XENSIV™ cost optimized miniature TMR current sensor

✓ RoHS

Features

- Contactless, galvanically isolated current measurement for reduced power losses and lowest parasitic inductance
- Non-amplified TMR bridge perfect for 1 to 1 shunt replacement reducing footprint and costs
- Accurate AC & DC current sensing with stable sensitivity and offset over temperature and lifetime
- Achievable accuracies (single point sensitivty calibration and sensitivity TC compensation) 3σ:
  - Sensitivity drift over temperature: 1.2%
  - Offset drift over temperature: 27 μT
- Bandwidth ≥ 1.1 MHz
- Ultra low noise, down to 5 µV_{RMS} until 100kHz bandwidth
- Magnetic input range of ±35 mT for low and high current applications

Potential applications

- Industrial and consumer DC/DC
- Battery powered tools
- Service robots and drones
- e-Bikes/e-Scooters
- Home appliances and smart home
- Telecom

Product validation

Product qualification according to JEDEC JESD47.

Description

The TLI5570 is a TMR (Tunnel Magneto Resistance) based coreless current sensor, suitable for low cost current sensing applications. The output of the TMR bridge is not amplified and directly provided on the package pins.

Product type	Description and feature	Package	Marking Type	Ordering code
TLI5570-RE35E1-E0001	Single TMR bridge current sensor, X sensitivity direction	PG-SOT23-6-4	70A	SP006025316

Please read the sections "Important notice" and "Warnings" at the end of this document

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1 Standard Configuration

Table 1 **TLI5570 standard configuration**

Product type	Sensitivity direction	Sensitivity (*S*) [mV/V/mT]	Full scale range (*FS*) [mT]
TLI5570-RE35E1-E0001	X axis	4.8	±35

2 Functional block diagram

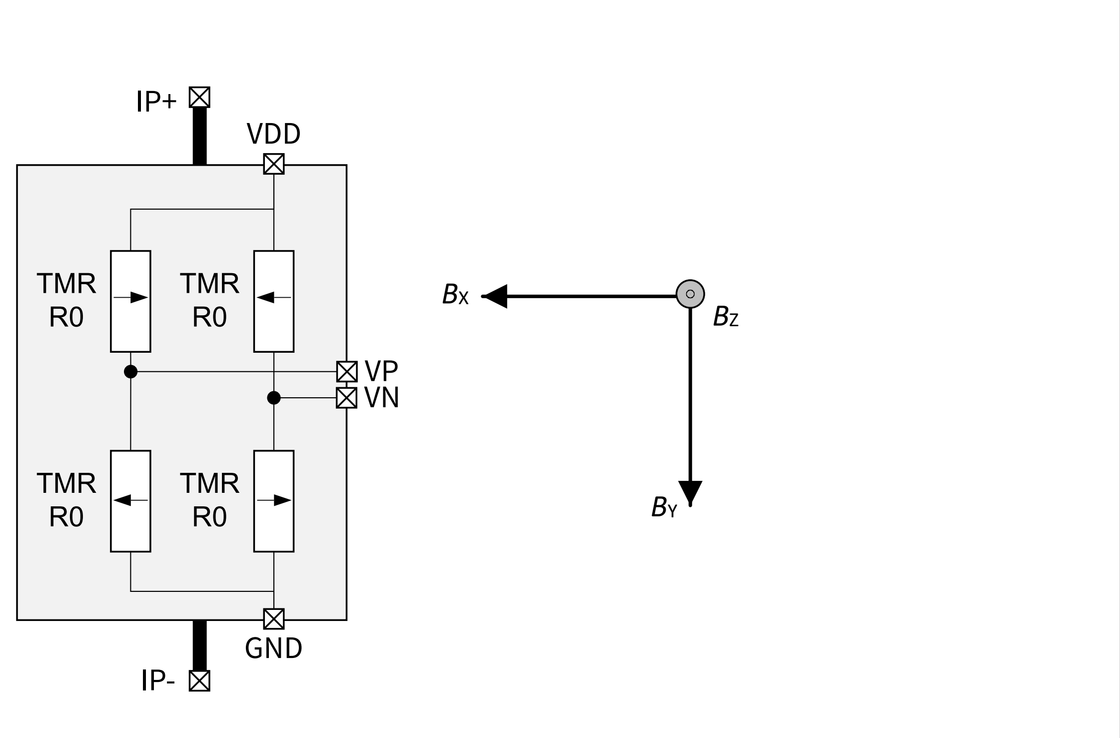

Figure 1 **Device functional block diagram**

The device measures a magnetic field via a Tunnel Magneto Resistance (TMR) Wheatstone bridge. For each TMR in the block diagram an arrow is used to indicate the direction of the reference layer magnetization, which indicate the positive sensing direction of the single TMR. The output of the Wheatstone bridge is made available on the VP and VN pins.

