ZES ZIMMER Electronic Systems

3-Phase Precision Power Meter LMG310

Basic Accuracy 0.05% Wide Bandwidth DC to 1MHz

Motors, Inverters, Transformers

Harmonics and Flicker according to IEC61000-3

LMG310

LMG310 e 09.00

General, application fields

Precision power measuring – this associates to the ZES ZIMMER power multimeter series,

- **LMG90** and **LMG95** for monophase
- **LMG310** and **LMG450** for multiphase measurements.

Both series are successful, approved and kept state of the art by continuous and steady research and development by the ZES ZIMMER engineering staff.

Due to its high sampling rate, simultaneous for all channels, the LMG310 is capable of performing extremely accurate measurements of power and energy in symmetrical and non-symmetrical 3-phase systems with any load and signals with frequencies from DC to 1MHz.

The wideband fully floating isolated inputs have a high immunity against electrical disturbances and a very high dynamic common-mode rejection, and feature wide measuring ranges: for current directly from 3mA to 30A, for voltage directly from 1V to 1000V. Measuring inputs for external shunt voltages extend the measuring ranges for the current in any way. This design of the wideband measuring inputs and the processing in real time with digital signal processors give reason for the preferred use of the LMG310 in measuring applications of pulsed power electronics (also at PWM-converters).

The LMG310 is used in the fields of development, manufacturing and quality control. There the simultaneous three-phase measurement of active power loss in reactive and nonlinear components like transformers, chokes, motors, capacitors is required; the power consumption and efficiency of power supplies, electrical lamp ballasts and inverters have to be specified.

Analysis of harmonics including the limit check of the harmonics according IEC61000-3-2 (classes A, B, C and D), the **flicker measuring** according IEC61000-3-3 and **transient recording** and monitoring are available options of the LMG310. These three options are used to evaluate the power line disturbances which may be emitted by electrical devices, further to analyse the quality of supplied power in the mains. The option to measure the loss power or transformers (**transformer version**) serves to measure the losses at very low cosφ (<0.01) with an error <0.006% related to the power range.

By means of the **integrated formula editor** all measured and calculated quantities as well as the signals of the **processing signal interface** (option) can be computed to new quantities and displayed on the screen.

The time diagrams of the signals of the screen in real time (option **scope-/plot function**) is another powerful feature of the instrument.

Driver for modern instrumentation and evaluation software like LabVIEW® are available as well as user programmes built and compiled by means of these software tools.

When connecting the LMG310 with a PC you easily can build measuring systems, motor and other test systems.

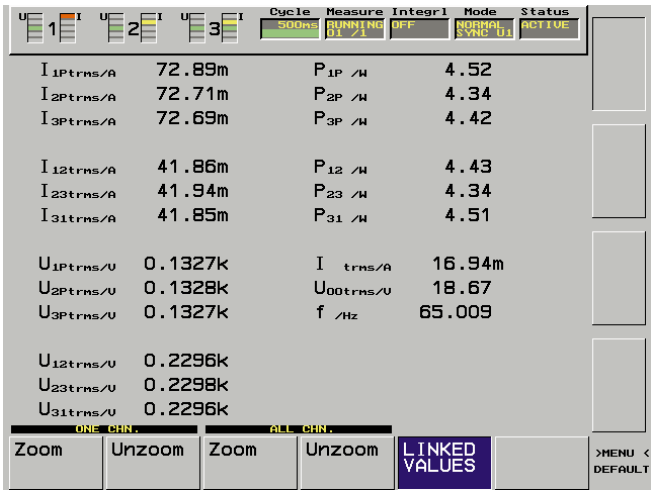
Easy to use

The high-resolution screen with the status line for input levels, cycle time and synchronization, the 10 softkeys on the bottom and right margin of the screen and the 15 menu keys for access to important menus provide a clear, simple and intuitively comprehensible operation of the instrument. To indicate the desired information, it is normally sufficient to press just one key. Menus for the instrument setup (configurations) as well as menus defined by the user for measuring values display can be stored and recalled when needed.

Interference immunity, dynamic common-mode rejection

The LMG310 has a high interference immunity, which is defined according IEC61000 (e.g. bursts up to 4kV on all measuring and supply-inputs) and widely exceeds the standards. In addition the excellent common-mode rejection of the instrument ensures the correct sampling and computing of measuring values even for measuring arrangements floating against earth with high frequencies (>100kHz), voltages up to 1000V and high slew rates (>20kV/µs).

