NXP AUTOMOTIVE
Technical Training and Cross Selling Camp

NXP FUNCTIONAL SAFETY ANALOG FOCUS

YVES LEGRAND
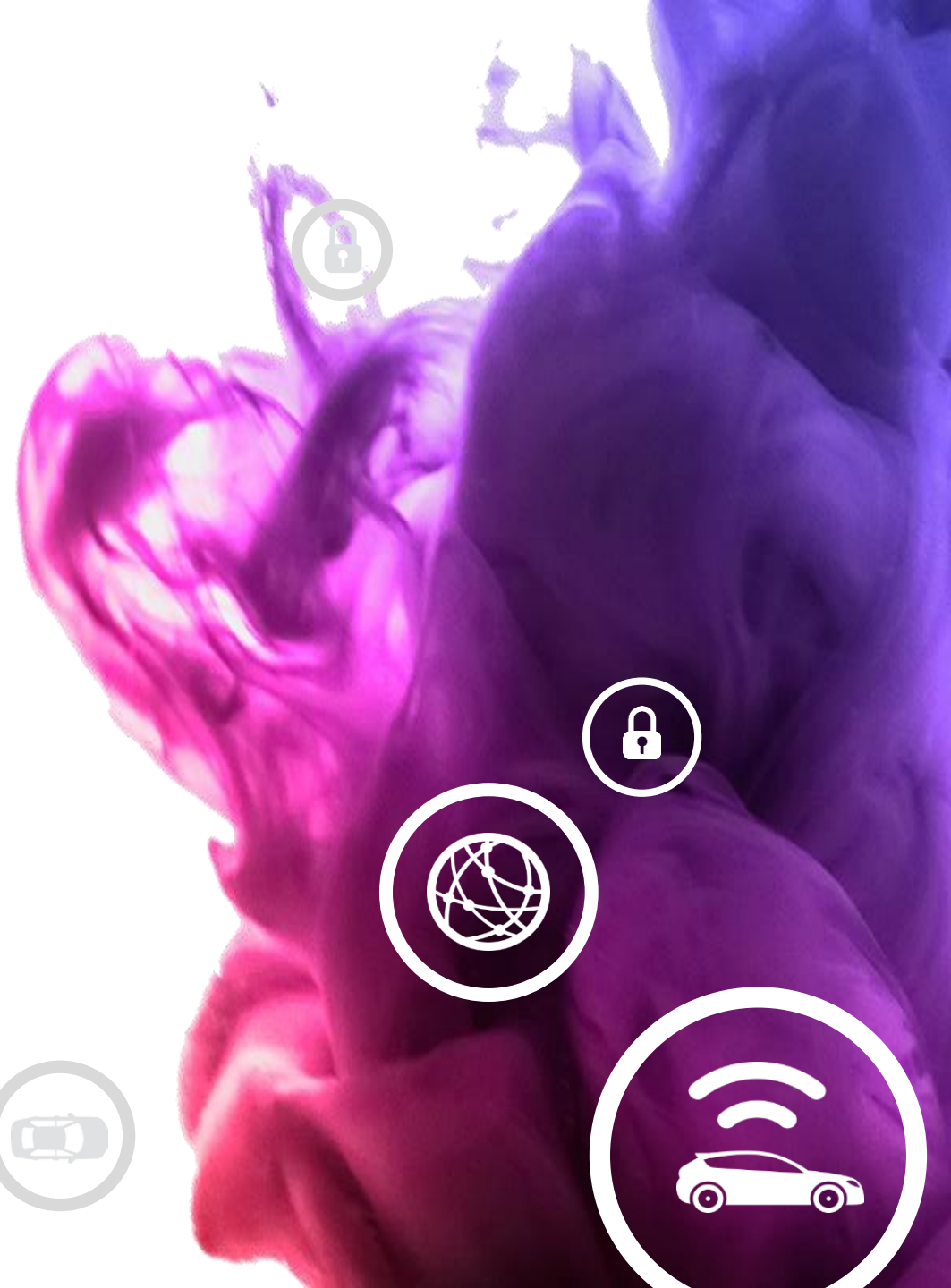
MARKETING & SYSTEMS

APRIL 2017

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SECURE CONNECTIONS
FOR A SMARTER WORLD

EXTERNAL

Agenda

- Market needs for safety
- Functional safety foundations
- Safe Assure solutions
- Safety system solution
- Evolution of functional safety

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What is Functional Safety?

Functional safety is the absence of **unreasonable risk** due to **hazards** caused by **malfunctioning** behavior of electrical or electronic **systems**

THINK SAFETY

Why is it important for society?

In 2020, road traffic accidents will be the 3rd worldwide Disability Adjusted Life Years (DALYs)
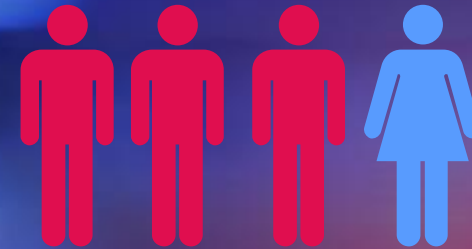
1.24 MILLION
road traffic deaths occur every year

#1
cause of death among those aged 15-29 years

3 out of 4
road deaths are among men

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Why Functional Safety Is Important For the Automotive Market

Legal – question of responsibility

Trust – knowing your car will do what it's meant to do

Standardization – platform consolidation and system harmonization

Trends – autonomous driving, electric vehicles

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WHAT IS DRIVING FUNCTIONAL SAFETY TODAY?

Level 0-2

Human driver performs part of the dynamic driving task

HUMAN DRIVER MONITORS DRIVING ENVIRONMENT

AUTOMATED DRIVING SYSTEM MONITORS DRIVING ENVIRONMENT

Level 3-5

Automated driving system performs the entire dynamic driving task

Needs more performance and towards fail operational safety (Beyond ASIL D as defined by ISO 26262)

0	1	2	3	4	5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation

SAE standard J3016

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SO WHAT DOES FUNCTIONAL SAFETY ACTUALLY MEAN?

POTENTIAL FAULT HAZARD

SYSTEM, SERVICE

HARM
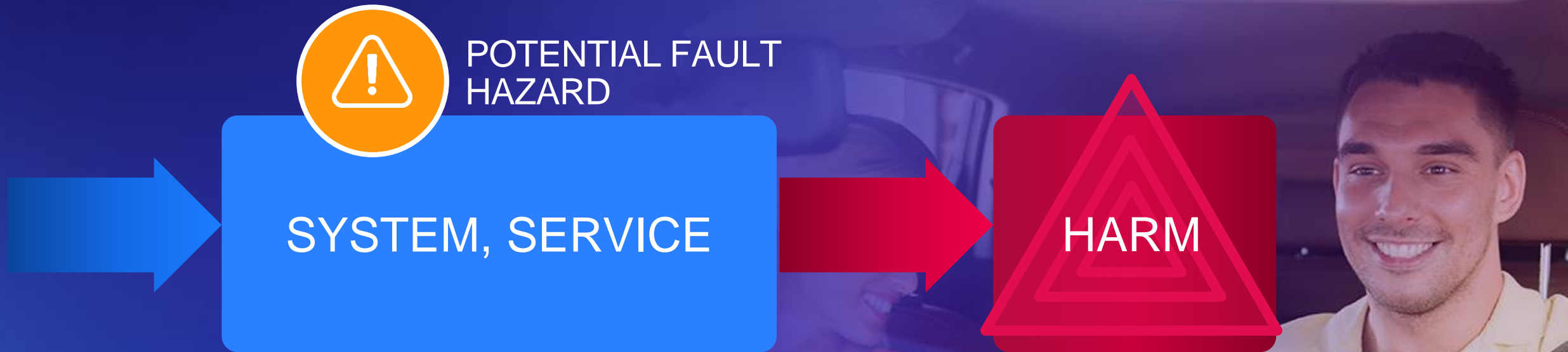
- ✓ Prevents risks of electronic system malfunctions
- ✓ Measures failures, mitigates impact, predict effects
- ✓ Industry defined standard: ISO 26262 for EE systems

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QUANTIFY A RISK: AUTOMOTIVE SAFETY INTEGRITY LEVEL (ASIL) DEFINITION

Severity

Exposure

Controllability

ASIL

How much
harm is done?

How often is it
likely to happen?

Can the hazard
be controlled

# QUANTIFY A RISK: ASIL DEFINITION

Severity

Exposure

Controllability

		C1 – SIMPLE	**C2** – NORMAL	**C3** – DIFFICULT
S1 LIGHT	E1 (very low)	QM	QM	QM
	E2 (low)	QM	QM	QM
	E3 (medium)	QM	QM	A
	E4 (high)	QM	A	B
S2 SEVERE	E1 (very low)	QM	QM	QM
	E2 (low)	QM	QM	A
	E3 (medium)	QM	A	B
	E4 (high)	A	B	C
S3 FATAL	E1 (very low)	QM	QM	A
	E2 (low)	QM	A	B
	E3 (medium)	A	B	C
	E4 (high)	B	C	D

(QM: "quality managed" → no requirements from standard applied explicitly)

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EXAMPLES OF A SYSTEM DREADED EVENT AND ASIL LEVELS
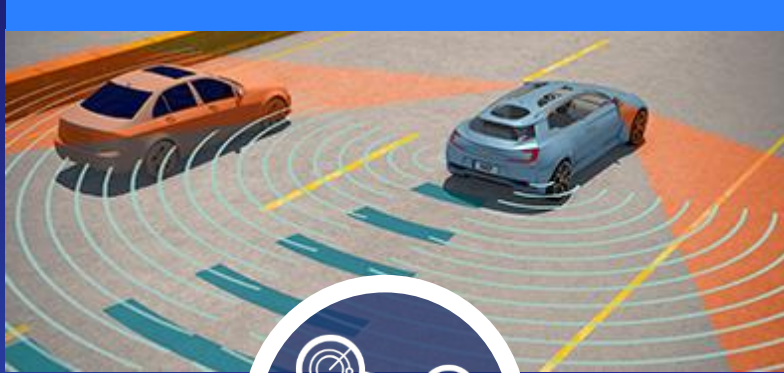
ADAS Sensor

Phantom detection
ASIL B

Battery Management

Fire
ASIL C

Power Steering

Auto steering, lock, loss
ASIL D

REDUCE THE RISK: TRACK AND UNDERSTAND THE FAILURES

Car OEM

SET SYSTEM **RISK CRITICITY** (HAZARD ANALYSIS) ASIL A, B, C or D
DEFINE **SAFETY GOALS**

Tier1 & Silicon

IMPLEMENT M**EASURES** TO **REDUCE RISK OF FAILURE**
DIFFERENT TYPE OF FAILURES

⚠ Avoid **SYSTEMATIC FAILURES**
during development

⚠ Avoid **RANDOM FAILURES**
during operation

- Process
- Safety management
- Best practices
- Lessons learned
- Verification & validation

- System safe state
- Safety architecture
- Quantitative & qualitative analysis
- Documentation

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Agenda

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NXP'S SAFE ASSURE PROGRAM

Simplify Customer experience
ISO26262 system compliance process

Optimize Customer R&D efficiency
Reduces time and complexity required to develop ISO26262 safety systems

Reduce risk of Harm
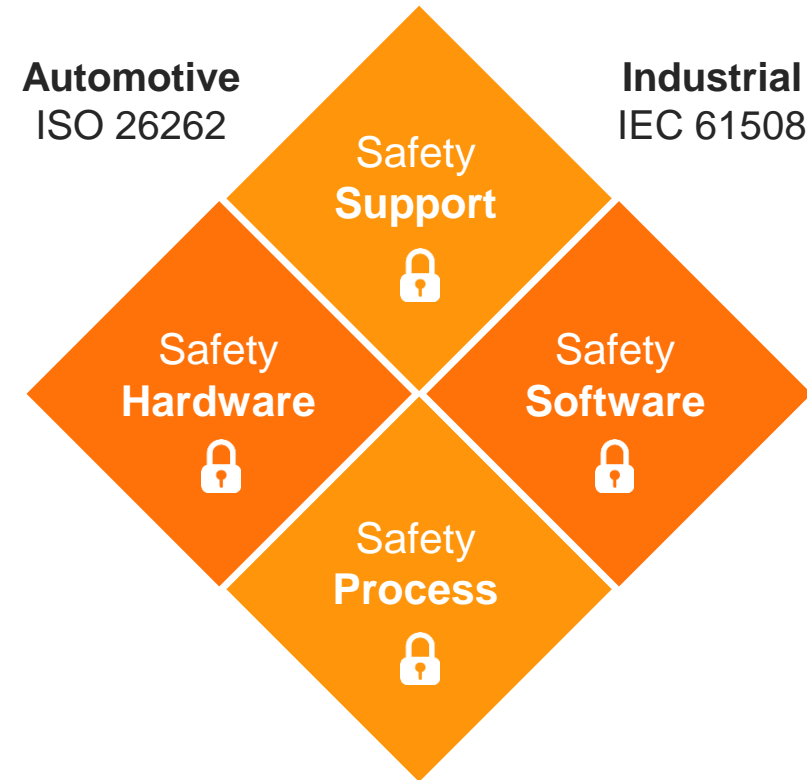Supports the most stringent Automotive Safety Integrity Levels (ASILs)

