ZES Sensors and Accessories

for precision power meters LMG series 90/310/95/450/500

ZES current and voltage sensors and accessories

This data book is the technical dokumentation of the current and voltage sensors from ZES ZIMMER Electronic Systems GmbH to enlarge the measuring ranges of the power meters series LMG.

The first section of this paper gives an survey of all ZES current sensors and the safety precautions. Selection table and several arguments should help you to find a suitable sensor family or fill out the support request form. The second section is about the general current sensors, which you can use with every precision power meter of the LMG series. In the following sections the special sensors, wiring cables and accessories for the different precision power meters are described. Then you find a chapter with the precision high voltage divider for meters of the LMG series. The last section with frequently asked questions will help you to optimize the accuracy and give you some hints for the usage of our sensors.

But in all cases if you need more information or detailed support for your application please don’t hesitate to contact us, the engineers of ZES ZIMMER will help you.

We reserve the right to implement technical changes at any time, particularly where these changes will improve the performance.

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Content

1 Introduction

1.1 Safety precautions

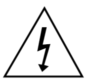
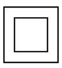
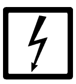
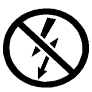
The following precautions are recommended to insure your safety and to provide the best conditions for the instruments.

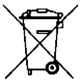
- When using voltage or current transformers please regard the applicable safety standards (earthing, isolation, ...)!
- The installation of powermeter and current sensors may be accomplished only by trained technical personnel!
- When operating the powermeter, current- and voltage sensors, certain parts can carry hazardous voltage (e.g. primary busbar, power supply). Ignoring this warning can lead to injury and/or cause serious damage.
- Read the user manual carefully and respect the safety precautions!
- Do not use these products in medical-related or any other equipment that may have a potential effect on human lives.
- Always observe the operating conditions and environmental requirements as indicated in this documentation when operating the product.
- Do not exceed the maximum specified voltage or current or use outside its measurement category.
- Always check the condition of the case and leads before use. Never operate the unit if it has a damaged cord or plug, if it is not working properly, or if it has been dropped or damaged or dropped into water.
- Avoid severe impacts or rough handling that could damage the instrument.
  Do not place any heavy object on the instrument.
- Keep the instruments away from water and other liquids.
- Use electrostatic discharge precautions while handling and making connections to the instrument.
- Do not block or obstruct the ventilation openings.

- Use suitable connection cables. Different current sensors have unique connection cables for each different precision power meter LMG. For example: the connection cable between PSU200 and LMG500 ‘PSU200-K-L50’ is neither suitable for PSU600 nor for LMG450.
- To avoid the risk of electrical shock, do not disassemble or attempt to repair the unit. Incorrect repair can cause risk of electrical shock or injury to persons when unit is used. For all repairs please return the devices to your distributor or to ZES ZIMMER Electronic Systems.
- Do not touch energized circuits.
- The power meter with its voltage and current sensors is not designed to detect hazards or similar! A wrong reading (e.g. by choosing a wrong filter or range) could give you the wrong impression of a safe state. Use appropriate tools instead of this instrument to detect dangerous situations.

1.1.1 Terms and symbols

These terms and symbols may appear in this manual or on the product.

	Warning, risk of danger! Refer to the operating instructions before using the device. In these operating instructions, failure to follow or carry out instructions preceded by this symbol may result in personal injury or damage to the device.
	Caution, risk of electric shock
	Earth (ground) terminal
	Protective conductor terminal
	Equipment protected throughout by double insulation or reinforced insulation.
	Application around and removal from hazardous live conductors is permitted.
	Do not apply around or remove from hazardous live conductors.

	This symbol indicates that this product is to be collected separately. This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste. For more information, contact the retailer or the local authorities in charge of waste management.

1.1.2 Definition of measurement categories

- Measurement category IV corresponds to measurements taken at the source of low voltage installations.
- Measurement category III corresponds to measurements on building installations.
- Measurement category II corresponds to measurements taken on circuits directly connected to low voltage installations.
- Measurement category I corresponds to measurements taken on circuits not directly connected to mains.

2 Current sensors

2.1 Active error compensated AC - current clamp 40A (LMG-Z406/-Z407)

(LMG-Z407 is a set of 4x LMG-Z406)

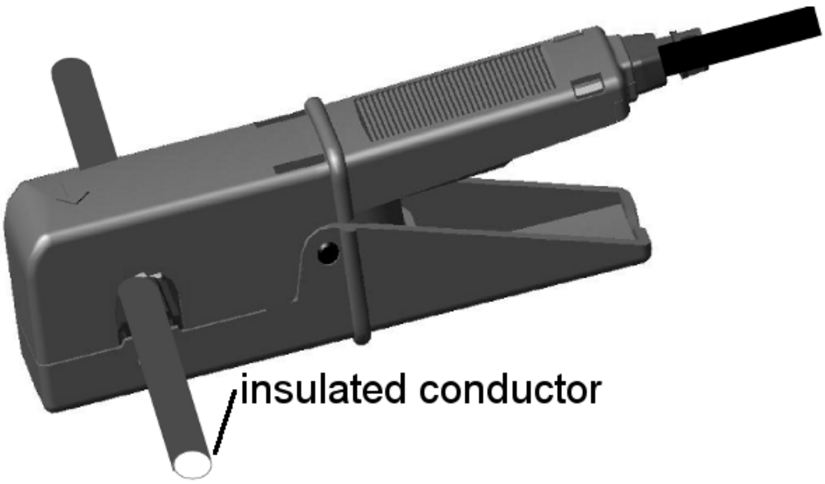


Figure 1: LMG-Z406/-Z407

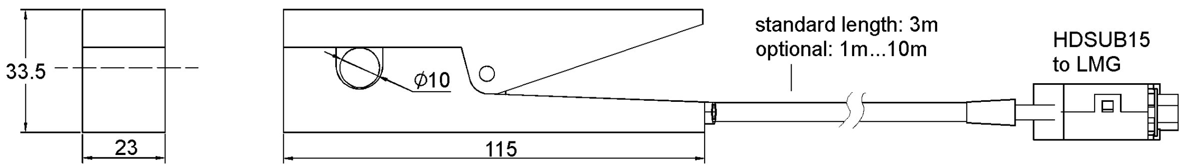


Figure 2: Dimensions of the LMG-Z406/-Z407

2.1.1 Safety warning!

No safety isolation, measurements only at insulated conductors allowed!
Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

2.1.2 Specifications

Nominal input current	40A
Max. trms value	80A
Measuring range current clamp	120Apk
Maximum input, overload capability	500A for 1s
Bandwidth	5Hz to 50kHz

Isolation	bare conductor: phase/ground 30Veff insulated conductor: see cable spec.
Degree of pollution	2
Temperature range	-10°C to +50°C
Weight	120g
Output connection	HD15 (with EEPROM) for LMG sensor input

With its high basic accuracy, the lower cut-off frequency of 5Hz and the upper cut-off frequency of 50kHz this clamp fits best for measurements at frequency inverter output. The internal error compensation circuit is designed especial for this application.

2.1.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp. The values are in ±(% of measuring value + % of measuring range current clamp) and in ±(phase error in degree)

Influence of coupling mode: This current clamp can transfer only AC currents. The compensation circuit may cause a DC signal wich is interpreted by the instrument as a DC current. This could cause additional errors. Therefore this clamp should only be used with the LMG setting: AC coupling. The accuracies are only valid for this case.

Frequency	5Hz to 10Hz	10Hz to 45Hz	45Hz to 65Hz	65Hz to 1kHz	1kHz to 5kHz	5kHz to 20kHz	20kHz to 50kHz
Current	1.5+0.25	0.4+0.15	0.15+0.05	0.15+0.05	0.3+0.15	1+0.25	4+0.5
Phase	6	3	0.5	0.5	2	6	20

Use LMG-Z406/-Z407 and LMG specifications to calculate the accuracy of the complete system.

2.1.4 Ordering guide

The current clamp LMG-Z406 is available in a package with 4 clamps, it is called LMG-Z407.

The standard connection length is 3m. Optionally can be ordered a custom defined length between 1m .. 10m.

2.1.5 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG.

2.1.6 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.1.7 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.1.8 Connection of the sensor with LMG450

Use the sensor input, you get the following ranges:

nominal value	1.25A	2.5A	5A	10A	20A	40A
max. trms value	2.5A	5A	10A	20A	40A	80A
max. peak value	3.75A	7.5A	15A	30A	60A	120A

2.1.9 Connection of the sensor with LMG500

Use L50-Z14, you get the following ranges:

nominal value	0.3A	0.6A	1.25A	2.5A	5A	10A	20A	40A
max. trms value	0.6A	1.25A	2.5A	5A	10A	20A	40A	80A
max. peak value	0.94A	1.88A	3.75A	7.5A	15A	30A	60A	120A

2.2 AC - current clamp 200A/0.2A (LMG-Z326)

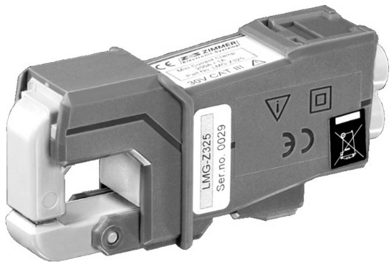


Figure 3: LMG-Z326

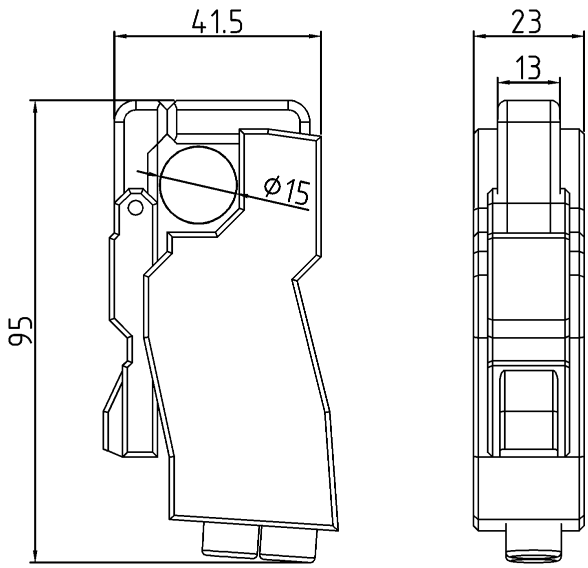


Figure 4: Dimensions of the LMG-Z326

2.2.1 ⚠ Safety warning!

No safety isolation, measurements only at insulated conductors allowed!
Always connect the sensor first to the meter, and afterwards to the device under test.
Please refer to chapter 1.1: ‘Safety precautions’!

2.2.2 Specifications

Nominal input current	200A
Transformation ratio	1000:1
Measuring range	600A
Maximum input	600A for 3min
Bandwidth	40Hz to 10kHz
Burden	1 to 10 ohms
Isolation	bare conductor: phase/ground 30Veff insulated conductor: see cable spec.

Degree of pollution	2
Temperature range	-10°C to +50°C
Weight	105g
Output connection	2 safety sockets for 4mm plugs

2.2.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp, signal frequency 50..60 Hz.

Current	Amplitude error ±(% of measuring value)	Phase error
1A to 10A	3	not specified
10A to 25A	2	2°
25A to 600A	1	1°

Use LMG-Z326 and LMG specifications to calculate the accuracy of the complete system.

2.2.4 Sensor operation without connection to LMG

It is important to assure a good connection from the sensor to the LMG before switching on the load current! The **operation** of the sensor with load current and **without connection to the LMG will cause damage** of the sensor and is **dangerous** for the user!

2.2.5 Connection of the sensor with LMG90/310 or other instruments with current input

Use direct current inputs I* and I.

2.2.6 Connection of the sensor with LMG95

Use direct current inputs I* and I.

2.2.7 Connection of the sensor with LMG450

Use direct current inputs I* and I.

2.2.8 Connection of the sensor with LMG500

Use direct current inputs I* and I.

2.3 AC - current clamp 200A/1A (LMG-Z325)

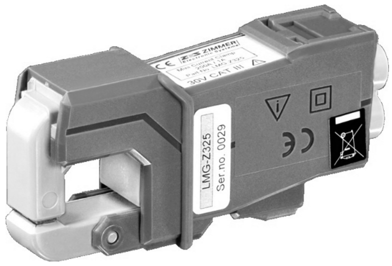


Figure 5: LMG-Z325

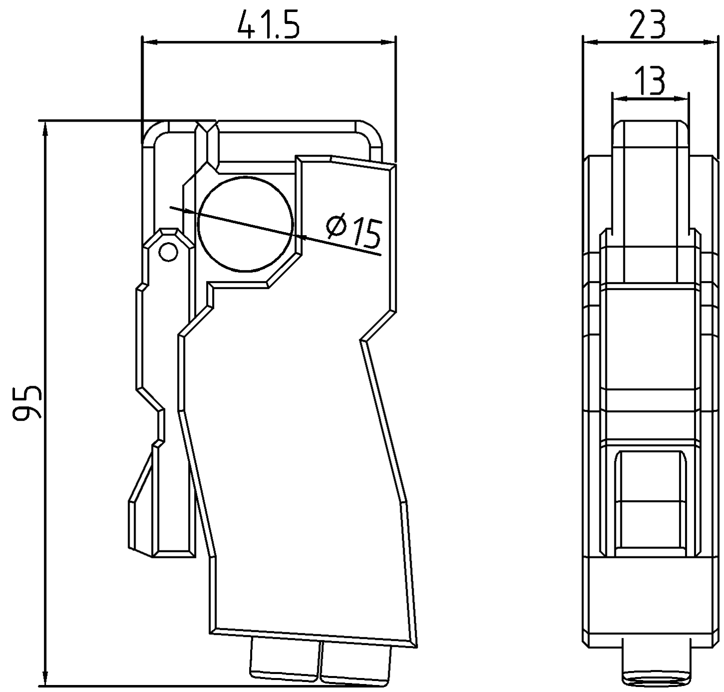


Figure 6: Dimensions of the LMG-Z325

2.3.1 ⚠ Safety warning!

No safety isolation, measurements only at insulated conductors allowed!
Always connect the sensor first to the meter, and afterwards to the device under test.
Please refer to chapter 1.1: 'Safety precautions'!

2.3.2 Specifications

Nominal input current	200A
Transformation ratio	200:1
Measuring range	250A
Maximum input	250A for 3min
Bandwidth	40Hz to 5kHz

Burden	1 to 2 ohms
Isolation	bare conductor: phase/ground 30Veff insulated conductor: see cable spec.
Degree of pollution	2
Temperature range	-10°C to +50°C
Weight	115g
Output connection	safety sockets for 4mm plugs

2.3.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, conductor in the middle of the clamp, signal frequency 50..60 Hz.

Current	Amplitude error ±(% of measuring value)	Phase error
5A to 10A	3	not specified
10A to 25A	2	2.5°
25A to 250A	1	1°

Use LMG-Z325 and LMG specifications to calculate the accuracy of the complete system.

2.3.4 Sensor operation without connection to LMG

It is important to assure a good connection from the sensor to the LMG before switching on the load current! The **operation** of the sensor with load current and **without connection to the LMG will cause damage** of the sensor and is **dangerous** for the user!

2.3.5 Connection of the sensor with LMG90/310 or other instruments with current input

Use direct current inputs I* and I.

2.3.6 Connection of the sensor with LMG95

Use direct current inputs I* and I.

2.3.7 Connection of the sensor with LMG450

Use direct current inputs I* and I.

2.3.8 Connection of the sensor with LMG500

Use direct current inputs I* and I.

2.4 Error compensated AC - current clamp 1000A (L45-Z10/-Z11)

(L45-Z11 is a set of 4x L45-Z10)

Figure 7: L45-Z10/-Z11

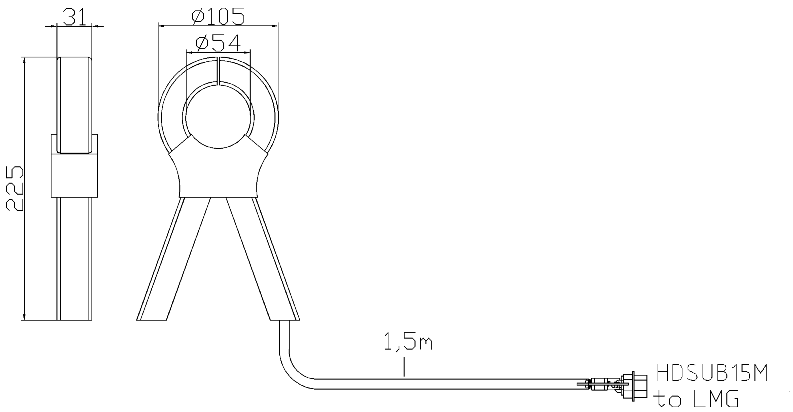


Figure 8: Dimensions of the L45-Z10/-Z11

2.4.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

2.4.2 Specifications

Nominal input current	1000A
Max. trms value	1200A
Measuring range current clamp	3000Apk
Maximum input	1200A for 30min
Bandwidth	2Hz to 40kHz
Protection class	600V CAT. III
Degree of pollution	2
Temperature range	-10°C to +50°C
Weight	650g
Output connection	HD15 (with EEPROM) for LMG sensor input

2.4.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp.
The values are in ±(% of measuring value + % of measuring range current clamp)
and in ±(phase error in degree)

Frequency	2Hz to 10Hz	10Hz to 45Hz	45Hz to 65Hz	65Hz to 1kHz	1kHz to 5kHz	5kHz to 10kHz	10kHz to 20kHz	20kHz to 40kHz
Current	0.7+0.2	0.2+0.05	0.1+0.05	0.1+0.05	0.3+0.05	0.4+0.1	0.5+0.2	2+0.4
Phase	5	1	0.3	0.3	1	2	5	30

Use L45-Z10 and LMG specifications to calculate the accuracy of the complete system.

Influence of coupling mode: This current clamp can transfer only AC currents. The compensation circuit may cause a DC signal wich is interpreted by the instrument as a DC current. This could cause additional errors. Therefore this clamp should only be used with the LMG setting: AC coupling. The accuracies are only valid for this case.

2.4.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.4.5 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.4.6 Connection of the sensor with LMG450

Use sensor input, you get the following ranges:

nominal value	31.2A	62.5A	125A	250A	500A	1000A
max. trms value	37.5A	75A	150A	300A	600A	1200A
max. peak value	93.8A	188A	375A	750A	1500A	3000A

2.4.7 Connection of the sensor with LMG500

Use L50-Z14, you get the following ranges:

nominal value	7.5A	15A	30A	62.5A	125A	250A	500A	1000A
max. trms value	9.4A	18.8A	37.5A	75A	150A	300A	600A	1200A
max. peak value	23.4A	46.9A	93.8A	188A	375A	750A	1500A	3000A

2.5 DC - current clamp 1000A (L45-Z26)

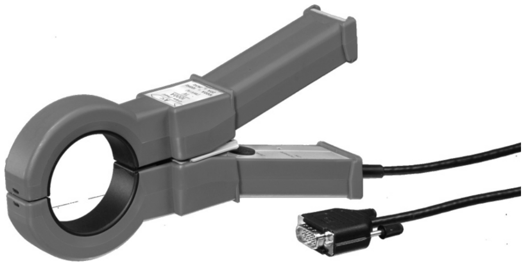


Figure 9: L45-Z26

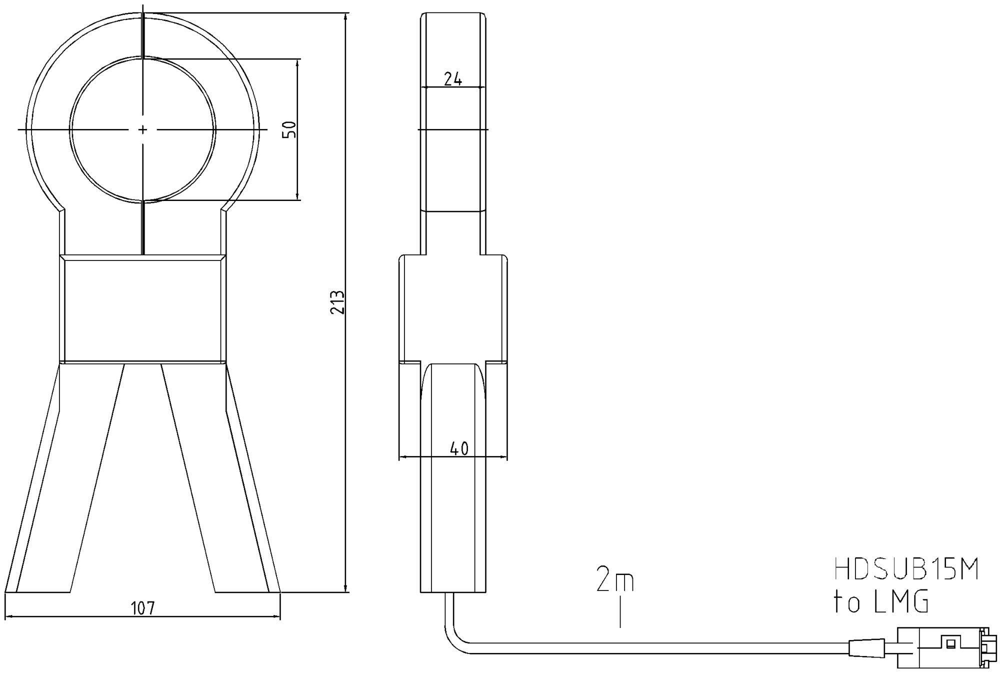


Figure 10: Dimensions of the L45-Z26

2.5.1  Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: 'Safety precautions'!

