Magnetic Sensors for Autonomous Cars

Outstanding Performance & Safety for Autonomous Driving

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Senior Director Product Architecture & Innovation magnetic Sensors

Sep 2019

SECURE CONNECTIONS
FOR A SMARTER WORLD

Secure Connections for A Smarter World

NXP Semiconductors N.V. (NASDAQ: NXPI) enables secure connections and infrastructure for a smarter world, advancing solutions that make lives easier, better, and safer.

As the world leader in secure connectivity solutions for embedded applications, NXP is driving innovation in the secure connected vehicle, end-to-end security & privacy, and smart connected solutions markets. Built on more than 60 years of combined experience and expertise, the company has approximately 30,000 employees in more than 30 countries and posted revenue of $9.41 billion in 2018.

A Position of Strength to Better Serve Our 26,000+ Customers

Employees in
30+ Countries
Headquartered in Eindhoven, Netherlands

~30,000
Employees

9,000
Patent Families

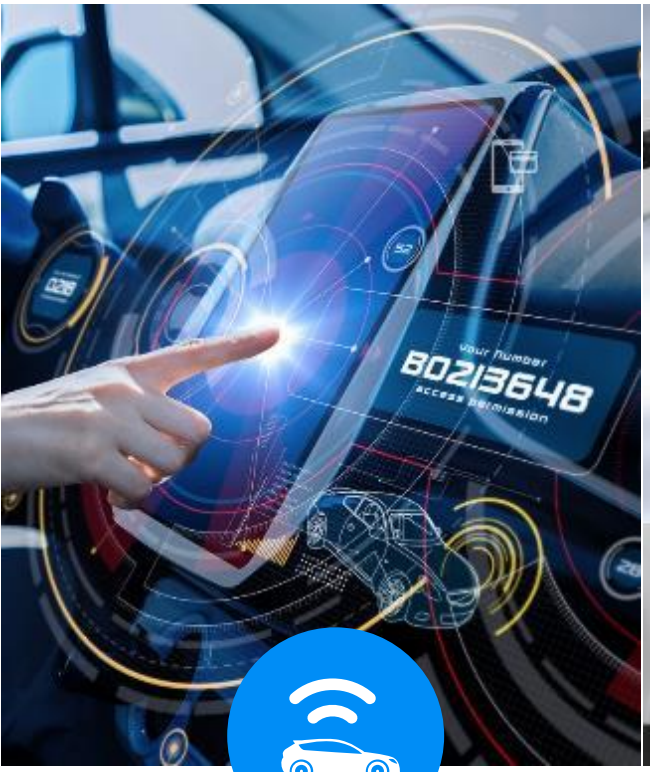
$9.41B
Annual Revenue[1]

60+
Year History

~9,000
R&D Engineers

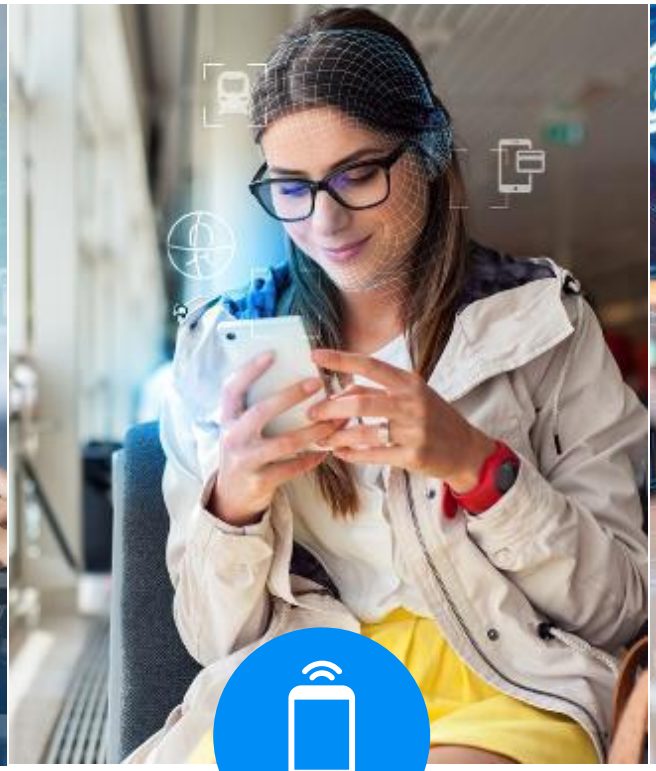
[1] Posted revenue for 2018 – Please refer to the Financial Information page of the Investor Relations section of our website at www.nxp.com/investor for additional information

