Automotive Auxilliary Motor Drives from Semiconductor Perspective

Dr. D. Graovac, T. Liebetrau, T. Otter

PWR SOC 16

Infineon

Agenda

1. Introduction
2. Impact of Control Architecture
3. Motor Control Partitionings & System Examples

Agenda

1. Introduction
2. Impact of Control Architecture
3. Motor Control Partitionings & System Examples

ADAS, CO_2 reduction and adoption of premium features drive semiconductor growth

Vehicle production

- ~2% growth p.a.
- Further growth in Western Europe, China, and ASEAN
- Electro-mobility gaining momentum, especially in China

Drivers for semiconductor content per car

CO_2 reduction

- Driven by legislation
- Improvements of ICE (e.g. electric steering, electric pumps and motors)
- Adoption of EV/HEV

Advanced safety

- Current: crash avoidance
- Next: assisted driving
- Future: autonomous driving

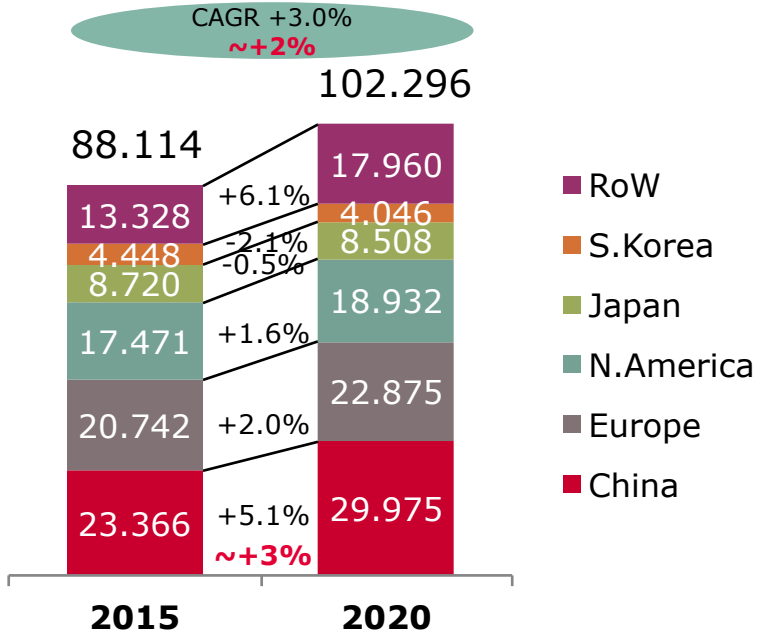
Comfort, premium

- Premium cars are early adopters of high-end comfort and safety features
- Trickling down to mid-range

~9% p.a. through-cycle growth

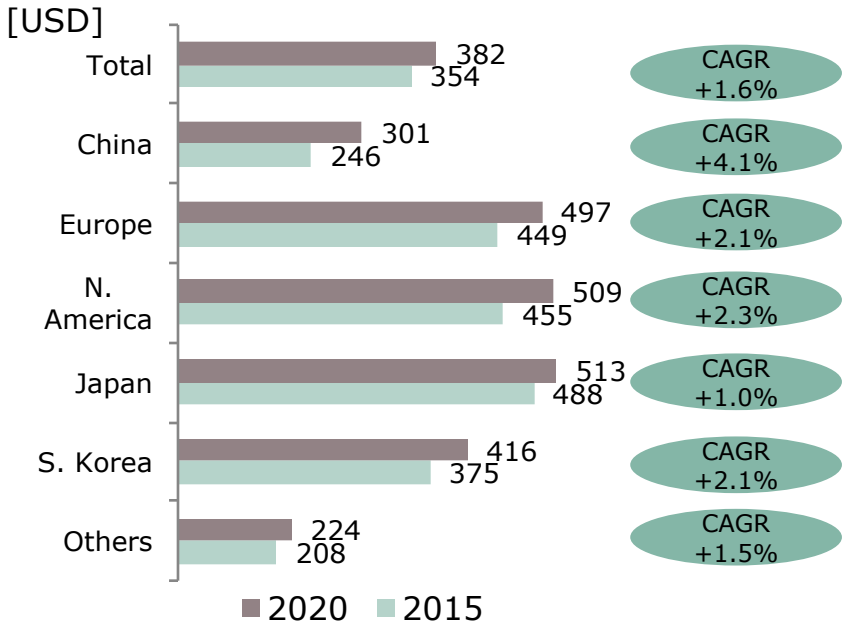
Market growth based on car production growth and increasing number of features

Light vehicle production forecast



Source: IHS, September 2015

Semiconductor value per car by region



Source: Strategy Analytics, based on LMC production forecasts Q1 2015

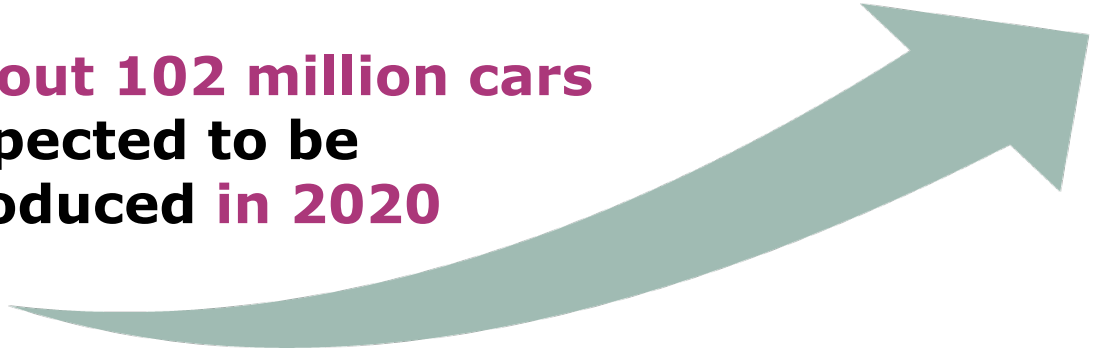
Market for electric motors in cars

~3.4 billion electric automotive motors in 2020

Unit CAGR of 5.7%

Average 33 motors per car

About 102 million cars expected to be produced in 2020



2.3 billion electric automotive motors in 2012

Approximately 68% were DC brushed and 15% were DC brushless

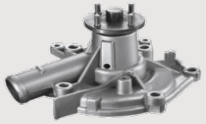
Average 28 motors per car

Source: IHS, "Electronic Motors in Automotive Applications - World - 2015"

CO2 reduction is not only xEV, but also possible through smart electrification of pumps and motors

Market trends

CO_2 reduction through motor electrification



Water pump (cooling)

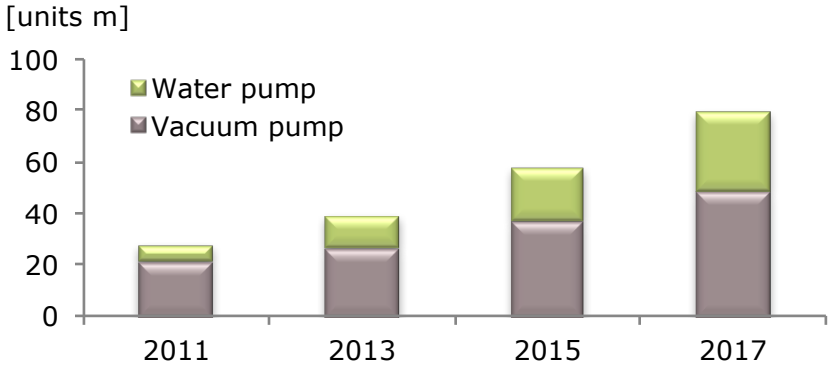
Saves ~4g CO_2/km

Vacuum pump (braking)

Saves ~1.5g CO_2/km

Source: Infineon estimates

Market forecast for motor electrification



Source: Strategy Analytics, worldwide market 2013

Infineon's system offering

Estimated water pump semi content: ~EUR 5-6

Microcontrollers

Bridge Drivers

MOSFETs

Power Supplies

Transceivers

Comments

Many motors are still on-off state driven while pumps are still belt-driven, thus always on. **Smart electrification** means pumps and motors are only activated on demand.

