Technical Information

LTSR: ASIC Based Closed-Loop Transducers from 6 A up to 25 A nominal with reference access

LTSR: ASIC Based Closed-Loop Transducers from 6 A up to 25 A nominal with reference access. *By Stéphane Rollier, Christophe Benz & Hans Dieter Huber.*

The LTS 25-NP and the other members of the LTS family, due to their innovative design, have become a popular solution for insulated current measurement in applications like drives and UPS. Although these products meet the design requirements for a great number of applications, LEM's mission to stay in tune with the power electronics market requirements, caused us to develop the next generation of the LTS family, providing additional functions and improved characteristics.

This updated family is called LTSR and allows nominal currents measurements of 6 ARMS with the LTSR 6-NP, 15 ARMS with the LTSR 15-NP and 25 ARMS with the LTSR 25-NP models. (Fig.1. A new LTS family).

The R in LTSR, is for Reference: LEM's aim was to create the best synergy between an isolated measuring solution and the customers' power electronics. The LTS family was already a step torward this by using a similar power supply as the one used in the power electronics (0 to +5 V) being more and more mastered by the digital components (processors). With the use of a new generation of LEM ASIC, the LTSR series based also on the Closed Loop Hall effect technology is still closer to the driving electronic than before with the LTS models while keeping its previous biggest advantages that is to say its compactness and its cost efficiency.

Indeed, LTSR items can supply their reference voltage to the surrounding electronic or even more can receive external voltage reference from DSP (Digital Signal Processor) or ADC (Analog Digital Converter) more and more commonly used in power electronics.

Some background

The LTS 25-NP is a small current sensor designed for PCB mounting. The development of this product was a challenge for LEM due to the demanding specification that required new technologies be employed, along with innovative manufacturing strategies.

The LTSR is a **closed-loop type transducer**. It works based on the principle of primary flux compensation. That means that the magnetic flux generated by the primary current (the measured current) is sensed by a hall element. This hall element drives the electronics that supplies a current to a coil generating an opposite magnetic flux to compensate the one generated by the primary. The current in the winding is a scaled reproduction of the primary current (Fig. 2).

This product has been designed to meet the following requirements: small size and 5V single-supplied transducer. The small case and corresponding magnetic subassembly result in a short distance between the primary and the secondary circuit of the transducer. This construction produces a device with excellent immunity to the high dv/dt encountered for example in motor drives. DV/dt is due to the switching of the bridge driving the current in the 3 phases of the load. (Fig. 3)

Any electrical component with a galvanic isolation between the primary and the secondary circuit has a capacitive coupling between the isolated potentials. In applications with high switching frequencies and consequently with steep switching slopes (i.e. fast voltage changes on the primary side), this leads 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 LTSR series, this would be eight times the nominal current.

Fig. 3 shows the behaviour at a voltage change of 6 kV/µs and an applied voltage of 1000 V with a LTSR 25-NP.

The interference of 15.3 % 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 800 ns which can be easily filtered (total recovery time: 1.6 µs). This is very important for the use with digital regulating circuits using pulse width modulation (PWM). In this

Fig. 1: A unique current transducer: LTSR

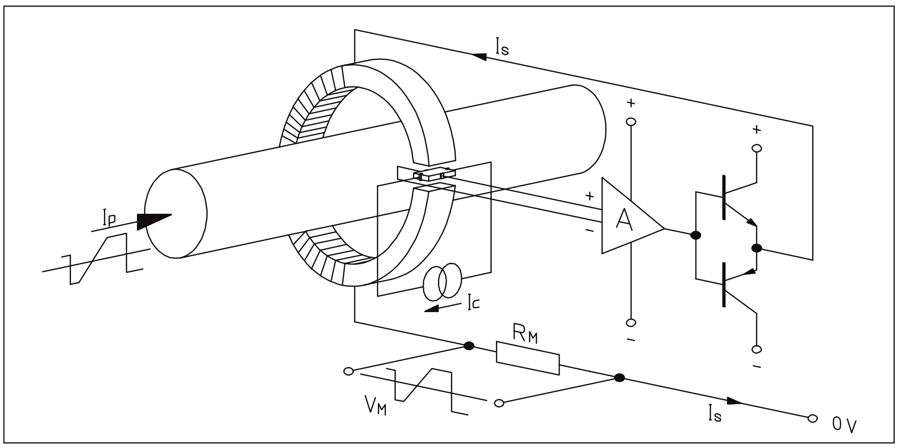


Fig. 2: Construction of a closed-loop current transducer

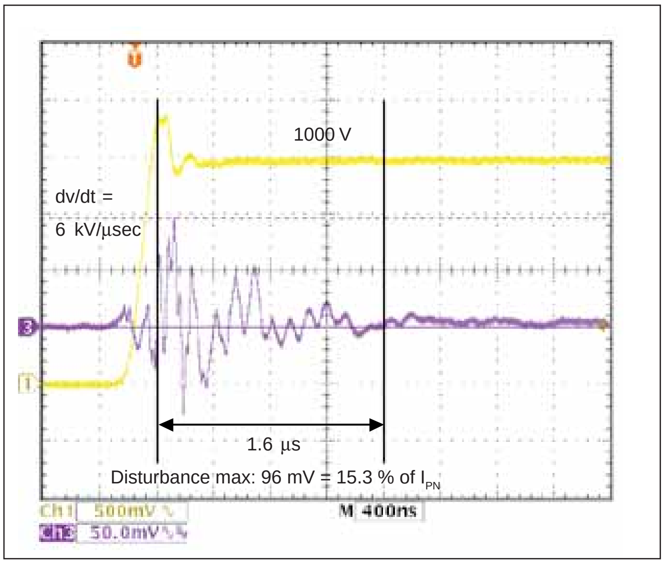


Fig. 3: Immunity to dV/dt variations of the LTSR (LTSR 25-NP)

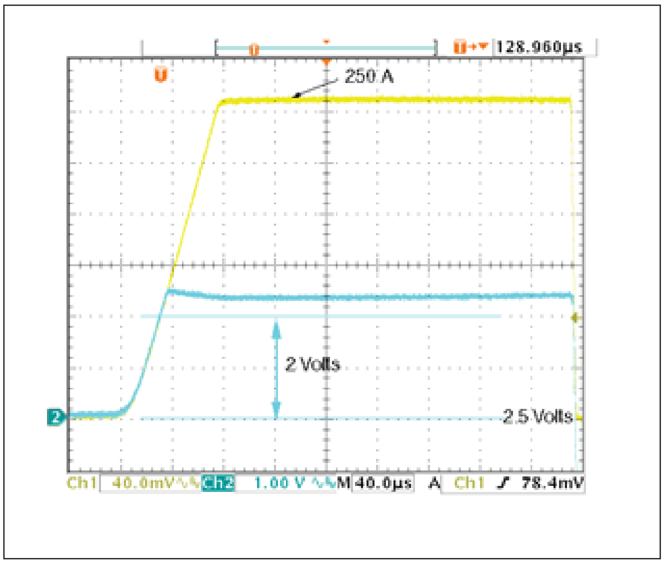


Fig. 5: Behaviour of the LTSR output during a positive overload of 10 x In

case, a small filter is sufficient for the attenuation, in order not to reduce the dynamic characteristics.