Measuring circuits



The LMG310 is suitable for all measurements of 1-, 2- and 3-phase systems.

The measuring channels can be used independently. When using the option **star/delta conversion** the input signals applied as phase and/or linked values will be evaluated according their wiring (current/voltage as ⅄⅄ ; △⅄; ⅄△ ; △△) and will be transformed.

In the figure the use of the softkey ´LINKED VALUES´ has activated a menu with the phase values (index 1p, 2p, 3p) and the linked values (index 12, 23, 31) for current, voltage and power.

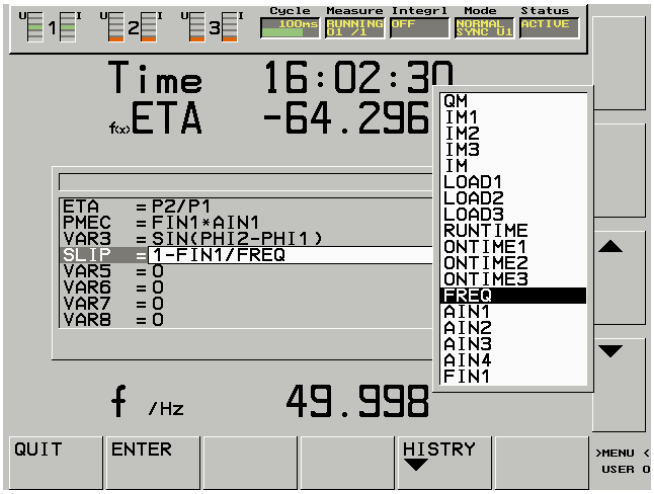
The magnitude physically applied to the measuring channel and directly measured is indexed with one digit only (index 1, 2, 3), as you see in the measuring value display on the front page.

The measurement with Aron measuring circuit (3-phase with 2 measuring channels) is also supported, so that the third measuring channel is available for additional measurements.

Measuring inputs, measuring accuracy

The measuring error (as sum of the percentages of reading and measuring range) for current and voltage is <1% valid for the whole precision range from DC to 400kHz.
The basic accuracy is 0.05%. This accuracy is valid for all current and voltage measuring ranges (3mA-30A, 1V-1000V)!
Above the 400kHz precision range measurements with high accuracy are also possible because of 1MHz bandwidth of the input channels.
The measuring accuracy will be decreased by the derating, starting at 400kHz. Common-mode signals in the precision range up to 400kHz have nearly no influence to the measuring results.
The measuring inputs for external shunt voltages with the ranges 15, 50, 150mV enlarge the measurements for currents.
In all current and voltage measuring ranges the LMG310 is capable of measuring up to the double nominal value, max. $60A_{peak}$ and $2000V_{peak}$.

Formula editor, user defined menus



Using the integrated **formula editor** the user can build new values (VARiables) from all measured and computed values.
The signals from the processing signal interface can be computed in the formula editor in the same way.
All fundamental arithmetics are available, also more complex operations such as $\sqrt{}$, sin and arcsin.

The user can build up his own menus for measuring value display.
The wanted parameters can be chosen from the selection list very easily. This list contains all measuring and calculated values as well as the VARiables and can be put into one of the **user defined menus.**
10 user defined menus, each with maximum 30 values, can be defined and stored.

Computer interfaces

The LMG310 can be coupled to a control computer over the serial interface RS232 or the parallel GPIB-Bus.
The bus is fulfilling the requirements of the IEEE488.2 so that a simplified control of the LMG310 by computer is possible.
The transmission rate goes up to 200 measuring values per second, also in the smallest measuring cycle.
For fast data transfer of the sample values there is a further high-speed RS232 interface available.
An optional driver for the instrumentation software LabVIEW® will be delivered.
By means of this software tools you can easily build complex measuring or quality control systems in very short time.

Printer interface

All numerical and graphical representations of the measuring values can be printed out.
The printing is initiated by a single button push or will be repeated periodically by a time interval.
This is used in quality control, where measurements of production samples have to be documented.

Printer drivers for common PC printers (matrix, laser, ink jet) are available and will be delivered as standard.

