Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

Angle Sensor

GMR-Based Angular Sensor
for Rotor-Position Sensing

TLE5012

TLE5012-E0318
TLE5012-E0742

Data Sheet

V 1.0, 2010-11
Final

Sensors

Edition 2010-11

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.

TLE5012 GMR-Based Angular Sensor

Revision History: 2010-11, V 1.0

Previous Version: -

Page	Major changes since last revision
general	correction of typing errors

We Listen to Your Comments

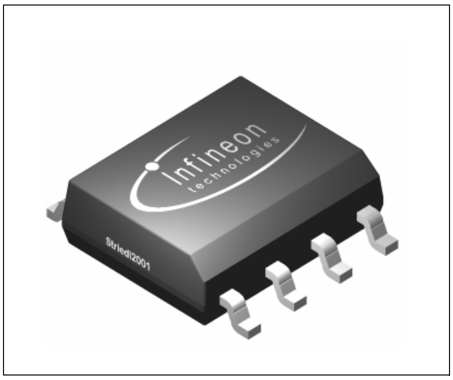
Any information within this document that you feel is wrong, unclear or missing at all?
Your feedback will help us to continuously improve the quality of this document.
Please send your proposal (including a reference to this document) to:
sensors@infineon.com

Table of Contents

List of Figures

List of Tables

1 Product Description



1.1 Overview

The TLE5012 is a 360° angle sensor that detects the orientation of a magnetic field by measuring sine and cosine angle components with monolithic integrated Giant Magneto Resistance (iGMR) elements.

Highly precise angle values are maintained at various temperatures throughout the device's lifetime using an internal autocalibration algorithm.

Data communications are accomplished with a bi-directional Synchronous Serial (SSC)-Interface that is Serial Peripheral Interface (SPI)-compatible.

The absolute angle value and other values are transmitted via SSC or via a Pulse-Width Modulation (PWM) protocol. The sine and cosine raw values can also be read out. These raw signals are digitally processed internally to calculate the angle orientation of the magnetic field (magnet).

The TLE5012 is a precalibrated sensor. The calibration parameters are stored in laser fuses. At start-up, the values of the fuses are written into flip-flops, where these values can be changed by the application-specific parameters. The TLE5012-E0318 and TLE5012-E0742 are especially configured in a Hall-Switch emulation mode for motors with three or seven pole pairs.

Online diagnostic functions are provided to ensure reliable operation.

Product Type	Marking	Ordering Code	Package
TLE5012	5012	SP000477068	PG-DSO-8
TLE5012-E0318	5012E03	SP000611246	PG-DSO-8
TLE5012-E0742	5012E07	SP000611250	PG-DSO-8

1.2 Features

- GMR-based principle
- Integrated magnetic field sensing for angle measurement
- Fully calibrated 0 - 360° angle measurement with revolution counter and angle speed measurement
- Two separate highly accurate single-bit SD-ADCs
- 15-bit representation of absolute angle value on the output (resolution of 0.01°)
- 16-bit representation of sine/cosine values on the interface
- Max. 1.0° angle error over lifetime and temperature with activated auto-calibration
- Bi-directional SSC Interface up to 8 Mbit/s
- Supports Safety Integrity Level (SIL) with diagnostic functions and status information
- Interfaces: SSC, PWM, Incremental Interface (IIF), Hall-Switch Mode (HSM)
- 0.25-µm CMOS technology
- Automotive qualified: -40°C to 150°C (junction temperature)
- ESD > 4 kV (HBM)
- RoHS-compliant (Pb-free package)

1.3 Typical Applications

The TLE5012 GMR-Based Angular Sensor is designed for angular position sensing in automotive applications, such as:

- Electrical commutated motor (e.g. used in Electric Power Steering (EPS))
- Rotary switch
- Steering angle
- General angular sensing

2 Functional Description

2.1 General

The GMR sensor uses vertical integration. This means that the GMR-sensitive areas are integrated above the logic portion of the TLE5012 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)

The advantage of a full-bridge structure is that the amplitude of the GMR signal is doubled and temperature effects cancel out each other.

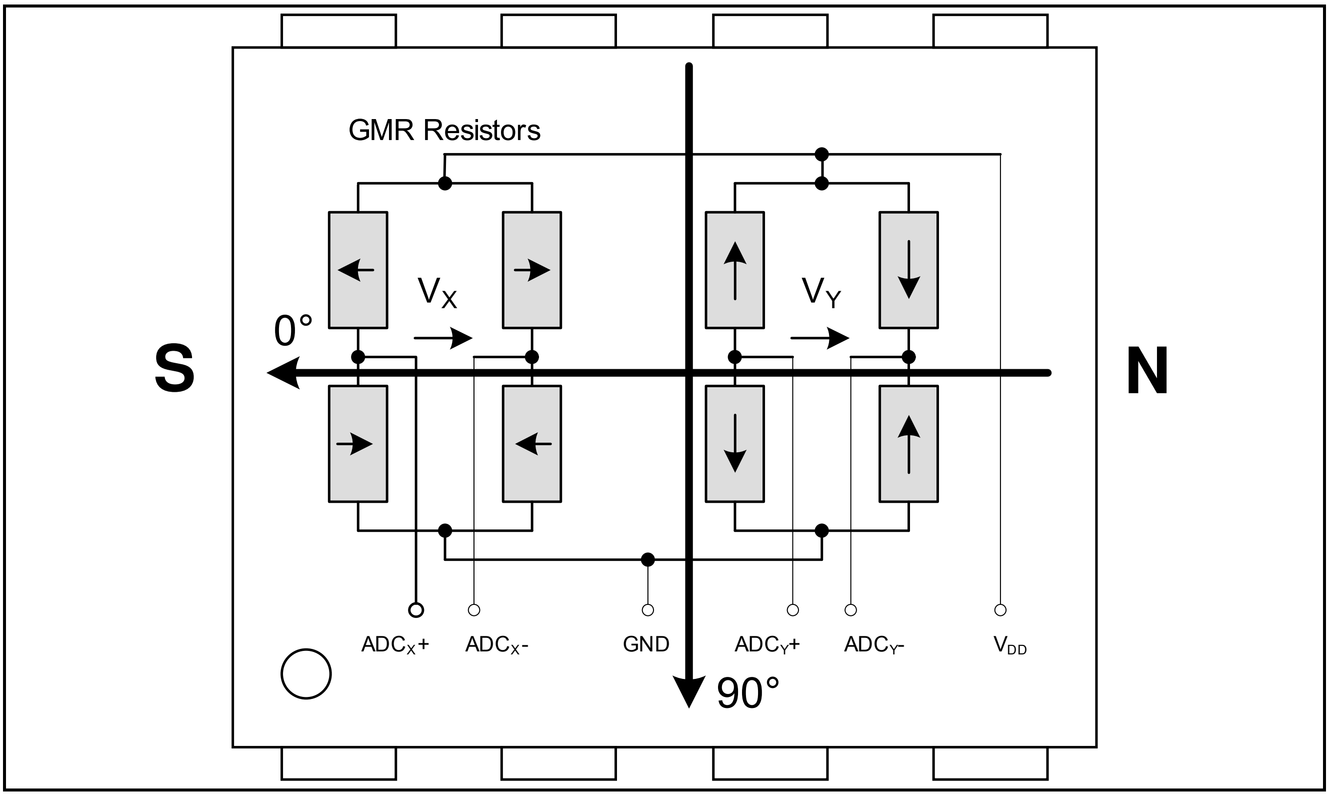


Figure 1 Sensitive bridges of the GMR sensor

*Note: In **Figure 1**, 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 ARCTAN, the true 360° angle value can be calculated, based on the relationship of X and Y signals.

