AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY
HAH3DR 1500-S0A

Introduction

The HAH3DR family is for the electronic measurement of DC, AC or pulsed currents in high power and low voltage automotive applications with galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).

The HAH3DR family gives you the choice of having different current measuring ranges in the same housing (from ±200 A up to ±1500 A).

Features

- Open Loop transducer using the Hall effect
- Low voltage application
- Unipolar +5 V DC power supply
- Primary current measuring range up to ±1500 A
- Maximum RMS primary admissible current: defined by busbar to have T < +150 °C
- Operating temperature range: −40 °C < T < +125 °C
- Output voltage: full ratio-metric (in sensitivity and offset).

Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- High frequency bandwith
- Non insertion losses
- Very fast delay time.

Automotive applications

- Starter Generators
- Inverters
- HEV application
- EV application
- DC / DC converter.

Principle of HAH3DR 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:

$$U_H = (c_H / d) \times I_H \times a \times I_P$$

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

$$U_H = b \times I_P$$

a	constant
b	constant
c_H	Hall coefficient
d	thickness of the Hall plate
I_H	current across the Hall plates

The measurement signal U_H amplified to supply the user output voltage or current.

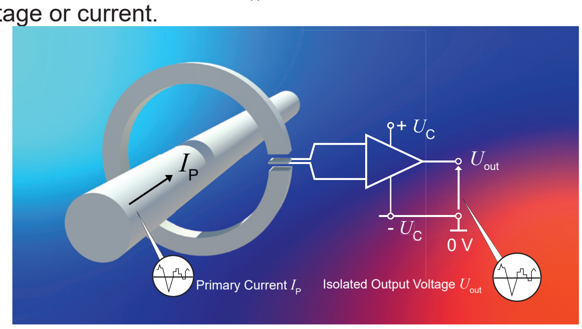
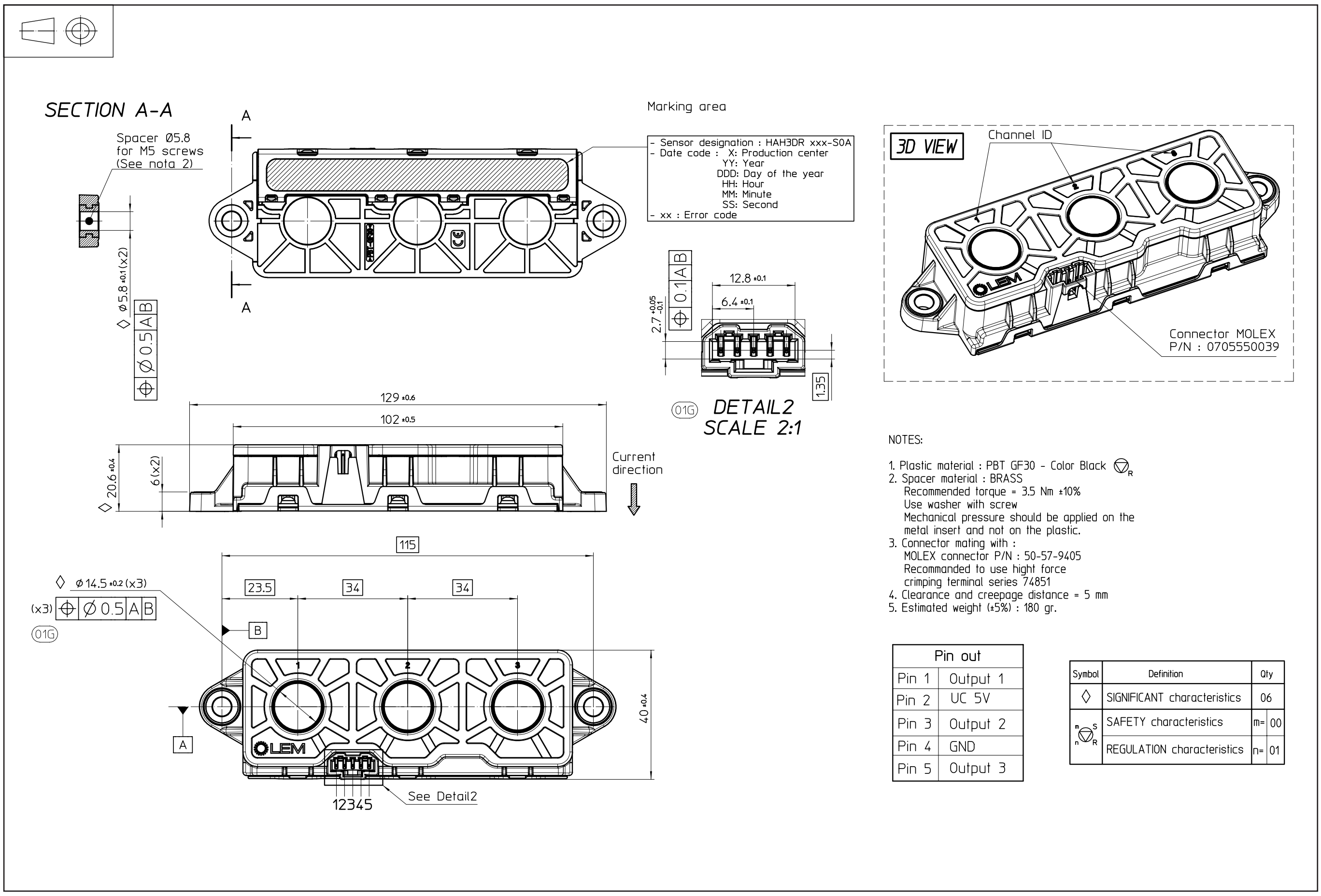


Fig. 1: Principle of the open loop transducer.

