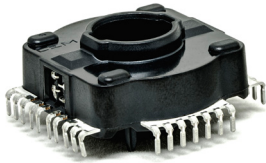


AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY

HC16F 1000-S00; HC16F 1100-S00; HC16F 1200-S00; HC16F 1300-S00; HC16F 1400-S00; HC16F 1500-S00; HC16F 1600-S00

THD version (S00)



Introduction

The HC16F family is for the electronic measurement of DC, AC or pulsed currents in high power and high and low voltage automotive applications with galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).

The HC16F family gives you the choice of having different current measuring ranges in the same housing.

Features

- Ratiometric transducer
- Open Loop transducer using the Hall Effect
- High and Low voltage application
- Unipolar +5 V DC power supply
- Primary current measuring range ± 1000 A to ± 1600 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)
- Compact design for PCB mounting.

Special features

- Housing with sleeve
- Dual air gap transducer
- Compact size.

Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- Galvanic separation
- High frequency bandwidth.

Automotive applications

- Electrical Power Steering
- Starter Generators
- Converters
- Motor drive application.

Principle of HC16F 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.

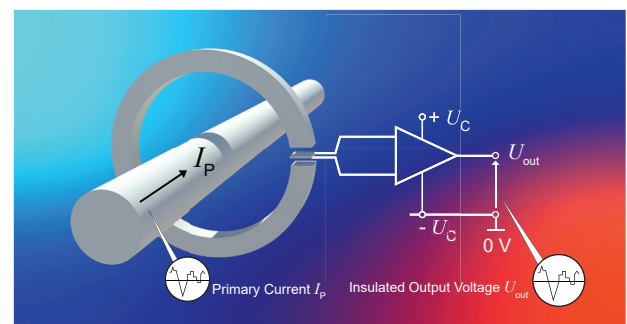
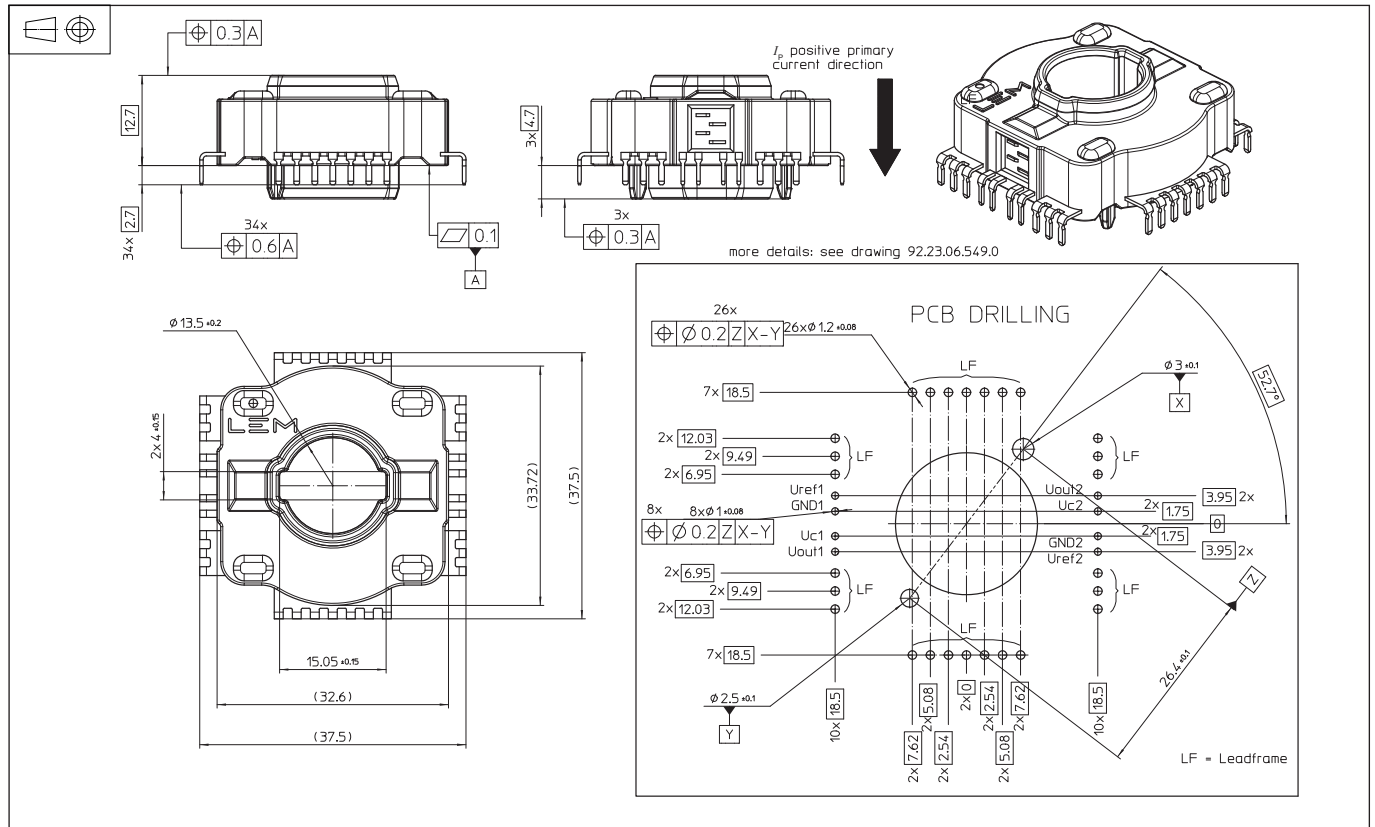


