# AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY

**HSTDR 300-000, HSTDR 400-000, HSTDR 600-000, HSTDR 900-000, HSTDR 1000-000, HSTDR 1200-000, HSTDR 1200/SP1-000, HSTDR 1300-000, HSTDR 1500-000**

## Introduction

The HSTDR-000 family is a transducer for DC, AC, or pulsed currents measurement in high power and low voltage automotive applications. It offers a galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).
The HSTDR-000 family gives you a choice of having different current measuring ranges in the same housing (from ±300 A up to ±1500 A).

## Features

- Open Loop transducer using the Hall effect sensor
- High insulation level
- Unipolar +5 V DC power supply
- Primary current measuring range up to ±1500 A
- Operating temperature range: −40 °C < $T$ < +125 °C
- Output voltage: fully ratio-metric (in sensitivity and offset).

## Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- High frequency bandwidth
- No insertion losses
- Very fast delay time.

## Automotive applications

- Starter Generators
- Inverters
- HEV applications
- EV applications
- DC / DC converters
- DC link.

## Principle of HSTDR-000 family

The open loop transducers uses a Hall effect integrated circuit. The magnetic flux density $B$, contributing to the rise of the Hall voltage, is generated by the primary current $I_P$ to be measured.
The current to be measured $I_P$ is supplied by a current source i.e. battery or generator (Figure 1).
Within the linear region of the hysteresis cycle, $B$ is proportional to:

$$B\,(I_P) = a \times I_P$$

The Hall voltage is thus expressed by:

$$U_{Hall} = (c_{Hall} / d) \times I_{Hall} \times a \times I_P$$

Except for $I_P$, all terms of this equation are constant.
Therefore:

$$U_{Hall} = b \times I_P$$

| | |
|---|---|
| $a$ | constant |
| $b$ | constant |
| $c_{Hall}$ | Hall coefficient |
| $d$ | thickness of the Hall plate |
| $I_{Hall}$ | current across the Hall plates |

The measurement signal $U_{Hall}$ amplified to supply the user output voltage or current.

