



The Bosch Steering Angle Sensor as a technical Solution for Multi-dimensional Requirements

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Contents

What were the main questions for this market analysis?

- Which systems need steering angle information?
- Which market trends can be identified?
- How dominant are the systems?
- Consequences derived from the market analysis

What is our answer?

- Sensor design
- Measurement principle
- Technical Data
- Variants



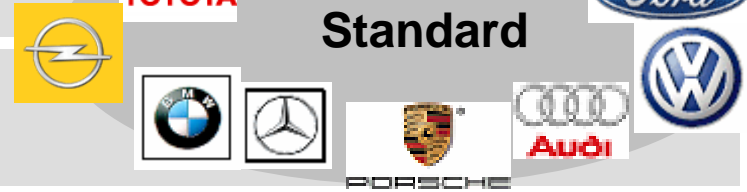
Steering Angle Sensor Market

Systems using the SAS Information

Electronic Stability Program (ESP)



Elektro-hydr./ Electric Power Steering (EHPS/EPS)



Active Steering (AS)



Advanced Front Lighting (AFS)



Lane Departure Warning (LDW)



4 Wheel Steering (4WS)



Active Suspension



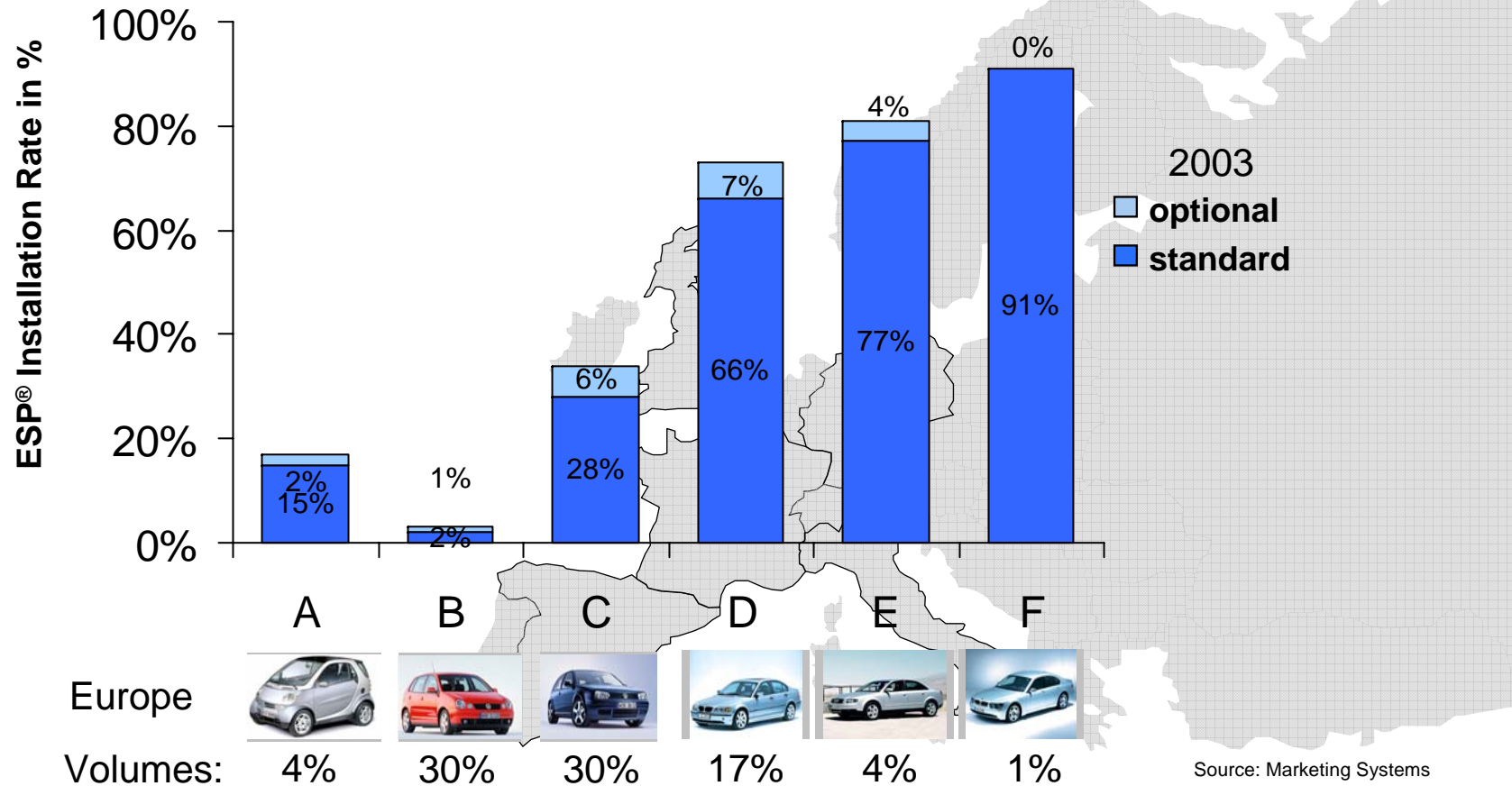
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Steering Angle Sensor Market – Installation Rate

