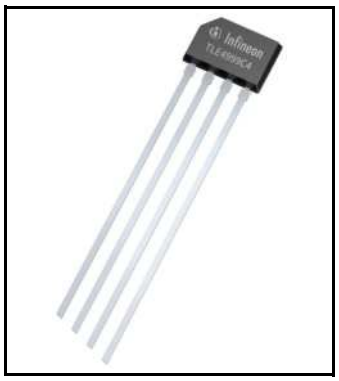
TLE4999C4

Programmable dual channel linear Hall sensor with fast SPC interface

AEC Qualified RoHS PRO SIL ISO 26262 compliant



Features

- Two highly accurate redundant Hall measurement channels (main and sub) integrated on one chip.
- Developed compliant to **ISO 26262** (first edition 2011) Safety Element out of Context for safety requirements rated up to **ASIL D.**
- High diagnostic coverage by plausibility checking of main and sub signal on system level.
- Fast digital SPC interface with min. 0.5µs unit time for transmission of main and sub signals in less than 500 µs.
- Bus-capability for up to 4 sensor ICs on one data line.
- Selectable 12/14/16bit output signals, protected by CRC and rolling counter.
- Thin 4 pin leaded single sensor package.
- Operating automotive temperature range -40°C to 150°C.
- Digital temperature and stress compensation.
- Reverse-polarity and over voltage protection for VDD, GND and OUT pins.
- Main and sub channel programmable independently in EEPROM.
- Multipoint calibration up to 9 points.
- Frameholder mechanism.
- Single-wire SICI programming interface on output pin.
- 2 x 16 bit user-configurable ID in EEPROM.

PRO-SIL™ Features

- Safety Manual and Safety Analysis Summary Report.

Potential 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 safety applications such as pedal position, throttle position, and steering torque sensing.

Product validation

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

Description

The TLE4999C4 is a dual channel linear Hall sensor with a bus-capable digital Short-PWM-Code (SPC) interface. Both channels are integrated on one die in the chip.

The highly accurate measurement channels (main and sub) can be used for a plausibility check on system level. This enables a high diagnostic coverage.

The sensor is developed in compliance to **ISO 26262** (first edition 2011), supporting safety requirements on system level rated up to **ASIL D**.

Highest accuracy over a wide temperature range and lifetime is achieved by an integrated digital temperature- and stress-compensation.

Table 1 Ordering Information

Product Name	Marking	Ordering Code	Package
TLE4999C4	4999C4	SP003420076	single sensor, PG-SSO-4-1

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1 Block diagram

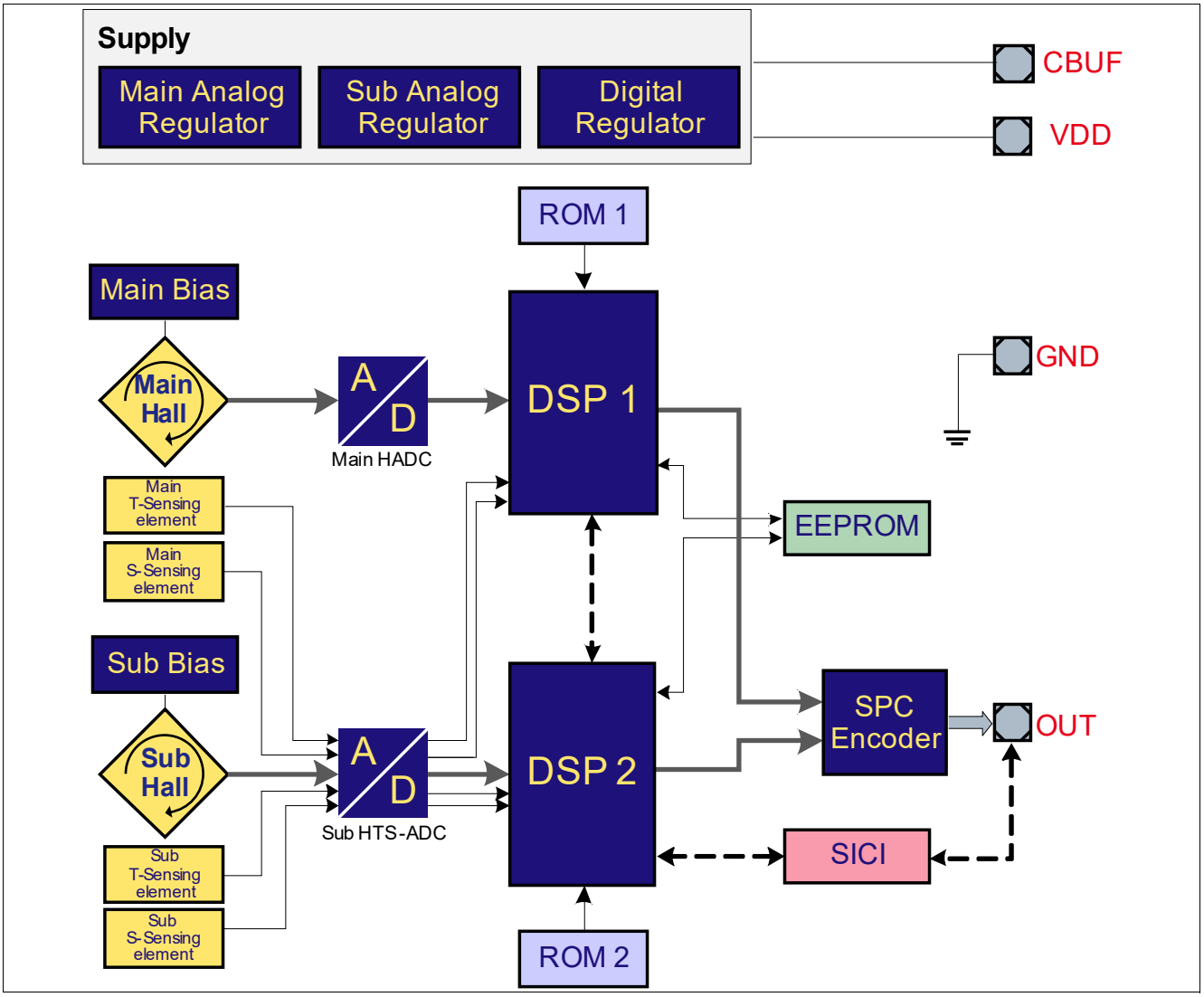


Figure 1 Block diagram

2 Pin and package configuration

Figure 2 shows the arrangement of the measurement channels of the TLE4999C4. The location of the Hall probes in the package and the pin configuration of the TLE4999C4 are shown in **Figure 3**.

