PULSED INDUCTANCE MEASUREMENT

POWER CHOKE TESTER

DPG10 B – SERIES

Description & Technical Specifications

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Issue 01/24

Product Description

The Power Choke Tester DPG10 series is an innovative measurement instrument series for all inductive power components.

The large-signal impulse measuring method provides a complete inductance curve as a function of the current L(i) or as a function of the applied time-voltage-integral L(∫Udt). Thus the saturation characteristics of the power inductor can be seen clearly at a glance.

Besides the differential inductance and the amplitude inductance a lot of other variables can be measured.

The Power Choke Tester DPG10 series has become a quasi-standard test device for the development, manufacture and quality control of inductive power components.

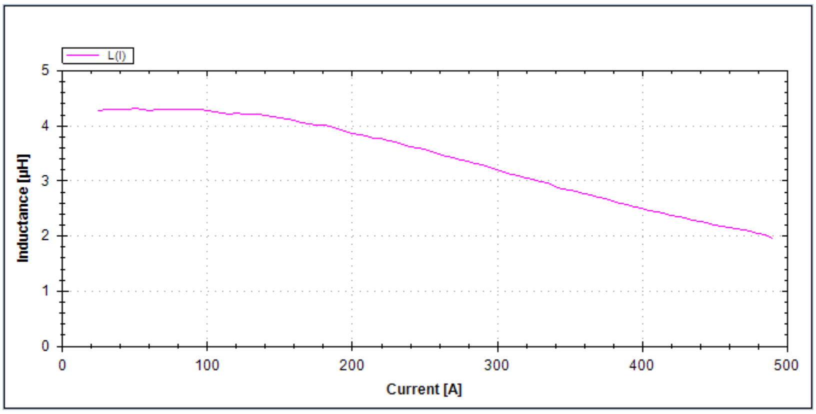


Fig 1: Inductance curve $L_{diff}(i)$

Features

* Measurement of the **differential inductance L_{diff}(i)** and the **amplitude inductance L_{amp}(i)**
* Measurement of the **flux linkage ψ(i)** and the **magnetic co-energy W_{co}(i)**
* Measurement of the **DC resistance**
* Calculation of the **flux density B(i)**
* By means of the optional 3-phase Extension Unit also suitable for **3-phase chokes**

Advantages

* Very **easy and fast** measurement
* **Small, lightweight and affordable price-point** despite of the high measuring current up to 4000A
* High sample rate and very wide pulse width range => suitable for **all core materials**
* **No thermal influence** on the inductor under test

Powerful software

* **Easy and intuitive operation** via a user-friendly graphical user-interface
* Measurement results shown as **diagram** and as **table**
* **Separate applications** optimized for **R&D + small batch routine testing (main application)** and routine testing in **mass production (production application)**
* **Data storage** in a **database** or in **XML format**

* **Measurement report** in pdf-format, **data export and data storage** (XML, CSV)
* **Easy integration in own automated test environments** by means of a DLL or by LabVIEW including sample applications in .NET, C# und C++
* **Updates** available **free of charge**

Applications

* **Development, research** and **quality inspection**
* **Routine tests** of small batch series and mass production
* Very wide current range from <0.1A up to 4000A => **suitable for all inductive components** from **small SMD inductors** to **very large power reactors in the MVA range**, e.g.
    - Filter inductors for switch mode power supplies, DC/DC converters etc.
    - Filter inductors for uninterruptible power supplies, inverters etc.
    - Power chokes for PFC etc. and commutation inductors
    - Suppression chokes and current compensated chokes
    - Solenoids, coils of valves
    - Transformers for flyback converters
    - Power transformers, motors
    - and much, much more inductive components

Performance characteristics

The maximum level of current, which when exceeded causes the measuring impulse to be terminated, is adjustable in steps of 1A (DPG10-100B in steps of 0.1A). There are three measuring ranges each.

