Technical
Information

ASIC Based Closed-Loop Transducers from 6 A up to 25 A nominal

Electronic Components

LEM

ASIC Based Closed-Loop Transducers from 6 A up to 25 A nominal

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The use of electronics is steadily increasing in all areas of daily life. It starts in the home with domestic appliances, modern communication devices, intelligent HVAC equipment and continues in many areas ranging from computer and automotive technologies to the fully automated control of industrial processes.
*In the field of power supplies, a fundamental change in circuit topologies has occurred during the 90's. Here, digital control components are becoming more and more important. This trend can also be observed in power electronics. IGBT power modules (IGBT = **I**nsulated **G**ate **B**ipolar **T**ransistor) are becoming increasingly efficient and compact, thus allowing designers, in conjunction with other electronic components, to build smaller, more compact devices. The objective is always an increase in power density (power per volume) and, at the same time, a reduction in costs. This innovation trend is only possible, if the multitude of new processors is also accompanied by the introduction of appropriate sensors in smaller and more cost-effective versions, equipped with an integrated, electrically isolated interface for measuring the process variables.*

*Thanks to the creation of ASIC based closed-loop current transducers LTS series, LEM has opened new opportunities for the use of galvanically isolated current measuring technologies in new market segments. The development of these current transducers combines the new construction technology of the magnetic circuit and the integration of the complete electronics in a customer-tailored ASIC (**A**pplication **S**pecific **I**ntegrated **C**ircuit).*

Closed-loop principle

The LTS series is based on the proven closed-loop principle, used by LEM years ago when building the first current transducer. Since that time, this principle has been used with success for electrically isolated measurements of currents and voltages.
Every current carrying conductor (Fig. 1) generates a magnetic field, which is concentrated in a magnetic circuit. This field can be measured in an air gap. For that purpose, a Hall element is used. When it is supplied with a constant current, it has the property of converting the magnetic flux into a voltage. When applying the closed-loop principle, this voltage is used only for balancing the primary and the secondary flux. An additional secondary compensating coil, for example with 2000 turns, carries 1/2000 of the primary current in order to compensate exactly for the field of the primary conductor. The total flux then equals zero.
The compensation circuit accepts DC and AC currents up to the frequency limit of the electronics. Above that value, the transducer works as a normal current transformer with a primary and a secondary winding. This allows electrically isolated measurements of currents up to several hundred kHz.

The LTS series offers the first ASIC based closed-loop current transducers

The complete know-how and experience of LEM has been used for the first time to create an ASIC. All active electronic components, including the Hall sensor, are combined in the central ASIC (Fig. 2).

This integration makes it a lot easier to compensate for the component tolerances and the temperature shift. Moreover, it improves the EMC, and the components design is optimised. In conjunction with the new technology for the construction of the magnetic circuit, it has been possible to obtain dimensions for the housing, (9.3 mm x 22.2 mm x 24 mm, Fig. 3) which are three times smaller than those of traditional closed-loop current transducers with similar current ranges.

Main characteristics

Table 1 gives an overview of the main characteristics of the current transducers. The power supply voltage is 0; +5 V, which matches the most commonly used processors. In contrast to the existing closed-loop current transducers, which generally exhibit a factor for current-range to nominal-current ratio of 1.5, a ratio of more than 3 can now be obtained. This is a great advantage for most applications. The LTS 25-NP series can precisely measure currents up to 80 A for a maximum nominal current of 25 A. The reference point without any primary current is 2.5 V, which is exactly half of the supply rail voltage. The variation span of the amplified output signal is