Our Target Markets



Automotive

Industrial & IoT

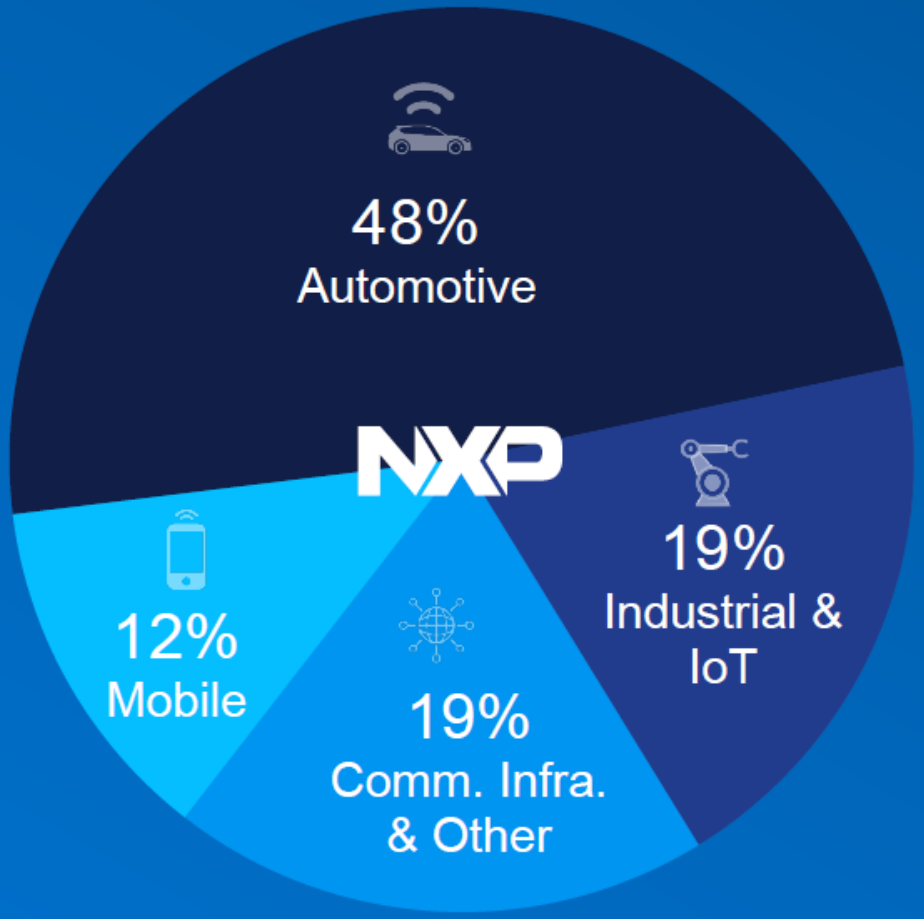


Mobile

Communication Infrastructure

Focused Leadership – End Markets[1,2,3]

NXP 2018 Revenue
by End-market Exposure



Broad end market exposure

- Long product life cycles
- High barriers to entry
- Application expertise

Recognized leadership in

- Automotive
- MCU and application processors
- Mobile transactions
- RF power solutions
- Secure identification, mobility, RFID

Note:
1. Please refer to the NXP Historic Financial Model file found on the Financial Information page of the Investor Relations section of our website at www.nxp.com/investor for additional information relative to our Non-GAAP Financial Measures
2. Chart excludes $136 million of Manufacturing Service Agreement revenue recognized in 2018 reported revenue
3. See page 24 of this presentation for a mapping of the new End-Market representation from the previous Operating Segment representation

Automotive

Solutions for Safe and Secure Mobility

Value Proposition

Solution portfolio

Comprehensive System Solutions for fast time to market and scalability

Innovation power

In-house high-performance processing, security and mobile eco-system capabilities

Automotive safety and reliability

Zero defects methodology
Leading with functional security and safety

NXP Makes Safe and Secure Mobility Happen

Technology Leadership

#1 Auto Analog / RF / DSP
#2 Auto Microcontrollers
#1 Auto Application Processors

+

Applications Leadership

#1 Car Infotainment
#1 Secure Car Access
#1 In-Vehicle Networking
#1 Safety
#2 Powertrain
#1 ABS Sensors

Innovation Leader ADAS
Innovation Leader Security

=

#1

in Auto Semiconductors

2017 Global Auto Semi Market: $34.5B

1. Based on 2017 Auto TAM
2. Auto RF/DSP includes Secure Car Access, Radio/Audio, V2X and Radar Transceivers
3. Source: Strategy Analytics, IHS Markit, NXP

TODAY: 90% of Auto innovation from Electronics

NXP MAGNETIC SENSORS ARE ESTABLISHED IN DEDICATED APPLICATION SEGMENTS.

ADAS

RADAR FRONTEND & MICROCONTROLLERS
V2X COMMUNICATION BASED ON ROADLINK
VISION & LIDAR PROCESSING
SENSOR FUSION

Security

1. SECURE INTERFACES (SE)
2. SECURE GATEWAY
3. SECURE NETWORKING
4. SECURE PROCESSING (MCU/MPU)

(+1) SECURE CAR ACCESS

POWERTRAIN & CHASSIS

MICROCONTOLLERS
PRESSURE/ MOTION SENSORS
POSITION/ ANGLE SENSORS
BATTERY MANAGEMENT
DRIVERS

#1 INFOTAINMENT

TUNERS
SOFTWARE-DEFINED DIGITAL RADIO
MULTIMEDIA PROCESSORS
SOUND SYSTEM DSPs & AMPLIFIERS
NFC BT PAIRING
WIRELESS POWER CHARGING
POWER MANAGEMENT

#1 SECURE CAR ACCESS

IMMOBILIZER/ SECURITY
REMOTE KEYLESS ENTRY
PASSIVE KEYLESS ENTRY/ GO
BI-DIRECTIONAL KEYS
NFC
ULTRA WIDE BAND

#1 VEHICLE NETWORKING

CAN/LIN/ FLEXRAY
ETHERNET
CENTRAL GATEWAY CONTROLLER
SECURITY

#1 SAFETY

MICROCONTROLLERS AIRBAG
ANALOG AIRBAG
MICROCONTROLLERS BRAKING
ANALOG BRAKING
SENSORS BRAKING
TIRE PRESSURE MONITORING

#1 BODY

MICROCONTROLLERS
POSITION/ ANGLE SENSORS
SYSTEM BASIS CHIPS

Megatrends Transform Automotive Industry

Connectivity

ZERO
Time Wasted

ADAS → Autonomy

ZERO
Accidents

Electrification

ZERO
Emissions

Safe and Secure Mobility

ROAD TRAFFIC ACCIDENTS - the causes

Critical Reasons	Number	%
Driver	2,046,000	94%
Vehicles	44,000	2%
Environment	52,000	2%
Unknown	47,000	2%
Total	2,189,000	100%