The LTS 25-NP was the first LEM transducer utilizing ASIC technology. A unique feature of the ASIC designed for the LTS was the integration of the field sensing element on to the same substrate as the electronics resulting in a solution to compensate partially the Hall cell's drift due to temperature variation.

A new generation of ASIC with a better temperature drift

The new ASIC generation is based on a silicon technology being different from the first generation ASIC used on LTS products today. This technology offers a better offset drift after compensation of the hall cell's drift than the old technology. This is an important factor when designing control loops integrating a transducer. If the drift is lower, the stability of the controlled loop is better.

With an LTS 25-NP in the temperature range from –40 °C to 85 °C, we achieve a max offset drift of 100 ppm/°C, with an LTSR 25-NP in the same temperature range and used in the best configuration, we can achieve 37.5 ppm/°C. (Fig 4)

	Out/0 V		**Out/Ref.**
	-40... -10 °C	-10... +85 °C	-40... +85 °C
LTSR 6-NP	250	200	150
LTSR 15-NP	164	114	64
LTSR 25-NP	137.5	87.5	37.5
Temperature Drift LTSR in ppm/°C			

Fig. 4: Drift of the different models

The new ASIC was also improved to be able to drive the coil current necessary to avoid an output voltage drop below the limit necessary for a short-circuit detection, i.e for a primary current of 10x the nominal current, the output voltage should not drop below 2 V referenced to 2.5 V to insure proper short-circuit detection. (Fig. 5)

What is the difference between an LTS and an LTSR?

Like the LTS, the LTSR is a closed-loop transducer, but it has an additional pin called REF. This pin is an access to the internal voltage reference of the ASIC, that is normally set around 2.5 V. The REF pin has two basic functional modes. (Fig. 6)

The first mode is called "ref out mode". In this mode, for a primary current of 0 A, the output voltage is equal to the voltage at pin REF (in fact there is an offset of max ±25 mV between the OUT pin and the REF pin). The voltage at REF pin stays stable although the primary current changes.

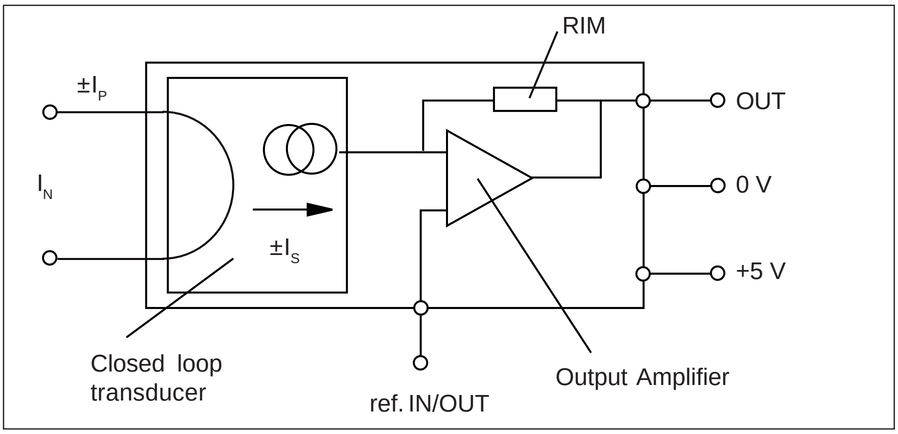


Fig. 6: LTSR 25-NP Operational principle

Differences between LTS and LTSR

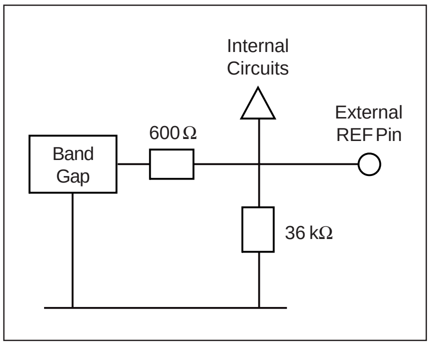


Fig. 7: Diagram of the REF pin

The second mode is called "Ref in mode". In this mode, you can apply an external voltage to the REF pin to overdrive the internal voltage reference. The allowed external voltage is minimum 1.9 V and maximum 2.7 V. The source should be able to sink or source 1 mA minimum. This level is necessary in order to ensure that the external reference will overdrive the internal reference. (Fig. 7)

The internal reference voltage V_{ref} is equal to 2.5 V ± 25 mV @ +25 °C and @ I_{ref} equal to 0. The voltage of the reference is function of:

- the I_{ref} current dependent on the connected load (Ref out mode). To keep the ref at 2.5 V ±25 mV, we impose a min load of 220 kΩ to keep I_{ref} to a minimum.
  In Ref out mode, the current sourced must be limited to -125 µA. Beyond this value a voltage breakdown can happen.
- the current supplied by the external reference (Ref in mode). In Ref in mode, the external reference supply should be able to sink or source (provide when external reference applied > V_{ref} internal = 2.5 V ± 25 mV or receive when external reference applied < V_{ref} internal) the required current as a function of the voltage level used: $V_{ref} = f(I_{ref})$.

Fig. 8 shows the reference voltage behaviour versus the current I_{ref} (for different LTSR 6-15-25-NP models).

