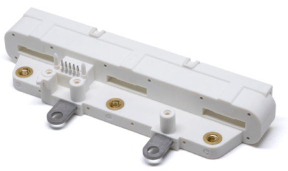
# AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY

**HAH3DR 800-S07/SP3, HAH3DR 900-S07/SP3, HAH3DR 1000-S07/SP3, HAH3DR 1100-S07/SP3, HAH3DR 1200-S07/SP3**



## Introduction

The HAH3DR-S07 family is a tri-phase transducer for DC, AC, or pulsed currents measurement in automotive applications. It offers a galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).

## Features

- Open Loop transducer using the Hall effect sensor
- Low voltage application
- Unipolar +5 V DC power supply
- Primary current measuring range up to ±1200 A
- Maximum RMS primary admissible current: defined by the busbar, the magnetic core or ASIC $T < +125$ °C
- Operating temperature range: −40 °C < $T$ < +125 °C
- Output voltage fully ratiometric (in sensitivity and offset).

## Special features

- All in one tri-phase transducer
- Perfect fit to Infineon IGBT
- Simplified installation with press fit contacts eliminates soldering
- Built-in nuts for busbar attachement.

## Advantages

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

## Automotive applications

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

## Principle of HAH3DR S07 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.

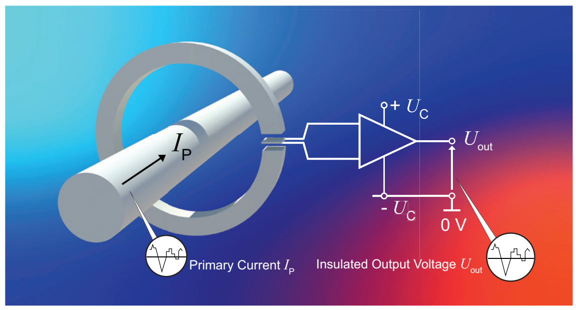



Fig. 1: Principle of the open loop transducer.



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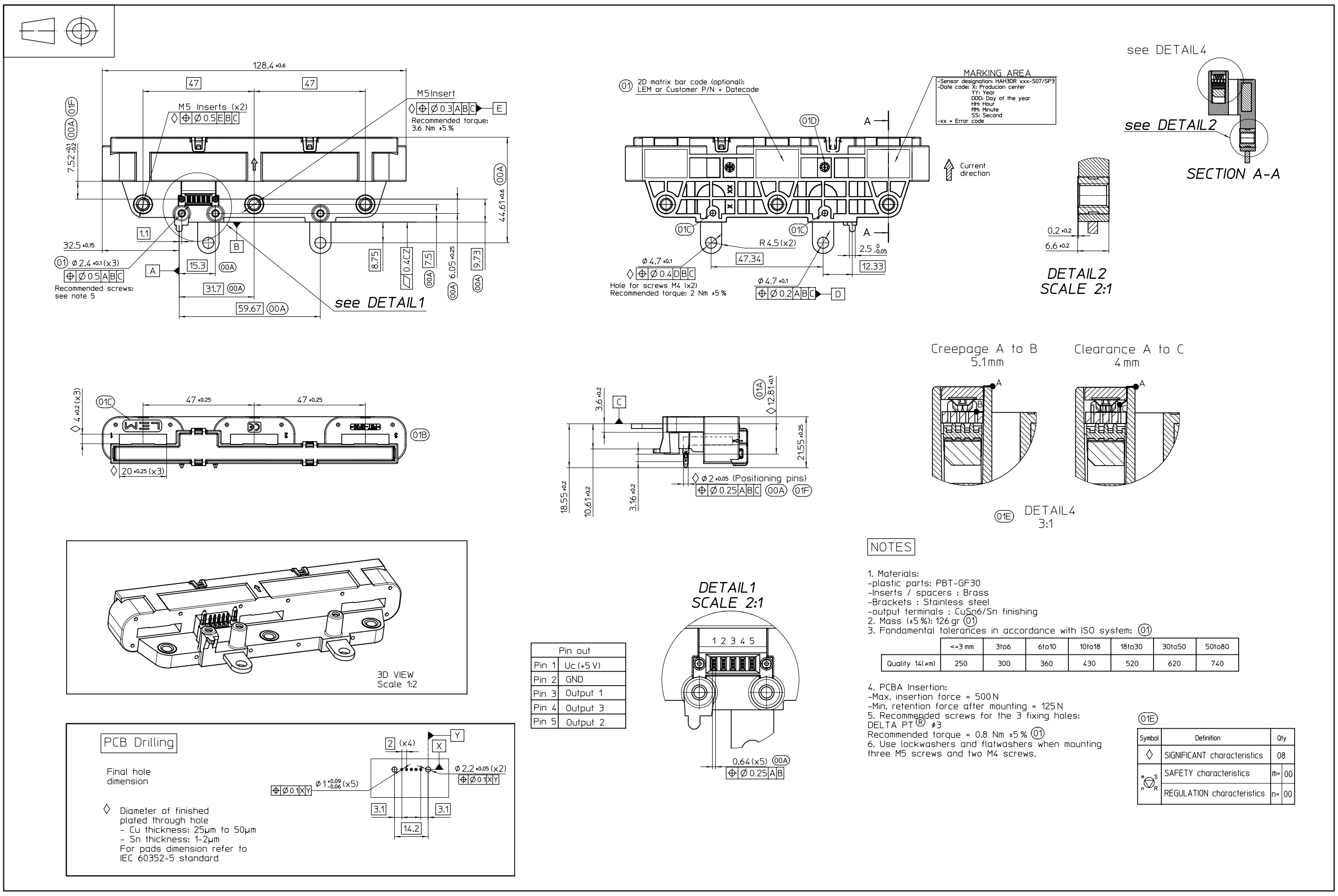
## Dimensions (in mm)