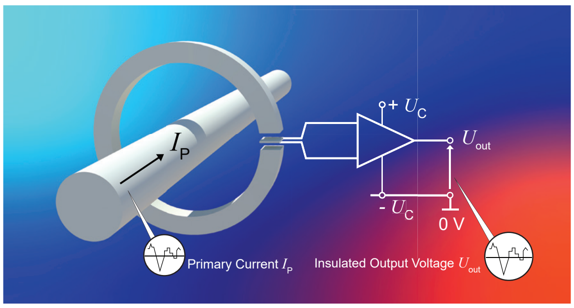
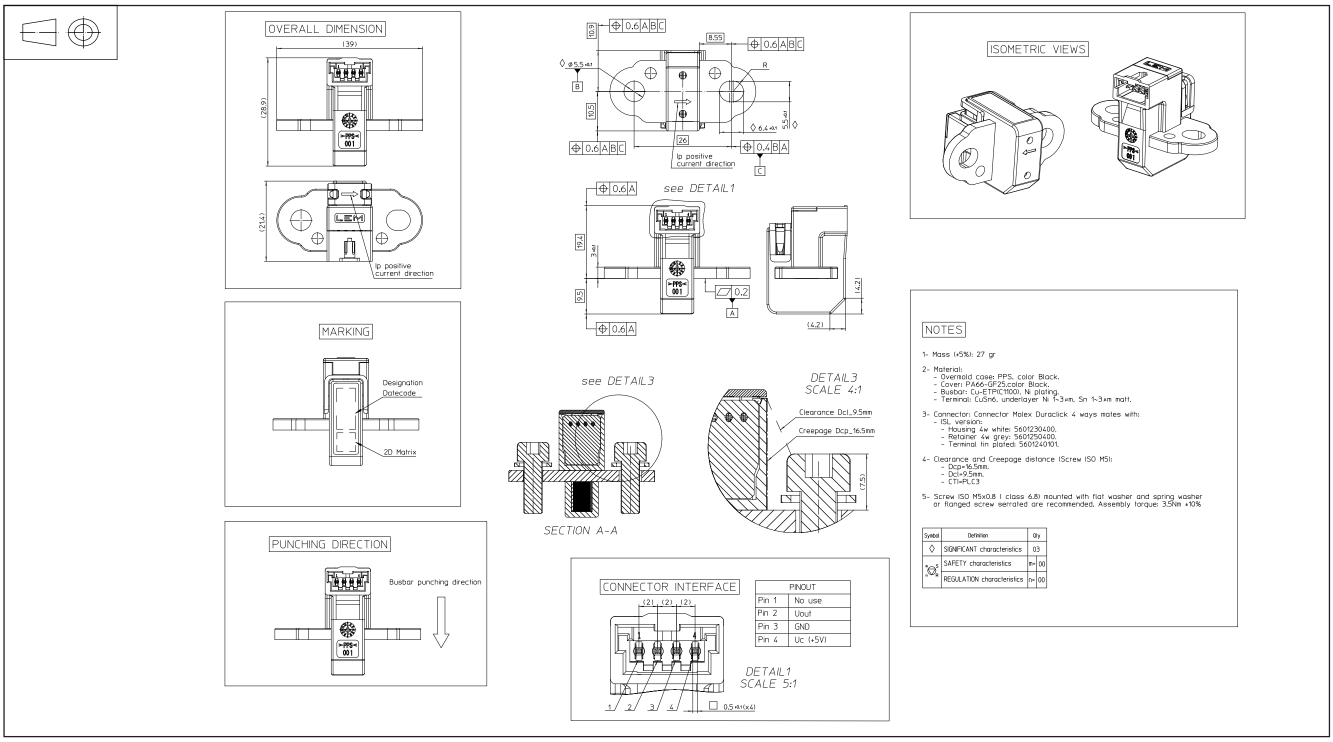



Fig. 1: Principle of the open loop transducer.

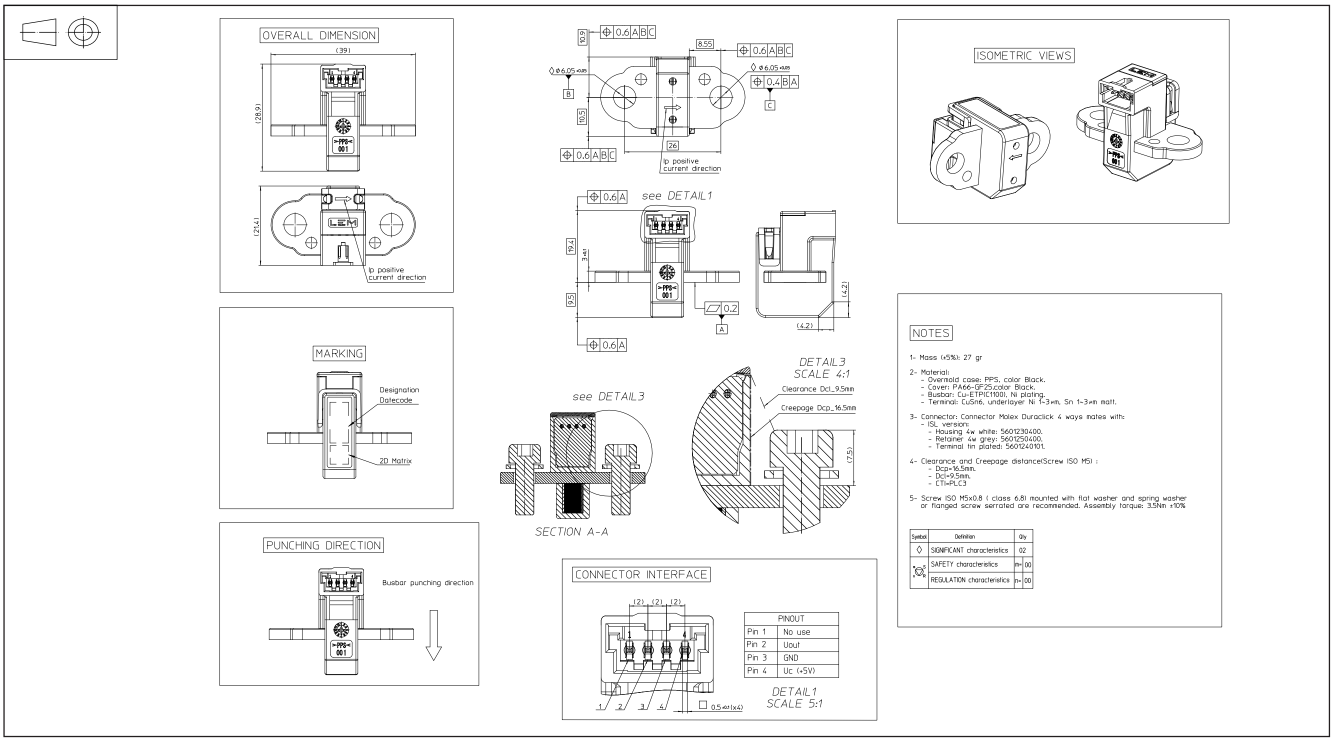
## Dimensions (in mm)

