TLE5014SP16 E0001

GMR-based Angle Sensor

Features

- Fast SSC interface up to 8MHz
- **G**iant **M**agneto **R**esistance (GMR)-based principle
- Integrated magnetic field sensing for angle measurement
- 360° angle measurement
- EEPROM for storage of configuration (e.g. zero angle) and customer specific ID
- 15 bit representation of absolute angle value on the output
- Max. 1° angle error over lifetime and temperature range
- 32 point look-up table to correct for systematic angle errors (e.g. magnetic circuit)
- 112 bit customer ID (programmable)
- Automotive qualified Q100, Grade 1: -40°C to 125°C (ambient temperature)
- ESD: 4 kV (HBM) on V_{DD} and 2kV (HBM) on output pins
- RoHS compliant and halogen free package

Product validation

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

Description

The TLE5014SP16 E0001 is an iGMR (integrated GMR) based angle sensor with a high speed serial interface (SSC interface). It provides high accurate angular position information for various applications.

Table 1 Derivative Ordering codes

Product Type	Marking	Ordering Code	Package	Comment
TLE5014SP16 E0001	014SP01	SP004232096	PG-TDSO-16	SSC Interface, single die

Table of contents

1 Functional Description

1.1 Block Diagram

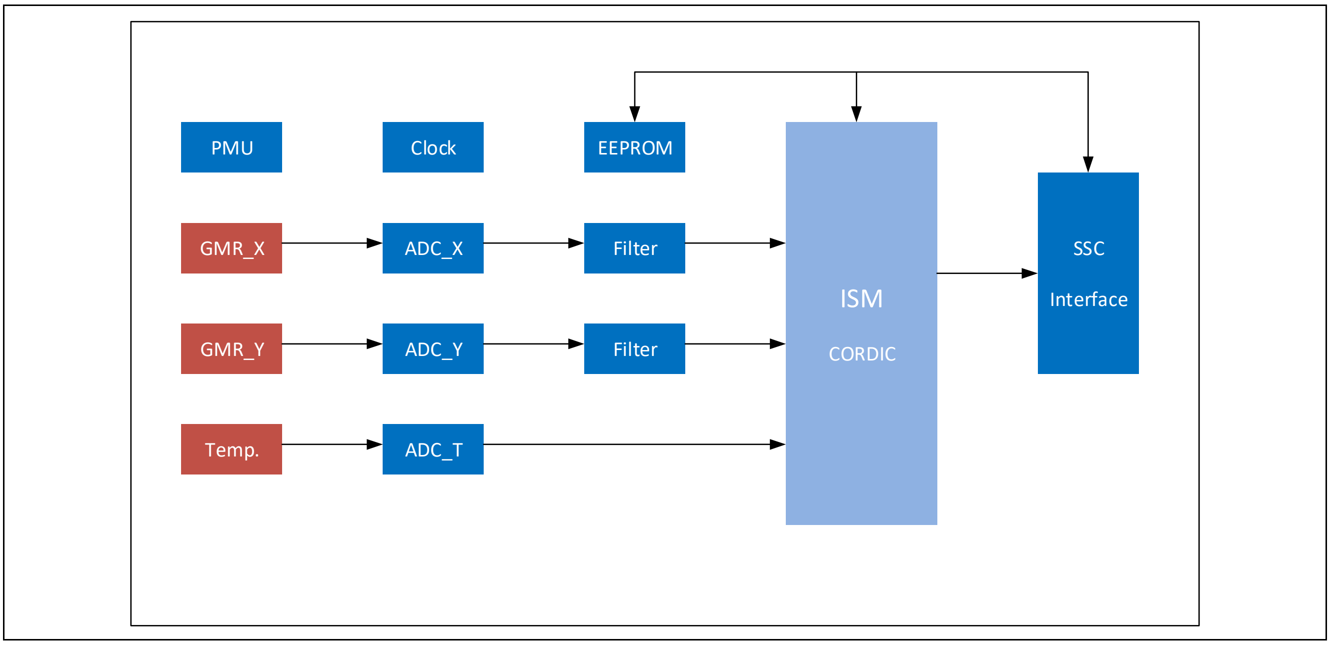

Figure 1-1 TLE5014SP16 E0001 block diagram

1.2 Functional Block Description

Internal Power Supply (PMU)

The internal blocks of the TLE5014 are supplied from several voltage regulators:

- GMR Voltage Regulator, VRS
- Analog Voltage Regulator, VRA
- Digital Voltage Regulator, VRD

These regulators are directly connected to the supply voltage VDD.

Oscillator and PLL (Clock)

The digital clock of the TLE5014 is given by the Phase-Locked Loop (PLL), which is fed by an internal oscillator.

SD-ADC

The Sigma-Delta Analog-Digital-Converters (SD-ADC) transform the analog GMR voltages and temperature voltage into the digital domain.

Digital Signal Processing Unit ISM

The Digital Signal Processing Unit ISM contains the:

- Intelligent State Machine (ISM), which does error compensation of offset, offset temperature drift, amplitude synchronicity and orthogonality of the raw signals from the GMR bridges.
- COordinate Rotation DIgital Computer (CORDIC), which contains the trigonometric function for angle calculation

Interface

The Interface block is used to generate the SSC signals

EEPROM

The EEPROM contains the configuration and calibration parameters. A part of the EEPROM can be accessed by the customer for application specific configuration of the device. Programming of the EEPROM is achieved with the SSC interface. Programming mode can be accessed directly after power-up of the IC.

1.3 Sensing Principle

The **G**iant **M**agneto **R**esistance (GMR) sensor is implemented using vertical integration. This means that the GMR-sensitive areas are integrated above the logic part of the TLE5014 device. These GMR elements change their resistance depending on the direction of the magnetic field.

Four individual GMR elements are connected to one Wheatstone sensor bridge. These GMR elements sense one of two components of the applied magnetic field:

- X component, V_x (cosine) or the
- Y component, V_y (sine)

With this full-bridge structure the maximum GMR signal is available and temperature effects cancel out each other.

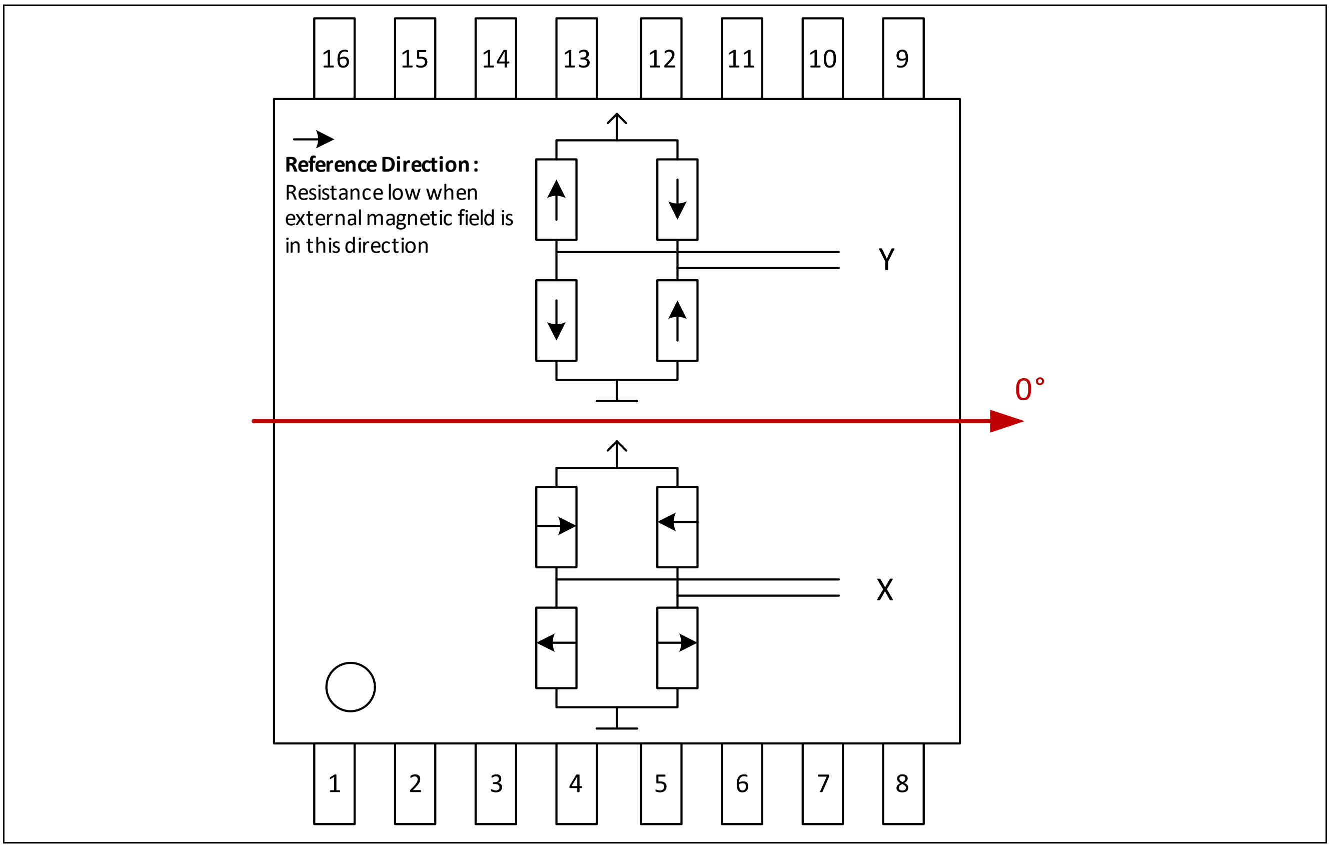

Figure 1-2 Sensitive bridges of the GMR sensor (not to scale)

In **Figure 1-2** the arrows in the resistors represent the magnetic direction which is fixed in the reference layer. If the external magnetic field is parallel to the direction of the Reference Layer, the resistance is minimal. If they are anti-parallel, resistance is maximal.