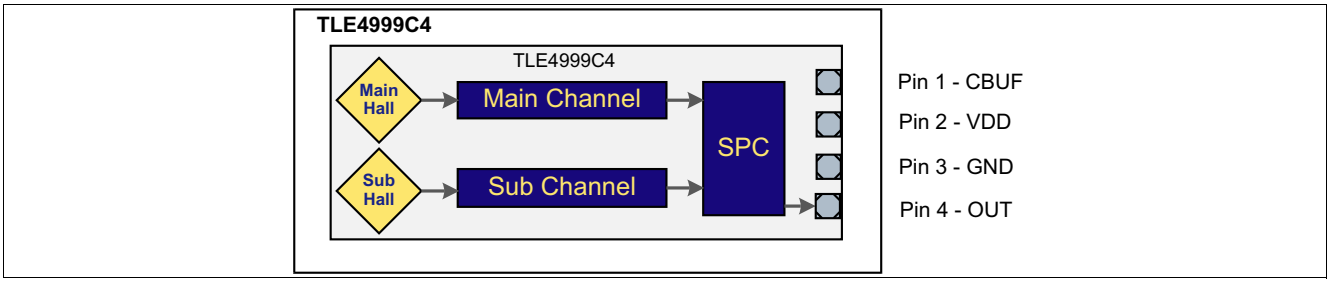


Figure 2 TLE4999C4 Package configuration

Table 2 TLE4999C4 **Pin definitions and functions**

Pin No.	Symbol	TLE4999C4 Function
1	CBUF	Buffer capacitor pin[1)]
2	VDD	Supply voltage
3	GND	Ground
4	OUT	SPC output / programming interface I/O

1) In case CBUF capacitor is not used, CBUF pin shall be left floating

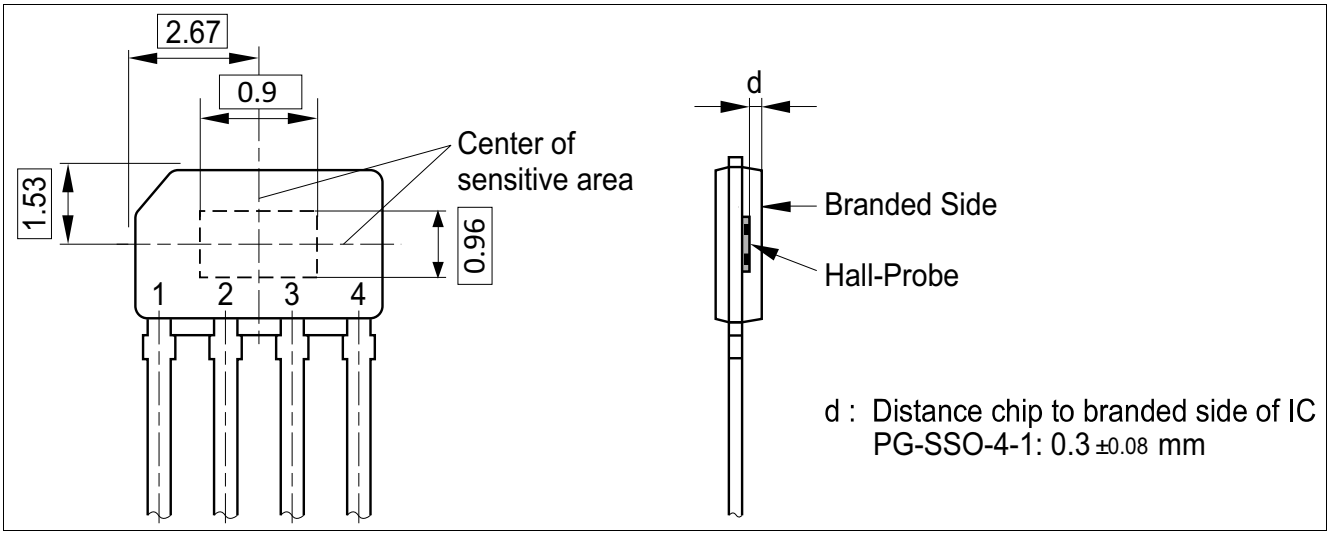


Figure 3 Pin Configuration of TLE4999C4 package

3 General

3.1 Functional description

The TLE4999C4 is a dual channel linear Hall sensor designed to meet the requirements of applications with highly accurate and reliable magnetic field measurement. The sensor provides a digital SPC (Short PWM Code) protocol on the OUT pin that is based on the SENT (Single Edge Nibble Transmission) standard. Configuration parameters can be programmed after assembly of the sensor in a module in an end-of-line calibration procedure using the serial inspection and configuration interface (SICI).

The two measurement channels have separate analog supply domains controlled by the main and sub analog regulators. These regulators feed separate biasing units for the main and sub Hall sensor elements.

A multiplexed second analog-digital converter (Sub HTS-ADC) is used to convert analog signals from the main and sub temperature sensors, and the sub Hall probe. The sub Hall, the temperature and the stress signals are fed into the second digital signal processing unit (DSP2).

The DSP2 uses the signals from all stress and temperature sensing elements for plausibility and range checks to ensure the integrity of the sensing elements and the analog signal path.

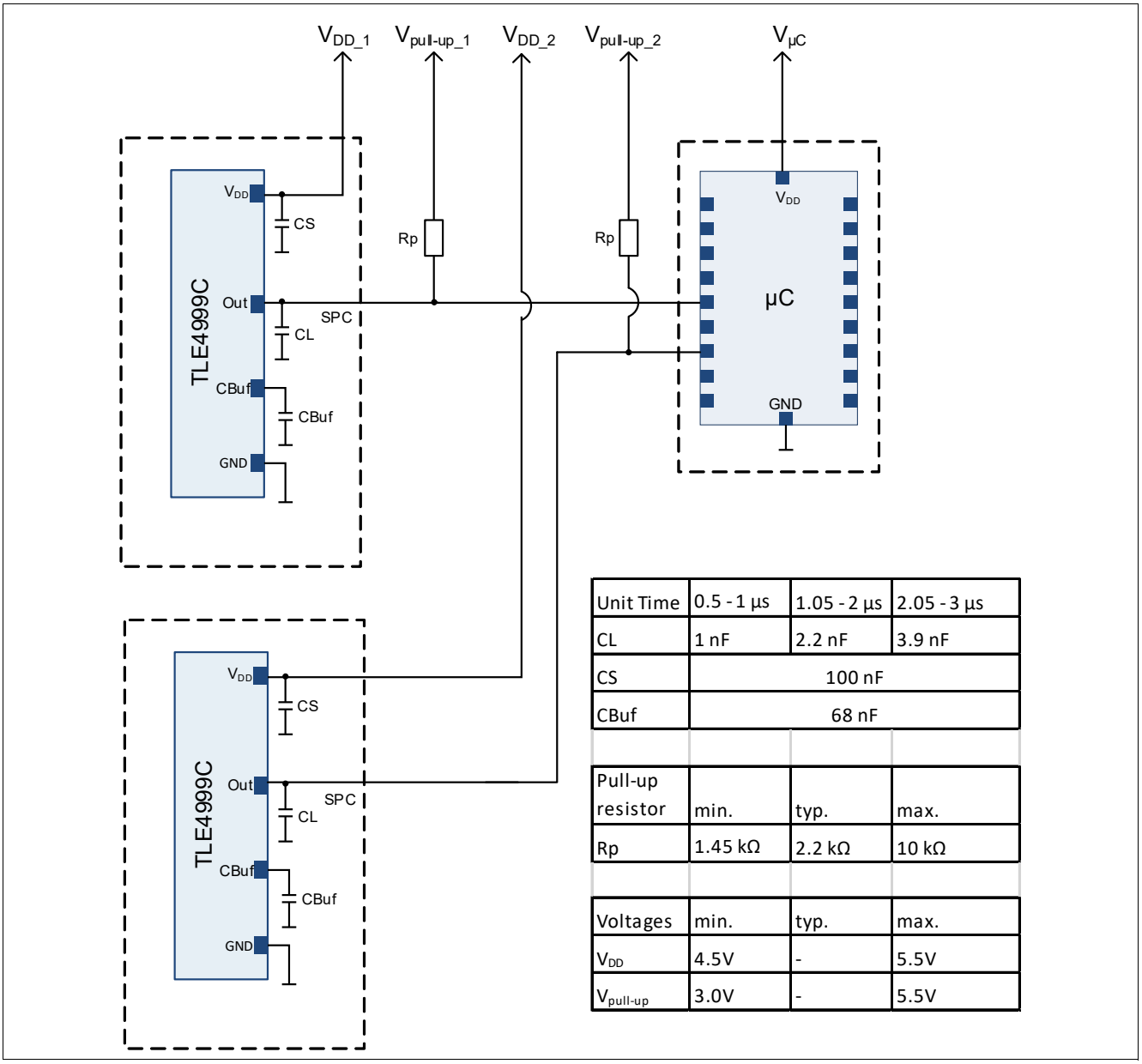
The analog signal of the main Hall probe is fed into an analog-digital converter (Main HADC), and is then processed in a digital signal processing unit (DSP1).