By using an external reference, it is easier to connect the transducer to devices such as an ADC. The compromise that has to be made for this advantage is a reduction of the measuring

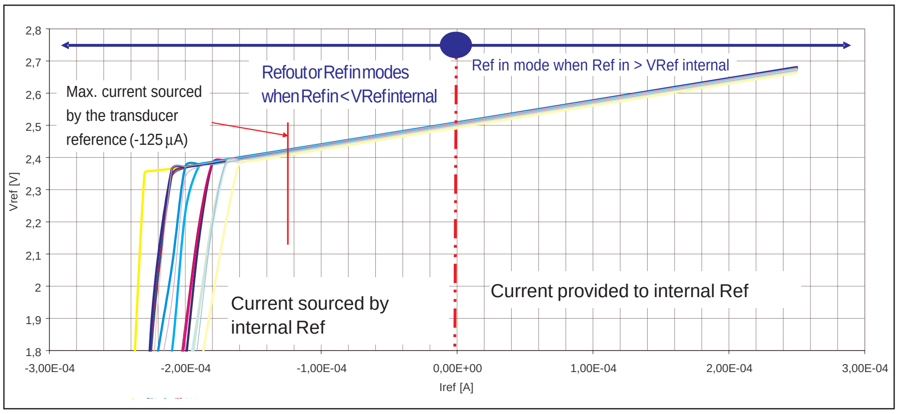


Fig. 8: V_{ref} performance versus reference current.

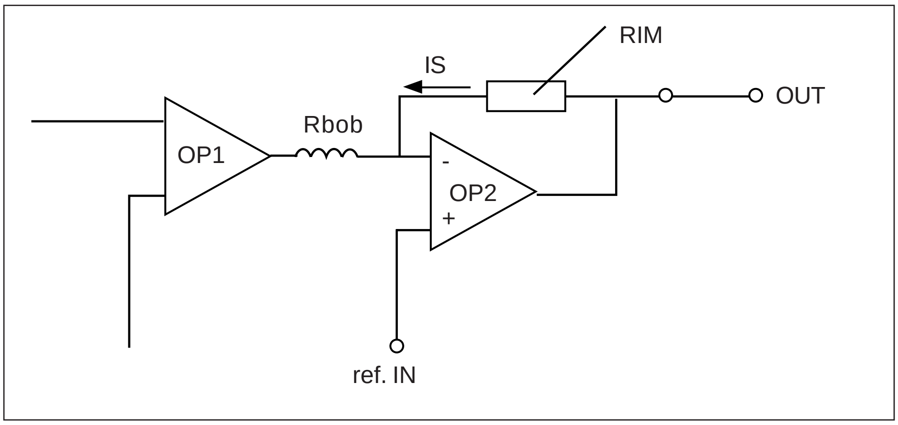


Fig. 9: Measuring range in Ref in mode. LTSR output schematic.

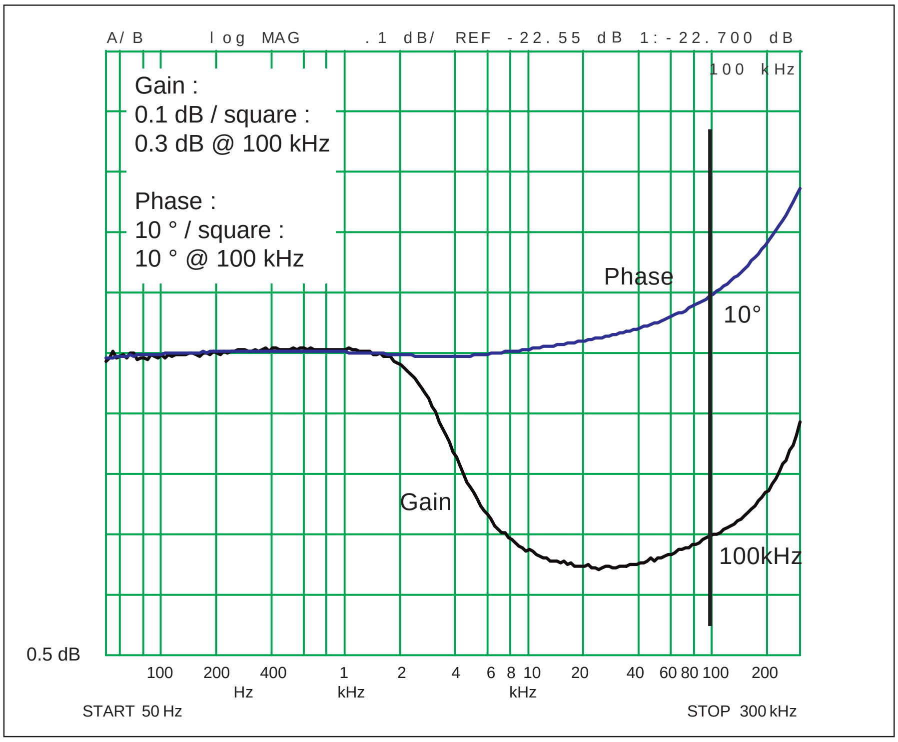


Fig. 10 & 11: Frequency and phase response of the LTSR 25-NP.

range. For example, if REF is set to 1.9 V, there is 0.6 V less available output range to measure negative primary current and, due to the architecture of the ASIC, also for positive primary current.

Let's look at an example with Ref in = 2.7 V for the LTSR 25-NP model:

- The positive measuring range is defined as follows: OP1 & OP2 (figure 9) saturate above 4.5 V and below 0.5 V.
  The voltage at the Rim connections is equal to: 4.5 V (max possible output) - V_{Refin} = 4.5 V - 2.7 V = 1.8 V.

  As $V_{Rim} = Rim \cdot I_S \rightarrow I_S = 36$ mA.
  with Rim = 50 Ω.

  The winding of the LTSR 25-NP has 2000 turns and is equal to 44 Ω (R_{bob}) at +25 °C then:
  $I_P = I_S \cdot 2000 = 72$ Apeak in positive side.

  To verify that OP1 is not saturated: OP1 output voltage = 2.7 V - $R_{bob} \cdot I_S$ = 1.116 V.
  1.116 V > 0.5 V = OP1 Saturation level, we can see that it will not be a problem to measure up to +72 Apeak.

- The negative measuring range is defined as follows:
  $V_{Rim} = V_{Ref\ in}$ -0,5 V(min possible output) = 2.7 V - 0.5 V = 2.2 V.
  As $V_{Rim} = Rim \cdot I_S \rightarrow I_S = 44$ mA.
  $I_P = I_S \cdot 2000 = -88$ Apeak in negative side.
  Again we check that OP1 is not saturated: OP1 output voltage = 2.7 V + $R_{bob} \cdot I_S$ = 4.636 V.