ESP[®] in all Vehicle Segments, Europe



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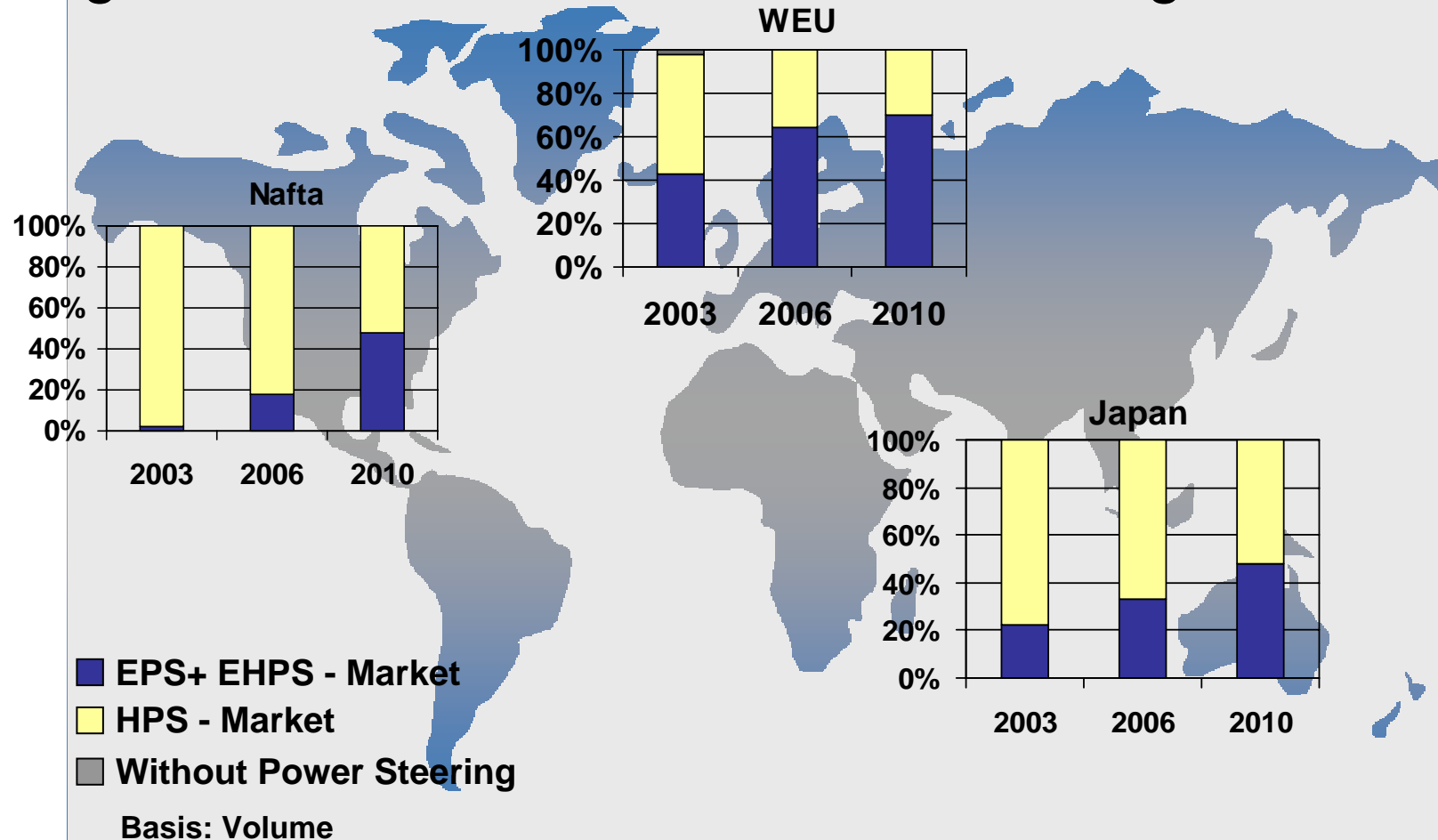
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Steering Angle Sensor Market – Installation Rate

Regional Market Share of Power Steering



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Steering Angle Sensor Market – Installation Rate

Installation Rates in Upper Class Segment 2008

System	Installation Rate Upper Class	Trend in other Segments
Advanced Front Lighting (AFS)	80 - 100 %	↑
Active Steering (AS)	30 - 50 %	→
Lane Departure Warning (LDW)	10 - 20 %	→



