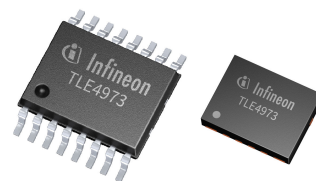


## XENSIV™ high accuracy coreless current sensor for external current rail applications

### Features

- High accurate, scalable, DC & AC current sensing
- Full scale up to  $\pm 34$  mT for current measurements above 1000 A
- 5 V supply voltage
- Configurable differential analog output (including ratiometricity option)
- ISO 26262 Safety Element out of Context for safety requirements up to ASIL B
- Small form factor enables high power density
- Very low sensitivity error over temperature and lifetime
- Excellent stability of offset over temperature and lifetime
- Differential sensor principle ensures superior magnetic stray field suppression
- High bandwidth provides fast response time and low phase delay
- Over-Current Detection with configurable threshold (max detection time  $< 1.0 \mu\text{s}$ )
- EEPROM with integrated charge-pump for in-system programming and end-of-line calibration without additional circuitry
- Different package solutions for optimal system integration in different wiring schemes
- Digital control and diagnostic interface. It provides: temperature readout, safety status readout, read/write programming access to internal EEPROM, control of diagnosis mode
- Pre-calibrated over temperature with possibility of in-system end-of-line calibration to compensate system-level errors



### Potential applications

- Main and auxiliary electrical drives
- Over-load and over-current detection
- Battery main switch
- Smart circuit breakers
- PV inverters
- Current monitoring and power supplies

### Product validation

Qualified for automotive applications. Product validation according to AEC-Q100, Grade 0.

### Description

TLE4973 is a high precision miniature coreless magnetic current sensor for AC and DC measurements with analog interface and fast over-current detection output. Negative effects (saturation, hysteresis) known from open loop sensors using flux concentration techniques are avoided. The differential measurement principle allows great stray field suppression for operation in harsh environments. The high configurability enables customization for a variety of applications. User-programmable parameters such as OCD thresholds and sensitivity settings are stored in an embedded EEPROM. Device configuration can be performed in-situ through a one-wire UART based interface called Digital Control Diagnostic Interface (DCDI). The DCDI interface provides read/write access to internal registers of the device and allows to trigger the diagnostic mode and to read temperature, OCD and safety status. It has an auto-addressing functionality and can handle up to 8 slaves on one bus.

| Product type         | Package    | Marking  | Ordering code |
|----------------------|------------|----------|---------------|
| TLE4973-AE35D5-S0001 | PG-TDSO-16 | H73E3A1I | SP005353128   |
| TLE4973-AE35S5-S0001 | PG-VSON-6  | H73E3A1I | SP005353131   |
| TLE4973-RE35D5-S0001 | PG-TDSO-16 | H73E3R1I | SP005448166   |
| TLE4973-RE35S5-S0001 | PG-VSON-6  | H73E3R1I | SP005448267   |

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## 1 Standard configuration

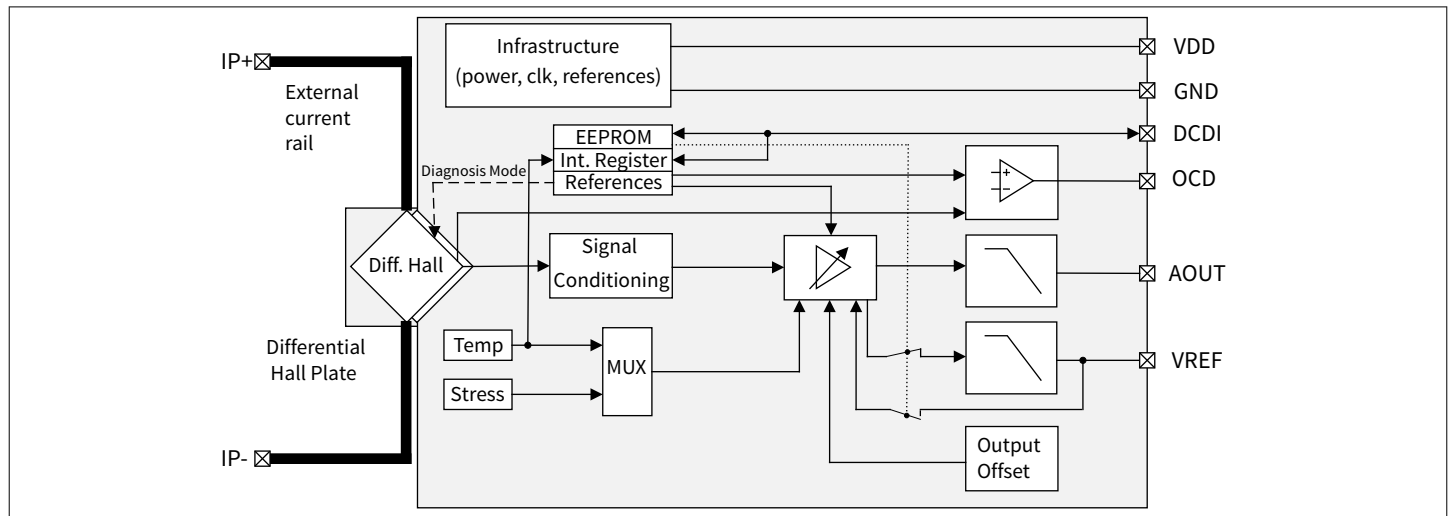
**Table 1** TLE4973 standard configuration

| Name                         | RATIO | FS [mT] <sup>1)</sup> | Sx [mV/<br>mT] <sup>1)</sup> | B <sub>THR</sub> [mT] <sup>1)</sup> | OCD <sub>GL_MUL</sub> <sup>1)</sup> | V <sub>OQ</sub> [V] <sup>1)</sup> | OP <sub>MODE</sub> <sup>1)</sup> |
|------------------------------|-------|-----------------------|------------------------------|-------------------------------------|-------------------------------------|-----------------------------------|----------------------------------|
| TLE4973-<br>RE35S5-<br>S0001 | on    | ±21.27                | 84.63                        | ±1.39 x FS                          | 0, filter<br>disabled               | V <sub>DD</sub> / 2               | Semi-<br>differential            |
| TLE4973-<br>RE35D5-<br>S0001 |       |                       |                              |                                     |                                     |                                   |                                  |
| TLE4973-<br>AE35S5-<br>S0001 | off   | ±21.27                | 84.63                        | ±1.39 x FS                          | 0, filter<br>disabled               | V <sub>DD</sub> / 2               | Semi-<br>differential            |
| TLE4973-<br>AE35D5-<br>S0001 |       |                       |                              |                                     |                                     |                                   |                                  |

RATIO = Ratiometricity to V<sub>DD</sub>, FS = Full Scale, Sx = Sensitivity, B<sub>THR</sub> = OCD threshold level, OCD<sub>GL\_MUL</sub> = Deglitch filter setting, V<sub>OQ</sub> = Quiescent output voltage, OP<sub>MODE</sub> = Output mode

1) Configuration can be changed by the customer. Allowed options for output mode are Semi-differential, Fully-differential and Single-ended. Single-ended AOUT only output mode is not allowed.

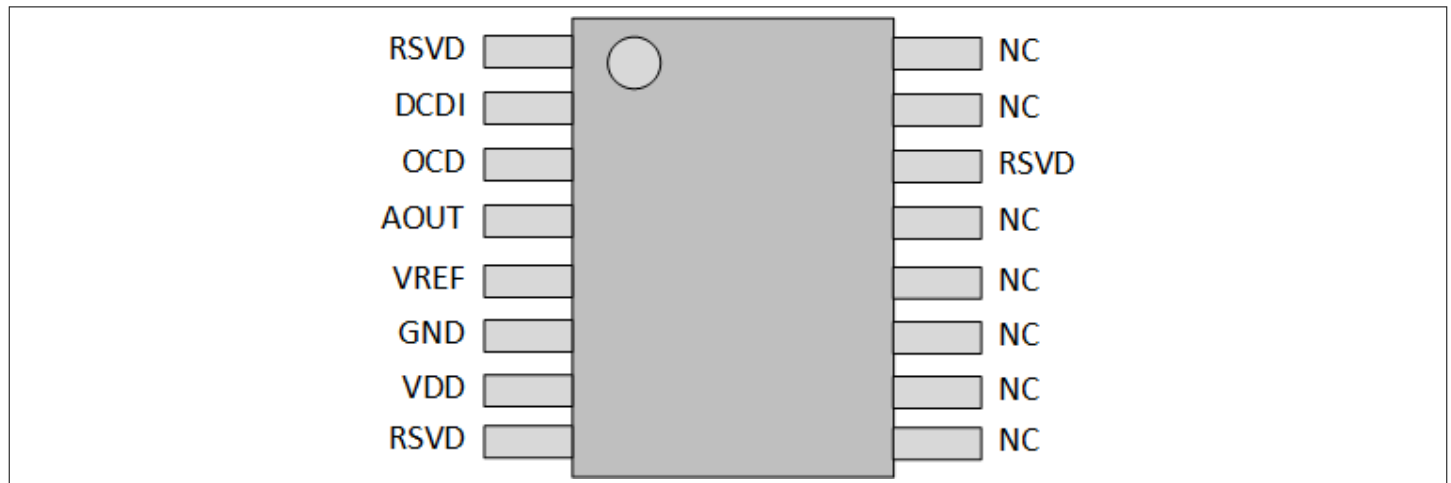
## 2 Functional block diagram



**Figure 1** Device functional block diagram

The current flowing through an external current rail induces a magnetic field that is measured by two Hall probes differentially. The differential measurement principle provides superior magnetic stray field suppression. A high-performance amplifier combines the signal resulting from the differential field and the compensation information provided by the temperature and stress compensation unit. Finally, the amplifier output signal is fed into a differential output amplifier which drives the analog output of the sensor.