Because only the relative values influence the result, the absolute magnitude of the two signals is of minor importance. Therefore, it is possible to compensate for most external influences on the amplitudes.

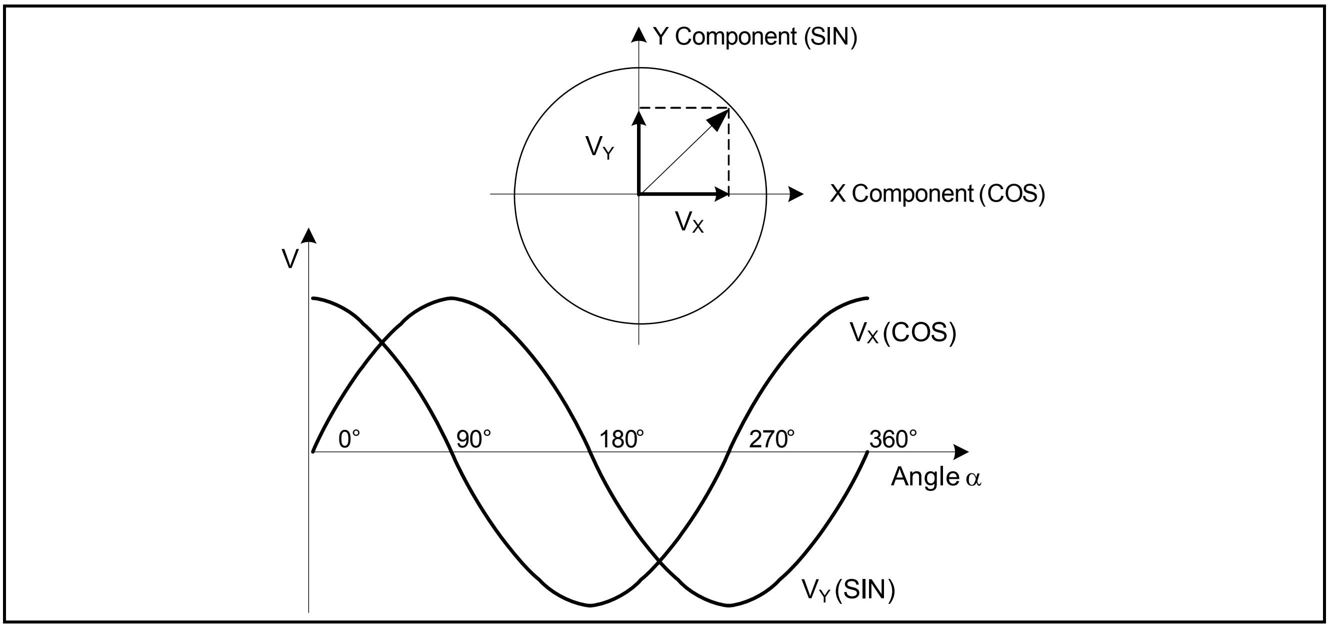


Figure 2 Theoretical output of the GMR sensor bridges

2.2 Pin Configuration

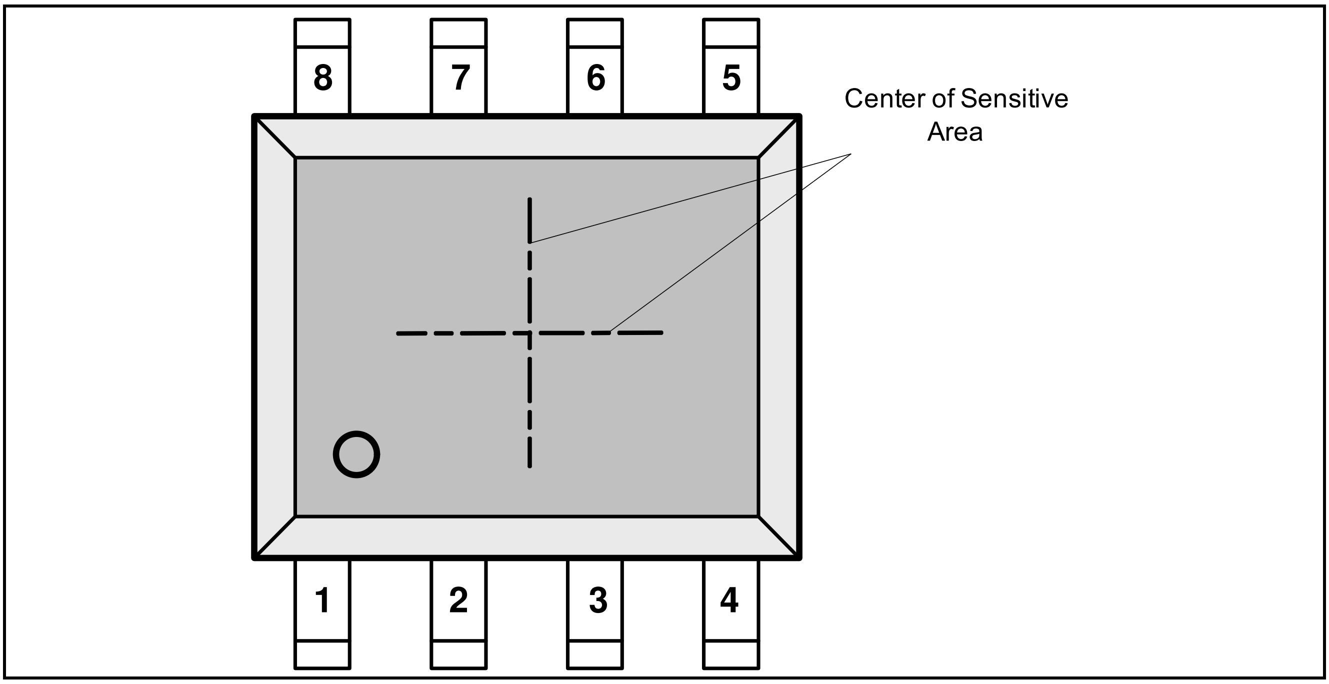


Figure 3 Pin configuration (top view)

