = 1 23 V to 1020 V 30 mA to 20.5 A	$0.32 \cdot 10^{-3} \cdot P$ to $0.48 \cdot 10^{-3} \cdot P$	
	220 W	45 Hz to 65 Hz 220 V; 1 A PF = 1	$0.16 \cdot 10^{-3} \cdot P$	
	198 W	PF = 0.9	$0.18 \cdot 10^{-3} \cdot P$	
	110 W	PF = 0.5	$0.29 \cdot 10^{-3} \cdot P$	
	22 W	PF = 0.1	$1.4 \cdot 10^{-3} \cdot P$	
	11 W	PF = 0.05	$2.7 \cdot 10^{-3} \cdot P$	
	10 W to 1 kW	33 V to 330 V 330 mA to < 3 A 45 Hz to 65 Hz $0.05 \le PF < 1$ Inductive, capacitive	0.22 W	
with clamp connection	0.5 W to 218 kW	33 V to 330 V 10 mA to 660 A 45 Hz to 65 Hz $0.05 \le PF \le 1$ 1 to 60 windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.4 \cdot 10^{-3} \cdot P$	W_{in} is the relative uncertainty of the active power of the single winding. The relative uncertainty of the device under test W_{DUT} in the measuring circuit and in the stray field of the current-carrying conductor must be taken into account
power factor	0 to 0.4	33 V to 330 V 330 mA to 2.2 A 45 Hz to 65 Hz	$0.15 \cdot 10^{-3}$	
	> 0.4 to < 1		$-60 \cdot 10^{-6} \cdot P + 0.16 \cdot 10^{-3}$	
	1		$89 \cdot 10^{-6}$	
AC reactive power Measuring instruments	0 var to 1 kvar	45 Hz to 65 Hz	$U_P \cdot$ var/W	U_P is the uncertainty of the active power

Permanent laboratory – Location Mannheim

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 18 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms 2 ns to 100 s 1 s to 100 h		1.2 ns $1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps $14 \cdot 10^{-6} \cdot \Delta t + U_{Tf}$	
Rotational frequency	0.02 s^{-1} to 18000 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	
Oscilloscope Vertical	0 V to 5 V 5 V to 130 V	DC to 10 kHz	$1.1 \cdot 10^{-3} \cdot U + 66$ µV $1.2 \cdot 10^{-3} \cdot U + 44$ µV	U = measured value
Oscilloscope Horizontal	1 ns to < 100 ns 100 ns to 20 ms > 20 ms to 5 s		$0.6 \cdot 10^{-6} \cdot T + 60$ fs $3.1 \cdot 10^{-6} \cdot T + 11$ fs $1.2 \cdot 10^{-3} \cdot T^2 + 29 \cdot 10^{-6} \cdot T$	T = measured value
Oscilloscopes Bandwidth f (frequency response)	50 kHz > 50 kHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 600 MHz > 600 MHz to 1.1 GHz > 1.1 GHz to 2 GHz > 2 GHz to 4 GHz		$3.3 \cdot 10^{-2} \cdot f$ $2.5 \cdot 10^{-2} \cdot f$ $3.1 \cdot 10^{-2} \cdot f$ $5.5 \cdot 10^{-2} \cdot f$ $6.5 \cdot 10^{-2} \cdot f$ $6.8 \cdot 10^{-2} \cdot f$ $9.5 \cdot 10^{-2} \cdot f$	f = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Rise time Oscilloscopes	50 ps to 1 ms 1 ns to 1 ms	0.05 V to 1.2 V 0.1 to 3 V	4 ps $+ 5.7 \cdot 10^{-3} \cdot T$ 2.5 ps $+ 5.8 \cdot 10^{-3} \cdot T$	
Rise time Generators, pulses	0.5 ns to < 2.5 ns 2.5 ns to 5 ms		28 ps $+ 14 \cdot 10^{-3} \cdot T$ 13 ps $+ 28 \cdot 10^{-3} \cdot T$	
RF power Output power and calibration factor of RF sources	10 µW to 80 mW	DC to 50 MHz 50 MHz to 4 GHz 4 GHz to 12 GHz 12 GHz to 18 GHz	$9.5 \cdot 10^{-3} \cdot P$ $14 \cdot 10^{-3} \cdot P$ $22 \cdot 10^{-3} \cdot P$ $36 \cdot 10^{-3} \cdot P$	N connector, 50 Ω $\lvert\Gamma_G\rvert \le 0.035$ $f \le 4$ GHz $\lvert\Gamma_G\rvert \le 0.056$ $f \le 12$ GHz $\lvert\Gamma_G\rvert \le 0.075$ $f \le 18$ GHz Other connectors and reflection factors increase the measurement uncertainty
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	22 mV to 2 V	DC to 18 MHz	$W(U_{HF}) = \frac{W(P)}{2}$	$W(P)$ is the relative uncertainty of the measured power at $Z_0 = 50$ Ω

Permanent laboratory – Location Mannheim

Matrix MM.1 Square-wave voltage

Square-wave voltage [V] / Frequency [Hz]	0.001	0.01	0.1	0.1	0.5	1	5	10	50	100
10	3.8E-07	512.2E-9	2.44E-06	2.37E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
100	7.4E-07	814.6E-9	2.52E-06	2.46E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
1000	6.4E-06	6.4E-6	6.99E-06	6.97E-06	1.34E-05	2.4E-05	111.6E-6	251.5E-6	1.2E-3	2.3E-3
10000	6.3E-05	63.7E-6	6.56E-05	6.56E-05	7.47E-05	8.7E-05	200.5E-6	369.5E-6	1.6E-3	3.2E-3

Matrix MM.2 Equivalent leakage current

Normal resistance R_N	**1 kΩ**		**10 kΩ**		**100 kΩ**		**1 MΩ**		**10 MΩ**		**100 MΩ**		**1 GΩ**	
Nominal voltage	**Current | expanded measurement uncertainty *U* in µA/A**										**Current | *U* in mA/A**			
60 V	60 mA	12	6 mA	12	600 µA	12	60 µA	20	6 µA	71	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Matrix MM.3 AC resistance

Voltage [V] / Current [A]	0.001 V	0.010 V	0.010 V	0.100 V	0.100 V	1.000 V	1.000 V	10.000 V	10.000 V	100.000 V
$2.2 \cdot 10^{-3}$ A	1.57E-03	4.66E-04	4.66E-04	3.00E-04	3.00E-04	2.98E-04	2.98E-04	3.00E-04	3.00E-04	3.78E-04
$22 \cdot 10^{-3}$ A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
0.22 A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
2.2 A	1.64E-03	6.78E-04	6.78E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	6.21E-04

Dimensional measurement quantities

Permanent laboratory – Location Mannheim

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement conditions / procedure	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length				*l* = measured value
Caliper gauge for external, internal, and depth dimensions *	0 mm to 500 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	$20\ \mu m + 15 \cdot 10^{-6} \cdot l$	
Bow micrometers *	0 mm to 300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	$2\ \mu m + 6 \cdot 10^{-6} \cdot l$	

Electrical measurement quantities

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage Sources	0 V				120 nV	Short-circuit bridge
	0	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	U = measured value
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	
	> 1050 V	to	10 kV		$0.17 \cdot 10^{-3} \cdot U$	
DC voltage Measuring instruments	0	to	220 mV		$6 \cdot 10^{-6} \cdot U + 0.6\ \mu V$	U = measured value
	> 220 mV	to	2.2 V		$5 \cdot 10^{-6} \cdot U + 1\ \mu V$	
	> 2.2 V	to	11 V		$4 \cdot 10^{-6} \cdot U + 3.5\ \mu V$	
	> 11 V	to	22 V		$4 \cdot 10^{-6} \cdot U + 6.5\ \mu V$	
	> 22 V	to	220 V		$5 \cdot 10^{-6} \cdot U + 80\ \mu V$	
	> 220 V	to	1050 V		$7 \cdot 10^{-6} \cdot U + 0.5\ mV$	
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Sources, measuring instruments	2 mV to 1000 V	10 Hz to 1 MHz	4.1 µV to 0.48 V	*U* = measured value
	2 mV to 10 mV	10 Hz to 40 Hz	$0.36 \cdot 10^{-3} \cdot U + 3.4$ µV	
		> 40 Hz to 1 kHz	$0.24 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 1 kHz to 20 kHz	$0.36 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 20 kHz to 50 kHz	$1.2 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 50 kHz to 100 kHz	$5.8 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 100 kHz to 300 kHz	$46 \cdot 10^{-3} \cdot U + 2.3$ µV	
	> 10 mV to 100 mV	10 Hz to 40 Hz	$86 \cdot 10^{-6} \cdot U + 4.6$ µV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 2.3$ µV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 50 kHz to 100 kHz	$0.93 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 12$ µV	
	> 100 mV to 1 V	10 Hz to 40 Hz	$83 \cdot 10^{-6} \cdot U + 46$ µV	
		> 40 Hz to 1 kHz	$82 \cdot 10^{-6} \cdot U + 23$ µV	
		> 1 kHz to 20 kHz	$0.16 \cdot 10^{-3} \cdot U + 23$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 23$ µV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 23$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 0.12$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 0.12$ mV	
	> 1 V to 10 V	10 Hz to 40 Hz	$85 \cdot 10^{-6} \cdot U + 0.46$ mV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 0.23$ mV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 1.2$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 1.2$ mV	
	> 10 V to 100 V	10 Hz to 40 Hz	$0.23 \cdot 10^{-3} \cdot U + 4.6$ mV	
		> 40 Hz to 1 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 1 kHz to 20 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 20 kHz to 50 kHz	$0.41 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 50 kHz to 100 kHz	$1.4 \cdot 10^{-3} \cdot U + 2.3$ mV	
	> 100 V to 1000 V	50 Hz to 1 kHz	$0.46 \cdot 10^{-3} \cdot U + 16$ mV	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	1 mV to 1100 V	10 Hz to 1 MHz	5 µV to 81 mV	*U* = measured value
	1 mV to 2.2 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 4.5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 13$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 2.2 mV to 22 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 22 mV to 220 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 13$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 8$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 8$ µV	
		> 20 kHz to 50 kHz	$0.28 \cdot 10^{-3} \cdot U + 8$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 25$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 25$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 35$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 80$ µV	
	> 220 mV to 2.2 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 80$ µV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 25$ µV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 6$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 16$ µV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 70$ µV	
		> 100 kHz to 300 kHz	$0.39 \cdot 10^{-3} \cdot U + 0.13$ mV	
		> 300 kHz to 500 kHz	$0.95 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 500 kHz to 1 MHz	$1.9 \cdot 10^{-3} \cdot U + 0.85$ mV	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	> 2.2 V to 22 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 0.8$ mV	U = measured value
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 0.25$ mV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 60$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 0.16$ mV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 100 kHz to 300 kHz	$0.45 \cdot 10^{-3} \cdot U + 1.5$ mV	
		> 300 kHz to 500 kHz	$1.2 \cdot 10^{-3} \cdot U + 4.3$ mV	
		> 500 kHz to 1 MHz	$2.5 \cdot 10^{-3} \cdot U + 8.5$ mV	
	> 22 V to 220 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 2.5$ mV	
		> 40 Hz to 20 kHz	$70 \cdot 10^{-6} \cdot U + 0.8$ mV	
		> 20 kHz to 50 kHz	$0.19 \cdot 10^{-3} \cdot U + 3.5$ mV	
		> 50 kHz to 100 kHz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
	> 220 V to 1100 V	15 Hz to 50 Hz	$0.36 \cdot 10^{-3} \cdot U + 16$ mV	
		> 50 Hz to 1 kHz	$70 \cdot 10^{-6} \cdot U + 3.5$ mV	
	1 mV to 220 V	1 Hz to 10 kHz Square-wave voltage	0.38 µV to 3.2 mV See matrix NM.1	
Sources	1100 V to 10 kV	45 Hz to 55 Hz	$0.46 \cdot 10^{-3} \cdot U$	U = measured value

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Measuring instruments, sources	0 mA to 220 µA		$40 \cdot 10^{-6} \cdot I + 8$ nA	I = measured value
	> 220 µA to 2.2 mA		$40 \cdot 10^{-6} \cdot I + 8$ nA	
	> 2.2 mA to 22 mA		$40 \cdot 10^{-6} \cdot I + 80$ nA	
	> 22 mA to 100 mA		$50 \cdot 10^{-6} \cdot I + 0.8$ µA	
	> 100 mA to 220 mA		$50 \cdot 10^{-6} \cdot I + 200 \cdot 10^{-6} \cdot I^2 + 0.8$ µA	
	> 220 mA to 1 A		$65 \cdot 10^{-6} \cdot I + 25$ µA	
	> 1 A to 2.2 A		$65 \cdot 10^{-6} \cdot I + 10 \cdot 10^{-6} \cdot I^2 + 25$ µA	
	> 2.2 A to 3 A		$0.38 \cdot 10^{-3} \cdot I + 40$ µA	
	> 3 A to 10.1 A		$0.5 \cdot 10^{-3} \cdot I + 0.5$ mA	
	> 10.1 A to 20.5 A		$1 \cdot 10^{-3} \cdot I + 0.75$ mA	
	0 pA to 1 pA		1 pA	
	> 1 pA to 100 nA		$35 \cdot 10^{-6} \cdot I + 46$ pA	
	> 100 nA to 1 µA		$23 \cdot 10^{-6} \cdot I + 46$ pA	
	> 1 µA to 10 µA		$23 \cdot 10^{-6} \cdot I + 0.12$ nA	
	> 10 µA to 100 µA		$23 \cdot 10^{-6} \cdot I + 0.92$ nA	
	> 100 µA to 1 mA		$23 \cdot 10^{-6} \cdot I + 6$ nA	
	> 1 mA to 10 mA		$23 \cdot 10^{-6} \cdot I + 58$ nA	
	> 10 mA to 100 mA		$41 \cdot 10^{-6} \cdot I + 580$ nA	
	> 100 mA to 1 A		$0.13 \cdot 10^{-3} \cdot I + 12$ µA	
	1 A to 400 A		$0.21 \cdot 10^{-3} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings	$3 \cdot 10^{-3} \cdot I$	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments, sources	10 µA to 20.5 A	10 Hz to 10 kHz	25 nA to 0.62 A	*I* = measured value
	0.01 mA to 0.22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 25$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 16$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ nA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ nA	
	> 0.22 mA to 2.2 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 40$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-4} \cdot I + 35$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 0.8$ µA	
	> 2.2 mA to 22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 0.35$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 8$ µA	
	> 22 mA to 220 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 3.5$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ µA	
	> 220 mA to 2.2 A	20 Hz to 1 kHz	$0.55 \cdot 10^{-3} \cdot I + 35$ µA	
		> 1 kHz to 5 kHz	$0.65 \cdot 10^{-3} \cdot I + 80$ µA	
		> 5 kHz to 10 kHz	$0.75 \cdot 10^{-3} \cdot I + 0.16$ mA	
	> 2.2 A to 3 A	10 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.1$ mA	
		> 45 Hz to 1 kHz	$0.6 \cdot 10^{-3} \cdot I + 0.1$ mA	
	> 3 A to 11 A	45 Hz to 100 Hz	$0.6 \cdot 10^{-3} \cdot I + 2$ mA	
		> 100 Hz to 1 kHz	$1.0 \cdot 10^{-3} \cdot I + 2$ mA	
	> 11 A to 20.5 A	45 Hz to 100 Hz	$1.2 \cdot 10^{-3} \cdot I + 5$ mA	
		> 100 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 5$ mA	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	5 µA to 1 A	20 Hz to 5 kHz	35 nA to 13 mA	*I* = measured value
	5 µA to 100 µA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 35$ nA	
		> 45 Hz to 1 kHz	$0.76 \cdot 10^{-3} \cdot I + 34$ nA	
	> 100 µA to 1 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 0.2$ µA	
	> 1 mA to 10 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 2$ µA	
	> 10 mA to 100 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 20$ µA	
	> 100 mA to 1 A	20 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.23$ mA	
		> 45 Hz to 100 Hz	$0.83 \cdot 10^{-3} \cdot I + 0.33$ mA	
		> 100 Hz to 5 kHz	$1.6 \cdot 10^{-3} \cdot I + 0.21$ mA	
AC current Sources, measuring instruments	10 mA to 500 A		3 µA to 0.2 A	*I* = measured value
	10 mA to 1 A	40 Hz to 1 kHz	$0.32 \cdot 10^{-3} \cdot I$	
	> 1 A to 100 A		$0.69 \cdot 10^{-3} \cdot I$	
	> 100 A to 450 A		$0.9 \cdot 10^{-3} \cdot I$	
Current clamps and current clamp transformers	1 mA to 1100 A	1 to *N* windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$4 \cdot 10^{-3} \cdot I$	*I* = measured value
Equivalent leakage current	0.2 µA to 200 mA	at R_N to 1 GΩ DC to 60 Hz	$17 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix NM.2	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Fixed values	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value
		4-wire short circuit	0.35 µΩ	
	100 µΩ 1 mΩ 10 mΩ 100 mΩ		$0.45 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.10 \cdot 10^{-3} \cdot R$	Intermediate values increase the measurement uncertainty
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ;		$40 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $14 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $9.5 \cdot 10^{-6} \cdot R$ $11 \cdot 10^{-6} \cdot R$ $15 \cdot 10^{-6} \cdot R$ $31 \cdot 10^{-6} \cdot R$ $100 \cdot 10^{-6} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ; 1 GΩ		$76 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $17 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $13 \cdot 10^{-6} \cdot R$ $19 \cdot 10^{-6} \cdot R$ $70 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-3} \cdot R$ $5.9 \cdot 10^{-3} \cdot R$	
Measuring instruments	0 to < 11 Ω 11 Ω to < 110 Ω 110 Ω to < 110 kΩ 110 kΩ to < 1.1 MΩ 1.1 MΩ to < 3.3 MΩ 3.3 MΩ to < 11 MΩ 11 MΩ to < 33 MΩ 33 MΩ to < 110 MΩ 110 MΩ to < 330 MΩ 330 MΩ to < 1.1 GΩ		$40 \cdot 10^{-6} \cdot R$ $35 \cdot 10^{-6} \cdot R$ $28 \cdot 10^{-6} \cdot R$ $32 \cdot 10^{-6} \cdot R$ $60 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.25 \cdot 10^{-3} \cdot R$ $0.5 \cdot 10^{-3} \cdot R$ $3 \cdot 10^{-3} \cdot R$ $15 \cdot 10^{-3} \cdot R$	
AC resistance (amount of impedance)	500 µΩ to 45 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ to $1.7 \cdot 10^{-3} \cdot R$ See matrix NM.3	R = measured value U_I = relative uncertainty of the calibration current U_U = relative uncertainty of the measured voltage at the resistor

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance Fixed values	0 µH	2-wire short circuit	0.03 µH	
	100 µH	100 Hz 1 kHz 10 kHz	$0.54 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$ $0.29 \cdot 10^{-3} \cdot L$	L = measured value Amount of impedance 50 mΩ ≤ |Z| ≤ 11 kΩ
	1 mH	100 Hz 1 kHz 10 kHz	$0.14 \cdot 10^{-3} \cdot L$ $0.14 \cdot 10^{-3} \cdot L$ $0.24 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz; 1 kHz; 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance Fixed values	0 pF		0.2 pF	No load
	1 pF	1 kHz 10 kHz	$0.63 \cdot 10^{-3} \cdot C$ $0.31 \cdot 10^{-3} \cdot C$	C = measured value Amount of impedance 1 Ω ≤ |Z| ≤ 110 MΩ
	10 pF	1 kHz 10 kHz; 100 kHz 1 MHz	$42 \cdot 10^{-6} \cdot C$ $53 \cdot 10^{-6} \cdot C$ $88 \cdot 10^{-6} \cdot C$ $0.24 \cdot 10^{-3} \cdot C$	
	100 pF	1 kHz	$39 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz 100 kHz	$71 \cdot 10^{-6} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz 1 kHz 10 kHz	$0.49 \cdot 10^{-3} \cdot C$ $0.21 \cdot 10^{-3} \cdot C$ $0.23 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz; 1 kHz; 10 kHz	$0.21 \cdot 10^{-3} \cdot C$ $0.20 \cdot 10^{-3} \cdot C$ $0.17 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz 10 kHz	$0.29 \cdot 10^{-3} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$ $0.29 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance f = frequency Different measurement conditions increase the measurement uncertainty
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power Measuring instruments	0 W to 21 kW	0 mV to 1020 V 0 µA to 20.5 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ $0.21 \cdot 10^{-3} \cdot P$ to $0.70 \cdot 10^{-3} \cdot P$	P = measured value
With clamp connection	0 W to 300 kW	0 V to 330 V 0 mA to 1000 A	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.2 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding
AC active power Measuring instruments	0.11 mW to 21 kW	PF = 1; 45 Hz to 65 Hz 33 mV to 1020 V 3.3 mA to 20 A	$0.7 \cdot 10^{-3} \cdot P$ to $1.4 \cdot 10^{-3} \cdot P$	P = measured value PF = power factor (capacitive or inductive)
	15 W; 60 W; 100 W; 400 W; 500 W; 1 kW; 2 kW; 4 kW	PF = 1; 45 Hz to 65 Hz 50 V; 200 V 0.3 A; 2 A; 10 A; 20 A	$0.16 \cdot 10^{-3} \cdot P$	
	1.5 W; 6 W	30 mA;	$0.26 \cdot 10^{-3} \cdot P$	
	2.3 W to 20.6 kW	45 Hz to 65 Hz; PF = 1 23 V to 1020 V 30 mA to 20.5 A	$0.32 \cdot 10^{-3} \cdot P$ to $0.48 \cdot 10^{-3} \cdot P$	
	220 W	45 Hz to 65 Hz 220 V; 1 A PF = 1	$0.16 \cdot 10^{-3} \cdot P$	
	198 W	PF = 0.9	$0.18 \cdot 10^{-3} \cdot P$	
	110 W	PF = 0.5	$0.29 \cdot 10^{-3} \cdot P$	
	22 W	PF = 0.1	$1.4 \cdot 10^{-3} \cdot P$	
	11 W	PF = 0.05	$2.7 \cdot 10^{-3} \cdot P$	
	10 W to 1 kW	33 V to 330 V 330 mA to < 3 A 45 Hz to 65 Hz $0.05 \le PF < 1$ inductive, capacitive	0.22 W	
With clamp connection	0.5 W to 218 kW	33 V to 330 V 10 mA to 660 A 45 Hz to 65 Hz $0.05 \le PF \le 1$ 1 to 60 windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.4 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding The relative uncertainty of the object under test W_{DUT} in the measuring circuit and in the stray field of the current-carrying conductor must be taken into account
Power factor	0 to 0.4	33 V to 330 V 330 mA to 2.2 A 45 Hz to 65 Hz	$0.15 \cdot 10^{-3}$	
	> 0.4 to < 1		$-60 \cdot 10^{-6} \cdot P + 0.16 \cdot 10^{-3}$	
	1		$89 \cdot 10^{-6}$	
AC reactive power Measuring instruments	0 var to 1 kvar	45 Hz to 65 Hz	U_P · var/W	U_P = uncertainty of the active power

Permanent laboratory – Location Nuremberg

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 18 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms 2 ns to 100 s 1 s to 100 h		1.2 ns $1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps $14 \cdot 10^{-6} \cdot \Delta t + U_{Tf}$	
Rotational frequency	0.02 s^{-1} to 18000 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	
Oscilloscope Vertical	0 V to 5 V 5 V to 130 V	DC to 10 kHz	$1.1 \cdot 10^{-3} \cdot U + 66$ µV $1.2 \cdot 10^{-3} \cdot U + 44$ µV	U = measured value
Oscilloscope Horizontal	1 ns to < 100 ns 100 ns to 20 ms > 20 ms to 5 s		$0.6 \cdot 10^{-6} \cdot T + 60$ fs $3.1 \cdot 10^{-6} \cdot T + 11$ fs $1.2 \cdot 10^{-3} \cdot T^2 + 29 \cdot 10^{-6} \cdot T$	T = measured value
Oscilloscopes Bandwidth f (frequency response)	50 kHz > 50 kHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 600 MHz > 600 MHz to 1.1 GHz > 1.1 GHz to 2 GHz > 2 GHz to 4 GHz		$3.3 \cdot 10^{-2} \cdot f$ $2.5 \cdot 10^{-2} \cdot f$ $3.1 \cdot 10^{-2} \cdot f$ $5.5 \cdot 10^{-2} \cdot f$ $6.5 \cdot 10^{-2} \cdot f$ $6.8 \cdot 10^{-2} \cdot f$ $9.5 \cdot 10^{-2} \cdot f$	f = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Rise time Oscilloscopes	50 ps to 1 ms 1 ns to 1 ms	0.05 V to 1.2 V 0.1 to 3 V	$4 \text{ ps} + 5.7 \cdot 10^{-3} \cdot T$ $2.5 \text{ ps} + 5.8 \cdot 10^{-3} \cdot T$	
Rise time Generators, pulses	0.5 ns to < 2.5 ns 2.5 ns to 5 ms		$28 \text{ ps} + 14 \cdot 10^{-3} \cdot T$ $13 \text{ ps} + 28 \cdot 10^{-3} \cdot T$	
RF power Output power and calibration factor of RF sources	10 µW to 80 mW	DC to 50 MHz 50 MHz to 4 GHz 4 GHz to 12 GHz 12 GHz to 18 GHz	$9.5 \cdot 10^{-3} \cdot P$ $14 \cdot 10^{-3} \cdot P$ $22 \cdot 10^{-3} \cdot P$ $36 \cdot 10^{-3} \cdot P$	N connector, 50 Ω $\lvert\Gamma_G\rvert \le 0.035$ $f \le 4$ GHz $\lvert\Gamma_G\rvert \le 0.056$ $f \le 12$ GHz $\lvert\Gamma_G\rvert \le 0.075$ $f \le 18$ GHz Other connectors and reflection coefficients increase the measurement uncertainty
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	22 mV to 2 V	DC to 18 MHz	$W(U_{HF}) = \frac{W(P)}{2}$	$W(P)$ = relative uncertainty of the measured power at Z_0 = 50 Ω

Permanent laboratory – Location Nuremberg

Matrix NM.1 Square-wave voltage

Square-wave voltage [V] / Frequency [Hz]	0.001	0.01	0.1	0.1	0.5	1	5	10	50	100
10	3.8E-07	512.2E-9	2.44E-06	2.37E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
100	7.4E-07	814.6E-9	2.52E-06	2.46E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
1000	6.4E-06	6.4E-6	6.99E-06	6.97E-06	1.34E-05	2.4E-05	111.6E-6	251.5E-6	1.2E-3	2.3E-3
10000	6.3E-05	63.7E-6	6.56E-05	6.56E-05	7.47E-05	8.7E-05	200.5E-6	369.5E-6	1.6E-3	3.2E-3

Matrix NM.2 Equivalent leakage current

Normal resistance R_N	**1 kΩ**		**10 kΩ**		**100 kΩ**		**1 MΩ**		**10 MΩ**		**100 MΩ**		**1 GΩ**	
Nominal voltage	**Current | expanded measurement uncertainty *U* in µA/A**										**Current | *U* in mA/A**			
60 V	60 mA	12	6 mA	12	600 µA	12	60 µA	20	6 µA	71	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Matrix NM.3 AC resistance