Each DSP uses its corresponding Hall signal, together with compensation parameters stored in the EEPROM, to calculate a Hall measurement value that is compensated for stress and temperature effects.

A high speed SPC protocol is generated containing the data of the two DSPs in the SPC protocol encoder and transmitted after a SPC trigger pulse.

4 Application circuit

Figure 4 shows the recommended application circuit for two TLE4999C4 sensors.



Unit Time	0.5 - 1 µs	1.05 - 2 µs	2.05 - 3 µs
CL	1 nF	2.2 nF	3.9 nF
CS	100 nF		
CBuf	68 nF		

Pull-up resistor	min.	typ.	max.
Rp	1.45 kΩ	2.2 kΩ	10 kΩ

Voltages	min.	typ.	max.
V_{DD}	4.5V	-	5.5V
$V_{pull\text{-}up}$	3.0V	-	5.5V

Figure 4 Application circuit

Attention: ***The system integrator shall take in consideration that the maximum value of CL shall include also the capacitance of the bus line.***

Note: *For improved EMC capability the usage of a twisted cable is recommended.*

5 Maximum ratings

All specifications are valid over the full temperature range and over lifetime. They refer to each of the implemented sensors IC's, unless otherwise noted.

Table 3 Absolute maximum ratings

Parameter	Symbol	Limit Values		Unit	Notes
		Min.	Max.		
Junction temperature	T_J	-40	175	°C	max. 96h at 175°C[1] (not additive)
Non-operating temperature	T_{NO}	-40	150	°C	max. 4400h (not additive)[1]
Maximum supply voltage	V_{DD}	-20	20	V	max. 24 h for -40°C to 30°C T_J max. 10 min. for 30°C to 80°C T_J max. 30 s for 80°C to 125°C T_J max. 15 s above 125°C T_J
Maximum voltage on OUT	V_{OUT}	-18	19.5	V	max. 40 h (not additive)
Maximum voltage on C_{Buf}	V_{Cbuf}	-0.3	20	V	max. 24 h for -40°C to 30°C T_J max. 10 min. for 30°C to 80°C T_J max. 30 s for 80°C to 125°C T_J max. 15 s above 125°C T_J
Maximum voltage between 2 pins	V_{Diff}	-20	20	V	max. 24 h for -40°C to 30°C T_J max. 10 min. for 30°C to 80°C T_J max. 30 s for 80°C to 125°C T_J max. 15 s above 125°C T_J
Voltage peaks	V_{DD}, V_{OUT}	–	30	V	for max. 50 µs
OUT short circuit current[2]	I_{OUT}	-130	130	mA	max. 1 h
Supply current in over voltage	$I_{DD, ov}$		45	mA	time limitation for V_{DD} applies
Supply current in reverse voltage	$I_{DD, rev}$	-75	–	mA	time limitation for V_{DD} applies
Magnetic flux density	B_{max}	–	1000	mT	
ESD Immunity	V_{HBM}	-4	+4	kV	Human Body Model[3]
	V_{CDM}	-0.75	+0.75	kV	Charged Device Model[4]

1) Maximum exposure time at other junction temperatures shall be calculated using the Arrhenius-model.
2) Short to V_{DD} or GND.
3) Human Body Model (HBM) according to ANSI/ESDA/JEDEC JS-001.
4) Charged Device Model (CDM) according to ANSI/ESDA/JEDEC JS-002.

*Note: Any stress exceeding the values listed in **Table 3** may cause permanent damage to the device. The values given are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

6 Operating range

The following operating conditions shall not be exceeded in order to ensure correct operation of the TLE4999C4. All parameters specified in the following sections refer to these operating conditions.

Table 4 Operating range

Parameter	Symbol	Values			Unit	Notes
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	4.5	–	5.5	V	
		$V_{DD, pon}$	–	$V_{DD, poff}$	V	Extended range[1)]
Supply voltage slew rate	$V_{DD,slew}$	0.1	–	10^8	V/s	[2)]
Operating junction temperature	T_J	-40	–	165	°C	max. 1000h at 165°C[3)] (not additive)
Output pull-up voltage	$V_{pull-up}$	3.0[4)]/4.5	–	5.5	V	[5)6)]
Pull-up resistance	R_P	1.45	2.2	10	kΩ	[7)]
Load capacitance	C_L	1	–	3.9	nF	[7)]
Supply capacitance	C_S	–	100	–	nF	
Buffer capacitor	C_{Buf}	–	68	–	nF	
Magnetic flux density	|B|	–	–	50	mT	Maximum measurement range

1) No magnetic performance degradation in extended range between supply under voltage release level and supply over voltage release level.
2) The slew rate is the maximum voltage change per time and relates to the **Application circuit**.
3) Maximum exposure time at other junction temperatures shall be calculated using the Arrhenius-model.
4) Value valid only when the 3.3V bus capability bit is set in the EEPROM.
5) Output protocol characteristics depend on these parameters, RL must be according to max. output current. For the maximum output pull up voltage value refer to the note on **Table 3**.
6) The SPC output protocol will be deactivated when permanent voltages higher then 7.5V are present at the OUT pin.
7) Pull-up resistance and load capacitance have to be chosen in accordance with configured unit time, please see **Application circuit**.

6.1 Calculation of the junction temperature

The internal power dissipation P_{TOT} of the sensor increases the chip junction temperature above the ambient temperature (TA).

The power multiplied by the total thermal resistance **RthJA** (junction to ambient) added to TA leads to the final junction temperature. **RthJA** is the sum of the addition of the two components, Junction to Case and Case to Ambient.

RthJA=R_{thJC} +R_{thCA}

TJ=TA +Δ T = R_{thJA} xP_{TOT} = R_{thJA} x(V_{DD} x I_{DD} +V_{OUT} x I_{OUT}); I_{DD}, I_{OUT} > 0, if direction is into IC

Example (assuming no load on V_{OUT}):

- VDD = 5.5 V
- IDD = 14.5mA
- Δ T= 165 [K/W] x (5.5 [V] x 0.0145 [A] + 0 [VA]) = 13.159K → 15K used for worst case scenario calculations

7 Electrical, magnetic and output parameters

All specifications are valid over the full temperature range and over lifetime. They refer to each of the implemented sensors IC's, if not otherwise noted.

