Technical
Information

Measuring small currents has never been easier and more economical than with LEM's HX series

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by Hans-Dieter Huber, Marc Laforet, Mikio Kurosawa, Stéphane Rollier

The HX series current transducer from LEM is the latest product developed to date in the compact and low cost product range for small current measurements. The standard ratings are from 3 ... 50 A.

It exists in two power supply versions: dual supply ±15 V and single supply +12...+15 V. A special two primary windings is also available for 5 A, 10 A and 15 A ratings.

Despite a drastic improvement on cost compared to previous models, the HX series does not compromise in terms of performances and quality. Response time is as fast as 3 µs. Linearity errors are within ±1 %.

On the other hand, the AC test voltage (50 Hz, 1 min) improved to 3 kV_{RMS} and clearance / creepage distance of more than 5.5 mm make this transducer ideal for isolated current measurements in the lower and middle power ranges.
Finally for those who are familiar to LEM, CE marking and material compliance to UL94V0 on our products also apply.

You've probably known from previous publications from LEM, for this kind of current measurement, there has been only a few choices: the traditional measuring methods using a resistive shunt, or a current transformer which are unsatisfactory, due to the inherent disadvantages such as the lack of galvanic isolation in the first case and a rather limited bandwidth in the second case. Both require considerable calibration efforts. Previous generations of LEM current transducers helps to overcome these problems, but the time has come for a complete reengineering of the product to meet today's cost requirement.

The HX series Hall effect current transducers (cover page) have been developed out of this objective. Besides, it boasts a tiny weight of 8 g and requires small mounting area, a mere 15 x 19 mm. It is particularly suitable for the following applications:

- Phase current control in AC/DC servo-drives
- Current regulation and display in UPS and switched mode power supply (SMPS)
- Current control and short circuit protection in industrial equipment
- Current control and short circuit protection in home appliances such as air conditioners, refrigerators, washing machines etc.

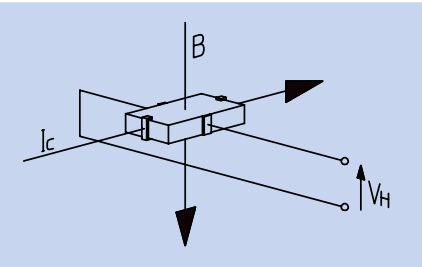


Figure 1. The Hall generator located in the gap of the magnetic circuit converts the magnetic field generated by the primary current into a proportional Hall voltage.

The Hall effect principle

The heart of the HX transducer is a Hall effect generator. In 1879, Edward H. Hall discovered the Hall effect, which is obtained when a current carrying thin sheet of conductive material (Hall generator) is placed in a perpendicular magnetic field. The electromagnetic Lorentz force will then push the mobile charge carriers to the opposite edges of the sheet, according to their polarity.

The Hall voltage VH generated between these two edges is directly proportional to the control current IC and the magnetic flux B (Fig. 1). The Hall generator used is made of a thin sheet of conductive material like Gallium Arsenide (GaAs), which is known for its reliability and steady performances over time. The Hall voltage obtained, with a control current IC of 5 mA is about 1.25 mV/mT.

Hall effect Open Loop current measurement

The magnetic field produced by the primary current generates a linear magnetic flux B in the gap of the magnetic circuit, which in turn induces a proportional Hall voltage VH in the Hall generator. This voltage is then amplified by an electronic circuit, resulting in an output analog signal that is proportional to the primary current. The HX series can as a consequence, measure both DC and AC currents, as well as the complex current waveforms found in phase-controlled rectifiers, line commutated power converters, PWM converters and switched mode power supplies. The output voltage is always a true image of the primary current (Fig. 2).