Voltage [V] / Current [A]	0.001 V	0.010 V	0.010 V	0.100 V	0.100 V	1.000 V	1.000 V	10.000 V	10.000 V	100.000 V
$2.2 \cdot 10^{-3}$ A	1.57E-03	4.66E-04	4.66E-04	3.00E-04	3.00E-04	2.98E-04	2.98E-04	3.00E-04	3.00E-04	3.78E-04
$22 \cdot 10^{-3}$ A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
0.22 A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
2.2 A	1.64E-03	6.78E-04	6.78E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	6.21E-04

Dimensional measurement quantities

Permanent laboratory – Location Nuremberg

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length				
Caliper gauge for external, internal, and depth dimensions *	0 mm to 500 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	20 µm + 15 · 10^{-6} · l	l = measured value
Bow micrometers *	0 mm to 300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	2 µm + 6 · 10^{-6} · l	
Cylindrical standards Rings * Diameter	1 mm to 90 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.9 µm + 10 · 10^{-6} · d	d = measured diameter
Gauge pin * Diameter	1 mm to 120 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.6 µm + 1.8 · 10^{-6} · d	
Test pins * Diameter	1 mm to 120 mm	VDI/VDE/DGQ 2618 Sheet 4.2:2007 Option 1	0.6 µm + 1.8 · 10^{-6} · d	
Thread gauges * (single and multiple thread cylindrical external and internal threads with straight flanks, symmetrical profile, nominal pitch, and nominal profile angle) External thread Simple flank diameter	1 mm to 120 mm	VDI/VDE/DGQ 2618 Sheet 4.8:2006 Option 1 Three-wire method (perpendicular to the thread axis)	2.9 µm + 7.7 · 10^{-6} · d	
Internal thread Simple flank diameter		VDI/VDE/DGQ 2618 Sheet 4.9:2006 Option 1 Two-ball method (perpendicular to the thread axis)	2.6 µm + 5.5 · 10^{-6} · d	

Electrical measurement quantities

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage	0 V				120 nV	Short-circuit bridge
Sources	0	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	U = measured value
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	
	> 1050 V	to	10 kV		$0.17 \cdot 10^{-3} \cdot U$	
DC voltage	0	to	220 mV		$6 \cdot 10^{-6} \cdot U + 0.6\ \mu V$	U = measured value
Measuring instruments	> 220 mV	to	2.2 V		$5 \cdot 10^{-6} \cdot U + 1\ \mu V$	
	> 2.2 V	to	11 V		$4 \cdot 10^{-6} \cdot U + 3.5\ \mu V$	
	> 11 V	to	22 V		$4 \cdot 10^{-6} \cdot U + 6.5\ \mu V$	
	> 22 V	to	220 V		$5 \cdot 10^{-6} \cdot U + 80\ \mu V$	
	> 220 V	to	1050 V		$7 \cdot 10^{-6} \cdot U + 0.5\ mV$	
	0 V	to	0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	
	> 0.1 V	to	1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V	to	10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V	to	100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V	to	500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V	to	1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Sources, measuring instruments	2 mV to 1000 V	10 Hz to 1 MHz	4.1 µV to 0.48 V	*U* = measured value
	2 mV to 10 mV	10 Hz to 40 Hz	$0.36 \cdot 10^{-3} \cdot U + 3.4$ µV	
		> 40 Hz to 1 kHz	$0.24 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 1 kHz to 20 kHz	$0.36 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 20 kHz to 50 kHz	$1.2 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 50 kHz to 100 kHz	$5.8 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 100 kHz to 300 kHz	$46 \cdot 10^{-3} \cdot U + 2.3$ µV	
	> 10 mV to 100 mV	10 Hz to 40 Hz	$86 \cdot 10^{-6} \cdot U + 4.6$ µV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 2.3$ µV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 50 kHz to 100 kHz	$0.93 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 12$ µV	
	> 100 mV to 1 V	10 Hz to 40 Hz	$83 \cdot 10^{-6} \cdot U + 46$ µV	
		> 40 Hz to 1 kHz	$82 \cdot 10^{-6} \cdot U + 23$ µV	
		> 1 kHz to 20 kHz	$0.16 \cdot 10^{-3} \cdot U + 23$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 23$ µV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 23$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 0.12$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 0.12$ mV	
	> 1 V to 10 V	10 Hz to 40 Hz	$85 \cdot 10^{-6} \cdot U + 0.46$ mV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 0.23$ mV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 1.2$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 1.2$ mV	
	> 10 V to 100 V	10 Hz to 40 Hz	$0.23 \cdot 10^{-3} \cdot U + 4.6$ mV	
		> 40 Hz to 1 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 1 kHz to 20 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 20 kHz to 50 kHz	$0.41 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 50 kHz to 100 kHz	$1.4 \cdot 10^{-3} \cdot U + 2.3$ mV	
	> 100 V to 1000 V	50 Hz to 1 kHz	$0.46 \cdot 10^{-3} \cdot U + 16$ mV	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	1 mV to 1100 V	10 Hz to 1 MHz	5 µV to 81 mV	*U* = measured value
	1 mV to 2.2 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 4.5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 13$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 2.2 mV to 22 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 22 mV to 220 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 13$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 8$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 8$ µV	
		> 20 kHz to 50 kHz	$0.28 \cdot 10^{-3} \cdot U + 8$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 25$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 25$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 35$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 80$ µV	
	> 220 mV to 2.2 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 80$ µV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 25$ µV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 6$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 16$ µV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 70$ µV	
		> 100 kHz to 300 kHz	$0.39 \cdot 10^{-3} \cdot U + 0.13$ mV	
		> 300 kHz to 500 kHz	$0.95 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 500 kHz to 1 MHz	$1.9 \cdot 10^{-3} \cdot U + 0.85$ mV	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	> 2.2 V to 22 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 0.8$ mV	U = measured value
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 0.25$ mV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 60$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 0.16$ mV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 100 kHz to 300 kHz	$0.45 \cdot 10^{-3} \cdot U + 1.5$ mV	
		> 300 kHz to 500 kHz	$1.2 \cdot 10^{-3} \cdot U + 4.3$ mV	
		> 500 kHz to 1 MHz	$2.5 \cdot 10^{-3} \cdot U + 8.5$ mV	
	> 22 V to 220 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 2.5$ mV	
		> 40 Hz to 20 kHz	$70 \cdot 10^{-6} \cdot U + 0.8$ mV	
		> 20 kHz to 50 kHz	$0.19 \cdot 10^{-3} \cdot U + 3.5$ mV	
		> 50 kHz to 100 kHz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
	> 220 V to 1100 V	15 Hz to 50 Hz	$0.36 \cdot 10^{-3} \cdot U + 16$ mV	
		> 50 Hz to 1 kHz	$70 \cdot 10^{-6} \cdot U + 3.5$ mV	
	1 mV to 220 V	1 Hz to 10 kHz Square-wave voltage	0.38 µV to 3.2 mV See matrix SM.1	
Sources	1100 V to 10 kV	45 Hz to 55 Hz	$0.46 \cdot 10^{-3} \cdot U$	U = measured value

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Measuring instruments, sources	0 mA to 220 µA		$40 \cdot 10^{-6} \cdot I + 8$ nA	I = measured value
	> 220 µA to 2.2 mA		$40 \cdot 10^{-6} \cdot I + 8$ nA	
	> 2.2 mA to 22 mA		$40 \cdot 10^{-6} \cdot I + 80$ nA	
	> 22 mA to 100 mA		$50 \cdot 10^{-6} \cdot I + 0.8$ µA	
	> 100 mA to 220 mA		$50 \cdot 10^{-6} \cdot I + 200 \cdot 10^{-6} \cdot I^2 + 0.8$ µA	
	> 220 mA to 1 A		$65 \cdot 10^{-6} \cdot I + 25$ µA	
	> 1 A to 2.2 A		$65 \cdot 10^{-6} \cdot I + 10 \cdot 10^{-6} \cdot I^2 + 25$ µA	
	> 2.2 A to 3 A		$0.38 \cdot 10^{-3} \cdot I + 40$ µA	
	> 3 A to 10.1 A		$0.5 \cdot 10^{-3} \cdot I + 0.5$ mA	
	> 10.1 A to 20.5 A		$1 \cdot 10^{-3} \cdot I + 0.75$ mA	
	0 pA to 1 pA		1 pA	
	> 1 pA to 100 nA		$35 \cdot 10^{-6} \cdot I + 46$ pA	
	> 100 nA to 1 µA		$23 \cdot 10^{-6} \cdot I + 46$ pA	
	> 1 µA to 10 µA		$23 \cdot 10^{-6} \cdot I + 0.12$ nA	
	> 10 µA to 100 µA		$23 \cdot 10^{-6} \cdot I + 0.92$ nA	
	> 100 µA to 1 mA		$23 \cdot 10^{-6} \cdot I + 6$ nA	
	> 1 mA to 10 mA		$23 \cdot 10^{-6} \cdot I + 58$ nA	
	> 10 mA to 100 mA		$41 \cdot 10^{-6} \cdot I + 580$ nA	
	> 100 mA to 1 A		$0.13 \cdot 10^{-3} \cdot I + 12$ µA	
	1 A to 400 A		$0.21 \cdot 10^{-3} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings	$3 \cdot 10^{-3} \cdot I$	I = measured value

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments, sources	10 µA to 20.5 A	10 Hz to 10 kHz	25 nA to 0.62 A	*I* = measured value
	0.01 mA to 0.22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 25$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 16$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ nA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ nA	
	> 0.22 mA to 2.2 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 40$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-4} \cdot I + 35$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 0.8$ µA	
	> 2.2 mA to 22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 0.35$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 8$ µA	
	> 22 mA to 220 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 3.5$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ µA	
	> 220 mA to 2.2 A	20 Hz to 1 kHz	$0.55 \cdot 10^{-3} \cdot I + 35$ µA	
		> 1 kHz to 5 kHz	$0.65 \cdot 10^{-3} \cdot I + 80$ µA	
		> 5 kHz to 10 kHz	$0.75 \cdot 10^{-3} \cdot I + 0.16$ mA	
	> 2.2 A to 3 A	10 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.1$ mA	
		> 45 Hz to 1 kHz	$0.6 \cdot 10^{-3} \cdot I + 0.1$ mA	
	> 3 A to 11 A	45 Hz to 100 Hz	$0.6 \cdot 10^{-3} \cdot I + 2$ mA	
		> 100 Hz to 1 kHz	$1.0 \cdot 10^{-3} \cdot I + 2$ mA	
	> 11 A to 20.5 A	45 Hz to 100 Hz	$1.2 \cdot 10^{-3} \cdot I + 5$ mA	
		> 100 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 5$ mA	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	5 µA to 1 A	20 Hz to 5 kHz	35 nA to 13 mA	I = measured value
	5 µA to 100 µA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I$ + 35 nA	
		> 45 Hz to 1 kHz	$0.76 \cdot 10^{-3} \cdot I$ + 34 nA	
	> 100 µA to 1 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I$ + 0.23 µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I$ + 0.23 µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I$ + 0.2 µA	
	> 1 mA to 10 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I$ + 2.3 µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I$ + 2.3 µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I$ + 2 µA	
	> 10 mA to 100 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I$ + 23 µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I$ + 23 µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I$ + 20 µA	
	> 100 mA to 1 A	20 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I$ + 0.23 mA	
		> 45 Hz to 100 Hz	$0.83 \cdot 10^{-3} \cdot I$ + 0.33 mA	
		> 100 Hz to 5 kHz	$1.6 \cdot 10^{-3} \cdot I$ + 0.21 mA	
AC current Sources, measuring instruments	10 mA to 500 A		3 µA to 0.2 A	I = measured value
	10 mA to 1 A	40 Hz to 1 kHz	$0.32 \cdot 10^{-3} \cdot I$	
	> 1 A to 100 A		$0.69 \cdot 10^{-3} \cdot I$	
	> 100 A to 450 A		$0.9 \cdot 10^{-3} \cdot I$	
Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$4 \cdot 10^{-3} \cdot I$	I = measured value
Equivalent leakage current	0.2 µA to 200 mA	at R_N to 1 GΩ DC to 60 Hz	$17 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix SM.2	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Fixed values	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value
		4-wire short circuit	0.35 µΩ	
	100 µΩ 1 mΩ 10 mΩ 100 mΩ		$0.45 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ $0.10 \cdot 10^{-3} \cdot R$	Intermediate values increase the measurement uncertainty
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ;		$40 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $14 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $9.5 \cdot 10^{-6} \cdot R$ $11 \cdot 10^{-6} \cdot R$ $15 \cdot 10^{-6} \cdot R$ $31 \cdot 10^{-6} \cdot R$ $100 \cdot 10^{-6} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ; 1 GΩ		$76 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $17 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $13 \cdot 10^{-6} \cdot R$ $19 \cdot 10^{-6} \cdot R$ $70 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-3} \cdot R$ $5.9 \cdot 10^{-3} \cdot R$	
Measuring instruments	0 Ω to < 11 Ω 11 Ω to < 110 Ω 110 Ω to < 110 kΩ 110 kΩ to < 1.1 MΩ 1.1 MΩ to < 3.3 MΩ 3.3 MΩ to < 11 MΩ 11 MΩ to < 33 MΩ 33 MΩ to < 110 MΩ 110 MΩ to < 330 MΩ 330 MΩ to < 1.1 GΩ		$40 \cdot 10^{-6} \cdot R$ $35 \cdot 10^{-6} \cdot R$ $28 \cdot 10^{-6} \cdot R$ $32 \cdot 10^{-6} \cdot R$ $60 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.25 \cdot 10^{-3} \cdot R$ $0.5 \cdot 10^{-3} \cdot R$ $3 \cdot 10^{-3} \cdot R$ $15 \cdot 10^{-3} \cdot R$	
AC resistance (amount of impedance)	500 µΩ to 45 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ to $1.7 \cdot 10^{-3} \cdot R$ See matrix SM.3	R = measured value U_I = relative uncertainty of the calibration current U_U = relative uncertainty of the measured voltage at the resistor

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance Fixed values	0 µH	2-wire short circuit	0.03 µH	
	100 µH	100 Hz	$0.54 \cdot 10^{-3} \cdot L$	L = measured value Amount of impedance 50 mΩ ≤ $\|Z\|$ ≤ 11 kΩ
		1 kHz	$0.28 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.29 \cdot 10^{-3} \cdot L$	
	1 mH	100 Hz	$0.14 \cdot 10^{-3} \cdot L$	
		1 kHz	$0.14 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.24 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz;	$0.13 \cdot 10^{-3} \cdot L$	
		1 kHz; 10 kHz	$0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz	$0.13 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.28 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance Fixed values	0 pF		0.2 pF	No load
	1 pF	1 kHz	$0.63 \cdot 10^{-3} \cdot C$	C = measured value Amount of impedance 1 Ω ≤ $\|Z\|$ ≤ 110 MΩ
		10 kHz	$0.31 \cdot 10^{-3} \cdot C$	
	10 pF	1 kHz	$42 \cdot 10^{-6} \cdot C$	
		10 kHz;	$53 \cdot 10^{-6} \cdot C$	
		100 kHz	$88 \cdot 10^{-6} \cdot C$	
		1 MHz	$0.24 \cdot 10^{-3} \cdot C$	
	100 pF	1 kHz	$39 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz	$71 \cdot 10^{-6} \cdot C$	
		100 kHz	$0.13 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz	$0.49 \cdot 10^{-3} \cdot C$	
		1 kHz	$0.21 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.23 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz;	$0.21 \cdot 10^{-3} \cdot C$	
		1 kHz;	$0.20 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.17 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz	$0.29 \cdot 10^{-3} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.29 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance f = frequency Different measurement conditions increase the measurement uncertainty
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power Measuring instruments	0 W to 21 kW	0 mV to 1020 V 0 µA to 20.5 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ $0.21 \cdot 10^{-3} \cdot P$ to $0.70 \cdot 10^{-3} \cdot P$	P = measured value
With clamp connection	0 W to 300 kW	0 V to 330 V 0 mA to 1000 A	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.2 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding
AC active power Measuring instruments	0.11 mW to 21 kW	PF = 1; 45 Hz to 65 Hz 33 mV to 1020 V 3.3 mA to 20 A	$0.7 \cdot 10^{-3} \cdot P$ to $1.4 \cdot 10^{-3} \cdot P$	P = measured value PF = power factor (capacitive or inductive)
	15 W; 60 W; 100 W; 400 W; 500 W; 1 kW; 2 kW; 4 kW	PF = 1; 45 Hz to 65 Hz 50 V; 200 V 0.3 A; 2 A; 10 A; 20 A	$0.16 \cdot 10^{-3} \cdot P$	
	1.5 W; 6 W	30 mA;	$0.26 \cdot 10^{-3} \cdot P$	
	2.3 W to 20.6 kW	45 Hz to 65 Hz; PF = 1 23 V to 1020 V 30 mA to 20.5 A	$0.32 \cdot 10^{-3} \cdot P$ to $0.48 \cdot 10^{-3} \cdot P$	
	220 W	45 Hz to 65 Hz 220 V; 1 A PF = 1	$0.16 \cdot 10^{-3} \cdot P$	
	198 W	PF = 0.9	$0.18 \cdot 10^{-3} \cdot P$	
	110 W	PF = 0.5	$0.29 \cdot 10^{-3} \cdot P$	
	22 W	PF = 0.1	$1.4 \cdot 10^{-3} \cdot P$	
	11 W	PF = 0.05	$2.7 \cdot 10^{-3} \cdot P$	
	10 W to 1 kW	33 V to 330 V 330 mA to < 3 A 45 Hz to 65 Hz $0.05 \le PF < 1$ Inductive, capacitive	0.22 W	
With clamp connection	0.5 W to 218 kW	33 V to 330 V 10 mA to 660 A 45 Hz to 65 Hz $0.05 \le PF \le 1$ 1 to 60 windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.4 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding The relative uncertainty of the device under test W_{DUT} in the measuring circuit and in the stray field of the current-carrying conductor must be taken into account
Power factor	0 to 0.4	33 V to 330 V 330 mA to 2.2 A 45 Hz to 65 Hz	$0.15 \cdot 10^{-3}$	
	> 0.4 to < 1		$-60 \cdot 10^{-6} \cdot P + 0.16 \cdot 10^{-3}$	
	1		$89 \cdot 10^{-6}$	
AC reactive power Measuring instruments	0 var to 1 kvar	45 Hz to 65 Hz	U_P · var/W	U_P = uncertainty of the active power

Permanent laboratory – Location Steinfurt

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 18 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms 2 ns to 100 s 1 s to 100 h		1.2 ns $1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps $14 \cdot 10^{-6} \cdot \Delta t + U_{Tf}$	
Rotational frequency	0.02 s^{-1} to 18000 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	
Oscilloscope Vertical	0 V to 5 V 5 V to 130 V	DC to 10 kHz	$1.1 \cdot 10^{-3} \cdot U + 66$ µV $1.2 \cdot 10^{-3} \cdot U + 44$ µV	U = measured value
Oscilloscope Horizontal	1 ns to < 100 ns 100 ns to 20 ms > 20 ms to 5 s		$0.6 \cdot 10^{-6} \cdot T + 60$ fs $3.1 \cdot 10^{-6} \cdot T + 11$ fs $1.2 \cdot 10^{-3} \cdot T^2 + 29 \cdot 10^{-6} \cdot T$	T = measured value
Oscilloscopes Bandwidth f (frequency response)	50 kHz > 50 kHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 600 MHz > 600 MHz to 1.1 GHz > 1.1 GHz to 2 GHz > 2 GHz to 4 GHz		$3.3 \cdot 10^{-2} \cdot f$ $2.5 \cdot 10^{-2} \cdot f$ $3.1 \cdot 10^{-2} \cdot f$ $5.5 \cdot 10^{-2} \cdot f$ $6.5 \cdot 10^{-2} \cdot f$ $6.8 \cdot 10^{-2} \cdot f$ $9.5 \cdot 10^{-2} \cdot f$	f = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Rise time Oscilloscopes	50 ps to 1 ms 1 ns to 1 ms	0.05 V to 1.2 V 0.1 V to 3 V	$4 \text{ ps} + 5.7 \cdot 10^{-3} \cdot T$ $2.5 \text{ ps} + 5.8 \cdot 10^{-3} \cdot T$	
Rise time Generators, pulses	0.5 ns to < 2.5 ns 2.5 ns to 5 ms		$28 \text{ ps} + 14 \cdot 10^{-3} \cdot T$ $13 \text{ ps} + 28 \cdot 10^{-3} \cdot T$	
RF power Output power and calibration factor of RF sources	10 µW to 80 mW	DC to 50 MHz 50 MHz to 4 GHz 4 GHz to 12 GHz 12 GHz to 18 GHz	$9.5 \cdot 10^{-3} \cdot P$ $14 \cdot 10^{-3} \cdot P$ $22 \cdot 10^{-3} \cdot P$ $36 \cdot 10^{-3} \cdot P$	N connector, 50 ohms $\lvert\Gamma_G\rvert \le 0.035$ $f \le 4$ GHz $\lvert\Gamma_G\rvert \le 0.056$ $f \le 12$ GHz $\lvert\Gamma_G\rvert \le 0.075$ $f \le 18$ GHz Other connectors and reflection coefficients increase the measurement uncertainty
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	22 mV to 2 V	DC to 18 MHz	$W(U_{HF}) = \frac{W(P)}{2}$	$W(P)$ is the relative uncertainty of the measured power at $Z_0 = 50$ Ω

Permanent laboratory – Location Steinfurt

Matrix SM.1 Square-wave voltage

Square-wave voltage [V] / Frequency [Hz]	0.001	0.01	0.1	0.1	0.5	1	5	10	50	100
10	3.8E-07	512.2E-9	2.44E-06	2.37E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
100	7.4E-07	814.6E-9	2.52E-06	2.46E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
1000	6.4E-06	6.4E-6	6.99E-06	6.97E-06	1.34E-05	2.4E-05	111.6E-6	251.5E-6	1.2E-3	2.3E-3
1000	6.3E-05	63.7E-6	6.56E-05	6.56E-05	7.47E-05	8.7E-05	200.5E-6	369.5E-6	1.6E-3	3.2E-3

Matrix SM.2 Equivalent leakage current

Normal resistance R_N	**1 kΩ**		**10 kΩ**		**100 kΩ**		**1 MΩ**		**10 MΩ**		**100 MΩ**		**1 GΩ**	
Nominal voltage	**Current | expanded measurement uncertainty *U* in µA/A**										**Current | *U* in mA/A**			
60 V	60 mA	12	6 mA	12	600 µA	12	60 µA	20	6 µA	71	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Matrix SM.3 AC resistance

Voltage [V] / Current [A]	0.001 V	0.010 V	0.010 V	0.100 V	0.100 V	1.000 V	1.000 V	10.000 V	10,000 V	100,000 V
$2.2 \cdot 10^{-3}$ A	1.57E-03	4.66E-04	4.66E-04	3.00E-04	3.00E-04	2.98E-04	2.98E-04	3.00E-04	3.00E-04	3.78E-04
$22 \cdot 10^{-3}$ A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
0.22 A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
2.2 A	1.64E-03	6.78E-04	6.78E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	6.21E-04

Dimensional measurement quantities

Permanent laboratory – Location Steinfurt

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length Caliper gauge for external, internal, and depth dimensions *	0 mm to 500 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	20 µm + 15 · 10^{-6} · *l*	*l* = measured value
Bow micrometers *	0 mm to 300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	2 µm + 6 · 10^{-6} · *l*	