Table 5 Electrical characteristics

Parameter	Symbol	Values			Unit	Notes
		Min.	Typ.	Max.		
Supply current	I_{DD}	4	–	14.5	mA	
Thermal resistance[1)]	R_{thJA}	–	–	165	K/W	junction to ambient
Power-on time[2)]	t_{pon}	–	–	5	ms	
Supply under voltage reset/release level	$V_{DD, pon}$	3.1	–	4.2	V	
Supply over voltage reset/release level	$V_{DD, poff}$	6	–	7.5	V	
Supply voltage reset hysteresis	$V_{DD,pon\ hyst}$	100	–	300	mV	
Out pin over voltage reset level	$V_{OUT, ov\ res}$	7.5	8.25	9	V	
Out pin over voltage release level	$V_{OUT, ov\ res}$	6	6.75	7.5	V	
Out pin over voltage reset hyteresis	$V_{OUT, ov\ hyst}$	1	1.5	2	V	
Output saturation voltage	V_{OL}	–	–	$0.1*V_{DD}$	–	for $I_{OUT} \leq 3.4mA$
Output fall and rise time	t_{fall}/t_{rise}	0.3	0.5	0.75	µs	for UT = 0.5 µs and 0.75 µs
		0.6	1	1.4	µs	for UT = 1 µs and 1.25 µs
		0.9	1.5	2.1	µs	for UT = 1.5 µs
		1.2	2	2.8	µs	for UT = 2 µs and 2.5 µs
		1.8	3	4.2	µs	for UT = 3 µs
Output current	$I_{OUT,avg}$			5	mA	
Output leakage current	$I_{OUT\ Leak}$	20	100	120	µA	$V_{pull-up}$= 5V and $0 < V_{DD} < V_{DD, pon}$
Oscillator frequency variation	Δf	-5	–	5	%	Nominal oscillator frequency: 20MHz

1) Measured on 2s0p PCB board
2) Time since the sensor starts, until it is ready to respond to the first trigger pulse

The following **Figure 5** shows the operating area of the device, the condition for over voltage and under voltage and the corresponding sensor reaction. The values for the over- and under voltage comparators are the typical values from **Table 5**.
In the extended range, the sensor fulfills the full specification. However, voltages above the operating range can only be applied for a limited time (see **Table 3**).

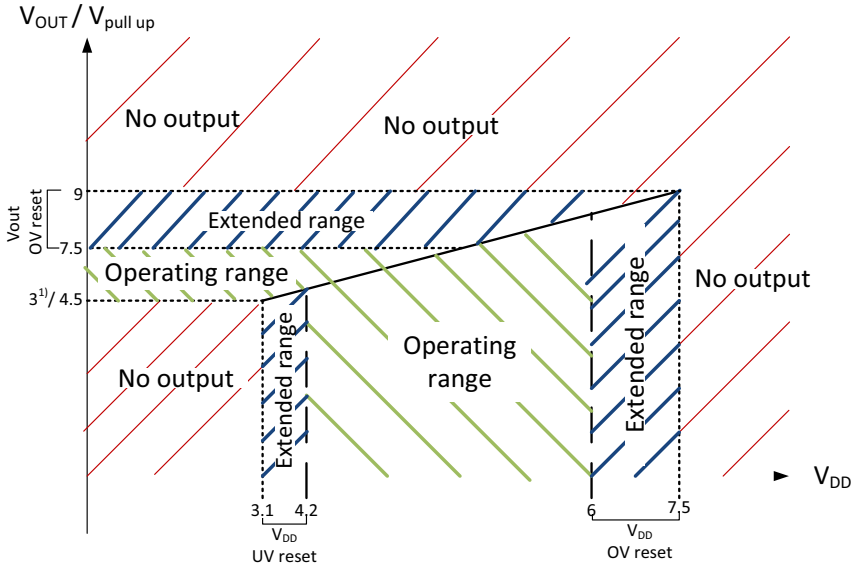


Figure 5 Operating area and sensor reaction for over- and under voltage.

[1] *Value valid only when the 3.3V bus capability bit is set in the EEPROM.*

Main and Sub channels of the TLE4999C4 provide highly accurate 12/14/16bit magnetic field signals. The output characteristics of the two channels are specified in **Table 6**.

Table 6 Magnetic and output characteristics of main and sub channel

Parameter	Symbol	Values			Unit	Notes
		Min.	Typ.	Max.		
Magnetic offset drift[1]	ΔB_{OS_Main}	-100	–	100	µT	Main channel offset drift
	ΔB_{OS_Sub}	-200	–	200	µT	Sub channel offset drift
Magnetic initial offset	B_{OS}	-300	–	300	µT	at 0h, 25 °C
Magnetic sensitivity drift[1]	ΔS	-2.0	–	2.0	%	
Output noise (RMS)[2][3]	OUT_{Noise_Main}	–	–	0.6	LSB_{12}	Main channel noise at 0h, 25 °C[4]
	OUT_{Noise_Main}	–	–	1	LSB_{12}	Main channel noise[1]
	OUT_{Noise_Sub}	–	–	1.5	LSB_{12}	Sub channel noise at 0h, 25 °C[4]
	OUT_{Noise_Sub}	–	–	2	LSB_{12}	Sub channel noise[1]
Magnetic hysteresis	B_{Hys}	–	–	40	µT	
Integral non-linearity[3]	INL	-4	–	4	LSB_{12}	
Signal latency[5][6]	$t_{latency}$	–	–	200	µs	not including interface transmission time

1) Drift over temperature and lifetime
2) For LP-Filter setting 8
3) Range 50 mT, gain 1.0 (scales linearly with gain)
4) Based on LSB16 calculation
5) Defined as phase shift of 100 Hz sine signal
6) For LP-Filter setting Off

Figure 6 shows the output characteristics of the sensor's main and sub channel in the default setting. The output characteristics can be changed by reconfiguring the zero point, gain and clamping ranges for main and sub channel (see **Chapter 9**).

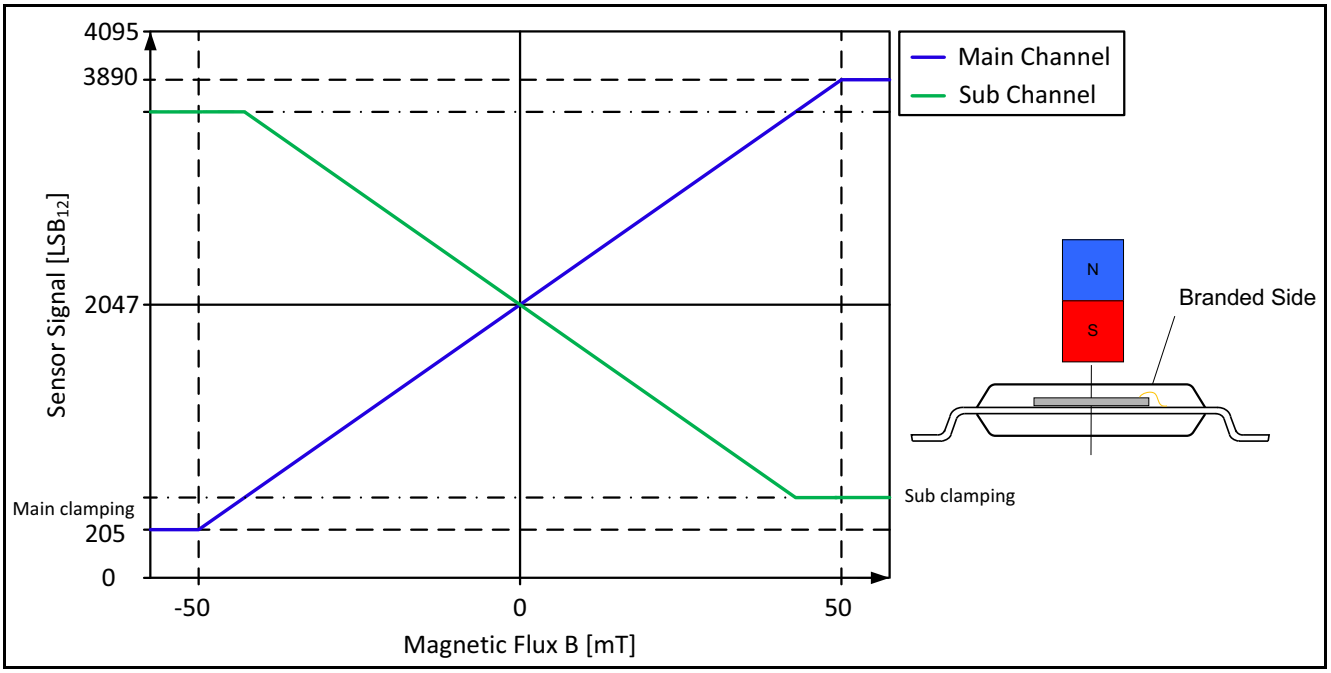


Figure 6 Output characteristic

8 SPC output

The TLE4999C4 features a fast SPC (Short PWM Code) protocol, which is based on the SENT standard (Single Edge Nibble Transmission) defined by SAE J2716. As opposed to SENT, which implies a continuous transmission of data, the SPC protocol transmits data only after receiving a specific trigger pulse from the micro controller. The required length of the trigger pulse depends if the sensor is configured in synchronous mode or in bus mode. In case of bus mode the trigger pulse depends on the sensor number, which is configurable. Thereby, SPC allows the operation of up to four sensors on one bus line.

