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

Features

- High accurate, scalable, DC & AC current sensing up to ±132 A for high current applications
- 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
- Integrated current rail with typical 220 µΩ insertion resistance enables ultra-low power loss
- Smallest form factor, 8x8 mm SMD, for easy integration and board area saving
- Very low sensitivity error over temperature and lifetime
- Excellent stability of offset over temperature and lifetime
- Galvanic functional isolation up to 1150 V VIORM. Partial discharge capability of at least 1200 V
- 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 µs)
- EEPROM with integrated charge-pump for in-system programming and end-of-line calibration
- 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

RoHS

AEC Qualified

ISO 26262 compliant
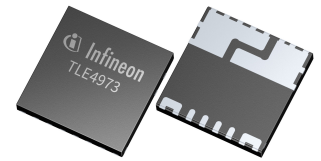
Potential applications

- General purpose electrical drives
- Chargers and on-board chargers
- PV inverters, smart circuit breakers and Uninterruptible Power Supply (UPS)
- Over-load and over-current detection
- Current monitoring and power supplies

Product validation

Qualified for automotive applications. Product validation according to AEC-Q100, Grade 1.

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 performend 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-R120T5-S0001	PG-TISON-8-6	H73E1R1IH	SP005448220
TLE4973-R075T5-S0001	PG-TISON-8-6	H73E3R1IH	SP005448224
TLE4973-R050T5-S0001	PG-TISON-8-6	H73E4R1IH	SP005448229
TLE4973-R025T5-S0001	PG-TISON-8-6	H73E6R1IH	SP005448239
TLE4973-A120T5-S0001	PG-TISON-8-6	H73E1A1IH	SP005448245
TLE4973-A075T5-S0001	PG-TISON-8-6	H73E3A1IH	SP005448249
TLE4973-A050T5-S0001	PG-TISON-8-6	H73E4A1IH	SP005448253
TLE4973-A025T5-S0001	PG-TISON-8-6	H73E6A1IH	SP005448257

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1 Standard configuration

Table 1   **TLE4973 standard configuration**

Name[1]	RATIO	FS [A][2]	I_{THR} [A][3]	OCD_{GL_MUL}[3]	V_{OQ} [V][2]	OP_{MODE}[3]
TLE4973-R120T5-S0001	on	±132	±1.39 x FS	0, filter disabled	V_{DD} / 2	Semi-differential
TLE4973-A120T5-S0001	off					
TLE4973-R075T5-S0001	on	±82				
TLE4973-A075T5-S0001	off					
TLE4973-R050T5-S0001	on	±55				
TLE4973-A050T5-S0001	off					
TLE4973-R025T5-S0001	on	±27				
TLE4973-A025T5-S0001	off					

RATIO = Ratiometricity to V_{DD}, FS = Full Scale, Sx = Sensitivity, I_{THR} = OCD threshold level, OCD_{GL_MUL} = Deglitch filter setting, V_{OQ} = Quiescent output voltage, OP_{MODE} = Output mode

1) For compatibility reason to family TLx4971 the product types are named accordingly to 120A, 75A, 50A and 25A full scale ranges. The linear range is as specified in Table 7.

2) Configuration can be changed by the customer (valid only for 131.87 A variant).

3) Configuration can be changed by the customer (valid for all variants). 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
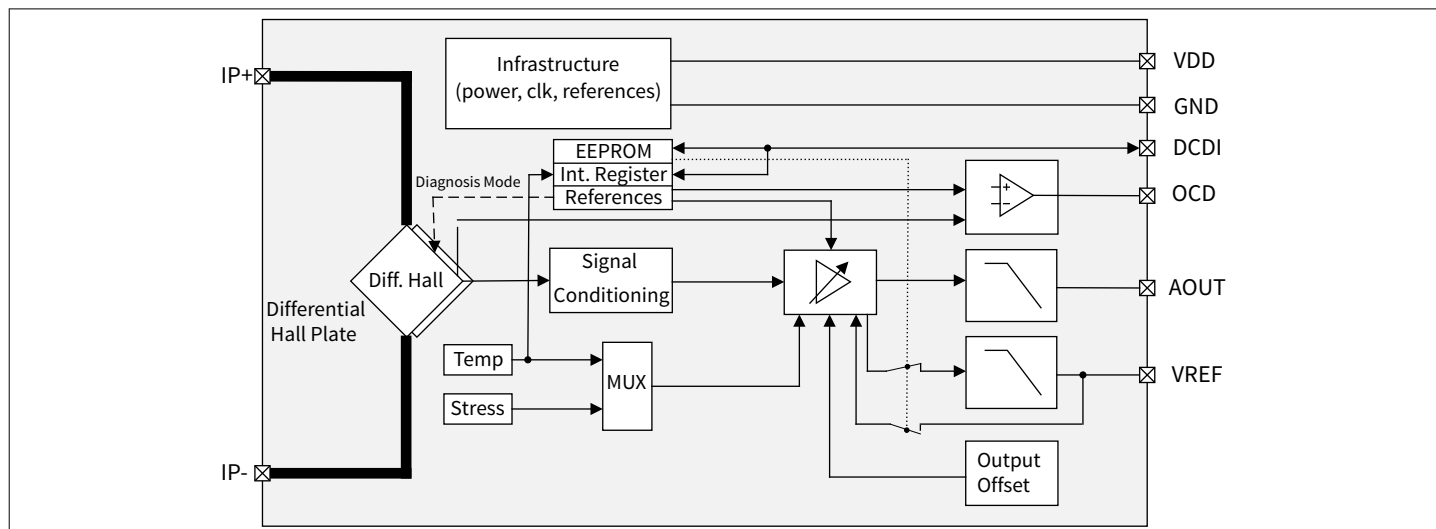
Figure 1 **Device functional block diagram**