2.3 Pin Description

Table 1 Pin description

Pin No.	Symbol	In/Out	Function
1	CLK	I	External Clock (selection of interface)[1]
2	SCK	I	SSC Clock
3	CSQ	I	SSC Chip Select
4	DATA (DATA / IIF_Index / HS3)	I/O	Interface DATA: SSC DATA; IIF Index; Hall Switch signal 3 [2]
5	IFA (IIF_A / HS1 / PWM)	O	Interface A: IIF phase A; Hall Switch signal 1; PWM [2]
6	V_{DD}	-	Supply voltage
7	GND	-	Ground
8	IFB (IIF_B / HS2)	O	Interface B: IIF phase B; Hall Switch signal 2 [2]

1) Connected to V_{DD} --> Incremental Interface is used; connected to GND--> Interface in IF_MD is used; sampling within Power-On Time; interface change within operation via SSC IF possible

2) Depends on external circuit of CLK and IF_MD setting

2.4 Block Diagram

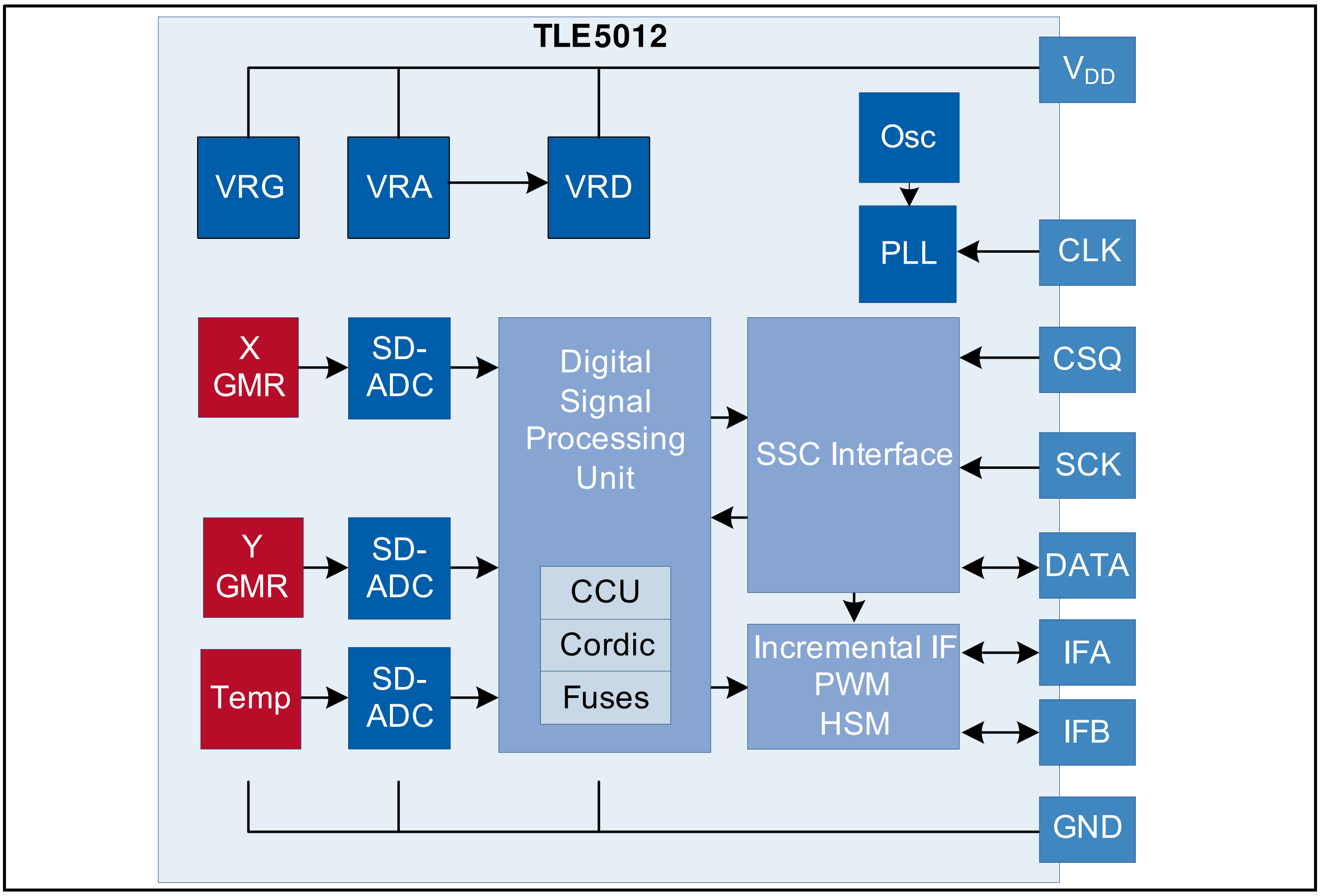


Figure 4 TLE5012 block diagram

2.5 Functional Block Description

2.5.1 Internal Power Supply

The internal stages of the TLE5012 have different voltage regulators.

- GMR Voltage Regulator VRG
- Analog Voltage Regulator VRA
- Digital Voltage Regulator VRD (derived from VRA)

These regulators are directly connected to the supply voltage V_{DD}.

2.5.2 Oscillator and PLL

The internal frequency oscillator feeds the Phase-Locked Loop (PLL). Therefore the external CLocK (CLK) can also be used.

2.5.3 SD-ADCs

The SD-ADCs transform the analog GMR voltages and temperature voltage into the digital domain.

2.5.4 Digital Signal Processing Unit

The Digital Signal Processing Unit (DSPU) contains the:

- **C**apture **C**ompare **U**nit (**CCU**), which is used to generate the PWM signal
- **CO**ordinate **R**otation **DI**gital **C**omputer (**CORDIC**), which contains the trigonometric function for angle calculation
- Fuses, which contain the calibration parameters

2.5.5 Interfaces

Different Interfaces can be selected:

- SSC Interface
- PWM
- Incremental Interface
- Hall Switch Mode

2.5.6 Safety Features

The TLE5012 offers a multiplicity of safety features to support Safety Integrity Level (SIL). Sensors with this performance are identified by the following logo:

Figure 5 PRO-SIL™ Logo

Safety features are:

- Test vectors switchable to ADC input
- Inversion or combination of filter input streams
- Data transmission check via 8-bit Cyclic Redundancy Check (CRC)
- Self-test routines
- Two independent active interfaces possible
- Overvoltage and undervoltage detection

Disclaimer

PRO-SIL™ is a Registered Trademark of Infineon Technologies AG.

The PRO-SIL™ Trademark designates Infineon products which contain SIL Supporting Features.

SIL Supporting Features are intended to support the overall System Design to reach the desired SIL (according to IEC61508) or A-SIL (according to ISO26262) level for the high efficiency Safety System.

SIL respectively A-SIL certification for such a system has to be reached on system level by the System Responsible at an accredited Certification Authority.