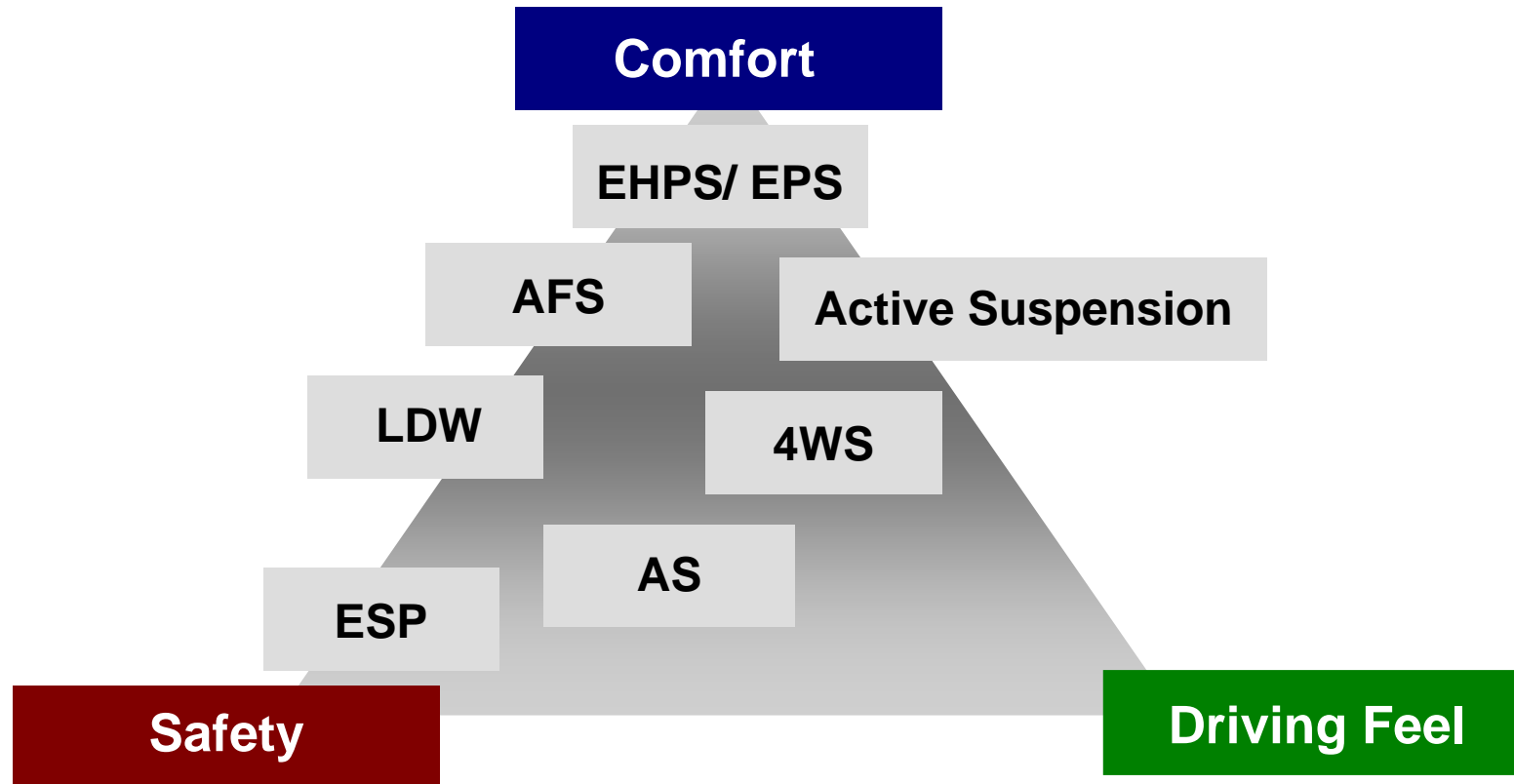
Market View based on Installation Rate

- Every System using steering angle information has a different averaged installation rate
 - An accumulation of such systems in specific segments cannot be recognized
 - The installation of these systems are distributed differently within the regions EU, AM, AP
 - Some systems migrate from upper to lower segments (ESP, AS, AFS) whereas others are can mainly be found in lower segments (EPS)
- In regards to the installation rate there is no system dominant enough to determine the requirements of a steering angle sensor.



Steering Angle Sensor Market

Systems sorted by Functions



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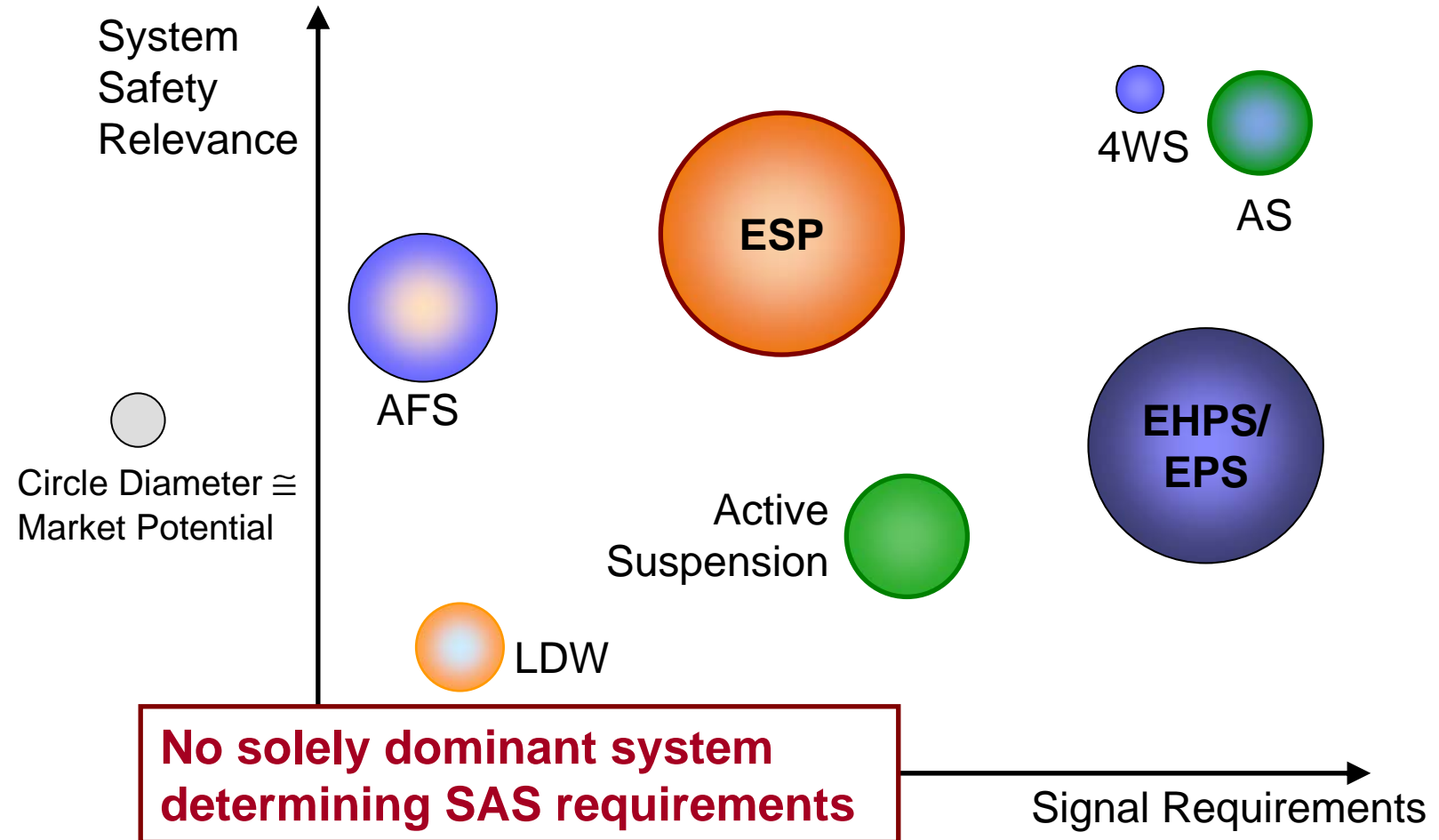
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Steering Angle Sensor Market