The current flowing through the integrated current rail induces a magnetic field that is measured by two Hall probes differentially. The differential measurement principle provides superior 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
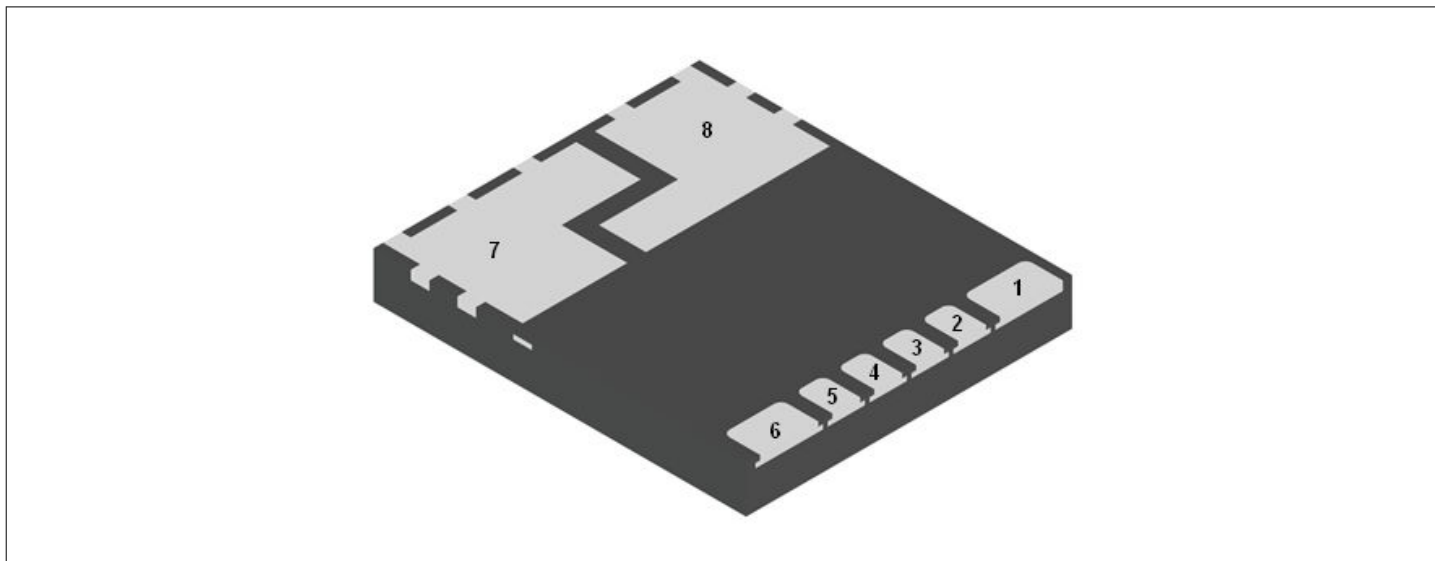
Figure 2   Pin configuration

Table 2   Pin definitions and functions

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	IP-	Negative current terminal pin	Current-out
8	IP+	Positive current terminal pin	Current-in

4 General product characteristics

4.1 Absolute maximum ratings

Table 3 **Absolute maximum ratings**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply voltage maximum ratings	V_{DD}	-0.3	–	6.5	V	
Primary current low frequency peak	I_{PNRLF}	-70	–	70	A	Peak, frequency < 10 Hz. Tested with primary nominal rated current of 70 A peak on Infineon reference PCB at Low Frequency (LF). Thermal equilibrium reached after 2 min.
Primary current high frequency rms	I_{PNRHF}	-70	–	70	A	RMS, frequency ≥ 10 Hz. Tested with primary nominal rated current of 70 A RMS on Infineon reference PCB at High Frequency (HF). Thermal equilibrium reached after 2 min
Primary current single peak	I_{PNS}	-250	–	250	A	Single peak for 10 μs, 10 assertions per lifetime
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
Voltage slew-rate on current rail	$\Delta V/dt$	–	–	10	V/ns	
Junction temperature maximum ratings	T_{J_MAX}	–	–	130	°C	
Storage temperature	T_{A_STORE}	-40	–	125	°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 4 **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 at solder point	T_S	-40	–	125	°C	Measured on soldering point
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

5 Product features

5.1 Electrical characteristics

Table 5 **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
Primary path resistance	R_{PN}	–	220	–	µΩ	25 °C, when soldered on PCB with 140 µm copper thickness
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	[1]
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

(table continues...)

