AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY

HSTDR 1000/SP1-000

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).

Special Feature

- Primary current measuring range: 1000 A
- The diameter on two busbar holes : 6.05 mm
- 2D matrix is dedicated for customer.

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

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.
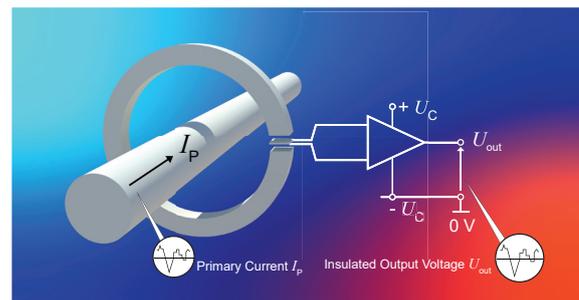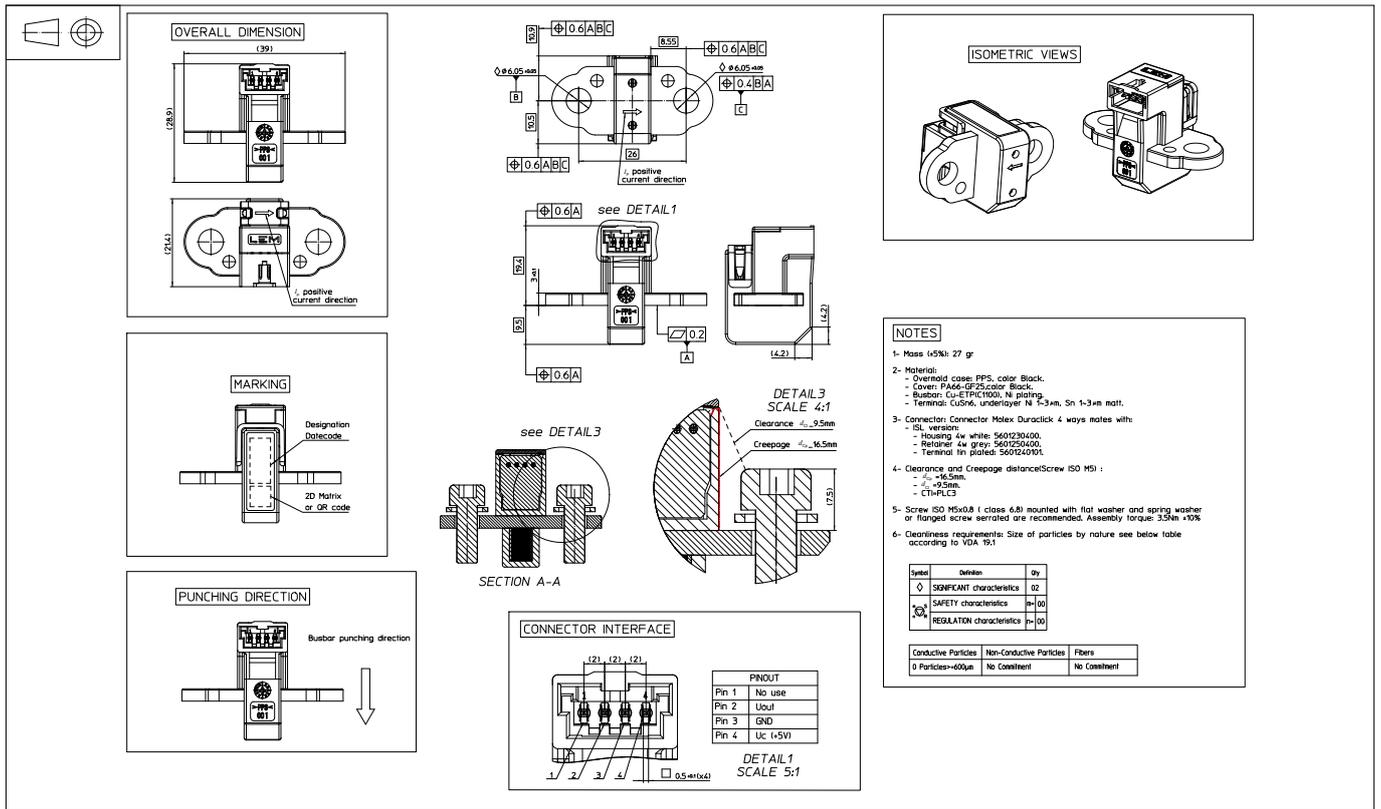

Fig. 1: Principle of the open loop transducer.