Systems sorted by SAS Signal Requirements



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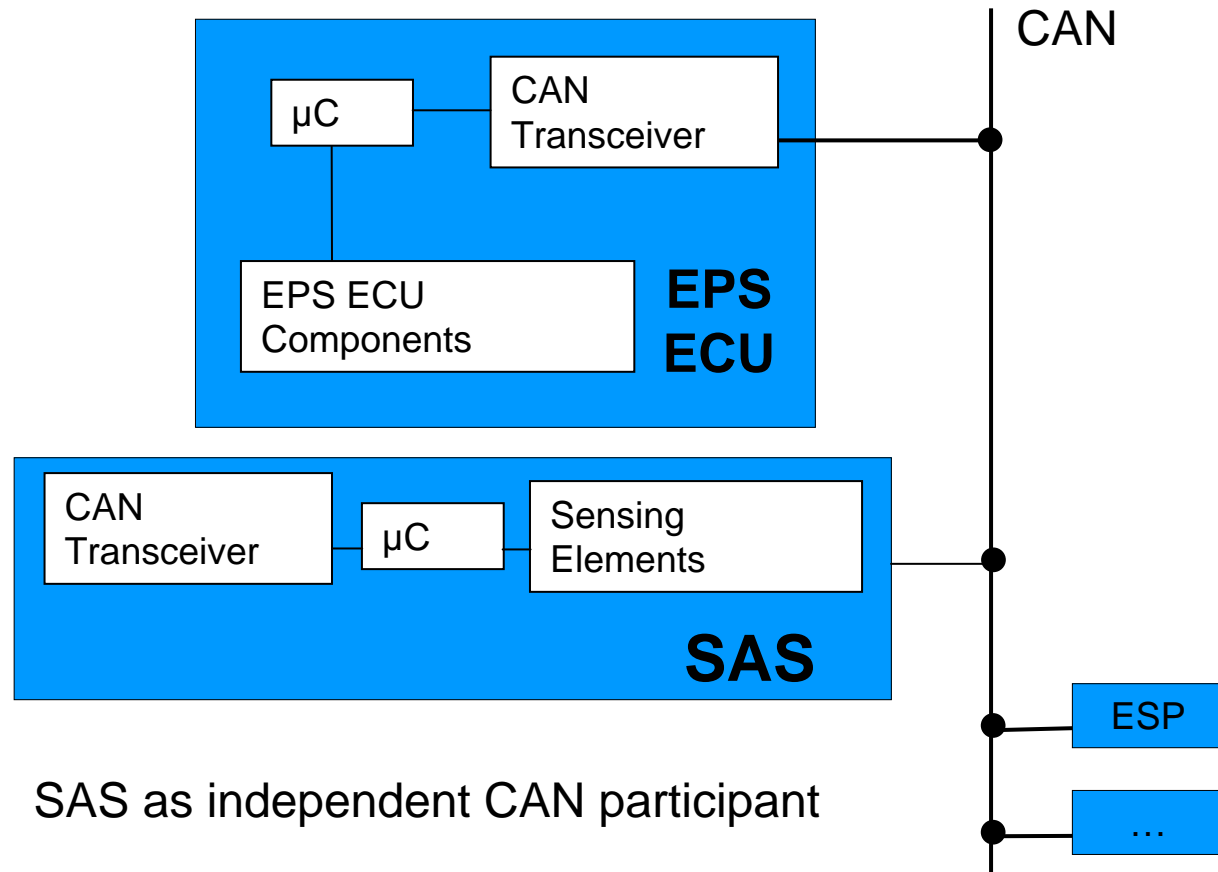
Further Aspects

- Mounting Area
 - Fully integrated in combi-switch unit or stand-alone sensor
 - Advantage of integrated SAS:
 - Reduced amount of parts
 - Only completed module has to be logistically handled
 - Advantage of stand-alone SAS:
 - Flexibility regarding vehicle equipment rate
 - Flexibility in supplier selection
- Power Supply
 - Increasing number of systems and components needing quiescent current favors the use of sensors without stand-by current
- Integration of SAS in EPS System