Application trend
Smart motor drive

1. Electrical motors replace mechanical solutions

Engine cooling fan

Source: Bosch
Product Page EC motor for Diesel thermal management

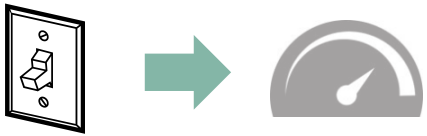
Electrical coolant pump

Source: KSPG Automotive, CWA 200
Pierburg product brochure

Park Brake

Source: Audi Q3

2. Dynamic DC motor control (PWM) improves efficiency, comfort, safety

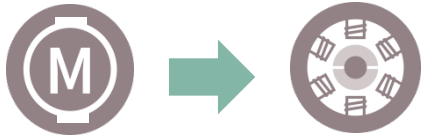


Sunroof

Window Lift

HVAC flap

3. Brushless DC (BLDC) motors for permanent loads enable higher reliability, less size, improved EMC



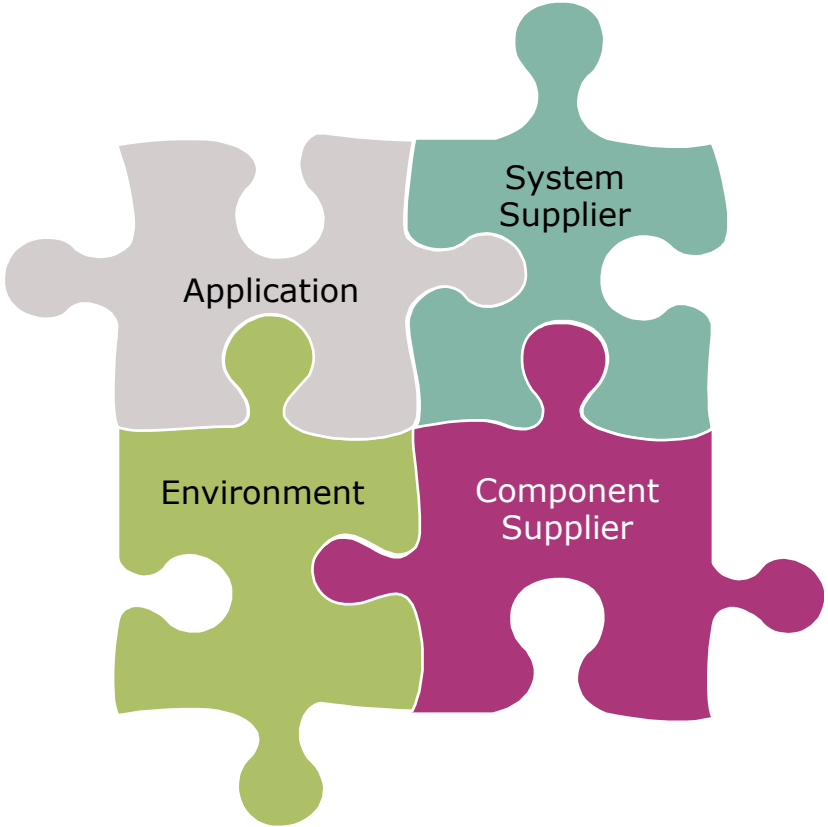
HVAC Blower

Source: Brose
Brose IAA 2013, Leightweight BLDC based

Fuel Pump

Solution comparison
Multi-dimensional criterias

- Power
- Voltage
- Size
- Weight
- Noise
- Efficiency
- Safety (ISO26262)
- etc.



- Development Resources
- SW Reuse (microcontroller)
- Second source
- etc.

- Temperature
- Specific conditions (cold start)
- Communication
- Car architecture
- etc.

- Technology roadmap
- Product portfolio
- Support ability
- etc.

Various users
Different constraints

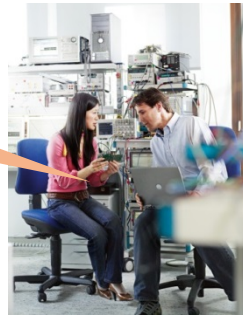
- I want to use my microcontroller platform.
- I need the cheapest BOM.

Purchasing driven

- I'm looking for integrated, ready-to-use systems.
- I do not want to invest into own electronic solution.

Preferring Turn Key

- I'm a looking for a special feature.
- I need to balance between development and BOM costs.



Technology focused

…and many more

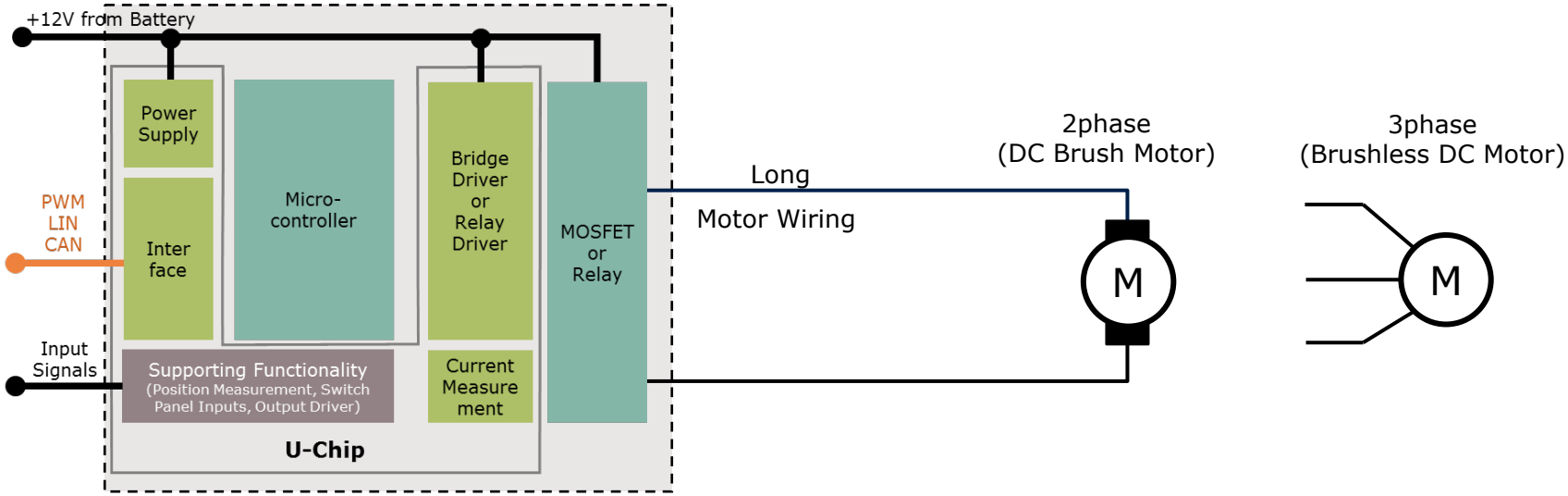
Drives applications vs. safety requirements

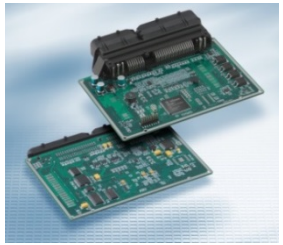
	Potential ASIL level	Small drives	Power drives
No or low safety requirements	ASIL QM ASIL A/B	Ventilation flaps Seat adjustment Headlight range adjustment Adaptive light functions	HVAC fan, engine cooling fan Fuel pump, oil pump, water pump Window lifts, sunroof, boot lid Windscreen wipers Seat belt pretensioners
High safety requirements	ASIL C/D	Steering wheel lock Power braking Clutch and gearbox actuators	Parking brake Stop-start and hybrid drives Electric power steering

Agenda

1. Introduction
2. Impact of Control Architecture
3. Motor Control Partitionings & System Examples

Motor control using remote electronics

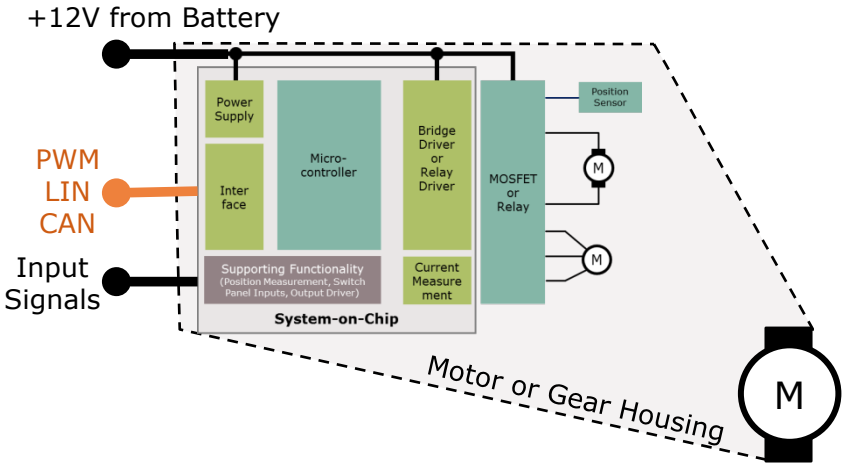


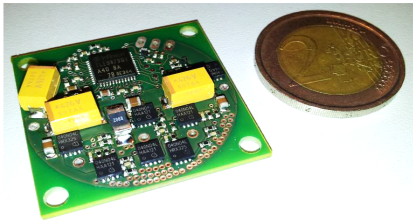


Generic ECU

Fuel Pump (DC motor)

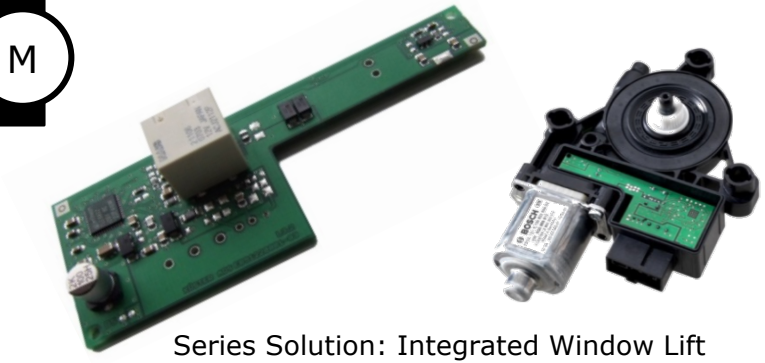
Integrated Motor Control
Into Motor or Gear Housing





