TLE4998P8D Grade1

High Performance Programmable Dual Linear Hall Sensor

Technical Product Description

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1 Overview

Characteristic	Supply Voltage	Supply Current	Sensitivity Range	Interface	Temperature
Programmable Dual Die Linear Hall Sensor	4.5~5.5 V	6 mA	±50mT ±100mT ±200mT	PWM Open Drain Output	-40°C to 125°C

Figure 1-1 SMD package PG-TDSO-8-2 for the TLE4998P8D

1.1 Features

- Integration of two individual programmable Linear Hall sensor IC’s with PWM open-drain output signal
- 20-bit Digital Signal Processing
- Digital temperature and stress compensation
- 12-bit overall resolution
- Operating automotive temperature range -40°C to 125°C
- Minimal drift of output signal over temperature and lifetime
- Programmable parameters stored in EEPROM with single bit error correction:
  - PWM output frequency
  - Magnetic range and magnetic sensitivity (gain), polarity of the output slope
  - Offset
  - Bandwidth
  - Clamping levels
  - Customer temperature compensation coefficients for all common magnets
  - Memory lock
- Re-programmable until memory lock
- Supply voltage 4.5 - 5.5 V (4.1 - 16 V extended range)
- Operation between -200 mT and +200 mT within three ranges
- Reverse-polarity and overvoltage protection for all pins
- Output short-circuit protection
- On-board diagnostics (overvoltage, EEPROM error)
- Digital readout of the magnetic field and internal temperature in calibration mode
- Programming and operation of multiple sensors with common power supply
- Two-point calibration of magnetic transfer function without iteration steps
- High immunity against mechanical stress, EMC, ESD

Table 1-1 Ordering Information

Product Name	Marking	Ordering Code	Package
TLE4998P8D	-	-	PG-TDSO-8-2

1.2 Target Applications

- Robust replacement of potentiometers: No mechanical abrasion, resistant to humidity, temperature, pollution and vibration
- Linear and angular position sensing in automotive and industrial applications with highest accuracy requirements
- Suited for ASIL applications such as pedal position, throttle position and steering torque sensing
- High-current sensing e.g. for battery management or motor control

1.3 Pin Configuration

Figure 1-2 shows the location of the Hall elements in the chip pin configuration of the package.

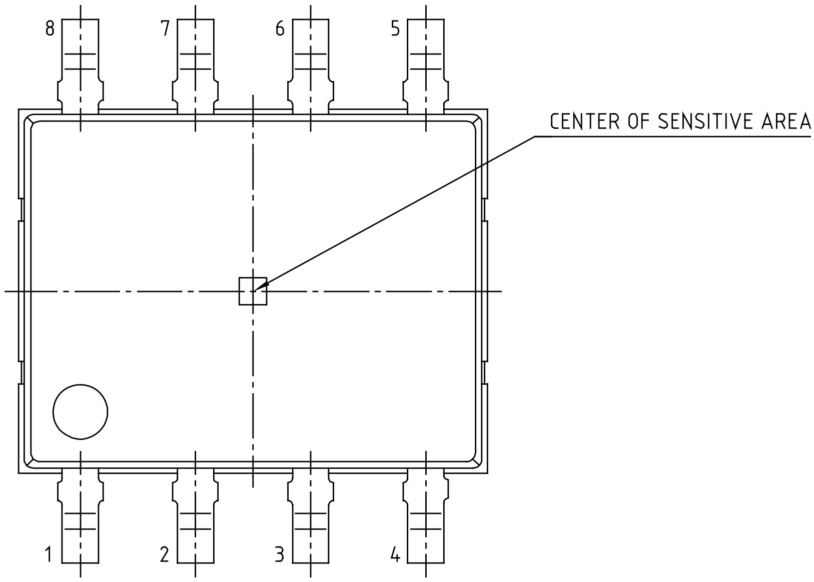

Figure 1-2 Pin Configuration of PG-TDSO-8-2 Package

Table 1-2 TLE4998P8D Pin Definitions and Functions

Pin No.	Symbol	Function
1	TST	Test pin (top die) (connection to GND is recommended)
2	V_{DD}	Supply voltage / programming interface (top die)
3	GND	Ground (top die)
4	OUT	Output / programming interface (top die)
5	OUT	Output / programming interface (bottom die)
6	GND	Ground (bottom die)
7	V_{DD}	Supply voltage / programming interface (bottom die)
8	TST	Test pin (bottom die) (connection to GND is recommended)

2 General

All further given descriptions are regarded to both implemented sensor IC’s, or otherwise noted.

2.1 Block Diagram

Figure 2-1 shows is a simplified block diagram.