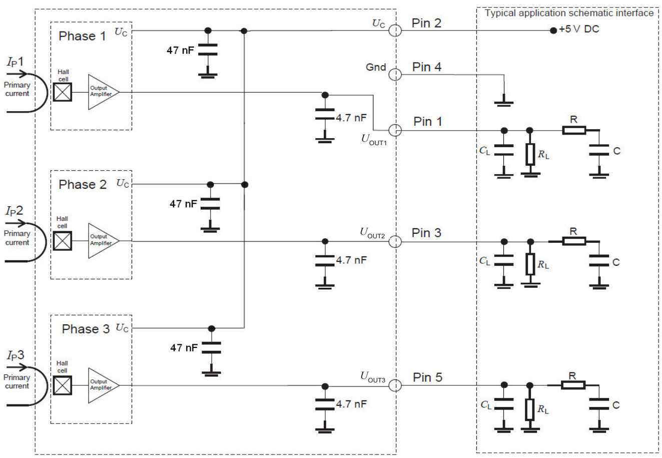
Dimensions (in mm)



Mechanical characteristics

- Plastic case PBT GF 30 % (color black)
- Magnetic core FeSi wound core
- Mass 180 g ±5 %
- Pins Copper alloy gold plated
- Degrees of protection provided by enclosure (IP Code... IPxx).

Electronic schematic



C_L < 2.2 nF EMC protection (optional)
RC Low pass filter (optional)

On board diagnostic

R_L > 10 kΩ. Resistor for signal line diagnostic (optional)

Parameter	Symbol	Unit	Specification Min	Typical	Max	Conditions
Maximum withstand primary peak current	$\hat{I}_P$	A			1)	
Supply voltage	U_C	V			8	Not operating
					6.5	Exceeding this voltage may temporarily reconfigure the circuit until next power-on
Output voltage low 3)	$U_{out\ L}$	V			0.2	@ $U_C = 5$ V, $T_A = 25$ °C
Output voltage high 3)	$U_{out\ H}$	V	4.8			@ $U_C = 5$ V, $T_A = 25$ °C
Ambient storage temperature	T_S	°C	−40		125	
Electrostatic discharge voltage (HBM)	$U_{ESD\ HBM}$	kV			2	JESD22-A-114-B-class 2
RMS voltage for AC insulation test, 50 Hz, 1 min	U_d	kV			2.5	50 Hz, 1 min, IEC 60664 part 1
Creepage distance	d_{Cp}	mm		5		
Clearance	d_{Cl}	mm		5		
Maximum reverse current (2)	$I_{R\ max}$	mA	−80		80	
Output current	I_{out}	mA	−1		1	$R_L = 10$ kΩ
Insulation resistance	R_{INS}	MΩ	500			500 V DC ISO 16750

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

Parameter	Symbol	Unit	Specification Min	Typical	Max	Conditions
Electrical Data						
Primary current	I_P	A	−1500		1500	
Supply voltage *)	U_C	V	4.75	5.00	5.25	
Output voltage (Analog) 3)	U_{out}	V	$U_{out} = (U_C/5) \times (U_O + S \times I_P)$			@ U_C
Sensitivity 3)*)	S	mV/A		1.33		@ $U_C = 5$ V
Offset voltage	U_O	V		2.5		
Current consumption (for 3 phases) *)	I_C	mA		45	60	@ $U_C = 5$ V, @ −40 < T_A < 125 °C
Load resistance	R_L	KΩ	10			
Ambient operating temperature	T_A	°C	−40		125	
Load capacitance	C_L	nF	1	4.7	6	
Output internal resistance	R_{out}	Ω			10	DC to 1 kHz
Performance Data 1)						
Ratiometricity error	ε_r	%		±0.5		@ $T_A = 25$ °C
Sensitivity error*)	ε_S	%		±0.5		@ $T_A = 25$ °C
				±1		@ $T_A = 25$ °C, after T cycles
Electrical offset voltage	$U_{O\ E}$	mV		±6		@ $T_A = 25$ °C, @ $U_C = 5$ V
Magnetic offset voltage	$U_{O\ M}$	mV	−7.5		7.5	@ $T_A = 25$ °C, @ $U_C = 5$ V, after ±I_P
Offset voltage*)	U_O	mV	−15		15	@ $T_A = 25$ °C, @ $U_C = 5$ V, hysteresis included
Average temperature coefficient of $U_{O\ E}$	$TCU_{O\ E\ AV}$	mV/°C	−0.08		0.08	@ −40 °C < T < 125 °C
Average temperature coefficient of S	TCS_{AV}	%	−0.03		0.03	@ −40 °C < T < 125 °C
Linearity error	ε_L	% I_P	−1		1	@ $U_C = 5$ V, @ $T_A = 25$ °C, @ $I = I_P$
Delay time to 90 % $I_{P\ N}$	$t_{D\ 90}$	µs			6	@ di/dt = 100 A/µs
Frequency bandwidth 2)	BW	kHz	40			@ −3 dB
Phase shift	$\Delta\varphi$	°	−4			@ DC to 1 kHz
Peak-to-peak noise voltage	$U_{no\ pp}$	mV			20	DC to 1 MHz
Start up time	t_{start}	µs			800	