Electrical measurement quantities

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage Sources	0 V		120 nV	Short-circuit bridge
	0 V to 0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	U = measured value
	> 0.1 V to 1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V to 10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V to 100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V to 500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V to 1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	
	> 1050 V to 10 kV		$0.17 \cdot 10^{-3} \cdot U$	
DC voltage Measuring instruments	0 to 220 mV		$6 \cdot 10^{-6} \cdot U + 0.6\ \mu V$	U = measured value
	> 220 mV to 2.2 V		$5 \cdot 10^{-6} \cdot U + 1\ \mu V$	
	> 2.2 V to 11 V		$4 \cdot 10^{-6} \cdot U + 3.5\ \mu V$	
	> 11 V to 22 V		$4 \cdot 10^{-6} \cdot U + 6.5\ \mu V$	
	> 22 V to 220 V		$5 \cdot 10^{-6} \cdot U + 80\ \mu V$	
	> 220 V to 1050 V		$7 \cdot 10^{-6} \cdot U + 0.5\ mV$	
	0 V to 0.1 V		$4 \cdot 10^{-6} \cdot U + 0.36\ \mu V$	
	> 0.1 V to 1 V		$3.7 \cdot 10^{-6} \cdot U + 0.35\ \mu V$	
	> 1 V to 10 V		$3.2 \cdot 10^{-6} \cdot U + 0.56\ \mu V$	
	> 10 V to 100 V		$5.3 \cdot 10^{-6} \cdot U + 34\ \mu V$	
	> 100 V to 500 V		$9.6 \cdot 10^{-6} \cdot U - 0.34\ mV$	
	> 500 V to 1050 V		$30 \cdot 10^{-6} \cdot U - 10\ mV$	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Sources, measuring instruments	2 mV to 1000 V	10 Hz to 1 MHz	4.1 µV to 0.48 V	*U* = measured value
	2 mV to 10 mV	10 Hz to 40 Hz	$0.36 \cdot 10^{-3} \cdot U + 3.4$ µV	
		> 40 Hz to 1 kHz	$0.24 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 1 kHz to 20 kHz	$0.36 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 20 kHz to 50 kHz	$1.2 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 50 kHz to 100 kHz	$5.8 \cdot 10^{-3} \cdot U + 1.3$ µV	
		> 100 kHz to 300 kHz	$46 \cdot 10^{-3} \cdot U + 2.3$ µV	
	> 10 mV to 100 mV	10 Hz to 40 Hz	$86 \cdot 10^{-6} \cdot U + 4.6$ µV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 2.3$ µV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 50 kHz to 100 kHz	$0.93 \cdot 10^{-3} \cdot U + 2.3$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 12$ µV	
	> 100 mV to 1 V	10 Hz to 40 Hz	$83 \cdot 10^{-6} \cdot U + 46$ µV	
		> 40 Hz to 1 kHz	$82 \cdot 10^{-6} \cdot U + 23$ µV	
		> 1 kHz to 20 kHz	$0.16 \cdot 10^{-3} \cdot U + 23$ µV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 23$ µV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 23$ µV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 0.12$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 0.12$ mV	
	> 1 V to 10 V	10 Hz to 40 Hz	$85 \cdot 10^{-6} \cdot U + 0.46$ mV	
		> 40 Hz to 1 kHz	$87 \cdot 10^{-6} \cdot U + 0.23$ mV	
		> 1 kHz to 20 kHz	$0.17 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 20 kHz to 50 kHz	$0.35 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 50 kHz to 100 kHz	$0.92 \cdot 10^{-3} \cdot U + 0.23$ mV	
		> 100 kHz to 300 kHz	$3.5 \cdot 10^{-3} \cdot U + 1.2$ mV	
		> 300 kHz to 1 MHz	$12 \cdot 10^{-3} \cdot U + 1.2$ mV	
	> 10 V to 100 V	10 Hz to 40 Hz	$0.23 \cdot 10^{-3} \cdot U + 4.6$ mV	
		> 40 Hz to 1 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 1 kHz to 20 kHz	$0.23 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 20 kHz to 50 kHz	$0.41 \cdot 10^{-3} \cdot U + 2.3$ mV	
		> 50 kHz to 100 kHz	$1.4 \cdot 10^{-3} \cdot U + 2.3$ mV	
	> 100 V to 1000 V	50 Hz to 1 kHz	$0.46 \cdot 10^{-3} \cdot U + 16$ mV	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	1 mV to 1100 V	10 Hz to 1 MHz	5 µV to 81 mV	*U* = measured value
	1 mV to 2.2 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 4.5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 4.5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 13$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 2.2 mV to 22 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 5$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 5$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 5$ µV	
		> 20 kHz to 50 kHz	$0.33 \cdot 10^{-3} \cdot U + 5$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 7$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 12$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 25$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 25$ µV	
	> 22 mV to 220 mV	10 Hz to 20 Hz	$0.5 \cdot 10^{-3} \cdot U + 13$ µV	
		> 20 Hz to 40 Hz	$0.19 \cdot 10^{-3} \cdot U + 8$ µV	
		> 40 Hz to 20 kHz	$95 \cdot 10^{-6} \cdot U + 8$ µV	
		> 20 kHz to 50 kHz	$0.28 \cdot 10^{-3} \cdot U + 8$ µV	
		> 50 kHz to 100 kHz	$0.75 \cdot 10^{-3} \cdot U + 25$ µV	
		> 100 kHz to 300 kHz	$1 \cdot 10^{-3} \cdot U + 25$ µV	
		> 300 kHz to 500 kHz	$1.5 \cdot 10^{-3} \cdot U + 35$ µV	
		> 500 kHz to 1 MHz	$3.1 \cdot 10^{-3} \cdot U + 80$ µV	
	> 220 mV to 2.2 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 80$ µV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 25$ µV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 6$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 16$ µV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 70$ µV	
		> 100 kHz to 300 kHz	$0.39 \cdot 10^{-3} \cdot U + 0.13$ mV	
		> 300 kHz to 500 kHz	$0.95 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 500 kHz to 1 MHz	$1.9 \cdot 10^{-3} \cdot U + 0.85$ mV	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Measuring instruments, sources	> 2.2 V to 22 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 0.8$ mV	U = measured value
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 0.25$ mV	
		> 40 Hz to 20 kHz	$65 \cdot 10^{-6} \cdot U + 60$ µV	
		> 20 kHz to 50 kHz	$0.11 \cdot 10^{-3} \cdot U + 0.16$ mV	
		> 50 kHz to 100 kHz	$0.21 \cdot 10^{-3} \cdot U + 0.35$ mV	
		> 100 kHz to 300 kHz	$0.45 \cdot 10^{-3} \cdot U + 1.5$ mV	
		> 300 kHz to 500 kHz	$1.2 \cdot 10^{-3} \cdot U + 4.3$ mV	
		> 500 kHz to 1 MHz	$2.5 \cdot 10^{-3} \cdot U + 8.5$ mV	
	> 22 V to 220 V	10 Hz to 20 Hz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
		> 20 Hz to 40 Hz	$0.14 \cdot 10^{-3} \cdot U + 2.5$ mV	
		> 40 Hz to 20 kHz	$70 \cdot 10^{-6} \cdot U + 0.8$ mV	
		> 20 kHz to 50 kHz	$0.19 \cdot 10^{-3} \cdot U + 3.5$ mV	
		> 50 kHz to 100 kHz	$0.45 \cdot 10^{-3} \cdot U + 8$ mV	
	> 220 V to 1100 V	15 Hz to 50 Hz	$0.36 \cdot 10^{-3} \cdot U + 16$ mV	
		> 50 Hz to 1 kHz	$70 \cdot 10^{-6} \cdot U + 3.5$ mV	
	1 mV to 220 V	1 Hz to 10 kHz Square-wave voltage	0.38 µV to 3.2 mV See matrix WM.1	
Sources	1100 V to 10 kV	45 Hz to 55 Hz	$0.46 \cdot 10^{-3} \cdot U$	U = measured value

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current Measuring instruments, sources	0 mA to 220 µA		$40 \cdot 10^{-6} \cdot I + 8$ nA	I = measured value
	> 220 µA to 2.2 mA		$40 \cdot 10^{-6} \cdot I + 8$ nA	
	> 2.2 mA to 22 mA		$40 \cdot 10^{-6} \cdot I + 80$ nA	
	> 22 mA to 100 mA		$50 \cdot 10^{-6} \cdot I + 0.8$ µA	
	> 100 mA to 220 mA		$50 \cdot 10^{-6} \cdot I + 200 \cdot 10^{-6} \cdot I^2 + 0.8$ µA	
	> 220 mA to 1 A		$65 \cdot 10^{-6} \cdot I + 25$ µA	
	> 1 A to 2.2 A		$65 \cdot 10^{-6} \cdot I + 10 \cdot 10^{-6} \cdot I^2 + 25$ µA	
	> 2.2 A to 3 A		$0.38 \cdot 10^{-3} \cdot I + 40$ µA	
	> 3 A to 10.1 A		$0.5 \cdot 10^{-3} \cdot I + 0.5$ mA	
	> 10.1 A to 20.5 A		$1 \cdot 10^{-3} \cdot I + 0.75$ mA	
	0 pA to 1 pA		1 pA	
	> 1 pA to 100 nA		$35 \cdot 10^{-6} \cdot I + 46$ pA	
	> 100 nA to 1 µA		$23 \cdot 10^{-6} \cdot I + 46$ pA	
	> 1 µA to 10 µA		$23 \cdot 10^{-6} \cdot I + 0.12$ nA	
	> 10 µA to 100 µA		$23 \cdot 10^{-6} \cdot I + 0.92$ nA	
	> 100 µA to 1 mA		$23 \cdot 10^{-6} \cdot I + 6$ nA	
	> 1 mA to 10 mA		$23 \cdot 10^{-6} \cdot I + 58$ nA	
	> 10 mA to 100 mA		$41 \cdot 10^{-6} \cdot I + 580$ nA	
	> 100 mA to 1 A		$0.13 \cdot 10^{-3} \cdot I + 12$ µA	
	1 A to 400 A		$0.21 \cdot 10^{-3} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Current clamps and current clamp transformers	1 mA to 1100 A	1 to N windings	$3 \cdot 10^{-3} \cdot I$	I = measured value

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Measuring instruments, sources	10 µA to 20.5 A	10 Hz to 10 kHz	25 nA to 0.62 A	*I* = measured value
	0.01 mA to 0.22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 25$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 16$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ nA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ nA	
	> 0.22 mA to 2.2 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 40$ nA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-4} \cdot I + 35$ nA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 0.8$ µA	
	> 2.2 mA to 22 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 0.4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 0.35$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 4$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 8$ µA	
	> 22 mA to 220 mA	10 Hz to 40 Hz	$0.6 \cdot 10^{-3} \cdot I + 4$ µA	
		> 40 Hz to 1 kHz	$0.12 \cdot 10^{-3} \cdot I + 3.5$ µA	
		> 1 kHz to 5 kHz	$0.5 \cdot 10^{-3} \cdot I + 40$ µA	
		> 5 kHz to 10 kHz	$1.4 \cdot 10^{-3} \cdot I + 80$ µA	
	> 220 mA to 2.2 A	20 Hz to 1 kHz	$0.55 \cdot 10^{-3} \cdot I + 35$ µA	
		> 1 kHz to 5 kHz	$0.65 \cdot 10^{-3} \cdot I + 80$ µA	
		> 5 kHz to 10 kHz	$0.75 \cdot 10^{-3} \cdot I + 0.16$ mA	
	> 2.2 A to 3 A	10 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.1$ mA	
		> 45 Hz to 1 kHz	$0.6 \cdot 10^{-3} \cdot I + 0.1$ mA	
	> 3 A to 11 A	45 Hz to 100 Hz	$0.6 \cdot 10^{-3} \cdot I + 2$ mA	
		> 100 Hz to 1 kHz	$1.0 \cdot 10^{-3} \cdot I + 2$ mA	
	> 11 A to 20.5 A	45 Hz to 100 Hz	$1.2 \cdot 10^{-3} \cdot I + 5$ mA	
		> 100 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 5$ mA	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	5 µA to 1 A	20 Hz to 5 kHz	35 nA to 13 mA	*I* = measured value
	5 µA to 100 µA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 35$ nA	
		> 45 Hz to 1 kHz	$0.76 \cdot 10^{-3} \cdot I + 34$ nA	
	> 100 µA to 1 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 0.23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 0.2$ µA	
	> 1 mA to 10 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 2.3$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 2$ µA	
	> 10 mA to 100 mA	20 Hz to 45 Hz	$1.7 \cdot 10^{-3} \cdot I + 23$ µA	
		> 45 Hz to 100 Hz	$0.71 \cdot 10^{-3} \cdot I + 23$ µA	
		> 100 Hz to 5 kHz	$0.73 \cdot 10^{-3} \cdot I + 20$ µA	
	> 100 mA to 1 A	20 Hz to 45 Hz	$1.8 \cdot 10^{-3} \cdot I + 0.23$ mA	
		> 45 Hz to 100 Hz	$0.83 \cdot 10^{-3} \cdot I + 0.33$ mA	
		> 100 Hz to 5 kHz	$1.6 \cdot 10^{-3} \cdot I + 0.21$ mA	
AC current Sources, measuring instruments	10 mA to 500 A		3 µA to 0.2 A	*I* = measured value
	10 mA to 1 A	40 Hz to 1 kHz	$0.32 \cdot 10^{-3} \cdot I$	
	> 1 A to 100 A		$0.69 \cdot 10^{-3} \cdot I$	
	> 100 A to 450 A		$0.9 \cdot 10^{-3} \cdot I$	
Current clamps and current clamp transformers	1 mA to 1100 A	1 to *N* windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$4 \cdot 10^{-3} \cdot I$	*I* = measured value
Equivalent leakage current	0.2 µA to 200 mA	at R_N to 1 GΩ DC to 60 Hz	$17 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ See matrix WM.2	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance Fixed values	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value
		4-wire short circuit	0.35 µΩ	
	100 µΩ		$0.45 \cdot 10^{-3} \cdot R$	Intermediate values increase the measurement uncertainty
	1 mΩ		$0.17 \cdot 10^{-3} \cdot R$	
	10 mΩ		$0.17 \cdot 10^{-3} \cdot R$	
	100 mΩ		$0.10 \cdot 10^{-3} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ;		$40 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $14 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $9.5 \cdot 10^{-6} \cdot R$ $11 \cdot 10^{-6} \cdot R$ $15 \cdot 10^{-6} \cdot R$ $31 \cdot 10^{-6} \cdot R$ $100 \cdot 10^{-6} \cdot R$	
	1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ; 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ; 1 GΩ		$76 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $17 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $10 \cdot 10^{-6} \cdot R$ $13 \cdot 10^{-6} \cdot R$ $19 \cdot 10^{-6} \cdot R$ $70 \cdot 10^{-6} \cdot R$ $0.59 \cdot 10^{-3} \cdot R$ $5.9 \cdot 10^{-3} \cdot R$	
Measuring instruments	0 to < 11 Ω 11 Ω to < 110 Ω 110 Ω to < 110 kΩ 110 kΩ to < 1.1 MΩ 1.1 MΩ to < 3.3 MΩ 3.3 MΩ to < 11 MΩ 11 MΩ to < 33 MΩ 33 MΩ to < 110 MΩ 110 MΩ to < 330 MΩ 330 MΩ to < 1.1 GΩ		$40 \cdot 10^{-6} \cdot R$ $35 \cdot 10^{-6} \cdot R$ $28 \cdot 10^{-6} \cdot R$ $32 \cdot 10^{-6} \cdot R$ $60 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.25 \cdot 10^{-3} \cdot R$ $0.5 \cdot 10^{-3} \cdot R$ $3 \cdot 10^{-3} \cdot R$ $15 \cdot 10^{-3} \cdot R$	
AC resistance (amount of impedance)	500 µΩ to 45 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$ $0.17 \cdot 10^{-3} \cdot R$ to $1.7 \cdot 10^{-3} \cdot R$ See matrix WM.3	R = measured value U_I = relative uncertainty of the calibration current U_U = relative uncertainty of the measured voltage at the resistor

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance Fixed values	0 µH	2-wire short circuit	0.03 µH	
	100 µH	100 Hz 1 kHz 10 kHz	$0.54 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$ $0.29 \cdot 10^{-3} \cdot L$	L = measured value Amount of impedance 50 mΩ ≤ |Z| ≤ 11 kΩ
	1 mH	100 Hz 1 kHz 10 kHz	$0.14 \cdot 10^{-3} \cdot L$ $0.14 \cdot 10^{-3} \cdot L$ $0.24 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz; 1 kHz; 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz 10 kHz	$0.13 \cdot 10^{-3} \cdot L$ $0.28 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance Fixed values	0 pF		0.2 pF	No load
	1 pF	1 kHz 10 kHz	$0.63 \cdot 10^{-3} \cdot C$ $0.31 \cdot 10^{-3} \cdot C$	C = measured value Amount of impedance 1 Ω ≤ |Z| ≤ 110 MΩ
	10 pF	1 kHz 10 kHz; 100 kHz 1 MHz	$42 \cdot 10^{-6} \cdot C$ $53 \cdot 10^{-6} \cdot C$ $88 \cdot 10^{-6} \cdot C$ $0.24 \cdot 10^{-3} \cdot C$	
	100 pF	1 kHz	$39 \cdot 10^{-6} \cdot C$	
	1 nF	1 kHz 100 kHz	$71 \cdot 10^{-6} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz 1 kHz 10 kHz	$0.49 \cdot 10^{-3} \cdot C$ $0.21 \cdot 10^{-3} \cdot C$ $0.23 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz; 1 kHz; 10 kHz	$0.21 \cdot 10^{-3} \cdot C$ $0.20 \cdot 10^{-3} \cdot C$ $0.17 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz 10 kHz	$0.29 \cdot 10^{-3} \cdot C$ $0.13 \cdot 10^{-3} \cdot C$ $0.29 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance f = frequency Different measurement conditions increase the measurement uncertainty
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power Measuring instruments	0 W to 21 kW	0 mV to 1020 V 0 µA to 20.5 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ $0.21 \cdot 10^{-3} \cdot P$ to $0.70 \cdot 10^{-3} \cdot P$	P = measured value
With clamp connection	0 W to 300 kW	0 V to 330 V 0 mA to 1000 A	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.2 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding
AC active power Measuring instruments	0.11 mW to 21 kW	PF = 1; 45 Hz to 65 Hz 33 mV to 1020 V 3.3 mA to 20 A	$0.7 \cdot 10^{-3} \cdot P$ to $1.4 \cdot 10^{-3} \cdot P$	P = measured value PF = power factor (capacitive or inductive)
	15 W; 60 W; 100 W; 400 W; 500 W; 1 kW; 2 kW; 4 kW	PF = 1; 45 Hz to 65 Hz 50 V; 200 V 0.3 A; 2 A; 10 A; 20 A	$0.16 \cdot 10^{-3} \cdot P$	
	1.5 W; 6 W	30 mA;	$0.26 \cdot 10^{-3} \cdot P$	
	2.3 W to 20.6 kW	45 Hz to 65 Hz; PF = 1 23 V to 1020 V 30 mA to 20.5 A	$0.32 \cdot 10^{-3} \cdot P$ to $0.48 \cdot 10^{-3} \cdot P$	
	220 W	45 Hz to 65 Hz 220 V; 1 A PF = 1	$0.16 \cdot 10^{-3} \cdot P$	
	198 W	PF = 0.9	$0.18 \cdot 10^{-3} \cdot P$	
	110 W	PF = 0.5	$0.29 \cdot 10^{-3} \cdot P$	
	22 W	PF = 0.1	$1.4 \cdot 10^{-3} \cdot P$	
	11 W	PF = 0.05	$2.7 \cdot 10^{-3} \cdot P$	
	10 W to 1 kW	33 V to 330 V 330 mA to < 3 A 45 Hz to 65 Hz $0.05 \le PF < 1$ Inductive, capacitive	0.22 W	
With clamp connection	0.5 W to 218 kW	33 V to 330 V 10 mA to 660 A 45 Hz to 65 Hz $0.05 \le PF \le 1$ 1 to 60 windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot P$ but not less than $0.4 \cdot 10^{-3} \cdot P$	W_{in} = relative uncertainty of the active power of the single winding The relative uncertainty of the object under test W_{DUT} in the measuring circuit and in the stray field of the current-carrying conductor must be taken into account
Power factor	0 to 0.4	33 V to 330 V 330 mA to 2.2 A 45 Hz to 65 Hz	$0.15 \cdot 10^{-3}$	
	> 0.4 to < 1		$-60 \cdot 10^{-6} \cdot P + 0.16 \cdot 10^{-3}$	
	1		$89 \cdot 10^{-6}$	
AC reactive power Measuring instruments	0 var to 1 kvar	45 Hz to 65 Hz	U_P · var/W	U_P = uncertainty of the active power

Permanent laboratory – Location Vienna

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 18 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms 2 ns to 100 s 1 s to 100 h		1.2 ns $1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps $14 \cdot 10^{-6} \cdot \Delta t + U_{Tf}$	
Rotational frequency	0.02 s^{-1} to 18000 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	
Oscilloscope Vertical	0 V to 5 V 5 V to 130 V	DC to 10 kHz	$1.1 \cdot 10^{-3} \cdot U + 66$ µV $1.2 \cdot 10^{-3} \cdot U + 44$ µV	U = measured value
Oscilloscope Horizontal	1 ns to < 100 ns 100 ns to 20 ms > 20 ms to 5 s		$0.6 \cdot 10^{-6} \cdot T + 60$ fs $3.1 \cdot 10^{-6} \cdot T + 11$ fs $1.2 \cdot 10^{-3} \cdot T^2 + 29 \cdot 10^{-6} \cdot T$	T = measured value
Oscilloscopes Bandwidth f (frequency response)	50 kHz > 50 kHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 600 MHz > 600 MHz to 1.1 GHz > 1.1 GHz to 2 GHz > 2 GHz to 4 GHz		$3.3 \cdot 10^{-2} \cdot f$ $2.5 \cdot 10^{-2} \cdot f$ $3.1 \cdot 10^{-2} \cdot f$ $5.5 \cdot 10^{-2} \cdot f$ $6.5 \cdot 10^{-2} \cdot f$ $6.8 \cdot 10^{-2} \cdot f$ $9.5 \cdot 10^{-2} \cdot f$	f = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Rise time Oscilloscopes	50 ps to 1 ms 1 ns to 1 ms	0.05 V to 1.2 V 0.1 VI to 3 V	$4 \text{ ps} + 5.7 \cdot 10^{-3} \cdot T$ $2.5 \text{ ps} + 5.8 \cdot 10^{-3} \cdot T$	
Rise time Generators, pulses	0.5 ns to < 2.5 ns 2.5 ns to 5 ms		$28 \text{ ps} + 14 \cdot 10^{-3} \cdot T$ $13 \text{ ps} + 28 \cdot 10^{-3} \cdot T$	
RF power Output power and calibration factor of RF sources	10 µW to 80 mW	DC to 50 MHz 50 MHz to 4 GHz 4 GHz to 12 GHz 12 GHz to 18 GHz	$9.5 \cdot 10^{-3} \cdot P$ $14 \cdot 10^{-3} \cdot P$ $22 \cdot 10^{-3} \cdot P$ $36 \cdot 10^{-3} \cdot P$	N connector, 50 Ω $\lvert\Gamma_G\rvert \le 0.035$ $f \le 4$ GHz $\lvert\Gamma_G\rvert \le 0.056$ $f \le 12$ GHz $\lvert\Gamma_G\rvert \le 0.075$ $f \le 18$ GHz Other connectors and reflection coefficients increase the measurement uncertainty
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	22 mV to 2 V	DC to 18 MHz	$W(U_{HF}) = \frac{W(P)}{2}$	$W(P)$ is the relative uncertainty of the measured power at Z_0 = 50 Ω

Permanent laboratory – Location Vienna

Matrix WM.1 Square-wave voltage

Square-wave voltage [V] / Frequency [Hz]	0.001	0.01	0.1	0.1	0.5	1	5	10	50	100
10	3.8E-07	512.2E-9	2.44E-06	2.37E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
100	7.4E-07	814.6E-9	2.52E-06	2.46E-06	1.12E-05	2.2E-05	110.4E-6	250.0E-6	1.2E-3	2.3E-3
1000	6.4E-06	6.4E-6	6.99E-06	6.97E-06	1.34E-05	2.4E-05	111.6E-6	251.5E-6	1.2E-3	2.3E-3
10000	6.3E-05	63.7E-6	6.56E-05	6.56E-05	7.47E-05	8.7E-05	200.5E-6	369.5E-6	1.6E-3	3.2E-3

Matrix WM.2 Equivalent leakage current

Normal resistance R_N	**1 kΩ**		**10 kΩ**		**100 kΩ**		**1 MΩ**		**10 MΩ**		**100 MΩ**		**1 GΩ**	
Nominal voltage	**Current | expanded measurement uncertainty of *U* in µA/A**										**Current | *U* in mA/A**			
60 V	60 mA	12	6 mA	12	600 µA	12	60 µA	20	6 µA	71	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

Matrix WM.3 AC resistance

Voltage [V] / Current [A]	0.001 V	0.010 V	0.010 V	0.100 V	0.100 V	1.000 V	1.000 V	10.000 V	10.000 V	100.000 V
$2.2 \cdot 10^{-3}$ A	1.57E-03	4.66E-04	4.66E-04	3.00E-04	3.00E-04	2.98E-04	2.98E-04	3.00E-04	3.00E-04	3.78E-04
$22 \cdot 10^{-3}$ A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
0.22 A	1.55E-03	3.97E-04	3.97E-04	1.75E-04	1.75E-04	1.72E-04	1.72E-04	1.75E-04	1.75E-04	2.89E-04
2.2 A	1.64E-03	6.78E-04	6.78E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	5.76E-04	6.21E-04

Dimensional measurement quantities

Permanent laboratory – Location Vienna

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Length				*l* = measured value
Caliper gauge for external, internal, and depth dimensions *	0 mm to 500 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	20 µm + $15 \cdot 10^{-6} \cdot l$	
Bow micrometers *	0 mm to 300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	2 µm + $6 \cdot 10^{-6} \cdot l$	