3 Pin configuration

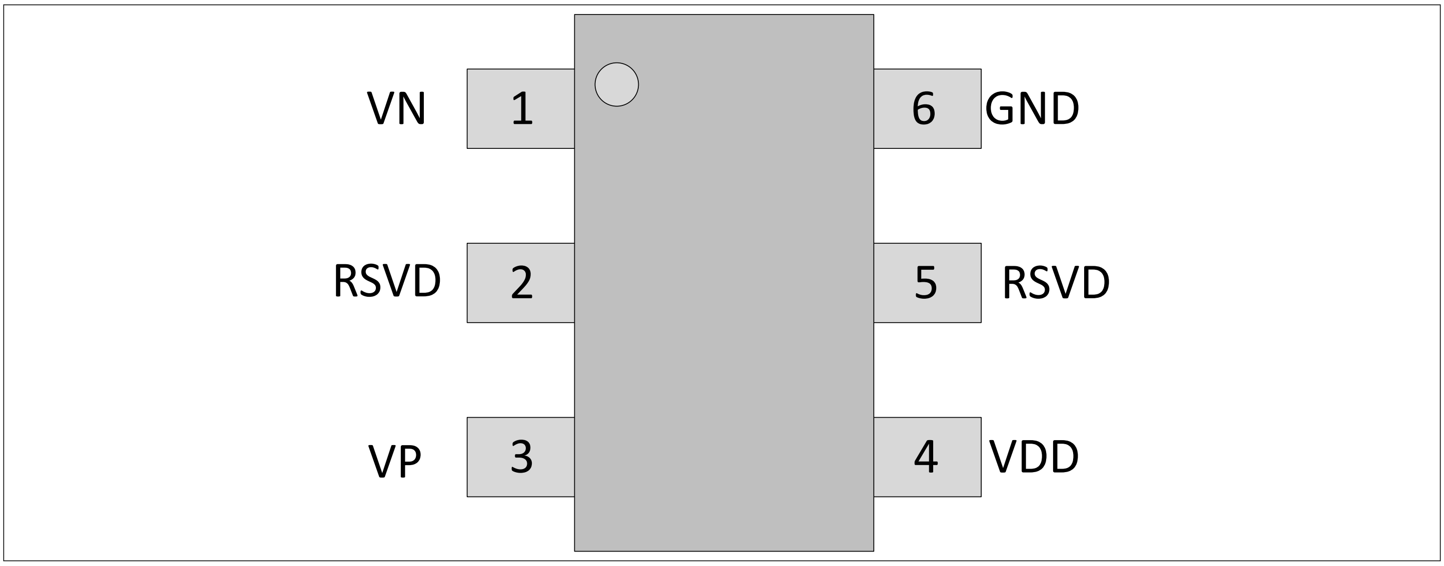

Figure 2 **Package pinout**

Table 2 **Pin definitions and function**

Pin No.	**Symbol**	**Function**	**Comment**
1	VN	Negative terminal of TMR Wheatstone bridge	–
2	RSVD	Pin shorted with sensor lead frame	1)
3	VP	Positive terminal of TMR Wheatstone bridge	–
4	VDD	Supply voltage	–
5	RSVD	Pin shorted with sensor lead frame	1)
6	GND	Ground	–

1) Lead frame shall be connected to GND. Only one of the pins connected to the lead frame shall be connected to GND to avoid GND loops through the lead frame. The other RSVD pins shall be left open.

4 General product characteristics

4.1 Absolute maximum ratings

Table 3 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Electrical						
Supply voltage	V_{DD_ABS}	-0.3	–	6.5	V	Maximum 10 hours between 5.5V to 6.5V
Voltage on VP and VN pins	V_{VPVN_ABS}	0.5	–	4.5	V	
ESD voltage	V_{ESD_HBM}	-2	–	2	kV	Human Body Model, according to ANSI/ESDA/JEDEC JS-001
	V_{ESD_CDM}	-1	–	1	kV	Charged Device Model, according to ANSI/ESDA/JEDEC JS-002
Temperature						
Storage temperature	T_S	-40	–	150	°C	
Junction Temperature	T_J	-40	–	150	°C	
Magnetic						
Magnetic field at TMR sensing element	B_{TMR_ABS}	-75	–	75	mT	$B_{TMR\_ABS} = \pm\sqrt{(B_X^2 + B_Y^2)}$

Attention: ***Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the section "functional range" is not implied. Furthermore, only single error cases are assumed. More than one stress/error case may also damage the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. During absolute maximum rating overload conditions the voltage on VDD pins with respect to ground shall not exceed the values defined by the absolute maximum ratings. Lifetime statements are an anticipation based on an extrapolation of Infineon’s qualification test results. The actual lifetime of a component depends on its form of application and type of use etc. and may deviate from such statement. Lifetime statements shall in no event extend the agreed warranty period.***

4.2 Functional range

The following functional range shall not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operating conditions unless otherwise indicated.