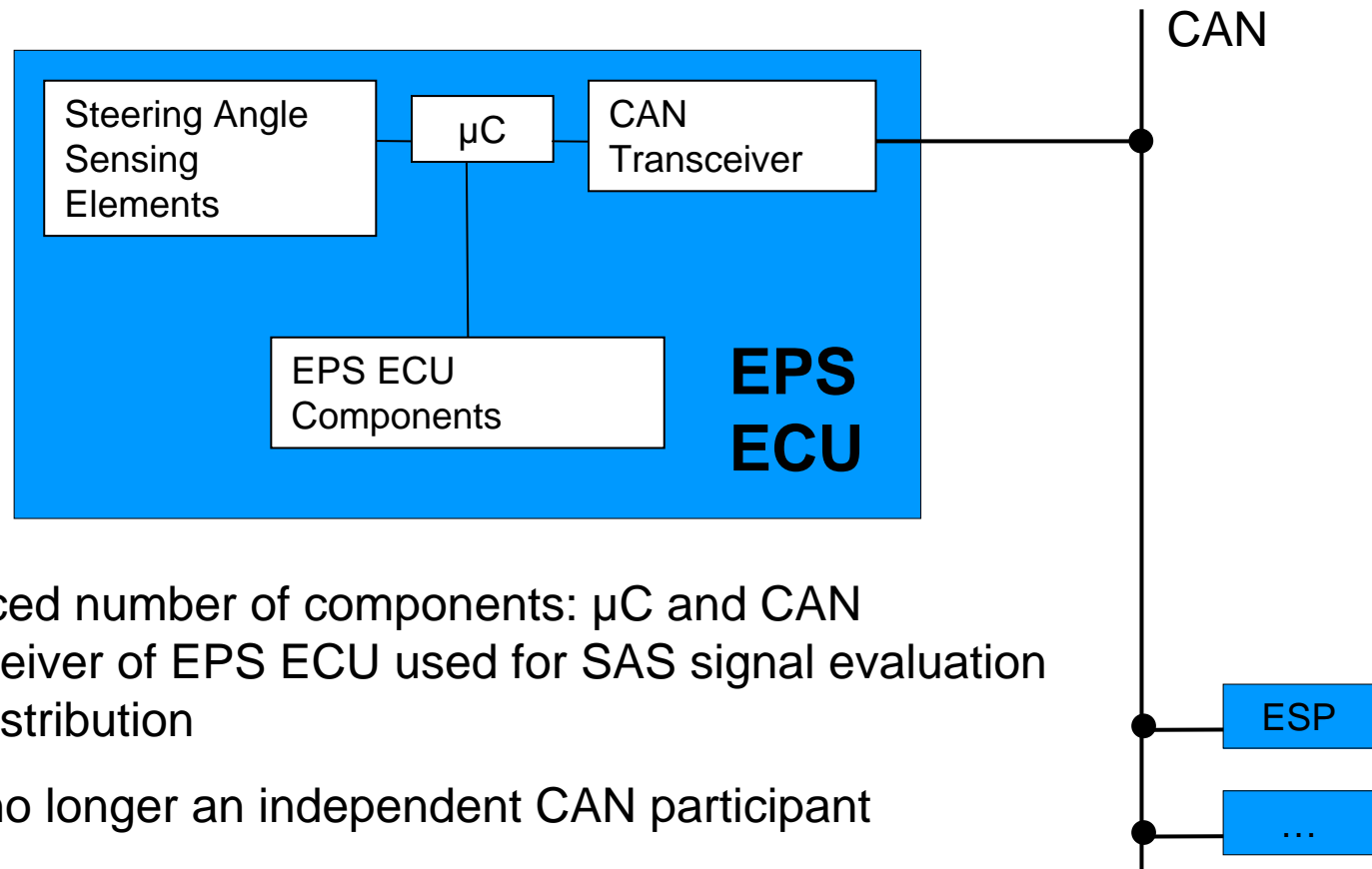
Steering Angle Sensor Market

Current System Architecture with SAS



Steering Angle Sensor Market

Trend: Integration of SAS in EPS Systems



- Reduced number of components: µC and CAN transceiver of EPS ECU used for SAS signal evaluation and distribution
- SAS no longer an independent CAN participant

Conclusions

- A large number of systems need the steering angle information
- In some cases the system requirements are quite different
- The market is inconsistent regarding the allocation of such systems in vehicle segments and their combination in one vehicle
- As many of these systems are offered optionally a market forecast is very complicated
- A trend towards SAS integration into the EPS System is recognized

→ **Result:**

The future SAS generation must be able to cope with the various different system requirements and also be able to offer the lowest market price possible

→ **Solution:**

A modular scalable steering angle sensor



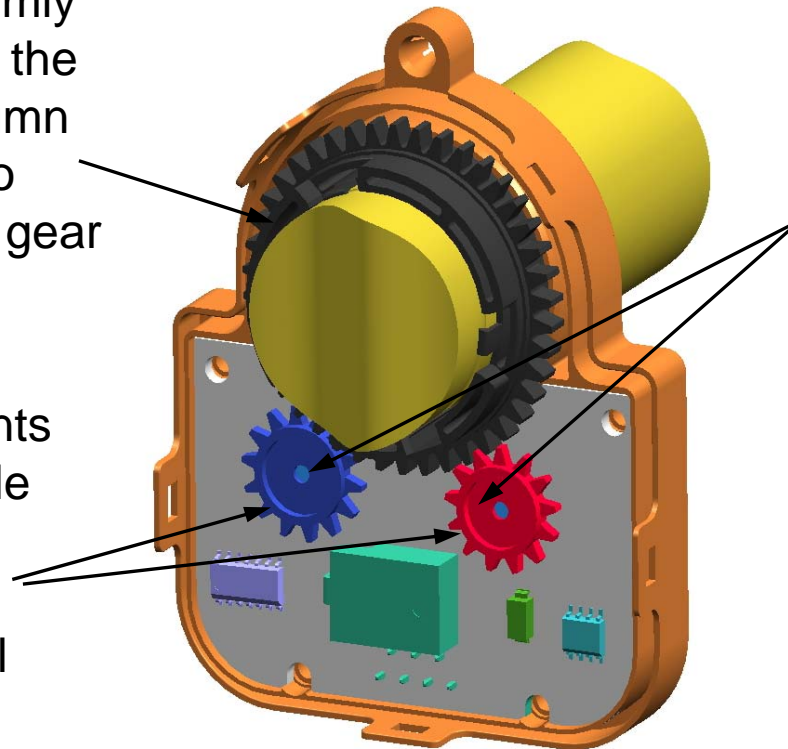
Steering Angle Sensor LWS5

Design

The hub is firmly connected to the steering column driving two measurement gear wheels

