TLE4998S8D Grade1

High Performance Programmable Dual Linear Hall Sensor

Technical Product Description

Revision 1.0, 2014-05-21

Sense & Control

Edition 2013-02-22

Published by
Infineon Technologies AG
81726 Munich, Germany

Legal Disclaimer

The information given in this document shall in no event be regarded as a guarantee of conditions or characteristics. With respect to any examples or hints given herein, any typical values stated herein and/or any information regarding the application of the device, Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind, including without limitation, warranties of non-infringement of intellectual property rights of any third party.

Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (**www.infineon.com**).

Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office.

Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

Revision History	
Page or Item	**Subjects (major changes since previous revision)**
Revision 1.0, 2013-02-22	
yy	y

Trademarks of Infineon Technologies AG

AURIX™, C166™, CanPAK™, CIPOS™, CIPURSE™, EconoPACK™, CoolMOS™, CoolSET™, CORECONTROL™, CROSSAVE™, DAVE™, EasyPIM™, EconoBRIDGE™, EconoDUAL™, EconoPIM™, EiceDRIVER™, eupec™, FCOS™, HITFET™, HybridPACK™, I²RF™, ISOFACE™, IsoPACK™, MIPAQ™, ModSTACK™, my-d™, NovalithIC™, OptiMOS™, ORIGA™, PRIMARION™, PrimePACK™, PrimeSTACK™, PRO-SIL™, PROFET™, RASIC™, ReverSave™, SatRIC™, SIEGET™, SINDRION™, SIPMOS™, SmartLEWIS™, SOLID FLASH™, TEMPFET™, thinQ!™, TRENCHSTOP™, TriCore™.

Other Trademarks

Advance Design System™ (ADS) of Agilent Technologies, AMBA™, ARM™, MULTI-ICE™, KEIL™, PRIMECELL™, REALVIEW™, THUMB™, µVision™ of ARM Limited, UK. AUTOSAR™ is licensed by AUTOSAR development partnership. Bluetooth™ of Bluetooth SIG Inc. CAT-iq™ of DECT Forum. COLOSSUS™, FirstGPS™ of Trimble Navigation Ltd. EMV™ of EMVCo, LLC (Visa Holdings Inc.). EPCOS™ of Epcos AG. FLEXGO™ of Microsoft Corporation. FlexRay™ is licensed by FlexRay Consortium. HYPERTERMINAL™ of Hilgraeve Incorporated. IEC™ of Commission Electrotechnique Internationale. IrDA™ of Infrared Data Association Corporation. ISO™ of INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. MATLAB™ of MathWorks, Inc. MAXIM™ of Maxim Integrated Products, Inc. MICROTEC™, NUCLEUS™ of Mentor Graphics Corporation. Mifare™ of NXP. MIPI™ of MIPI Alliance, Inc. MIPS™ of MIPS Technologies, Inc., USA. muRata™ of MURATA MANUFACTURING CO., MICROWAVE OFFICE™ (MWO) of Applied Wave Research Inc., OmniVision™ of OmniVision Technologies, Inc. Openwave™ Openwave Systems Inc. RED HAT™ Red Hat, Inc. RFMD™ RF Micro Devices, Inc. SIRIUS™ of Sirius Satellite Radio Inc. SOLARIS™ of Sun Microsystems, Inc. SPANSION™ of Spansion LLC Ltd. Symbian™ of Symbian Software Limited. TAIYO YUDEN™ of Taiyo Yuden Co. TEAKLITE™ of CEVA, Inc. TEKTRONIX™ of Tektronix Inc. TOKO™ of TOKO KABUSHIKI KAISHA TA. UNIX™ of X/Open Company Limited. VERILOG™, PALLADIUM™ of Cadence Design Systems, Inc. VLYNQ™ of Texas Instruments Incorporated. VXWORKS™, WIND RIVER™ of WIND RIVER SYSTEMS, INC. ZETEX™ of Diodes Zetex Limited.

Last Trademarks Update 2011-02-24

Table of Contents

List of Figures

List of Tables

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	SENT (Single Edge Nibble Transmission) Open Drain Output	-40°C to 125°C

Figure 1-1 SMD package PG-TDSO-8-2 for the TLE4998S8D

1.1 Features

- Integration of two individual Linear Hall sensor IC's with Single Edge Nibble Transmission (SENT) open-drain output signal (SAE J2716)
- 20-bit Digital Signal Processing (DSP)
- Digital temperature and stress compensation
- 16-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:
  - SENT unit time
  - Magnetic range and 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, start up)
- Output of internal magnetic field values and temperature
- 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
TLE4998S8D	tbd	tbd	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.

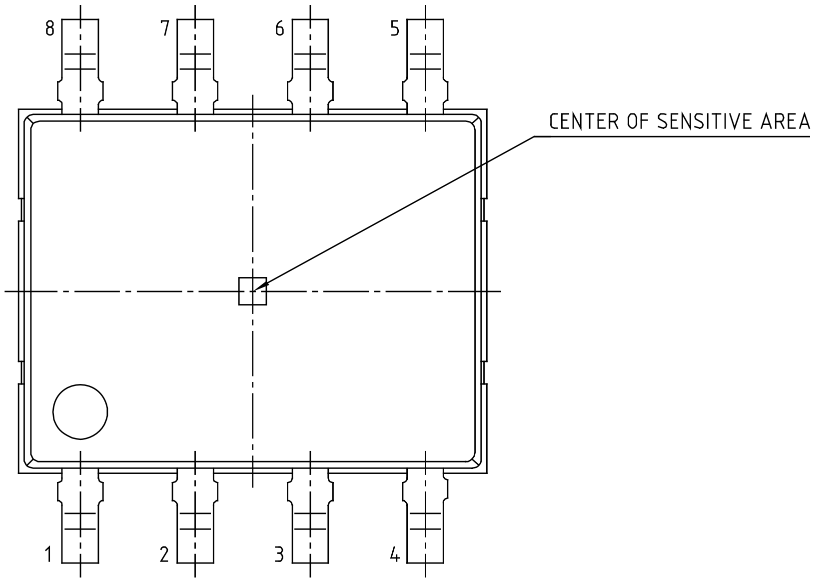


Figure 1-2 Pin Configuration of PG-TDSO-8-2 package

Table 1-2 TLE4998S8D 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.