Table 4 **Functional range**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Electrical						
Operating supply voltage	V_{DD}	1	–	5.5	V	
Temperature						
Operating ambient temperature	T_A	-40	–	125	°C	
Operating junction temperature	T_{J_OP}	-40	–	128	°C	
Magnetic						
Operating magnetic field at TMR sensing element	B_{TMR}	-35	–	35	mT	$B_{TMR} = \pm\sqrt{(B_X^2+B_Y^2)}$
Circuit						
Capacitance on VDD pin	C_{VDD}	–	100	–	nF	External capacitance connected to VDD pin. Typical value is a condition valid for all performance parameters unless otherwise specified
Capacitance on VP pin	C_{VP}	–	33	–	pF	External capacitance connected to VP pin. Typical value is a condition valid for all performance parameters unless otherwise specified
Capacitance on VN pin	C_{VN}	–	33	–	pF	External capacitance connected to VN pin. Typical value is a condition valid for all performance parameters unless otherwise specified

4.3 Thermal resistance

Table 5 Thermal resistance

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Thermal resistance	$R_{\mathrm{th,JA}}$	–	250	300	K/W	Junction to air, according to JEDEC JESD51-7

5 Product features

5.1 Electrical characteristics

Table 6 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Current consumption	I_{DD}	–	0.7	1.5	mA	I(VP) = 0A. I(VN) = 0A. V_{DD} = 5V
Bridge Resistance	$R0$	5000	8200	10600	Ω	$B_X = 0$
Linear temperature resistance coefficient	T_{C_R0}	-950	-750	-550	ppm/K	

5.2 Sensing characteristics

Table 7 Sensing characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Sensitivity	S	4	4.8	6.3	mV/V/mT	Sensitivity dependent on voltage at V_{DD} pin, hence the addition V inside of the unit. T_A = 25 °C, 0h; it can be compensated in the application by EOL-calibration at RT in the microcontroller (1)
Output noise	V_{NOISE}	–	5	35	μV_{RMS}	BW = 1 MHz. Referenced to magnetic input field. Typical value is at RT and BW = 100 kHz
Initial offset	E_{OFF_INIT}	-10	–	10	mV/V	T_A = 25 °C, 0h; it can be compensated in the application by EOL-calibration at RT in the microcontroller (1)
Linear temperature coefficient of electrical offset	T_{CO}	-4	–	4	µV/V/K	Difference with respect to 25°C (1)
Linear temperature coefficient of mean sensitivity	T_{CS}	-950	-700	-450	ppm/K	Difference with respect to 25°C (1)
Non-linearity error over temperature range 12mT	$E_{NL\ 12mT}$	-1	–	1	%	% of utilized 12mT range (1)
Non-linearity error over temperature	$E_{NL\ 35mT}$	-1.8	–	1.8	%	% of utilized FS range (1)
Hysteresis error over temperature	E_{HYST}	-0.5	–	0.5	%	% of B_{FS} (1)

(1) Typical values are ±3σ.

5.3 Functional description

5.3.1 Output voltage and current polarity

The sensor is sensitive to the sensing element plane magnetic field component directed from pin 5 to pin 2. The magnetic field on the sensing element location is positive when directed from pin 5 to pin 2. The magnetic field generated by a current flowing in an external conductor is positive when the current flows from pin 1 to pin 3. The sensor provides an output voltage *VOUT* higher than 0V when the magnetic field is positive and lower than 0V when the magnetic field is negative.