SIL stands for Safety Integrity Level (according to IEC 61508)

A-SIL stands for Automotive-Safety Integrity Level (according to ISO 26262)

3 Specifications

3.1 Application Circuit

The application circuits shown in **Figure 6**, **Figure 7**, **Figure 8** and **Figure 9** show the various communication possibilities of the TLE5012.

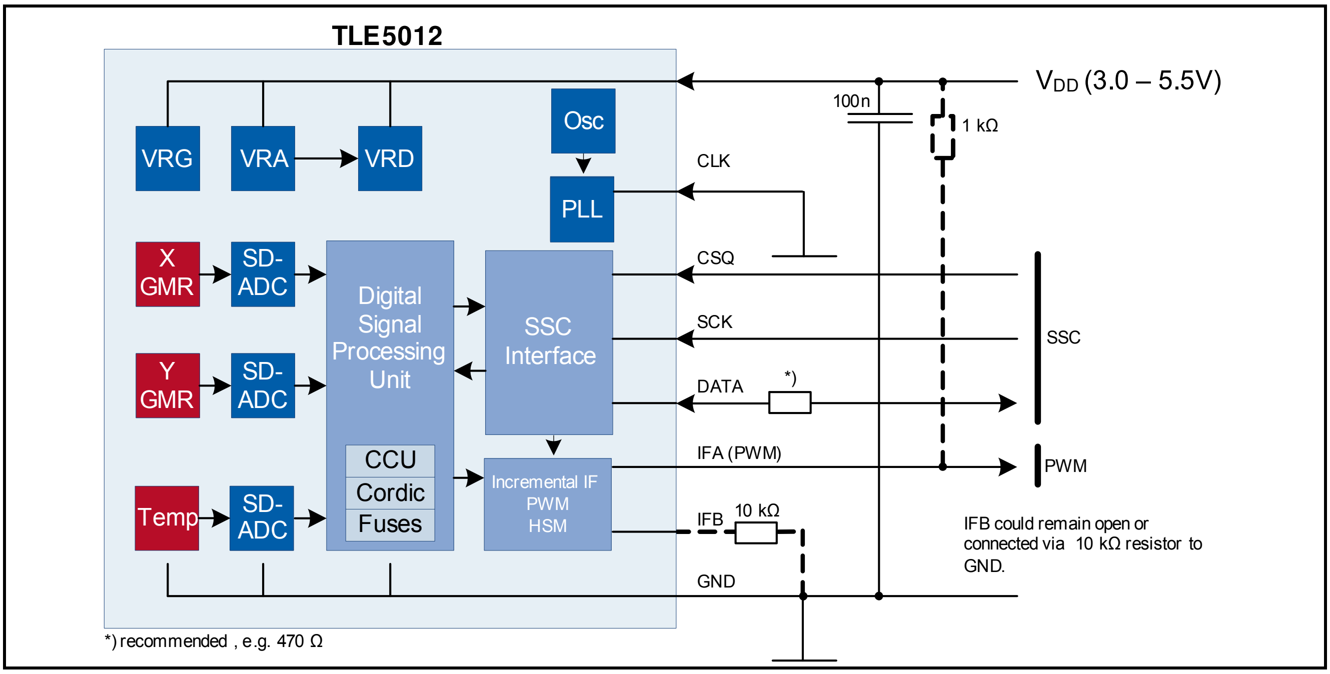
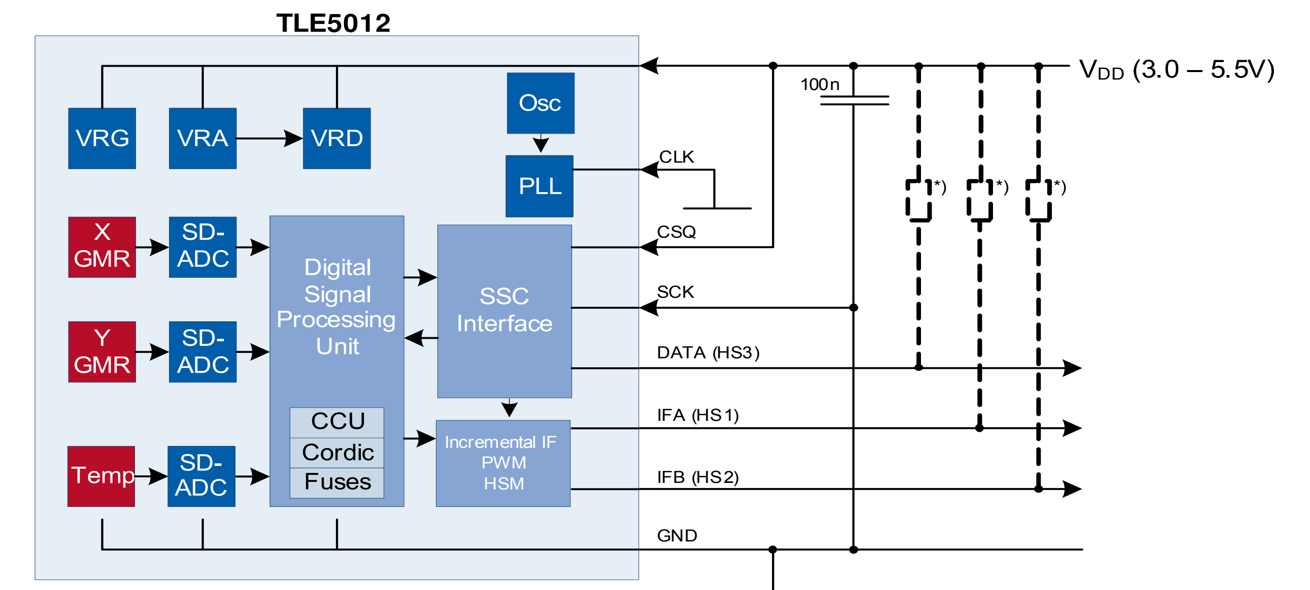


Figure 6 Application circuit for TLE5012 with SSC and PWM Interface (using internal CLK)