Infineon Demonstrator Board
Full Integration into motor housing

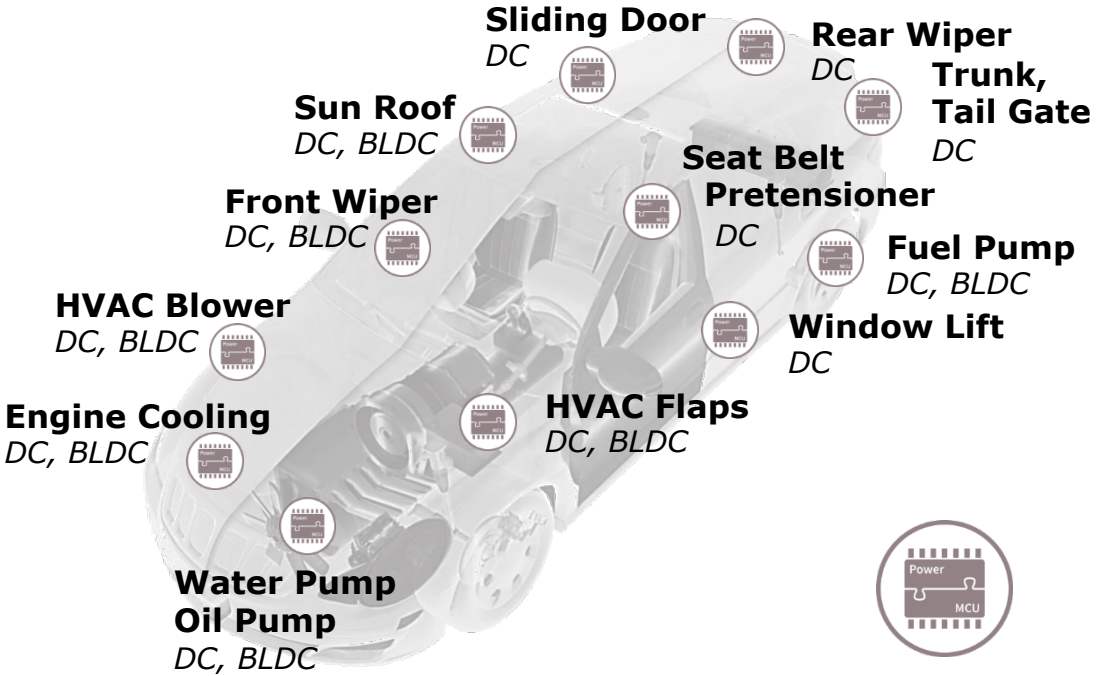
BLDC Motor



Series Solution: Integrated Window Lift
Source: Küster ADS GmbH http://www.kuester.net

Window Lift

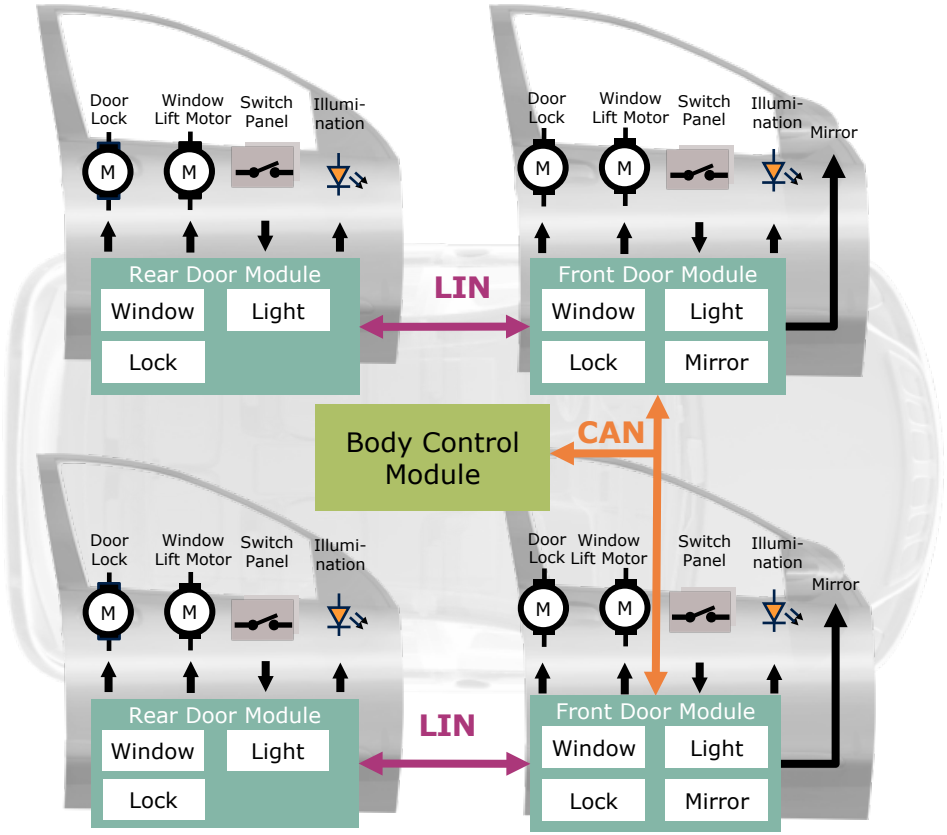
Examples of Distributed Motor Applications



Benefits of distributed motor intelligence

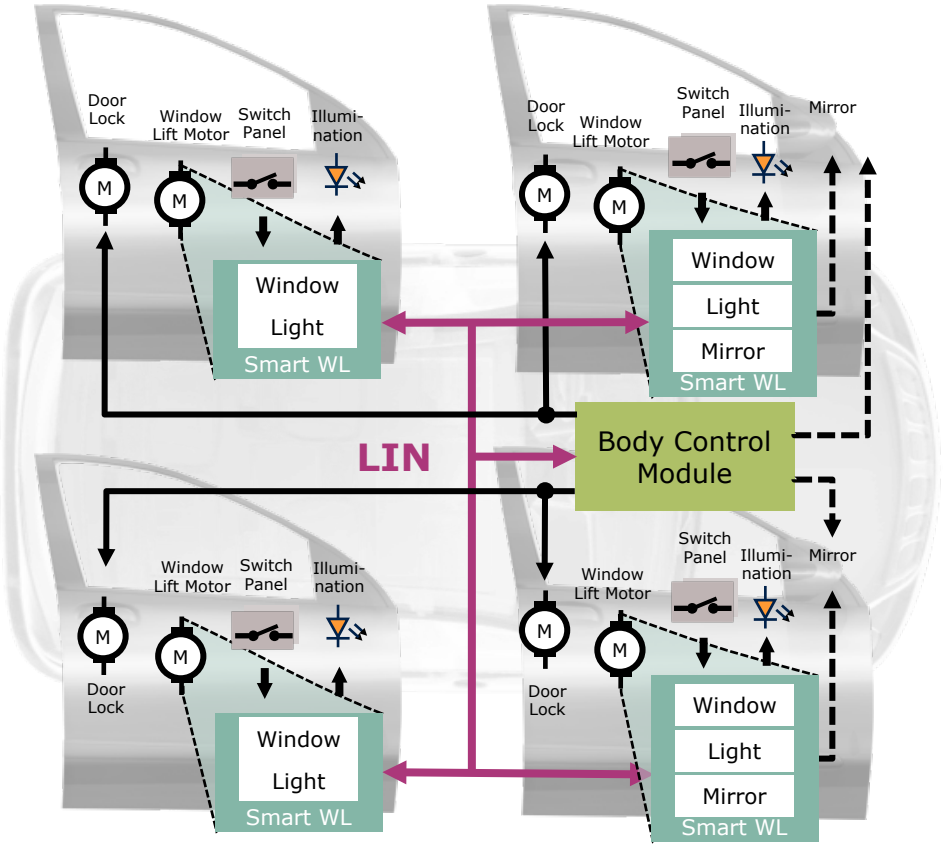
- Minimized wiring
- Reduced weight/space
- Reduced overhead/complexity for options
- Distributed computing power
- Improved diagnostics
- Balanced power dissipation
- Improved EMC performance
- Standardized and low-cost physical layer/protocol handler

Example: Door module architecture
Centralized electronics – central door module ECU



- Low wiring effort
- Low scalability
- Optimized for full featured door electronics
- Premium cars

Example: Door module architecture
Smart WL architecture – Motor integrated electronics



