Angle Sensor
GMR-Based Dual Die Angle Sensor

TLE5012BD

Data Sheet
Rev. 1.2, 2017-01-13
Revision History

Page or Item | Subjects
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**Rev. 1.2, 2017-01-13**
6 | Changed in Rev. 1.1: Table 1-1: package version number removed
10 | Changed in Rev. 1.1: Table 4-2 ESD protection modified
13 | Changed in Rev. 1.1: Figure 6-2 updated with improved chip placement tolerance
15 | Changed in Rev. 1.1: Table 6-2 updated with improved chip placement tolerance
17 | Changed in Rev. 1.1: Figure 6-6 added with marking on frontside and backside
6 | Changed in Rev. 1.2: Table 1-1 marking corrected
15 | Changed in Rev. 1.2: Figure 6-3 added
15 | Changed in Rev. 1.2: Table 6-2 modified
16 | Changed in Rev. 1.2: Chapter 6.5: marking table corrected

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Preface

This document is an addendum to the TLE5012B datasheet and describes the TLE5012BD dual die angle sensor. For all parameters which are not specified here, the TLE5012B datasheet is valid.

1 Product Description

Figure 1-1  PG-TDSO-16 package

1.1 Overview

The TLE5012BD is a fully redundant 360° angle sensor that detects the orientation of a magnetic field. This is achieved by measuring sine and cosine angle components with monolithic integrated Giant Magneto Resistance (iGMR) elements.

Highly precise angle values are determined over a wide temperature range and a long lifetime using an internal autocalibration algorithm.

Data communications are accomplished with a bi-directional Synchronous Serial Communication (SSC) that is 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 TLE5012BD is a pre-calibrated 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.

Online diagnostic functions are provided to ensure reliable operation.

Table 1-1 Derivate Ordering codes (see Chapter 5 for description of derivates)

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Marking</th>
<th>Ordering Code</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLE5012BD E1200</td>
<td>121200</td>
<td>SP001205296</td>
<td>PG-TDSO-16</td>
</tr>
<tr>
<td>TLE5012BD E9200</td>
<td>129200</td>
<td>SP001205300</td>
<td>PG-TDSO-16</td>
</tr>
</tbody>
</table>
1.2 Features

- Giant Magneto Resistance (GMR)-based principle
- Fully redundant design with two sensor ICs in one package
- Integrated magnetic field sensing for angle measurement
- 360° angle measurement with revolution counter and angle speed measurement
- Two separate highly accurate single bit SD-ADC
- 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-range with activated auto-calibration
- Bi-directional SSC Interface up to 8Mbit/s
- Supports Safety Integrity Level (SIL) with diagnostic functions and status information
- Interfaces: SSC, PWM, Incremental Interface (IIF), Hall Switch Mode (HSM), Short PWM Code (SPC, based on SENT protocol defined in SAE J2716)
- Output pins can be configured (programmed or pre-configured) as push-pull or open-drain
- Bus mode operation of multiple sensors on one line is possible with SSC or SPC interface in open-drain configuration
- 0.25 μm CMOS technology
- AEC-Q100 automotive qualified
- ESD > 4kV (HBM)
- Green package with lead-free (Pb-free) plating, halogen free

1.3 Application Example

The TLE5012BD GMR-based dual die angle sensor is designed for angular position sensing in automotive applications such as:

- Electrical commutated motor (e.g. used in Electric Power Steering (EPS) and actuators)
- Steering angle measurements
- General angular sensing
2 Pin Configuration

Figure 2-1 Pin configuration (top view)

2.1 Pin Description

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>In/Out</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IFC1</td>
<td>I/O</td>
<td>Die 1 Interface C: External Clock[1] / IIF Index / Hall Switch Signal 3</td>
</tr>
<tr>
<td></td>
<td>(CLK / IIF_IDX / HS3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SCK1</td>
<td>I</td>
<td>Die 1 SSC Clock</td>
</tr>
<tr>
<td>3</td>
<td>CSQ1</td>
<td>I</td>
<td>Die 1 SSC Chip Select</td>
</tr>
<tr>
<td>4</td>
<td>DATA1</td>
<td>I/O</td>
<td>Die 1 SSC Data</td>
</tr>
<tr>
<td>5</td>
<td>DATA2</td>
<td>I/O</td>
<td>Die 2 SSC Data</td>
</tr>
<tr>
<td>6</td>
<td>CSQ2</td>
<td>I</td>
<td>Die 2 SSC Chip Select</td>
</tr>
<tr>
<td>7</td>
<td>SCK2</td>
<td>I</td>
<td>Die 2 SSC Clock</td>
</tr>
<tr>
<td>8</td>
<td>IFC2</td>
<td>I/O</td>
<td>Die 2 Interface C: External Clock[1] / IIF Index / Hall Switch Signal 3</td>
</tr>
<tr>
<td></td>
<td>(CLK / IIF_IDX / HS3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>IFB2</td>
<td>O</td>
<td>Die 2 Interface B: IIF Phase B / Hall Switch Signal 2</td>
</tr>
<tr>
<td></td>
<td>(IIF_B / HS2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>GND2</td>
<td>-</td>
<td>Die 2 Ground</td>
</tr>
<tr>
<td>11</td>
<td>VDD2</td>
<td>-</td>
<td>Die 2 Supply Voltage</td>
</tr>
</tbody>
</table>
3 Dual Die Angle Output