## Mechanical characteristics

- Materials — PBT-GF 30
- Magnetic core — FeSi wound core
- Pins — CuSn 6 /Sn finishing
- Mass — 126 g ±5 %

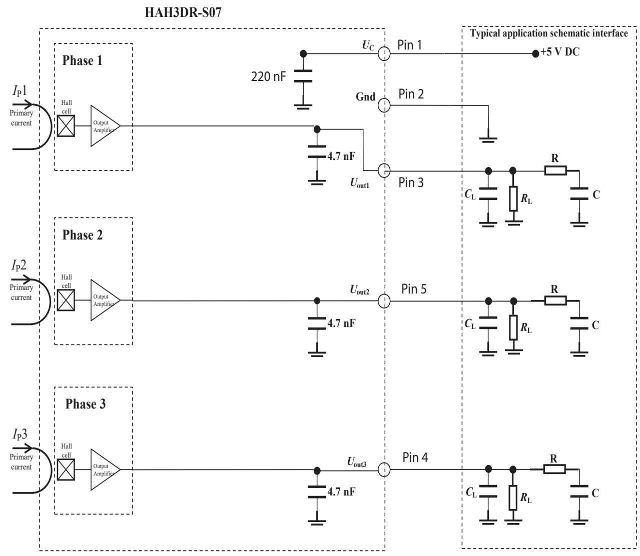
## Mounting recommendation (Shown as page 3)

- PCBA insertion:
  - Max. insertion force for 5 press fit pins = 500 N
  - Min. retention force after mounting = 125 N
  - Max. insertion force for plastic bosses = 1500 N
- Recommended 3 fasteners for plastic:
  - DELTA PT ® Ø 3 wn 5451, torque = 0.8 N·m ±5 %
- Recommended M5 screws:
  - L = 10 mm, torque: 3.6 N·m ±5 %
- Recommended M4 screws:
  - L = 14 mm, torque: 2 N·m ±5 %
- Use both lockwashers and flatwashers when mounting three M5 screws and two screws.

## Remark

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

## System architecture (example)



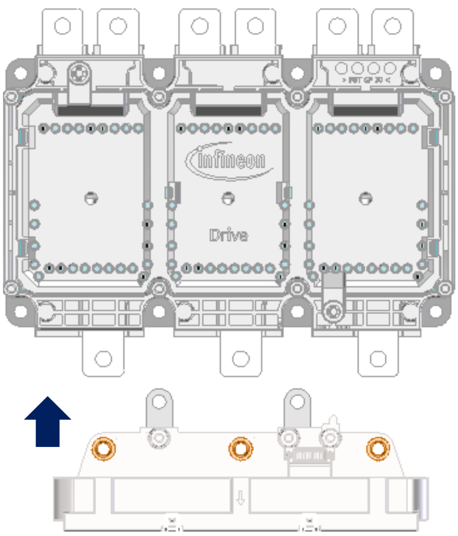

$C_L$ < 2.2 nF EMC protection (optional)
RC Low pass filter (optional)

