Integrated Current Sensor FHS AH 600

Definition

The FHS AH field sensor is a contact-less, open loop surface mounted device based on the Hall effect principle. The device uses an Integrated Magnetic Circuit (IMC) combined with improved sensitivity, offset and temperature stress compensation allowing high accuracy and low-noise current sensing. With 160 kHz bandwidth and fast delay time < 2 µs, the FHS AH sensor is highly suitable for DC, AC, pulsed and mixed current measurements. Contact-less current sensing solution allows no additional power losses and high dielectric insulation between the primary circuit and transducer electronics. By using an Integrated Magnetic Circuit (IMC), the FHS AH removes the need for an external magnetic core, offers flexibility in compact design and makes it the perfect solution to measure current flowing through a conductor such as a PCB track.

Main features & advantages

- Hall effect current sensor with Integrated Magnetic Concentrator (IMC)
- Magnetic field measurement range ±3.3 mT
- Supply voltage 5 V
- Low power consumption
- Operating temperature range : −40 ... 125 °C
- High bandwidth: 160 kHz
- Excellent linearity < 0.5 % Full Scale
- Sensitivity error < 1 % from −40 ... 125 °C
- Insulated current measurement
- Small footprint with standard SOIC8 surface mount PCB
- Low cost, Small size
- Internal reference voltage.

Typical applications

- Small drives
- BMS
- Motor control
- UPS
- HVAC
- White goods
- PCB track current sensing.

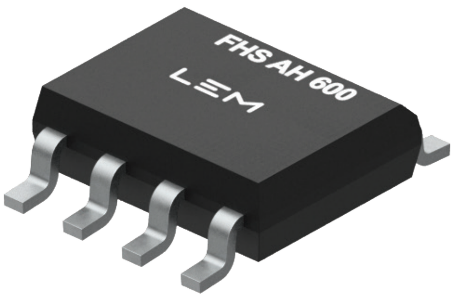

Figure 1: FHS AH package - SOIC-8

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Application circuit and pinout

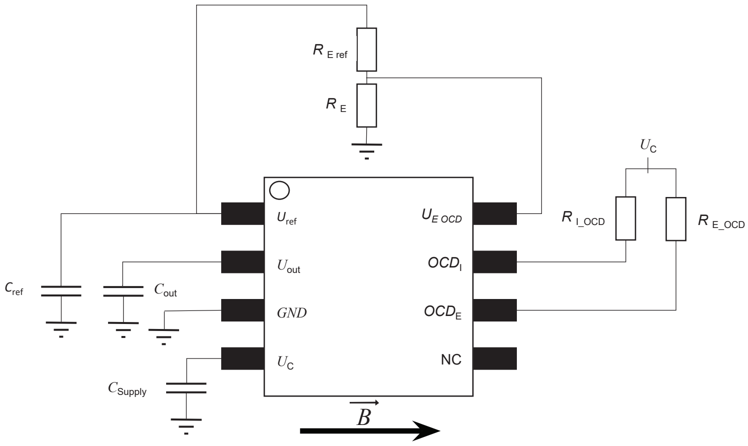

Figure 2: Application circuit

Table 1: Pin definition

Pin#	Name	Description
1	U_{ref}	Rerence voltage
2	U_{out}	Output voltage
3	GND	Ground terminal
4	U_C	Supply voltage
5	NC	Not connected or GND
6	OCD_E	External OCD
7	OCD_I	Internal OCD
8	$U_{E\ OCD}$	External OCD threshold voltage terminal

Polarity

$U_{out} - U_{ref}$ is positive following the direction of the arrow.

Table 2: External circuit components

External circuit example#	Unit	Value	Comment
C_{supply}	nF	47	< 100
C_{out}	nF	4.7	< 6
C_{ref}	nF	4.7	
$R_{I\ OCD}$	kΩ	4.7	< 50
$R_{E\ OCD}$	kΩ	4.7	< 50
R_E	kΩ	100	
$R_{E\ ref}$	kΩ	100	

C_{supply}, C_{out} and C_{ref} should be mounted as close as to the pins.

Ideally, $R_{E\ ref} + R_E$ should have a value around 200 kΩ due to current limitation on U_{ref}.

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Absolute maximum ratings

Parameter	Symbol	Unit	Rating
Ambient operating temperature	T_A	°C	−40 ... +125
Ambient storage temperature	$T_{A\ st}$	°C	−55 ... +165
Maximum junction temperature	$T_{J\ max}$	°C	165
Output sink current		mA	−50
Output source current		mA	25
Magnetic flux density	B_{max}	T	±3

Absolute maximum ratings apply at 25 °C unless otherwise noted.
Stresses above these ratings may cause permanent damage.
Exposure to absolute maximum ratings for extented periods may degrade reliability.

Environmental and mechanical characteristics

Parameter	Symbol	Unit	Value
Maximum supply voltage	$U_{C\ max}$	V	8
Electrostatic discharge voltage (HMB-Human Body Model)	$U_{ESD\ HBM}$	kV	2
Mass	m	g	0.08

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Electrical data

At T_A = 35 °C, U_C = +5 V, R_L = 100 kΩ unless otherwise noted (see Definition of typical, minimum and maximum values paragraph).

Parameter	Symbol	Unit	Min	Typ	Max	Conditions
DC supply voltage	U_C	V	4.5	5	5.5	−40 °C ... 125 C
Current consumption	I_C	mA	12	14	19	−40 °C ... 125 C; without R_L
Magnetic flux density measuring range	B_M	mT		±3.3		U_C > 4.6 V
Output voltage in a flux density B	U_{out}	V	0.5		4.5	$U_{ref} + U_{O\,E} + (S_N \times B)$ −40 °C ... 125 C
Linearity error 0 … B_M	ε_L	% of B_M	−0.5		0.5	
Nominal sensitivity	S_N	mV/mT		600		
Sensitivity error	ε_S	%	−1	±0.5	1	
Temperature coefficient of S	TCS	ppm/K	−200		200	−40 °C ... 125 °C, referred to 35 °C
Lifetime sensitivity drift	S_L	%		±1.5		
Internal reference voltage @ B = 0 T	$U_{I\,ref}$	V	2.48	2.5	2.52	
Output internal resistance of U_{ref}	$R_{I\,ref}$	Ω	120	200	333	−40 ° C... +125 °C
Electrical offset voltage	$U_{O\,E}$	mV	−10		10	$U_{out} - U_{ref}$
Lifetime offset drift	$U_{O\,E\,L}$	mV		±15		$U_{out} - U_{ref}$
Remanent field/Magnetic offset	$U_{O\,M}$	mV	−9		9	After $\pm B_M$, on FS
Temperature coefficient of U_{ref}	TCU_{ref}	ppm/K	−150		150	−40 ° C ... +125 °C; referred to 35 °C
Temperature coefficient of $U_{O\,E}$	$TCU_{O\,E}$	mV/K	−0.1		0.1	−40 ° C... +125 °C; referred to 35 °C
Output internal resistance of U_{out}	R_{out}	Ω			5	DC
Noise voltage spectral density	U_{no}	µV/Hz $^{1/2}$		17		
Delay time to 10 % of the final output value for B_N step	$t_{D\,10}$	µs			1.6	Input signal rise time 2 µs
Delay time to 90 % of the final output value for B_N step	$t_{D\,90}$	µs			1.4	Input signal rise time 2 µs
Frequency bandwidth	BW	kHz		160		@ −3 dB
				100		@ −1 dB

Definition of typical, minimum and maximum values

Unless otherwise stated (e.g. “100 % tested”), the LEM definition “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. The definition of “typical” is that the probability for values of samples to lie in this interval is 68.27 %, corresponding to an interval between −sigma and +sigma for a normal distribution.
Typical, maximal and minimal values are determined during the initial characterization of the product.