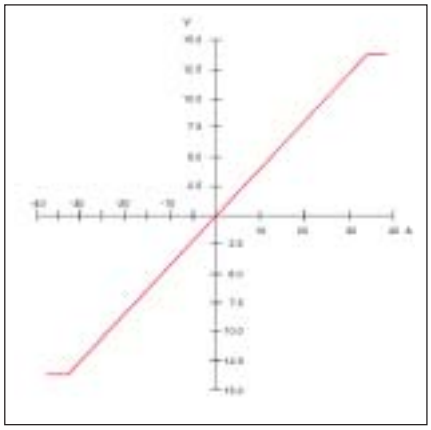


Figure 2. HX 10-P output offer good linearity from 0...±3 x I_N

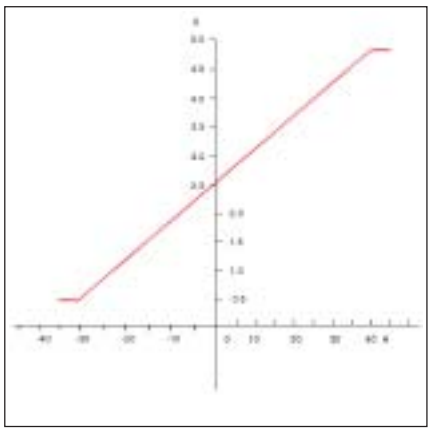
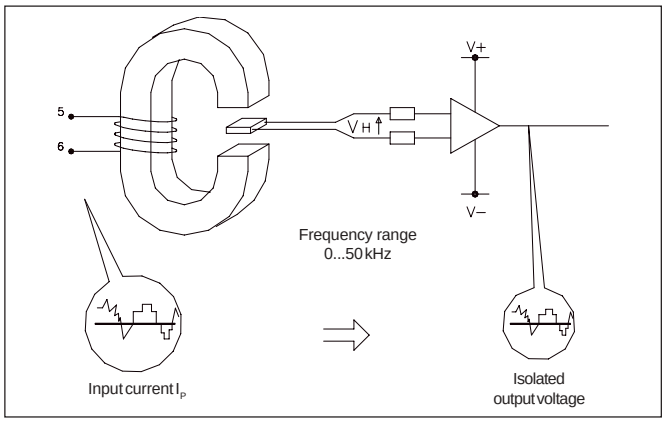
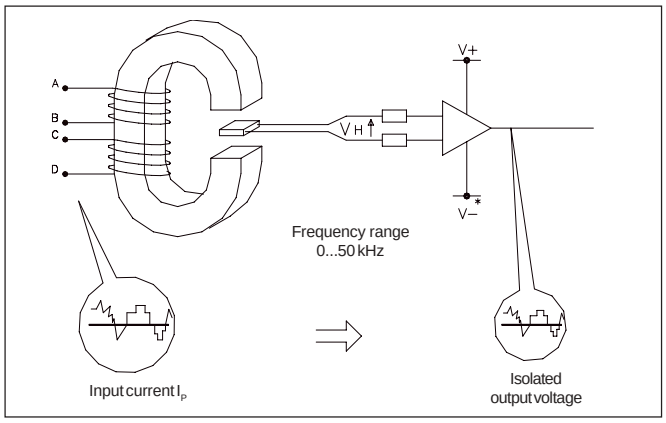


Figure 3. HX 10-P/SP2 output linearity

The HX current transducers exist in 7 standard ratings, from 3 ... 50 A with a built-in primary winding for direct PCB mounting. Measuring span is up to three





Figures 4 & 5. Operating principle of the HX series current transducers with one or two primary windings, P1 and P2

times I_N. The output voltage is adjusted to 4 V at the nominal current (Fig. 2). (Remark to linearity Fig.3).

Overall accuracy, within ±1 %, at 25 °C (± 2 K), excluding offset is obtained for all the current ratings by means of different primary turns so that the total Ampere x turns is 60 AT (Fig. 4) for models up to 20 A nominal and 50 A.t for HX 25-P and HX 50-P models.

It's noted in most applications, there is a possibility to reset the offset at power on.

This reduces considerably the effect of this parameter.
The HX is designed with a dual power supply ±15 V. However, it also works with ±12 V power sources. The lower voltage will reduce the measuring span of the transducer to 2.5 x I_N. The effects of a ±12V power supply on the offset and gain values are small.

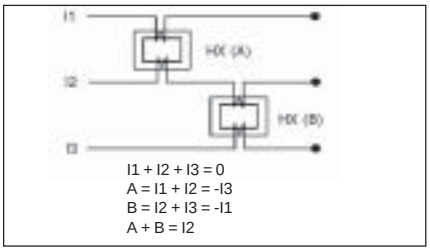


Figure 6. Measurement of 3-phase currents with only 2 transducers

The offset tends to increase by less than 0.3 %, while the gain becomes smaller to not more than 0.5% compared to the factory adjusted values with a ±15V power supply.
A single supply version, type HX..-SP2 operates with any voltage between +12 V and +15 V, and can measure from 0 to three times I_N with similar accuracy. The zero current offset point is set to +2.5 V while the gain is calibrated to 0.625 V at I_N (Fig. 3). This version allows direct connection of the transducers to the 5 V inputs of A/D converter, micro-controllers and instrumentation cards. Additional circuitry to protect the sensitive inputs against excess voltage is not required.

In addition, the HX 05-NP, HX 10-NP and HX 15-NP models have two primary windings, P1 and P2 (Fig. 5). The primary windings can be put in series or parallel through the printed circuit board pattern layout. As such, it's possible to cover 5 ratings range from 5 A to 30 A with only 3 HX-NP models, simplifying logistic problems. In some inverter applications, a pair of transducers is used to measure all three phases, with two phases per transducer (Fig. 6). This eliminates the need for a third unit, which contributes to a cost reduction. The HX..-NP version with double primary windings is ideally suited to this method.

