SMART ACTUATORS:

ENABLING AUTONOMOUS VEHICLES

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STRATEGY & BUSINESS DEVELOPMENT
BUSINESS LINE ADVANCED AUTOMOTIVE ANALOG

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NXP

SECURE CONNECTIONS
FOR A SMARTER WORLD

AGENDA

- The Autonomous Car of the Future
- Safety and Power Management
- Smart Actuators: Overview
- Battery Management
- Gate Drivers
- Solenoid Drivers
- Conclusion
- Q&A

01.
The Autonomous Car of the Future

Cars today …

- Safe
- Reliable
- Dynamic/Sporty ⇔ Family Van
- Personal

… The Individual Joy of Riding

Your Car tomorrow

- Your personal moving space

- Tailored to your preferences

- Transports you autonomously

- Seamlessly connected

- Energy efficient at low/no carbon footprint

wordlesstech.com

Autonomos Cars:
Robots on wheels

- A **robot** is a machine — especially one programmable by a computer — capable of carrying out a complex series of actions automatically.[2] Robots can be guided by an external control device or the control may be embedded within.

- Robots can be autonomous or semi-autonomous and range from humanoids, to industrial, or medical operating robots, UAV drones and more

- By mimicking a lifelike appearance or automating movements, a robot may convey a sense of intelligence or thought of its own.

Autonomos Cars: Robots on wheels

Sense:
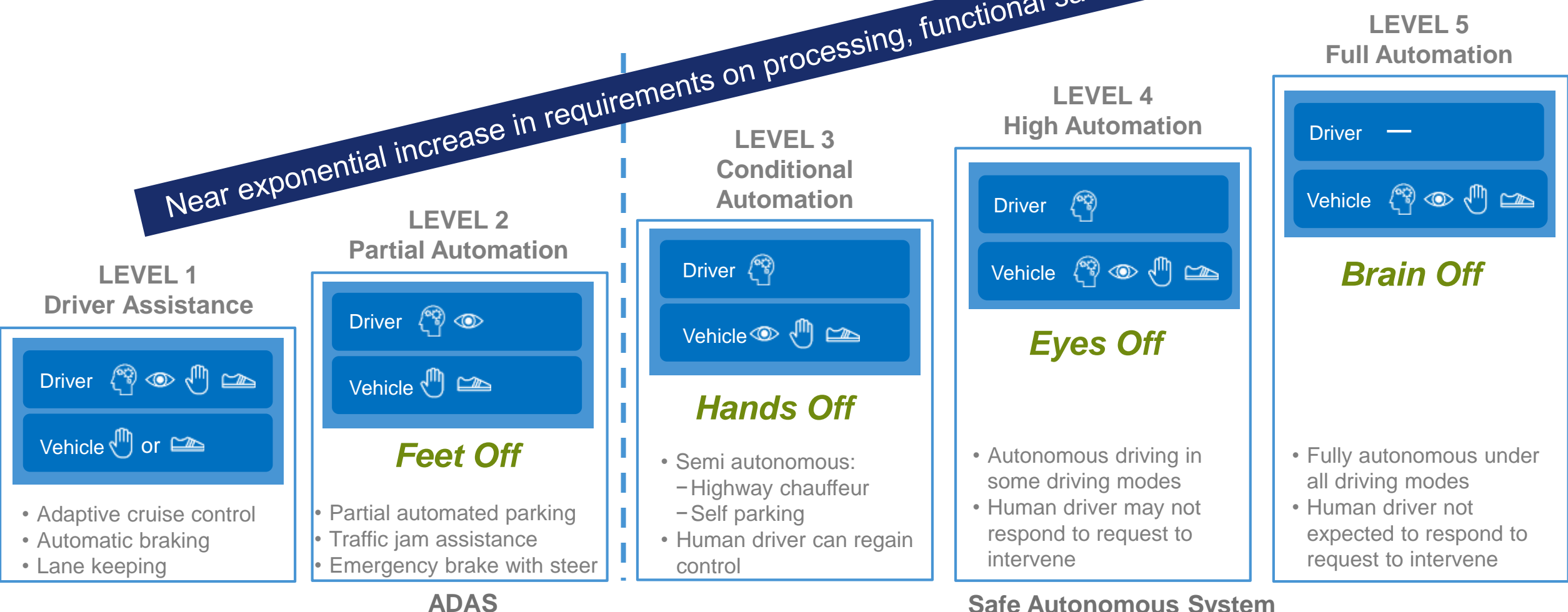- Translate analog world into digital data

Think:
- Process/aggegate/calculate digital data
- decide on arithmetic rules or advanced algorithms (AI)

Act:
- translate the „digital" decision back into the analog world

Autonomous Drive: Definitions

Near exponential increase in requirements on processing, functional safety and reliability

LEVEL 1
Driver Assistance

Driver

Vehicle ✋ or 👟

- Adaptive cruise control
- Automatic braking
- Lane keeping

LEVEL 2
Partial Automation

Driver

Vehicle

Feet Off

- Partial automated parking
- Traffic jam assistance
- Emergency brake with steer

ADAS

LEVEL 3
Conditional Automation

Driver

Vehicle

Hands Off

- Semi autonomous:
  − Highway chauffeur
  − Self parking
- Human driver can regain control

LEVEL 4
High Automation

Driver

Vehicle

Eyes Off

- Autonomous driving in some driving modes
- Human driver may not respond to request to intervene

LEVEL 5
Full Automation

Driver —

Vehicle

Brain Off

- Fully autonomous under all driving modes
- Human driver not expected to respond to request to intervene

Safe Autonomous System

Responsibility for safe operation   Control of complete vehicle   Control of steering   Control of vehicle speed

ADAS to Increase Safety, Reduce Road Fatalities

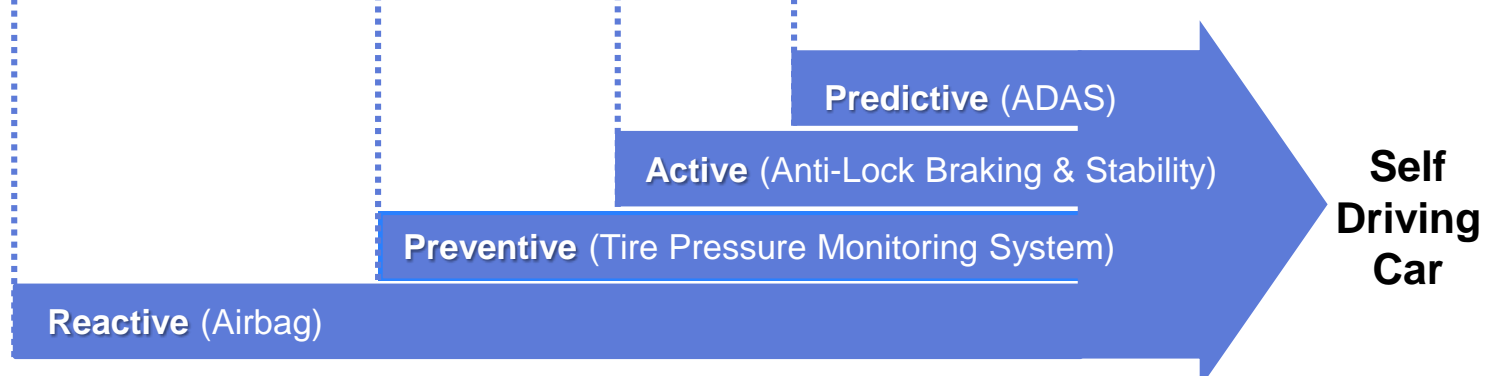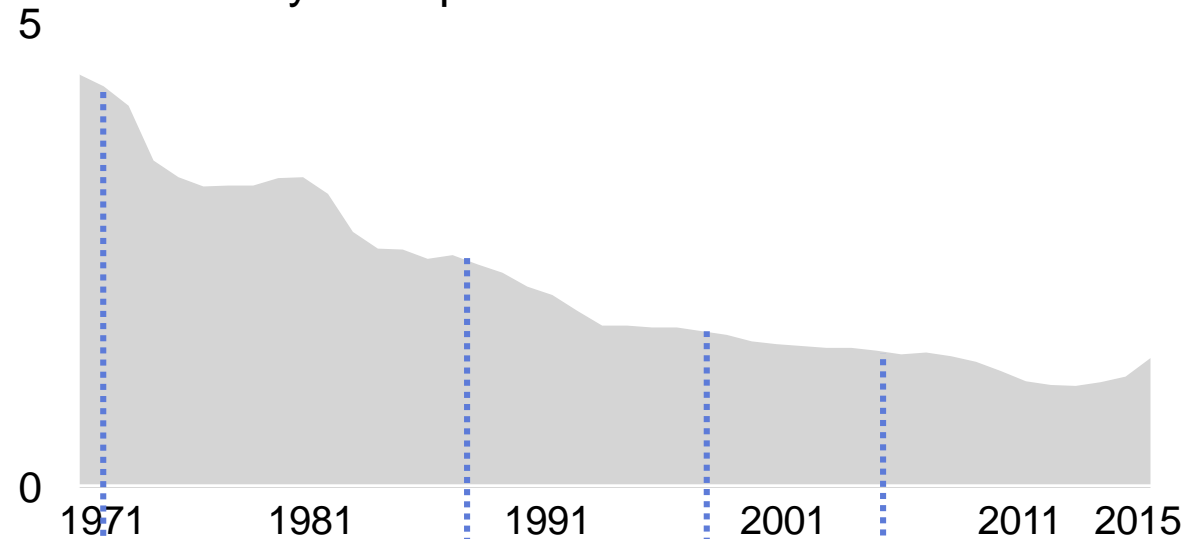## Safety: crucial for autonomous car