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Overcurrent detection (OCD)

Overcurrent detection is a feature included on FHS AH product in order to detect high peaks of currents happening during operation.
Two overcurrent detection types are included in this product: Internal OCD and External OCD.

At T_A = 35 °C, U_C = +5 V, R_L = 100 kΩ unless otherwise noted.

Parameter	Symbol	Unit	Min	Typ	Max	Comment
INTERNAL OCD						
Internal OCD detection threshold	$B_{\text{I OCD Th}}$	mT		4.8		1.45 × B_M, −40 ° C... +125 °C
Internal OCD threshold error	$\varepsilon_{\text{I OCD Th}}$	%	−10		10	Referred to B @ $U_{\text{out}} - U_{\text{ref}}$ = 0.8 V
Internal OCD output on resistance	$R_{\text{on I OCD}}$	Ω	70	95	150	Open drain output, active low
Internal OCD output hold time	$t_{\text{hold I OCD}}$	µs	7	10	14	
Internal OCD delay time	$t_{\text{D I OCD}}$	µs	1.3		2.1	
EXTERNAL OCD						
External OCD detection threshold	$B_{\text{E OCD Th}}$	T				Calculated from external resistors - see formula below
External OCD threshold error	$\varepsilon_{\text{E OCD Th}}$	%	−5		5	Referred to B @ $U_{\text{out}} - U_{\text{ref}}$ = 0.8 V
External OCD output on resistance	$R_{\text{on E OCD}}$	Ω	35	200	280	Open drain output, active low
External OCD output hold time	$t_{\text{hold E OCD}}$	µs		10		
External OCD delay time	$t_{\text{D E OCD}}$	µs		10		

Setting External OCD threshold:

The external Over-Current-Detection threshold is directly set by user with the external resistors R_E and $R_{\text{E ref}}$ using the following formula:

$$U_{\text{E OCD}} = \frac{R_E}{R_E + R_{\text{E ref}}} \cdot U_{\text{ref}}$$

The corresponding sensed magnetic field threshold is defined by the external voltage threshold and device sensitivity using the following formula:

$$B_{\text{E OCD}} = \frac{U_{\text{ref}} - U_{\text{E OCD}}}{S_N} \quad \text{with } 0.5 < U_{\text{E OCD}} < U_{\text{ref}} - 0.5$$

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Terms and definitions

Sensitivity and linearity

To measure sensitivity and linearity, the primary current (DC) is cycled from 0 to B_M, then to $-B_M$ and back to 0 (equally spaced B_M /10 steps).
The sensitivity S is defined as the slope of the linear regression line for a cycle between $\pm B_M$.

The linearity error ε_L is the maximum positive or negative difference between the measured points and the linear regression line, expressed in % of B_M.

Thermal coefficient of Sensitivity

$$TCS(T) = \left(\frac{\varepsilon_{S \text{ at } T} - \varepsilon_{S \text{ at RT}}}{T - \text{RT}} \right) \times 10^4 \text{ ppm/K}$$

Thermal coefficient of U_{ref}

$$TCU_{\text{ref}}(T) = \left(\frac{U_{\text{ref at } T} - U_{\text{ref at RT}}}{U_{\text{ref at RT}}} \right) \times \frac{1}{(T - \text{RT})} \times 10^6 \text{ ppm/K}$$

RT: Room Temperature
T: temperature which TCS is calculated.

Delay times

The delay time $t_{D\,10}$ @ 10 % and the delay time $t_{D\,90}$ @ 90 % with respect to the primary are shown in the next figure.
They are measured at nominal cuurent with a current rise time of 2 µs.