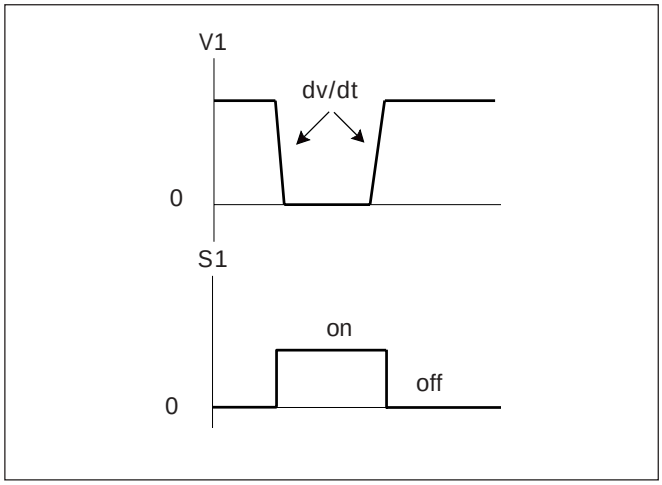


Figure 7. dv/dt appear as a consequence of fast switching components

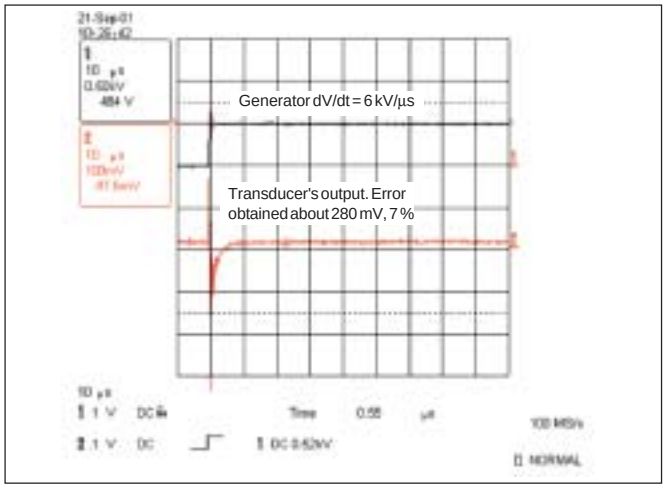


Figure 8. Sensitivity to common mode voltage variation. Perturbation voltage variation : 500 Volts, dv/dt = 6 kV/µs

High immunity to dv/dt noise

One of the problems encountered by engineers in the design of drive controls and switching devices is the high dv/dt noise caused by fast voltage changes during commutation (Fig. 7).

Improvements in power semiconductors have been very steady. IGBTs with very high commutation speed can be found in many semiconductor manufacturer's catalogues. Because of this, today's general purpose inverters tend to operate at high switching frequency, 20 kHz and more. The benefits are obvious, such as smoother waveforms, quiet operations and better efficiency.

The high dv/dt values generated at each turn on/off of the switching device will produce a capacitive current between the primary cable and the electronic circuit of the transducer.

Most analogic, linear amplifiers are sensitive to this parasitic current. Because of this, dv/dt noises will be superimposed on the output signal. Depending on the amplitude and the slope of the changing voltage, the initial spike and the following oscillations are sometimes so high that they activate the current protection circuit, and therefore, bring the inverter to a halt. The long experience at LEM helps a lot during the design phase of the HX to ensure an excellent immunity to critical noise levels without compromising its bandwidth, that no other product of a comparable size can match (Fig. 8 - 9).

