Digital Rutronik Forum 2020
Infineon Predictive Maintenance Demo

Tobias Bukowski (Global Marketing Manager Sensors)
23rd of June 2020
Predictive maintenance - background

**Requirements**
- Efficiency
- Monitor live status
- Remote control/maintenance
- Trusted device and secure information flow

**Target**
- Avoid unpredicted downtime
- Prevent from spontaneous events
- Analyze and compare data
- Saving resources
- Build-up knowledge
- Probability of occurrence

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Predictive maintenance Demo - Overview

Sense & control, actuate & secure – all-round Industry 4.0 solution

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Top View – Functions & interaction points
Brake and linear table
Top View – Components
Sense, control & actuate
Interaction Point 1: Cloud Dashboard
Look and feel

Current

Angle Error

Speed

Sound
Interaction Point 1: Starting the BLDC motor
Control & Actuate – Let’s start the motor
Infineon’s XMC family and ePower solutions

› XMC4800 running Amazon Free RTOS
  › powered by 32-bit ARM® Cortex®-M4
  › Connected via Ethernet to Internet
  › Secured Cloud Communication with Security Controller Optiga Trust X

› XMC1100 Main Controller
  › Powered by 32-bit ARM® Cortex®-M0
  › CPU at 32MHz
  › Programmed via Arduino IDE
  › Collecting sensor data & controlling motor Logic

› 3-Phase BLDC Motor Driver Shield
  › Equipped with TLE9879QXA40 single chip 3-phase motor driver
  › Arduino compatible & handles motor commutation
  › Several motor control algorithms (sensorless FOC, Back EMF, hall sensor based block commutation)
Interaction Point 1: Starting the motor
Short glimpse at the dashboard

- Current and speed increase
- Angle values and sound frequency change
XENSIV™ MEMS microphone IM69D130

Premium audio raw data

Define the benchmark in speech recognition with IM69D130

Noise free audio raw data
69 dB [A] signal to noise ratio

Distortion free audio signal capture
<1% total harmonic distortion up to 128 dB SPL

Microphone matching
< ±1 dB sensitivity and < ±2° phase response variations

Digital PDM interface
ultra-low group delay for latency-critical applications (6 μs at 1 kHz)

Wide frequency response
28 Hz to 20 kHz
Interaction Point 2: Break
Simulating resistance/ shaft friction

Pressing the handle

- Intenion: Simulates increased shaft friction
- Breaks motor
  - Speed decreases shortly
- But: motor is controlled for constant speed
  - Speed increases again
  - Current consumption increases

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Interaction Point 2: Hitting the brake

Results

- Current increase
- Speed decrease
TLI4971 – Industrial Current Sensor
Accurate in-phase current measurement

› TLI4971 – industrial current sensor
  › Hall based, magnetic current sensor
  › Full scale up to 120A
  › Increased current consumption at same conveyor load can come from motor failure
Magnetic sensing using HALL technology
Core-less vs. core-based

<table>
<thead>
<tr>
<th>Core-less</th>
<th>Core-based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open Loop</strong></td>
<td><strong>Closed Loop</strong></td>
</tr>
<tr>
<td>2 Hall probes for differential measurement</td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>Conductor</td>
<td>‣ Stray field suppression through <em>differential voltage measurement</em> of 2 Hall probes/cell</td>
</tr>
<tr>
<td><strong>Infineon’s choice for next generation current sensor</strong></td>
<td>‣ No saturation, no hysteresis, high linearity</td>
</tr>
<tr>
<td></td>
<td>‣ Low dependency on temperature and lifetime</td>
</tr>
<tr>
<td></td>
<td>‣ Sensor comes in small SMD packages</td>
</tr>
</tbody>
</table>

- Field concentrator
- Field probe
- Compensation winding
- Conductor

- Current
- $i_{comp}$

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XENSIV™ magnetic current sensor TLI4971
Current sensing in industrial applications

Product characteristics

› High precision, strayfield robust current sensor for bi-directional AC and DC measurements
› Measurement range up to 120A
› High accuracy over temperature and lifetime
› Analog output with high bandwidth (120kHz)
› Two fast overcurrent detection outputs (<1µs)
› Integrated primary conductor (current rail) with very low insertion resistance
› Galvanic isolation due to contactless magnetic sensing principle
› Variant with UL certification available

Block diagram

Package

PG-TISON-8 with integrated current rail
TLI4971 - TISON-8
Light & small package for HV isolation

Top view with mold compound
Differential Hall-plates
Bottom view current rail & signal pins

High Voltage 1150V
Insulation plate
Clearance 4mm
Low Voltage

Size PG- TISON-8: 8x8x1mm
TLI4971 designed for low power loss

Current path thru the package

220µΩ resistance soldered on PCB

Hockey-Stick design allows a maximum on sensitivity by minimal power loss!