Data source: NMVCCS

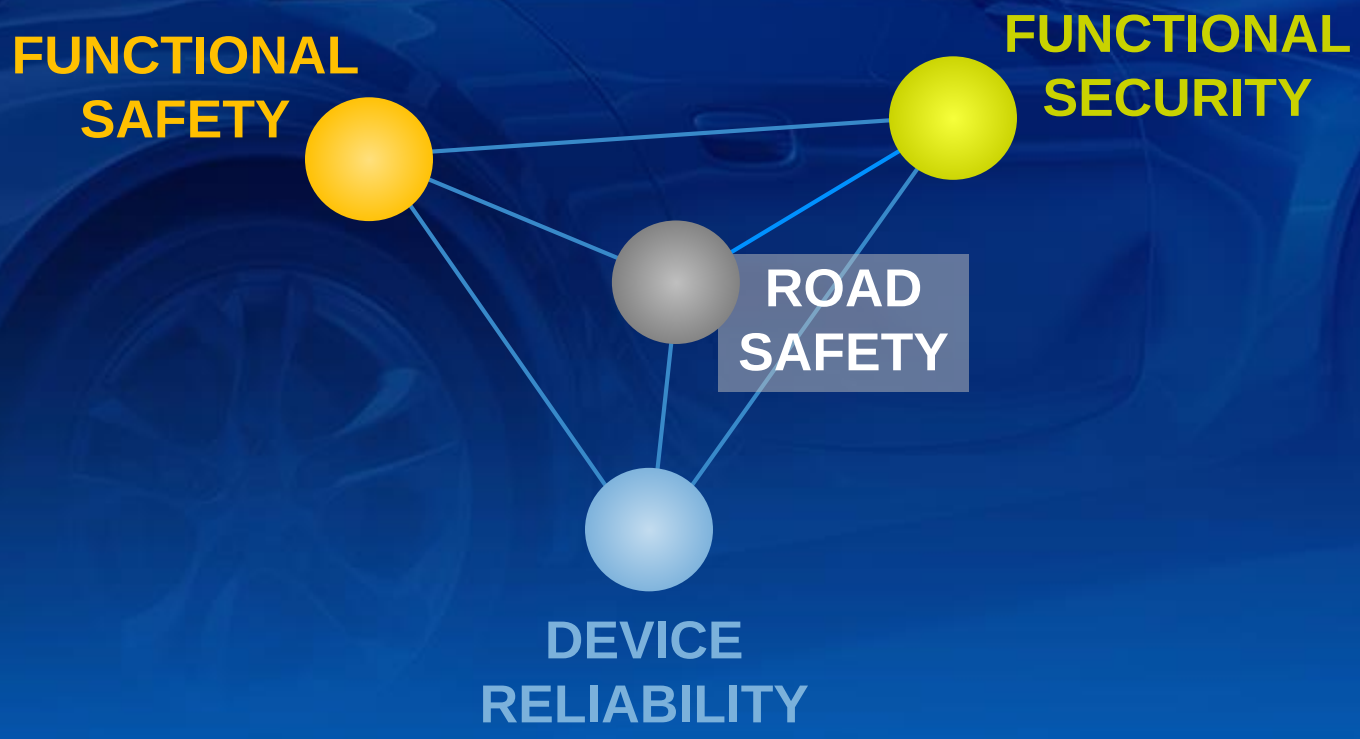
Driver-Related Critical Reasons	Number	%
Recognition Error	845,000	41%
Decision Error	684,000	33%
Performance Error	210,000	11%
Non-performance Error (e.g. Sleep)	145,000	7%
Other	162,000	8%
Total	2,046,000	100%

Every year!

- ~1.3 m fatalities
- >50 m people seriously injured
- >$3 trillion cost of road accidents
- >90% caused by human mistakes

We need to get the *Human Error* out of the equation!

THE ROBUSTNESS TETRAHEDRON



FUNCTIONAL SAFETY: Zero accidents by system failures (ISO 26262)
FUNCTIONAL SECURITY: Zero accidents by system hacks
DEVICE RELIABILITY: Zero components failures (robust design)
ROAD SAFETY: Zero accidents by human error (ADAS)

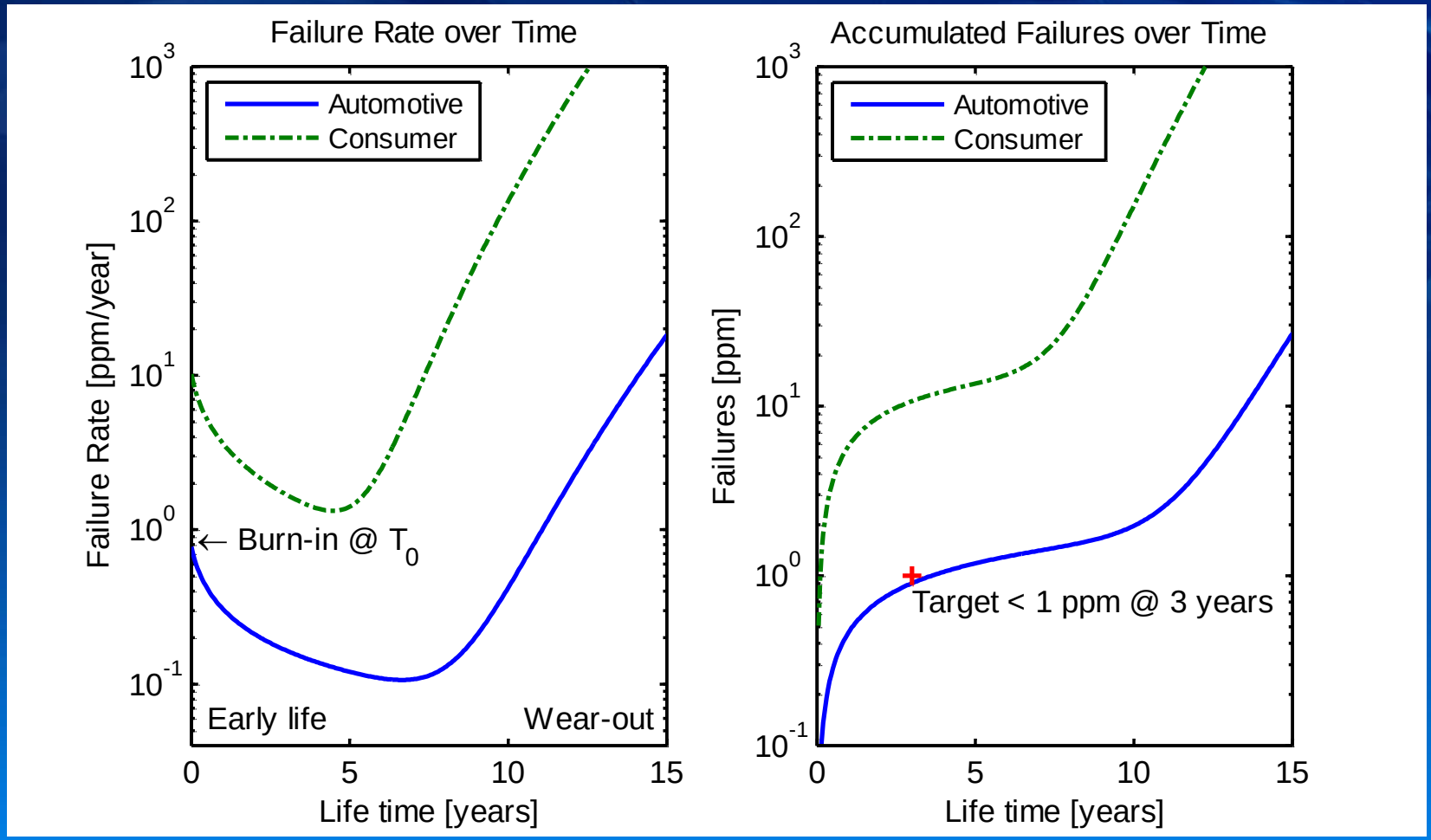
RECALLS - AN INDICATOR FOR FUNCTIONAL SAFETY