Fig. 1: Principle of the open loop transducer

Dimensions (in mm)

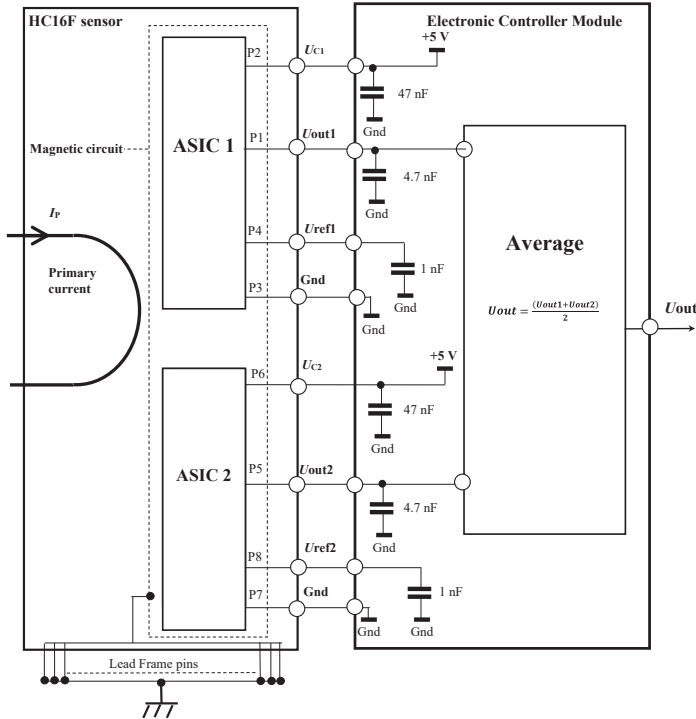
THD Version (S00)



Mechanical characteristics

- Plastic case >PPS-I-(GF + MD) 50<
- Magnetic core FeSi alloy
- Mass 29 g
- Lead frame Bronze tin plated

Electronic schematic



Remark

HC16F xxxx-S00

$U_{out} > U_0$ when I_p flows in the positive direction (see arrow on drawing).

- C_L Nominal value 4.7 nF $\pm 10\%$
- C_L is required for stabilization, EMC and ESD protection
- All the capacitors mentioned in the Electronic schematic should be mounted as close as possible to the ASIC pins
- The specifications are based on the average values of U_{out1} and U_{out2} (Computed by customer)
- For further information, please see "Applications" on page 9/12.

Absolute ratings (not operating)

| Parameter | Symbol | Unit | Specification | | | Conditions |
|--|--|-------------------|---------------|---------|-----------------------|--|
| | | | Min | Typical | Max | |
| Maximum supply voltage | $U_{C\max}$ | V | -0.5 | | 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 | $T_{A\text{st}}$ | °C | -40 | | 125 | |
| Electrostatic discharge voltage | $U_{\text{ESD HBM}}$ | kV | | | 2 | JESD 22-A 114-B Class 2 |
| Maximum admissible vibration (random) | γ_{\max} | m·s ⁻² | | | 107.3 | ISO 16750-3 § 4.1.2.5 with Temperature |
| RMS voltage for AC insulation test, 50 Hz, 1 min | U_d | kV | | | 3.6 | IEC 60664-1, PD = 2, OV III altitude 400 m |
| Creepage distance | d_{Cp} | mm | 11 | | | |
| Clearance | d_{Cl} | mm | 5 | | | |
| Comparative tracking index | CTI | | | PLC3 | | |
| Maximum output current | $I_{\text{out 1 max}}, I_{\text{out 2 max}}$ | mA | -10 | | 10 | Not operating |
| Maximum output voltage (Analog) | $U_{\text{out 1 max}}, U_{\text{out 2 max}}$ | V | -0.5 | | $U_C + 0.5 \text{ V}$ | Not operating |
| Maximum output short-circuit duration | $t_{\text{c max}}$ | s | | | 2 | |