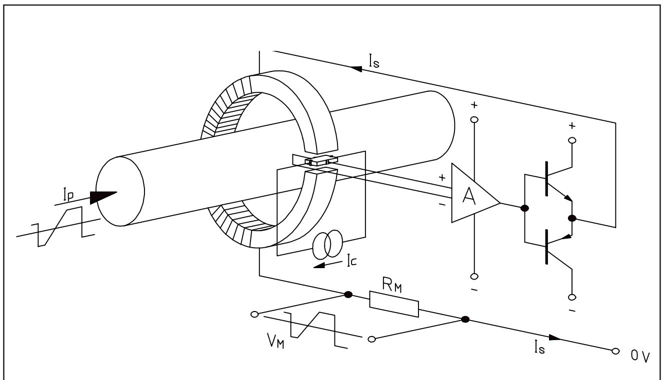


Figure 1 Construction of a closed-loop current transducer

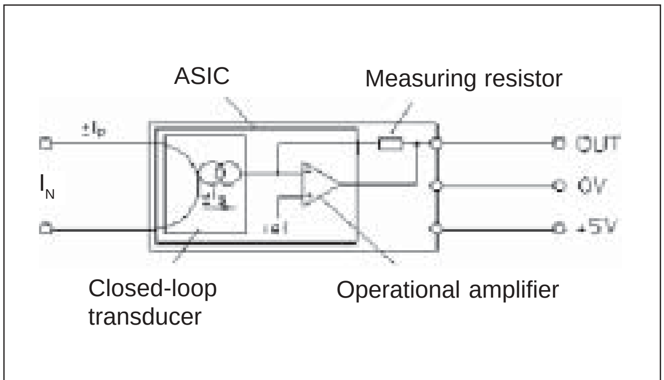


Figure 2 Block diagram of the LTS series

Main characteristics

Primary nominal current I_{PN} of LTS 6/15/25	A rms	6 - 15 - 25
Measuring range	A	19.2 - 48 - 80
Accuracy of the transducer at +25 °C (Non-linearity + amplification + long-term stability)	% x I_{PN}	± 0.2
Total error at +25 °C (0.2% + 0.5% of built-in measuring resistor)	% x I_{PN}	± 0.7
Supply voltage	V	0, + 5 (± 5%)
Reference voltage	V	+2.5 (± 1%)
Temperature drift of reference voltage (typically)	ppm/K	50
Response time @ 90% of I_{PN}	ns	< 400
Bandwidth, < 0,5 dB	kHz	0...100
Test voltage, 50-60 Hz, 1 min	kV	3
Standards		EN 50 178 EN 60 950
Dimensions l x w x h	mm	9.3 x 22.2 x 24
Mass	g	10

Table 1 Technical data of the LTS series

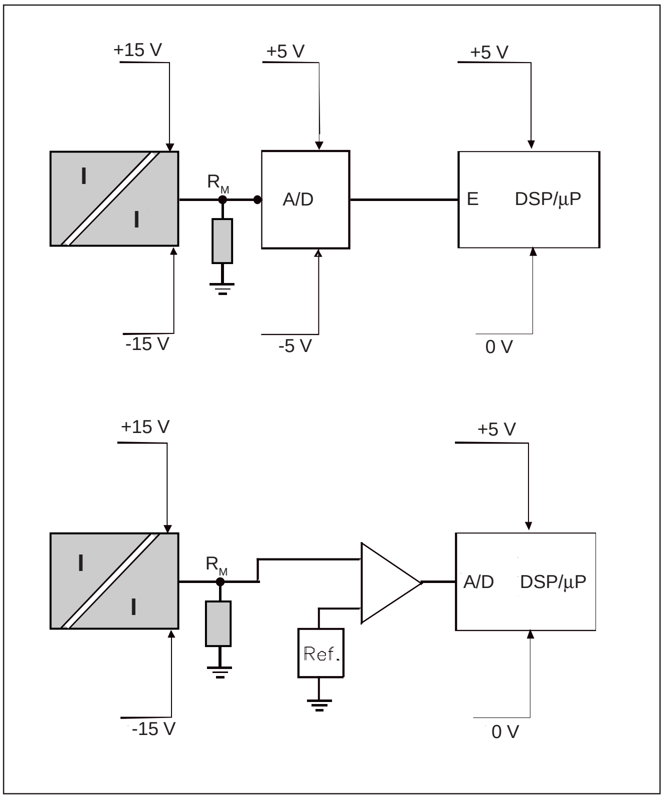


Figure 4 Block diagram of existing digital systems for current measurements

0.625 V/I_{PN}, which results in an output voltage of 4.5 V at +80 A and 0.5 V at -80 A (e.g. LTS 25-NP). The current transducers also meet the usual standards for Power Electronics Systems.

Excellent accuracy and temperature stability

The series LTS current transducers achieve a total accuracy better than ±0.2 % at 25 °C. This value includes all kinds of transducer specific tolerances, such as linearity errors, error of the number of turns and effects on the long-term stability.