  4,636 V > 4,5 V = OP1 Saturation level, then it is not OK. The OP1 saturation limits its output voltage to 4.5 V. Then V_{bob} can't be higher than: 4.5 V - 2.7 V =1.8 V and $V_{bob} = R_{bob} \cdot I_S$ & I_P = Is x 2000 → I_P measurable in negative side = -81 APeak which leads to $V_{OUT} = 2.7\ V - V_{Rim}$ = 2.7 V - 50 • 81/2000 = 0.675 V > 0.5 V then OP2 is not saturated.

The same logic is also applicable with another V_{Refin} value.

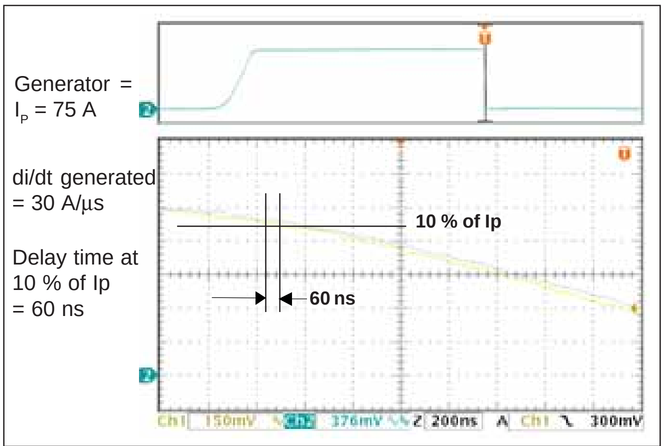


Fig. 12: Behaviour of the LTSR series at a current change.

Mechanically, there are also some changes due to the additional REF pin. The footprint has changed. And, the spacing between the secondary pins is 1.905 mm instead of 2.54 mm like the standard LTS.

The LTSR case remains the same as the LTS except its primary and secondary pins dimensionned for an inserting length of 3.5 mm.

Wide frequency bandwidth

The excellent coupling characteristics are also reflected in the bandwidth. The 0.3 dB limit is situated at approx. 100 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 (Fig. 10 & 11)

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 30 A/µs (Fig. 12), 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 optimised.

Excellent accuracy and temperature stability

The series LTSR 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 provided externally for the user, has a temperature stability of 50 ppm/K max (-10...+85 °C) and 100 ppm/K max (-40...-10 °C). The absolute accuracy of the reference is less important with the LTSR since, in most cases, either external circuitry or digital processing can manage it (Ref out mode).
(Similar cancellation can also happen for the initial output offset @I_P = 0)

Also in the case when the reference is provided externally to the transducer by the electronics of the user, the drift is managed by the processor as explained before. In this configuration (Ref in mode), you can provide between 1.9 to 2.7 V to the transducer reference, but this voltage is under processor control and then the offset is abolished, as its thermal drift.

The output voltage V_{OUT} reaches a max thermal stability of (for LTSR 25-NP into -10...+85 °C as operating temperature range @ I_P = 0):

- 37.5 ppm/K with regards to V_{Ref}, also valid from -40 to -10 °C
- 87.5 ppm/K with regards to 0 V, 137.5 ppm/K with -40 to -10 °C as operating temperature range.

87.5 ppm/K are made of the V_{out} drift vs V_{ref} (37.5 ppm/K) + the V_{ref} drift vs 0 V (50 ppm/K).
137.5 ppm/K due to the fact that V_{ref} drift is equal to 100 ppm/K into a -40 to -10 °C operating temperature range.
As explained previously, if the procesor allows the cancellation of the V_{ref} drift, V_{ref} offset and V_{OUT} initial offset @ I_P = 0, then you improve your accuracy. By adding up all tolerances in a temperature range from -10 °C to +85 °C for example the following accuracy table is obtained for the LTSR 25-NP (for ΔT = 60 °K in Ref out mode) (table 1).

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 V_{ref} in regards with I_{PN} (50 ppm/K Max) @ I_P = 0	±1.2 %
Temperature drift of V_{OUT}/V_{ref} in regards with I_{PN} (37.5 ppm/K Max) @ I_P = 0	±0.9 %
Total error	**±3.1 %**
Total error if Thermal drift of V_{ref} is cancelled	**±1.9 %**

Table 1: LTSR 25-NP accuracy

Main characteristics

Table 2 gives an overview of the main characteristics of the LTSR current transducers.

The power supply voltage is 0 to +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 be obtained. This is a great advantage for most applications. The LTSR 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 (in Ref out mode or external reference voltage in Ref in mode), which is exactly half of the supply rail voltage. The variation span of the amplified output signal is 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. LTSR 25-NP in Ref out mode).

The current transducers also meet the usual standards for Power Electronics Systems.

Primary nominal current I_{PN} of LTSR 6/15/25-NP	ARMS	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 %)
Output voltage @ I_P = 0 in Ref out mode	V	+2.5 ± 1 %
Reference voltage Ref out mode	V	+2.5 ± 1 %
Reference voltage Ref in mode	V	+1.9...+2.7
Thermal drift of internal reference voltage (Max,-10...+85 °C) @ I_P=0 (Max,-40...-10 °C) @ I_P=0	ppm/K ppm/K	50 100
Thermal drift of V_{OUT} @ I_P = 0 vs Ref (Max, -40...+85 °C)	ppm/K	150 - 64 - 37.5
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 50178/IEC 60950-1
Dimensions l x w x h	mm	9.3 x 22.2 x 24
Mass	g	10

Table 2: Technical data of the LTSR series

More flexibility in applications

The LTSR, due to its additional functionality fits in more demanding topologies than its predecessor.
In most applications the output of the transducer is connected to an ADC whose output is processed by a DSP or a microcontroller.

The LTSR was designed to be connected directly to a DSP supplied with 5 V, today's DSPs or ADCs are supplied with 3.3 V.
The internal reference of these 3.3 V DSPs or ADCs can go down to 1.8 V.
In this application if you have an internal reference in the DSP with external access you can supply the transducer's reference in with it.
With this architecture you can cancel reference temperature drift.

Alternatively, you can use the internal reference of the transducer to feed in the reference of an ADC (Please refer previously for Ref out current rating).

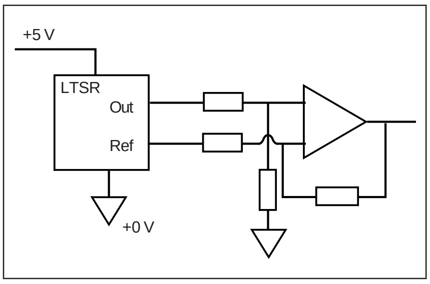


Fig. 13: LTSR in Diff-Amp Configuration.