For the SPC interface the push pull setting with controlled slopes is used (the push-pull mode is only active during the slope controlled mode). In this configuration, the TLE4999C4 has controlled rising and falling slopes. Between the slope controlled transitions the HIGH level is maintained by the external pull-up resistor. Once the SPC protocol telegram is sent, the TLE4999C4 goes in to receiving mode (OUT Pin in Tri-sate mode) and waits until a valid trigger signal is received.

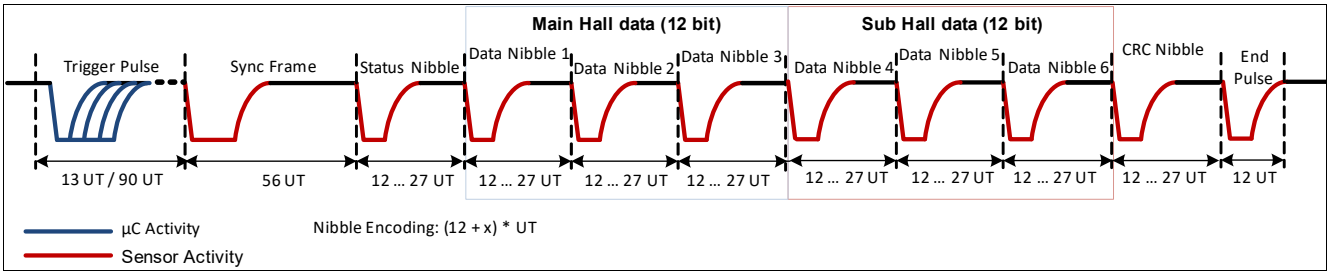


Figure 7 SPC default protocol example

As in the SENT protocol, the time between two consecutive falling edges defines the value of a 4-bit nibble, thus representing numbers between 0 and 15. The transmission time therefore depends on the transmitted data values. All values are multiples of a unit time frame (see **Table 8**). A SPC frame consists of the following nibbles (see **Table 7**):

- A trigger pulse by the master, which initiates the data transmission.
- A synchronization period of 56 UT.
- A status nibble of 12-27 UT, containing over voltage/ error signaling and short serial message (SSM) data or the sensor ID.
- Between 3 and 4 data nibbles of 12-27 UT each (number is programmable), representing the Main Hall value
- Between 3 and 4 data nibbles of 12-27 UT each (number is programmable), representing the Sub Hall value.
- Optional 2 temperature nibbles of 12-27 UT each (programmable).
- Optional 2 /4 bit rolling counter of 12-27 UT (programmable).
- One or two checksum (CRC) nibbles of 12-27 UT each (programmable).
- An end pulse of 12 UT to terminate the SPC frame transmission.

The sensor is available for the next sample after the falling edge of the end pulse. The sensor's sampling time is at the beginning of the synchronization period, i.e. when a correct trigger is received.

SPC output

Table 7 Frame selection

Frame Type	Parameter F	Data nibbles	Temperature nibbles	Rolling Counter	CRC bits
12 bit Main Hall, 12 Bit Sub Hall	A (default)	6 nibbles	–	–	4 bits
16 bit Main Hall, 16 Bit Sub Hall	B	8 nibbles	–	–	4 bits
12 bit Main Hall, 12 bit Sub Hall	C	6 nibbles	2 nibbles	–	4 bits
14 bit Main Hall, 14 bit Sub Hall	D	7 nibbles	–	2 x 2 bits[1)]	8 bits
12 bit Main Hall, 12 Bit Sub Hall	E	6 nibbles	–	2 bits[2)]	6 bits

1) Rolling counters combined with data nibbles, see **Figure 8**
2) Rolling counter combined with CRC nibble, see **Figure 8**