In contrast to the majority of closed-loop current transducers available in the market today, which generally have a current output, here the measuring resistor has been integrated into the transducer. LEM has chosen resistors with an accuracy of ±0.5 % and a temperature drift of 50 ppm/K maximum.
The built-in reference, which is also new, reaches a temperature stability of 100 ppm/K max. The absolute accuracy of the reference is not important since, in most cases, it can be compensated by a processor.

By adding up all tolerances in a temperature range from -10 °C to +85 °C, the following accuracy is obtained for the LTS series for ΔT = 60 K:

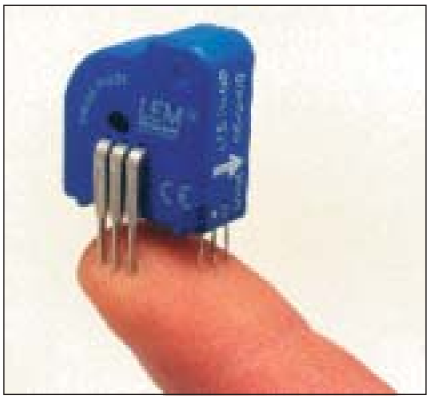


Fig. 3 The compact LTS 25-NP

Accuracy at 25 °C	±0.2 %
Tolerance of the measuring resistor	±0.5 %
Temperature drift of the measuring resistor 50 ppm/K, ΔT = 60 K	±0.3 %
Temperature drift of the reference with regards to I_{PN} (50 ppm/K typ.)	±1.2 %
Total error	**±2.2 %**

Power supply with new voltage values

Digital control systems generally operate with a supply voltage of 0; +5 V (in the future also 0; +3.3 V). This does not always apply to peripheral active components, as is the case with current transducers available in the market today, since they normally require ±12V or ±15 V to function. So far, the signals have been conditioned by using the A/D converter or analogue converter circuits (Fig. 4). The LTS series (Fig. 5) can do without such conversion feeding directly into the signal processor. The user can now save costs both on the component itself and on surrounding components:

- suppression of additional operational amplifiers, measuring resistor and external reference voltage no longer required,
- smaller size of the printed circuit board, since some components are omitted
- the circuit can possibly do without the ±15 V supply voltage

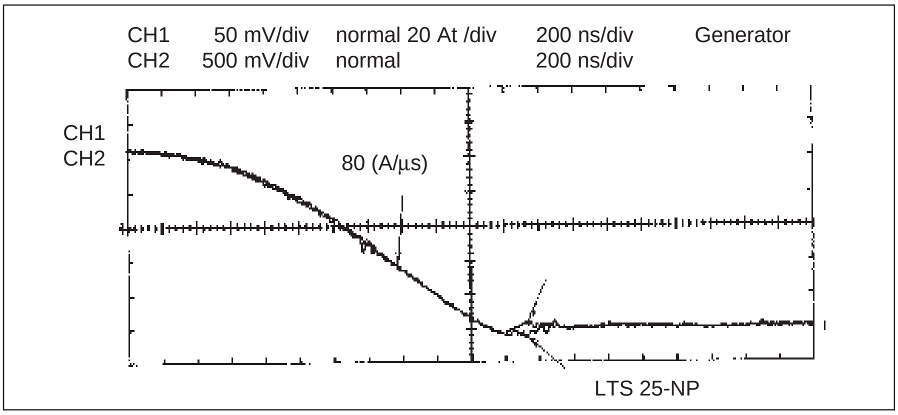


Figure 6 Behaviour of the LTS series at a current change.

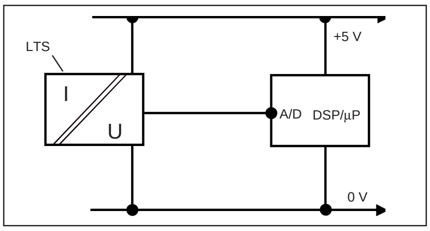


Fig. 5 Block diagram of a digital system for current measurements using the LTS series

Exact reproduction of the waveform at the transducer output

Fast power switching devices such as IGBT's (IGBT = **I**nsulated **G**ate **B**ipolar **T**ransistor) require a very fast detection of overcurrents for their protection. At a current slope of 80 A/µs (Fig. 6), there is practically no delay to be seen, with regards to the primary current. Thanks to the optimum coupling between the primary circuit and the compensating coil, the transformer effect can be optimized.