Airbags	20,807,538
Ignition keys/switches	16,299,079
Electrical/Electronics	4,964,662
Brakes	4,754,297
Powertrains	3,882,814
Steering	2.552,484
Fuel Systems, leaks	2,050,443
Suspension	1,697,464
Seatbelts	1,631,278
Seats (including child-seat latches)	1,253,729
Engine and Cooling	1.054,061
Tires, Tire-pressure-systems, Wheels	617.223
Accessoires and Labels	153,737
Throttle	19,202

PEOPLE MUST BE ABLE TO TRUST THEIR CARS

Source: National Highway Traffic Safety Administration

RELIABILITY COMPARISON
AUTOMOTIVE VS CONSUMER PRODUCTS



Business Line Sensors

Automotive Sensors one Foundation to Safety & Highly Autonomous Driving

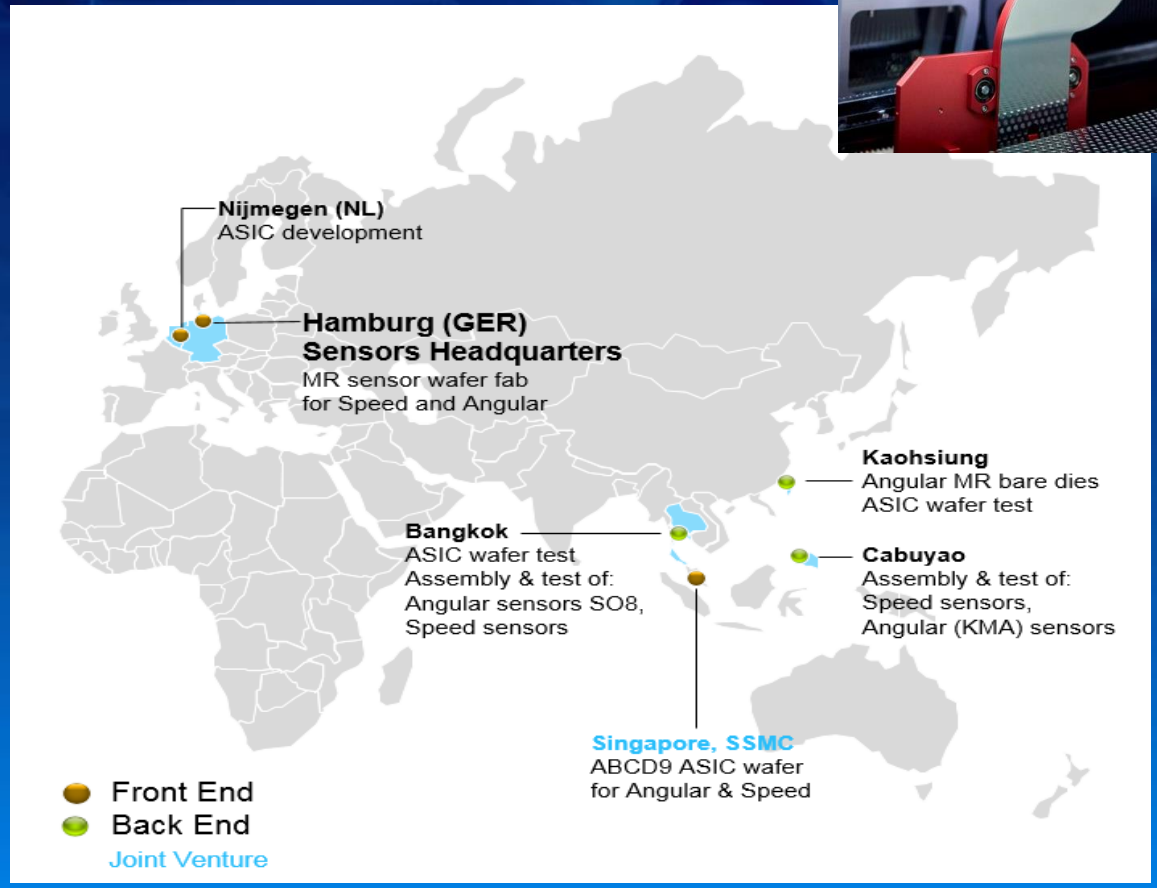
Motion Sensor	Pressure Sensors	Magnetic Sensors
		