Safety, quality & reliability at the heart of automotive engineering

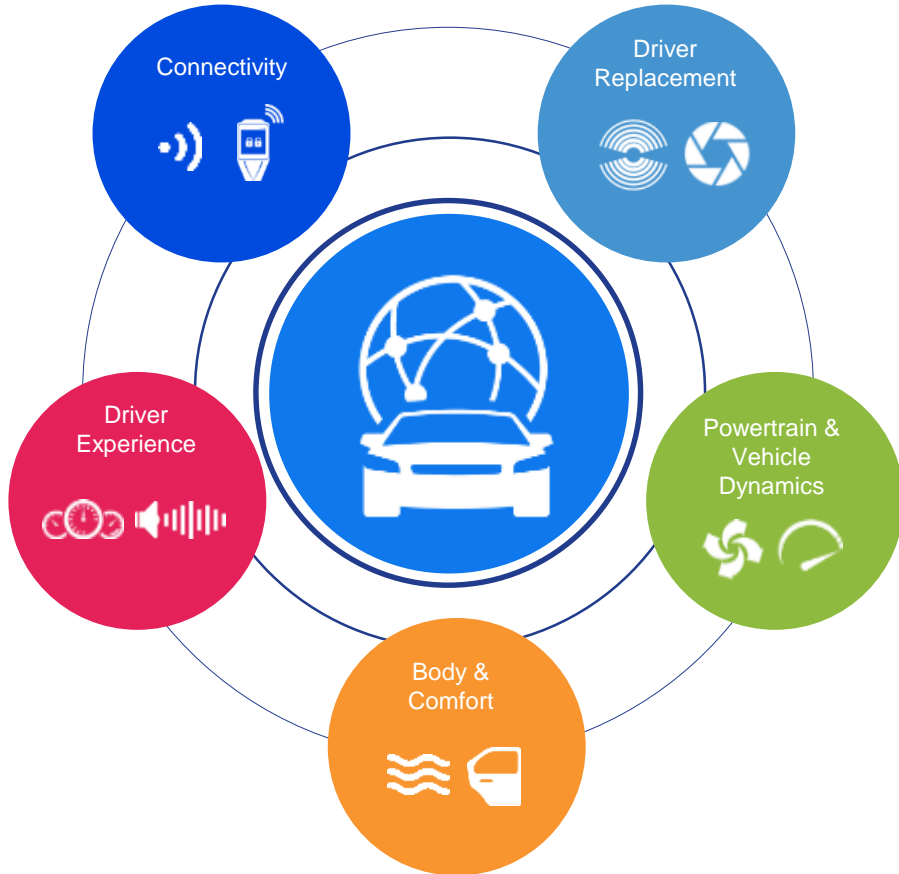Trusted technology and functional safety track-record essential

Safety system adoption accelerated by mandates & NCAP ratings

ADAS needed to reverse recent increase in fatality rate (texting)

US Fatality Rate per 100-Million Vehicle Miles Traveled

5

0

1971   1981   1991   2001   2011   2015

Predictive (ADAS)

Active (Anti-Lock Braking & Stability)

Preventive (Tire Pressure Monitoring System)

Reactive (Airbag)

Self Driving Car

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Domain Based Architectures

Domain	Product Offer
Connectivity	Smart Antenna, Secure Car Access, V2X, Broadcast Reception
Driver Replacement	Radar, Vision, Lidar Autonomy & Fusion Processors
Powertrain and Vehicle Dynamics	Engine Control Battery Management Electronic Stability Control, Braking Motion & Speed sensing
Body & Comfort	Smart Lighting, AirCon, Passive Safety Seat Control, …
Driver Experience	Multimedia Processing Audio Processing

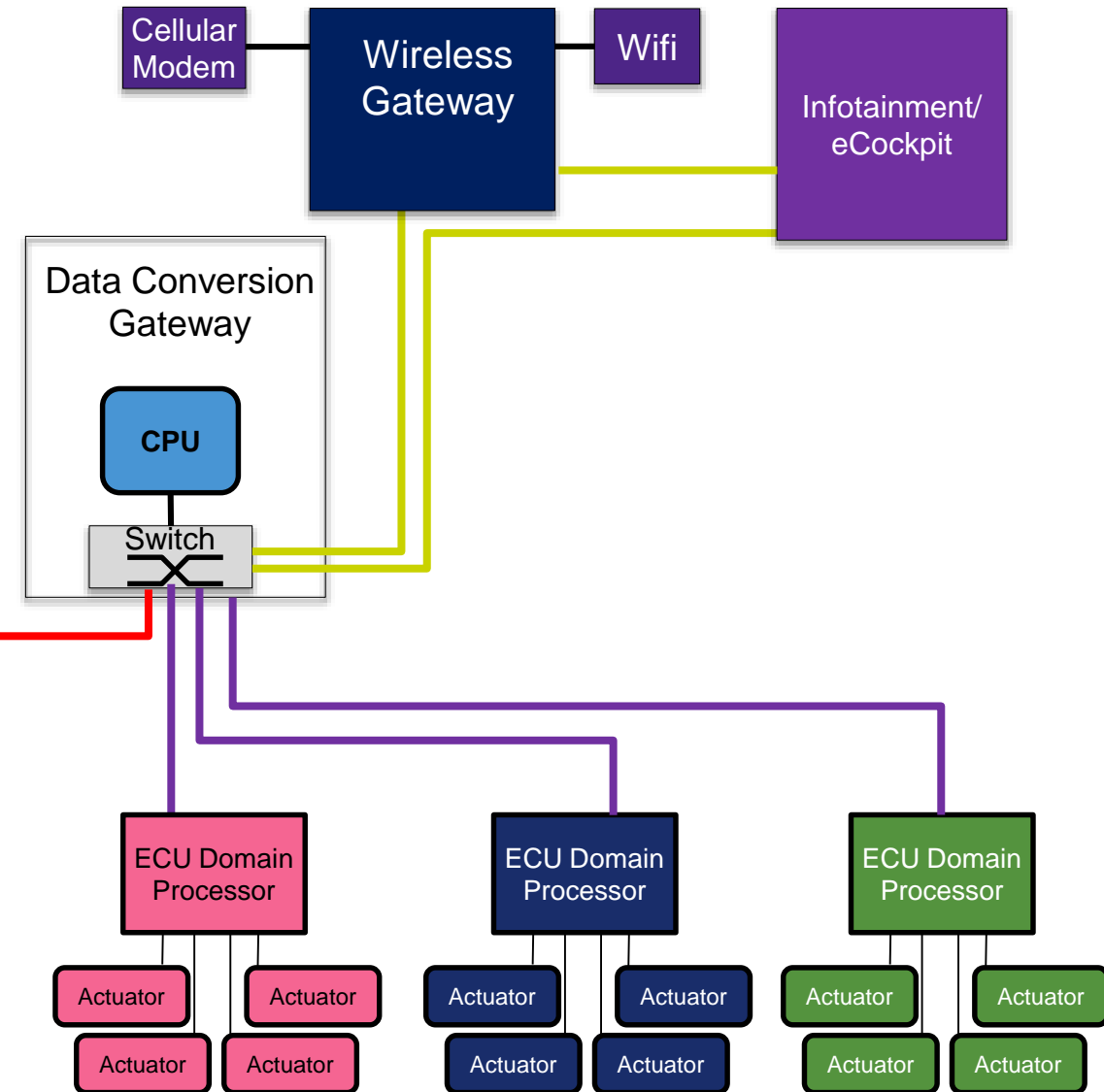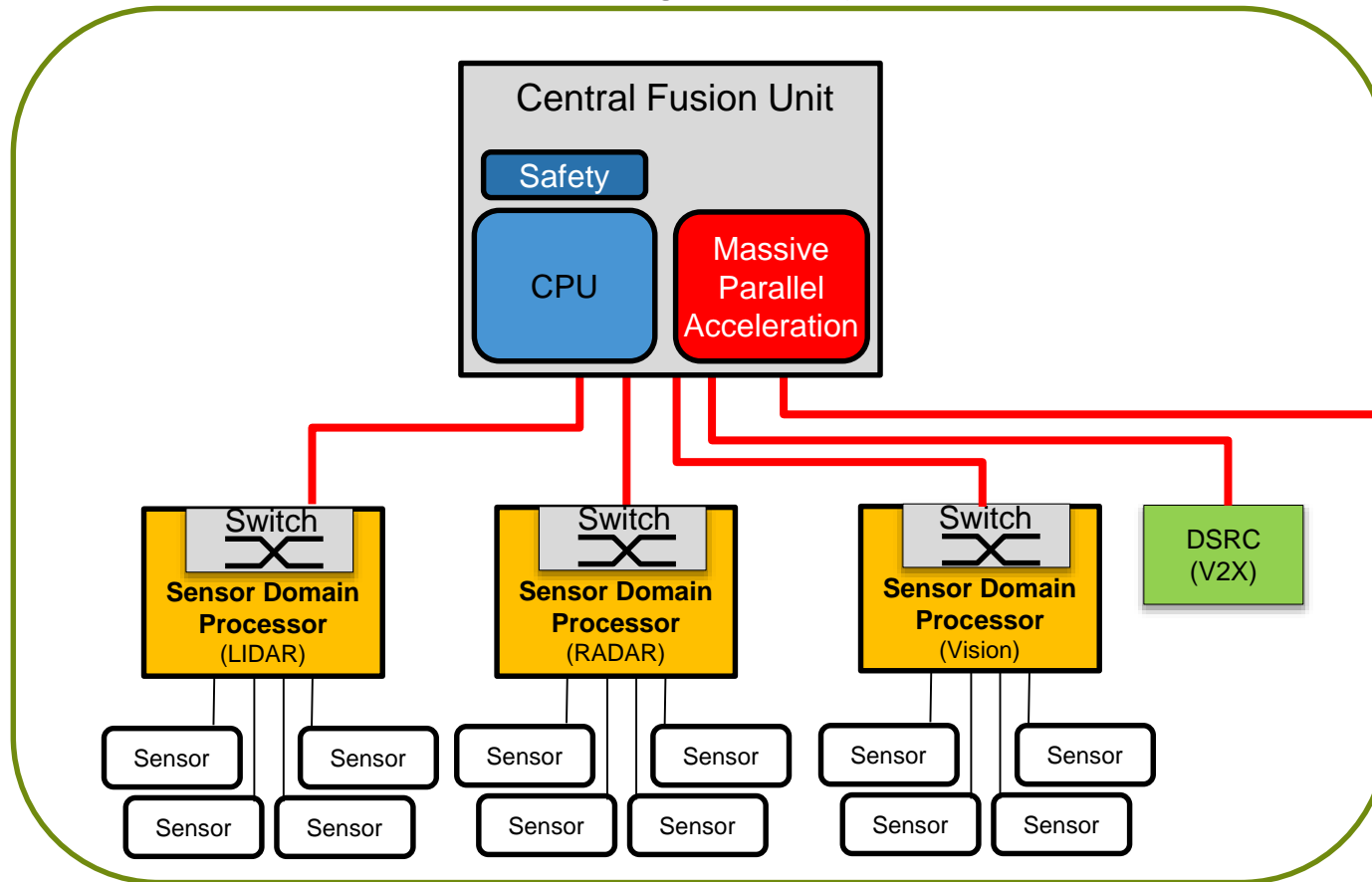# NXP OFFERS MOST COMPLETE SYSTEM SOLUTIONS FOR FASTEST TTM AND SCALABILITY