Table 5   **(continued) Electrical characteristics**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Analog output diagnosis mode output amplitude variation	$V_{\text{DIAG\_VAR}}$	-20	–	20	%	Over temperature and life time with respect to diagnosis mode test signal
Thermal resistance	R_{THJS}	–	0.25	–	K/W	Current rail to soldering point, on Infineon reference PCB

1)   Can be programmed by the user (valid only for 131.87 A version).

5.2 Isolation characteristics

The device conforms functional isolation.

Table 6 **Isolation characteristics**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Maximum rated working voltage (sine wave)	V_{IOWM}	–	–	690	V	RMS, at 4000 m altitude [1] [2]
Maximum rated working voltage (sine wave)	V_{IOWMP}	–	–	975	V	Peak, at 4000 m altitude [1] [2]
Maximum repetitive isolation voltage	V_{IORM}	–	–	1150	V	Max DC voltage, spike, at 4000 m altitude [2]
Apparent charge voltage capability (method B)	V_{PD_TEST}	1500	–	–	V	Partial discharge < 5 pC peak at 0 m altitude [2]
Isolation production test voltage	V_{ISOP}	3000	–	–	V	RMS, in production, 1.2 s
Isolation pulse test voltage	V_{PULSE}	6500	–	–	V	Peak, rise time = 1.2 µs, fall time = 50 µs
Minimum external creepage distance	CPG	4	–	–	mm	
Minimum external clearance distance	CLR	4	–	–	mm	
Minimum comparative tracking index	CTI	Material group II	–	–		
Isolation resistance	R_{IO}	10	–	–	GΩ	U_{IO} = 500 V DC, 1 min.

1) The given value is considered an example based on pollution degree 2.
2) After stress test according to qualification plan.

5.3 Sensing characteristics

Table 7 Sensing characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Sensitivity, range S1	$S1$	–	13.65	–	mV/A	Bidirectional output mode: FS = ±131.87 A Unidirectional output mode: FS = 223.44 A [1]
Sensitivity, range S2	$S2$	–	16.38	–	mV/A	Bidirectional output mode: FS = ±109.89 A Unidirectional output mode: FS = 186.2 A [1]
Sensitivity, range S3	$S3$	–	21.84	–	mV/A	Bidirectional output mode: FS = ±82.42 A Unidirectional output mode: FS = 139.65 A [1]
Sensitivity, range S3.5	$S3.5$	–	27.3	–	mV/A	Bidirectional output mode: FS = ±67.53 A Unidirectional output mode: FS = 111.72 A [1]
Sensitivity, range S4	$S4$	–	32.76	–	mV/A	Bidirectional output mode: FS = ±54.95 A Unidirectional output mode: FS = 93.1 A [1]
Sensitivity, range S4.5	$S4.5$	–	38.22	–	mV/A	Bidirectional output mode: FS = ±47.09 A Unidirectional output mode: FS = 79.8 A [1]
Sensitivity, range S5	$S5$	–	43.68	–	mV/A	Bidirectional output mode: FS = ±41.21 A Unidirectional output mode: FS = 69.83 A [1]
Sensitivity, range S5.5	$S5.5$	–	49.15	–	mV/A	Bidirectional output mode: FS = ±36.63 A Unidirectional output mode: FS = 62.05 A [1]
Sensitivity, range S6	$S6$	–	65.52	–	mV/A	Bidirectional output mode: FS = ±27.47 A Unidirectional output mode: FS = 46.55 A [1]
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	φ_{DELAY}	–	43.2	60.5	°	f_{SIGNAL} = 120 kHz
Output group delay	φ_{G_DELAY}	–	1.0	1.4	µs	
Output group delay variation	$\varphi_{G\_DELAY\_VAR}$	-20	–	20	%	Over temperature and lifetime
Output noise density	I_{NOISE}	–	290	680	µA/√Hz	Referenced to input current. Typical value is for T_A = 25 °C. Max value is for T_A ≤ 125 °C [2]

(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
Sensitivity error	E_{SENS}	–	±1.5	–	%	Typical value is ±3 sigma. T_S = 25 °C, 0h [3]
Sensitivity error over temperature	E_{SENS_T}	–	±2 ±1.5	–	%	-40°C≤T_S<25°C 25°C≤T_S≤125°C Typical value is ±3 sigma. At 0h. [3]
Sensitivity error over temperature and lifetime	E_{SENS_L}	-3	±2	3	%	[4] [3]
Output offset	E_{OFF}	–	±135	–	mA	Typical value is ±3 sigma. T_S = 25 °C, 0h [3]
Output offset error over temperature	E_{OFF_T}	–	±140 ±140	–	mA	-40°C≤T_S<25°C 25°C≤T_S≤125°C Typical value is ±3 sigma. At 0h. [3]
Output offset error over temperature and lifetime	E_{OFF_L}	-500	±140	500	mA	[4] [3]
Total error	E_{TOT}	–	±1.7	–	%	Typical value is ±3 sigma. T_S = 25 °C, 0h. Percentage of full scale, sensitivity $S1$. Includes sensitivity, offset and linearity errors. [3]
Total error	E_{TOT}	–	±1.5	–	%	Typical value is ±3 sigma. T_S = 25 °C, 0h. Percentage of full scale, sensitivity $S6$. Includes sensitivity, offset and linearity errors. [3]
Total error over temperature	E_{TOT_T}	–	±2.3 ±1.7	–	%	-40°C≤T_S<25°C 25°C≤T_S≤125°C Typical value is ±3 sigma. At 0h. Percentage of full scale, sensitivity $S1$. Includes sensitivity, offset and linearity errors. [3]
Total error over temperature	E_{TOT_T}	–	±2.3 ±1.8	–	%	-40°C≤T_S<25°C 25°C≤T_S≤125°C Typical value is ±3 sigma. At 0h. Percentage of full scale, sensitivity $S6$. Includes sensitivity, offset and linearity errors. [3]

(table continues...)