On-site calibration – Electrical measurement quantities

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC voltage	0 V		35 nV	Short-circuit bridge
	0 V to 1 V		$0.46 \cdot 10^{-6} \cdot U + 0.18\ \mu V$	U = measured value
	> 1 V to 10 V		$0.18 \cdot 10^{-6} \cdot U + 0.67\ \mu V$	
	> 10 V to 100 V		$0.28 \cdot 10^{-6} \cdot U - 0.34\ \mu V$	
	> 100 V to 1050 V		$0.24 \cdot 10^{-6} \cdot U + 64\ \mu V$	
High voltage Sources	1 kV to 10 kV		$7.9 \cdot 10^{-6} \cdot U + 17$ mV	U = measured value
	> 10 kV to 60 kV		$46 \cdot 10^{-6} \cdot U + 0.95$ V	
AC voltage	2 mV to 10 mV	10 Hz; 12.5 Hz	$26 \cdot 10^{-6} \cdot U + 0.11\ \mu V$	U = measured value Calibration on the Josephson voltmeter When calibrating measuring instruments, the influence of load impedance and repeatability must also be taken into account
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$28 \cdot 10^{-6} \cdot U + 23$ nV	
		48 Hz; 60 Hz; 62.5 Hz	$19 \cdot 10^{-6} \cdot U + 0.11\ \mu V$	
		625 Hz; 937.5 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot U + 0.12\ \mu V$	
	> 10 mV to 60 mV	10 Hz; 12.5 Hz	$13 \cdot 10^{-6} \cdot U + 0.19\ \mu V$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$8.6 \cdot 10^{-6} \cdot U + 0.16\ \mu V$	
		48 Hz; 60 Hz; 62.5 Hz	$10 \cdot 10^{-6} \cdot U + 0.16\ \mu V$	
		625 Hz; 937.5 Hz; 1 kHz	$9.1 \cdot 10^{-6} \cdot U + 0.16\ \mu V$	
	> 60 mV to 7.2 V	10 Hz; 12.5 Hz	$10 \cdot 10^{-6} \cdot U + 0.14\ \mu V$	
		20 Hz; 25 Hz; 30 Hz; 37.5 Hz; 40 Hz; 75 Hz; 80 Hz; 125 Hz; 312.5 Hz; 375 Hz	$2.2 \cdot 10^{-6} \cdot U + 0.16\ \mu V$	
		48 Hz; 60 Hz; 62.5 Hz	$4.2 \cdot 10^{-6} \cdot U + 0.14\ \mu V$	
		625 Hz; 937.5 Hz; 1 kHz	$1.4 \cdot 10^{-6} \cdot U + 0.16\ \mu V$	
AC voltage	2 mV to < 22 V	10 Hz to 1 MHz		U = measured value
	2 mV	10 Hz; 20 Hz; 40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz; 300 kHz	$0.29 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.32 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.43 \cdot 10^{-3} \cdot U$	
	6 mV	10 Hz	$0.16 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.14 \cdot 10^{-3} \cdot U$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage	6 mV	40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$0.13 \cdot 10^{-3} \cdot U$	U = measured value Calibration on AC/DC transfer standard When calibrating measuring instruments, the influence of load/connection impedance and repeatability must be taken into account
		300 kHz	$0.15 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.17 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.22 \cdot 10^{-3} \cdot U$	
	10 mV	10 Hz	$0.13 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.12 \cdot 10^{-3} \cdot U$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$0.10 \cdot 10^{-3} \cdot U$	
		300 kHz	$0.12 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.16 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.21 \cdot 10^{-3} \cdot U$	
	20 mV	10 Hz	$0.12 \cdot 10^{-3} \cdot U$	
		20 Hz	$0.11 \cdot 10^{-3} \cdot U$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz; 200 kHz	$86 \cdot 10^{-6} \cdot U$	
		300 kHz	$0.11 \cdot 10^{-3} \cdot U$	
		500 kHz	$0.13 \cdot 10^{-3} \cdot U$	
		1 MHz	$0.17 \cdot 10^{-3} \cdot U$	
	60 mV	10 Hz	$54 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$32 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$46 \cdot 10^{-6} \cdot U$	
		500 kHz	$60 \cdot 10^{-6} \cdot U$	
		1 MHz	$95 \cdot 10^{-6} \cdot U$	
	100 mV	10 Hz	$22 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$20 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$17 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$15 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$25 \cdot 10^{-6} \cdot U$	
		500 kHz	$34 \cdot 10^{-6} \cdot U$	
		1 MHz	$53 \cdot 10^{-6} \cdot U$	
	200 mV	10 Hz	$37 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$18 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$15 \cdot 10^{-6} \cdot U$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage	200 mV	400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$12 \cdot 10^{-6} \cdot U$	U = measured value Calibration on AC/DC transfer standard When calibrating measuring instruments, the influence of load/connection impedance and repeatability must be taken into account
		100 kHz	$13 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$23 \cdot 10^{-6} \cdot U$	
		500 kHz	$33 \cdot 10^{-6} \cdot U$	
		1 MHz	$49 \cdot 10^{-6} \cdot U$	
	600 mV	10 Hz	$31 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$13 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$10 \cdot 10^{-6} \cdot U$	
		100 kHz	$11 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$21 \cdot 10^{-6} \cdot U$	
		500 kHz	$33 \cdot 10^{-6} \cdot U$	
		1 MHz	$50 \cdot 10^{-6} \cdot U$	
	1 V	10 Hz	$17 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$11 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$7 \cdot 10^{-6} \cdot U$	
		100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$13 \cdot 10^{-6} \cdot U$	
		500 kHz	$17 \cdot 10^{-6} \cdot U$	
		1 MHz	$30 \cdot 10^{-6} \cdot U$	
	2 V	10 Hz	$38 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$12 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$7 \cdot 10^{-6} \cdot U$	
		100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$11 \cdot 10^{-6} \cdot U$	
		500 kHz	$16 \cdot 10^{-6} \cdot U$	
		1 MHz	$29 \cdot 10^{-6} \cdot U$	
	4 V; 6 V	10 Hz	$32 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$13 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$9 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$21 \cdot 10^{-6} \cdot U$	
		500 kHz	$32 \cdot 10^{-6} \cdot U$	
		1 MHz	$35 \cdot 10^{-6} \cdot U$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage	8 V; 10 V	10 Hz	$19 \cdot 10^{-6} \cdot U$	U = measured value
		20 Hz	$13 \cdot 10^{-6} \cdot U$	
		40 Hz	$10 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz; 100 kHz	$8 \cdot 10^{-6} \cdot U$	Calibration on AC/DC transfer standard When calibrating measuring instruments, the influence of load/connection impedance and repeatability must be taken into account
		200 kHz; 300 kHz	$15 \cdot 10^{-6} \cdot U$	
		500 kHz	$30 \cdot 10^{-6} \cdot U$	
		1 MHz	$47 \cdot 10^{-6} \cdot U$	
	20 V	10 Hz	$29 \cdot 10^{-6} \cdot U$	
		20 Hz	$14 \cdot 10^{-6} \cdot U$	
		40 Hz	$11 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz; 70 kHz	$9 \cdot 10^{-6} \cdot U$	
		100 kHz	$10 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$16 \cdot 10^{-6} \cdot U$	
		500 kHz	$32 \cdot 10^{-6} \cdot U$	
		1 MHz	$49 \cdot 10^{-6} \cdot U$	
	12 V; 15 V; 19 V	1 kHz; 10 kHz; 100 kHz	$10 \cdot 10^{-6} \cdot U$	
	> 22 V to 70 V	10 Hz to 300 kHz		
	60 V	10 Hz	$23 \cdot 10^{-6} \cdot U$	
		20 Hz; 40 Hz	$15 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$13 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz	$9 \cdot 10^{-6} \cdot U$	
		70 kHz	$10 \cdot 10^{-6} \cdot U$	
		100 kHz	$14 \cdot 10^{-6} \cdot U$	
		200 kHz; 300 kHz	$22 \cdot 10^{-6} \cdot U$	
	> 70 V to 110 V 100 V	10 Hz to 200 kHz 10 Hz; 20 Hz	$19 \cdot 10^{-6} \cdot U$	
		40 Hz	$15 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz; 50 kHz	$13 \cdot 10^{-6} \cdot U$	
		70 kHz	$20 \cdot 10^{-6} \cdot U$	
		100 kHz	$32 \cdot 10^{-6} \cdot U$	
		200 kHz	$37 \cdot 10^{-6} \cdot U$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage	> 110 V to 700 V 200 V	10 Hz to 100 kHz 10 Hz	$27 \cdot 10^{-6} \cdot U$	U = measured value Calibration on AC/DC transfer standard When calibrating measuring instruments, the influence of load/connection impedance and repeatability must be taken into account
		20 Hz	$21 \cdot 10^{-6} \cdot U$	
		40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz	$15 \cdot 10^{-6} \cdot U$	
		400 Hz; 500 Hz; 1 kHz;	$13 \cdot 10^{-6} \cdot U$	
		10 kHz; 20 kHz; 50 kHz	$17 \cdot 10^{-6} \cdot U$	
		70 kHz	$20 \cdot 10^{-6} \cdot U$	
		100 kHz	$31 \cdot 10^{-6} \cdot U$	
	600 V	40 Hz	$17 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$14 \cdot 10^{-6} \cdot U$	
		1 kHz; 10 kHz; 20 kHz; 50 kHz	$16 \cdot 10^{-6} \cdot U$	
		70 kHz	$25 \cdot 10^{-6} \cdot U$	
		100 kHz	$37 \cdot 10^{-6} \cdot U$	
	> 700 V to 1000 V 1000 V	10 Hz to 100 kHz 40 Hz	$16 \cdot 10^{-6} \cdot U$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz; 20 kHz	$14 \cdot 10^{-6} \cdot U$	
		50 kHz	$25 \cdot 10^{-6} \cdot U$	
		70 kHz	$32 \cdot 10^{-6} \cdot U$	
		100 kHz	$42 \cdot 10^{-6} \cdot U$	
High voltage Sources	1 kV to 10 kV	10 Hz to 20 kHz	$50 \cdot 10^{-6} \cdot U + 2$ V	
		> 20 kHz to 50 kHz	$0.34 \cdot 10^{-3} \cdot U + 1.6$ V	
		> 50 kHz to 100 kHz	$1.6 \cdot 10^{-3} \cdot U + 0.9$ V	
	> 10 kV to 40 kV	10 Hz to 20 kHz	$0.10 \cdot 10^{-3} \cdot U + 3.7$ V	
		> 20 kHz to 50 kHz	$0.43 \cdot 10^{-3} \cdot U + 2.1$ V	
		> 50 kHz to 100 kHz	$1.7 \cdot 10^{-3} \cdot U + 0.7$ V	
Measuring instruments	1 kV to 10 kV	45 Hz to 65 Hz	$50 \cdot 10^{-6} \cdot U + 2$ V	
	> 10 kV to 30 kV		$0.10 \cdot 10^{-3} \cdot U + 3.7$ V	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Square-wave voltage	5 mV to 220 mV	1 Hz to 10 kHz	$10 \cdot 10^{-6} \cdot U + 0.36\ \mu V + 6.4 \cdot 10^{-9}\ V/Hz \cdot f$	Sampling method at 10 MΩ load Range specified in peak-to-peak voltage U = peak value of the voltage f = frequency The additional influence of deviating load conditions (such as 50 Ω or 1 MΩ) must be taken into account
	> 220mV to 2.2 V		$9.3 \cdot 10^{-6} \cdot U + 0.35\ \mu V + 7.0 \cdot 10^{-9}\ V/Hz \cdot f$	
	> 2.2 V to 22 V		$9.3 \cdot 10^{-6} \cdot U + 0.58\ \mu V + 14 \cdot 10^{-9}\ V/Hz \cdot f$	
	> 22 V to 220 V		$12 \cdot 10^{-6} \cdot U + 35\ \mu V + 75 \cdot 10^{-9}\ V/Hz \cdot f$	
AC voltage Amplitude parameters	5 mV to 5 V	DC to 10 MHz > 10 MHz to 100 MHz > 100 MHz to 300 MHz > 300 MHz to 1 GHz	$25 \cdot 10^{-3} \cdot U + 0.2\ \mu V$ $37 \cdot 10^{-3} \cdot U + 0.5\ \mu V$ $44 \cdot 10^{-3} \cdot U + 0.4\ \mu V$ $70 \cdot 10^{-3} \cdot U$	Oscilloscope as standard U = measured value
	> 5 V to 50 V	DC to 2 kHz > 2 kHz to 10 MHz	$12 \cdot 10^{-3} \cdot U + 0.7\ \mu V$ $25 \cdot 10^{-3} \cdot U + 0.7\ \mu V$	
	0% to 30%	45 Hz to 5 kHz > 5 kHz to 30 kHz	$0.5 \cdot 10^{-3} \cdot k + 0.012\%$ $0.8 \cdot 10^{-3} \cdot k + 0.012\%$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC voltage Harmonics Sources and measuring instruments	RMS value of the 1st harmonic	45 Hz ≤ f_1 ≤ 65 Hz 1 mV ≤ U_n ≤ 200 V 1% ≤ (U_n/U_1) ≤ 40% 2 ≤ n ≤ 100 f_n ≤ 6 kHz		Measured value = RMS value of the 1st harmonic U_1 = RMS value of the 1st harmonic U_n = RMS value of the nth harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic
	100 mV to 500 V		$20 \cdot 10^{-6} \cdot U_1$ to $39 \cdot 10^{-6} \cdot U_1$	
	100 mV		$26 \cdot 10^{-6} \cdot U_1$	
	200 mV		$25 \cdot 10^{-6} \cdot U_1$	
	1.2 V		$20 \cdot 10^{-6} \cdot U_1$	
	8 V		$25 \cdot 10^{-6} \cdot U_1$	
	16 V		$30 \cdot 10^{-6} \cdot U_1$	
	30 V		$20 \cdot 10^{-6} \cdot U_1$	
	60 V		$20 \cdot 10^{-6} \cdot U_1$	
	120 V		$30 \cdot 10^{-6} \cdot U_1$	
	240 V		$39 \cdot 10^{-6} \cdot U_1$	
	460 V		$39 \cdot 10^{-6} \cdot U_1$	
	RMS value of the higher harmonic 1 mV to 200 V	45 Hz ≤ f_1 ≤ 65 Hz 100 mV ≤ U_1 ≤ 500 V 1% ≤ (U_n/U_1) ≤ 40% 2 ≤ n ≤ 100 f_n ≤ 6 kHz	$0.13 \cdot 10^{-3} \cdot U_n$ to $1.1 \cdot 10^{-3} \cdot U_n$ see matrix VM.17	Measured value = RMS value of the higher harmonic U_1 = RMS value of the 1st harmonic U_n = RMS value of the higher harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Harmonics Sources and measuring instruments	100 mA to 60 A	45 Hz ≤ f_1 ≤ 65 Hz 2 ≤ n ≤ 100 I_s ≤ 113 A	$32 \cdot 10^{-6} \cdot I_1$ to $71 \cdot 10^{-6} \cdot I_1$	Measured value = RMS value of the 1st harmonic I_1 = RMS value of the 1st harmonic I_n = RMS value of the higher harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1 The number of higher harmonics is limited to one higher harmonic I_s = peak value of the current signal The measurement uncertainty may increase for measuring instruments with a connected (clamp) current transformer The measuring range is extended to I_1 ≤ 600 A Current transformers are calibrated in conjunction with the display device for the secondary signal
	100 mA	1 mA ≤ I_n ≤ 4.8 A f_n ≤ 6 kHz 1% ≤ (I_n/I_1) ≤ 30%	$32 \cdot 10^{-6} \cdot I_1$	
	200 mA		$47 \cdot 10^{-6} \cdot I_1$	
	400 mA		$47 \cdot 10^{-6} \cdot I_1$	
	800 mA		$47 \cdot 10^{-6} \cdot I_1$	
	1.6 A		$45 \cdot 10^{-6} \cdot I_1$	
	4 A		$57 \cdot 10^{-6} \cdot I_1$	
	5 A		$57 \cdot 10^{-6} \cdot I_1$	
	16 A		$55 \cdot 10^{-6} \cdot I_1$	
	30 A	160 mA ≤ I_n ≤ 18 A f_n ≤ 3 kHz 1% ≤ (I_n/I_1) ≤ 30%	$71 \cdot 10^{-6} \cdot I_1$	
	60 A		$71 \cdot 10^{-6} \cdot I_1$	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Harmonics Sources and measuring instruments		45 Hz ≤ f_1 ≤ 65 Hz 2 ≤ n ≤ 100 I_s ≤ 113 A		Measured value = RMS value of the higher harmonic I_1 = RMS value of the 1st harmonic I_n = RMS value of the higher harmonic f_1 = frequency of the 1st harmonic f_n = frequency of the higher harmonic n = f_n / f_1, n > 1
	1 mA to 4.8 A	100 mA ≤ I_1 ≤ 16 A f_n ≤ 6 kHz 1% ≤ I_n/I_1 ≤ 30%	$0.22 \cdot 10^{-3} \cdot I_n$ to $0.46 \cdot 10^{-3} \cdot I_n$ see matrix VM.18	
	160 mA to 18 A	16 A ≤ I_1 ≤ 60 A f_n ≤ 3 kHz 1% ≤ (I_n/I_1) ≤ 30%	$0.22 \cdot 10^{-3} \cdot I_n$ to $0.46 \cdot 10^{-3} \cdot I_n$ see matrix VM.18	The number of higher harmonics is limited to one higher harmonic I_s = peak value of the current signal The measurement uncertainty may increase for measuring instruments with a connected (clamp) current transformer The measuring range is extended to I_n ≤ 200 A Current transformers are calibrated in conjunction with the display device for the secondary signal

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Flicker Modulation depth Sources	0.407% to 4.837%	1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V rectangular modulation		*ΔU/U* = modulation depth *U* = effective value of the modulated AC voltage s-signal *f* = frequency of the modulated AC voltage s-signal *CPM* = changes per minute The combinations of *ΔU/U* and *CPM* defined in DIN EN 61000-4-15:2011, Table 5, apply
		1 min^{-1} ≤ *CPM* ≤ 39 min^{-1} *f* = 50 Hz; *f* = 60 Hz	1.0 · 10^{-3}%	
		CPM = 110 min^{-1} *f* = 50 Hz; *f* = 60 Hz	3.7 · 10^{-3}%	
		CPM = 1620 min^{-1} *f* = 50 Hz; *f* = 60 Hz	12 · 10^{-3}%	
		CPM = 4000 min^{-1}; *CPM* = 4800 min^{-1} *f* = 51 Hz; *f* = 61 Hz	12 · 10^{-3}%	
Flicker Modulation depth Measuring instruments	0.407% to 4.837%	1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V rectangular modulation		*ΔU/U* = modulation depth *U* = effective value of the modulated AC voltage s-signal *f* = frequency of the modulated AC voltage s-signal *CPM* = changes per minute The combinations of *ΔU/U* and *CPM* defined in DIN EN 61000-4-15:2011, table 5, apply
		1 min^{-1} ≤ *CPM* ≤ 39 min^{-1} *f* = 50 Hz; *f* = 60 Hz	1.0 · 10^{-3}%	
		CPM = 110 min^{-1} *f* = 50 Hz; *f* = 60 Hz	3.7 · 10^{-3}%	
		CPM = 1620 min^{-1} *f* = 50 Hz; *f* = 60 Hz	12 · 10^{-3}%	
		CPM = 4000 min^{-1}; *CPM* = 4800 min^{-1} *f* = 50 Hz; *f* = 60 Hz	28 · 10^{-3}%	

On-site calibration – DC and AC voltage

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Flicker Frequency Sources and measuring instruments	8.3 mHz to 40 Hz	0.407% ≤ $\Delta U/U$ ≤ 4.837% 1 min^{-1} ≤ *CPM* ≤ 4800 min^{-1} *U* = 120 V; *U* = 230 V *f* = 50 Hz; *f* = 60 Hz rectangular modulation	$1.0 \cdot 10^{-6} \cdot f_{Flicker}$	$\Delta U/U$ = modulation depth *U* = effective value of the modulated AC voltage s-signal *f* = frequency of the modulated AC voltage s-signal *CPM* = changes per minute $f_{Flicker}$ = *CPM* / 120 The combinations of $\Delta U/U$ and *CPM* defined in DIN EN 61000-4-15:2011, table 5, apply
P_{st} value	only P_{st} = 1		$2.5 \cdot 10^{-3}$	Value at $\Delta U/U$ expressed in $\Delta U/U$ rectangular flicker
AC voltage Distortion factor *k*	0% to 30%	45 Hz to 5 kHz > 5 kHz to 30 kHz	$0.5 \cdot 10^{-3} \cdot k + 0.012\%$ $0.8 \cdot 10^{-3} \cdot k + 0.012\%$	Values expressed in % distortion

Matrix VM.17 Relative measurement uncertainty of the effective value U_n of the harmonic at the frequency $f_1 = 50\ \mathrm{Hz}$ in mV/V

		n													
U_1/V	U_n/V	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**10**
0.10	**0.001**	1.1	1.1	0.57	0.57	0.50	0.49	0.49	0.49	0.48	0.48	0.48	0.48	0.48	0.48
0.10	**0.01**	0.17	0.17	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.20	**0.025**	0.17	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1.2	**0.15**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
8.0	**1.0**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
16	**4.5**	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
30	**9.0**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
60	**18**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
120	**36**	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
240	**72**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
460	**130**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Matrix VM.18 Relative measurement uncertainty of the effective value I_n of the harmonic at the frequency $f_1 = 50\ \mathrm{Hz}$ in mA/A

		n													
I_1/A	I_n/A	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0.1	**0.01**	0.24	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.2	**0.025**	0.24	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.4	**0.05**	0.24	0.24	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
0.8	**0.1**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
1.6	**0.016**	0.46	0.46	0.46	0.46	0.32	0.28	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22
1.6	**0.2**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
4	**0.5**	0.25	0.25	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
8	**1**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
16	**2**	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
30	**8**	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	-	-	-	-
60	**15**	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	-	-	-	-

On-site calibration – DC and AC current

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC current	0 pA to 10 nA		0.85 fA to 51 fA	I = measured value
	0 pA 1 pA 10 pA 100 pA 1 nA 10 nA		12 fA $0.85 \cdot 10^{-3} \cdot I$ $0.53 \cdot 10^{-3} \cdot I$ $75 \cdot 10^{-6} \cdot I$ $10 \cdot 10^{-6} \cdot I$ $5.1 \cdot 10^{-6} \cdot I$	
	> 10 nA to 100 nA		$4.1 \cdot 10^{-6} \cdot I$ + 10 fA	
	> 100 nA to < 1 µA		$1.4 \cdot 10^{-6} \cdot I$ + 0.21 pA	
	1 µA to 10 µA		$1.4 \cdot 10^{-6} \cdot I$ + 0.19 pA	
	> 10 µA to 20 µA		$1.4 \cdot 10^{-6} \cdot I$ + 1.8 pA	
	20 µA to 200 µA		$1.4 \cdot 10^{-6} \cdot I$ + 14 pA	
	200 µA to 2 mA		$0.54 \cdot 10^{-6} \cdot I$ + 0.23 nA	
	2 mA to 10 mA		$1.1 \cdot 10^{-6} \cdot I$ + 2.4 nA	
	10 mA to 50 mA		$0.90 \cdot 10^{-6} \cdot I$ + 25 nA	
	50 mA to 200 mA	T = (23 ± 2) °C	$0.33 \cdot 10^{-6} \cdot I$ + 0.26 µA	
	200 mA to 1 A		$12 \cdot 10^{-6} \cdot I$	
	1 A to 10 A		$16 \cdot 10^{-6} \cdot I$	
	10 A to 100 A		$28 \cdot 10^{-6} \cdot I$	
	100 A to 300 A	T = (23 ± 2) °C	$37 \cdot 10^{-6} \cdot I$	
	300 A to 600 A		$100 \cdot 10^{-6} \cdot I$	
DC current / Sources and sources with a measurement function	600 A to 1000 A		$100 \cdot 10^{-6} \cdot I$	
DC current Sources	300 A to 700 A		$27 \cdot 10^{-6} \cdot I$ + 2.3 mA	
DC current Current clamps and current clamp transformers	0 A to 3000 A	1 to N windings	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot I$ but not less than $8 \cdot 10^{-6} \cdot I$ or 6 nA	W_{in} is the relative uncertainty of the current of the single winding W_{DUT} is the relative uncertainty of the object under test in the stray field of the current-carrying conductor

On-site calibration – DC and AC current

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current	100 µA to 100 A	10 Hz to 10 kHz	4.4 nA to 6.5 mA	I = measured value
	100 µA	10 Hz; 20 Hz	$76 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$44 \cdot 10^{-6} \cdot I$	
		10 kHz	$47 \cdot 10^{-6} \cdot I$	
	200 µA	10 Hz; 20 Hz	$68 \cdot 10^{-6} \cdot I$	
		40 Hz	$39 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$36 \cdot 10^{-6} \cdot I$	
		10 kHz	$39 \cdot 10^{-6} \cdot I$	
	0.5 mA	10 Hz; 20 Hz	$64 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz	$28 \cdot 10^{-6} \cdot I$	
		400 Hz; 500 Hz; 1 kHz	$27 \cdot 10^{-6} \cdot I$	
		10 kHz	$32 \cdot 10^{-6} \cdot I$	
	1 mA	10 Hz	$33 \cdot 10^{-6} \cdot I$	
		20 Hz	$30 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz	$26 \cdot 10^{-6} \cdot I$	
		120 Hz; 400 Hz; 500 Hz; 1 kHz	$25 \cdot 10^{-6} \cdot I$	
		10 kHz	$27 \cdot 10^{-6} \cdot I$	

On-site calibration – DC and AC current

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current	2 mA	10 Hz	$32 \cdot 10^{-6} \cdot I$	I = measured value f = frequency
		20 Hz	$29 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$24 \cdot 10^{-6} \cdot I$	
	5 mA	10 Hz	$32 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$29 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$24 \cdot 10^{-6} \cdot I$	
	10 mA	10 Hz	$26 \cdot 10^{-6} \cdot I$	
		20 Hz	$24 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$19 \cdot 10^{-6} \cdot I$	
		10 kHz	$22 \cdot 10^{-6} \cdot I$	
	20 mA	10 Hz	$25 \cdot 10^{-6} \cdot I$	
		20 Hz	$23 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot I$	
		10 kHz	$19 \cdot 10^{-6} \cdot I$	
	50 mA	10 Hz	$25 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$23 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$17 \cdot 10^{-6} \cdot I$	
		10 kHz	$19 \cdot 10^{-6} \cdot I$	
	100 mA	10 Hz	$26 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$24 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$18 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$20 \cdot 10^{-6} \cdot I$	
	200 mA	10 Hz	$27 \cdot 10^{-6} \cdot I$	
		20 Hz; 40 Hz	$24 \cdot 10^{-6} \cdot I$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$18 \cdot 10^{-6} \cdot I$	
		10 kHz	$20 \cdot 10^{-6} \cdot I$	
	500 mA	10 Hz	$36 \cdot 10^{-6} \cdot I$	
		20 Hz	$34 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$31 \cdot 10^{-6} \cdot I$	

On-site calibration – DC and AC current

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current	1 A	10 Hz	$32 \cdot 10^{-6} \cdot I$	I = measured value f = frequency
		20 Hz	$29 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$25 \cdot 10^{-6} \cdot I$	
	2 A	10 Hz; 20 Hz	$40 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$34 \cdot 10^{-6} \cdot I$	
	5 A; 10 A	10 Hz	$39 \cdot 10^{-6} \cdot I$	
		20 Hz	$37 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$32 \cdot 10^{-6} \cdot I$	
	20 A	10 Hz; 20 Hz	$57 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$53 \cdot 10^{-6} \cdot I$	
	50 A	10 Hz; 20 Hz	$64 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$59 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$68 \cdot 10^{-6} \cdot I$	
	100 A	10 Hz; 20 Hz	$75 \cdot 10^{-6} \cdot I$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$65 \cdot 10^{-6} \cdot I$	
		1 kHz; 10 kHz	$75 \cdot 10^{-6} \cdot I$	
	100 A to 200 A	QMH Chap. VIb.1.1 Version 5.0	12 mA to 24 mA	
		10 Hz to 10 kHz	$0.13 \cdot 10^{-3} \cdot I$	

On-site calibration – DC and AC current

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC current Sources	200 A to 300 A	10 Hz to 1 kHz	$0.30 \cdot 10^{-3} \cdot I - 0.53$ mA	I = measured value f = frequency
	300 A to 495 A	10 Hz to 65 Hz	$0.48 \cdot 10^{-3} \cdot I + 11$ mA	
		65 Hz to 100 Hz	$0.49 \cdot 10^{-3} \cdot I + 11$ mA	
		100 Hz to 400 Hz	$0.74 \cdot 10^{-3} \cdot I + 7.7$ mA	
		400 Hz to 1 kHz	$1.5 \cdot 10^{-3} \cdot I + 4.0$ mA	
Current clamps and current clamp transformers	10 µA to 2400 A	1 to N windings 10 Hz to 1 kHz > 1 kHz to 10 kHz/N	$\sqrt{W_{in}^2 + W_{DUT}^2} \cdot I$ but not less than $90 \cdot 10^{-6} \cdot I$ or 8 nA	W_{in} = relative uncertainty of the current of the single winding W_{DUT} = relative uncertainty of the object under test in the stray field of the current-carrying conductor
Equivalent leakage current I	0.2 µA to 200 mA	at R_N to 1 GΩ	$10 \cdot 10^{-6} \cdot I$ to $5.8 \cdot 10^{-3} \cdot I$ see matrix VM.1	The total uncertainty U depends on the relative uncertainty $U(R_N)/R_N$ of the calibration resistor R_N
Charge Q	20 pC to 200 pC		$0.50 \cdot 10^{-3} \cdot Q + 0.025$ pC	Rectangular current pulses ≥ 1 s, duration t and rise times ≤ 10 µs as product $Q = I \cdot t$ Total uncertainty calculated from the relative uncertainty W(Iin) of the calibration current
	> 200 pC to 2 nC		$0.33 \cdot 10^{-3} \cdot Q + 0.05$ pC	
	> 2 nC to 11 C		$60 \cdot 10^{-3} \cdot Q + 0.5$ pC	

Matrix VM.1 Equivalent leakage current, on-site calibration

Normal resistance R_N	1 kΩ		10 kΩ		100 kΩ		1 MΩ		10 MΩ		100 MΩ		1 GΩ	
Nominal voltage	**Current | expanded measurement uncertainty U in µA/A**										**Current | U in mA/A**			
60 V	60 mA	10	6 mA	10	600 µA	13	60 µA	19	6 µA	70	600 nA	0.6	60 nA	5.8
110 V	110 mA		11 mA		1.1 mA		110 µA		11 µA		1.1 µA		110 nA	
230 V	230 mA		23 mA		2.3 mA		230 µA		23 µA		2.3 µA		230 nA	
400 V	400 mA		40 mA		4 mA		400 µA		40 µA		4.0 µA		400 nA	