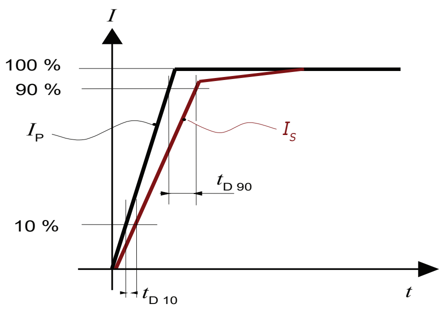

Figure 3: Delay time $t_{D\,10}$ @ 10 % and delay time $t_{D\,90}$ @ 90 %

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Internal OCD behavior

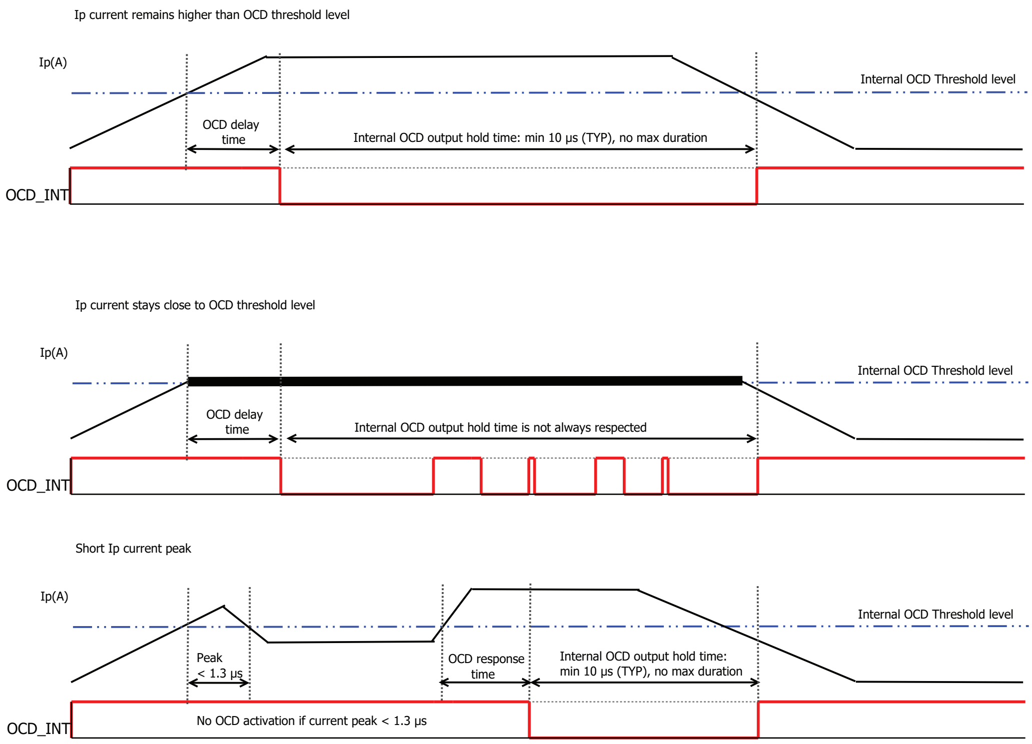

Figure 4: Internal OCD behaviour

External OCD behavior

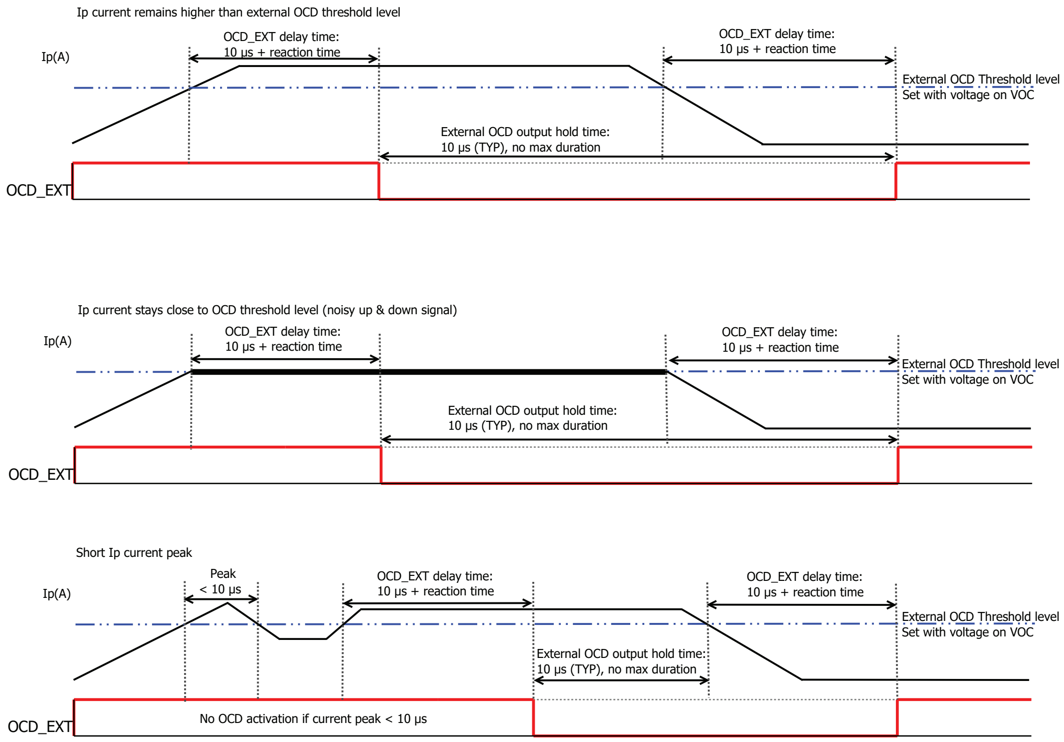

Figure 5: External OCD behaviour

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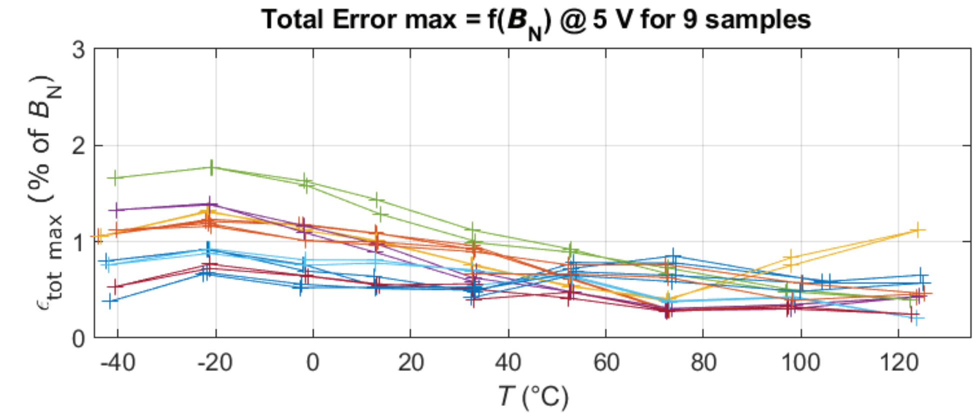
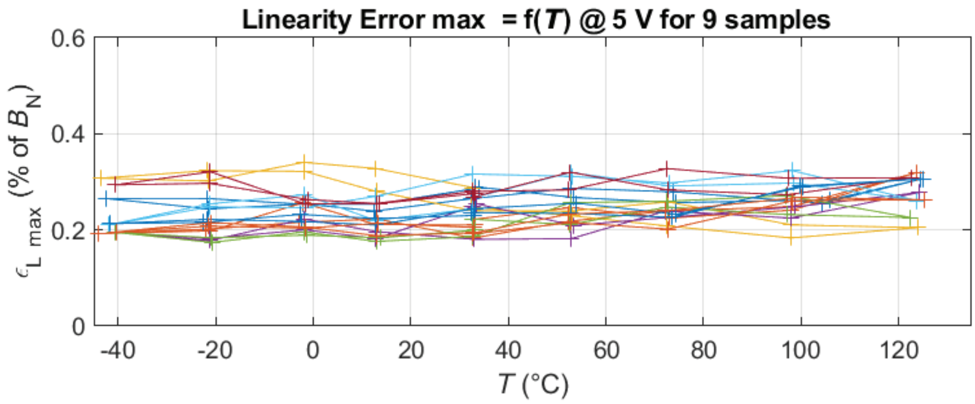
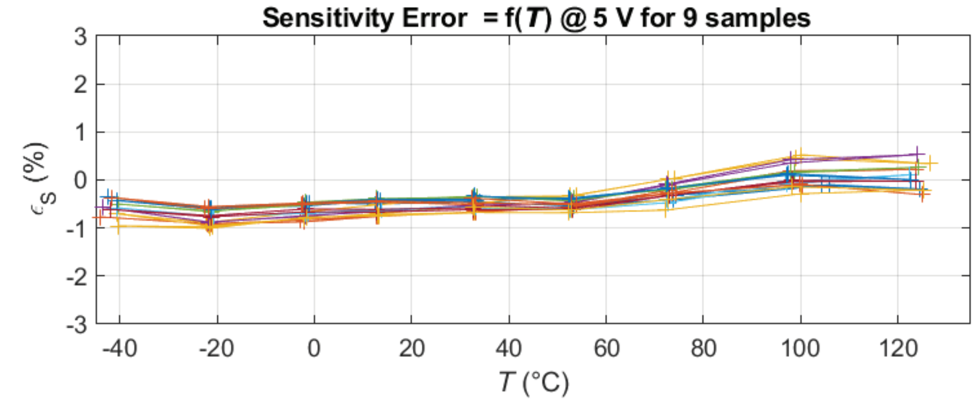
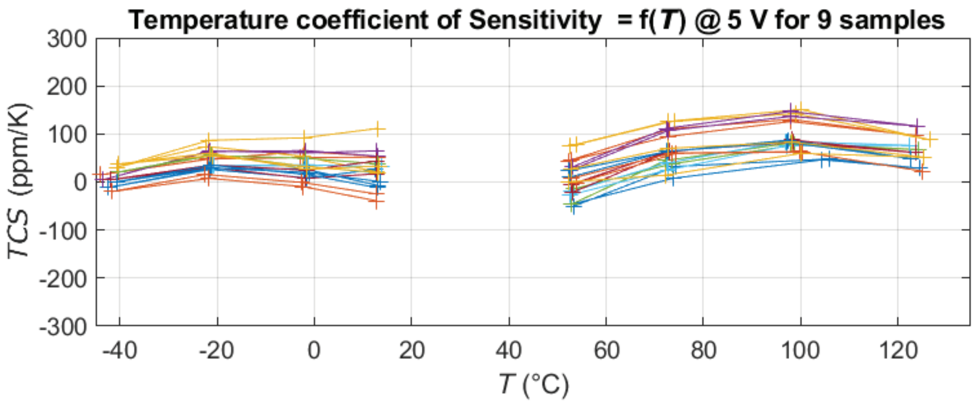
Accuracy