Safety starts with Quality
Zero defect methodology from design to manufacturing to help ensure our products meet the stringent demands of safety applications
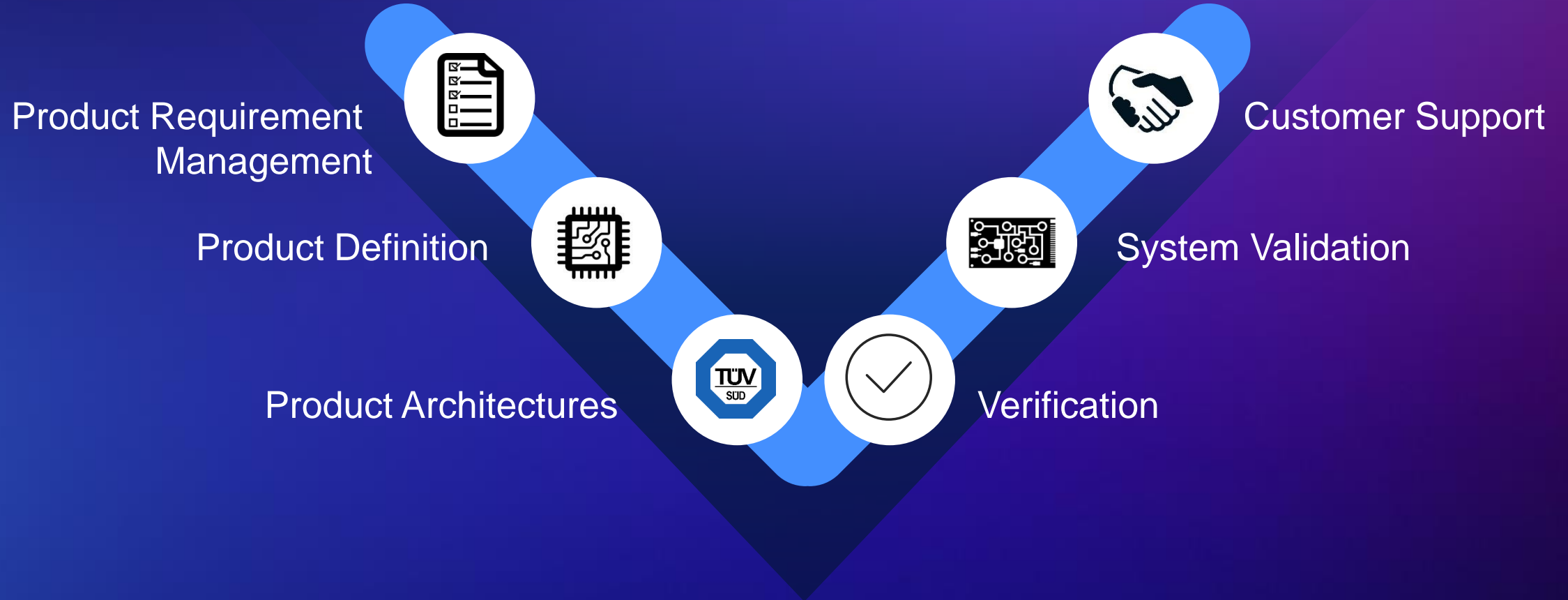
Functional Safety Standards

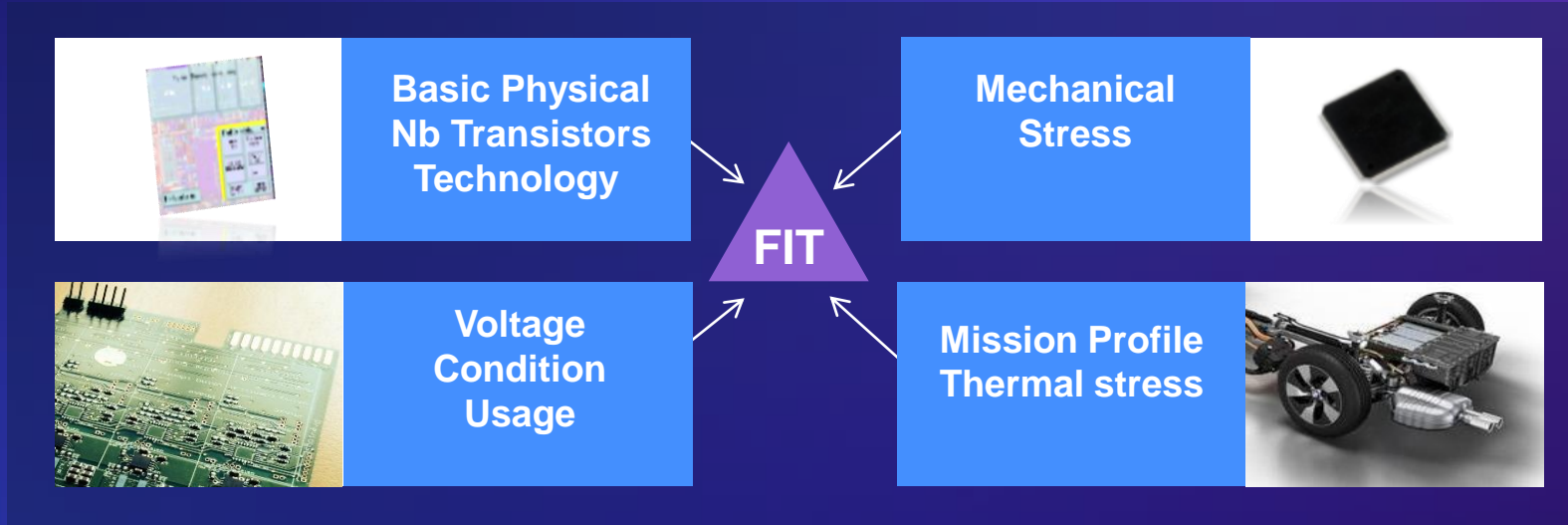Automotive
ISO 26262

Industrial
IEC 61508

Safety **Support**

Safety **Hardware**

Safety **Software**

Safety **Process**

NXP Quality Foundation

SAFE ASSURE
by NXP

SAFE ASSURE HW SOLUTIONS: FROM DEFINITION TO CUSTOMER SUPPORT

Product Requirement Management

Product Definition

Product Architectures

Verification

System Validation

Customer Support

FUNCTIONAL SAFETY IS BASED ON QUALITY QUANTITATIVE ANALYSIS

| Basic Physical Nb Transistors Technology | | Mechanical Stress |
| Voltage Condition Usage | FIT | Mission Profile Thermal stress |

FIT
=
Failure In Time

SafeAssure — FMEDA

→ SPFM
→ LFM
→ PMHF

	ASIL B	ASIL C	ASIL D
PMHF = Random Hardware Failure	< 10^{-7}	<10^{-7}	<10 -8
SPFM	>90%	>97%	>99%
LFM	>60%	>80%	>90%

FAULT MANAGEMENT & ASIL
POWER SUPPLY QUANTITATIVE ANALYSIS
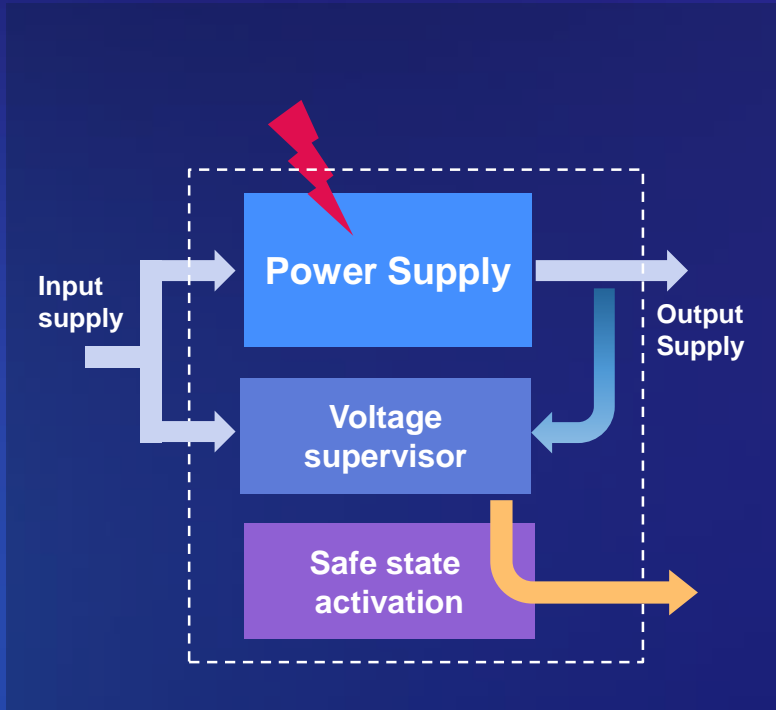
Single Point Fault

ISO26262 ASIL level	ASIL B	ASIL D
SPFM (Single Point Failure Metric)	> 90%	> 99%

Latent Fault
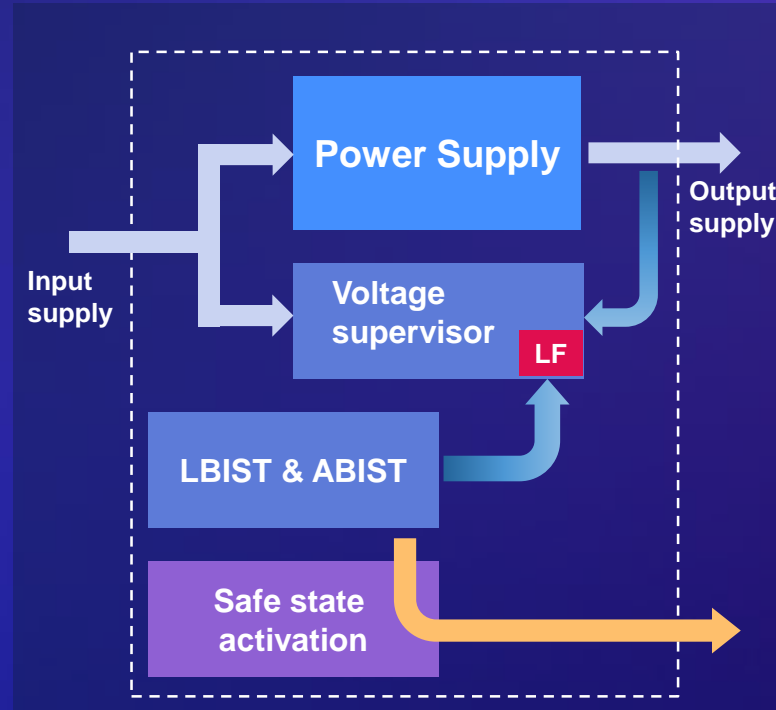
ISO26262 ASIL level	ASIL B	ASIL D
LFM (Latent Point Failure Metric)	> 60%	> 90%

Common Cause Fault
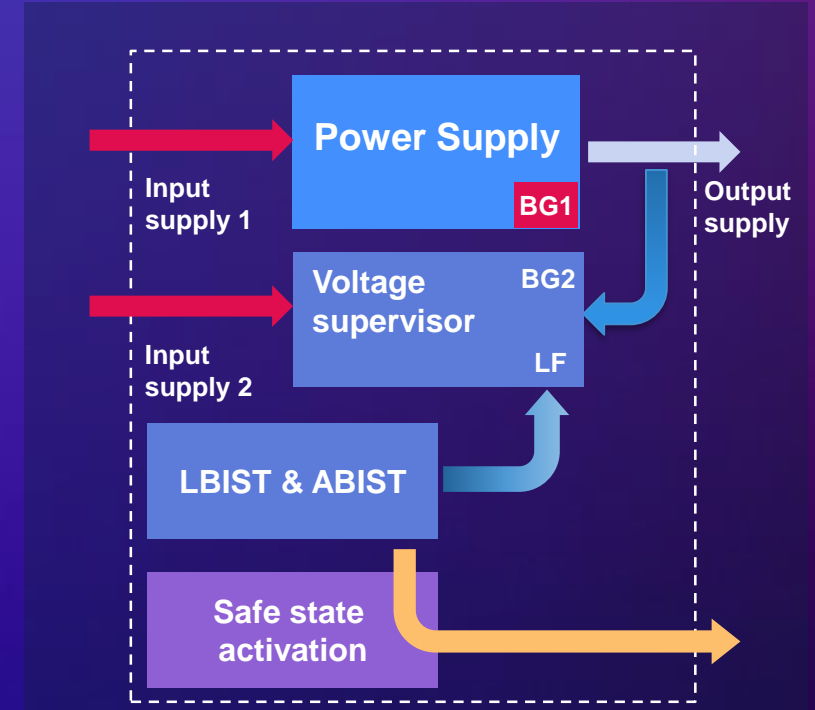
ISO26262 ASIL level	ASIL B	ASIL D
PMHF (Probability Metric of Hardware Failure)	< 10E-7	< 10E-8

FAULT MANAGEMENT & ASIL
MCU & SW QUANTITATIVE ANALYSIS
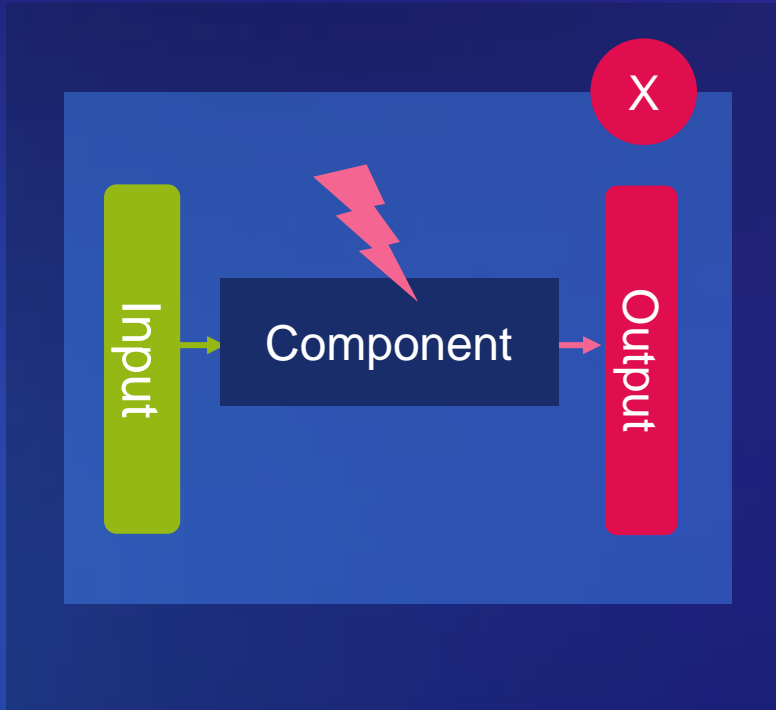
Single Point Fault	
Structural redundancy	
Information redundancy	
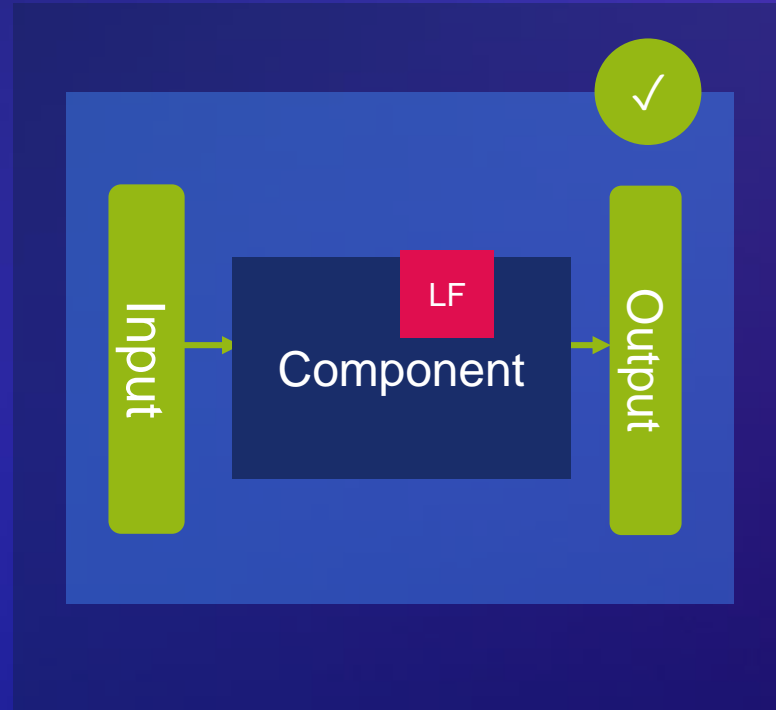
Latent Fault	
Periodic self test	ADC, register configuration
Memory & logic <50 ms	Startup & shutdown LBIST
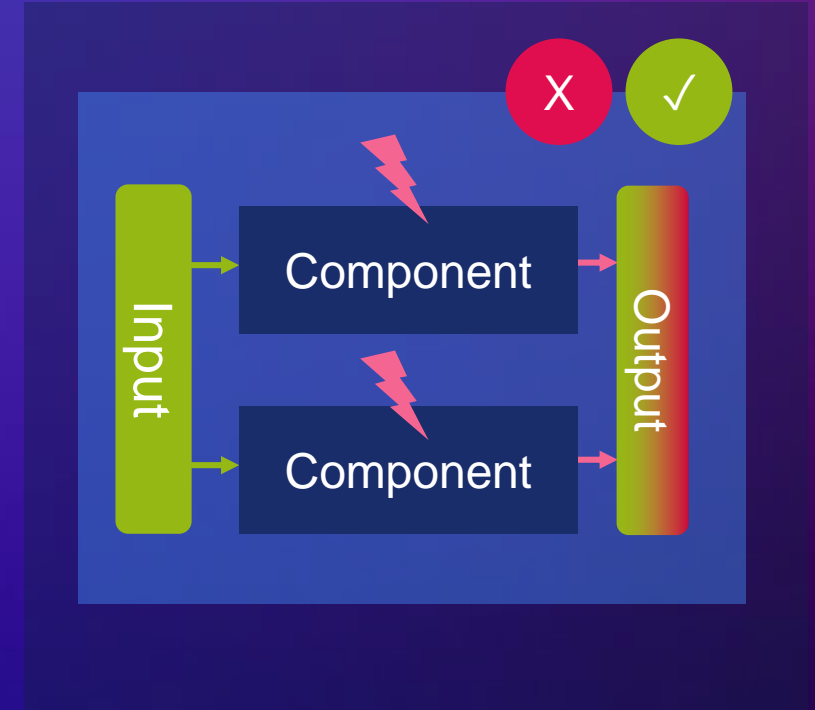
Common Cause Fault	
Independent safety clock	Independent failure signaling
Delayed checker core	