There is also the possibility of connecting the reference pins of up to three transducers together, the resulting voltage reference would be a balance between each of the internal references.
This technique is also applicable in "Ref in mode".

Fig. 14, 15 & 16 are block diagrams of a system using three transducers with their REF pin connected together.

Fig. 13 shows a typical use of the Ref out and a differential amplifier to eliminate the output offset. In addition, the circuit zero referenced output for convenient bipolar signal processing.

Fig. 14 shows a typical application of the Ref out signal to provide a reference input to an analog to digital converter.

Fig. 16 demonstrates how the Ref in feature might be used to synchronize several transducers to the same reference level.

The resistor at the output of the follower amplifier in figure 16 is to avoid ringing at the amplifier output due to the loading by the 47 nF capacitor located internally on the Ref pin of the LTSR (Fig. 17).

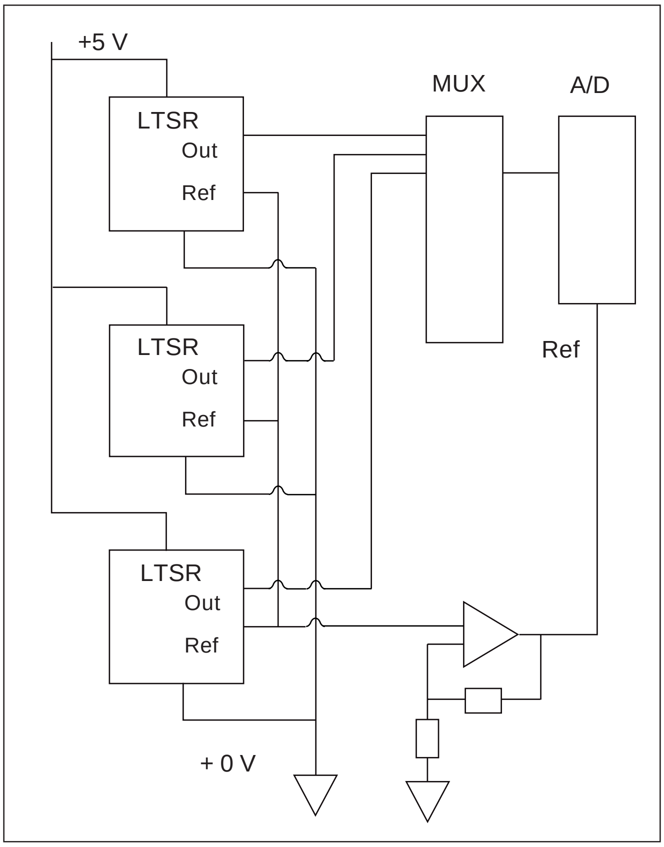


Fig. 14: LTSR in Refout configuration.

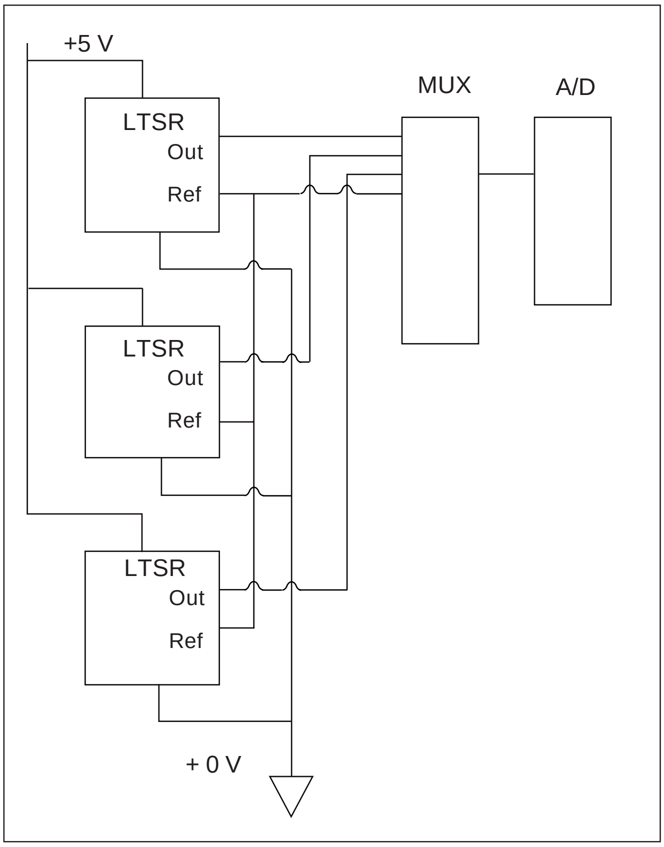


Fig. 15: LTSR with A/D processed Ref in.

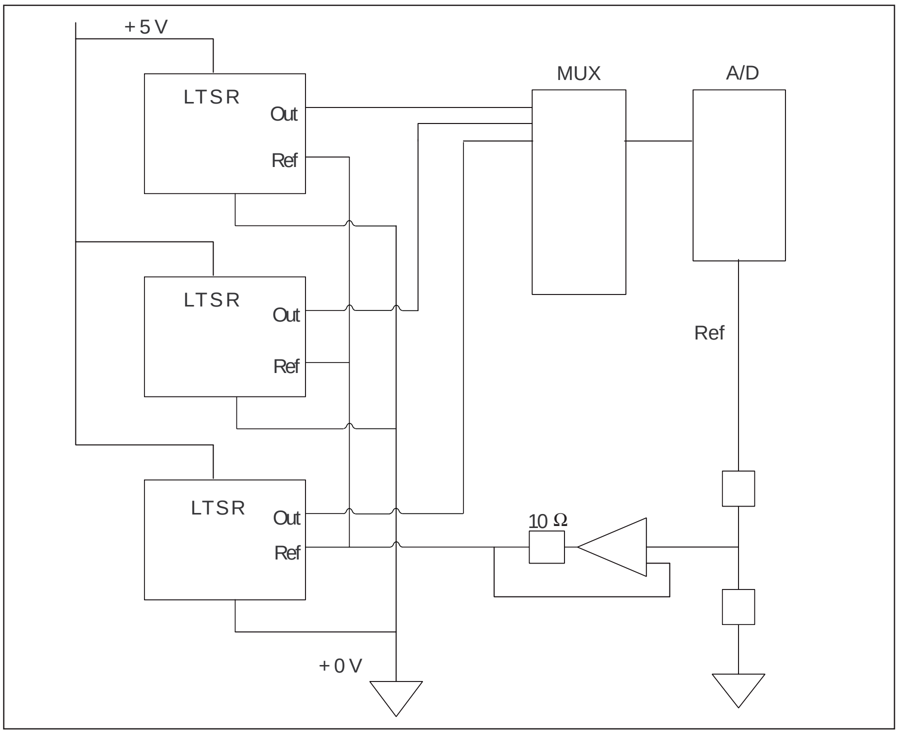


Fig. 16: LTSR in Ref in configuration.