### 3 Pin configuration



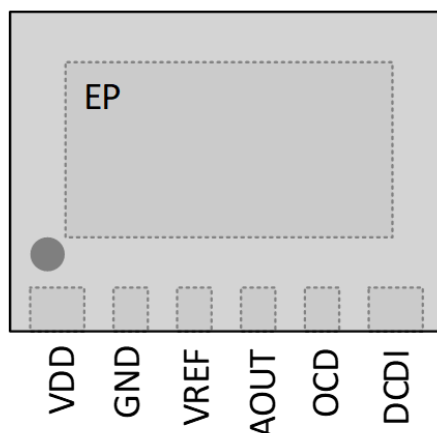
**Figure 2** Pin configuration (PG-TDSO-16)

**Table 2** Pin definitions and functions (PG-TDSO-16)

| Pin No. | Symbol | Function                                | Comment                                             |
|---------|--------|-----------------------------------------|-----------------------------------------------------|
| 1       | RSVD   | Pin shorted with sensor lead frame      | 1)                                                  |
| 2       | DCDI   | DCDI communication interface            | Open drain input / output, short to VDD if not used |
| 3       | OCD    | Over Current Detection output           | Open drain output, short to GND if not used         |
| 4       | AOUT   | Analog output                           | –                                                   |
| 5       | VREF   | Reference voltage                       | Input or output                                     |
| 6       | GND    | Ground                                  | –                                                   |
| 7       | VDD    | Supply voltage                          | –                                                   |
| 8       | RSVD   | Pin shorted with sensor lead frame      | 1)                                                  |
| 9-13    | NC     | Not connected with lead frame or sensor | –                                                   |
| 14      | RSVD   | Pin shorted with sensor lead frame      | 1)                                                  |
| 15-16   | NC     | Not connected with lead frame or sensor | –                                                   |

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

## 3 Pin configuration



**Figure 3** Pin configuration (PG-VSON-6)

**Table 3** Pin definitions and functions (PG-VSON-6)

| Pin No. | Symbol | Function                      | Comment                                             |
|---------|--------|-------------------------------|-----------------------------------------------------|
| 1       | VDD    | Supply voltage                | –                                                   |
| 2       | GND    | Ground                        | –                                                   |
| 3       | VREF   | Reference voltage             | Input or output                                     |
| 4       | AOUT   | Analog output                 | –                                                   |
| 5       | OCD    | Over Current Detection output | Open drain output, short to GND if not used         |
| 6       | DCDI   | DCDI communication interface  | Open drain input / output, short to VDD if not used |
| 7       | EP     | Exposed pad                   | Shall be connected to GND                           |

## 4 General product characteristics

### 4.1 Absolute maximum ratings

**Table 4** Absolute maximum ratings

| Parameter                              | Symbol         | Values |      |          | Unit | Note or condition                                                     |
|----------------------------------------|----------------|--------|------|----------|------|-----------------------------------------------------------------------|
|                                        |                | Min.   | Typ. | Max.     |      |                                                                       |
| Supply voltage maximum ratings         | $V_{DD}$       | -0.3   | –    | 6.5      | V    |                                                                       |
| Voltage on interface pins VREF, AOUT   | $V_{IO\_A}$    | -0.3   | –    | $V_{DD}$ | V    | Pull-up resistors are connected to $V_{DD}$                           |
| Voltage on interface pins OCD, DCDI    | $V_{IO\_D}$    | -0.3   | –    | $V_{DD}$ | V    | Pull-up resistors of the open-drain drivers are connected to $V_{DD}$ |
| ESD voltage HBM (human body model)     | $V_{ESD\_HBM}$ | -2     | –    | 2        | kV   | Human Body Model (HBM), according to AEC Q100-002 standard            |
| ESD voltage CDM (charged device model) | $V_{ESD\_CDM}$ | -1     | –    | 1        | kV   | Charged Device Model (CDM), according to JEDEC JS-002 standard        |
| Junction temperature maximum ratings   | $T_{J\_MAX}$   | –      | –    | 175      | °C   |                                                                       |
| Storage temperature                    | $T_{A\_STORE}$ | -40    | –    | 150      | °C   |                                                                       |

**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” of this data sheet 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  $V_{DD}$  pins with respect to ground must 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 operating range must 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 5 Functional range**

| Parameter                         | Symbol         | Values |      |      | Unit | Note or condition                                                                                                       |
|-----------------------------------|----------------|--------|------|------|------|-------------------------------------------------------------------------------------------------------------------------|
|                                   |                | Min.   | Typ. | Max. |      |                                                                                                                         |
| Operating supply voltage          | $V_{DD}$       | 4.5    | 5    | 5.5  | V    |                                                                                                                         |
| Ambient temperature               | $T_A$          | -40    | –    | 150  | °C   |                                                                                                                         |
| Operating junction temperature    | $T_{J\_OP}$    | -40    | –    | 160  | °C   |                                                                                                                         |
| Capacitance on AOUT pin           | $C_{AOUT}$     | 6      | 6.8  | 8    | nF   | Without series resistor, including parasitic capacitance on the board                                                   |
| Capacitance on VREF pin           | $C_{VREF}$     | 6      | 6.8  | 8    | nF   | Without series resistor, including parasitic capacitance on the board                                                   |
| Reference input voltage           | $V_{REF\_NOM}$ | –      | 2.5  | –    | V    | Allowed values: 2.5 V and 1.25 V. The chosen nominal value has to be programmed in EEPROM                               |
| Reference input voltage variation | $V_{REF\_VAR}$ | -10    | –    | 10   | %    | In single-ended mode                                                                                                    |
| Sensitivity calibration range     | $S_{CAL\_MG}$  | -15    | –    | 15   | %    | Minimum residual calibration range available for customer sensitivity calibration after Infineon end of production line |

## 5 Product features

### 5.1 Electrical characteristics

**Table 6** Electrical characteristics

| Parameter                                               | Symbol          | Values         |                |          | Unit | Note or condition                                                                                                                                                                                                             |
|---------------------------------------------------------|-----------------|----------------|----------------|----------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                         |                 | Min.           | Typ.           | Max.     |      |                                                                                                                                                                                                                               |
| Current consumption                                     | $I_{DD}$        | –              | 21             | 25       | mA   | $I_{AOUT} = 0$ mA                                                                                                                                                                                                             |
| Programming current                                     | $I_{PROG}$      | –              | –              | 25       | mA   | Total current consumption during EEPROM programming                                                                                                                                                                           |
| VREF leakage current                                    | $I_{VREF}$      | –              | –              | 5        | μA   | VREF current consumption in single-ended mode                                                                                                                                                                                 |
| Power-on delay time                                     | $t_{POR}$       | –              | –              | 1.5      | ms   | $V_{DD}$ rising 0 V to 5.0 V. Starts when the $V_{DD}$ reaches the minimum allowed operating conditions and stops when the device is fully operational. OCD is set to GND within this time. DCDI pin is set to high ohmic 'Z' |
| Voltage on AOUT pin                                     | $V_{AOUT}$      | -0.3           | –              | $V_{DD}$ | V    |                                                                                                                                                                                                                               |
| Voltage on DCDI pin                                     | $V_{DCDI}$      | -0.3           | –              | $V_{DD}$ | V    |                                                                                                                                                                                                                               |
| Voltage on OCD pin                                      | $V_{OCD}$       | -0.3           | –              | $V_{DD}$ | V    |                                                                                                                                                                                                                               |
| Quiescent output voltage bidirectional                  | $V_{OQBID}$     | –              | $V_{DD}/2$     | –        | V    |                                                                                                                                                                                                                               |
| Quiescent output voltage unidirectional                 | $V_{OQUNI}$     | –              | $V_{DD}/3.984$ | –        | V    |                                                                                                                                                                                                                               |
| Analog output drive capability                          | $I_{AOUT}$      | -6.53          | –              | 6.53     | mA   | DC current                                                                                                                                                                                                                    |
| Analog output saturation voltage, source                | $V_{CL\_H}$     | –              | –              | 300      | mV   | $I_{SINK} = 6.53$ mA                                                                                                                                                                                                          |
| Analog output saturation voltage, sink                  | $V_{CL\_L}$     | $V_{DD} - 0.3$ | –              | –        | V    | $I_{SOURCE} = 6.53$ mA                                                                                                                                                                                                        |
| Analog output diagnosis mode output amplitude variation | $V_{DIAG\_VAR}$ | -20            | –              | 20       | %    | Over temperature and life time with respect to diagnosis mode test signal                                                                                                                                                     |

## 5.2 Sensing characteristics

**Table 7** Sensing characteristics

| Parameter                          | Symbol                    | Values |        |      | Unit   | Note or condition                                                                                                                     |
|------------------------------------|---------------------------|--------|--------|------|--------|---------------------------------------------------------------------------------------------------------------------------------------|
|                                    |                           | Min.   | Typ.   | Max. |        |                                                                                                                                       |
| Sensitivity, range S1              | S1                        | –      | 52.89  | –    | mV/mT  | Bidirectional output mode: $FS = \pm 34.04$ mT<br>Unidirectional output mode: $FS = 57.67$ mT                                         |
| Sensitivity, range S2              | S2                        | –      | 63.47  | –    | mV/mT  | Bidirectional output mode: $FS = \pm 28.36$ mT<br>Unidirectional output mode: $FS = 48.05$ mT                                         |
| Sensitivity, range S3              | S3                        | –      | 84.63  | –    | mV/mT  | Bidirectional output mode: $FS = \pm 21.27$ mT<br>Unidirectional output mode: $FS = 36.04$ mT                                         |
| Sensitivity, range S3.5            | S3.5                      | –      | 105.8  | –    | mV/mT  | Bidirectional output mode: $FS = \pm 17.01$ mT<br>Unidirectional output mode: $FS = 28.83$ mT                                         |
| Sensitivity, range S4              | S4                        | –      | 126.95 | –    | mV/mT  | Bidirectional output mode: $FS = \pm 14.18$ mT<br>Unidirectional output mode: $FS = 24.03$ mT                                         |
| Sensitivity, range S4.5            | S4.5                      | –      | 148.12 | –    | mV/mT  | Bidirectional output mode: $FS = \pm 12.15$ mT<br>Unidirectional output mode: $FS = 20.59$ mT                                         |
| Sensitivity, range S5              | S5                        | –      | 169.26 | –    | mV/mT  | Bidirectional output mode: $FS = \pm 10.64$ mT<br>Unidirectional output mode: $FS = 18.02$ mT                                         |
| Sensitivity, range S5.5            | S5.5                      | –      | 190.44 | –    | mV/mT  | Bidirectional output mode: $FS = \pm 9.45$ mT<br>Unidirectional output mode: $FS = 16.02$ mT                                          |
| Sensitivity, range S6              | S6                        | –      | 253.89 | –    | mV/mT  | Bidirectional output mode: $FS = \pm 7.09$ mT<br>Unidirectional output mode: $FS = 12.01$ mT                                          |
| Quiescent ratiometricity factor    | $K_{OQ}$                  | –      | 1      | –    | –      |                                                                                                                                       |
| Sensitivity ratiometricity factor  | $K_S$                     | –      | 1      | –    | –      |                                                                                                                                       |
| Transfer function cutoff frequency | $BW$                      | 120    | 210    | –    | kHz    | -3dB criterion, $C_{AOUT} = 6.8$ nF                                                                                                   |
| Output phase delay                 | $\varphi_{DELAY}$         | –      | 43.2   | 60.5 | °      | $f_{SIGNAL} = 120$ kHz                                                                                                                |
| Output group delay                 | $\varphi_{G\_DELAY}$      | –      | 1.0    | 1.4  | μs     |                                                                                                                                       |
| Output group delay variation       | $\varphi_{G\_DELAY\_VAR}$ | -20    | –      | 20   | %      | Over temperature and lifetime                                                                                                         |
| Output noise density               | $B_{NOISE}$               | –      | 70     | 175  | nT/√Hz | Referenced to input differential magnetic field. Typical value is for $T_A = 25$ °C. Max value is for $T_A \leq 150$ °C <sup>1)</sup> |

(table continues...)