DEPENDABILITY: SAFETY VS AVAILABILITY QUALITATIVE ANALYSIS
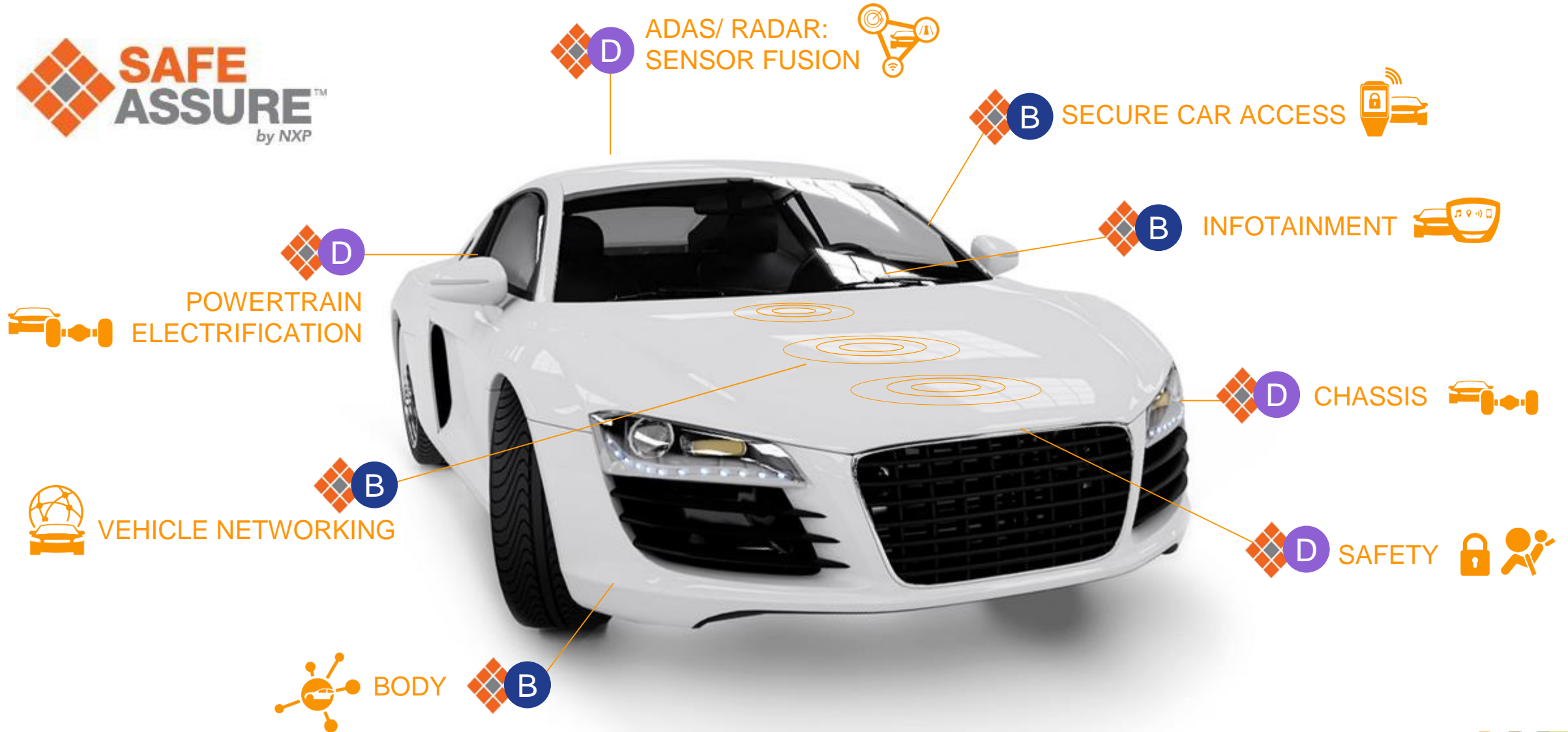

MPC5744P + MC33907
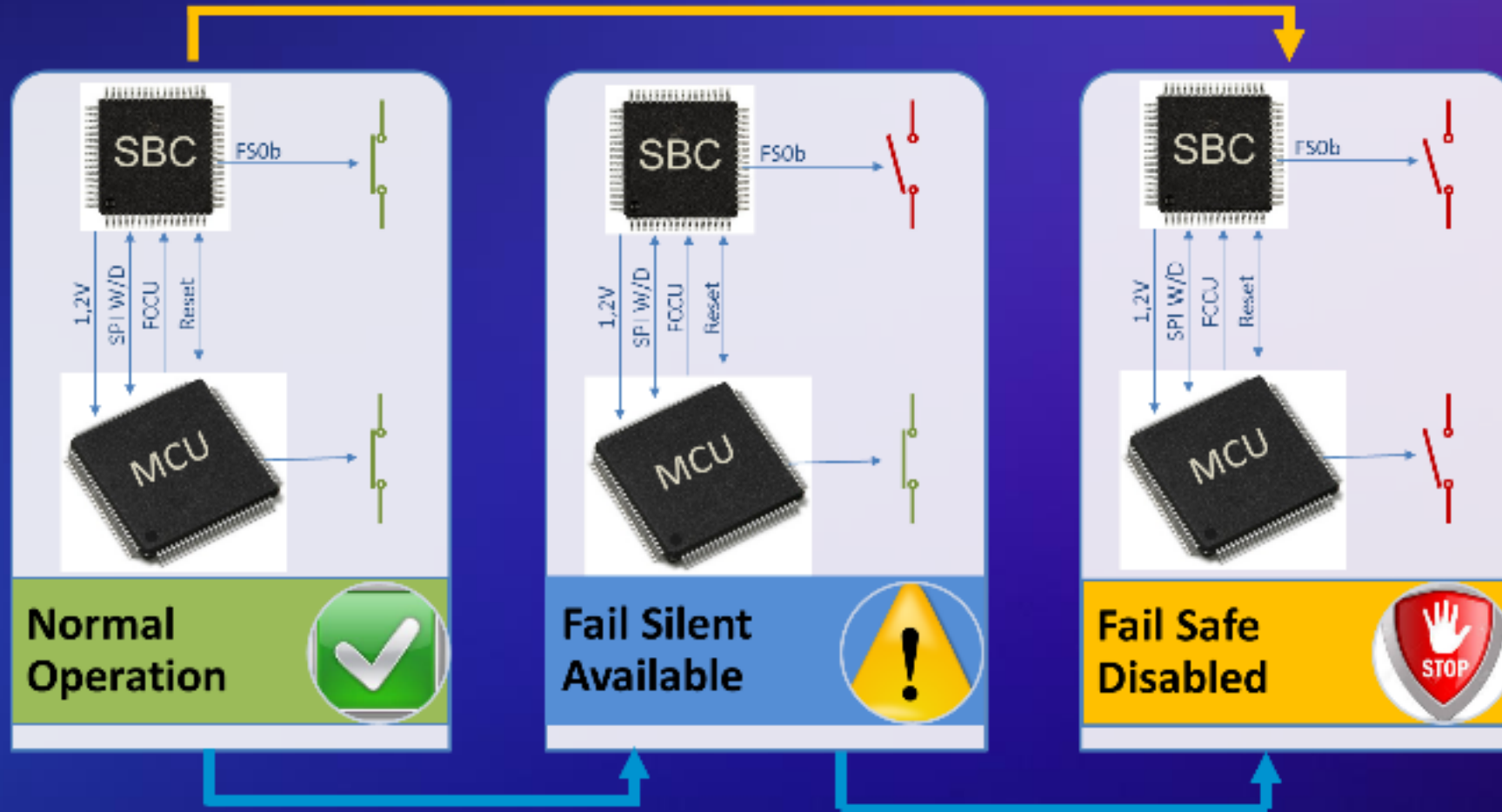
S32R + FS65

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NXP FUNCTIONAL SAFETY SYSTEM SOLUTIONS

ARCHITECTING OUR FUTURE

More than a brain on 4 wheels.
The core of safe and secure mobility.