## On board diagnostic

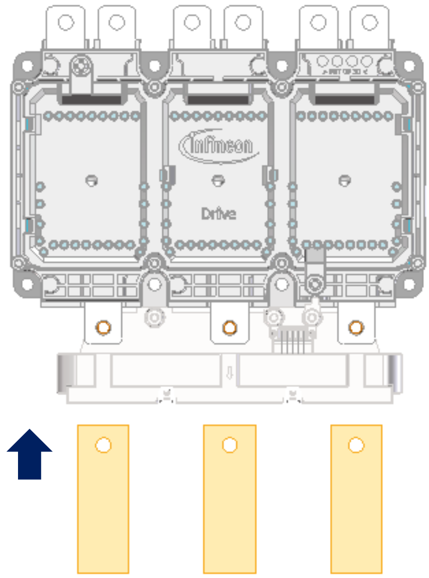
$R_L$ > 10 kΩ Resistor for signal line diagnostic (optional)

## Mounting Operation and Recommendations

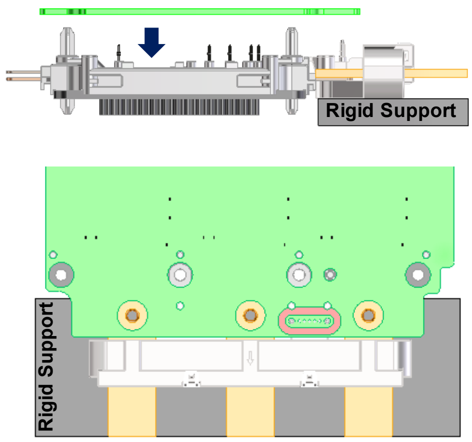
### OP10 – Transducer insertion



### OP20 – Busbar insertion

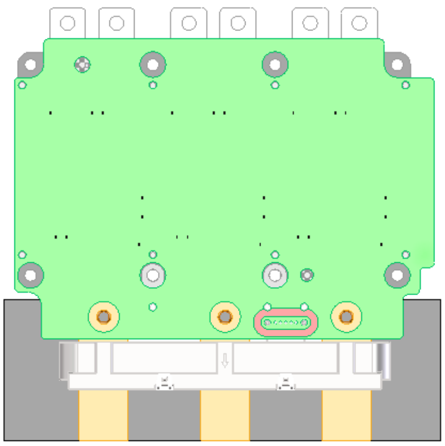


### OP30 – PCB insertion




Notes:
1. Rigid support under LEM transducer during insertion
2. Press-fit terminal refers to outline drawing

### OP40 – Screws mounting



Notes:
1. Stainless Iron M3 self-tapping screws (3 pcs)
2. Stainless Iron M5 screws (3 pcs)
3. Torque refers to outline drawing







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## Absolute ratings (not operating)

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| Maximun supply voltage | $U_{C\ max}$ | V | −0.5 | | 8 | Continuous not operating |
| | | | | | 6.5 | Exceeding this voltage may temporarily reconfigure the circuit until the next power on |
| Ambient storage temperature | $T_{A\ st}$ | °C | −40 | | 125 | |
| Electrostatic discharge voltage | $U_{ESD\ HBM}$ | kV | | | 8 | IEC 61000-4-2 |
| RMS voltage for AC insulation test | $U_d$ | kV | | | 2.5 | 50 Hz, 1 min, IEC 60664 part 1 |
| Creepage distance | $d_{Cp}$ | mm | | 5.1 | | |
| Clearance | $d_{Cl}$ | mm | | 4 | | |
| Comparative traking index | $CTI$ | | | PLC 3 | | |
| Insulation resistance | $R_{INS}$ | MΩ | 500 | | | 500 V DC, ISO 16750 |

## Operating characteristics

### All characteristics noted under conditions $-I_{P\ M} \le I_P \le I_{P\ M}$, 4.75 V ≤ $U_C$ ≤ 5.25 V, −40 °C ≤ $T_A$ ≤ 125 °C, unless otherwise noted.