- Cheap bus system
- High Scalability

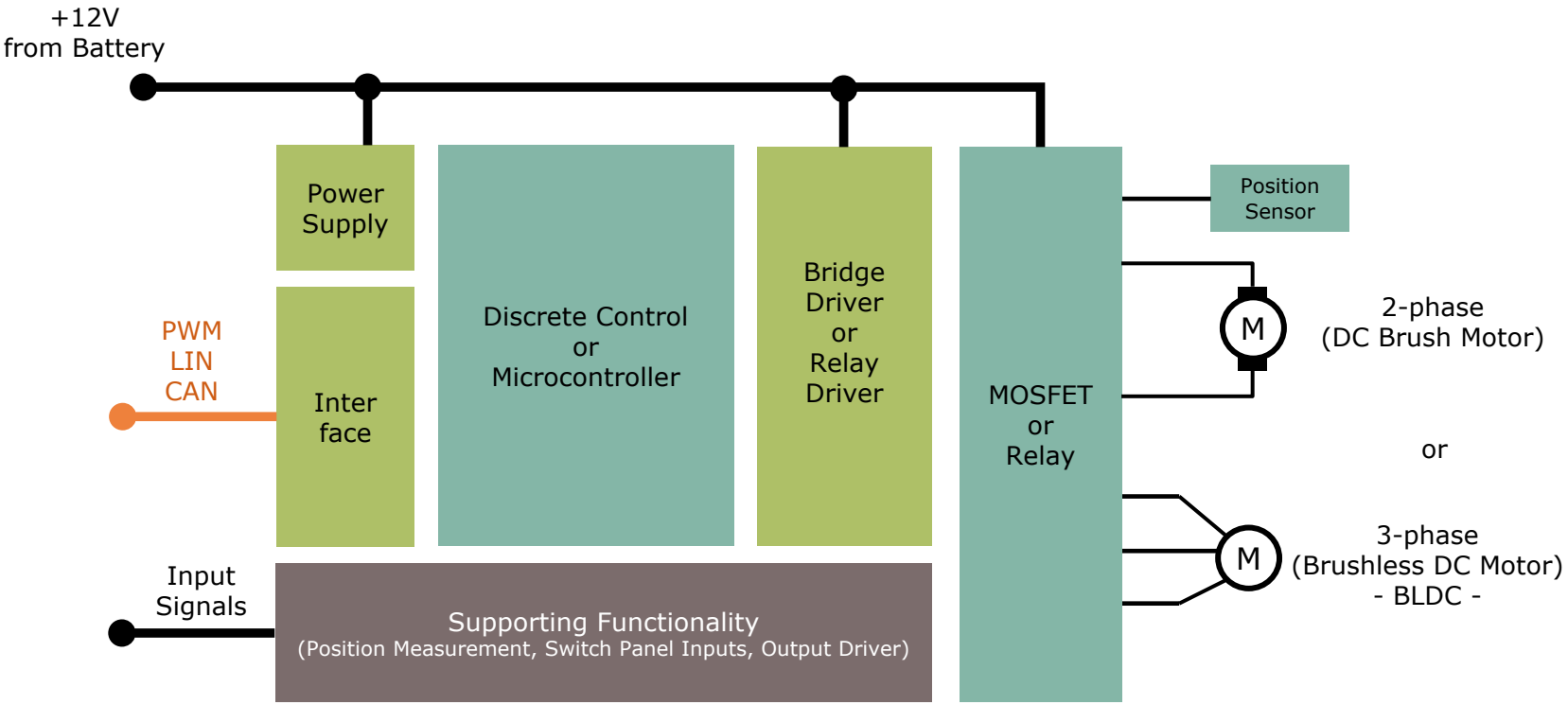
- Higher wiring effort

- Limited capability for sophisticated options
- Global car platforms

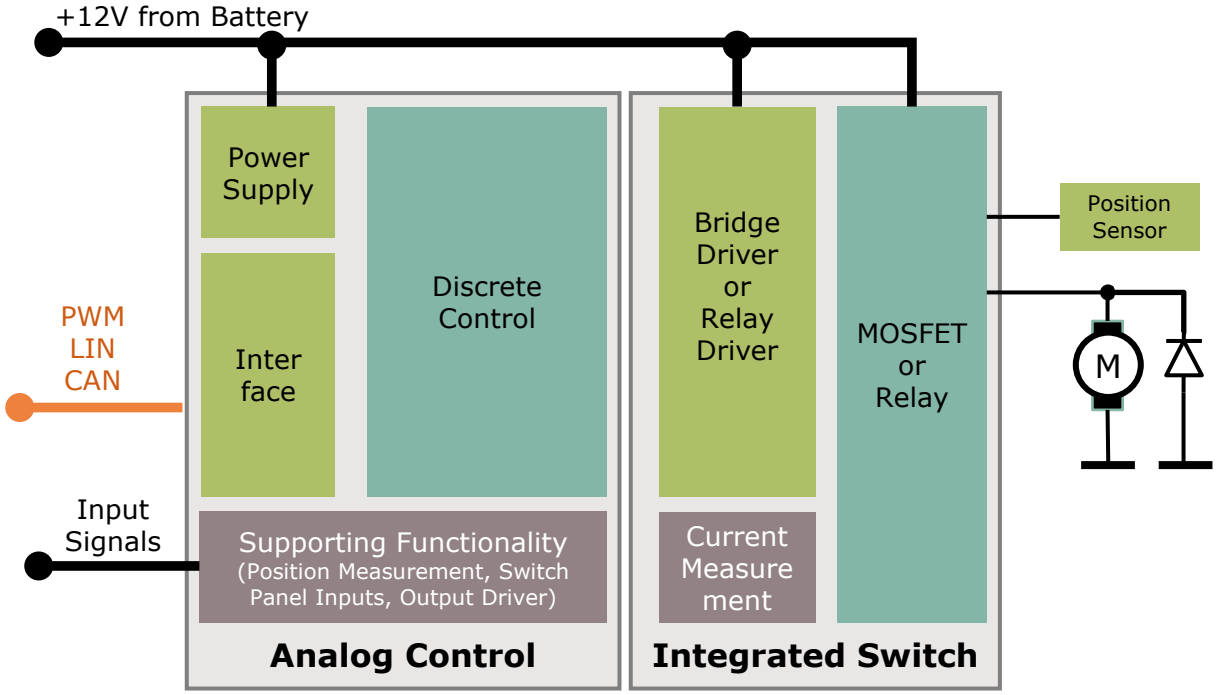
Agenda

1. Introduction
2. Impact of Control Architecture
3. Motor Control Partitionings & System Examples

Motor control
Generic block diagram



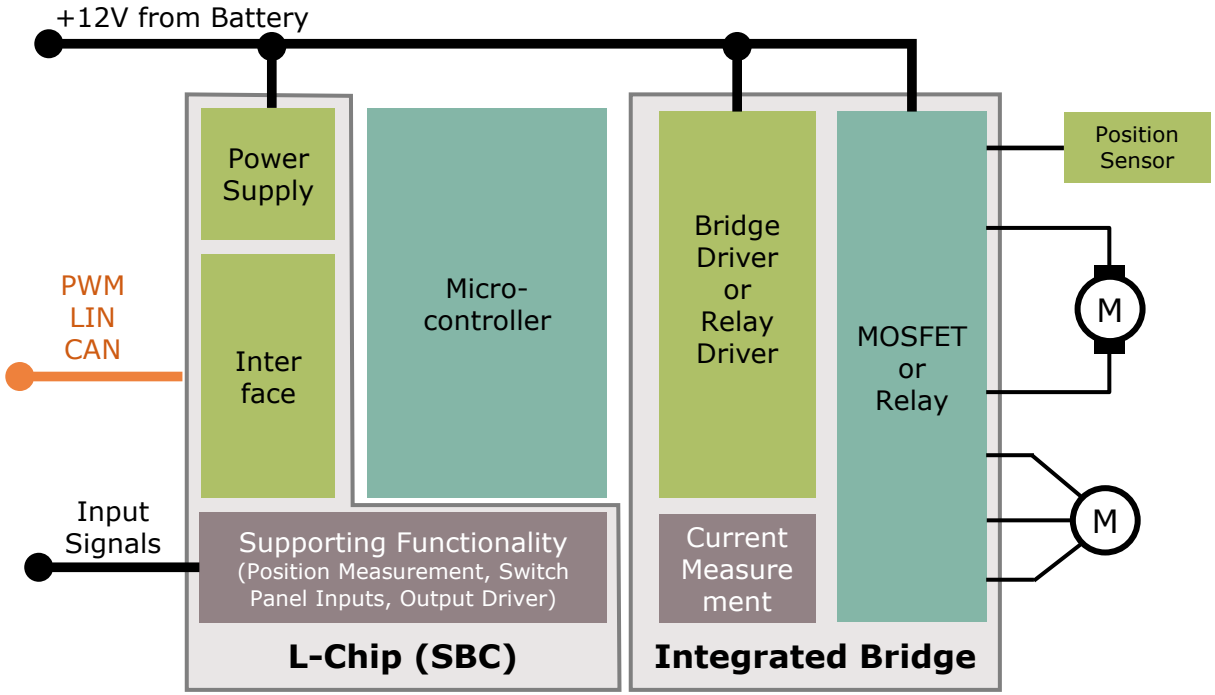
Motor control
Various chip integration levels



- Low development effort
- Simple design
- No software
- Discrete control scheme
- Integrated Switch with incorporated protection concept

Simple unidirectional motor drive (fans, blowers)