	DPG10-100B	DPG10-1000B	DPG10-2000B	DPG10-2000B/E	DPG10-3000B/E	DPG10-4000B/F
Pulse current range 1	1A	10A	20A	20A	30A	40A
Pulse current range 2	10A	100A	200A	200A	300A	400A
Pulse current range 3	100A	1000A	2000A	2000A	3000A	4000A
Pulse energy, max.	1350J	1350J	1350J	2750J	2750J	8000J
Pulse voltage	10 - 400V					
Pulse width, max.	3µs – 1s					
Power supply	207 - 253VAC / 50 - 60Hz; optional 108 - 132VAC; 450VA max.					
Dimensions [mm³]	365 (B) x 325 (T) x 167 (H)					470 x 500 x 167
Weight [kg]	9.2	9.2	9.2	11.0	11.0	22.8

All core materials show a more or less a strong frequency dependency. To get realistic measurement results the measurement has to be performed with the same pulse width as in the real application.

Due to the high sample rate and the wide pulse width range of 3µs to 1s the DPG10 series is suitable for all core materials in the power electronics.

Measuring principle

The DPG10 works on the principle that a rectangular voltage pulse is applied to the test inductor, which corresponds to the inductor's real operational conditions. This will result in a current ramp in the test component, whose slew rate di/dt is subject to inductance.

If the pre-set maximum current limit is reached, the measurement impulse is cut off.

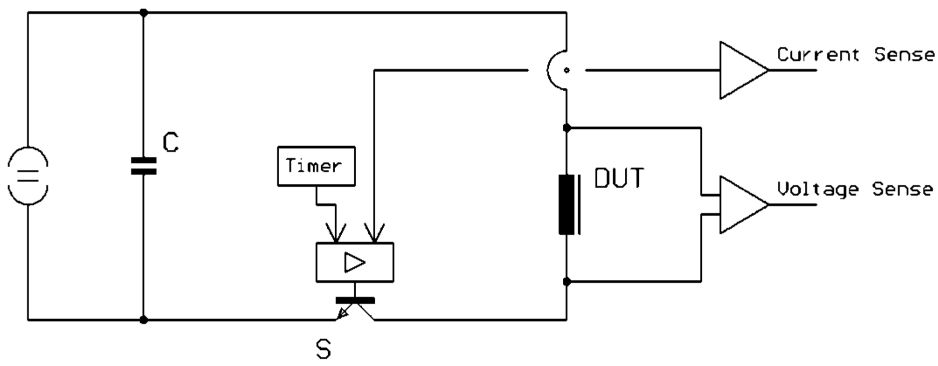


Fig 2: Principle circuit diagram

The current through the test component as well as the voltage applied to the test component (voltage sense lines) are sampled very fast and accurate during the measuring impulse. Based on the shape of the current and voltage impulse, the differential inductance, the amplitude inductance, the flux linkage and the magnetic co-energy can be calculated.
By taking a single measurement impulse the differential inductance as well as the amplitude inductance can be displayed as a complete inductance curve, either as a function of the current $L_{diff}(i)$ and $L_{amp}(i)$ or as a function of the applied voltage-time-integral $L_{diff}(\int Udt)$ and $L_{amp}(\int Udt)$.
(Remark: Sometimes the amplitude inductance is also called secant inductance.)

Advantages of the pulse measuring principle:

Pulse measurement with switchable IGBT power stages using the Power Choke Tester DPG10/20 series enables an extremely wide range of applications that cannot be achieved with any other measurement method and any other commercially available inductance meter.

The current range of the available models presently extends from < 0.1 A to 10 kA. The pulse energy stored in the choke can lie between a few µJ and 15kJ.

In most power electronics applications, the voltages at the inductor are rectangular. Only the pulse measurement method of the Power Choke Tester DPG10/20 series enables the measurement of the inductance with the same voltage, the same waveform and the same pulse width as in the real application. It therefore provides more realistic measurement results than other measurement methods.

Operating the instrument

A PC is used to operate the instrument and display results from the Power Choke Tester DPG10 via a user-friendly graphical user interface. The measuring instrument can be connected either to the USB port or the RS232 port of the PC.

The following parameters can be set before measuring inductance:

* Maximum current:
  The measuring impulse is terminated when this value is reached, so long as the pre-set maximum duration of the measuring impulse has not been reached before.