Notes:

*) The parameter with *) will be checked 100 % during the calibration phase

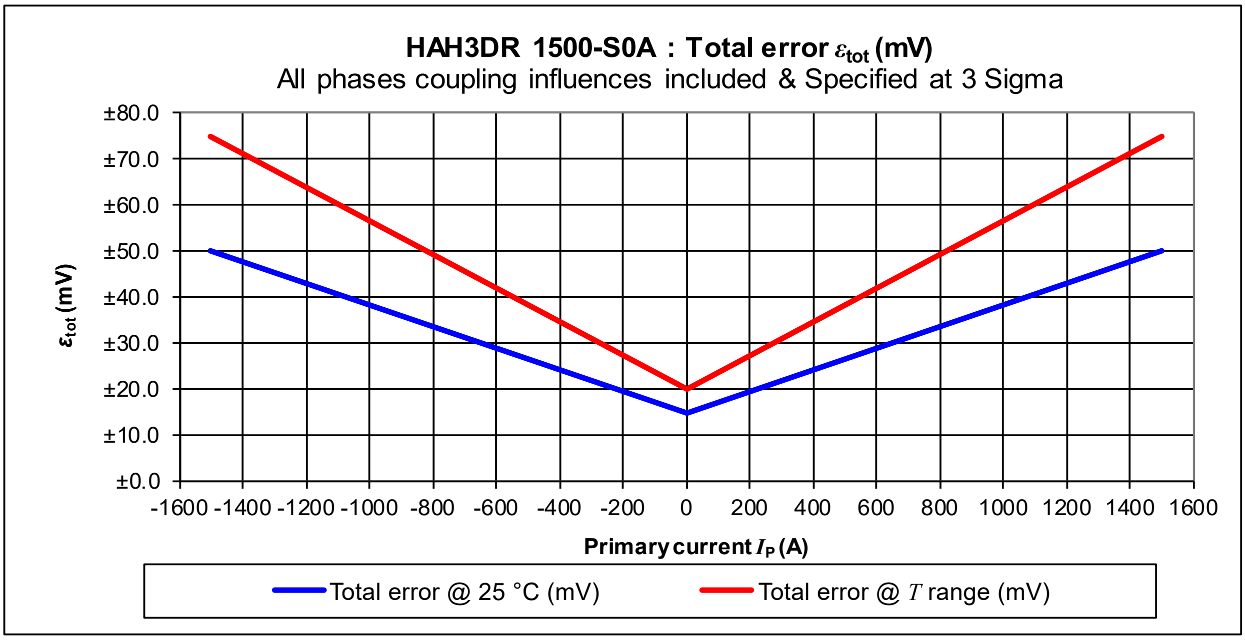
1) Busbar temperature must be below 150 °C

2) Transducer not protected against reverse polarity

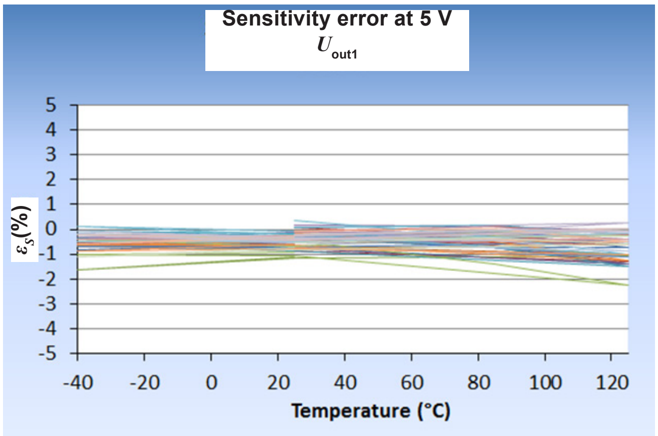
3) The output voltage U_{out} is fully ratiometric. The offset and sensitivity are dependent on the supply voltage U_C relative to the following formula:

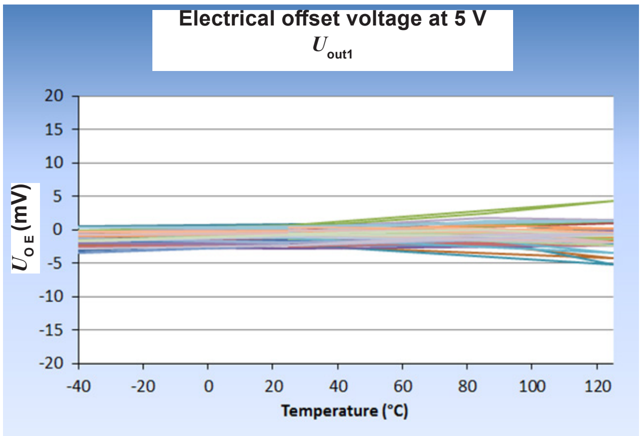
$$I_P = \left(\frac{5}{U_C} \times U_{out} - U_O\right) \times \frac{1}{S} \text{ with } S \text{ in (V/A)}$$