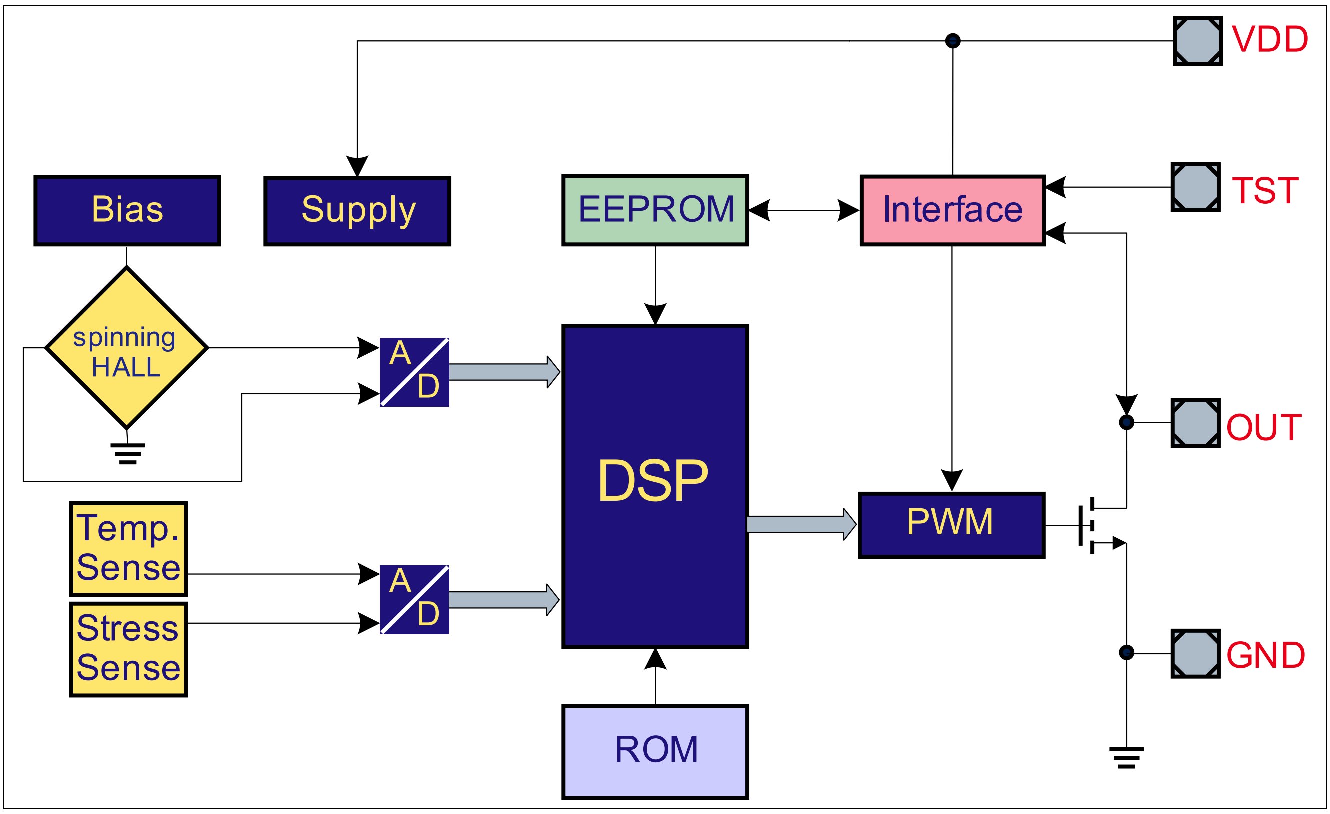

Figure 2-1 Block Diagram of the TLE4998P8D with the PWM interface

2.2 Functional Description

The linear Hall IC TLE4998P8D has been designed specifically to meet the requirements of highly accurate angle and position detection, as well as for current measurement applications. Especially the dual Die version with electrical insulated sensor IC’s, mounted on top and bottom side of the lead frame will give designs/designers a competitive advantage when stringent safety requirements in automotive applications have to be met.

The sensor provides a digital PWM signal, which is ideally suited for direct decoding by any unit measuring a duty cycle of a rectangular signal (usually a timer/capture unit in a microcontroller).Furthermore, it is possible to attach an external lowpass filter, which allows an A/D conversion using the sensor supply voltage as a reference.

The output stage is an open-drain driver pulling the output pin to low only. Therefore, the high level needs to be obtained by an external pull-up resistor. This output type has the advantage that the receiver may use an even lower supply voltage (e.g. 3.3 V). In this case the pull-up resistor must be connected to the given receiver supply.

The IC is produced in BiCMOS technology with high voltage capability and it also has reverse-polarity protection.

Digital signal processing using a 16-bit DSP architecture together with digital temperature and stress compensation guarantees excellent stability over the whole temperature range and life time.

While the overall resolution is 12 bits, some internal stages work with resolutions up to 20 bits.

The PWM output frequency can be selected within the range of 122 Hz up to 1953 Hz.

2.3 Principle of Operation

- A magnetic flux is measured by a Hall-effect cell
- The output signal from the Hall-effect cell is converted from analog to digital signals
- The chopped Hall-effect cell and continuous-time A/D conversion ensure a very low and stable magnetic offset
- A programmable low-pass filter to reduce noise
- The temperature is measured and A/D converted
- Temperature compensation is done digitally using a second-order function
- Digital processing of the output value is based on zero field and sensitivity value
- The output value range can be clamped by digital limiters
- The final output value is transferred in a rectangular, periodic signal with varying duty cycle (Pulse Width Modulation)
- The duty cycle is proportional to the 12-bit output value

2.4 Further Notes

Product qualification is based on “AEC Q100 Rev. G” (Automotive Electronics Council - Stress test qualification for integrated circuits).