Operating characteristics in nominal range (I_{PN})

| Parameter | Symbol | Unit | Specification | | | Conditions |
|--|--------------------------------|------------|--|---------|------|--|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Supply voltage ¹⁾ | U_C, U_{C1}, U_{C2} | V | 4.85 | 5 | 5.15 | |
| Ambient operating temperature | T_A | °C | -40 | | 125 | |
| Average of output voltages | \overline{U}_{out} | V | $\overline{U}_{out} = (U_C/5) \times (\overline{U}_O + \overline{S} \times I_P)$ | | | |
| Current consumption | I_C | mA | | 28 | 35 | @ $U_C = 5\text{ V}$ |
| Load capacitance | C_L | nF | 1 | 4.7 | 10 | |
| Output internal resistance | R_{out1}, R_{out2} | Ω | | | 10 | |
| Performance Data ¹⁾ | | | | | | |
| Ratiometricity error | ε_r | % | | ±0.3 | | |
| Average of Sensitivity error | $\overline{\varepsilon}_S$ | % | | ±0.5 | | @ $T_A = 25\text{ °C}$ (calibration error without T cycles), @ $U_C = 5\text{ V}$ |
| Average of electrical offset voltage | \overline{U}_{OE} | mV | | ±3 | | @ $T_A = 25\text{ °C}$, @ $U_C = 5\text{ V}$ |
| Average of magnetic offset voltage | \overline{U}_{OM} | mV | | ±2 | | @ $T_A = 25\text{ °C}$, after ± I_P , @ $U_C = 5\text{ V}$ |
| Average temperature coefficient of \overline{U}_{OE} | \overline{TCU}_{OEAV} | mV/K | -0.08 | | 0.08 | @ $-40\text{ °C} < T < 125\text{ °C}$, $U_C = 5\text{ V}$ |
| Average temperature coefficient of \overline{S} | \overline{TCS}_{AV} | %/K | -0.03 | | 0.03 | @ $-40\text{ °C} < T < 125\text{ °C}$, $U_C = 5\text{ V}$ |
| Average linearity error | $\overline{\varepsilon}_{LAV}$ | % I_{PM} | | ±0.5 | | Of full range I_{PM} |
| Delay time to 90 % of the final output value for I_{PN} step | t_{D90} | μs | | 2 | 4 | @ 100 A/μs, I_{PM} Without C optional (see schematic1 on page9) |
| Frequency bandwidth ²⁾ | BW | kHz | 40 | | | @ -3 dB, Without C optional |
| Peak-to-peak noise voltage | $U_{no\ pp}$ | mV | | | 15 | DC to 1 MHz |
| Phase shift | $\Delta\Phi$ | ° | -3 | | | DC to 1 kHz , Without C optional |

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:

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

The specifications are based on the average values of $U_{\text{out 1}}$ and $U_{\text{out 2}}$ (completed by the customer).

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).

HC16F 1000-S00

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | −1000 | | 1000 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 2.00 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

HC16F 1100-S00

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | −1100 | | 1100 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.82 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

HC16F 1200-S00

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | -1200 | | 1200 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.67 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

HC16F 1300-S00

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | -1300 | | 1300 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.54 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

HC16F 1400-S00

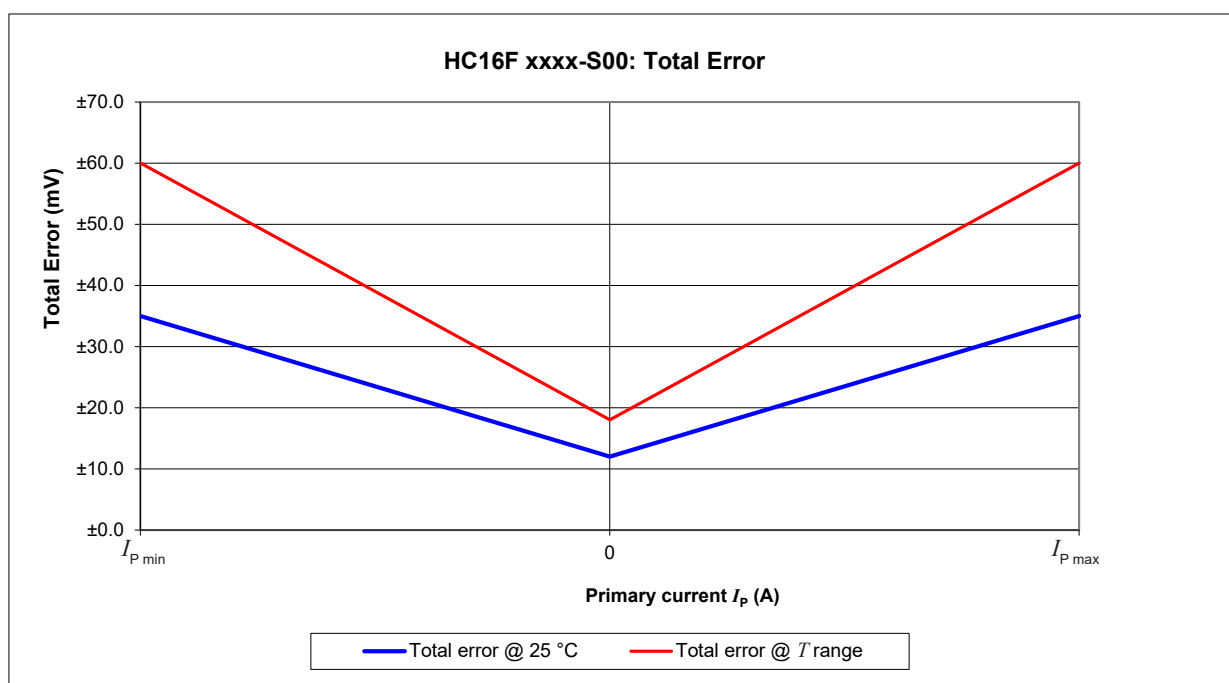
| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | −1400 | | 1400 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.43 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