The output signal of each bridge is only unambiguous over 180° between two maxima. Therefore two bridges are oriented orthogonally to each other to measure 360°.

With the trigonometric function ARCTAN2, the true 360° angle value is calculated out of the raw X and Y signals from the sensor bridges.

1.4 Pin Configuration

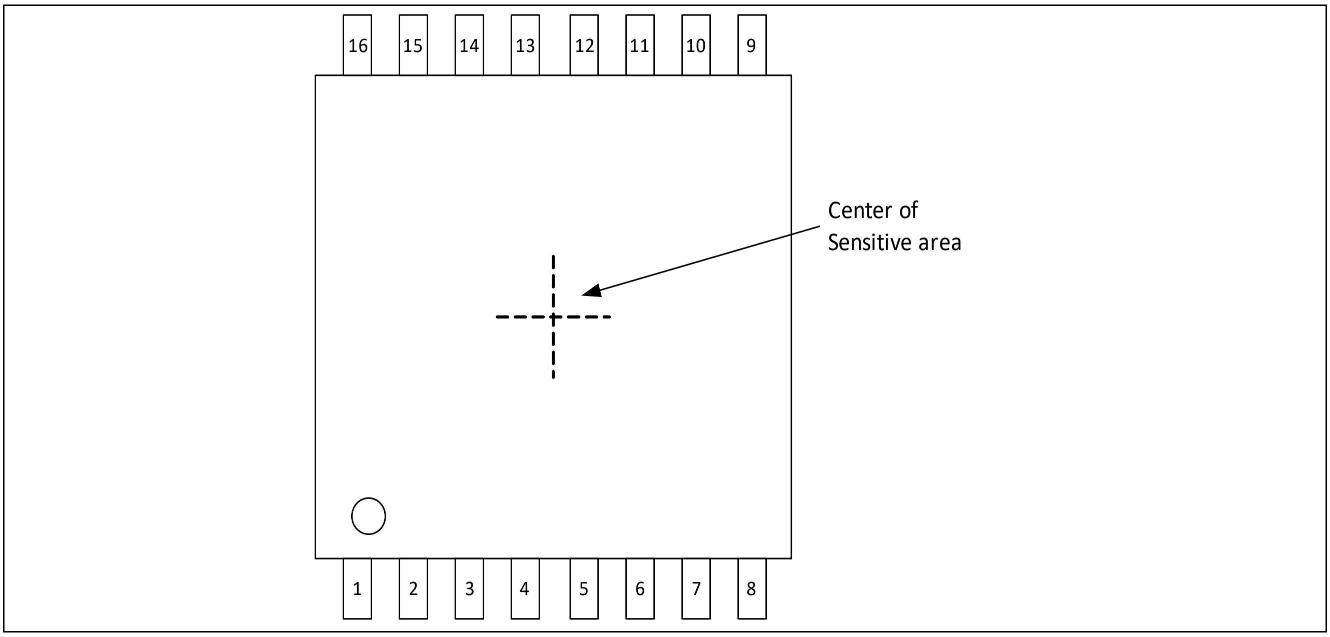

Figure 1-3 Pin configuration (top view)

1.5 Pin Description

The following **Table 1-1** describes the pin-out of the chip.

Table 1-1 Pin description TLE5014SP16

Pin	Symbol	In/Out	Function
1	IF1	I/O	DATA (MOSI/MISO)
2	IF2	I	SCK (SSC clock)
3	IF3	I	CSQ (chip select)
4	VDD	–	Supply voltage, positive
5	GND	–	Supply voltage, ground
6	IFA	–	Connect to GND
7	IFB	–	Connect via pull-up to V_{DD}
8	IFC	–	Keep open
9-16	-	–	n.c.

2 Application Circuits

The application circuit in this chapter shows the communication possibilities of the TLE5014SP16 E0001. To improve robustness against electro-magnetic disturbances, a capacitor of 100nF on the supply is recommended. This capacitor shall be placed as close as possible to the corresponding sensor pins. The load capacitor C_L shall not exeed the specified value (**Table 3-5**). The DATA line is actively driven to HIGH and LOW but the driver is switched off once reaching the HIGH state. Therefore, a pull-up resistor is recommended to maintain a stable HIGH level.

In case of a high speed communication, an additional serial resistor in the range of 140Ω can be implemented in the DATA, SCK and CSQ line to avoid reflections and enhance communication reliability. In this case the user is responsible to verify that the intended communication speed can be reached in his specific setup.

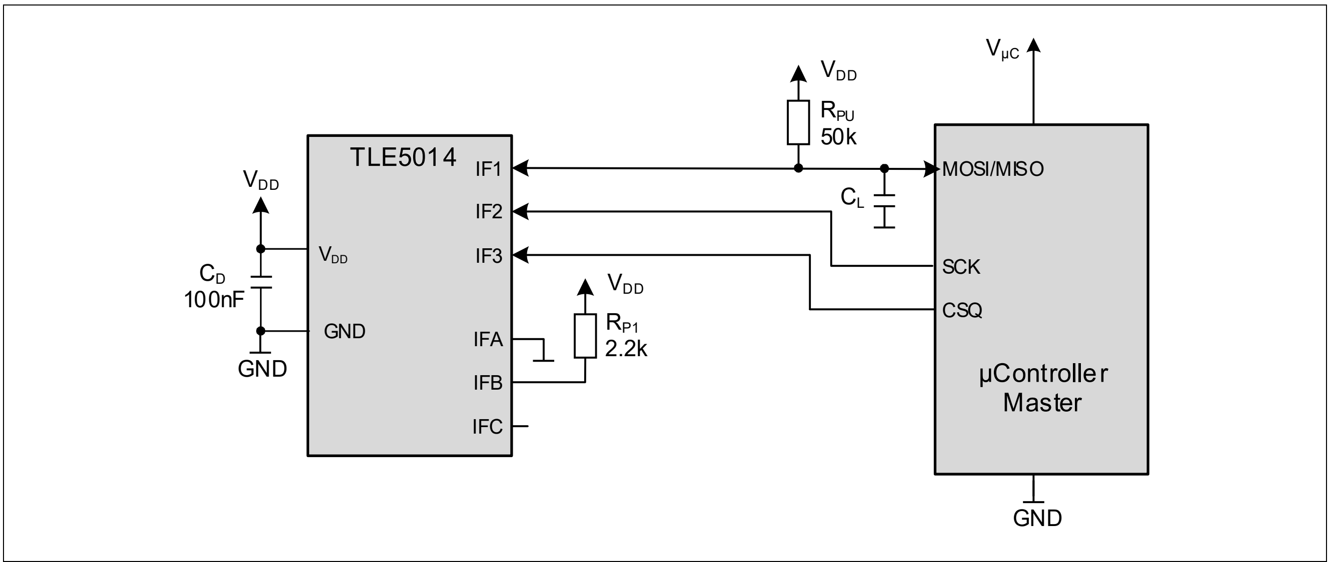

Figure 2-1 Application circuit for TLE5014SP16 E0001 with SSC interface, microcontroller switches pin between MISO and MOSI

3 Specification

3.1 Absolute Maximum Ratings

Stresses above the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the device.