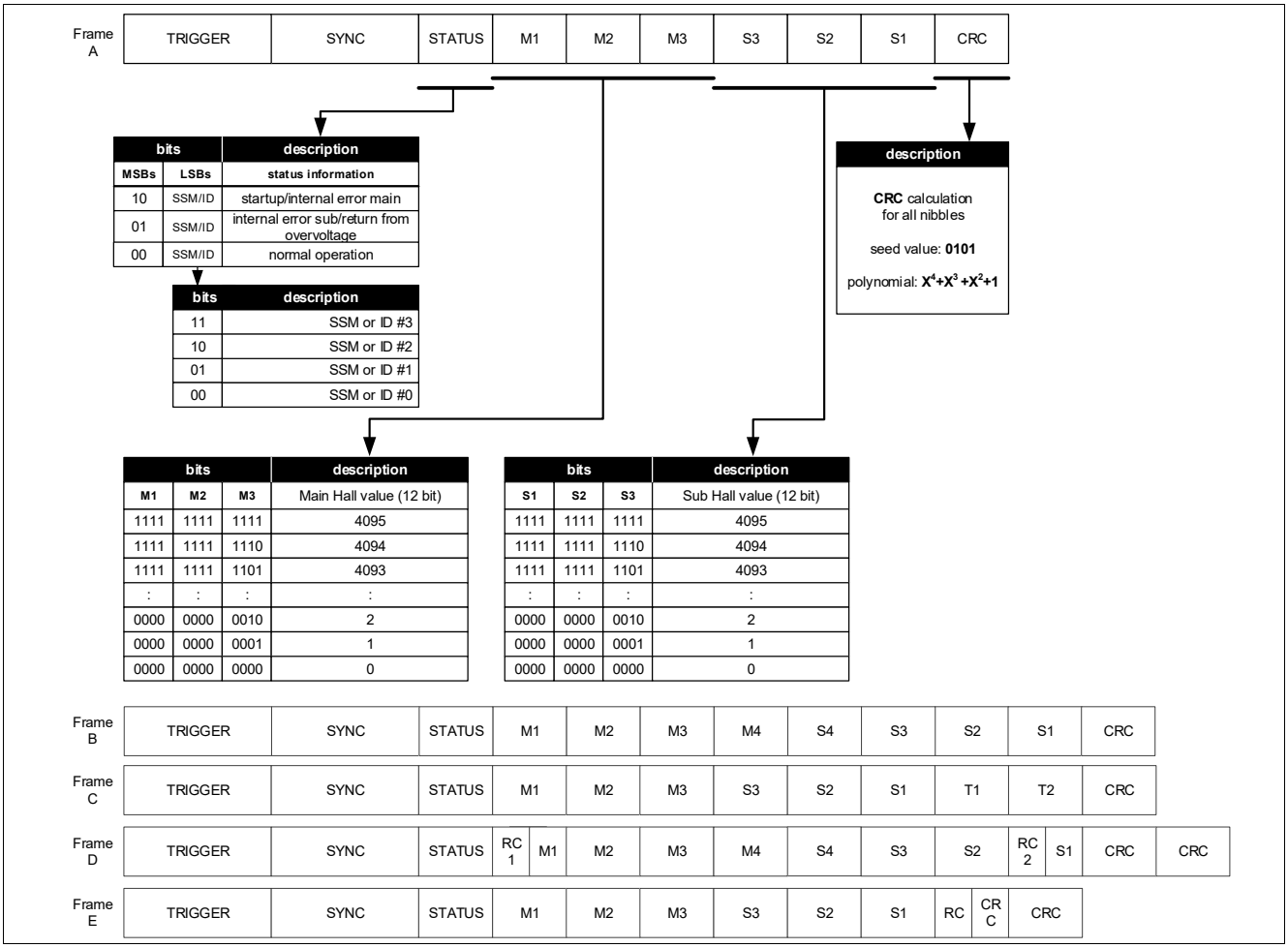


Figure 8 Content of the SPC protocol

8.1 SPC bus mode

When the sensor is used in a bus mode with other sensors on a common SPC line, individual addresses have to be assigned to each sensor for identification. For the operation of the sensor in a SPC bus mode, it is strongly recommended that the sensor ID is written into the EEPROM of the sensor, as all sensors are pre configured with the default value “ID = 0” (see the ***TLE4999C User Manual*** for further details).

A corresponding trigger nibble from the micro controller can therefore address each sensor individually.

SPC output

The trigger nibble low time is shown in **Table 10**. Each low time corresponds to an individual sensor address. The total length of the trigger nibble can be selected to be constant at 90 UT (constant trigger length) or variable according to **Table 9**(variable trigger length).

8.2 SPC unit times

Table 8 Programmable unit times

Parameter	Symbol	Values	Unit	Note or Test Condition
SPC unit time[1)]	UT	0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, 3.0	µs	Clkunit=20MHz

1) Default setting is 3 µs nominal SPC unit time.

8.3 SPC trigger pulse

A SPC transmission is initiated by a trigger pulse from the ECU on the OUT pin. To detect a low-level on the OUT pin, the voltage has to be below the threshold $V_{th, falling}$. The sensor detects that the OUT line has been released as soon as $V_{th, rising}$ is crossed. **Table 9** and **Figure 9** show the timing specification for the trigger pulse.

The master low time t_{mlow} as well as the total trigger time t_{mtr} are different for SPC bus mode on or off. With bus mode switched off, the total trigger time t_{mtr} is shortest. This leads to a significantly shorter overall protocol transmission time for configurations where only one sensor IC is connected to the SPC line.

With bus mode switched on, it is possible to use up to four SPC sensors on one data line. The total trigger time in bus mode is longer, and can be selected between a constant trigger or a variable trigger.

The master low time t_{mlow} is used to identify the sensor ID of the addressed sensor IC, see **Table 10**. A proper addressing requires all sensors on the bus to be programmed with the same nominal SPC unit time.

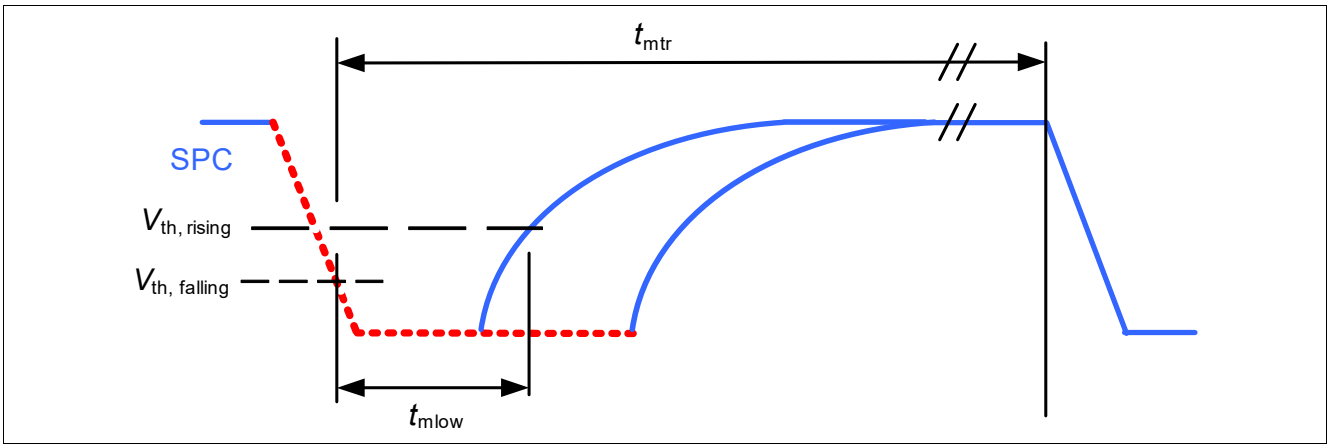


Figure 9 SPC master pulse timing

Table 9 SPC master pulse parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Falling edge threshold	V_{thf}	–	35	–	% of V_{DD}	1)2)
Rising edge threshold	V_{thr}	–	50	–	% of V_{DD}	1)2)

SPC output

Table 9 SPC master pulse parameters (cont'd)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Total trigger time	t_{mtr}	–	13	–	UT	Bus mode off[3]
		–	90	–	UT	Bus mode on, with constant trigger length[3]
		–	$t_{mlow,min}$ + 12	–	UT	Bus mode on, with variable trigger length[3]

1) Not subject to production test - verified by design/characterization
2) Unit is % of nominal VDD (4.5V - 5.5V)
3) Trigger time in the sensor is fixed to the number of unit times specified in the "typ." column, but the effective trigger time varies due to the sensor's oscillator variation

The below **Table 10** shows the trigger time window to which the sensor responds:

Table 10 Sensor SPC trigger parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Master nibble low time	t_{mlow}	2	–	7	UT	Bus mode off[1]
Master nibble low time	t_{mlow}	8	–	15	UT	Bus mode on, ID = 0
Master nibble low time	t_{mlow}	16	–	28	UT	Bus mode on, ID = 1
Master nibble low time	t_{mlow}	29	–	49	UT	Bus mode on, ID = 2
Master nibble low time	t_{mlow}	50	–	82	UT	Bus mode on, ID = 3

1) The combination of CL and pull-up resistor Rp may prevent use of some master nibble low times due to increased output rise time. Infineon recommends that for fast unit times (<=1.0us) the sensor is used in bus mode (with variable trigger option) with ID0 instead of bus mode off.

The below **Table 11** shows the trigger time window to be programmed in the ECU:

Table 11 ECU SPC trigger parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Master nibble low time	t_{mlow}	2	–	4	UT	Bus mode off[1]
Master nibble low time	t_{mlow}	9	–	12	UT	Bus mode on, ID = 0
Master nibble low time	t_{mlow}	19	–	23	UT	Bus mode on, ID = 1
Master nibble low time	t_{mlow}	35.5	–	40.5	UT	Bus mode on, ID = 2
Master nibble low time	t_{mlow}	61.5	–	67.5	UT	Bus mode on, ID = 3

1) The combination of CL and pull-up resistor Rp may prevent use of some master nibble low times due to increased output rise time. Infineon recommends that for fast unit times (<=1.0us) the sensor is used in bus mode (with variable trigger option) with ID0 instead of bus mode off.

Attention: For detailed description of the master nibble low times, please consult the application note for the TLE4999C, "Master nibble low time parameter and related tolerances".