* Measuring impulse voltage:

A value should be entered here that corresponds to the test component's voltage levels during normal operating conditions.

* Maximum duration of the measuring impulse:
  The measuring impulse is terminated when this value is reached, so long as the maximum current level is not reached before.

All settings can be saved and reloaded when required. This considerably eases conducting a series of measurements for quality control checks during production.

If the instrument is incorrectly used (i.e. incorrect connection of the DUT or inadequate measurement parameters), then detailed error warnings help to quickly solve any problems.

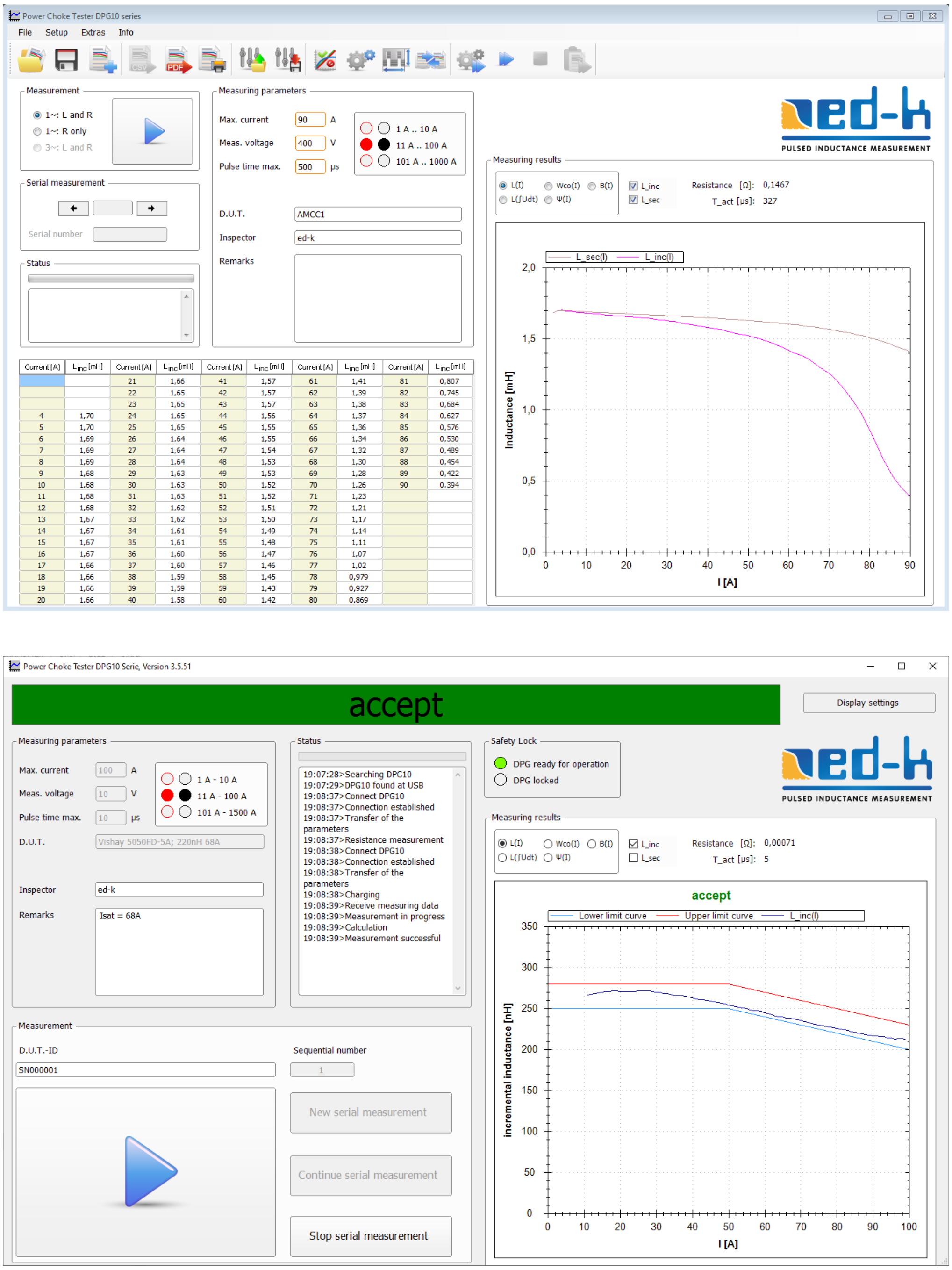


Fig 3: Graphical user interface of the main and the production application with L(i) diagram