Table 3-1 Maximum Ratings for Voltages and Output Current

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Absolute maximum supply voltage	V_{DD}	-18		26	V	for 40h, no damage of device; -18V means V_{DD} < GND
Voltage Peaks	V_{DD}			30	V	for 50µs, no current limitation
Absolute maximum voltage for pin IF1, IF2, IF3	V_{IF}	-0.3		6	V	no damage of device
Absolute maximum voltage for pin IFB	V_{IO}	-18		19.5	V	for 40h; no damage of device, -18V means V_{DD} < GND
Voltage Peaks (for pin IFB)	V_{IO}			30	V	for 50µs, no current limitation

Table 3-2 Maximum Temperature and Magnetic Field

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Maximum ambient temperature	T_A	-40		125	°C	Q100, Grade 1
Maximum allowed magnetic field	B			200	mT	max 5 min @ T_A = 25°C
Maximum allowed magnetic field	B			150	mT	max 5 h @ T_A = 25°C
Storage & Shipment[1) 2)]	$T_{storage}$	5		40	°C	for dry packed devices, Relative humidity < 90%, storage time < 3a

1) Air-conditioning of ware houses, distribution centres etc. is not necessary, if the combination of the specified limits of 75% R.H. and 40 °C will not be exceeded during storage for more than 10 events per year, irrespective of the duration per event, and one of the specified limits (75 % R.H. or 40 °C) will not be exceeded for longer than 30 days per year

2) See Infineon Application Note: “Storage of Products Supplied by Infineon Technologies”

Table 3-3 Mission Profile

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Mission Profile	$T_{A,max}$			125	°C	for 2000h

Table 3-4 Lifetime & Ignition Cycles

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Operating life time	t_{op_life}			15.000	h	see **Table 3-3** for mission profile
Total life time	t_{tot_life}			19	a	additional 2a storage time1)
Ignition cycles	$N_{ignition}$			200.000		during operating lifetime t_{op_life}

1) The lifetime shall be considered as an anticipation with regard to the product that shall not extend the warranty period

The device qualification is done according to AEC Q100 Grade 1 for ambient temperature range -40°C < T_A < 125°C

3.2 Operating Range

The following operating conditions must not be exceeded in order to ensure correct operation of the angle sensor. All parameters specified in the following sections refer to these operating conditions, unless otherwise noted. **Table 3-5** is valid for -40°C < T_A < 125°C unless otherwise noted.

Table 3-5 Operating Range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Operating supply voltage	V_{DD}	3.0		5.5	V	-
Supply Voltage Slew Rate	V_{DD_slew}	0.1		10^8	V/s	-
Operating ambient temperature	T_A	-40		125	°C	-
Angle speed	n			30000	rpm	-
Capacitive output load on SSC interface (DATA pin)	C_L	–	–	50	pF	

Magnetic Field Range

The operating range of the magnetic field describes the field values where the performance of the sensor, especially the accuracy, is as specified in **Table 3-11** and **Table 3-12**. This value is valid for a NdFeB magnet with a Tc of -1300ppm/K. In case a different magnet is used, the individual Tc of this magnet has to be considered and ensured that the limits are not exceeded. The allowed magnetic field range is given in **Figure 3-1**.

Table 3-6 Magnetic Field Range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Angle measurement field range @ 25°C	B	25		80	mT	T_A = 25°C, valid for NdFeB magnet

The below figure **Figure 3-1** shows the magnetic field range which shall not be exceeded during operation at the respective ambient temperature. The temperature dependency of the magnetic field is based on a NdFeB magnet with Tc = -1300ppm/K.

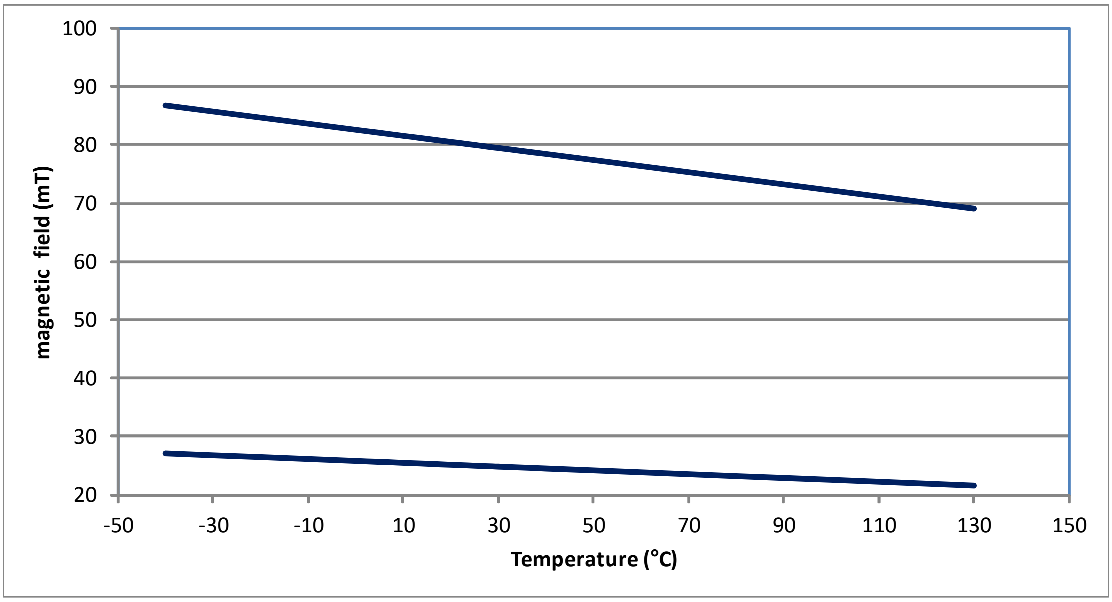

Figure 3-1 Allowed magnetic field range within operating ambient temperature range.

It is also possible to widen the magnetic field range for higher temperatures. In that case, additional angle errors have to be considered.

3.3 Electrical Characteristics

3.3.1 Input/Output Characteristics

The indicated parameters apply to the full operating range, unless otherwise specified. The typical values correspond to a supply voltage V_{DD} = 5.0V and an ambient temperature T_A = 25°C, unless individually specified. All other values correspond to -40°C < T_A < 125°C.

Table 3-7 Electrical Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Operating Supply Current	I_{DD}		12	15	mA	-
Time between supply voltage reaches reset value and valid angle value is available on the output (without interface delay	t_{Pon}			7	ms	
Overvoltage detection on V_{DD}	V_{OV}	–	6.5	7.0	V	In an overvoltage condition the output switches to tri-state
Undervoltage detection on V_{DD}	V_{UV}	2.3	2.5	2.7	V	In an undervoltage condition the sensor performs a reset
Internal clock tolerance	Δf_{clock}	-5		5	%	including temperature and lifetime

The following **Figure 3-2** shows the operating area of the device, the condition for overvoltage and undervoltage and the corresponding sensor reaction. The values for the over- and undervoltage comparators are the typical values from **Table 3-7**.

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 3-1**).

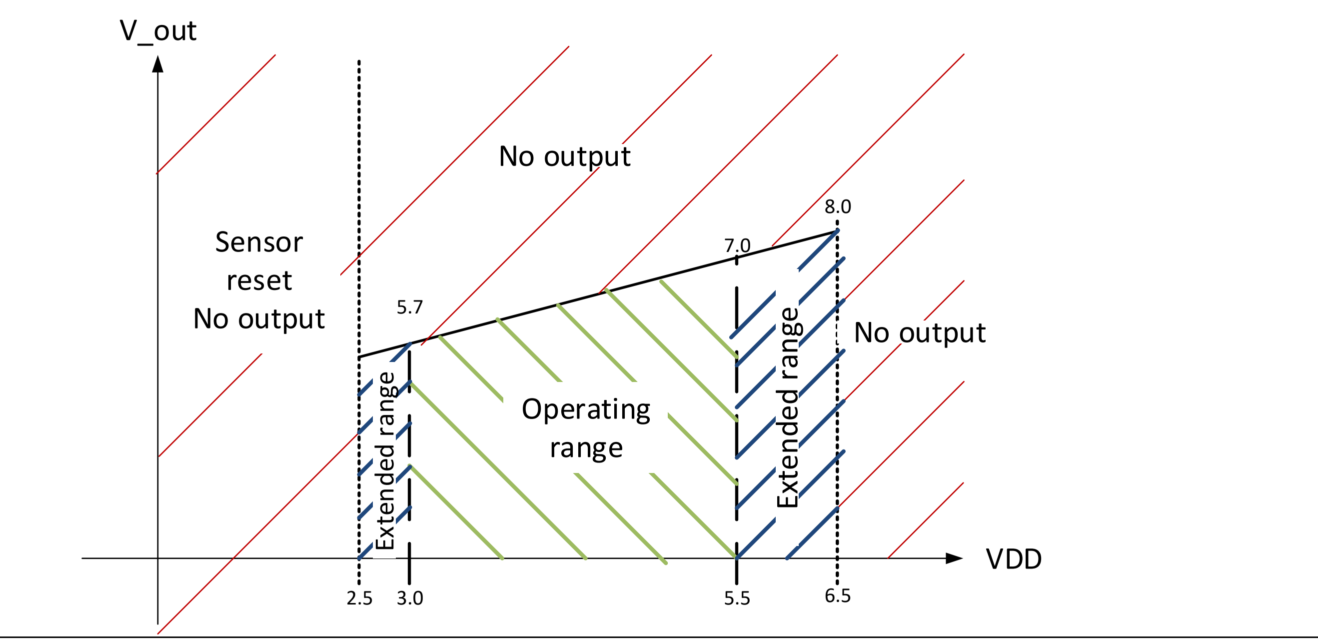

Figure 3-2 Operating area and sensor reaction for over- and undervoltage.