Dimensions (in mm)
HSTDR 1000/SP1-000

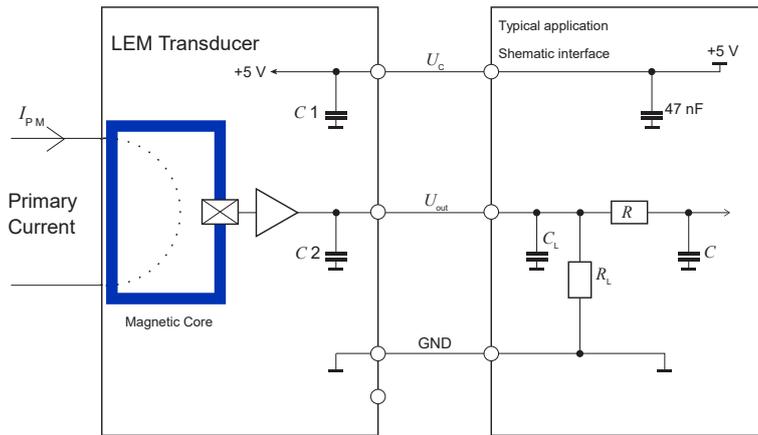## Mechanical characteristics

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).

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

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.

Absolute ratings (not operating)

Parameter	Symbol	Unit	Specification Min	Specification Typical	Specification 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	Specification Typical	Specification 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	ε_r	%		±0.3		@ T_A = 25 °C
Sensitivity error	ε_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	ε_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	di/dt = 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.

HSTDR 1000/SP1-000

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

Total error

HSTDR 1000/SP1-000: Absolute Total error ε_{tot} @ U_c = 5 V
specified @ 3 sigma
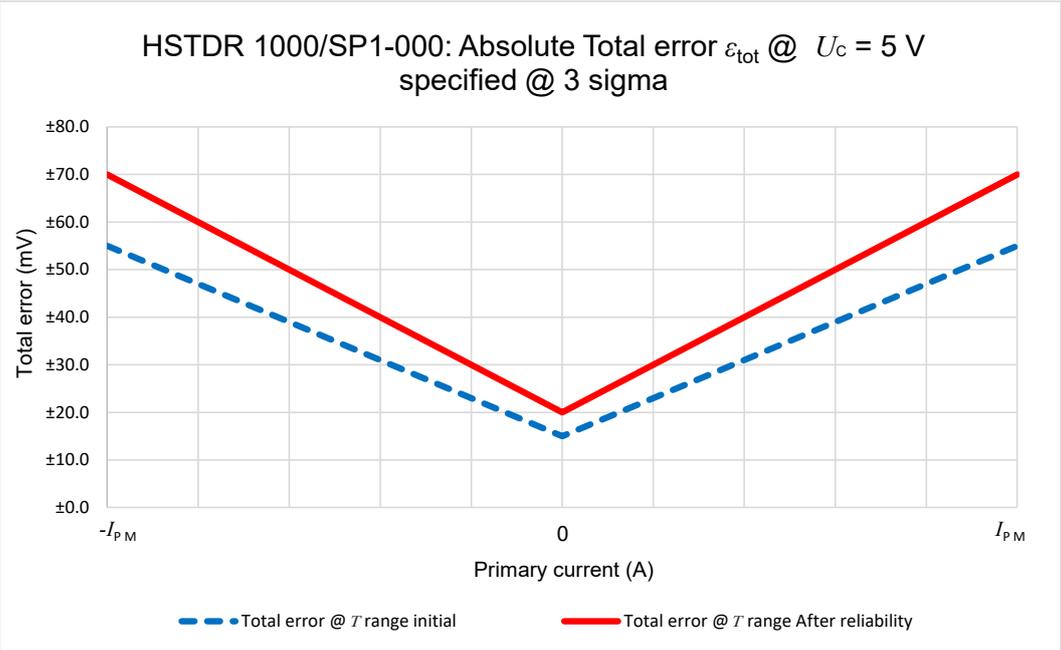
Primary current	Total error T = 25 °C, U_c = 5 V initial		Total error −40 °C ≤ T ≤ 125 °C, U_c = 5 V initial		Total error T = 25 °C, U_c = 5 V After reliability		Total error −40 °C ≤ T ≤ 125 °C, U_c = 5 V After reliability	
(A)	(mV)	(%)	(mV)	(%)	(mV)	(%)	(mV)	(%)
−1000	±40	±2 %	±55	±2.75 %	±65	±3.25 %	±70	±3.5 %
0	±10	±0.5 %	±15	±0.75 %	±15	±0.75 %	±20	±1 %
1000	±40	±2 %	±55	±2.75 %	±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 reserves the right to carry out modifications on its transducers,
in order to improve them.