Table 7 (continued) Sensing characteristics

| Parameter                                             | Symbol          | Values |            |      | Unit          | Note or condition                                                                                                                                                                                |
|-------------------------------------------------------|-----------------|--------|------------|------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                       |                 | Min.   | Typ.       | Max. |               |                                                                                                                                                                                                  |
| External homogeneous magnetic field suppression       | $B_{SR}$        | 34     | 40         | –    | dB            | With respect to the external homogeneous field applied, up to 20 mT. Frequency up to 4 kHz                                                                                                       |
| Initial sensitivity error                             | $E_{SENS}$      | -5.0   | $\pm 2.7$  | 5.0  | %             | Typical value is $\pm 3$ sigma. $T_A = 25^\circ\text{C}$ ; can be compensated in the application by end-of-line calibration at RT.                                                               |
| Sensitivity calibration resolution                    | $E_{SENS\_CAL}$ | –      | 0.12       | –    | %             | Calibration resolution varies with calibration code. Further details to be found in the user manual                                                                                              |
| Sensitivity drift over temperature                    | $E_{SENS\_T}$   | -1.35  | $\pm 0.8$  | 1.35 | %             | Bidirectional output mode. Typical is $\pm 3$ sigma. At 0h. <sup>2)</sup>                                                                                                                        |
| Sensitivity drift over temperature and lifetime       | $E_{SENS\_L}$   | -1.9   | $\pm 1.23$ | 1.9  | %             | Bidirectional output mode. $T_A = 25^\circ\text{C}$ to $150^\circ\text{C}$ . <sup>3) 2)</sup>                                                                                                    |
| Initial offset error                                  | $E_{OFF\_INIT}$ | -200   | $\pm 40$   | 200  | $\mu\text{T}$ | Typical value is $\pm 3$ sigma. $T_A = 25^\circ\text{C}$ ; can be compensated in the application by end-of-line calibration at RT                                                                |
| Offset calibration resolution                         | $E_{OFF\_CAL}$  | –      | 12.9       | –    | $\mu\text{T}$ | Further details to be found in the user manual                                                                                                                                                   |
| Output offset variation over temperature              | $E_{OFF\_T}$    | -100   | $\pm 30$   | 100  | $\mu\text{T}$ | Bidirectional output mode. Typical is $\pm 3$ sigma. At 0h. <sup>2)</sup>                                                                                                                        |
| Output offset variation over temperature and lifetime | $E_{OFF\_L}$    | -100   | $\pm 40$   | 100  | $\mu\text{T}$ | Bidirectional output mode. <sup>3) 2)</sup>                                                                                                                                                      |
| Total drift over temperature                          | $E_{TOT\_T}$    | -1.6   | $\pm 1$    | 1.6  | %             | Bidirectional output mode. Typical is $\pm 3$ sigma. At 0h. <sup>2)</sup><br>Percentage of full scale, sensitivity $S1$ . Includes sensitivity, offset and linearity errors.                     |
| Total drift over temperature and lifetime             | $E_{TOT\_L}$    | -2     | $\pm 1.3$  | 2    | %             | Bidirectional output mode. $T_A = 25^\circ\text{C}$ to $150^\circ\text{C}$ . <sup>3) 2)</sup><br>Percentage of full scale, sensitivity $S1$ . Includes sensitivity, offset and linearity errors. |

(table continues...)

Table 7 (continued) Sensing characteristics

| Parameter                                                      | Symbol                 | Values |            |      | Unit                    | Note or condition                                                              |
|----------------------------------------------------------------|------------------------|--------|------------|------|-------------------------|--------------------------------------------------------------------------------|
|                                                                |                        | Min.   | Typ.       | Max. |                         |                                                                                |
| Sensitivity ratiometricity error over temperature and lifetime | $E_{\text{SRATIO\_L}}$ | -      | $\pm 0.05$ | -    | %/% $V_{\text{DD}}$     | Bidirectional output mode. $\pm 10\%$ $V_{\text{DD}}$ variation. <sup>3)</sup> |
| Offset ratiometricity error over temperature and lifetime      | $E_{\text{ORATIO\_L}}$ | -      | $\pm 6$    | -    | $\mu\text{T}$           | Bidirectional output mode. $\pm 10\%$ $V_{\text{DD}}$ variation. <sup>3)</sup> |
| Temperature sensor sensitivity                                 | $S_{\text{TEMP}}$      | -      | 16         | -    | LSB/ $^{\circ}\text{C}$ |                                                                                |
| Temperature sensor RMS noise                                   | $NRMS_{\text{TEMP}}$   | -      | -          | 0.5  | $^{\circ}\text{C}$      | In the range of 25 $^{\circ}\text{C}$ to max operating $T_{\text{J}}$          |
| Temperature sensor linearity error                             | $E_{\text{TEMP}}$      | -5     | -          | 5    | $^{\circ}\text{C}$      | In the range of 25 $^{\circ}\text{C}$ to max operating $T_{\text{J}}$          |

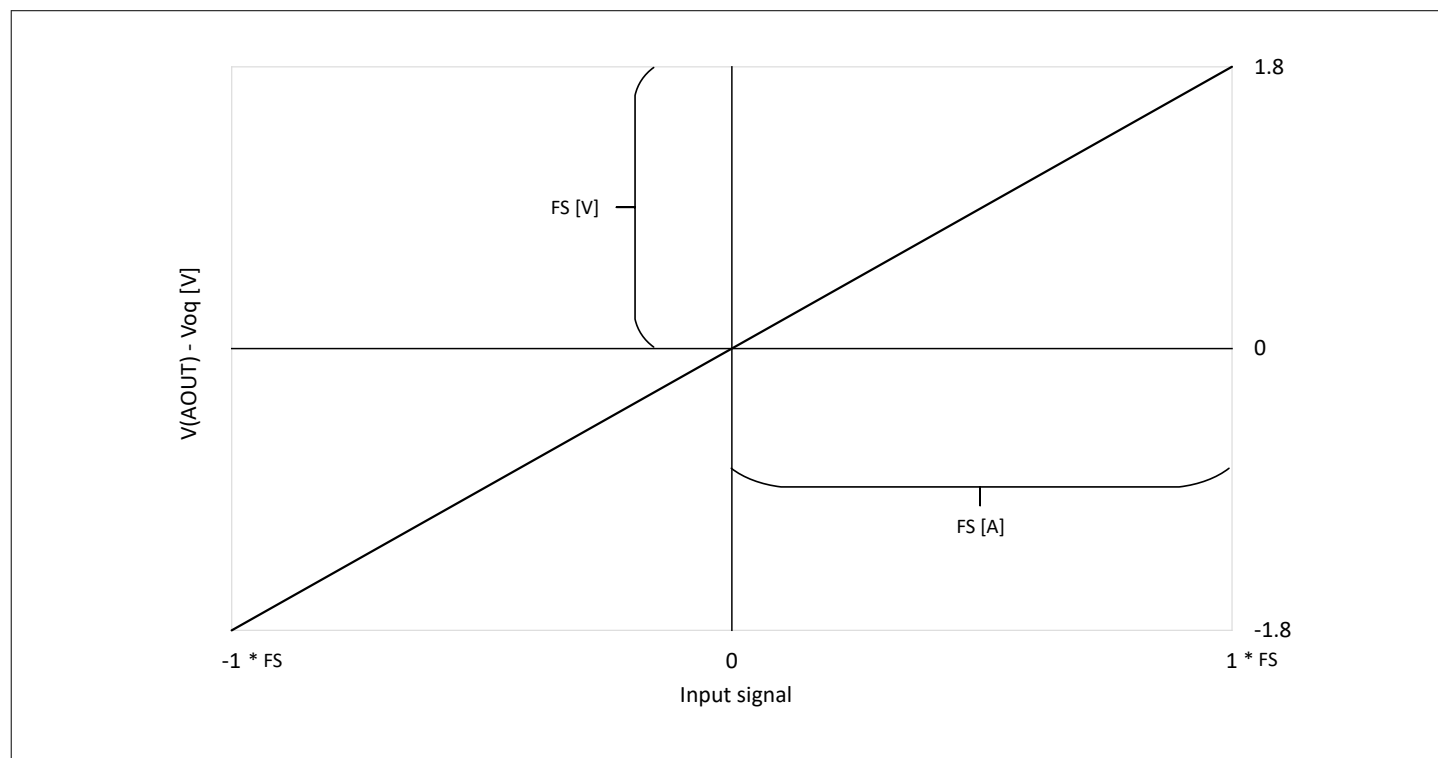
1) Output noise density can be expressed according to the formula shown in [Chapter 5.3.3](#).

2) Specified accuracy errors are only valid for the pre-programmed ratiometricity setting.

3) Min/Max values derived from AEC-Q100 qualification. Typical values are  $\pm 3$  sigma values measured during AEC-Q100 qualification.

### 5.2.1 Full scale definition

The full scale input and full scale output voltage are defined as follows.



**Figure 4** Full scale definition

The total error specification in [Table 7](#) considers the full scale  $FS$  to be the maximum absolute value measurable by the sensor and not the whole excursion from  $-FS$  to  $+FS$ . Referring the total error to the whole excursion would make the total error factor 2 better.