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| **Electrical Data** | | | | | | |
| Supply voltage [1] | $U_C$ | V | 4.75 | 5 | 5.25 | |
| Ambient operating temperature | $T_A$ | °C | −40 | | 125 | |
| Output voltage (Analog) | $U_{out}$ | V | | $U_{out} = (U_C/5) \times (U_o + S \times I_P)$ | | @ $T_A$ = 25 °c |
| Offset voltage | $U_O$ | V | | 2.5 | | |
| Current consumption | $I_C$ | mA | | 45 | 60 | @ $U_C$ = 5 V |
| Load resistance | $R_L$ | KΩ | 10 | | | |
| Output internal resistance | $R_{out}$ | Ω | | 1 | 10 | DC to 1 kHz |
| **Performance Data** | | | | | | |
| Ratiometricity error | $\varepsilon_r$ | % | | ±0.5 | | |
| Sensitivity error | $\varepsilon_S$ | % | | ±1 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V |
| Electrical offset voltage | $U_{O\ E}$ | mV | | ±2 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V |
| Magnetic offset voltage | $U_{O\ M}$ | mV | | ±2 | | @ $T_A$ = 25 °C, @ $U_C$ = 5 V, after ± $I_{P\ M}$ |
| Average temperature coefficient of $U_{O\ E}$ | $TCU_{O\ E\ AV}$ | mV/°C | | ±0.04 | | |
| Average temperature coefficient of $S$ | $TCS_{AV}$ | %/°C | | ±0.02 | | |
| Linearity error | $\varepsilon_L$ | % | −0.5 | | 0.5 | % of Full range, −800 A < $I_P$ < 800 A |
| | | | −2 | | 2 | % of Full range, 800 A < $\|I_P\|$ < 1200 A |
| Delay time to 90 % to the final output value for $I_{P\ N}$ step | $t_{D\ 90}$ | µs | | 2 | 6 | d$i$/d$t$ = 100 A /µs |
| Frequency bandwidth [2] | $BW$ | kHz | 40 | | | @ −3 dB |
| Peak-to-peak noise voltage | $U_{no\ pp}$ | mV | | | 20 | @ DC to 1 MHz |
| Phase shift | $\Delta\varphi$ | ° | −4 | | | @ DC to 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] Primary current frequencies must be limited in order to avoid excessive heating of the busbar, magnetic core and the ASIC (see feature paragraph in page 1).

## HAH3DR 800-S07/SP3

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| **Electrical Data** | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −800 | | 800 | |
| Sensitivity | $S$ | mV/A | | 2.50 | | |

## HAH3DR 900-S07/SP3

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

## HAH3DR 1000-S07/SP3

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| **Electrical Data** | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1000 | | 1000 | |
| Sensitivity | $S$ | mV/A | | 2.00 | | |

## HAH3DR 1100-S07/SP3

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| **Electrical Data** | | | | | | |
| Primary current, measuring range | $I_{PM}$ | A | −1100 | | 1100 | |
| Sensitivity | $S$ | mV/A | | 1.82 | | |

## HAH3DR 1200-S07/SP3

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





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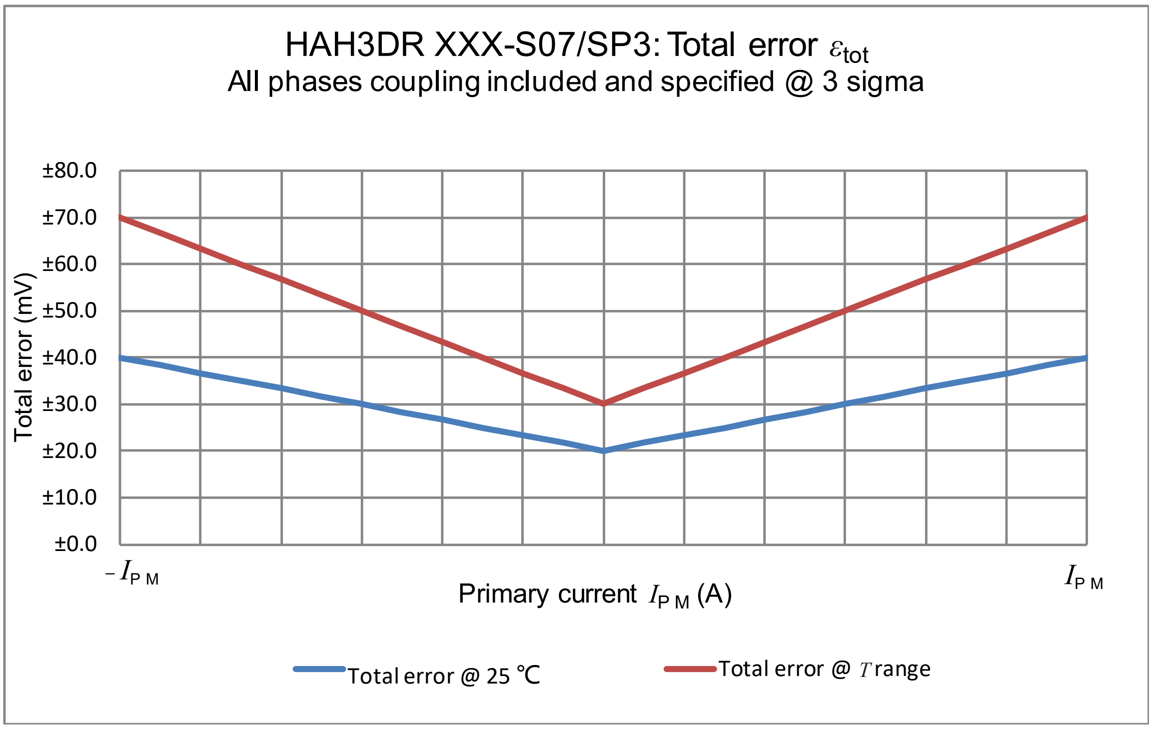
## Total error