HC16F 1500-S00

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | −1500 | | 1500 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.33 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

| Parameter | Symbol | Unit | Specification | | | Conditions |
|----------------------------------|------------------|------|---------------|---------|------|----------------------|
| | | | Min | Typical | Max | |
| Electrical Data | | | | | | |
| Primary current, measuring range | I_{PM} | A | −1600 | | 1600 | |
| Average of sensitivities | S_1, S_2 | mV/A | | 1.25 | | @ $U_c = 5\text{ V}$ |
| | \overline{S} | | | | | |
| Average of offset voltages | $\overline{U_o}$ | V | | 2.5 | | @ $U_c = 5\text{ V}$ |

Total error of U_{out} (Average value)

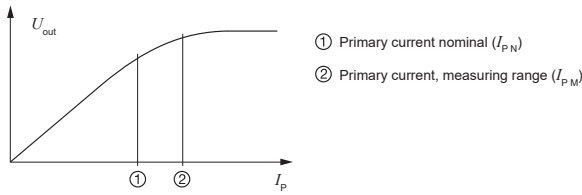


| Primary current I_P | Total error @ 25 °C | | Total error @ T range | |
|-----------------------|---------------------|-----------|-----------------------|-------|
| | in A | in mV | in mV | in % |
| $I_{P\ min}$ | | ±35.0 (*) | ±60.0 | ±3.00 |
| 0 | | ±12.0 | ±18.0 | ±0.90 |
| $I_{P\ max}$ | | ±35.0 (*) | ±60.0 | ±3.00 |

(*): ±45 mV after High T °C High Humidity (1000 h 85 °C / 85 % RH).

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 $-\text{sigma}$ and $+\text{sigma}$ for a normal distribution. Typical, minimum and maximum values are determined during the initial characterization of a product.

Output noise voltage:

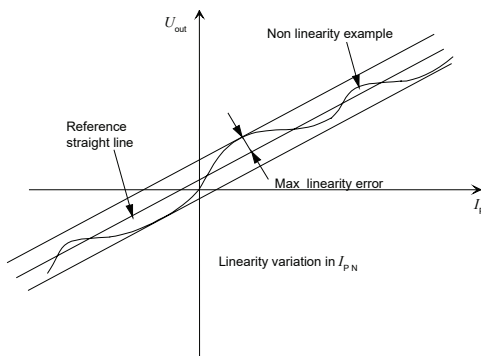
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

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.

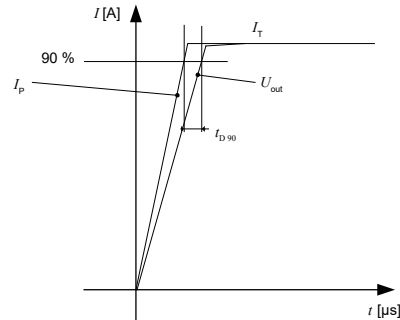
Linearity:

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_{D90} :

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

$\bar{U}_{out} = f(I_p)$, it must establish the relation:

$$\bar{U}_{out}(I_p) = U_C / 5 (\bar{S} \times I_p + \bar{U}_O)$$

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:

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

The offset drift $\overline{TCI}_{OE \Delta V}$ 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:
 $S_T = (\text{Sensitivity max} - \text{Sensitivity min}) / \text{Sensitivity at } 25^\circ\text{C}$.

The sensitivity drift $\overline{TCS}_{\Delta V}$ 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.

Environmental test specifications:

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

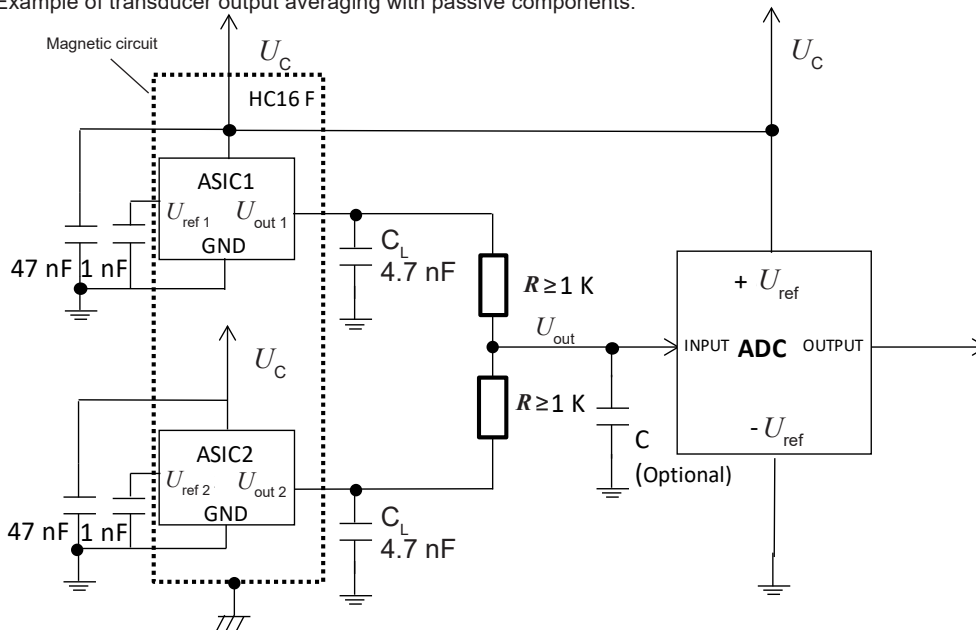
| Name | Standard | Conditions |
|--|---|--|
| ELECTRICAL TESTS | | |
| Phase shift, frequency bandwidth | LEM Procedure | 100 Hz to 100 kHz, 100 A peak |
| Noise measurement | LEM Procedure | Sweep from DC to 1 MHz |
| Delay time di/dt | LEM Procedure | 100 A/ μ s $I_{pulse} = I_{p\ max}$ |
| du/dt | LEM Procedure | 5 ;10 ; 20 kV/ μ s $U = 1000\ V$ |
| RMS voltage for AC insulation test | IEC 60664 part 1 | 3.6 kV AC / 1 min / 50 Hz ($I < 0.1\ mA$) |
| Insulation resistance test | ISO 16750-2 (2010) | 500 V DC time = 60 s $R_{INS} \geq 500\ M\Omega\ Min$ |
| ENVIRONMENTAL TESTS | | |
| High $T^{\circ}C$ High Humidity Electrical connection | JESD 22-A 101 (03/2009) | 1000 h 85 $^{\circ}C$ / 85 % RH $U_c = 5\ V\ DC, I_p = 0\ A$ |
| Thermal Cycle Test (Simplified profile) | IEC 60068-2-14 Test Nb (01/2009) | $T_{min} -40\ ^{\circ}C, T_{max} = +125\ ^{\circ}C$ 1 cycle = 480 min, 30 cycles |
| Thermal Shock | ISO 16750-4 § 5.3.2 (04/2010) | 1000 cycles 30 min "-40 $^{\circ}C$ " // 30 min "+85 $^{\circ}C$ " U_c not connected $I_p = 0\ A$ |
| High $T^{\circ}C$ Storage | IEC 60068-2-2 Bd (07/2007) | 125 $^{\circ}C$ for 1000 h U_c not connected $I_p = 0\ A$ |
| Low $T^{\circ}C$ Storage | IEC 60068-2-1 Ad (03/2007) | -40 $^{\circ}C$ for 240 h U_c not connected $I_p = 0\ A$ |
| Mechanical Shock | ISO 16750-3 § 4.2.2 (12/2012) | 500 ms/s ² , 6 ms Half Sine @ 25 $^{\circ}C$ 10 shocks of each direction U_c not connected $I_p = 0\ A$ |
| Random Vibration in $T^{\circ}C$ profile 1 | ISO 16750-3 § 4.1.2.5 IEC 60068-2-27 (02/2008) | Vibration profile E- For Unsprung masses (chassis) in $T^{\circ}C$: 8 h/axis, 107.3 m/s ² RMS |
| Random Vibration in $T^{\circ}C$ profile 2 | ISO 16750-3 § 4.1.2.2.3 IEC 60068-2-27 (02/2008) | Vibration profile: Passenger car, Gearbox in $T^{\circ}C$: 22 h/axis, 96.6 m/s ² RMS |
| EMC TESTS | | |
| Radiated Emission Absorber Lined Shielded Enclosure (ALSE) | CISPR 25 (2008) Table 9 - Class 5 | $f = 150\ kHz$ to 2.5 GHz Criteria A acceptance @ 5 % of 2 V |
| Radiated Immunity Bulk Current Injection (BCI) | GWM 3097 § 3.4.1 (2015) | Level : GMW 3097 (2015) § 3.4.1 Table 13 - Level 1 (100 mA) (ISO 11452 - 4 (2011) Annex E Table E 1 Level 2) $f = 1\ MHz$ to 400 MHz , Criteria A acceptance @ 5 % of 2 V |
| Radiated Immunity Anechoic chamber | GWM 3097 § 3.4.2 (2015) | Level : GMW 3097 (2015) § 3.4.2 Table 14 - Level 2 (100 V/m) $f = 400\ MHz$ 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 % of 2 V |
| ESD Test | GWM 3097 § 3.6.3 (2015) | Level : GMW 3097 (2015) § 3.6.3.3 Table 28 Contact discharges: $\pm 4, \pm 6\ kV$; Air discharges: $\pm 8\ kV$ $U_c = NO$ power supply (\equiv unconnected), Criteria B |
| Free Fall | ISO 16750-3 § 4.3 (12/2012) | Height = 1 m Concrete floor 3 axis, 2 directions by axis, 1 sample by axis |

Applications:

Customers have to compute the Average value of U_{out1} and U_{out2} . This could be done by a resistive bridge as showing in schematic 1 or any other means defined by customers (for example with a micro-controller as showing in schematic 2).