5.2.2 Typical performance over temperature

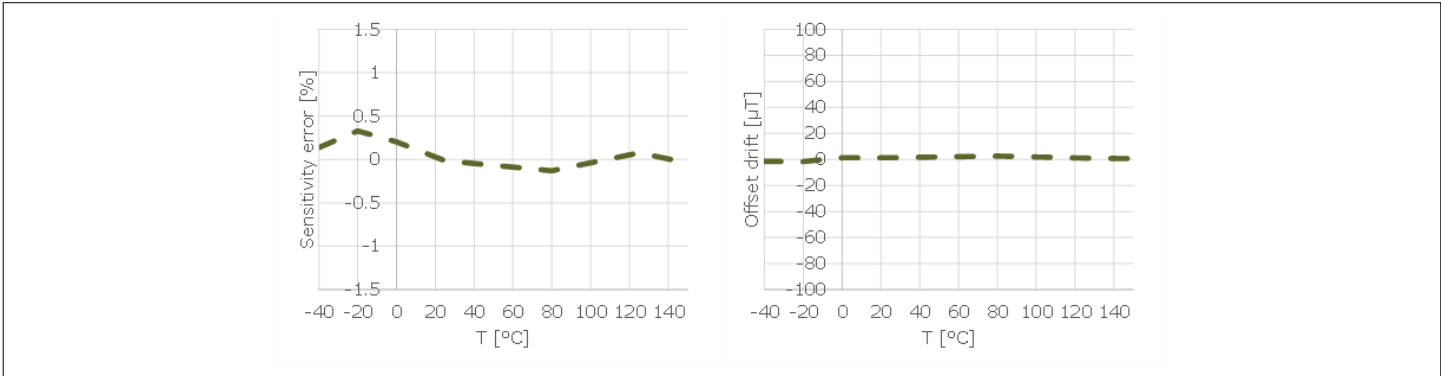


Figure 5 PG-VSON-6, semi-differential bidirectional, sensitivity S1

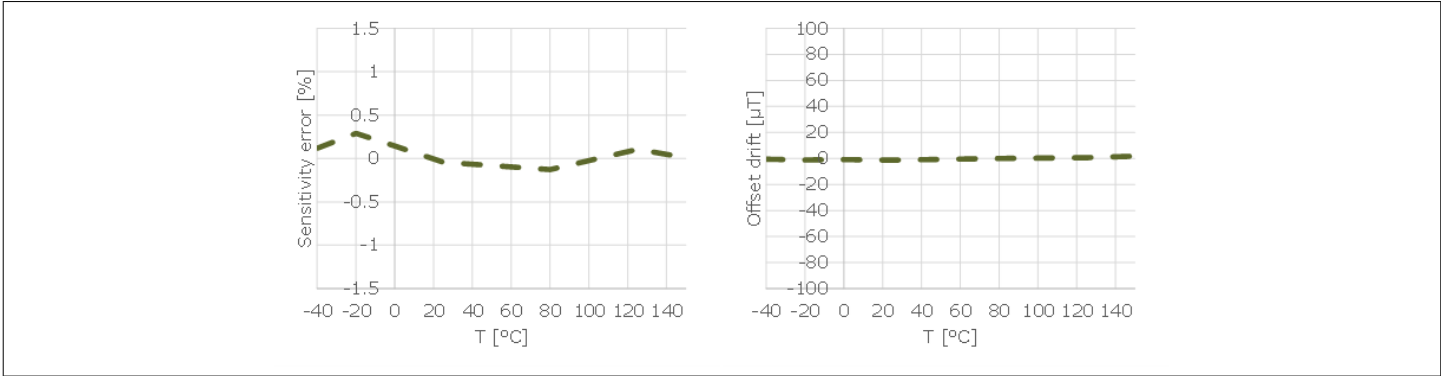


Figure 6 PG-VSON-6, semi-differential bidirectional, sensitivity S6

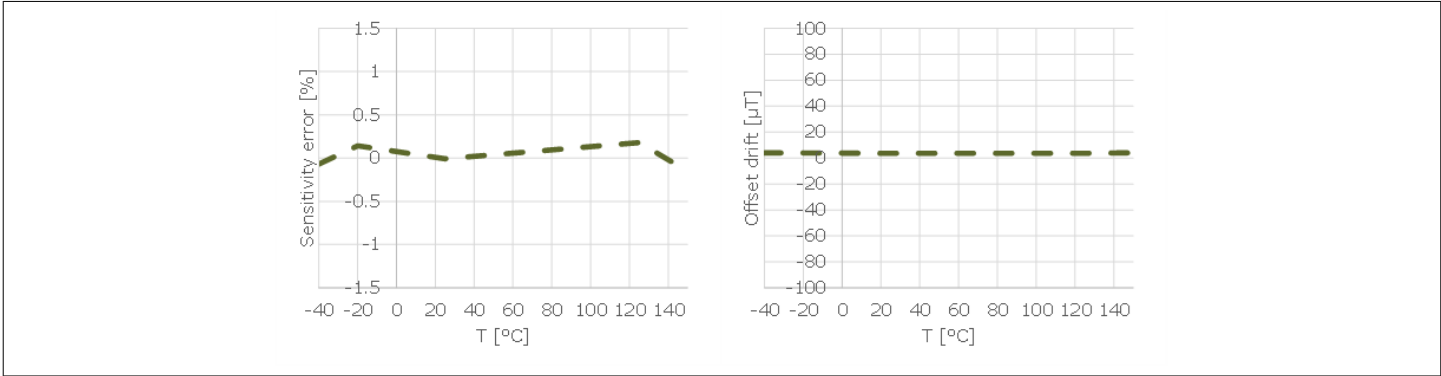


Figure 7 PG-TDSO-16, semi-differential bidirectional, sensitivity S1

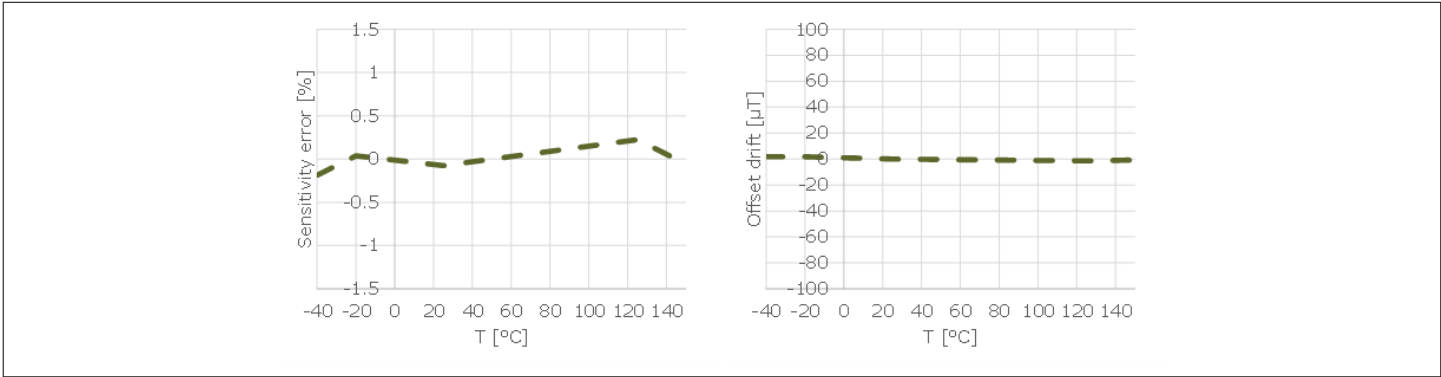
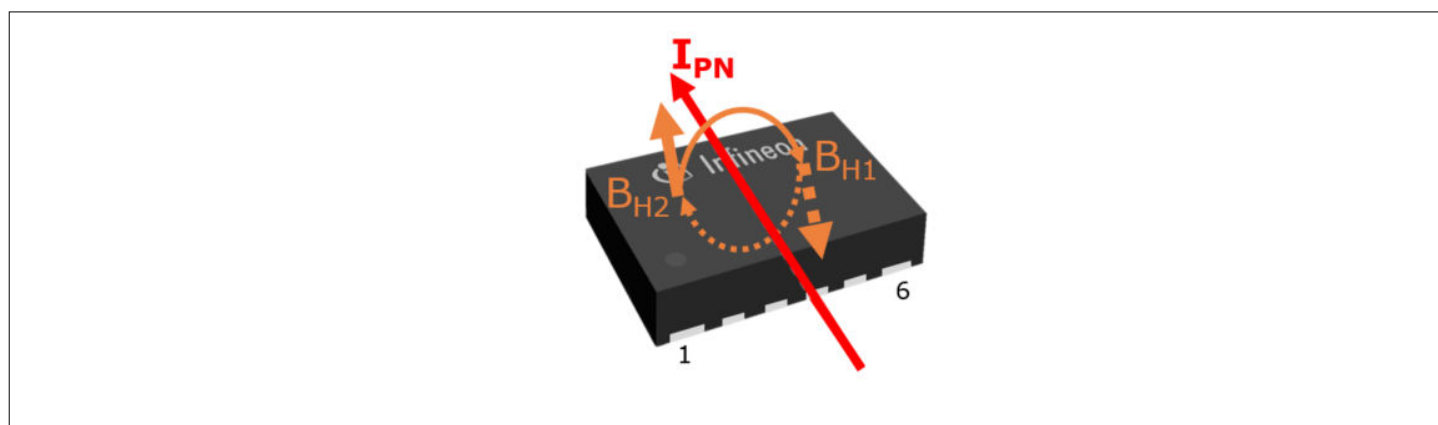


Figure 8 PG-TDSO-16, semi-differential bidirectional, sensitivity S6

## 5.3 Functional Description

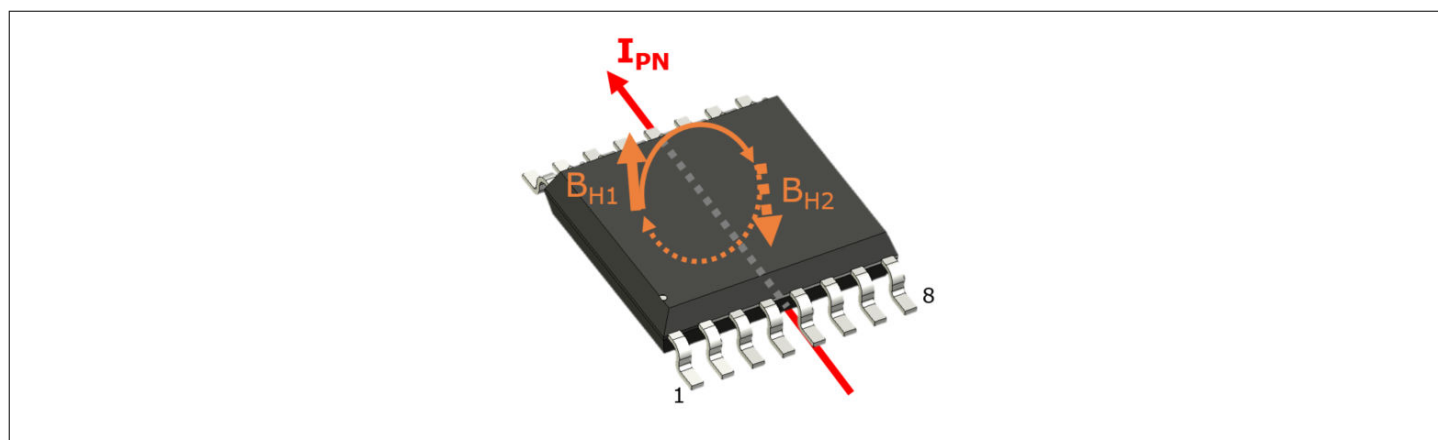
### 5.3.1 Output voltage and current polarity

TLE4973 coreless magnetic current sensor measures the differential magnetic field caused by a current flowing in an external conductor. The figures below show that the magnetic fields  $B_{H1}$  and  $B_{H2}$  at the sensor's Hall cell position depend on the current  $I_{PN}$ . The sensor provides an output voltage with the same polarity of the current  $I_{PN}$ .



**Figure 9** Current polarity (PG-VSON-6)

The current  $I_{PN}$  is positive when it flows in the direction as shown in the figure above through an external current rail.



**Figure 10** Current polarity (PG-TDSO-16)

The current  $I_{PN}$  is positive when it flows in the direction from pin 1 (+) to pin 9 (-) through an external current rail.

### 5.3.2 Output behavior

The device can be set into three different modes:

- Single-ended;
- Fully-differential;
- Semi-differential.

The mode is selected by programmable configuration.