Table 7   **(continued) Sensing characteristics**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	**Typ.**	**Max.**		
Total error over temperature and lifetime	E_{TOT_L}	-3.45	±2.3	3.45	%	Percentage of full scale, sensitivity *S1*. Includes sensitivity, offset and linearity errors. [4] [3]
Sensitivity ratiometricity error over temperature and lifetime	E_{SRATIO_L}	–	±0.05	–	%/%V_{DD}	±10% V_{DD} variation. [4]
Offset ratiometricity error over temperature and lifetime	E_{ORATIO_L}	–	±5	–	mA	±10% V_{DD} variation. [4]
Temperature sensor sensitivity	S_{TEMP}	–	16	–	LSB/°C	
Temperature sensor RMS noise	$NRMS_{TEMP}$	–	–	0.5	°C	In the range of 25 °C to max operating T_J
Temperature sensor linearity error	E_{TEMP}	-5	–	5	°C	In the range of 25 °C to max operating T_J

1) Can be programmed by the user (valid only for 131.87 A version).
2) Output noise density can be expressed according to the formula shown in Chapter 5.4.3.
3) Specified accuracy errors are only valid for the pre-programmed ratiometricity setting.
4) Min/Max values derived from AEC-Q100 qualification. Typical values are ±3 sigma values measured during AEC-Q100 qualification.

5.3.1 Full scale definition

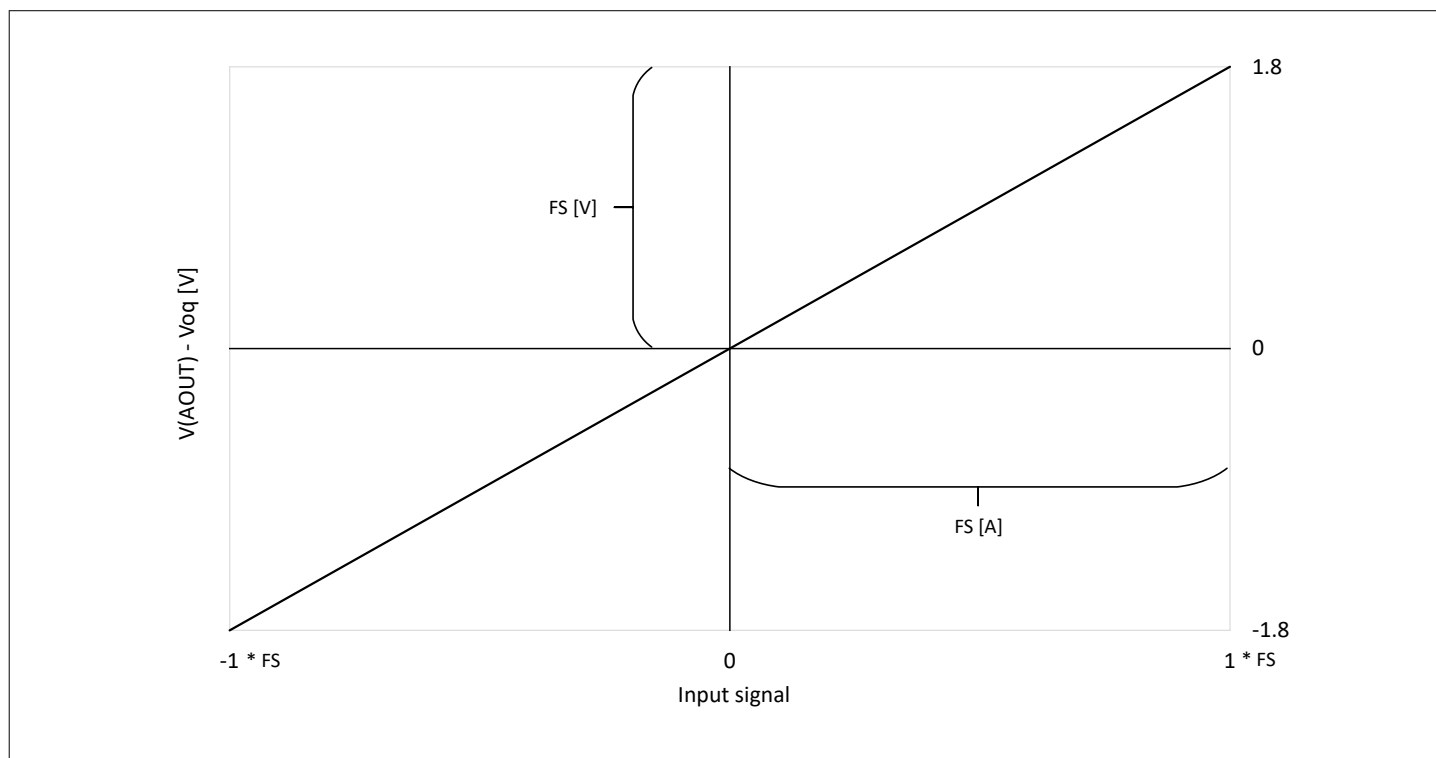The full scale input and full scale output voltage are defined as follows.