Schematic 1:

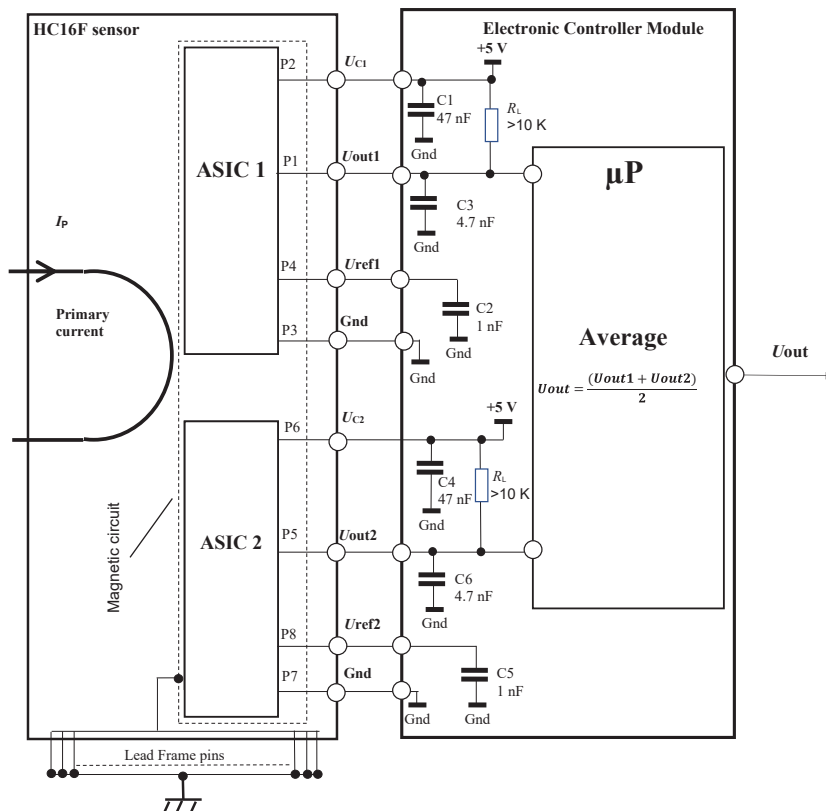
Example of transducer output averaging with passive components.



Resistance: $R \geq 1 K$, 1 %, 100 ppm/ °C, 100 mW, 75 V, -40 ... 155 °C, 0603 (or better)

Schematic 2:

Example of transducer averaging with a micro-controller.

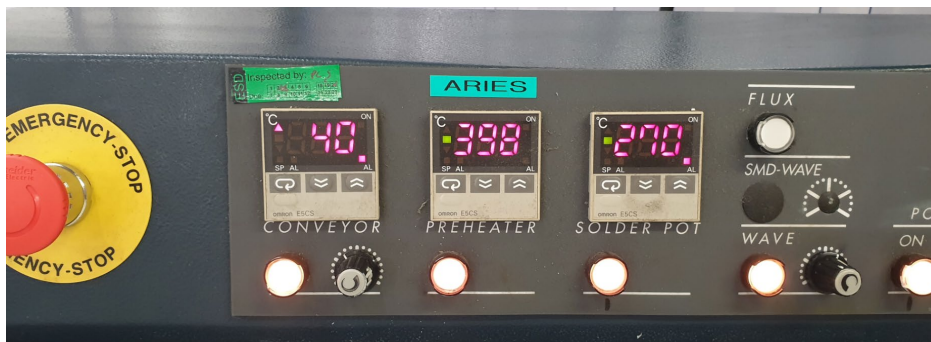


Soldering recommendation:

LEM recommends to use the following equipment parameters for the soldering of HC16F xxxx-S00 family. Nevertheless, customer is remaining responsible for final solder joints validation as it's deeply depending on many parameters not controlled by LEM.