#### 5.3.2.1 Single-ended output mode

The VREF pin operates as an input for the reference voltage, if the single-ended output mode is selected.

The AOOUT pin provides the output voltage representing the measured differential magnetic field  $B_{DIFF}$  at the Hall probes location, if the single-ended output mode is selected.

Being  $S$  the sensitivity and  $V_{OQ}$  the quiescent voltage, the output voltage at AOOUT can be expressed as:



$$V(AOUT) = V_{OQ} + S \cdot B_{DIFF} \quad (1)$$

Where  $B_{DIFF}$  is defined as the average differential magnetic field at the Hall probes location:

$$B_{DIFF} = \frac{B_{H1} - B_{H2}}{2} \quad (2)$$

The quiescent voltage  $V_{OQ}$  is equal to the voltage applied on VREF pin, if the single-ended output mode is selected.

$$V_{OQ} = V(VREF) \quad (3)$$

The output sensitivity is programmable and ratiometric with respect to the supply voltage  $V_{DD}$  as defined in the following formula, if the single-ended output mode is selected and if the sensitivity ratiometricity is enabled.

$$S(V_{DD}) = S(5V) \cdot \left[ 1 + \frac{(V_{DD} - 5V) \cdot K_S}{5V} \right] \quad (4)$$

The proportionality between the sensitivity  $S$  and the supply voltage  $V_{DD}$  is defined with the sensitivity ratiometricity factor  $K_S$ . Since the ratiometricity factor  $K_S$  nominal value is 1 the formula becomes:

$$S(V_{DD}) = S(5V) \cdot \frac{V_{DD}}{5V} \quad (5)$$

If the sensitivity ratiometricity is not enabled the sensitivity is always equal to the nominal value independently from the value of  $V_{DD}$ .

### 5.3.2.2 Fully-differential output mode

The VREF pin operates as an output to provide the inverted signal of the differential output signal, if the fully-differential output mode is selected.

Being  $S$  the sensitivity and  $V_{OQ}$  the quiescent voltage, the output voltage at VREF can be expressed as:

$$V(VREF) = V_{OQ} - S \cdot B_{DIFF} \quad (6)$$

The AOUT pin operates as an output to provide the non-inverted signal of the differential output signal, if the fully-differential output mode is selected.

Being  $S$  the sensitivity and  $V_{OQ}$  the quiescent voltage, the output voltage at AOUT can be expressed as:

$$V(AOUT) = V_{OQ} + S \cdot B_{DIFF} \quad (7)$$

The nominal quiescent voltage value at the two pins AOUT and VREF is set to  $V_{DD}/2$  (see  $V_{OQBID}$ ), if the fully-differential mode is selected. It is ratiometric with respect to  $V_{DD}$  as defined in the following formula, when the offset ratiometricity is enabled. In this case the quiescent voltages can be expressed as follows to show the dependency from the actual  $V_{DD}$  value:

$$V_{OQ}(V_{DD}) = V_{OQ}(5V) \cdot \left[ 1 + \frac{(V_{DD} - 5V) \cdot K_{OQ}}{5V} \right] \quad (8)$$

Since nominal value of the ratiometric factor  $K_{OQ}$  is 1, the formula becomes:

$$V_{OQ}(V_{DD}) = \frac{V_{DD}}{2} \quad (9)$$

The output sensitivity is programmable and ratiometric with respect to the supply voltage  $V_{DD}$  as defined in the following formula, if fully-differential mode is selected and if the sensitivity ratiometricity is enabled.

$$S(V_{DD}) = S(5V) \cdot \left[ 1 + \frac{(V_{DD} - 5V) \cdot K_S}{5V} \right] \quad (10)$$

The proportionality between the sensitivity  $S$  and the supply voltage  $V_{DD}$  is defined with the sensitivity ratiometricity factor  $K_S$ . Since the ratiometricity factor  $K_S$  nominal value is 1 the formula becomes:

$$S(V_{DD}) = S(5V) \cdot \frac{V_{DD}}{5V} \quad (11)$$

Considering the differential output voltage, for the fully-differential mode the sensitivity values are doubled compared to the ones referred to single-ended mode. If the sensitivity ratiometricity is not enabled, the sensitivity will always be equal to the nominal value, independently from  $V_{DD}$ .

### 5.3.2.3 Semi-differential output mode

The VREF pin operates as an output at which the chip-internal reference voltage is provided, if the semi-differential output mode is selected.

The AOUT pin provides the output voltage representing the measured differential magnetic field  $B_{DIFF}$  at the Hall probes location, if the semi-differential output mode is selected. The formulas for  $V(AOUT)$ ,  $S$  and  $V_{OQ}$  are the same as the ones described in single-ended output mode.

The quiescent voltage on AOUT is nominally equal to the internal reference voltage that is provided as an output on VREF pin. For the applications in which the current to be measured is bidirectional the quiescent voltage will be set to a value in the middle of the voltage range ( $V_{OQBID}$ ), whereas when the direction of the current is already known by the application, the quiescent voltage can be set to a lower value ( $V_{OQUNI}$ ) in order to better exploit the full voltage range.

### 5.3.3 Output noise density

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

$$B_{NOISE} = \frac{V_{NOISE}}{\sqrt{\frac{\pi}{2}} \cdot BW} \cdot \frac{1}{S} \cdot 10^9 \quad (12)$$

Where:

- $B_{NOISE}$  is the output noise density in [nT/√Hz];
- $V_{NOISE}$  is the output noise voltage in [VRMS];
- $BW$  is the transfer function cutoff frequency in [Hz];
- $S$  is the sensitivity in [mV/mT].

## 5.3.4 Safety and diagnostic

### 5.3.4.1 OCD - Over Current Detection

The device provides fast Over Current Detection (OCD) output on OCD pin in case of an over-current event. Over-current condition is present when the input current absolute value (positive or negative) is higher than the chosen threshold level.

#### 5.3.4.1.1 OCD pins external connection

The OCD pin operates as active low, open-drain output. This allows easy setup of a wired-AND configuration enabling the monitoring of several current sensors outputs via only one microcontroller pin. The OCD pins can be connected to a logic input pin of the microcontroller and/or the gate-driver, to quickly react to over current events.

The device has an EEPROM option to configure over current detection output to latched or not-latched mode.

In case latched mode is selected, OCD output is permanently latched to low state on over-current event. Latch can be reset via DCDI interface.

In case not-latched mode is selected, OCD output is set to low state on overcurrent event on the current rail and is released when overcurrent event disappears.

### 5.3.4.1.2 OCD thresholds

The threshold level of the OCD output is programmable. Threshold level is used symmetrically for positive and negative over current events. The possible thresholds levels can be calculated with the formulas below.

For sensitivity values between S1 and S3.5 the following formula applies:

$$OCD_{THR} = \frac{B_{THR} \cdot 1000}{TF} = \frac{[(OCD_{CODE} \cdot 1.745) + 10.714]_{[mT]} \cdot 1000}{TF} \quad (13)$$

For sensitivity values between S4 and S6 the following formula applies:

$$OCD_{THR} = \frac{B_{THR} \cdot 1000}{TF} = \frac{[(OCD_{CODE} \cdot 0.698) + 4.286]_{[mT]} \cdot 1000}{TF} \quad (14)$$

Where:

- $OCD_{THR}$  is the OCD threshold level in [A];
- $B_{THR}$  is the nominal OCD threshold level in [mT]
- $OCD_{CODE}$  is the decimal value of a 6 bits code. Minimum allowed value for S4-S6 is 5;
- $TF$  is the current rail transfer factor in [ $\mu T/A$ ].

**Table 8 TLE4973 OCD thresholds between S1 and S3.5**

| $OCD_{CODE}$ | $B_{THR}$ [mT] | Notes                  |
|--------------|----------------|------------------------|
| 0            | 10.7           | Minimum setting        |
| 11           | 29.9           | Pre-programmed setting |
| 63           | 121            | Maximum setting        |

**Table 9 TLE4973 OCD thresholds between S4 and S6**

| $OCD_{CODE}$ | $B_{THR}$ [mT] | Notes           |
|--------------|----------------|-----------------|
| 5            | 7.78           | Minimum setting |
| 63           | 48.3           | Maximum setting |

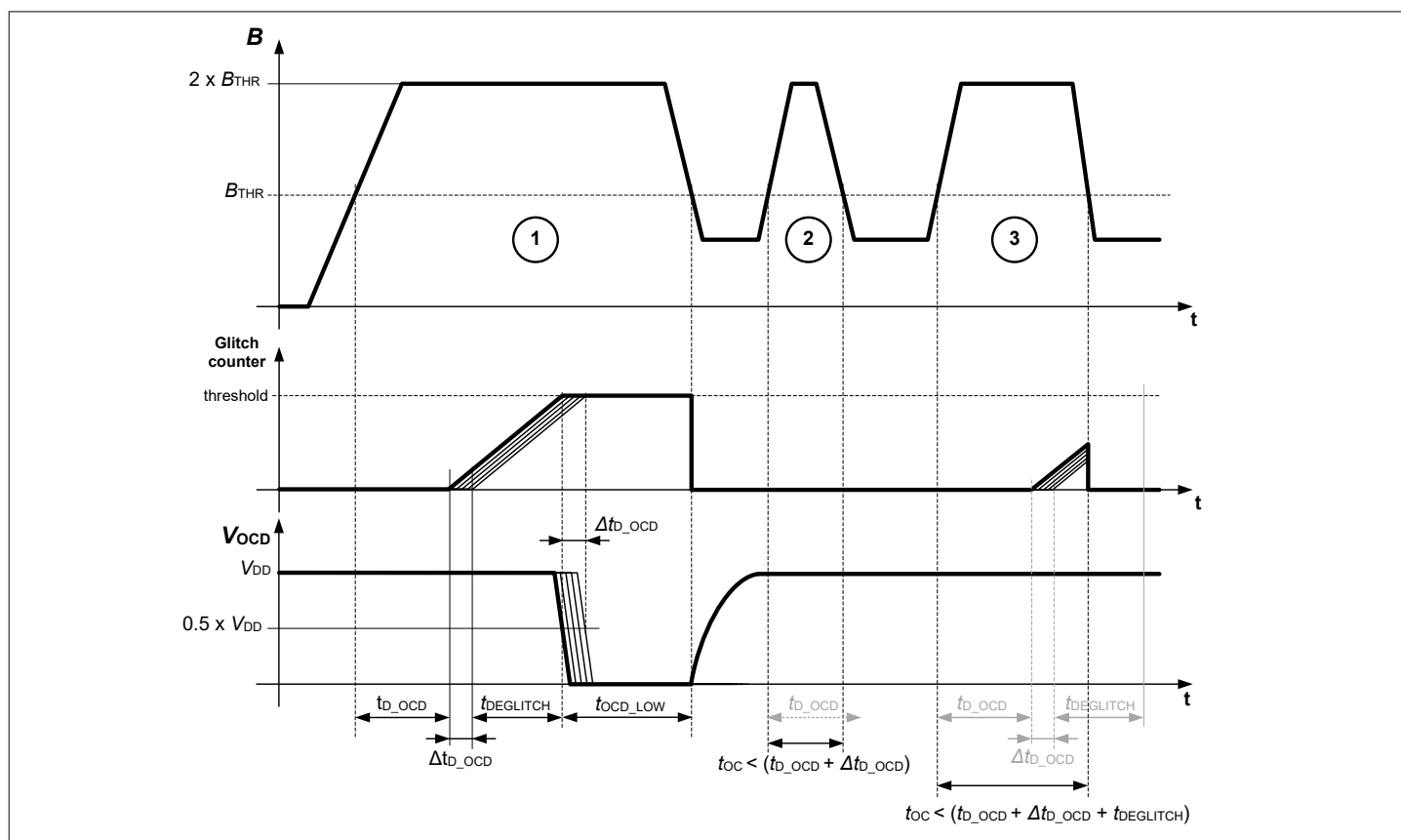
### 5.3.4.1.3 OCD output timing behavior

OCD output features a deglitch filter with programmable deglitching delay time in order to avoid false OCD triggers due to noise spikes on the current rail. The specified deglitching timing is valid when the input current step overtakes the threshold of at least 10%. As a consequence, the OCD output will only be activated when the over-current condition is present for a time interval longer than the chosen deglitching delay. See more detailed explanation in the OCD timing diagram. Available options for deglitching delay include 0 and are listed in the OCD parameters table.