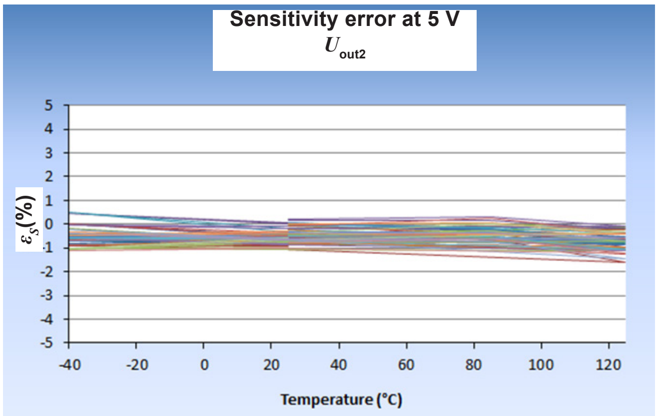
4) Tested only with small signal only to avoid excessive heating of the magnetic core.

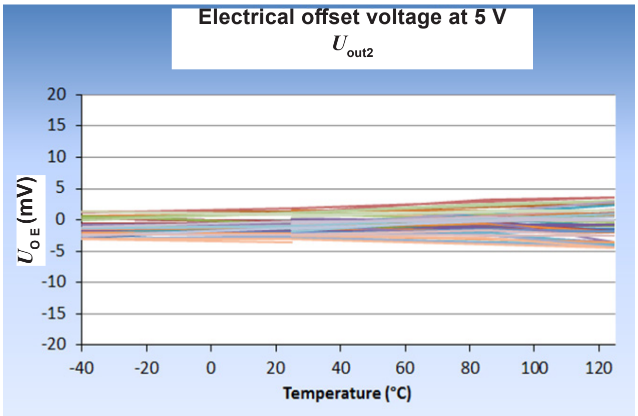


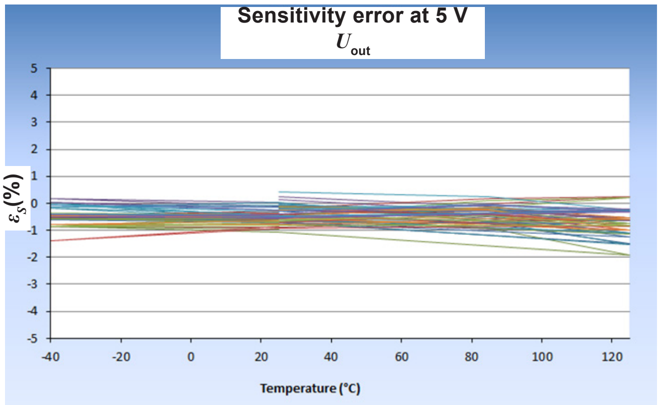
I_P (A)	Total error @ 25 °C (mV)	Total error @ T range (mV)
−1500	±50.0	±75.0
0	±15.0	±20.0
1500	±50.0	±75.0

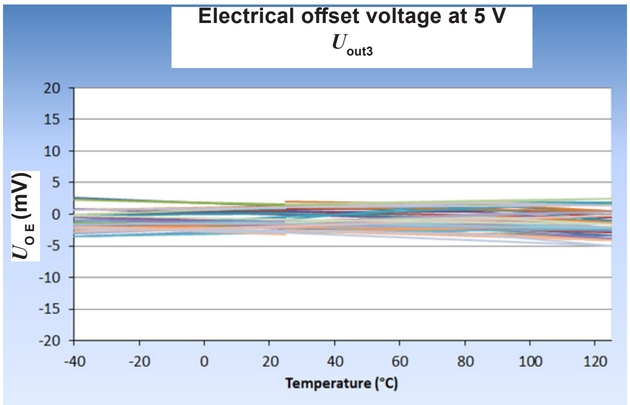

Sensitivity error at 5 V
U_{out1}
ε_S(%)
Temperature (°C)

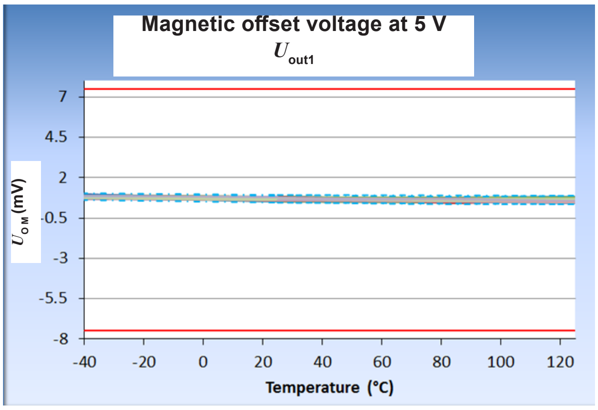

Electrical offset voltage at 5 V
U_{out1}
U_{OE} (mV)
Temperature (°C)