2.5 Transfer Functions

The examples in **Figure 2-2** show how different magnetic field ranges can be mapped to the desired output value ranges.

- Polarity Mode:
  - **Bipolar**: Magnetic fields can be measured in both orientations. The limit points do not necessarily have to be symmetrical around the zero field point
  - **Unipolar**: Only north- or south-oriented magnetic fields are measured
- Inversion: Both gain can be set to positive values, negative values or positive/negative values.

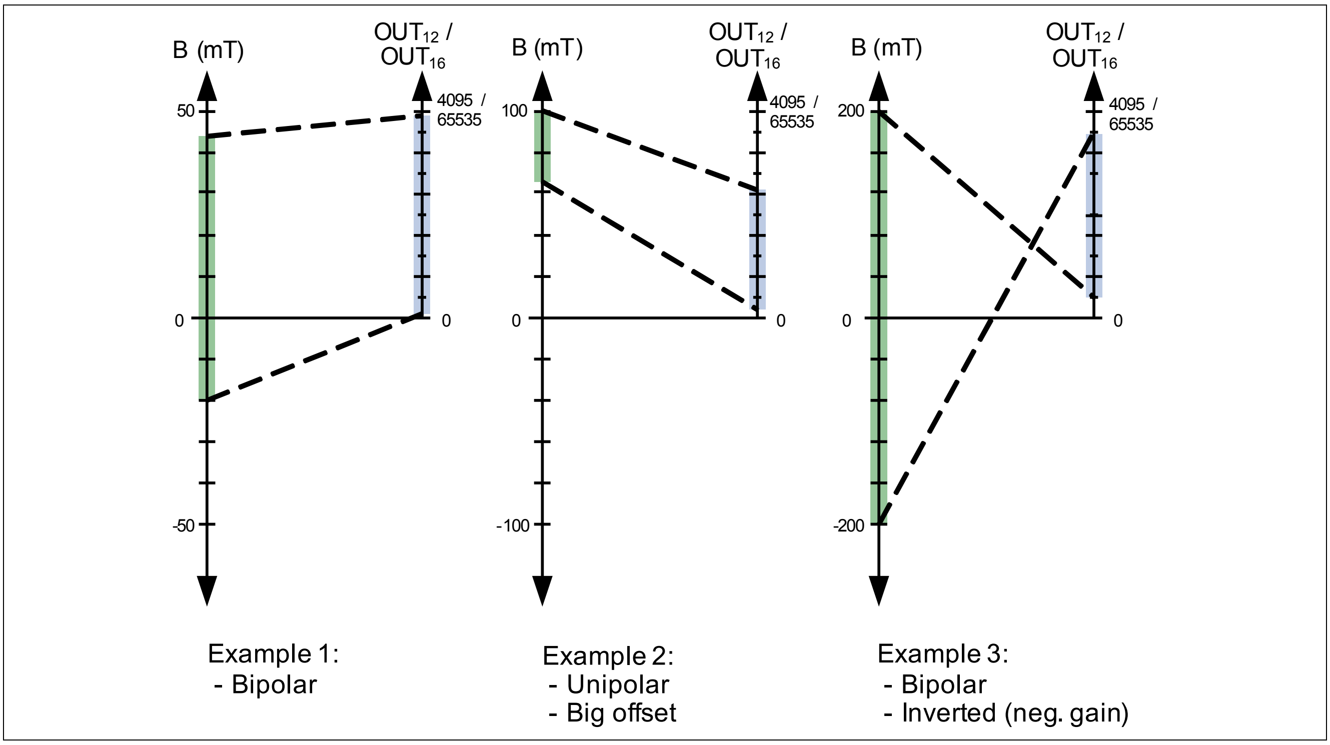

Figure 2-2 Examples of Operation

3 Maximum Ratings

All further given descriptions are regarded to each of the implemented sensors IC's, or otherwise noted.

Table 3-1 Absolute Maximum Ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Junction temperature	T_J	- 40	–	140	°C	–
Voltage on V_{DD} pin with respect to ground	V_{DD}	-18	–	18.35	V	1)2)
Supply current @ overvoltage V_{DD} max.	I_{DDov}	–	–	15	mA	–
Reverse supply current @ V_{DD} min.	I_{DDrev}	-1	–	0	mA	–
Voltage on output pin with respect to ground	V_{OUT}	-1[3]	–	18.35[4]	V	–
Magnetic field	B_{MAX}	-	–	1	T	–
ESD protection	V_{ESD}	-2	-	+2	kV	According HBM JESD22-A114-B[5]

1) Higher voltage stress than absolute maximum rating, e.g. 150% in latch-up tests is not applicable. In such cases, R_{series} ≥100 Ω for current limitation is required.
2) Max 1h, in operating temperature range.
3) I_{DD} can exceed 10 mA when the voltage on OUT is pulled below -1 V (-5 V at room temperature).
4) V_{DD} = 5 V, open drain permanent low, for max. 10 minutes
5) 100 pF and 1.5 kΩ

4 Operating Range

The following operating conditions must not be exceeded in order to ensure correct operation of the TLE4998P8D. All parameters described in the following sections refer to these operating conditions and each of the implemented sensors IC's if applicable or unless otherwise indicated.