NXP Leads Domain Based Vehicle Architectures:

- ▶ Connectivity
- ▶ Driver Replacement
- ▶ Powertrain & Vehicle Dynamics
- ▶ Body & Comfort
- ▶ Driver Experience

SENSE   **THINK**   **ACT**

1 Connectivity
- V2X
- Broadcast Radio
- Cellular
- WiFi, BT, NFC
- Smart Car Access

2 Driver Replacement
- Radar
- Camera
- Lidar

Fusion

3 Powertrain & Vehicle Dynamics
- Motion
- Speed
- Ultrasonic

Powertrain & Vehicle Dynamics
Engine, Transmission, Brake, Steering, Airbag, Suspension

4 Body & Comfort
- Smart Light
- Access, Door Ctrl

5 Driver Experience
Infotainment
- eCockpit
- Amplifiers

Conceptual Vehicle Architecture

NXP Enables Transformation of In-Vehicle Networks

Today

2020 — Central GW as comm & security hub

2025 — Fast, secured, scalable domains

...after 2025 — Central Brains + Smart Nodes + Communication hubs
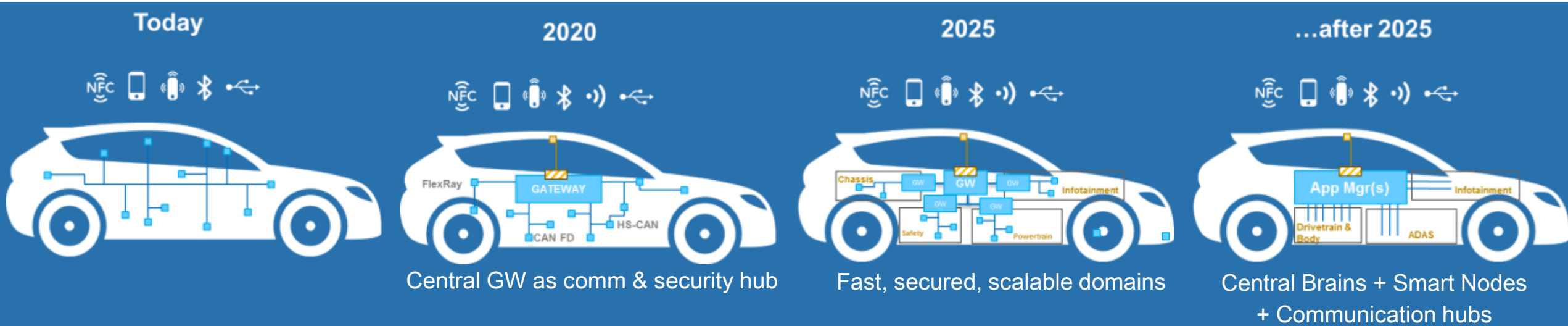
IVN TODAY
- Dominated by classic CAN
- No security
- Limited scalability and design-freedom
- Gateways being adopted
- Low bandwidth
- Functional safety by practice

OEM challenges
- Connect many more ECUs, sensors and actuators
- Manage multiple networking interfaces
- Introduce CAN FD in the network
- Enable 100Mb Ethernet network connectivity
- Enable >100Mb private connections
- Comply with increasing security & robustness
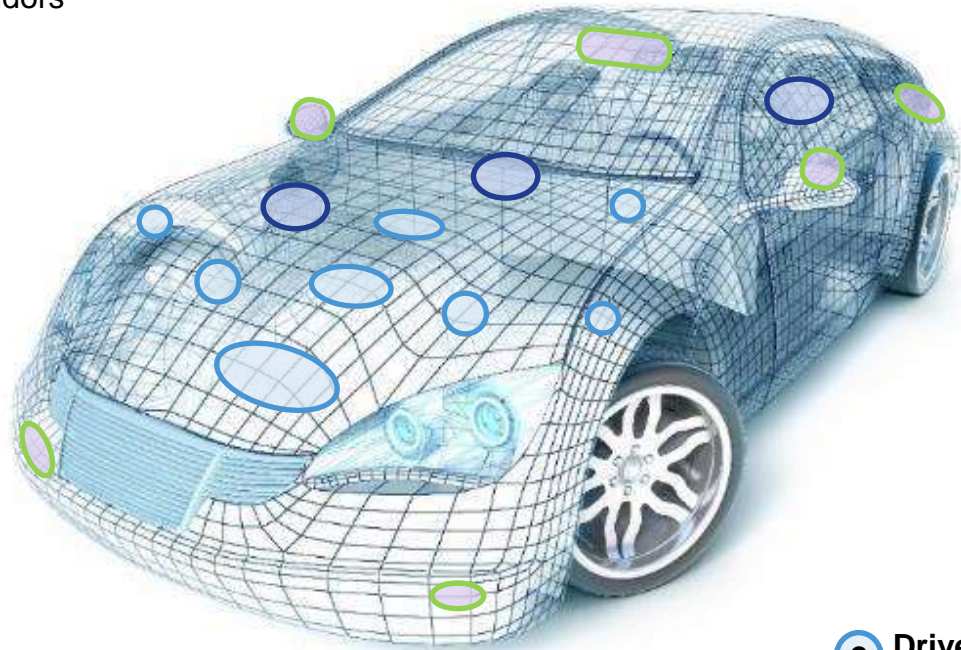- Transition to new architectures

IVN TOMORROW
- Multiple secure high-bandwidth networks (CAN FD, Ethernet, …)
- Various domains (functions, tasks)
- Centralized functions
- ASIL B & D on module level
- Security is a hygiene factor

02.
Safety / Power Management Solutions

Safety Integrity Level Requirements

Domain Gateway
Body, Safety, Chassis – up to ASIL `D`
FS652x with MPC574xC
or with other MCU vendors

ADAS – Vision
Data Fusion – ASIL `B`, up to ASIL `D` (Autonomous Drive)
FS652x with MPC5777C