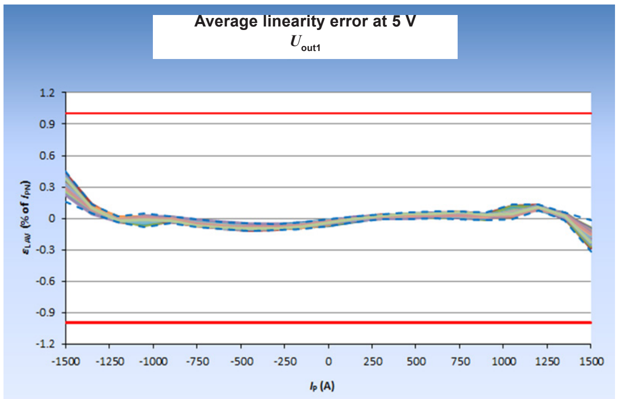

Sensitivity error at 5 V
U_{out2}
ε_S(%)
Temperature (°C)

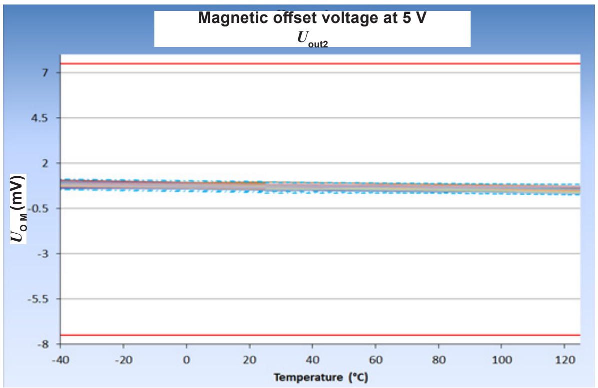

Electrical offset voltage at 5 V
U_{out2}
U_{OE} (mV)
Temperature (°C)

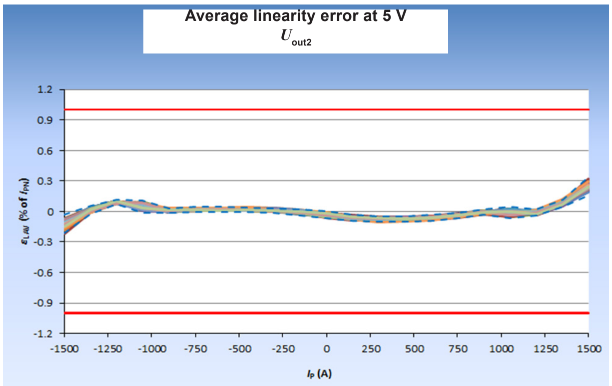

Sensitivity error at 5 V
U_{out}
ε_S(%)
Temperature (°C)

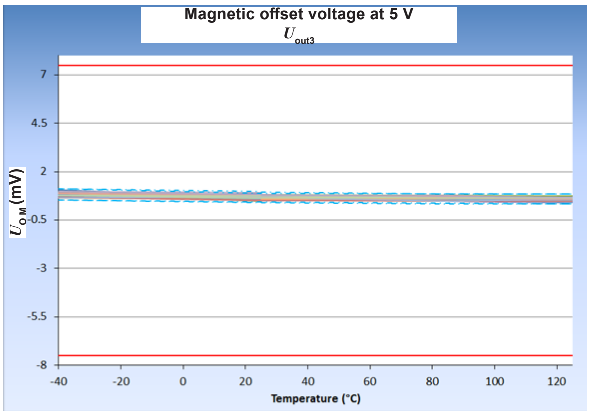

Electrical offset voltage at 5 V
U_{out3}
U_{OE} (mV)
Temperature (°C)

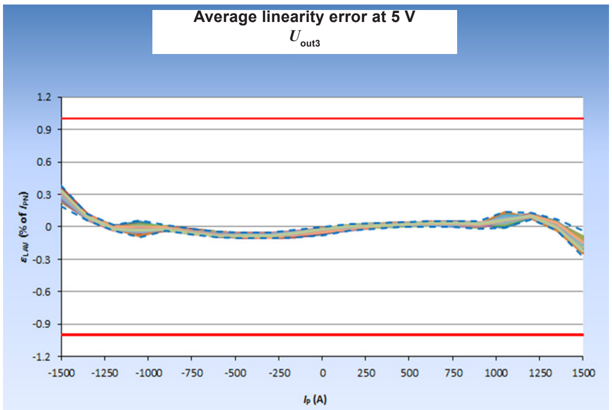

Magnetic offset voltage at 5 V
U_{out1}
$U_{O M}$ (mV)
7
4.5
2
-0.5
-3
-5.5
-8
-40 -20 0 20 40 60 80 100 120
Temperature (°C)

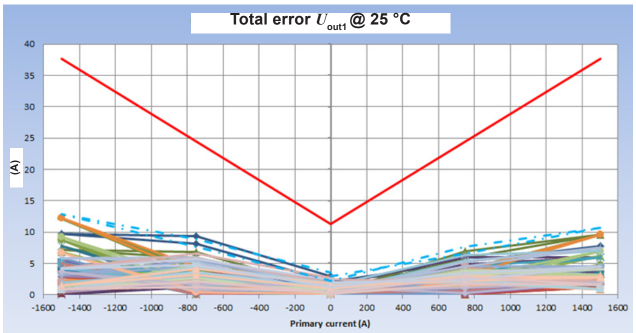

Average linearity error at 5 V
U_{out1}
1.2 0.9 0.6 0.3 0 -0.3 -0.6 -0.9 -1.2
-1500 -1250 -1000 -750 -500 -250 0 250 500 750 1000 1250 1500
I_P (A)