Key differentiator vs existing products:
- Ultra low insertion resistance
- Optimized thermal management
- Temperature and lifetime performance
## TLI4971 - Application example motor drive

### Block diagram motor drive

![Block diagram of a motor drive system](image)

### Current sensor Requirement

- Enabling motor control for smooth operation
- Protection of output stages against overcurrent events
- Accurate in-phase measurement in harsh environment
- Galvanic isolated measurement for high voltage applications

### TLI4971 solution

- Highly accurate (<3%) measurement over temperature and lifetime
- Two independent output pins for overload detection
- Stray field robust through differential measurement of magnetic field
- Galvanic isolation between current rail and sensor
TLI4971 - Programmer & kits
Order information

<table>
<thead>
<tr>
<th>Name</th>
<th>Picture</th>
<th>Order number</th>
<th>ISAR type</th>
</tr>
</thead>
<tbody>
<tr>
<td>XENSIV™ magnetic current sensors – programmer</td>
<td></td>
<td>SP004441438</td>
<td>CUR SENSOR PROGRAMMER</td>
</tr>
<tr>
<td><strong>Note:</strong> can be used with all TLI4971 and TLE4971 evaluation boards!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XENSIV™ magnetic current sensors TLI4971 – evaluation board</td>
<td></td>
<td>SP005343588</td>
<td>TLI4971 EVAL 120A</td>
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<tr>
<td>XENSIV™ magnetic current sensors TLI4971 – S2GO</td>
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<td>SP005345472</td>
<td>S2GO_CUR-SENSE_TLI4971</td>
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<tr>
<td>XENSIV™ magnetic current sensors TLI4971 – MS2GO</td>
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<td>SP005345474</td>
<td>TLI4971_MS2GO</td>
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</tbody>
</table>
Interaction Point 2: Overcurrent Protection
Prevent motor from severe damage

Current consumption > 7A OCD Threshold exceeded
-> Motor is shut down by main controller
TLE4966G – Double Hall switch
Rotational speed and direction

- Double Hall-Switch
- Measures speed and direction of conveyor belt
XENSIV™ magnetic hall switches

Overview

› Based on Hall-technology
› Detects the strength of a magnetic field
› Is used for proximity as well as rotational speed and direction detection
› Available for consumer, industrial and automotive applications
TLE4966– Family of Double Hall Latches
Rotational speed and direction measurement

Highlights

› **Direction detection and speed** due to two integrated Hall sensor elements
› **Excellent sensitivity** and **stability** of the magnetic switching points
› **Operation** even from **unregulated power supply** plus reverse battery protection (-18V)
› Sensors for **horizontal** (TLE4966) and **vertical** (TLE4966V) **sensing** for mounting flexibility

Technical features

<table>
<thead>
<tr>
<th>TLE4966</th>
<th>TLE4966V-1G</th>
</tr>
</thead>
<tbody>
<tr>
<td>› Horizontal sensing</td>
<td>› Vertical Hall for In-Plane Sensing</td>
</tr>
<tr>
<td>› 2.7V to 24V operating supply voltage</td>
<td>› 3.5V to 32V operating supply voltage</td>
</tr>
<tr>
<td></td>
<td>› Overvoltage capability up to 42V without external resistor</td>
</tr>
<tr>
<td></td>
<td>› Low current consumption</td>
</tr>
<tr>
<td>› PG SSO-4-1 and PG-TSOP6</td>
<td>› PG-TSOP6</td>
</tr>
</tbody>
</table>
TLE4966 - Index Counting

Anti-pincho detection

Index counting

Power Closing Systems

Garage doors
Sun blinds
Shutters
Automated doors
...

TLE4966 family - Double Hall sensors

› Speed and Direction information
› Combination of 2 sensing elements in one sensor

Speed: Direction:

Speed 1
Speed 2
Direction

Position

+10

0

-10
Interaction Point 3: Out-of-shaft vs end-of-shaft
Simulating anomaly in two differing modes of angle calculation

**Linear table**
- Moves 3D sensor away from ring magnet  
  -> angle error increases
- Simulates shaft failure, e.g. wobbling of the shaft
Interaction point 3 – linear table
Simulating anomaly in two differing modes of angle calculation
TLE5014SP - End-of- Shaft configuration
Highly precise digital GMR angle sensor with SPI

TLE5014SP

- Digital GMR Angle Sensor
- End-of-Shaft configuration
- Detects rotation of fast spinning motor shaft
- Can be used for motor commutation
Infineon XENSIV™ – Angle sensor portfolio