Table 4-1 Operating Range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	4.5	–	5.5	V	–
		4.1[1]	–	16[2)3)]	V	Extended range
Supply undervoltage	V_{DDuv}	V_{DDpon}[4]	–	4.1	V	Extended range
Output pull-up voltage[5]	$V_{pull\text{-}up}$	–	–	18.35	V	–
Load resistance[5]	R_L	1	–	–	kΩ	–
Output current[5]	I_{out}	0	–	5	mA	–
Load capacitance[5]	C_L	1	–	8	nF	–
Junction temperature[6]	T_J	- 40	–	140[7]	°C	

1) May have reduced EMC robustness
2) For supply voltages > 12 V, a series resistance R_{series} ≥100 Ω is recommended
3) The open drain switch off, due to overvoltage on the V_{DD} line, can take place in the range of 16.65 V to 18.35 V, as defined in **Chapter 7.1** of the data sheet. The supply voltage range can be further extended until the overvoltage reset is taking place, but the given accuracy specification in the product data sheet is only applicable until the output switch off occurs
4) V_{DDpon} ... power-on reset level, see **Table 5-1**
5) Output protocol characteristics depend on these parameters, R_L must be according to max. output current
6) R_{THja} ≤ 150 K/W.
7) For reduced magnetic accuracy

Note: Keeping signal levels within the limits described in this table ensures operation without overload conditions.

5 Electrical, Thermal and Magnetic Parameters

All further given specifications are regarded to each of the implemented sensors IC's, or otherwise noted.

Table 5-1 Electrical Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
PWM output frequency	f_{PWM}	122	–	1953	Hz	programmable[1]
Output duty caycle range	DY_{PWM}	0	–	100	%	programmable
Supply current	I_{DD}	3	6	8	mA	–
Output current @ OUT shorted to supply lines	I_{OUTsh}	–	95	–	mA	V_{OUT} = 5 V, max. 10 minutes
Thermal resistance PG-TDSO-8-2	R_{thJA}	–	150	–	K/W	junction to air
	R_{thJC}	–	85	–	K/W	junction to case
Power-on time[2]	t_{Pon}	–	0.7 15	2 20	ms	$\Delta DY_{PWM} \leq \pm 5\%$ $\Delta DY_{PWM} \leq \pm 1\%$
Power-on time[3]	t_{Pon}	–	0.7 15	2 20	ms	≤ ±5% target out value ≤ ±1% target out value
Power-on reset level[4]	V_{DDpon}	3.45	3.65	3.87	V	at -40°C
		3.36	3.55	3.77	V	at 25°C
		3.15?	3.33?	3.54?	V	at 125°C
Output impedance	Z_{OUT}	19	30	44	kΩ	[5]
Output fall time	t_{fall}	2	3.5	5	µs	V_{OUT} 4.5 V to 0.5 V[6]
Output rise time	t_{rise}	–	20	–	µs	V_{OUT} 0.5 V to 4.5 V[6)7]
Output low saturation voltage	V_{OUTsat}	–	0.3	0.6	V	$I_{OUTsink}$= 5 mA
			0.2	0.4		$I_{OUTsink}$= 2.2 mA
Output noise (rms)	OUT_{noise}	–	1	2.5	LSB_{12}	[8]
Insulation resistance	R_{DIES}		tbd		kΩ	between Dice

1) Internal RC oscillator variation +/- 20%
2) Response time to set up output data at power on when a constant field is applied. The first value given has a ±5% error, the second value has a ±1% error. Measured with 640-Hz low-pass filter.
3) Response time to set up output data at power on when a constant field is applied. The first value given has a ±5% error, the second value has a ±1% error. Measured with 640-Hz low-pass filter.
4) Power-on and power-off
5) V_{DD}=5V, V_{OUT}=2.6V, open drain high state
6) For V_{DD} = 5 V, R_L = 2.2 kW, C_L = 4.7 nF, at room temperature, not considering capacitor tolerance or influence of external circuitry
7) Depends on External R_L and C_L, See **Figure 5-1**
8) Range 100 mT, Gain 2.23, internal LP filter 244 Hz, B = 0 mT, T = 25 °C