On-site calibration – DC and AC resistance

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC resistance	0 Ω	2-wire short circuit	0.5 mΩ	R = measured value Calibration of measuring instruments at the nominal values of the standards
		4-wire short circuit	0.35 µΩ	
	10 µΩ to < 1 GΩ	T = (23 ± 2) °C	1.6 nΩ to 110 Ω	
	10 µΩ 100 µΩ 1 mΩ 10 mΩ 100 mΩ 1 Ω; 10 Ω; 100 Ω; 1 kΩ; 10 kΩ 100 kΩ; 1 MΩ; 10 MΩ; 100 MΩ	I = 100 A I = 50 A I = 10 A	$0.16 \cdot 10^{-3} \cdot R$ $34 \cdot 10^{-6} \cdot R$ $23 \cdot 10^{-6} \cdot R$ $20 \cdot 10^{-6} \cdot R$ $5.6 \cdot 10^{-6} \cdot R$ $0.43 \cdot 10^{-6} \cdot R$ $1.0 \cdot 10^{-6} \cdot R$ $0.60 \cdot 10^{-6} \cdot R$ $0.57 \cdot 10^{-6} \cdot R$ $1.4 \cdot 10^{-6} \cdot R$ $1.5 \cdot 10^{-6} \cdot R$ $4.2 \cdot 10^{-6} \cdot R$ $11.2 \cdot 10^{-6} \cdot R$	
	1 GΩ to 120 TΩ 1 GΩ; 10 GΩ; 100 GΩ; 1 TΩ	Measuring voltage 100 V or 1000 V	88 kΩ to 240 MΩ $88 \cdot 10^{-6} \cdot R$ $0.13 \cdot 10^{-3} \cdot R$ $0.24 \cdot 10^{-3} \cdot R$	
	> 1 TΩ to 120 TΩ 10 TΩ; 100 TΩ	Measuring voltage 1000 V	0.48 GΩ to 187 GΩ $0.48 \cdot 10^{-3} \cdot R$ $1.87 \cdot 10^{-3} \cdot R$	
AC resistance (amount of impedance)	100 µΩ to 100 Ω	T = (23 ± 2) °C 100 µA ≤ I ≤ 100 A 10 Hz to 10 kHz	13 nΩ to 1.7 mΩ	R = measured value I = current f = frequency
	100 µΩ	10 Hz; 20 Hz	$0.17 \cdot 10^{-3} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$0.14 \cdot 10^{-3} \cdot R$	
		1 kHz; 10 kHz	$0.15 \cdot 10^{-3} \cdot R$	
	1 mΩ	10 Hz	$65 \cdot 10^{-6} \cdot R$	
		20 Hz	$63 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$58 \cdot 10^{-6} \cdot R$	
		1 kHz	$61 \cdot 10^{-6} \cdot R$	
		10 kHz	$64 \cdot 10^{-6} \cdot R$	

On-site calibration – DC and AC resistance

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (impedance value)	10 mΩ	10 Hz	$46 \cdot 10^{-6} \cdot R$	R = measured value I = current f = frequency
		20 Hz	$43 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz	$37 \cdot 10^{-6} \cdot R$	
		1 kHz; 10 kHz	$35 \cdot 10^{-6} \cdot R$	
	20 mΩ	10 Hz	$45 \cdot 10^{-6} \cdot R$	
		20 Hz	$42 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$36 \cdot 10^{-6} \cdot R$	
	50 mΩ	10 Hz	$45 \cdot 10^{-6} \cdot R$	
		20 Hz	$42 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$36 \cdot 10^{-6} \cdot R$	
	100 mΩ; 200 mΩ	10 Hz	$39 \cdot 10^{-6} \cdot R$	
		20 Hz	$35 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$30 \cdot 10^{-6} \cdot R$	
	0.5 Ω	10 Hz	$36 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$31 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$26 \cdot 10^{-6} \cdot R$	
	1 Ω	10 Hz	$34 \cdot 10^{-6} \cdot R$	
		20 Hz	$30 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz; 10 kHz	$25 \cdot 10^{-6} \cdot R$	
	2 Ω; 5 Ω	10 Hz	$31 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$26 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$20 \cdot 10^{-6} \cdot R$	
		10 kHz	$23 \cdot 10^{-6} \cdot R$	
	10 Ω	10 Hz	$30 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$26 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$21 \cdot 10^{-6} \cdot R$	
		10 kHz	$23 \cdot 10^{-6} \cdot R$	
	20 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	
		20 Hz; 40 Hz	$25 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz; 1 kHz	$19 \cdot 10^{-6} \cdot R$	
		10 kHz	$22 \cdot 10^{-6} \cdot R$	

On-site calibration – DC and AC resistance

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (amount of impedance)	50 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	R = measured value I = current f = frequency
		20 Hz	$25 \cdot 10^{-6} \cdot R$	
		40 Hz	$20 \cdot 10^{-6} \cdot R$	
		55 Hz; 120 Hz; 400 Hz; 500 Hz	$19 \cdot 10^{-6} \cdot R$	
		1 kHz	$21 \cdot 10^{-6} \cdot R$	
		10 kHz	$25 \cdot 10^{-6} \cdot R$	
AC resistance (amount of impedance)	100 Ω	10 Hz	$29 \cdot 10^{-6} \cdot R$	R = measured value I = current f = frequency
		20 Hz	$25 \cdot 10^{-6} \cdot R$	
		40 Hz; 55 Hz	$19 \cdot 10^{-6} \cdot R$	
		120 Hz; 400 Hz	$18 \cdot 10^{-6} \cdot R$	
		500 Hz	$20 \cdot 10^{-6} \cdot R$	
		1 kHz	$31 \cdot 10^{-6} \cdot R$	
		10 kHz	$75 \cdot 10^{-6} \cdot R$	
	100 µΩ to 10 kΩ	10 Hz to 10 kHz	$\sqrt{U_I^2 + U_U^2} \cdot R$	R = measured value Constant current method U_I = relative uncertainty of the calibration current U_U = relative uncertainty of the measured voltage at the resistor
	0 Ω to 10 kΩ	20 Hz to 50 Hz	$2.5 \cdot 10^{-3} \cdot R + 3.1$ mΩ	R = measured value Direct measurement method
	> 10 kΩ to 110 MΩ		$2.3 \cdot 10^{-9} \cdot R^2/\Omega + 2.5 \cdot 10^{-3} \cdot R$	
	0 Ω to 20 kΩ	> 50 Hz to 100 Hz	$1.0 \cdot 10^{-3} \cdot R + 2.6$ mΩ	
	> 20 kΩ to 110 MΩ		$2.3 \cdot 10^{-9} \cdot R^2/\Omega + 1.3 \cdot 10^{-3} \cdot R$	
	0 Ω to 50 kΩ	> 100 Hz to 1 kHz	$0.5 \cdot 10^{-3} \cdot R + 1.3$ mΩ	
	> 50 kΩ to 110 MΩ		$1.1 \cdot 10^{-9} \cdot R^2/\Omega + 1.2 \cdot 10^{-3} \cdot R$	
	0 Ω to < 50 Ω	> 1 kHz to 30 kHz	$1.1 \cdot 10^{-3} \cdot R + 1.2$ mΩ	
	50 Ω to 20 kΩ		$0.5 \cdot 10^{-3} \cdot R$	
	> 20 kΩ to 110 MΩ		$1.1 \cdot 10^{-9} \cdot R^2/\Omega + 0.79 \cdot 10^{-3} \cdot R$	
	0 Ω to 20 Ω	> 30 kHz to 100 kHz	$1.1 \cdot 10^{-3} \cdot R + 1.2$ mΩ	
	> 20 Ω to 20 kΩ		$0.5 \cdot 10^{-3} \cdot R$	

On-site calibration – DC and AC resistance

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC resistance (amount of impedance)	> 20 kΩ to 110 MΩ		$1.3 \cdot 10^{-9} \cdot R^2/\Omega + 1.0 \cdot 10^{-3} \cdot R$	R = measured value Direct measurement method
	0 Ω to 100 Ω	> 100 kHz to 300 kHz	$1.1 \cdot 10^{-3} \cdot R + 2.2$ mΩ	
	> 100 Ω to 2 kΩ		$0.5 \cdot 10^{-3} \cdot R$	
	> 2 kΩ to 110 MΩ		$4.5 \cdot 10^{-9} \cdot R^2/\Omega + 0.9 \cdot 10^{-3} \cdot R$	
	0 Ω to 50 Ω	> 300 kHz to 1 MHz	$1.3 \cdot 10^{-3} \cdot R + 3.2$ mΩ	
	> 50 Ω to 2 kΩ		$0.7 \cdot 10^{-3} \cdot R$	
	> 2 kΩ to 22 MΩ		$15 \cdot 10^{-9} \cdot R^2/\Omega + 1.1 \cdot 10^{-3} \cdot R$	
Energy E Defibrillator tester	5 J to 150 J		$2.3 \cdot 10^{-3} \cdot E + 49$ mJ	E = energy Monophasic or biphasic
	> 150 J to 360 J		$1.1 \cdot 10^{-3} \cdot E + 0.27$ J	
Voltage ratio Bridge standards and measuring instruments	0 mV/V to 100 mV/V	DC voltage Bridge voltage: 1 V to 10 V	0.1 µV/V to 1.6 µV/V See matrix VM.2	

Matrix VM.2 Voltage ratio

Bridge voltage / Measured value	10 V	5 V	2 V	1 V
0 mV/V	0.10 µV/V	0.10 µV/V	0.17 µV/V	0.35 µV/V
± 2 mV/V	0.10 µV/V	0.11 µV/V	0.26 µV/V	0.51 µV/V
± 5 mV/V	0.10 µV/V	0.13 µV/V	0.27 µV/V	0.52 µV/V
± 10 mV/V	0.10 µV/V	0.16 µV/V	0.31 µV/V	0.56 µV/V
± 20 mV/V	0.16 µV/V	0.20 µV/V	0.38 µV/V	0.66 µV/V
± 50 mV/V	0.35 µV/V	0.39 µV/V	0.58 µV/V	1 µV/V
± 100 mV/V	0.65 µV/V	0.73 µV/V	1.0 µV/V	1.6 µV/V

On-site calibration – Electrical power

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
DC power	0 W to 110 kW	0 mV to 1100 V 0 µA to 100 A	$\sqrt{W_U^2 + W_I^2} \cdot P$ but not less than $44 \cdot 10^{-6} \cdot P + 5$ fW	P = measured value
Power factor Sources, measurement instruments	0 to 1	10 Hz ≤ f ≤ 10 kHz [i)] 1 mV ≤ U ≤ 1 kV [i)] 1 mA ≤ I ≤ 100 A	$6.8 \cdot 10^{-12}$ to $2.1 \cdot 10^{-3}$	$PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I$ = phase angle U = effective value of the AC voltage I = effective value of the AC current The measurement uncertainties apply to sinusoidal signals
		Additional range for measuring instruments with current clamp/current transformer: 10 Hz ≤ f ≤ 100 Hz 1 mV ≤ U ≤ 1 kV [i)] 100 A ≤ I ≤ 1 kA	$7.8 \cdot 10^{-9}$ to $1.5 \cdot 10^{-4}$	See also matrices VM.21 to VM.25

On-site calibration – Electrical power

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC active power Sources, measuring instruments	0 W to 100 kW	10 Hz ≤ f ≤ 10 kHz [i)] 1 mV ≤ U ≤ 1 kV [i)] 1 mA ≤ I ≤ 100 A 0 ≤ PF ≤ 1	7.5 pW to 210 W	$P(U;I;PF) = U \cdot I \cdot PF$ = AC active power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = effective value of AC voltage I = effective value of the AC power The measurement uncertainties apply to sinusoidal signals See also matrices VM.26 to VM.35
	0 W to 1 MW	Additional range for measuring instruments with current clamp/current transformer: 10 Hz ≤ f ≤ 100 Hz [i)] 1 mV ≤ U ≤ 1 kV [i)] 100 A < I ≤ 1 kA 0 ≤ PF ≤ 1	Current transformer: $3.8 \cdot 10^{-4} \cdot P$ not less than 2 µW Current clamps: $4.6 \cdot 10^{-3} \cdot P$ not less than 2 µW	
AC reactive power Sources, measuring instruments	-100 kvar to 100 kvar	10 Hz ≤ f ≤ 10 kHz [i)] 1 mV ≤ U ≤ 1 kV [i)] 1 mA ≤ I ≤ 100 A 0 ≤ PF ≤ 1	7.5 pvar to 210 var	$Q = U \cdot I \cdot \sin(\Delta\varphi) =$ AC reactive power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = effective value of AC voltage I = effective value of AC power The measurement uncertainties apply to sinusoidal signals See also matrices VM.26 to VM.35
	-1 Mvar to 1 Mvar	Additional range for measuring instruments with current clamp/current transformer: 10 Hz ≤ f ≤ 100 Hz [i)] 1 mV ≤ U ≤ 1 kV [i)] 100 A < I ≤ 1 kA 0 ≤ PF ≤ 1	Current transformer: $3.8 \cdot 10^{-4} \cdot Q$ not less than 2 µvar Current clamps: $4.6 \cdot 10^{-3} \cdot Q$ not less than 2 µvar	

On-site calibration – Electrical power

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
AC apparent power Sources, measuring instruments	0 VA to 100 kVA	10 Hz ≤ f ≤ 10 kHz [i)] 1 mV ≤ U ≤ 1 kV [i)] 1 mA ≤ I ≤ 100 A	59 pVA to 7.6 VA	$S = U \cdot I$ $= P(U; I; PF = 1) =$ AC apparent power $PF = \cos(\Delta\varphi)$ = power factor $\Delta\varphi = \varphi_U - \varphi_I =$ phase angle U = effective value of AC voltage I = effective value of AC current P = active power of AC current The measurement uncertainties apply to sinusoidal signals See also matrices VM.26 to VM.35 for $PF = 1$
	0 VA to 1 MVA	Additional range for measuring instruments with current clamps / current transformers: 1 mV ≤ U ≤ 1 kV [i)] 10 Hz ≤ f ≤ 100 Hz [i)]: 1 mA ≤ I ≤ 1 kA	Current transformers: $3.8 \cdot 10^{-4} \cdot S$ Current clamps: $4.6 \cdot 10^{-3} \cdot S$	

Matrix VM.21: Absolute measurement uncertainty of the **power factor PF**
For the calibration of **sources** in the range **2 A < I ≤ 20 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.1 \cdot 10^{-6}$	$3.0 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.5 \cdot 10^{-6}$	$1.9 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$6.8 \cdot 10^{-12}$
45	$9.8 \cdot 10^{-6}$	$9.6 \cdot 10^{-6}$	$9.0 \cdot 10^{-6}$	$7.9 \cdot 10^{-6}$	$5.9 \cdot 10^{-6}$	$4.3 \cdot 10^{-6}$	$6.8 \cdot 10^{-11}$
111	$1.9 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.8 \cdot 10^{-5}$	$1.5 \cdot 10^{-6}$	$1.2 \cdot 10^{-5}$	$8.4 \cdot 10^{-6}$	$2.6 \cdot 10^{-10}$
1000	$1.6 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$9.7 \cdot 10^{-5}$	$7.1 \cdot 10^{-5}$	$1.9 \cdot 10^{-8}$
10000	$1.6 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$	$9.7 \cdot 10^{-4}$	$7.1 \cdot 10^{-4}$	$1.6 \cdot 10^{-6}$

Matrix VM.22: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **sources** in the range **20 A < I ≤ 100 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.8**	**1**
10	$3.4 \cdot 10^{-6}$	$3.4 \cdot 10^{-6}$	$3.2 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.1 \cdot 10^{-6}$	$1.5 \cdot 10^{-6}$	$8.4 \cdot 10^{-12}$
45	$1.1 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$9.1 \cdot 10^{-6}$	$6.8 \cdot 10^{-6}$	$5.0 \cdot 10^{-6}$	$9.2 \cdot 10^{-11}$
111	$2.4 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.2 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.4 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$4.0 \cdot 10^{-10}$
1000	$2.0 \cdot 10^{-4}$	$2.0 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$8.8 \cdot 10^{-5}$	$2.9 \cdot 10^{-8}$
10000	$2.0 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$8.8 \cdot 10^{-4}$	$2.9 \cdot 10^{-6}$

Matrix VM.23: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **measuring instruments** in the range **2 A < I ≤ 20 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.2 \cdot 10^{-6}$	$3.2 \cdot 10^{-6}$	$2.9 \cdot 10^{-6}$	$2.6 \cdot 10^{-6}$	$1.9 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$7.3 \cdot 10^{-12}$
45	$1.0 \cdot 10^{-5}$	$1.0 \cdot 10^{-5}$	$9.5 \cdot 10^{-6}$	$8.3 \cdot 10^{-6}$	$6.2 \cdot 10^{-6}$	$4.5 \cdot 10^{-6}$	$7.6 \cdot 10^{-11}$
111	$2.1 \cdot 10^{-5}$	$2.0 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.6 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$9.0 \cdot 10^{-6}$	$3.0 \cdot 10^{-10}$
1000	$1.7 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$	$7.6 \cdot 10^{-5}$	$2.1 \cdot 10^{-8}$
10000	$1.7 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$	$1.0 \cdot 10^{-3}$	$7.6 \cdot 10^{-4}$	$2.1 \cdot 10^{-6}$

Matrix VM.24: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **measuring instruments** in the range **20 A < I ≤ 100 A & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10	$3.6 \cdot 10^{-6}$	$3.5 \cdot 10^{-6}$	$3.3 \cdot 10^{-6}$	$2.8 \cdot 10^{-6}$	$2.1 \cdot 10^{-6}$	$1.5 \cdot 10^{-6}$	$8.9 \cdot 10^{-12}$
45	$1.2 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$9.5 \cdot 10^{-6}$	$7.1 \cdot 10^{-6}$	$5.2 \cdot 10^{-6}$	$1.0 \cdot 10^{-10}$
111	$2.5 \cdot 10^{-5}$	$2.4 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.0 \cdot 10^{-5}$	$1.5 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$	$4.4 \cdot 10^{-10}$
1000	$2.1 \cdot 10^{-4}$	$2.1 \cdot 10^{-4}$	$2.0 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$9.3 \cdot 10^{-5}$	$3.3 \cdot 10^{-8}$
10000	$2.1 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$	$9.3 \cdot 10^{-4}$	$3.3 \cdot 10^{-6}$

Matrix VM.25: Absolute measurement uncertainty of the **power factor PF**
for the calibration of **measuring instruments with current clamps / current transformers**
in the range **100 A < I ≤ 1 kA & 15 mV < U ≤ 1 kV**

	PF						
f (Hz)	**0**	**0.2**	**0.4**	**0.6**	**0.8**	**0.9**	**1**
10 Hz to 100 Hz	$1.5 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$8.9 \cdot 10^{-5}$	$6.5 \cdot 10^{-5}$	$7.8 \cdot 10^{-9}$

Matrix VM.26: Absolute measurement uncertainty of the **AC active power $P = U \cdot I \cdot \cos(\varphi)$** (see values for PF), the **AC reactive power $Q = U \cdot I \cdot \sin(\varphi)$** (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power $S = U \cdot I$** (see values for $PF = 1$) for the calibration of **sources** with **U = 2 mV and I = 100 µA**

	$\cos(\varphi) = PF$ | $\sin(\varphi) = \pm\sqrt{1 - PF^2}$					
f (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
10	48 pW	54 pW	60 pW	68 pW	72 pW	77 pW
1000	34 pW	39 pW	44 pW	51 pW	55 pW	59 pW
10000	340 pW	310 pW	270 pW	210 pW	160 pW	59 pW

Matrix VM.27: Absolute measurement uncertainty of the **AC active power $P = U \cdot I \cdot \cos(\varphi)$** (see values for PF), the **AC reactive power $Q = U \cdot I \cdot \sin(\varphi)$** (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power $S = U \cdot I$** (see values for $PF = 1$) for the calibration of **measuring instruments** with **U = 2 mV and I = 1 mA**

	$\cos(\varphi) = PF$ | $\sin(\varphi) = \pm\sqrt{1 - PF^2}$					
f (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.0 nW	1.0 nW	1.1 nW	1.1 nW	1.1 nW	1.2 nW
1000	230 pW	320 pW	400 pW	490 pW	530 pW	580 pW
10000	2.3 nW	2.1 nW	1.9 nW	1.5 nW	1.1 nW	580 pW

Matrix VM.28: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 20 mV and** $\boldsymbol{I}$ **= 100 µA**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
10	7.5 pW	110 pW	170 pW	230 pW	260 pW	280 pW
1000	340 pW	320 pW	290 pW	250 pW	230 pW	190 pW
10000	3.4 nW	3.1 nW	2.7 nW	2.0 nW	1.5 nW	200 pW

Matrix VM.29: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 mV and** $\boldsymbol{I}$ **= 1 mA**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	150 pW	730 pW	1.1 nW	1.4 nW	1.6 nW	1.8 nW
1000	2.3 nW	2.3 nW	2.2 nW	2.0 nW	1.9 nW	1.8 nW
10000	23 nW	21 nW	19 nW	14 nW	10 nW	1.8 nW

Matrix VM.30: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 1 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	140 µW	250 µW	350 µW	440 µW	500 µW	550 µW
1000	2.1 mW	1.9 mW	1.7 mW	1.3 mW	1.0 mW	530 µW
10000	21 mW	19 mW	17 mW	13 mW	9.1 mW	530 µW

Matrix VM.31: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 1 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	150 µW	260 µW	350 µW	450 µW	500 µW	550 µW
1000	2.3 mW	2.1 mW	1.9 mW	1.5 mW	1.1 mW	530 µW
10000	23 mW	21 mW	19 mW	14 mW	10 mW	530 µW

Matrix VM.32: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **sources** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 20 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	3.5 mW	9.2 mW	13 mW	17 mW	20 mW	22 mW
1000	65 mW	60 mW	53 mW	43 mW	34 mW	22 mW
10000	650 mW	590 mW	520 mW	390 mW	280 mW	22 mW

Matrix VM.33: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) for the calibration of **measuring instruments** with $\boldsymbol{U}$ **= 20 V and** $\boldsymbol{I}$ **= 20 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	3.7 mW	9.3 mW	13 mW	17 mW	20 mW	22 mW
1000	70 mW	65 mW	58 mW	46 mW	36 mW	22 mW
10000	700 mW	650 mW	560 mW	420 mW	310 mW	22 mW

Matrix VM.34: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) when calibrating **sources** with $\boldsymbol{U}$ **= 1 kV and** $\boldsymbol{I}$ **= 100 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.0 W	2.8 W	4.1 W	5.4 W	6.0 W	6.7 W
1000	20 W	19 W	17 W	14 W	11 W	7.6 W
10000	200 W	190 W	160 W	120 W	89 W	7.6 W

Matrix VM.35: Absolute measurement uncertainty of the **AC active power** $\boldsymbol{P = U \cdot I \cdot \cos(\varphi)}$ (see values for PF), the **AC reactive power** $\boldsymbol{Q = U \cdot I \cdot \sin(\varphi)}$ (see values for $\sqrt{1 - PF^2}$) and the **AC apparent power** $\boldsymbol{S = U \cdot I}$ (see values for $PF = 1$) when calibrating **measuring instruments** with $\boldsymbol{U}$ **= 1 kV and** $\boldsymbol{I}$ **= 100 A**

	$\boldsymbol{\cos(\varphi) = PF \mid \sin(\varphi) = \pm\sqrt{1 - PF^2}}$					
$\boldsymbol{f}$ (Hz)	**0 | ± 1**	**0.4 | ± 0.92**	**0.6 | ± 0.8**	**0.8 | ± 0.6**	**0.9 | ± 0.44**	**1 | ± 0**
40	1.1 W	2.8 W	4.1 W	5.4 W	6.0 W	6.7 W
1000	21 W	20 W	18 W	14 W	12 W	7.6 W
10000	210 W	200 W	170 W	130 W	93 W	7.6 W

[i] The specified range applies only when the maximum volt-hertz product is maintained as shown in Figure A of the Operator's Manual Multi-Function Calibrator 5700A/5720A Series II May 1996 Rev. 2, 3/05.

On-site calibration – Phase angle

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal voltage signal and sinusoidal current signal Sources	-180° to 180°	10 Hz ≤ f ≤ 10 kHz 1 mV ≤ $U_{\text{eff.}}$ ≤ 1 kV		$\Delta\varphi = \varphi_{\text{U}} - \varphi_{\text{I}} =$ phase angle $I(t) = \sqrt{2} I_{\text{eff.}} \sin(2\pi f t + \varphi_{\text{I}})$ $U(t) = \sqrt{2} U_{\text{eff.}} \sin(2\pi f t + \varphi_{\text{U}})$ f = frequency $I_{\text{eff.}}$ = effective value of AC current $U_{\text{eff.}}$ = effective value of AC voltage Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as deviating measurement conditions, can increase the measurement uncertainty
		100 µA ≤ $I_{\text{eff.}}$ ≤ 10 mA		
		f = 10 Hz	0.21 m°	
		f = 45 Hz	0.57 m°	
		f = 111 Hz	1.1 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 27\ \text{ns}$	
		10 mA < $I_{\text{eff.}}$ ≤ 200 mA		
		f = 40 Hz	0.37 m°	
		f = 100 Hz	0.72 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 18\ \text{ns}$	
		200 mA < $I_{\text{eff.}}$ ≤ 2 A		
		f = 40 Hz	0.40 m°	
		f = 100 Hz	0.68 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 17\ \text{ns}$	
		2 A < $I_{\text{eff.}}$ ≤ 20 A		
		f = 10 Hz	0.18 m°	
		f = 45 Hz	0.57 m°	
		f = 111 Hz	1.1 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 26\ \text{ns}$	
		20 A < $I_{\text{eff.}}$ ≤ 100 A		
		f = 10 Hz	0.20 m°	
		f = 45 Hz	0.65 m°	
		f = 111 Hz	1.4 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 32\ \text{ns}$	

On-site calibration – Phase angle

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Phase angle between sinusoidal voltage signal and sinusoidal current signal Measuring instruments	-180° to 180°	10 Hz ≤ f ≤ 10 kHz 1 mV ≤ $U_{\mathrm{eff.}}$ ≤ 1 kV		$\Delta\varphi = \varphi_{\mathrm{U}} - \varphi_{\mathrm{I}} =$ Phase angle
		1 mA ≤ $I_{\mathrm{eff.}}$ ≤ 2 A		$I(t) = \sqrt{2} I_{\mathrm{eff.}} \sin(2\pi f t + \varphi_{\mathrm{I}})$
		f = 40 Hz	0.42 m°	
		f = 100 Hz	0.76 m°	$U(t) = \sqrt{2} U_{\mathrm{eff.}} \sin(2\pi f t + \varphi_{\mathrm{U}})$
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 19\ \mathrm{ns}$	
		2 A < $I_{\mathrm{eff.}}$ ≤ 20 A		
		f = 10 Hz	0.18 m°	f = frequency
		f = 45 Hz	0.60 m°	$I_{\mathrm{eff.}}$ = effective value of AC current
		f = 111 Hz	1.2 m°	$U_{\mathrm{eff.}}$ = effective value of AC voltage
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 28\ \mathrm{ns}$	
		20 A < $I_{\mathrm{eff.}}$ ≤ 100 A		
		f = 10 Hz	0.21 m°	Measurements at voltages ≤ 15 mV in the frequency range 10 Hz to < 1 kHz, as well as deviating measurement conditions, can increase the measurement uncertainty
		f = 45 Hz	0.68 m°	
		f = 111 Hz	1.4 m°	
		1 kHz ≤ f ≤ 10 kHz	$360° \cdot f \cdot 34\ \mathrm{ns}$	