Motor control
Various chip integration levels

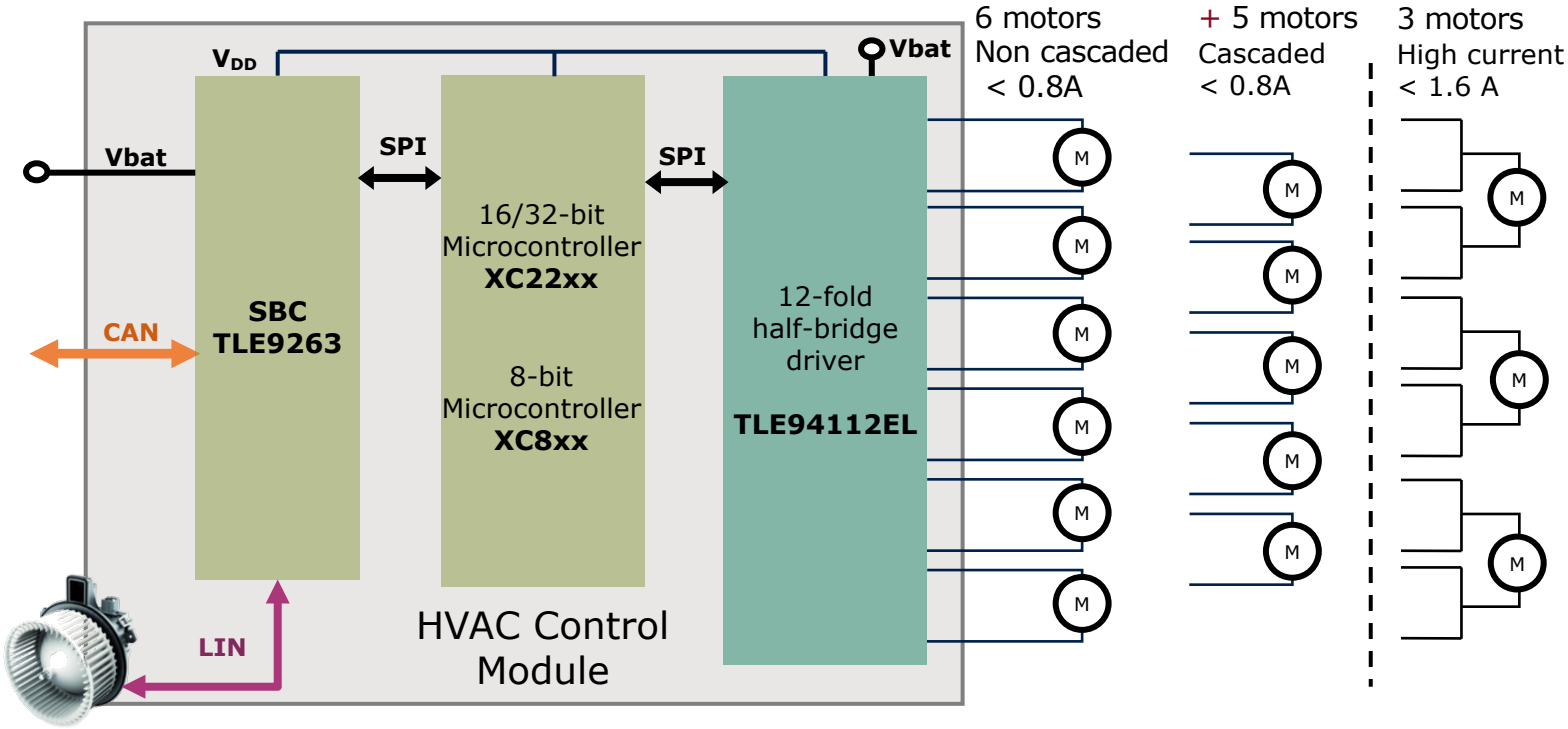


- Low development effort
- Free micro-controller choice
- Software flexibility
- Integrated motor full-/half-bridge with incorporated protection concept
- SBC with supply and bus interface

Small uni- and bidirectional drives

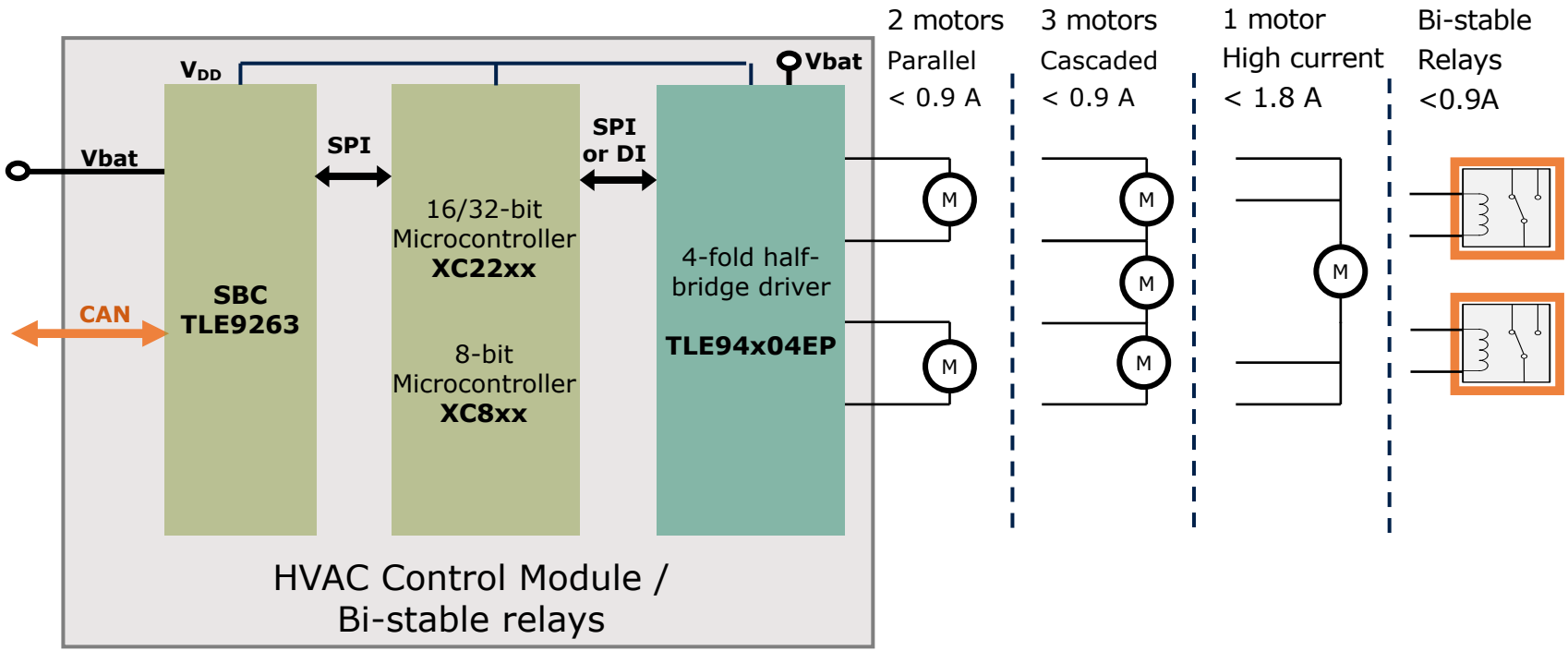
Application example
HVAC control module

Example with 12-fold half-bridge for 6, 11 or 3 motors

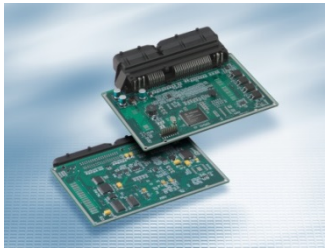


Application example
HVAC control module

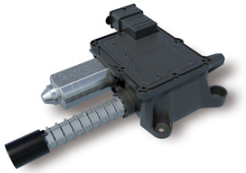
2/3 Flap System or 1 High Current Motor or 2 bi-stable relays



Electrical parking brake
Safe and easy to design with integrated half bridge

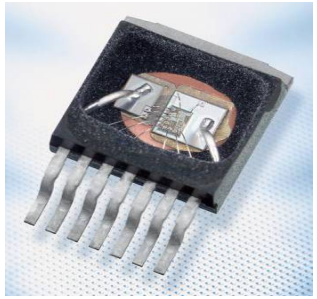


Generic ECU



Source: Brose
[Product Webpage Electric Parking Brake]

NovalithIC™
½-Bridge system in a package

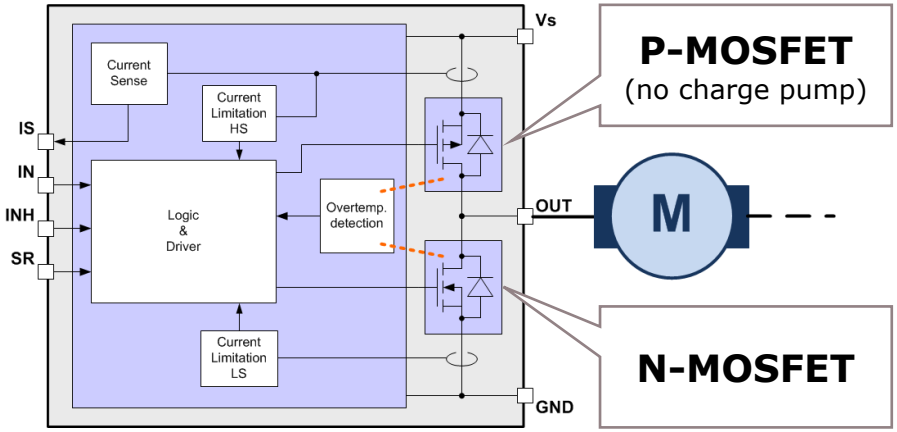


$R_{DS,on\text{-}path}$ = 10mΩ

@ 25°C (typ.)

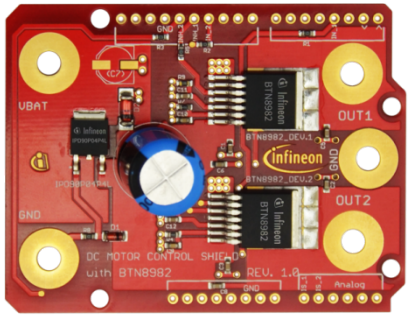
BTN8982

http://www.infineon.com/novalithic
http://www.infineon.com/trilithic



- Integrated Current Sense
- Low Emission (EMC)
- Current Limitation and Temperature Protection