Wide frequency bandwidth

The excellent coupling characteristics are also reflected in the bandwidth. The 1 dB limit is situated at approx. 200 kHz, and thus exceeds all values of conventional state-of-the-art Hall effect transducers. So far, the 3 dB limit of closed-loop current transducers has been between 100 and 200 kHz.

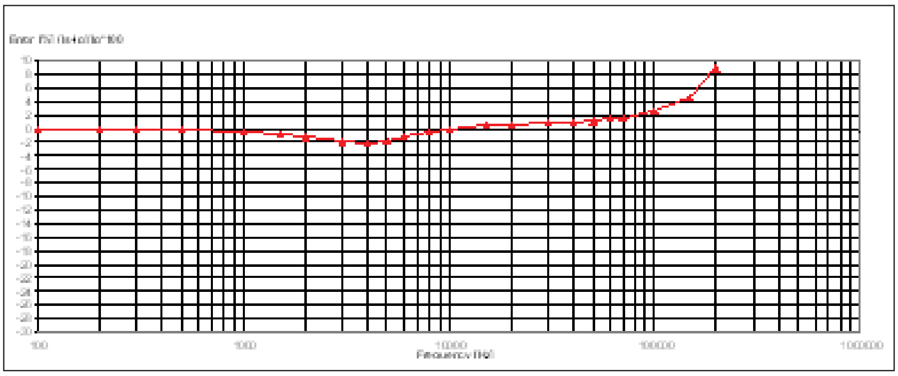


Figure 7 Frequency response of the LTS 25-NP type

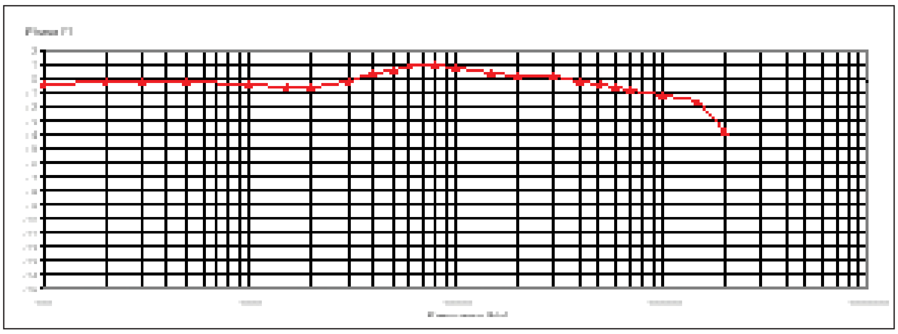


Figure 8 Phase response of the LTS 25-NP

Multifunctional Primary Circuit

The construction uses three U-shaped primary terminals and an additional circular hole in the housing, offering the designer greater flexibility to perfectly adapt the measuring range of the current transducer to his application. Fig. 9 shows the different connection possibilities.

In **Variant 1**, all three U-shaped terminals are connected in parallel. This allows the user to measure the maximum primary current.

Variant 2 corresponds to a series connection of the primary terminals, and leads to a reduction of the measuring range by a factor of 3. This offers an accuracy which is three times better at low currents.

The measurement of differential currents is possible with **Variant 3**. The current measured is the difference of the currents I_1-I_2. The second current, which is intentionally fed through the hole, creates any desired clearance distance on the printed circuit board, depending on the potential difference between the two phases.

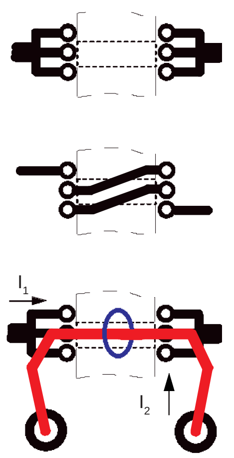


Figure 9 The different possibilities for connecting the primary current circuit (e.g. LTS 25-NP)