SENSE   **THINK**   **ACT**
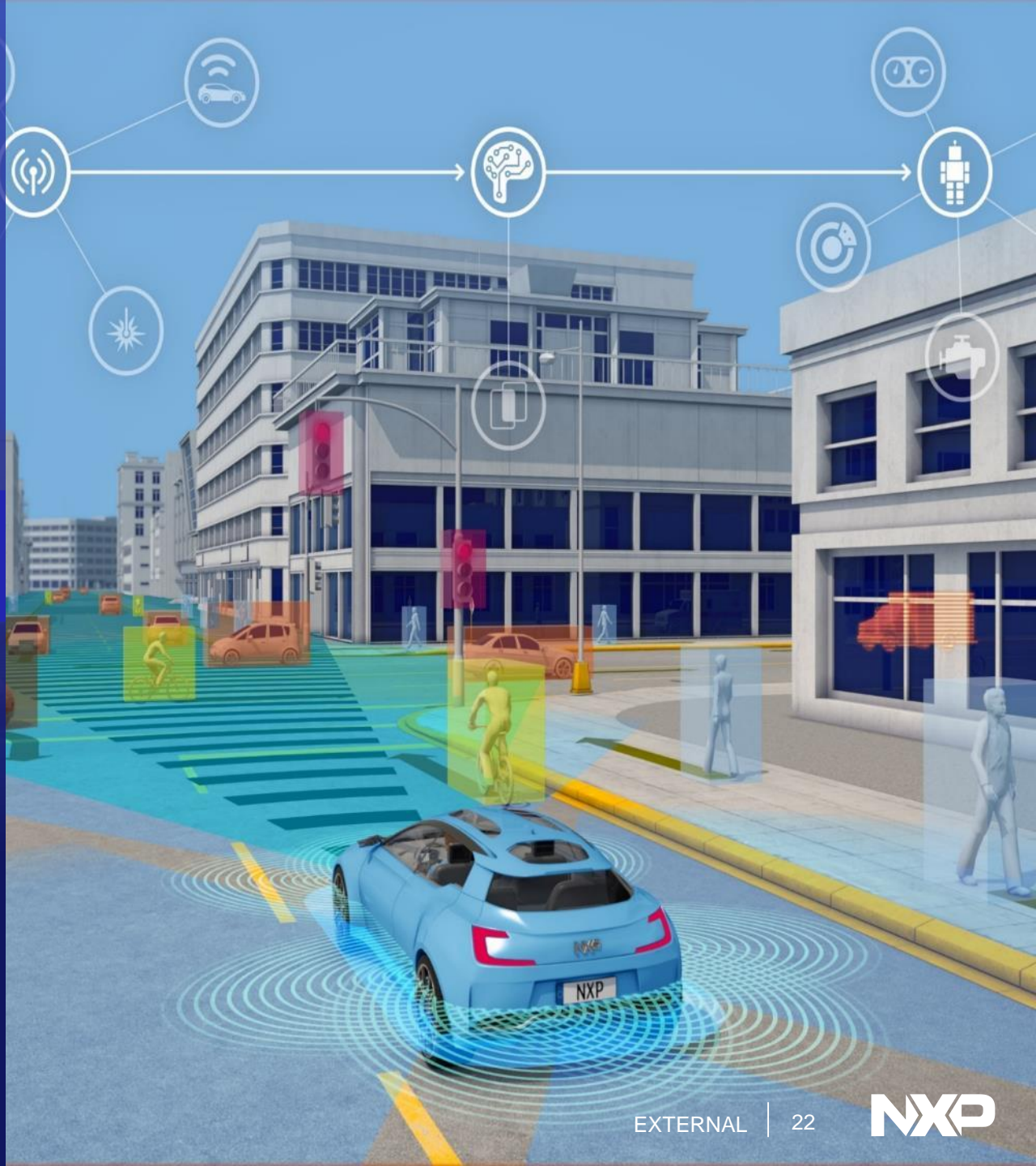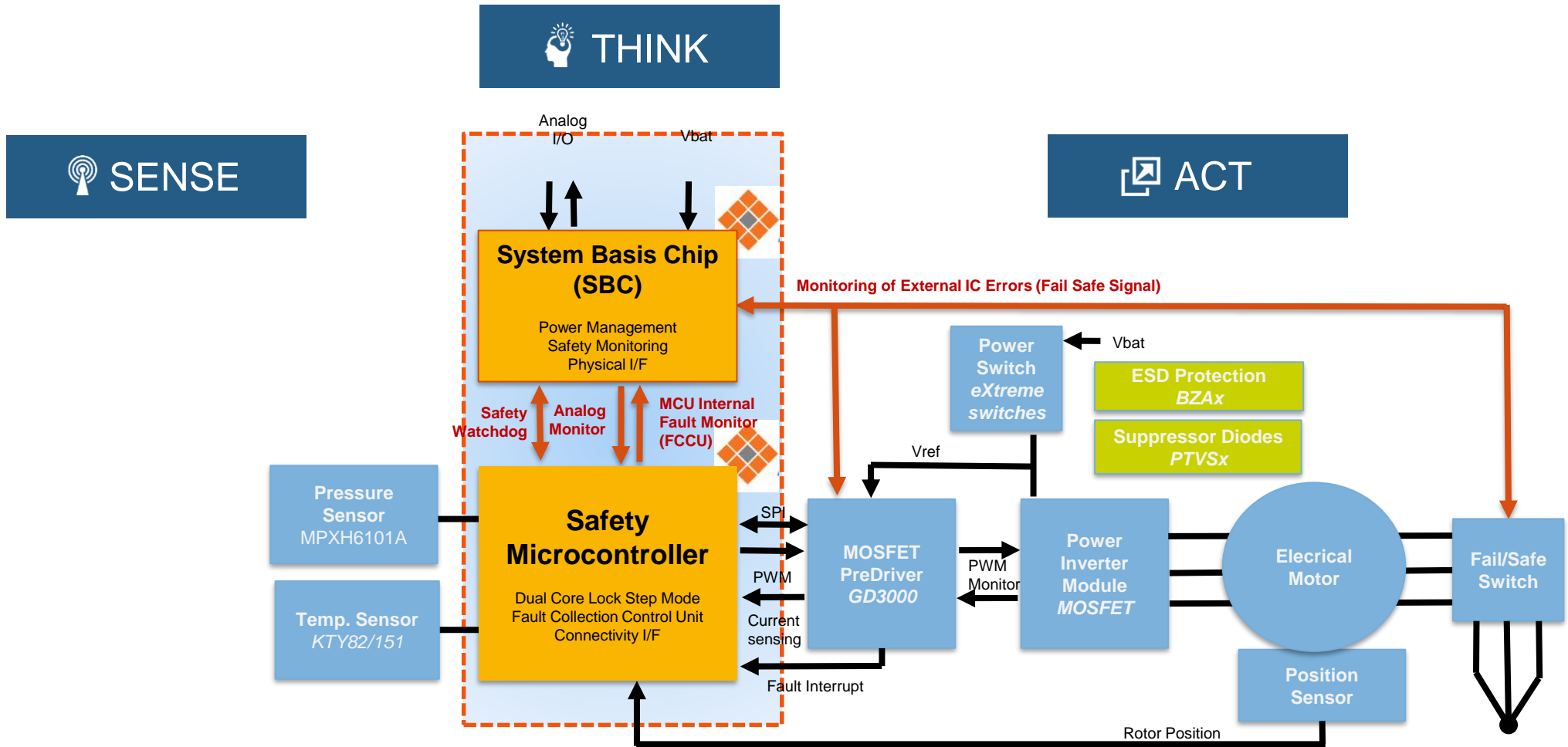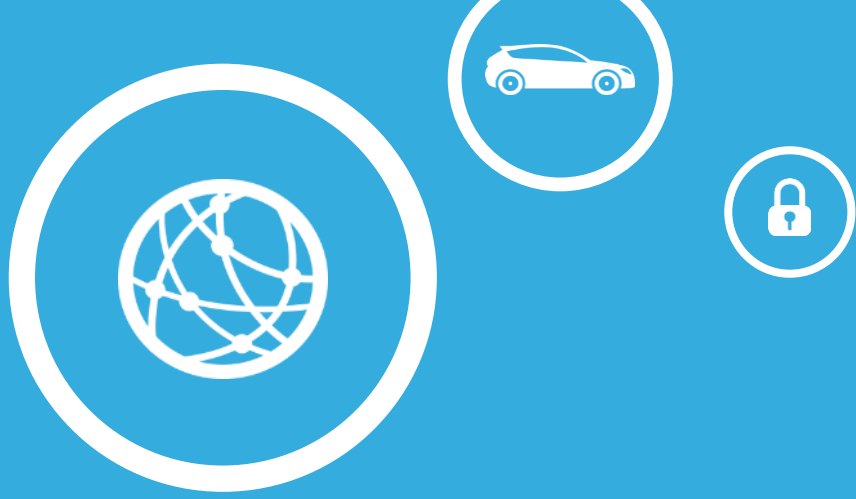
- Safety MCU
- System Basis Chip
- Motor Control
- Valve Control
- Engine (Solenoid) Control
- Battery Management
- Load Driver
- Add-on Wireless Connectivity

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SAFETY MCU AND SBC AS A BACKBONE OF NXP SAFETY SOLUTIONS
For a Safer World

FUNCTIONAL SAFETY MCU

Truly Different | Auto MCU vs. Consumer Components

- ZVEI work group classified 6 categories for potenial 66 differences

Automotive Requirements: Reliabilty, Zero Defects, Supply, Security, ...

| Technology Semiconductor & Packaging | Design incl. DFT and DFM* | Validation, Characterization, Qualification | Manufacturing | Production & Test | Support |

Standards: IEC 61508, AEC Q100, ISO TS 16949, ...
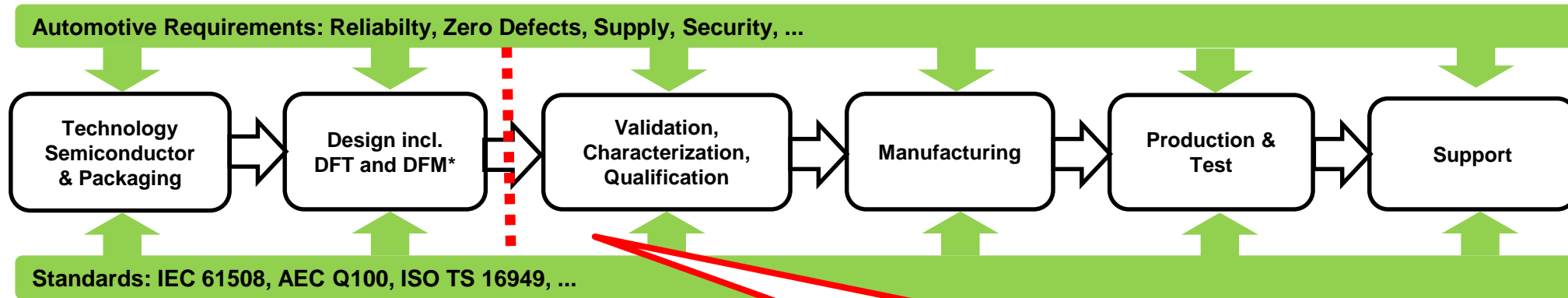
Note: DFT = Design for Test; DFM = Design for Manufacturability
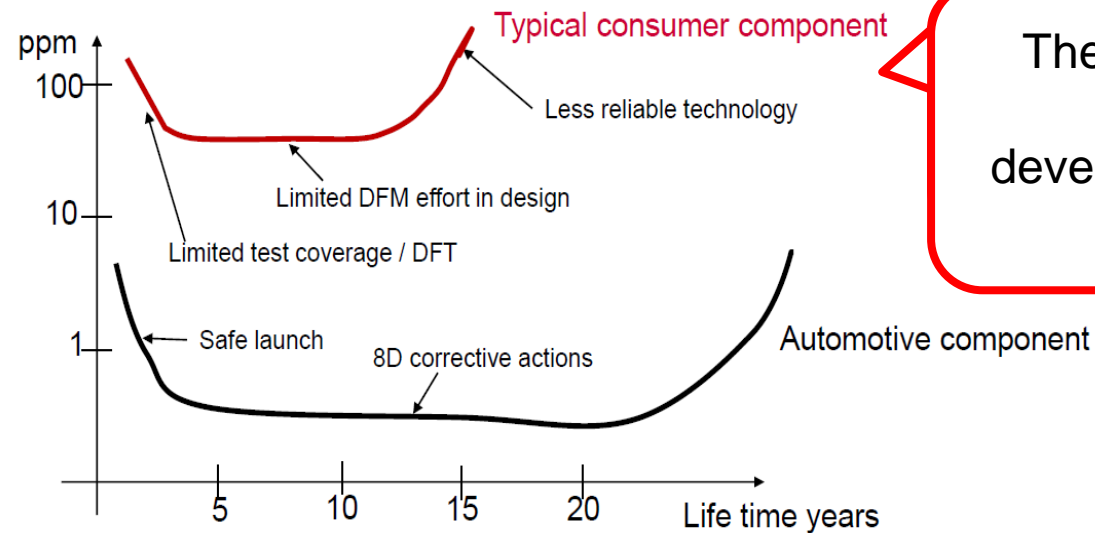
The component capability is frozen after technology, packaging & product development and impacts the right slope of the „Bath Tub Curve"

Quality & Reliability in a Typical Automotive 125°C (Ta) Mission Profile

MPC574xP | Safety MCU Introduction

Key Technical Characteristics

► **Multi-core architecture (2x e200z4 up to 200MHz)** with local memory (64KB)

► Scalable Embedded Flash (up to 2.5MB) with EE emulation (up to 384KB SRAM)

► **Delayed lock-step architecture**, duplicated periphery, LBIST / MBIST, ADC self test & FCCU for highest safety integrity level (ASIL D, SIL 4 or PL e)

► **Developed according to the ISO 26262** automotive safety norm (derived from generic IEC 61508)

► Option for **extended temperature** up to 165°C Tj

Integration and Peripherals

► Maximum **compatibility to previous NXP safety generation** (MPC5643L)

► **Supporting up to 2 motors**

► Inter-processor high speed serial I/F (SIPI)

► SENT I/F for Chassis applications

► **Ethernet** (in BGA package), LIN, CAN & Flexray I/F options

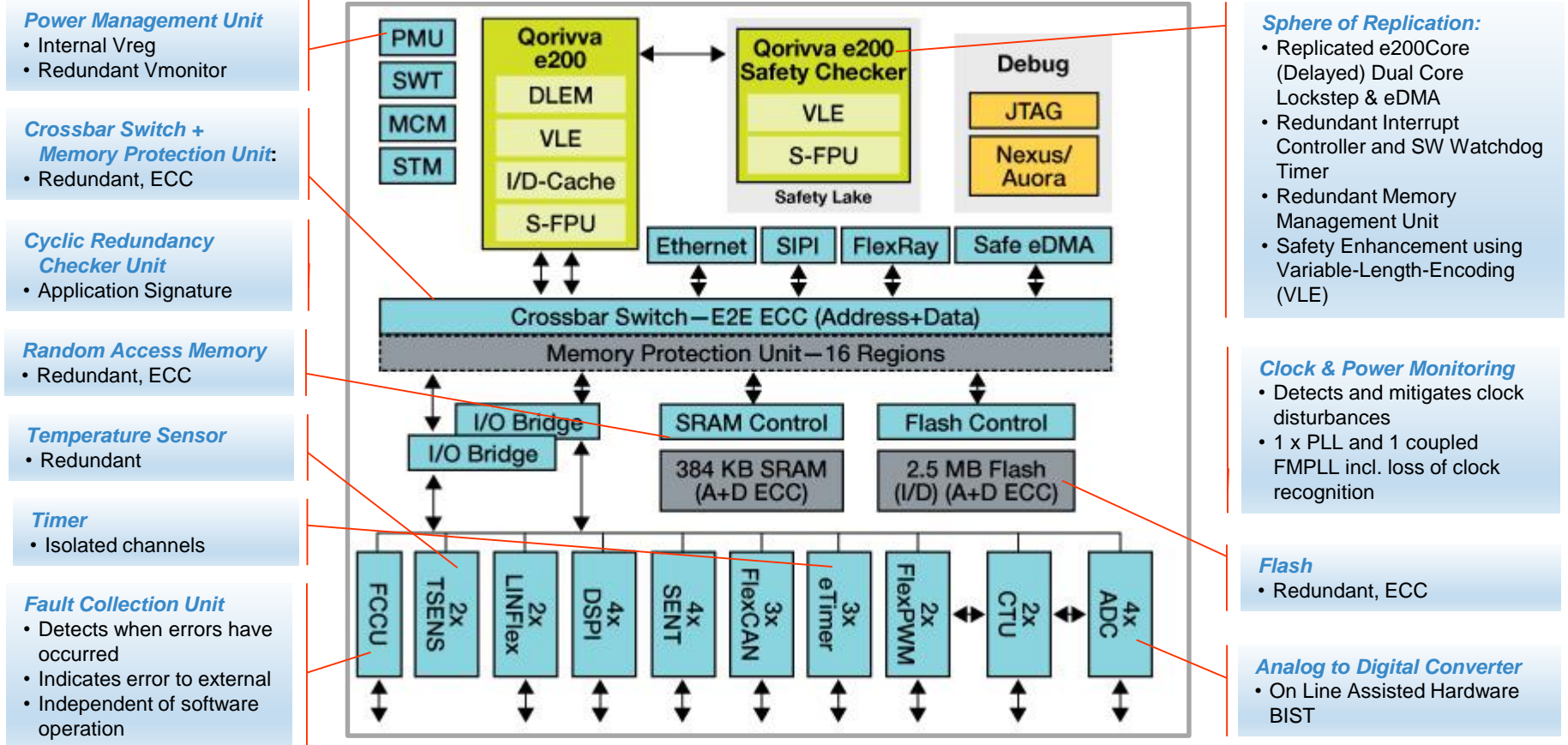► 4x multi-chip DSPI for ASIC communication