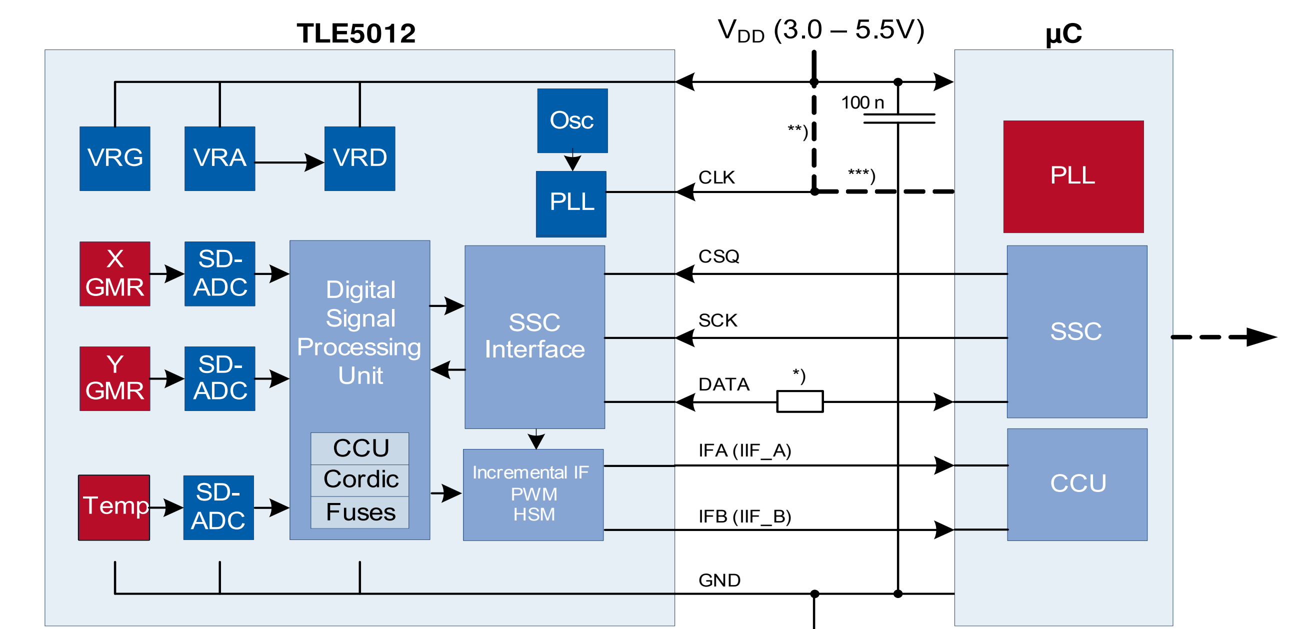
Figure 6 shows a basic block diagram of the TLE5012 with PWM Interface. This interface is selectable by connecting CLK to GND. In addition to the PWM, the SSC Interface could be used. Within the SSC Interface, the PWM Mode is selectable between push-pull and open drain.



*) recommended , e.g. 2.2 kΩ

Figure 7 Application circuit for TLE5012 with HS Mode (using internal CLK)

Figure 7 shows a basic block-diagram of the TLE5012 in the Hall Switch Mode. This interface is selectable by connecting CLK to GND and CSQ to V_{DD}. In addition to the HSM, the SSC Interface can be used by pulling CSQ to GND. Within the SSC Interface, the HSM is selectable between push-pull and open drain.



*) recommended , e.g. 470 Ω
**) connected to V_{DD} for use of internal CLK
***) connected to microcontroller for use of external CLK

Figure 8 Application circuit for TLE5012 with SSC Interface and IIF (using external CLK)

Figure 8 shows a basic block diagram of an angle sensor system using a TLE5012 and a microcontroller for rotor-positioning applications. The interface configuration depicted is needed for high-speed applications such as electrical commutated motor drives. It is possible to connect the TLE5012 to a microcontroller via the Incremental Interface, and for safety reasons also via the SSC Interface.

The TLE5012 Exxxx can be configured with PWM only (**Figure 9**). This is not possible with the Standard TLE5012 type.[1)]

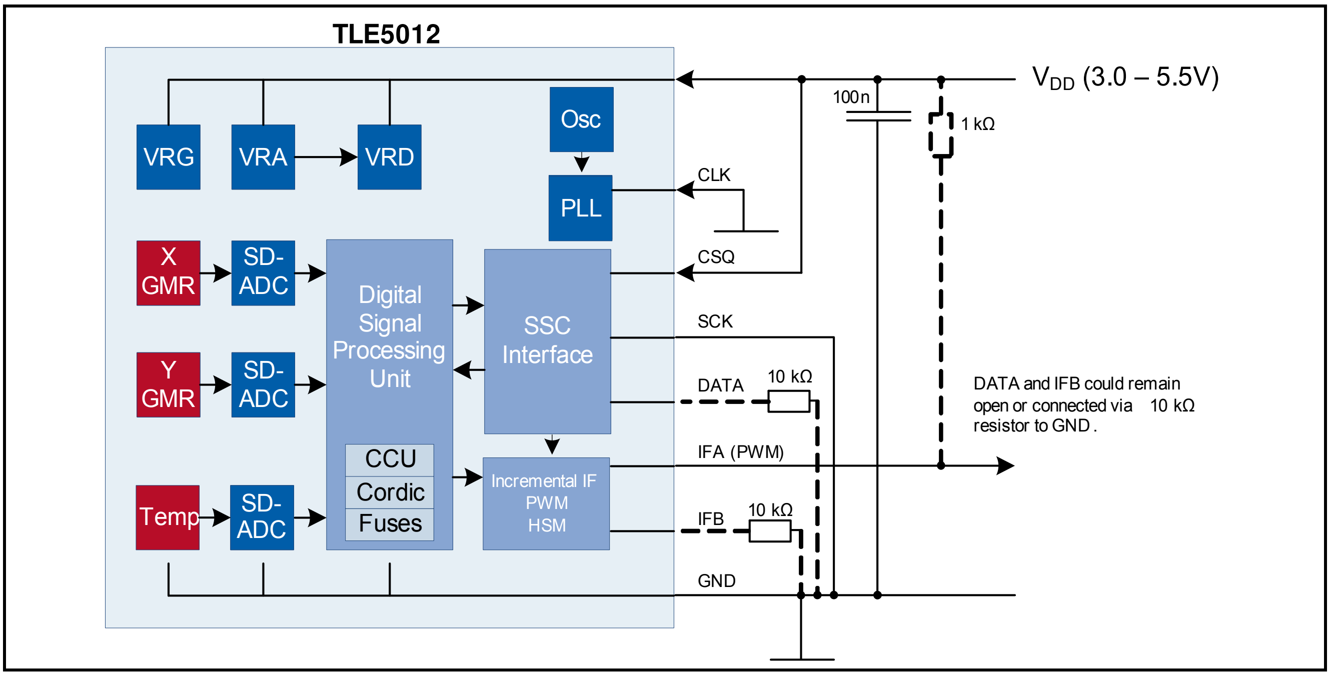


Figure 9 Application circuit for TLE5012 with only PWM Interface (using internal CLK)

1) For more information, please contact Infineon

3.2 Absolute Maximum Ratings

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Voltage on V_{DD} pin with respect to ground (V_{SS})	V_{DD}	-0.5	-	6.5	V	Max. 40 h/lifetime
Voltage on any pin with respect to ground (V_{SS})	V_{IN}	-0.5	-	6.5	V	Additionally V_{DD} + 0.5 V may not be exceeded
Junction temperature	T_J	-40	-	150	°C	
		-	-	150	°C	For 1000 h not additive
Magnetic field induction	B	-	-	|125|	mT	Max. 5 min @ T_A = 25°C
		-	-	|100|	mT	Max. 5 h @ T_A = 25°C
Storage temperature	T_{ST}	-40	-	150	°C	Without magnetic field

Attention: 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.