Table 3-8 Output driver

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Output low level[1)]	V_{OL}			$0.3*V_{DD}$		
Output high level[1)]	V_{OH}	$0.7*V_{DD}$				

1) In case several sensors are connected in a bus mode, the output levels may be influenced and out of specification in case a malfunction of one of the sensors on the bus occurs (e.g. one sensors has loss of V_{DD}).

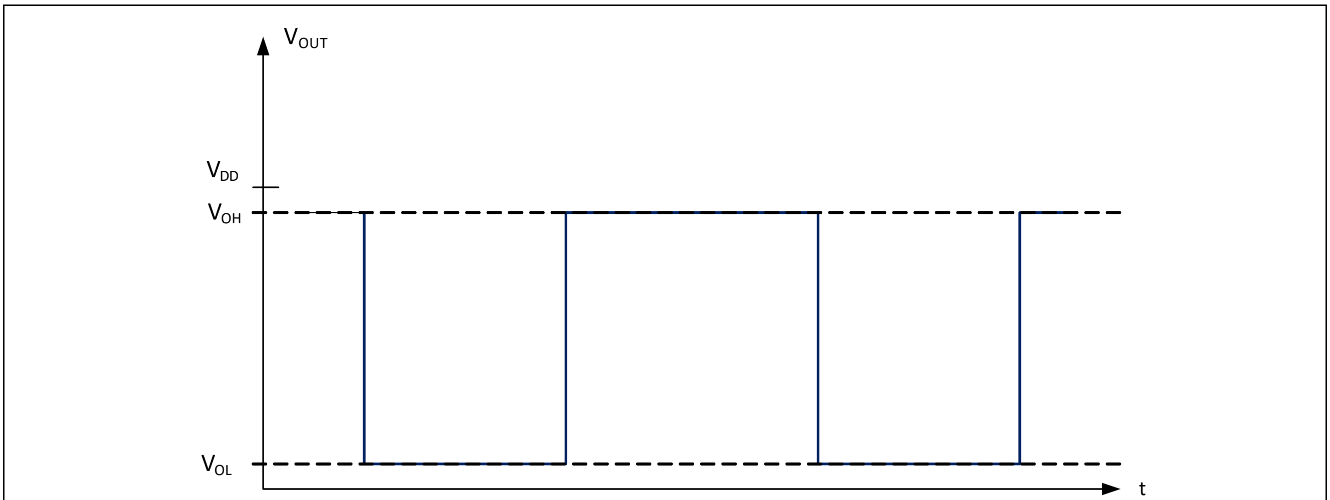

Figure 3-3 Output level high / low

Output Delay Time and Jitter

Due to the internal signal sampling and signal conditioning, there will be a delay of the provided angle value at the output. The definition of this delay is described in below **Figure 3-4**

Table 3-9 Signal delay and delay time jitter

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Delay time between real angle and angle value available at the AVAL register	t_{adel}	60.8	64	67.2	µs	Min/max values include clock tolerance
Variation of delay time t_{adel}	t_{deljit}	+/-12.0	+/-12.8	+/-14.0	µs	Min/max values include clock tolerance
Angle update rate (new angle value is provided in the AVAL register)	t_{update}	24.3	25.6	27.0	µs	Min/max values include clock tolerance

The sensor calculates a new angle value every t_{update}. The delay time (latency) of the angle value is determined by the time needed for the sampling of the sin/cos raw signals and angle calculation. The calculated angle is then transferred into the corresponding SSC register. This register is updated every t_{update}. As the reading of the angle value with the SSC interface is asynchronous to the internal angle update rate, a jitter on the delay time of the angle value is introduced in the range of t_{deljit} = +/- t_{update}/2. **Figure 3-4** shows this relation.

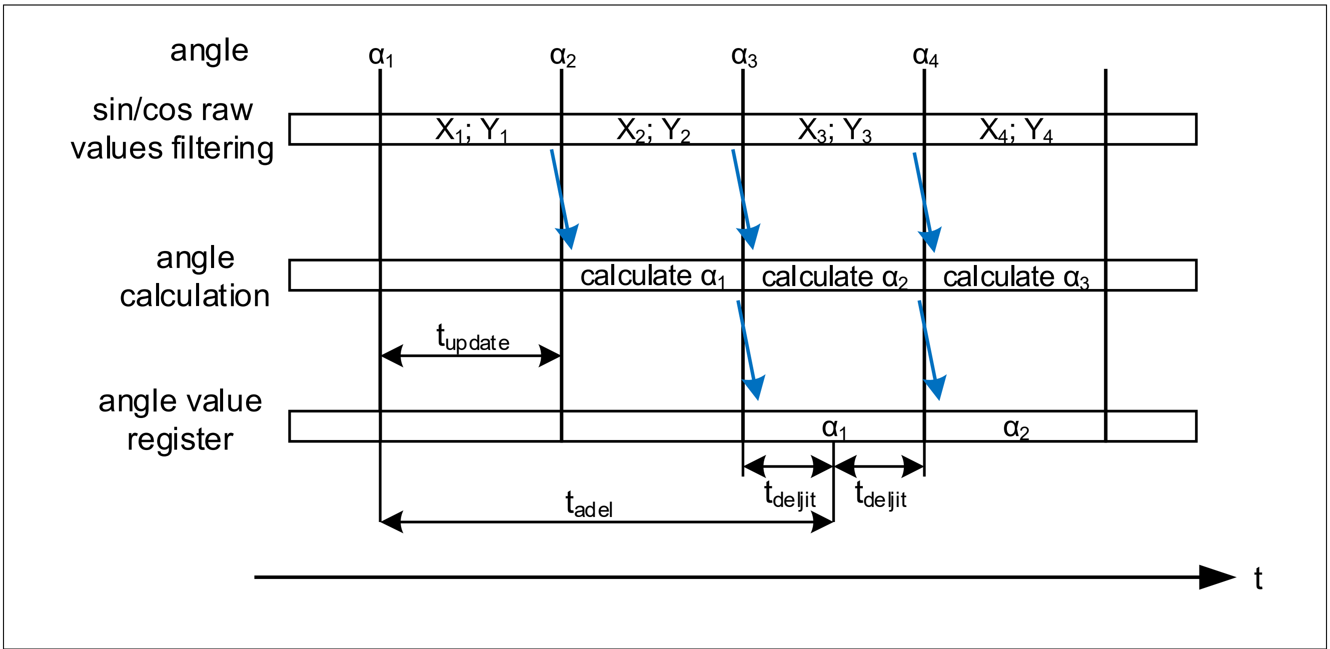

Figure 3-4 Definition of update rate t_{update}, delay time t_{adel} and jitter of delay time t_{deljit}

3.3.2 ESD Protection

Table 3-10 ESD Voltage

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Electro-Static-Discharge voltage (HBM), according to ANSI/ESDA/JEDEC JS-001	V_{HBM}			±4	kV	HBM contact discharge for pins VDD, GND, IFB
Electro-Static-Discharge voltage (HBM), according to ANSI/ESDA/JEDEC JS-001	V_{HBM}			±2	kV	HBM contact discharge for pins IF1, IF2, IF3, IFA, IFC
Electro-Static-Discharge voltage (CDM), according to JESD22-C101	V_{CDM}			±0.5	kV	for all pins except corner pins
				±0.75	kV	for corner pins only

3.3.3 Angle Performance

After internal angle calculation, the sensor has a remaining error, as shown in **Table 3-11** for an ambient temperature range up to 85°C and a reduced magnetic field range and in **Table 3-12** for the ambient temperature range up to 125°C and full magnetic operating range. The error value refers to B_Z= 0mT.

The overall angle error represents the relative angle error. This error describes the deviation from the reference line after zero-angle definition. It is valid for a static magnetic field.

If the magnetic field is rotating during the measurement, an additional propagation error is caused by the angle delay time (see **Table 3-9**).