**HSTDR 300-000, HSTDR 400-000, HSTDR 600-000, HSTDR 900-000, HSTDR 1000-000, HSTDR 1200-000, HSTDR 1300-000, HSTDR 1500-000**




## Dimensions (in mm)

**HSTDR 1200/SP1-000**




## Mechanical characteristics

Refer to Outline Drawing.

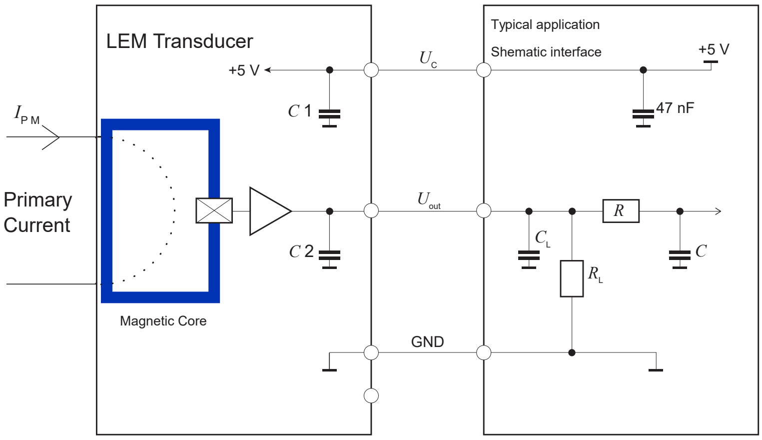
## Mounting recommendation

Assembly refer to Outline Drawing.

## Remark

- $U_{out}$ > $U_O$ when $I_P$ flows in the positive direction (see arrow on drawing).

## Electronic recommendation




$R_L$ > 10 kΩ optional resistor for signal line diagnostic (optional)
$C_L$ < 2.2 nF EMC protection (optional)
RC: low pass filter (optional)


LEM reserves the right to carry out modifications on its transducers, in order to improve them.
LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