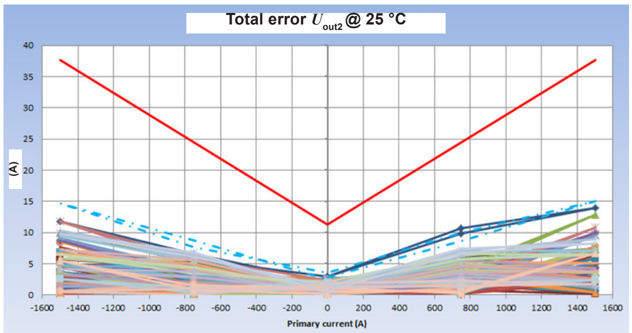

Magnetic offset voltage at 5 V
U_{out2}
$U_{O M}$ (mV)
7
4.5
2
-0.5
-3
-5.5
-8
-40 -20 0 20 40 60 80 100 120
Temperature (°C)

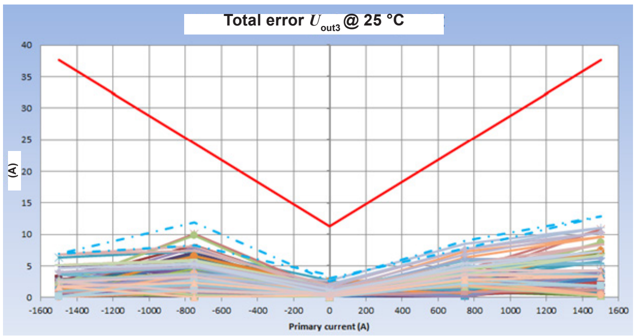

Average linearity error at 5 V
U_{out2}
1.2 0.9 0.6 0.3 0 -0.3 -0.6 -0.9 -1.2
-1500 -1250 -1000 -750 -500 -250 0 250 500 750 1000 1250 1500
I_P (A)

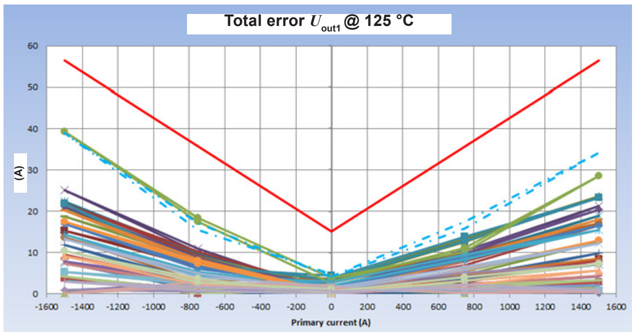

Magnetic offset voltage at 5 V
U_{out3}
$U_{O M}$ (mV)
7
4.5
2
-0.5
-3
-5.5
-8
-40 -20 0 20 40 60 80 100 120
Temperature (°C)

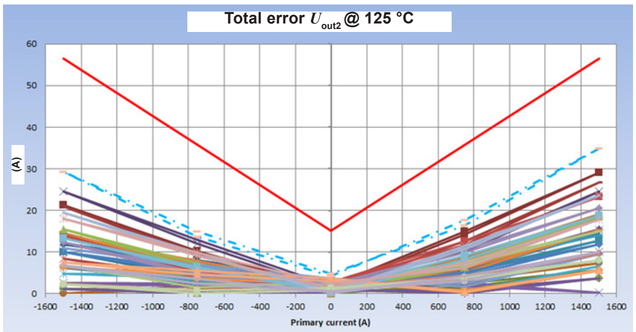

Average linearity error at 5 V
U_{out3}
1.2 0.9 0.6 0.3 0 -0.3 -0.6 -0.9 -1.2
-1500 -1250 -1000 -750 -500 -250 0 250 500 750 1000 1250 1500
I_P (A)

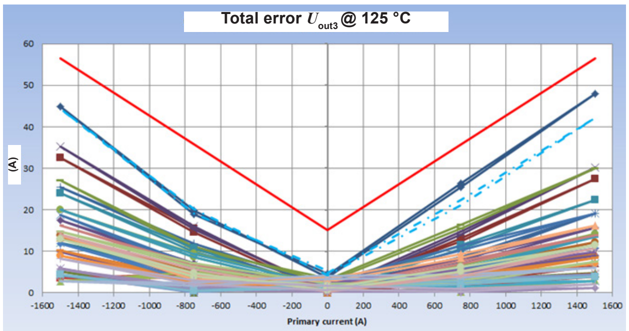

Total error U_{out1} @ 25 °C
(A)
Primary current (A)

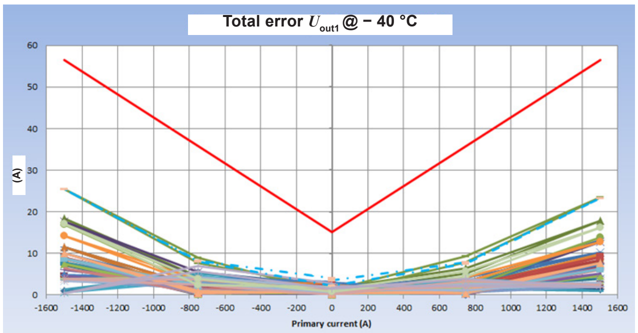

Total error U_{out2} @ 25 °C
(A)
Primary current (A)