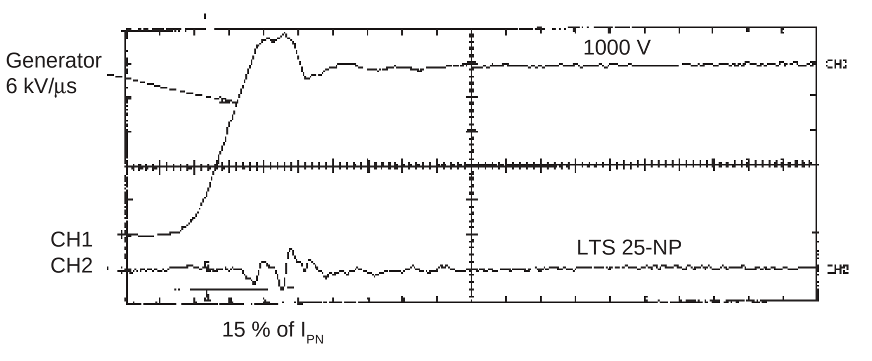


Figure 10 Immunity of the LTS series to dv/dt noise

Behaviour against dv/dt

Any electrical component with galvanic isolation between the primary and the secondary circuit has a capacitive coupling between the isolated potentials. In applications, high switching frequencies, and steep switching slopes (i.e. fast voltage changes on the primary side), will lead to undesirable EMI influences (EMI = **E**lectro **M**agnetic **I**nterference).

On the secondary side, i.e. at the output of the component, an interference signal appears. A voltage change of 10 kV/µs in combination with a 10 pF coupling capacity generates a parasitic output current of 100 mA. For the LTS series, this would be eight times the nominal current.

Figure 10 shows the behavior at a voltage change of 6 kV/µs and an applied voltage of 1000 V. The interference of 15 % of I_{PN} is mainly due to the cabling layout of the test bench during measurement. Note the very short duration of the disturbance of less than 200 ns, which can be easily filtered. This is very important with digital regulating circuits using pulse width modulation (PWM). In this case, a small filter is sufficient for the attenuation, in order not to reduce the dynamic characteristics.

Standards

During the design of the LTS series, the regulations of the EN 50178 standard have been taken into consideration. All products comply with 3 kV AC-isolation test voltage, more than 1.5 kV partial discharge extinction voltage and withstand an impulse voltage (1.2/50 µs: waveform according to EN 50178 standard) of more than 8 kV.

The material used for the case is listed IIIa as insulating material group according to the same previous standard. All these elements can easily lead to a dimensioning voltage (by using the directives described into the EN 50 178 standard) dependent of the conditions of use in the application. As conditions of use, we can list: simple or reinforced isolation need, pollution Degree linked to the application, the category of overvoltage, PCB tracks layout (to define the creepage and clearance distances - when the product is mounted into the PCB application) and these are inherent in the applications.

All materials are UL-listed (UL = **U**nderwriter's **L**aboratories).
The marking of the product with the CE mark testifies the conformity with the European EMC Directive 89/336 EEC and the low voltage Directive 72/23 EEC.

Practical examples

1. **Electrically isolated current measurements on a converter**

The LTS series is open to all applications in low-power electronic systems. A typical application field is the classic frequency inverter. Due to its excellent accuracy and immunity to dv/dt noise, it is ideally suited for servo-drive applications.

Figure 11 gives an overview of the various possibilities of electrically isolated current measurements.

Advantages

- excellent linearity for exact measurements of the motor currents
- fast response for obtaining short switch-off times in case of a fault condition, such as an earth leakage or a short circuit,
- good temperature stability allows precise repeatable measurements,
- immunity to high capacitive current changes which can result from long motor cables.

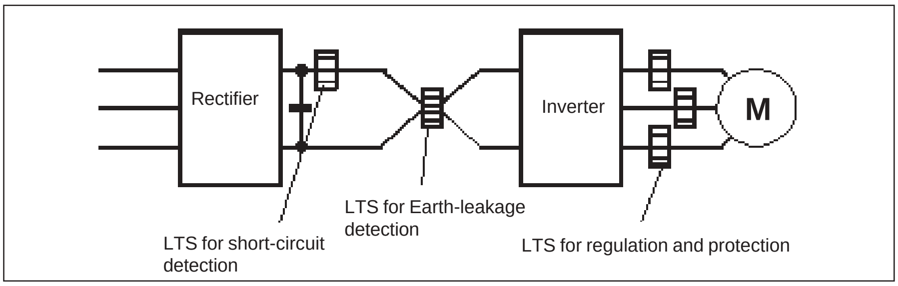


Figure 11: Possibilities of electrically isolated current measurements using the LTS series in an inverter

Figure 12 Use of the LTS series in an inverter for its regulation and protection. (Photo LEM, with the kind permission of REFU ELEKTRONIK GmbH)

2. Use in vehicles

For the use in vehicles (electric vehicles, fork lift trucks, cars etc.) with voltages up to approx. 80 V, the electrical isolation performance is not important. Here, other product advantages are more decisive:

- construction meets requirements of pick-and-place machines for PCB's
- high availability, as only one active component is integrated,
- the component is fully potted and thus immune to environmental influences.