PERFORMANCES PARAMETERS DEFINITIONS

Primary current definition:

① Primary current nominal ($I_{P\,N}$)

② Primary current, measuring range ($I_{P\,M}$)
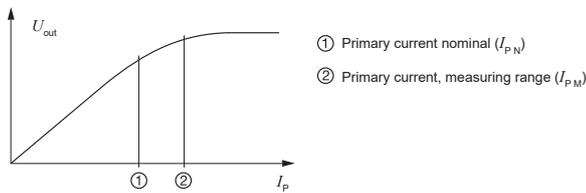
Definition of typical, minimum and maximum values:

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.
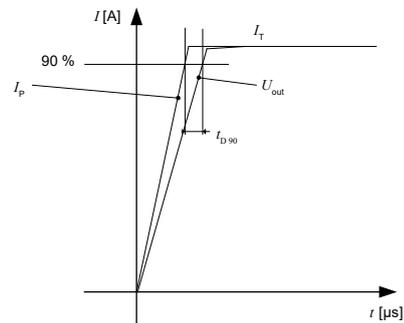
Linearity:

The maximum positive or negative discrepancy with a reference straight line $U_{out} = f(I_P)$.
Unit: linearity (%) expressed with full scale of $I_{P\,N}$.
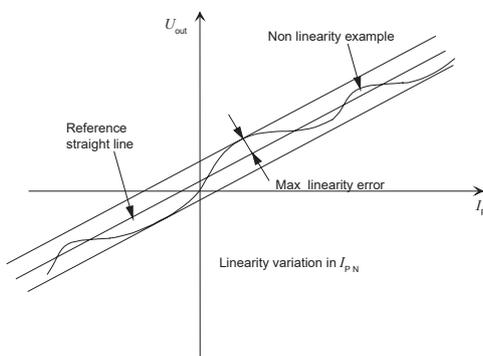
Response time (delay time) $t_{D\,90}$:

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:

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

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.

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 ; ≥ 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; At 20 A peak
Output voltage Noise (peak-to-peak)	LEM 98.20.00.575.0	Sweep from DC to 1 MHz
Delay time ; di/dt	LEM 98.20.00.545.0	100 A/μs ; $t_{D\,90}$ of $I_{P\,N}$ ≤ 6 μs
du/dt	LEM 98.20.00.545.0	Slope: 5 kV/μs U = 1000 V
ENVIRONMENTAL TESTS		
Ageing 85 °C /85 % RH	JESD 22-A101 (03/2009)	85 °C/85 % RH; Duration = 1000 h; Power supply 5 V ; primary current 0 A; Monitoring output 1 time/hr
Low temperature operating endurance	ISO 16750-4 § 5.1.1.2 (04/2010)	−40 °C, 24 h; Power supply 5 V Monitoring: 2 times/hr
High temperature operating endurance	ISO 16750-4 § 5.1.2.2 (04/2010)	Temperature 125 °C; 96 h; power supply 5 V 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 (04/2010)	Temperature range −10 °C/ +65 °C, 93 % RH Duration = 240 h (10 cycles)
Thermal shock	ISO 16750-4 § 5.3.2 (04/2010)	Temperature range −40 °C& 125 °C, 300 cycles; 40 min/40 min, no power supply
Sinus Vibration	ISO 16750-3 § 4.1.2.2.2.2 (12/2012)	Monitoring U_C and U_{out} is mandatory, Temperature −40/125 °C, 22 H/axis, 100 Hz to 440 Hz Sweep: ≤ 0.5 oct/min
Random Vibration	ISO 16750-3 § 4.1.2.2.2.3 (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 (12/2012)	Operating mode: 3.2 Pulse shape: half sine, 50 G, 6 ms 10 shocks per direction (total 60)
Free Fall	ISO 16750-3 § 4.3 (12/2012)	3 pcs, Falls/DUT: 2 times, Height = 1 m 3 axes, 2 directions by axis, Operating mode: 1.1
Cross section checking on PCBA	IPC-A-610G: 2017 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 (04/2010)	Refer to JESD22-A121A (04/2010) Class 2
Whisker checking on PIN	Refer to JESD201-A (04/2010)	Refer to JESD22-A121A (04/2010) Class 2
INSULATION TESTS		
Dielectric withstand voltage	ISO 16750-2 § 4.11 (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 (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 Contact discharges: ±4.6 kV, Air discharges: ±8 kV U_c = NO power supply, Criteria B
Immunity to Radiated disturbances (ALSE)	ISO 11452-2 (2019)	Power supply: 5 V f = 400 MHz to 1 GHz; Level = 100 V/m (CW, AM 80 %) f = 0.8 GHz to 2 GHz; Level = 70 V/m (CW, PM PRR = 217 Hz f = 1 GHz to 2 GHz; Level = 70 V/m (CW) 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) f = 1 MHz to 400 MHz Criteria A acceptance @ 5 % of 2 V
Emission Radiated (ALSE)	CISPR 25 §6.5 (2016)	Table 7, Class 5 by default f = 150 kHz to 2.5 GHz Load simulator will be provided (R&D)