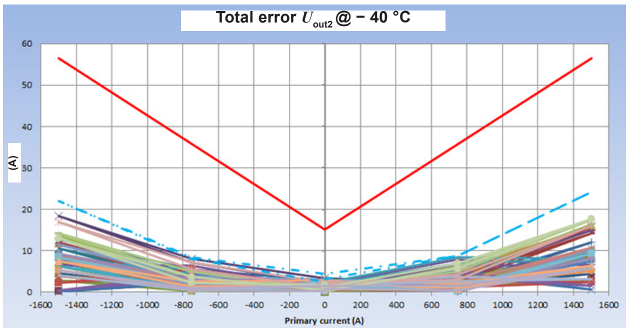

Total error U_{out3} @ 25 °C
(A)
Primary current (A)

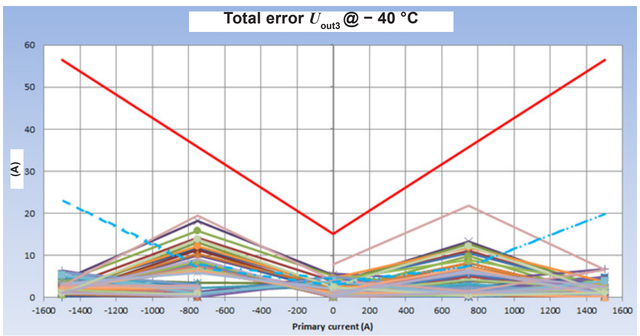

Total error U_{out1} @ 125 °C
(A)
Primary current (A)


Total error U_{out2} @ 125 °C
(A)
Primary current (A)


Total error U_{out3} @ 125 °C
(A)
Primary current (A)

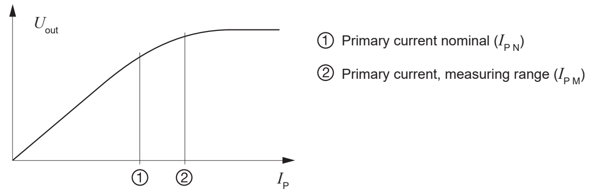

Total error U_{out1} @ − 40 °C
(A)
Primary current (A)


Total error U_{out2} @ − 40 °C
(A)
Primary current (A)


Total error U_{out3} @ − 40 °C
(A)
Primary current (A)

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:

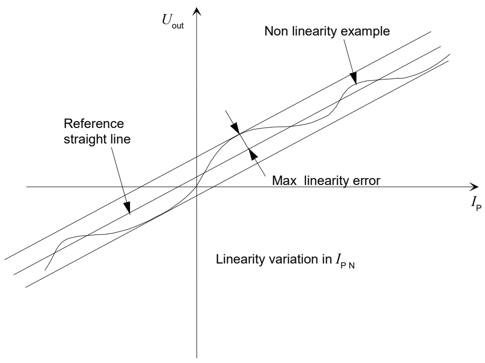
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

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.

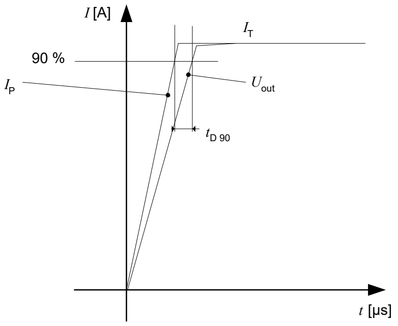
Linearity:

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



Delay time $t_{D\,90}$:

The time between the primary current signal (I_{PN}) 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.