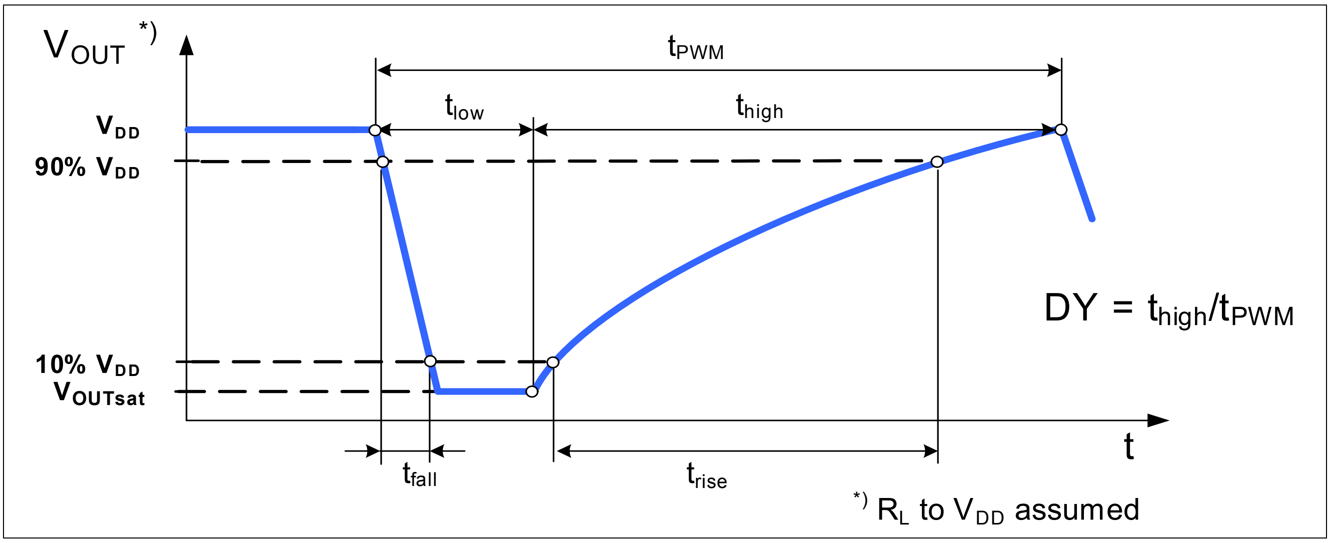

Figure 5-1 Output Characteristic

Magnetic Parameters

Table 5-2 Magnetic Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sensitivity	S[1]	±0.2	±1.2	±6	%/mT	programmable[2]
Sensitivity drift	ΔS	-2		+2	%	[3]
Magnetic field range	MFR	±50	±100[4]	±200	mT	programmable[5]
Integral nonlinearity	INL	–	±0.05	±0.1	%MFR	[7]
Magnetic offset	B_{OS}	–	±100	±400	µT	[6][7]
Magnetic offset drift	ΔB_{OS}	–	±1	±5	µT/°C	error band[7]
Magnetic hysteresis	B_{HYS}	–	–	10 20	µT	in 100mT range in 50mT range

1) Defined as ΔDY_{PWM} / ΔB, programming see **Chapter 6.2**.
2) Programmable in steps of 0.024%.
3) For any 1st and 2nd order polynomial, coefficient within definition in **Chapter 8**. Valid for characterization at 0 h.
4) This range is also used for temperature and offset pre-calibration of the IC.
5) Depending on offset and gain settings, the output may already be saturated at lower fields.
6) In operating temperature range and over lifetime.
7) Measured at ±100 mT range.

Supply Undervoltage Range

Table 5-3 Electrical and Magnetic Characteristics in Supply Undervoltage Range[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sensitivity drift	$S_{E(T)}$	–	–	+2.5/-7.5	%	Error band
Sensitivity error over lifetime[2)]	$S_E(L)$			±1.8	%	at 25°C
Magnetic offset drift	ΔB_{OS}	–	–	±400	µT	Error band
Integral nonlinearity	INL	–	–	±0.2	%MFR	Error band
Output noise (rms)	OUT_{noise}	–	–	37.5	LSB_{12}	50mT range, LP=1.39kHz, Gain=1.5, B=0mT

1) The operation in supply undervoltage range is not intended for continuous operation, it has to be understood as an extraordinary operation condition in order to cover the needs in safety relevant applications

2) Measurement condition at ±100 mT range

Overall Accuracy

Overall accuracy covers different sources of error within the operating temperature range, including the following:

- Temperature: Output deviation over the specified temperature range
- Aging: Parameter drift over life time

For the determination of the overall accuracy of the sensor with regard to specific application operation condition the method of statistical sum of different sources of error can be used:
Overall error = $\mathrm{sqrt}(B_{OS}^2+TC^2+S_E(L)^2+Inl^2+OUT_{noise}^2)$

Abbreviations:

- B_{OS}: Magnetic offset error
- TC: Temperature coefficient of sensitivity
- S_E: Sensitivity error over lifetime
- Inl: Integral nonlinearity
- OUT_{noise}: output noise

5.1 Magnetic Field Direction Definition

Figure 5-2 shows the definition of the magnetic field direction. By standard the south pole field defines the positive field values of the top die of TLE4998P8D.

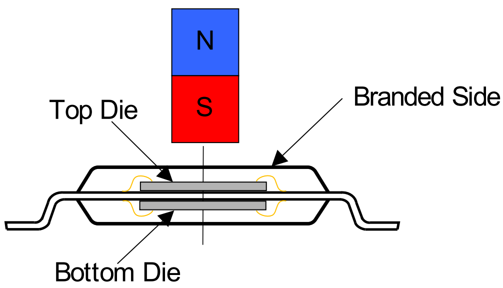

Figure 5-2 Definition of magnetic field direction of the PG-TDSO-8-2

Without reconfiguration the bottom die measures the inverted field value of the top die. This leads to a characteristics as shown in **Figure 5-3**.