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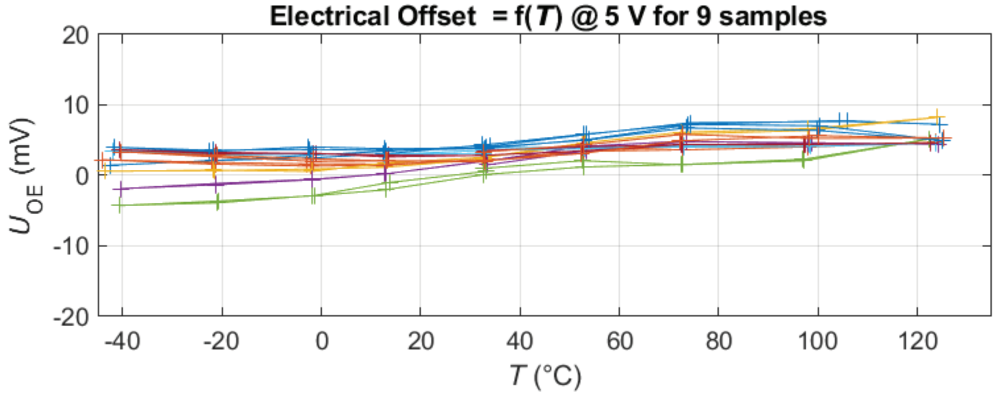
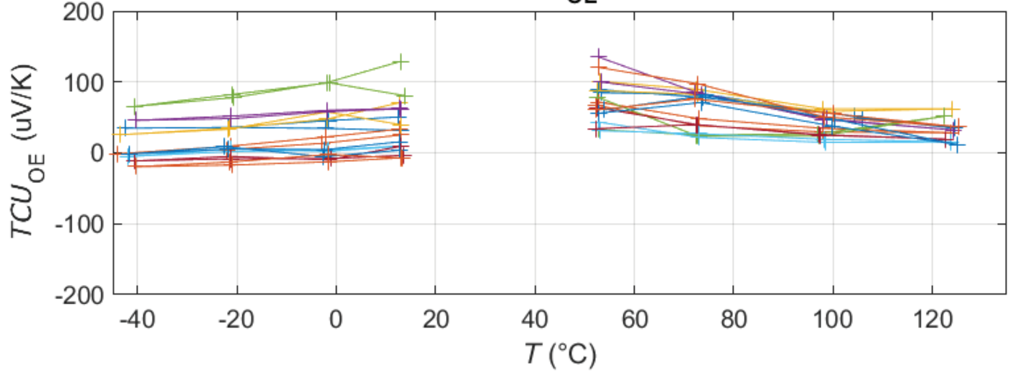
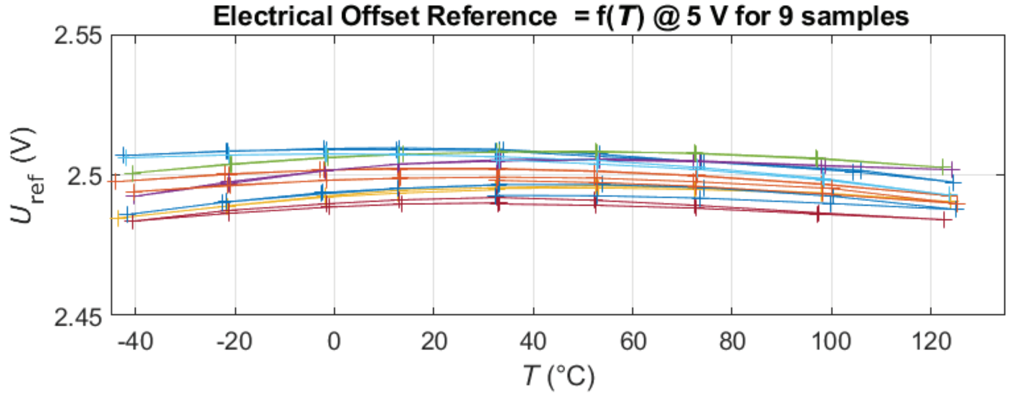
Electrical Offset = f(*T*) @ 5 V for 9 samples



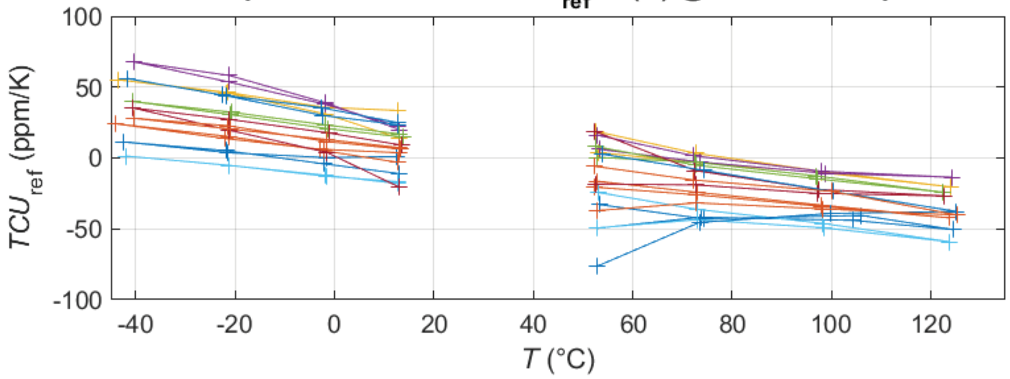
Temperature Coefficient of U_{OE} = f(*T*) @ 5 V for 9 samples