The bottom sensor element of the TLE5012BD is flipped relative to the orientation of the top sensor element. Therefore the rotation direction sensed by the bottom element is opposite to the top element. This is advantageous for safety critical applications, as the two sensor elements do generally not output the same angle. Figure 3-1 shows the output of the two sensor ICs for a given external magnetic field orientation.

![Figure 3-1 Dual die angle output](image)

For applications where an identical angle output of both ICs is desired, the rotation direction and angle offset of one sensor IC can be reconfigured by changing the settings in the ANG_BASE and ANG_DIR registers via SSC interface.

Table 2-1 Pin Description (cont’d)

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>In/Out</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>IFA2</td>
<td>O</td>
<td>Die 2 Interface A: IIF Phase A / Hall Switch Signal 1 / PWM / SPC output</td>
</tr>
<tr>
<td></td>
<td>(IIF_A / HS1 / PWM / SPC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>IFA1</td>
<td>O</td>
<td>Die 1 Interface A: IIF Phase A / Hall Switch Signal 1 / PWM / SPC output</td>
</tr>
<tr>
<td></td>
<td>(IIF_A / HS1 / PWM / SPC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>VDD1</td>
<td>-</td>
<td>Die 1 Supply Voltage</td>
</tr>
<tr>
<td>15</td>
<td>GND1</td>
<td>-</td>
<td>Die 1 Ground</td>
</tr>
<tr>
<td>16</td>
<td>IFB1</td>
<td>O</td>
<td>Die 1 Interface B: IIF Phase B / Hall Switch Signal 2</td>
</tr>
<tr>
<td></td>
<td>(IIF_B / HS2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) External clock feature is not available in IIF or HSM interface mode
4 Specification

4.1 Absolute Maximum Ratings

Table 4-1  Absolute maximum ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>$T_A$</td>
<td>-40</td>
<td></td>
<td>125 °C qualification acc. to AEC Q100 grade 1</td>
</tr>
<tr>
<td>Junction temperature</td>
<td>$T_J$</td>
<td>-40</td>
<td></td>
<td>150 °C</td>
</tr>
</tbody>
</table>

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.

Table 4-2  ESD protection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Max.</td>
<td></td>
</tr>
<tr>
<td>ESD voltage</td>
<td>$V_{HBM}$</td>
<td>±4.0 kV</td>
<td></td>
<td>1) ground pins connected</td>
</tr>
<tr>
<td></td>
<td>$V_{HBM}$</td>
<td>±2.0 kV</td>
<td></td>
<td>1) Human Body Model (HBM) according to ANSI/ESDA/JEDEC JS-001</td>
</tr>
<tr>
<td></td>
<td>$V_{CDM}$</td>
<td>±0.5 kV</td>
<td></td>
<td>2) Charged Device Model (CDM) according to JESD22-C101</td>
</tr>
<tr>
<td></td>
<td>$V_{CDM}$</td>
<td>±0.75 kV</td>
<td></td>
<td>2) for corner pins</td>
</tr>
</tbody>
</table>

1) Human Body Model (HBM) according to ANSI/ESDA/JEDEC JS-001
2) Charged Device Model (CDM) according to JESD22-C101

4.2 Calculation of the Junction Temperature

The total power dissipation $P_{TOT}$ of the chips leads to self-heating, which increases the junction temperature $T_J$ above the ambient temperature.