Measurement result

After the measurements are complete, the results $L_{diff}(i)$, $L_{amp}(i)$, $\psi(i)$ and $W_{co}(i)$ are displayed in the form of both a diagram and in a table (see Fig 4).

Alternatively in some cases it could be useful to display the inductance as a function of the voltage-time-integral $\int U(t)dt$ applied to the inductor. The display mode is togglable.

A resistance test is automatically carried out before every inductance measurement is undertaken because the ohmic portion of the inductor must be considered in the calculation of the inductance curve. A resistance test can also be carried out separately.

Further functions

* Limit curves

  To make routine testing easier during production, minimum and maximum limit curves can be defined. If the measured inductance curve falls within the range created by these two limit curves, then the test component is passed, if not then it is failed..

* Routine tests

  The production app was optimized for routine testing in mass production. When using a scanner, it enables semi-automatic routine testing without user intervention. With automatic handling and contacting of the DUT via a specimen-specific test adapter, a fully automatic test is even possible.

  For small batch routine testing there are special functions in the laboratory application.

  To integrate the instrument in existing automated test environments a dynamic link library (DLL) as well as LabVIEW support is available.

* Saving measuring diagrams and exporting data

  Measuring diagrams including all measuring parameters and other data can be saved and restored later as required. It is possible to create a pdf measurement report at any time. To process the data in other applications it is also possible to export data in .csv format.

* Comparison of different measurements curves

  Saved measurements can be loaded into one diagram at the same time. Therefore comparing different measurements is very easy.

The PC software for the Power Choke Tester DPG10 is subject to continuous improvement. Further functions and diagram modes will be added in the future. Updates are available free of charge.

Safety Lock Interface

On the rear panel of the device there is a safety lock interface to which a floating safety switch (e.g. from a protective cover or a light curtain) can be connected.

If the safety switch is open the measuring pulse is locked. Therefore the measuring instrument can be operated outside of a laboratory environment by non-skilled workers according to the safety regulations. For laboratory use this function can be deactivated.

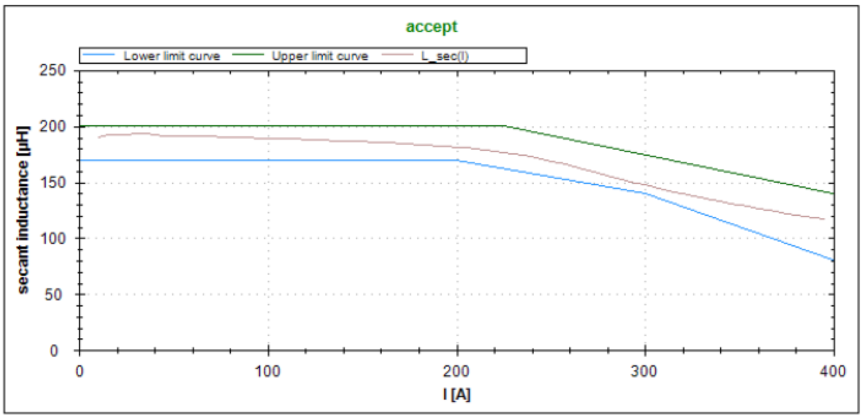
Measuring of Three-Phase Inductors

For measuring 3-phase-inductors an Extension Unit for the Power Choke Tester DPG10 series is available. The 3 windings of the inductor will be measured consecutively and automatically without reconnecting the terminals.

Due to other magnetic flux conditions in the core with 3-phase sinusoidal currents the software corrects the measurement results with a sophisticated algorithm.