Electrical Offset Reference = f(*T*) @ 5 V for 9 samples



Temperature Coefficient of U_{ref} = f(*T*) @ 5 V for 9 samples



Noise

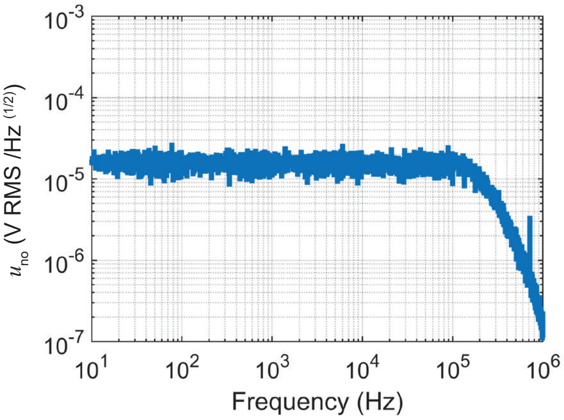


Figure 6: Noise voltage spectral density

Frequency response

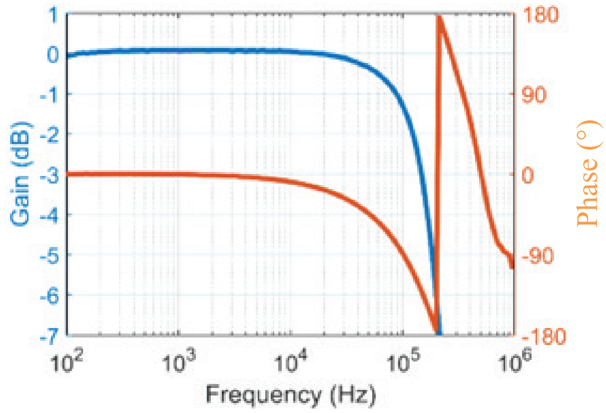
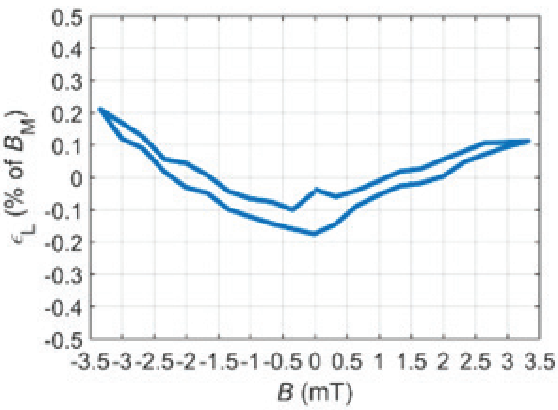
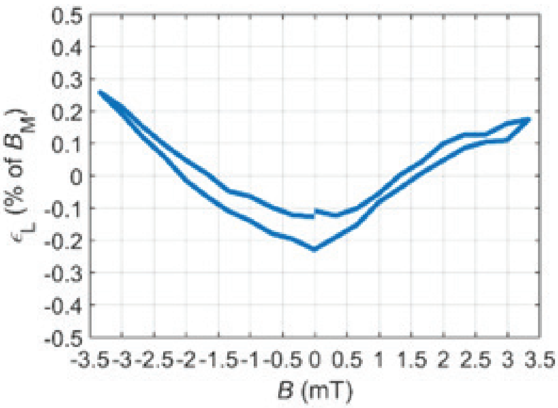


Figure 7: Gain and phase over frequency

Linearity





Figures 8, 9: Linearity error @ 35 °C and @ 125 °C

d*i*/d*t*

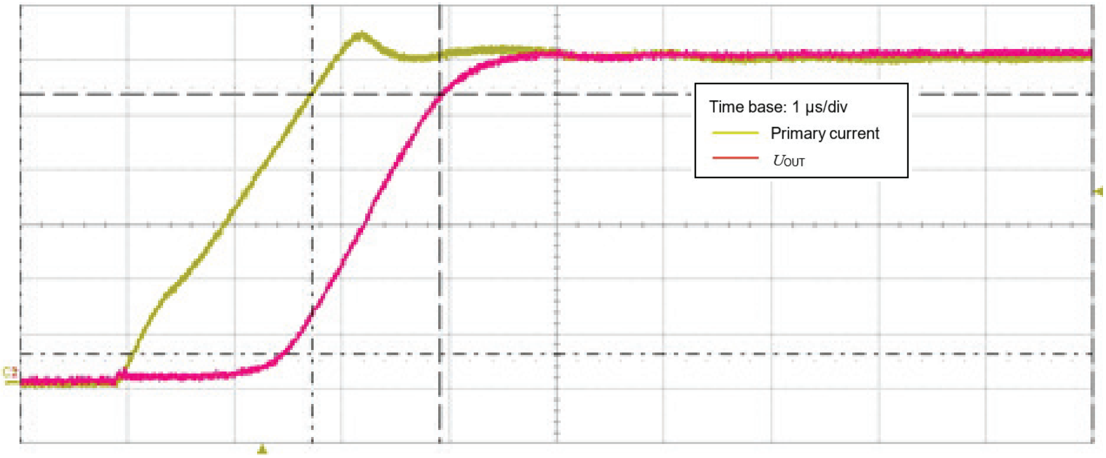


Figure 10: delay time to current step (d*i*/d*t*)

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Application information

Basic operation: example with a long thin conductor

FHS AH is a galvanically insulated current transducer.
It senses the magnetic field generated by the measured current and transforms it into an output voltage.
If the current is bidirectional, FHS AH will sense the polarity of the magnetic field and generate a positive or negative output voltage relative to the reference voltage.

A simple case is presented which illustrates the current to magnetic field and then to output voltage conversion.

A current flowing in a long thin conductor generates a flux density around it: $B(T) = \frac{\mu_0}{2\pi} \cdot \frac{I_P}{r}$ T

With:

I_P the current to be measured (A)
r the distance from the center of the wire (m)
µ0 the permeability of vacuum (physical constant, µ0 = 4.π. 10-7 (H/m)

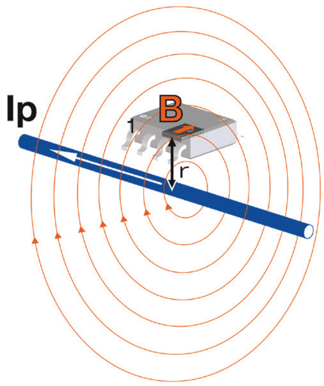

Figure 11: FHS AH orientation to measure the magnetic field generated by a current along a conductor

If FHS AH is now placed in the vicinity of the conductor (with its sensitivity direction colinear to the flux density B), it will sense the flux density and the output voltage will be:

$$U_{out} = S_N \cdot B = S_N \cdot \frac{\mu_0}{2\pi} \cdot \frac{I_P}{r} = 1.2 \cdot 10^{-4} \cdot \frac{I_P}{r} \text{ V}$$

where S_N is the FHS AH sensitivity (600 V/T).

The transducer sensitivity to current is therefore:

$$S = \frac{U_{out}}{I_P} = \frac{1.2 \cdot 10^{-4}}{r} \text{ V/A}$$

The next graph shows how the output voltage decreases when r increases.

Note: that the sensitivity also depends on the primary conductor shape.