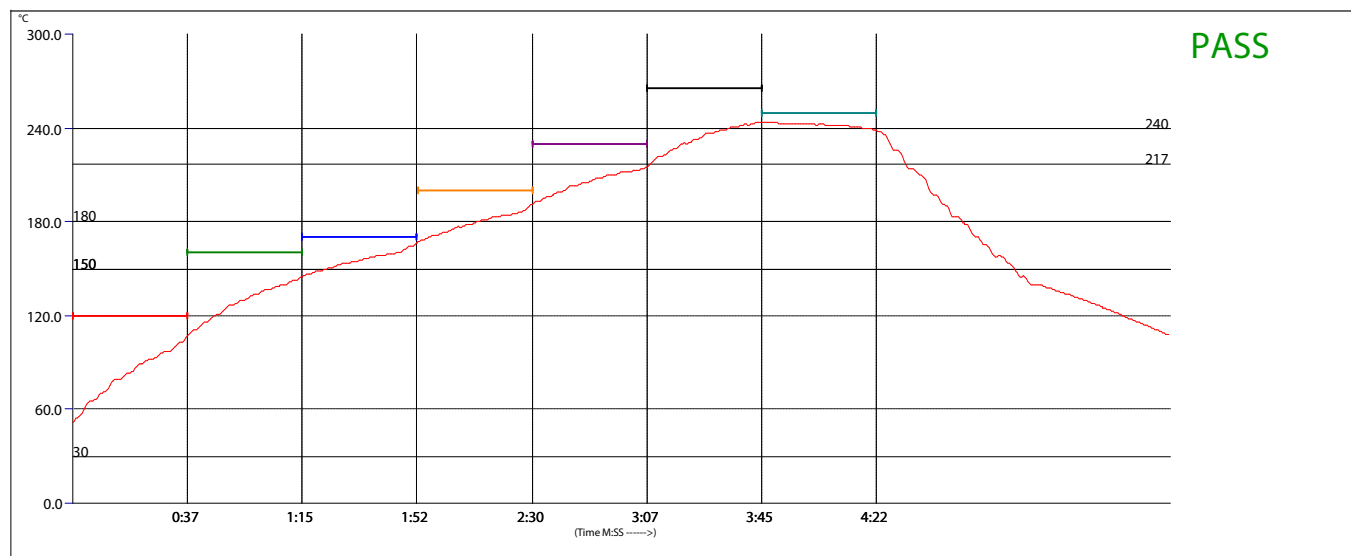
1. Wave soldering Thru Holes Device (THD) for HC16F xxxx-S00:

- Machine ARIES
- SN 100C lead free solder
- Flux FS 110 (of Sodiflux)
- LEM recommended - PCB layout : according to gerber file of PCB 2569-00
- Temperature profile as below:
Conveyor speed = 40 cm/min; Preheater = 400 °C; Solder pot = 270 °C.



2. Reflow soldering THD (by Pin in Paste for HC16F xxx-S00) :

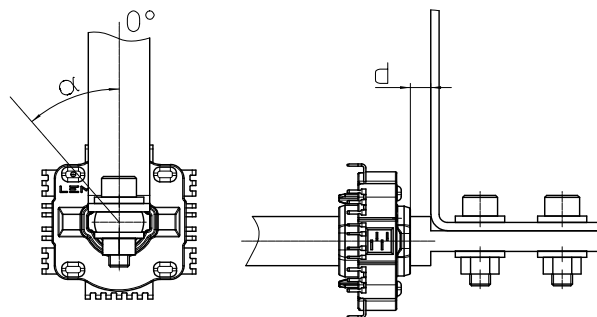
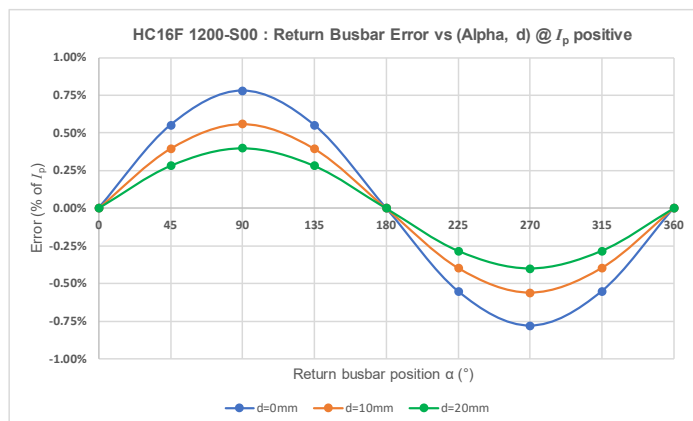
- Machine HELLER 1707 MK3
- Solder Paste Ecorel Free 305-16T4
- Solder paste thickness 200 µm
- LEM recommended - PCB layout : according to gerber file of PCB 2569-00 for THD version
- Temperature profile as below:



| Process parameters | | | | Consign of zones (Machine Heller 1707 MK III) | | | | | | | |
|-------------------------------|--------------------------------|-----|---------|---|-----|-----|-----|-----|-----|-----|-----|
| Type of alloy (Solder paste) | INVENTEC ECOREL FREE 305-16 T4 | | | | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 |
| | Min | Max | Units | Upper Heat (°C) | 120 | 160 | 170 | 200 | 230 | 265 | 250 |
| Preheat time (150 °C -180 °C) | 30 | 130 | seconds | Lower heat (°C) | 120 | 160 | 170 | 200 | 230 | 265 | 250 |
| Liquidus time (r °C > 217 °C) | 45 | 100 | seconds | | | | | | | | |
| Pick T °C | 230 | 250 | °C | Speed (cm/min) | 40 | | | | | | |