Airbag Accelerometers Active Safety Combos	TPMS, Engine Management & Satellite Pressure for Airbags	Angular for Engine Control & steering ABS Speed Sensors

#1 in Automotive Safety Sensors

MAGNETIC SENSORS

over 2B sensors sold to market

- Headquarters in Hamburg, Germany
  - Sensor (AMR) wafer fab and test
  - Process and product development
  - Product quality and engineering
  - Application support and innovations
  - Product and commercial marketing

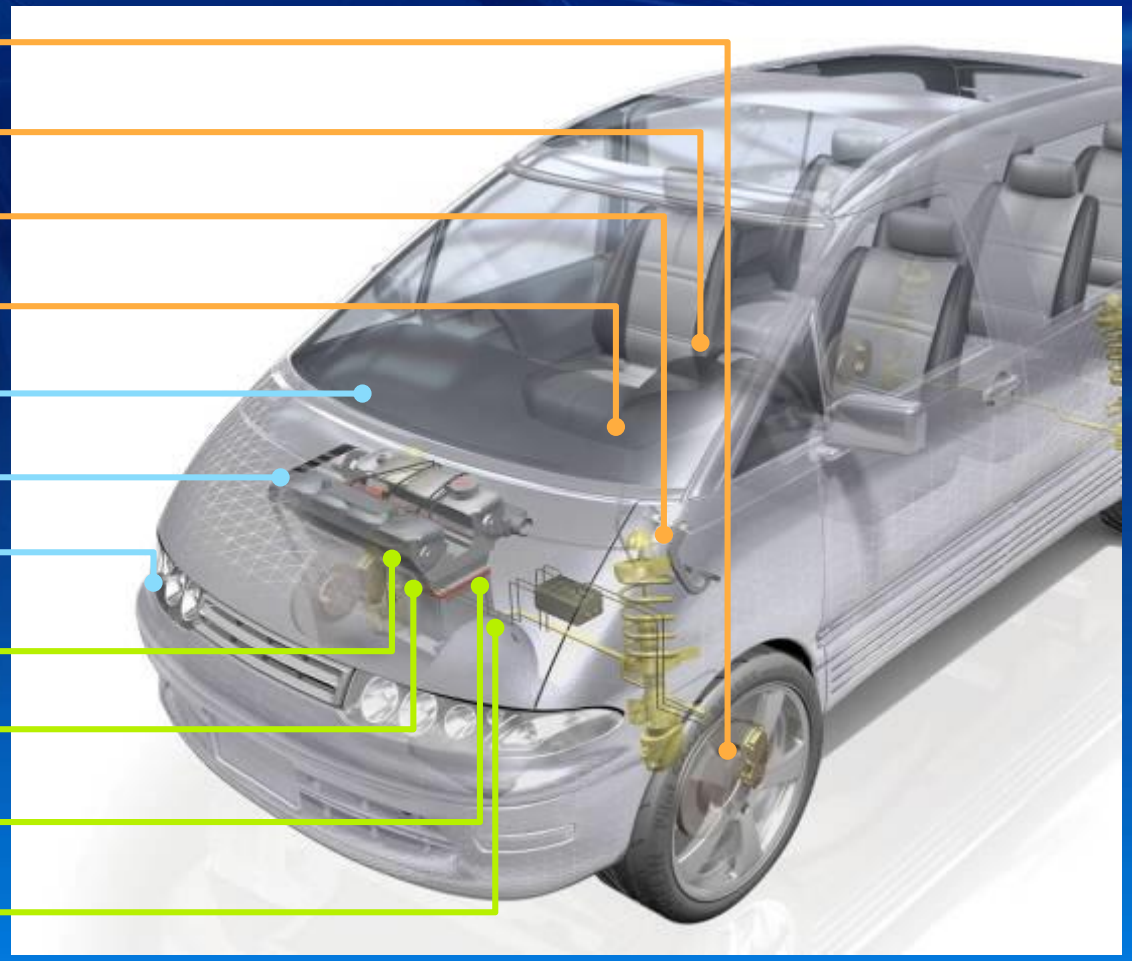


Tier-1s, EMS & Distributors
are our customers

BOSCH, Continental, DELPHI, PIERBURG, BOURNS, Panasonic, Valeo, Aisan, EDOM TECHNOLOGY CO., LTD., MAGNETI MARELLI, DENSO, AVNET, TRW Automotive, HELLA, FUTURE ELECTRONICS

Magnetoresistive Sensor applications and its location under the hood (some examples)