3.3 Operating Range

The following operating conditions must not be exceeded in order to ensure correct operation of the TLE5012. All parameters specified in the following sections refer to these operating conditions, unless otherwise noted. **Table 3** is valid for -40°C < T_J < 150°C unless otherwise noted.

Table 3 Operating range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	3.0	5.0	5.5	V	1)
Output current (DATA-Pad)	I_Q	-	-	-25	mA	PAD_DRV ='0x', sink current2)3)
		-	-	-5	mA	PAD_DRV ='10', sink current2)3)
		-	-	-0.4	mA	PAD_DRV ='11', sink current2)3)
Output current (IFA / IFB-Pad)	I_Q	-	-	-15	mA	PAD_DRV ='0x', sink current2)3)
		-	-	-5	mA	PAD_DRV ='1x', sink current2)3)
Input voltage	V_{IN}	-0.3	-	5.5	V	V_{DD} + 0.3 V may not be exceeded

Table 3 Operating range (cont'd)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Magnetic induction at T_A = 25°C 4)5)	B_{XY}	30	-	50	mT	-40°C < T_J < 150°C
	B_{XY}	30	-	60	mT	-40°C < T_J < 100°C
	B_{XY}	30	-	70	mT	-40°C < T_J < 85°C
Expanded magnetic induction at T_A = 25°C 4)5)	B_{XY}	25	-	30	mT	Additional angle error of 0.1° 6)
Angle range	Ang	0	-	360	°	

1) Directly blocked with 100-nF ceramic capacitor
2) Max. current to GND over open-drain output
3) At V_{DD} = 5V
4) Values refer to an homogenous magnetic field (B_{XY}) without vertical magnetic induction (B_Z = 0mT)
5) See **Figure 10**
6) 0 h

The field strength of a magnet can be selected within the colored area in **Figure 10**. By limitation of the junction temperature, a higher magnetic field can be applied. In case of a maximum temperature T_J=100°C a magnet with up to 60mT at T_A=25°C is allowed.

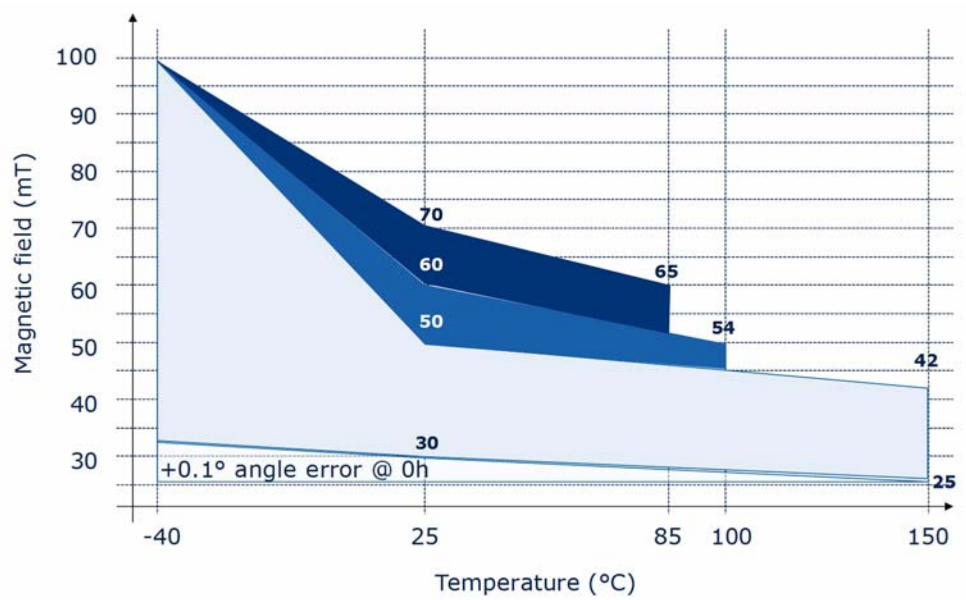


Figure 10 Magnet performance (ambient temperature)

*Note: The thermal resistances listed in **Table 29 "Package parameters" on Page 61** must be used to calculate the corresponding ambient temperature.*

Calculation of the Junction Temperature

The total power dissipation P_{TOT} of the chip increases its temperature above the ambient temperature.

The power multiplied by the total thermal resistance R_{thJA} (Junction to Ambient) leads to the final junction temperature. R_{thJA} is the sum of the addition of the values of the two components Junction to Case and Case to Ambient.

$$R_{thJA} = R_{thJC} + R_{thCA}$$
$$T_J = T_A + \Delta T$$
$$\Delta T = R_{thJA} \times P_{TOT} = R_{thJA} \times (V_{DD} \times I_{DD} + V_{OUT} \times I_{OUT}) \quad (I_{DD}, I_{OUT} > 0\text{, if direction is into IC}) \tag{1}$$

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

$$V_{DD} = 5V$$
$$I_{DD} = 14mA$$
$$\Delta T = 150\left[\frac{K}{W}\right] \times (5[V] \times 0.014[A] + 0[VA]) = 10.5K \tag{2}$$

For molded sensors, the calculation with R_{thJC} is more appropriate.

3.4 Characteristics

3.4.1 Electrical Parameters

The indicated electrical parameters apply to the full operating range, unless otherwise specified. The typical values correspond to a supply voltage V_{DD} = 5.0 V and 25 °C, unless individually specified. All other values correspond to -40 °C < T_J < 150°C.

Table 4 Electrical parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply current	I_{DD}	-	14	16	mA	
POR level	V_{POR}	2.0	-	2.9	V	Power-On Reset
POR hysteresis[1]	V_{PORhy}	-	30	-	mV	
Pull-Up current	I_{PU}	-10	-	-225	µA	CSQ
		-10	-	-150	µA	DATA
Pull-Down current	I_{PD}	10	-	225	µA	SCK
		10	-	150	µA	CLK, IFA, IFB
Power-on time	t_{Pon}	-	5	7	ms	$V_{DD} > V_{DDmin}$[2]

1) Not subject to production test - verified by design/characterization
2) Within “Power-On Time,” write access is not permitted

Table 5 Electrical parameters for 4.5V < V_{DD} < 5.5V

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input signal low level	V_{L5}	-	-	0.3 V_{DD}	V	
Input signal high level	V_{H5}	0.7 V_{DD}	-	-	V	
Output signal low level	V_{OL5}	-	-	1	V	DATA; I_Q = - 25 mA (PAD_DRV='0x'), I_Q = - 5 mA (PAD_DRV='10'), I_Q = - 0.4 mA (PAD_DRV='11')
		-	-	1	V	IFA,IFB; I_Q = - 15 mA (PAD_DRV='0x'), I_Q = - 5 mA (PAD_DRV='1x')