## Total error table

| | Total error $\varepsilon_{tot}$ Specification | | | |
|---|---|---|---|---|
| $I_P$ (A) | $T_A$ = 25 °C, $U_C$ = 5 V | | −40 °C ≤ $T_A$ ≤ 125 °C, $U_C$ = 5 V | |
| $I_{PM}$ | ±40 mV | ±2 % | ±70 mV | ±3.5 % |
| 0 | ±20 mV | ±1 % | ±30 mV | ±1.5 % |
| $-I_{PM}$ | ±40 mV | ±2 % | ±70 mV | ±3.5 % |



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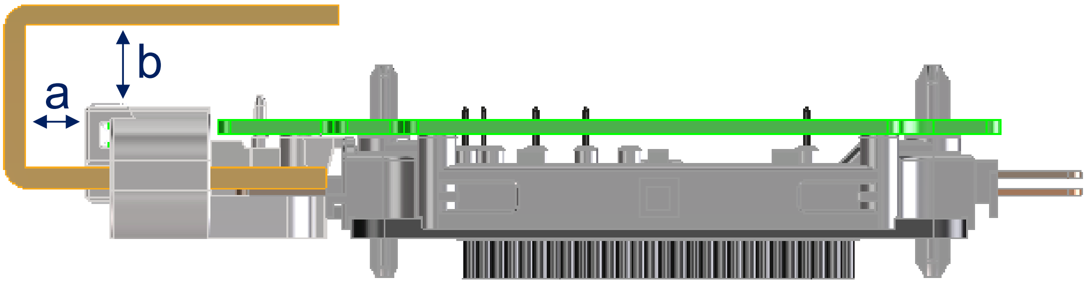
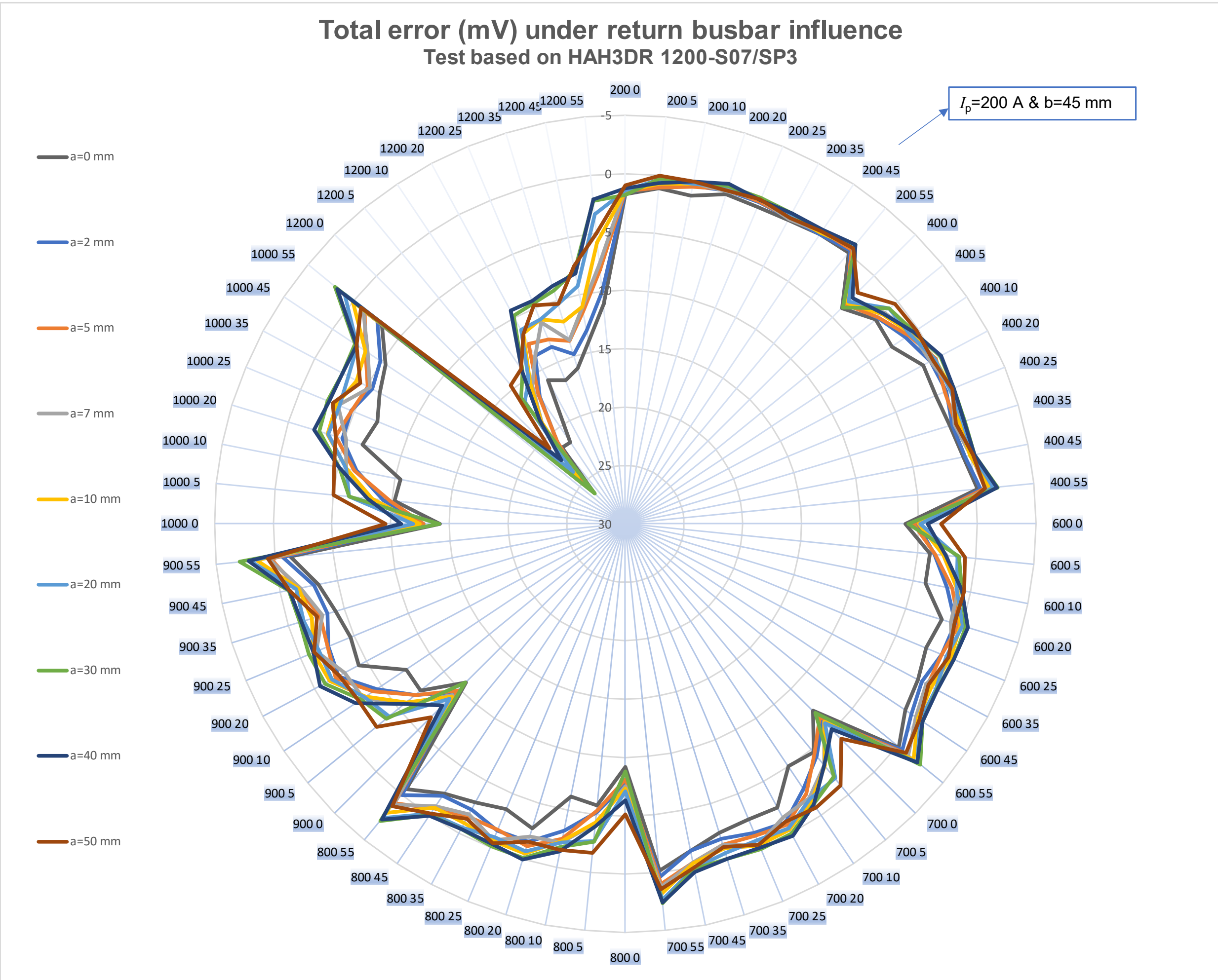
## Return Busbar Influence On Transducer Output




*Return Busbar Influence:

Difference of the $U_{out}$ between the return busbar (U-shape) vs reference (straight busbar).