PV TESTS PLAN - HAH3DR 1500-S0A			
TEST[1]	Standard or Procedure		Specific conditions(*)
CHARACTERIZATION @ 25 °C			
Sensitivity / Overall Accuracy / Accuracy at 0 .. $\pm I_{PN}$	LEM CO.60.09.014.0	-	
Offset / Electrical Offset / Magnetic Offset	LEM CO.60.09.014.0	-	
Linearity error at 0 .. $\pm I_{PN}$	LEM CO.60.09.014.0	Method 2: ε_L AV	
Current Consumption	LEM CO.60.09.014.0	-	
CHARACTERIZATION WITH T °C (initial)			
Sensitivity / Overall Accuracy / Accuracy at 0 .. $\pm I_{PN}$	LEM CO.60.09.014.0	-	
T °C variation of ... / Temperature Coefficient of S	LEM CO.60.09.014.0	Method 2: TCS_{AV}	
Offset / Electrical Offset / Magnetic Offset	LEM CO.60.09.014.0	-	
T °C variation of ... /Temperature Coefficient of Offset	LEM CO.60.09.014.0	Method 2: $TCS_{O\,AV}$	
ELECTRICAL TESTS @ 25 °C			
Phase delay check	LEM 98.20.00.538.0		30 Hz to 100 KHz; @ 20 A peak; ≥ −4 °C from DC to 1 KHz
Frequency Bandwidth	LEM 98.20.00.538.0		30 Hz to 100 kHz; @ 20A peak; ≥ 40 kHz @ −3 dB
Noise measurement	LEM 98.20.00.575.0		Sweep from DC to 1 MHz ; ≤ 15 mVpp
Delay time di/dt	LEM 98.20.00.545.0		100 A/µs, I pulse = I_{PN} A ; $t_{D\,90}$ @ 90 % of I_{PN} ≤6 µs
dv/dt	LEM 98.20.00.545.0		Slope: 5 kV/µs U= 1000V; Criteria ≤ ±100 mV ; Disturbance < ±100 mV; Recovery time max 4 µs
Isolation Resistance test after ageing 85/85		ISO 16750-2 § 4.12 (11/2012)	500 V DC, time = 60 s; R_{INS} ≥ 500 MΩ Minimum. Functional test before and after test.
Dielectric Withstand Voltage test after ageing 85/85		ISO 16750-2 § 4.12 (11/2012)	2500 VAC / 1 min / 50 Hz
ENVIRONMENTAL TESTS (CLIMATIC)			
Low temperature storage test	IEC 60068-2-1 Ad (03/2007)	ISO 16750-4 § 5.1.1.1 (04/2010)	T °C = "T" °C Storage −40 °C Duration =1000 h U_C = NO power supply (≡ unconnected) Check After stab. @ 25 °C (End test)
High temperature storage test	IEC 60068-2-2 Bd (07/2007)	ISO 16750-4 § 5.1.2.1 (04/2010)	T °C = "T" °C Storage 125 °C Duration =1000 h U_C = NO power supply (≡ unconnected) Check After stab. @ 25 °C (End test)
Thermal shock	IEC 60068-2-14 Na (01/2009)	ISO 16750-4 § 5.3.2 (04/2010)	T °C = "T"°C Operating −40 °C & 125 °C Duration =100 cycles; 30 min / 30 min U_C = NO power supply (≡ unconnected) Check After stab. @ 25 °C (End test)
Power Temperature cycle test	IEC 60068-2-14 Nb (01/2009)	ISO 16750-4 § 5.3.1 (04/2010)	T °C = "T" °C Operating −40 °C & 125 °C 30 cycles of 8h: ramp 1 °/min; Lower T duration 60 min, higher T duration 110 min operating from 20 ° C to 125 °C (see profile)
Steady state T°C Humidity bias life test	JESD 22-A101 (03/2009)	-	T °C = 85 °C; RH = 85 %; Duration = 1000 h U_C = 5 V (≡ connected); I_P = 0 A; Check After stab. @ 25 °C (End test)

TEST[1]	Standard or Procedure		Specific conditions(*)
MECHANICAL TESTS			
Sinus Vibration in T °C	IEC 60068-2-xx	ISO 16750-3 § 4.1.2.2 (12/2012)	Sinus; Level = 30 - 60 m/s²g; Frequency = 100 Hz to 440 Hz; 22 hr/axis; −40 °C < T < 95 °C U_C = 5 V (≡ connected); I_P = 0 A; Monitoring Check After stab. @ 25 °C (End test); & Meas. torque Bef. and After.
Random Vibration in T °C	IEC 60068-2-64 (02/2008)	ISO 16750-3 § 4.1.2.2 (vib. profil: spung masses) ISO 16750-3 § 4.1.1 (T °C) (12/2012)	Random; Level = 96 m/s²g; Frequency = 10 Hz - 2000 Hz ; 22 hour/axis ; −40 °C < T < 95 °C U_C = 5 V (≡ connected); I_P = 0 A; Monitoring Check After stab. @ 25 °C (End test); & Meas. torque Bef. and After
Shocks	IEC 60068-2-27 (02/2008)	ISO 16750-3 § 4.2 (12/2012)	Acceleration: 500 m/s²; Duration: 6 ms; Half-sine pulse: 10 * in each direction (total 60 shocks) U_C = NO power supply Check After stab. @25 °C (End test); & Meas. torque Bef. and After
Free Fall (Device not packaged)	IEC 60068-2-31 §5.2: method 1 (05/2008)	ISO 16750-3 § 4.3 (12/2012)	Height = 1 m; Concrete floor 3 axes; 2 directions by axis; 1 sample by axis
EMC TESTS			
Immunity to Electrostatic Discharges (Handling of devices)	ISO 10605 (07/2008)	-	Contact discharges: ±4, 6 kV Air discharges: ±8 kV U_C = NO power supply (≡ unconnected) Criteria B
Immunity to Conducted disturbances (BCI)	ISO 11452-4 (12/2011)	-	Level = 2 F = 1 MHz to 400 MHz Criteria A acceptance @ 5 %
Immunity to Radiated disturbances (ALSE)	ISO 11452-2 (11/2004)	-	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 PD = 0.57 ms) F = 1 GHz to 2 GHz; Level = 70 V/m (CW) Criteria A acceptance @ 5 %
Immunity to Radiated disturbances (ALSE)	CISPR 25 (03/2008)	-	Table 9, Class 5 by default Freq = 150 kHz to 2.5 GHz
Connector test			
connector test	LEM		45 N with lock; >17 N without lock, 50 cycles mate-unmate