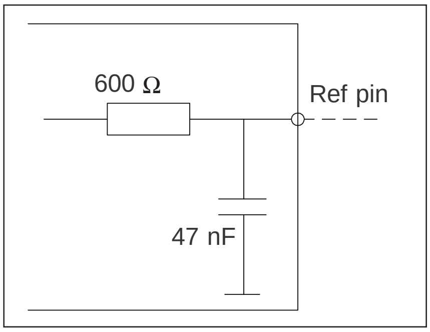


Fig. 17: REF pin of the LTSR

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. 18 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, but offering an accuracy which is 3 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 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.

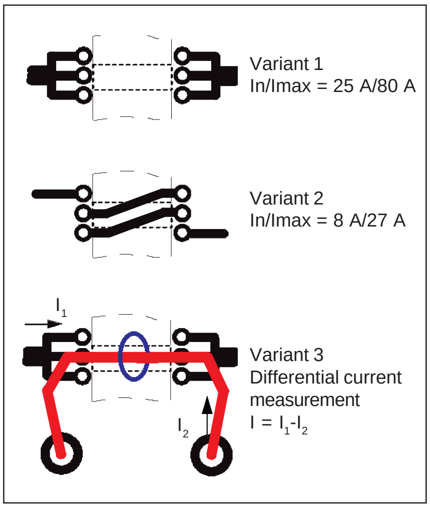


Fig. 18: The different possibilities for connecting the primary current circuit (e.g. LTSR 25-NP)

Standards

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.

During the design of the LTS and LTSR series, the regulations of the EN 50178 standard were taken into consideration.

All products comply with 3 kV AC-isolation test voltage, more than 1.5 kV partial discharge extinction voltage (@10 pC) 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 50178 standard) dependent on 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 application.

As an application example according to EN 50178 standard on the LTSR models:

Clearance distance

This is the minimum distance in the air between the primary and secondary potentials and in the LTSR case it is on the PCB
→ **Clearance distance: 6.27mm (fig. 19) (soldering pattern included)**

Let's assume the following:

- Single insulation
- Overvoltage category: OV3 or Category III (IEC 61010-1)
- Pollution degree: PD2
- U = 849 Vpeak → d = 5.5 mm = needed distance.
- U =1410 Vpeak → d = 8 mm = needed distance.

We choose the rated insulation voltage of 849 Vpeak as primary voltage (600 V_{RMS}). This is in accordance with IEC 61010-1 standard (table 3).

Creepage distance

This is the minimum distance creeping along the material between the primary and secondary potentials.
On the PCB → **Creepage distance: 6.27 mm**
On Housing → **Creepage distance: 15.35 mm** (fig. 20 + 21)
(d1 + d2 with d1 = 3.22 mm + 3.61 mm + 2 x 0.5 mm & d2 = 7.52 mm)
(3.61 mm due to the round shape).

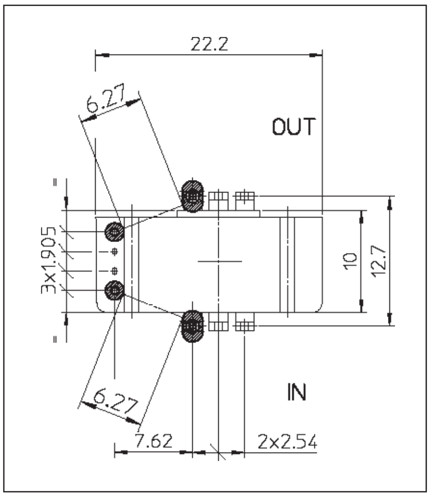


Fig. 19: Clearance distance

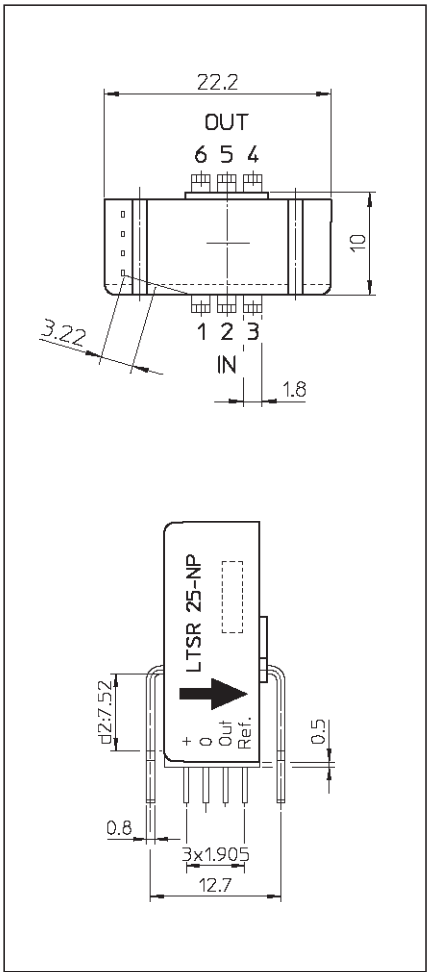


Fig. 20 + 21: Creepage distance

Power Supply	Transducer Insulation Requirement	Category
Ground connected	Single	CAT III 600 VRMS
No ground connection	Double	CAT III 300 VRMS

Table 3: IEC 61010-1 standard

Let's assume the following

- Single insulation
- Overvoltage category: OV3
- Pollution degree: PD2
- We want U_{RMS} = 320 V_{RMS}
- CTI = 175 (IIIa)
- Then d = 3.2 mm = needed distance for housing & d =1.6 mm = needed distance when mounted on PCB.

As creepage distance must be > or = to the Clearance distance, the LTSR clearance and creepage distances allow in this example a rated isolation voltage (for a single insulation requirement) of 320 VRMS with or without the use of a PCB.