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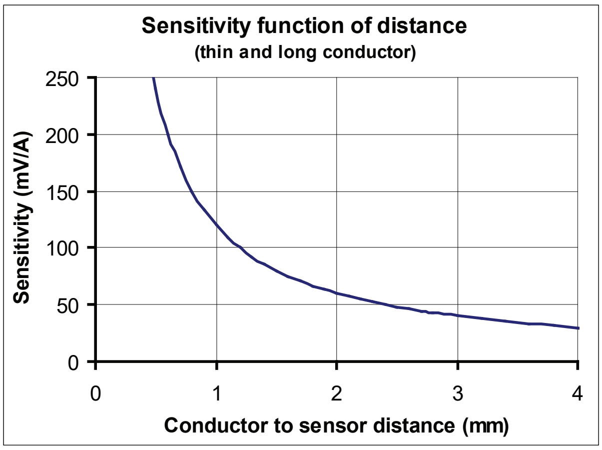

Figure 12: Sensitivity versus the distance between the conductor and the FHS AH sensing elements

The example above is of limited practical use as most conductors are not round and thin but explains the principles of FHS AH operation.
The measuring range limit ($I_{P\,M}$) is reached when the output voltage ($U_{out} - U_{ref}$) reaches 2 V.
This limit is due to electrical saturation of the output amplifier.
The input current or field may be increased above this limit without risk for the circuit.
Recovery will occur without additional delay (same delay time as usual).
The maximum current that can be continuously applied to the sensor ($I_{P\,M}$) is only limited by the primary conductor carrying capacity.

Single track on PCB

The main practical configuration for FHS AH is to measure current flowing directly through a PCB track (single or multi-layers), offering the following advantages:

- Insulation is guaranteed by PCB design. Very high insulation can be achieved by placing the primary (current carrying) track on the opposite side of the PCB.
- Cost effective solution
- Wide input current range (up to 100 A)
- Compact solution
- No added power losses
- No change on current track impedance

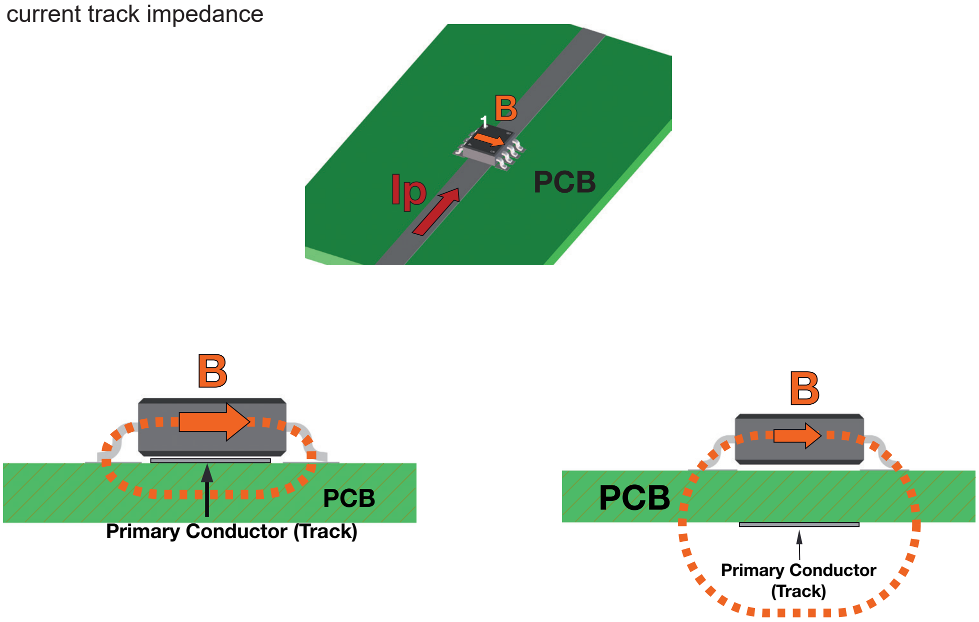

Figure 13: Principle of FHS AH used to measure current in a PCB track

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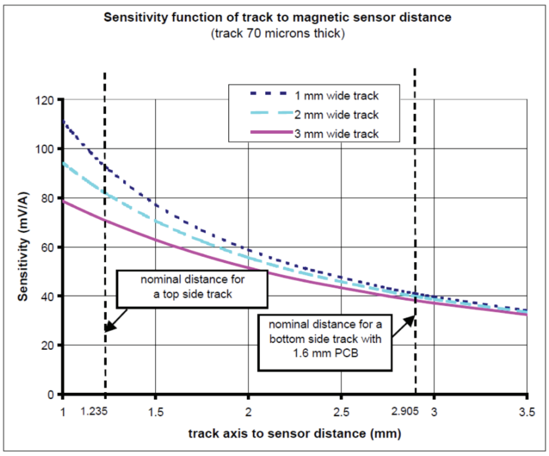


Figure 14: Sensitivity versus track width and versus distance between the track and the FHS AH sensing elements (TBC).

The sensitivity depends on the track width and distance, as shown in above figure.

The maximum current that can be safely applied continuously is determined by the temperature rise of the track.
The use of a track with varying width gives the best combination of sensitivity and track temperature rise.

Multi-turns
For low currents (under 10 A), it is advisable to make several turns with the primary track to increase the magnetic field generated by the primary current.

Busbar
For very large currents (> 50 A), FHS AH can be used to measure the current flowing in a busbar.
The position of FHS AH relatively to the conductor has to be stable to avoid sensitivity variations.