DPG10 Power Choke Tester

D.U.T.: Sample
Inspector: ed-k
Date: 2017-9-19
Parameters: 400 A / 150 V / 600 (323) µs
Resistance [Ohm]: 0,0131



Current [A]	L_{sec} [µH]	Current [A]	L_{sec} [µH]	Current [A]	L_{sec} [µH]	Current [A]	L_{sec} [µH]	Current [A]	L_{sec} [µH]
		105	189	205	180	305	145		
10	190	110	189	210	180	310	143		
15	193	115	188	215	179	315	142		
20	192	120	188	220	178	320	140		
25	192	125	188	225	177	325	138		
30	193	130	187	230	176	330	136		
35	193	135	187	235	174	335	134		
40	192	140	187	240	173	340	133		
45	191	145	187	245	171	345	131		
50	191	150	186	250	169	350	130		
55	191	155	186	255	167	355	128		
60	191	160	185	260	165	360	126		
65	191	165	185	265	162	365	125		
70	191	170	185	270	160	370	124		
75	190	175	184	275	158	375	122		
80	190	180	184	280	156	380	121		
85	190	185	183	285	154	385	119		
90	190	190	182	290	152	390	118		
95	189	195	182	295	149	395	117		
100	189	200	181	300	147				

Remarks:
3x AMCC63
60 turns 508x0.1 HF litz wire
air gap 4mm

Fig 4: Measuring report of an inductor with upper and lower limits curves

Sample Applications

With the exception of air-core coils, all power inductors posses certain saturation characteristics. That means inductance decreases with increasing levels of current. This is due to the various core materials, which start to lose their permeability more or less strongly after a certain induction level B is reached and in extreme cases take on the characteristics of air. The saturation characteristics of an inductor can be influenced by

* the type of core material,
* core geometry,
* the number of turns,
* and the air gap.

However, deviations often exist between the calculated inductance at a certain current level (i.e. rated current) and the real inductance, because

* the inductor geometry causes a non-homogenous field distribution
* the core's spec sheet entries are inaccurate or incomplete
* production spread of the core is available
* manufacturing tolerances
* Thermal influences

For this reason it is important to measure saturation characteristics during the development phase and quality inspection of power inductors.

Filter choke with ferrite core E32

In this case, the test component is a filter choke for a switch mode power supply with an output voltage of 5V and a power of 100W. The E-core (E32) consists of standard ferrite material N27 and is fitted with an air gap.

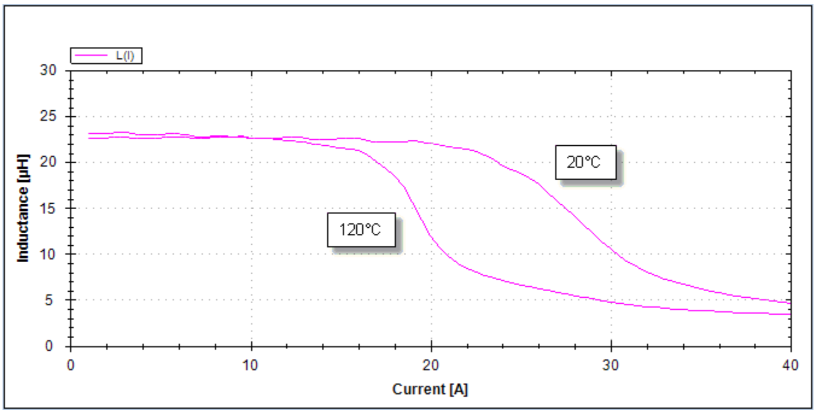


Fig 5: Measuring protocol of a filter choke with E32 ferrite core

In this example, occurrences of saturation are clearly linked to temperature. Inductance decreases by 25°C at 24A with 20µH. At 120°C, this threshold is reached at only 17A. Other core materials quite often demonstrate much less susceptibility to temperature

Inductors from the standard product range of manufacturers are particularly unsuited to or completely unrated with regard to inductance at higher temperatures. In this case, only taking saturation characteristic measurements yourself can do any good.

Balance choke with ribbon core

This balance choke is installed in a 12 pulse rectifier and is made up of a SU39 silicon iron ribbon core with an air gap. The rated current is 25A per coil. For the most part, the current flow is compensated by the circuit's topology. The rest of the uncompensated current lies at around 2 x 6A (max.)