On-site calibration – Inductance and capacitance

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Inductance	0 µH		0.03 µH	2-wire short circuit
	0 µH to 1.1 H	100 Hz to 10 kHz		
	100 µH	100 Hz	$0.65 \cdot 10^{-3} \cdot L$	L = measured value
		1 kHz	$0.24 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.27 \cdot 10^{-3} \cdot L$	Impedance value
	1 mH	100 Hz	$0.14 \cdot 10^{-3} \cdot L$	50 mΩ ≤ |Z| ≤ 11 kΩ
		1 kHz	$0.13 \cdot 10^{-3} \cdot L$	Smallest specified fixed measurement uncertainties for direct measurement or substitution on GR 1482 or identical construction
		10 kHz	$0.17 \cdot 10^{-3} \cdot L$	
	10 mH	100 Hz; 1 kHz	$0.11 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.16 \cdot 10^{-3} \cdot L$	
	100 mH	100 Hz; 1 kHz	$0.12 \cdot 10^{-3} \cdot L$	
		10 kHz	$0.26 \cdot 10^{-3} \cdot L$	
	1 H	100 Hz, 1 kHz	$0.20 \cdot 10^{-3} \cdot L$	
Capacitance	0 pF		0.2 pF	No load
	0 pF To 10 µF	100 Hz to 1 MHz		
	1 pF	1 kHz	$0.47 \cdot 10^{-3} \cdot C$	C = measured value
		10 kHz	$0.31 \cdot 10^{-3} \cdot C$	
	10 pF	1 kHz	$84 \cdot 10^{-6} \cdot C$	
		10 kHz; 100 kHz	$0.10 \cdot 10^{-3} \cdot C$	Impedance magnitude
		1 MHz	$0.13 \cdot 10^{-3} \cdot C$	1 Ω ≤ |Z| ≤ 110 MΩ
	100 pF	1 kHz	$56 \cdot 10^{-6} \cdot C$	Smallest specified fixed measurement uncertainties for direct measurement or substitution on HP 16381A or GR 1404 / 1409 or identical models
	1 nF	1 kHz	$58 \cdot 10^{-6} \cdot C$	
		100 kHz	$0.11 \cdot 10^{-3} \cdot C$	
	10 nF	100 Hz	$0.21 \cdot 10^{-3} \cdot C$	
		1 kHz	$0.14 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.13 \cdot 10^{-3} \cdot C$	
	100 nF	100 Hz; 1 kHz; 10 kHz	$0.16 \cdot 10^{-3} \cdot C$	
	1 µF	100 Hz; 1 kHz	$0.12 \cdot 10^{-3} \cdot C$	
		10 kHz	$0.21 \cdot 10^{-3} \cdot C$	
Capacitance	> 1 µF to 120 mF			C = capacitance f = frequency
	> 1 µF to 12 µF	0.5 Hz ≤ f ≤ 110 Hz	$9.0 \cdot 10^{-4} \cdot C + 3$ nF	
	> 12 µF to 120 µF	0.5 Hz ≤ f ≤ 40 Hz	$1.0 \cdot 10^{-3} \cdot C + 25$ nF	Different measurement conditions increase the measurement uncertainty
	> 120 µF to 1.2 mF	0.1 Hz ≤ f ≤ 11 Hz	$1.7 \cdot 10^{-3} \cdot C + 250$ nF	
	> 1.2 mF to 12 mF	0.03 Hz ≤ f ≤ 4 Hz	$1.7 \cdot 10^{-3} \cdot C + 3$ µF	
	> 12 mF to 120 mF	0.01 Hz ≤ f ≤ 1.3 Hz	$3.5 \cdot 10^{-3} \cdot C + 30$ µF	

On-site calibration – Time and frequency

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Frequency f Measurement and synthesis	0.01 Hz to 40 GHz		$0.5 \cdot 10^{-9} \cdot f + U_{Tf}$	f = measured value U_{Tf} = trigger uncertainty
Time interval Δt	0 ns to 0.7 ms		1.3 ns	
	0 ns to 200 s		$1.5 \cdot 10^{-6} \cdot \Delta t + 50$ ps	
	1 µs to 100 h		$10 \cdot 10^{-9} \cdot \Delta t + 1$ µs	
	1 s to 100 h		$13 \cdot 10^{-6} \cdot \Delta t + 0.82$ s	
Accuracy deviation	0 s/d to 100 s/d		$1.3 \cdot 10^{-7} = 0.011$ s/d	Electronic or mechanical clocks
Rotational frequency	0.02 s^{-1} to 3500 s^{-1}		$3.7 \cdot 10^{-6} \cdot f$	f = measured value

On-site calibration – High-frequency and radiation measurement quantities

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Oscilloscopes Vertical	1 mV to 5 V 5 mV to 200 V	DC to 10 kHz	$1.2 \cdot 10^{-3} \cdot U + 12$ µV	U = measured value 50 Ω 1 MΩ
Oscilloscope horizontal	25 ps to 40 s		$0.12 \cdot 10^{-6} \cdot T + 0.1$ ps	T = measured value
Bandwidth f (frequency response)	40 Hz to 6 GHz		$6.3 \cdot 10^{-3} \cdot f^2$/GHz $+ 20 \cdot 10^{-3} \cdot f$	f = measured value
	> 6 GHz to 40 GHz		$75 \cdot 10^{-3} \cdot f$	
Rise time	30 ps to 45 ps > 45 ps to 1 ms	0.1 V to 3 V	5 ps $10 \cdot 10^{-3} \cdot T + 3$ ps	Fluke 9500/9550
	70 ps to 85 ps > 85 ps to 310 ps > 310 ps to 650 ps > 650 ps to 1 ms	0.1 V to 3 V	$78 \cdot 10^{-3} \cdot T$ $67 \cdot 10^{-3} \cdot T$ $58 \cdot 10^{-3} \cdot T$ $56 \cdot 10^{-3} \cdot T$	calculated from 3 dB bandwidth T = measured value
Frequency f Time base	10 MHz		$0.2 \cdot 10^{-6} \cdot f$	
Burst generator Output voltage Peak value U_s	100 V to 4 kV	under 50 Ω or 1 kΩ load	$48 \cdot 10^{-3} \cdot U_s$	
Rise time and pulse duration T_r	3 ns to 1 µs		$41 \cdot 10^{-3} \cdot T_r$	
Burst duration and burst period T	10 µs to 1 s		$5 \cdot 10^{-3} \cdot T$	
Pulse frequency f	100 Hz to 500 kHz		$1 \cdot 10^{-3} \cdot f$	
Surge voltage generator Front time $t_{r,Us}$ of the open-circuit voltage	15 ns to 100 ms		$3\% \cdot t_{r,Us} + 1$ ns	
Front time $t_{r,Is}$ of the short-circuit current	100 ns to 100 ms		$3\% \cdot t_{r,Is} + 2$ ns	
Rear half-value time t_H of the waveform	0.5 µs to 100 ms		$5\% \cdot t_H$	
Peak value of open-circuit voltage U_S	0.1 kV to 7 kV		$3.3\% \cdot U_S$	
Peak value of short-circuit current I_S	10 A to 5 kA		$3.5\% \cdot I_S$	
	> 5 kA to 10 kA		$3.8\% \cdot I_S$	

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Pulse-shaped measurement quantities *		EN 55016-1-1:2015		
Measuring receiver display behavior with pulses	9 kHz to 150 kHz		0.35 dB	Band A
	> 150 kHz to 30 MHz			Band B
	> 30 MHz to 300 MHz		0.40 dB	Band C
Amplitude relationship (absolute calibration)	> 300 MHz to 1 GHz			Band D
Change in display with the pulse frequency (relative calibration)	Pulse repetition frequency			
	0.1 Hz to 2 kHz		0.30 dB	Band A
	0.1 Hz to 50 kHz		0.35 dB	Band B
	0.1 Hz to 1 MHz			Band C and band D

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF power Input power and calibration factor of RF power meters	10 fW to < 100 fW	DC to 2 GHz	$21 \cdot 10^{-3} \cdot P$	PC Type N *) to 18 GHz PC-3.5 mm *) to 33 GHz PC-2.92 mm *) to 40 GHz *) Other connectors increase the measurement uncertainty P = measured value (W)
		> 2 GHz to < 5 GHz	$26 \cdot 10^{-3} \cdot P$	
		5 GHz to < 9 GHz	$34 \cdot 10^{-3} \cdot P$	
		9 GHz to < 12 GHz	$40 \cdot 10^{-3} \cdot P$	
		12 GHz to 15 GHz	$48 \cdot 10^{-3} \cdot P$	
		> 15 GHz to 18 GHz	$54 \cdot 10^{-3} \cdot P$	
	100 fW to 1 pW	DC to 100 MHz	$18 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$22 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$24 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$29 \cdot 10^{-3} \cdot P$	
	> 1 pW to 10 pW	DC to 100 MHz	$13 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$18 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 26.5 GHz	$26 \cdot 10^{-3} \cdot P$	
		> 26.5 GHz to 40 GHz	$29 \cdot 10^{-3} \cdot P$	
	> 10 pW to 1 nW	DC to 100 MHz	$12 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$14 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$22 \cdot 10^{-3} \cdot P$	
	> 1 nW to 100 nW	DC to 2 GHz	$10 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$12 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$15 \cdot 10^{-3} \cdot P$	

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF power Input power and calibration factor of RF power meters	> 100 nW to 10 µW	DC to 100 MHz	$7.1 \cdot 10^{-3} \cdot P$	PC Type N *) to 18 GHz PC-3.5 mm *) to 33 GHz PC-2.92 mm *) to 40 GHz *) Other connectors increase the measurement uncertainty P = measured value (W)
		> 100 MHz to 2 GHz	$9.4 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$15 \cdot 10^{-3} \cdot P$	
	> 10 µW to 100 mW	DC to 100 MHz	$6.1 \cdot 10^{-3} \cdot P$	
		> 100 MHz to 2 GHz	$7.9 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$9.3 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 12 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 40 GHz	$13 \cdot 10^{-3} \cdot P$	
RF power	1 mW	50 MHz	$5 \cdot 10^{-3} \cdot P$	Substitution
Output power and calibration factor of RF sources	0.1 pW to < 10 pW	50 MHz	$27 \cdot 10^{-3} \cdot P$	PC Type N *) to 18 GHz PC-3.5 mm *) to 33 GHz PC-2.92 mm *) to 40 GHz *) Other connectors increase measurement uncertainty $f \leq 5$ GHz: $\lvert\Gamma_G\rvert \leq 0.025$ 5 GHz < $f \leq 20$ GHz: $\lvert\Gamma_G\rvert \leq 0.1$ 20 GHz < $f \leq 33$ GHz: $\lvert\Gamma_G\rvert \leq 0.15$ 33 GHz < $f \leq 40$ GHz: $\lvert\Gamma_G\rvert \leq 0.3$ f = frequency (Hz) P = measured value (W) $\lvert\Gamma_G\rvert$ = reflection coefficient of the calibration object
		10 MHz to 2 GHz	$30 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 3 GHz	$35 \cdot 10^{-3} \cdot P$	
	10 pW to < 1 nW	50 MHz	$21 \cdot 10^{-3} \cdot P$	
		10 MHz to 2 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 3 GHz	$31 \cdot 10^{-3} \cdot P$	
	1 nW to < 100 nW	50 MHz	$17 \cdot 10^{-3} \cdot P$	
		10 MHz to 2 GHz	$21 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 4 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 12 GHz	$38 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 18 GHz	$71 \cdot 10^{-3} \cdot P$	
		> 18 GHz to 26.5 GHz	$93 \cdot 10^{-3} \cdot P$	
	100 nW to < 1 µW	8 kHz to < 10 MHz	$28 \cdot 10^{-3} \cdot P$	
		10 MHz to 50 MHz	$13 \cdot 10^{-3} \cdot P$	
		> 50 MHz to 4 GHz	$14 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 5 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 5 GHz to 12 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 20 GHz	$28 \cdot 10^{-3} \cdot P$	
		> 20 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF power Output power and calibration factor of RF sources	1 µW to < 10 µW	8 kHz to < 10 MHz	$18 \cdot 10^{-3} \cdot P$	PC Type N *) to 18 GHz PC-3.5 mm *) to 33 GHz PC-2.92 mm *) to 40 GHz *) Other connectors increase measurement uncertainty $f \leq 5$ GHz: $\lvert\Gamma_G\rvert \leq 0.025$ 5 GHz < $f \leq 20$ GHz: $\lvert\Gamma_G\rvert \leq 0.1$ 20 GHz < $f \leq 33$ GHz: $\lvert\Gamma_G\rvert \leq 0.15$ 33 GHz < $f \leq 40$ GHz: $\lvert\Gamma_G\rvert \leq 0.3$ f = frequency (Hz) P = measured value (W) $\lvert\Gamma_G\rvert$ = reflection coefficient of the calibration object
		10 MHz to 50 MHz	$13 \cdot 10^{-3} \cdot P$	
		> 50 MHz to 4 GHz	$14 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 5 GHz	$17 \cdot 10^{-3} \cdot P$	
		> 5 GHz to 12 GHz	$21 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 20 GHz	$25 \cdot 10^{-3} \cdot P$	
		> 20 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	
	10 µW to < 100 µW	DC to < 10 MHz	$9.0 \cdot 10^{-3} \cdot P$	
		10 MHz to 100 MHz	$10 \cdot 10^{-3} \cdot P$	
		>100 MHz to 2 GHz	$12 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 10 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 10 GHz to 12 GHz	$16 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 30 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 30 GHz to 33 GHz	$37 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$90 \cdot 10^{-3} \cdot P$	
	100 µW to 0.1 W	DC to < 10 MHz	$5.6 \cdot 10^{-3} \cdot P$	
		10 MHz to 100 MHz	$7.5 \cdot 10^{-3} \cdot P$	
		>100 MHz to 2 GHz	$10 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 8 GHz	$11 \cdot 10^{-3} \cdot P$	
		> 8 GHz to 10 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 10 GHz to 12 GHz	$15 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 30 GHz	$19 \cdot 10^{-3} \cdot P$	
		> 30 GHz to 33 GHz	$39 \cdot 10^{-3} \cdot P$	
		> 33 GHz to 40 GHz	$53 \cdot 10^{-3} \cdot P$	
	> 0.1 W to 1 W	DC to 50 MHz	$11 \cdot 10^{-3} \cdot P$	
		> 50 MHz to 2 GHz	$13 \cdot 10^{-3} \cdot P$	
		> 2 GHz to 4 GHz	$16 \cdot 10^{-3} \cdot P$	
		> 4 GHz to 12 GHz	$20 \cdot 10^{-3} \cdot P$	
		> 12 GHz to 18 GHz	$30 \cdot 10^{-3} \cdot P$	
	> 1 W to 70 W	DC to 3 GHz	$38 \cdot 10^{-3} \cdot P$	
	> 70 W to 250 W	DC to 500 MHz	$37 \cdot 10^{-3} \cdot P$	

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF voltage U_{RF} Sources with RF voltage display relative to 50 Ω	2.2 µV to 220 µV	DC to 3 GHz	$W(U_{RF}) = \frac{W(P)}{2}$	$W(P)$ = relative uncertainty of the Measured power at Z_0 = 50 Ω
	220 µV to 7 V	DC to 18 GHz		**)
	2.2 µV to 220 µV	DC to 3 GHz		***)
	2.2 mV to 2 V	DC to 40 GHz		
RF voltage U_{RF} Measuring instruments and receivers with RF voltage display relative to 50 Ω	0.7 µV to 2 V	DC to 18 GHz	$W(U_{RF}) = \frac{W(P_{inc})}{2}$	$W(P_{inc})$ = relative uncertainty of the radiated power relative to Z_0 = 50 Ω
	2.2 mV to 2 V	DC to 40 GHz		**)
				***)
RF power Noise display of receivers	DC to 40 GHz		1.6 dB	Power > -170 dB (1 mW) relative to 1 Hz bandwidth
Signal level difference	0 dBc to 100 dBc	100 Hz to 26.5 GHz 100 Hz to 40 GHz	1.3 dB 2.7 dB	SNR ≥ 12 dB

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Bandwidth Filter	1 Hz to 10 MHz		0.5%	Signal-to-noise ratio SNR ≥ 70 dB
Form factor	> 1:1 to 5:1 > 5:1 to 10:1 > 10:1 to 20:1		3% 6% 12%	Signal-to-noise ratio SNR ≥ 15 dB
Switching deviation			0.02 dB	
Display linearity	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB > 80 dB to 100 dB > 100 dB to 110 dB	100 kHz to 500 MHz	0.06 dB 0.07 dB 0.09 dB 0.1 dB 0.2 dB	SNR ≥ 50 dB $\lvert\Gamma_{L,\,DUT}\rvert \leq 0.05$ $f \leq 500$ MHz
Input attenuator or IF amplifier	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB > 80 dB to 100 dB > 100 dB to 110 dB	100 kHz to 500 MHz	0.06 dB 0.07 dB 0.09 dB 0.1 dB 0.2 dB	Comparison with external attenuator $\lvert\Gamma_{L,\,DUT}\rvert \leq 0.05$ $f \leq 500$ MHz
	0 dB to 30 dB > 30 dB to 60 dB > 60 dB to 80 dB	100 kHz to 500 MHz	0.04 dB 0.06 dB 0.08 dB	Stepwise display comparison SNR ≥ 50 dB, receiver linearity < (0.01 dB + 0.005 dB/10 dB)
RF amplification Amplifier	0 dB to 70 dB	DC to 100 MHz > 100 MHz to 2 GHz > 2 GHz to 4 GHz > 4 GHz to 18 GHz	0.19 dB 0.26 dB 0.3 dB 0.5 dB	BNC connector to max. 2 GHz N connector and BNC connector, 50 Ω, other connectors increase measurement uncertainty
	0 dB to 70 dB	DC to 100 MHz > 100 MHz to 4 GHz > 4 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.21 dB 0.3 dB 0.6 dB 0.7 dB	2.92 mm compatible connector, 50 Ω, other connectors increase measurement uncertainty
RF current Current clamps	100 µA to 50 mA	40 Hz to 10 MHz > 10 MHz to 30 MHz > 30 MHz to 65 MHz	$14 \cdot 10^{-3} \cdot I$ $18 \cdot 10^{-3} \cdot I$ $20 \cdot 10^{-6} f^2 \cdot I$	Tektronix 015-0601-50. In combination with oscilloscope I = measured value f = frequency in MHz
Non-linearity of RF power meters	10 nW to 1 W	50 MHz	$5.5 \cdot 10^{-3}$ (0.024 dB)	R&S NRVC-B2 60 dB max.

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF reflection coefficient * $\|\Gamma\|$	0 to 1	9 kHz to 18 GHz EURAMET cg-12 (version 3.0)	0.003 to 0.013 See matrix VM.3	N connector, 50 Ω, other connectors increase the measurement uncertainty Measurement uncertainty in units of the reflection coefficient
	0 to 1	9 kHz to 33 GHz EURAMET cg-12 (version 3.0)	0.003 to 0.016 See matrix VM.4	3.5 mm connector Measurement uncertainty in units of the reflection coefficient
	0 to 1	45 MHz to 45 GHz EURAMET cg-12 (version 3.0)	0.004 to 0.017 See matrix VM.5	2.92 mm connector Measurement uncertainty in units of the reflection coefficient
RF reflection coefficient * Phase angle φ	-180° to +180°	9 kHz to 18 GHz EURAMET cg-12 (version 3.0)	0.2° to 4.7° See matrix VM.6	N connector, 50 Ω, other connectors increase measurement uncertainty
	-180° to +180°	9 kHz to 33 GHz EURAMET cg-12 (version 3.0)	0.3° to 5.8° See matrix VM.7	3.5 mm connector
	-180° to +180°	45 MHz to 45 GHz EURAMET cg-12 (version 3.0)	0.3° to 6.3° See matrix VM.8	2.92 mm connector
RF attenuation Attenuators	0 dB to 30 dB	100 kHz to 10 GHz > 10 GHz to 18 GHz > 18 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.03 dB 0.05 dB 0.09 dB 0.10 dB	L is the measured attenuation, ****) $\|\Gamma_{DUT}\| \leq 0.01$ $F \leq 500$ MHz $\|\Gamma_{L,\,DUT}\| \leq 0.05$ 500 MHz < $f \leq$ 10 GHz $\|\Gamma_{L,\,DUT}\| \leq 0.08$ 10 GHz < $f \leq$ 18 GHz $\|\Gamma_{L,\,DUT}\| \leq 0.1$ 18 GHz < $f \leq$ 40 GHz
	> 30 dB to 60 dB	100 kHz to 10 GHz > 10 GHz to 18 GHz > 18 GHz to 26.5 GHz > 26.5 GHz to 40 GHz	0.001 dB/dB · L 0.02 dB + 0.001 dB/dB · L 0.10 dB + 0.001 dB/dB · L 0.11 dB + 0.001 dB/dB · L	

On-site calibration – High-frequency measurement quantities

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
RF attenuation Attenuators	> 60 dB to 70 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.07 dB 0.10 dB	$\lvert\Gamma_{L,\,DUT}\rvert \leq 0.01$ $f \leq 500$ MHz $\lvert\Gamma_{L,\,DUT}\rvert \leq 0.05$ 500 MHz < $f \leq 3$ GHz
	> 70 dB to 80 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.08 dB 0.2 dB	
	> 80 dB to 100 dB	100 kHz to 500 MHz > 500 MHz to 3 GHz	0.1 dB 0.3 dB	
RF attenuation *	0 dB to 60 dB	9 kHz to 18 GHz EURAMET cg-12 (version 3.0)	0.01 dB to 0.09 dB See matrix VM.9	N connector, 50 Ω, other connectors increase measurement uncertainty
	0 dB to 60 dB	9 kHz to 33 GHz EURAMET cg-12 (version 3.0)	0.01 dB to 0.22 dB See matrix VM.10	3.5 mm connector
	0 dB to 60 dB	45 MHz to 45 GHz EURAMET cg-12 (version 3.0)	0.01 dB to 0.32 dB See matrix VM.11	2.92 mm connector
RF attenuation * Phase angle φ	-180° to +180°	9 kHz to 18 GHz 0 dB to 60 dB EURAMET cg-12 (version 3.0)	0.2° to 0.8° See matrix VM.12	N connector, 50 Ω, other connectors increase measurement uncertainty
	-180° to +180°	9 kHz to 33 GHz 0 dB to 60 dB EURAMET cg-12 (version 3.0)	0.2° to 1.8° See matrix VM.13	3.5 mm connector
	-180° to +180°	45 MHz to 45 GHz 0 dB to 60 dB EURAMET cg-12 (version 3.0)	0.2° to 2.5° See matrix VM.14	2.92 mm connector

Matrix VM.3 RF reflection coefficient, magnitude $|\Gamma|$; N connector 50 Ω

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0	0.003 to 0.004	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.1	0.003 to 0.005	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.2	0.003 to 0.005	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.3	0.003 to 0.006	0.003 to 0.004	0.003 to 0.008	0.008 to 0.009
0.4	0.003 to 0.005	0.004	0.003 to 0.008	0.008 to 0.009
0.5	0.003 to 0.006	0.004	0.004 to 0.009	0.008 to 0.009
0.6	0.004 to 0.006	0.004 to 0.005	0.004 to 0.009	0.009
0.7	0.004 to 0.006	0.005	0.005 to 0.010	0.009 to 0.010
0.8	0.004 to 0.006	0.005 to 0.006	0.005 to 0.010	0.010
0.9	0.004 to 0.007	0.006	0.005 to 0.011	0.011 to 0.012
1	0.003 to 0.006	0.004 to 0.006	0.004 to 0.012	0.011 to 0.013

Matrix VM.4 RF reflection coefficient, magnitude $|\Gamma|$; 3.5 mm connector

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0	0.003 to 0.004	0.003	0.003 to 0.004	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.1	0.003 to 0.005	0.003	0.003 to 0.004	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.2	0.003 to 0.006	0.003 to 0.004	0.004 to 0.005	0.004 to 0.005	0.005 to 0.008	0.008 to 0.010
0.3	0.003 to 0.006	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.011
0.4	0.004 to 0.005	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.011
0.5	0.004 to 0.006	0.004 to 0.005	0.004 to 0.005	0.005 to 0.006	0.005 to 0.008	0.008 to 0.011
0.6	0.004 to 0.006	0.005	0.005 to 0.006	0.006	0.006 to 0.009	0.009 to 0.012
0.7	0.004 to 0.006	0.005 to 0.006	0.005 to 0.006	0.006 to 0.007	0.006 to 0.010	0.009 to 0.013
0.8	0.004 to 0.007	0.005 to 0.006	0.005 to 0.007	0.006 to 0.007	0.006 to 0.010	0.010 to 0.014
0.9	0.004 to 0.007	0.006 to 0.007	0.006 to 0.008	0.007 to 0.008	0.007 to 0.011	0.011 to 0.015
1	0.004 to 0.006	0.005 to 0.006	0.005 to 0.008	0.006 to 0.009	0.007 to 0.012	0.011 to 0.016

Matrix VM.5 RF reflection coefficient, magnitude $|\Gamma|$; 2.92 mm connector

Measurement uncertainty in units of the magnitude of the reflection coefficient

Magnitude $\|\Gamma\|$	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.1	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.2	0.004	0.004	0.004	0.004	0.004 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.3	0.004	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.4	0.004	0.004	0.004 to 0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.011
0.5	0.004 to 0.005	0.005	0.005	0.005	0.005 to 0.008	0.008 to 0.010	0.010	0.010 to 0.012
0.6	0.005	0.005	0.005 to 0.006	0.005 to 0.006	0.005 to 0.009	0.008 to 0.011	0.010 to 0.011	0.010 to 0.012
0.7	0.005 to 0.006	0.005	0.005 to 0.006	0.006	0.006 to 0.009	0.009 to 0.012	0.011 to 0.012	0.011 to 0.013
0.8	0.005 to 0.006	0.006	0.006 to 0.007	0.006 to 0.007	0.006 to 0.010	0.009 to 0.013	0.012 to 0.013	0.012 to 0.014
0.9	0.005 to 0.007	0.006 to 0.007	0.006 to 0.008	0.007 to 0.008	0.007 to 0.011	0.010 to 0.014	0.013 to 0.014	0.013 to 0.015
1	0.005 to 0.007	0.005 to 0.006	0.005 to 0.008	0.007 to 0.008	0.006 to 0.012	0.011 to 0.015	0.014 to 0.015	0.014 to 0.017

Matrix VM.6 RF reflection coefficient, phase angle φ; N connector 50 Ω

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0.1	1.4° to 2.2°	1.5° to 1.9°	1.5° to 4.5°	4.4° to 4.7°
0.2	0.7° to 1.4°	0.8° to 1.0°	0.8° to 2.3°	2.2° to 2.4°
0.3	0.5° to 1.0°	0.6° to 0.7°	0.6° to 1.5°	1.5° to 1.6°
0.4	0.4° to 0.7°	0.5° to 0.6°	0.5° to 1.2°	1.2°
0.5	0.4° to 0.6°	0.4° to 0.5°	0.4° to 1.0°	1.0°
0.6	0.4° to 0.5°	0.4° to 0.5°	0.4° to 0.9°	0.9°
0.7	0.3° to 0.5°	0.4°	0.4° to 0.8°	0.8°
0.8	0.3° to 0.5°	0.4°	0.4° to 0.8°	0.7° to 0.8°
0.9	0.3° to 0.4°	0.4°	0.4° to 0.8°	0.7° to 0.8°
1	0.2° to 0.4°	0.3° to 0.4°	0.3° to 0.7°	0.7° to 0.8°

Matrix VM.7 RF reflection coefficient, phase angle φ; 3.5 mm connector

Magnitude $\|\Gamma\|$	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0.1	1.5° to 2.6°	1.6° to 1.7°	1.7° to 2.3°	2.3° to 2.6°	2.4° to 4.2°	4.1° to 5.8°
0.2	0.8° to 1.5°	0.9°	0.9° to 1.2°	1.2° to 1.4°	1.3° to 2.2°	2.2° to 3.0°
0.3	0.6° to 1.1°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.0°	1.0° to 1.6°	1.6° to 2.1°
0.4	0.5° to 0.8°	0.5° to 0.6°	0.6° to 0.8°	0.7° to 0.9°	0.8° to 1.3°	1.3° to 1.7°
0.5	0.5° to 0.7°	0.5°	0.5° to 0.7°	0.7° to 0.8°	0.8° to 1.2°	1.1° to 1.5°
0.6	0.4° to 0.6°	0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.1°	1.1° to 1.4°
0.7	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
0.8	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
0.9	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.3°
1	0.3° to 0.4°	0.3° to 0.4°	0.3° to 0.5°	0.5° to 0.7°	0.7° to 1.0°	0.9° to 1.2°