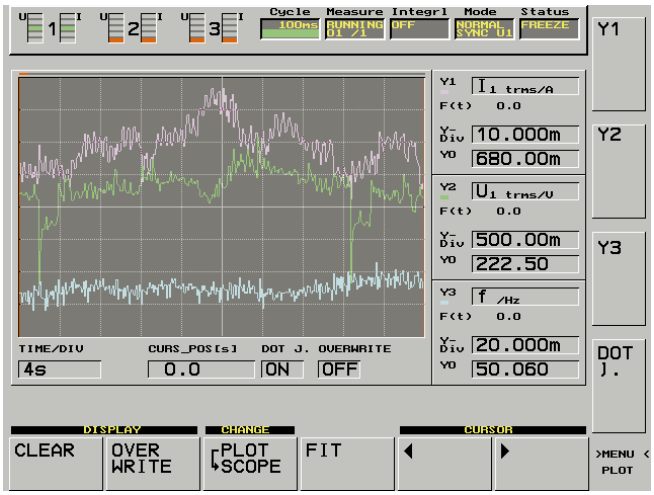
Memory card

The memory card option for PC cards (PCMCIA) is capable of recording up to 150 measuring values per measuring cycle.
The transfer of the sampling values to the memory card after recording a measuring cycle or a single event in the transient mode is also possible.
The recording of sample values is needed, when analysis and evaluation of the signals shall be done by other algorithms than implemented in the instrument. Non periodical processes, like the start of a motor, can then be analysed by evaluation and analysis software, available as standard on market.
The recording of data on a memory card as an external portable medium is superior against other methods, like magnetic recording technics.
Thus because of: short access time, no mechanically movable parts, high interference immunity against electrical and magnetical fields. This is specially important in the typical measuring environments of motors and transformers.
In addition to the recording of measuring values the memory card can also be used to store and recall individual LMG310 setups of different users.

Processing signal interface

This module enables the input and output of analogue and digital signals.
The **8 analogue outputs**, which are usually connected to plotters for longtime protocols, can be assigned with any measured and computed value.
The **16 digital outputs** are used as limit indicators.
They are activated when the corresponding assigned value is lower or higher than a preset limit, respectively.
The **digital outputs** are also used to switch on/off external devices and components like the net impedance simulation of the flicker measuring or to control the scanning of different measuring points.
The **6 digital inputs** generally show the status of external devices and actuators, for example the transforming ratio of an adjustable transformer controlling a motor start.
Over the **4 analogue inputs** additional quantities can be captured like torque, motor speed or temperature.
The **2 frequency inputs** measure rotation speed and direction, received from pulse generating devices. These quantities can be computed with other measuring values, using the formula editor.
Application: Calculation of the efficiency of motors or determination of slip by stator frequency (fundamental of feeding inverter) and mechanical speed.
In this manner, the LMG310 can be turned into an extended measuring system without additional computer!
Very remarkable: all inputs are isolated and have a high interference immunity.

Graphical indication as a function of time



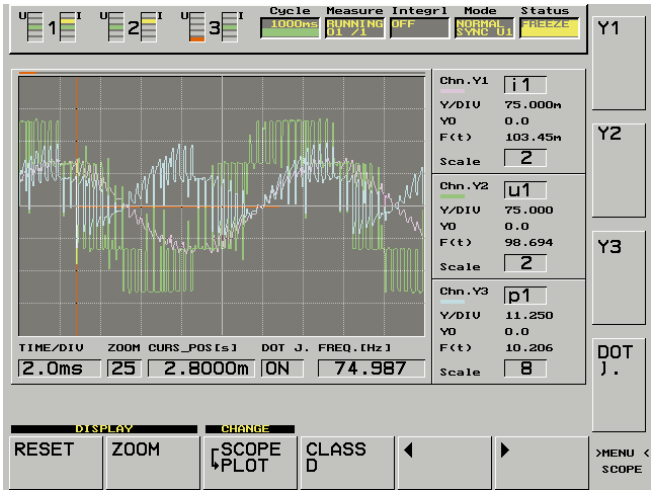
On pressing the ´Graph´ key, the LMG310 switches to graphical display, showing the signals as a function of the time. The softkey ´PLOT/SCOPE´ is used to select between the plot function showing the values by measuring cycles and the scope function showing the sampling values.