A small-signal measurement shows an inductance of 1.31mH at 1kHz and 1.33mH at 100Hz. In this example it is clear to see, that the initial inductance which is measurable by a small-signal measuring device lies considerably under the real inductance level (1.9mH) present during operations.

Power inductors with iron based cores cannot be usefully measured using a small-signal AC measuring process, due to their extremely non-linear characteristics! Only a large signal measurement as used by the Power Choke Tester DPG10, can deliver the correct results.

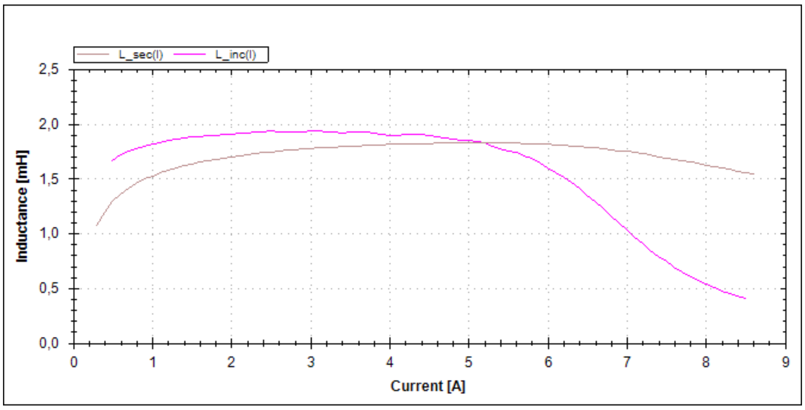


Fig 6: Measurement protocol L_{diff}(i) and L_{amp}(i) of a balance choke with a SU39 ribbon core

Filter choke with high flux core

This inductor has an initial inductance of 4.5µH and consists of three ring cores (high flux core material) with an outer diameter of 58mm. This is normally used in a switch mode power supply of 48V / 300A.

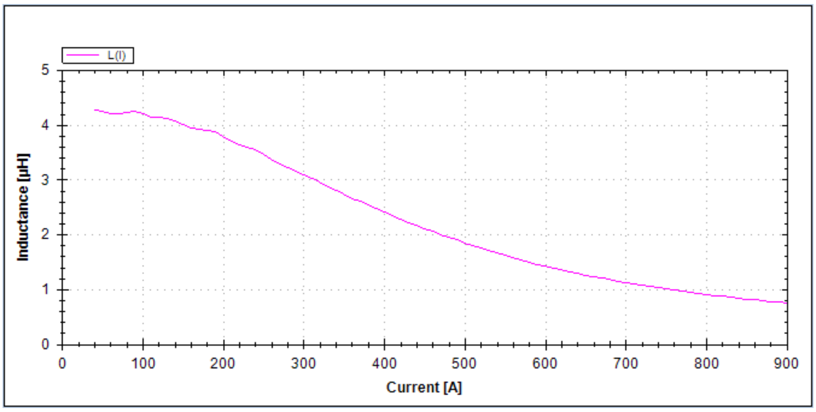


Fig 7: Measurement protocol of a filter choke with high flux core (3x R58)

The typical slope of the saturation profile of this core is very easy to discern. However, because this core material is very expensive, an optimal economic solution requires that the operational point at rated current lies beneath the level of initial inductance.

Technical Specifications

For general technical data please see the table on page 3

Accuracy*

DPG10 – 4000B /F:

Inductance measurement $L_{diff}(i)$, $L_{amp}(\int U dt)$

Measuring range 1:	
$I_{measmax} \leq 13$ A	± (1.0% + 13 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 13$ A	± (1.0% + 40 / $I_{measmax}$ * 0.9%)
Measuring range 2:	
$I_{measmax} \leq 133$ A	± (1.0% + 133 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 133$ A	± (1.0% + 400 / $I_{measmax}$ * 0.9%)
Measuring range 3:	
$I_{measmax} \leq 1333$ A	± (1.0% + 1333 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 1333$ A	± (1.0% + 4000 / $I_{measmax}$ * 0.9%)
Resistance measurement R_{DC}	
0 - 35.00 mΩ	±(0.1% + 0.1 mΩ)
35.0 - 350.0 mΩ	±(0.1% + 0.5 mΩ)
0.350 - 3.500 Ω	±(0.1% + 5 mΩ)
3.50 - 35.00 Ω	±(0.1% + 50 mΩ)