According to EN 50178 and IEC 61010-1 Standards, hereafter is the working voltage in regards with the required insulation type and with the creepage distances found on the LTSR models (on PCB or on Housing):

Insulation type / Distances	Single	Double
PCB (d = 6.3 mm)	1250 VRMS	630 VRMS
Housing (d = 12.5 mm)	1250 VRMS	630 VRMS

Always according to EN 50178 and IEC 61010-1 Standards, taking into account the clearance and the creepage distances of the LTSR models (on PCB or Housing) with the previous conditions of use, we can then achieve for a single insulation level a working voltage of 600 VRMS and for a double insulation level a working voltage of 300 VRMS.

ESD-EMC compatibility

- Electrostatic discharge immunity test IEC 61000-4-2 (+ 6 kV Indirect Contact Discharges): Category B.
- Radiated electromagnetic field immunity test IEC 61000-4-3 (10 V/m AM @ 1 kHz, 80 % (80 MHz - 1 GHz)): Category A with deviation < 5 % of I_{pn}.
- Electrical fast transient burst immunity test IEC 61000-4-4 (± 2 kV): Category B.
- Immunity to conducted disturbances IEC 61000-4-6 (10 V AM @ 1 kHz, 80 % (150 kHz-80 MHz)): Category A with deviation < 10 % of I_{pn}.
- Power frequency magnetic field immunity test IEC 61000-4-8 (100 A/m (DC and AC 50 Hz)):
  Category A with deviation < 1 % of I_{pn} for LTSR 15 & 25-NP and < 1.5 % of I_{pn} for LTSR 6-NP.

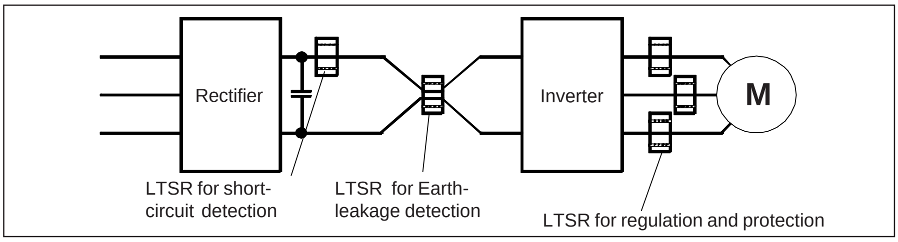


Fig. 22: Possibilities of electrically isolated current measurements using the LTSR series in an inverter

Practical examples

1. Electrically isolated current measurements on a converter

An LTSR typical application is the classic frequency inverter. Due to its excellent accuracy and immunity to dv/dt noise, it is ideally suited for servo-drive applications as well.

Fig. 22 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.

2. General current monitoring and regulation

The application possibilities are many: Where currents have to be precisely detected, regulated and monitored, the LTSR 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. Here, the LTSR 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 4 shows all advantages and applications of the LTSR series.

Advantages of the LTSR series

- Using a unipolar power supply 0/+5 V, positive and negative currents can be measured.
- Access to internal reference voltage: Ref out mode
- The possibility to feed the transducer reference from external supply: Ref in mode
- High temperature stability and low drift.
- MultiRange concept allows the same device to cover a wide span of primary currents
- 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-friendly due to simple mounting.
- Cost-effective solution.

Applications

The LTSR 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, fork lift trucks and general applications of current monitoring.

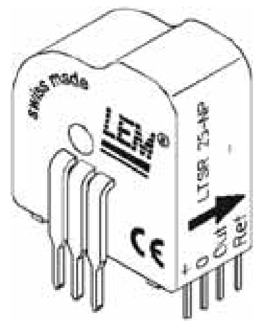
Table 4: Advantages and applications of the LTSR current transducer in an overview

Multi-Range Current Transducer

I_{PN} = 6 - 15 - 25 A

LTSR 6-NP, LTSR 15-NP, LTSR 25-NP

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 [1]	At
V_{OUT}	Analog output voltage @ I_P	2.5 ± (0.625·I_P/I_{PN})	V
	$I_P = 0$	2.5 [2]	V
V_{REF}	Voltage reference (internal reference), refout mode	2.5 [3]	V
	Voltage reference (external reference), Ref in mode	1.9 .. 2.7 [4]	V
N_S	Number of secondary turns (± 0.1 %)	2000	
R_L	Load resistance	≥ 2	kΩ
C_L	Max. capacitive loading	500	pF
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	28+I_S[5]+(V_{OUT}/R_L)	mA
V_d	RMS voltage for AC isolation test, 50/60 Hz, 1 mn	3	kV
V_e	RMS voltage for partial discharge extinction @ 10 pC	> 1.5	kV
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	%
		Max.	
TCV_{OUT}	Thermal drift of V_{OUT}/V_{REF} @ $I_P = 0$		
	- 40°C .. +85°C	150/64/37.5	ppm/K
$TC\varepsilon_G$	Thermal drift of the gain - 40°C .. +85°C	50 [6]	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
TCV_{REF}	Thermal drift of internal V_{REF} @ $I_P = 0$		
	- 10°C .. + 85°C	50	ppm/K
	- 40°C .. - 10°C	100	ppm/K
t_{ra}	Reaction time @ 10 % of I_{PN}	< 100	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

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
- Access to the internal voltage reference
- Possibility to feed the transducer reference from external supply.