3. **General current monitoring and regulation**

The application possibilities are many: Where currents have to be precisely detected, regulated and monitored, the LTS series offers possibilities which, perhaps, have not been seriously considered yet. This applies especially to systems in which, until now, only the alternating current has been measured. Non-linear loads are increasingly generating non-sinusoidal waveforms, which contain DC currents. The LTS series offers a good alternative to the classic transformers, because they can measure both DC and AC currents with the same device.

It can also be used in DC devices such as power supplies, battery-powered equipment or DC drives.
In this case, the LTS series offers the following advantages over a shunt resistor:

- much lower power losses,
- electrical isolation,
- better EMI immunity.

Summary

Table 2 shows all advantages and applications of the LTS series. This product is the result of a long development process based on many application-specific solution details. These have been created in partnership and co-operation with development and design engineers, where the exchange of ideas and information has played a major role. The objective was to improve the customers' products in a very competitive environment.

This allows LEM to create innovative and cost-effective product solutions, which offer both the user and the manufacturer new possibilities of automated production with repeatable performances and a high quality level.

Based on the technologies used for the LTS series, further ASIC based closed-loop current transducers offering higher current ranges or larger operating temperature ranges will follow.

Table 2 Advantages and applications of the LTS current transducer in an overview

Advantages of the LTS series

- Using a unipolar power supply 0; +5 V, positive and negative currents can be measured.
- High temperature stability and low drift.
- Multirange concept allows a multitude of terminal wirings.
- Low power consumption.
- The closed loop principle provides an excellent linearity, a wide frequency range with a short response time, a wide measuring range and the capability of measuring short current pulses.
- Production-friendliness due to simple mounting.
- Cost-effective solution.

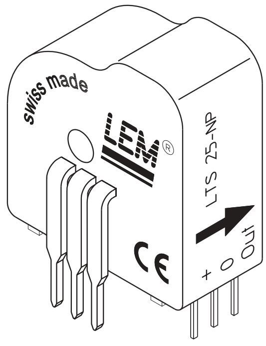
Applications

The LTS opens all applications in low-power electronic systems such as variable speed drives, electrical drives for industrial use in heating, ventilation and air conditioning as well as in appliances and industrial devices, servo drives, small uninterruptible power supplies (UPS), power supplies and amplifiers, energy management systems and general applications of current monitoring.

Multi-Range Current Transducer
LTS 6-NP, LTS 15-NP, LTS 25-NP

I_{PN} = 6 - 15 - 25 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

I_{PN}	Primary nominal r.m.s. current	6/15/25	At
I_P	Primary current, measuring range	0 .. ± 19.2/48/80	At
V_{OUT}	Analog output voltage @ I_P	2.5 ± (0.625·I_P/I_{PN})	V
	I_P = 0	2.5 [1]	V
N_S	Number of secondary turns (± 0.1 %)	2000	
R_L	Load resistance	≥ 2	kΩ
R_{IM}	Internal measuring resistance (± 0.5 %)	208.33/83.33/50	Ω
TCR_{IM}	Thermal drift of R_{IM}	< 50	ppm/K
V_C	Supply voltage (± 5 %)	5	V
I_C	Current consumption @ V_C = 5 V Typ	23+I_S [2]+(V_{OUT}/R_L)	mA
V_d	R.m.s. voltage for AC isolation test, 50/60 Hz, 1 mn	3	kV
V_e	R.m.s. voltage for partial discharge extinction @ 10 pC	> 1.5	kV
$\hat{V}_w$	Impulse withstand voltage 1.2/50 µs	> 8	kV