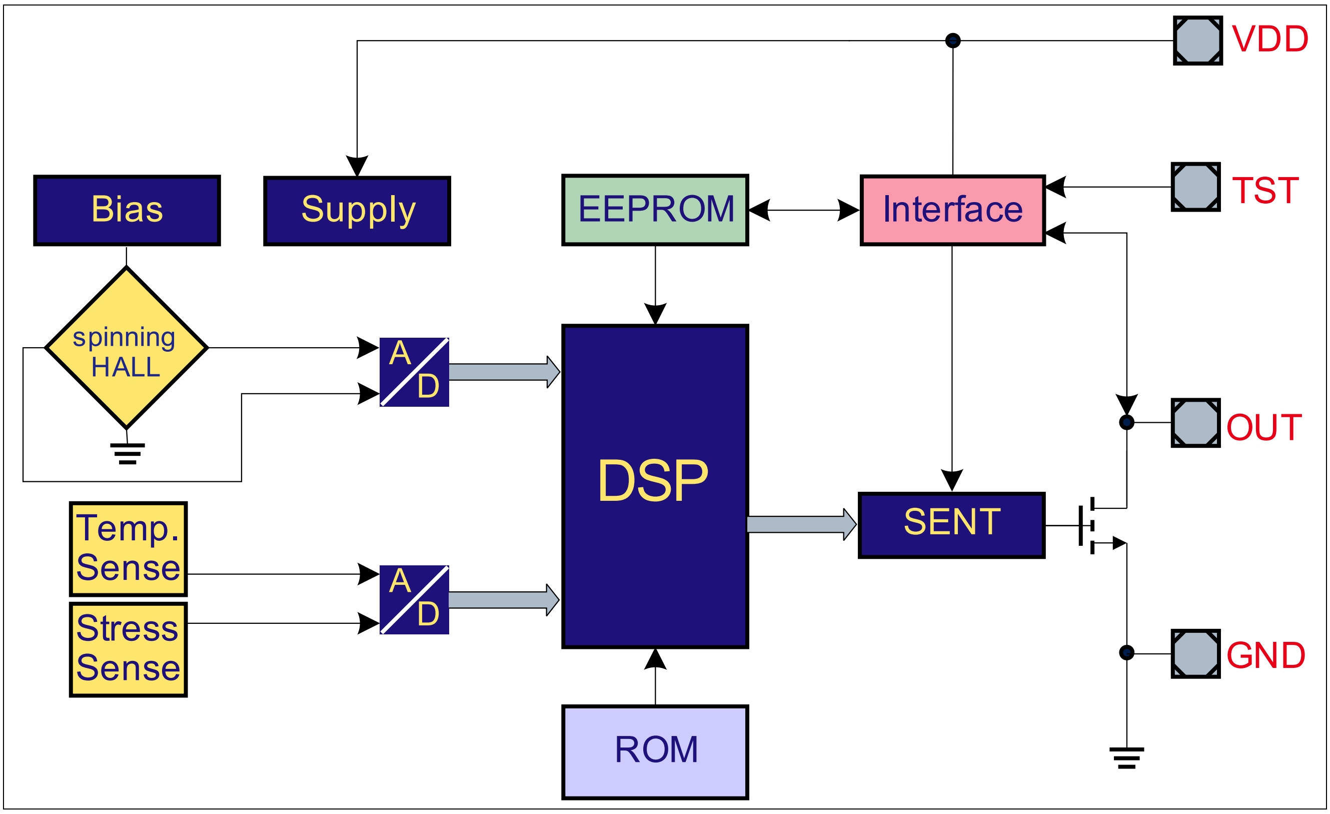


Figure 2-1 Block Diagram of the TLE4998S8D with the SENT interface

2.2 Functional Description

The linear Hall IC TLE4998S8D 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 SENT signal based on the SAE J2716 standard, which consists of a sequence of pulses. Each transmission has a constant number of nibbles containing the Hall value, the temperature and status information of the sensor.

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 16 bits, some internal stages work with resolutions up to 20 bits.

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 represented by the data nibbles of the SENT protocol

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.