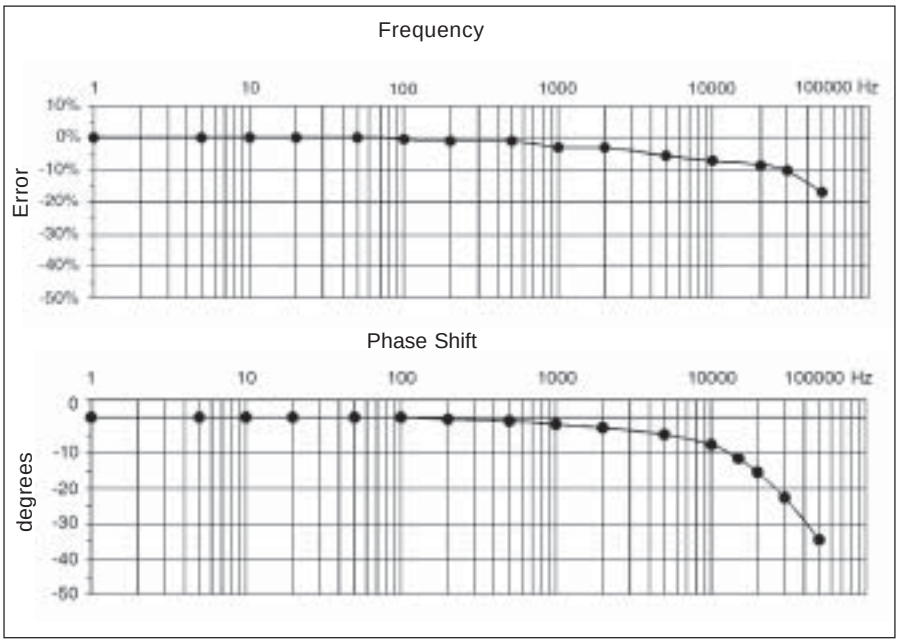


Figure 9.The HX series' frequency characteristics are typical to an open loop current transducer

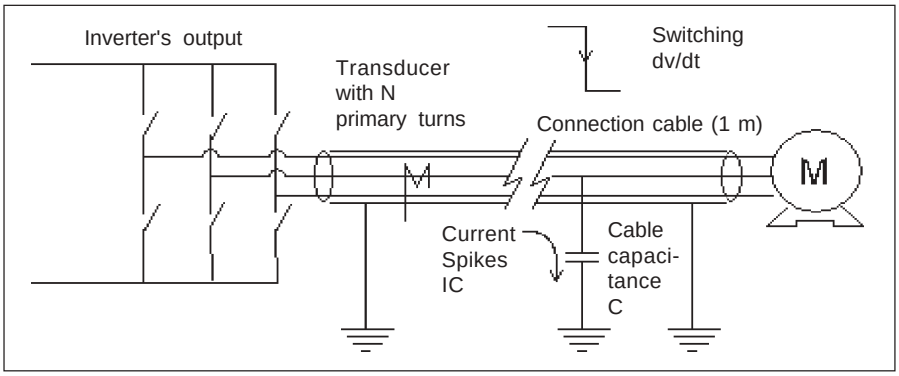


Figure 10.Current spikes appear as a result of the switching dv/dt on the capacitance of the connection cable.

Besides, dv/dt may cause excessive heating of the magnetic core. It's well known that, when an inverter is connected to a motor through a very long cable (e.g. 100 m or more), the current spikes caused by the switching dv/dt at high frequency on the capacitance of the cable will generate a lot of heat in the magnetic core, due to iron losses (Fig. 10).

The HX employs a core made with solft magnetic material to alleviate the core heating.

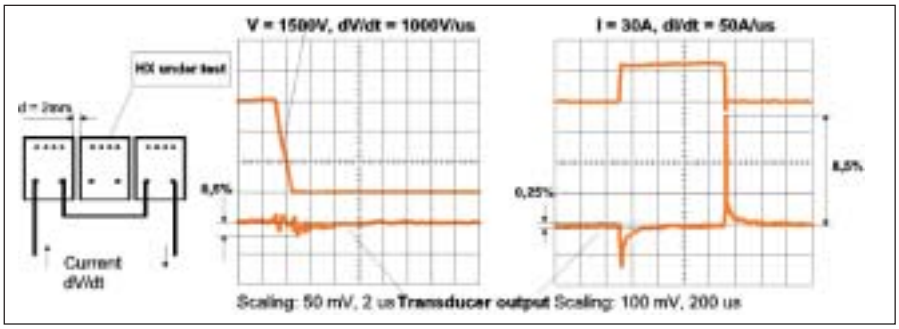


Figure 11.The mutual disturbance caused by current transducers mounted side by side in a three-phase application is very small

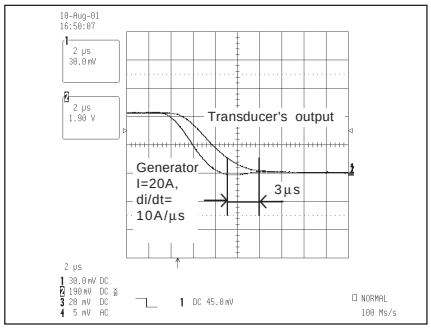


Figure 12. Very fast response time is needed in short-circuit protection

However, we've also a special version that employs a different core material that exhibits low irons losses at high frequency. The table below illustrates the extent of the improvement. Please contact us or a LEM sales representative for more information.

Also, another common headache for design engineers is space. Small transducers can help, thanks to their limited mounting area. However, every-one knows that when these transducers are placed side by side in a three-phase application, the respective primary currents affect the other transducers' electronics. The HX series excels in this respect as shown in Fig. 11.