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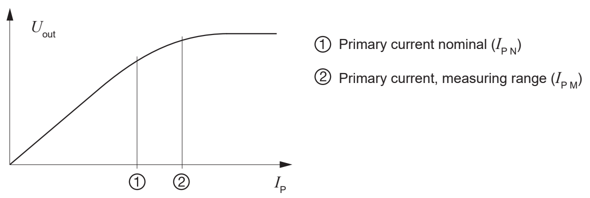
## PERFORMANCES PARAMETERS DEFINITIONS

### 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:

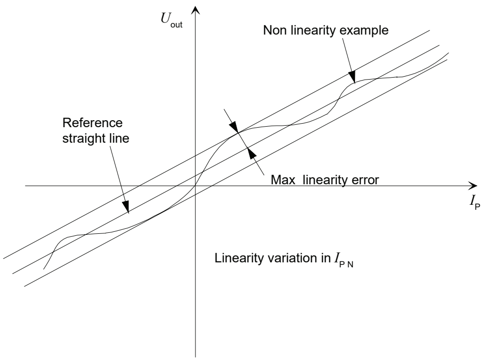
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

### 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.

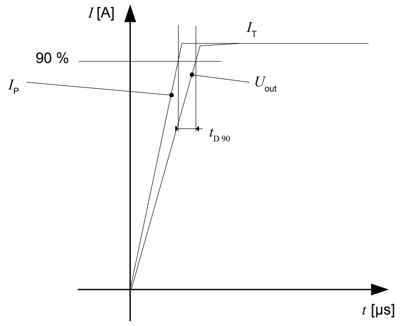
### Linearity:

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 $I_{OT}$ is a maximum variation the offset in the temperature range:

$$I_{OT} = I_{OE}\,\text{max} - I_{OE}\,\text{min}$$

The offset drift $TCI_{OE\,AV}$ is the $I_{OT}$ 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.