Target Applications

► **Safety Critical Domain / Gateway Control** e.g.
  - ► Industrial Automation
  - ► Building Control
  - ► Braking & Stability
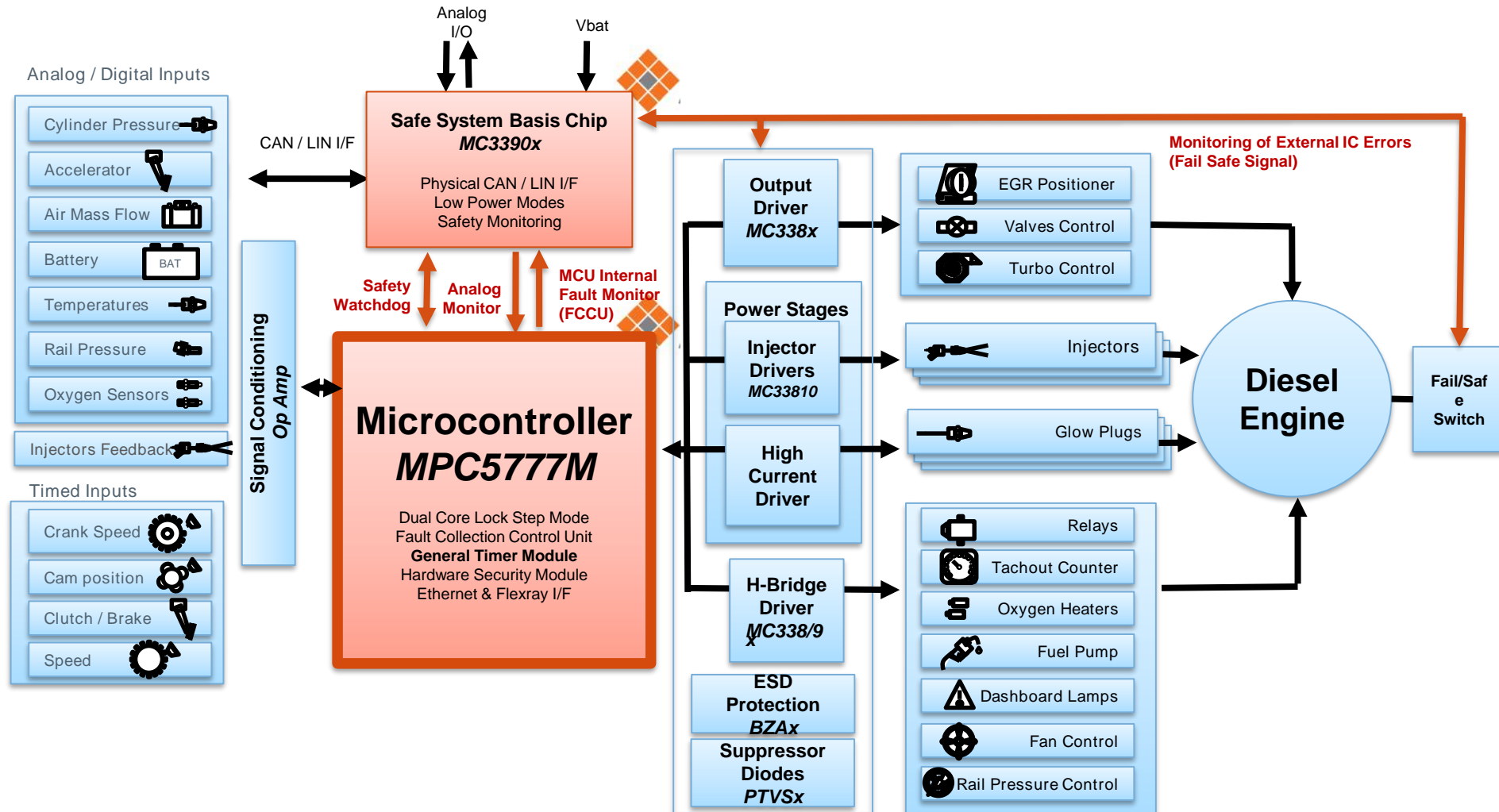 - ► DCDC Converter
  - ► Medical

Packages

► 144LQFP
► 257MAPBGA

MPC574xP | Safety Features

Power Management Unit
- Internal Vreg
- Redundant Vmonitor

Crossbar Switch + Memory Protection Unit:
- Redundant, ECC

Cyclic Redundancy Checker Unit
- Application Signature

Random Access Memory
- Redundant, ECC

Temperature Sensor
- Redundant

Timer
- Isolated channels

Fault Collection Unit
- Detects when errors have occurred
- Indicates error to external
- Independent of software operation

Sphere of Replication:
- Replicated e200Core (Delayed) Dual Core Lockstep & eDMA
- Redundant Interrupt Controller and SW Watchdog Timer
- Redundant Memory Management Unit
- Safety Enhancement using Variable-Length-Encoding (VLE)

Clock & Power Monitoring
- Detects and mitigates clock disturbances
- 1 x PLL and 1 coupled FMPLL incl. loss of clock recognition

Flash
- Redundant, ECC

Analog to Digital Converter
- On Line Assisted Hardware BIST

Diagram labels

PMU, SWT, MCM, STM

Qorivva e200: DLEM, VLE, I/D-Cache, S-FPU

Qorivva e200 Safety Checker: VLE, S-FPU — Safety Lake

Debug: JTAG, Nexus/Auora

Ethernet, SIPI, FlexRay, Safe eDMA

Crossbar Switch—E2E ECC (Address+Data)

Memory Protection Unit—16 Regions

I/O Bridge, I/O Bridge

SRAM Control, Flash Control

384 KB SRAM (A+D ECC), 2.5 MB Flash (I/D) (A+D ECC)

FCCU, 2x TSENS, 2x LINFlex, 4x DSPI, 4x SENT, 3x FlexCAN, 3x eTimer, 2x FlexPWM, 2x CTU, 4x ADC

[More details in MPC5744P Safety Manual](#)

SAFE ASSURE™

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Example | Fct Safety | Diesel Engine | MPC5777M

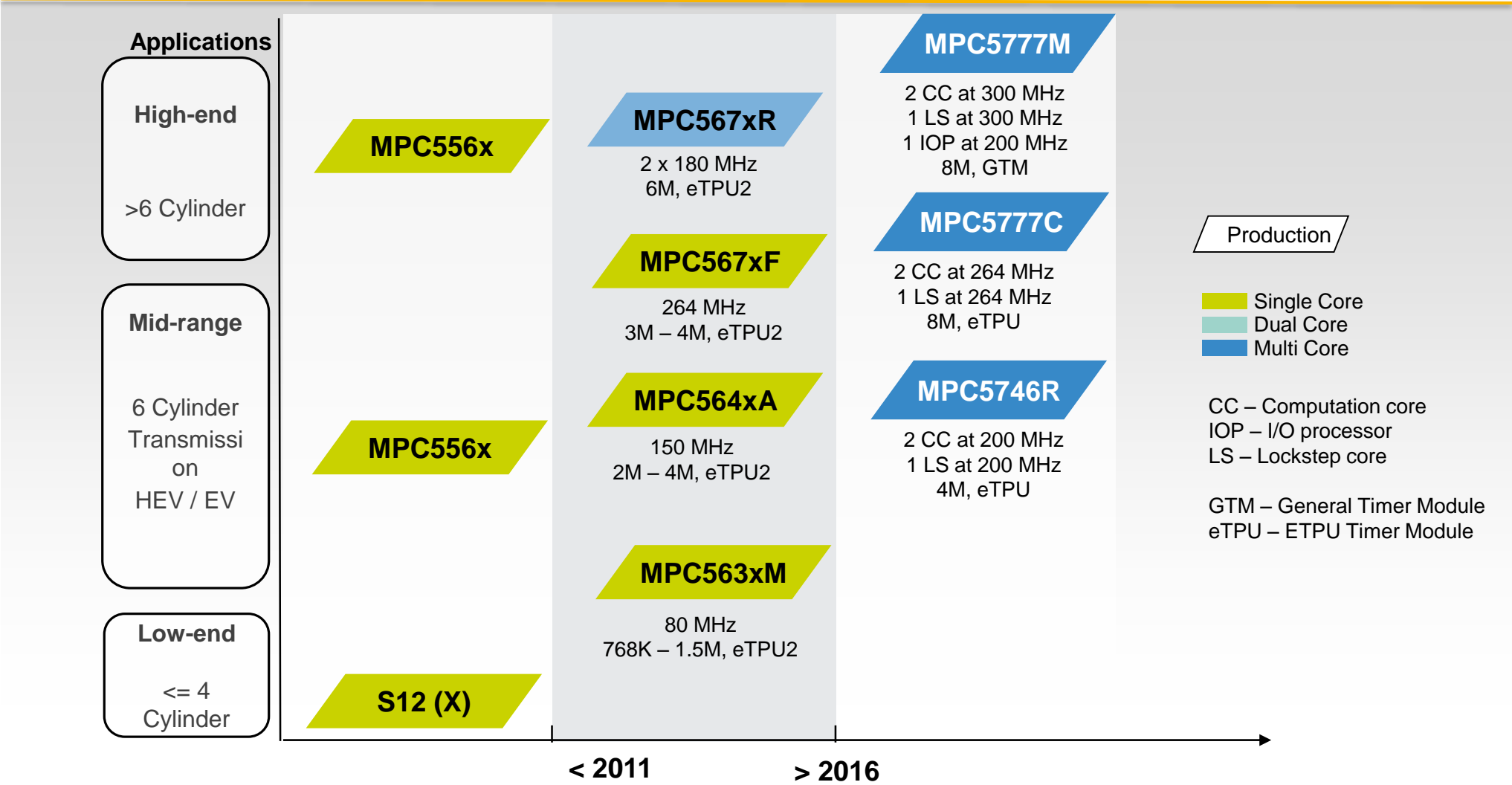# MPC57xx Powertrain | Device Comparison

Feature	MPC5777M	MPC5777C	MPC5746R
Cores	2x z7 1x z7 Lockstep **1z z4 IO**	2x z7 1x z7 Lockstep	2x z4 1x z4 Lockstep
Speed	**300MHz z7** 200MHz z4	264MHz	200MHz
Flash	**8M**	**8M**	2M-4M
Timer	**GTM**	eTPU	eTPU
FlexRay	**Yes**	No	No
Ethernet	Yes	Yes	Yes
ISO CAN FD	No	**Yes**	No
Security	**HSM**	**CSE**	No
Temperature	125°C Ta / 150°C Tj	125°C Ta / 150°C Tj	125°C Ta / 150°C Tj
Package	416 / 512 BGA	416 / 516 BGA	144 / 176 LQFP 252 BGA
Qualified Product Availability	**Launched 2016**	**Launched 2016**	**Launched 2016**

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MPC5777C | Advanced Architecture
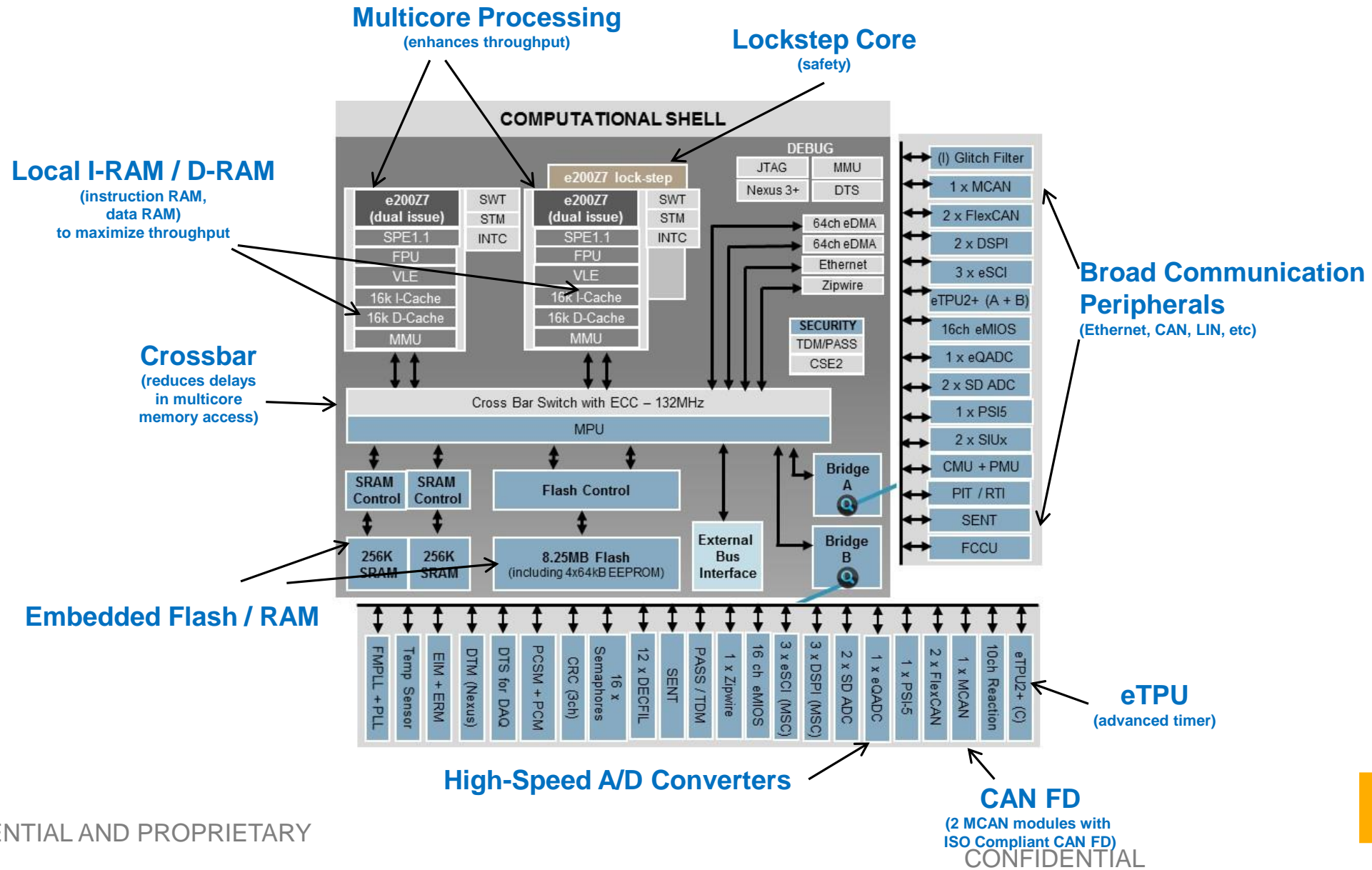
Powertrain | MCU Portfolio

Applications

High-end

\>6 Cylinder

Mid-range

6 Cylinder
Transmissi
on
HEV / EV

Low-end

<= 4
Cylinder

MPC556x

MPC556x

S12 (X)