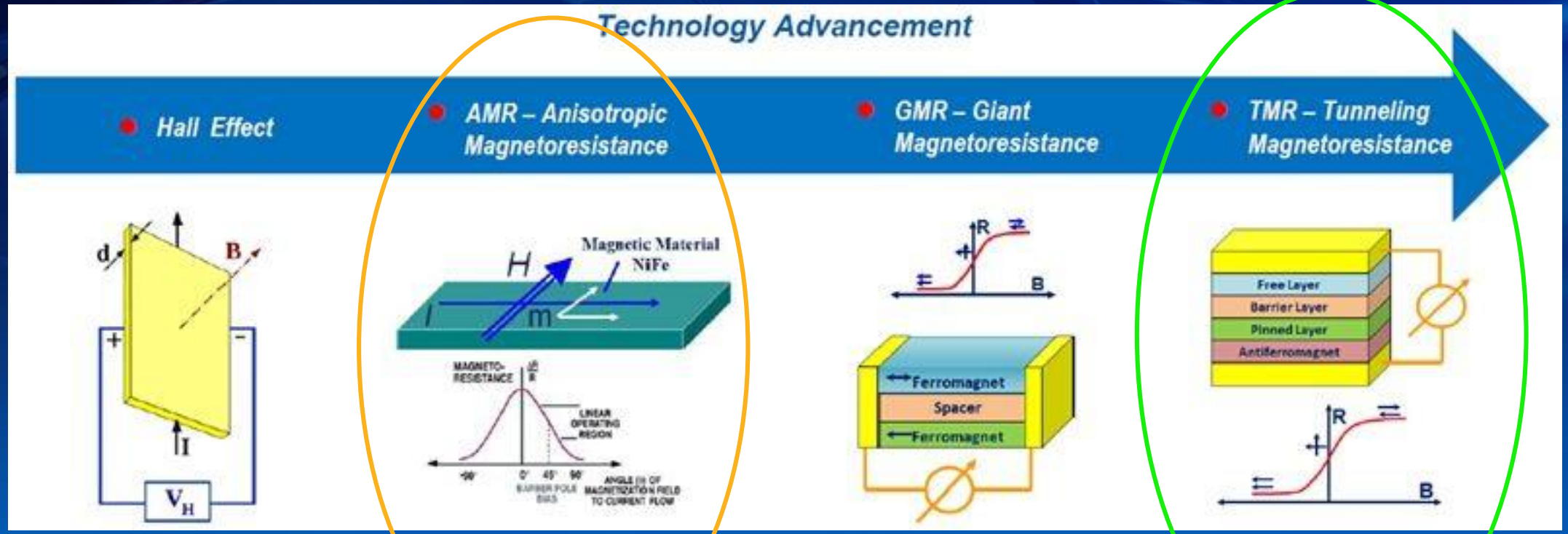
- ABS
- Steering angle
- E-Gas
- Steering torsion
- Window wipers
- Oil, water temperature
- Headlight adjustment
- Variable valve timing
- E-throttle
- EPAS motor positioning
- Active transmission



Benefits of Magnetoresitive Sensing

- Only 3 elements visible to magnetic fields: Fe, Co, Ni + some rare earth
- Wear free: MR elements and magnets are hardly degrading over lifetime
- Robust: no influence by humidity, or dirt within the magnetic field
- Standard Material Housings: standard mold compounds, etc.
- Efficient production: fully integrated onto ASIC technology
  integrated AMR in production moving to integrated TMR

Magnetic Sensing Technologies



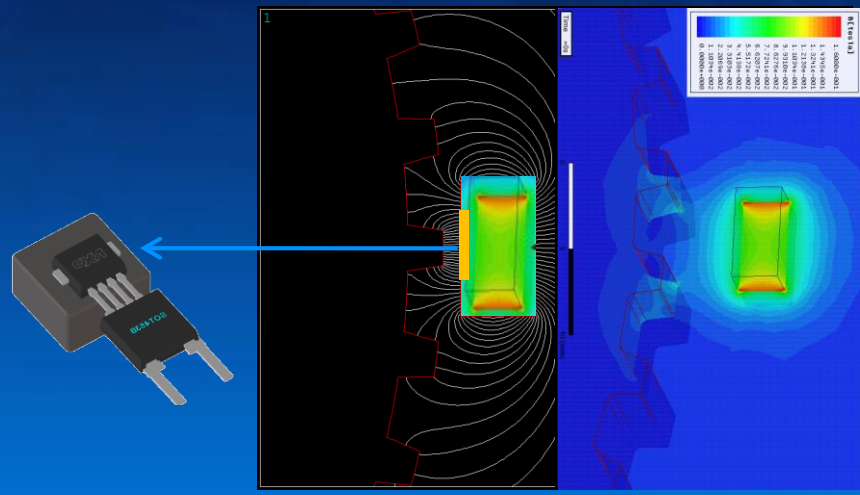
NXP Magnetic Sensors focus

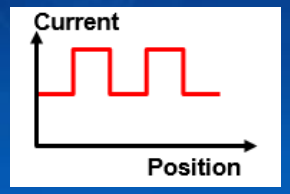
Rotational speed movement

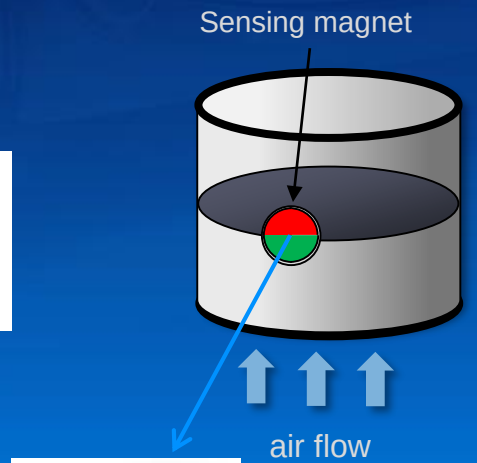
- Current pulse output, digital info signals
- Direction recognition
- Air gap information
- Vibration suppression
- Diagnostic functions
- Stray field robustness
- Extreme high repeatability / low jitter

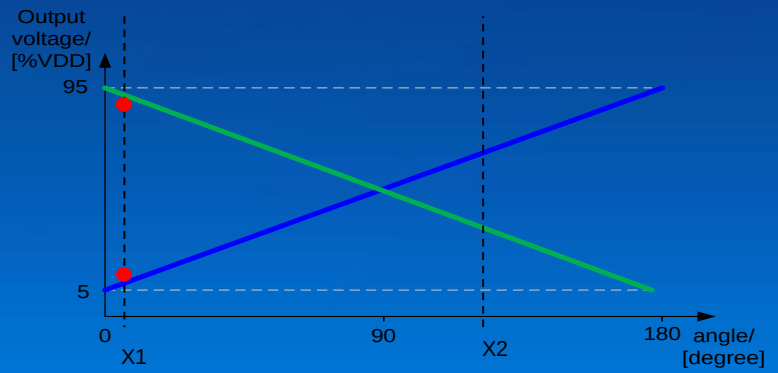
Mechanical angular position

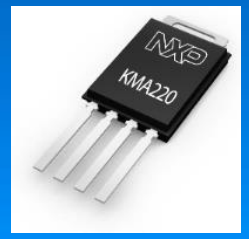
- Analog voltage, digital output signals
- Customer output adjustments
- Magnet loss detection
- Temperature information
- Diagnostic functions