Motor control shield with BTN8982 for Arduino



DC Motor Control Shield for Arduino

XMC1100 Boot Kit

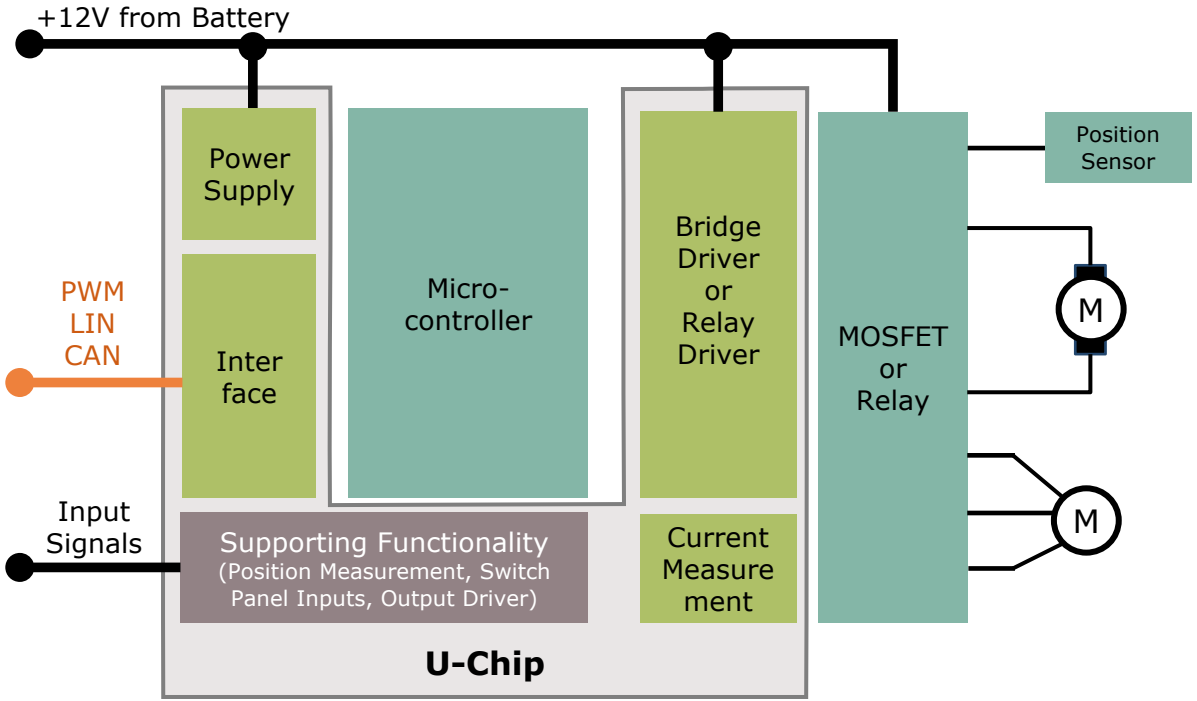
Power Shield for Arduino with 2x BTN8982 Half-Bridge NovalithIC™ drives

- Two uni-directional Brushed DC Motors, or
- One bi-directional Brushed DC Motor in an H-Bridge configuration
- Compatible with the Infineon XMC1100 Boot Kit

Benefits

- Easy & low cost evaluation & test of Infineon Motor Control Solution
- Professional support from the huge Arduino Open Source Community
- Software Examples for Arduino Uno and XMC1100 Boot-Kit (DAVE™)

Motor control
Various chip integration levels



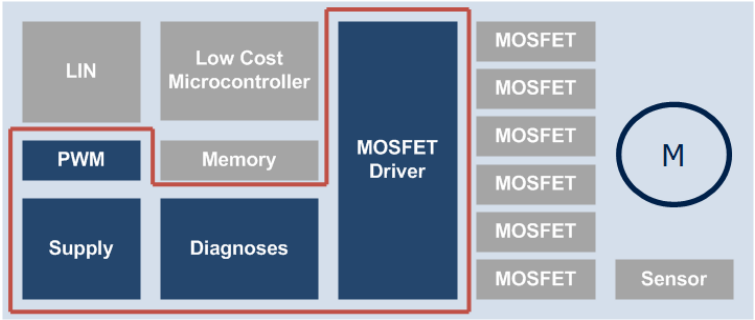
- High integration level
- Free micro-controller choice
- Software flexibility
- Given U-chip feature set
- Less current limitation

All applications

De-centralized motor control electronics
U-chip TLE7184/86

Key Feature

- Integrated N-Channel MOSFET Driver
- PWM interface
- Voltage supply for µC



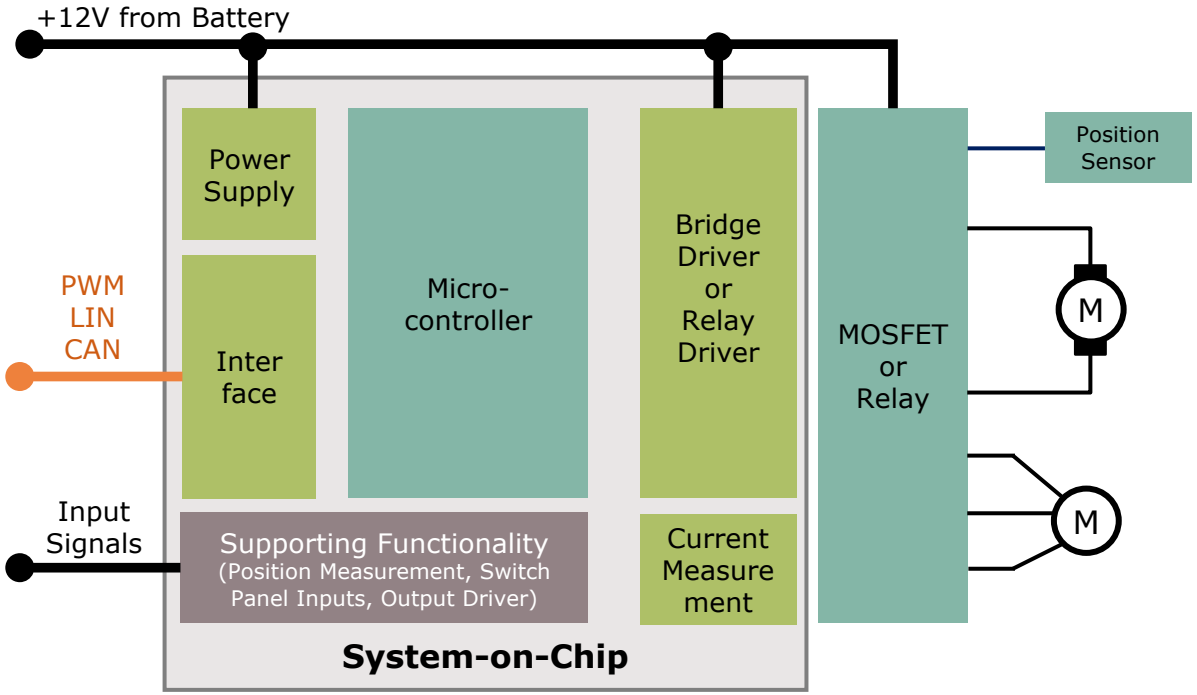
Main Benefit

- Well known at customers
- Optimized system cost for applications with PWM interface (without LIN)

U - Chip

TLE7184/86

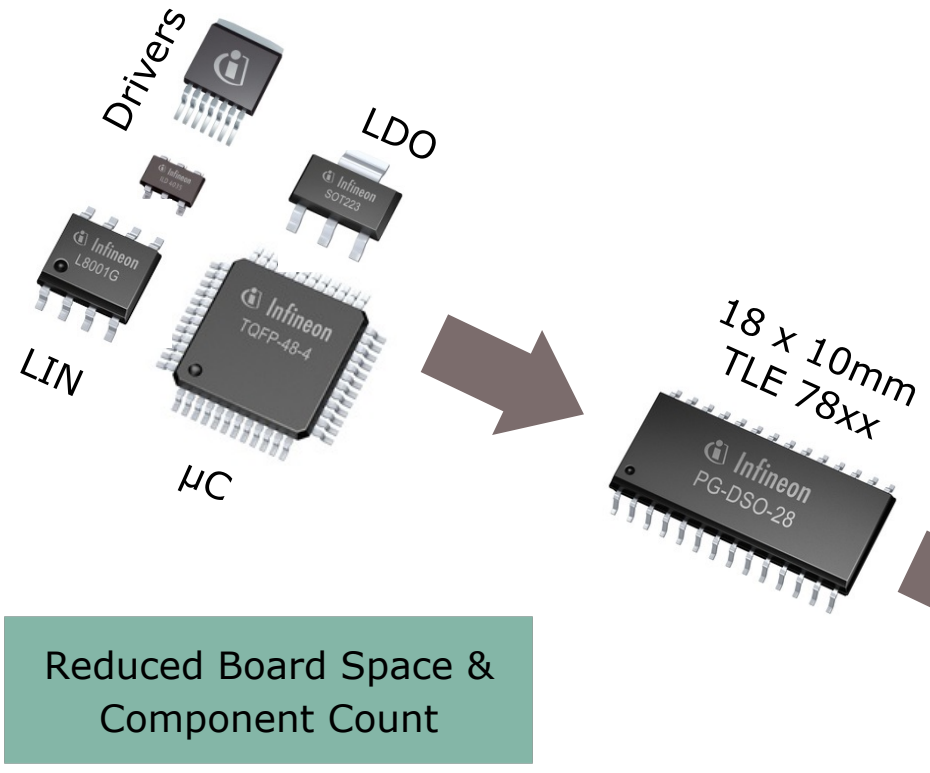
Motor control
Various chip integration levels



- Least internal wiring effort
- Least components
- Smallest installation space
- Given microcontroller
- Dedicated bus interfaces
- Less current limitation

Designed for specific applications, expanding scope

Infineon® embedded power – system on chip solutions
Integration & flexibility



- Standard CPU
- Smaller footprint
- System cost reduction
- Customer Microcontroller Strategy
- Software Migration Effort

Reduced Board Space & Component Count

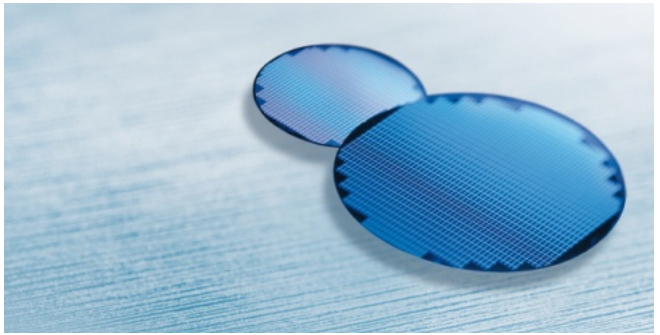
Infineon® embedded power IC: 3rd generation based on Industry standard ARM µC