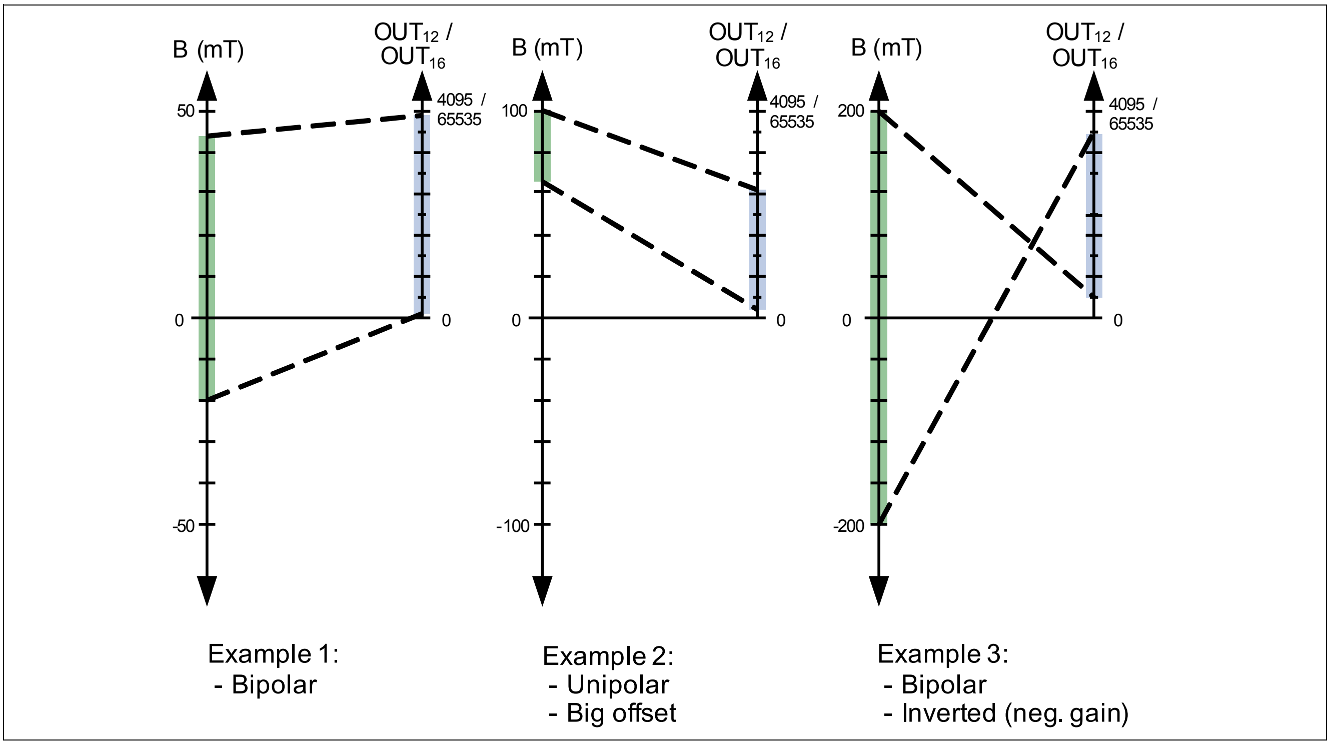


Figure 2-2 Examples of Operation

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 TLE4998S8D. 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]	$V_{pull-up}$	–	–	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	Example for profil see **Table 4-2**

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 see 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.

Table 4-2 Exampe for Ambient Temperature Profile [1)]

Temperature /°C	Active Lifetime / h
-40°C ..<20°C	100
20°C .. <60°C	600
60°C .. <90°C	8000
90°C .. <110°C	2000
110°C .. <125°C	1000
125°C	300

1) This lifetime statement is 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. The lifetime statement shall in no event extend the agreed warranty period.

5 Electrical, Thermal and Magnetic Parameters

All further given descriptions 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.		
SENT transmission time	t_{SENT}	–	–	1	ms	1)
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	2	ms	≤ ±5% target out value
			15	20		≤ ±1% target out value
Power-on reset level[3)]	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	4)
Output fall time	t_{fall}	2	3.5	5	µs	V_{OUT} 4.5 V to 0.5 V[5)]
Output rise time	t_{rise}	–	20	–	µs	V_{OUT} 0.5 V to 4.5 V[5)6)]
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}	7)
Insulation resistance	R_{DIES}		tbd		kΩ	between Dies

1) Transmission time depends on the data values being sent and on internal RC oscillator frequency variation of ± 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) Power-on and power-off
4) V_{DD}=5V, V_{OUT}=2.6V, open drain high state
5) 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
6) Depends on External R_L and C_L, See **Figure 5-1**
7) Range 100 mT, Gain 2.23, internal LP filter 244 Hz, B = 0 mT, T = 25 °C

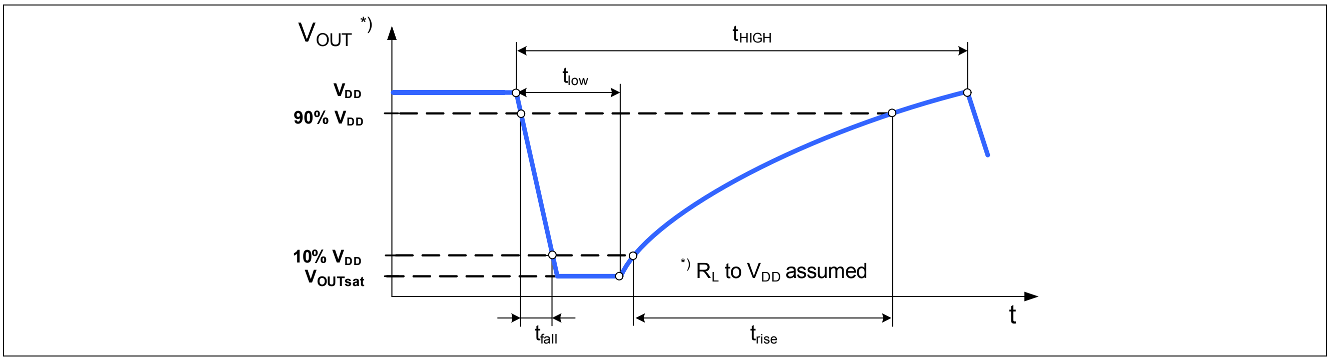


Figure 5-1 Output Characteristic

Magnetic Parameters

Table 5-2 Magnetic Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sensitivity	S[1]	±8.2	–	±245	LSB_{12}/mT	programmable[2]
Sensitivity drift	ΔS	-2.0		+2	%	[3] over temperature
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 ΔOUT / ΔB.
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
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

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 TLE4998S8D.

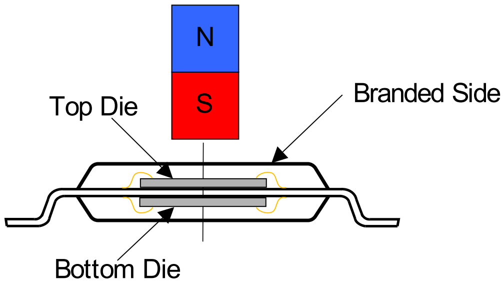


Figure 5-2 Definition of magnetic field direction of the PG-TDSO-8-2

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**.