The HX series has remarkable, dynamic characteristics. Current changing at rates of more than 50 A/µs can be followed accurately (Fig. 12). The response to a step current is as fast as 3 µs, which is critical in short-circuit protection for IGBT's.

Experience and a thorough reengineering process lead to a cost breakthrough, without compromising quality and performance.

The experience and know-kow of the R&D team have been put in the reengineering process of a Japanese best seller, the SY series, into the HX series.
As a result of this, the number of components has been greatly reduced. Automation of production and laser trimming also helped shorten production time.
This leads to a considerable improvement of cost, that will benefit the customer.

Special construction (patent pending) allows 5.5 mm of clearance and creepage distance without the need of potting. All materials are UL94V0 and the transducers are CE marked in accordance with the European Directive 89/336/EEC and thus satisfy the derived local EMC regulations.
Recognition to UL 508 is pending.

5 year warranty

The experience and know-how acquired over decades have allowed LEM to meet their objectives for this new generation in the lower power range: The highly automated production line and test equipment offer the users current transducers of a very high quality, reliability and compact size at a minimum cost.
LEM Components has produced and sold more than a hundred million of highly reliable current transducers on the market during the last three decades. The experience acquired in all the applications, and the high quality level allow us to offer a "Five Year Warranty" on all data sheet specifications of these products.

CE

LEM TRANSDUCERS 5 YEARS WARRANTY

Table 1: HX 20-P special version with low iron losses at high frequency versus HX-20-P

Model	HX 20-P	HX 20-P special	Test conditions
Core's temperature rise	64 °C	32 °C	20 A / 8 kHz
	> 75 °C	38 °C	IGBT inverter with 75 m shielded cable (0.65 uF / 1000 m) to motor, switching at 20 A / 8 kHz

Current Transducer HX 03...50-P

I_{PN} = 3 .. 50 A

For the electronic measurement of currents: DC, AC, pulsed, mixed, with a galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit).

Electrical data

Primary nominal r.m.s. current I_{PN} (A)	Primary current measuring range I_P (A)	Primary Conductor Diameter x Turns (mm)	Type
3	± 9	0.6d x 20T	**HX 03-P**
5	± 15	0.8d x 12T	**HX 05-P**
10	± 30	1.1d x 6T	**HX 10-P**
15	± 45	1.4d x 4T	**HX 15-P**
20	± 60	1.6d x 3T	**HX 20-P**
25	± 75	1.6d x 2T	**HX 25-P**
50	± 150	1.2 x 6.3 x 1T	**HX 50-P**

V_{OUT}	Output voltage @ ± I_{PN}, R_L = 10 kΩ, T_A = 25°C	± 4	V
R_{OUT}	Output impedance	< 50	Ω
R_L	Load resistance	≥ 10	kΩ
V_C	Supply voltage (± 5 %)[1]	± 15	V
I_C	Current consumption	< ± 15	mA
V_d	R.m.s. voltage for AC isolation test, 50/60Hz, 1 mn	> 3	kV
V_e	R.m.s. voltage for partial discharge extinction at 10pC	≥ 1	kV
	Impulse withstand voltage, 1.2/50µs	≥ 6	kV

Accuracy-Dynamic performance data

X	Accuracy @ I_{PN}, T_A = 25°C (without offset)		< ± 1	% of I_{PN}
ε_L	Linearity (0 .. ± I_{PN})		< ± 1	% of I_{PN}
V_{OE}	Electrical offset voltage, T_A = 25°C		< ± 40	mV
V_{OH}	Hysteresis offset voltage @ I_P = 0; after an excursion of 3 x I_{PN}		< ± 15	mV
V_{OT}	Thermal drift of V_{OE}	max.	± 1.5	mV/K
$TC\varepsilon_G$	Thermal drift of the gain (% of reading)		± 0.1	%/K
t_r	Response time @ 90% of I_P		≤ 3	µs
f	Frequency bandwidth (-3 dB) [2]		50	kHz

General data

T_A	Ambient operating temperature	- 25 .. + 85	°C
T_S	Ambient storage temperature	- 25 .. + 85	°C
m	Mass	8	g
	Min. internal creepage distance/clearance	≥ 5.5	mm
	Isolation material group	I	
	Standards	EN50178	

Notes : [1] Also operate at ±12V power supplies, measuring range reduced to ±2.5 x I_{PN}
[2] Small signal only to avoid excessive heating of the magnetic cores

Features

- Galvanic isolation between primary and secondary circuit
- Hall effect measuring principle
- Isolation voltage 3000V
- Low power consumption
- Extended measuring range(3x I_{PN})
- Power supply from ±12V to ±15V
- Material according to UL94-V0

Advantages

- Low insection losses
- Easy to mount with automatic handling system
- Small size and space saving
- Only one design for wide current ratings range
- High immunity to external interference.