Table 6 Electrical parameters for 3.0V < V_{DD} < 3.6V

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input signal low level	V_{L3}	-	-	0.2 V_{DD}	V	
Input signal high level	V_{H3}	0.8 V_{DD}	-	-	V	
Output signal low level	V_{OL3}	-	-	0.9	V	DATA; I_Q = - 15 mA (PAD_DRV='0x'), I_Q = - 3 mA (PAD_DRV='10'), I_Q = - 0.24 mA (PAD_DRV='11')
		-	-	0.9	V	IFA,IFB; I_Q = - 10 mA (PAD_DRV='0x'), I_Q = - 3 mA (PAD_DRV='1x')

3.4.2 ESD Protection

Table 7 ESD protection

Parameter	Symbol	Values		Unit	Notes
		min.	max.		
ESD voltage	V_{HBM}	-	±4.0	kV	Human Body Model[1)]
	V_{SDM}	-	±0.5	kV	Socketed Device Model[2)]

1) Human Body Model (HBM) according to AEC-Q100-002
2) Socketed Device Model (SDM) according to ESDA/ANSI/ESD SP5.3.2-2008

3.4.3 GMR Parameters

All parameters apply over B_{XY} = 30mT and T_A = 25°C, unless otherwise specified.

Table 8 Basic GMR parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
X, Y output range	RG_{ADC}	-	-	±23230	digits	4)
X, Y amplitude 1)	A_X, A_Y	6000	9500	15781	digits	
		3922	-	20620	digits	operating range
X, Y synchronism 2)	k	87.5	100	112.49	%	
X, Y offset 3)	O_X, O_Y	-2048	0	+2047	digits	
X, Y orthogonality error	Φ	-11.25	0	+11.24	°	
X, Y without field	X_0, Y_0	-5000	-	+5000	digits	without magnet 4)

1) See **Figure 11**
2) $k = 100^*(A_X/A_Y)$
3) $O_Y=(Y_{MAX} + Y_{MIN}) / 2$; $O_X = (X_{MAX} + X_{MIN}) / 2$
4) Not subject to production test - verified by design/characterization

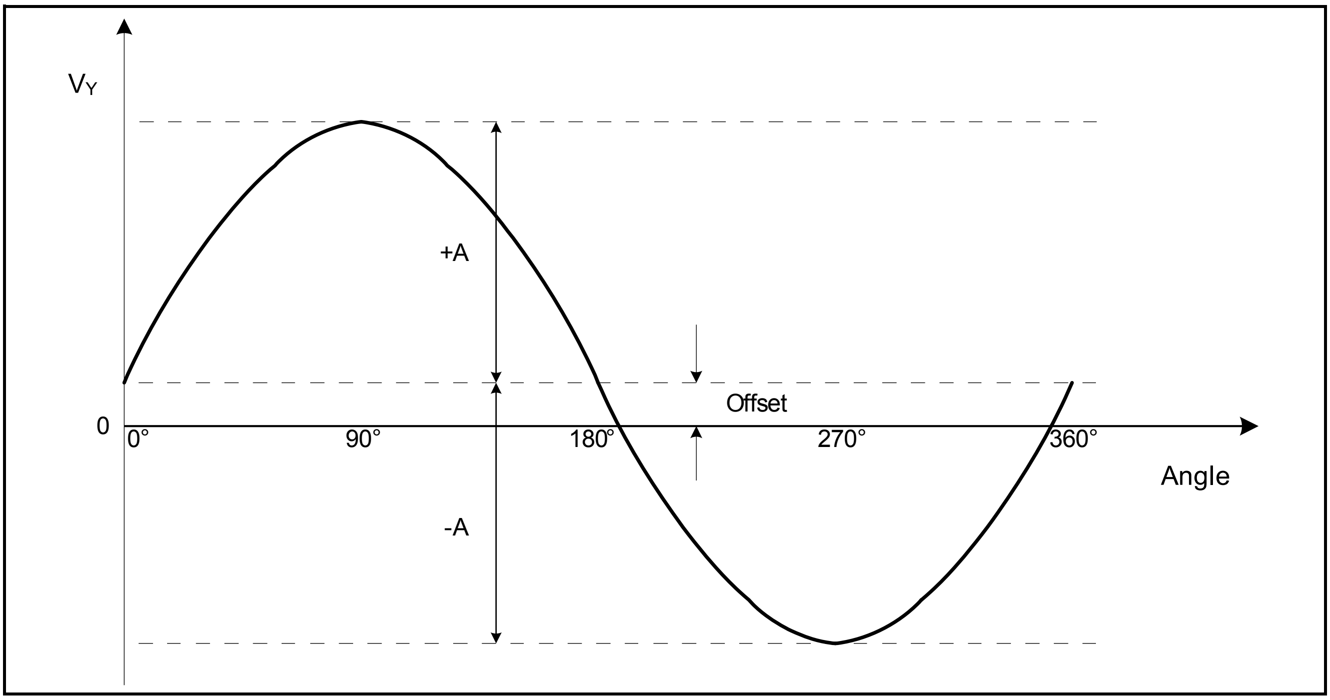


Figure 11 Offset and amplitude definition

3.4.4 Angle Performance

After internal calculation the sensor has a remaining error, as shown in **Table 11**. The error value refers to B_Z = 0mT and the operating conditions given in **Table 3 "Operating range" on Page 18**.

The overall angle error represents the relative angle error. This error describes the deviation from the reference line after zero angle definition.

Table 9 Angle performance

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Overall Angle Error (with auto-calibration)	α_{Err}	-	0.6[1)]	1.0	°	including lifetime and temperature drift[2)3)4)]
Overall Angle Error (without auto-calibration)	α_{Err}	-	0.6[1)]	1.6	°	including temperature drift[2)3)5)]

1) At 25°C, B = 30 mT
2) Including hysteresis error, caused by revolution direction change.
3) Only with calibrated GMR-compensation parameters of customer setup; Relative error after zero angle definition.
4) Not subject to production test - verified by design/characterization
5) 0 h

Autocalibration

The autocalibration enables online parameter calculation and therefore reduces the angle error due to temperature drift, lifetime drift, and misalignments.

The TLE5012 is a pre-calibrated sensor. After start-up, the parameters out of the laser fuses get loaded into flip-flops. The TLE5012 needs more than a full revolution to generate new parameters. The update mode can be chosen within the Interface Mode 2 register (AUTOCAL). The parameters are updated in a smooth way to avoid an angle jump on the output. Therefore only one LSB will be changed within the choosen range or time. The autocalibration is done continuously.