Table 3-11 Angle Error for -40°C < T_A < 85°C and magnetic field range 33mT < B < 50mT

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Accuracy[1] over temperature w/o look-up table	$A_{Err,T}$			0.8	°	0h[2], over temperature
Accuracy[1] over temperature and lifetime, w/o look-up table	$A_{Err,s}$			0.9	°	lifetime stress: T_A=85°C/1000h/50mT
Accuracy[1)3] over temperature and lifetime, with look-up table	$A_{Err,sLUT}$			0.65	°	lifetime stress: T_A=85°C/1000h/50mT with look-up table correction
Hysteresis[4]	A_{Hyst}		0.1	0.16	°	value includes quantization error

1) Hysteresis and noise are included in the angle accuracy specification
2) "0h" is the condition when the part leaves the production at Infineon
3) Verified by characterization
4) Hysteresis is the maximum difference of the angle value for forward and backward rotation

Table 3-12 Angle Error for -40°C < T_A < 125°C

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Accuracy[1] over temperature w/o look-up table	$A_{Err,T}$			0.8	°	0h[2], over temperature B = 33mT to 80mT[3]
Accuracy[1] over temperature and lifetime, w/o look-up table	$A_{Err,s}$			1.0	°	33mT…80mT[3] lifetime stress: T_A=125°C/2000h
Accuracy[1)4] over temperature and lifetime, with look-up table	$A_{Err,sLUT}$			0.85	°	B = 33mT to 80mT[3], lifetime stress: T_A=125°C/2000h with look-up table correction
Hysteresis[5]	A_{Hyst}		0.1	0.16	°	B = 33mT to 80mT[6], value includes quantization error

1) Hysteresis and noise are included in the angle accuracy specification
2) "0h" is the condition when the part leaves the production at Infineon
3) For the magnetic field range of 25mT < B < 33mT, 0.2° have to be added to the max. angle accuracy
4) Verified by characterization
5) Hysteresis is the maximum difference of the angle value for forward and backward rotation

6) For the magnetic field range of 25mT < B < 33mT, 0.1° have to be added to the max. hysteresis A_{Hyst}

3.4 EEPROM Memory

The sensor includes a non-volatile memory (NVM) where calibration data and sensor configuration data are stored. The customer has access to a part of this memory for storage of application specific data (e.g. look-up table & customer ID)

The time for programming the customer relevant part of the NVM as well as maximum cycles of programming and data retention is given in **Table 3-13**

Table 3-13 EEPROM

Parameter	Symbol	Values			Unit	Note / Test Condition	Number
		Min.	Typ.	Max.			
Number of possible NVM programming cycles	n_{Prog}			100		-	
NVM data retention	$t_{retention}$		-	21	a	includes 19a lifetime and 2a storage	
Time for programming of whole NVM (customer relevant part)	t_{Prog}		0.5		s	incl. look-up table, configuration, customer ID; with 100kbit/s	

3.5 Reset Concept and Fault Monitoring

Some internal and external faults of the device can trigger a reset. During this reset, all output pins are high-ohmic to avoid any disturbance of other sensors which may be connected together in a bus mode. A reset is indicated as soon as the sensor is back at operational mode by a status bit.

3.6 External & Internal Faults

In case of an occurrence of external or internal faults, as for example overvoltage or undervoltage, the sensor reacts in a way that these faults are indicated to the customer.

All errors are indicated as long as they persist, but at least once. After disappearance of the error, the error indication is also cleared.

Overvoltage, undervoltage

It is ensured, that the sensor provides a valid output value as long as the voltage is within the operating range or no under- or overvoltage is indicated. At occurrence of an undervoltage, the sensor performs a reset. The implemented undervoltage comparator at V_{DD} detects an undervoltage at ~2.5V (typ. value). At occurrence of an overvoltage, the sensor output goes to tristate and no protocol is transmitted. The implemented overvoltage comparator at V_{DD} detects an overvoltage at ~6.5V (typ. value).

Open and Shorts

All pins of the device withstand a short to ground (GND) and a short to V_{DD} (as long as V_{DD} is within the operating range). In case of an open V_{DD} connection or an open GND the sensor provides a detectable wrong signal (e.g. no valid output protocol).

It is also ensured that a short between two neighboring pins leads to a detectable wrong output signal.

Communication Failures

An external fault can happen where an ongoing communication is interrupted before it is finished correctly. In such an event, no sensor malfunction or dead-lock will occur.

3.7 Power Dissipation

Following table describes the calculated power dissipation for the different application cases within the operating range defined in **Table 3-5**. It is a worst case assumption with the maximum values within the operating range.

Table 3-14 Power Dissipation

Scenario	Configuration	V_{DD} (V)	I_{DD} (mA)	V_{OUT} (V)	I_{OUT} (mA)	P (mW)
1	SSC	3.3	15		~0	49.5
2	SSC	5.5	15		~0	82.8

3.8 Device Programming

It is possible to do the programming of the EEPROM with the SSC interface. The programming mode can be accessed directly after start-up of the IC by sending the appropriate command.

Following parameters can be programmed and stored in the EEPROM:

- Zero angle (angle base)
- Rotation direction (clock wise or counter clock wise)
- Look-up table (32 points)
- Customer ID (112bit individual data)

To align the angle output of the sensor with the application specific required zero angle direction this value can be programmed. All further output angles are in reference to this zero angle.

Look-Up Table

To increase the accuracy of the provided angle value, a look-up table is implemented which allows to compensate for external angle errors which may be introduced for example by the magnetic circuit. Alignment tolerances (eccentricity or tilt) may lead to a non-linearity of the output signal which can be compensated using the implemented look-up table. This look-up table has 32 equidistant points over 360° angle range with a linear interpolation between the 32 defined values

Further details for programming and configuration of the device can be found in the corresponding user manual of the TLE5014.

4 Synchronous Serial Communication (SSC) interface

The SSC interface is a half-duplex communication protocol. The communication is always initiated by the microcontroller by sending a command to the TLE5014SP16 E0001. The command can be either a Read access (**Figure 4-3**) or a Write access (**Figure 4-4**). According to the command, the microcontroller can either send a data word to the TLE5014SP16 E0001 (Write access) or receive data word from the TLE5014SP16 E0001 (Read access). At the end of the communication the TLE5014SP16 E0001 sends a safety word.

The 3-pin SSC Interface is composed of:

- DATA: Bidirectional data line. Data bits are sent synchronously with the clock line.
- SCK: Unidirectional clock line. Generated by the microcontroller, TLE5014SP16 E0001 is always a slave.
- CSQ: Chip select, active low. Asserted by the microcontroller to select a slave.

4.1 Data transmission

The data communication via SSC interface has the following characteristic:

- The SSC Interface is word-aligned. All functions are activated after each transmitted word.
- The microcontroller selects a TLE5014SP16 E0001 by asserting the CSQ to low. A “high” condition on the negated Chip Select pin (CSQ) of the selected TLE5014SP16 E0001 interrupts the transfer immediately. The CRC calculator is automatically reset.
- Data is put on the data line with the rising edge on SCK and read with the falling edge on SCK. Similar to a SPI configuration with CPOL=0 and CPHA=1.
- After changing the data direction, a delay (t_{wr_delay}) has to be considered before continuing the data transfer. This is necessary for internal register access.
- After sending the Safety Word the transfer ends. To start another data transfer, the CSQ has to be deselected once for t_{CSoff}.
- The SSC is default Push-Pull. The Push-Pull driver is only active, if the TLE5014SP16 E0001 has to send data, otherwise the Push-Pull is disabled for receiving data from the microcontroller.

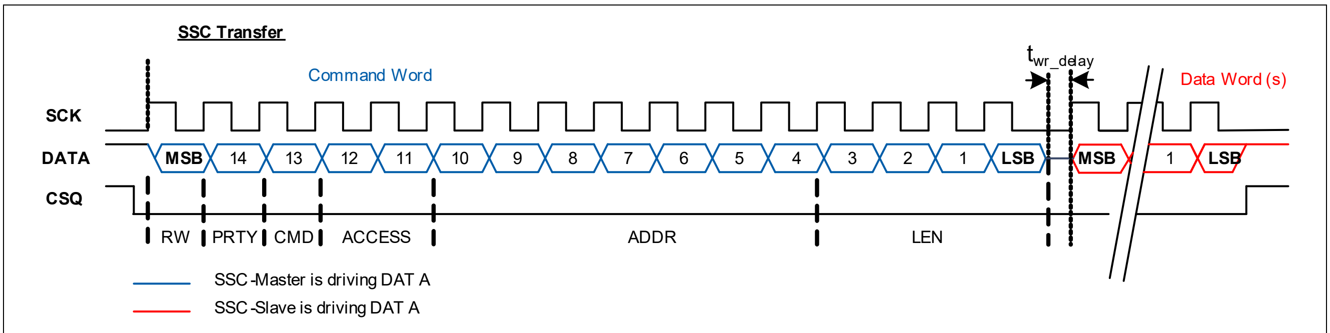

Figure 4-1 SSC data transmission

4.1.1 Bit Numbering

The SSC communication is using the convention: Most Significant Bit (MSB) first. **Figure 4-1** shows the Command Word and the beginning of the Data Word to demonstrate the bit numbering.