Applications

- Switched Mode Power Supplies (SMPS)
- AC variable speed drives
- Uninterruptible Power Supplies (UPS)
- Electrical appliances
- Battery supplied applications
- DC motor drives

Current Transducer HX 03...50-P/SP2

I_{PN} = 3 .. 50 A

For the electronic measurement of currents: DC, AC, pulsed, mixed, with a galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit).

Electrical data

Primary nominal r.m.s. current I_{PN} (A)	Primary current measuring range I_P (A)[1]	Primary Conductor Diameter x Turns (mm)	Type
3	± 9	0.6d x 20T	**HX 03-P/SP2**
5	± 15	0.8d x 12T	**HX 05-P/SP2**
10	± 30	1.1d x 6T	**HX 10-P/SP2**
15	± 45	1.4d x 4T	**HX 15-P/SP2**
20	± 60	1.6d x 3T	**HX 20-P/SP2**
25	± 75	1.6d x 2T	**HX 25-P/SP2**
50	± 150	1.2 x 6.3x 1T	**HX 50-P/SP2**

V_{OUT}	Output voltage @ ± I_{PN}, R_L = 2 kΩ, T_A = 25°C	± 0.625	V
R_{OUT}	Output impedance	< 50	Ω
R_L	Load resistance	≥ 2	kΩ
V_C	Supply voltage (± 5 %)	+12...+15	V
I_C	Current consumption	< 15	mA
V_d	R.m.s. voltage for AC isolation test, 50/60Hz, 1 mn	> 3	kV
V_e	R.m.s. voltage for partial discharge extinction at 10pC	≥ 1	kV
	Impulse withstand voltage, 1.2/50µs	≥ 6	kV

Accuracy-Dynamic performance data

X	Accuracy @ I_{PN}, T_A = 25°C (without offset)		< ± 1	% of I_{PN}
ε_L	Linearity (0 .. ± I_{PN})		< ± 1	% of I_{PN}
V_{OE}	Electrical offset voltage, T_A = 25°C		+2.5V±50	mV
V_{OH}	Hysteresis offset voltage @ I_P = 0; after an excursion of 3 x I_{PN}		< ± 10	mV
V_{OT}	Thermal drift of V_{OE}	max.	± 1.5	mV/K
$TC\varepsilon_G$	Thermal drift of the gain (% of reading)		± 0.1	%/K
t_r	Response time @ 90% of I_P		≤ 3	µs
f	Frequency bandwidth (-3 dB) [2]		50	kHz

General data

T_A	Ambient operating temperature	- 25 .. + 85	°C
T_S	Ambient storage temperature	- 25 .. + 85	°C
m	Mass	8	g
	Min. internal creepage distance/clearance	≥ 5.5	mm
	Isolation material group	I	
	Standards	EN50178	

Notes: [1] With R_L=2kΩ
[2] Small signal only to avoid excessive heating of the magnetic core

Features

- Galvanic isolation between primary and secondary circuit
- Hall effect measuring principle
- Isolation voltage 3000V
- Low power consumption
- Extended measuring range(3x I_{PN})
- Single supply from +12V to +15V
- Material according to UL94-V0

Advantages

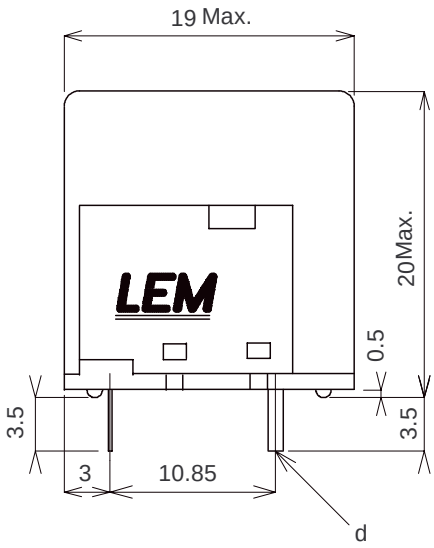
- Low insection losses
- Easy to mount with automatic handling system
- Small size and space saving
- Only one design for wide current ratings range
- High immunity to external interference.