1. Plot function

The values resulting of measuring cycles are for example trms current and voltage, active power or peak values etc.
The figure beneath shows the plot function. The time diagram of the quantities current, voltage and frequency, that are needed for a net analysis, are displayed. The fluctuations of the mains frequency can be very well observed due to the appropriately selected resolution (20mHz/division) and shifting the signal into screen by scaling screen centre (Y0) to 50,060Hz.
All signals are displayed in real time on the screen, the output on a printer replaces a 3-channel analogue recorder.

2. Scope function

The sampled values of the input quantities u and i as well as the momentary value of power p calculated by the sampled values can be shown in a time diagram in real time.
The figure shows the voltage, current and power of a PWM-converter.
The amplitude of the pulse modulated voltage (in green) jumps in the characteristic way after each 1/6 period, when the converter switches to the next bridge branch.
The current i (in red) has nearly sinusoidal wave form because of the smoothing by the motor inductance.

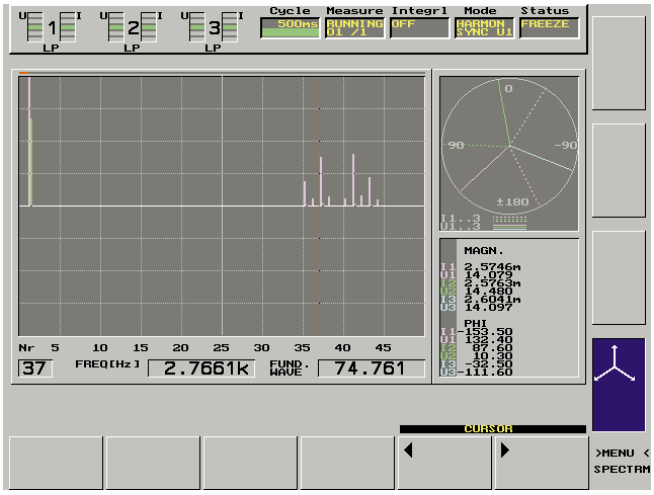


Fundamental harmonic determination, low-pass filter

A sampling over one or more complete periods is necessary to determine trms values.
If the fundamental frequency can´t be determined by its zero crossing points, it can be found by automatic detection.
For three-phase motors supplied by converters, the determined fundamental is equal to the stator frequency. The low-pass filters are necessary for more exact examinations of a motor.
The filters are of 8th degree, the cutoff frequency automatically adapts to the fundamental (0.1Hz to 5kHz) or it can be set in the range of 0.1Hz to 50kHz.
The low-pass filter can be activated and deactivated independently for each channel (but U and I together).
Application: When controlling motors via frequency converters, only the fundamental, not the harmonics, contributes to rotation and torque of the motor.
The low-pass filters, eliminating the harmonics, provide measurements enabling a clearer motor analysis.

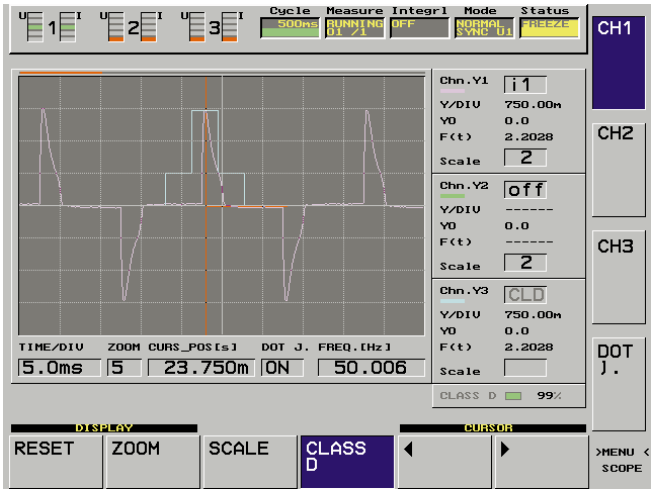
Analysis of the Harmonics

By use of the harmonic analysis mode the frequency spectrum of current, voltage and power (amount and phase) for all channels can be determined.
The common factors for specification of distortion (THD, THF, HVF, HDF) are computed.
The harmonics are displayed as numerical values or graphically as bar diagrams (frequency spectrum).
In the graphical frequency spectrum three quantities can be displayed simultaneously. They are distinguishable by different colours. Similar to the scope function, the indication is updated after each measuring cycle with newly computed values.
When optimizing a circuit for lowest emission of harmonics, the effects of a modification of the circuitry can be monitored immediately.
As you see in the figure, the phasor (Fresnel)-diagram of each harmonics can be displayed.
The figure shows the harmonic frequency spectrum of a frequency inverter.
The fundamental frequency is 74,761Hz. The cursor is positioned onto the 37. Harmonic (2,7661kHz).