ABS Sensor evolution

1996

Pure ABS to detect wheel rotation

Simple AMR bridge 192 transistors

Add basic ESP functionality

Digital protocol Direction, Mounting position Simple diagnostic

Increased performance for iTPMS

2017

Advanced diagnostic Error messaging

Magnetic stray field suppression

2021

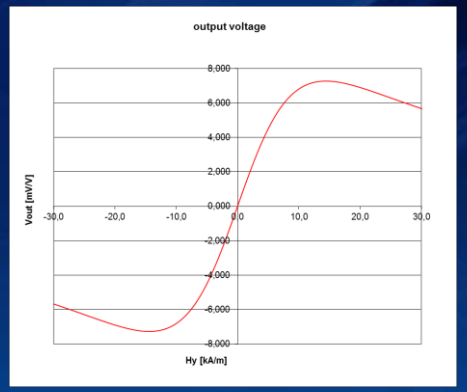
Redundant ABS sensing internal safety High resolution

2nd order VTMR gradiometer mixed signal ASIC, ADCs, E2PROM, BIST

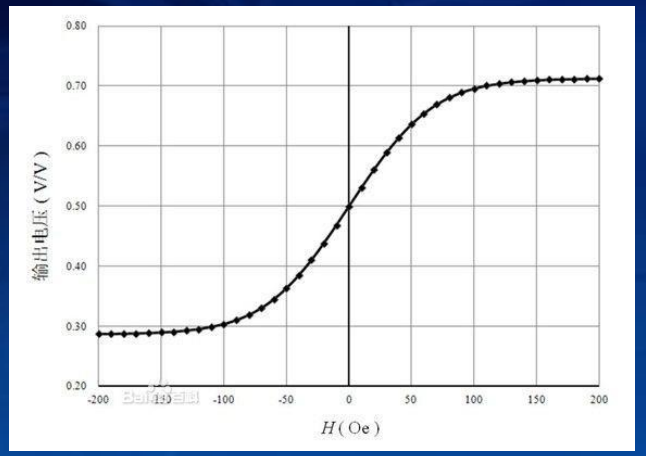
Why move to TMR

- Based on the need for stray field suppression (hybrid and electrical vehicles)

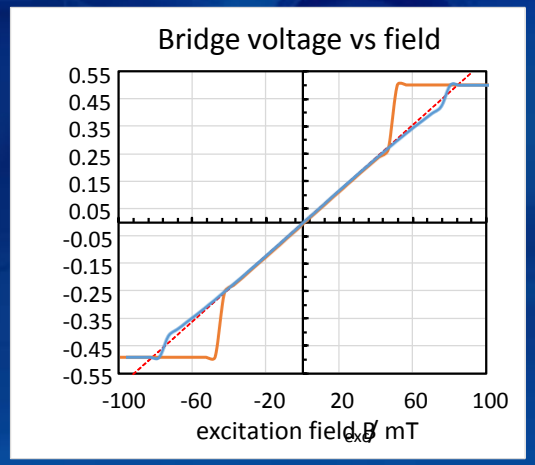
AMR



TMR



Vortex TMR

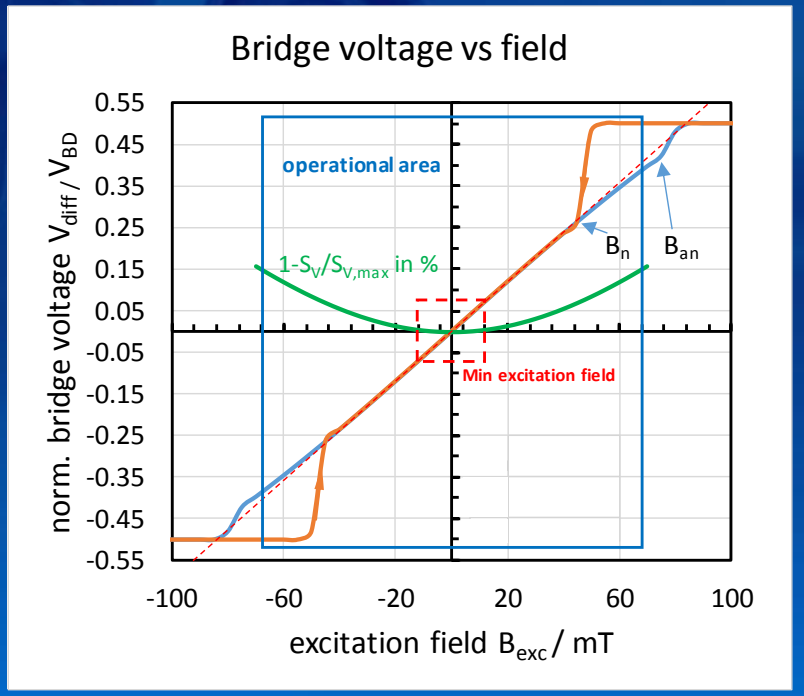


- AMR has hardly any linear response → difficult to build a gradiometer
- TMR is improved but shares AMRs Crossfield sensitivity
- V-TMR allow a good gradiometer