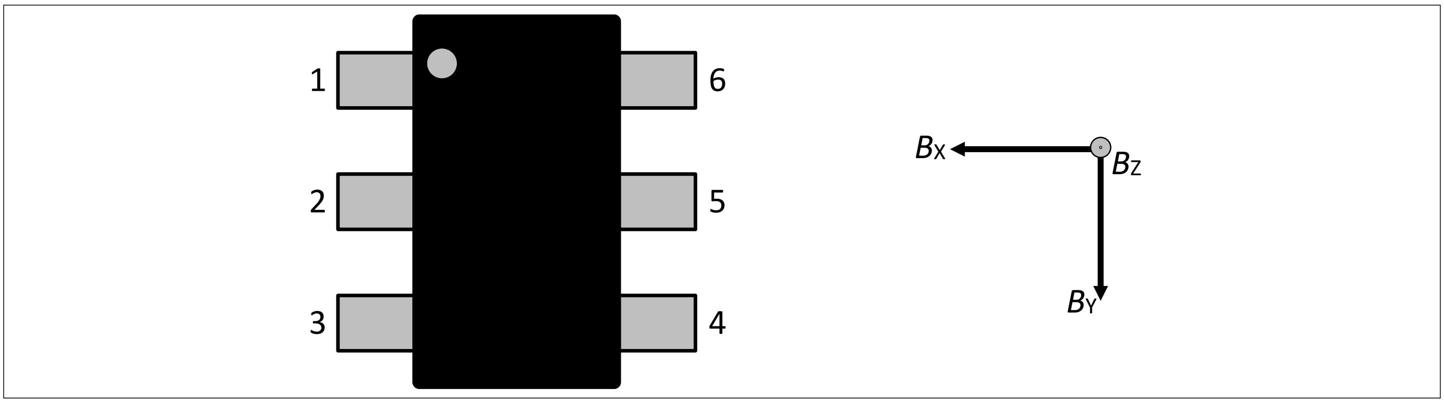

Figure 3 **Polarity definition**

5.3.2 Full scale definition

The magnetic input full scale and analog output full scale are defined in the following figure.

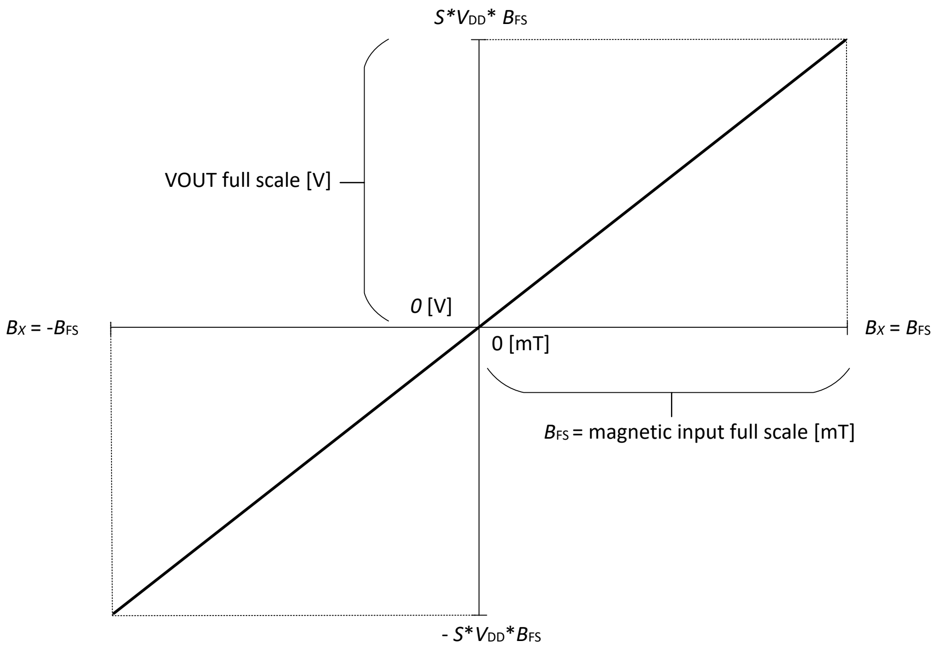

Figure 4 **Full scale (B_{FS}) definition**

The errors specified in Chapter 5.2 are referred to the magnetic input full scale (B_{FS}). Referring the errors to the whole [-B_{FS}... B_{FS}] range would reduce the errors by a factor of two.

5.3.3 Output behavior

The VP and VN pins operates as an output and provide an output voltage with high bandwidth. Being *S* the sensitivity and V_{OQ} the quiescent voltage of the sensor, the output voltage on VP and VN is described as follows:

$$V\left(VP\right) = V_{OQ} + \frac{S \cdot V_{DD}}{2} \cdot B_X = \frac{V_{DD}}{2} + \frac{S \cdot V_{DD}}{2} \cdot B_X \tag{1}$$

$$V\left(VN\right) = V_{OQ} - \frac{S \cdot V_{DD}}{2} \cdot B_X = \frac{V_{DD}}{2} - \frac{S \cdot V_{DD}}{2} \cdot B_X \tag{2}$$