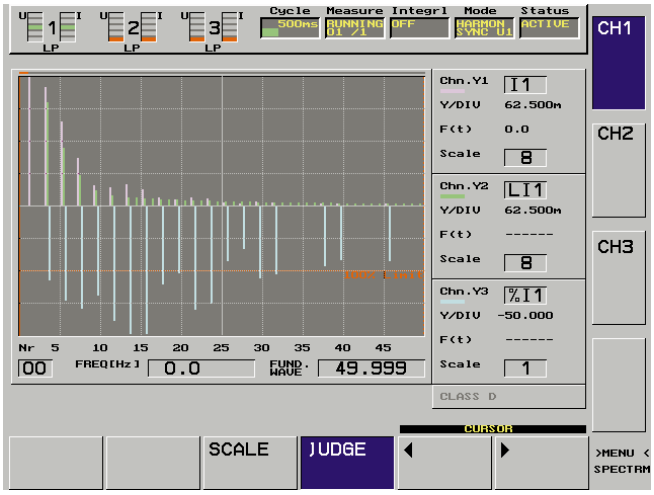
In the same way the shown phasor diagram belongs to the 37th. This frequency spectrum shows a very good suppression of the harmonics in the lower frequency range.

Harmonic limit checking according to instrument classes A, B, C, D



According IEC61000-3-2 the emission of harmonics may not pass certain limits.
The standard defines limit values for different instrument classes (A, B, C and D).
These limits may not be surpassed.
Class D instruments have to be tested on harmonics within limitation and in addition the wave form has to be checked in the time domain on certain criteria. This can easily performed with the LMG310 scope function.
The enveloping curve, built by steps at 1/6 period, has to cover 95% of the current signal.

The menu in the figure beneath shows an emission of harmonics in relation to its limits. Current I1 is examined according the limits of instrumentation class D.
The harmonics of the current are shown as red bars, the related limits as green bars.
For better visualisation the ratio of actual value I1 to limit value LI1 for each harmonic is represented as a bar going downward.
When the bar passes the red margin line (=100%) downwards, the magnitude of the harmonic is too big and has to be decreased.



Flicker measuring

The LMG310 can be extended to a flicker meter according IEC868 (EN60868).
The flicker meter will measure and evaluate voltage fluctuations caused by the current surges on the utility power line according standards IEC61000-3-3.
The characteristics for flicker are measured and computed: P_{st} (short term flicker indicator) and P_{lt} (long term flicker indicator), further the relative stady state voltage change d_c as well as the maximum relative voltage change d_{max} and the relative voltage change characteristics d(t).
Evaluation and display of the values run in real time. An external PC is not necessary.

Transient recording and monitoring

Recording transients is another operating mode of the LMG310 and can be seen as an extension of the scope function with different trigger conditions.
Like the scope function the momentary values of current i, voltage u and the power p (derived from i and u) are recorded.
Three quantities are simultaneously monitored, each are stored with a storage depth of 20,000 values.
The time for recording this storage depth can be set in the range of 500ms to 60s. The pretrigger can be set in steps (0%, 25%, 50%, 75%, 100%).
All trigger conditions used in common transient recorders are implemented:

- level under or over a certain limit,
- level inside or outside a window,
- slew rate to detect surges and spikes,
- no positive, no negative slope,
- signal time-out.

The trigger conditions can be set for the three quantities in different ways, they can be logically combined.
The trigger event will be signalized and documented in different ways:

- trigger impulse output
- counting the trigger impulses and logging them on memory card and printer
- display of the found signals on monitor and storing the signals (sample values) on memory card.

You can set on single or repetitive recording at each new occurrence of the trigger condition.

External monitor

An additional VGA-color monitor can be connected for large screen display.
Application: laboratory, machine hall or auditorium, when the measuring values have to be read from a greater distance or presented to a larger audience.