Deglitching delay associated with OCD output is reset as soon as the over-current condition is removed.

Figure below shows the OCD output pin nominal behavior during an overcurrent event and defines important timing quantities for which the limits are listed in the parameters table.

Overcurrent pulse 1 is an overcurrent event, where the duration of the overcurrent condition exceeds the overcurrent response time  $t_{D\_OCD}$  + response time jitter  $\Delta t_{D\_OCD}$  + deglitch filter time  $t_{DEGLITCH}$ . Overcurrent conditions 2 and 3 are not long enough to trigger the OCD output. Pulse 2 is shorter than the overcurrent response time  $t_{D\_OCD}$  and therefore no OCD event is generated. In overcurrent condition 3, the overcurrent condition is longer than the response time  $t_{D\_OCD}$  + response time jitter  $\Delta t_{D\_OCD}$ , but is not exceeding the glitch filter time  $t_{DEGLITCH}$  and no OCD event is generated.



**Figure 11** OCD output timing behavior

**Note:** General conditions (unless otherwise specified):  $C_{OCD} = 1 \text{ nF}$ ;  $R_{OCD\_PU} = 4.7 \text{ k}\Omega$

Table 10 OCD characteristics

| Parameter                       | Symbol              | Values |      |      | Unit | Note or condition                                                                              |
|---------------------------------|---------------------|--------|------|------|------|------------------------------------------------------------------------------------------------|
|                                 |                     | Min.   | Typ. | Max. |      |                                                                                                |
| Threshold level tolerance       | $OCD_{THR\_TOL}$    | -10    | –    | +10  | %    |                                                                                                |
| OCD detection minimum time      | $t_{OCD\_LOW}$      | 3      | –    | –    | μs   | Once the over-current is signaled on the OCD, the signal is kept active for at least this time |
| OCD response time               | $t_{D\_OCD}$        | –      | 0.7  | 1.0  | μs   | $B_{DIFF} = 2 \times B_{THR}$ <sup>1)</sup>                                                    |
| OCD fall time                   | $t_{F\_OCD}$        | –      | 100  | 150  | ns   | From 90% to 10% $V_{DD}$ . Load capacitance $C_L = 1$ nF                                       |
| OCD response time jitter        | $\Delta t_{D\_OCD}$ | –      | –    | 0.11 | μs   | standard deviation, $B_{DIFF} = 2 \times B_{THR}$ , input rise time 1 μs                       |
| OCD de-glitch filter basic time | $t_{OCDGL}$         | 400    | 500  | 600  | ns   |                                                                                                |
| OCD de-glitch filter setting    | $OCD_{GL\_MUL}$     | 0      | –    | 7    | –    | $t_{DEGLITCH} = OCD_{GL\_MUL} \times t_{OCDGL}$ ; pre-configured setting = 0 <sup>2)</sup>     |
| OCD load capacitance            | $C_{OCD}$           | –      | 1    | 1.3  | nF   |                                                                                                |
| OCD pull-up resistor            | $R_{OCD\_PU}$       | 0.9    | 4.7  | 10   | kΩ   | To $V_{DD}$                                                                                    |
| OCD low-side resistance         | $R_{OCD\_LOW}$      | –      | –    | 100  | Ω    | From OCD pin to GND, when OCD pin is driven low                                                |

1) Falling edge level of OCD-pin < 0.5 x  $V_{DD}$ .

2) The specified deglitching timing is valid when input current step overtakes the threshold of at least 10%.

The device triggers an OCD diagnosis mode when a correspondent command is received through the DCDI interface, in regular operating mode (after the startup time).

It is possible to set the OCD output pin into over current detection mode only. In this mode the OCD pin would not indicate an error except under or overvoltage on the OCD pin.

### 5.3.4.2 Undervoltage / Overvoltage detection

The device activates OCD output and suspends DCDI communication if its own voltage power supply ( $V_{DD}$ ) is in an under-voltage condition.

Under-voltage condition is present when  $V_{DD}$  is between the values indicated in the  $V_{DD\_OCD}$  parameter.

In case of overvoltage condition, the sensor provides supply fault indication by disabling the DCDI interface.

Over-voltage condition is present if  $V_{DD}$  higher than the over-voltage threshold parameter ( $V_{OV\_RES}$ ).

**Table 11 Undervoltage / Overvoltage characteristics**

| Parameter                                       | Symbol            | Values |      |               | Unit    | Note or condition         |
|-------------------------------------------------|-------------------|--------|------|---------------|---------|---------------------------|
|                                                 |                   | Min.   | Typ. | Max.          |         |                           |
| Undervoltage/<br>Overvoltage<br>detection delay | $t_{UVOV\_DELAY}$ | 1      | 2.4  | 3             | $\mu s$ |                           |
| Undervoltage<br>reset threshold                 | $V_{UV\_RES}$     | 4.2    | –    | –             | V       | $V_{DD}$ falling          |
| Undervoltage<br>release<br>threshold            | $V_{UV\_REL}$     | –      | –    | 4.5           | V       | $V_{DD}$ rising           |
| OCD<br>undervoltage<br>condition                | $V_{DD\_OCD}$     | 2.7    | –    | $V_{UV\_REL}$ | V       | OCD pulled to "low" level |
| Overvoltage<br>reset threshold                  | $V_{OV\_RES}$     | –      | –    | 5.8           | V       | $V_{DD}$ rising           |
| Overvoltage<br>release<br>threshold             | $V_{OV\_REL}$     | 5.5    | –    | –             | V       | $V_{DD}$ falling          |

### 5.3.4.3 DCDI - Digital Control Diagnostic Interface

The device provides a bus compatible fast one-wire DCDI communication interface on pin DCDI operating as input/output.

The DCDI interface is a single-master, multi-slave UART based interface.

The DCDI pin operates as open-drain.

The device provides a mechanism to detect an internal saturation of the analog output. The detection information is provided on the DCDI interface.

#### 5.3.4.3.1 DCDI slave addressing

The device provides an auto-addressing functionality in order to allow the master in the system to address different sensors connected on a bus.

After the device receives the auto addressing broadcast the slave provides its dynamic address (modulated in a voltage level) to the master via the AOUT pin. The master performs the auto addressing broadcast command as long as all sensors provide a unique dynamic address on the dedicated AOUT pin. After the master addresses the dynamic slave address and reassign a static address to each slave, the static address will be stored in the device EEPROM. Up to 8 independent slaves can be addressed by the system.

It is possible that the sensor uses the static address stored in EEPROM, if the EEPROM is configured to use stored address (static). In this case broadcast command to automatically change the address is ignored.

#### 5.3.4.3.2 DCDI features

The EEPROM of the device is programmable via the DCDI interface.

It is possible to read the calibration related register content via the DCDI interface.

The DCDI interface protocol layer provides internal errors status information to the master node within each communication frame.

If OCD diagnosis mode or analog output diagnosis mode are activated, the diagnosis mode status bit in the DCDI interface frame will be set to '1'.

The sensor provides the status of the single internal safety mechanisms if requested by master.

Digital value proportional to the internally measured temperature can be read through the DCDI interface.

The DCDI end-to-end frame protection provides a failure detection rate of more than 99%.

For additional information please refer to the user manual of the device.

**Table 12 DCDI characteristics**

| Parameter                | Symbol          | Values |          |       | Unit  | Note or condition                                                                                                                  |
|--------------------------|-----------------|--------|----------|-------|-------|------------------------------------------------------------------------------------------------------------------------------------|
|                          |                 | Min.   | Typ.     | Max.  |       |                                                                                                                                    |
| DCDI number of slaves    | $DCDI_{SLV}$    | –      | –        | 8     | –     | The number of slaves to be addressed and served in one system                                                                      |
| DCDI communication speed | $DCDI_{SP}$     | 2400   | –        | 57600 | bit/s | The baud rate is programmable in 6 different speeds (57600 / 38400 / 19200 / 9600 / 4800 / 2400 bit/s) configurable through 3 bits |
| DCDI bus voltage         | $DCDI_{VBUS}$   | –      | $V_{DD}$ | –     | V     | The voltage level for the pull up resistor has the same specification as the sensor supply voltage $V_{DD}$                        |
| DCDI low voltage level   | $V_{DCDI\_LOW}$ | –      | –        | 1     | V     | Low state, transition from high to low                                                                                             |

(table continues...)



Table 12 (continued) DCDI characteristics

| Parameter                | Symbol                  | Values |      |      | Unit     | Note or condition                                                                     |
|--------------------------|-------------------------|--------|------|------|----------|---------------------------------------------------------------------------------------|
|                          |                         | Min.   | Typ. | Max. |          |                                                                                       |
| DCDI high voltage level  | $V_{\text{DCDI\_HIGH}}$ | 1.6    | –    | –    | V        | High state, transition from low to high                                               |
| DCDI pull-up resistor    | $R_{\text{DCDI\_PU}}$   | 433    | –    | 1320 | $\Omega$ |                                                                                       |
| DCDI low-side resistance | $R_{\text{DCDI\_LOW}}$  | –      | –    | 100  | $\Omega$ | From DCDI pin to GND, when DCDI pin is driven low                                     |
| DCDI maximum bus load    | $C_{\text{DCDI}}$       | –      | –    | 1.25 | nF       | Baud rate = 57600 bit/s. For slower baud rates higher capacitance values are allowed. |

### 5.3.4.4 Diagnostic mode

The device triggers an analog diagnosis mode when the corresponding command is received through DCDI interface in regular operating mode (after the startup time).