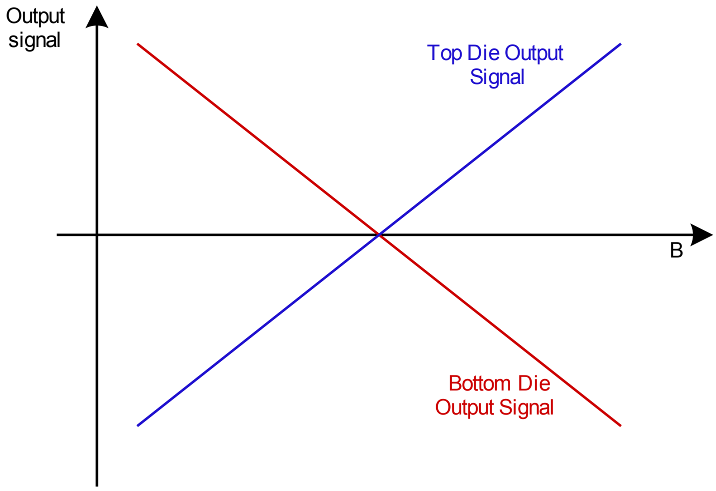


Figure 5-3 Example of the dual die output signaling

6 Application Circuit

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

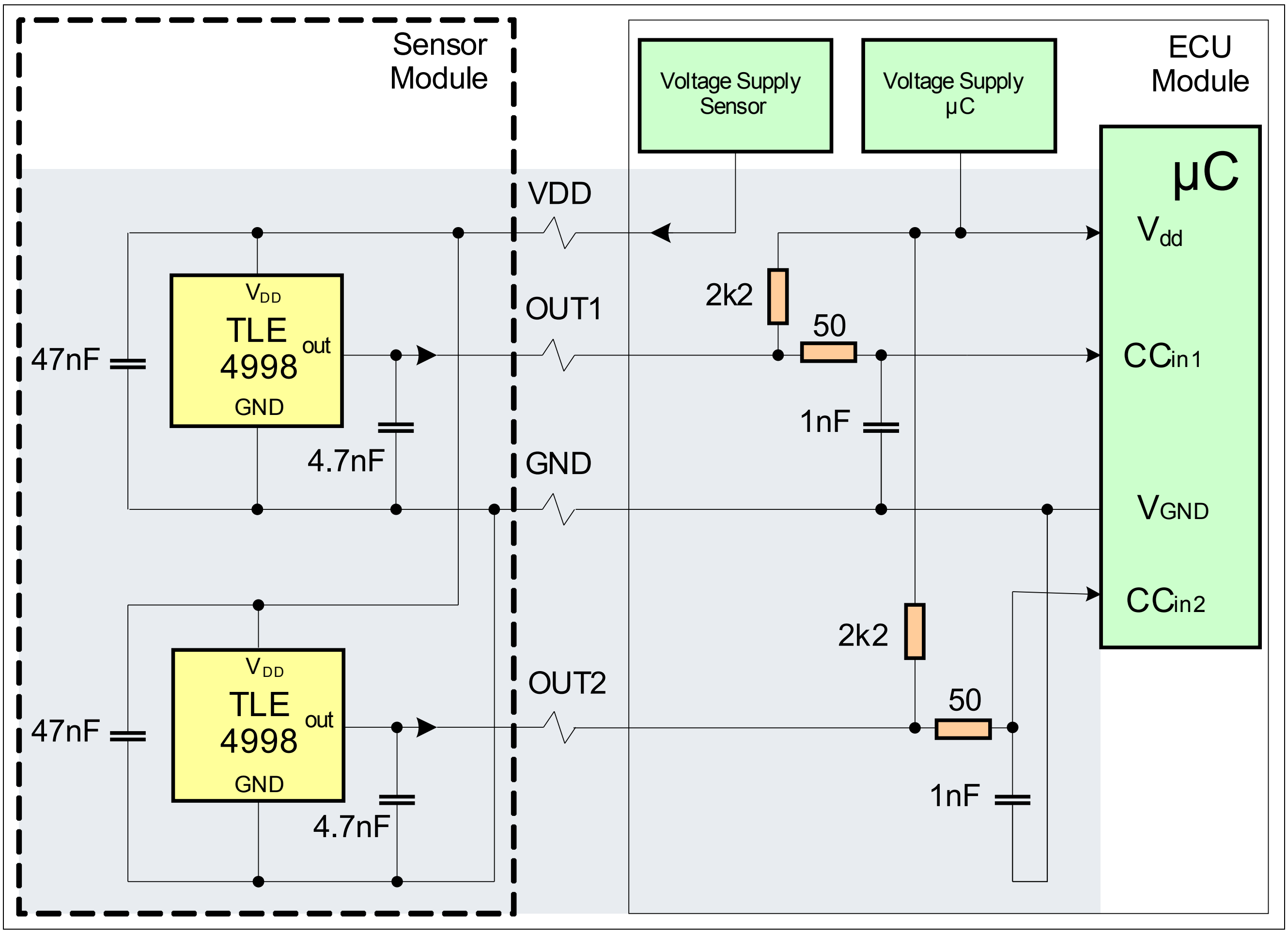


Figure 6-1 Application Circuit

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 described applications. Further information is given in **Chapter 9**.