## Absolute ratings (not operating)

| Parameter | Symbol | Unit | Specification Min | Typical | Max | Conditions |
|---|---|---|---|---|---|---|
| Maximum supply voltage | $U_{C\ max}$ | V | 0 | | 8 | Continuous, not operating |
| | | | | | 6.5 | Exceeding this voltage may temporarily reconfigure the circuit until $U_C$ comes back to 5 V |
| Ambient storage temperature | $T_{A\ st}$ | °C | −40 | | 125 | |
| Electrostatic discharge voltage (HBM - Human Body Model) | $U_{ESD\ HBM}$ | kV | | | 8 | |
| RMS voltage for AC insulation test | $U_d$ | kV | | | 4.7 | 50 Hz, 1 min, IEC 60664 part1 |
| Creepage distance | $d_{Cp}$ | mm | | 16.5 | | |
| Clearance | $d_{Cl}$ | mm | | 9.5 | | |
| Comparative tracking index | $CTI$ | - | | PLC3 | | |
| Maximum output current | $I_{out\ max}$ | mA | −10 | | 10 | |
| Maximum output voltage | $U_{out\ max}$ | V | −0.5 | | $U_C$ + 0.5 | |
| Insulation resistance | $R_{INS}$ | MΩ | 500 | | | 1000 V DC |

## Operating characteristics in nominal range ($I_{P\ N}$)

| Parameter | Symbol | Unit | Specification Min | Typical | Max | Conditions |
|---|---|---|---|---|---|---|
| **Electrical Data** | | | | | | |
| Supply voltage 1) | $U_C$ | V | 4.75 | 5 | 5.25 | |
| Ambient operating temperature 2) | $T_A$ | °C | −40 | | 125 | |
| Load capacitance | $C_L$ | nF | | | 2.2 | |
| Output voltage (Analog) | $U_{out}$ | V | | $U_{out} = (U_C/5) \times (U_O + S \times I_P)$ | | |
| Offset voltage | $U_O$ | V | | 2.5 | | @ $U_C$ = 5 V |
| Current consumption | $I_C$ | mA | | 15 | | @ $U_C$ = 5 V, @ $T_A$ = 25 °C |
| Load resistance | $R_L$ | KΩ | 10 | | | |
| Output internal resistance | $R_{out}$ | Ω | | | 10 | DC to 1 KHz |
| **Performance Data** | | | | | | |
| Ratiometricity error | $\varepsilon_r$ | % | | ±0.3 | | @ $T_A$ = 25 °C |
| Sensitivity error | $\varepsilon_S$ | % | | ±1 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V |
| Electrical offset voltage | $U_{O\ E}$ | mV | | ±4 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V |
| Magnetic offset voltage | $U_{O\ M}$ | mV | | ±2 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V |
| Average temperature coefficient of $U_{O\ E}$ | $TCU_{O\ E\ AV}$ | mV/°C | −0.08 | ±0.04 | 0.08 | @ −40 °C < $T_A$ < 125 °C |
| Average temperature coefficient of $S$ | $TCS_{AV}$ | %/°C | −0.03 | ±0.01 | 0.03 | @ −40 °C < $T_A$ < 125 °C |
| Linearity error | $\varepsilon_L$ | % $I_{P\ M}$ | | ±1 | | @ $U_C$ = 5 V, @ $T_A$ = 25 °C, @ $I_P$ = $I_{P\ M}$ |
| Delay time to 90 % of the final output value for $I_{P\ N}$ step | $t_{D\ 90}$ | µs | | 2 | 6 | d$i$/d$t$ = 100 A /µs |
| Frequency bandwidth 3) | $BW$ | kHz | 40 | | | @ −3 dB |
| Peak-to-peak noise voltage | $U_{no\ pp}$ | mV | | 9 | | @ DC to 1 MHz for HSTDR 1500-000 |
| Peak-to-peak noise voltage | $U_{no\ pp}$ | mV | | 22 | | @ DC to 1 MHz for HSTDR 300-000 |
| Phase shift | $\Delta\varphi$ | ° | −4 | | | @ 1 kHz |

Notes:
1) The output voltage $U_{out}$ is fully ratiometric. The offset and sensitivity are dependent on the supply voltage $U_C$ relative to the following formula:

$$I_P = \left(\frac{5}{U_C} \times U_{out} - U_O\right) \times \frac{1}{S} \text{ with } S \text{ in (V/A)}$$

2) Absolute maximum ambient operating temperature (include busbar): +150 °C
3) Primary current frequencies must be limited in order to avoid excessive heating of the sensor higher than 125 °C.







LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

## HSTDR 300-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −300 | | 300 | |
| Sensitivity | $S$ | mV/A | | 6.67 | | @ $U_C$ = 5 V |

## HSTDR 400-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −400 | | 400 | |
| Sensitivity | $S$ | mV/A | | 5 | | @ $U_C$ = 5 V |

## HSTDR 600-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −600 | | 600 | |
| Sensitivity | $S$ | mV/A | | 3.33 | | @ $U_C$ = 5 V |

## HSTDR 900-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −900 | | 900 | |
| Sensitivity | $S$ | mV/A | | 2.22 | | @ $U_C$ = 5 V |

## HSTDR 1000-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1000 | | 1000 | |
| Sensitivity | $S$ | mV/A | | 2 | | @ $U_C$ = 5 V |

## HSTDR 1200-000, HSTDR 1200/SP1-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1200 | | 1200 | |
| Sensitivity | $S$ | mV/A | | 1.67 | | @ $U_C$ = 5 V |

## HSTDR 1300-000

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1300 | | 1300 | |
| Sensitivity | $S$ | mV/A | | 1.54 | | @ $U_C$ = 5 V |

## HSTDR 1500-000

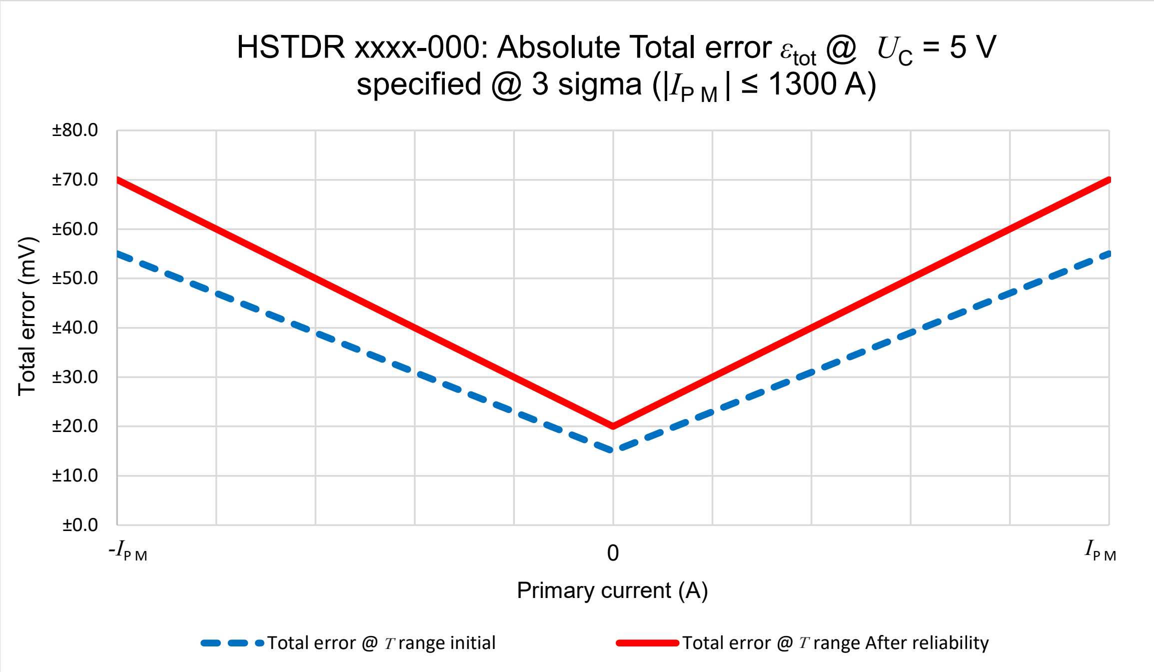
| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Electrical Data | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1500 | | 1500 | |
| Sensitivity | $S$ | mV/A | | 1.33 | | @ $U_C$ = 5 V |





LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

## Total error




| Primary current | Total error<br>$T$ = 25 °C,<br>$U_c$ = 5 V initial | | Total error<br>−40 °C ≤ $T$ ≤ 125 °C,<br>$U_c$ = 5 V initial | | Total error<br>$T$ = 25 °C,<br>$U_c$ = 5 V After reliability | | Total error<br>−40 °C ≤ $T$ ≤ 125 °C,<br>$U_c$ = 5 V After reliability | |
|---|---|---|---|---|---|---|---|---|
| (A) | (mV) | (%) | (mV) | (%) | (mV) | (%) | (mV) | (%) |
| $-I_{PM} \geq -1300$ | ±40 | ±2 % | ±55 | ±2.75 % | ±65 | ±3.25 % | ±70 | ±3.5 % |
| 0 | ±10 | ±0.5 % | ±15 | ±0.75 % | ±15 | ±0.75 % | ±20 | ±1 % |
| $I_{PM} \leq 1300$ | ±40 | ±2 % | ±55 | ±2.75 % | ±65 | ±3.25 % | ±70 | ±3.5 % |
| $-1500 \leq -I_{PM} < -1300$ | ±55 | ±2.75 % | ±70 | ±3.5 % | ±65 | ±3.25 % | ±70 | ±3.5 % |
| $1500 \geq I_{PM} > 1300$ | ±55 | ±2.75 % | ±70 | ±3.5 % | ±65 | ±3.25 % | ±70 | ±3.5 % |

## Remark

Specific application, please refer to LEM document_'Application Note N°ANE230327' available on our Web site:
https://www.lem.com/sites/default/files/marketing/hstdr__hsndr__ham_application_note_v0.pdf

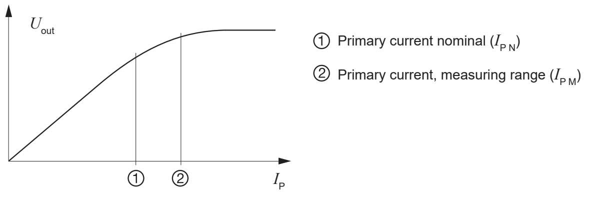




LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

## PERFORMANCES PARAMETERS DEFINITIONS

### Primary current definition:




### Definition of typical, minimum and maximum values:

Minimum and maximum values for specified limiting and safety conditions have to be understood as such as values shown in "typical" graphs. On the other hand, measured values are part of a statistical distribution that can be specified by an interval with upper and lower limits and a probability for measured values to lie within this interval. Unless otherwise stated (e.g. "100 % tested"), the LEM definition for such intervals designated with "min" and "max" is that the probability for values of samples to lie in this interval is 99.73 %. For a normal (Gaussian) distribution, this corresponds to an interval between −3 sigma and +3 sigma. If "typical" values are not obviously mean or average values, those values are defined to delimit intervals with a probability of 68.27 %, corresponding to an interval between −sigma and +sigma for a normal distribution. Typical, minimum and maximum values are determined during the initial characterization of a product.

### Output noise voltage:

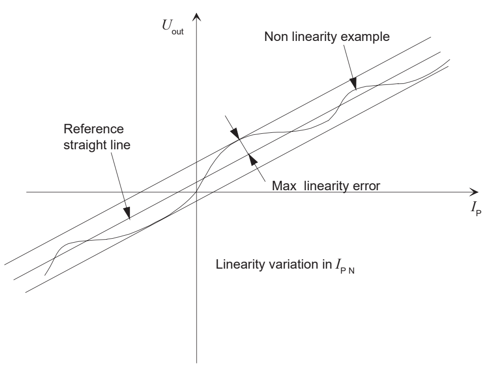
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

### Magnetic offset:

The magnetic offset is the consequence of an any current on the primary side. It's defined after a stated excursion of primary current.