7 Drive Train – S&C
Suspension / Dumping – ASIL `C`
MC33907 with other MCU vendors

ADAS – RADAR
SRR, MRR, LRR – ASIL `B`
FS652x with S32R2

6 Drive Train – S&C
Electric Power Steering – **ASIL `D`**
MC33907 & FS65 with MPC5744P

ADAS – ACC
Adaptive Cruise Control – ASIL `C`
MC33907 with MPC5744P

5 Drive Train – PowerTrain
Engine Management Unit – ASIL `B`
MC33908 with MPC57x
FS651x with other MCU vendors

1 Drive Train – Electrification
Battery Management (12V, 48V, HV) – ASIL `C`
FS650x with MPC5744P and MC33771

4 Drive Train – PowerTrain
Transmission, Transfer Case – ASIL `D`
MC33907 and FS650x
with other MCU vendors

2 Drive Train – Electrification
Electric Motor (Alterno Starter, eAxel drive…) – ASIL `C`
FS45 with other MCU vendors

3 Drive Train – Electrification
Inverter, DCDC Converter - ASIL `C`
FS650x or FS45 with other MCU vendors

ASIL

D	
C	
B	
A	
QM	

LEGEND

Safety & Power Management Product Paradigm
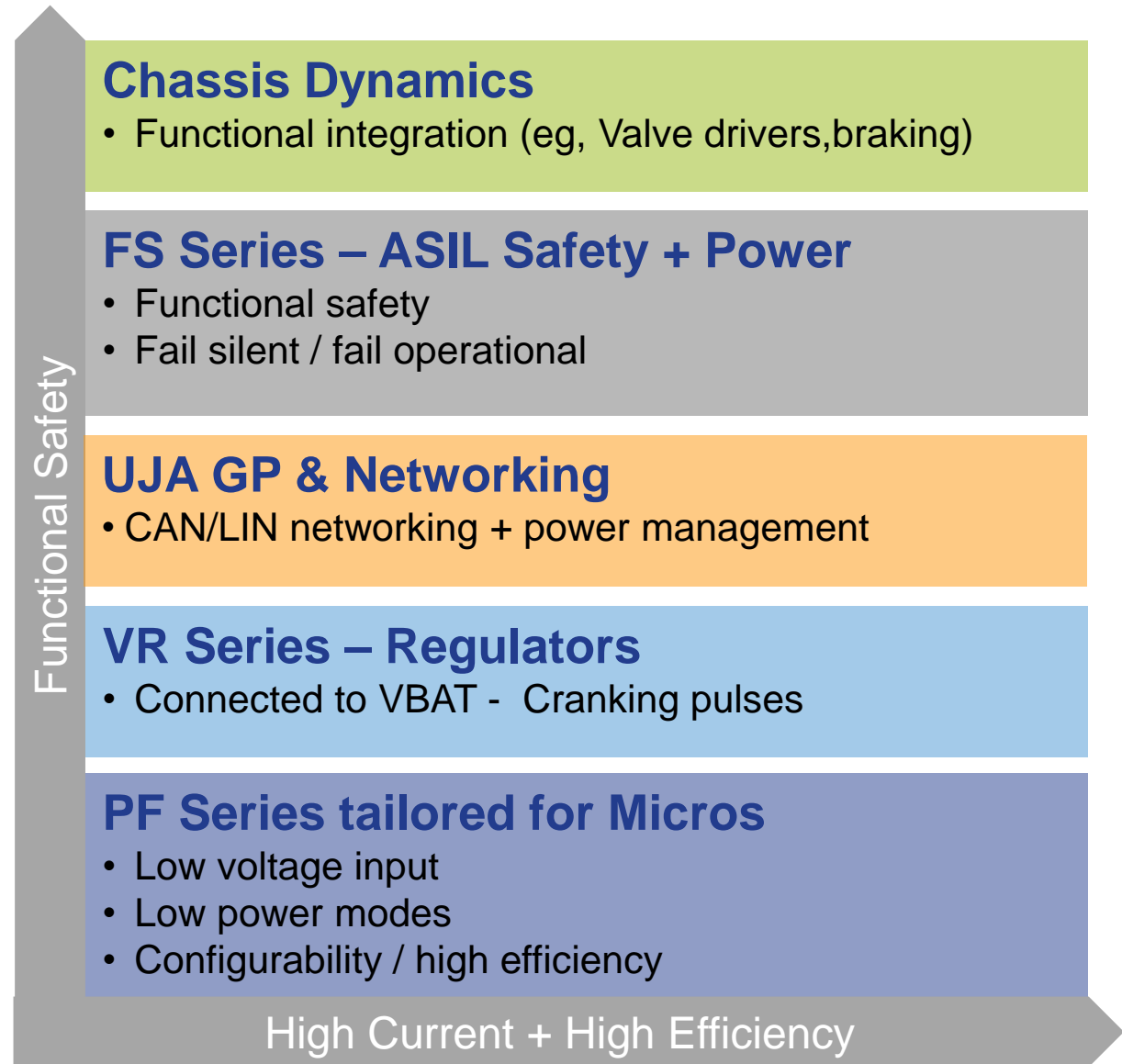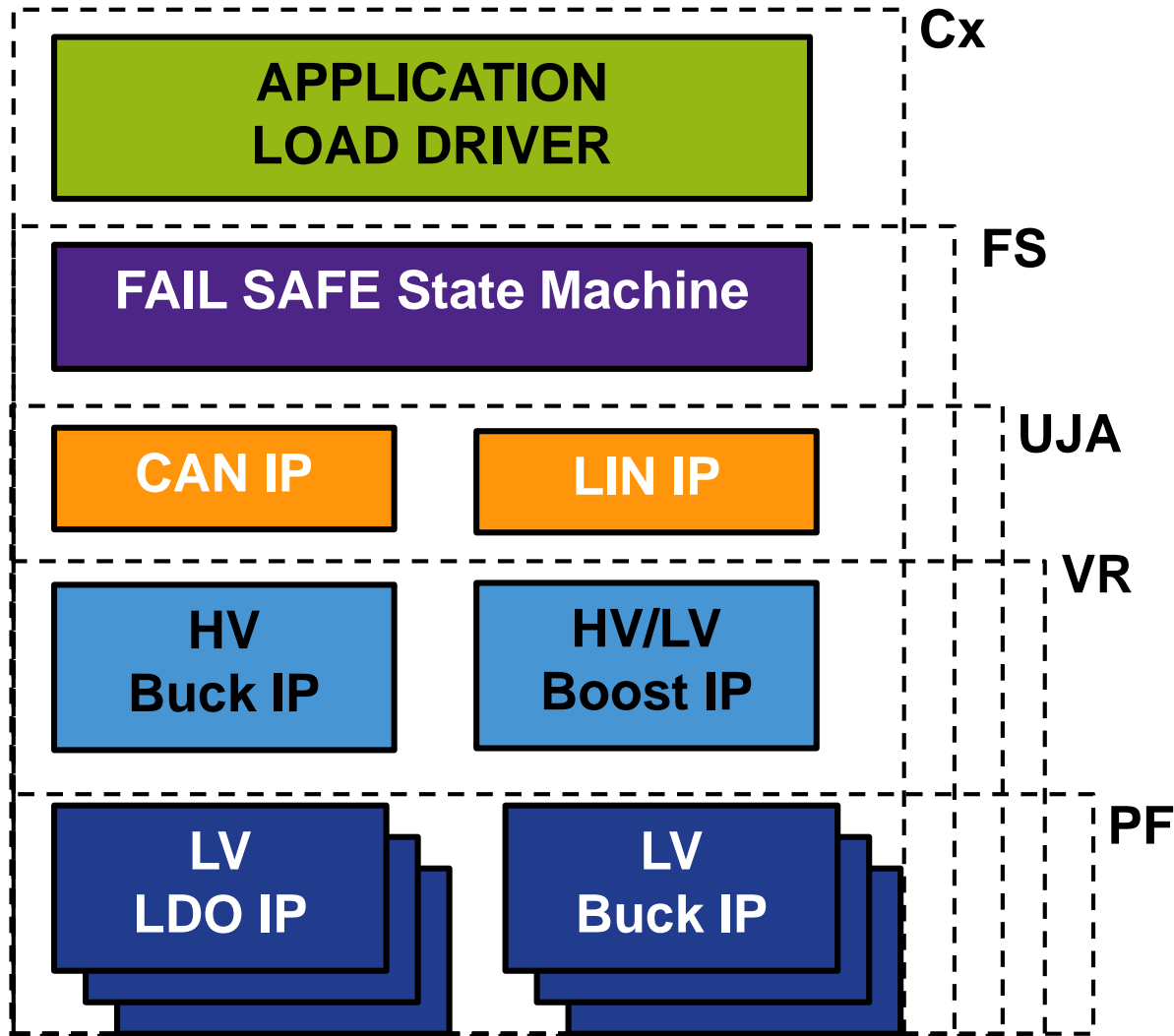
FS65/FS45 – Functional Safety SBC
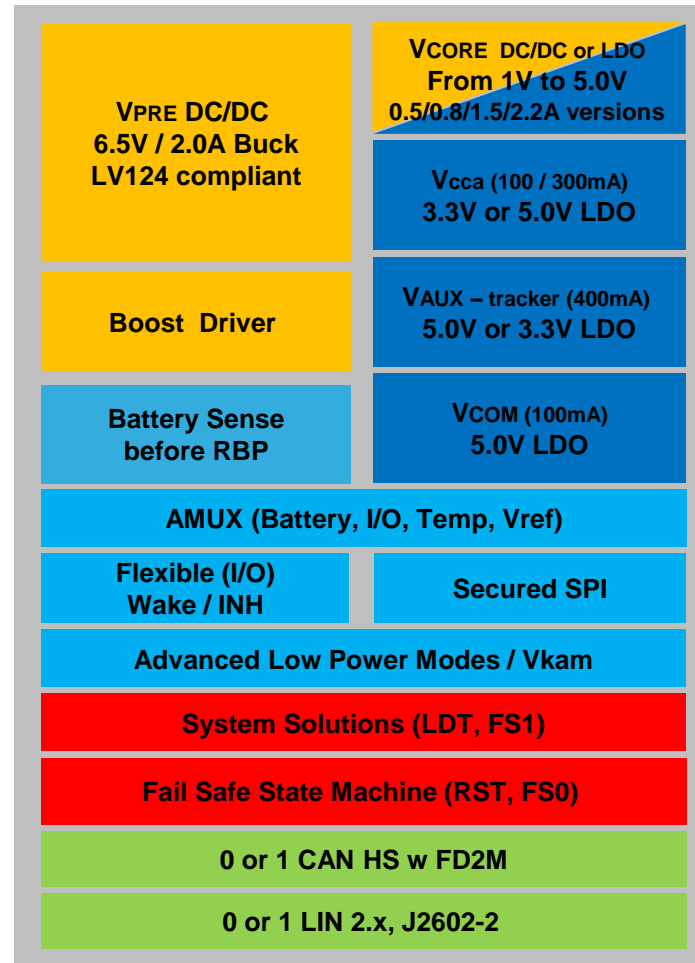
Advanced Power Management