2.5.2 Specifications

Nominal input current	1000A
Max. trms value	1000A
Measuring range	1500Apk
Maximum input	1500A
Bandwidth	DC to 2kHz
Protection class	600V CAT. III

Degree of pollution	2
Temperature range	-5°C to +50°C
Weight	0.6kg
Output connection	HD15 (with EEPROM) for LMG sensor input

2.5.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp.
The accuracy is valid only with manual zero adjustment at the DC-Clamp prior clamp on!
The values are in ±(% of measuring value+% of nominal input current), phase in degree

Current	Amplitude error DC to 2kHz	Phase error at 45 to 66Hz	Phase error at 1kHz
10A to 1500A	1.5%+0.1%	<0.3°	<3°

Use L45-Z26 and LMG specifications to calculate the accuracy of the complete system.

2.5.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.5.5 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.5.6 Connection of the sensor with LMG450

Use sensor input, , internal supply via LMG, you get the following ranges:

nominal value	31.3A	62.5A	125A	250A	500A	1000A
max. trms value	31.3A	62.5A	125A	250A	500A	1000A
max. peak value	46.9A	93.8A	188A	375A	750A	1500A

2.5.7 Connection of the sensor with LMG500

Use L50-Z14, internal supply via LMG, you get the following ranges:

nominal value	7.8A	15.6A	31.3A	62.5A	125A	250A	500A	1000A
max. trms value	7.8A	15.6A	31.3A	62.5A	125A	250A	500A	1000A
max. peak value	11.7A	23.4A	46.9A	93.8A	188A	375A	750A	1500A

2.6 Error compensated AC - current clamp 3000A (L45-Z16/-Z17)

(L45-Z17 is a set of 4x L45-Z16)

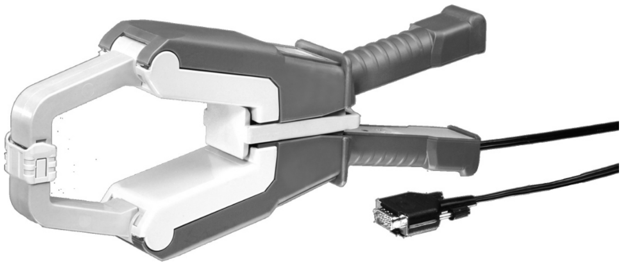


Figure 11: L45-Z16/-Z17

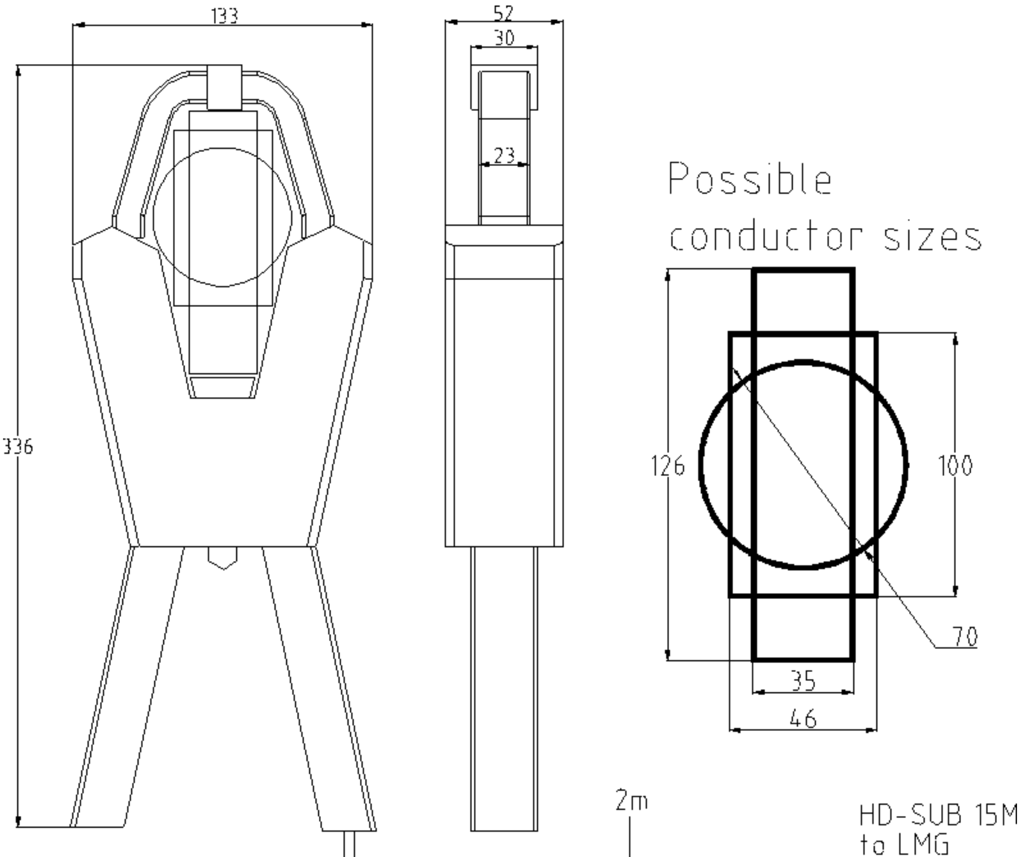


Figure 12: Dimensions of the L45-Z16/-Z17

2.6.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

2.6.2 Specifications

Nominal input current	3000A
Max. trms value	3600A
Measuring range current clamp	9000Apk
Maximum input	6000A for 5min
Bandwidth	5Hz to 10kHz
Protection class	600V CAT. III
Degree of pollution	2
Temperature range	-5°C to +50°C
Weight	1,6kg
Output connection	HD15 (with EEPROM) for LMG sensor input

2.6.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp. The values are in ±(% of measuring value + % of measuring range current clamp) and in ±(phase error in degree)

Frequency/Hz	2Hz to 10Hz	10Hz to 45Hz	45Hz to 65Hz	65Hz to 1kHz	1kHz to 2.5kHz	2.5kHz to 5kHz	5kHz to 10kHz
Current	0.7+0.2	0.2+0.05	0.1+0.05	0.2+0.05	0.4+0.1	1+0.3	2+0.4
Phase	5	1	0.3	0.5	2	10	30

Use L45-Z16 and LMG specifications to calculate the accuracy of the complete system.

Influence of coupling mode: This current clamp can transfer only AC currents. The compensation circuit may cause a DC signal wich is interpreted by the instrument as a DC current. This could cause additional errors. Therefore this clamp should only be used with the LMG setting: AC coupling. The accuracies are only valid for this case.

2.6.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.6.5 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.6.6 Connection of the sensor with LMG450

Use sensor input, you get the following ranges:

nominal value	100A	200A	400A	800A	1600A	3200A
max. trms value	113A	225A	450A	900A	1800A	3600A
max. peak value	281A	563A	1125A	2250A	4500A	9000A

2.6.7 Connection of the sensor with LMG500

Use L50-Z14, you get the following ranges:

nominal value	25A	50A	100A	200A	400A	800A	1600A	3200A
max. trms value	28A	56A	113A	225A	450A	900A	1800A	3600A
max. peak value	70A	141A	281A	563A	1125A	2250A	4500A	9000A

2.7 Hall current sensors, 50/100/200A (L45-Z28-HALLxx)

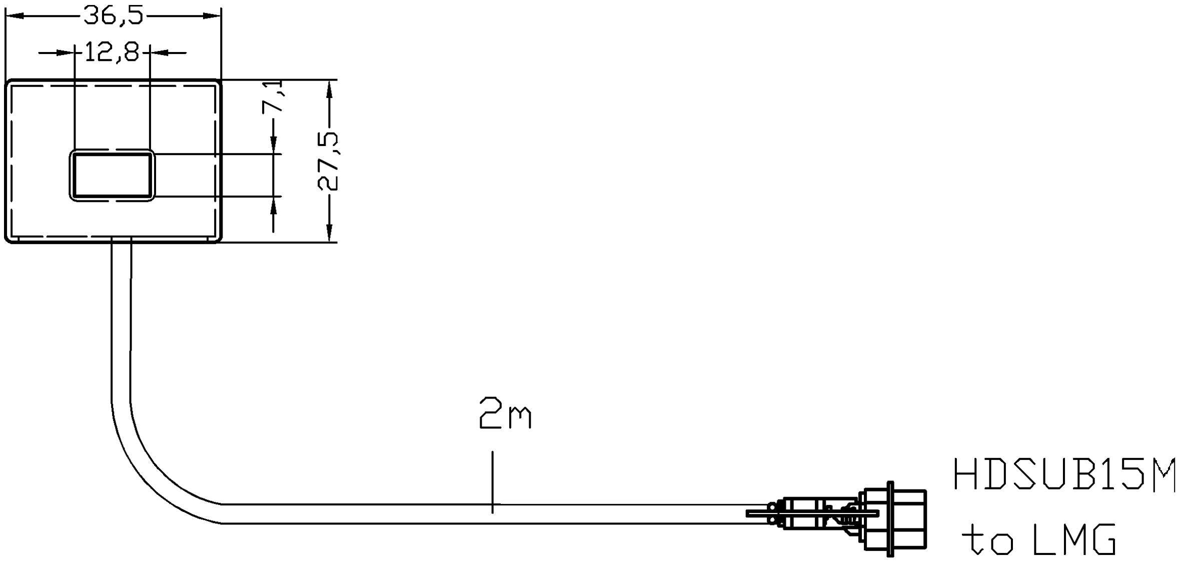


Figure 13: Dimensions of the L45-Z28-HALL50 and HALL100

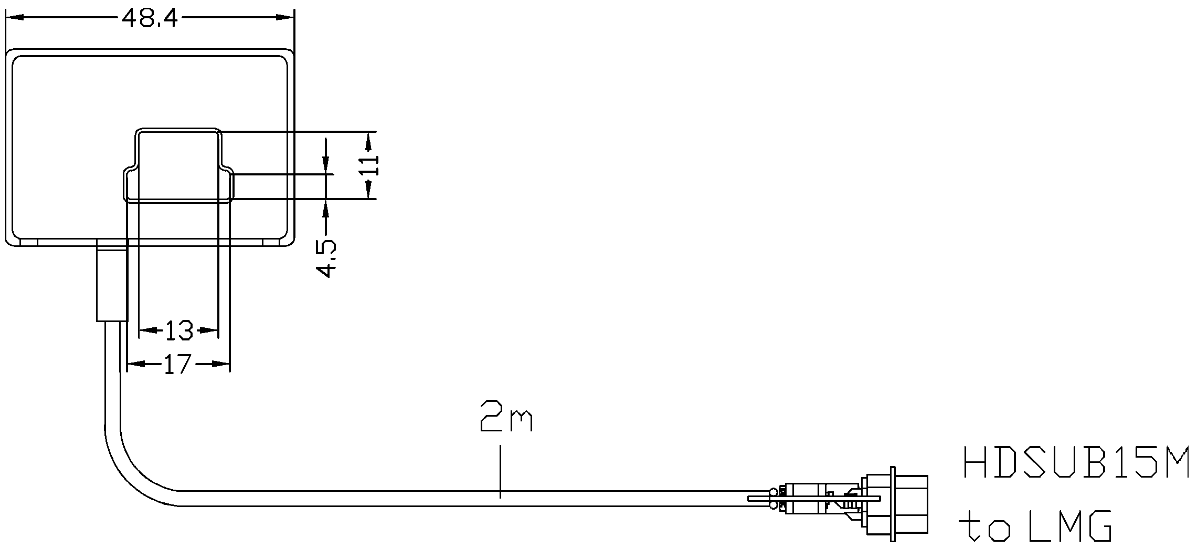


Figure 14: Dimensions of the L45-Z28-HALL200

2.7.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Do not overload any current sensor with more than the measurable TRMS value!
Please refer to chapter 1.1: ‘Safety precautions’!

2.7.2 Specifications and accuracies

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the hall sensor.

Sensor	HALL50	HALL100	HALL200
Rated range value	35A	60A	120A
Measurable TRMS value	50A	100A	200A
Permissible peak value	70A	120A	240A
Accuracies in % of measurable TRMS value at DC .. 100Hz	±0.9	±0.7	±0.65
Linearity	0.15%	0.15%	0.15%
DC offset error at 25°C	±0.2A	±0.2A	±0.4A
DC offset thermal drift (0°C.. 70°C)	±0.5A	±0.5A	±0.5A
Response time at 90% of measurable TRMS value	<1µs	<1µs	<1µs
di/dt accurately followed	> 200A/µs	> 200A/µs	> 200A/µs
Bandwidth (-1dB)	DC to 200kHz	DC to 200kHz	DC to 100kHz

Use HALLxx and LMG specifications to calculate the accuracy of the complete system.
This sensors are supplied by the HD15 sensor connector of the LMG.

The transformers are only allowed to operate with cables which - according to the printing on the cable - are designed for this individual transformer.

2.7.3 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG/supply unit!
To remove the LMG/supply unit from the test location without removing the sensors from the current path, disconnect the HD15 plug from the LMG and connect all of the 15pins together with ground (shield of the plug). To do this, the load current has to be switched off!

2.7.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.7.5 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.7.6 Connection of the sensor with LMG450

Use sensor input, you get the following ranges:

HALL50:

nominal value	1.09A	2.19A	4.38A	8.75A	17.5A	35A

max. trms value	1.57A	3.13A	6.25A	12.5A	25A	50A
max. peak value	2.19A	4.38A	8.75A	17.5A	35A	70A

HALL100:

nominal value	1.88A	3.75A	7.5A	15A	30A	60A
max. trms value	3.13A	6.25A	12.5A	25A	50A	100A
max. peak value	3.75A	7.5A	15A	30A	60A	120A

HALL200:

nominal value	3.75A	7.5A	15A	30A	60A	120A
max. trms value	6.25A	12.5A	25A	50A	100A	200A
max. peak value	7.5A	15A	30A	60A	120A	240A

2.7.7 Connection of the sensor with LMG500

Use L50-Z14, you get the following ranges:

HALL50:

nominal value	0.27A	0.55A	1.09A	2.19A	4.38A	8.75A	17.5A	35A
max. trms value	0.39A	0.79A	1.57A	3.13A	6.25A	12.5A	25A	50A
max. peak value	0.55A	1.09A	2.19A	4.38A	8.75A	17.5A	35A	70A

HALL100:

nominal value	0.47A	0.94A	1.88A	3.75A	7.5A	15A	30A	60A
max. trms value	0.79A	1.57A	3.13A	6.25A	12.5A	25A	50A	100A
max. peak value	0.94A	1.88A	3.75A	7.5A	15A	30A	60A	120A

HALL200:

nominal value	0.94A	1.88A	3.75A	7.5A	15A	30A	60A	120A
max. trms value	1.57A	3.13A	6.25A	12.5A	25A	50A	100A	200A
max. peak value	1.88A	3.75A	7.5A	15A	30A	60A	120A	240A

2.8 Hall current sensors, 300/500/1k/2kA (L45-Z29-HALLxx)

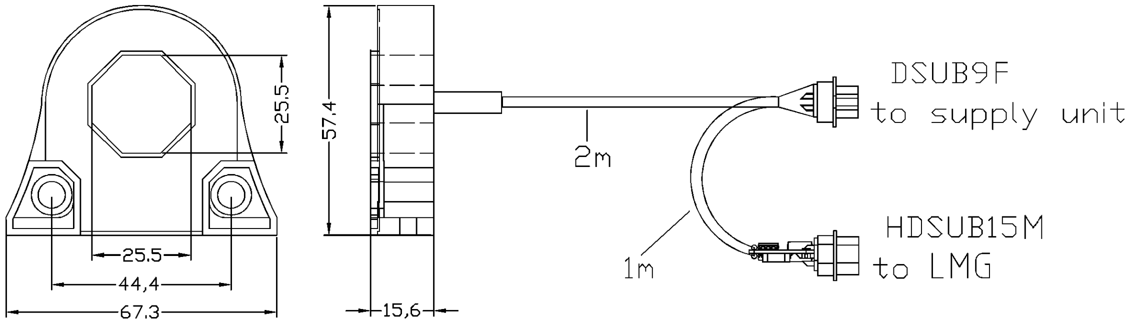


Figure 15: Dimensions of the L45-Z29-HALL300

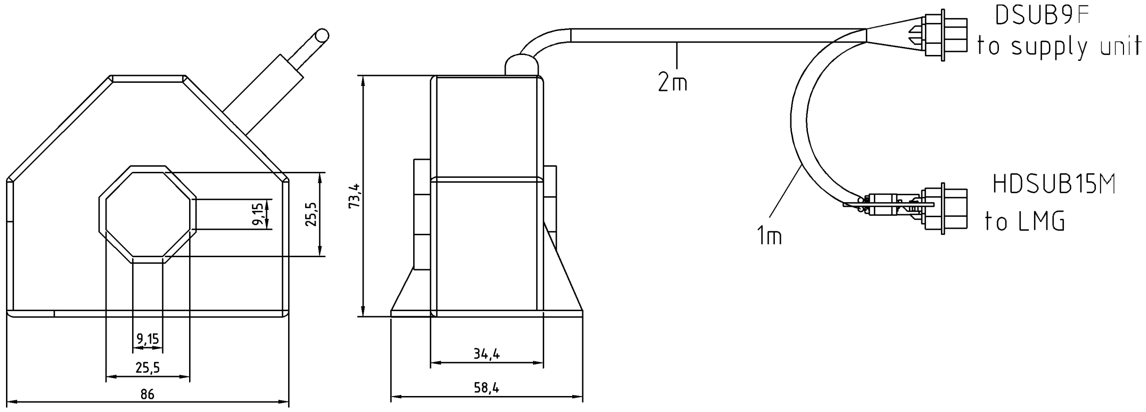


Figure 16: Dimensons of the L45-Z29-HALL500

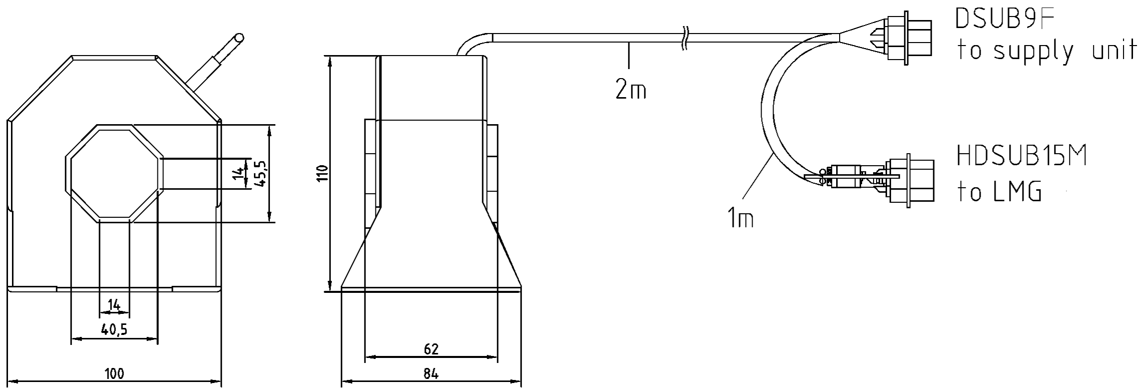


Figure 17: Dimensions of the L45-Z29-HALL1000

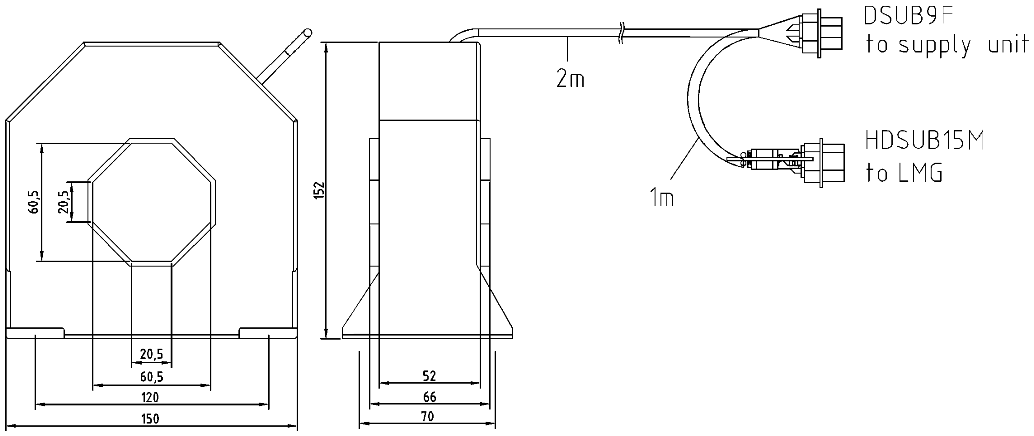


Figure 18: Dimensions of the L45-Z29-HALL2000

2.8.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test. Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Do not overload any current sensor with more than the measurable TRMS value!
Please refer to chapter 1.1: ‘Safety precautions’!

2.8.2 Specifications and accuracies

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the hall sensor.