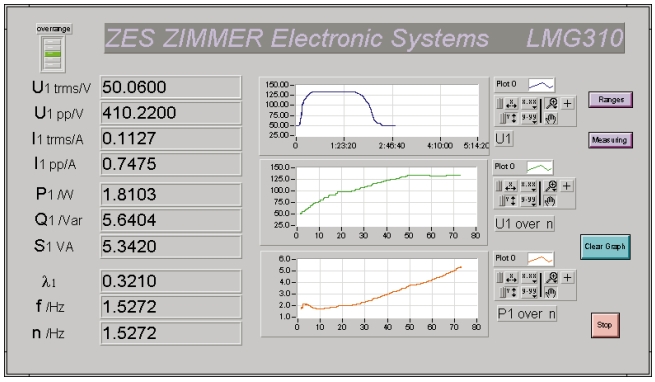
Design

The LMG310 is manufactured as desktop instrument. By using a mounting kit it can be built into 19"-racks.
A color flat display in TFT technology is used.
For all applications where the LMG310 is bound into systems the **measuring box LMG310-B** may be used because of its reasonable price. This unit has neither display, nor operating keys nor buttons.
It is only operated via the computer interface.

User software

A powerful **LabVIEW® driver** is available as well as user programs under this software well structured for extension on user side:

- X/Y diagrams (motor characteristics P = f(n) like fig.)
- harmonic analysis of transients
- synchronization and synchronous measurement of several LMG power meters
- individual operating shell (e.g. for LMG310-B)
- INSITU: Program for determination of the impedances in medium voltage systems



Artificial midpoint

The artificial midpoint is used at measuring probes where the neutral is missing or not accessible but the phase like measurement is preferred.

Adaptations for measuring signals

Precision high voltage divider HST in 3-phase design with measuring voltages of max. 20kV against earth will be delivered on customers demand.
At currents bigger than 30A the precision current sensors series PSU are used.
They convert the current to low current values with high precision, very small loss in bandwidth and without affecting the measuring circuit.
The PSU sensors are available for currents up to 10kA.
(Leaflet HST and PSU)

Calibration

The LMG-instruments will be delivered with ISO9000 calibration certificate on request. Then the instrument can be used as reference instrument for traceable calibrations.
The ZES ZIMMER standard **LMG95-REF**, a high precision reference instrument for current, voltage, active power and electrical energy is manufactured with basic accuracy of 0.01% for use of calibrations in compliance with ISO9000.
It is delivered with calibration certificate and documentation of the German standard organisation PTB.
(Leaflet LMG95-REF)

Technical data

Voltage measuring ranges

trms values /V	1	3	10	30	100	300	1000
Permissible peak values /V	2	6	20	60	200	600	2000
Overload strength	1500V permanently			2000V for 3s		8000V for 1.2/50µs	
Input resistance / Ω	>1.5MΩ II 50pF						
Crest factor	8...2 for U_{trms}=25...100% of the selected measuring range 20...8 for U_{trms}=10...25% of the selected measuring range						

Current measuring ranges

trms values / A	3m	10m	30m	0,1	0,3	1	3	10	30
Permissible peak values / A	6m	20m	60m	0,2	0,6	2	6	20	60
Overload strength permanently / A	1,5	1,5	1,5	1,5	1,5	1,5	35	35	35
Overload strength for 3s / A	4	4	4	4	4	4	45	45	45
Input resistance / Ω	5	5	5	0.3	0.3	0.3	0.01	0.01	0.01
Crest factor	8...2 for I_{trms}=25...100% of the selected measuring range 20...8 for I_{trms}=10...25% of the selected measuring range								

External shunt voltage measuring ranges

trms values / mV	15	50	150
Permissible peak values / mV	30	100	300
Overload strength permanently / V	3	3	3
Input resistance / Ω	>1.5MΩ		
Crest factor	8...2 for U_{trms}=25...100% of the selected measuring range 20...8 for U_{trms}=10...25% of the selected measuring range		

Range selection
Auto, manual or remote-controlled, separately for each current and voltage channel, input of factors for transformers (U and I), level control display for each channel in the status line

Isolation
Current and voltage path may float against each other and against earth up to 1500V

Measuring method
Simultaneous sampling of the current and voltage inputs and A/D conversion of the instantaneous values

Measuring cycle, synchronization averaging
For the measurement of the trms values for current, voltage and active power, the measuring cycle time is adjustable in the range of 100ms to 60s. The synchronization can be performed on the measuring signal, the fundamental harmonic of the measuring signal, the mains or an external signal. A single measurement with automatic stop after 1 measuring cycle is possible. Averaging over 1 to 16 measuring cycles.