Accuracy - Dynamic performance data

X	Accuracy @ I_{PN}, T_A = 25°C	± 0.2		%
	Accuracy with R_{IM} @ I_{PN}, T_A = 25°C	± 0.7		%
ε_L	Linearity	< 0.1		%
		Typ	Max	
TCV_{OUT}	Thermal drift of V_{OUT} @ I_P = 0 - 10°C .. + 85°C LTS 6	80	250	ppm/K
	LTS 15	65	120	ppm/K
	LTS 25	50	100	ppm/K
$TC\varepsilon_G$	Thermal drift of the gain - 10°C .. + 85°C		50 [3]	ppm/K
V_{OM}	Residual voltage @ I_P = 0, after an overload of 3 x I_{PN}		± 0.5	mV
	5 x I_{PN}		± 2	mV
	10 x I_{PN}		± 2	mV
t_{ra}	Reaction time @ 10 % of I_{PN}	< 50		ns
t_r	Response time @ 90 % of I_{PN}	< 400		ns
di/dt	di/dt accurately followed	> 15/35/60		A/µs
f	Frequency bandwidth (0 .. - 0.5 dB)	DC .. 100		kHz
	(- 0.5 .. 1 dB)	DC .. 200		kHz

General data

T_A	Ambient operating temperature	- 10 .. + 85	°C
T_S	Ambient storage temperature	- 25 .. + 100	°C
	Insulating material group	III a	
m	Mass	10	g
	Standards [4]	EN 50178 EN 60950	

Notes: [1] Absolute value @ T_A = 25°C, 2.475 < V_{OUT} < 2.525
[2] Please see the operation principle on the other side
[3] Only due to TCR_{IM}
[4] Specification according to IEC 1000-4-3 are not guaranteed between 180 and 220 MHz.

Features

- Closed loop (compensated) multi-range current transducer using the Hall effect
- Unipolar voltage supply
- Compact design for PCB mounting
- Insulated plastic case recognized according to UL 94-V0
- Incorporated measuring resistance
- Extended measuring range.

Advantages

- Excellent accuracy
- Very good linearity
- Very low temperature drift
- Optimized response time
- Wide frequency bandwidth
- No insertion losses
- High immunity to external interference
- Current overload capability.

Applications

- AC variable speed drives and servo motor drives
- Static converters for DC motor drives
- Battery supplied applications
- Uninterruptible Power Supplies (UPS)
- Switched Mode Power Supplies (SMPS)
- Power supplies for welding applications.

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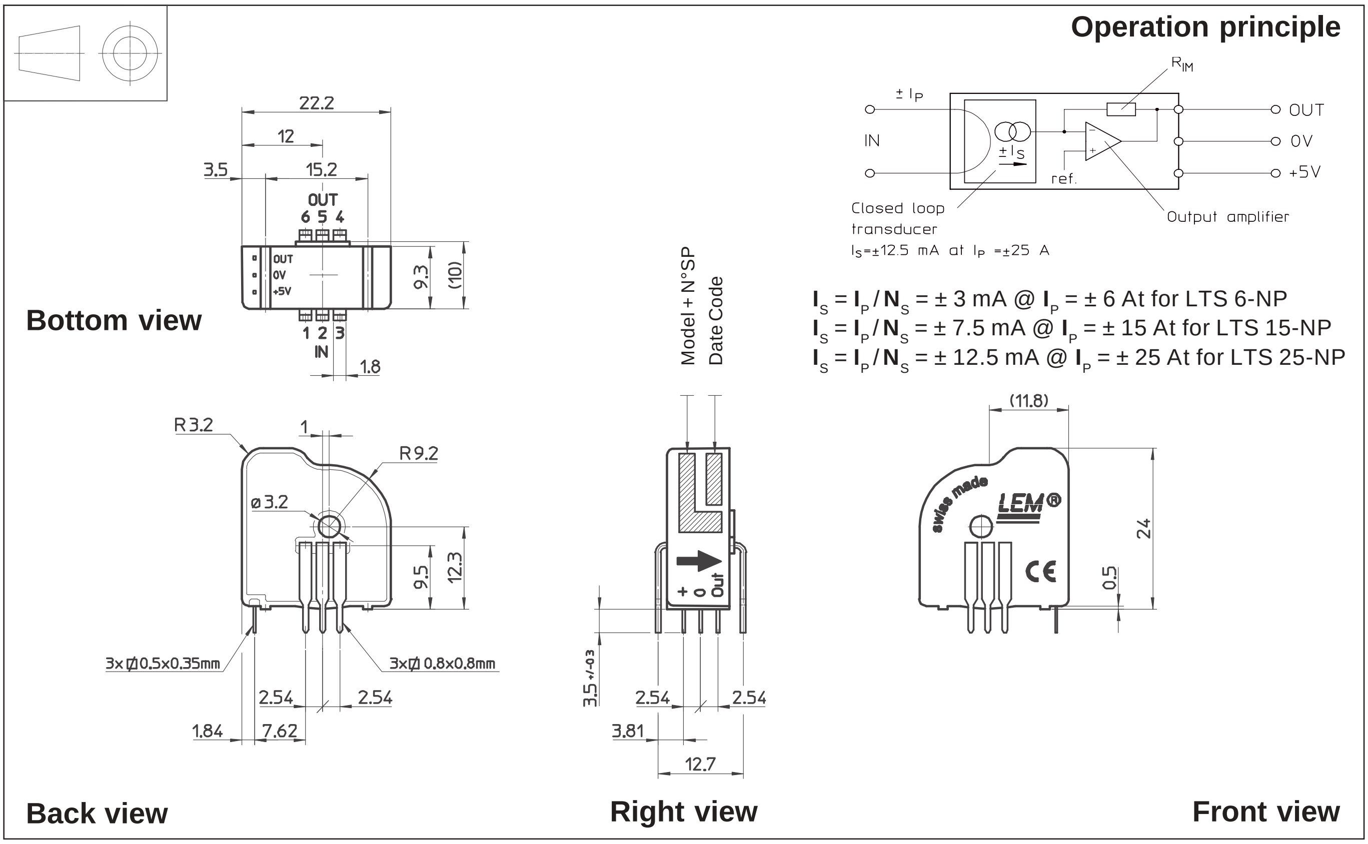
Dimensions LTS 6, LTS 15, LTS 25-NP (in mm. 1 mm = 0.0394 inch)