8.4 Status nibble

The status nibble consists of 4 bits. The first two bits are status bits to monitor the internal status of the sensor whereas the last two bits can represent a short serial message (see **Chapter 8.5**) or the sensor ID. **Table 12** shows the usage of the status bits.

The status nibble, which is sent with each SPC data frame, provides an error indication. In case the sensor detects an error or an over voltage condition, the corresponding error bit in the status nibble is set. As long as the error or over voltage condition is present the error bit is set and the sensor output is disabled. After returning from the over voltage condition the corresponding error bit is set in the first transmitted frame in the status nibble.

Table 12 Structure of SPC status nibble

Bits	Description
[0] LSB	Short Serial Message bit (data) or bus mode ID LSB
[1]	Short Serial Message bit (start indication) or bus mode ID MSB
[2]	Return from over voltage condition/ internal error sub channel
[3] MSB	Startup/ internal error main channel

8.5 Short serial message

The short serial message is an additional option which can be enabled or disabled. The short serial message provides additional information in a slow channel transmitting an 8 bit temperature value of the main hall and 32 bit sensor ID (16 bits from main channel ID1 and 16 bits from sub channel ID2).

In each SPC frame, one bit of information is transmitted. The start of the short serial message is indicated by a “1” in bit [1] of the status nibble. For the next 15 SPC frames, this bit will contain a “0”. The Information is transmitted in blocks of 16 bit with 1 bit per SPC frame in bit [0] of the status nibble.

4 bit message ID

8 bit data

4bit CRC (calculated from message ID and data bits)

The message ID is used for identification of the type of data received. All data are transmitted in the bit [0] of the status nibble in the order MSB to LSB.

The transmitted information is as follows:

Message -ID 0: 8 bit temperature value starting with MSB

Message -ID 1: 8 bit of sensor ID1 (starting with MSB)

Message -ID 2: 8 bit of sensor ID1 (starting with MSB-8)

Message -ID 3: 8 bit of sensor ID2 (starting with MSB)

Message -ID 4: 8 bit of sensor ID2 (starting with MSB-8)

*Note: For further details please see the **TLE4999C User Manual.***

8.6 Temperature nibbles

The temperature is coded as an 8 bit value. The value is transferred in unsigned integer format and corresponds to the range between -55 °C and +200 °C, so a transferred value of 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 13** shows the mapping between junction temperature and the transmitted value in the SPC frame.

Table 13 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.

8.7 Rolling Counter

The rolling counter is an additional option for a safety check implementation. Therefore the counter counts the number of transmitted frames with rollover back to 0 and increments with each message. The ECU can use this data for verification that no frame is missed or that no frame is sent repeatedly from the sensor.

There are two selectable protocols that include the rolling counter (see **Figure 8**), on frame D a 2 bit rolling counter is included in the first main data nibble and another 2 bit rolling counter in the first sub data nibble.

On frame E a 2 bit rolling counter is included in the CRC nibble, further details can be found in **Chapter 8.8**. There are frames without rolling counter bits, but to meet the safety requirements and target ASIL level of the application, it is recommended to use this function.

8.8 CRC nibble

The CRC checksum can be used to check the validity of the decoded data. In the checksum included is the status nibble and the data nibbles. It is calculated using a polynomial($x^4 + x^3 + x^2 + 1$) with a seed value of 0101_B. The remainder after the last data nibble is transmitted as CRC.

To allow enhanced checksum for higher diagnostic coverage also 6 and 8 bit checksum are available to secure the data transmission (see **Table 7**).

The 6 bit checksum is calculated using a polynomial ($x^6 + x + 1$) with a seed value of 010101_B and the 8 bit checksum is calculated using a polynomial ($x^8 + x^5 + x^3 + x^2 + x + 1$) with a seed value of 01010101_B.

The calculation scheme of the CRC is described in detail in the **TLE4999C User Manual.**

8.9 SPC frameholder

The frameholder functionality allows the user to operate multiple sensors in a bus configuration with synchronized sampling of the measurement value. This is achieved by having (apart from the SPC Bus ID) a separate frameholder ID for each chip on the bus which is used as a common signal trigger.

For further information please see **TLE4999C User Manual.**

9 Configuration and calibration parameters

To perform the EEPROM programming with application and customer specific data the Serial Inspection and Configuration Interface (SICI) is used. The single wire interface uses the same pin as the SPC output for communication.

The TLE4999C4 has several configurable parameters which are stored in the EEPROM. These parameters affect the internal data processing and the output protocol. **Table 14** gives an overview of the magnetic measurement parameters, which can be configured separately for main and sub channel. **Table 15** shows the SPC interface parameters.

Table 14 TLE4999C4 Magnetic measurement parameters for main and sub Channel

Parameter	Setting range	Note
Magnetic range	±50 mT (default) ±25 mT	
Gain	-7.59...7.59	Gain value of +1.0 corresponds to typical 36.875 LSB_{12}/mT sensitivity in 50mT range, with ±5% clamping,(73.75 LSB_{12}/mT in 25mT range, with ±5% clamping).
Zero point	0 LSB_{16} ... 65535 LSB_{16} [1)]	The user zero point setting is independently configurable for main and sub channels with 12, 14 or 16 bit granularity. Default setting: 32768 LSB_{16}.
Clamping low level	0 LSB_{16} ... 65535 LSB_{16} [1)]	Output clamping settings, see **Figure 6**. Default setting: CL: 205 LSB_{16} CH: 3890 LSB_{16}
Clamping high level	0 LSB_{16} ... 65535 LSB_{16} [1)]	
Multi point linearization	0 ... 9 point	9 user selectable linearization points configurable in the EEPROM. The user can select the concentration either at the corners or around the middle point. For further details please see the
Low-pass filter[2)]	0: Off[3)] 1: 80Hz 2: 160 Hz 3: 200 Hz 4: 240 Hz 5: 320 Hz 6: 400 Hz 7: 470 Hz 8: 500 Hz (default) 9: 650 Hz 10: 870 Hz 11: 980 Hz 12: 1070 Hz 13: 1270 Hz 14: 1380 Hz 15: 1530 Hz	Low pass filter cut-off (-3 dB) frequency.

Table 14 TLE4999C4 Magnetic measurement parameters for main and sub Channel

Parameter	Setting range	Note
1st order temperature coefficient TC_1 4)	-2400 ppm/°C ... 5400 ppm/°C	Second order user configurable temperature compensation.
2nd order temperature coefficient TC_2 4)	-30 ppm/°C^2 ... 30 ppm/°C^2	
Reference Temperature T_0	0°C ... 127°C	

1) The internal value is always 16 bit, in case the 12 or 14 bit setting range is used, the output will be clamped accordingly.
2) Subject to oscillator variation ±5%.
3) Set programmable low pass filter off, inherent filter of ADC stays on.
4) Adjusting the temperature coefficients (TC1 & TC2) can lead to a slight increase of the ADC noise level.

Table 15 TLE4999C4 SPC Interface parameters

Parameter	Setting range	Note
SPC protocol frames	2x 12 bit Hall + 4 bit CRC (default) 2x 16 bit Hall +4 bit CRC 2x 12 bit Hall + 8 bit temperature + 4 bit CRC 2x 14 bit Hall + 2x 2 bit RC + 8 bit CRC 2x 12 bit Hall + 2 bit RC + 6 bit CRC	see **Table 7**
SPC unit time1)	0.5 µs ... 3.0 µs	See chapter **Chapter 8.2**
SPC bus mode	On Off (default)	See chapter **Chapter 8.1**
SPC bus pull-up voltage	3.3V/5V	Default 5V
SPC ID	0 ... 3	Default ID0
SPC variable trigger	On Off (default)	
SPC frameholder address2)	0 ... 3	Default ID0

1) Subject to oscillator variation ±5%.
2) The SPC frameholder is deactivated in case the frameholder address is equal to the SPC address.