7 PG-TDSO-8-2 Package Outlines

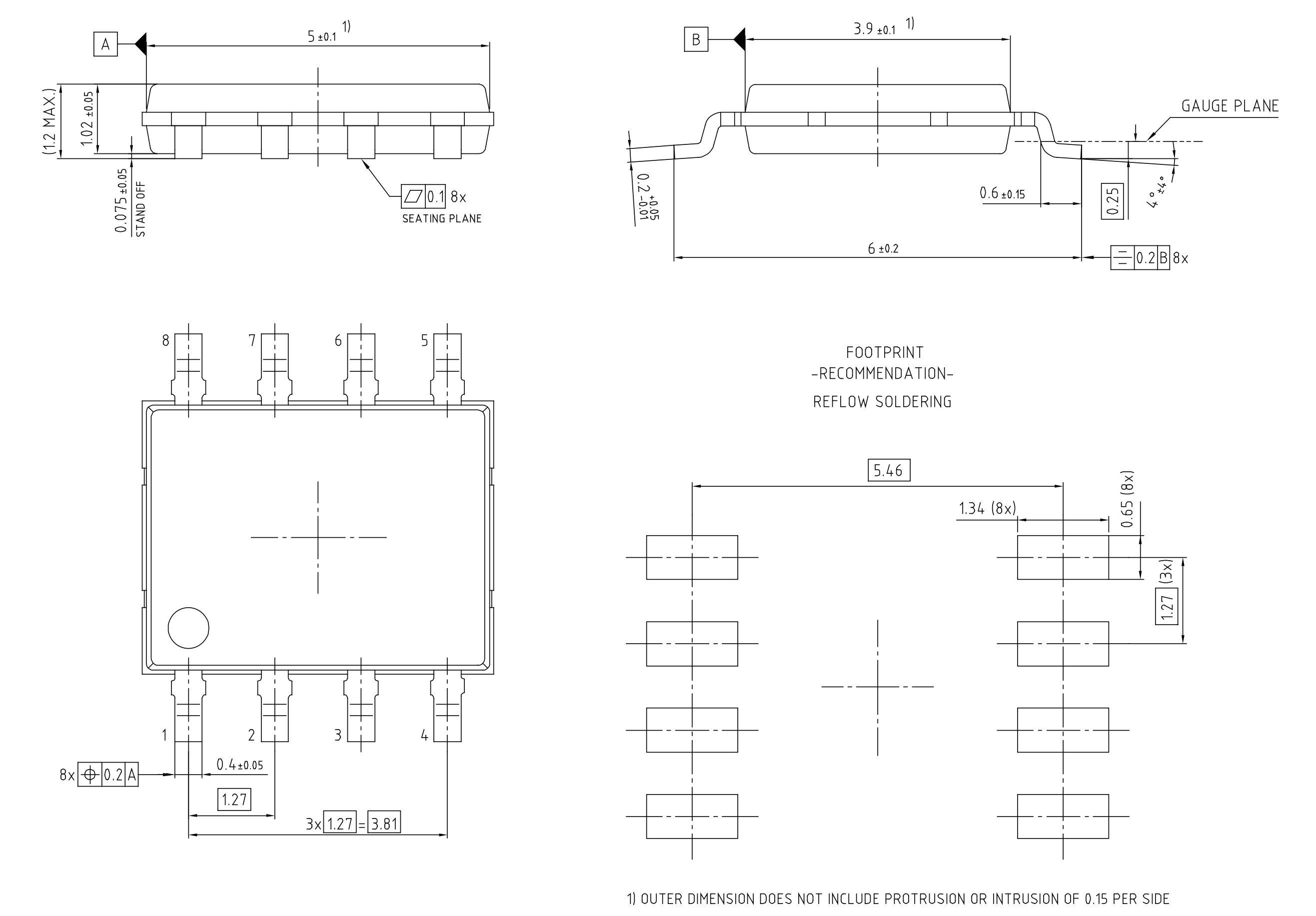


Figure 7-1 PG-TDSO-8-2 (PG-TDSO-Plastic Green Thin Dual Small Outline), Package Dimensions