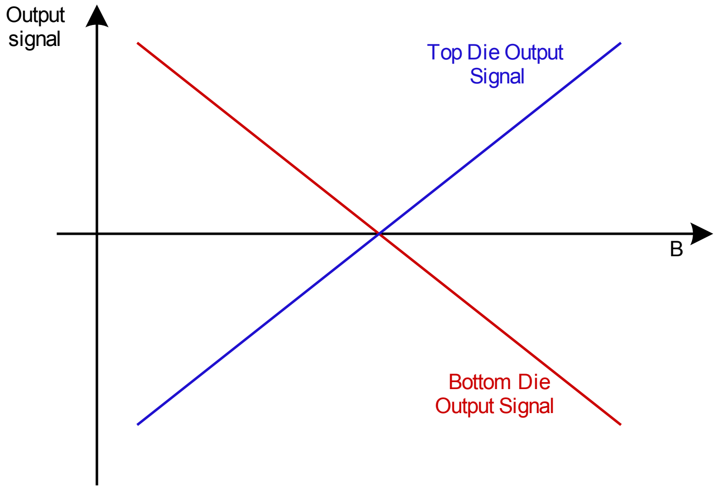

Figure 5-3 Example of the dual die output signaling

6 Application Circuit

Figure 6-1 shows the connection of two Linear Hall sensors to a micro controller.

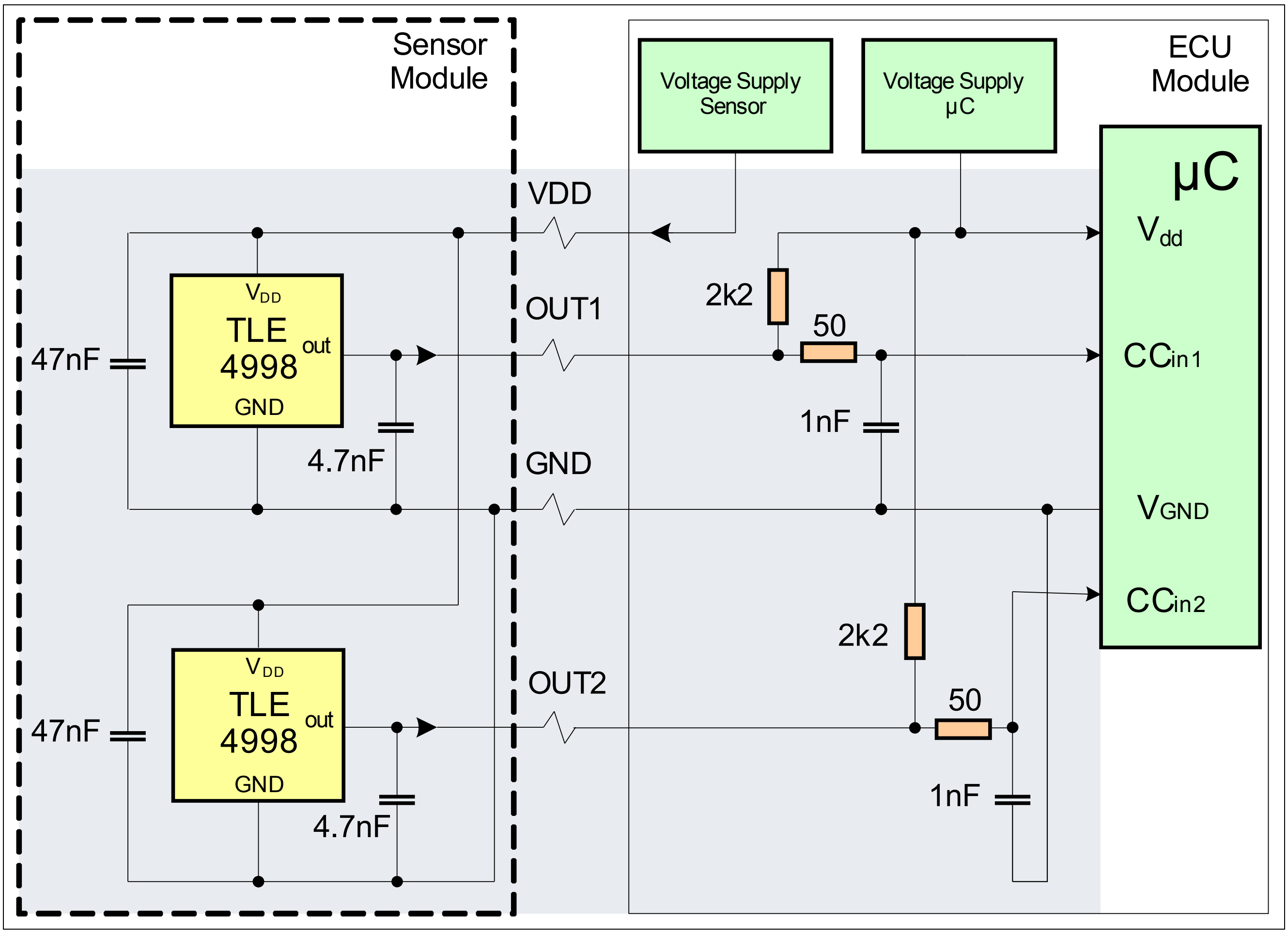

Figure 6-1 Application Circuit

Note: For calibration and programming, the interface has to be connected directly to the OUT pin.