Figure 3 **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.
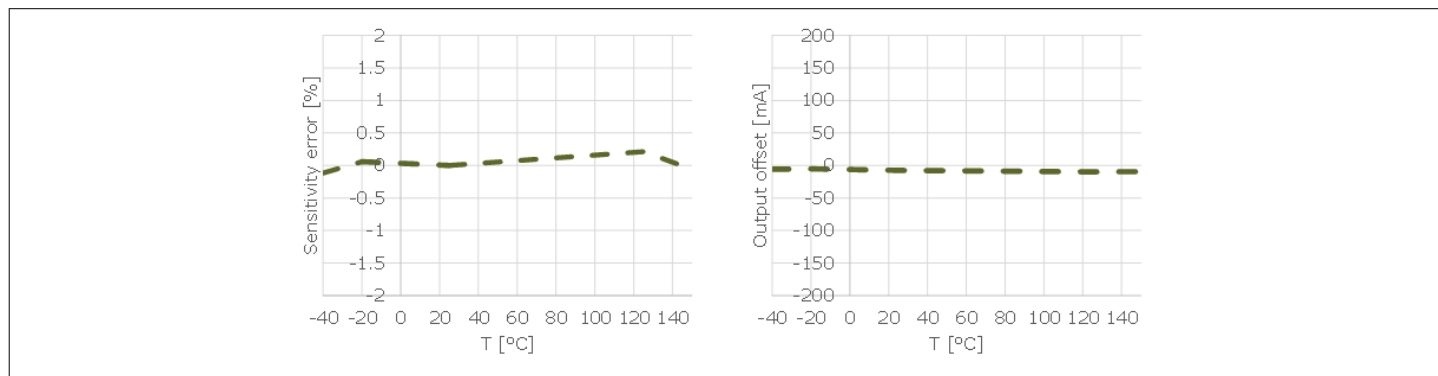
5.3.2 Typical performance over temperature

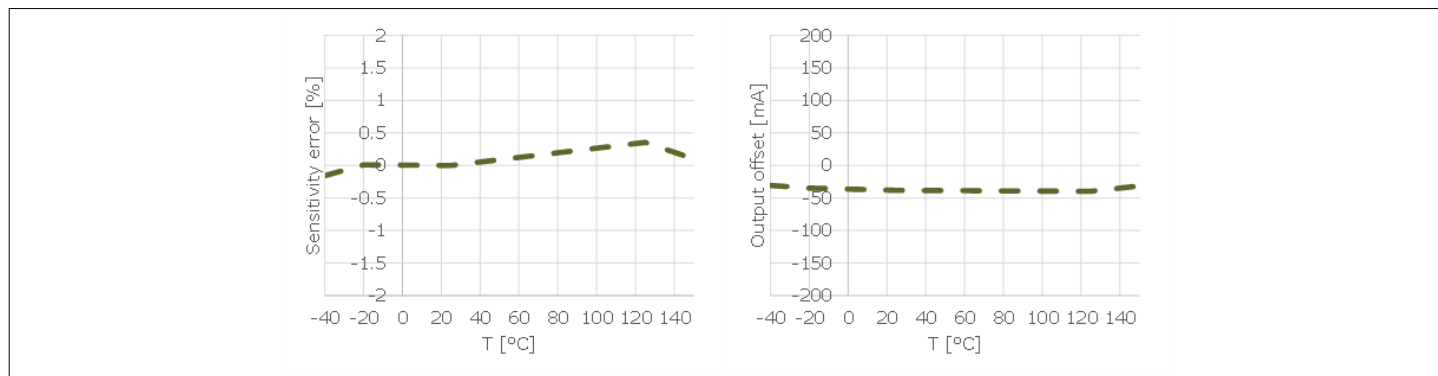**Figure 4**   **PG-TISON-8-6, semi-differential, sensitivity *S1***