![Diagram of angle sensor portfolio]

- **iAMR**
  - Digital angle
  - TLI5012B
  - TLE5012B(D)

- **iGMR**
  - Digital sin/cos
  - TLE5011

- **iTMR**
  - Analog sin/cos
  - TLE5109A16(D)
  - TLE5009
  - TLE5009A16(D)
  - TLE5309D

(D) = Single and dual die
D = Dual die only
TLE5014: GMR, digital angle sensors

TLE5014 – Characteristics

› Easy-to-use plug & play sensors: pre-configured and pre-calibrated
› Offering high flexibility:
   – Available as single and dual die products
   – 12bit digital interface with protocol options PWM, SENT, SPC, SPI
   – E²PROM and look-up table for customer configuration and calibration
› High angle accuracy: max. 1.0° over temperature and lifetime
› High voltage capability up to 26 V
› Fully compliant development according ISO26262
   – developed acc. ASIL-D level
   – sensor reaching ASIL-C metrics

TLE5014 – Products

<table>
<thead>
<tr>
<th>TLE5014 C16</th>
<th>TLE5014 C16D</th>
<th>TLE5014 P16</th>
<th>TLE5014 P16D</th>
<th>TLE5014 S16</th>
<th>TLE5014 S16D</th>
<th>TLE5014 SP16</th>
<th>TLE5014 SP16D</th>
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<tbody>
<tr>
<td>SPC</td>
<td>PWM</td>
<td>SENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single die</td>
<td>Dual die</td>
<td>Single die</td>
<td>Dual die</td>
<td>Single die</td>
<td>Dual die</td>
<td>Single die</td>
<td>Dual die</td>
</tr>
<tr>
<td>NEW - IN PRODUCTION</td>
<td>NEW - IN PRODUCTION</td>
<td></td>
<td></td>
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</tbody>
</table>
TLE5014SP(D)
SPI interface for high dynamic applications

Optimal for angle sensing for motor commutation

Highlights
› Fully compliant sensor developed according ASIL-D with ASIL-C metric
› 3-pin SPI with access to
  - Sin/cos raw values
  - Calculated angle (15 bits)
  - Diagnostic information
› SPI Data rate: 8MHz
› Internal update rate: 25µs
› Signal delay: ~ 60µs
› 3.3V and 5V versions
› Accuracy < 1°

Product Information
› SMD package (PG-TDSO-16)
› Tape & reel (2.5k)
› EES: Q4/2017
› QS: Q4/2018
TLE493D-W2B6 - Out-of-Shaft configuration
3D magnetic sensor with wake-up functionality

- 3D Magnetic Sensor
- Out-of-Shaft configuration
- Detects rotation of slowly spinning conveyor shaft

Calculation of angle error for predictive maintenance
- Difference between End-of-Shaft and Out-of-Shaft angle can be used for predictive maintenance
- Detects failures of motor gear and shaft misalignments (e.g. a wobbling or unbalanced shaft)
XENSIV™ 3D magnetic sensors

Overview

› Based on Hall-technology
› Detects the strength of a magnetic field in all three dimensions, i.e. x-, y- and z-axis
› In addition able to detect linear movements & the angular position of a rotating magnetic field
› Is available for consumer, industrial and automotive applications
# 3D Hall Sensor
## Our 3D Sensors in a Nutshell

## PRODUCTS

<table>
<thead>
<tr>
<th>Industrial &amp; Consumer</th>
<th>Automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV493D-A1B6</td>
<td>TLE493D-A2B6</td>
</tr>
<tr>
<td>TLI493D-A2B6</td>
<td>TLE493D-W2B6</td>
</tr>
<tr>
<td>JESD47 Qualified Products</td>
<td>AEC-Q100 Qualified Products</td>
</tr>
</tbody>
</table>

## How to read 3D-Sensors nomenclature?

<table>
<thead>
<tr>
<th>TLE</th>
<th>49</th>
<th>3D</th>
<th>A</th>
<th>1</th>
<th>B</th>
<th>6</th>
<th>A0</th>
</tr>
</thead>
</table>

## KEY FEATURES AND BENEFITS

### TLV493D-A1B6
- Reduced update frequency and field range
- Power down mode (7nA)
- Low current consumption
- Integrated temperature sensing

### TLI493D-A2B6
- Increased update frequency and field range
- Power down mode (7nA)
- Component reduction
- Sensor address read back

### TLE493D-W2BW Ax
- Small WLB package
- Wake-up upon magnetic field mode
- Power down mode (7nA)
- Integrated temperature sensing