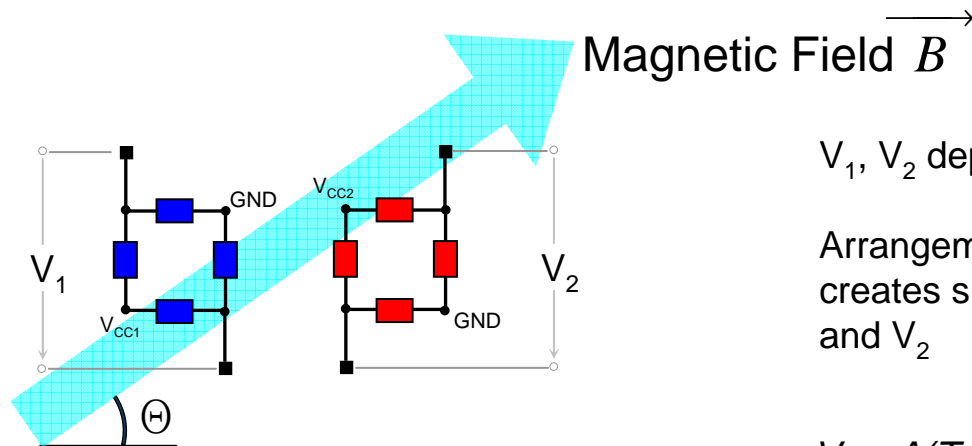
Magnets are integrated into the measurement gear wheels with different number of teeth

The iGMR elements measure the angle values and are mounted below each gear wheel



Steering Angle Sensor LWS5

iGMR: Angle Measurement per Gear Wheel



V_1, V_2 dependant on direction of magnet field

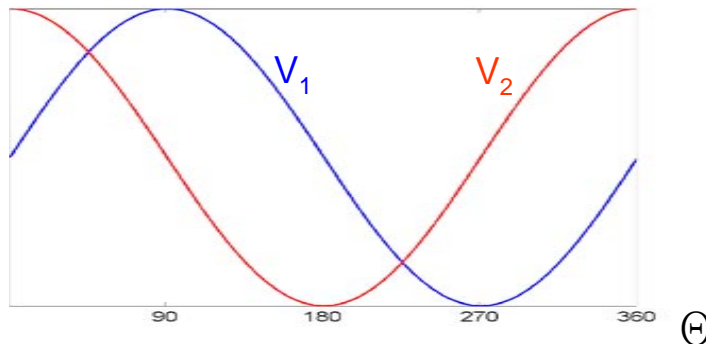
Arrangement of both measurement circuits creates signal phase shift of 90° between V_1 and V_2

$$V_1 = A(T) \cdot \sin \Theta$$

$$V_2 = A(T) \cdot \cos \Theta$$

$$\Theta = \arctan\left(\frac{V_1}{V_2}\right)$$

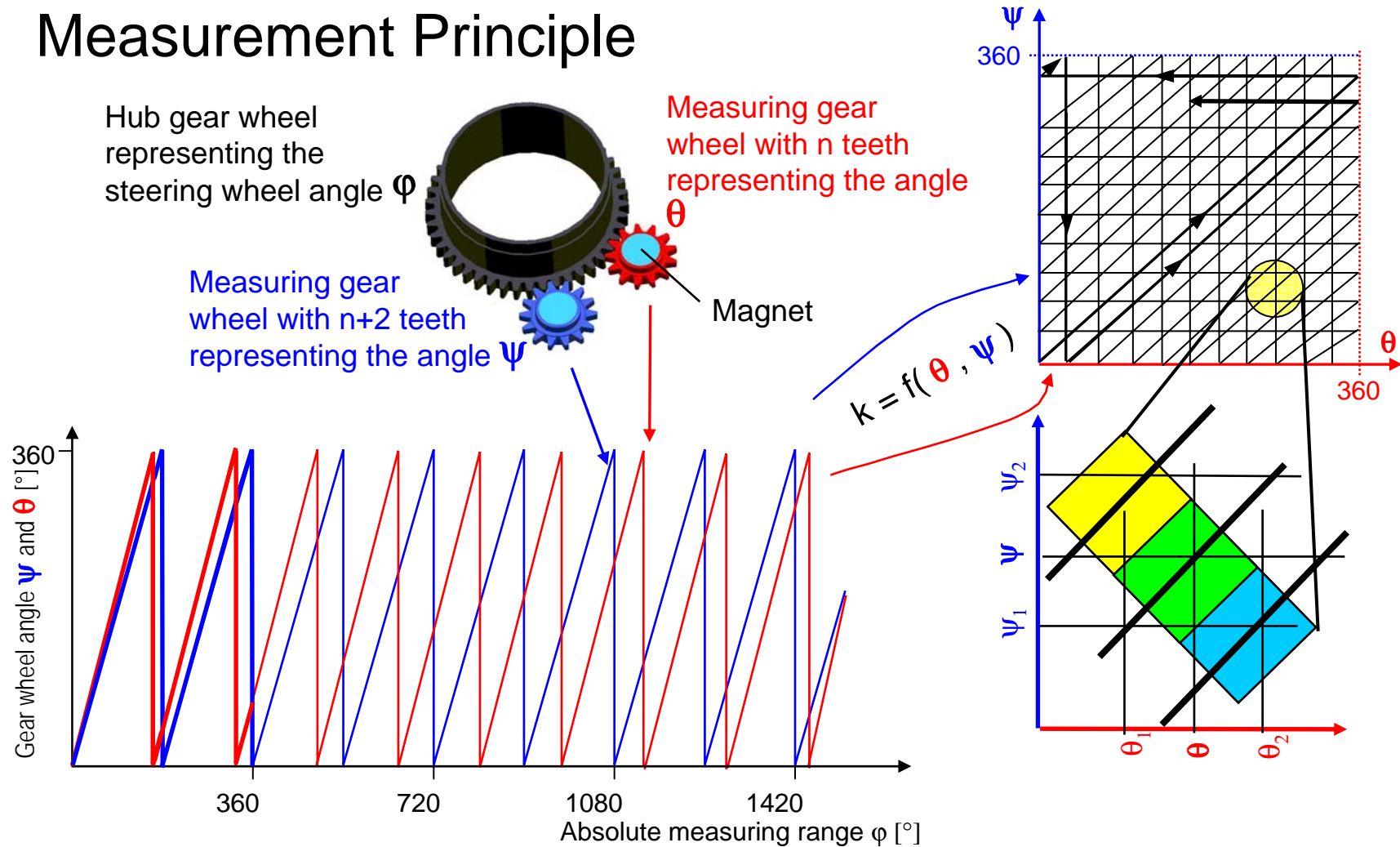
Measurement range of iGMR elements is 360°