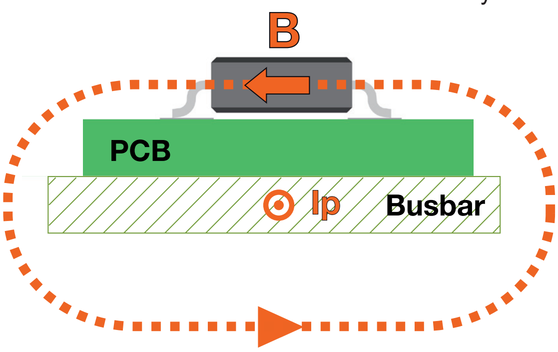
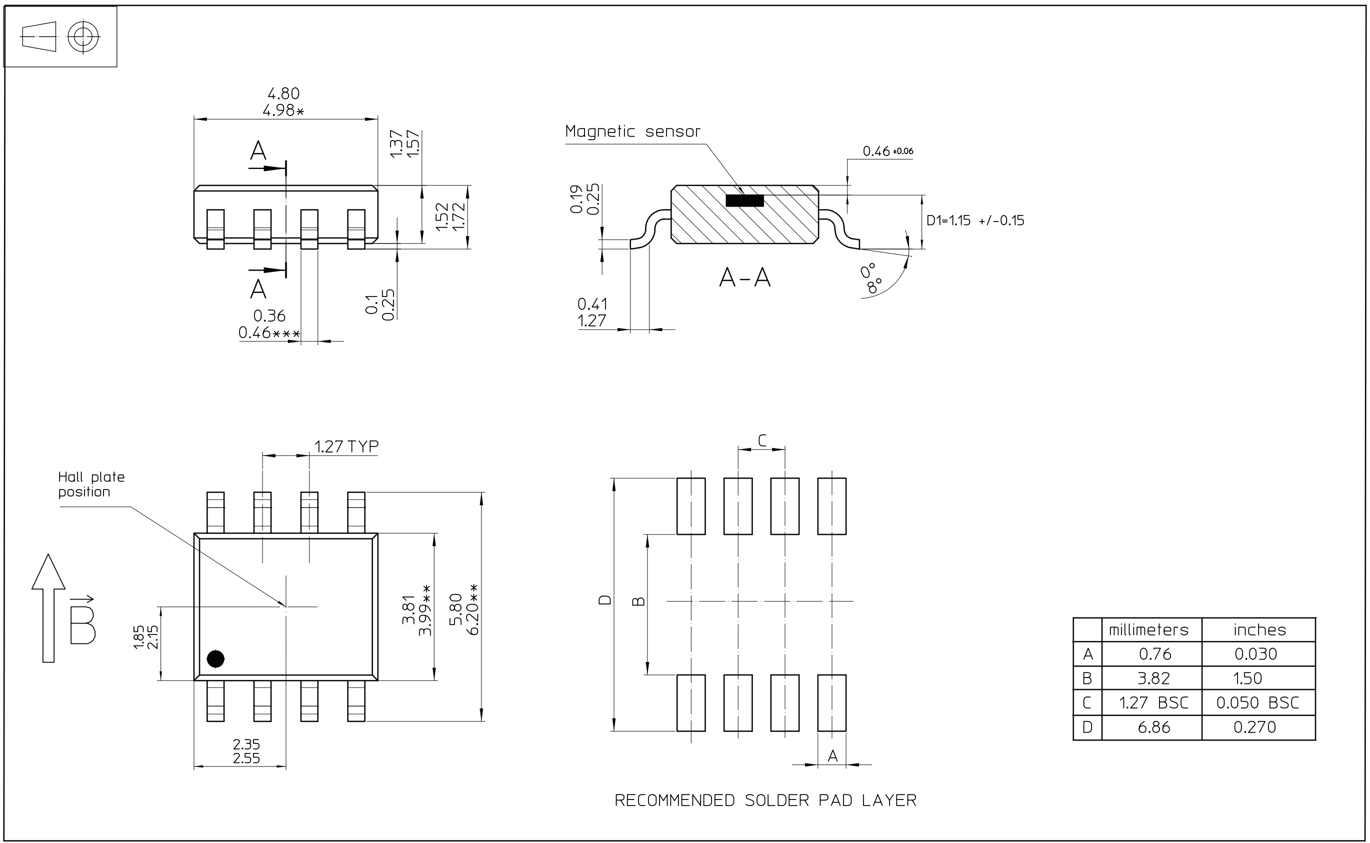


Figure 15: Example with busbar

Accuracy considerations
Several factors influence the output accuracy of FHS AH as a current sensor:
- The sensitivity of the FHS AH
- The distance and shape of the primary conductor
- The circuit output offset
- The circuit non-linearity
- Stray fields.

The sensitivity of the FHS AH is calibrated during production at 600 V/T.
As mentioned above, the distance and shape of the primary conductor also influence the sensitivity.
For best performance, no relative mouvement of the primary conductor to FHS AH should be possible.
Mechanical tolerances on device position and primary conductor design can have an impact on performance and part-to-part deviation and should therefore be minimized.
The magnetic fields generated by neighboring conductors, the earth's magnetic field, magnets, etc. are also measured if they have a component in the direction to which FHS AH is sensitive.
As a rule, the stronger the field generated by the primary current, the smaller the influence of stray fields and offset.
The primary conductor should therefore be designed to maximize the output voltage.

PCB footprint & dimensions (in mm)



	millimeters	inches
A	0.76	0.030
B	3.82	1.50
C	1.27 BSC	0.050 BSC
D	6.86	0.270

Notes:

All dimensions are in millimeters (angles in degrees)
* Dimensions do not include mold flash, protrusions or gate burrs (shall not exceed 0.15 per side)
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side)
*** Dimension does not include dambar protrusion.
Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition.
Dambar cannot be located on the lower radius of the foot.

Soldering:

Recommended reflow soldering profile as standard: IPC/JEDEC J-STD-020 revision C.

Typical connection diagram and ground plane

Good EMC practice requires the use of ground planes on PCBs. In drives where high dv/dt transients are present, a ground plane between the primary conductor and FHS AH will reduce or avoid output perturbations due to capacitive currents. However, the ground plane has to be designed to limit eddy currents that would otherwise slow down the delay time.
The effect of eddy currents is made negligible by cutting the copper plane under the package as shown in bellow figure.

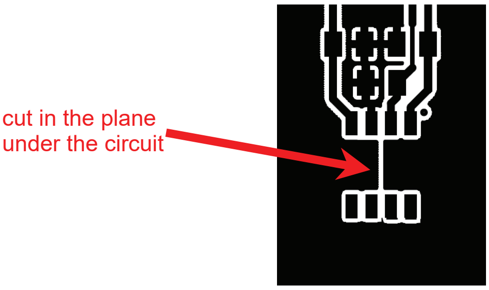


Figure 16: Top side copper plane has a cut under the IC to optimize delay time

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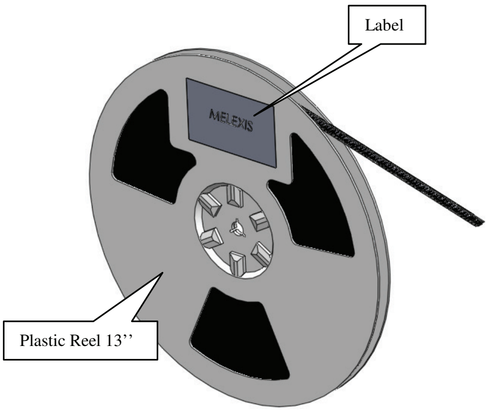
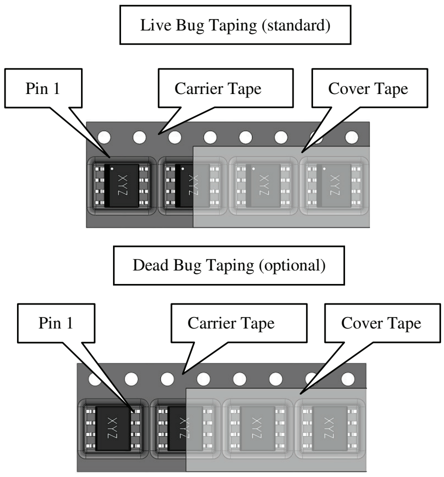
Tape & Reel





Remark:
Pay attention to the marking orientation because it is used for component (pin1) orientation. Some devices may have different marking orientation.

Plastic 13'' Reel:
Made by antistatic high-impact molded polystyrene. The mechanical integrity of the reel is not affected by humidity.

Moisture Barrier Bag (MBB):
Made in 5 different layers with total thickness of 0.18 mm.
At the core is a layer of polyester sandwiched between aluminum shields. The outside layer: dissipative polyester, innermost layer: static dissipative polyethylene.