Matrix VM.8 RF reflection coefficient, phase angle φ; 2.92 mm connector

Magnitude $\lvert\Gamma\rvert$	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0.1	2.0° to 2.1°	2.0°	2.0° to 2.3°	2.2° to 2.3°	2.2° to 4.2°	4.2° to 5.3°	5.3° to 5.4°	5.3° to 6.3°
0.2	1.0° to 1.1°	1.0° to 1.1°	1.0° to 1.2°	1.2°	1.2° to 2.2°	2.1° to 2.7°	2.7°	2.7° to 3.2°
0.3	0.7° to 0.8°	0.7°	0.7° to 0.9°	0.8° to 0.9°	0.8° to 1.5°	1.5° to 1.9°	1.9°	1.9° to 2.2°
0.4	0.6°	0.6°	0.6° to 0.7°	0.7°	0.7° to 1.2°	1.1° to 1.5°	1.5°	1.5° to 1.7°
0.5	0.5° to 0.6°	0.5°	0.5° to 0.6°	0.6°	0.6° to 1.0°	1.0° to 1.3°	1.2° to 1.3°	1.3° to 1.5°
0.6	0.4° to 0.5°	0.5°	0.5° to 0.6°	0.5° to 0.6°	0.6° to 0.9°	0.9° to 1.1°	1.1° to 1.2°	1.1° to 1.3°
0.7	0.4° to 0.5°	0.5°	0.5° to 0.6°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.1°	1.0° to 1.1°	1.1° to 1.2°
0.8	0.4° to 0.5°	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.0°	1.0°	1.0° to 1.2°
0.9	0.3° to 0.5°	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.5° to 0.8°	0.8° to 1.0°	1.0°	1.0° to 1.2°
1	0.3° to 0.4°	0.3° to 0.4°	0.3° to 0.5°	0.5°	0.5° to 0.8°	0.7° to 1.0°	0.9° to 1.0°	0.9° to 1.2°

Matrix VM.9 RF attenuation; N connector 50 Ω

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB
3 dB	0.04 dB to 0.05 dB	0.05 dB	0.05 dB	0.05 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB
10 dB	0.05 dB	0.05 dB	0.06 dB	0.05 dB to 0.06 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
40 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB to 0.07 dB
50 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB
60 dB	0.05 dB to 0.09 dB	0.08 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB

Matrix VM.10 RF attenuation; 3.5 mm connector

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB	0.02 dB	0.02 dB
3 dB	0.04 dB to 0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB
10 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB
40 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.07 dB
50 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.09 dB	0.08 dB to 0.10 dB
60 dB	0.05 dB to 0.09 dB	0.07 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB	0.08 dB to 0.19 dB	0.15 dB to 0.22 dB

Matrix VM.11 RF attenuation; 2.92 mm connector

Absolute attenuation	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0 dB	0.01 dB	0.01 dB to 0.02 dB	0.01 dB to 0.02 dB	0.02 dB	0.02 dB	0.02 dB	0.02 dB to 0.04 dB	0.03 dB
3 dB	0.04 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB
6 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB
10 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB
20 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB	0.07 dB to 0.08 dB
30 dB	0.05 dB	0.05 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.07 dB	0.07 dB	0.07 dB to 0.08 dB
40 dB	0.05 dB	0.05 dB to 0.06 dB	0.05 dB to 0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.07 dB	0.07 dB to 0.08 dB	0.08 dB to 0.09 dB
50 dB	0.05 dB	0.06 dB	0.06 dB	0.06 dB to 0.07 dB	0.06 dB to 0.09 dB	0.08 dB to 0.10 dB	0.09 dB to 0.10 dB	0.10 dB to 0.13 dB
60 dB	0.06 dB	0.08 dB to 0.09 dB	0.07 dB to 0.09 dB	0.08 dB to 0.09 dB	0.08 dB to 0.18 dB	0.15 dB to 0.22 dB	0.17 dB to 0.22 dB	0.20 dB to 0.32 dB

Matrix VM.12 RF attenuation; phase angle φ; N connector 50 Ω

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°
50 dB	0.4°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°
60 dB	0.4° to 0.6°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°

Matrix VM.13 RF attenuation; phase angle φ; 3.5 mm connector

Absolute attenuation	9 kHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°	0.6° to 0.9°	0.9° to 1.0°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°
50 dB	0.4° to 0.5°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°
60 dB	0.4° to 0.6°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°	0.8° to 1.5°	1.3° to 1.8°

Matrix VM.14 RF attenuation; phase angle φ; 2.92 mm connector

Absolute attenuation	45 MHz to 1 GHz	1 GHz to 3 GHz	3 GHz to 12 GHz	12 GHz to 18 GHz	18 GHz to 26.5 GHz	26.5 GHz to 33 GHz	33 GHz to 40 GHz	40 GHz to 45 GHz
0 dB	0.2°	0.2°	0.2° to 0.4°	0.4° to 0.6°	0.6° to 0.9°	0.9° to 1.0°	1.0° to 1.2°	1.2° to 1.4°
3 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
6 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
10 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
20 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
30 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 0.9°	0.9° to 1.1°	1.1° to 1.3°	1.3° to 1.5°
40 dB	0.4°	0.4°	0.4° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°	1.2° to 1.3°	1.3° to 1.5°
50 dB	0.4°	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 1.0°	1.0° to 1.2°	1.2° to 1.4°	1.4° to 1.7°
60 dB	0.4° to 0.5°	0.5° to 0.6°	0.6° to 0.7°	0.7° to 0.8°	0.8° to 1.5°	1.3° to 1.8°	1.6° to 1.9°	1.8° to 2.5°

On-site calibration – Radiometry

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Optical radiation power Fiber optic power meters	1 µW to 0.5 mW	1310 nm, 1550 nm	1.3%	Connector FC, ST, SC, SMA, HMS-10, or adaptable Different wavelengths (780 nm, 635 nm, 1625 nm) interpolated
		850 nm	2.2%	
		654 nm	2.2%	
Nonlinearity of fiber optic radiation receivers	10 nW to 160 µW	Wavelengths: 1310 nm, 1550 nm, 850 nm	$1.8 \cdot 10^{-3}$ (0.008 dB)	Addition method
	0.1 nW to < 0.32 nW		$20 \cdot 10^{-3}$ (0.085 dB)	Comparison method
	0.32 nW to < 3.2 nW		$7.1 \cdot 10^{-3}$ (0.031 dB)	
	3.2 nW to 0.5 µW		$6.0 \cdot 10^{-3}$ (0.026 dB)	
Attenuation or amplification of fiber optic components	0 dB to 50 dB	Wavelengths: 1310 nm, 1550 nm, 850 nm Reference power: approx. 0.5 mW	$6.0 \cdot 10^{-3}$ (0.026 dB)	
	> 50 dB to 60 dB		$7.1 \cdot 10^{-3}$ (0.031 dB)	
	> 60 dB to 70 dB		$20 \cdot 10^{-3}$ (0.085 dB)	
Central wavelength λ	350 nm to < 700 nm		0.5 nm	
	700 nm to <1250 nm		2.5 pm	
	1250 nm to 1700 nm		2 pm	

On-site calibration – Photometry

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Transmission filter Transmission *T*	16% to 60%	QMH Chapter XXXIV v4.0 Nominal values in the turbidity values of the standard	0.65%	
	> 60% to 76%		0.70%	
	> 76% to < 100%		0.80%	
Degree of turbidity *N*	> 0% to < 24%		0.80%	
	24% to < 40%		0.70%	
	40% to 84%		0.65%	
Turbidity coefficient *k*	Measuring chamber length 0.43 m > 0 m^{-1} to 4.3 m^{-1}		0.020 m^{-1} to 0.050 m^{-1}	Turbidity coefficient *k* calculated from the degree of turbidity *N* Uncertainty interval *U(k)* calculated from the uncertainty interval of the turbidity degree *U(N)* Other measuring chamber lengths increase the measurement uncertainty

**) N connector 50 Ω, other connectors and reflection coefficients increase the measurement uncertainty
***) 2.92 mm connector
****) > 18 GHz 3.5 mm or 2.92 mm connector

On-site calibration – Dimensional measurement quantities

On-site calibration – Length

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Caliper gauge for external, internal, and depth measurements *	0 mm	to	1000 mm	VDI/VDE/DGQ 2618 Sheet 9.1:2006	20 µm + 15 · 10^{-6} · l	l = measured value
Bow micrometers *		to	300 mm	VDI/VDE/DGQ 2618 Sheet 10.1:2001	2 µm + 6 · 10^{-6} · l	
	> 300 mm	to	1000 mm		0.30 µm + 12 · 10^{-6} · l	
Circumference measuring tapes made of steel Diameter	150 mm	to	300 mm	QMH-L.VIII.2 Section 3 Version 1.0	0.71 mm	Calibration at the nominal values of the standards
	> 300 mm	to	400 mm		0.104 mm	
Circumference	470 mm	to	950 mm		0.22 mm	
	> 950 mm	to	1257 mm		0.328 mm	
Cylindrical standards Rings * Diameter	1 mm	to	90 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.9 µm + 10 · 10^{-6} · d	d = measured diameter
Mandrels * Diameter	1 mm	to	120 mm	VDI/VDE/DGQ 2618 Sheet 4.1:2006 Option 3	0.6 µm + 1.8 · 10^{-6} · d	
Test pins * Diameter	1 mm	to	20 mm	VDI/VDE/DGQ 2618 Sheet 4.2:2006 Option 1	0.6 µm + 1.8 · 10^{-6} · d	

On-site calibration – Length

Calibration and Measurement Capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Thread gauges * (single and multiple thread cylindrical external and internal threads with straight flanks, symmetrical profile, nominal pitch, and nominal profile angle) External thread Simple flank diameter	1 mm to 120 mm	VDI/VDE/DGQ 2618 Sheet 4.8:2006 Option 1 Three-wire method (perpendicular to thread axis)	2.9 µm + 7.7 · 10^{-6} · d	d = measured flank diameter
Internal thread Simple flank diameter	3 mm to 90 mm	VDI/VDE/DGQ 2618 Sheet 4.9:2006 Option 1 Two-ball method (perpendicular to thread axis)	2.6 µm + 5.5 · 10^{-6} · d	
Length measuring instrument Gauges	0 mm to 75 mm	QMH-L.VIII.3 Section 2.1 Version 1.0 External measurement	31 µm	Assumed temperature range: 20 °C ± 1 K Assumed thermal expansion coefficient: α = 11.5 · 10^{-6} K^{-1} Deviating ambient conditions and materials of the test gauges to be calibrated increase the measurement uncertainty
	> 75 mm to 150 mm		37 µm	
	0 mm to 150 mm	QMH-L.VIII.3 Section 2.2 Version 1.0 Internal measurement	36 µm	
	0 mm to 150 mm	QMH-L.VIII.3 Section 2.3 Version 1.0 Depth measurement	39 µm	
	0 mm to 75 mm	QMH-L.VIII.3 Section 2.4 Version 1.0 Step measurement	55 µm	
	> 75 mm to 150 mm		76 µm	

Abbreviations used:

AA	Work instruction (self-developed procedure) of esz AG (Arbeitsanweisung)
CMC	Calibration and measurement capabilities
DIN	German Institute for Standardization (Deutsches Institut für Normung e.V.)
DKD-R	Guideline of the German Calibration Service (DKD), published by the Physikalisch-Technische Bundesanstalt (Richtlinie des Deutschen Kalibrierdienstes)
EN	European standard (Europäische Norm)
EURAMET	European Association of National Metrology Institutes
QMH	Quality management manual (self-developed procedure) of esz AG (Qualitätsmanagementhandbuch)

German Accreditation Body

Annex to the Accreditation Certificate D-K-15019-01-02 in accordance with DIN EN ISO/IEC 17025:2018

Valid from: **22.07.2026**

Date of issue: 22.07.2026

This annex is a part of the accreditation certificate D-K-15019-01-00.

Holder of the accreditation certificate:

esz AG calibration & metrology
Max-Planck-Straße 16, 82223 Eichenau

with the locations

esz AG calibration & metrology
Max-Planck-Straße 16, 82223 Eichenau

esz AG calibration & metrology
Nordostpark 12, 90411 Nuremberg

esz AG calibration & metrology
Ladehofstraße 26, 93053 Regensburg

esz AG calibration & metrology
Webereistraße 3, 48565 Steinfurt

esz AG calibration & metrology
Lemböckgasse 49, A-1230 Vienna, AUSTRIA

The calibration laboratory meets the requirements of DIN EN ISO/IEC 17025:2018 to carry out the conformity assessment activities listed in this annex. The calibration laboratory meets additional legal and normative requirements, if applicable, including those in relevant sectoral schemes, provided that these are explicitly confirmed below.

The management system requirements of DIN EN ISO/IEC 17025 are written in the language relevant to the operations of calibration laboratories and they conform to the principles of DIN EN ISO 9001.

Calibrations in the fields of:

Thermodynamic measurement quantities

Temperature measurement quantities

- **Block calibrators** [a)]
- **Direct reading thermometers** [a)]
- **Climatic chambers (temperature)** [a)]
- **Temperature indicators and simulators** [a)]
- **Thermocouples** [a)]
- **Resistance thermometers** [a)]

Humidity measurement quantities

- **Climatic chambers (humidity)** [a)]
- **Measuring instruments for absolute humidity** [a)]
- **Measuring instruments for relative humidity** [a)]

Mechanical measurement quantities

- **Torque** [a)]
- **Pressure** [a)]
- **Force** [a)]
- **Mass** [b)]
- **Scales** [a)]

Measuring instruments in the automotive industry

- **Exhaust gas analyzers for spark ignition engines** [b)]
- **Exhaust gas analyzers for compression ignition engines** [a)]
- **Installation surfaces for headlight testers** [b)]
- **Plate brake testers** [b)]
- **Roller brake testers** [b)]
- **Headlight testers** [b)]

Flow measurement quantities

- **Gas flow** [a)]

a) **also on-site calibration**

b) **only on-site calibration**

For the measurement quantities/calibration objects marked with *), the calibration laboratory is permitted to apply the standards/calibration guidelines listed here with different issue numbers without the need for prior notification and approval by DAkkS. The calibration laboratory has a current list of all standards/calibration guidelines in the flexible accreditation area.

Calibration and measurement capabilities

Location Eichenau

Mechanical measurement quantities – Pressure

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedures	Expanded measurement uncertainty	Remarks
Pressure Absolute pressure p_{abs} *)	> 0 bar to 3.0 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$2.9 \cdot 10^{-5} \cdot p_{abs}$ + 15 µbar	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 3.0 bar to 21 bar		$3.4 \cdot 10^{-5} \cdot p_{abs}$ + 0.19 mbar	
	> 21 bar to 101 bar		$3.9 \cdot 10^{-5} \cdot p_{abs}$ + 0.44 mbar + U_{baro}	
	> 101 bar to 251 bar		$5.1 \cdot 10^{-5} \cdot p_{abs}$ + 30 mbar + U_{baro}	
Absolute pressure p_{abs}	900 mbar to 1000 mbar	esz QMH XXIII.4.2 v5.0	$2.9 \cdot 10^{-5} \cdot p_{abs}$ + 15 µbar	Reference value ($p_{abs} = p_{amb}$) Single-point measurement at current ambient pressure
Absolute pressure p_{abs} *)	1 bar; 2 bar to 71 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$7.8 \cdot 10^{-5} \cdot p_{abs}$ + 0.36 mbar + U_{baro}	Reference value ($p_{abs} = p_{amb}$) Pressure medium: oil The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 71 bar to 701 bar		$8.2 \cdot 10^{-5} \cdot p_{abs}$ + 0.72 mbar + U_{baro}	
Absolute pressure p_{abs} *)	> 0 bar to 301 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$5.1 \cdot 10^{-5} \cdot p_{abs}$ + 30 mbar + U_{baro}	Pressure medium: water The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 301 bar to 1001 bar		$7.4 \cdot 10^{-5} \cdot p_{abs}$ + 40 mbar + U_{baro}	
Positive and negative overpressure p_e *)	-200 mbar to 200 mbar	DKD-R 6-1:2014 Calibration method: $p_e = p_{abs} - p_{amb}$	25 µbar	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	> -1 bar to 2 bar		$2.3 \cdot 10^{-5} \cdot p_e$ + 55 µbar + U_{baro}	
	> 2 bar to 20 bar		$3.7 \cdot 10^{-5} \cdot p_e$ + 0.19 mbar + U_{baro}	
	> 20 bar to 100 bar		$3.9 \cdot 10^{-5} \cdot p_e$ + 0.44 mbar	
	> 100 bar to 150 bar		$9 \cdot 10^{-5} \cdot p_e$ + 23 mbar	
	> 150 bar to 250 bar		$5.1 \cdot 10^{-5} \cdot p_e$ + 30 mbar	
Overpressure p_e *)	0 bar; 1 bar to 70 bar	DKD-R 6-1:2014	$7.8 \cdot 10^{-5} \cdot p_e$ + 0.36 mbar	Reference value (p_e = 0 bar) Pressure medium: oil
	> 70 bar to 700 bar		$8.2 \cdot 10^{-5} \cdot p_e$ + 0.72 mbar	
Overpressure p_e *)	> 0 bar to 300 bar	DKD-R 6-1:2014	$5.1 \cdot 10^{-5} \cdot p_{abs}$ + 30 mbar	Pressure medium: water
	> 300 bar to 1001 bar		$7.4 \cdot 10^{-5} \cdot p_{abs}$ + 40 mbar	

Mechanical measurement quantities – Flow measurement quantities

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Volume flow Q of flowing gases Flow meter or regulator with a display or transducer with electronic interface	5 mL/min to 50 L/min	Volumeter as standard	0.3% · Q + 0.02 mL/min	Q = measured value Calibration medium: dry air (rel. humidity < 10%) Measurement ranges based on dry air at 0 °C, 1013.25 mbar
	10 mL/min to 200 mL/min	Laminar flow elements as standard	0.5% · Q + 0.02 mL/min	
	> 0.2 L/min to 3.2 L/min		0.5% · Q + 0.32 mL/min	
	> 3.2 L/min to 40 L/min		0.5% · Q + 4 mL/min	
	> 40 L/min to 620 L/min		0.5% · Q + 0.06 L/min	

Mechanical measurement quantities – Force

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Force Measuring instruments and transducers *)	50 N to 50 kN	Tensile and compressive force according to DKD-R 3-3:2018	0.05%	

Mechanical measurement quantities – Torque

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Torque Hand-operated torque screwdrivers *)	0.2 N · m to < 1 N · m	DIN EN ISO 6789-2:2017	0.9%	Torque screwdriver
	1 N · m to 10 N · m		0.5%	
	0.4 N · m to < 4 N · m		0.7%	Torque wrench
	4 N · m to 1110 N · m		0.5%	

Mechanical measurement quantities – Mass

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Mass or conventional weight value *)	10 mg	OIML R111-01:2004	0.025 mg	for weights according to OIML R 111-1:2004 in accordance with class F_2
	20 mg		0.03 mg	
	50 mg		0.04 mg	
	100 mg		0.016 mg	for weights according to OIML R 111-1:2004 in accordance with class F_1
	200 mg		0.020 mg	
	500 mg		0.025 mg	
	1 g		0.03 mg	
	2 g		0.04 mg	
	5 g		0.05 mg	
	10 g		0.06 mg	
	20 g		0.08 mg	
	50 g		0.10 mg	
	100 g		0.16 mg	
	200 g		0.3 mg	
	500 g		2.5 mg	for weights according to OIML R 111-1:2004 in accordance with class F_2
	1 kg		1.6 mg	for weights according to OIML R 111-1:2004 in accordance with class F_1
	2 kg		30 mg	For weights according to OIML R 111-1:2004 in accordance with class M_1
	5 kg		25 mg	for weights according to OIML R 111-1:2004 in accordance with class F_2
	10 kg		0.5 g	for weights according to OIML R 111-1:2004 in accordance with class M_2
	20 kg		0.3 g	for weights according to OIML R 111-1:2004 in accordance with class M_1
	50 kg		0.8 g	
	10 mg to 20 mg	OIML R111-01:2004	0.03 mg	Free nominal values
	> 20 mg to 100 mg		0.04 mg	
	> 100 mg to 200 mg		0.02 mg	

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Mass or conventional weight value *)	> 200 mg to 500 mg		0.025 mg	Free nominal values
	> 500 mg to 1 g		0.03 mg	
	> 1 g to 2 g		0.04 mg	
	> 2 g to 5 g		0.05 mg	
	> 5 g to 10 g		0.06 mg	
	> 10 g to 20 g		0.08 mg	
	> 20 g to 50 g		0.10 mg	
	> 50 g to 100 g		0.16 mg	
	> 100 g to 200 g	OIML R111-01:2004	0.3 mg	
	> 200 g to 500 g		2.5 mg	
	> 500 g to 1 kg		1.6 mg	
	> 1 kg to 2 kg		30 mg	
	> 2 kg to 5 kg		25 mg	
	> 5 kg to 10 kg		0.5 g	
	> 10 kg to 20 kg		0.3 g	
	> 20 kg to 50 kg		0.8 g	
	> 50 kg to 65 kg		1.6 g	

Mechanical measurement quantities – Scales

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Scales Non-automatic electronic scales *)	≤ 50 kg	EURAMET cg-18:2015 DKD-R 7-2:2018	$1 \cdot 10^{-6}$	With weights accuracy class E_2 according to OIML R111-1:2004
	≤ 150 kg		$2 \cdot 10^{-5}$	With weights accuracy class F_2 according to OIML R111-1:2004

Thermodynamic measurement quantities – Temperature measurement quantities

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Resistance thermometer, direct reading thermometers with resistance sensor *)	0.01 °C	DKD-R 5-1:2018 Triple point of water	15 mK	Calibration at fixed temperature point
	-80 °C to < -40 °C	DKD-R 5-1:2018 in ethanol bath	45 mK	Comparison with standard resistance thermometers T = temperature in °C
	-40 °C to < 0 °C		25 mK	
	0 °C to 100 °C	DKD-R 5-1:2018 in silicone oil bath	20 mK	
	> 100 °C to 180 °C		25 mK	
	> 180 °C to 200 °C		35 mK	
	> 200 °C to 300 °C		50 mK	
	> 300 °C to 400 °C	DKD-R 5-1:2018 in block calibrator	80 mK	
	> 400 °C to 570 °C		$(1.6 \cdot 10^{-3} \cdot T/°C - 0.56)$ K	
	> 570 °C to 700 °C		350 mK	
Base metal thermocouples, direct reading thermometers with base metal thermocouple sensor *)	-80 °C to < -35 °C	DKD-R 5-3:2018 in ethanol bath	$(-1.2 \cdot 10^{-3} \cdot T/°C + 0.13)$ K	Comparison with standard resistance thermometer T = temperature in °C
	-35 °C to < 0 °C		$(-1.2 \cdot 10^{-3} \cdot T/°C + 0.09)$ K	
	0 °C to 35 °C	DKD-R 5-3:2018 in silicone oil bath	0.09 K	
	> 35 °C to 300 °C		$(0.5 \cdot 10^{-3} \cdot T/°C + 0.072)$ K	
	> 300 °C to 700 °C	DKD-R 5-3:2018 in block calibrator	$(0.6 \cdot 10^{-3} \cdot T/°C + 0.07)$ K	
	> 700 °C to 1210 °C	DKD-R 5-3:2018 in block calibrator	$(1.4 \cdot 10^{-3} \cdot T/°C + 1.3)$ K	Comparison with standard thermocouple T = temperature in °C
Precious metal thermocouples, direct reading thermometers with precious metal thermocouple sensor *)	0 °C to 35 °C	DKD-R 5-3:2018 in silicone oil bath	0.21 K	Comparison with standard resistance thermometer T = temperature in °C
	> 35 °C to 300 °C		$(0.3 \cdot 10^{-3} \cdot T/°C + 0.2)$ K	
	> 300 °C to 400 °C	DKD-R 5-3:2018 in block calibrator	$(0.3 \cdot 10^{-3} \cdot T/°C + 0.2)$ K	
	> 400 °C to 700 °C		$(0.7 \cdot 10^{-3} \cdot T/°C + 0.25)$ K	
	> 700 °C to 1210 °C	DKD-R 5-3:2018 in block calibrator	$(1.4 \cdot 10^{-3} \cdot T/°C + 1.3)$ K	Comparison with standard thermocouple T = temperature in °C
Block calibrators *)	-80 °C to 0 °C	DKD-R 5-4:2018	0.10 K	Comparison with standard resistance thermometer T = temperature in °C
	> 0 °C to 50 °C		0.056 K	
	> 50 °C to 700 °C		$(0.21 \cdot 10^{-3} \cdot T/°C + 0.045)$ K	

Permanent laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Temperature display devices and simulators for resistance thermometers *) Pt100	-199 °C	DKD-R 5-5:2018 Artifact calibration	1.0 mK	T = temperature in °C
	0 °C		2.4 mK	
	239 °C		4.8 mK	
	-200 °C to 800 °C	DKD-R 5-5:2018	$(12 \cdot 10^{-3} \cdot T/°C + 4)$ mK	
Pt25	-200 °C to -150 °C		2.3 mK	
	> -150 °C to 800 °C		$(19 \cdot 10^{-3} \cdot T/°C + 10)$ mK	
Pt500	-200 °C to 300 °C		$(13 \cdot 10^{-3} \cdot T/°C + 3.5)$ mK	
	> 300 °C to 800 °C		$(18 \cdot 10^{-3} \cdot T/°C + 5.4)$ mK	
Pt1000	-200 °C to 800 °C		$(17 \cdot 10^{-3} \cdot T/°C + 3.8)$ mK	
for base metal thermocouples *) Type K	-200 °C to < 0 °C	DKD-R 5-5:2018 without reference point compensation	$(-85 \cdot 10^{-3} \cdot T/°C + 11)$ mK	T = temperature in °C
	0 °C to 1300 °C		$(5.7 \cdot 10^{-6} \cdot (T/°C)^2 + 0.17 \cdot 10^{-3} \cdot T/°C + 11)$ mK	
Type J	-200 °C to < 0 °C		$(-61 \cdot 10^{-3} \cdot T/°C + 8)$ mK	
	0 °C to 1200 °C		$(5.6 \cdot 10^{-3} \cdot T/°C + 8)$ mK	
Type T	-200 °C to < 0 °C		$(-80 \cdot 10^{-3} \cdot T/°C + 11)$ mK	
	0 °C to 400 °C		11 mK	
Type E	-200 °C to < 0 °C		$(-56 \cdot 10^{-3} \cdot T/°C + 7)$ mK	
	0 °C to 1000 °C		$(4.4 \cdot 10^{-3} \cdot T/°C + 7)$ mK	
Type N	-200 °C to < 0 °C		$(-0.12 \cdot T/°C + 16)$ mK	
	0 °C to 1300 °C		$(12 \cdot 10^{-6} \cdot (T/°C)^2 + 10 \cdot 10^{-3} \cdot T/°C + 16)$ mK	
for precious metal thermocouples *) Type R, Type S	0 °C to 500 °C	DKD-R 5-5:2018 without reference point compensation	$(-64 \cdot 10^{-3} \cdot T/°C + 75)$ mK	T = temperature in °C
	> 500 °C to 1768 °C		45 mK	
Type B	50 °C to 1200 °C		$(26 \cdot 10^{-3} \cdot (T/°C)^{-0.85})$ mK	
	> 1200 °C to 1820 °C		60 mK	
for thermocouples *)	-200 °C to 1500 °C	DKD-R 5-5:2018 with reference point compensation	$\sqrt{\frac{U_{TC}^2}{(mK)} + 60^2}$ mK	U_{TC} = uncertainty of the display device or simulator for thermocouples without reference point compensation in mK
Measurement locations in climate chambers *)	-80 °C to 180 °C	DKD-R 5-7:2018 Method C	0.50 K	
	> 180 °C to 300 °C		0.70 K	
Climate chambers *)	-80 °C to 100 °C	DKD-R 5-7:2018 Method A or B	0.55 K	
	> 100 °C to 180 °C		0.75 K	
	> 180 °C to 300 °C		1.0 K	