Figure 5   **PG-TISON-8-6, semi-differential, sensitivity *S6***

5.4 Functional Description

5.4.1 Output voltage and current polarity

TLE4973 coreless magnetic current sensor measures the differential magnetic field caused by a current flowing in the internal current rail. 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}.
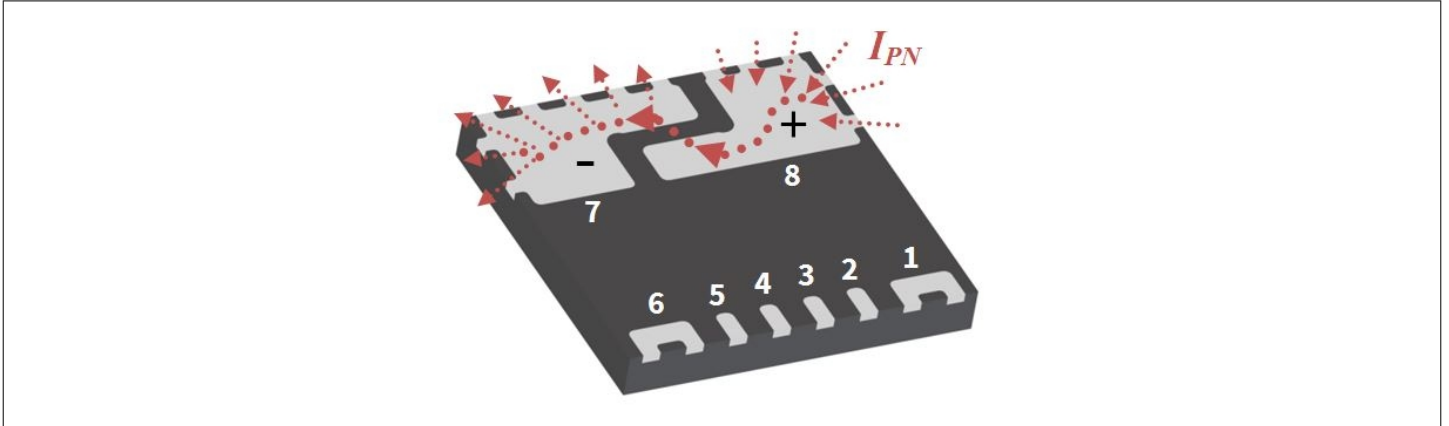

Figure 6   **Polarity illustration PG-TISON-8-6 package**

The current I_{PN} is positive when it flows from pin 8 (+) to pin 7 (-) through the integrated current rail.

5.4.2 Output behavior

The device can be set into three different modes:
- Single-ended;
- Fully-differential;
- Semi-differential.

The mode is selected by programmable configuration.

5.4.2.1 Single-ended output mode

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

The AOUT pin provides the output voltage representing the measured current I_{PN} flowing in the current rail, if the single-ended output mode is selected.

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

$$V(AOUT) = V_{OQ} + S \cdot I_{PN} \tag{1}$$

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

$$V_{OQ} = V(VREF) \tag{2}$$

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.

$$S(V_{DD}) = S(5V) \cdot \left[1 + \frac{(V_{DD} - 5V) \cdot K_S}{5V} \right] \tag{3}$$

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:

$$S(V_{DD}) = S(5V) \cdot \frac{V_{DD}}{5V} \tag{4}$$

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

5.4.2.2 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:

$$V(VREF) = V_{OQ} - S \cdot I_{PN} \tag{5}$$

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:

$$V(AOUT) = V_{OQ} + S \cdot I_{PN} \tag{6}$$

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:

$$V_{OQ}\left(V_{DD}\right) = V_{OQ}\left(5V\right) \cdot \left[1 + \frac{(V_{DD} - 5V) \cdot K_{OQ}}{5V}\right] \tag{7}$$

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

$$V_{OQ}\left(V_{DD}\right) = \frac{V_{DD}}{2} \tag{8}$$

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.

$$S\left(V_{DD}\right) = S\left(5V\right) \cdot \left[1 + \frac{(V_{DD} - 5V) \cdot K_S}{5V}\right] \tag{9}$$

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:

$$S\left(V_{DD}\right) = S\left(5V\right) \cdot \frac{V_{DD}}{5V} \tag{10}$$

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}.

5.4.2.3 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 current I_{PN} flowing in the current rail, 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.

5.4.3   Output noise density

Output noise density referenced to input current can be expressed according to the following formula:

$$I_{NOISE} = \frac{V_{NOISE}}{\sqrt{\frac{\pi}{2} \cdot BW}} \cdot \frac{1}{S} \cdot 10^9$$

(11)

Where:

- I_{NOISE} is the output noise density in [µA/√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/A].

5.4.4   Safety and diagnostic

5.4.4.1   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.

5.4.4.1.1   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.

5.4.4.1.2   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:

$$OCD_{THR} = [(OCD_{CODE} \cdot 6.76) + 41.51]_{[A]} \tag{12}$$

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

$$OCD_{THR} = [(OCD_{CODE} \cdot 2.7) + 16.6]_{[A]} \tag{13}$$

Where:
- OCD_{THR} is the OCD threshold level in [A];
- OCD_{CODE} is the decimal value of a 6 bits code. Minimum allowed value for S4-S6 is 5.