Number of primary turns	Primary nominal r.m.s. current I_{PN} [A]	Nominal output voltage V_{OUT} [V]	Primary resistance R_P [mΩ]	Primary insertion inductance L_P [µH]	Recommended connections
1	LTS 6-NP ± 6 LTS 15-NP ± 15 LTS 25-NP ± 25	2.5 ± 0.625	0.18	0.013	6 5 4 OUT IN 1 2 3
2	LTS 6-NP ± 3 LTS 15-NP ± 7.5 LTS 25-NP ± 12	2.5 ± 0.625 2.5 ± 0.625 2.5 ± 0.600	0.81	0.05	6 5 4 OUT IN 1 2 3
3	LTS 6-NP ± 2 LTS 15-NP ± 5 LTS 25-NP ± 8	2.5 ± 0.625 2.5 ± 0.625 2.5 ± 0.600	1.62	0.12	6 5 4 OUT IN 1 2 3

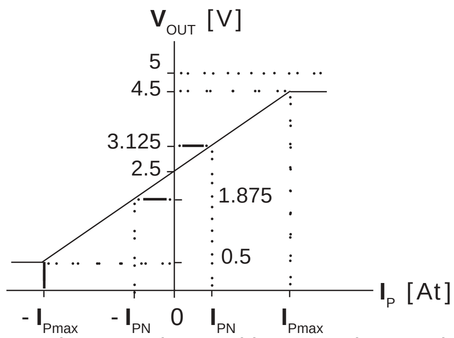
Mechanical characteristics

- General tolerance ± 0.2 mm
- Fastening & connection of primary 6 pins 0.8 x 0.8 mm
  Recommended PCB hole 1.3 mm
- Fastening & connection of secondary 3 pins 0.5 x 0.35 mm
  Recommended PCB hole 0.8 mm
- Additional primary through-hole ∅ 3.2 mm

Remark

- V_{OUT} is positive when I_P flows from terminals 1, 2, 3 to terminals 6, 5, 4.

Output Voltage - Primary Current



LEM reserves the right to carry out modifications on its transducers, in order to improve them, without previous notice.

Notes

Technical Information "ASIC Based Closed-Loop Transducers from 6 A up to 25 A nominal"

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The paper of this publication is produced with pulp bleached without chlorine, neutral sized and non-aging.

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
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President of LEM Components

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