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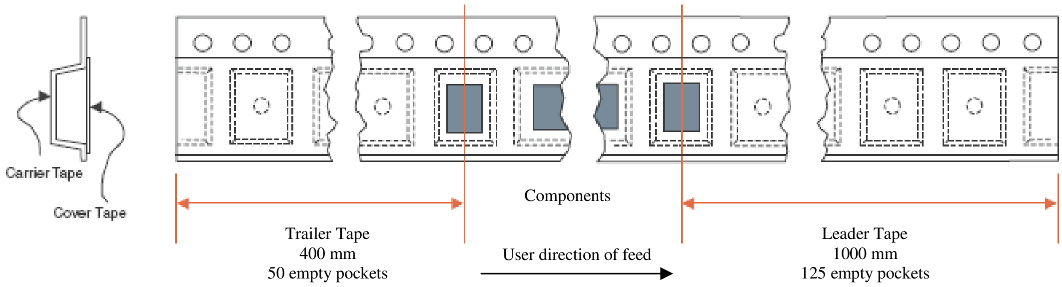
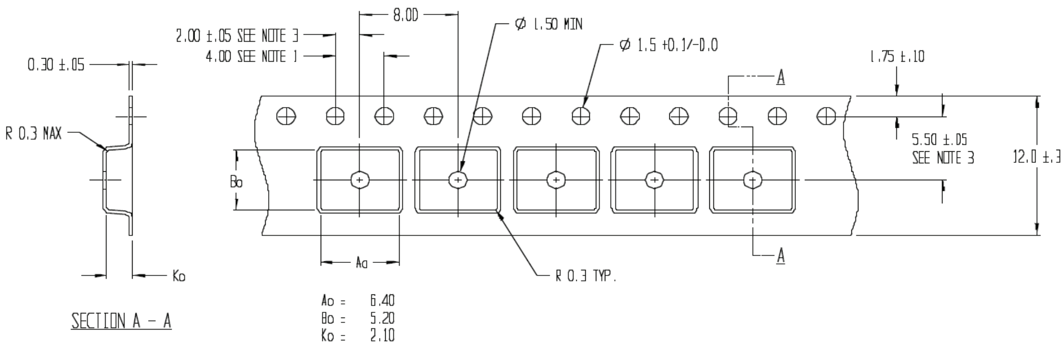
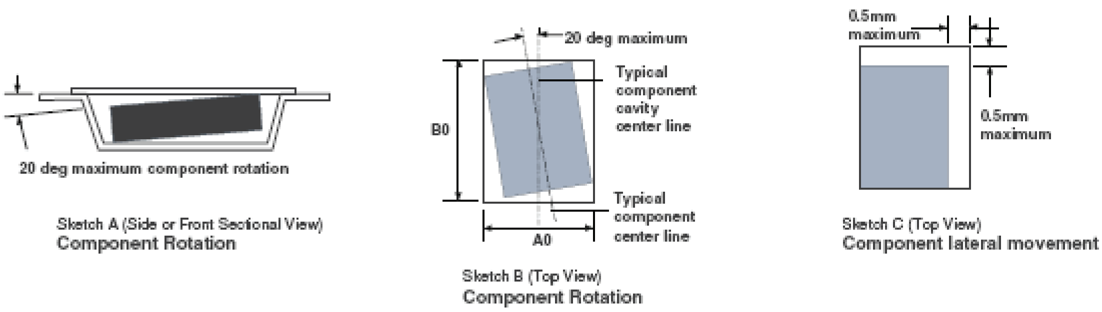
Leader and Trailer



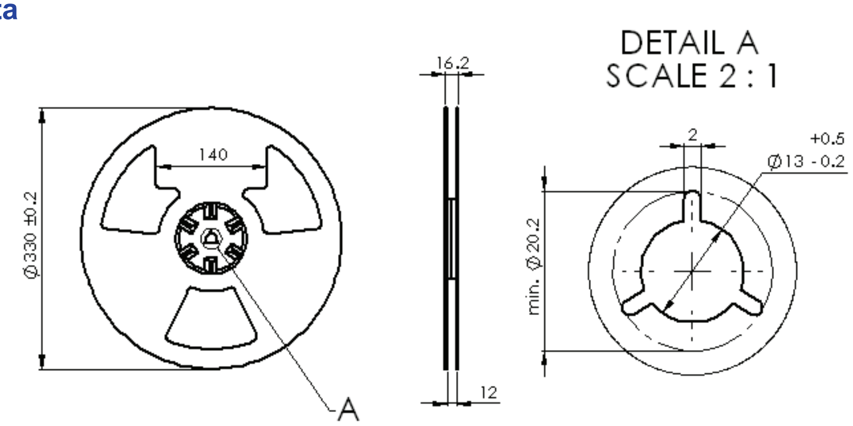
Carrier Tape Data



Component Rotation and Lateral Movement



Plastic Reel Data



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

Safety

Caution

If the device is used in a way that is not specified by the manufacturer, the protection provided by the device may be compromised.
Always inspect the electronics unit and connecting cable before using this product and do not use it if damaged.
Mounting assembly shall guarantee the maximum primary conductor temperature, fulfill clearance and creepage distance, minimize electric and magnetic coupling, and unless otherwise specified can be mounted in any orientation.

Caution, risk of electrical shock

This transducer must be used in limited-energy secondary circuits SELV according to IEC 61010-1, in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the manufacturer's operating specifications.
Use caution during installation and use of this product; certain parts of the module can carry hazardous voltages and high currents (e.g., power supply, primary conductor).
Ignoring this warning can lead to injury and or/or cause serious damage.
De-energize all circuits and hazardous live parts before installing the product.
All installations, maintenance, servicing operations and use must be carried out by trained and qualified personnel practicing applicable safety precautions.
This transducer is a build-in device, whose hazardous live parts must be inaccessible after installation.
This transducer must be mounted in a suitable end-enclosure.
Besides make sure to have minimum 30 mm between the primary terminals of the transducer and other neighboring components.
Main supply must be able to be disconnected.
Always inspect the flexible probe for damage before using this product.
Never connect or disconnect the external power supply while the primary circuit is connected to live parts.
Never connect the output to any equipment with a common mode voltage to earth greater than 30 V.
Always wear protective clothing and gloves if hazardous live parts are present in the installation where the measurement is carried out.
This transducer is a built-in device, not intended to be cleaned with any product. Nevertheless, if the user must implement cleaning or washing process, validation of the cleaning program has to be done by himself.
When defining soldering process, please use no cleaning process only.

ESD susceptibility

The product is susceptible to be damaged from an ESD event and the personnel should be grounded when handling it.
Do not dispose of this product as unsorted municipal waste. Contact a qualified recycler for disposal.
Although LEM applies utmost care to facilitate compliance of end products with applicable regulations during LEM product design, use of this part may need additional measures on the application side for compliance with regulations regarding EMC and protection against electric shock.
Therefore, LEM cannot be held liable for any potential hazards, damages, injuries or loss of life resulting from the use of this product.

Version history

Date	Version	Comments
8 June 2023	0	New datasheet

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