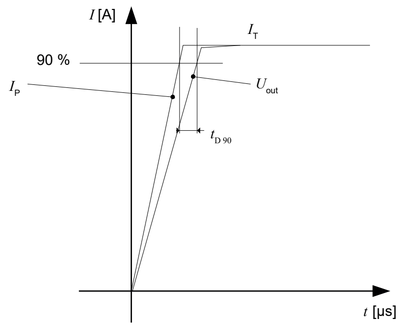
### Linearity:

The maximum positive or negative discrepancy with a reference straight line $U_{out} = f(I_P)$.
Unit: linearity (%) expressed with full scale of $I_{P N}$.




### Response time (delay time) $t_{D 90}$:

The time between the primary current signal ($I_{P N}$) and the output signal reach at 90 % of its final value.




### Sensitivity:

The transducer's sensitivity $S$ is the slope of the straight line $U_{out} = f(I_P)$, it must establish the relation:

$$U_{out}(I_P) = U_C / 5 \, (S \times I_P + U_O)$$

### Offset with temperature:

The error of the offset in the operating temperature is the variation of the offset in the temperature considered with the initial offset at 25 °C.

The offset variation $I_{O\,T}$ is a maximum variation the offset in the temperature range:

$$I_{O\,T} = I_{O\,E}\,\text{max} - I_{O\,E}\,\text{min}$$

The offset drift $TCI_{O\,E\,AV}$ is the $I_{O\,T}$ value divided by the temperature range.

### Sensitivity with temperature:

The error of the sensitivity in the operating temperature is the relative variation of sensitivity with the temperature considered with the initial offset at 25 °C.

The sensitivity variation $S_T$ is the maximum variation (in ppm or %) of the sensitivity in the temperature range: $S_T$ = (Sensitivity max − Sensitivity min) / Sensitivity at 25 °C.

The sensitivity drift $TCS_{AV}$ is the $S_T$ value divided by the temperature range. Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

### Offset voltage @ $I_P$ = 0 A:

The offset voltage is the output voltage when the primary current is zero. The ideal value of $U_O$ is $U_C / 2$. So, the difference of $U_O - U_C / 2$ is called the total offset voltage error. This offset error can be attributed to the electrical offset (due to the resolution of the ASIC quiescent voltage trimming), the magnetic offset, the thermal drift and the thermal hysteresis. Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

### Environmental test specifications:

Refer to LEM GROUP test plan laboratory CO.11.11.515.0 with "Tracking_Test Plan_Auto" sheet.





LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

## Validation test specifications

| Name | Standard | Condition |
|---|---|---|
| **ELECTRICAL TESTS** | | |
| Frequency bandwidth | LEM 98.20.00.538.0 | 30 Hz to 100 kHz; At 20 A peak ;<br>≥ 40 kHz @ −3 dB |
| Phase delay | LEM 98.20.00.538.0 | Power supply 5 V, $I_P$ = 0 A 30 Hz to 100 kHz;<br>At 20 A peak |
| Output voltage Noise (peak-to-peak) | LEM 98.20.00.575.0 | Sweep from DC to 1 MHz |
| Delay time ; d$i$/d$t$ | LEM 98.20.00.545.0 | 100 A/µs ; $t_{D\ 90}$ of $I_{P\ N}$ ≤ 6 µs |
| d$u$/d$t$ | LEM 98.20.00.545.0 | Slope: 5 kV/µs $U$ = 1000 V |
| **ENVIRONMENTAL TESTS** | | |
| Ageing 85 °C /85 % $RH$ | JESD 22-A101<br>(03/2009) | 85 °C/85 % $RH$; Duration = 1000 h; Power supply 5 V ;<br>primary current 0 A; Monitoring output 1 time/hr |
| Low temperature operating endurance | ISO 16750-4 § 5.1.1.2<br>(04/2010) | −40 °C, 24 h; Power supply 5 V<br>Monitoring: 2 times/hr |
| High temperature operating endurance | ISO 16750-4 § 5.1.2.2<br>(04/2010) | Temperature 125 °C; 96 h; power supply 5 V<br>Monitoring 2 times/hr |
| High temperature storage | AQG 324 (2019) § 9.4 | $T$ = 125 °C; Duration = 1000 h; $U_C$ = no powersupply ( unconnected) |
| Low temperature storage | ISO 16750-4 5.1.1.1(2006) | $T$ = −40 °C; Duration = 1000 h; $U_C$ = no powersupply ( unconnected) |
| Humidity heat, cyclic test: Test 2 Composite temperature/humidity cyclic test | ISO 16750-4 § 5.6.2.3<br>(04/2010) | Temperature range −10 °C/ +65 °C, 93 % $RH$<br>Duration = 240 h (10 cycles) |
| Thermal shock | ISO 16750-4 § 5.3.2<br>(04/2010) | Temperature range −40 °C& 125 °C, 300 cycles;<br>40 min/40 min, no power supply |
| Sinus Vibration | ISO 16750-3 § 4.1.2.2.2.2<br>(12/2012) | Monitoring $U_C$ and $U_{out}$ is mandatory,<br>Temperature −40/125 °C, 22 H/axis, 100 Hz to 440 Hz<br>Sweep: ≤ 0.5 oct/min |
| Random Vibration | ISO 16750-3 § 4.1.2.2.2.3<br>(12/2012) | Monitoring $U_C$ and $U_{out}$ is mandatory, Temperature −40/125 °C, 22 H/axis, 10 to 2000 Hz 10 G (RMS) |
| Mechanical Shocks | ISO 16750-3 § 4.2.2<br>(12/2012) | Operating mode: 3.2<br>Pulse shape: half sine, 50 G, 6 ms<br>10 shocks per direction (total 60) |
| Free Fall | ISO 16750-3 § 4.3<br>(12/2012) | 3 pcs, Falls/DUT: 2 times, Height = 1 m<br>3 axes, 2 directions by axis,<br>Operating mode: 1.1 |
| Cross section checking on PCBA | IPC-A-610G: 2017<br>Class 3W | IPC-TM-650 2.1.1F:2015 |
| Cross section checking on solderless connections | GB/T 18290.5-2015 | IPC-TM-650 2.1.1F:2015 |
| Whisker checking on PCBA | Refer to JESD201-A<br>(04/2010) | Refer to JESD22-A121A (04/2010)<br>Class 2 |
| **INSULATION TESTS** | | |
| Dielectric withstand voltage | ISO 16750-2 § 4.11<br>(11/2012) | 4.7 kV test voltage, time = 60 s, No dielectric breakdown, no flash-over, functional after test |
| Insulation test | ISO 16750-2 § 4.12<br>(11/2012) | 1000 V DC, time = 60 s, $R_{INS}$ ≥ 500 MΩ Minimum |

| EMC TESTS | | |
|---|---|---|
| Immunity to Electrostatic Discharges (Handling of devices) | ISO 10605 (07/2008) | Discharge module: 150 pF/2000 Ω<br>Contact discharges: ±4.6 kV, Air discharges: ±8 kV<br>$U_C$ = NO power supply, Criteria B |
| Immunity to Radiated disturbances (ALSE) | ISO 11452-2 (2019) | Power supply: 5 V<br>$f$ = 400 MHz to 1 GHz; Level = 100 V/m (CW, AM 80 %)<br>$f$ = 0.8 GHz to 2 GHz; Level = 70 V/m (CW, PM PRR = 217 Hz<br>$f$ = 1 GHz to 2 GHz; Level = 70 V/m (CW)<br>Criteria A acceptance @ 5 % of 2 V |
| Immunity to Conducted disturbances (BCI) | ISO 11452-4 (12/2011) | Level = see Annex E Fig. & Table E.1 (Test Level II)<br>$f$ = 1 MHz to 400 MHz<br>Criteria A acceptance @ 5 % of 2 V |
| Emission Radiated (ALSE) | CISPR 25 §6.5 (2016) | Table 7, Class 5 by default<br>$f$ = 150 kHz to 2.5 GHz<br>Load simulator will be provided (R&D) |



LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com