4.1.2 Update of update-registers

At a rising edge of CSQ without a preceding data transfert (no SCK pulse), the content of all registers which have an update buffer is saved into the buffer. The content of the update buffer can be read by sending a read command for the desired register and setting the ACCESS bits of the Command Word to 11_B. This feature allows to take a snapshot of all necessary system parameters at the same time.

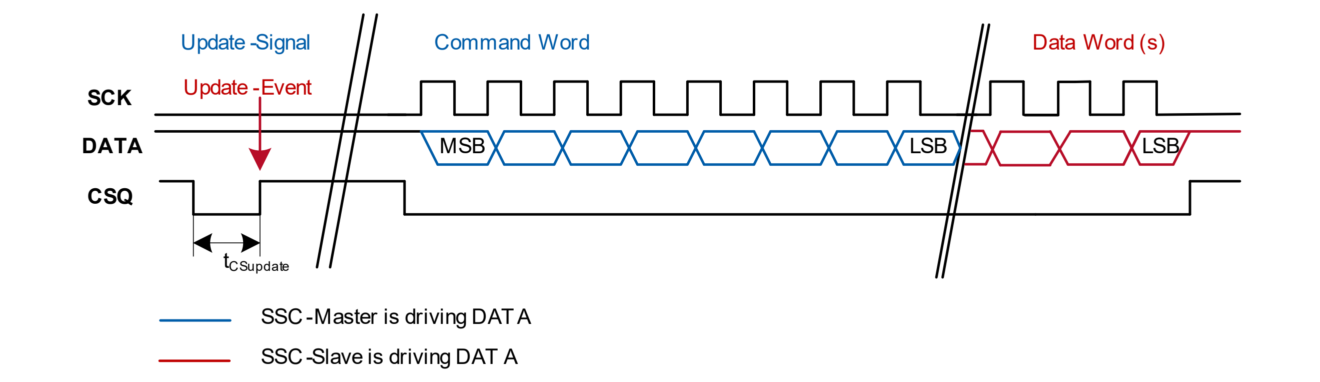

Figure 4-2 Update of update-registers

The types of functions used in the registers are listed here:

Table 4-1 Bit types

Abbreviation	Function	Description
R	Read	Read-only registers
W	Write	Read and write registers
U	Update	Update buffer for this bit is present. If an update is issued and the Update-Register Access bits (ACCESS in Command Word) are set, the immediate values are stored in this update buffer simultaneously. This enables a snapshot of all necessary system parameters at the same time

4.2 Data transfer

The SSC data transfer is word aligned. The following transfer words are possible:

- Command word (to access and change operating modes of the TLE5014SP16 E0001)
- Data words (any data transferred in any direction)
- Safety word (confirms the data transfer and provide status information)

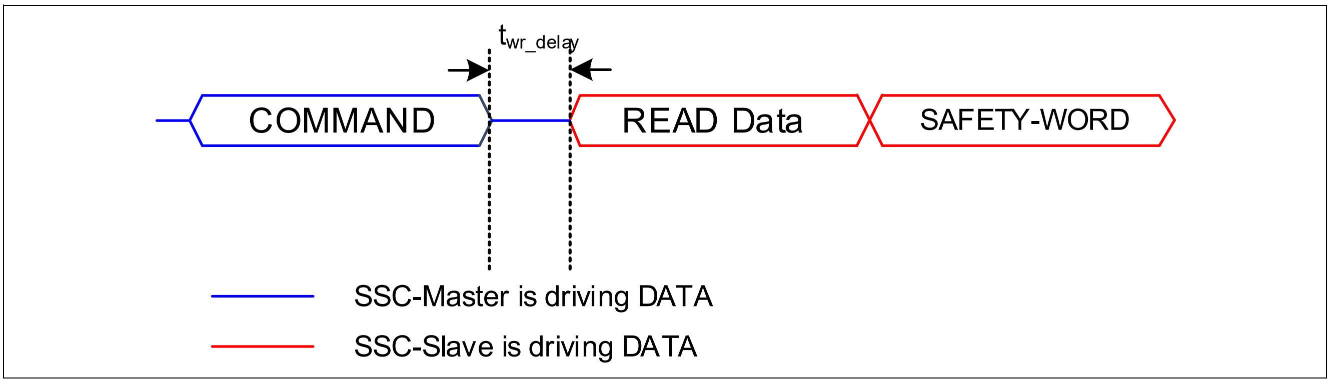

Figure 4-3 SSC data transfer (data read example)

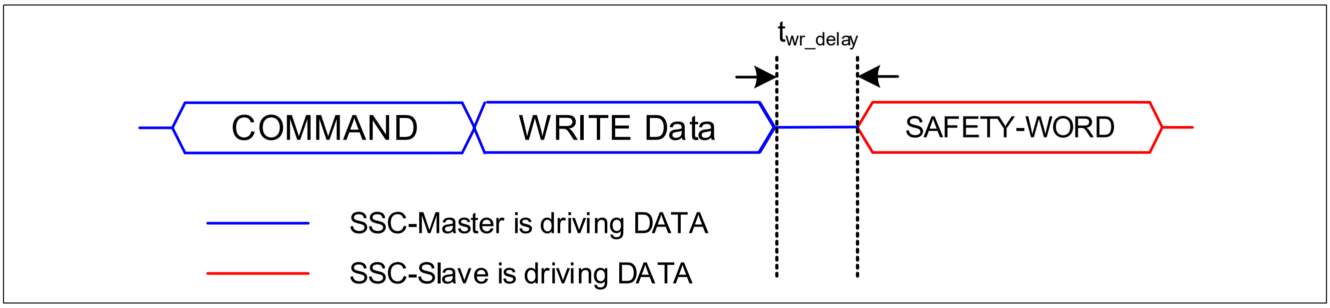

Figure 4-4 SSC data transfer (data write example)

4.2.1 Command Word

The TLE5014SP is controlled by a command word. It is sent first at every data transmission.The structure of the command word is shown in **Table 4-2**.

Table 4-2 Structure of the command word

Name	Bits	Description
RW	[15]	Read - Write 0: Write 1: Read
PRTY	[14]	Command parity Odd parity of all Command-Word-bits. Number of “1”s has to be odd
CMD	[13]	Set to 0_B
ACCESS	[12:11]	Access mode to registers 00_B: Direct access 11_B: Update register; read-access
ADDR	[10:4]	7-bit Address
LEN	[3:0]	Set to 1_B

4.2.2 Safety word

The safety word contains following bits:

Table 4-3 Structure of the safety word

Name	Bits	Description
STAT	Chip and Interface Status.	
	[15]	Indication of chip reset (undervoltage, watchdog) (resets after readout via SSC) 0: Reset occurred 1: No reset
	[14]	System Error (e.g. Overvoltage; Undervoltage; V_{DD}-, GND- off; ROM) 0: Error occurred 1: No error
	[13]	Interface Access Error (access to wrong address; wrong lock, wrong parity, wrong access) 0: Error occurred 1: No error
	[12]	Angle Value error (ADC , vectorlength or redundant angle calculation error) 0: Angle value invalid 1: Angle value valid
RESP	[11:8]	Sensor Number Response Indicator The sensor no. bit is pulled low and the other bits are high
CRC	[7:0]	Cyclic Redundancy Check (CRC) includes Command Word, Data-words, STAT and RESP

4.2.3 Cyclic Redundancy Check (CRC)

- This CRC is according to the J1850 Bus-Specification.
- Every new transfer resets the CRC generation.
- Every Byte of a transfer will be taken into account to generate the CRC (also the sent command(s)).
- Generator-Polynomial: $X^8+X^4+X^3+X^2+1$, but for the CRC generation the fast-CRC generation circuit is used (see **Figure 4-5**).
- The remainder of the fast CRC circuit is initial set to 11111111_B.
- Remainder is inverted before transmission.