Sensor	HALL300	HALL500	HALL1000	HALL2000
Rated range value	250A	400A	600A	1000A
Measurable TRMS value	300A	500A	1000A	2000A
Permissible peak value	500A	800A	1200A	2100A
Accuracies in % of measurable TRMS value at DC .. 100Hz	±0.4	±0.8	±0.4	±0.3
Linearity	0.1%	0.1%	0.1%	0.1%
DC offset error at 25°C	±0.4A	±0.5A	±2A	±4A
DC offset thermal drift (0°C.. 70°C)	±1.3A	±0.6A	±2.5A	±1.5A
Response time at 90% of measurable TRMS value	<1µs	<1µs	<1µs	<1µs
di/dt accurately followed	> 100A/µs	> 100A/µs	> 50A/µs	> 50A/µs
Bandwidth (-1dB)	DC..100kHz	DC..100kHz	DC..150kHz	DC..100kHz
Supply current @ ±15V	270mA	420mA	270mA	460mA

Use HALLxx and LMG specifications to calculate the accuracy of the complete system.

The transformers are only allowed to operate with cables which - according to the printing on the cable - are designed for this individual transformer.

This sensors have an additional 9 pin SUB-D connector for an external supply (for example SSU4). If you want to use your own supply, you have to use the following pins of the 9 pin SUB-D connector:

GND: Pin 3 **and** Pin 4 (always connect both)
-15V Pin 5
+15V Pin 9

Please make sure, that your own power supply can drive the needed supply current. If you offer too few current you will get distortions and other accuracy losses in your measured current without warning!

2.8.3 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG/supply unit!
To remove the LMG/supply unit from the test location without removing the sensors from the current path, disconnect the DSUB9 plug and the HD15 plug from the LMG and connect all of the 9pins and all of the 15pins together with ground (shield of the plugs). To do this, the load current has to be switched off!

2.8.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.8.5 Connection of the sensor with LMG95

The use with LMG95 is not recommended, better use: L50-Z29-Hallxx and L95-Z07. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.8.6 Connection of the sensor with LMG450

Use sensor input, you get the following ranges:

HALL300:

nominal value	7.8A	15.6A	31.1A	62.5A	125A	250A
max. trms value	9.4A	18.7A	37.5A	75A	150A	300A
max. peak value	15.6A	31.1A	62.5A	125A	250A	500A

HALL500:

nominal value	12.5A	25A	50A	100A	200A	400A
max. trms value	15.6A	31.1A	62.5A	125A	250A	500A
max. peak value	25A	50A	100A	200A	400A	800A

HALL1000:

nominal value	18.7A	37.5A	75A	150A	300A	600A
max. trms value	31.1A	62.5A	125A	250A	500A	1000A
max. peak value	37.5A	75A	150A	300A	600A	1200A

HALL2000:

nominal value	31.1A	62.5A	125A	250A	500A	1000A
max. trms value	62.5A	125A	250A	500A	1000A	2000A

max. peak value	65.6A	131A	263A	525A	1050A	2100A

2.8.7 Connection of the sensor with LMG500

The use with LMG500 is not recommended, please see L50-Z29-Hallxx

2.9 Hall current sensors, 300/500/1k/2kA (L50-Z29-HALLxx)

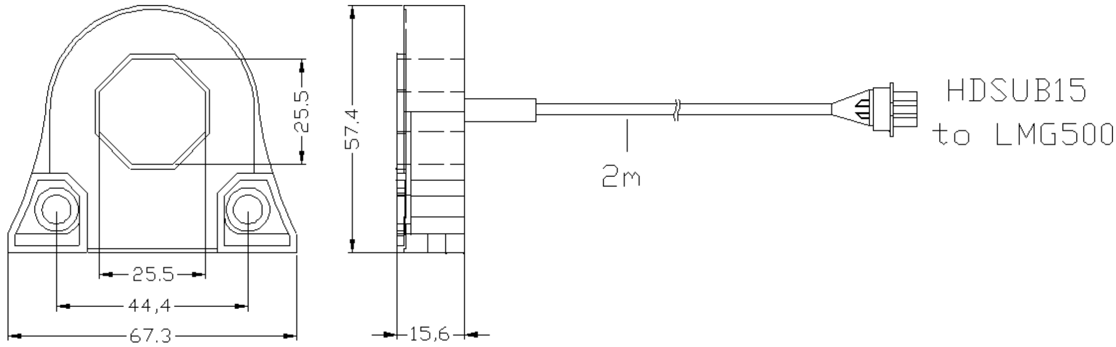


Figure 19: Dimensions of the L50-Z29-Hall300

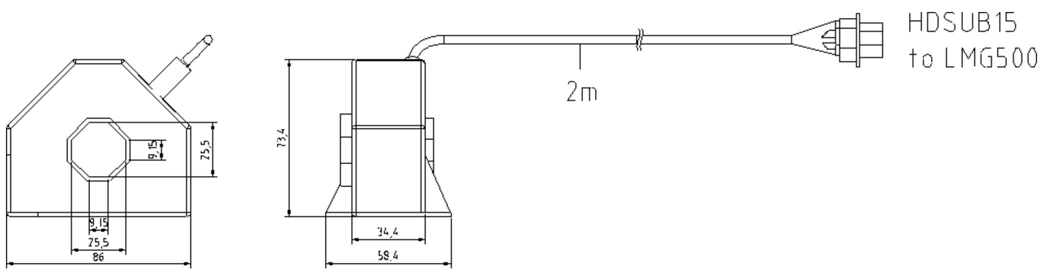


Figure 20: Dimensons of the L50-Z29-Hall500

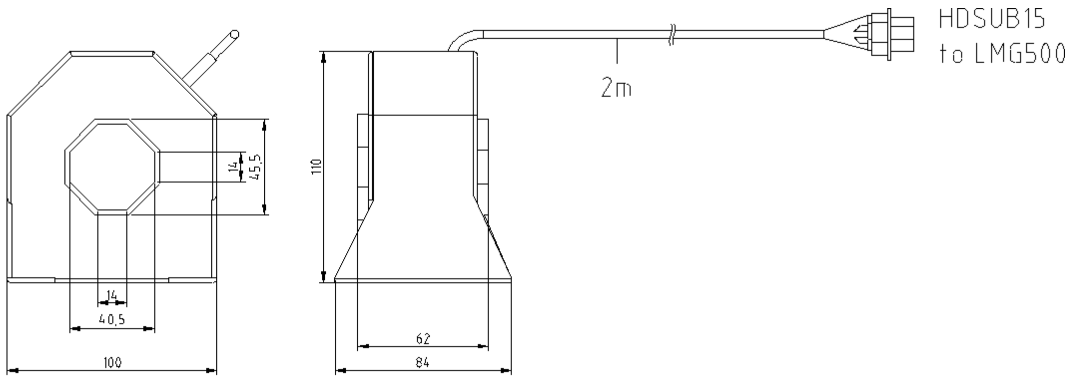


Figure 21: Dimensions of the L50-Z29-Hall1000

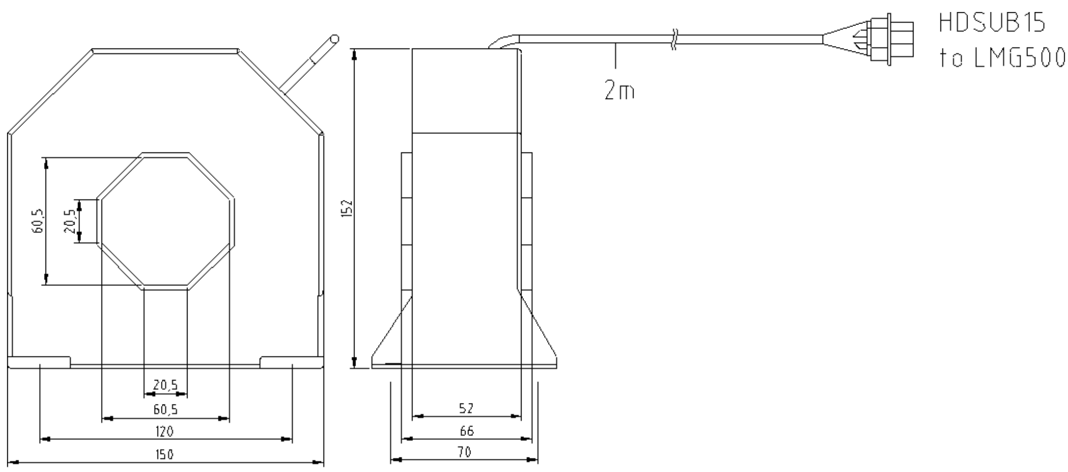


Figure 22: Dimensions of the L50-Z29-Hall2000

2.9.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Do not overload any current sensor with more than the measurable TRMS value!
Please refer to chapter 1.1: 'Safety precautions'!

2.9.2 Specifications and accuracies

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the hall sensor.

Sensor	HALL300	HALL500	HALL1000	HALL2000
Rated range value	250A	400A	600A	1000A
Measurable TRMS value	300A	500A	1000A	2000A
Permissible peak value	500A	800A	1200A	2100A
Accuracies in % of measurable TRMS value at DC .. 100Hz	±0.4	±0.8	±0.4	±0.3
Linearity	0.1%	0.1%	0.1%	0.1%
DC offset error at 25°C	±0.4A	±0.5A	±2A	±4A
DC offset thermal drift (0°C.. 70°C)	±1.3A	±0.6A	±2.5A	±1.5A
Response time at 90% of measurable TRMS value	<1µs	<1µs	<1µs	<1µs
di/dt accurately followed	> 100A/µs	> 100A/µs	> 50A/µs	> 50A/µs
Bandwidth (-1dB)	DC..100kHz	DC..100kHz	DC..150kHz	DC..100kHz

Use HALLxx and LMG specifications to calculate the accuracy of the complete system.

The transformers are only allowed to operate with cables which - according to the printing on the cable - are designed for this individual transformer.

2.9.3 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG/supply unit!
To remove the LMG/supply unit from the test location without removing the sensors from the current path, disconnect the HD15 plug from the LMG and connect all of the 15pins together with ground (shield of the plug). To do this, the load current has to be switched off!

2.9.4 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.9.5 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.9.6 Connection of the sensor with LMG450

The use with LMG450 is **not possible!**

2.9.7 Connection of the sensor with LMG500

Use L50-Z14, internal supply via LMG, you get the following ranges:

HALL300:

nominal value	2A	3.9A	7.8A	15.6A	31.1A	62.5A	125A	250A
max. trms value	2.4A	4.7A	9.4A	18.7A	37.5A	75A	150A	300A
max. peak value	3.9A	7.8A	15.6A	31.1A	62.5A	125A	250A	500A

HALL500:

nominal value	3.13A	6.25A	12.5A	25A	50A	100A	200A	400A
max. trms value	3.9A	7.8A	15.6A	31.1A	62.5A	125A	250A	500A
max. peak value	6.25A	12.5A	25A	50A	100A	200A	400A	800A

HALL1000:

nominal value	4.7A	9.4A	18.7A	37.5A	75A	150A	300A	600A
max. trms value	7.8A	15.6A	31.1A	62.5A	125A	250A	500A	1000A
max. peak value	9.4A	18.7A	37.5A	75A	150A	300A	600A	1200A

HALL2000:

nominal value	7.8A	15.6A	31.1A	62.5A	125A	250A	500A	1000A
max. trms value	15.6A	31.1A	62.5A	125A	250A	500A	1000A	2000A
max. peak value	16.4A	32.8A	65.6A	131A	263A	525A	1050A	2100A

2.10 Rogowski flex sensors (L45-Z32-FLEXxx)

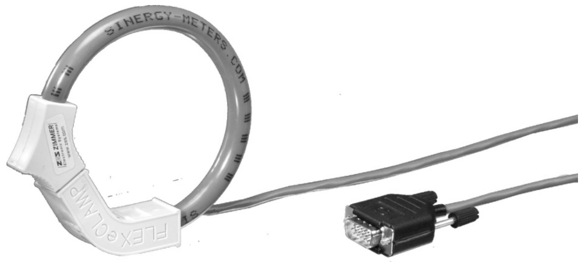


Figure 23: Dimensions of the L45-Z32-FLEX xx

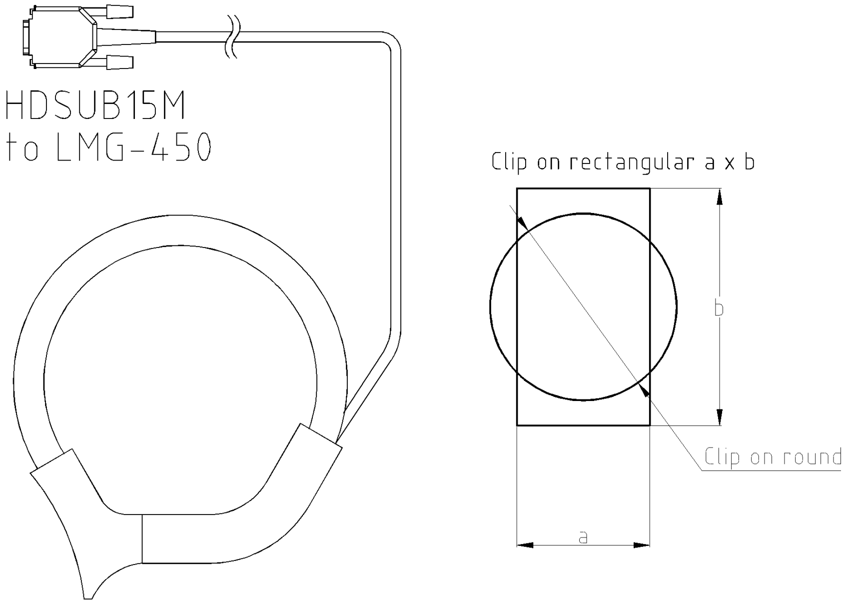


Figure 24: Dimensions of the L45-Z32-FLEX xx

2.10.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

2.10.2 Specifications

Sensor	**FLEX 500**	**FLEX 1000**	**FLEX 3000**
Rated range value	500A	1000A	3000A
Permissible peak range value	700A	1400A	4200A
Position sensitivity	±5%	±2%	±2%
Frequency range	10Hz .. 5kHz	10Hz .. 5kHz	10Hz .. 5kHz
Phase Shift (at 50/60Hz, cable in middle of the head)	0.1°	0.1°	0.1°
Rogowski sensor length	30cm	40cm	75cm
Connection cable length	2m	2m	2m
Clip on round (diameter)	75mm	110mm	200mm

Clip on rectangular (a x b)	20mm x 85mm	30mm x 120mm	60mm x 250mm
max. loops	1	1	3
Weight	100g	120g	160g
Temperature range	-20°C .. +85°C		
Protection class	600V / CATIII		
Degree of pollution	2		
Output connection	HD15 plug (with EEPROM) for LMG sensor input		

2.10.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year, conductor in the middle of the clamp.

The values are: ±(% of measuring value + % of rated range value)

Frequency/Hz	**10Hz to 45Hz**	**45Hz to 65Hz**	**65Hz to 1kHz**	**1kHz to 5kHz**
FLEX xx current accuracy	0.5+1.5	0.5+0.6	0.5+1.5	5+5

Use FLEXxx and LMG specifications to calculate the accuracy of the complete system.

2.10.4 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG/supply unit!
To remove the LMG/supply unit from the test location without removing the sensors from the current path, disconnect the HD15 plug from the LMG and connect all of the 15pins together with ground (shield of the plug). To do this, the load current has to be switched off!

2.10.5 Connection of the sensor with LMG90/310

The use with LMG90 and LMG310 is not possible.

2.10.6 Connection of the sensor with LMG95

Use L95-Z07, internal supply via LMG and the Isensor/external shunt input. Set LMG current scaling factor appropriate to the scaling factor marked on the label on L95-Z07.

2.10.7 Connection of the sensor with LMG450

Use sensor input, internal supply via LMG, you get the following ranges:

FLEX500:

nominal value	15.6A	31.3A	62.5A	125A	250A	500A

max. trms value	15.6A	31.3A	62.5A	125A	250A	500A
max. peak value	21.9A	43.8A	87.5A	175A	350A	700A

FLEX1000:

nominal value	31.3A	62.5A	125A	250A	500A	1000A
max. trms value	31.3A	62.5A	125A	250A	500A	1000A
max. peak value	43.8A	87.5A	175A	350A	700A	1400A

FLEX3000:

nominal value	93.8A	188A	375A	750A	1500A	3000A
max. trms value	93.8A	188A	375A	750A	1500A	3000A
max. peak value	131A	263A	525A	1050A	2100A	4200A

2.10.8 Connection of the sensor with LMG500

Use L50-Z14, internal supply via LMG, you get the following ranges:

FLEX500:

nominal value	3.9A	7.8A	15.6A	31.3A	62.5A	125A	250A	500A
max. trms value	3.9A	7.8A	15.6A	31.3A	62.5A	125A	250A	500A
max. peak value	5.5A	10.9A	21.9A	43.8A	87.5A	175A	350A	700A

FLEX1000:

nominal value	7.8A	15.6A	31.3A	62.5A	125A	250A	500A	1000A
max. trms value	7.8A	15.6A	31.3A	62.5A	125A	250A	500A	1000A
max. peak value	10.9A	21.9A	43.8A	87.5A	175A	350A	700A	1400A

FLEX3000:

nominal value	23.5A	46.9A	93.8A	188A	375A	750A	1500A	3000A
max. trms value	23.5A	46.9A	93.8A	188A	375A	750A	1500A	3000A
max. peak value	32.8A	65.6A	131A	263A	525A	1050A	2100A	4200A

2.11 Low current shunt (LMG-SHxx)

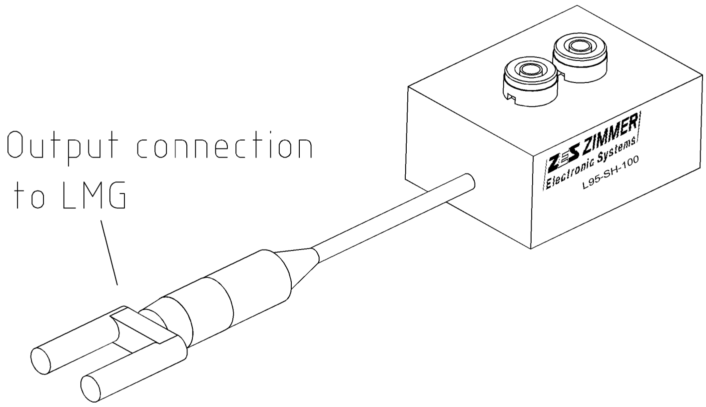


Figure 25: LMG-SHxx

2.11.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test. Please regard that there is **no isolation inside the Sensor**, therefore the instrument needs isolated inputs! The Sensor is suitable for LMG95, LMG500 and LMG310, but not for LMG450!
Please refer to chapter 1.1: 'Safety precautions'!

2.11.2 Selection of the resistance value

Select an applicable shunt resistance according to the necessary load current range. Values between 1 ohm and 1000 ohms are available. But take into concern, that this shunt resistance is connected in series to your device under test. Oversized resistors may distort and take influence on the load current.

2.11.3 Specifications, Accuracy

The specified accuracy is valid in combination with the LMG95 / LMG500 sensor input impedance of 100kOhm and the correct setting of the scaling ratio (see table). Accuracies based on: sinusoidal current, frequency 45-65 Hz, ambient temperature 23±3°C, calibration interval 1 year. The values are in ±(% of measuring value). Use LMG-SHxx and LMG specifications to calculate the accuracy of the complete system.

nominal resistance	1 ohm	2 ohms	5 ohms	10 ohms	20 ohms	50 ohms	100 ohms	200 ohms	500 ohms	1000 ohms
scaling ratio	1.00001	0.50001	0.20001	0.10001	0.05001	0.02001	0.01001	0.00501	0.00201	0.00101
accuracy	0.15%									
maximum trms input current	1000 mA	710 mA	450 mA	320 mA	160 mA	100 mA	70 mA	50 mA	31 mA	22 mA

bandwidth	DC to 100kHz
protection class	600V CAT III
degree of pollution	2
temperature range	0°C to +40°C
weight	100g
output connection	Security BNC cable and adapter

2.11.4 Connection of the sensor with LMG90/310

The use with LMG90 is not possible. With LMG310 use Isensor/external Shunt input.

2.11.5 Connection of the sensor with LMG95

Use external Shunt input, you get the following ranges (all in A):

1ohm:

nominal value	30m	60m	120m	250m	500m	1	*(2)*	*(4)*
max. trms value	60m	130m	270m	540m	1	*(2)*	*(4)*	*(8)*
max. peak value	97.7m	195.3m	390.6m	781.3m	1.563	3.125	*(6.25)*	*(12.5)*

(regard maximum trms input current!)

2ohms:

nominal value	15m	30m	60m	125m	250m	500m	*(1)*	*(2)*
max. trms value	30m	65m	135m	270m	500m	*(1)*	*(2)*	*(4)*
max. peak value	48.85m	97.65m	195.3m	390.7m	781.5m	1.563	*(3.125)*	*(6.25)*

(regard maximum trms input current!)

5ohms:

nominal value	6m	12m	24m	50m	100m	200m	400m	*(800m)*
max. trms value	12m	26m	54m	108m	200m	400m	*(0.8)*	*(1.6)*
max. peak value	19.54m	39.06m	78.12m	156.3m	312.6m	625m	1.25	*(2.5)*

(regard maximum trms input current!)