- Buck/Boost Vpre from 2.7 to 36V
- 2.0A / 6.5V Vpre capable
- FS65xx with Vcore 2.4MHz SMPS 0.8/1.5/2.2A
- FS450x with Vcore LDO 0.5A
- Configurable Vcore (external resistor bridge)
- Multiple LDO and Tracker
- Ultra Low Standby Current 30µA

System Solution

- Analog Multiplexer to sense multiple critical signal
- Small package size :49 mm²
- Robust CAN PHY FD 2M
- Configurable I/Os
- Long Duration Timer, Keep Alive memory supply

V$_{PRE}$ DC/DC 6.5V / 2.0A Buck LV124 compliant

V$_{CORE}$ DC/DC or LDO From 1V to 5.0V 0.5/0.8/1.5/2.2A versions

V$_{CCA}$ (100 / 300mA) 3.3V or 5.0V LDO

Boost Driver

V$_{AUX}$ – tracker (400mA) 5.0V or 3.3V LDO

Battery Sense before RBP

V$_{COM}$ (100mA) 5.0V LDO

AMUX (Battery, I/O, Temp, Vref)

Flexible (I/O) Wake / INH

Secured SPI

Advanced Low Power Modes / Vkam

System Solutions (LDT, FS1)

Fail Safe State Machine (RST, FS0)

0 or 1 CAN HS w FD2M

0 or 1 LIN 2.x, J2602-2

Independent Safety Monitoring

- **Single Point Failure :** UV/OV Monitoring Unit
- **Latent Failure :** ABIST & LBIST
- **Common Cause Failure :** Independent electrical and physical fail safe circuitry and state machine
- **Reset, Fail Safe** pin to set system in predictive state when system is failing.
- **Configurable Fail Safe State**, while allowing system availibility, diagnostic and possible recovery.
- Optional **Fail Silent** operation
- **Second Fail Safe** pin to manage safe delay after failure event
- **Advanced SafeAsssure documentation** to fit for safety assessment
- **BOM cost savings :** No need for external MCU challenger
- MCU & external IC **Safety Monitoring**

| **SCALABLE** Family concept | **PROVEN** Designed at OEMs | **SAFE** Flexible Fail Silent | **ROBUST** PASS 4200h HTOL | **SIMPLIFIED** Tools & Documents |

Electronic Stability Control - ESC
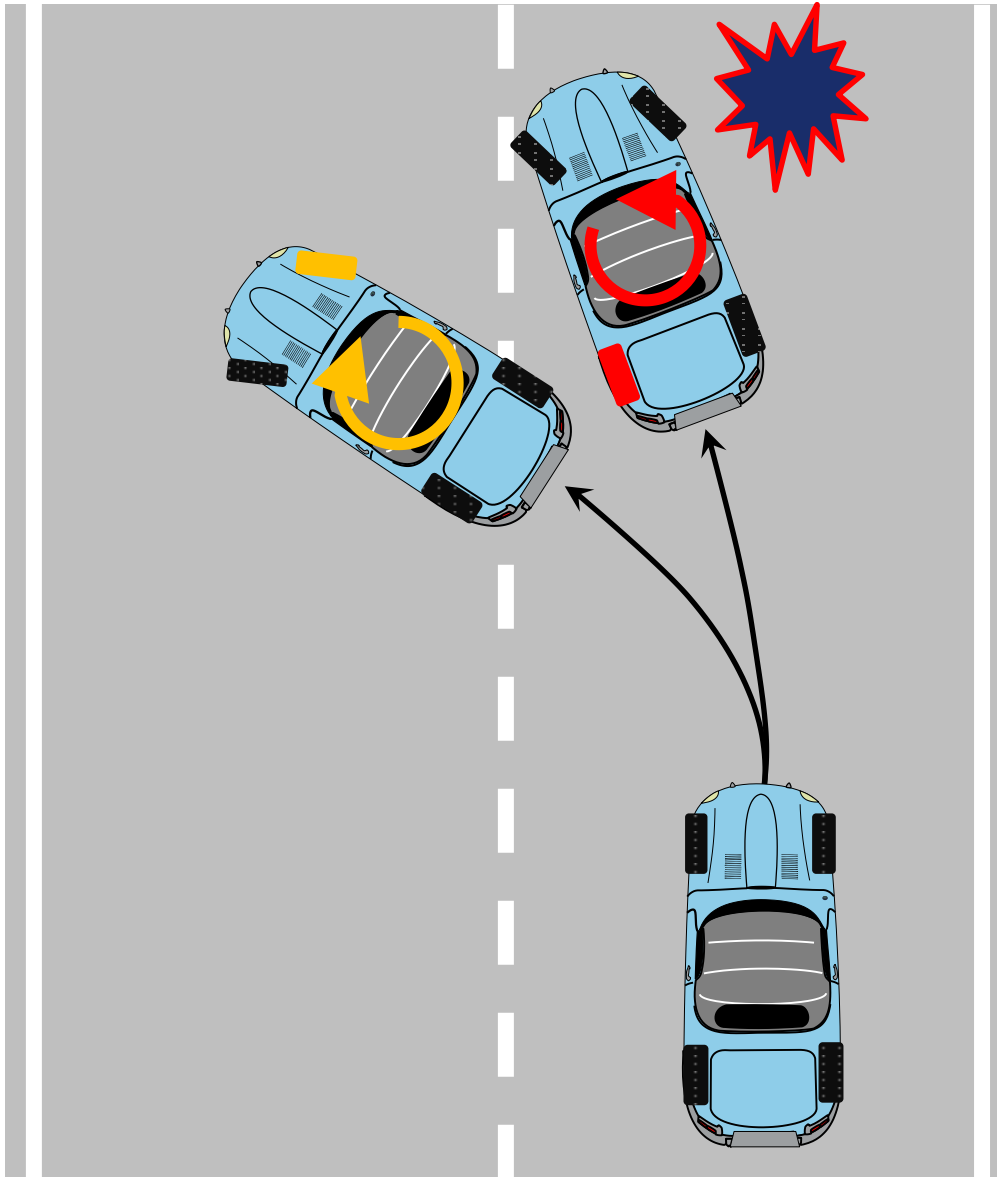
- ESC is the sum of

  - **ABS** Anti-lock Brake System

  - **EBD** Electronic Brake force Distribution

  - **TCS** Traction Control System

  - **AYC** Active Yaw Control

- ESC processes inputs from various sensors and controls braking action on wheels to keep car safely on the road or avoid obstacles

- ESC has high requirements on dependability and intrinsic safety of components used

SBCs as Backbone for NXP MCUs

Domain Based In-Vehicle Architectures

Domain	Applications	NXP Products
Connectivity	Smart Antenna, Secure Car Access, V2X, Broadcast Reception	i.MX – VR55, PF8x
Driver Replacement	Radar, Vision, Lidar / Autonomy & Fusion	S32R – FS84-85 / S32V – FS85
Powertrain and Vehicle Dynamics	Engine Control / Battery Management / Braking / Motion & Speed sensing	S32K2 – FS45/UJA
Body & Comfort	Smart Lighting, AirCon, Passive Safety / Seat Control, …	S32K – MC33903/UJA / S32K2 – FS45/UJA
Driver Experience	Multimedia Processing / Audio Processing	i.MX – PF8x

03.
Smart Actuators

SENSE

THINK

ACT

Powertrain & Vehicle Dynamics

Motion

Speed

Ultrasonic

Battery Management

Powertrain & Vehicle Dynamics

Engine Steering
Transmission Airbag
Brake Suspension

SMART ACTUATORS:
Advanced Analog Solutions for Efficient and Safe Energy Management