Where B_X is the magnetic field at the TMR sensing element location for X sensitive direction. The differential output voltage *VOUT* is described as follows:

$$VOUT \quad = V(VP) - V(VN) = S \cdot V_{DD} \cdot B_X \tag{3}$$

5.3.4 Output noise

Output noise referenced to magnetic input field can be expressed according to the following formula:

$$B_{NOISE} = \frac{V_{NOISE}}{S \cdot V_{DD}} \tag{4}$$

Where:

- B_{NOISE} is the output noise referenced to magnetic input field [μT_{RMS}]
- V_{NOISE} is the output noise voltage in [μV_{RMS}]
- *S* is the sensitivity in [mV/V/mT]

5.3.5 Output error definitions and calculations

Initial offset (E_{OFF_INIT}) and initial sensitivity error (E_{SENS}) are part-to-part variations that can be compensated by the customers at 0h and room temperature, as explained in Chapter 6.3.

Both offset and sensitivity can drift due to temperature changes and lifetime effects. Temperature drifts are defined by the E_{OFF_T}, E_{SENS_T} parameters.

If we consider sensitivity and offset drifts over temperature and over lifetime to have zero mean and statistically independent from each other, the total drift over temperature (E_{TOT_T}) expressed in % of the sensor full scale *FS* can be estimated as:

$$E_{OFF\_T\,[\%\,FS]} = \frac{\left|T_{CO\_max} - T_{CO\_min}\right|}{2} \cdot \frac{V_{DD} \cdot \Delta T}{FS_{[V]}} \cdot 100\,\% \tag{5}$$

$$E_{SENS\_T\,[\%\,FS]} = \frac{\left|T_{CS\_max} - T_{CS\_min}\right|}{2} \cdot \frac{[V(VP) - V(VN)] \cdot \Delta T}{FS_{[V]}} \cdot 100\,\% \tag{6}$$

$$E_{\mathrm{TOT\_T}\,[\%\,FS]} = \sqrt{E_{OFF\_T\,[\%\,FS]}^{\;2} + E_{SENS\_T\,[\%\,FS]}^{\;2}} \tag{7}$$

Additionally, the following error sources should be taken in consideration for the calculation of the total error at system level.

Output noise (B_{NOISE}) is specified in [μT_{RMS}], as explained in Chapter 5.3.4. The RMS noise is dependent on utilized bandwidth in the application. The error due to the noise in % of full scale can be estimated as:

$$E_{\mathrm{NOISE}\;[\%FS]} = \frac{B_{\mathrm{NOISE}\;[\mu T]}}{FS_{[mT]} \cdot 10^3}\,\% \tag{8}$$

The residual offset and sensitivity errors after user calibration depend on the accuracy of the calibration environment. It is possible to consider them to have zero mean and being statistically independent from the other error components.

In case of variants with very low magnetic full scale range, and in case no shielding is done at system level, the Earth magnetic field contribution on the total error is non negligible and must be added arithmetically to the total error. The calculation below takes into account two times $B_{\mathrm{EARTH\_MAX}}$ because the B_{EARTH} seen by the sensor in the application can be oriented in the opposite direction with respect to the B_{EARTH} seen by the sensor during user calibration:

$$E_{EARTH\;[\%FS]} = \frac{2 \times B_{EARTH\_MAX\;[mT]}}{FS_{[mT]}}\,\% \tag{9}$$

The total error from the sensor over temperature and lifetime can be estimated as:

$$E_{\mathrm{TOT}\;[\%FS]} = E_{EARTH} + E_{\mathrm{NL}} + \sqrt{{E_{HYST}}^2 + {E_{TOT\_T}}^2 + {E_{RES}}^2} \tag{10}$$

6 Application information

6.1 Application circuit

The figure below shows an example application circuit of the device. Please refer to Table 4 for the value of passive components.