Applications

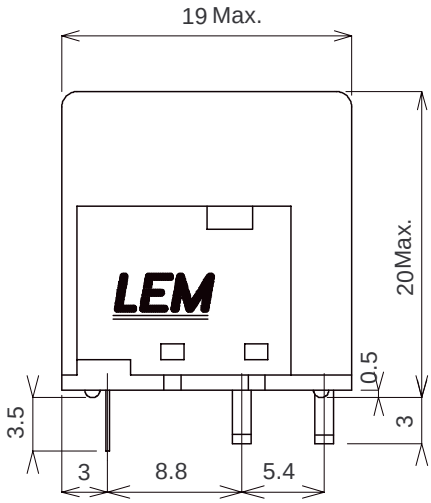
- Switched Mode Power Supplies (SMPS)
- AC variable speed drives
- Uninterruptible Power Supplies (UPS)
- Electrical appliances
- Battery supplied applications
- DC motor drives

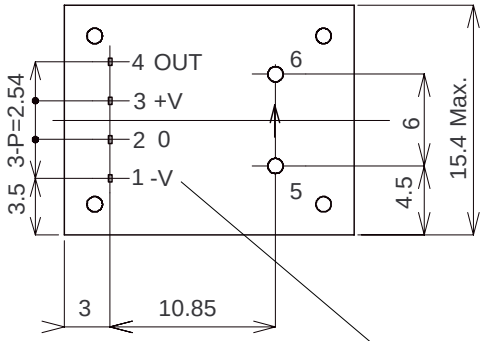
Dimension (in mm)

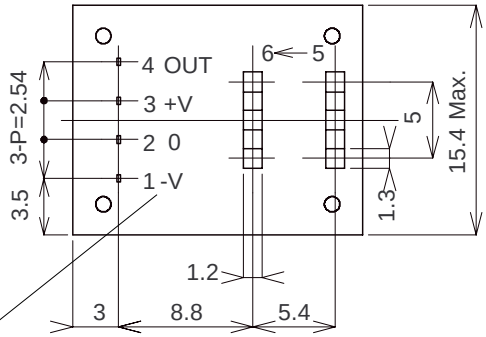
HX 03...25-P & SP2



HX 50-P & SP2

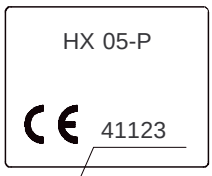






0 for SP2 type

Top view



Lot No.

Terminal Pin Identification

1....-12..-15V (0 for SP2 type)

2.....0V

3...+12...+15V

4.....Output

5.....Primary input Current(+)

6.....Primary input Current(-)

Primary conductor diameter /dimension

HX	03-P	05-P	10-P	15-P	20-P	25-P	50-P
	03-P/SP2	05-P/SP2	10-P/SP2	15-P/SP2	20-P/SP2	25-P/SP2	50-P/SP2
d	0.6	0.8	1.1	1.4	1.6	1.6	1.2x6.3

Secondary pins dimension

0.5x0.25

Current Transducer HX 05...15-NP

I_{PN} = 5 .. 15 A

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Electrical data

Primary nominal r.m.s. current I_{PN} (A)		Primary current measuring range I_P (A)		Primary Conductor Diameter x Turns (mm)	Type
Series	Parallel	Series	Parallel		
± 5	± 10	± 15	± 30	0.8d x (6T+6T)	**HX 05-NP**
± 10	± 20	± 30	± 60	1.0d x (3T+3T)	**HX 10-NP**
± 15	± 30	± 45	± 90	1.1d x (2T+2T)	**HX 15-NP**

V_{OUT}	Output voltage @ ± I_{PN}, R_L = 10 kΩ, T_A = 25°C	± 4	V
R_{OUT}	Output impedance	< 50	Ω
R_L	Load resistance	≥ 10	kΩ
V_C	Supply voltage (± 5 %)[1]	± 15	V
I_C	Current consumption	< ± 15	mA
V_d	R.m.s. voltage for AC isolation test, 50/60Hz, 1 mn		
	Primary to secondary	> 3	kV
	Primary 1 to primary 2	> 1	kV
V_e	R.m.s. voltage for partial discharge extinction at 10pC	≥ 1	kV
	Impulse withstand voltage, 1.2/50µs	≥ 6	kV