AUTOCAL Modes:

- 00: No autocalibration
- 01: Autocalibration Mode 1. Only one LSB to final values within the update time t_{upd} (depending on FIR_MD setting).
- 10: Autocalibration Mode 2. Only one LSB update over one full revolution. After update of one LSB, the autocalibration will calculate the parameters again.
- 11: Autocalibration Mode 3. Only one LSB to final values within an angle range of 11.25°.

3.4.5 Signal Processing

The signal path of the TLE5012 is depicted in **Figure 12**. It consists of the GMR bridge, ADC, filter, and angle calculation. Depending on the filter configuration, various total delay times are achieved. In addition to this delay time, the delay time of the interface has to be considered. The delay time leads to an additional angle error at higher speeds. By enabling the prediction, the signal delay time can be reduced (**Figure 13**). The prediction uses the difference between current and last angle value and calculates the output value by adding this difference to the current value. A linear prediction is thereby achieved.

$$\alpha(t+1) = 2 \cdot \alpha(t) - \alpha(t-1) \tag{3}$$

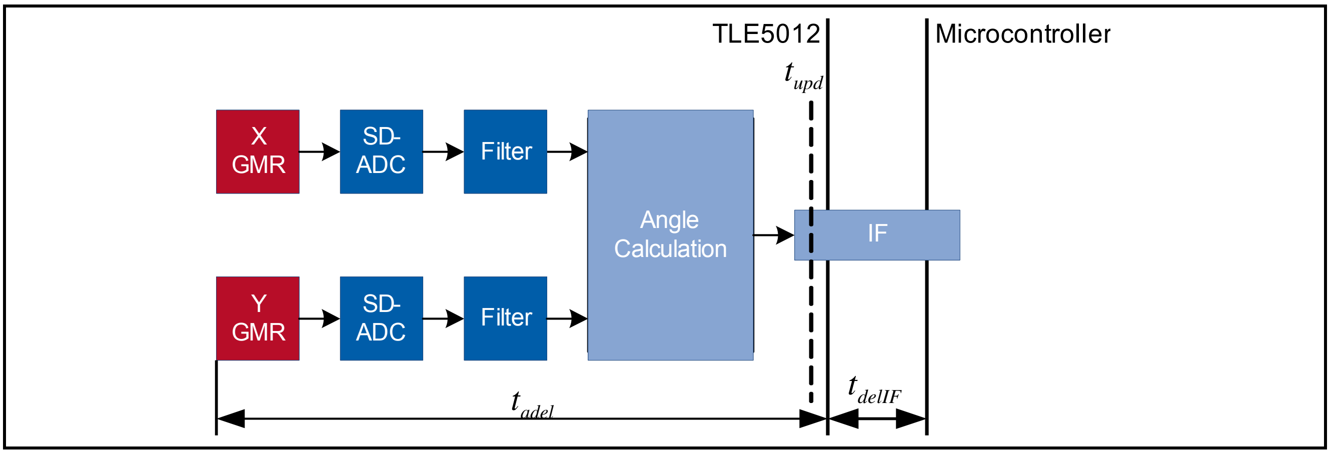


Figure 12 TLE5012 signal path

At FIR_MD = 0 only raw values can be read out, due to the more time consuming angle calculation.

Table 10 Signal processing

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Update rate at interface	t_{upd}	-	21.3	-	µs	FIR_MD = 0 (only raw values)[1,2]
		-	42.7	-	µs	FIR_MD = 1[1,2]
		-	85.3	-	µs	FIR_MD = 2 (default)[1,2]
		-	170.6	-	µs	FIR_MD = 3[1,2]
Angle delay time[3]	t_{adel}	-	60	70	µs	FIR_MD = 1[1,2]
		-	80	95	µs	FIR_MD = 2[1,2]
		-	120	140	µs	FIR_MD = 3[1,2]
Angle delay time with prediction[3]	t_{adel}	-	20	30	µs	FIR_MD = 1; PREDICT = 1 [1,2]
		-	5	20	µs	FIR_MD = 2; PREDICT = 1 [1,2]
		-	-40	-20	µs	FIR_MD = 3; PREDICT = 1 [1,2]
Angle noise	N_{Angle}	-	0.11	-	°	FIR_MD = 0, (1 sigma)[2]
		-	0.08	-	°	FIR_MD = 1, (1 sigma)[2]
		-	0.05	-	°	FIR_MD = 2, (1 sigma)[2] (default)
		-	0.04	-	°	FIR_MD = 3, (1 sigma)[2]

1) Depends on internal oscillator frequency variation (**Section 3.4.6**)
2) Not subject to production test - verified by design/characterization
3) Valid at constant rotation speed

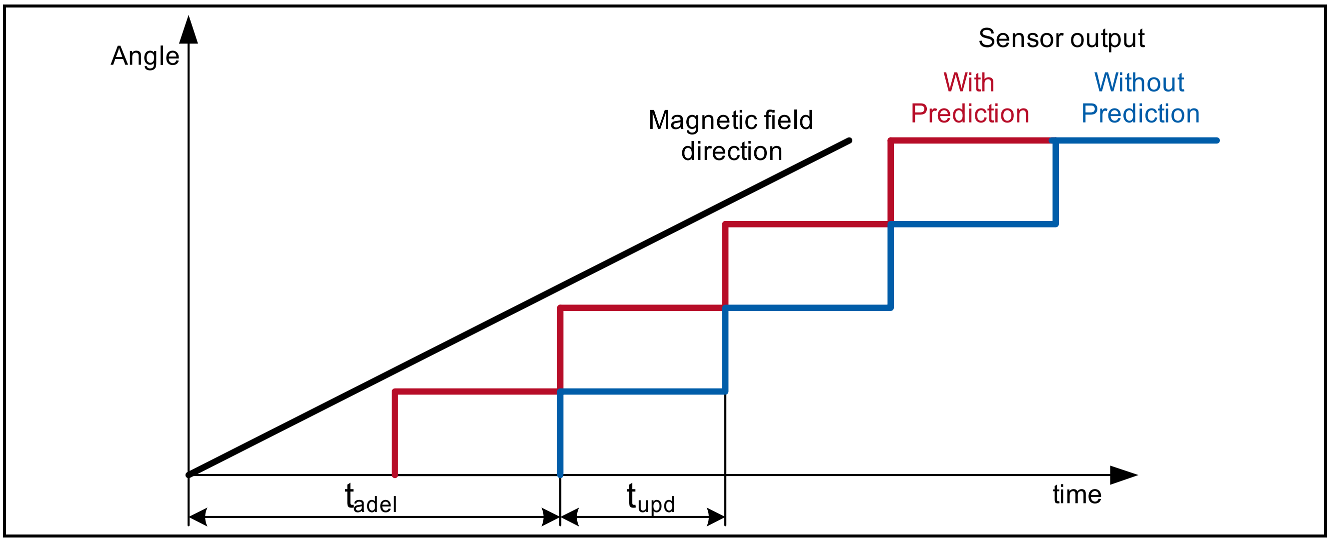


Figure 13 Delay of sensor output