10ohms:

nominal value	3m	6m	12m	25m	50m	100m	200m	*(400m)*

max. trms value	6m	13m	27m	54m	100m	200m	*(0.4)*	*(800m)*
max. peak value	9.77m	19.53m	39.06m	78.13m	156.3m	312.5m	625m	*(1.25)*

(regard maximum trms input current!)

20ohms:

nominal value	1.5m	3m	6m	12.5m	25m	50m	100m	*(200m)*
max. trms value	3m	6.5m	13.5m	27m	50m	100m	*(0.2)*	*(400m)*
max. peak value	4.885m	9.765m	19.53m	39.07m	78.15m	156.3m	312.5m	*(625m)*

(regard maximum trms input current!)

50ohms:

nominal value	600u	1.2m	2.4m	5m	10m	20m	40m	80m
max. trms value	1.2m	2.6m	5.4m	10.8m	20m	40m	80m	*(0.16)*
max. peak value	1.954m	3.906m	7.812m	15.63m	31.26m	62.5m	125m	0.25

100ohms:

nominal value	300u	600u	1.2m	2.5m	5m	10m	20m	40m
max. trms value	600u	1.3m	2.7m	5.4m	10m	20m	40m	*(80m)*
max. peak value	977u	1.953m	3.906m	7.813m	15.63m	31.25m	62.5m	125m

200ohms:

nominal value	150u	300u	600u	1.25m	2.5m	5m	10m	20m
max. trms value	300u	650u	1.35m	2.7m	5m	10m	20m	40m
max. peak value	488.5u	976.5u	1.953m	3.907m	7.815m	15.63m	31.25m	62.5m

500ohms:

nominal value	60u	120u	240u	500u	1m	2m	4m	8m
max. trms value	120u	260u	540u	1.08m	2m	4m	8m	16m
max. peak value	195.4u	390.6u	781.2u	1.563m	3.126m	6.25m	12.5m	25m

1000ohms:

nominal value	30u	60u	120u	250u	500u	1m	2m	4m

max. trms value	60u	130u	270u	540u	1m	2m	4m	8m
max. peak value	97.7u	195.3u	390.6u	781.3u	1.563m	3.125m	6.25m	12.5m

2.11.6 Connection of the sensor with LMG450

The use with LMG450 is **not possible!**

2.11.7 Connection of the sensor with LMG500

Use external sensor input, you get the following ranges (all in A):

1ohm:

nominal value	30m	60m	120m	250m	500m	1	*(2)*	*(4)*
max. trms value	37m	75m	150m	300m	600m	*(1.2)*	*(2.5)*	*(5)*
max. peak value	63m	125m	250m	500m	1	2	*(4)*	*(8)*

(regard maximum trms input current!)

2ohms:

nominal value	15m	30m	60m	125m	250m	500m	*(1)*	*(2)*
max. trms value	18.5m	37.5m	75m	150m	300m	600m	*(1.25)*	*(2.5)*
max. peak value	31.5m	62.5m	125m	250m	500m	1	*(2)*	*(4)*

(regard maximum trms input current!)

5ohms:

nominal value	6m	12m	24m	50m	100m	200m	400m	*(800m)*
max. trms value	7.4m	15m	30m	60m	120m	240m	*(0.5)*	*(1)*
max. peak value	12.6m	25m	50m	100m	200m	400m	800m	*(1.6)*

(regard maximum trms input current!)

10ohms:

nominal value	3m	6m	12m	25m	50m	100m	200m	*(400m)*
max. trms value	3.7m	7.5m	15m	30m	60m	120m	250m	*(500m)*
max. peak value	6.3m	12.5m	25m	50m	100m	200m	400m	*(800m)*

(regard maximum trms input current!)

20ohms:

nominal value	1.5m	3m	6m	12.5m	25m	50m	100m	*(200m)*
max. trms value	1.85m	3.75m	7.5m	15m	30m	60m	125m	*(250m)*
max. peak value	3.15m	6.25m	12.5m	25m	50m	100m	200m	*(400m)*

(regard maximum trms input current!)

50ohms:

nominal value	600u	1.2m	2.4m	5m	10m	20m	40m	80m
max. trms value	740u	1.5m	3m	6m	12m	24m	50m	100m
max. peak value	1.26m	2.5m	5m	10m	20m	40m	80m	160m

(regard maximum trms input current!)

100ohms:

nominal value	300u	600u	1.2m	2.5m	5m	10m	20m	40m
max. trms value	370u	750u	1.5m	3m	6m	12m	25m	50m
max. peak value	630u	1.25m	2.5m	5m	10m	20m	40m	80m

(regard maximum trms input current!)

200ohms:

nominal value	150u	300u	600u	1.25m	2.5m	5m	10m	20m
max. trms value	185u	375u	750u	1.5m	3m	6m	12.5m	25m
max. peak value	315u	625u	1.25m	2.5m	5m	10m	20m	40m

(regard maximum trms input current!)

500ohms:

nominal value	60u	120u	240u	500u	1m	2m	4m	8m
max. trms value	74u	150u	300u	600u	1.2m	2.4m	5m	10m
max. peak value	126u	250u	500u	1m	2m	4m	8m	16m

(regard maximum trms input current!)

1000ohms:

nominal value	30u	60u	120u	250u	500u	1m	2m	4m
max. trms value	37u	75u	150u	300u	600u	1.2m	2.5m	5m
max. peak value	63u	125u	250u	500u	1m	2m	4m	8m

(regard maximum trms input current!)

2.12 Low current shunt with overload protection (LMG-SHxx-P)

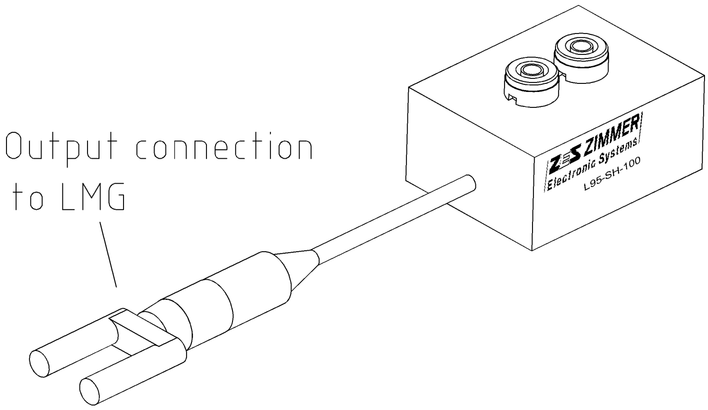


Figure 26: LMG-SHxx-P

2.12.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test. Please regard that there is **no isolation inside the Sensor**, therefore the instrument needs isolated inputs! The Sensor is suitable for LMG95, LMG500 and LMG310, but not for LMG450!
Please refer to chapter 1.1: ‘Safety precautions’!

2.12.2 Selection of the resistance value

Select an applicable shunt resistance according to the necessary load current range. Values between 1 ohm and 200 ohms are available. Select the resistance value by the maximum peak input current according to the table in chapter 2.31.3. But take into concern, that this shunt resistance is connected in series to your device under test. Oversized resistors may distort and take influence on the load current.

2.12.3 Specifications, Accuracy

The specified accuracy is valid in combination with the LMG95 / LMG500 sensor input impedance of 100kOhm and the correct setting of the scaling ratio (see table). Accuracies based on: sinusoidal current, frequency 45-65 Hz, ambient temperature 23±3°C, calibration interval 1 year. The values are in ±(% of measuring value). Use LMG-SHxx-P and LMG specifications to calculate the accuracy of the complete system.

nominal resistance	1 ohm	2 ohms	5 ohms	10 ohms	20 ohms	50 ohms	100 ohms	200 ohms
scaling ratio	1.00001	0.50001	0.20001	0.10001	0.05001	0.02001	0.01001	0.00501
accuracy	0.15%					0.3%		
maximum peak	710	350	140	70	18	10	5	2.5

input current for specified accuracy	mApk	mApk	mApk	mApk	mApk	mApk	mApk	mApk
maximum trms input current, overload	20A (overload protection) for max. 1 minute							
bandwidth	DC to 10kHz							
protection class	600V CAT III							
degree of pollution	2							
temp. range	0°C to +40°C							
weight	150g							
output connection	Security BNC cable and adapter							

2.12.4 Connection of the sensor with LMG90/310

The use with LMG90 is not possible. With LMG310 use Isensor/external Shunt input.

2.12.5 Connection of the sensor with LMG95

Use external Shunt input, you get the following ranges (all in A):

1ohm:

nominal value	30m	60m	120m	250m	500m	~~1~~	~~2~~	~~4~~
max. trms value	60m	130m	270m	540m	1	~~2~~	~~4~~	~~8~~
max. peak value	97.7m	195.3m	390.6m	781.3m	1.563	~~3.125~~	~~6.25~~	~~12.5~~

(don’t use the upper ranges, outside accuracy specification!)

2ohms:

nominal value	15m	30m	60m	125m	250m	~~500m~~	~~1~~	~~2~~
max. trms value	30m	65m	135m	270m	500m	~~1~~	~~2~~	~~4~~
max. peak value	48.85m	97.65m	195.3m	390.7m	781.5m	~~1.563~~	~~3.125~~	~~6.25~~

(don’t use the upper ranges, outside accuracy specification!)

5ohms:

nominal value	6m	12m	24m	50m	100m	~~200m~~	~~400m~~	~~800m~~
max. trms value	12m	26m	54m	108m	200m	~~400m~~	~~800m~~	~~1.6~~
max. peak value	19.54m	39.06m	78.12m	156.3m	312.6m	~~625m~~	~~1.25~~	~~2.5~~

(don’t use the upper ranges, outside accuracy specification!)

10ohms:

nominal value	3m	6m	12m	25m	50m	~~100m~~	~~200m~~	~~400m~~
max. trms value	6m	13m	27m	54m	100m	~~200m~~	~~400m~~	~~800m~~
max. peak value	9.77m	19.53m	39.06m	78.13m	156.3m	~~312.5m~~	~~625m~~	~~1.25~~

(don't use the upper ranges, outside accuracy specification!)

20ohms:

nominal value	1.5m	3m	6m	12.5m	~~25m~~	~~50m~~	~~100m~~	~~200m~~
max. trms value	3m	6.5m	13.5m	27m	~~50m~~	~~100m~~	~~200m~~	~~400m~~
max. peak value	4.885m	9.765m	19.53m	39.07m	~~78.15m~~	~~156.3m~~	~~312.5m~~	~~625m~~

(don't use the upper ranges, outside accuracy specification!)

50ohms:

nominal value	600u	1.2m	2.4m	5m	~~10m~~	~~20m~~	~~40m~~	~~80m~~
max. trms value	1.2m	2.6m	5.4m	10.8m	~~20m~~	~~40m~~	~~80m~~	~~160m~~
max. peak value	1.954m	3.906m	7.812m	15.63m	~~31.26m~~	~~62.5m~~	~~125m~~	~~250m~~

(don't use the upper ranges, outside accuracy specification!)

100ohms:

nominal value	300u	600u	1.2m	2.5m	~~5m~~	~~10m~~	~~20m~~	~~40m~~
max. trms value	600u	1.3m	2.7m	5.4m	~~10m~~	~~20m~~	~~40m~~	~~80m~~
max. peak value	977u	1.953m	3.906m	7.813m	~~15.63m~~	~~31.25m~~	~~62.5m~~	~~125m~~

(don't use the upper ranges, outside accuracy specification!)

200ohms:

nominal value	150u	300u	600u	1.25m	~~2.5m~~	~~5m~~	~~10m~~	~~20m~~
max. trms value	300u	650u	1.35m	2.7m	~~5m~~	~~10m~~	~~20m~~	~~40m~~
max. peak value	488.5u	976.5u	1.953m	3.907m	~~7.815m~~	~~15.63m~~	~~31.25m~~	~~62.5m~~

(don't use the upper ranges, outside accuracy specification!)

2.12.6 Connection of the sensor with LMG450

The use with LMG450 is **not possible!**

2.12.7 Connection of the sensor with LMG500

Use external sensor input, you get the following ranges (all in A):

1ohm:

nominal value	30m	60m	120m	250m	500m	~~*1*~~	~~*2*~~	~~*4*~~
max. trms value	37m	75m	150m	300m	600m	~~*1.2*~~	~~*2.5*~~	~~*5*~~
max. peak value	63m	125m	250m	500m	1	~~*2*~~	~~*4*~~	~~*8*~~

(don't use the upper ranges, outside accuracy specification!)

2ohms:

nominal value	15m	30m	60m	125m	250m	~~*500m*~~	~~*1*~~	~~*2*~~
max. trms value	18.5m	37.5m	75m	150m	300m	~~*600m*~~	~~*1.25*~~	~~*2.5*~~
max. peak value	31.5m	62.5m	125m	250m	500m	~~*1*~~	~~*2*~~	~~*4*~~

(don't use the upper ranges, outside accuracy specification!)

5ohms:

nominal value	6m	12m	24m	50m	100m	~~*200m*~~	~~*400m*~~	~~*800m*~~
max. trms value	7.4m	15m	30m	60m	120m	~~*240m*~~	~~*500m*~~	~~*1*~~
max. peak value	12.6m	25m	50m	100m	200m	~~*400m*~~	~~*800m*~~	~~*1.6*~~

(don't use the upper ranges, outside accuracy specification!)

10ohms:

nominal value	3m	6m	12m	25m	50m	~~*100m*~~	~~*200m*~~	~~*400m*~~
max. trms value	3.7m	7.5m	15m	30m	60m	~~*120m*~~	~~*250m*~~	~~*500m*~~
max. peak value	6.3m	12.5m	25m	50m	100m	~~*200m*~~	~~*400m*~~	~~*800m*~~

(don't use the upper ranges, outside accuracy specification!)

20ohms:

nominal value	1.5m	3m	6m	12.5m	25m	~~*50m*~~	~~*100m*~~	~~*200m*~~
max. trms value	1.85m	3.75m	7.5m	15m	30m	~~*60m*~~	~~*125m*~~	~~*250m*~~
max. peak value	3.15m	6.25m	12.5m	25m	50m	~~*100m*~~	~~*200m*~~	~~*400m*~~

(don't use the upper ranges, outside accuracy specification!)

50ohms:

nominal value	600u	1.2m	2.4m	5m	~~*10m*~~	~~*20m*~~	~~*40m*~~	~~*80m*~~
max. trms value	740u	1.5m	3m	6m	~~*12m*~~	~~*24m*~~	~~*50m*~~	~~*100m*~~
max. peak value	1.26m	2.5m	5m	10m	~~*20m*~~	~~*40m*~~	~~*80m*~~	~~*160m*~~

(don't use the upper ranges, outside accuracy specification!)

100ohms:

nominal value	300u	600u	1.2m	2.5m	~~*5m*~~	~~*10m*~~	~~*20m*~~	~~*40m*~~
max. trms value	370u	750u	1.5m	3m	~~*6m*~~	~~*12m*~~	~~*25m*~~	~~*50m*~~
max. peak value	630u	1.25m	2.5m	5m	~~*10m*~~	~~*20m*~~	~~*40m*~~	~~*80m*~~

(don't use the upper ranges, outside accuracy specification!)

200ohms:

nominal value	150u	300u	600u	1.25m	~~*2.5m*~~	~~*5m*~~	~~*10m*~~	~~*20m*~~
max. trms value	185u	375u	750u	1.5m	~~*3m*~~	~~*6m*~~	~~*12.5m*~~	~~*25m*~~
max. peak value	315u	625u	1.25m	2.5m	~~*5m*~~	~~*10m*~~	~~*20m*~~	~~*40m*~~

(don't use the upper ranges, outside accuracy specification!)

3 LMG95 connection cables and adapter

3.1 Adapter for the use of HD15-Sensors with LMG95 (L95-Z07)

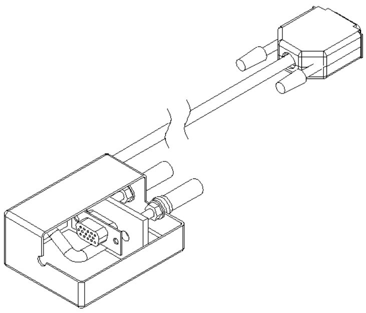


Figure 27:Adapter for the use of HD15-Sensors with LMG95 (L95-Z07)

3.1.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test
Connecting cables without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: 'Safety precautions'!

3.1.2 Specifications

suitable sensors	**remarks**
L45-Z26	DC current clamp 1000A
L45-Z28-HALLxx	Hall-transducer 50A, 100A, 200A
L50-Z29-HALLxx	Hall-transducer 300A, 500A, 1000A, 2000A
L45-Z32-FLEXxx	Rogowski-transducer 500A, 1000A, 3000A
PSUxx-K-L50	PSU60, -200, -400, -700
L45-Z406	
L45-Z10	better use: LMG-Z322
L45-Z16	better use: LMG-Z329

Plug the DSUB connector to LMG95 external supply and the two 4mm jacks to LMG95 ext.Shunt/I.

3.1.3 Accuracy

If you order the accessory L95-Z07 together with the suitable current sensor, then you can find a label with the scaling factor on L95-Z07. Please set this current scaling in the range menue of the LMG95. For the use of different current sensors e.g. alternating with LMG450 (not ordered at the same time with L95-Z07) you have to calibrate the sensor together with the LMG95 to find the correct scaling. Use the sensor- and LMG specifications to calculate the accuracy of the complete system.

3.2 PSU/PCT-K-L95

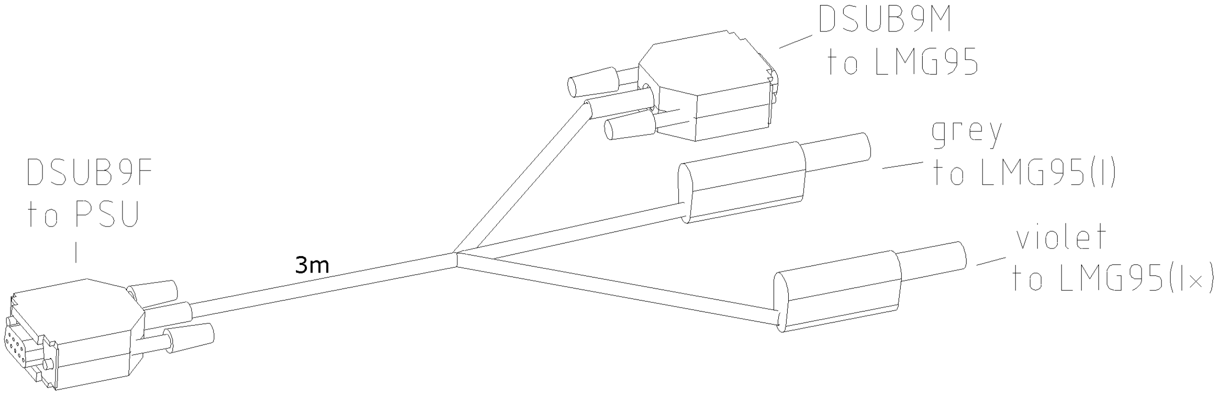


Figure 28: PSU/PCT-K-L95, for direct connection of the PSU60/200/400/700 and PCT200/600 to the current input of the LMG95

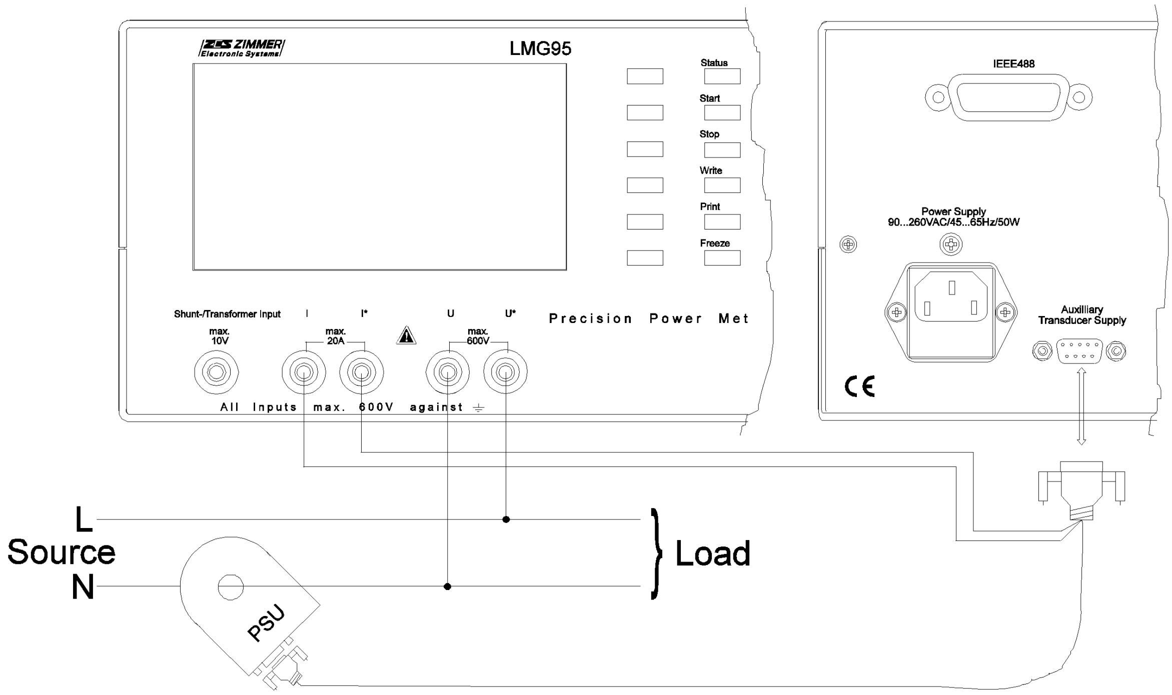


Figure 29: Connection of PSU60/200/400/700 and PCT200/600 to the LMG95

3.2.1 ⚠ Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test
Connecting cables without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

3.2.2 Installation

No additional supply needed. Cable length between PSU/PCT and LMG: 2.5m

3.2.3 LMG95 ranges (direct current input) with PCT200

Iscale=500

nominal value	75A	150A
max. trms value	150A	300A
max. peak value	234.5A	*469A*

limited by PCT200 to max. 300Apk!