The power multiplied by the total thermal resistance $R_{thJA}$ (junction to ambient) yields the junction temperature. $R_{thJA}$ is the sum of the two components Junction to Case and Case to Ambient.

$$ R_{thJA} = R_{thJC} + R_{thCA} $$  \hspace{1cm} (4.1)

$$ T_J = T_A + \Delta T $$

$$ \Delta T = R_{thJA} \times P_{TOT} = R_{thJA} \times (V_{DD} \times 2I_{DD} + \sum V_Q \times 2I_Q) \quad (I_{DD}, I_Q > 0, \text{ if direction is into IC}) $$
Factors of 2 in the calculation account for the two sensor ICs in the TLE5012BD. Example (assuming no load on \( V_{\text{out}} \)).

\[
\begin{align*}
V_{DD} &= 5V \\
2I_{DD} &= 28 mA \\
\Delta T &= 120 \left[ \frac{K}{W} \right] \times (5[V] \times 0.028 [A] + 0[V/A]) = 16.8 K
\end{align*}
\]

For molded sensors, the calculation with \( R_{\text{thJC}} \) is more appropriate.
5  Pre-Configured Derivates

Derivates of the TLE5012BD are available with different pre-configured register settings for specific applications. The configuration of all derivates can be changed via SSC interface. A detailed table of settings of the derivates can be found in the latest TLE5012B Register Setting User Manual.

5.1  IIF-type: E1200

The TLE5012BD-E1200 is preconfigured for Incremental Interface and fast angle update rate (42.7 μs). It is most suitable for BLDC motor commutation.

• Autocalibration mode 1 enabled.
• Prediction disabled.
• Hysteresis is set to 0.625°.
• 12bit mode, one count per 0.088° angle step.
• Incremental Interface A/B mode.

5.2  SPC-type: E9200

The TLE5012BD-E9200 is preconfigured for Short-PWM-Code interface. It is most suitable for steering angle and actuator position sensing.

• Angle update time is 85.4 μs.
• Autocalibration, Prediction, and Hysteresis are disabled.
• SPC unit time is 3 μs.
• SPC interface is set to open-drain output.
6 Package Information

6.1 Package Parameters

Table 6-1 Package Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal resistance</td>
<td>R_{th,JA}</td>
<td>120</td>
<td>140</td>
<td>K/W</td>
</tr>
<tr>
<td></td>
<td>R_{th,JC}</td>
<td>35</td>
<td></td>
<td>K/W</td>
</tr>
<tr>
<td></td>
<td>R_{th, JL}</td>
<td>70</td>
<td></td>
<td>K/W</td>
</tr>
<tr>
<td>Moisture Sensitivity Level</td>
<td>MSL 3</td>
<td></td>
<td>260°C</td>
<td></td>
</tr>
<tr>
<td>Lead Frame</td>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plating</td>
<td>Sn 100%</td>
<td></td>
<td>&gt; 7 μm</td>
<td></td>
</tr>
</tbody>
</table>

1) \(R_{th}\) values only valid for both dies supplied with \(V_{DD}\)
2) according to Jedec JESD51-7

6.2 Package Outline

Figure 6-1 PG-TDSO-16 package dimension
Figure 6-2  Position of sensing element, reference to package
Table 6-2  Sensor IC placement tolerances in package

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>position eccentricity</td>
<td>-100</td>
<td>100 µm</td>
<td>in X- and Y-direction, reference to package</td>
</tr>
<tr>
<td>position eccentricity</td>
<td>-150</td>
<td>150 µm</td>
<td>in X-direction, reference to lead frame</td>
</tr>
<tr>
<td>position eccentricity</td>
<td>-200</td>
<td>200 µm</td>
<td>in Y-direction, reference to lead frame</td>
</tr>
<tr>
<td>rotation</td>
<td>-3</td>
<td>3 °</td>
<td>affects zero position offset of sensor</td>
</tr>
<tr>
<td>tilt</td>
<td>-3</td>
<td>3 °</td>
<td></td>
</tr>
</tbody>
</table>
6.3 Footprint

![Footprint of PG-TDSO-16](image)

Figure 6-4 Footprint of PG-TDSO-16

6.4 Packing

![Tape and Reel](image)

Figure 6-5 Tape and Reel

6.5 Marking

The device is marked on the frontside with a date code, the device type and a lot code. On the backside is a 8 x 18 data matrix code.

<table>
<thead>
<tr>
<th>Position</th>
<th>Marking</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Line</td>
<td>Gxxxx</td>
<td>G = green, 4-digit = date code</td>
</tr>
<tr>
<td>2nd Line</td>
<td>12x200</td>
<td>Type (6 digits), See ordering Table 1-1</td>
</tr>
<tr>
<td>3rd Line</td>
<td>xxx</td>
<td>Lot code (3 digits)</td>
</tr>
</tbody>
</table>

*Note: For processing recommendations, please refer to Infineon’s Notes on processing*
Figure 6-6  Marking