DPG10 – 3000B /E:

Inductance measurement $L_{diff}(i)$, $L_{amp}(\int U dt)$

Measuring range 1:	
$I_{measmax} \leq 10$ A	± (1.0% + 10 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 10$ A	± (1.0% + 30 / $I_{measmax}$ * 0.9%)
Measuring range 2:	
$I_{measmax} \leq 100$ A	± (1.0% + 100 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 100$ A	± (1.0% + 300 / $I_{measmax}$ * 0.9%)
Measuring range 3:	
$I_{measmax} \leq 1000$ A	± (1.0% + 1000 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 1000$ A	± (1.0% + 3000 / $I_{measmax}$ * 0.9%)
Resistance measurement R_{DC}	
0 - 35.00 mΩ	±(0.1% + 0.1 mΩ)
35.0 - 350.0 mΩ	±(0.1% + 0.5 mΩ)
0.350 - 3.500 Ω	±(0.1% + 5 mΩ)
3.50 - 35.00 Ω	±(0.1% + 50 mΩ)

DPG10 – 2000B (/E):

Inductance measurement $L_{diff}(i)$, $L_{amp}(\int U dt)$

Measuring range 1:	
$I_{measmax} \leq 6$ A	± (1.0% + 6 / $I_{measmax}$ * 0.9%)
$I_{measmax} > 6$ A	± (1.0% + 20 / $I_{measmax}$ * 0.9%)

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* Accuracy values remain valid up to one year after calibration.
Accuracy values do not take account of effects caused by core losses or AC ohmic resistance considerably larger than the DC ohmic resistance. The influence of these effects on the measurement results is however negligible with most inductive components.

Measuring range 2:	
$I_{measmax}$ ≤ 66 A	± (1.0% + 66 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 66 A	± (1.0% + 200 / $I_{measmax}$ * 0.9%)
Measuring range 3:	
$I_{measmax}$ ≤ 666 A	± (1.0% + 666 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 666 A	± (1.0% + 2000 / $I_{measmax}$ * 0.9%)
Resistance measurement R_{DC}	
0 - 35.00 mΩ	±(0.1% + 0.1 mΩ)
35.0 - 350.0 mΩ	±(0.1% + 0.5 mΩ)
0.350 - 3.500 Ω	±(0.1% + 5 mΩ)
3.50 - 35.00 Ω	±(0.1% + 50 mΩ)

<u>DPG10 – 1000B:</u>

Inductance measurement L_{diff}(i), L_{amp}(∫Udt)	
Measuring range 1:	
$I_{measmax}$ ≤ 3 A	± (1.0% + 3 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 3 A	± (1.0% + 10 / $I_{measmax}$ * 0.9%)
Measuring range 2:	
$I_{measmax}$ ≤ 30 A	± (1.0% + 30 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 30 A	± (1.0% + 100 / $I_{measmax}$ * 0.9%)
Measuring range 3 (DPG10 – 1000B):	
$I_{measmax}$ ≤ 309 A	± (1.0% + 300 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 309 A	± (1.0% + 1000 / $I_{measmax}$ * 0.9%)
Resistance measurement R_{DC}	
0 - 35.00 mΩ	±(0.1% + 0.1 mΩ)
35.0 - 350.0 mΩ	±(0.1% + 0.5 mΩ)
0.350 - 3.500 Ω	±(0.1% + 5 mΩ)
3.50 - 35.00 Ω	±(0.1% + 50 mΩ)