3.2.4 LMG95 ranges (direct current input) with PCT600

Iscale=1500

nominal value	225A	450A
max. trms value	450A	900A
max. peak value	703.5A	*1407A*

limited by PCT600 to max. 900Apk!

3.2.5 LMG95 ranges (direct current input) with PSU200

Iscale=1000

nominal value	150A
max. trms value	*300A*
max. peak value	*469A*

limited by PSU200 to max. 200Apk!

3.2.6 LMG95 ranges (direct current input) with PSU400

Iscale=2000

nominal value	300A
max. trms value	*600A*
max. peak value	*938A*

limited by PSU400 to max. 400Apk!

3.2.7 LMG95 ranges (direct current input) with PSU700

Iscale=1750

nominal value	262.5A	525A
max. trms value	525A	*1050A*

max. peak value	*820.75A*	*1641.5A*

limited by PSU700 to max. 700Apk!

3.2.8 Accuracy

Use PSU/PCT and LMG95 specifications to calculate the accuracy of the complete system.

3.2.9 Sensor operation without supply

It is important to assure a stable power supply of the sensor before switching on the load current! The **operation** of the sensor with load current and **without supply will cause damage** of the sensor and/or of the LMG/supply unit!
To remove the LMG/supply unit from the test location without removing the sensors from the current path, disconnect the DSUB9 plug and the savety laboratory plugs from the LMG and connect all of the 9pins together with ground (shield of the plug) and together with the hot-wired savety laboratory plugs. To do this, the load current has to be switched off!

4 LMG450 connection cables and adapter

The special design of all LMG450 sensors makes them very easy and comfortable to use. The HD15 SUB D plug contains the identification of the sensor type, the measuring ranges, including the needed scaling and several more parameters. The LMG450 reads this values and the meter will automatically configured to the optimum adjustments for using this special sensor. The LMG range setup is automaticaly taken from the sensor EEPROM. Further on we correct some of the sensor errors (transfer error, delay time, ...). So you get the best measuring results with each sensor.

4.1 BNC adapter to sensor input HD15 without EEPROM (L45-Z09)

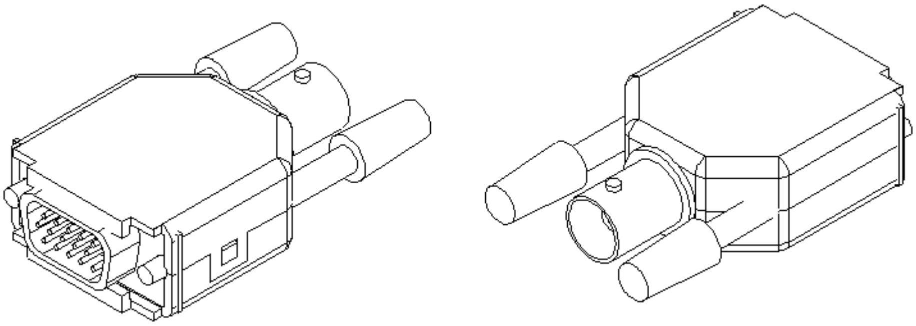


Figure 30: L45-Z09

By this adapter you can connect a voltage via a BNC cable to the LMG450 external current sensor input. This voltage has to be isolated, because the BNC screen is electrically connected to the case of the LMG450!

This is a simple electrical adapter. No values can be stored!

4.2 Adapter for isolated custom current sensors with 1A output (L45-Z22)

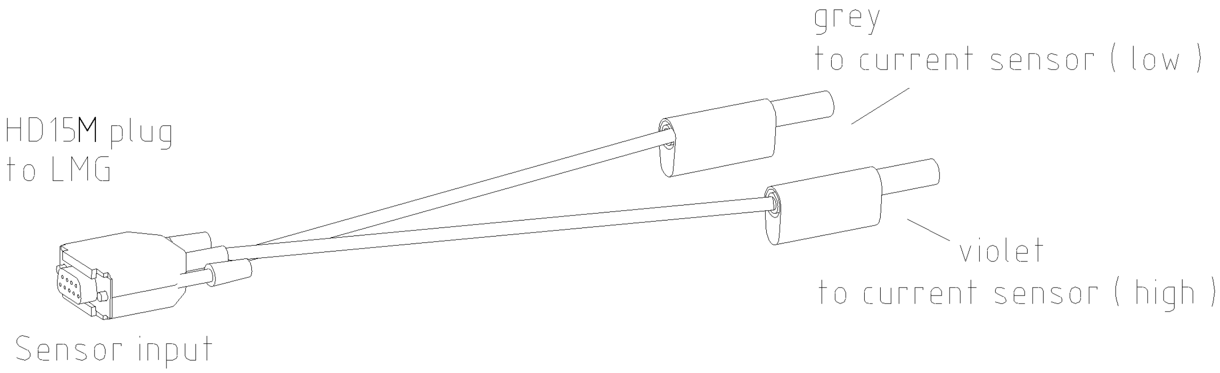


Figure 31: L45-Z22

4.2.1 Safety warning!

Use only galvanic separating current sensors! There is no potential separation in this adapter and in the LMG450 sensor input! NOT FOR DIRECT CURRENT MEASUREMENT!!
Please refer to chapter 1.1: ‘Safety precautions’!

4.2.2 Specifications

L45-Z22 is an accessory for the precision power meter LMG450. Its benefit is the usage of isolated custom current sensors with 1A output current e.g. current transducers or clamps with the LMG450 sensor input. In comparison to the usage of the direct current inputs of the LMG450, the accessory L45-Z22 is optimized for the sensor output current of 1A and a dynamic range down to 31.25mA as full range.

Nominal input current	1A
Max. trms value	1.2A
Measuring range	3Apk
Input resistance	340mOhms
Bandwidth	DC to 20kHz
Isolation	NO ISOLATION! NOT FOR DIRECT CURRENT MEASUREMENT!
Connection	HD15 (with EEPROM) for LMG sensor input, length about 80cm

4.2.3 Accuracy

Accuracies based on: sinusoidal current, ambient temperature 23±3°C, calibration interval 1 year. The values are: ±(% of measuring value + % of measuring range)

Frequency/Hz	DC to 45Hz	45Hz to 65Hz	45Hz to 5kHz	5kHz to 20kHz
Current	0.05+0.05	0.05+0.05	0.1+0.1	0.25+0.25

Use L45-Z22 and LMG specifications to calculate the accuracy of the complete system.

4.2.4 Connection of the sensor with LMG90/310

not possible

4.2.5 Connection of the sensor with LMG95

not possible

4.2.6 Connection of the sensor with LMG450

nominal value	0.03A	0.06A	0.12A	0.25A	0.5A	1A
max. trms value	0.04A	0.08A	0.15A	0.3A	0.6A	1.2A
max. peak value	0.09A	0.19A	0.375A	0.75A	1.5A	3A

4.2.7 Connection of the sensor with LMG500

not necessary, because of good current dynamic range of LMG500

5 LMG500 connection cables and adapter

5.1 LMG500 current sensor adapter (L50-Z14)

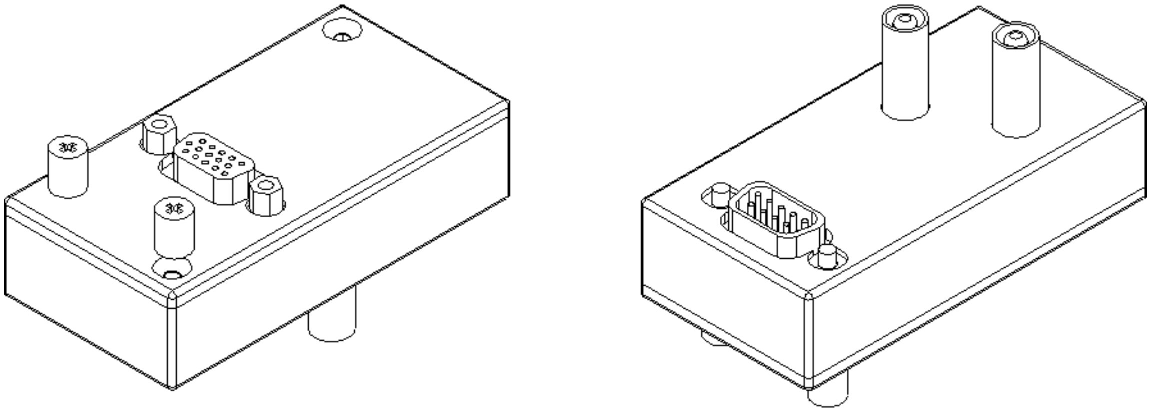


Figure 32: L50-Z14

The special design of all LMG500 sensors makes them very easy and comfortable to use. The HD15 SUB D plug contains the identification of the sensor type, the measuring ranges, including the needed scaling and several more parameters. The LMG500 reads this values and the meter will automatically configured to the optimum adjustments for using this special sensor. The LMG range setup is automaticaly taken from the sensor EEPROM. Further on we correct some of the sensor errors (transfer error, delay time, ...). So you get the best measuring results with each sensor.
For all LMG500 sensors the Adapter L50-Z14 is needed, because internally it is necessary to connect the system ground (CPU, Sensor supply, ...) with the ground of the measuring channel. Both signals are connected with a HD15 SUB D plug, without galvanic separation. The adapter L50-Z14 guarantees that no measuring leads are connected to the measuring channel at the same time and prevents electrical shock.

6 Accessories

6.1 Sensor supply unit for up to 4 current sensors (SSU4)

The SSU4 is a supply unit to feed up to 4 pieces of current sensors. Each sensor can be supplied with +15V / 500mA, -15V / 500mA at the same time. The transducers are connected to the four 9 pin SUB-D connectors. Depending on the sensor the output signal can be accessed directly from the sensor or via the 15 pin SUB-D connector.

6.1.1 Technical data

Mains supply	85...264V, 47...440Hz, ca. 40W, Fuse 5x20mm T3.15A/250V IEC127-2/3
Protection method	IP20 according DIN40050
Protection class	I; Mains supply: Overvoltage class II and pollution degree 2 according IEC61010-1
EMC	EN55011, EN50082
Safety	EN61010
Dimensions	Desktop: 320mm (W) x 49mm (H) x 307mm (D) 19“ rack: 63DU x 1HU x 360mm
Output voltage	±15V ±2%
Output current	max. 500mA on each jack
Climatic class	KYG according to DIN 40040 0°C...40°C, humidity max. 85%, annual average 65%, no dewing
Storage temperature	-20°C to +55°C
Weight	3kg

6.1.2 Technical drawings

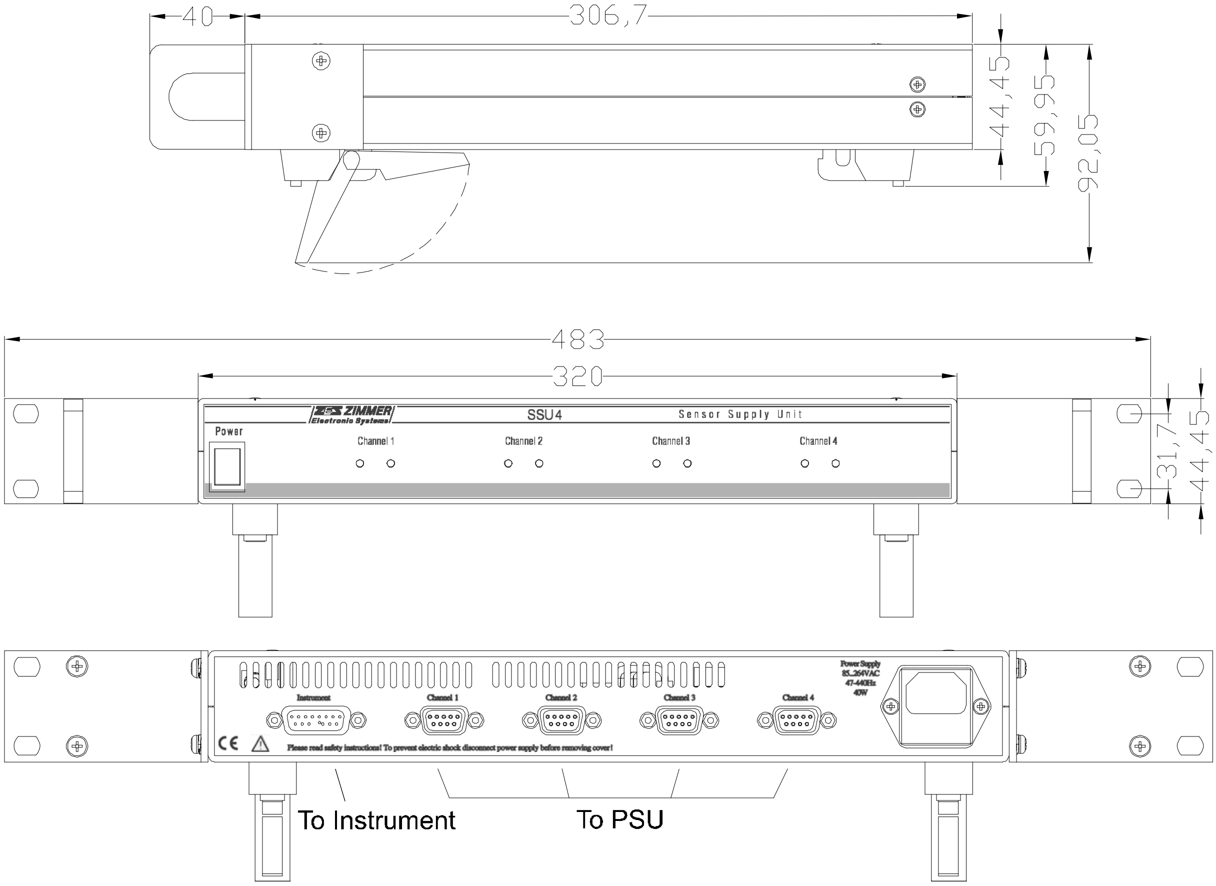


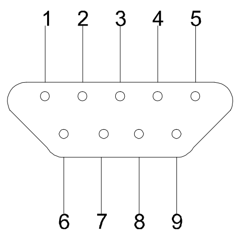
Figure 33: Dimensions of the SSU4

In the Figure 33 you see the desktop instrument, also attended the angles for rack mounting

6.1.3 Connectors

6.1.3.1 9 Pin SUB-D connectors for the sensors

Via the following connector the sensors (e.g. PSU600, L45-Z29-xxxx, ...) are connected to the SSU4 sensor supply unit. For each channel there is one connector.



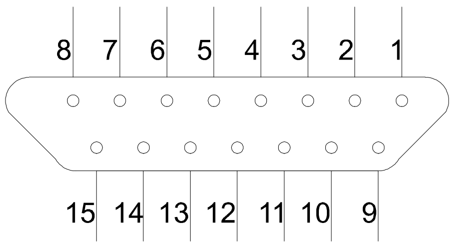
Connector to the sensors

Pin	Usage
1, 2	Not used. Do not connect!
3, 4	Ground (GND)
5	-15V. max. 500mA
6	Current output signal of the sensor (max. 500mA!)
7	Not used. Do not connect!
8	Signal input to indicate a proper operation of the sensor: +15V or n.c.: The red LED is on GND: The green LED is on
9	+15V, max. 500mA

The current output signal of the sensor is connected via a 2.7Ω resistor to the corresponding channel of the 15 pin connector for the instrument. When the current returns from the instrument it is fed into ground.

6.1.3.2 15 Pin SUB-D connectors for the measuring instrument

Via the following connector the measuring instrument can be connected to the sensor supply unit:



Connector to the instrument

Pin	Usage
1, 2	Current output channel 1
3, 4	Current output channel 2
5, 6	Current output channel 3
7, 8	Current output channel 4
9-15	Ground

The output current of each channel can be measured and has then to be returned to Ground.

6.1.4 Mounting

6.1.4.1 Rack mounting

Fix the two rack mounting metal sheets with the four screws at the two sides of the SSU4 case. Now you can mount it into any 19“ rack.

6.1.4.2 Instrument mounting

You can mount the SSU4 directly under a LMG95 or LMG450. Please do this in following order:

- Switch off both instruments and remove all cables.
- Remove the four feets of the LMG450 or LMG95 case. To do this, just remove the four screws. The nuts are fixed inside the LMG450 or LMG95.
- Remove the four feets of the SSU4 case. The four screws are mounted into the four screw-nuts which are accessable from the top of the case. Remove also this nuts.
- With the four M4x55 screws (which are added) you mount now the four feets of the SSU4 with following orientation:
  LMG95: mount the front feets in the 2nd position from the front plate.
  mount the rear feets in the 2nd position from the rear plate.
  LMG450: mount the front feets in the position closest to the front plate.
  mount the rear feets in the position closest to the rear plate.
  In both cases: The small white rubber on the feets has to be mounted in direction to the rear/front plate. The four screws are fixed into the nuts of the LMG450/LMG95 bottom (where the original feeds were fixed).

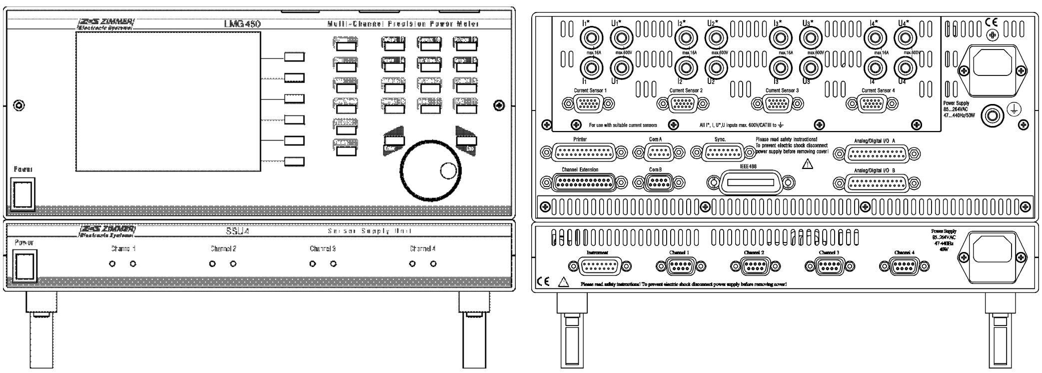


Figure 34: SSU4 mounted under LMG450

Dimensions W*D*H	320mm * 306.7mm * 224.6mm with feets, 176.9 without feets

6.1.5 SSU4 connector cables

6.1.5.1 Cable to connect measuring signal plugs of SSU4 with LMG310 current inputs (SSU4-K-L31)

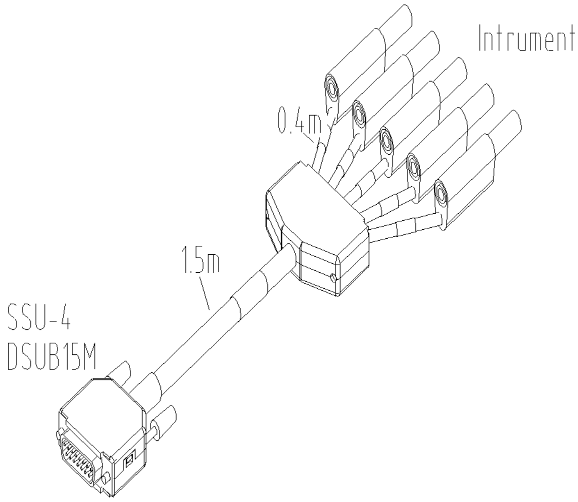


Figure 35: SSU4-K-L31, to connect measuring signal plug of SSU4 to LMG310 current inputs.

Cable to connect up to four PSU600 to the current input channels of:

1 LMG310
1 LMG310 and 1 LMG95
1 LMG450 (but better using PSU600-K-L45)
2 LMG310 in Aron wiring
or any other amperemeter

6.1.5.2 Connection cable PSU600 to SSU4 (PSU600-K3, K5, K10)

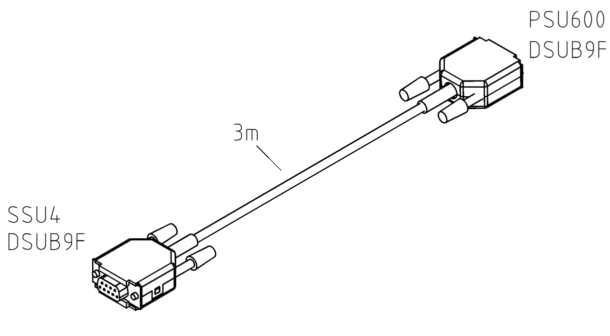


Figure 36: PSU600-K3, to connect the PSU600 to the SSU4 (length 3m).