Recommendation on Return busbar's position

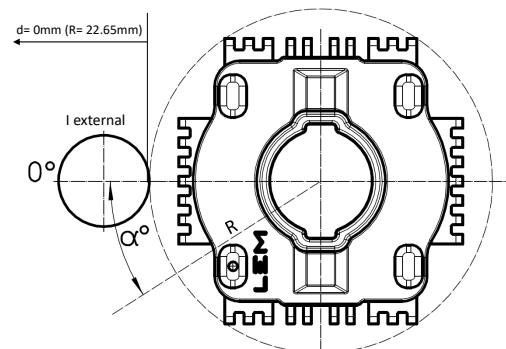
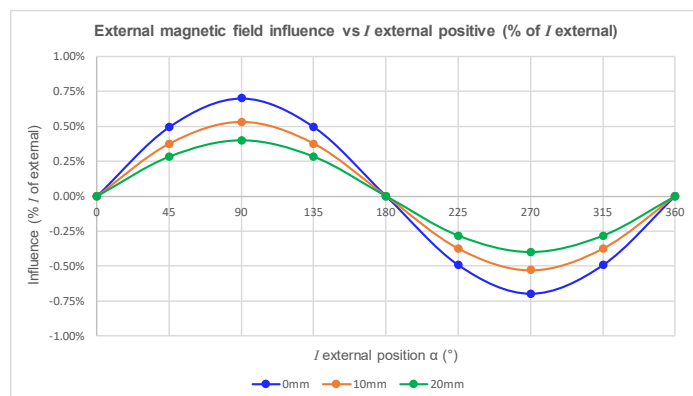
Busbar return influence @ I_p : the positive current direction as defined on page 2.
The best position $\alpha = 0^\circ$ and 180° .



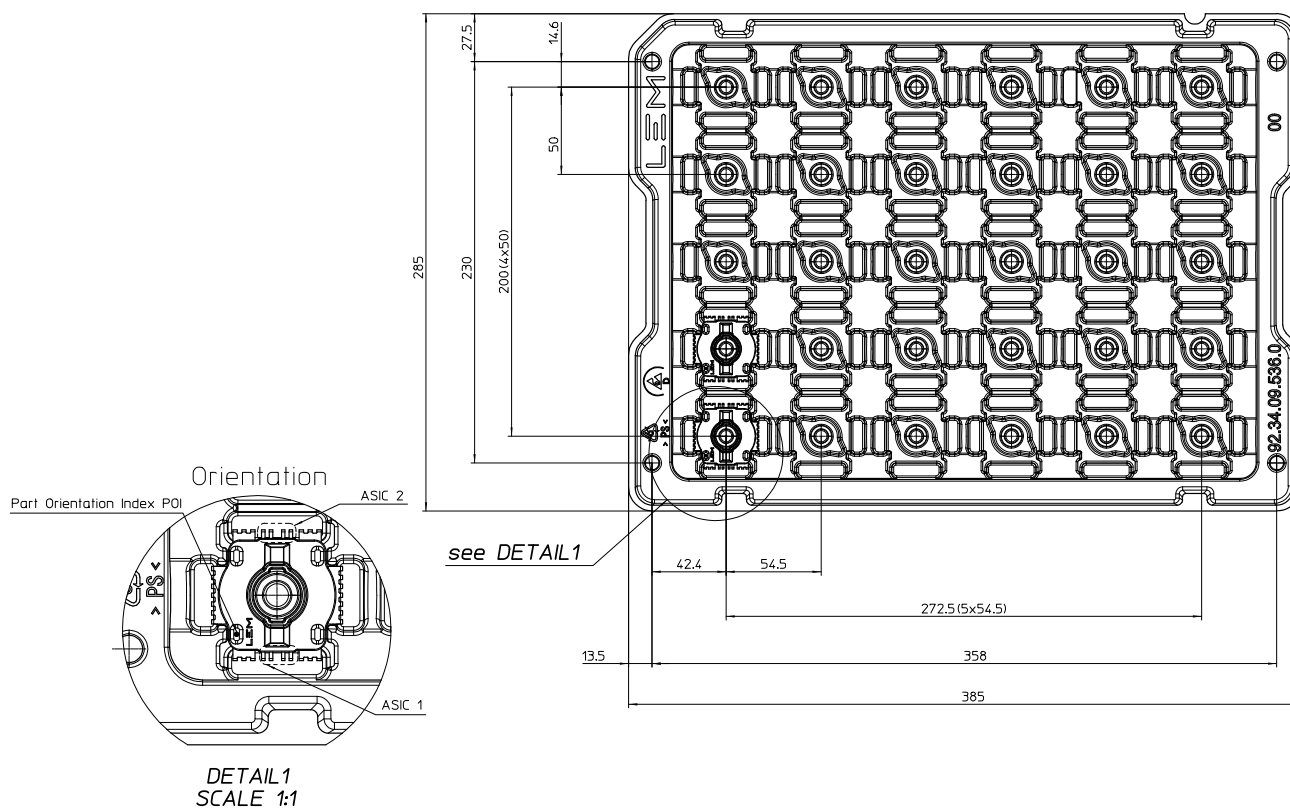
The return busbar error is the relative error generated by the return busbar in comparison with the straight busbar.

Recommendation – External magnetic sources position

External magnetic field influence @ I_{external} : the positive current direction as defined on page 2.
The best position $\alpha = 0^\circ$ and 180° .



Tray packaging of transducer HC16F



Notes : For the dimensions of the transducers HC16F, please see page 2/12
Advice insertion force of 4N minimum for an automatic placement on the PCBA.