Solid State Lighting Control
LED Drivers, Intelligent Matrix Controllers

- 1st driver with 2 stage scalable buck boost
- Driver supports high current LED, laser
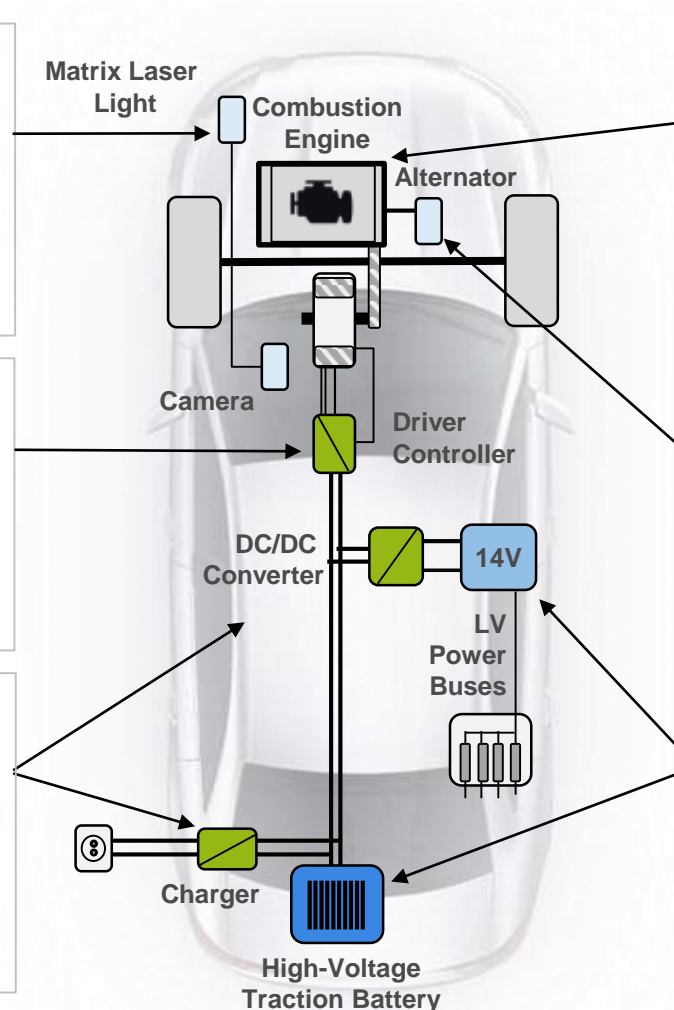- Controller with ramp curve generation

Motor Control
H-Bridge Drivers, 3-Phase Gate Drivers

- SPI control with configurable slew
- Real-time load current monitoring
- Functional safety ASIL-C solution

EV Power Inverters
IGBT, 48V Gate Drivers

- Low IGBT module BOM cost
- Small footprint over-current protection
- Integrated HV isolation
- Functional Safety: ASIL-D

Power Train Solenoid Control
Direct Fuel Injection (DFI), Automatic Transmission Solenoid Controllers

- Integrated End-of-Injection measurement
- Low latency and high dynamic precision
- Lowest system BOM implementation
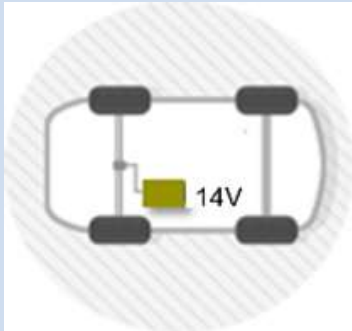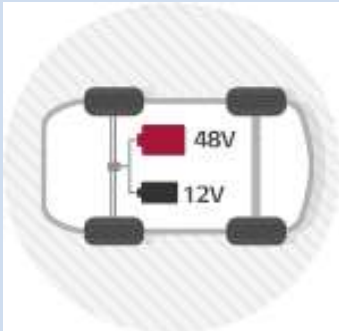
Engine Energy Management
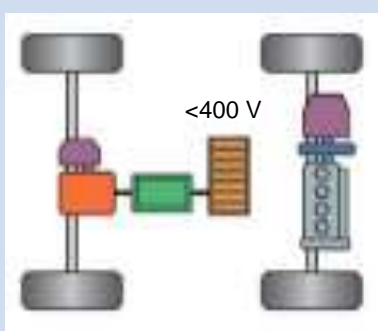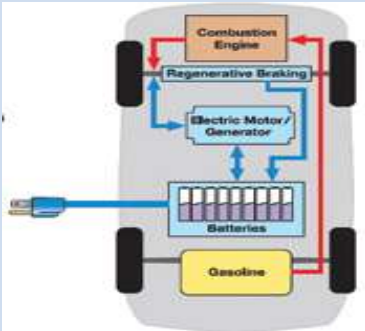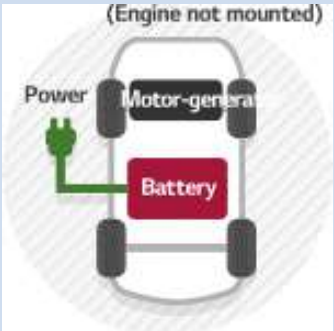LIN-based Alternator-Regulators

- High regulation accuracy, 12A capable
- Robust low battery operation
- Highly configurable

Li-Ion Battery Management
14V, 48V & HV Li-Ion Battery Cell Controllers

- Highest integration
- Single-chip ASIL-C
- High speed isolated daisy-chain
- Time aligned impedance measurement

Matrix Laser Light

Combustion Engine

Alternator

Camera

Driver Controller

DC/DC Converter

14V

LV Power Buses

Charger

High-Voltage Traction Battery

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Automotive xEV Landscape

	Micro Hybrid (Advanced Start-Stop)	Mild Hybrid Vehicle (MHV)	Full Hybrid Vehicle (FHV)	Plug-in Hybrid Vehicle (PHEV)	Electric Vehicle (EV)
Architecture					
Power Source(s)	Internal Combustion Engine (ICE)	ICE + electric motor	ICE + electric motor	ICE + electric motor	electric motor
Battery Capacity	<0.5 kWh	<0.5 kWh	1~1.5 kWh	7~16 kWh	20 ~90 kWh
Functions (cumulative)	Regenerative Braking	Acceleration assist	EV mode	Charge from power outlet	Full EV
Emission reduction	< 5%	< 30%	< 50%	< 70%	100%

04.
Battery Management

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Root cause: Li-battery fire

BREAKING NEWS
PLANE FIRE AT HEATHROW AIRPORT
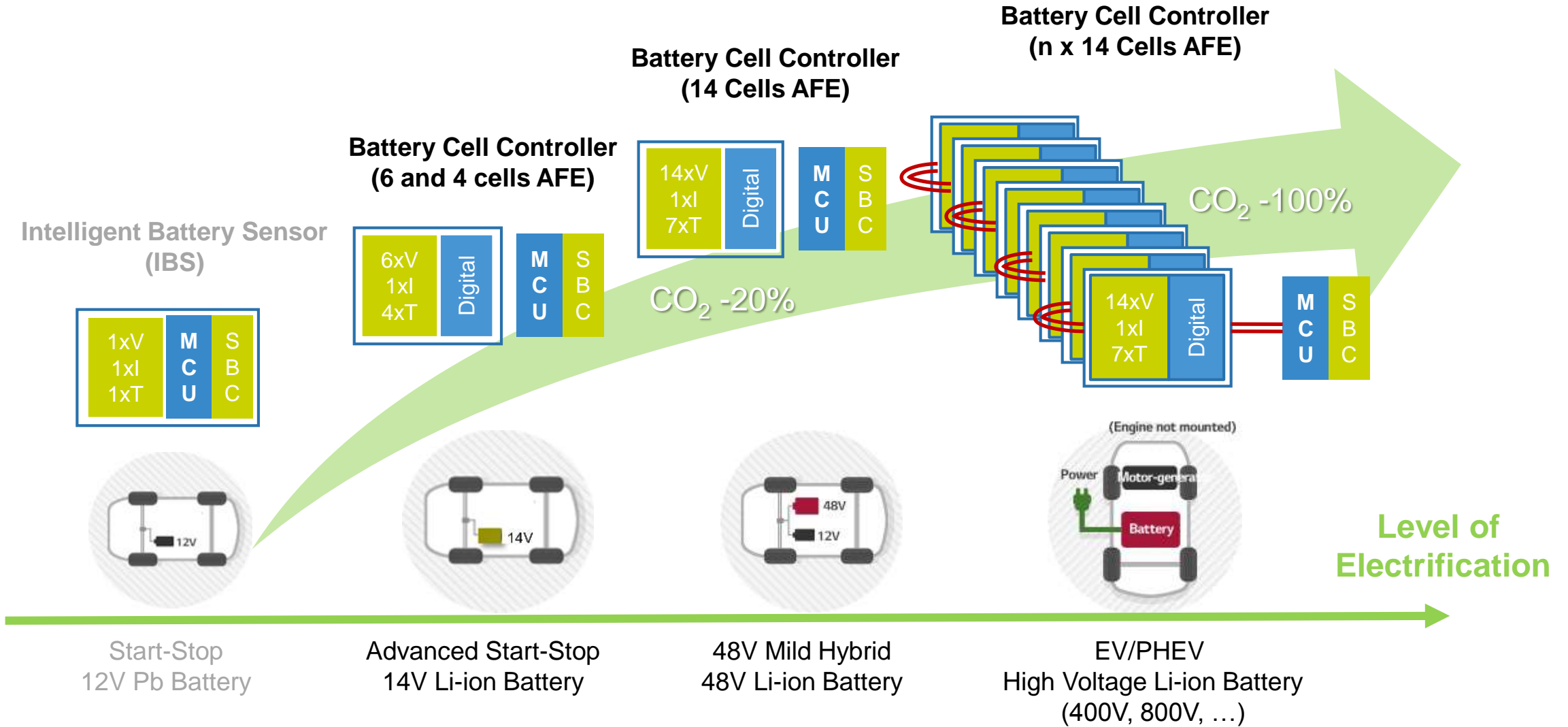Vacant plane catches fire, disrupts traffic at Heathrow