Connection cable from SSU4 to PSU600; length 3m, 5m or 10m.

6.1.6 Modification option of SSU4 available for the use of PCT200, PCT600, PSU60, PSU200, PSU400 and PSU700 together with SSU4-K-L31

The modification is needed only for the use of PCT200, PCT600, PSU60, PSU200, PSU400 or PSU700 with SSU4-K-L31, no modification is necessary for PSU200-K-L45 or something like that.

The following changes concerning this documentation are done:

1. In the four connector to the sensors: **pin1** is connected with **gnd** for current return

2. The current output signal of the sensor is connected via a **0 ohms** resistor to the corresponding channel of the 15 pin connector for the instrument. When the current returns from the instrument it is fed into ground.

3. The SSU4 with modification can **not** be used with **PSU600!**

6.1.7 Modification option of SSU4 available for the use of PSU1000HF together with LMG450 and LMG500

The following changes concerning this documentation are done:

1. DSUB9 connectors for the sensors:

Pin	Usage
5	-15V. max. **1000mA**
6	Current output signal of the sensor (max. **1000mA**)
9	+15V, max. **1000mA**

6.2 Adapter for incremental rotation speed encoders (L45-Z18)

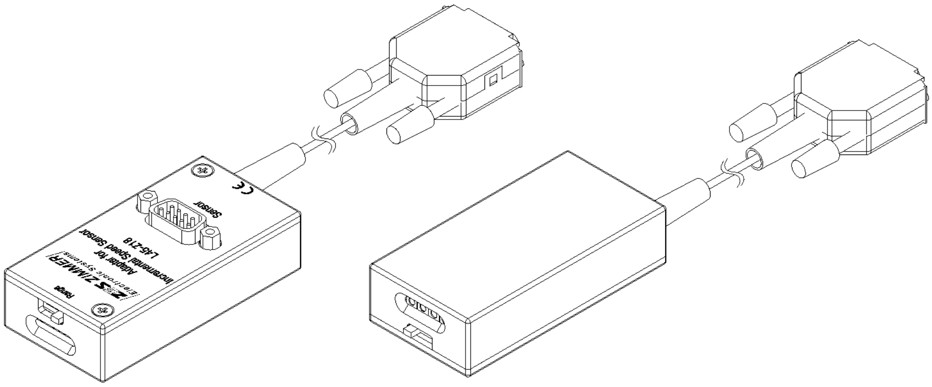


Figure 37:L45-Z18

6.2.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

6.2.2 General

This plugon adapter for LMG450 converts pulses of common industrial incremental encoders with two 90 degree phase shifted pulse outputs into analogue voltage. This voltage can be analysed graphically with high temporal resolution by using sensor input of LMG450.

Compared to this, digital encoder input of process signal interface provides only one value each measuring cycle and with L45-Z18 you get a fast, high dynamic response to changes in rotation speed!

6.2.3 Description

Incremental encoders (speed sensors) with TTL technology (supply +5V and GND) or HTL technology (supply +5V and –5V) can be connected. There are four colour coded measuring ranges of the adapter to align with different pulse rates Z of the incremental encoder and maximum revolutions per minute Nmax.

Attention! Read measuring value Idc, only this presents exact speed values according to absolute value and sign (depending on sense of rotation)! Positive output voltage is seen in case A signal leads electrically by 90° to B signal. This equates usually to clockwise rotation when looking onto the encoder shaft.

6.2.4 Ripple

As a matter of principle of frequency to voltage conversion there is a ripple at low revolution on output voltage. Built-in filters are optimised for short settling time without overshooting. In case that remaining ripple is too high, this can be reduced with the settings of LMG, for example:

- Select adjustable lowpass filter in measuring channel
- Extend the measuring cycle time
- Average over a couple of measurement cycles

Selection of the filter is always a compromise of fast reaction on variation of input signal and reduction of ripple on output signal. The user can find optimal setting weighing these antithetic approaches.

6.2.5 Incremental encoders with two 90 degree phase shifted pulse outputs

Measuring range	**LED Colour**	**Red**	**Yellow**	**Green**	**Blue**
Position of the slide switch adjacent of the LEDs	Unit	Left most	Left	Right	Right most
Z*Nmax (Pulse rate * max. revolution speed)	1 / min	144000	576000	2304000	9216000
Specified tolerance	% of m.value + % of m.range	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)
Max. pulse input frequency using input A and B	Hz	2400	9600	38400	153600
Formula for "Scale"	1 / min	1152000 / Z	1152000 / Z	1152000 / Z	1152000 / Z

“Z” is the number of pulses per rotation of the used incremental encoder (speed sensor)

6.2.6 Incremental encoders with single pulse outputs

Measuring range	LED Colour	Red	Yellow	Green	Blue
Position of the slide switch adjacent of the LEDs	Unit	Left most	Left	Right	Right most
Z*Nmax (Pulse rate * max. revolution speed)	1 / min	288000	1152000	4608000	9216000
Specified tolerance	% of m.value + % of m.range	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)
Max. pulse input frequency using input A	Hz	4800	19200	76800	153600
Formula for "Scale"	1 / min	2304000 / Z	2304000 / Z	2304000 / Z	1152000 / Z

“Z” is the number of pulses per rotation of the used incremental encoder (speed sensor)

The recognition of the rotating direction is not possible.
The output voltage is always negative if input B is left open.
The output voltage is always positive if input B is tied to pin ‘supply +5V’

6.2.7 Scaling

In range menu of LMG450 you can set the calculated scale value of the last line from above mentioned chart, depending on the pulse rate Z per rotation of the used incremental encoder. Then the revolution will be presented correctly in value 1/min on the display. The unit will however be A (or V)! Displayed 1.465kA means 1465 1/min. For further user-friendly presentation utilise capabilities of LMG450 built-in formula editor and user defined menu.

6.2.8 Pin assignment

9 pin D-Sub connector (male) to incremental encoder

Pin No.	1	2	3	4	5	6	7	8	9	Screen
Function	Supply +5V	Supply -5V	GND (on screen)	Input A	Input B	No connection (internal test pins)				Screen (on GND)

6.2.9 Pulse input A and B

Permissible input voltage:	Ulowmin = -30V at -1.4mA, Ulowmax=+0.8V at 0.001mA Uhighmin=+2V at 0.002mA, Uhighmax=+30V at 1.2mA
Input resistance:	1Mohms at 0V<Uin<+5V 22kohms at -30V<Uin<+30V

6.2.10 Encoder supply

Voltage:	±5V, ±10%
Load:	max. ±100mA

6.2.11 Connection of the sensor with LMG90/310/95

not possible

6.2.12 Connection of the sensor with LMG450

Plug-and-use solution like current sensors. Use current channel.

6.2.13 Connection of the sensor with LMG500

not possible, use L50-Z18

6.3 Adapter for incremental rotation speed encoders (L50-Z18)

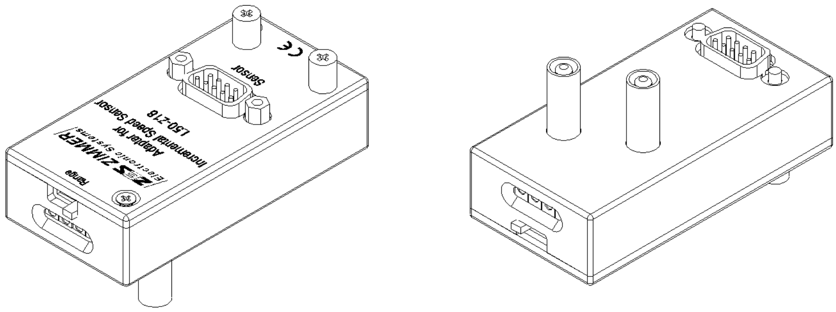


Figure 38:L50-Z18

6.3.1 Safety warning!

Always connect the sensor first to the meter, and afterwards to the device under test.
Connecting cable without savety isolation! Avoid contact to hazardous voltage!
Please refer to chapter 1.1: ‘Safety precautions’!

6.3.2 General

This plugon adapter for LMG500 converts pulses of common industrial incremental encoders with two 90 degree phase shifted pulse outputs into analogue voltage. This voltage can be analysed graphically with high temporal resolution by using sensor input of LMG500.

Compared to this, digital encoder input of process signal interface provides only one value each measuring cycle and with L50-Z18 you get a fast, high dynamic response to changes in rotation speed!

6.3.3 Description

Incremental encoders (speed sensors) with TTL technology (supply +5V and GND) or HTL technology (supply +5V and –5V) can be connected. There are four colour coded measuring ranges of the adapter to align with different pulse rates Z of the incremental encoder and maximum revolutions per minute Nmax.

Attention! Read measuring value Idc, only this presents exact speed values according to absolute value and sign (depending on sense of rotation)! Positive output voltage is seen in case A signal leads electrically by 90° to B signal. This equates usually to clockwise rotation when looking onto the encoder shaft.

6.3.4 Ripple

As a matter of principle of frequency to voltage conversion there is a ripple at low revolution on output voltage. Built-in filters are optimised for short settling time without overshooting. In case that remaining ripple is too high, this can be reduced with the settings of LMG, for example:

- Select adjustable lowpass filter in measuring channel
- Extend the measuring cycle time
- Average over a couple of measurement cycles

Selection of the filter is always a compromise of fast reaction on variation of input signal and reduction of ripple on output signal. The user can find optimal setting weighing these antithetic approaches.

6.3.5 Incremental encoders with two 90 degree phase shifted pulse outputs

Measuring range	**LED Colour**	**Red**	**Yellow**	**Green**	**Blue**
Position of the slide switch adjacent of the LEDs	Unit	Left most	Left	Right	Right most
Z*Nmax (Pulse rate * max. revolution speed)	1 / min	144000	576000	2304000	9216000
Specified tolerance	% of m.value + % of m.range	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)
Max. pulse input frequency using input A and B	Hz	2400	9600	38400	153600
Formula for "Scale"	1 / min	1152000 / Z	1152000 / Z	1152000 / Z	1152000 / Z

“Z” is the number of pulses per rotation of the used incremental encoder (speed sensor)

6.3.6 Incremental encoders with single pulse outputs

Measuring range	LED Colour	Red	Yellow	Green	Blue
Position of the slide switch adjacent of the LEDs	Unit	Left most	Left	Right	Right most
Z*Nmax (Pulse rate * max. revolution speed)	1 / min	288000	1152000	4608000	9216000
Specified tolerance	% of m.value + % of m.range	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)	±(0.1+0.1)
Max. pulse input frequency using input A	Hz	4800	19200	76800	153600
Formula for "Scale"	1 / min	2304000 / Z	2304000 / Z	2304000 / Z	1152000 / Z

“Z” is the number of pulses per rotation of the used incremental encoder (speed sensor)

The recognition of the rotating direction is not possible.
The output voltage is always negative if input B is left open.
The output voltage is always positive if input B is tied to pin ‘supply +5V’

6.3.7 Scaling

In range menu of LMG500 you can set the calculated scale value of the last line from above mentioned chart, depending on the pulse rate Z per rotation of the used incremental encoder. Then the revolution will be presented correctly in value 1/min on the display. The unit will however be A (or V)! Displayed 1.465kA means 1465 1/min. For further user-friendly presentation utilise capabilities of LMG500 built-in formula editor and user defined menu.

6.3.8 Pin assignment

9 pin D-Sub connector (male) to incremental encoder

Pin No.	1	2	3	4	5	6	7	8	9	Screen
Function	Supply +5V	Supply -5V	GND (on screen)	Input A	Input B	No connection (internal test pins)				Screen (on GND)

6.3.9 Pulse input A and B

Permissible input voltage:	Ulowmin = -30V at -1.4mA, Ulowmax=+0.8V at 0.001mA Uhighmin=+2V at 0.002mA, Uhighmax=+30V at 1.2mA
Input resistance:	1Mohms at 0V<Uin<+5V 22kohms at -30V<Uin<+30V

6.3.10 Encoder supply

Voltage:	±5V, ±10%
Load:	max. ±100mA

6.3.11 Connection of the sensor with LMG90/310/95

not possible

6.3.12 Connection of the sensor with LMG450

not possible, use L45-Z18

6.3.13 Connection of the sensor with LMG500

Plug-and-use solution like current sensors. Use current channel.

6.4 Synchronisation adapter with adjustable lowpass filter (L50-Z19)

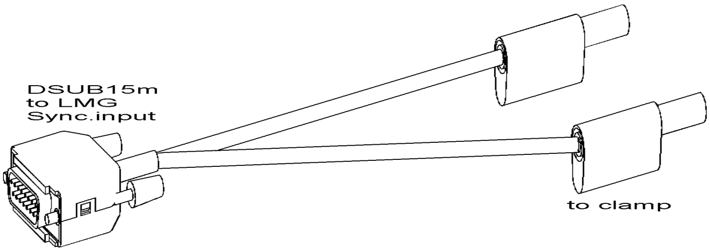


Figure 39:L50-Z19

6.4.1 ⚠ Safety warning!

1.) first connect the clamp to L50-Z19

2.) connect L50-Z19 to LMG500 Sync.input and switch the power meter on

3.) then connect the clamp to the device under test.

Synchronisation adapter without safety isolation! Only for current clamps with galvanic isolation! NO DIRECT CONNECTION TO ANY EXTERNAL VOLTAGES!!

Please refer to chapter 1.1: ‘Safety precautions’!

L50-Z19 is an accessory for the precision power meter LMG500. It can be used with any xxA:1A current clamp, e.g. LMG-Z325, LMG-Z326, LMG-Z322 or LMG-Z329. A burden resistor, a high sensitivity amplifier and a 8th order Butterworth lowpass filter are included in the DSUB15 plug to assure stable synchronisation to any disturbed signal.

It simplifies the synchronisation to the fundamental current frequency of a frequency inverter output. It needs about 100uA fundamental current at the signal input. That means with a 1000A:1A current clamp it is possible to detect the fundamental in a wide current range from 100mA to 1000A. If the fundamental current is lower than 100mA, several load current windings in the clamp can be used to enlarge the sensitivity or use an other clamp with 100A:1A ratio. LMG500 settings in the measure menue: set ‘Sync’ to ‘ExClmp’ and adjust the lowpass corner frequency.

Important: L50-Z19 can be configured only in Group A, if it is configured in Group A, it can be used in Group B as well via ‘Sync ext.’.

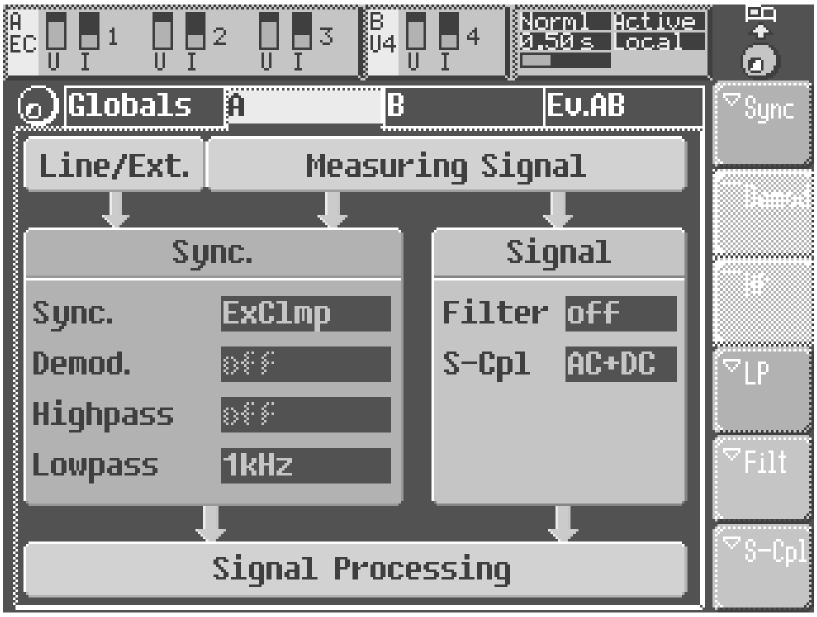


Figure 40:L50-Z19

Select a filter with a lowpass frequency bigger than every possible fundamental frequency and(!) lower than every possible switching frequency, under all conditions of starting, breaking and acceleration of the motor.

6.4.2 Specifications

filter name	200Hz	500Hz	1kHz	2kHz	5kHz	10kHz	20kHz
-3dB corner frequency	312.5Hz	625Hz	1.25kHz	2.5kHz	5kHz	10kHz	20kHz
filter type	8th order Butterworth						
min. current for stable synchronisation	about 100uA						
max. current	1Atrms						
isolation	NO ISOLATION! (see safety warning)						
connection length	about 50cm (but can be extended with usual savety laboratory leads)						

6.4.3 Connection of the sensor with LMG90/310/95/450

not possible

6.5 Ethernet Adapter (L95-Z318, L45-Z318, L50-Z318, LMG-Z318)

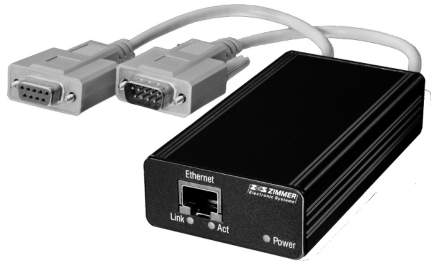


Figure 41: L95-Z318, L45-Z318, L50-Z318 - supply via LMG

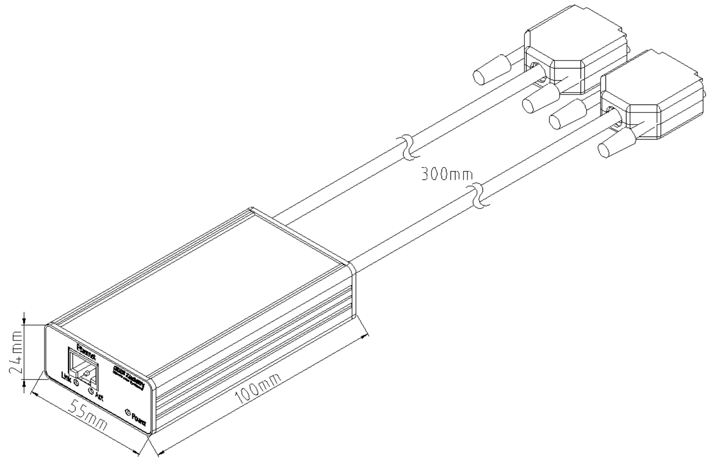


Figure 42: L95-Z318, L45-Z318, L50-Z318 - supply via LMG

Figure 43: LMG-Z318 - external supply via wall wart

This LAN adapter Z318 is useful for the communication with a power meter LMG located anywhere in a local area network LAN via a virtual COM port simulation. The communication is transmitted by the driver over LAN to the LMG for user purposes in the same way as e.g. the direct connection of PC/COM1 to LMG/COMa. The power meter LMG will be accessible via this virtual COM port. Perfect suitable for LMG Control software.

6.5.1 Safety warning!

Please refer to chapter 1.1: ‘Safety precautions’!

6.5.2 System requirements, hardware specifications

- Windows XP home / Windows XP professional / Windows7 / 32bit or 64bit.
  For other operating systems (including Windows: 98 / 2000 / NT /Vista, Linux: Debian / Mandriva / RedHat / Suse / Ubuntu) see http://www.digi.com -> support -> drivers and download the driver appropriate for your operating system for ‘Digi Connect SP’.
- auto-sensing to 10/100 Mbit/s Ethernet
- throughput up to 230.400 baud
- data flow control with RTS/CTS, hardware reset with ‘break’
- data throughput with LMG95/450/500
  binary mode: about 3000 measuring values (trms, ac, dc, ..., harmonics, flicker, sample values, ...) per second!
  ascii mode: about 1000 measuring values per second

6.5.3 Connection of the adapter L95-Z318 with LMG95 / LMG95e

- Plug the connector of L95-Z318 labeled with „to LMG’s COM B conn.“ to the LMG95 / LMG95e COM B jack.
- Plug the connector of L95-Z318 labeled with „supply“ to the LMG95 / LMG95e auxilary transducer supply jack, if your application uses the supply jack e.g. for PSU600, then use LMG-Z318 with external supply via wall wart.
- Switch on the power meter and connect the LAN cable.
- assure that the LMG firmware is 3v136 or newerfor LMG95, 5v136 or newer for LMG95e

6.5.4 Connection of the adapter L45-Z318 with LMG450

- Plug the connector of L45-Z318 labeled with „to LMG’s COM B conn.“ to the LMG450 COM B jack.

- Plug the connector of L45-Z318 labeled with „supply“ to one of the LMG450 current clamp 1/2/3/4 jacks whichever is free, if your application uses four current sensors, then use LMG-Z318 with external supply via wall wart.
- Switch on the power meter and connect the LAN cable.
- assure that the LMG firmware is 2v121 or newer

6.5.5 Connection of the adapter L50-Z318 with LMG500

- Plug the connector of L50-Z318 labeled with „to LMG's COM B conn.“ to the LMG500 COM B jack.
- Plug the connector of L50-Z318 labeled with „supply“ to one of the LMG500 sensor ID jacks whichever is free.
- Switch on the power meter and connect the LAN cable.
- assure that the LMG firmware is 4v077 or newer

6.5.6 Connection of the adapter LMG-Z318 with any LMGxx

- Connect the DSUB9 jack of LMG-Z318 with a 1:1 serial connection cable to LMGs COMa.
- Connect the wall wart with power input of LMG-Z318.
- Switch on the power meter and connect the LAN cable.