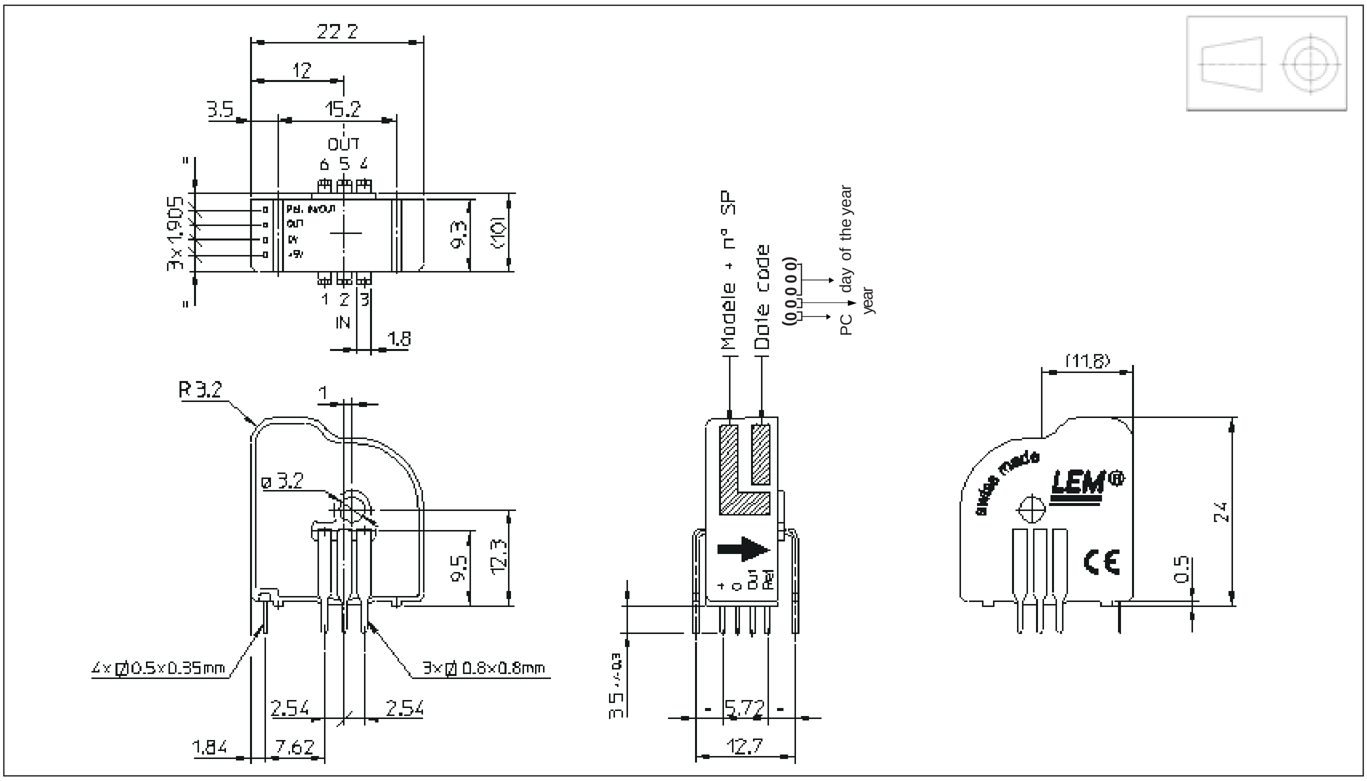
Advantages

- 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.

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



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

* V_{REF} = 2.5 V ± 25 mV in Refout mode, V_{REF} = External reference (1.9 .. 2.7 V ± 25 mV) in Ref in mode

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 4 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.
- The transducer installation in the application must respect the installations rules defined by the IEC 61010-1 Standard.
- The indicated performances are reached by using the primary conductor integrated to the case.

LTSR 6, LTSR 15, LTSR 25-NP

General data

T_A	Ambient operating temperature	- 40 .. + 85	°C
T_S	Ambient storage temperature	- 40 .. + 100	°C
	Insulating material group	III a	
m	Mass	10	g
	Standards [7)]	EN 50178 (97.10.01) IEC 60950-1 (01.10.26)	

Notes:

1) Only in Ref out mode or with external REF less than 2.525 V and greater than 2.475 V. For external REF, out of these limits, see leaflet.

2) $\mathbf{V}_{OUT}$ is linked to $\mathbf{V}_{REF}$, by conception the difference between these two nodes is maximum ± 25 mV, 2.475 V < $\mathbf{V}_{OUT}$ < 2.525 V.

3) In Refout mode at $\mathbf{T}_A$ = 25°C, 2.475 V < $\mathbf{V}_{REF}$ < 2.525 V.
The minimal impedance loading the ref pin should be > 220 kΩ.
Internal impedance = 600 Ω.
For most applications, you need to buffer this output to feed it into an ADC for example.

4) To overdrive the REF (1.9 V .. 2.7 V), max. ± 1 mA is needed.

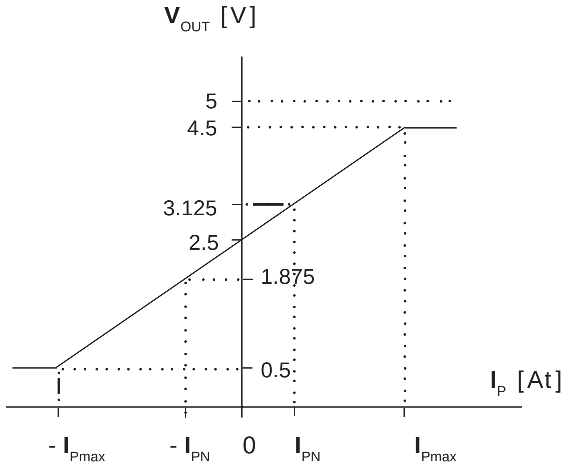
5) Please see hereafter the operation principle.

6) Only due to $\mathbf{TCR}_{IM}$.

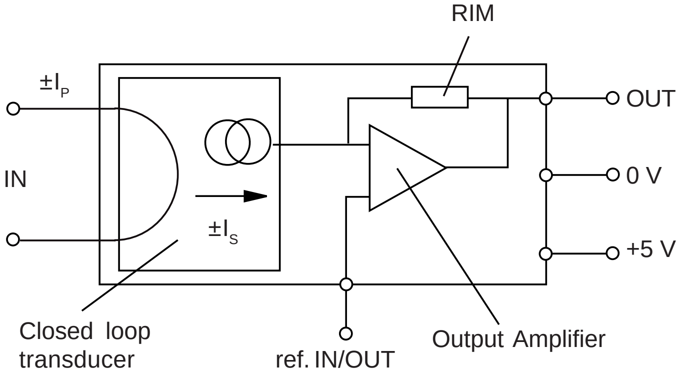
7) Specifications according to IEC 1000-4-8 not adherent to in DC, error according to two axes 1.5 % instead of 1 % for the LTSR 6-NP.

Output Voltage - Primary Current

$\mathbf{V}_{REF}$ = 2.5 V (in this example)



Operation principle



$\mathbf{I}_S = \mathbf{I}_P / \mathbf{N}_S$ = ± 3 mA @ $\mathbf{I}_P$ = ± 6 At for LTSR 6-NP
$\mathbf{I}_S = \mathbf{I}_P / \mathbf{N}_S$ = ± 7.5 mA @ $\mathbf{I}_P$ = ± 15 At for LTSR 15-NP
$\mathbf{I}_S = \mathbf{I}_P / \mathbf{N}_S$ = ± 12.5 mA @ $\mathbf{I}_P$ = ± 25 At for LTSR 25-NP

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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