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

OCD_{CODE}	OCD_{THR} [A]	Notes
0	41.5	Minimum setting
11	116	Pre-programmed setting for TLE4973-x075T5-S00xx
21	184	Pre-programmed setting for TLE4973-x120T5-S00xx
63	467	Maximum setting

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

OCD_{CODE}	OCD_{THR} [A]	Notes
5	30	Minimum setting
8	38	Pre-programmed setting for TLE4973-x025T5-S00xx
22	76	Pre-programmed setting for TLE4973-x050T5-S00xx
63	187	Maximum setting

5.4.4.1.3 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 Δt_{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 Δt_{D_OCD}, but is not exceeding the glitch filter time $t_{DEGLITCH}$ and no OCD event is generated.
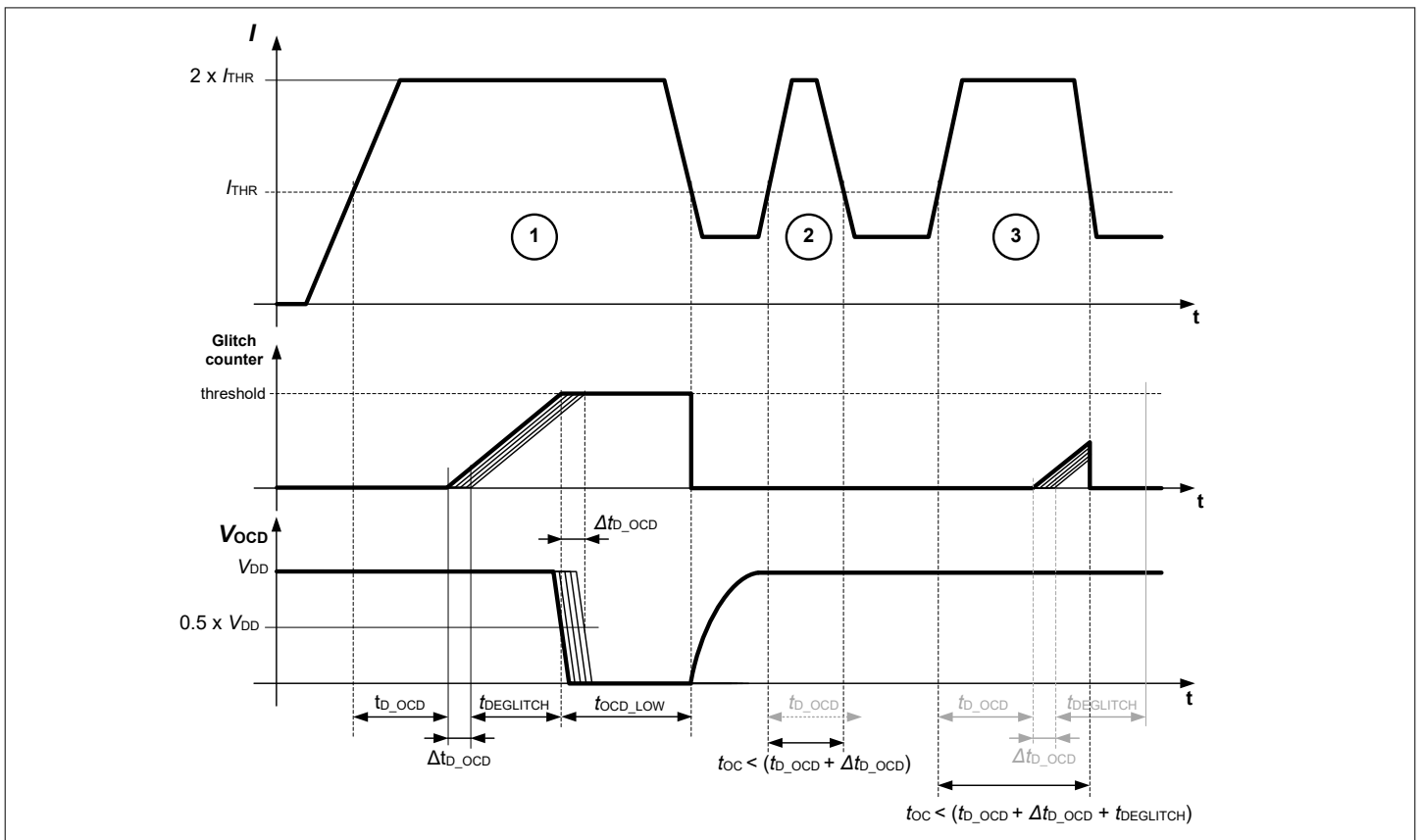

Figure 7   **OCD output timing behavior**

Note: *General conditions (unless otherwise specified): C_{OCD} = 1 nF; R_{OCD_PU} = 4.7 kΩ*

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	$I_{PN} = 2 \times I_{THR}$ [1]
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	Δt_{D_OCD}	–	–	0.11	µs	standard deviation, $I_{PN} = 2 \times I_{THR}$, 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 [2]
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.

5.4.4.2 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/ Overvoltage detection delay	t_{UVOV_DELAY}	1	2.4	3	µs	
Undervoltage reset threshold	V_{UV_RES}	4.2	–	–	V	V_{DD} falling
Undervoltage release threshold	V_{UV_REL}	–	–	4.5	V	V_{DD} rising
OCD undervoltage condition	V_{DD_OCD}	2.7	–	V_{UV_REL}	V	OCD pulled to "low" level
Overvoltage reset threshold	V_{OV_RES}	–	–	5.8	V	V_{DD} rising
Overvoltage release threshold	V_{OV_REL}	5.5	–	–	V	V_{DD} falling

5.4.4.3 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.

5.4.4.3.1 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.