6.5.7 Configure the LAN connection with the Realport setup wizard

- You will find the setup wizard on the ZES support CD under driver\z318 or on the webpage http://www.zes.com. Start setup32.exe for 32-bit systems or setup64.exe for 64-bit systems.
  Press 'next', the wizard trys to find the ethernet adapter. If it is not found, press reset for about 3 seconds at the backside of the ethernet adapterbox to remove possible given prior IP address and wait for about 1 minute before searching again.
  This is the most important point in the installation. If the wizard still can not find the Z318 in your LAN, please ask your system administrator before you contact the support hotline of ZES. The support engineers of ZES will need a lot of detailed information about your local network to consult.
- If the wizard found one or more devices choose the appropriate one and press 'next'.

- Take care, that Z318 gets the same IP address after its next startup. Configure your local DHCP server that the fix MAC address of Z318 gets everytime the same IP address or set a fix (and free!) IP address manually. This is important, because in the next step you assign a virtual COM port to this IP address and if the IP address was different after the next startup, the virtual COM port would be not available.

- Select: ‘add a new device’. It might be necessary to remove previous installed drivers with ‘remove an existing device’.

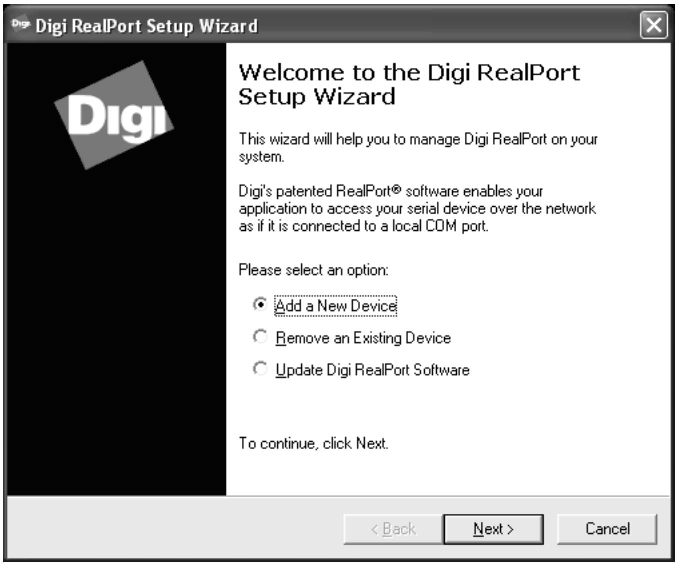


Figure 44

- Select the device ..

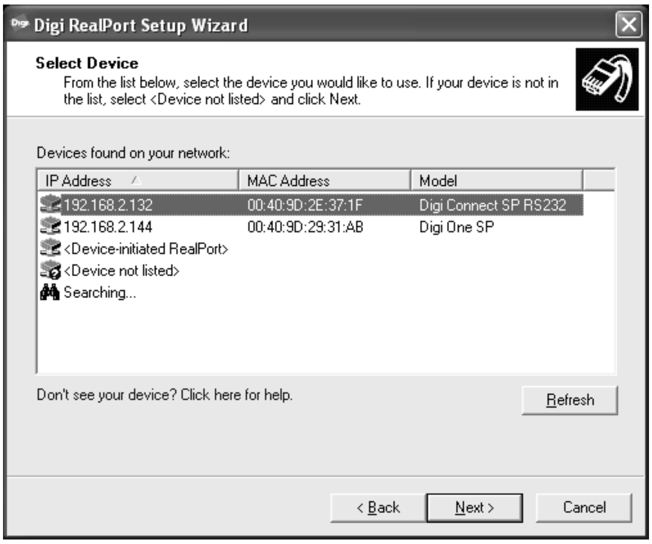


Figure 45

- .. and assign a virtual COM port:

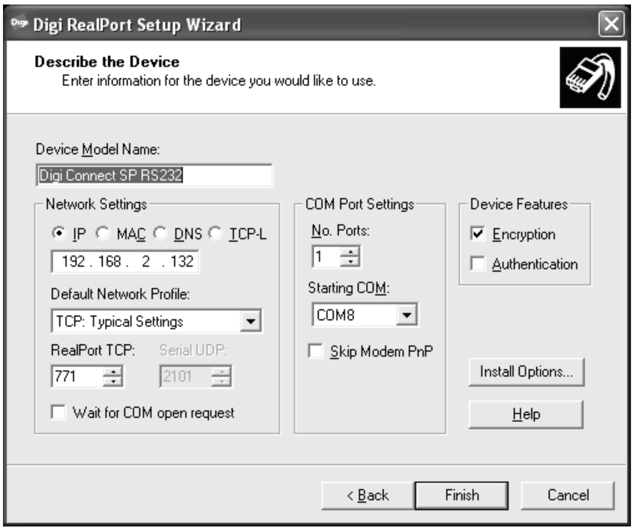


Figure 46

The power meter LMG is now accessible via this virtual COM port.

6.5.8 Configuration and Management by web interface

- Start your Browser and login to the IP adress obtained to your LAN adapter Z318 http://192.168.x.xx/login.htm with the username ‘root’ and the password ‘dbps’:

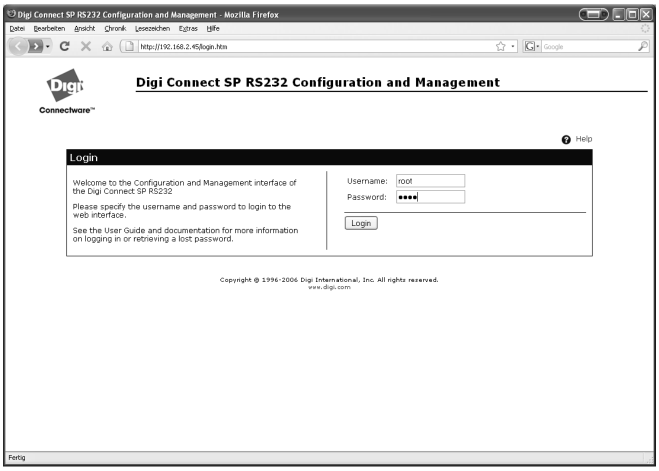


Figure 47

- Here you can manage the settings in a comfortable way: e.g. check MAC Address, IP Adress, firmware update and so on.

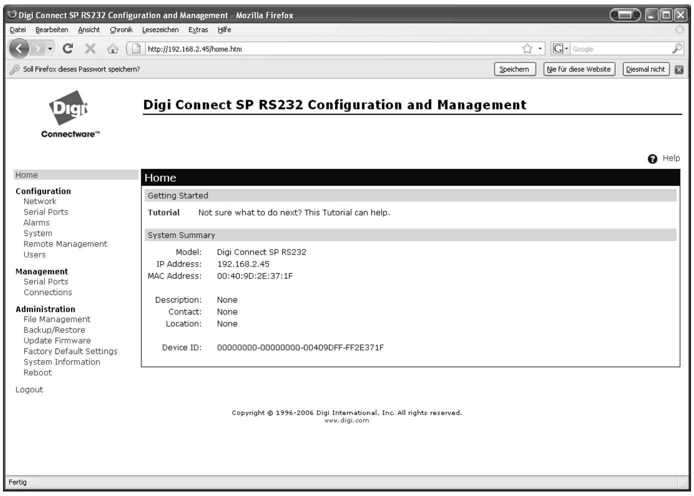


Figure 48

6.5.9 Troubleshooting

The following problems may appear while installing the ethernet adapter. If the problem remains after checking the following points, please contact ZES at sales@zes.com or ++49 6171 628750

- please check all connections: supply, RS232, LAN,
  in case of LMG-Z318 and LMGx COMa: use 1:1 serial cable, no nullmodem

- connect the ethernet adapter to the power supply, press reset, wait for about 1 minute and try again

- switch off your antivirus protection software, the firewall may block the communication

6.6 USB-RS232 Adapter (LMG-Z316)

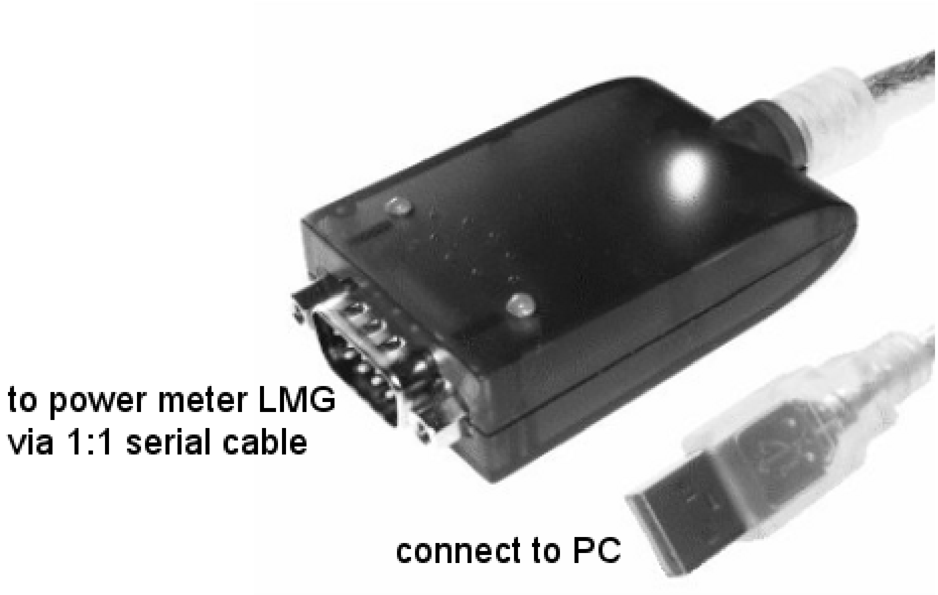


Figure 49: LMG-Z316

This USB-RS232 adapter Z316 is useful for the communication with a power meter LMG and a PC with USB port via a virtual COM port simulation. The communication is transmitted by the driver over USB to the adapter for user purposes in the same way as e.g. the direct connection of PC/COMx to LMG/COMa. The power meter LMG will be accessible via this virtual COM port. Perfect suitable for LMG Control software.

6.6.1 ⚠ Safety warning!

Please refer to chapter 1.1: ‘Safety precautions’!

6.6.2 System requirements, hardware specifications

- Windows: driver available for Windows XP home or professional / Windows Vista, see ZES support CD ‘LMG500 USB driver’
- Linux: driver is part of the kernel 2.4.x or newer (ftdi_sio Modul)
- throughput up to 230.400 baud
- supports data flow control with RTS/CTS, hardware reset with ‘break’

- adapter length about 1m, standard RS232 DSUB9 male with UNC nuts and USB typ A plug
- connection to LMG with standard 1:1 serial cable, elongation possible up to 15m

6.6.3 RS232 plug

DSUB9 male connector with UNC screw nuts, pin assignment:

pin1:	CD (carrier detect)
pin2:	RX (receive data)
pin3:	TX (transmit data)
pin4:	DTR (data terminal ready)
pin5:	GND
pin6:	DSR (dataset ready)
pin7:	RTS (request to send)
pin8:	CTS (clear to send)
pin9:	RI (ring indicator)

6.6.4 Included in delivery

- USB-RS232 Adapter
- DSUB9m to DSUB9f connection cable, pin assignment 1:1, about 1.8m

7 Voltage sensors

7.1 Precision high voltage divider (HST3/6/9/12)

Figure 50: precision high voltage divider HST12-3

7.1.1 ⚠ Safety warning!

The HST Series is not designed for working on medium voltage grids!

The normal use of the HST3/ 6/ 9/ 12 series needs a connection to high voltages. To fulfill the safety requirements it is under all conditions **absolutely necessary to earth the case** of the HST3/ 6/ 9/ 12 **to obtain safety** and functionality! Use sufficient cross section of the earthing conductor to match the possible shortcircuit currents!

Connection to voltages of more than 1000V should only be done with the use of external high-voltage high breaking capacity fuses!

To prevent partial discharges the unshielded high-voltage leads of HST must have a distance between each other, to other conductive parts and against earth of at least 25mm (HST3 and HST6) and 50mm (HST9 and HST12)! Don’t touch the high-voltage leads to avoid partial discharges.

Because the measuring inputs of HST are designed for voltages >1000V, the respective safety rules for electrical equipment and installations above 1000V have strictly to be regarded!
Please refer to chapter 1.1: ‘Safety precautions’!

7.1.2 General

The wide band precision high voltage divider of series HST expand the voltage measuring range of ZES ZIMMER precision power meter LMG for use at nominal voltages over 1000V. The high voltage inputs are equipped with 2m leads that is attached to the voltage measured against earth. The open leads can be aligned by the customer.

The HST 3 (resp. HST6/9/12) divides DC, AC or any distorted voltages with very high accuracy by the factor 1000 (resp. 2000/3000/4000). The divided voltage is available at the buffered low impedance BNC output. To avoid noise interference it is recommended to use shielded cables to the measuring input of the LMG.

The HST can be delivered in one, two or three channel version as to match the particular measuring task.

The single phase HST is used in single ended systems (e.g. lighting, plasma generation, induction heating, ultrasonic applications). Line to line voltages can be measured as difference between the output signals of the channels. For floating (difference) voltage measuring therewith the 2-phase HST is best suitable.

The HST has been designed for measurements at gas discharge lamps, to measure the high frequency burning voltage and the ignition voltage with high precision. These characteristics enable the use of the HST at frequency inverters with voltage peaks above 1000V. These applications have no risk of surge and transient overvoltages by lightning or switching operations. The voltage peaks in these applications are well definded and are produced by the application itself with a limited energy.

However the HST should be protected by external high voltage high breaking capacity fuses. A further improvement of operational reliability is possible with external surge arresters. It should be connected on the HST input behind the fuse against earth.

7.1.3 Specifications for serial numbers starting with ‘B...’, ‘C...’, ‘D...’

Series	**HST3**	**HST6**	**HST9**	**HST12**
maximum trms input voltage	3.15kV	6.3kV	9.45kV	12.6kV
maximum peak voltage for full scale	5kV	10kV	15kV	20kV
input impedance	10MΩ‖50pF	20MΩ‖25pF	30MΩ‖22pF	40MΩ‖20pF
dividing ratio	1/1000	1/2000	1/3000	1/4000
accuracy of dividing ratio	max. ±0.08% (45Hz ... 65Hz) typ. ±2% (300kHz; burden<100pF)			
influence of power measurement	max. ±0.1% (45Hz ... 65Hz; PF>0.8) typ. ±3% (300kHz; burden<100pF; PF>0.8)			
measurement input	one fixed high voltage lead (length 2m) for each channel, earth jack as the common reference point			
signal output	one BNC socket for each channel			
output burden	min. 500Ω; max. 2nF			
safety class	class I; **device must be earthed additionally to PE of mains supply cord.**			
enclosure	robust aluminium case			
size (L x W x H) without cable and connectors	330mm x 230mm x 110mm		400mm x 230mm x 110mm	
weight	approx. 6.1kg		approx. 7.2kg	
mains supply	230V / 50Hz; approx. 20VA			

Overvoltage capabilities of high voltage input against earthed case:
No transient overvoltages allowed!

7.1.4 Specifications for serial numbers starting with ‘E...’

	Series	**HST3**			**HST6**			**HST9**			**HST12**		
	no. of channels	1	2	3	1	2	3	1	2	3	1	2	3
	ordering type	HST 3-1	HST 3-2	HST 3-3	HST 6-1	HST 6-2	HST 6-3	HST 9-1	HST 9-2	HST 9-3	HST 12-1	HST 12-2	HST 12-3
Nominal electrical rating of measuring inputs	maximum sine trms voltage for full scale	3.5kV			7kV			10.5kV			14kV		
	maximum trms input voltage	4.2kV			8.4kV			12.6kV			16.8kV		
	maximum peak voltage for full scale	5kV			10kV			15kV			20kV		
	input impedance	10MΩ‖50pF			20MΩ‖25pF			30MΩ‖22pF			40MΩ‖20pF		
	dividing ratio	1/1000			1/2000			1/3000			1/4000		
	<u>measuring accuracy</u>	<u>tolerance of ratio</u>			<u>tolerance of phase</u>								
	DC	max. ±0.1%			-								
	0.05Hz ... 45Hz	max. ±0.1%			±0.06°								
	45Hz ... 65Hz	max. ±0.05%			±0.06°								
	65Hz ... 2.5kHz	max. ±0.1%			±0.2°								
	2.5kHz ... 10kHz	max. ±0.2%			±0.4°								
	10kHz ... 100kHz	max. ±0.3%			±0.5°								
	100kHz...300kHz;	typ. ±2%			±2.5°								
	conditions for accuracy specifications	input voltage from 3% to 100% of maximum trms input voltage output burden min. 1kΩ ‖ max. 1nF (except min 1kΩ ‖ max. 100pF at 100kHz...300kHz)											
Overvoltage capability of highvoltage input against earthed case *) voltages in accordance to EN61010:2010, valid for max. altitude 2000m over sea level	maximum trms voltage*	4.2kV			8.4kV			12.6kV			16.8kV		
	maximum periodic peak voltage*	5kV			10kV			15kV			20kV		
	maximum transient overvoltage*	3.8kV			6.8kV			8.8kV			10.2kV		
	non-repetitive maximum peak voltage*	8.8kV			16.8kV			23.8kV			30.2kV		
Mechanical	measurement input	one fixed high voltage lead (length 2m) for each channel, earth jack as the common reference point											
	signal output	one BNC socket for each channel											
	enclosure	robust aluminium case											
	size (L x W x H)	330mm x 230mm x 110mm						400mm x 230mm x 110mm					
	installation dimension (L x W x H)	490mm x 230mm x 110mm						590mm x 230mm x 110mm					
	weight	approx. 6.1kg						approx. 7.2kg					
Other	temperature range	5...40°C, indoor use only											
	safety class	class I; **device must be earthed additionally to PE of mains supply cord.**											
	mains supply	85..265V; 45..65Hz; approx. 20VA											

7.1.5 Measurement principle HST

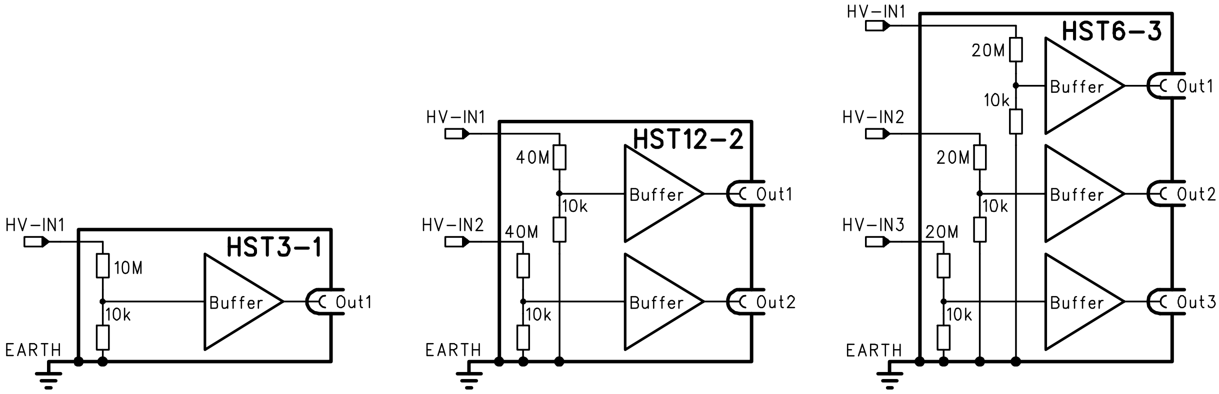


Figure 51: principle structure of different HST types

7.1.6 Example wirings

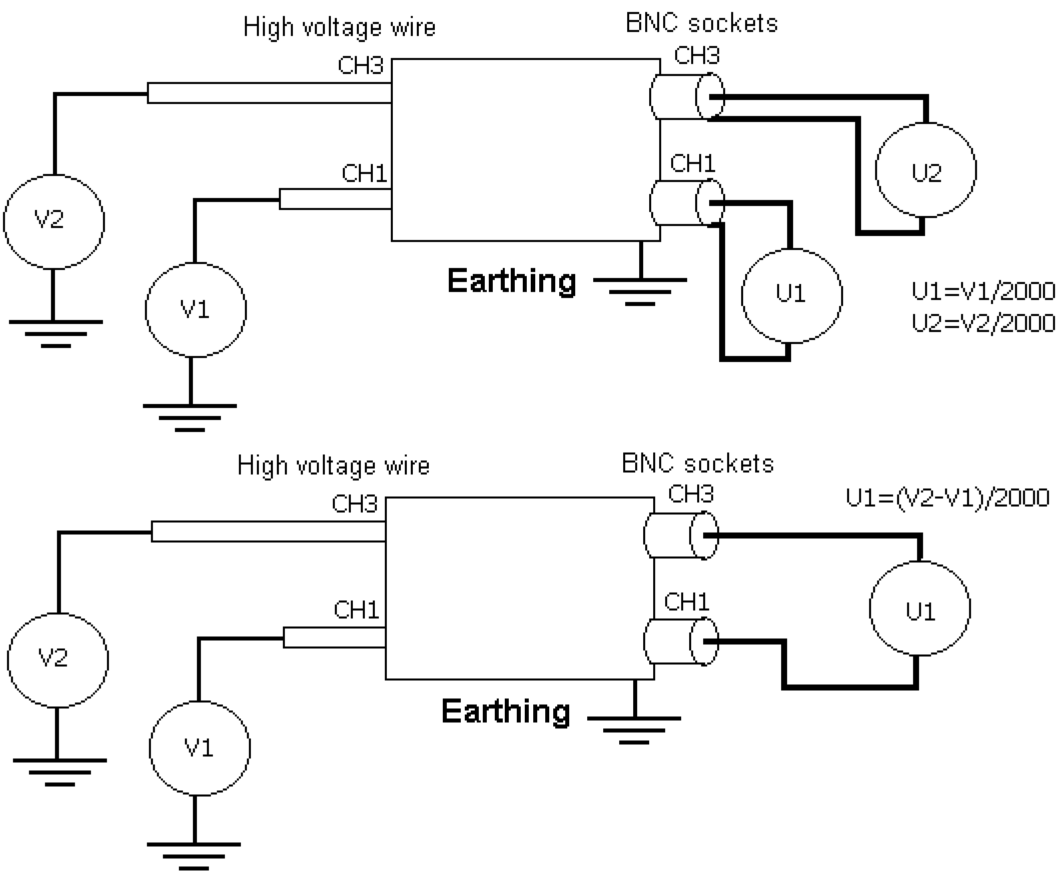


Figure 52: example wirings HST6-2

Two possible example wirings are shown: A two channel measurement in the upper part of the figure and a differential voltage measurement in the lower part of the figure.