The application circuit shown should be regarded as an example only. It will need to be adapted to meet the requirements of other specific applications.

7 PG-TDSO-8-2 Package Outlines

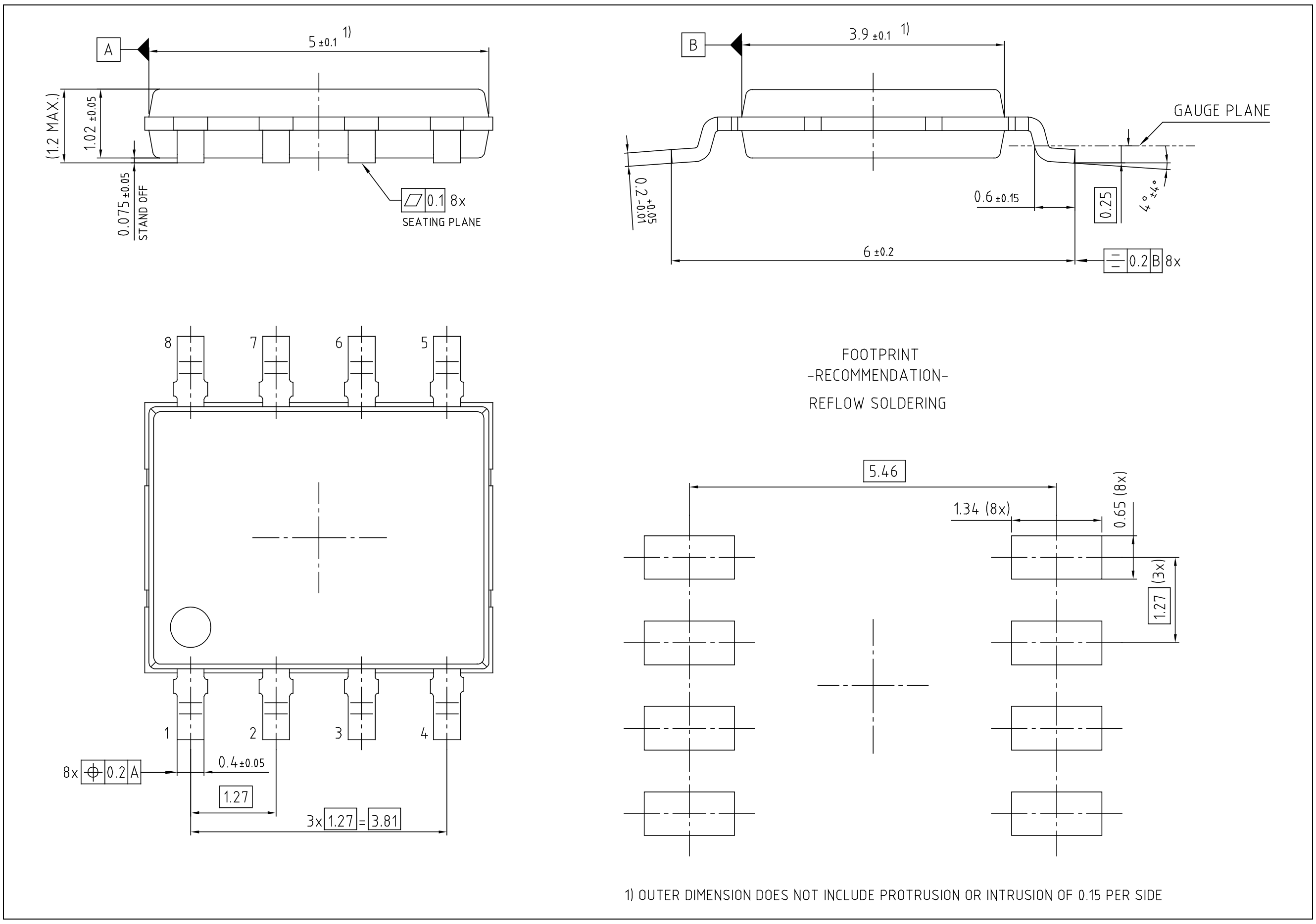

Figure 7-1 PG-TDSO-8-2 (PG-TDSO-Plastic Green Thin Dual Small Outline), Package Dimensions

7.1 Distance Chip to package

Figure 7-2 shows the distance of the chip surface to the PG-TDSO-8-2 surface.