Temperature dependence of the amplitudes of V_1 and V_2 is eliminated

Steering Angle Sensor LWS5

Measurement Principle

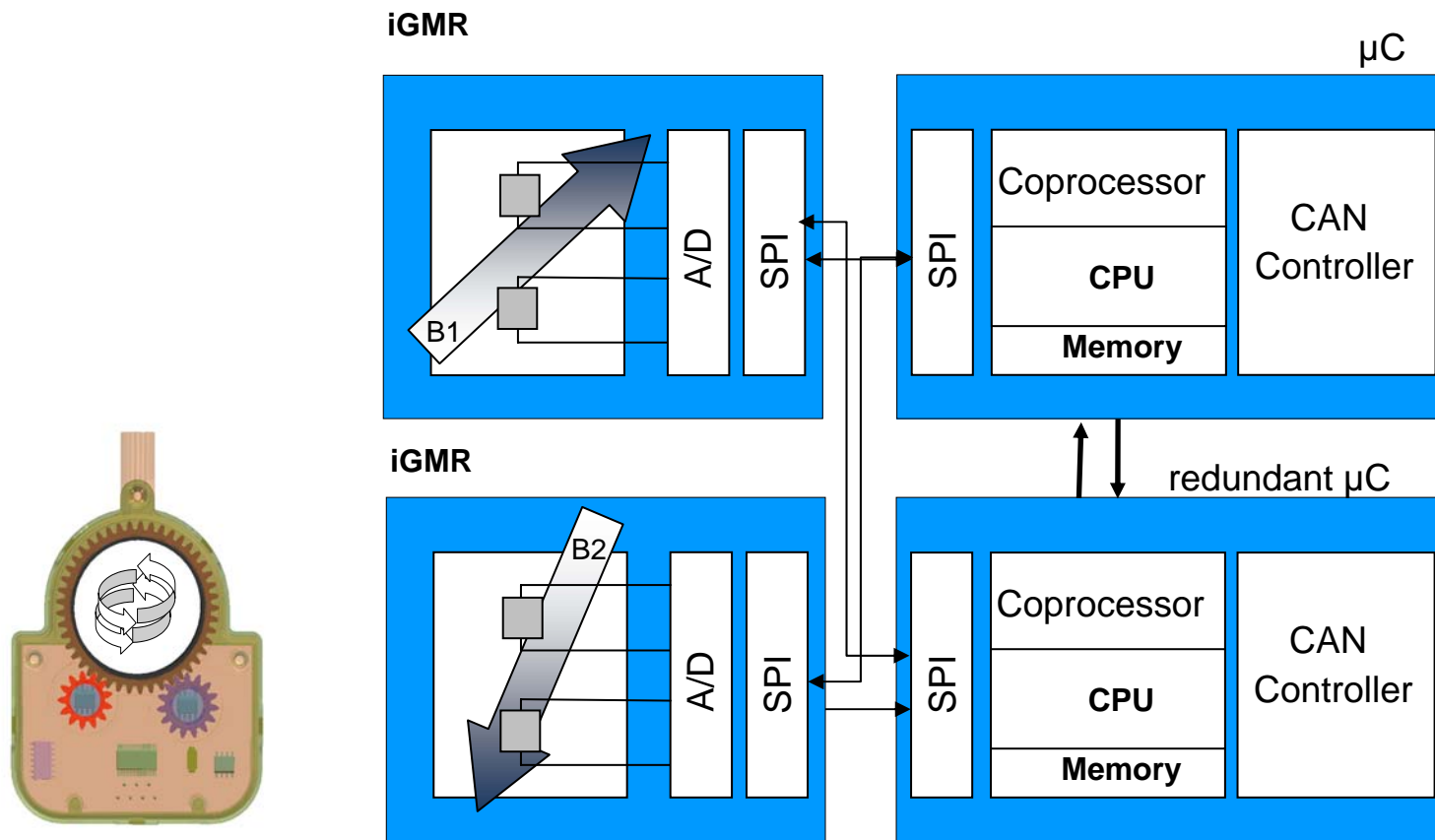


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Steering Angle Sensor LWS5

Modular Concept



Steering Angle Sensor LWS5

Failure Probability and Safe Failure Fraction

Error definition: angle deviation of $>8^\circ$ not detected within 10ms

	Failure Probability (Q)	SFF (*)
SIL3 (***) Requirement	$< 10^{-9} / \text{h}$	$> 99\%$ for HFT0(**)
1 μC	$6.1 * 10^{-10} / \text{h}$	98.2%
2 μC	$3.5 * 10^{-10} / \text{h}$	99.0%

* SFF Safe Failure Fraction: fraction of safe (controlled) errors out of all errors