7.1.7 HST wiring of 3-phase systems

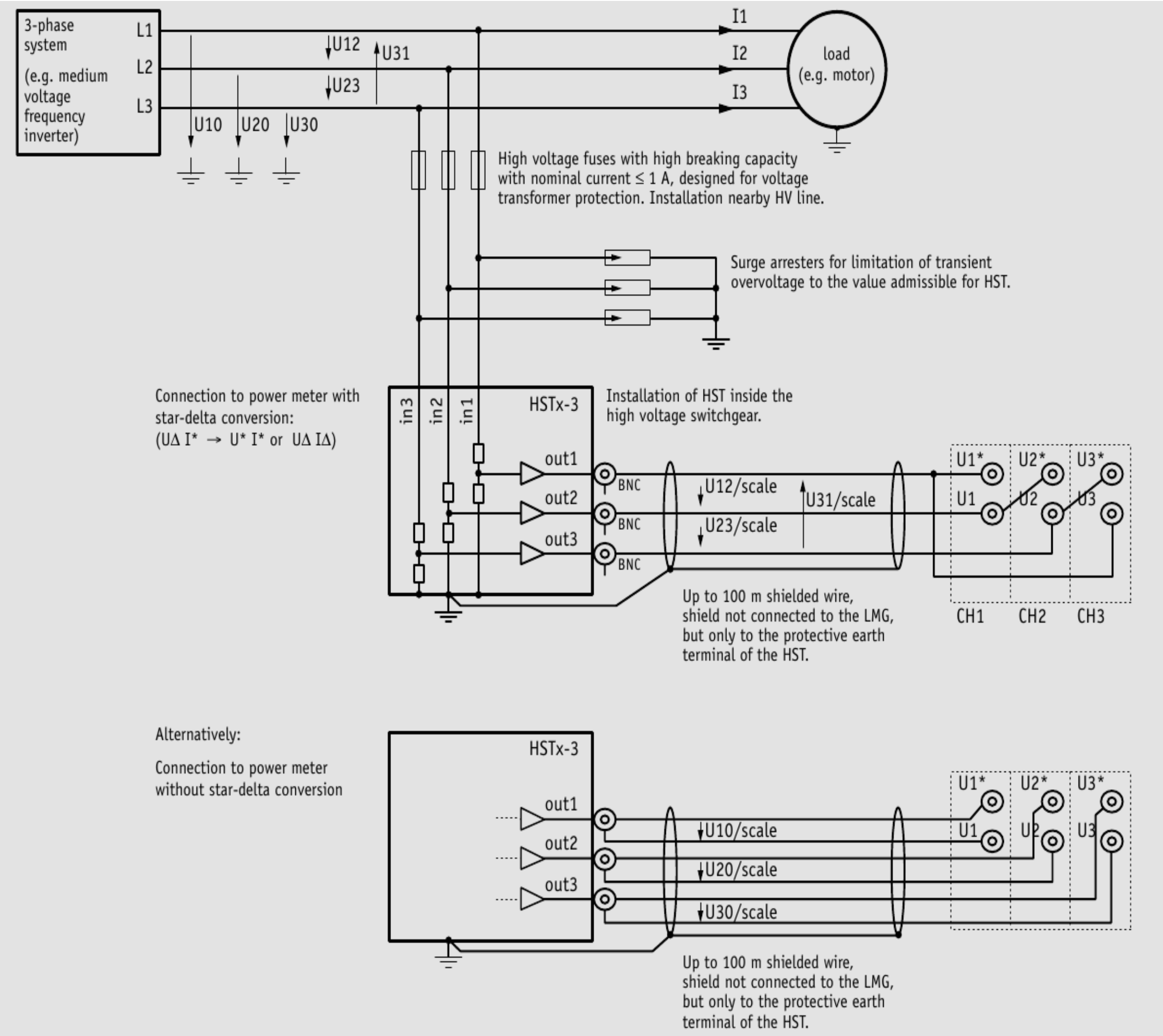


Figure 53: HST wiring of 3-phase systems

On the highvoltage side HST input1, input2 and input3 connects to L1, L2 and L3. All voltage measurements have the same reference potential: earth.
Also isolated sources as these are always bound to earth by their earth capacities can be measured with the earthed HST.

On the low voltage side, the connection to the power meter LMG or other instruments can be done in two different ways:

1. Instruments with internal star-delta conversion are connected like shown in the upper part of the drawing. Advantage is that unbalanced sources are measured correctly, the total power is determined correctly as well as the power of each phase.

2. Instruments without star-delta conversion are connected like shown in the lower part of the drawing. The line voltages with reference potential earth can be tapped directly at the BNC jacks. Even with unbalanced sources, the total power is determined correctly.

7.1.8 Included in delivery

- precision high voltage divider (HST)
- about 3m BNC connection cable from HST to the power meter LMG
- adapter BNC to 4mm plugs

7.1.9 Option mounting clips (HST-Z01/Z02)

This option has to be specified at the order, respectively a refitting can be only made by ZES ZIMMER.

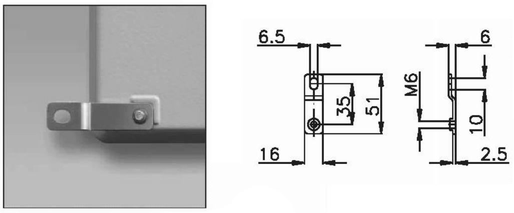


Figure 54: HST mounting clips, Dimensions in mm

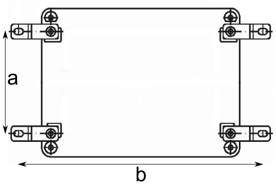


Figure 55: HST-Z01

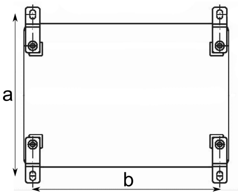


Figure 56: HST-Z02

HST	Option	a	b
HST3 HST6	HST-Z01	180mm	380mm
	HST-Z02	250mm	310mm

HST9 HST12	HST-Z01	180mm	450mm
	HST-Z02	250mm	380mm

7.1.10 Option HST-O1-1 supply connection via IEC320 connector

Supply connection mating to commonly used IEC-320-C13 appliance connectors.

Figure 57: HST-O1-1

7.1.11 Option HST-O1-2 supply connection via NEMA 5-15P connector

Supply connection mating to NEMA 5-15 sockets commonly used in USA.

Figure 58: HST-O1-2

7.1.12 External high-voltage high breaking capacity fuses

Although HV fuse-links are not able to protect the HST in the case of an internal fault, they should be installed. In the case of a fault the HST shall be disconnected from the supply as fast as possible in order to limit the fault effects. This is why HV fuse-links of lowest possible rated currents are recommended.

Possible suppliers of this fuses are:

- SIBA (www.siba.com):
  Indoor and outdoor voltage Transformer fuses HHD-BVT,
  Voltage transformer fuses HHZ-BVT

- ABB (www.abb.com):
  Indoor voltage transformer fuses WBP,
  Outdoor voltage transformer fuses BRT

Fuse selection criterias
Ambient conditions
Rated voltage: 6kV for HST3 and HST6
Rated voltage: 12kV for HST9 and HST12
Rated current: 0.6A to 1A

ZES ZIMMER can not guarantee that the fuses of above mentioned suppliers are suitable for every purpose and application! It is the responsibility of the user to find and install a fuse appropriate to the application.

7.1.13 External surge arrester

To improve the operational reliability the usage of a surge arrester is recommended. With a surge arrester meeting the requirements and placed behind the previously mentioned HV-fuse, overvoltages can be held below the maximum non repetitive peak voltages of the HST.

Possible suppliers of surge arresters are:

- TRIDELTA (www.tridelta.de)
  Medium voltage arrester Series SBK

- SIEMENS (www.siemens.com)
  Medium voltage arrester Series 3EK7

Surge arrester selection criterias
Ambient conditions
Continuos operating voltage at installation point
Temporary overvoltage at installation point
Residual voltage against earth at possible impulse current:
max. 8.8kV for HST3
max. 16.8kV for HST6
max. 23.8kV for HST9
max. 30.2kV for HST12

ZES ZIMMER can not guarantee that the surge arresters of above mentioned suppliers are suitable for every purpose and application! It is the responsibility of the user to find and install a surge arrester appropriate to the application.

8 FAQ - frequently asked questions / Knowledge base

8.1 Example of an error calculation: general derivation

The calculations illustrate how to calculate the errors of U, I or P when using an external sensor. The following parameters of the measurement are given:

The measurement is made with a LMG95, the accuracies of the channels are in ±(% of measuring value + % of measuring range):

Frequency/Hz	45 to 65
Voltage	0.01+0.02
Current	0.01+0.02
Active Power	0.015+0.02

The clamp with which is measured is the LMG-Z322 with an accuracy of:

Current	Amplitude error	Phase error
10A to 200A	1.5%	2°
200A to 1000A	0.75%	0.75°
1000A to 1200A	0.5%	0.5°

Ratio of 1000:1.

At the I channel we are using a scaling of 1000 to get the correct currents at the display. In the following examples all values are calculated for the primary side, what means on measured signal level. The readings are:

U_{trms}: 230.000V, range 250V ⇒ range peak value 400V

I_{trms}: 100.000A primary ⇒ 0.1A secondary; range 150mA ⇒ range peak value 469mA
calculated back to the primary side: range 150A ⇒ range peak value 469A

f: 50Hz

φ: 45°

P: 16.2635kW, range 37.5kW ⇒ range peak value 187.6kW

AC coupling mode for the signal is selected (what means you have no errors because of the DC offset of the signal).

From the table above the following errors of the LMG95 itself for voltage and current can be determined (using the peak values of the respective measuring range):

$$\Delta U = \pm(0.01\%\ of\ \ Rdg. + 0.02\%\ of\ \ Rng.) = \pm(0.023V + 0.08V) = \pm 0.103V$$

$$\Delta I_{LMG95} = \pm(0.01\%\ of\ \ Rdg. + 0.02\%\ of\ \ Rng.) = \pm(0.01A + 0.0938A) = \pm 0.1038A$$

$$\Delta P_{LMG95} = \pm(0.015\%\ of\ \ Rdg. + 0.02\%\ of\ \ Rng.) = \pm(0.00244kW + 0.03752kW) = \pm 0.03996kW$$

Additional to these three errors there is the error caused by the current clamp. First the amplitude error which will be added to the ΔI_{LMG95}:

$$\Delta I_{clamp} = \pm(1.5\% \text{ of rdg.}) = \pm 1.5A$$

So you get a total current error of:

$$\Delta I_{total} = \Delta I_{LMG95} + \Delta I_{clamp} = \pm 1.6038A$$

The second error which is caused by the clamp is the error of the additional phase shift of 2°. This error will influence the active power. In this example the power can be calculated as:

$$P = U * I * \cos\varphi$$

So the total differential gives you the error:

$$\Delta P_{clamp} = \left|\frac{\partial P}{\partial U} * \Delta U\right| + \left|\frac{\partial P}{\partial I} * \Delta I_{total}\right| + \left|\frac{\partial P}{\partial \varphi} * \Delta\varphi\right|$$

you get:

$$\Delta P_{clamp} = \left|I * \cos\varphi * \Delta U\right| + \left|U * \cos\varphi * \Delta I_{total}\right| + \left|-U * I * \sin\varphi * \Delta\varphi\right|$$

At this point only the errors of the clamp are used, the errors of the LMG are already calculated:

$\Delta U=0!$

$\Delta I=\Delta I_{clamp}$

$\Delta\varphi = 2°$: $\frac{2° * 2\pi}{360°} = 0.035\,\text{rad}$.

For the angles you have to use the radient: 45° = $\frac{\pi}{4}\,\text{rad}$

$$\Delta P_{clamp} = \left|100A * \cos\frac{\pi}{4} * 0.0V\right| + \left|230V * \cos\frac{\pi}{4} * 1.5A\right| + \left|-230V * 100A * \sin\frac{\pi}{4} * 0.035\right|$$
$$= \left|0.0W\right| + \left|243.95W\right| + \left|-569.22W\right| = 813.17W$$

At this point the error values caused by the clamp should be marked:
The amplitude error of the clamp 243.95W and the phase shift causes 569.22W, what means 813.17W error are caused by the clamp.

The total error of the active power is:

$$\Delta P_{total} = \Delta P_{LMG95} + \Delta P_{clamp} = \pm(0.03996kW + 0.81317kW) = 0.85313kW$$

The relative error of the active power is:

$$\Delta P_{relative} = \frac{\Delta P_{total}}{P} = 0.0525 \mathrel{\hat{=}} 5.25\%$$

8.1.1 Improving the accuracy

If you use a current clamp like in this example with a nominal current of 1000A and your current is only 10% what means 100A a simple trick to increase the accuracy is to wind the conductor several times through the clamp. In the example the accuracy of the clamp changes with three windings to 0.75%, because of the primary current of 300A, the phase shift is 0.75°. The next example of calculation is done for three windings:

U_{trms}: 230.000V, range 250V ⇒ range peak value 400V

I_{trms}: Scaling $\frac{1000}{3} = 333.333$, what means all current values are divided by 3, <u>even the errors</u>! The ratio of the clamp stays at 1000:1!

Values: 300.000A primary ⇒ 0.3A secondary; range 300mA ⇒ range peak value 0.938A calculated back to the primary side: range 100A ⇒ range peak value 312.7A

f: 50Hz

φ: 45°

P: 16.2635kW, range 25kW ⇒ range peak value 125.080kW

$$\Delta U = \pm(0.01\%\ of\ Rdg. + 0.02\%\ of\ Rng.) = \pm(0.023V + 0.08V) = \pm 0.103V$$

$$\Delta I_{LMG95} = \pm(0.01\%\ of\ Rdg. + 0.02\%\ of\ Rng.) = \pm(0.01A + 0.06254A) = \pm 0.07254A$$

$$\Delta P_{LMG95} = \pm(0.015\%\ of\ Rdg. + 0.02\%\ of\ Rng.) = \pm(0.00244kW + 0.02502kW) = \pm 0.027456kW$$

$\Delta I_{clamp} = \pm(0.75\%\text{ of primary current} = \text{in this case the "reading"}) = \pm 2.25A$, now with the scaling this error is divided by 3 as well, what means:

$$\Delta I_{clamp} = \pm(0.75\%\ of\ Rdg.) = \pm 0.75A$$

$$\Delta I_{total} = \Delta I_{LMG95} + \Delta I_{clamp} = \pm 0.82254A$$

Again the total differential has to be used, but now with the following values:

$\Delta U=0!$
$\Delta I=\Delta I_{clamp}$
$\Delta\varphi = 0.75°$: $\frac{0.75° * 2\pi}{360°} = 0.013\,\text{rad.}$

With this the error of the clamp of the active power is:

$$\Delta P_{clamp} = \left|100A * \cos\frac{\pi}{4} * 0.0V\right| + \left|230V * \cos\frac{\pi}{4} * 0.75\text{A}\right| + \left|\text{- }230\text{V} * 100\text{A} * \sin\frac{\pi}{4} * 0.013\right|$$
$$= 333.40\text{W}$$

$$\Delta P_{total} = \Delta P_{LMG95} + \Delta P_{clamp} = \pm(0.027456kW + 0.33340kW) = 0.360856kW$$

The relative error of the active power is:

$$\Delta P_{relative} = \frac{\Delta P_{total}}{P} = 0.0222 \mathrel{\widehat{=}} 2.22\%$$

With this simple trick the error of the current amplitude could be reduced by 51.2%. The error of the active power even by 42.3%.

8.2 Example of an error calculation: LMG500 with external shunt

Particularly with regard to the standby power measurements compliant to EN62301 and ENERGY STAR it might be profitable and necessary to use an external shunt to increase the current dynamic and accuracy at low currents. This example shows how to calculate the measuring tolerance of the complete system consisting of LMG500 and the external shunt LMG-SH100.

- **External shunt**
  LMG-SH100, 100ohms, ±0.15%

- **Voltage measurement**
  Ueff=230V
  LMG500 Urange=250V / 400Vpk (range spec.: see documentation of LMG500)
  (in 115V supply networks: Urange=130V / 200Vpk, the remaining calculation is the same)

- **Current measurement**
  Ieff=4mA
  LMG500 Irange=5mA / 15.63mApk (range spec.: see documentation of LMG-SHxx)
  LMG500 I measuring accuracy: ±(0.01% of measuring value+0.02% of measuring range)

- **Power measurement**
  PF=0.1
  f=50Hz (or 60Hz)
  S=0.92VA
  P=92mW
  LMG500 Prange=Urange*Irange=400V*15.63mA=6.252W
  LMG500 P measuring accuracy: ±(0.015% of measuring value+0.01% of measuring range)

- **Tolerance of current and power measurement**
  Because the shunt tolerance is a purely scaling error without a term of measuring range, the error analysis can be simplified to the following calculation:

		shunt error term	*LMG error of meas.value*	*LMG error of meas.range*
ΔI	= ±(	0.15/100*4mA	+ 0.01/100*4mA	+ 0.02/100*15.63mA)
	= ±(	6uA	+ 0.4uA	+ 3.126uA)
	= ±9.526uA			
ΔP	= ±(	0.15/100*92mW	+ 0.015/100*92mW	+ 0.01/100*6.252W)
	= ±(	138uW	+ 13.8uW	+ 625.2uW)
	= ±777uW			

8.3 Example of an error calculation: LMG500 with HST3

In this example an error calculation is shown with the LMG500 and HST3 measuring the loss power of a 3000V / 10A / 60Hz, pure sinewave voltage and current / PF=0.3 device under test

- **HST high voltage divider**
  HST3 scale = 1000:1
  HST3 tolerance: ±0.05% / ±0.06° @ 45 .. 65Hz
  Δphi_HST3 = ±0.06°/360°*2*pi = ±0.001047197551 rad

- **Voltage measurement**
  Ueff = 3000V / 60Hz
  LMG500 Uscale = 1000
  LMG500 Urange = (3V / 6Vpk) = 3000V / 6000Vpk
  LMG500 U measuring accuracy: ±(0.01% of measuring value+0.02% of measuring range)

- **Current measurement**
  Ieff = 10A / 60Hz
  LMG500 Irange = 10A / 30Apk, direct current input
  LMG500 I measuring accuracy: ±(0.01% of measuring value+0.02% of measuring range)

- **Power measurement**
  PF = 0.3, pure sinewave voltage and current -> phi = acos(PF)
  f = 60Hz
  S = Ueff*Ieff = 30kVA
  P = Ueff*Ieff*PF = 9kW
  LMG500 Prange = Urange*Irange = 6000V*30A = 180kW
  LMG500 P measuring accuracy: ±(0.015% of measuring value+0.01% of measuring range)

Tolerance of voltage and power measurement

ΔU_LMG500 = ±(0.01/100*3000V + 0.02/100*6000V) = ±(0.3V + 1.2V) = ±1.5V
ΔU_HST3 = ±(3000V*0.05/100) = ±1.5V
ΔU_total = ±(ΔU LMG500 + ΔU HST3) = **±3V**

ΔP_LMG500 = ±(0.015/100*P + 0.01/100*Prange) = ±(1.35W + 18W) = ±19.35W
with P = U*I*cos(phi)
ΔP_HST3 = ±(|dP/dU*ΔU_HST3| + |dP/dI*ΔI_HST3| + |dP/dphi*Δphi_HST3|)
with ΔI_HST3=0 (current measurement has no influence on voltage measurement)
ΔP_HST3 = ±(|I*cos(phi)* ΔU_HST3| + |U*I*sin(phi)* Δphi_HST3|)
ΔP_HST3 = ±(10A*0.3*1.5V + 3000*10*sin(acos(0.3))*0.001047197551) = ±34.47W
ΔP_total = ΔP_LMG500 + ΔP_HST3 = **±53.82W**