MPC567xR

2 x 180 MHz
6M, eTPU2

MPC567xF

264 MHz
3M – 4M, eTPU2

MPC564xA

150 MHz
2M – 4M, eTPU2

MPC563xM

80 MHz
768K – 1.5M, eTPU2

MPC5777M

2 CC at 300 MHz
1 LS at 300 MHz
1 IOP at 200 MHz
8M, GTM

MPC5777C

2 CC at 264 MHz
1 LS at 264 MHz
8M, eTPU

MPC5746R

2 CC at 200 MHz
1 LS at 200 MHz
4M, eTPU

Production

- Single Core
- Dual Core
- Multi Core

CC – Computation core
IOP – I/O processor
LS – Lockstep core

GTM – General Timer Module
eTPU – ETPU Timer Module

< 2011   > 2016

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

Block diagram

- **VPRE DC/DC** 6.5V / 2.0A Buck LV124 compliant
- **Boost Driver**
- **Battery Sense before RBP**
- **VCORE DC/DC or LDO** From 1V to 5.0V 0.5/0.8/1.5/2.2A versions
- **Vcca (100 / 300mA)** 3.3V or 5.0V LDO
- **VAUX – tracker (400mA)** 5.0V or 3.3V LDO
- **VCOM (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	PROVEN	SAFE	ROBUST	SIMPLIFIED
Family concept	**Designed at OEMs**	**Flexible Fail Silent**	**PASS 4200h HTOL**	**Tools & Documents**

Safety SBC Integrate External Safety Monitoring
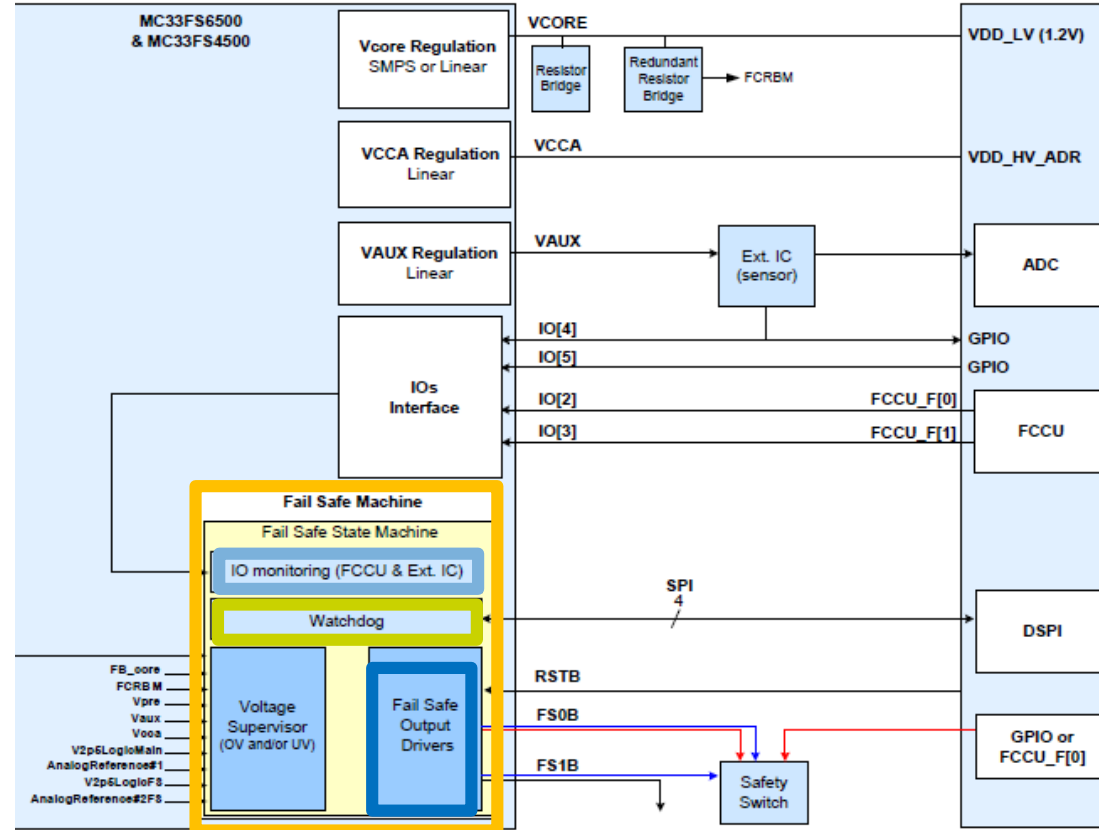
Safety SBC FS65

Safety MCU

Independent Fail Safe State Machine
✓ Physical & Electrical independance to fit for ASILD
✓ Power Management Monitoring Unit (UV / OV)
✓ Analog & Digital Built In Self Test to minimize Latent Faults
✓ Own Reference & Supply to Reduce Common Cause Failure

Advanced Watchdog
✓ Challenger
✓ Replace external MCU Monitoring

HW Redundancy
✓ Vcore external Monitoring

MCU Monitoring
✓ FCCU : Fault Collection Control Unit
✓ Monitor Dual Core Lock Step Modes MCUs

RSTb – Fail Silent Mode
✓ Configurable RSTb activation giving more system availability

Fail Safe Output Pins
✓ Redundant System Fail Safe enabler
✓ Second Fail Safe pin to assert safety path with configurable delay after failure

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Safety SBC Integrate External Safety Monitoring

Independent Fail Safe State Machine
- ✓ Physical & Electrical independance to fit for ASILD
- ✓ Power Management Monitoring Unit (UV / OV)
- ✓ Analog & Digital Built In Self Test to minimize Latent Faults
- ✓ Own Reference & Supply to Reduce Common Cause Failure

Advanced Watchdog
- ✓ Challenger
- ✓ Replace external MCU Monitoring

Safety SBC FS65
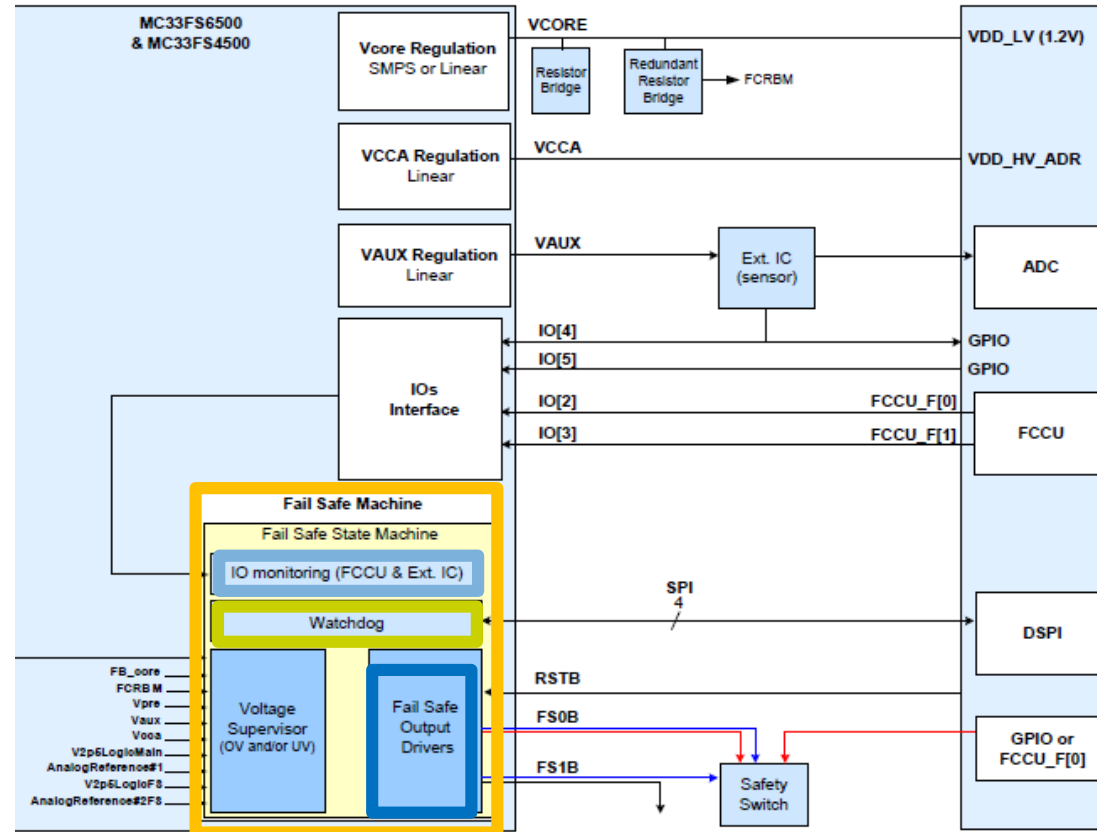
Safety MCU

HW Redundancy
- ✓ Vcore external Monitoring

MCU Monitoring
- ✓ FCCU : Fault Collection Control Unit
- ✓ Monitor Dual Core Lock Step Modes MCUs

RSTb – Fail Silent Mode
- ✓ Configurable RSTb activation giving more system availability

Fail Safe Pin (FS0b) :
- ✓ Redundant System Fail Safe enabler
- ✓ Second Fail Safe pin to assert safety path with configurable delay after failure

Dependability: Safety vs Availability
Qualitative Analysis – Enabling Fail Silent Operations

MC33907 & MC33908

FS65 and FS45 family

Normal Operation

Fail Silent Available

Fail Safe Disabled

Dual-Clutch Transmission use case

- All gears available
- Latest gear locked
- Clutch open
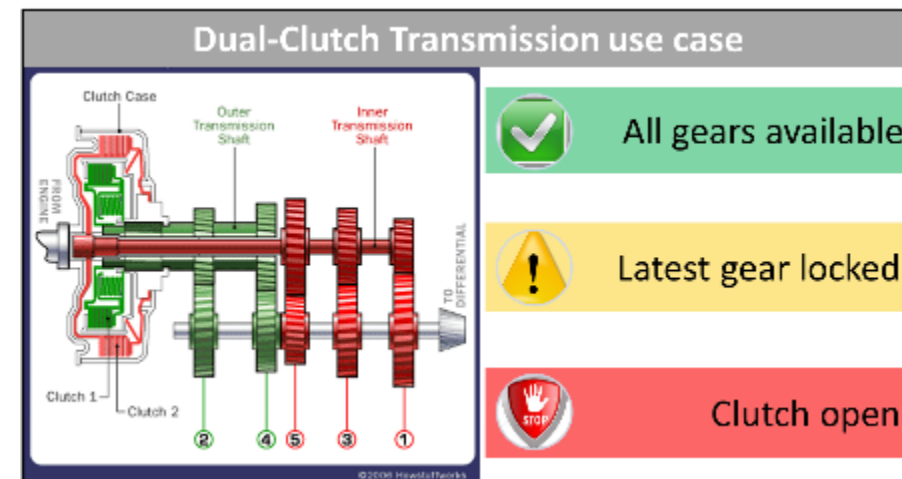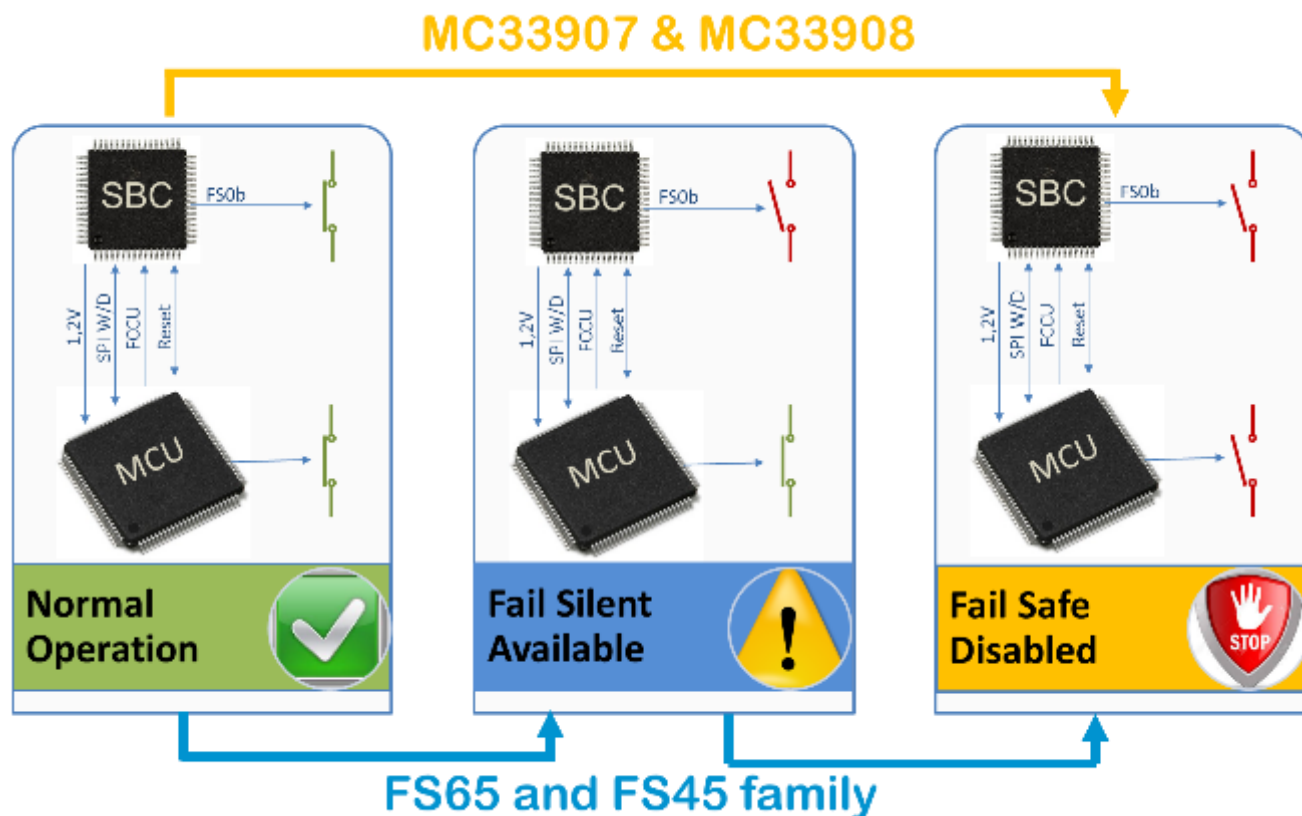
1. **CONFIGURABLE RESET** at SAFE STATE activation to enable **MCU Diagnostic**.
2. **CONFIGURABLE SAFE STATE**, independently for each failure with **2nd Fail Safe output**.
3. **HIGH AVAILABILITY : No MCU shutdown** in case of multiple failures.
4. **SMART DEGRADED MODE :** Application is failing with **safe and available** operation