7.1 Distance Chip to package

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

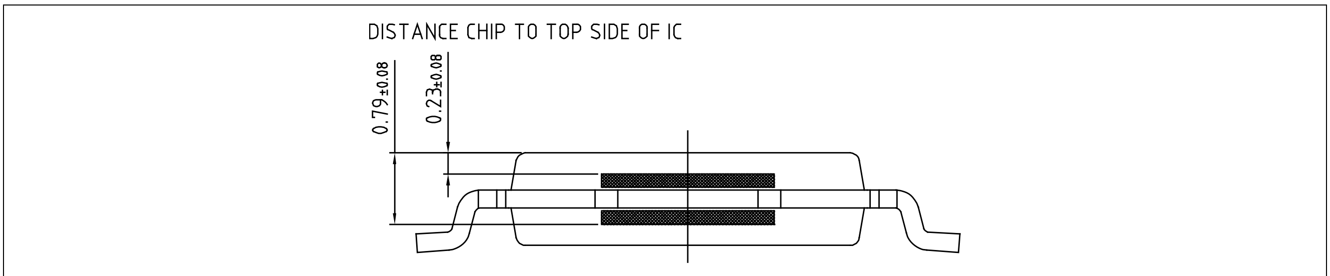


Figure 7-2 Distance of chip surface to package surface

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

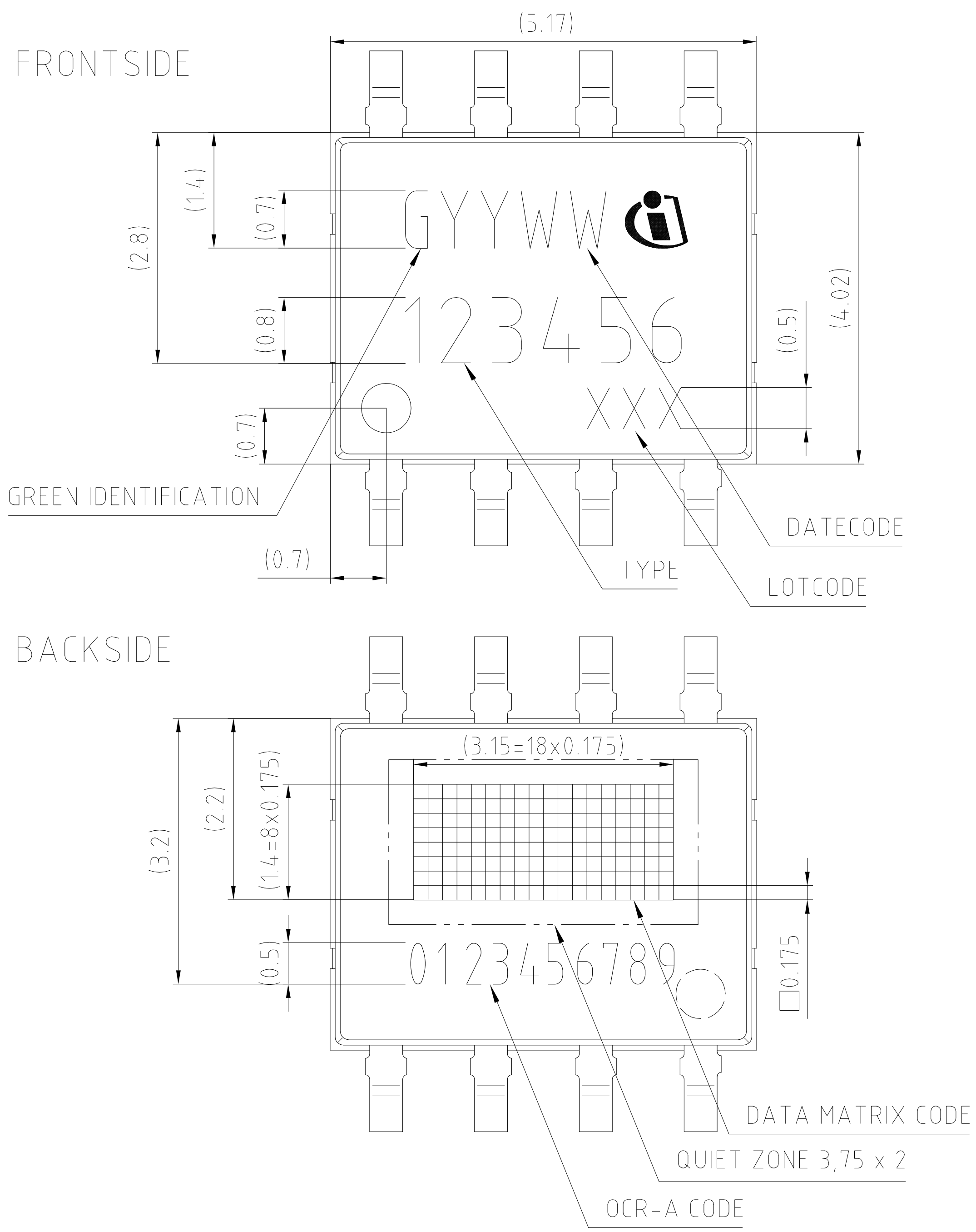


Figure 8-1 PG-TDSO-8-2 (PG-TDSO-Plastic Green Thin Dual Small Outline), Package Marking

9 SENT Output Definition (SAE J2716)

The sensor supports a basic version of the Single Edge Nibble Transmission (SENT) protocol defined by SAE. The main difference between the standard version and its implementation in the TLE4998 is the usage of an open drain instead of a push-pull output.

9.1 Basic SENT Protocol Definition

- The single edge is defined by a 9-µs low pulse on the output, followed by the high time defined in the protocol (nominal values, may vary by tolerance of internal RC oscillator and the programming, see **Chapter 9.2**). All values are multiples of a 3-µs unit time frame concept. A transfer consists of the following parts:A synchronization period of 168 µs (in parallel, a new sample is calculated)
- A synchronization period of 56 UT (in parallel, a new sample is calculated)
- A status nibble of 38-81 µs
- Three data nibbles of 36-81 µs (data packet 1 with a length of 103-243 µs)
- Three data nibbles of 36-81 µs (data packet 2 with a length of 103-243 µs)
- A CRC nibble of 38-81 µs

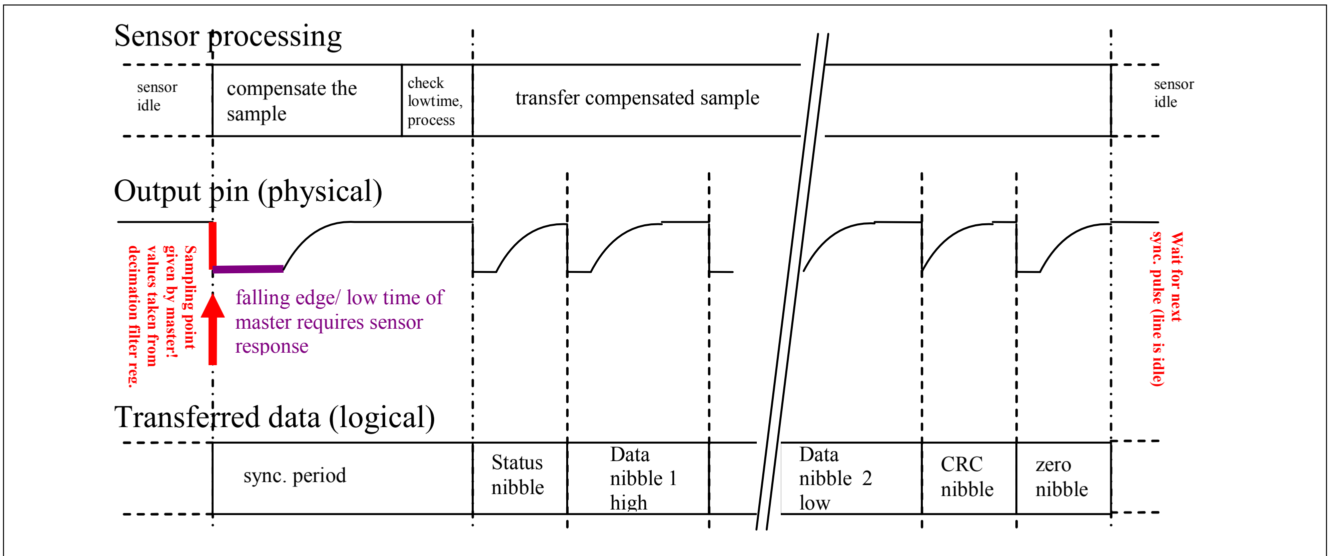


Figure 9-1 SENT Frame

The CRC checksum calculation includes the status nibble and the data nibbles. This leads to a minimum transfer time of 456 µs, and a maximum transfer time of 816 µs per sample.