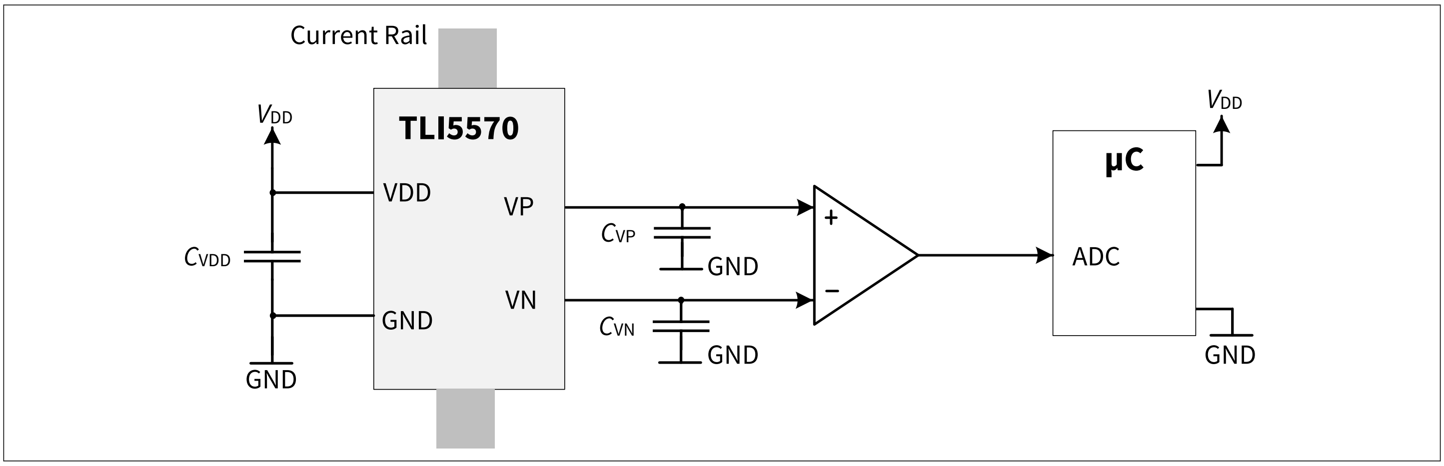

Figure 5 **Application circuit example**

Note: This is a simplified example of an application circuit. The function must be verified in the real application.

6.2 External current rail design

TLI5570 senses the current flowing in an external conductor like a PCB track or a bus-bar. Depending on the external conductor design, different transfer factors [µT/A] can be achieved. Additionally, depending on the conductor design and sensor placement, different performance in terms of accuracy and response time are obtained at system level.

There is evaluation hardware available and we offer online simulation tools for current rail designs. For further guidance please get in touch with us.

The following figure shows an example of straight conductor configuration. In this example, the center of TLI5570 is aligned to the middle of the straight conductor.