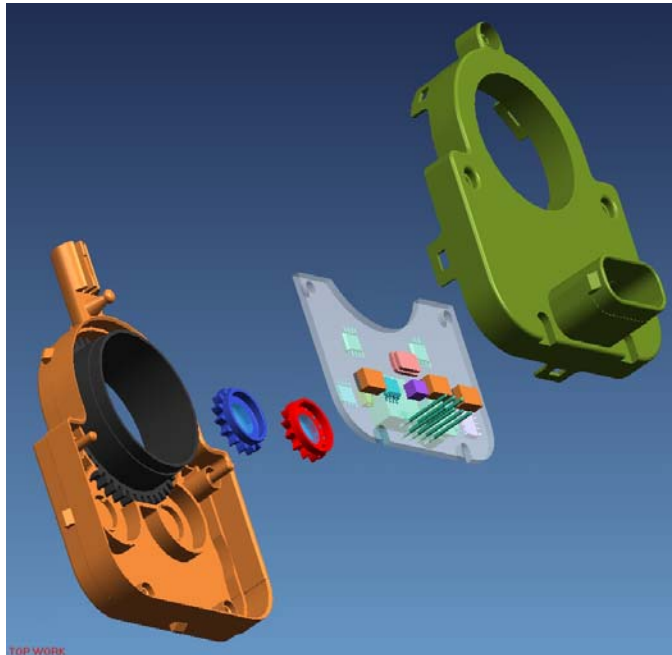
** HFT Hardware Failure Tolerance, HFT0: one channel system

*** IEC 61508



Steering Angle Sensor LWS5

Technical Data of Standard Version LWS 5.3



- Measuring Range: 1560°
- Resolution
 - Angle: 0.1°
 - Angle Speed: 4°/s
- Accuracy
 - Angle: ±2.5°
 - Angle Speed: ± 15°/s
- Max. Angle Speed: 2500°/s
- Refresh Rate: 10 ms
- Temperature Range: -40°C ... +85°C

Steering Angle Sensor LWS5

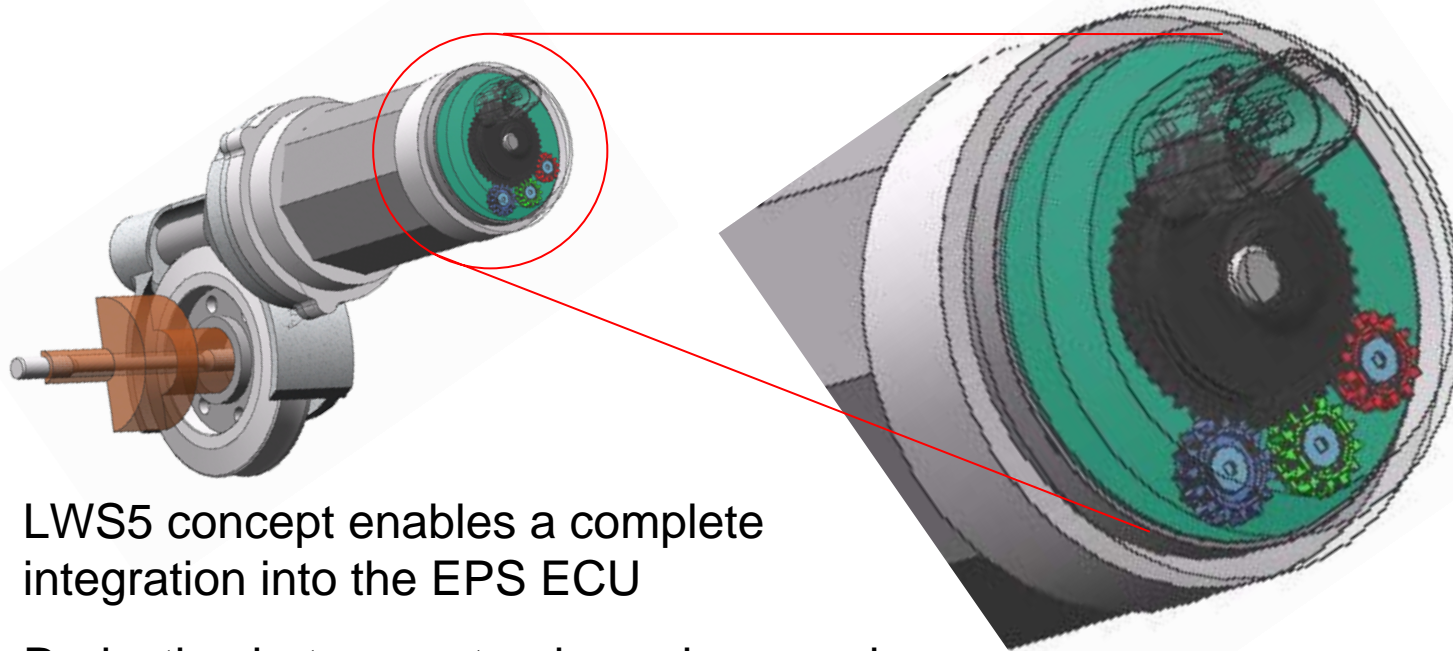
Variants



	LWS 5.4.yz	LWS 5.3.yz	LWS 5.2.yz
Interface	customer specific	CAN	CAN
iGMR ICs	2	2	1
Class [Measuring Range]	3 [±780°]	3 [±780°]	2 [±90°]
Characteristics	Enhanced performance due to more powerful μ C	Standard LWS for ESP applications	Measuring range dependant on gear ratio between hub measuring gear

Steering Angle Sensor LWS5

Integration of SAS in EPS System



- LWS5 concept enables a complete integration into the EPS ECU
- Reduction between steering column and EPS motor calls for a extremely wide angle measurement range
- Angle range covered by a special Vernier principal patented by Bosch

Steering Angle Sensor LWS5

Summary

- The angle resolution of $0,1^\circ$ enables the use of the LWS5 in systems with much more stringent requirements than ESP, such as Driver Surveillance Systems and some EPS applications
- The refresh rate and performance of the sensor are scalable and can be adjusted to the system requirements
- The modular design of the sensor enables us to offer a cost efficient solution exactly meeting all customer needs
- The patented Vernier measurement principle stores the absolute angle position mechanically and therefore the sensor does not need any stand-by current
- An integration of the LWS 5 concept into an EPS system is possible





Thank you very much for your attention!

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