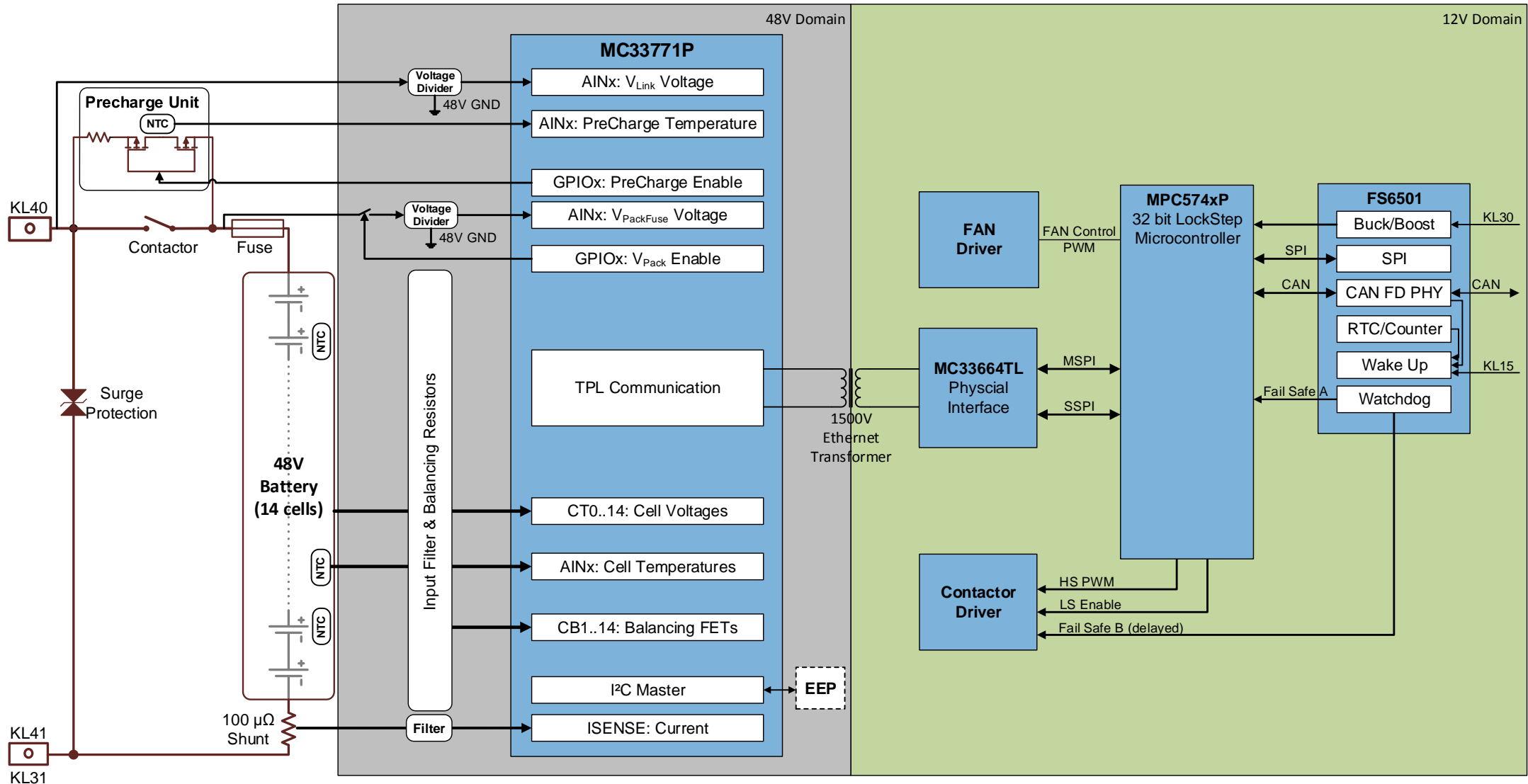# Functional Safety Requirements on Battery Management

- A Battery system consists of several 10s of individual Li-cells connected in series/parallel
- Li-cell run the risk of thermal runaway
- A lithium battery fire can generate heat up to 1100°C
- Battery management systems monitor all cells individually for current flow, cell voltage and temperature.
- Our SOI process enables products to have up to 14 (16) cells put in series

Li-Ion Battery Cell Controllers – Scalable System Solution

Battery Cell Controller (n x 14 Cells AFE)

Battery Cell Controller (14 Cells AFE)

Battery Cell Controller (6 and 4 cells AFE)

Intelligent Battery Sensor (IBS)

CO_2 -100%

CO_2 -20%

14xV 1xI 7xT | Digital | **M C U** | S B C

6xV 1xI 4xT | Digital | **M C U** | S B C

14xV 1xI 7xT | Digital | **M C U** | S B C

1xV 1xI 1xT | **M C U** | S B C

(Engine not mounted)

Power | Motor-generator

Battery

12V

14V

48V

12V

Level of Electrification

Start-Stop 12V Pb Battery

Advanced Start-Stop 14V Li-ion Battery

48V Mild Hybrid 48V Li-ion Battery

EV/PHEV High Voltage Li-ion Battery (400V, 800V, …)

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Total NXP System Solution – 48V Battery Management Use Case

05.
Gate Drivers

GD3100 IGBT Gate Driver for High Voltage Inverter

Differentiation:

- **Fast short circuit protection via direct feedback through i-sense IGBTs**
- **High speed over current protection with soft shutdown**
- **SPI interface for ASIL C/D monitor and reporting, device programmability and flexibility**
- Integrated temperature sense for system warning and ultimately soft shutdown for system protection
- Integrated galvanic signal isolation between the low-voltage drive electronics and the high-voltage power electronics in single package to reduce PCB area

Features:

- SPI for configurability and for providing detailed fault & status data for integrated protection and programmability
- High speed over current protection with soft shutdown
- Isolated AMUX for monitoring key circuit voltages and currents
- Gate-emitter clamp eliminates the need for negative gate supply voltage
- Integrated gate drive power stage capable of 10A source and sink
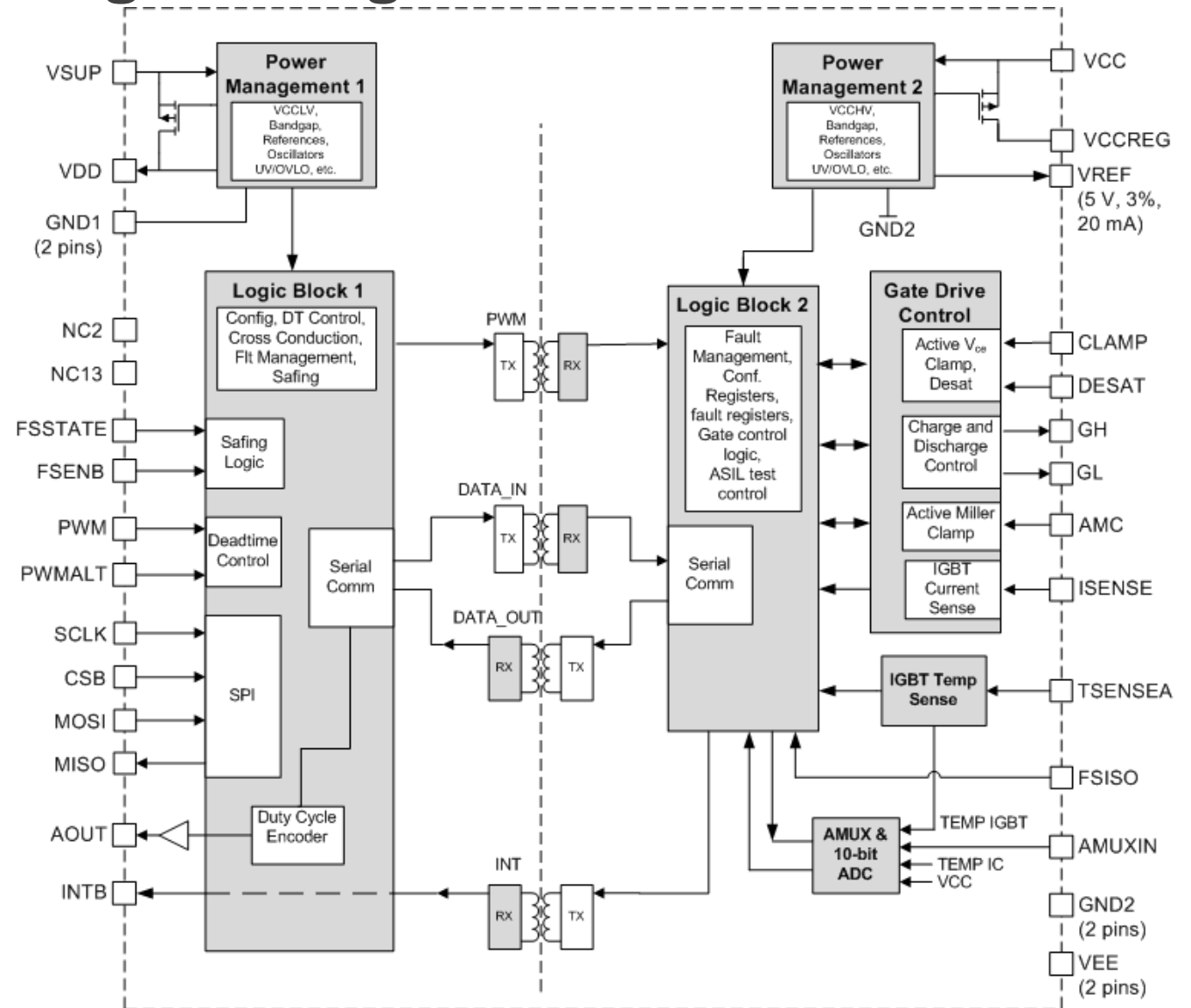- Compatible with 200V to 1200V IGBTs, power range >125kW