FS65 FS1B Tdelay Use Case: Motor Demagnetization
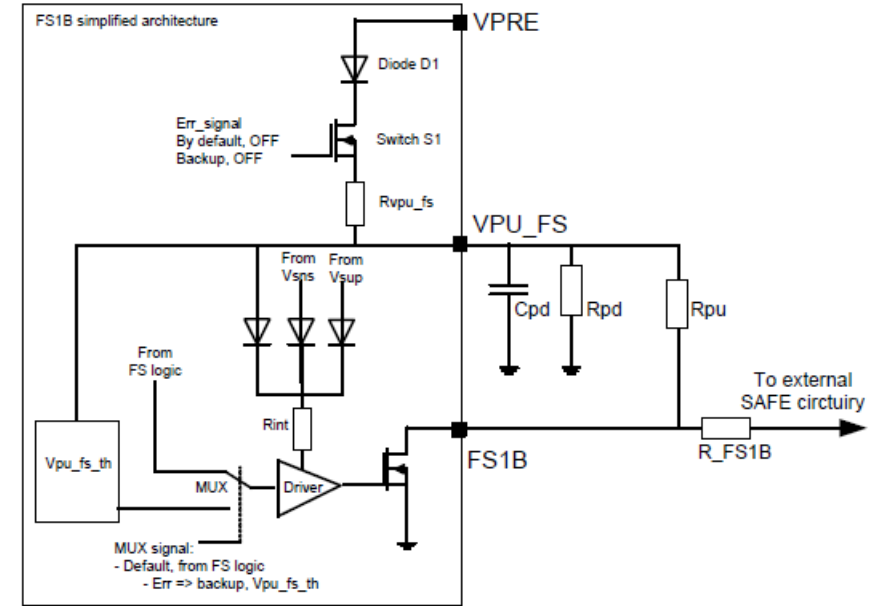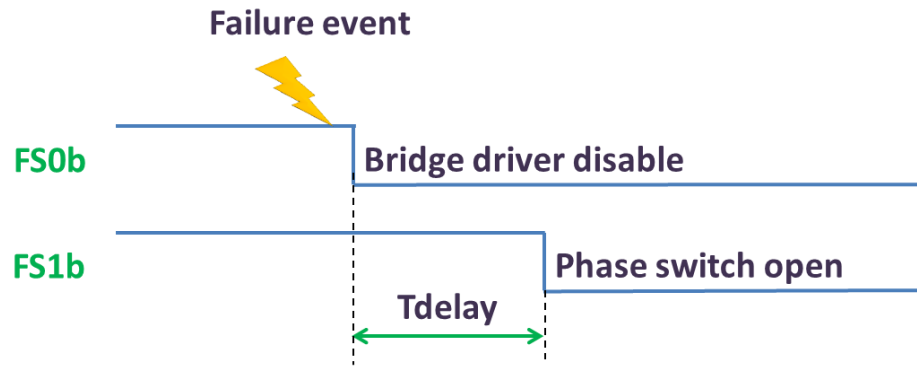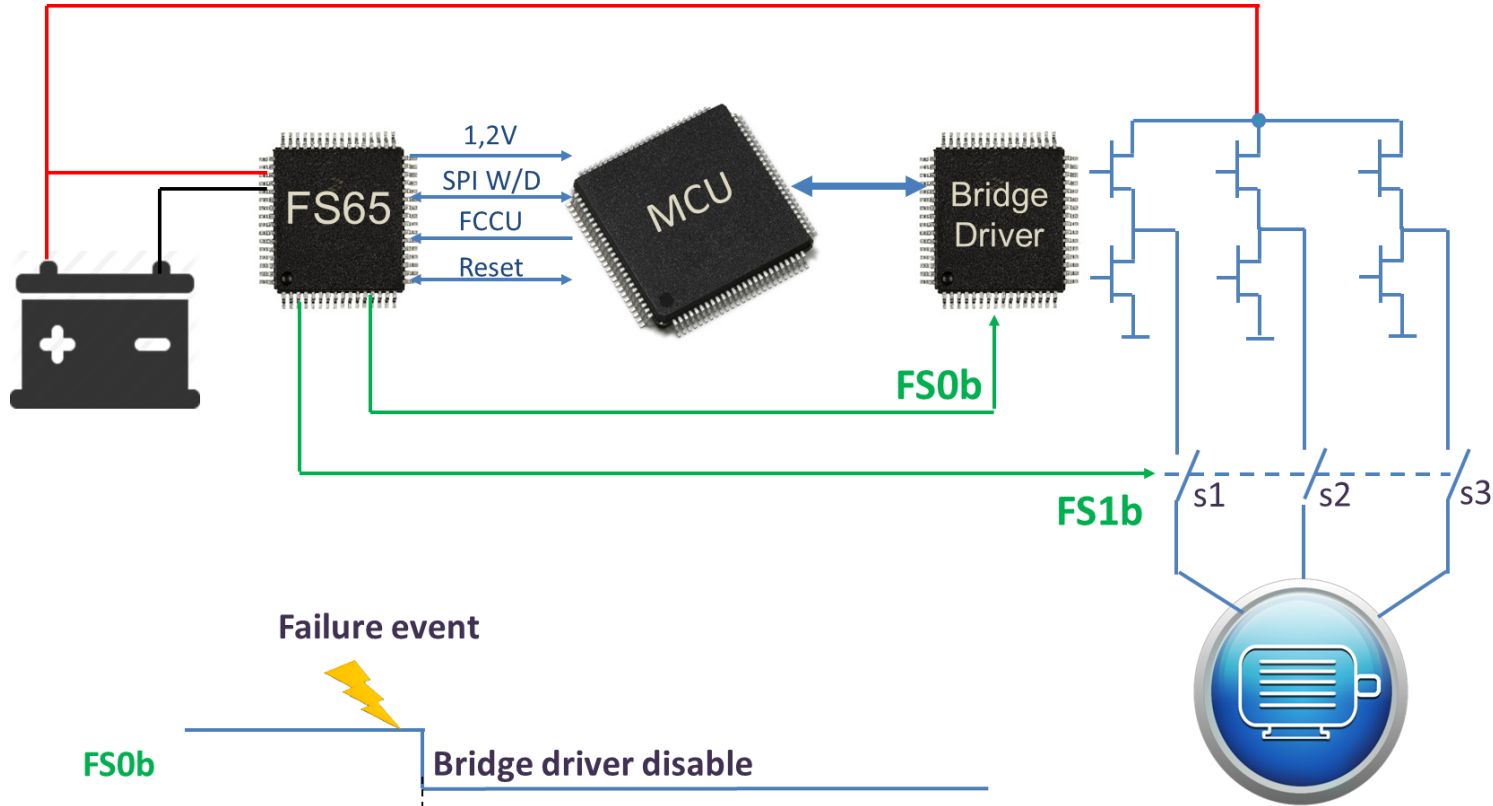
- Digital Tdelay configurable from 0 to 3150 ms during INIT phase

- Analog Tdelay configurable through Rpd/Cpd in case of battery or oscillator loss (16 KΩ/ 3.3 uF for 35 ms)

Functional Robustness - Integrated & Automated Test Platform

Battery environment & Non-ISO Pulses

Triangular

VBAT_max
VBAT_start
VBAT_min

1st pulse   Last pulse

● VBAT_slope applicable

0.1V/us → Class A & Vcore load=1A + MCU
1V/s → Class C & Vcore load=300mA + MCU
1V/mn → Class C & Vcore load=300mA + MCU

BrownOut

14V
10V
9V

0V

T1 T2 T3 T4 T5

Damped Sinus

IG1 voltage
12.0V   1sec   7sec   13.0V

V1   V2

Started with 2Vp-p 30Hz

Sweepy

LabView

FAST LV

Hardware

Control & Monitoring

Configuration & Results
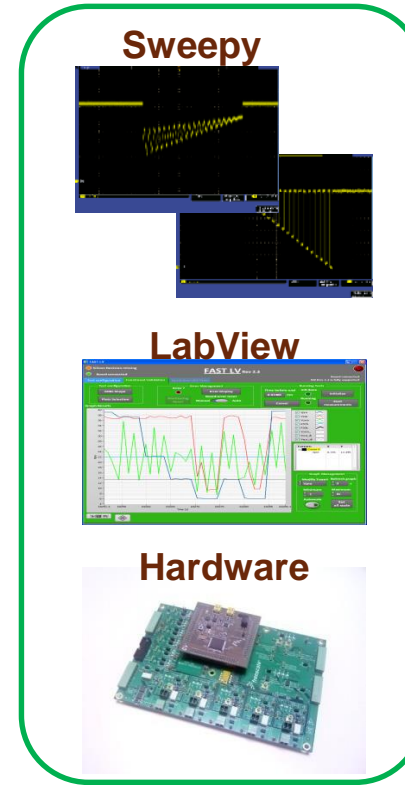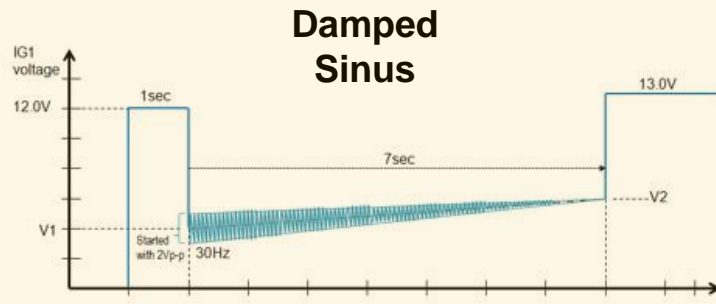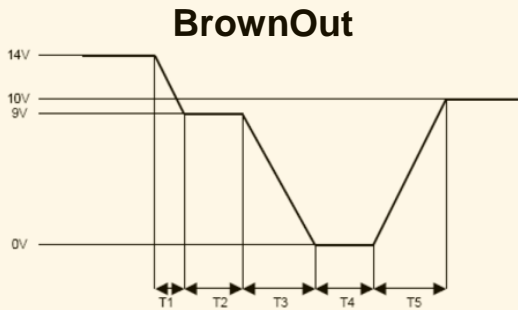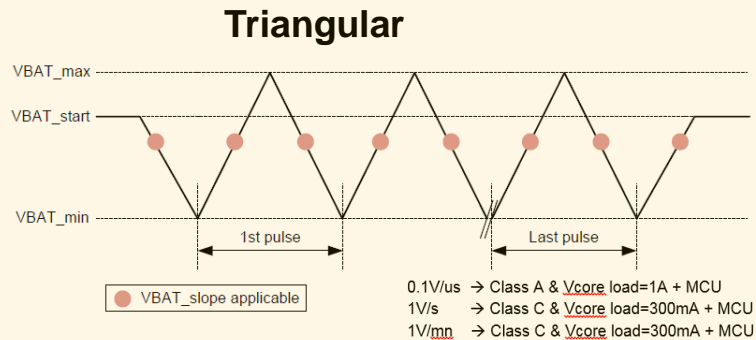
Automated Execution

Equipments

DUT

NXP FS65

Reports

BENEFITS – EXTENDED VALIDATION

✓ **UNIQUE VERSUS COMPETITION**

Car OEMs PULSES - **Database**

INCREASE USE CASE Coverage - **Break the limit. (x10)**

ACCELERATE VALIDATION – **Reduce validation by 4**

ISO26262 COMPLIANT - **Full Traceability**

MULTIPURPOSE - ***Non-ISO, Funct. Validation***

FS65/FS45 High Reliability Performance for Car Electrification
Results higher than AEC-Q100 requirement

✓ FS65/FS45 family has been qualified with 2200Hrs of HTOL stress @Tj=150°C (PPAP)

✓ Extended reliability stress have been performed to cover more aggressive mission profiles like EV/HEV and transmission applications.

HTOL @Tj=150°C (Grade 1)				HTOL @Tj=160°C (extended Grade 1)
Minimum AEC-Q100	Safety Manual mission profile	Start/Stop alterno starter mission profile	EV/HEV mission profile	Transmission mission profile
1000Hrs	1300Hrs	2200Hrs	4200Hrs	2700Hrs
PASS	**PASS**	**PASS**	**PASS**	**PASS**

✓ **UNIQUE VERSUS COMPETITION**

Proven FS45 and FS65 PowerSBC
1st fit for ASIL D Industry Certifications

• **Electrical Conformance**

- CAN, LIN C&S **granted**
- CAN Velio **granted**

• **EMC/ESD Conformance**

- **IBEE** Zwickau **granted**
- **MOOSER** J2962 **granted**
- **AN5238** PCB Design & EMC guideline

• **Safety Assessment**

- Internal **Positive** assessment regarding design capability to be used in a safety application up to **ASIL D** based on **TUV SAAR certified process**

Documentation Available

Safety Power System Basis Chip with CAN FD and LIN Transceivers

The FS6500/FS4500 SMARTMOS devices are a multi-output, power supply, integrated circuit, including CAN Flexible Data (FD) and/or LIN transceivers, dedicated to the automotive market.

Multiple switching and linear voltage regulators, including low-power mode (32 µA) are available with various wake-up capabilities. An advanced power management scheme is implemented to maintain high efficiency over a wide range of input voltages (down to 2.7 V) and output current ranges (up to 2.2 A).

The FS6500/FS4500 includes configurable Fail-safe/Fail silent safety behavior and features, with two fail-safe outputs, becoming a full part of a safety oriented system partitioning, to reach a high integrity safety level (up to ASIL D).

The built-in CAN FD interface fulfills the ISO11898-2 and -5 standards. The LIN interface fulfills LIN protocol specifications 2.0, 2.1, 2.2, and SAEJ2602-2.