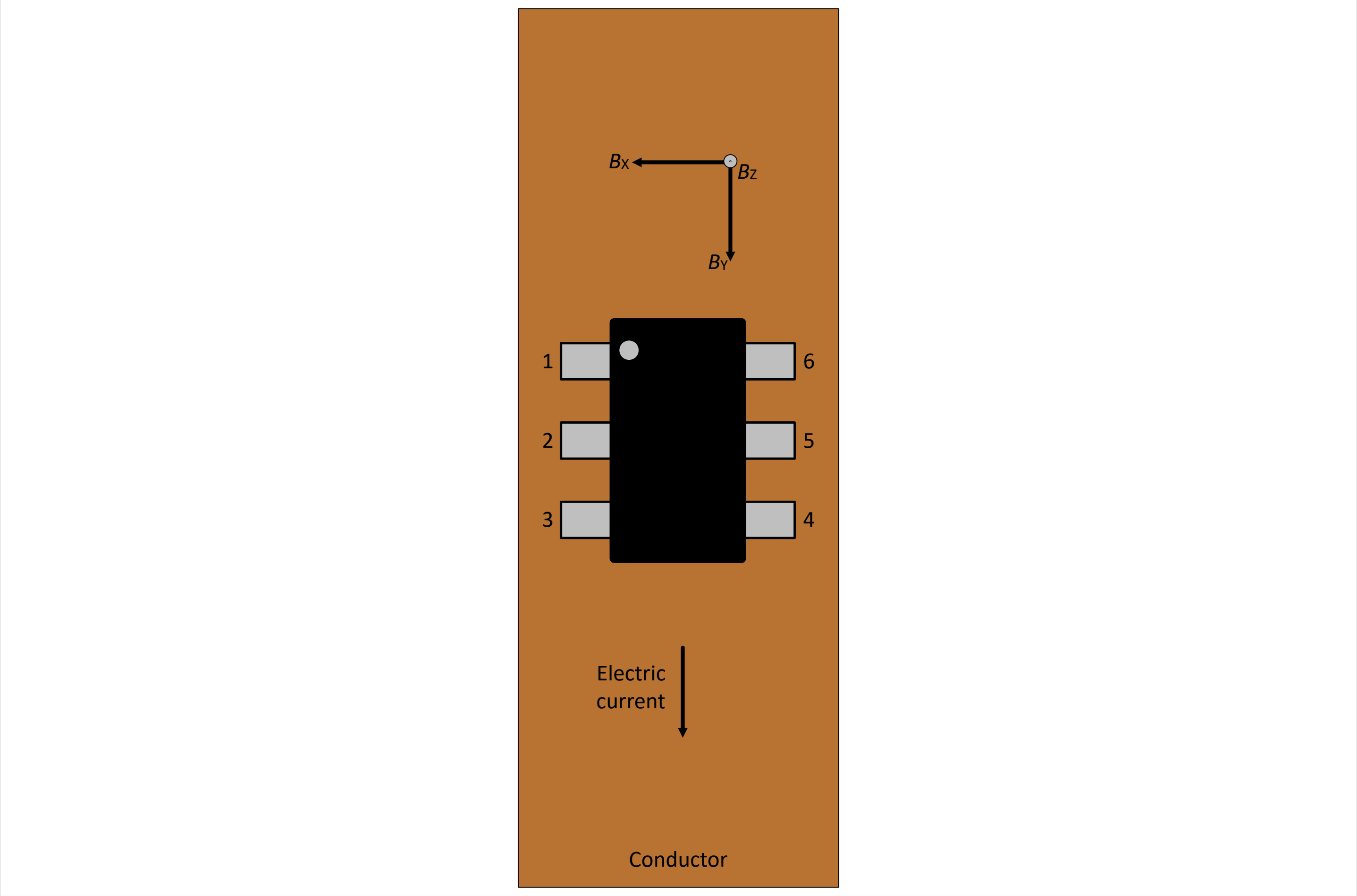

Figure 6 **Example of straight conductor**

6.3 In-system calibration

In order to achieve optimal accuracy performance at system level, it is recommended to perform the calibration of sensitivity [V/A] and offset [V] at room temperature when the sensor is integrated into the system. This calibration is usually performed in an update of the parameter set in the micro controller at end of line.

The sensitivity needs to be calibrated in order to compensate the errors due to displacement of the sensor during mounting and soldering, mechanical tolerances of the package as well as the initial sensitivity error of the sensor [mV/mT] due to part to part variation.

The offset needs to be calibrated in order to compensate the offset introduced by the interface between sensor and microcontroller, as well as the initial offset error of the sensor due to part to part variation.

To further enhance accuracy, it is possible to incorporate an additional compensation mechanism that accounts for the typical temperature coefficients of sensitivity and offset. This can be achieved by multiplying the actual temperature of the sensor with the temperature coefficients (TCs) at microcontroller level.

6.3.1 Error due to mechanical displacement

Due to mechanical placement and production tolerances, the sensor actual position with respect to the conductor will be affected, hence the transfer factor of the system [mT/A] may be different compared to the nominal value simulated during the design. An inital "sensitivity calibration procedure" as mentioned below will also compensate this placement tolerance error.

6.3.2 Initial offset error calibration procedure

The initial offset error V_{OFF} is defined as the output voltage *VOUT* when no current is flowing in the external conductor:

$$V_{\mathrm{OFF}} \quad = \quad VOUT_{0A} = [V(VP) - V(VN)]_{0A} \tag{11}$$

In order to measure the offset (Vout at 0A) of the sensor, the user can:

- control the current in the external conductor to zero
- measure the voltage on the VP and VN pins in correspondence of zero current and calculate *VOUT*

6.3.3 Initial sensitivity error calibration procedure

In order to measure the sensitivity of the sensor the user can:

- Supply the sensor with V_{DD}
- inject a test current I_{TEST} in the sensing structure. I_{TEST} shall be at least 10% of the target full scale current in order to achieve low noise in the sensitivity measurement and it shall be low enough to prevent a high temperature rise of the device during calibration
- measure *VOUT* when no current is flowing in order to measure the offset
- measure *VOUT* in correspondence of I_{TEST}
- measure the I_{TEST} itself using a calibrated current source, a shunt combined with a multimeter or any other precise current measurement device

The measured sensitivity S_{M}[mV/V/A] is then calculated using the following formula:

$$S_{\mathrm{M}} \quad = \quad \frac{VOUT(I_{\mathrm{TEST}}) \quad - \quad VOUT(0\mathrm{A})}{I_{\mathrm{TEST}} \cdot V_{DD}} \tag{12}$$

6.3.4 Initial errors calibration procedure

Once the initial offset and sensitivity errors due to mechanical displacement and part to part variations are known, they can be compensated in the microcontroller by using the following formula:

$$I = \frac{VOUT - V_{\mathrm{OFF}}}{S_{\mathrm{M}} \cdot V_{DD}} \tag{13}$$

7 Package

The device is mounted in the PG-SOT23-6-4 package.