Applications

- HEV Motor Inverters
- HV UPS Inverters
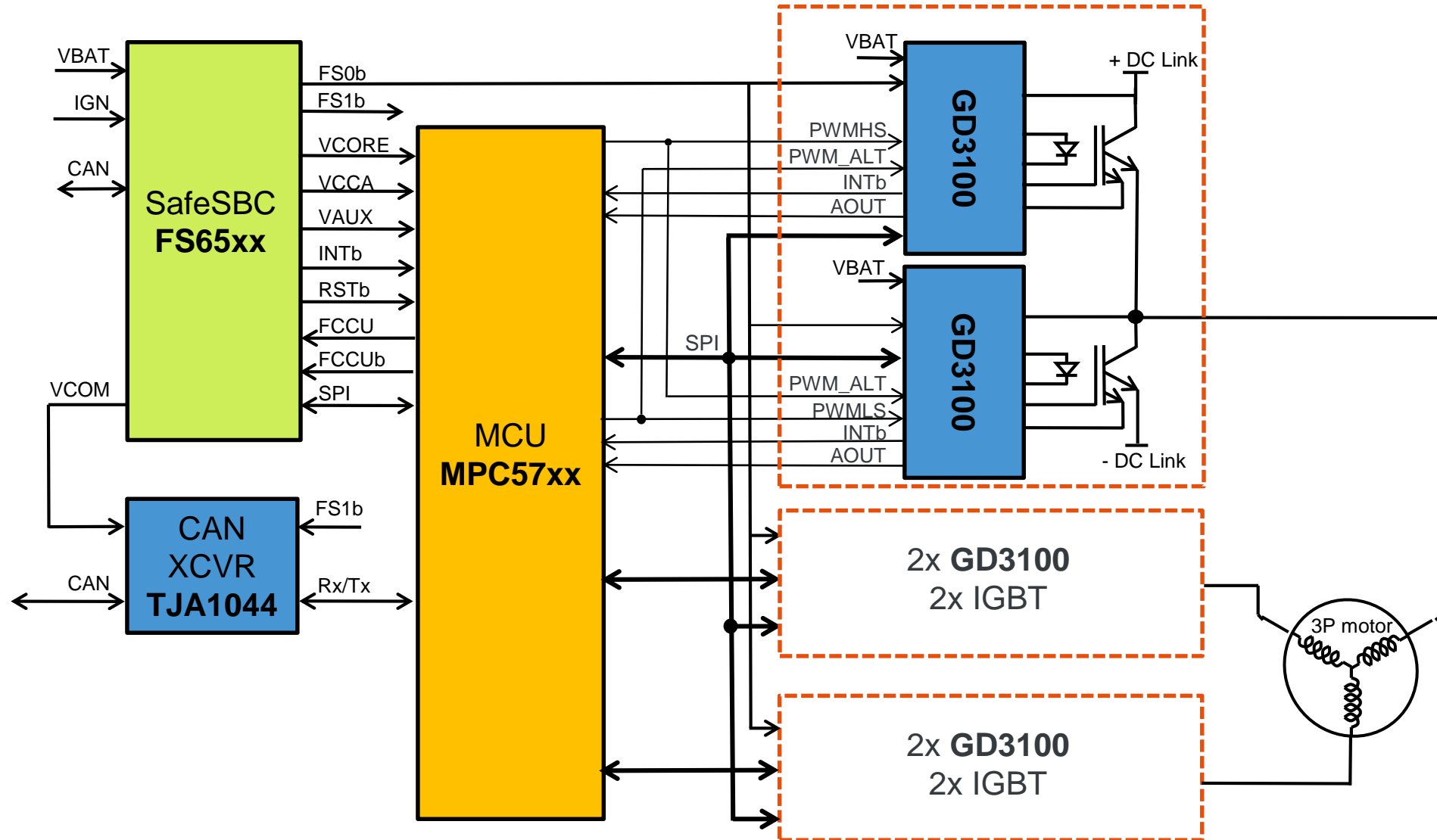- Alternate Energy Inverters

32-Pin
SOIC-WB

PART #	PKG	SAMPLES	RELEASE
MC33HB3100EK	SOICWB32	OCT (P2.0)	Q1'18

System Block Diagram

06.
Solenoid Drivers

# PT2000 / MC33816 Programmable Solenoid Controller

Programmable DFI controllers with 72V high & low side pre-drivers for driving up to 8 solenoids with precision output current profiles in dynamic load environments targeting 3, 4 & 6 cylinder engines

Differentiation

- High precision drive in dynamic load environments
- Low latency feedback with <900 ns response time
- Flexible current profiles through programmable μCores
- Redundant drive disable for functional safety compliance
- Programmable End-of-Injection measurement (PT2000)

Features

- 5 – 72V operation w/ 12 – 72V DC/DC boost converter
- Supports 2 or 3 bank Vboost configurations w/ full overlap
- Programmable diagnostics: OV, UV, OC, OT, Open Load
- 16-bit SPI control with IRQB and interrupt flags
- Integrated microcode encryption for enhanced security
- LQFP with exposed pad (PB-free):
  - PT2000 6 channel: 12 x 12 mm 80 pin
  - MC33816 4 channel 10 x 10 mm 65 pin
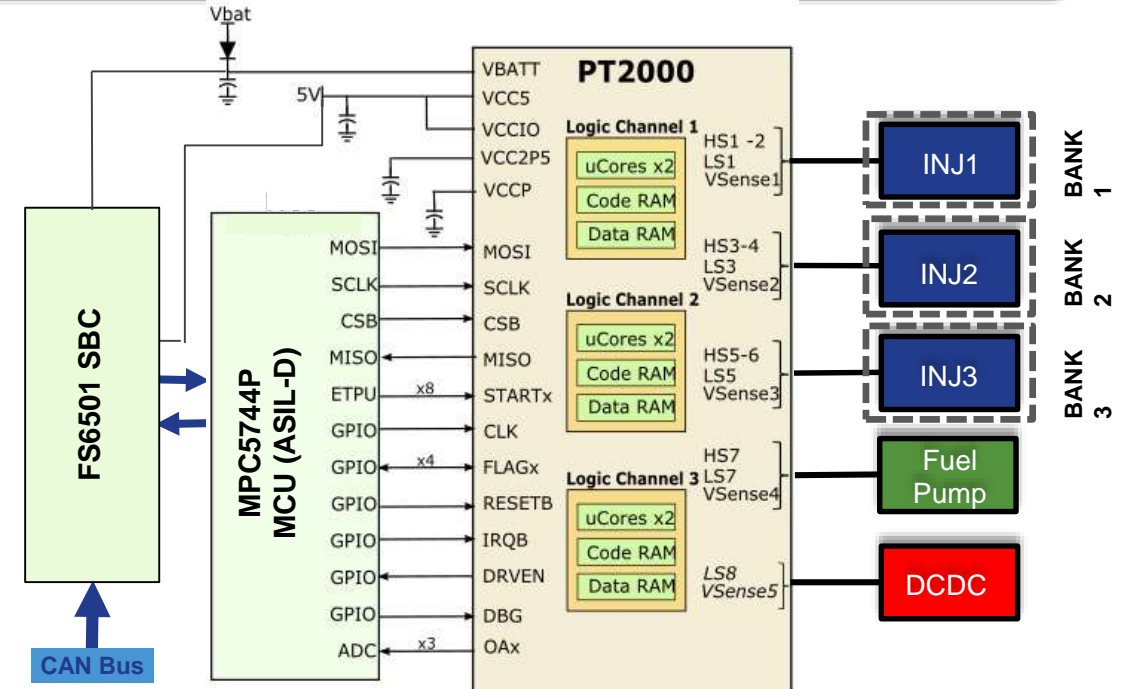
Typical Applications

- Gasoline direct injection (GDI) for 3, 4 & 6 cylinders
- Diesel direct injection (DDI)
- CNG / LNG engines & variable valve actuators (VVA)
- Active suspension & transmissions

07.
Conclusion

Summary

- The autonomous car of the future will depend on reliable networking and power management architectures, therein from an increasing number of devices that can take smart, dependable and safe action

- These smart devices will either include intelligence or cooperate with a local MCU or central compute engine, offer connectivity and functional safety

- Such high current, high voltage products are enabled by NXP's unique and leading SOI and smart HV technologies

- Additional questions, follow-up?
  please contact **Adrian Koh, Automotive Business Development**
  adrian.koh@nxp.com

LET's make the driving robot a reality

08.
Q&A

SECURE CONNECTIONS
FOR A SMARTER WORLD