Measuring accuracy

Measuring accuracy	+/- (% of measuring value + % measuring range)						
	DC, 0.1...15Hz	15...500Hz	0.5...50kHz	50...150kHz	150...250kHz	250...400kHz	400kHz...1MHz
Voltage	0.1 + 0.05	0.05 + 0,05	0.1 + 0.05	0.2 + 0.1	0.3 +0.2	0.5 + 0.5	1.0+ 0.1*(f-400kHz)/kHz
Current	0.1 + 0.05	0.05 + 0.05	0.1 + 0.05	0.2 + 0.1	0.3 + 0.2	0.5 + 0.5	1.0+ 0.1*(f-400kHz)/kHz
Active Power	0.15 + 0.1	0.07 + 0.08	0.15 + 0.1	0.3 + 0.2	0.5 + 0.5	0.7 + 1.0	1.5 + 0.15*(f-400kHz)/kHz

Accuracies based on:
1. sinusoidal voltages and currents
2. ambient temperature 20...25°C
3. warm up time 15 minutes
4. definition of power range as the product of current and voltage measuring range, $0 \leq \lambda \leq 1$
5. calibration interval 12 month

Other values
All other values are derived from the values for current, voltage and active power. Accuracies or error limits, respectively, for the derived values depend on the functional relation (e.g. $S = I * U$, $\Delta S/S = \Delta I/I + \Delta U/U$)

Frequency measurement
0.01Hz...250kHz ±0.01% of measuring value, any measuring channel selectable

Measuring wirings
a) phase current with phase voltage (star/star)
b) phase current with linked voltage (star/delta)
c) linked current with phase voltage (delta/star)
d) linked current with linked voltage (delta/delta)
e) Aron-wiring (2-watt-meter-method, third channel free)

With the optional star/delta conversion the displaying of values from the respectively other wiring is possible (only wiring a) to d))

Display of measured and computed values

Representation
With standard abbreviation of electrical quantity, phase and dimension, 5-digits (0...99999), with sign, decimal point and unit prefix after the digits (e.g. $I2_{trms/A}$ 0.7385m). 1 to 30 values can be displayed simultaneously, selectable via default or user-defined menus (max. 10)

Voltage/Current
Trms value, peak values (min, max, pp), rectified value (rect), mean value (dc), rms value of ac-component, form factor, crest factor

Power
Active power (P), reactive power (Q), apparent power (S), phase anglel (ρ), power factor (λ)

Impedance
Amount (Z), real and imaginary part of parallel or serial equivalent circuit

Integrated values depending on the measuring time
The integration can be controlled manually, automatically using start and stop times, via external trigger or remote-controlled via computer interface

Energy, charge
Active energy (Ep), reactive energy (Eq), apparent energy (Es), charge (q)

Date and time, measuring time
Current date (day, month, year) with time (hours, minutes, seconds), accu-buffered real time clock, start time for measurement, running measuring time, on-time, all measuring times with day, hours, minutes, seconds

Adjustable parameters
Scaling factors for external shunts, current and voltage transformers, basic load (stand-by power)

Values of harmonic analysis
Amount and phase of harmonics for current, voltage and power, angle between phase voltages and phase currents, phasor (Fresnel) diagram, THD (Total Harmonic Distortion), THF (Telephone Harmonic Factor), HVF (Harmonic Voltage Factor), HDF (Harmonic Distortion Factor)

Computer interfaces
Plug-in unit for 2 interfaces: **RS232** and **IEEE488.2**, only one interface can be used, selectable by user in the setup (**High-speed RS232** with 115kBd for sample values available)

Remote control
All functions can be remote controlled, keyboard-lock possible

Output data
Output of all displayable data possible, data format identical for both interfaces