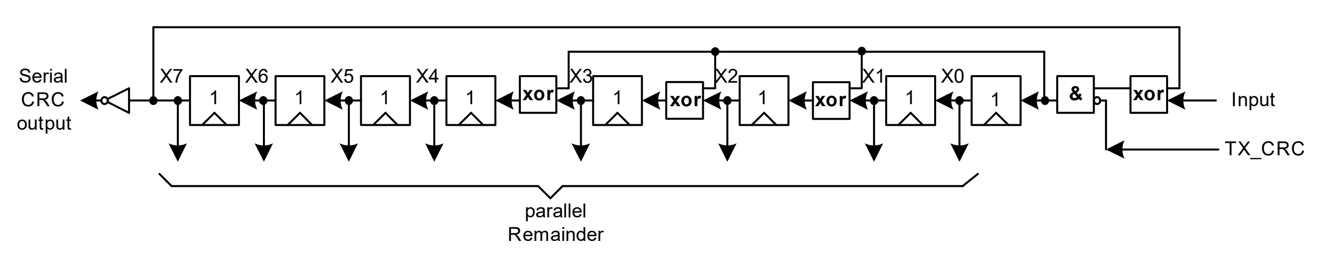

Figure 4-5 Fast CRC polynomial division circuit

Two code examples to compute the CRC are provided. The first implementation is based on a two loops implentation. This implementation is recommended if the memory space is critical in the application. The second implementation replaces the inner loop by a look-up-table. It requires more memory space but the computation time is lower.

5 Package Information

The device is qualified with a MSL level of 3. It is halogen free, lead free and RoHS compliant.

5.1 Package Parameters

Table 5-1 Package Parameters

Parameter	Symbol	Limit Values			Unit	Notes
		Min.	Typ.	Max.		
Thermal resistance	R_{thJA}			150	K/W	Junction to air[1)]
	R_{thJC}			45	K/W	Junction to case
	R_{thJL}			70	K/W	Junction to lead
Moisture Sensitively Level	MSL 3					260°C[2)]
Lead Frame	Cu					
Plating	Sn 100%					> 7 µm

1) according to Jedec JESD51-7
2) suitable for reflow soldering with soldering profiles according to JEDEC J-STD-020E (December 2014)

Table 5-2 Position of the die in the package

Parameter	Symbol	Limit Values			Unit	Notes
		Min.	Typ.	Max.		
Tilt				3	°	in respect to the z-axis and reference plane (see **Figure 5-1**),
Rotational displacement				3	°	in respect to the reference axis (see **Figure 5-1**)
Placement tolerance in package				100	µm	in x and y direction

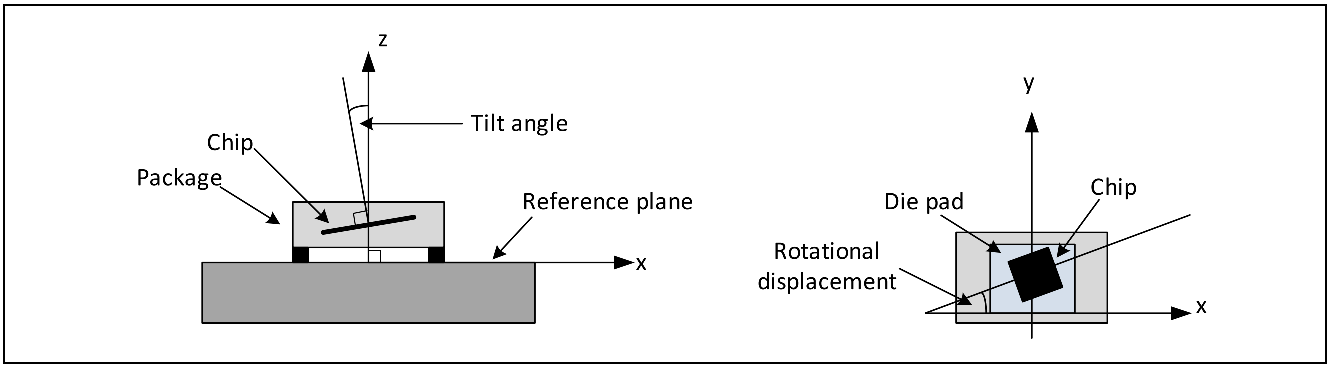

Figure 5-1 Tolerance of the die in the package

The active area of the GMR sensing element is 360µm x 470µm.

It has to be ensured that a magnet is used which has sufficient size to provide a homogeneous magnetic field over the total sensing element area. For a practical application design this means that the magnet has to be large enough to ensure that the non-homogeneity of the magnetic field in this area (plus relevant positioning tolerances) is negligible. In case the magnet diameter is too small or there is a misalignment of the magnet to the sensor, an additional angle error may occur which has to be taken into account by the user.