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V_{OE}	Electrical offset voltage, T_A = 25°C	< ± 40	mV
V_{OH}	Hysteresis offset voltage @ I_P = 0; after an excursion of 3 x I_{PN}	< ± 15	mV
V_{OT}	Thermal drift of V_{OE}	max. ± 1.5	mV/K
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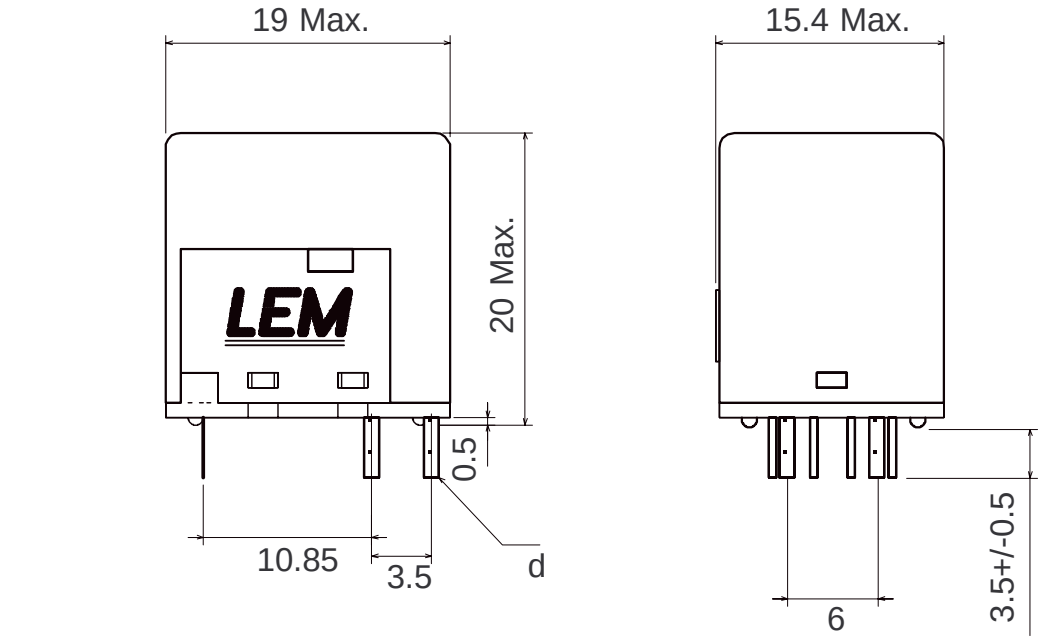
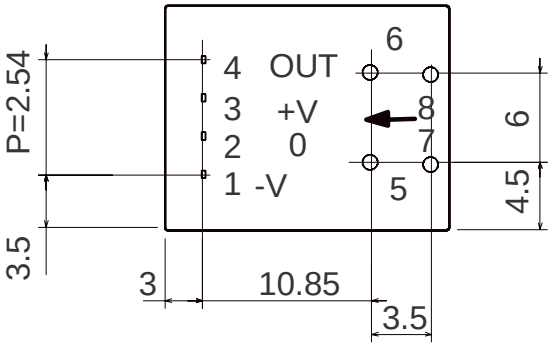
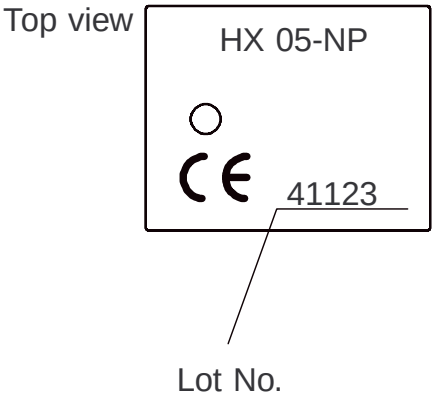
HX 05...15-NP (in mm)







Terminal Pin Identification

1.....-12V... -15V
2..... 0V
3..... +12V...+15V
4..... Output
5..... Primary 1 input Current(-)
7..... Primary 1 input Current(+)
6..... Primary 2 input Current(-)
8..... Primary 2 input Current(+)

Primary conductor diameter

HX	05-NP	10-NP	15-NP
d	0.8	1.0	1.1

Secondary pins dimension
0.5 x 0.25

5 Years Warranty
on LEM Transducers

LEM designs and manufactures high quality and
high reliability products for its customers over the entire world.

Since 1972, we have delivered several million current and voltage transducers which are, for most of them, still in operation on traction vehicles, industrial motor drives, UPS systems and many other applications requiring high quality standards.

Our 5 years warranty applies on all LEM transducers delivered from the 1st. of January 1996 and is valid in addition to the legal warranty. The warranty granted on our Transducers is for a period of 5 years (60 months) from the date of their delivery.

During this period we shall replace or repair at our cost all defective parts (provided the defect is due to defective material or workmanship).

Further claims as well as claims for the compensation of damages, which do not occur on the delivered material itself, are not covered by this warranty.

All defects must be notified to us immediately and faulty material must be returned to the factory along with a description of the defect.

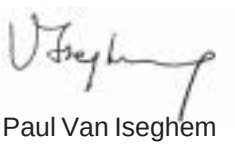
Warranty repairs and or replacements are carried out at our discretion. The customer bears the transport costs. An extension of the warranty period following repairs undertaken under warranty cannot be granted.

The warranty will be invalidated if the buyer has modified or repaired, or has had repaired by a third party the material without LEM's written consent.

The warranty does not cover any damage caused by incorrect conditions of use and cases of force majeure. No responsibility will apply except legal requirements regarding product liability.

The warranty explicitly excludes all claims exceeding the above conditions.

LEM, Geneva, January 1. 2001
Business Area Components



Paul Van Iseghem
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