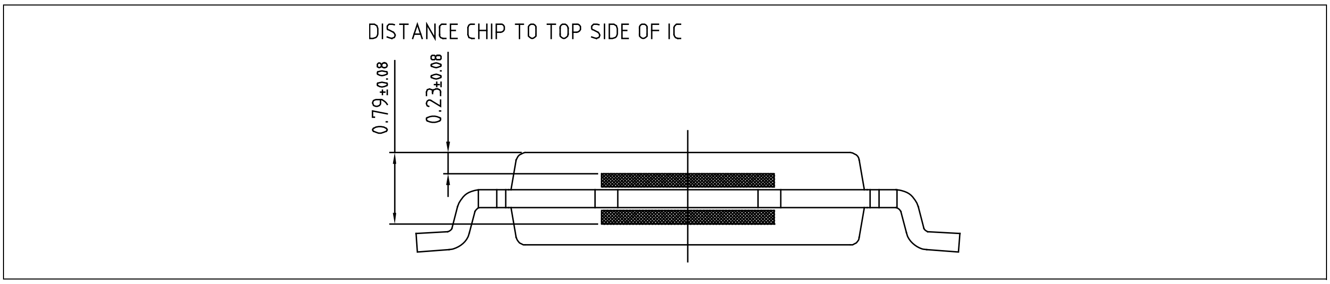

Figure 7-2 Distance of chip surface to package surface

7.2 Moisture Sensitivity Level (MSL)

The PG-TDSO-8-2 fulfills the MSL level 3 according to IPC/JEDEC J-STD-033B.1.

8 PG-TDSO-8-2 Package Marking

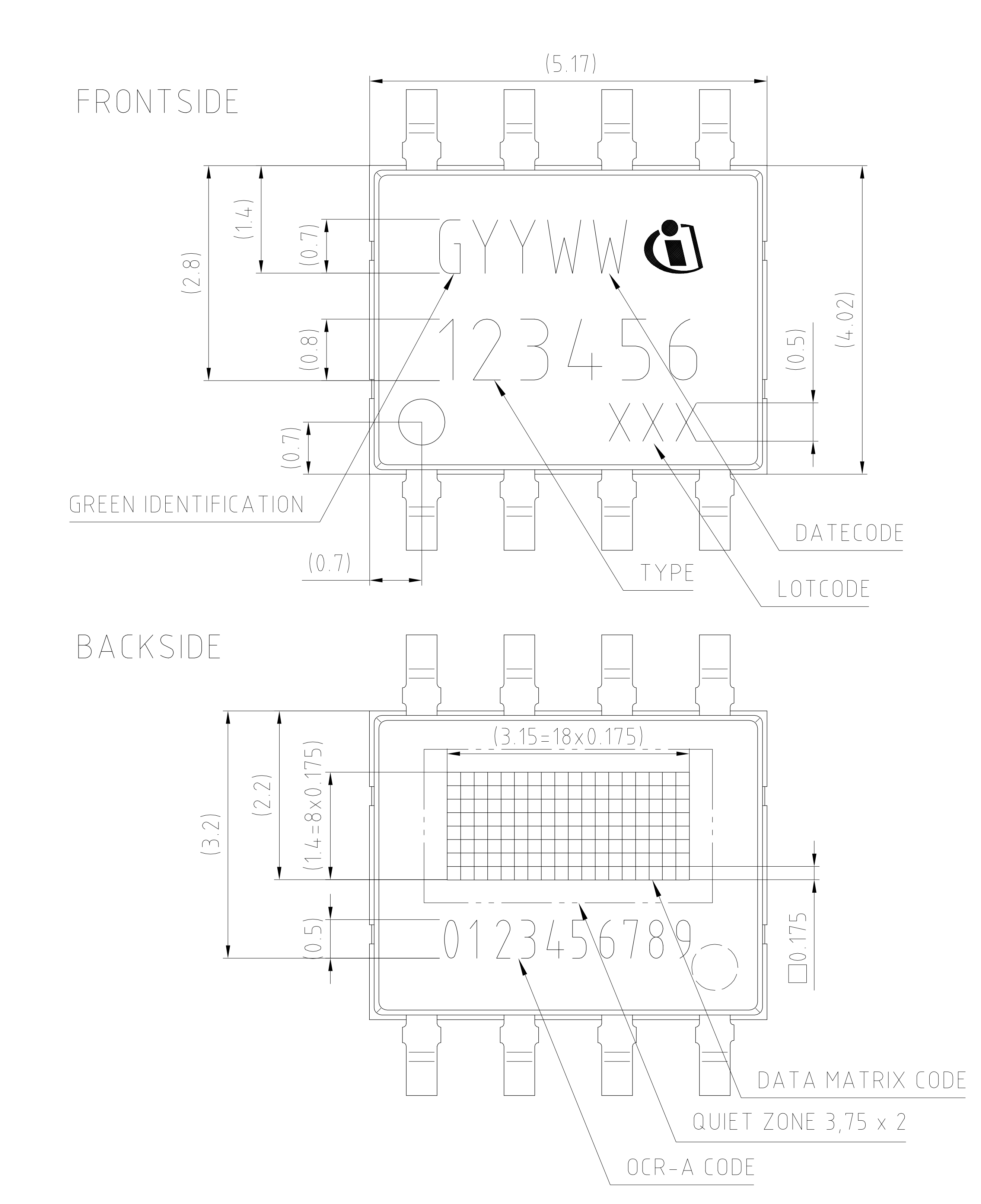

Figure 8-1 PG-TDSO-8-2 (PG-TDSO-Plastic Green Thin Dual Small Outline), Package Marking

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