Data rates
RS232: max. 38400 Baud, IEEE488.2: max. 1MByte/sec

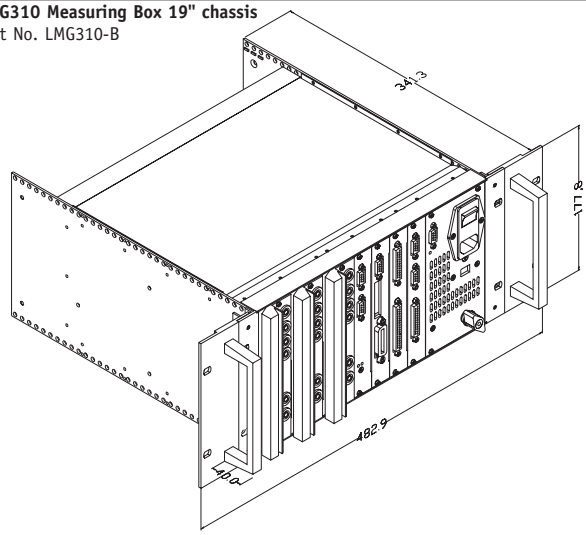
Isolation
Interfaces isolated against other interface and against other electronics, isolation voltage 500V

Printer interface	Parallel PC printer interface with 25-pin SUB-D-connector for printing of measurement values, tables and graphics on pin, ink jet or laser printers
Memory Card	For PC cards (PCMCIA), datalogging of measuring and sampling values, storing and restoring of setups
Monitoring and storing of transients	Storing and graphical displaying of transients with a resolution of 25µs. Storing depth is 20,000 measuring values per channel, selectable recording duration from 0.5 to 60 seconds. Adjustable pre-trigger, different possibilities of triggering, logically combinable between channels
Processing signal interface	4 analogue inputs for registration of auxiliary quantities (13 bit, ±10V) 8 analogue outputs for output of any measured or computed values (16 bit, ±10V) 6 digital inputs for registration of status signals and 2 inputs for registration of frequencies (0.1Hz...2MHz) 16 digital outputs to signal states and alarms (at exeeded limits) All inputs and outputs are isolated against each other and against other electronics, isolation voltage 500V
Low pass filter, fundamental harmonic determination	Low pass filter of 8th degree, manually adjustable in the range from 0.1Hz to 50kHz, automatically on fundamental in the range from 0.1Hz to 5kHz
Analysis of harmonic	Analysis of the frequency spectrum of voltage, current and power of 50 harmonics in the range from 0.1Hz to 32kHz in accordance with IEC61000-3-2, representation as table or graphically
Flicker measurement	Flicker meter by IEC868 in full compliance with IEC61000-3-3
Scope and plot function	Graphical representation of sampled or computed values as a function of time
External monitor	VGA connector for use with an external monitor

Other data

External synchronization/trigger	Isolated interfaces for external control of measurement cycle and integration times, outputs for status signals about the actual measuring, isolation voltage 500V
Design, dimensions	• standard desktop case, 230 mm x 440 mm x 475 mm (H x W x D) • 19"- mounting kit, 6HU/84PU • Measuring box, 19"chassis, 63PU (front panel expandable to 84PU), 4HU, 179 mm x 376 mm x 350mm (H x W x D) • Measuring box, bench case, 230 mm x 483 mm x 350 mm (H x W x D)
Weight	Depends on design and equipment, 12kg or above
Protection class	EN61010 (IEC61010, VDE0411), protection class I
Electromagnetic compatibility	EN61000 (IEC61000), EN50081, EN50082
Protection system	IP20 in accordance with DIN40050
Operation/storage temperature	0...40°C / -20...50°C
Climatic class	KYG in accordance with DIN40040
Power supply	230V/115V (selectable) ±15%, 45...400Hz, about 100VA (70W)

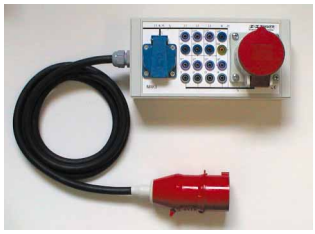
LMG310 Measuring Box 19" chassis
Part No. LMG310-B



LMG310 Accessories

Adapter for 3-phase measurements

- CEE-Plug, 5 pins, 16A, 2m supply cord
- CEE-Socket, 5 pins, 16A, for EUT
- Socket for supplying the meter LMG310
- 4mm safety sockets, measuring access to current and voltage
- Safety acc. IEC61010: 300V/CATIII
- Part No. LMG-MAK3



Mid Point Simulation

- For 3-Phase/3-Wire Systems
- Part No. L31-Z03

Subject to technical changes, especially to improve the product, at any time without prior notification.

ZES ZIMMER Electronic Systems

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