Thermodynamic measurement quantities – Humidity measurement quantities

Permanent calibration laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Dew point temperature Dew point hygrometer	-28 °C to 24.8 °C	QMH XIV.5 Version 7.0 Air flow temperature: 10 °C to 25 °C Relative humidity: 5% to 98%	0.080 K	Comparison with dew point mirror hygrometer in climate generator or climate chamber
	-17 °C to 44.8 °C	QMH XIV.5 Version 7.0 Air flow temperature: > 25 °C to 45 °C Relative humidity: 5% to 98%	0.10 K	
	-3 °C to 59.8 °C	QMH XIV.5 Version 7.0 Air flow temperature: > 45 °C to 60 °C Relative humidity: 5% to 98%	0.15 K	
	17 °C to 89.8 °C	QMH XIV.5 Version 7.0 Air flow temperature: > 60 °C to 90 °C Relative humidity: 10% to 98%	0.3 K	Comparison with dew point mirror hygrometer in climate chamber
Relative humidity Humidity meters and transducers	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: 10 °C to 25 °C Dew point temperature t_d: -28 °C to 24.8 °C	0.25%	Comparison with dew point mirror in climate generator or climate chamber Measurement uncertainty expressed as absolute value of relative humidity
	> 20% to 40%		0.50%	
	> 40% to 60%		0.75%	
	> 60% to 80%		1.0%	
	> 80% to 98%		1.2%	
	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: > 25 °C to 45 °C Dew point temperature t_d: -17 °C to 44.8 °C	0.65%	
	> 20% to 40%		0.90%	
	> 40% to 60%		1.2%	
	> 60% to 80%		1.4%	
	> 80% to 98%		1.6%	
	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: > 45 °C to 60 °C Dew point temperature t_d: -3 °C to 59.8 °C	0.85%	
	> 20% to 40%		1.1%	
	> 40% to 60%		1.4%	
	> 60% to 80%		1.6%	
	> 80% to 98%		1.8%	
	10% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: > 60 °C to 90 °C Dew point temperature t_d: 17 °C to 89.8 °C	1.7%	Comparison with dew point mirror in climate chamber Measurement uncertainty expressed as absolute value of relative humidity
	> 20% to 40%		1.9%	
	> 40% to 60%		2.1%	
	> 60% to 80%		2.3%	
	> 80% to 98%		2.5%	

Permanent calibration laboratory – Location Eichenau

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Measurement locations in climate chambers with recirculating air *)	5% to 30%	DKD-R 5-7:2018 Method C Air flow temperature: 10 °C to 90 °C Dew point temperature t_d: -28 °C to 89.8 °C	1.0%	Humidity reference value is calculated from the dew point temperature and air flow temperature at the measurement location Measurement uncertainty expressed as absolute value of relative humidity
	> 30% to 60%		1.5%	
	> 60% to 80%		2.0%	
	>80% to 98%		2.5%	
Climate chambers with recirculating air *)	5% to 30%	DKD-R 5-7:2018 Method A or B Air flow temperature: 10 °C to 90 °C Dew point temperature t_d: -28 °C to 89.8 °C	1.5%	Humidity reference value is calculated from the dew point temperature and air flow temperature at the measurement location Measurement uncertainty expressed as absolute value of relative humidity
	> 30% to 60%		2.0%	
	> 60% to 80%		2.5%	
	> 80% to 98%		3.0%	

Location Nuremberg

Permanent laboratory – Location Nuremberg

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span			Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Temperature Resistance thermometer, direct reading thermometer with resistance sensor *)	-40 °C	to	0 °C	DKD-R 5-1:2018 in block calibrator	$\left(-1.8 \cdot 10^{-3} \cdot \frac{t}{°C} + 0.063\right)$ K	Comparison with standard resistance thermometers t = temperature in °C
	> 0 °C	to	155 °C		$\left(0.3 \cdot 10^{-3} \cdot \frac{t}{°C} + 0.063\right)$ K	
Torque Hand-operated torque screwdrivers *)	0.2 N · m	to	< 1 N · m	DIN EN ISO 6789-2:2017	0.9%	Torque screwdriver
	1 N · m	to	10 N · m		0.5%	
	0.4 N · m	to	< 4.0 N · m		0.7%	Torque wrench
	4 N · m	to	1100 N · m		0.5%	

Location Regensburg

Permanent laboratory – Location Regensburg

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Exhaust gas analyzers for compression ignition engines Particle number concentration Particle generators and analyzers (aerosol)	$5 \cdot 10^3$ cm^{-3} to $50 \cdot 10^3$ cm^{-3}	AA0399 Version 1.0 Verkehrsblatt 2021 Issue 11, No. 133	20%	The average particle size must be in the range of 10 nm to 200 nm
	> $50 \cdot 10^3$ cm^{-3} to $3 \cdot 10^6$ cm^{-3}		13%	
Particle concentration reduction factor PCRF	1:1 to 1:30000	AA0398 Version 1.0	9%	The particle size must be in the range of 10 nm to 200 nm
Particle analyzers *)	1000 cm^{-3} to 30000 cm^{-3}	10 nm to 200 nm ISO 27891:2015-03	11%	

Location Steinfurt

Permanent laboratory – Location Steinfurt

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Temperature Resistance thermometers, direct reading thermometers with resistance sensor *)	-40 °C to 0 °C	DKD-R 5-1:2018 in block calibrator	$\left(-1.8 \cdot 10^{-3} \cdot \frac{t}{°C} + 0.063\right)$ K	Comparison with standard resistance thermometers t = temperature in °C
	> 0 °C to 155 °C		$\left(0.3 \cdot 10^{-3} \cdot \frac{t}{°C} + 0.063\right)$ K	
Pressure Absolute pressure p_{abs} *)	0 bar to 21 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$45 \cdot 10^{-6} \cdot p_{abs}$ + 0.6 mbar + U_{baro}	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 21 bar to 700 bar		$79 \cdot 10^{-3} \cdot p_{abs} + U_{baro}$	Pressure medium: water The measurement uncertainty of the barometer U_{baro} must be taken into account
Negative and positive overpressure p_e *)	-200 mbar to 200 mbar	DKD-R 6-1:2014	$25 \cdot 10^{-3}$ mbar	Pressure medium: gas
	-1 bar to 2 bar		$33 \cdot 10^{-6} \cdot p_e$ + 0.25 mbar	
	> 2 bar to 20 bar		$45 \cdot 10^{-6} \cdot p_e$ + 0.6 mbar	
	> 20 bar to 700 bar		$79 \cdot 10^{-3} \cdot p_e$	Pressure medium: water

Location Vienna

Permanent laboratory – Location Vienna

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Temperature Resistance thermometer, direct reading thermometer with resistance sensor *)	-20 °C to 100 °C	DKD-R 5-1:2018 in silicone oil bath	0.047 K	Comparison with standard resistance thermometers t = temperature in °C
Pressure Absolute pressure p_{abs} *)	0 bar to 21 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$45 \cdot 10^{-6} \cdot p_{abs}$ + 0.46 mbar + U_{baro}	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 21 bar to 200 bar		$2.9 \cdot 10^{-4} \cdot p_{abs}$ + 27 mbar + U_{baro}	
	> 200 bar to 1000 bar		$9.7 \cdot 10^{-4} \cdot p_{abs}$ + 59 mbar + U_{baro}	Pressure medium: water The measurement uncertainty of the barometer U_{baro} must be taken into account
Negative and positive overpressure p_e *)	-400 mbar to 400 mbar	DKD-R 6-1:2014	0.10 mbar	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	-1 bar to 20 bar		$45 \cdot 10^{-6} \cdot p_e$ + 0.46 mbar	
	> 20 bar to 200 bar		$2.9 \cdot 10^{-4} \cdot p_e$ + 27 mbar	
	> 200 bar to 1000 bar		$9.7 \cdot 10^{-4} \cdot p_e$ + 59 mbar	Pressure medium: water
Volume flow Q of flowing gases Flow meter or regulator with a display or transducer with electronic interface	0.005 L/min to 0.03 L/min	QMH Chapter XXV.6: Version 7 Laminar flow elements as standard	0.3 mL/min	Q = measured value Calibration medium: air (rel. humidity < 10%) Measurement ranges based on dry air at 0 °C, 1013.25 mbar
	> 0.03 L/min to 200 L/min		1% · Q	
	> 200 L/min to 500 L/min	MFC as standard	$0.89 \cdot 10^{-2} \cdot Q$ + 0.52 L/min	

On-site calibration

Thermodynamic measurement quantities – Temperature measurement quantities

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Resistance thermometers, direct reading thermometers with resistance sensor *)	0 °C	DKD-R 5-1:2018 ice point	20 mK	Comparison with standard resistance thermometer T = temperature in °C
	-40 °C to 100 °C	DKD-R 5-1:2018 in block calibrator	50 mK	
	> 100 °C to 200 °C		75 mK	
	> 200 °C to 400 °C		80 mK	
	> 400 °C to 570 °C		$(1.6 \cdot 10^{-3} \cdot T/°C - 0.56)$ K	
	> 570 °C to 700 °C		350 mK	
Base metal thermocouples, direct reading thermometers with base metal thermocouple sensor *)	-40 °C to 200 °C	DKD-R 5-3:2018 in block calibrator	$(0.8 \cdot 10^{-3} \cdot T/°C + 0.1)$ K	Comparison with standard resistance thermometer T = temperature in °C
	> 200 °C to 400 °C		$(1.0 \cdot 10^{-3} \cdot T/°C + 0.08)$ K	
	> 400 °C to 700 °C		$(0.6 \cdot 10^{-3} \cdot T/°C + 0.07)$ K	
	> 700 °C to 1210 °C		$(1.4 \cdot 10^{-3} \cdot T/°C + 1.3)$ K	Comparison with standard thermocouple T = temperature in °C
Precious metal thermocouples, direct reading thermometers with precious metal thermocouple sensor *)	0 °C to 100 °C	DKD-R 5-3:2018 in block calibrator	0.22 K	Comparison with standard resistance thermometer T = temperature in °C
	> 100 °C to 200 °C		0.25 K	
	> 200 °C to 400 °C		$(0.3 \cdot 10^{-3} \cdot T/°C + 0.2)$ K	
	> 400 °C to 700 °C		$(0.7 \cdot 10^{-3} \cdot T/°C + 0.25)$ K	
	> 700 °C to 1210 °C		$(1.4 \cdot 10^{-3} \cdot T/°C + 1.3)$ K	Comparison with standard thermocouple T = temperature in °C
Block calibrators *)	-80 °C to 0 °C	DKD-R 5-4:2018	0.10 K	Comparison with standard resistance thermometer T = temperature in °C
	> 0 °C to 50 °C		0.056 K	
	> 50 °C to 700 °C		$(0.21 \cdot 10^{-3} \cdot T/°C + 0.045)$ K	

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Temperature display devices and simulators for resistance thermometers *)	-199 °C	DKD-R 5-5:2018 Artifact calibration	1.0 mK	T = temperature in °C
	0 °C		2.4 mK	
	239 °C		4.8 mK	
Pt100	-200 °C to 800 °C	DKD-R 5-5:2018 without reference point compensation	$(12 \cdot 10^{-3} \cdot T/°C + 4)$ mK	
Pt25	-200 °C to -150 °C		2.3 mK	
	> -150 °C to 800 °C		$(19 \cdot 10^{-3} \cdot T/°C + 10)$ mK	
Pt500	-200 °C to 300 °C		$(13 \cdot 10^{-3} \cdot T/°C + 3.5)$ mK	
	> 300 °C to 800 °C		$(18 \cdot 10^{-3} \cdot T/°C + 5.4)$ mK	
Pt1000	-200 °C to 800 °C		$(17 \cdot 10^{-3} \cdot T/°C + 3.8)$ mK	
for base metal thermocouples *)	-200 °C to < 0 °C		$(-85 \cdot 10^{-3} \cdot T/°C + 11)$ mK	T = temperature in °C
Type K	0 °C to 1300 °C		$(5.7 \cdot 10^{-6} \cdot (T/°C)^2 + 0.17 \cdot 10^{-3} \cdot T/°C + 11)$ mK	
Type J	-200 °C to < 0 °C		$(-61 \cdot 10^{-3} \cdot T/°C + 8)$ mK	
	0 °C to 1200 °C		$(5.6 \cdot 10^{-3} \cdot T/°C + 8)$ mK	
Type T	-200 °C to < 0 °C		$(-80 \cdot 10^{-3} \cdot T/°C + 11)$ mK	
	0 °C to 400 °C		11 mK	
Type E	-200 °C to < 0 °C		$(-56 \cdot 10^{-3} \cdot T/°C + 7)$ mK	
	0 °C to 1000 °C		$(4.4 \cdot 10^{-3} \cdot T/°C + 7)$ mK	
Type N	-200 °C to < 0 °C		$(-0.12 \cdot 10^{-3} \cdot T/°C + 16)$ mK	
	0 °C to 1300 °C		$(12 \cdot 10^{-6} \cdot (T/°C)^2 + 10 \cdot 10^{-3} \cdot T/°C + 16)$ mK	
for precious metal thermocouples *)	0 °C to 500 °C	DKD-R 5-5:2018 without reference point compensation	$(-64 \cdot 10^{-3} \cdot T/°C + 75)$ mK	T = temperature in °C
Type R, Type S	> 500 °C to 1768 °C		45 mK	
Type B	50 °C to 1200 °C		$(26 \cdot 10^{-3} \cdot (T/°C)^{-0.85})$ mK	
	> 1200 °C to 1820 °C		60 mK	
for thermocouples *)	-200 °C to 1500 °C	DKD-R 5-5:2018 with reference point compensation	$\sqrt{\frac{U_{TC}^2}{(mK)} + 60^2}$ mK	U_{TC} = uncertainty of the display device or simulator for thermocouples without reference point compensation in mK
Measurement locations in climate chambers *)	-80 °C to 180 °C	DKD-R 5-7:2018 Method C	0.50 K	
	> 180 °C to 300 °C		0.70 K	
Climate chambers *)	-80 °C to 100 °C	DKD-R 5-7:2018 Method A or B	0.55 K	
	> 100 °C to 180 °C		0.75 K	
	> 180 °C to 300 °C		1.0 K	

Thermodynamic measurement quantities – Humidity measurement quantities

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Dew point temperature Dew point hygrometers	-28 °C to 24.5 °C	QMH XIV.5 Version 7.0 Air flow temperature: 10 °C to 25 °C Relative humidity: 5% to 95%	0.080 K	Comparison with dew point mirror hygrometer in climate generator
	-17 °C to 44 °C	QMH XIV.5 Version 7.0 Air flow temperature: > 25 °C to 45 °C Relative humidity: 5% to 95%	0.10 K	
	-3 °C to 58 °C	QMH XIV.5 Version 7.0 Air flow temperature: > 45 °C to 60 °C Relative humidity: 5% to 90%	0.15 K	
Relative humidity Humidity meters and transducers	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: 10 °C to 25 °C Dew point temperature t_d: -28 °C to 24.5 °C	0.25%	Measurement uncertainty expressed as absolute value of relative humidity Comparison with dew point mirror in climate generator
	> 20% to 40%		0.50%	
	> 40% to 60%		0.75%	
	> 60% to 80%		1.0%	
	> 80% to 95%		1.2%	
	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: > 25 °C to 45 °C Dew point temperature t_d: -17 °C to 44 °C	0.65%	
	> 20% to 40%		0.90%	
	> 40% to 60%		1.2%	
	> 60% to 80%		1.4%	
	> 80% to 95%		1.6%	
	5% to 20%	QMH XIV.5 Version 7.0 Air flow temperature: > 45 °C to 60 °C Dew point temperature t_d: -3 °C to 58 °C	0.85%	
	> 20% to 40%		1.1%	
	> 40% to 60%		1.4%	
	> 60% to 80%		1.6%	
	> 80% to 90%		1.8%	

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Measurement locations in climate chambers with recirculating air *)	5% to 30%	DKD-R 5-7:2018 Method C Air flow temperature: 10 °C to 90 °C Dew point temperature t_d: -28 °C to 89.8 °C	1.0%	Measurement uncertainty expressed as absolute value of relative humidity Humidity reference value is calculated from dew point temperature and air flow temperature at the measurement location
	> 30% to 60%		1.5%	
	> 60% to 80%		2.0%	
	> 80% to 98%		2.5%	
Climate chambers with recirculating air *)	5% to 30%	DKD-R 5-7:2018 Method A or B Air flow temperature: 10 °C to 90 °C Dew point temperature t_d: -28 °C to 89.8 °C	1.5%	Measurement uncertainty expressed as absolute value of relative humidity Humidity reference value is calculated from dew point temperature and air flow temperature at the measurement location
	> 30% to 60%		2.0%	
	> 60% to 80%		2.5%	
	> 80% to 98%		3.0%	

Mechanical measurement quantities – Flow measurement quantities

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Volume flow Q of flowing gases Flow meter or regulator with a display or transducer with electronic interface	0.005 L/min to 0.03 L/min	Laminar flow elements as standard	0.3 mL/min	Q = measured value Calibration medium: dry air (rel. humidity < 10%) Measurement ranges based on dry air at 0 °C, 1013.25 mbar
	> 0.03 L/min to 200 L/min		$1 \cdot 10^{-2} \cdot Q$	
	> 200 L/min to 500 L/min	MFC as standard	$0.89 \cdot 10^{-2} \cdot Q + 0.52$ L/min	

Mechanical measurement quantities – Pressure

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Pressure Absolute pressure p_{abs} *)	> 0 bar to 21 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$5.0 \cdot 10^{-5} \cdot p_{abs} + 1.2$ mbar + U_{baro}	Pressure medium: gas The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 21 bar to 251 bar		$5.1 \cdot 10^{-5} \cdot p_{abs} + 30$ mbar + U_{baro}	
Absolute pressure p_{abs} *)	1 bar; 2 bar to 71 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$7.8 \cdot 10^{-5} \cdot p_{abs} + 0.36$ mbar + U_{baro}	Reference value ($p_{abs} = p_{amb}$) Pressure medium: oil The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 71 bar to 701 bar		$8.2 \cdot 10^{-5} \cdot p_{abs} + 0.72$ mbar + U_{baro}	
Absolute pressure p_{abs}	900 mbar to 1100 mbar	esz QMH XXIII.4.2 v5.0	$2.9 \cdot 10^{-5} \cdot p_{abs} + 15$ µbar	Reference value ($p_{abs} = p_{amb}$) Single-point measurement at current ambient pressure
Absolute pressure p_{abs} *)	> 0 bar to 301 bar	DKD-R 6-1:2014 Calibration method: $p_{abs} = p_e + p_{amb}$	$5.1 \cdot 10^{-5} \cdot p_{abs} + 30$ mbar	Pressure medium: water The measurement uncertainty of the barometer U_{baro} must be taken into account
	> 301 bar to 1001 bar		$7.4 \cdot 10^{-5} \cdot p_{abs} + 40$ mbar	
Positive and negative overpressure p_e *)	-200 mbar to 200 mbar	DKD-R 6-1:2014	25 µbar	Pressure medium: gas
	-1 bar to 2 bar		$3.3 \cdot 10^{-5} \cdot p_e + 0.25$ mbar	
	> 2 bar to 20 bar		$4.3 \cdot 10^{-5} \cdot p_e + 0.61$ mbar	
	> 20 bar to 100 bar		$9.0 \cdot 10^{-5} \cdot p_e + 3.7$ mbar	
	> 100 bar to 300 bar		$5.1 \cdot 10^{-5} \cdot p_e + 30$ mbar	
Overpressure p_e *)	0 bar; 1 bar to 70 bar	DKD-R 6-1:2014	$7.8 \cdot 10^{-5} \cdot p_e + 0.36$ mbar	Reference value ($p_e = 0$ bar) Pressure medium: oil
	> 70 bar to 700 bar		$8.2 \cdot 10^{-5} \cdot p_e + 0.72$ mbar	
Overpressure p_e *)	> 0 bar to 300 bar	DKD-R 6-1:2014	$5.1 \cdot 10^{-5} \cdot p_{abs} + 30$ mbar	Pressure medium: water
	> 300 bar to 1000 bar		$7.4 \cdot 10^{-5} \cdot p_{abs} + 40$ mbar	

Mechanical measurement quantities – Force

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Force Measuring instruments and transducers *)	50 N to 50 kN	Tensile and compressive force according to DKD-R 3-3:2018	0.05%	

Mechanical measurement quantities – Torque

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Torque Hand-operated torque screwdrivers *)	0.2 N · m to < 1 N · m	DIN EN ISO 6789-2:2017	0.9%	Torque screwdriver
	1 N · m to 10 N · m		0.5%	
	0.4 N · m to < 4 N · m		0.7%	Torque wrench
	4 N · m to 1110 N · m		0.5%	
Torque Torque transducer in test benches	0 N · m to 100 N · m	AA0397 Version 1.0 (August 16, 2023)	0.001 · *M* + 0.025 N · m	*M* = measured value in N · m Bending moments and transverse forces acting on the calibration device must be taken into account
	> 100 N · m to 10 kN · m		0.002 · *M* + 0.050 N · m	

Mechanical measurement quantities – Scales

On-site calibration

Calibration and measurement options (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Scales Non-automatic electronic scales *)	≤ 50 kg	EURAMET cg-18:2015 DKD-R 7-2:2018	$1 \cdot 10^{-6}$	With weights accuracy class E_2 according to OIML R111-1:2004
	≤ 150 kg		$2 \cdot 10^{-5}$	With weights accuracy class F_2 according to OIML R111-1:2004

Mechanical measurement quantities – Measuring instruments in the automotive industry

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Roller brake testers	0 N to < 2 kN	Verkehrsblatt 2016 Issue 14, No. 115 QMH Chapter XXVII.1.2: Version 5 Comparison method: XXVII.1.2.1 Mass lever Procedure: XXVII.1.2.2	19 N	*F* = force displayed on the brake tester Measurement system: force transducer with load frame
	2 kN to 4 kN		0.46% · *F* + 7 N	
	> 4 kN to 8 kN		0.43% · *F* + 8 N	
	> 8 kN to 40 kN		0.70% · *F*	
	0 kN to 4 kN		0.40% · *F* + 4 N	*F* = force displayed on the brake tester Measurement system: lever with weights
	> 4 kN to 8 kN		0.65% · *F*	
	> 8 kN to 40 kN		0.90% · *F*	
Plate brake testers	0 N to < 2 kN	Verkehrsblatt 2016 Issue 14, No. 115 QMH Chapter XXVII.1.2: Version 5	0.20% · *F* + 12 N	*F* = force displayed on the brake test stand Measurement system: force transducer
	2 kN to 10 kN		0.70% · *F* + 2 N	
Headlight testers Inclination	0% to 6%	Verkehrsblatt 2016 Issue 14, No. 115 Verkehrsblatt 2018 Issue 23, No. 174 QMH Chapter XXIX. 3: Version 6.0	0.1%	Statement of measurement uncertainty as absolute value of inclination
Installation surfaces for headlight testers Inclination	0% to 10%	Verkehrsblatt 2018 Issue 23, No. 174 QMH Chapter XXIX. 3: Version 6.0	0.038%	Statement of measurement uncertainty as absolute value of inclination
Installation surfaces for motor vehicles Inclination	0 m to 10 m 0% to 10%	Verkehrsblatt 2018 Issue 23, No. 174 QMH Chapter XXIX. 3: Version 6.0	0.23 mm/m + 0.53 mm/*L*	Measurement system: self-leveling line laser DIN 18202:2013 *L* = measured length in meters *R* = grid point spacing in meters
Flatness	0 mm to 50 mm		0.53 mm + 0.23 mm/m · *R*	

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Exhaust gas analyzers for spark ignition engines Gas concentration Propane C_3H_8	80 ppm vol 200 ppm vol 2000 ppm vol	Verkehrsblatt 2018, Issue 11, No. 100 QMH Chapter 26-7 XXX	2 ppm vol 3 ppm vol 24 ppm vol	ppm vol = $10^{-6} \cdot m^3/m^3$ % vol = $10^{-2} \cdot m^3/m^3$
Carbon dioxide CO_2	3% vol 6% vol 14% vol		0.039% vol 0.072% vol 0.17% vol	
Carbon monoxide CO	0.1% vol 0.5% vol 3.5% vol		0.0039% vol 0.0070% vol 0.042% vol	
Oxygen O_2	20.9% vol		0.31% vol	
Exhaust gas analyzers for compression ignition engines Turbidity level	10%; 30%; 50%; 70%		0.9%	Turbidity measurement with neutral gray filter Measurement uncertainty is the absolute value of the turbidity level
Turbidity coefficient	0.25 m^{-1}		0.02 m^{-1}	The turbidity coefficient is calculated from the turbidity level
	0.83 m^{-1}		0.03 m^{-1}	
	1.61 m^{-1}		0.04 m^{-1}	
	2.80 m^{-1}		0.07 m^{-1}	

On-site calibration

Calibration and measurement capabilities (CMC)

Measurement quantity / calibration object	Measurement range / measurement span	Measurement conditions / procedure	Expanded measurement uncertainty	Remarks
Exhaust gas analyzers for compression ignition engines Particle number concentration Particle generators and analyzers (aerosol)	$5 \cdot 10^3$ cm^{-3} to $50 \cdot 10^3$ cm^{-3}	AA0399 Version 1.0 Verkehrsblatt 2021 Issue 11, No. 133	20%	The average particle size must be in the range of 10 nm to 200 nm
	> $50 \cdot 10^3$ cm^{-3} to $3 \cdot 10^6$ cm^{-3}		13%	

Abbreviations used:

AA	Work instruction (self-developed procedure) of esz AG (Arbeitsanweisung)
CMC	Calibration and measurement capabilities
DIN	German Institute for Standardization (Deutsches Institut für Normung e.V.)
DKD-R	Guideline of the German Calibration Service (DKD), published by the Physikalisch-Technische Bundesanstalt (Richtlinie des Deutschen Kalibrierdienstes)
EN	European standard (Europäische Norm)
EURAMET	European Association of National Metrology Institutes
OIML	International Organization of Legal Metrology
QMH	Quality management manual (self-developed procedure) of esz AG (Qualitätsmanagementhandbuch)