<u>DPG10 – 100B:</u>

Inductance measurement L_{diff}(i), L_{amp}(∫Udt)	
Measuring range 1:	
$I_{measmax}$ ≤ 0.3 A	± (1.0% + 0.3 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 0.3 A	± (1.0% + 1 / $I_{measmax}$ * 0.9%)
Measuring range 2:	
$I_{measmax}$ ≤ 3,0 A	± (1.0% + 3 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ >3.0 A	± (1.0% + 10 / $I_{measmax}$ * 0.9%)
Measuring range 3:	
$I_{measmax}$ ≤ 30,9 A	± (1.0% + 30 / $I_{measmax}$ * 0.9%)
$I_{measmax}$ > 30.9 A	± (1.0% + 100 / $I_{measmax}$ * 0.9%)
Resistance measurement R_{DC}	
0 - 35.00 mΩ	±(0.1% + 0.1 mΩ)
35.0 - 350.0 mΩ	±(0.1% + 0.5 mΩ)
0.350 - 3.500 Ω	±(0.1% + 5 mΩ)
3.50 - 35.00 Ω	±(0.1% + 50 mΩ)

Please note:
The accuracy data are valid for impulse times > 10 µs and inductance > 10 µH as well as proper connection of the device under test as specified with low parasitic inductive coupling between Force lines and Sense lines. The accuracy data are not valid for I < 0.08 * $I_{messmax}$. The impulse time can be roughly estimated as follows: $T = L_{average} * I_{max} / U_{meas}$

Scope of delivery

* DPG10 – 100B | - 1000B | - 2000B | - 2000B/E | - 3000B/E | - 4000B/F
* Cable set
    - Test leads Force, 0.6m, connector 4mm
    - Test leads Force, 0.6m, connector 6mm
    - Test leads Sense, 0.6m
    - 8 alligator clips
    - USB cable
    - RS232 cable
    - Power cord
* PC software for DPG10
* Instruction manual (German or English)
* Calibration certificate
* Dynamic Link Library (DLL)
    - Library for integration of the instrument in automated test environments

Accessories

* 3-Phase Extension Unit (EXT1 and EXT2)
    - Additional unit for the DPG10 Power Choke Tester series to measure the inductance of 3-phase chokes
    - All three coils of the choke are automatically measured in succession without changing the connections of the test specimen
    - In relation to other measurement principles, this method is much simpler, faster and more accurate

	EXT1	**EXT2**
Width	370 mm	470 mm
suitable for	DPG10-100B DPG10-1000B DPG10-2000B DPG10-2000B/E DPG10-3000B/E	DPG10-4000B/F

* Kelvin test leads (KK12-4)
    - Length: approx. 0.75m; connector: 4mm
    - Clampable wire diameter: 0 to 10mm
    - Max. measuring current: up to 30A
    - Avoid use when L < 5µH (uncertainty will increase)
* Kelvin test leads (KK11-4)
    - Length: approx. 1m; connector: 4mm
    - Clampable wire diameter: 1 to 25mm
    - Max. measuring current: up to 250A
    - Avoid use when L < 10µH (uncertainty will increase)
* Kelvin test leads (KK12-6)
    - Length: approx. 1.2m; connector: 6mm
    - Clampable wire diameter: up to 32mm
    - Max. measuring current: up to 1500A
    - Avoid use when L < 30µH (uncertainty will increase)
* Kelvin test leads (KK11-6)

- Length: approx. 1.4m; connector: 6mm
- Clampable wire diameter: up to 35mm
- Max. measuring current: up to 5000A
- Avoid use when L < 30µH (uncertainty will increase)

* Test lead set long, Force and Sense (KL11-4)
    - Length: approx. 2m; connector 4mm
    - Clampable wire diameter: 0 to 20mm
    - Max. measuring current: up to 1500A
    - Avoid use when L < 30µH (uncertainty will increase)

* Test lead set long, Force and Sense (KL11-6)
    - Length: approx. 2m; connector 6mm
    - Clampable wire diameter: 0 to 20mm
    - Max. measuring current: up to 1500A
    - Avoid use when L < 30µH (uncertainty will increase)

* Hard-top case (CASE1)
    - robust design made of aluminium profiles with compartments for accessories
    - 2 automatic locks, 3 hinges, 8 corner protections of steel
    - Internal dimensions: 650 x 410 x 230 mm^3