Standard µC core

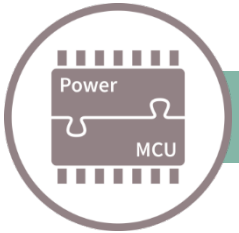
ARM®

32-bit ARM® Cortex™-M3

Leading edge automotive qualified technology

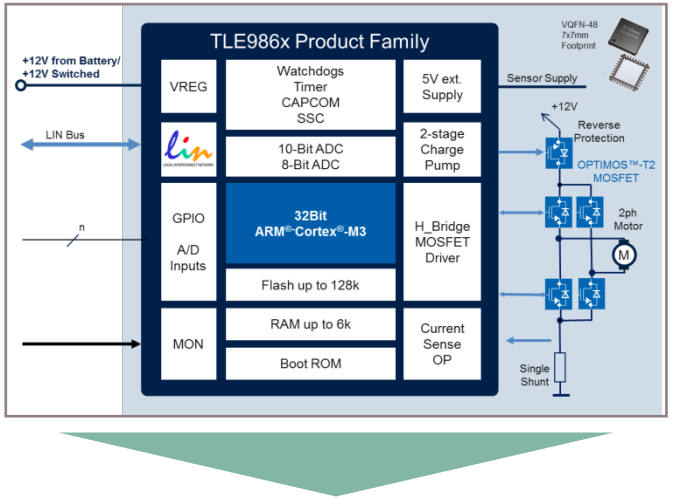


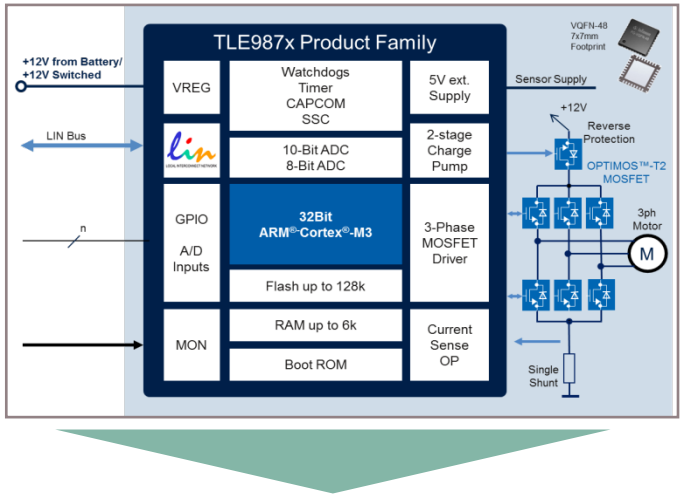
Integrated on Infineon 130nm BCD process

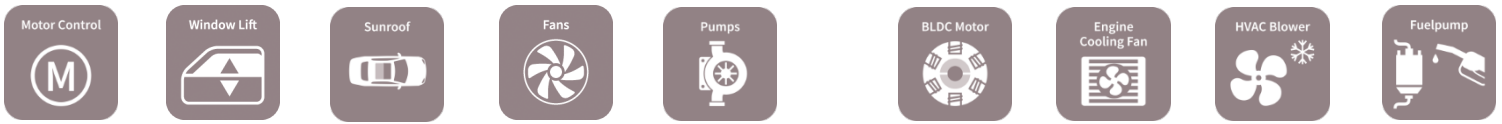


Intelligence and Power on a single die

One Product Family for DC and Brushless DC Motor Control







Further motor applications

TLE986x and TLE987x key features
Inspired by automotive target applications

Target Application Fields

- High-End Sunroof
- Power Window Lift
- Advanced H-Bridge DC Motor Control
- Pumps
- Blowers
- 3-Phase Motor control



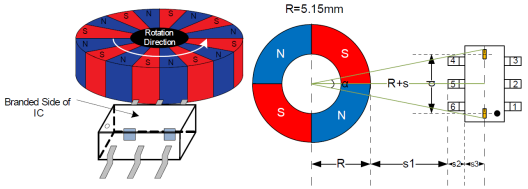

Key Features

- ARM® **Cortex™-M3 processor**, 24/40MHz
- Enables **field oriented** motor control
- Scalable **Flash** memory: **36kB to 128kB**
- Current programmable **NFET driver**
  - optimized **EMC behavior**
  - **Scalable** MOSFET driver
- **Integrated PWM/LIN transceiver** compatible with LIN standard 2.x and SAE J2602-supports fast programming via LIN
- 10-Bit SAR ADC for current sensing **synchronized** with the internal **PWM signal generation** unit
- Wide Operating Range, **Vs=5.4V to 28V**

TLE4966V-1K for speed & direction
Vertical sensing

Window Lifter

Power Closing Systems



Automotive qualified

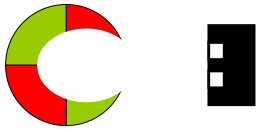
Key Features

- Vertical Hall for In-Plane Sensing – sensor can be mounted parallel to magnetic encoder Direction Detection
- Index Counting
- 3.5V to 32V operating supply voltage
- Overvoltage capability up to 42V without external resistor
- Over current and over temperature protection
- Low jitter (typ. 0.3us)
- SMD package PG-TSOP6-6-5
- ESD (HBM): 2kV, 6kV (ISO10605)

K-package:
PG-TSOP6

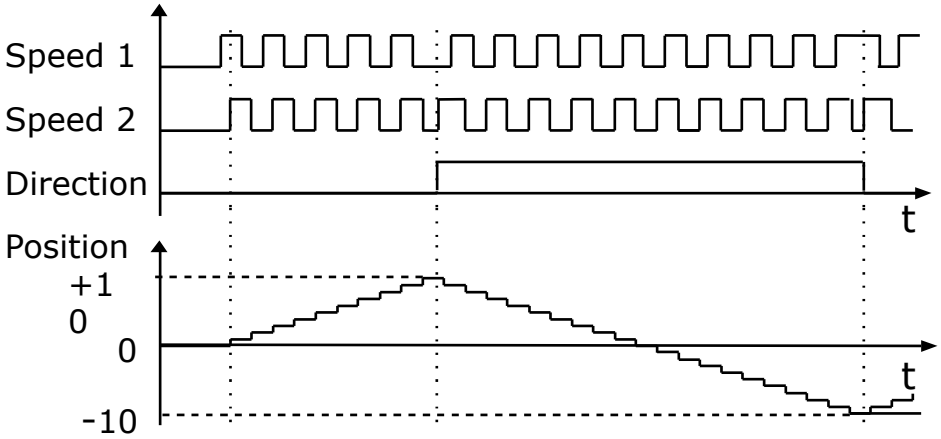
Index counting with the TLE4966 family

2 Sensing elements are used



TLE4966 double Hall sensors

combine 2 sensing elements in one sensor



Index counting for Power Closing Systems

Window Lifter

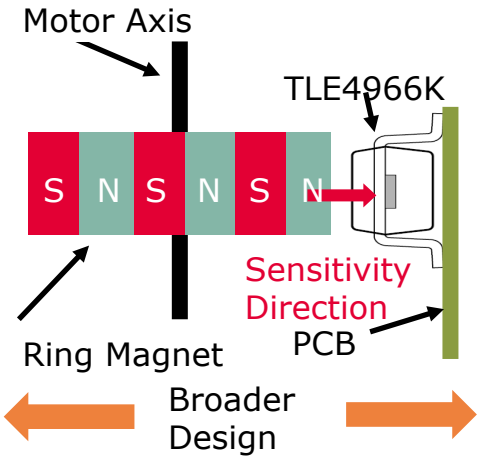
Sunroof

Electronic Doors

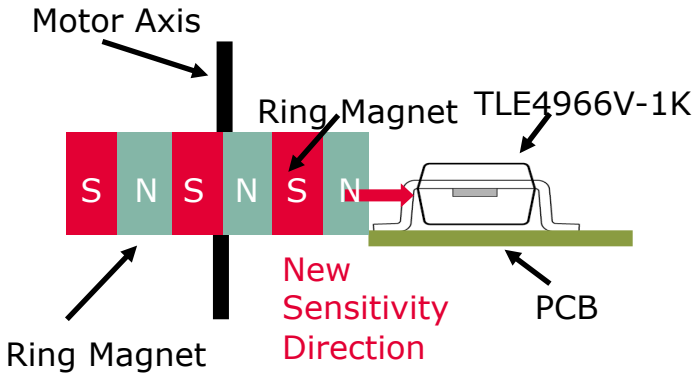
Trunk Power Closing

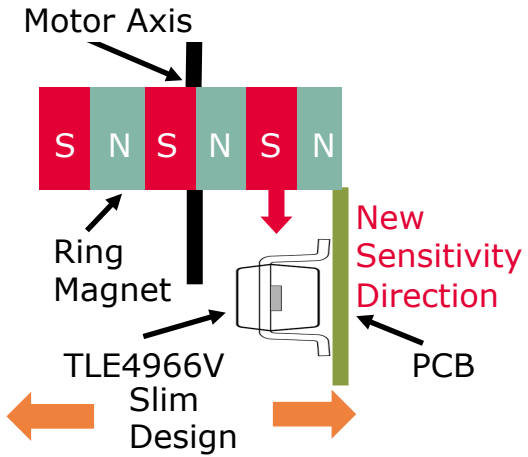
Vertical hall elements in TLE4966V-1K – open up new design flexibilities