It is important to know that the sampling time (when values are taken for temperature compensation) here is always defined as the beginning of the synchronization period; during this period, the resulting data is always calculated from scratch.

As only one Hall value needs to be transferred within one sequence, the second data package is divided into two parts (see **Figure 9-2**).

- First, the remaining 4 LSBs of the Hall signals are transferred in the first data nibble. This means the receiver may use the whole 16-bit data available in the sensor when reading and using all 4 nibbles transferred.
- Second, the temperature is transferred as an 8-bit value. The value is transferred in unsigned integer format and corresponds to -55°C to 200°C. For example, transferring the value 55 corresponds to 0°C. The temperature is additional information and although it is not calibrated, may be used for a plausibility check, for example.

Table 9-1 Mapping of Temperature Value

Junction Temperature	Typ. Decimal Value from Sensor	Note
- 55 °C	0	Theoretical lower limit[1)]
0 °C	55	–
25 °C	80	–
200 °C	255	Theoretical upper limit[1)]

1) Theoretical range of temperature values, not operating temperature range.

The status nibble as defined in the SAE standard has two free bits (the LSBs or first and second bit). These bits contain the selected magnetic range of the sensor and therefore allow the received data to be interpreted easily.

As no serial data is transferred with the IC, the remaining bits of the status nibble are not required. The MSB (fourth bit) notifying a start of a serial transmission and the data bit (or third bit) would be kept zero. Thus, these bits are used in a more suitable way for this sensor, as shown in **Figure 9-2**.

In case of startup- or supply overvoltage condition, the open-drain stage is disabled (high ohmic) and the corresponding status bits are set. After VDD has returned to the normal operating range, this status information will be transmitted within the first SENTtransmission.

In case of uncorrectable EEPROM failure, the open-drain stage is disabled and is kept in “switched off” state permanently (high ohmic/ sensor defect). The fourth bit is switched to “1” for the first data package transferred after a reset. This allows the receiver to detect low-voltage situations or EMC problems of the sensor. The third bit is set to “1” in case of an over-voltage condition of the IC. This signals that a sensor is still functioning, but its performance may be out of specification. It enables an early warning for high supply voltage, before the sensor completely stops functioning (e.g. VDD > 17.5 V, see **Chapter 7.1**).

9.2 Unit Time Setup

The basic SENT protocol unit time granularity is defined as 3 µs. Every timing is a multiple of this basic time unit. To achieve more flexibility, trimming of the unit time can be used to:

- Allow a calibration trim within a timing error of less than 20% clock error (as given in SAE standard)
- Allow a modification of the unit time for small speed adjustments

This enables a setup of different unit times, even if the internal RC oscillator varies by ±20%. Of course, timing values that are too low could clash with timing requirements of the application and should therefore be avoided, but in principle it is possible to adjust the timer unit for a more precise protocol timing.

Table 9-2 Pre-divider Setting

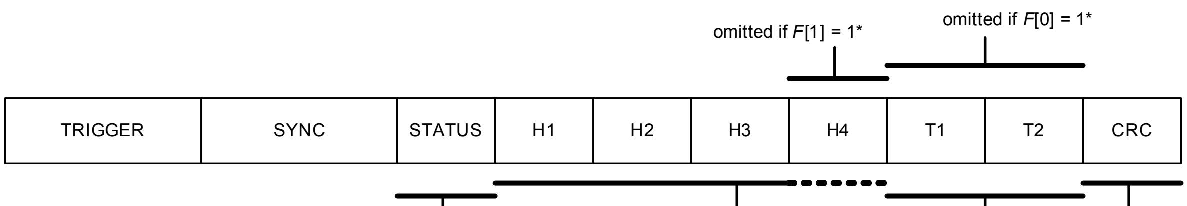
Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Register size	Prediv		4		bit	Pre-divider[1)]
Unit time	t_{UNIT}	2.0		4.0	µs	Clk_{UNIT}=8 MHz[2)]

1) Useable predivider range is decimal 7 to 15. Prediv < 7 is internally kept at 7. Prediv default is decimal = 11 for 3 µs nominal unit time

2) RC oscillator frequency variation ± 20%.

The nominal unit time is calculated by:

$$f_{UNIT} = (\text{Prediv} \times 2 + 2) / Clk_{UNIT}$$
$$Clk_{UNIT} = 8\,MHz \pm 20\,\% \qquad (9.1)$$



bits		description
state	state	status information
10	RR/ID	startup condition in RR / of ID
01	RR/ID	overvoltage in RR / of ID
00	RR/ID	normal state in RR / of ID

bits	description
11	+/- 50mT or ID #3
10	+/- 100mT or ID #2
01	+/- 100mT or ID #1
00	+/- 200mT or ID #0

description

CRC calculation for all nibbles

seed value: **0101**

polynomial: $X^4+X^3+X^2+1$

bits				description 1	description 2
H1	H2	H3	H4	decimal: OUT_{12} (= H1*256+H2*16 +H3)	decimal: OUT_{16} (= OUT12*16+H4)
1111	1111	1111	1111	4095 (FSR)	65535 (FSR)
1111	1111	1111	1110	4095	65534
1111	1111	1111	:	4095	:
1111	1111	1111	0000	4095	65520
1111	1111	1110	1111	4094	65519
1111	1111	1110	1110	4094	65518
1111	1111	1110	:	4094	:
1111	1111	1110	0000	4094	65504
1111	1111	1101	1111	4093	65503
:	:	:	:	:	:
0000	0000	0010	0000	2	32
0000	0000	0001	1111	1	31
0000	0000	0001	:	1	:
0000	0000	0001	0000	1	16
0000	0000	0000	1111	0	15
0000	0000	0000	1110	0	14
0000	0000	0000	:	0	:
0000	0000	0000	0001	0	1
0000	0000	0000	0000	0	0

bits		description
T1	T2	decimal: $TEMP_8$ (= T1*16 + T2)
1111	1111	200 °C
1111	1110	199 °C
1111	:	:
1111	0000	185 °C
1110	1111	184 °C
:	:	:
0101	0000	25 °C
0100	1111	24 °C
:	:	:
0011	0111	0°C
0011	0110	-1°C
:	:	:
0000	0001	-54 °C
0000	0000	-55 °C