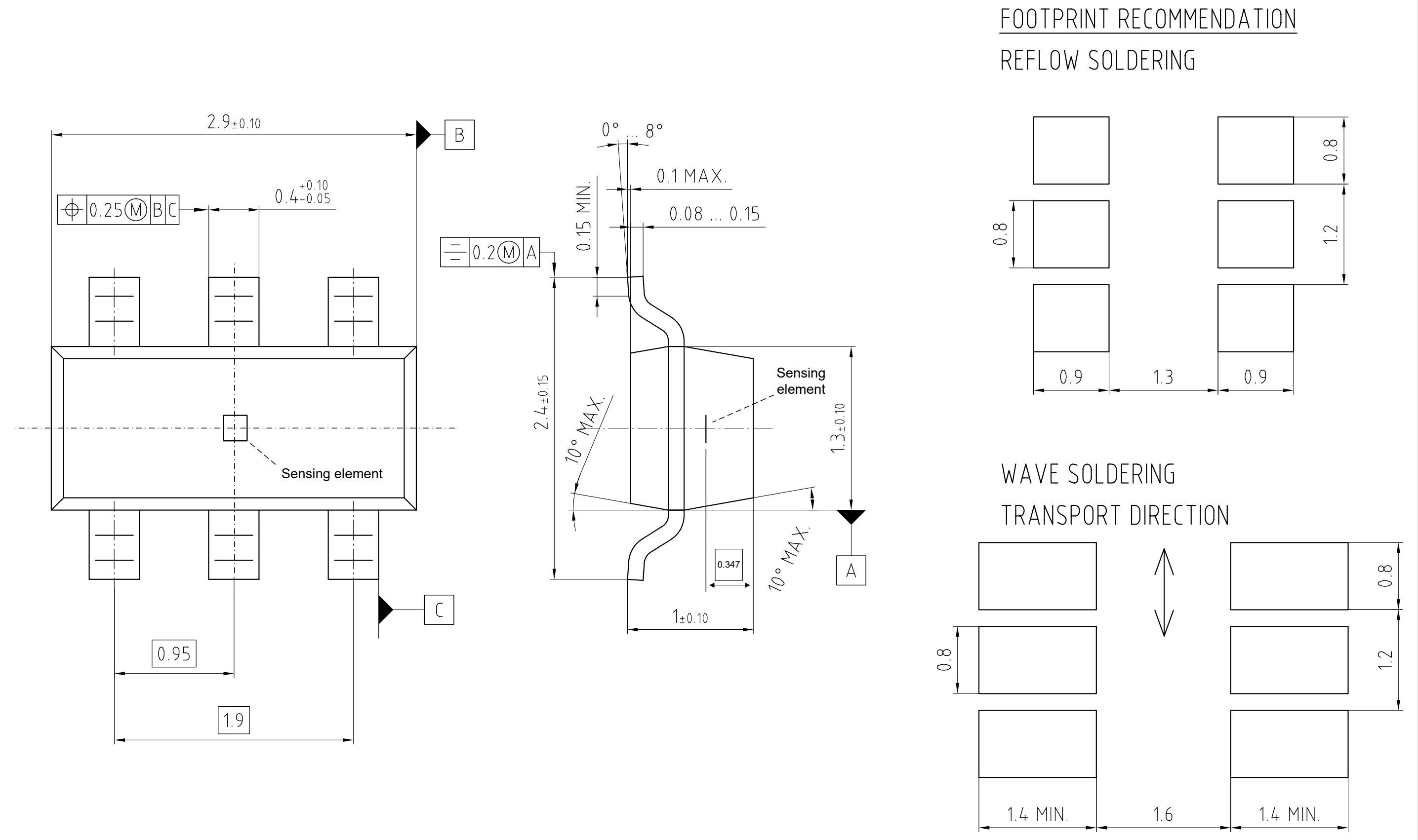

Figure 7 **PG-SOT23-6-4 package outline. Sensing element dimensions and position are not in scale**

The PG-SOT23-6-4 package fulfills the MSL level 1 according to IPC/JEDEC J-STD-033C February 2012

The package marking of the device is as shown in the figure below.

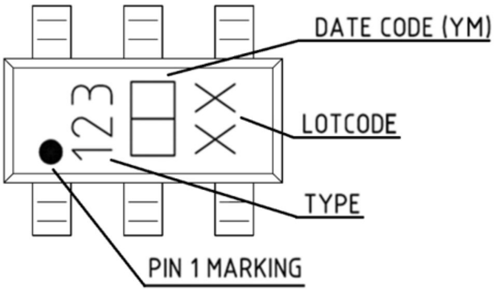

Figure 8 **Package marking - front side**

8 Revision history

Table 8 **Revision history**

Revision number	**Date of release**	**Description of changes**
Rev. 1.00	2024-12-05	First release

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