5.2 Package Outline

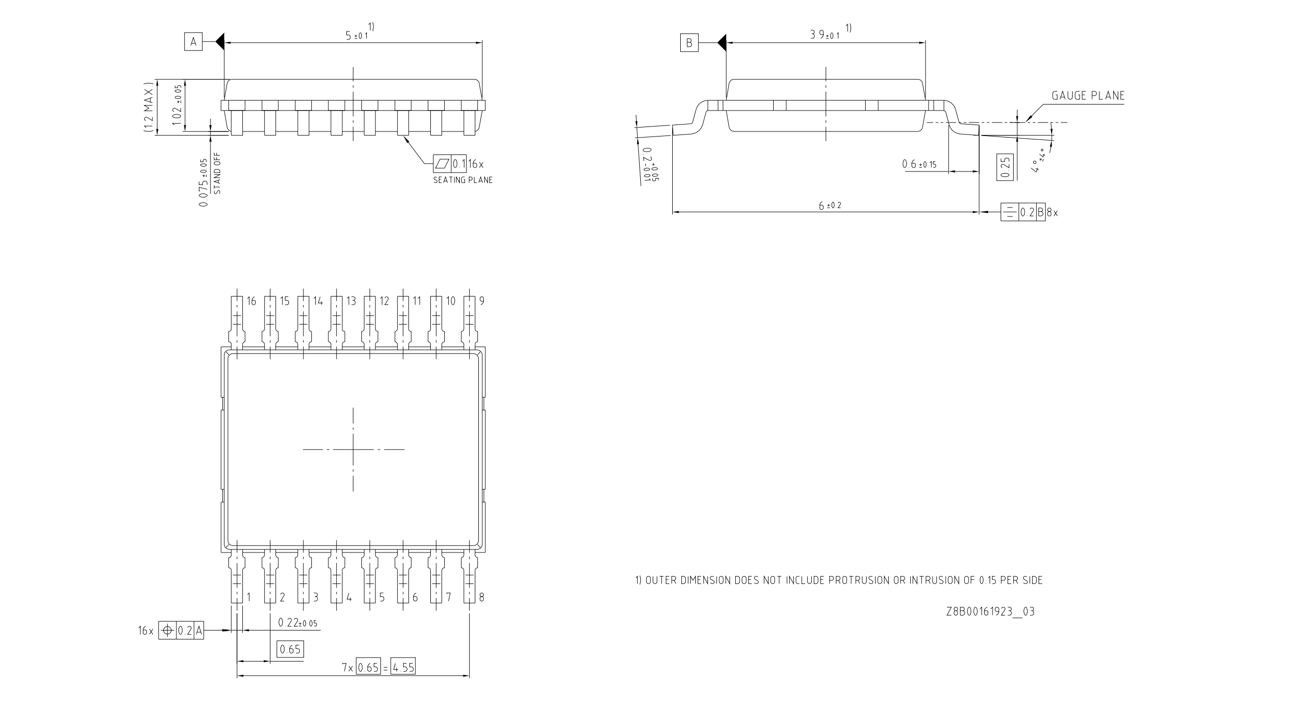

Figure 5-2 PG-TDSO-16 package dimension

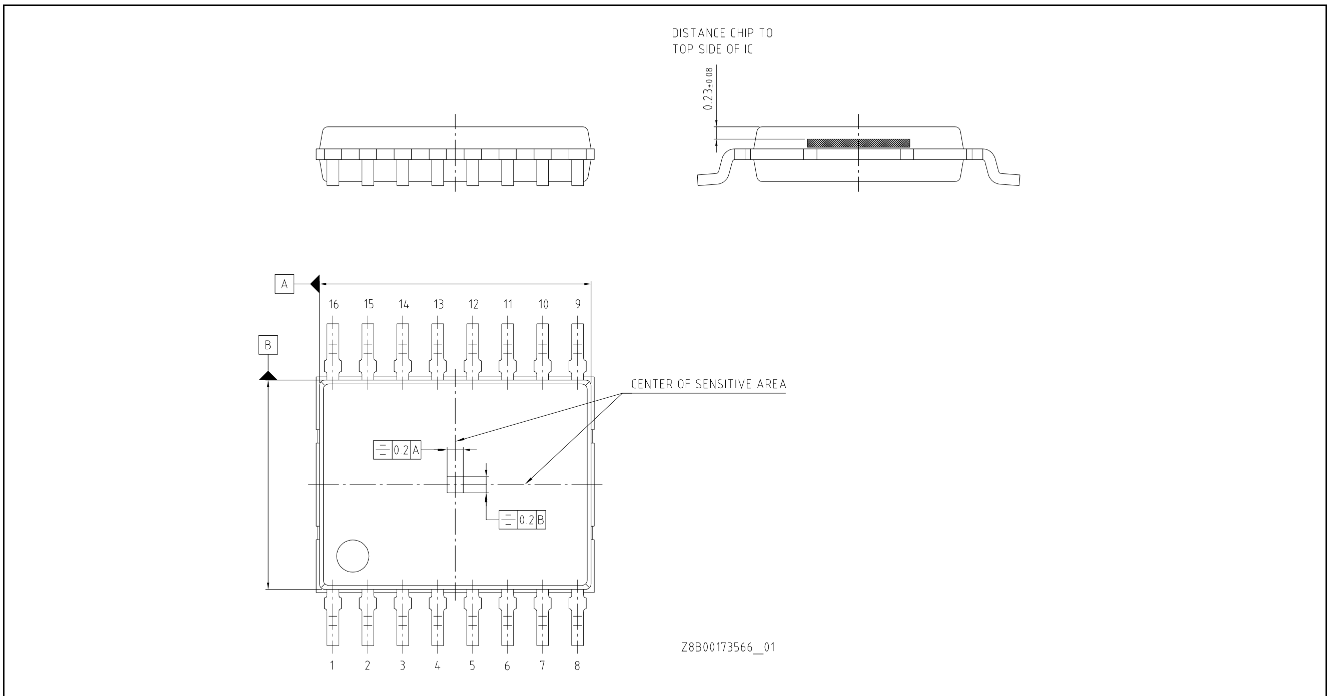

Figure 5-3 Position of sensing element

5.3 Footprint

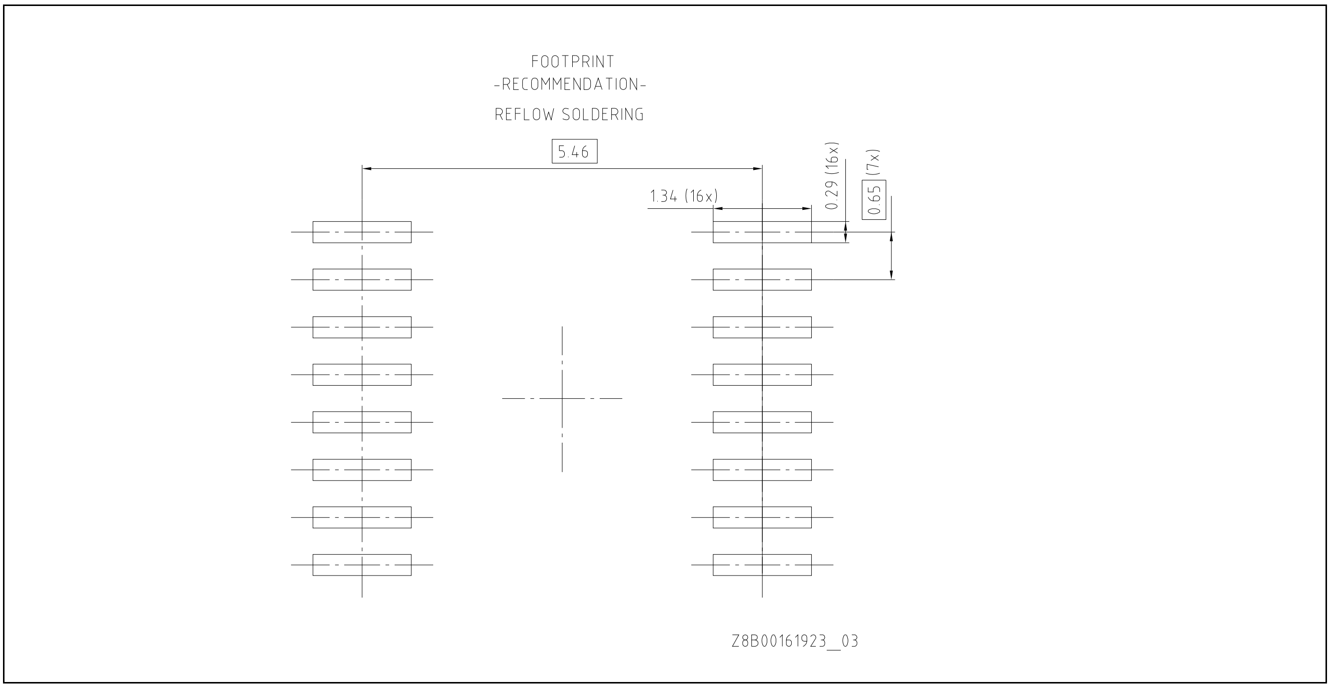

Figure 5-4 Footprint of PG TDSO-16

5.4 Packing

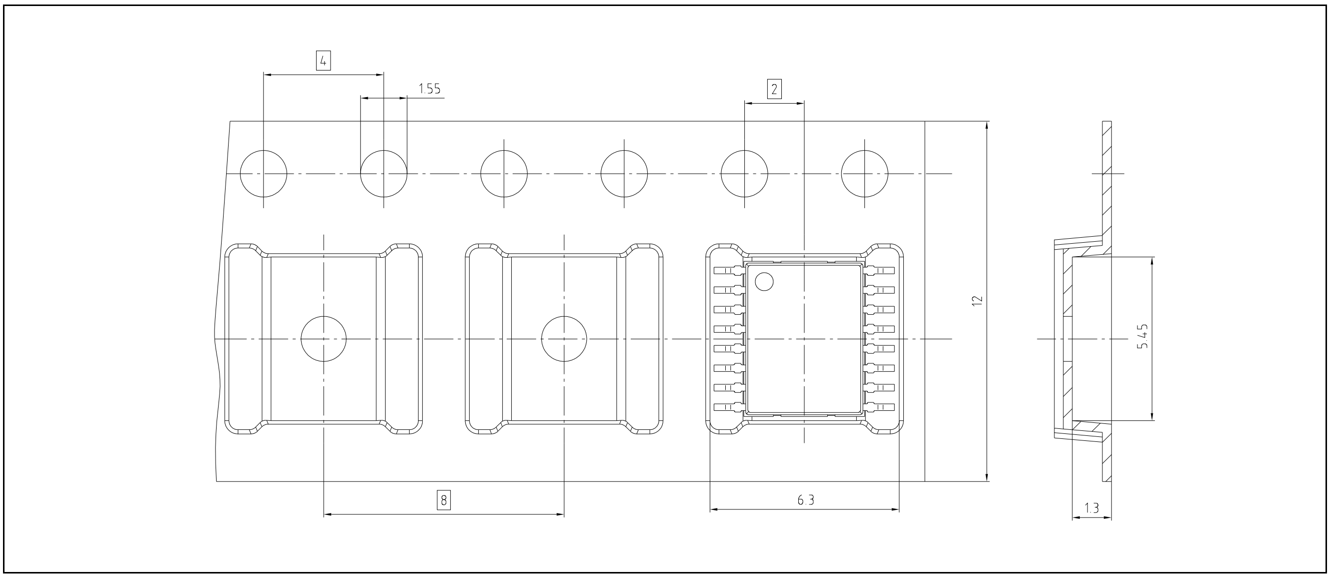

Figure 5-5 Tape and Reel

5.5 Marking

Position	Marking	Description
1st Line	Gxxxx	G: green, 4-digit date code: YYWW e.g. “1801”: 1st week in 2018
2nd Line	xxxxxxxx	Interface type and version
3rd Line	xxx	Lot code

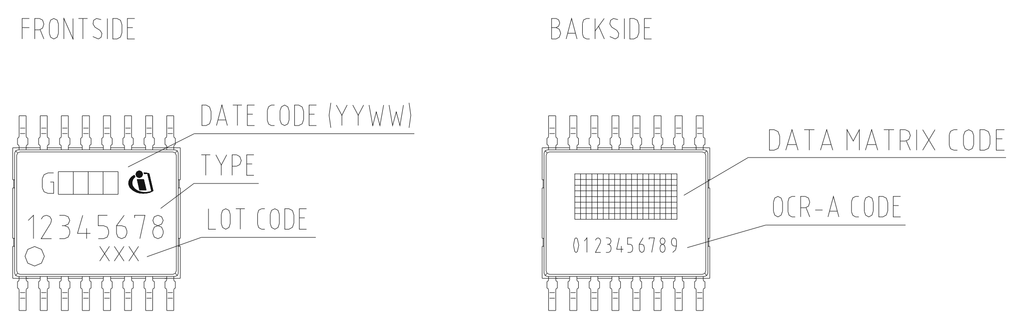

Figure 5-6 Marking of PG-TDSO-16

6 Revision history

Revision	Date	Changes
1.0	2019-01-15	Initial creation.
1.1	2019-04-04	Remove Register chapter

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