Established Concept
– using TLE4966K



Vertical measurement Concept
– with TLE4966V

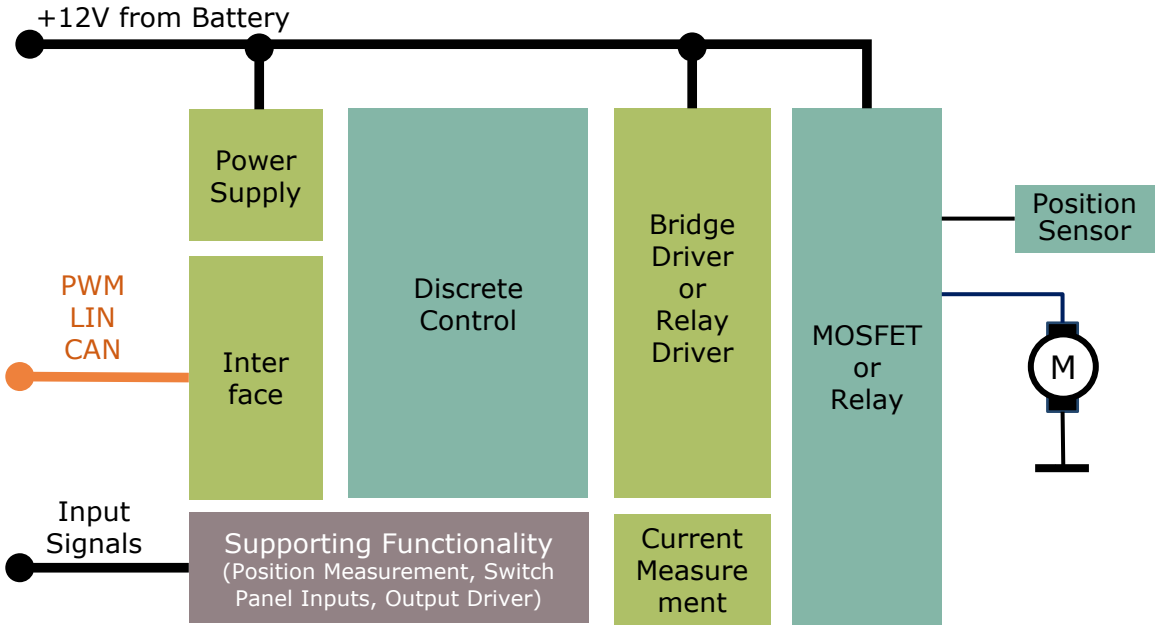




The new vertical measurement principle:

- saves space
- easy mounting of sensor and PCB board
- allows for more mounting flexibility
- enables new, compact systems designs

Motor control
Various chip integration levels

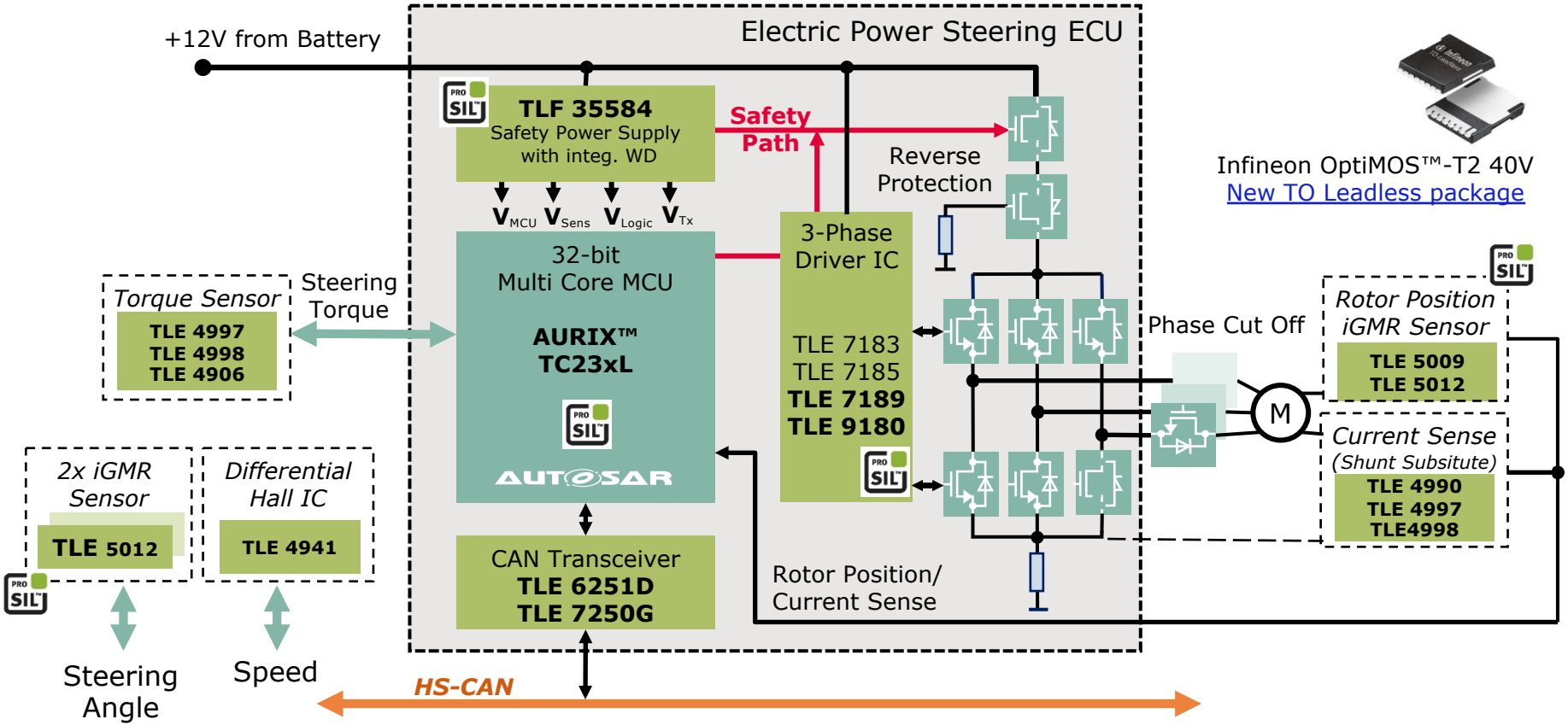


- Additional safety measures
- High Power

- Full Discrete Approach
- Shared functionality

Safety Applications

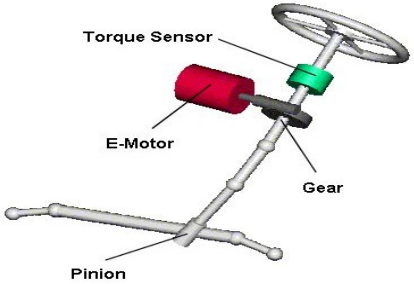
Electric power steering
High safety level using discrete components



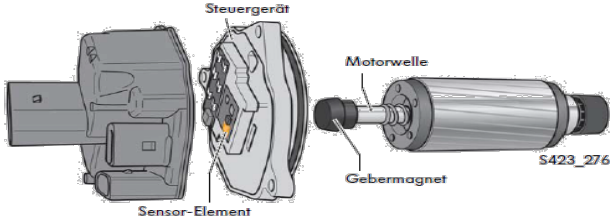
Infineon OptiMOS™-T2 40V
New TO Leadless package

Fail operational actuators for automated/autonomous driving
BOM to grow by factor 1,3 with Level 3-5

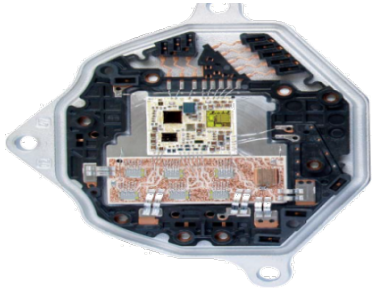
EPS System



EPS E-Motor



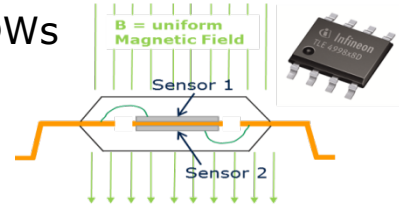
EPS Electronic Control Unit



© ZF Lenksysteme

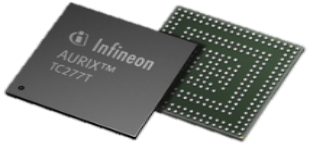
Sense

DWs

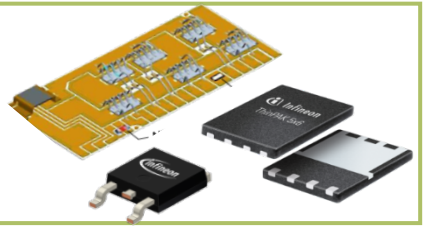


Compute

-> 20%

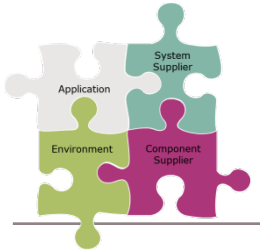


Actuate



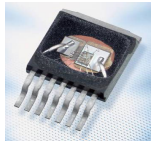
Safe Power Supply

Summary



Diverse Range of technical & economic constraints
lead to high variety of solutions and dedicated products

Functional integration of electronics into specific devices
due to cost and size reduction



Integrated motor bridges provide safe solution,
simple to use at low development effort

Discrete solution using best-in-class MOSFETs
for larger currents and high safety functionality

Summary
Comparison chart

	Micro-controller + Bridge Driver + MOSFET	Micro-controller + Integrated Motor Bridge	Embedded Power + MOSFET
Current	★★★	★	★★
Protection	★★	★★★	★★
Space	★	★★	★★★
Flexibility	★★★	★★	★
Benefits	Higher Ambient Temperatures	Low Development Effort	Least Wiring Smallest Space
Applications	All applications	Small uni- and bipolar drives	Motor Integrated Drives

Part of your life. Part of tomorrow.

Infineon