The test signal is programmable at four nominal values.

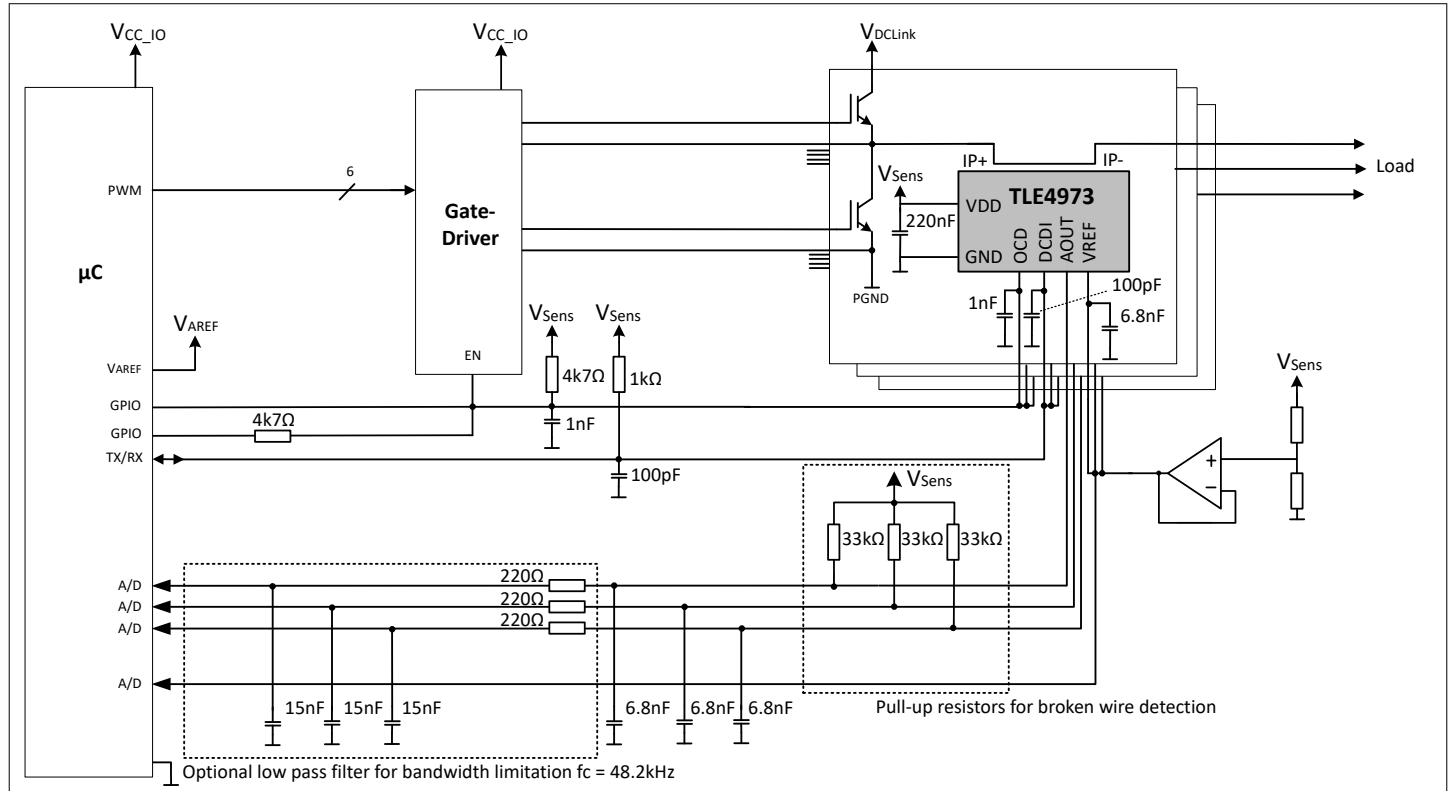
Table 13 Diagnostic mode

| Parameter                       | Symbol                    | Values |      |      | Unit | Note or condition |
|---------------------------------|---------------------------|--------|------|------|------|-------------------|
|                                 |                           | Min.   | Typ. | Max. |      |                   |
| Diagnosis mode test amplitude 1 | $B_{\text{TST\_DIAG\_1}}$ | –      | 5    | –    | mT   |                   |
| Diagnosis mode test amplitude 2 | $B_{\text{TST\_DIAG\_2}}$ | –      | 10   | –    | mT   |                   |
| Diagnosis mode test amplitude 3 | $B_{\text{TST\_DIAG\_3}}$ | –      | 15   | –    | mT   |                   |
| Diagnosis mode test amplitude 4 | $B_{\text{TST\_DIAG\_4}}$ | –      | 20   | –    | mT   |                   |



## 6.2 Application circuit example for single-ended output mode

The figure below shows an example application circuit of the device. Numbers in the application diagram are examples for typical values that could be used in the application.