5.4.4.3.2 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
DCDI high voltage level	V_{DCDI_HiGH}	1.6	–	–	V	High state, transition from low to high
DCDI pull-up resistor	R_{DCDI_PU}	433	–	1320	Ω	
DCDI low-side resistance	R_{DCDI_LOW}	–	–	100	Ω	From DCDI pin to GND, when DCDI pin is driven low
DCDI maximum bus load	C_{DCDI}	–	–	1.25	nF	Baud rate = 57600 bit/s. For slower baud rates higher capacitance values are allowed.

5.4.4.4 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	$I_{TST\_DIAG\_1}$	–	18.76	–	A	
Diagnosis mode test amplitude 2	$I_{TST\_DIAG\_2}$	–	37.52	–	A	
Diagnosis mode test amplitude 3	$I_{TST\_DIAG\_3}$	–	56.29	–	A	
Diagnosis mode test amplitude 4	$I_{TST\_DIAG\_4}$	–	75.02	–	A	

6 Application Information

6.1 Application circuit example for semi-differential and fully-differential output modes

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.
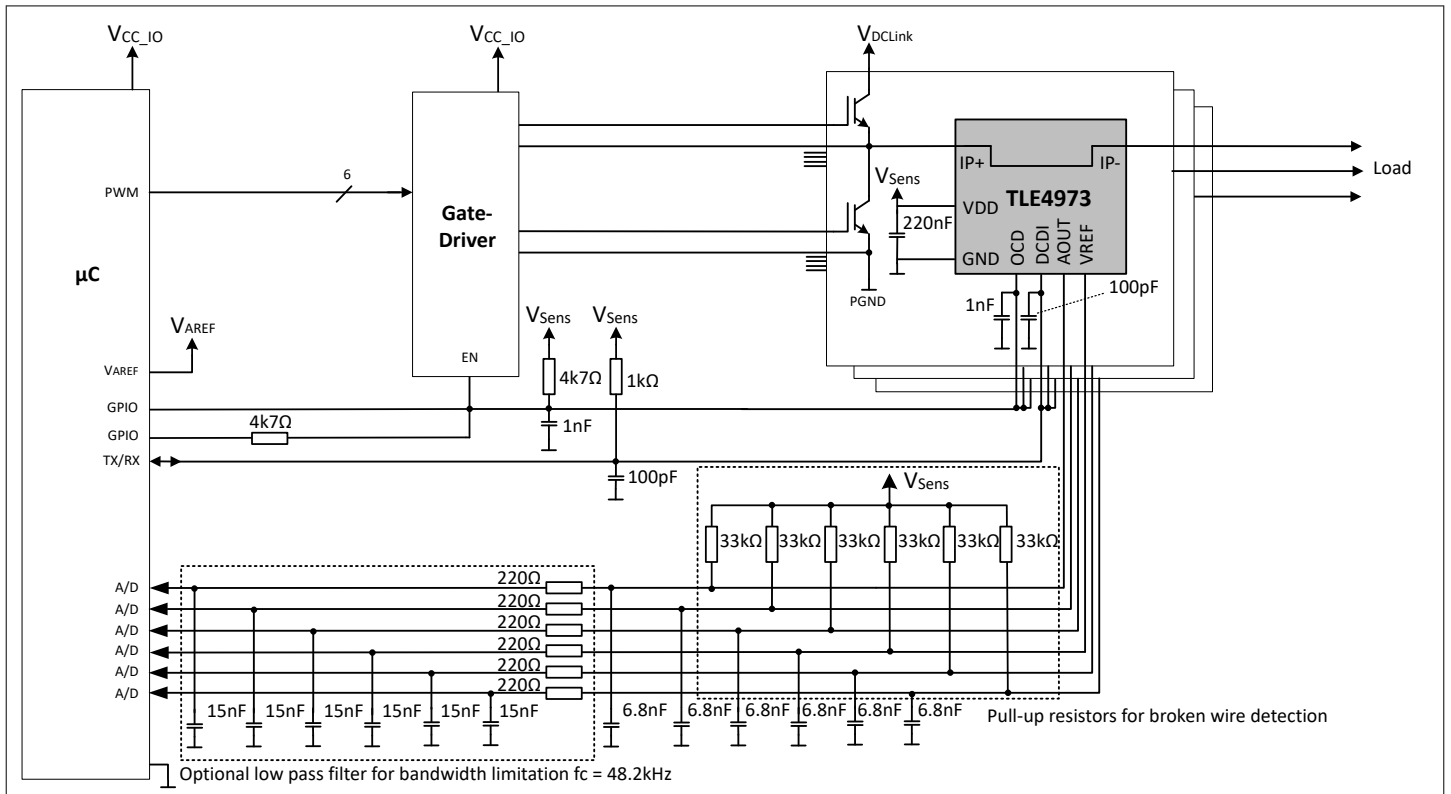
Figure 8 **Example application diagram for semi-differential and fully differential output modes**

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

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 9 **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

The device is mounted in the PG-TISON-8-6 Package.

Figure 10   **PG-TISON-8-6 package outline**

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

Package	Grade	MSL
PG-TISON-8-6	1	3

The package marking of the device in PG-TISON-8-6 package is as shown in the figure below.

Figure 11   **Package marking**

8 Revision History

Table 15 **Revision History**

Revision number	Date of release	Description of changes
1.1	2023-11-30	Updated application diagram examples
1.0	2023-07-04	Initial release

Trademarks

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