Abbreviations:
TRIGGER – trigger nibble
SYNC – synchronization nibble
STATUS – status nibble
CRC – cyclic redundancy code nibble
FSR – full scale range
H1..4 – hall value
T1..2 – temperature value
OUT_{12} – 12 bit output value
OUT_{16} – 16 bit output value
$TEMP_8$ – 8 bit temperature value

* The number of nibbles is programmed in the frame register *F*

Figure 9-2 Content of a SENT Data Frame (8 Nibbles)

9.2.1 Checksum Nibble Details

The Checksum nibble is a 4-bit CRC of the data nibbles including the status nibble. The CRC is calculated using a polynomial $x^4 + x^3 + x^2 + 1$ with a seed value of 0101.

In the TLE4998S8D it is implemented as a series of XOR and shift operations as shown in the following flowchart:

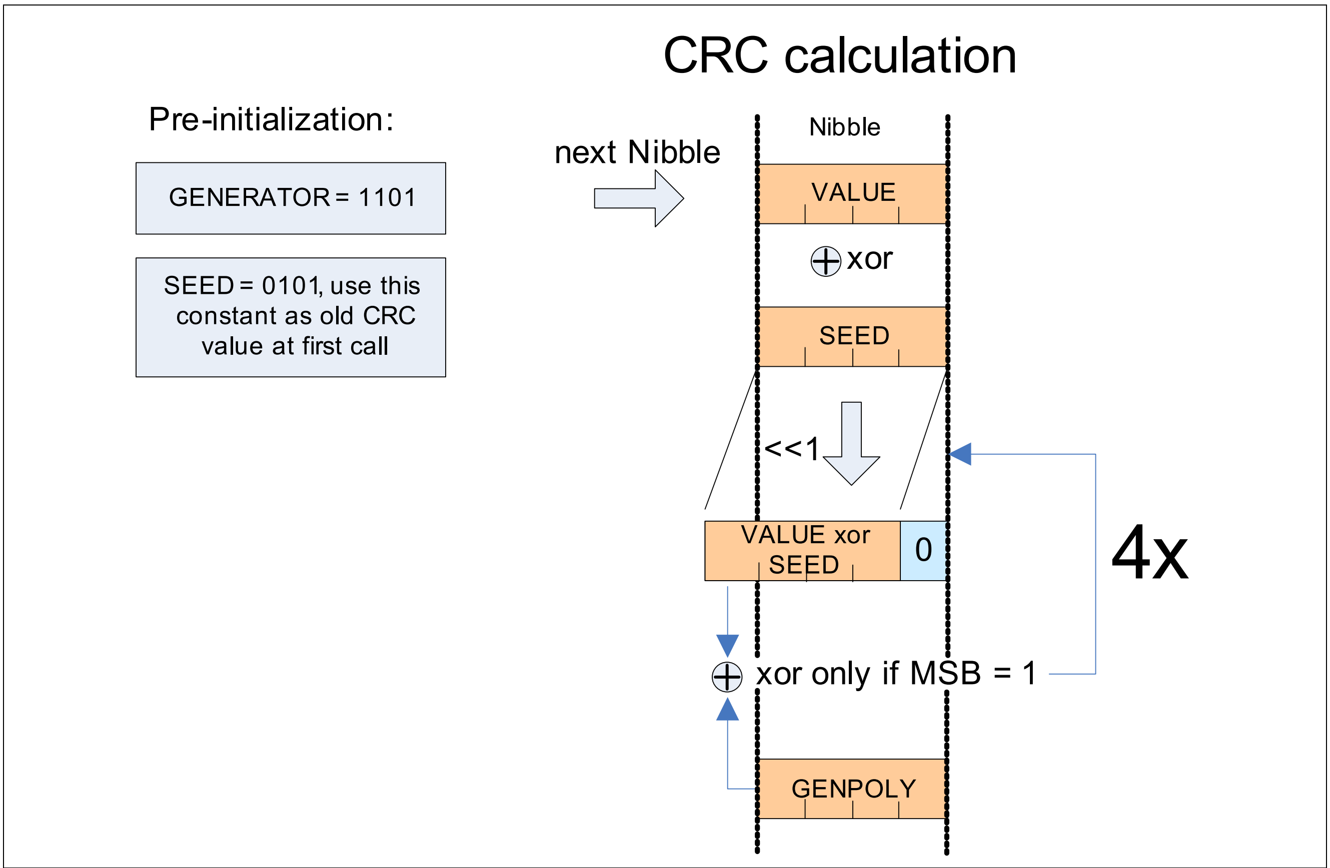


Figure 9-3 CRC Calculation

A micro controller implementation may use an XOR command plus a small 4-bit lookup table to calculate the CRC for each nibble.

```
// Fast way for any µC with low memory and compute capabilities
char Data[8] = {…};  // contains the input data (status nibble, 6 data nibble, CRC)
// required variables and LUT
char CheckSum, i;
char CrcLookup[16] = {0, 13, 7, 10, 14, 3, 9, 4, 1, 12, 6, 11, 15, 2, 8, 5};
CheckSum = 5; // initialize checksum with seed "0101"
for (i=0; i<7; i++) {
    CheckSum = CheckSum ^ Data[i];
    CheckSum = CrcLookup[CheckSum];
}
; // finally check if Data[7] is equal to CheckSum
```

Figure 9-4 Example Code for CRC Generation

w w w . i n f i n e o n . c o m

Published by Infineon Technologies AG