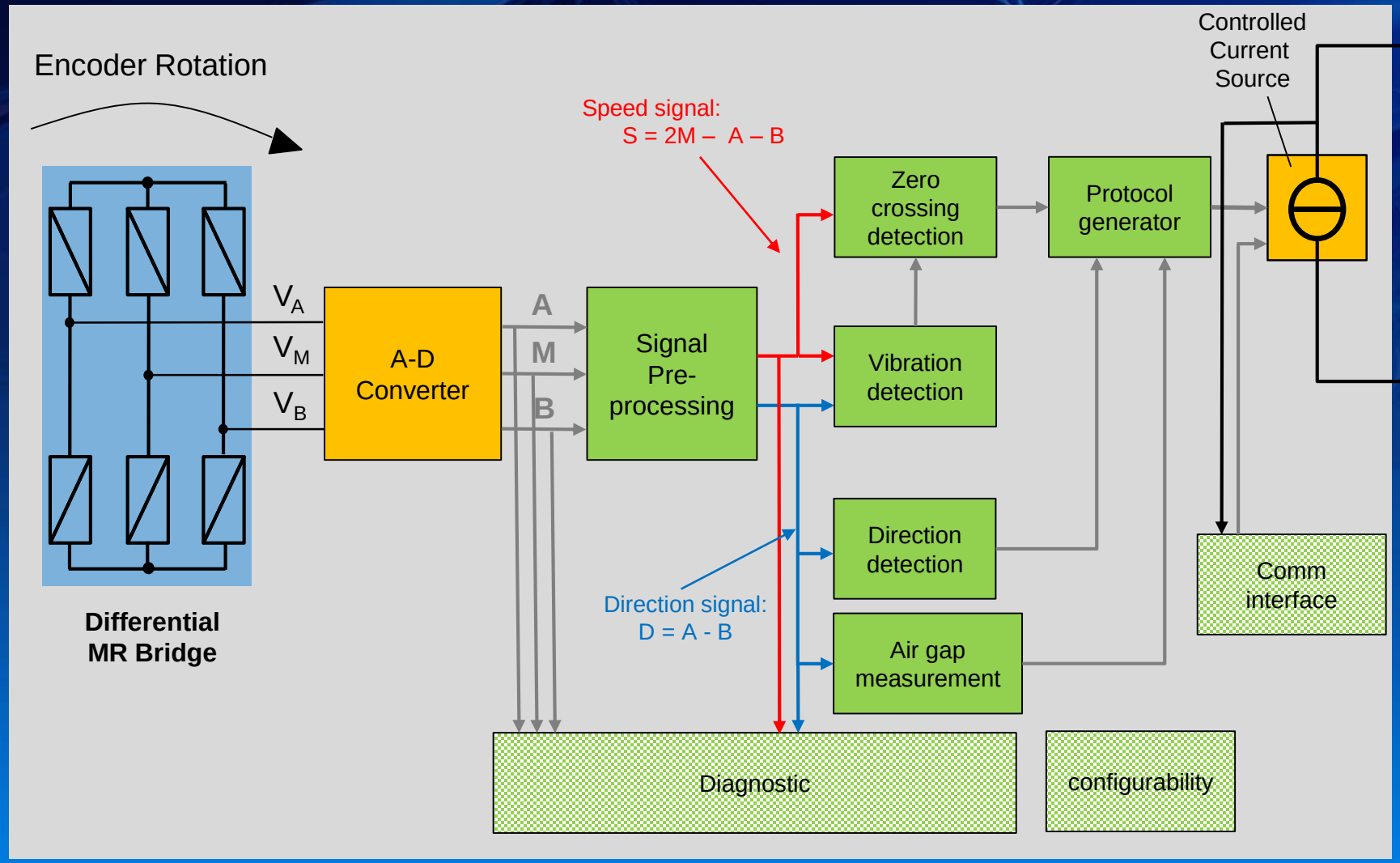
Comparison of NXPs AMR and V-TMR based speed sensor

- Right diagram summarizes main full bridge V-TMR parameters
  - The green line shows the deviation from pure linear characteristics over the complete operation range (< 0.15%, excellent for gradiometer designs)

TMR vortex sensor based advantages:	TMR	AMR	unit
Linear working range:	**±68**	**±8**	**mT**
Sensitivity S_V:	**20**	**1.33**	**V/T**
Full bridge resistance:	20	5	kΩ
Cross sensitivity:	**0.08**	**30**	**%**
Design area:	0.02	0.4	mm^2
SNR (NBW=10kHz):	112	85	dB
Fold-back	>200	~10	mT
White spectral noise density:	1	7.	nT/√Hz



Simplified Signal Flow ABS Wheel Speed Sensor

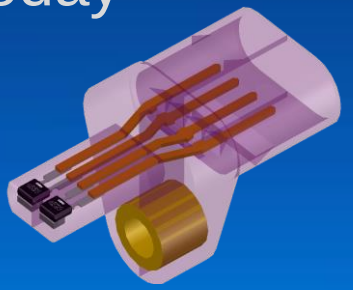


Failure Detection and Diagnostic

- Diagnostic features:
  - TMR bridge integrity via three channel comparison
  - ADC channel errors
  - Digital data path failure detection based on BISTand signal plausification
  - Oscillator frequency out of range detection
  - CRC error in the MTP
  - Parity error in the MTP
  - internal voltage failures
- ISO26262 support: diagnostic coverage for
  - missing/additional pulses ≤ 10 FIT
  - wrong (but valid) direction info ≤ 10 FIT
  - not signalized critical air gap reserve ≤ 10 FIT
- ASIL level B (D)

Future proof features

- Integrated TMR
  - ➔ higher robustness due to less bond connections
  - ➔ direct thermal coupling of MR and ASIC allows perfect temp compensation
- Extended temperature range -40° to 205° junction
- Linear response leads to outstanding Jitter <0.1%
  - ➔ iTPMS in a wide driving range
- Small formfactor enables redundant ABS in same formfactor as single today
- High resolution adding 3 additional pulses
  - ➔ movement accuracy of 5mm per individual tire



SUMMARY

Advanced sensing platforms and secure connections make self-driving cars a reality

- Robust sensors to sense the own movement (speed, steering engine)
- Functional safety at the highest level to guarantee correct data
- Compact sensor solutions based on optimum technologies
- Secure, high-performance communication
- Reliable and high quality production facilities → ABCD9 TMR

SECURE CONNECTIONS
FOR A SMARTER WORLD