### TLE493D-A2B6
- Variable update frequencies and power modes
- Power down mode (7nA)
- Integrated temperature sensing
- ISO ready

### TLE493D-W2B6 Ax
- Wake-up upon magnetic field mode
- Power down mode (7nA)
- Integrated temperature sensing
- ISO ready

## USE CASES

+ A global support structure with 3D magnetic sensor experts that can address customer’s requirements

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2020-06-23  
restricted

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TLE493D-W2B6 - Bus Mode
Differentiation Between Variants A0-A3

Unique Characteristics

› Possibility to connect up to 4 sensors (A0 – A3) to one I²C bus system

› **Specific addressing** done via the sensor variants A0 – A3

› Technically same sensor, but preconfigured with “individual startup ID”

› Four different orderable address types (Individual OPN for A0, A1, A2, A3, A4)

› For functional safety critical applications a separate bus for each sensor is highly recommended
TLE493D-W2B6 – Wake Up Feature
When low power consumption is key

Figure 15  Static or Dynamic Wake Up Threshold Operation of the TLE493D-W2B6
Interaction Point 3: Linear table
Simulating wobbling - Moving sensor away

![Graph showing significantly increased angle error](image-url)
# XENSIV™ Evaluation Tool Environment

## 2GO Kits and Shield2Go

### 2GO Kits
- One Infineon sensor IC combined with an ARM® Cortex™-M0 CPU.
- USB connection for fast evaluation
- Ob board debugging

### Shield2Go
- Comprise **one board with one single Infineon IC**
- Comes with solderless connectors
- The **Software** for the Shield2Go is based on **Arduino**

### Software
- Graphical User interface (GUI)
- Arduino library

### Add on components
- Joystick - Rotation knob - Linear slider - Out of shaft adapter - Drill trigger - Mini Control
The backbone of Shield2Go
Unleash your creativity

1. Reusable blocks with our HW
   - PCBs in standardized formfactor for our sensors
   - Standardized footprints and pin order

2. Combine blocks to systems

3. Flexible evaluation boards compatible with existing solutions

4. Arduino software

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# XENSIV™ Shield2Go – Portfolio overview

## Sensors

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPS310</td>
<td>Barometric Pressure Sensor</td>
</tr>
<tr>
<td>MEMS Microphone IM69D130</td>
<td></td>
</tr>
<tr>
<td>TLI4970-D050T4</td>
<td>Current Sensor</td>
</tr>
<tr>
<td>TLV493D-A1B6</td>
<td>3D Magnetic Sensor</td>
</tr>
<tr>
<td>TLE4966K</td>
<td>Double Hall Shield2Go</td>
</tr>
<tr>
<td>TLE4964-3M</td>
<td>Hall Sense Shield2Go</td>
</tr>
<tr>
<td>TLE493DW2B6</td>
<td>3DSense Shield2Go</td>
</tr>
</tbody>
</table>

## Microcontroller

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XMC™ 2Go</td>
<td></td>
</tr>
</tbody>
</table>

## Adapter for Arduino Uno

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>My IoT Adapter</td>
<td></td>
</tr>
</tbody>
</table>

## Security ICs

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIGA™ Trust E</td>
<td>Security Controller</td>
</tr>
<tr>
<td>OPTIGA™ Trust X</td>
<td>Security Controller</td>
</tr>
</tbody>
</table>
Unleash your creativity –
How is that looking like?

**Shield2Go + Infineon XMC™ 2Go**

![Image of Shield2Go + Infineon XMC™ 2Go]

- XMC™ 2Go stacked with the TLV493D 3DSense Shield2Go and rotate knob

**Shield2Go + My IoT Adapter + XMC™ bootkit**

![Image of Shield2Go + My IoT Adapter + XMC™ bootkit]

- Stacked XMC1100 Boot Kit with My IoT Adapter and Shield2Go
Online Simulation tools – fast and easy
Simulation for Hall switches, 3D magnetic and angle sensors

3D Magnetic Sensors

Hall Switches

Angle Sensors

One widget for three simulation tools – the guide to identify the most suitable Infineon sensor IC combined with the best-fit magnet

Sensor Product Portfolio
Various sensors for plenty of applications

- **Magnetic Position**
  - 3D Magnetic
  - Angle Sensor
  - Hall switch
  - Linear Hall

- **Rotational Speed**
  - Wheel Speed
  - Engine
  - Transmission

- **Pressure**
  - Side Airbag
  - Barometric
  - Manifold
  - TPMS

- **ADAS & Wireless**
  - 77GHz Radar
  - Wireless Control
  - LIDAR
  - ToF (3D Imager)
  - 24/60GHz Radar

Silicon Microphone
Part of your life. Part of tomorrow.