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## Environmental test specifications:

| Name | Standard | Conditions |
|---|---|---|
| **Electrical tests** | | |
| Phase delay check | LEM Procedure | 30 Hz to 100 kHz @ 20 A peak |
| Frequency Bandwidth | LEM Procedure | 30 Hz to 100 kHz @ 20 A peak |
| Noise measurement | LEM Procedure | Sweep from DC to 1 MHz |
| Delay time $di/dt$ | LEM Procedure | 100 A/µs, $I$ pulse = 1200 A |
| $dv/dt$ | LEM Procedure | 5000 V/µs, $U$ = 1000 V |
| Dielectric Withstand Voltage test | ISO 16750-2 § 4.11 | 2500 V AC/ 1 min/ 50 Hz |
| Insulation resistance | GBT 18488.1-2015 | 1000 V DC, time = 60 s<br>$R_{INS}$ ≥ 20 MΩ minimum |
| **Environmental tests** | | |
| Steady state $T$ °C Humidity bias life test | JESD 22-A101 (03.2009) | 1000 hours +85 °C/ 85 % $RH$ $U_C$ = 5 V , $I_P$ = 0 A |
| Low temperature storage test | ISO 16750-4 § 5.1.1.1<br>(04.2010)<br>IEC 60068-2-1 Ad<br>(03.2007) | Storage: −40 °C for 96 h<br>$U_C$ not connected, $I_P$ = 0 A |
| High temperature storage test | ISO16750-4 § 5.1.2.1<br>(04.2010)<br>IEC 60068-2-2 Bd<br>(07.2007) | Storage: 125 °C for 1000 h<br>$U_C$ not connected, $I_P$ = 0 A |
| Thermal Shock | ISO16750-4 § 5.3.2<br>(04.2010)<br>IEC 60068-2-14 Na<br>(01.2009) | 1000 cycles (1000 hours),<br>30 min @ −40 °C//30 mn @ +125 °C<br>$U_C$ not connected, $I_P$ = 0 A |
| Power Temperature cycle test | ISO 16750-4 § 5.3.1<br>(04.2010)<br>IEC 60068-2-14 Na<br>(01.2009) | 30 cycles(240 h), −40 °C ±125 °C<br>$U_C$ = 5 V , $I_P$ = 0 A |
| **Mechanical tests** | | |
| Mechanical Shock | ISO 16750-3 § 4.2.2<br>(12.2012) | 50 g/ 6 ms Half Sine @ 25 °C<br>10 shocks of each direction (Total: 60)<br>$U_C$ not connected, $I_P$ = 0 A |
| Sine Vibration in 25 °C | IEC 60068-2-6 | Sine 30-60 m/s², 100 Hz - 440 Hz@ 25 °C<br>22 hr/axis<br>$U_C$ = 5 V , $I_P$ = 0 A |
| Random Vibration in $T$ °C | IEC 60068-2-64 | 96 m/s² ,10 Hz - 2000 Hz, −40 °C < $T$ < 125 °C<br>22 hr/axis<br>$U_C$ = 5 V , $I_P$ = 0 A |
| Free Fall<br>(Device not packed) | ISO 16750-3 § 4.3<br>(12.2012) | Height = 1 m, Concrete floor<br>3 axes, 2 directions by axis, 1 sample by axis |
| **EMC test** | | |
| Radiated Emission | CISPR 25:2016 | 0.15 MHz to 2500 MHz Table 9,Class 5 |
| Bulk Current Injection (BCI) | ISO 11452-4:2005 | 1 MHz to 400 MHz Level: 2 Criteria: A |
| Absorber-lined shielded enclosure | ISO 11452-2:2004 | F = 400 MHz to 1 GHz;<br>Level = 100 V/m (CW, AM 80 %) F = 0.8 GHz to 2 GHz;<br>Level = 70 V/m (CW, PM PRR = 217 Hz , PD = 0.57 ms) |
| ESD Test | ISO 10605<br>(07.2008)<br>IEC 61000-4-2 | Contact: ±4, ±6 kV Air: ±8 kV<br>$U_C$ not connected |





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