10 Package outlines

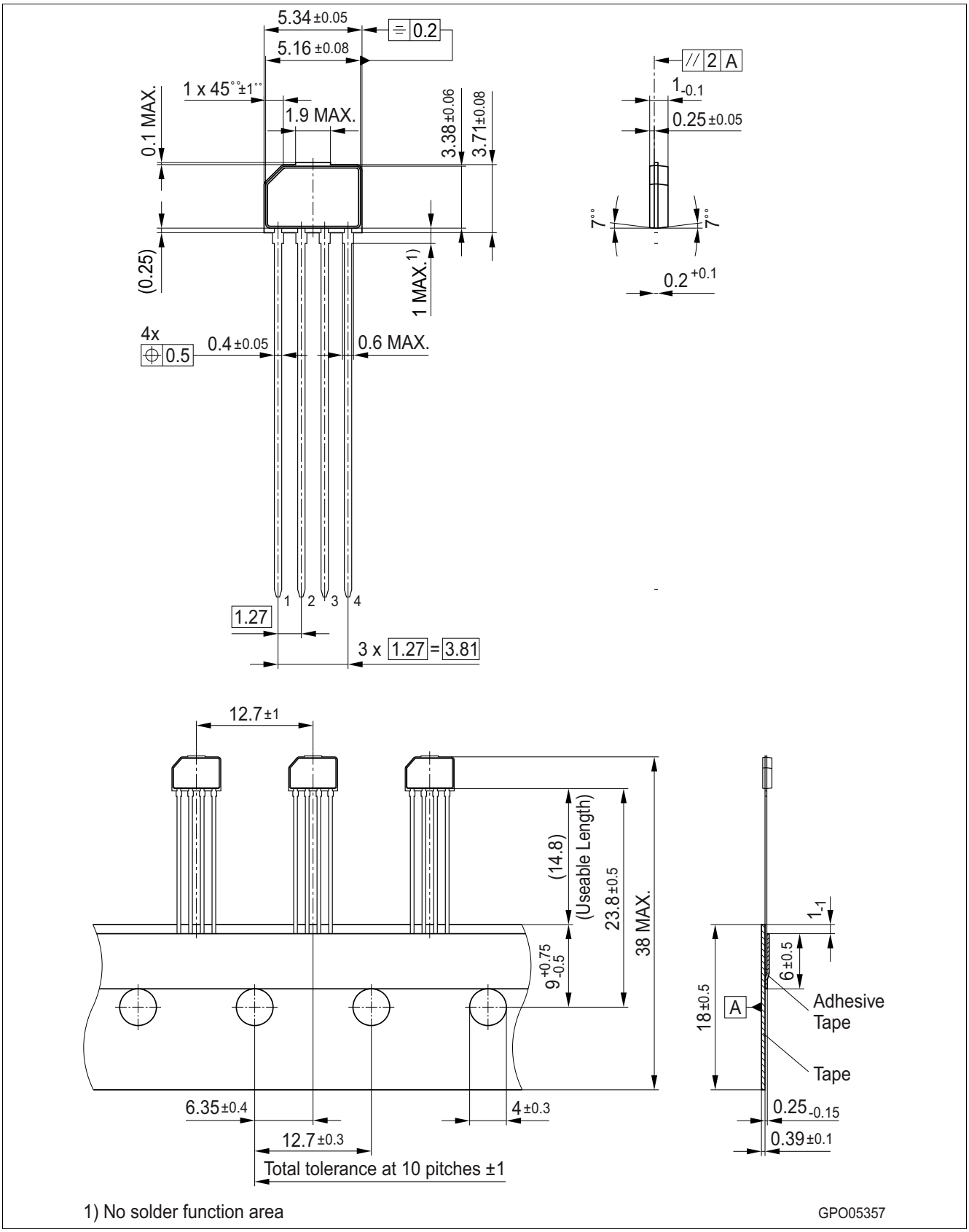


Figure 10 PG-SSO (Plastic Green Single Small Outline), package dimensions

10.1 Package marking

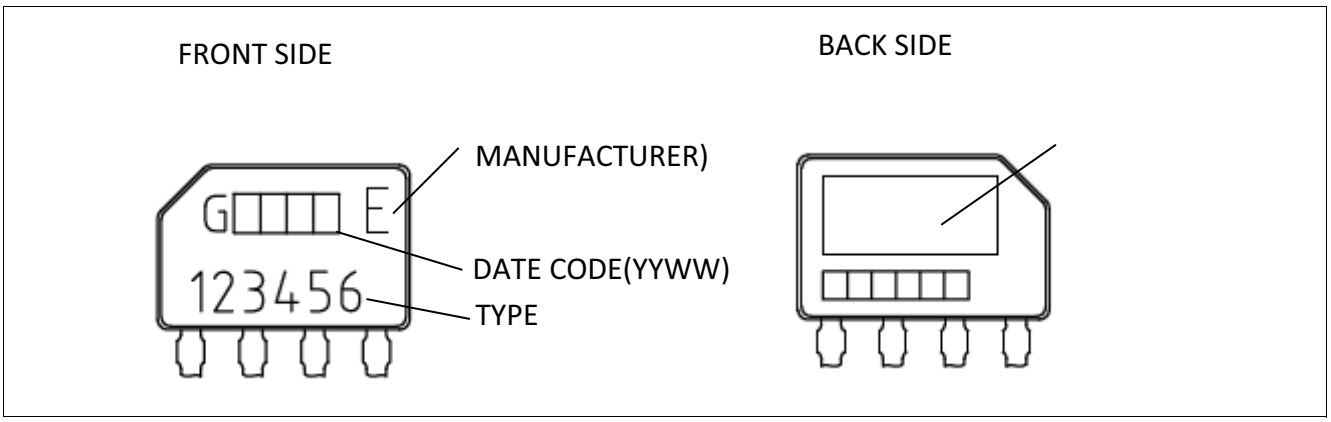


Figure 11 PG-SSO (Plastic Green Single Small Outline), package marking

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products, and to be compliant with government regulations the device is available as a green product. Green products are RoHS Compliant (i.e Pb free finish on leads and suitable for Pb free soldering according to IPC/JEDEC J-STD-020)

Terminology

A	
ADC	Analog to digital converter
B	
BIST	Built-in self-test
C	
CBUF	Buffer capacitor
CRC	Cyclic redundancy check
D	
DSP	Digital Signal Processing unit
E	
ECC	Error correction code to protect EEPROM content
EEPROM (abbrev. EEP)	Electrically erasable and programmable read only memory - programmable memory for sensor calibration and configuration data
G	
GND	Ground - ground line of sensor
H	
HADC	Hall analog to digital converter
HTS-ADC	Hall, temperature, stress analog to digital converter
I	
ID	Identification
L	
LP-Filter	Low pass filter
LSB	Least significant bit
M	
MSB	Most significant bit
MVS	Margin voltage selector
O	
OUT	Digital output pin of the sensor
P	
PWM	Pulse Width Modulation
R	
RMS	Root mean square
ROM	Read only memory
S	
SICI	Serial Inspection and Configuration Interface - Programming interface of the TLE4999C4
SPC	Short PWM Code
T	
TBD	To be done

11 Revision History

Revision	Date	Changes
v01.00	2020-12-13	Initial release

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Edition 2021-12-13
Published by
Infineon Technologies AG
81726 Munich, Germany

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