**Figure 13**      **Example application diagram for single-ended output mode**

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

7 Package

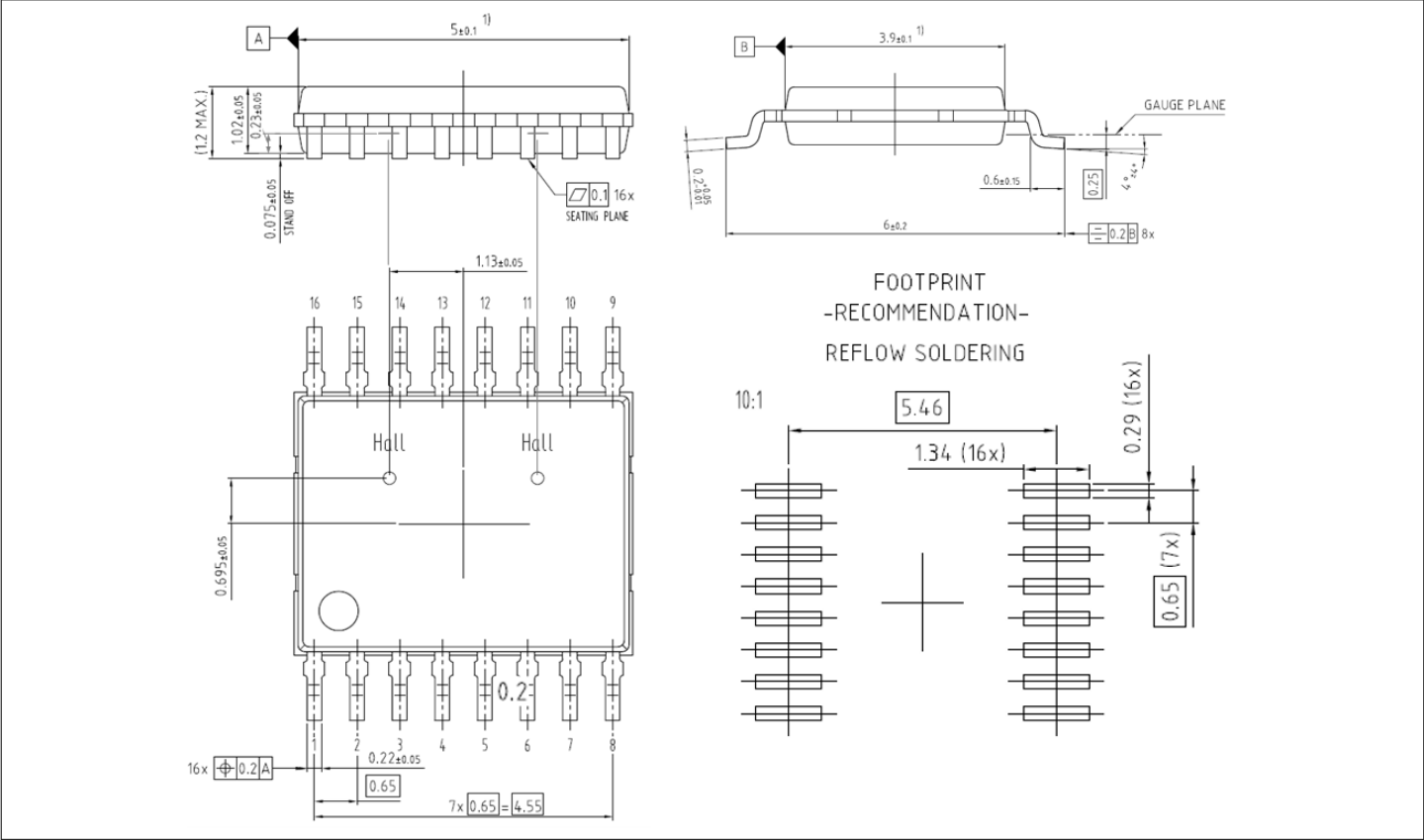


Figure 14 PG-TDSO-16 package outline. Sensing elements position not in scale

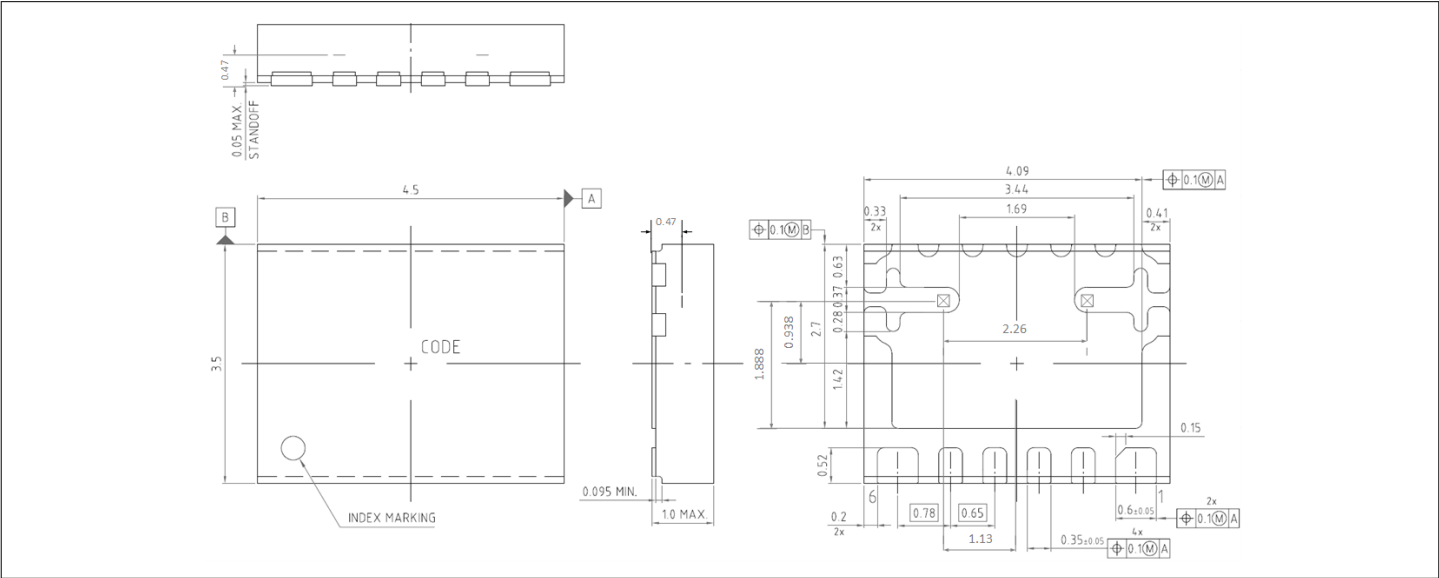
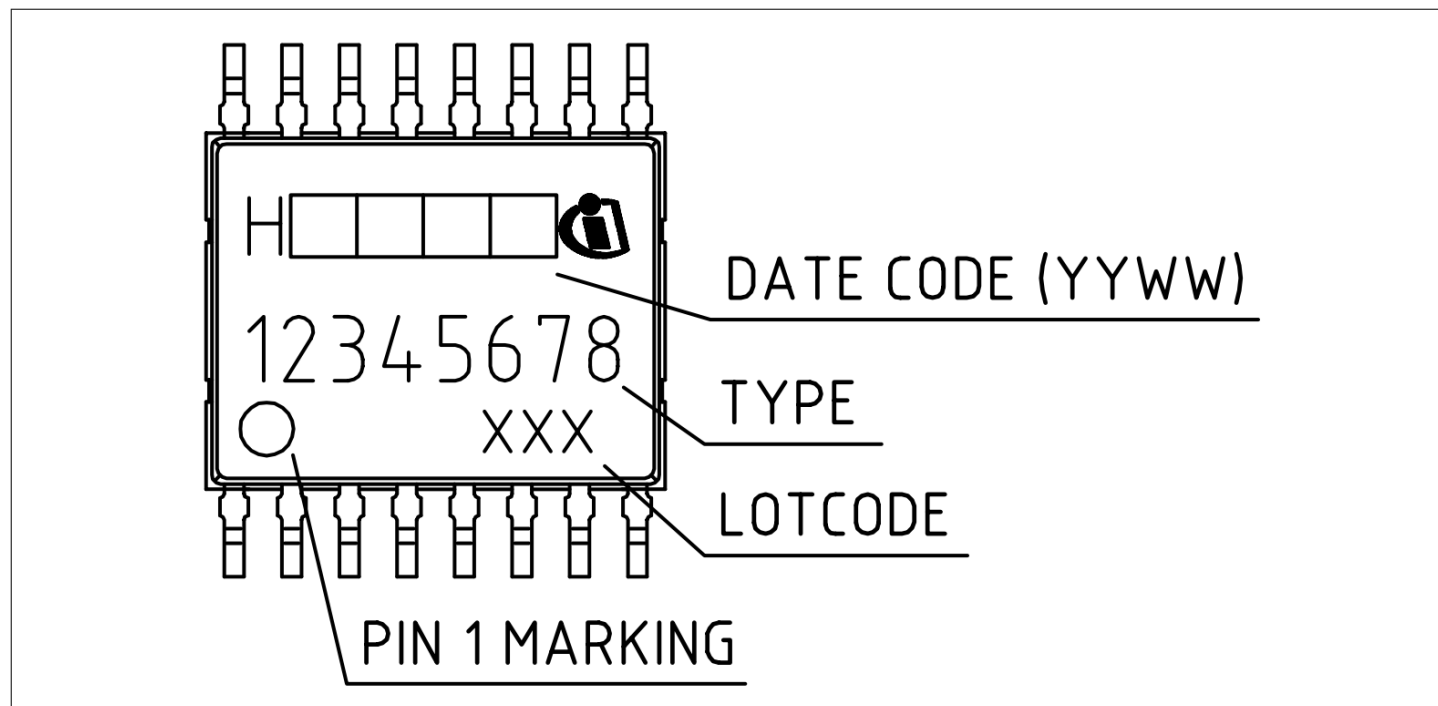


Figure 15 PG-VSON-6 package outline. Sensing elements position not in scale

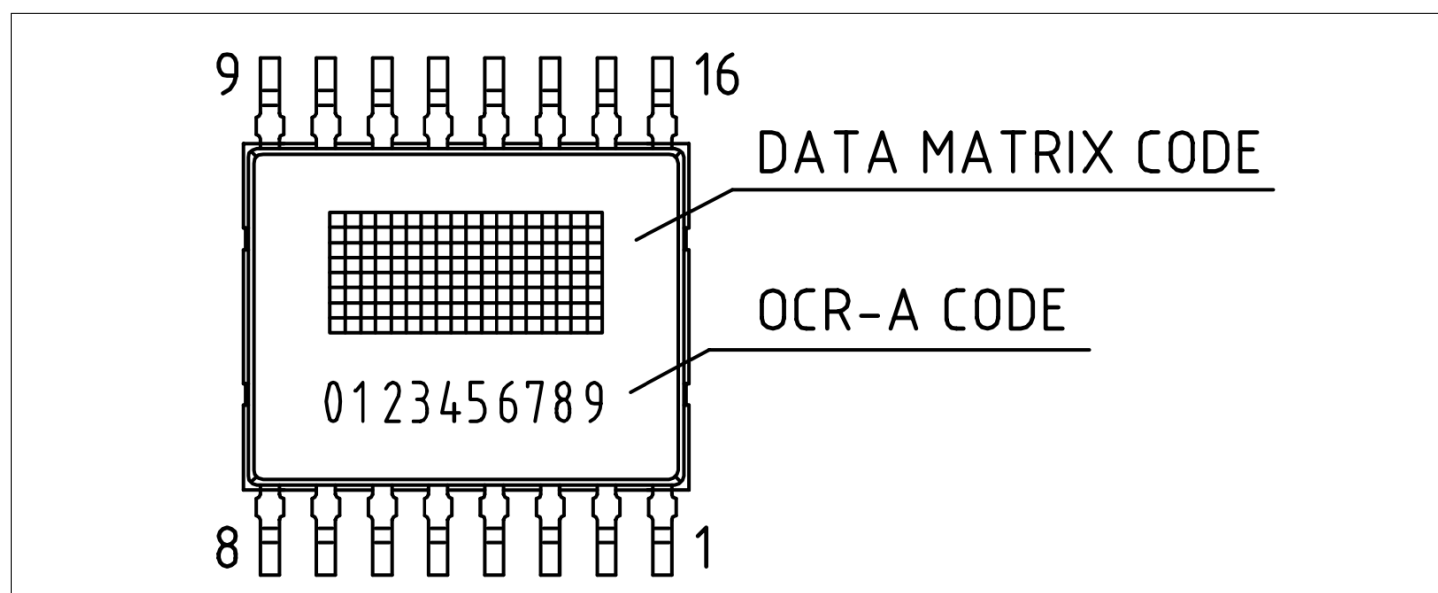
Table 14 Package grade and moisture sensitivity level according to AEC Q100 standard

| Package    | Grade | MSL |
|------------|-------|-----|
| PG-VSON-6  | 0     | 3   |
| PG-TDSO-16 | 0     | 3   |

The package marking of the device in PG-TDSO-16 package is as shown in the figures below.

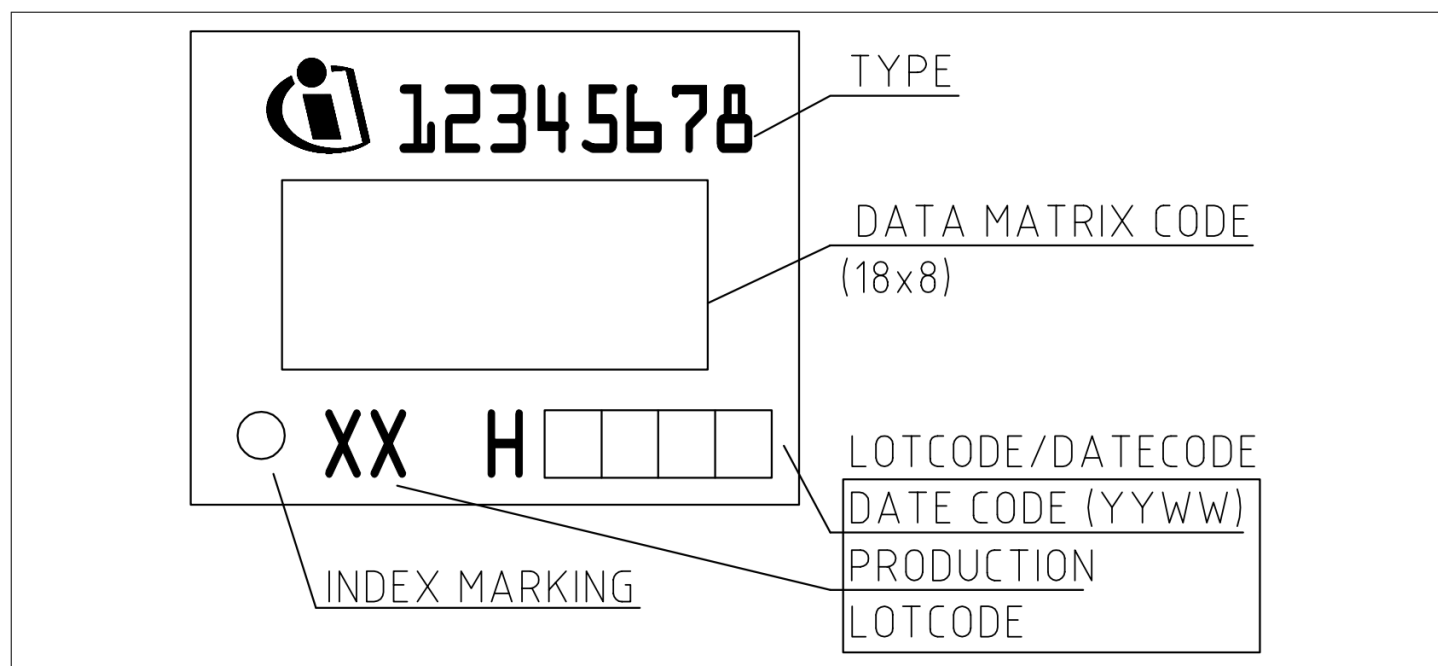


**Figure 16** Package marking front side (PG-TDSO-16)



**Figure 17** Package marking back side (PG-TDSO-16)

The package marking of the device in PG-VSON-6 is as shown in the figure below.



**Figure 18** Package marking (PG-VSON-6)

## 8 Revision History

**Table 15** Revision History

| Revision number | Date of release | Description of changes                                                                                                                                                                              |
|-----------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2.1             | 2023-11-30      | Updated application diagram examples                                                                                                                                                                |
| 2.0             | 2023-07-04      | <ul style="list-style-type: none"><li>Updated pin configuration: the correct pin configuration in case DCDI is not utilized is to connect the DCDI pin to VDD;</li><li>Editorial changes.</li></ul> |
| 1.0             | 2023-03-13      | Initial release                                                                                                                                                                                     |

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