Features

- Battery voltage sensing & MUX output pin
- Highly flexible SMPS pre-regulator, allowing two topologies: non-inverting buck-boost and standard buck
- Family of devices to supply MCU core from 1.0 V to 5.0 V, with SMPS (0.8 A, 1.5 A or 2.2 A) or LD0 (0.5 A)
- Linear voltage regulator dedicated to auxiliary functions, or to sensor supply (V_{CCA} tracker or independent), 5.0 V or 3.3 V
- Linear voltage regulator dedicated to MCU A/D reference voltage or I/Os supply (V_{CCA}), 5.0 V or 3.3 V
- 3.3 V keep alive memory supply available in low-power mode
- Long duration timer, counting up to 6 months with 1.0 s resolution
- Multiple wake-up sources in low-power mode: CAN, LIN, IOs, LDT
- Five configurable I/Os

FS6500
FS4500

Power System Basis Chip

AE SUFFIX (PB-FREE)
98ASA00173D
48-PIN LQFP-EP

Applications

- Drive Train Electrification (BMS, Hybrid EV and HEV, Inverter, DCDC, Alterno Starter)
- Drive Train - Chassis & Safety (Active Suspension, Steering, Safety Domain Gateway)
- Power Train (EMS, TCU, Gear Box)
- ADAS (LDW, Radar, Sensor Fusion Safety area)

✓ **Data sheet**

FS6500 and FS4500 safe system basis chip hardware design and product guidelines

1 Introduction

This application note provides design guidelines for integrating the FS6500 and FS4500 system basis chip (SBC) family of devices into automotive and industrial electronic systems. It shows how to optimize PCB layouts and gives recommendations regarding external components.

To minimize the EMC impact from embedded DC/DC converters, pay attention to PCB component routing when designing with the FS6500 and FS4500.
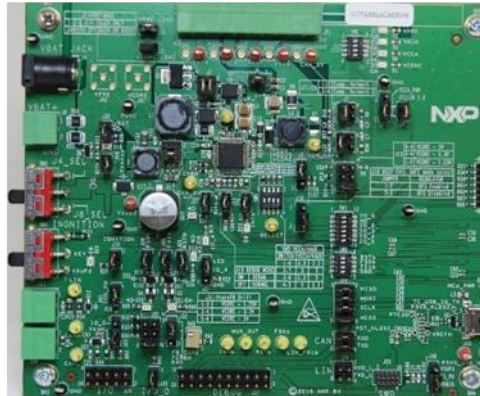
Contents

✓ **AN5238**

FS6500

✓ **Qualified**

✓ **FMEDA**

✓ **KITFS6523CAEEVM**

✓ **FRDMFS6523CAEVM**

Safety Manual for FS6500 and FS4500

2.1 Generic safety system architecture

The FS6500 and FS4500 are designed to be used in automotive or industrial applications which are needed to fulfill functional safety requirements, as defined by functional safety integrity levels (for example, ASIL D of ISO 26262).

The Figure 6 shows a generic safety system architecture example. The FS6500 and FS4500 are intended to be the main power supply for the MCU (V_{CORE} and V_{CCA}) and the sensor (V_{AUX}), with MCU monitoring (watchdog and FCCU) and Fail-safe outputs (FS0B and FS1B) to put the system in safe-state.
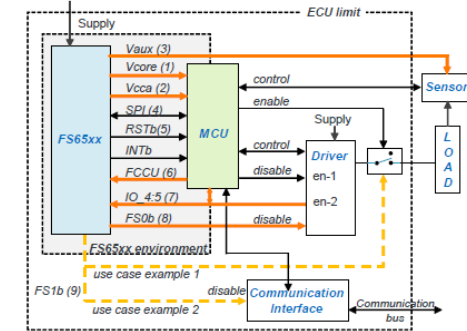
Figure 6. Generic safety system architecture

✓ **Safety Manual**

FRDMFS6523CAEVM kit – Hardware description 1/2

- Size 33mm x 33mm

- Support wide range of FS65xx / FS45xx family

- Close partnership with best in class passive components suppliers (Coil, Capacitor, Diode, Transistor)

- Low cost evaluation board & Arduino compatible

- 2 kits available: **FRDMFS6523CAEVM** & **FRDMFS4503CAEVM**

PC with FlexGUI installed

USB Cable

13.5V Power supply

FRDMFS6522LAEVB

J1

FRDM KL25Z

External load board
(Resistor load or MCU power supply)

Regulator LEDs Status

FSx & RST LEDs Status

CAN / LIN connector

Regulator Output

Vbat

VDDIO Selection

Debug / Normal

Debug Area

FS6500 Area

Debug Ressources

Customer Focus

FRDMFS6523CAEVM kit - FLEX GUI 1/2

FRDMFS6523CAEVM kit – FLEX GUI 2/2

Registers window
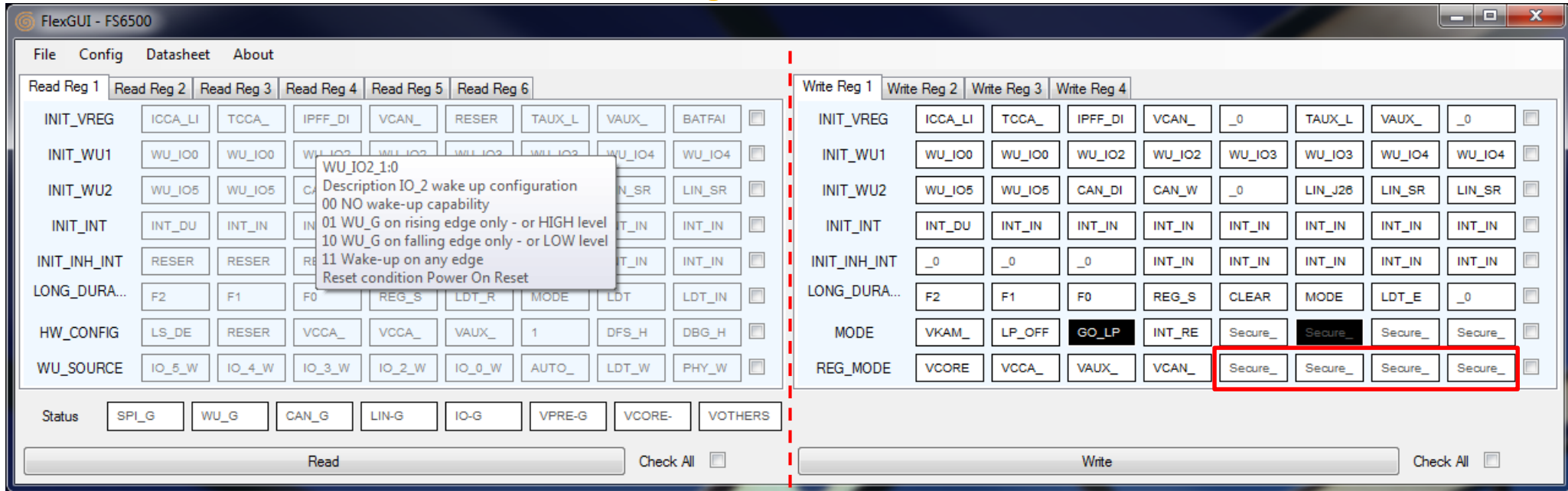
On the left side, **read registers** content:
- 1 by 1 by checking the individual register checkbox
- All together by checking the "Check All" checkbox
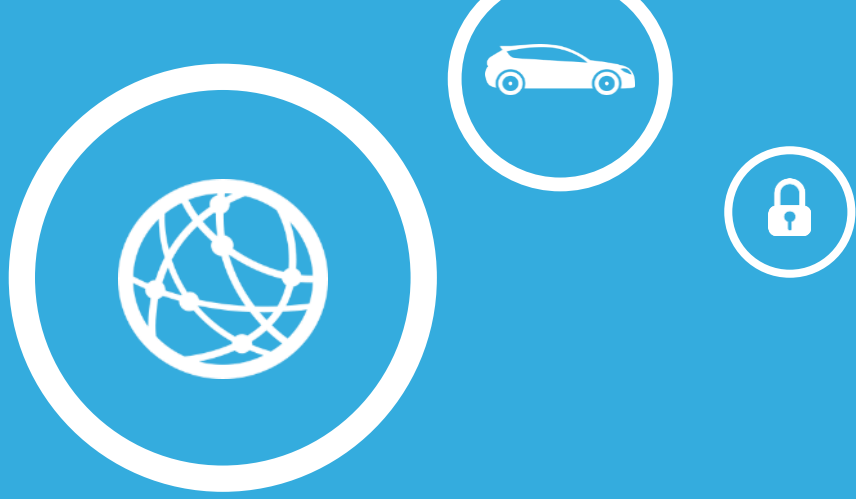
Tips:
- Maintain the mouse on a bit to get on-line help

On the right side, **write registers** content
- 1 by 1 by checking the individual register checkbox
- All together by checking the "Check All" checkbox

Tips:
- **The secure bits,** and the **parity bit**, are **automatically** calculated by the tool

FUNCTIONAL SAFETY MOTOR CONTROL

MC33HB2000 & MC33HB2001 Motor Driver

High availability 5 Amp H-Bridge driver with enhanced ISO26262 safety features, flexible SPI control, and patented thermal management for continuous operation

Differentiation

- ISO26262 qualifiable
- Current feedback with 5% real time accuracy
- Lowest $R_{DS(ON)}$ of 65 mΩ (typical)
- Lowest thermal resistance < 1°C/W
- Smallest package with 6 x 6mm QFN
- Patented thermal protection current limiting

Features

- 4.5 – 36V supply, 40V transient
- Pin compatible $R_{DS(ON)}$ options (65 / 120 mΩ)
- SPI selectable 4x current limits (5.4 - 10.7 A)
- SPI selectable 8x slew rates (0.25 - 16 V/µs)
- Optional 10 x 11mm SOIC-EP & 8 x 8mm PQFN

Electronic Throttle Control Reference Design

Applications

- Electronic throttle control (ETC)
- Electronic gas recirculation (EGR)
- Multi-port injection (MPI) flaps control
- Gasoline direct injection (GDI) swirl & whirl flaps
- Industrial, commercial & medical motor control

HB2000 & HB2001 H-Bridge Circuit Block Diagram

VPWR （ Power Supply Input）
5 V < VPWR < 28 V （UVLO < VPWR < 40 V）

CCP （Charge Pump Capacitor connect pin) CCP Clamp=VPWR+12V

CFB （Current Mirror Output）
±5% current accuracy @ 2 A<Iload<10 A

FS_B （Fault output, open drain）
IN1, IN2 （Output Control）
Two control modes support by SPI
H Bridge Mode (Default)
IN1=Direction control, IN2=PWM input
Half Bridge Mode
IN1=OUT1 control, IN2=OUT2 control
ENBL （IC Enable）
DIS （ Output Disable）

VDDQ （P/S for SPI_MISO output ）
SCLK,CS_B, MOSI, MISO （SPI Communication I/O）
Supports configuration, check fault status and daisy chain connection.
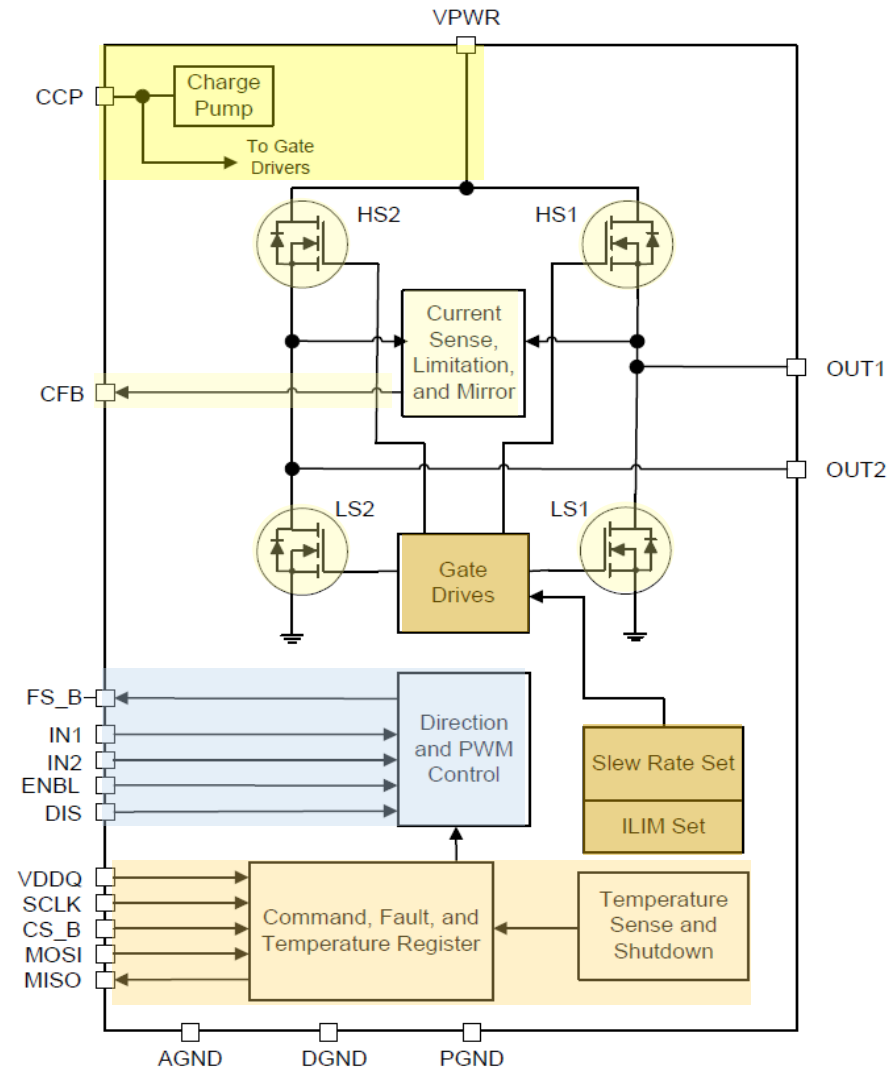
Rdson @8 V<VPWR<28 V ,
TJ=150°C, Iload=3 A

125 mΩ (33HB2001)
235 mΩ (33HB2000)

Programmable Slew Rate
Bypass / 16 / 8 / 4 / 2 / 1 / 0.5 / 0.25 V/us

Programmable Current Limit
5.4 / 7.0 / 8.8 / 10.7 Amps

Full Diagnostics

HB2000 & HB2001 Enhanced Diagnostics & Safety

- Any status bit can be programmed to feedback via status pin
- SPI register always provides detailed status bits
  - Over Temperature Shutdown
  - Thermal Warning
  - Over Current
  - Open Load (in standby mode and in normal full H-bridge operating mode)
  - Short Circuit to Ground Output 1
  - Short Circuit to Ground Output 2
  - Short Circuit to Power Output 1
  - Short Circuit to Power Output 2
  - Vpwr Over Voltage
  - Vpwr Under Voltage
  - Charge Pump Under Voltage
  - SPI Framing Error
  - I/O withstands 36V

HB2000 & HB2001 Active Current Limit

Programmable Current Limit
- 4 settings from nominal 5.4 A to 10.7 A average
- Short Circuit threshold scales up/down as per the current limit selected
- Patented thermal management does not compromise the current set point; delivers more torque

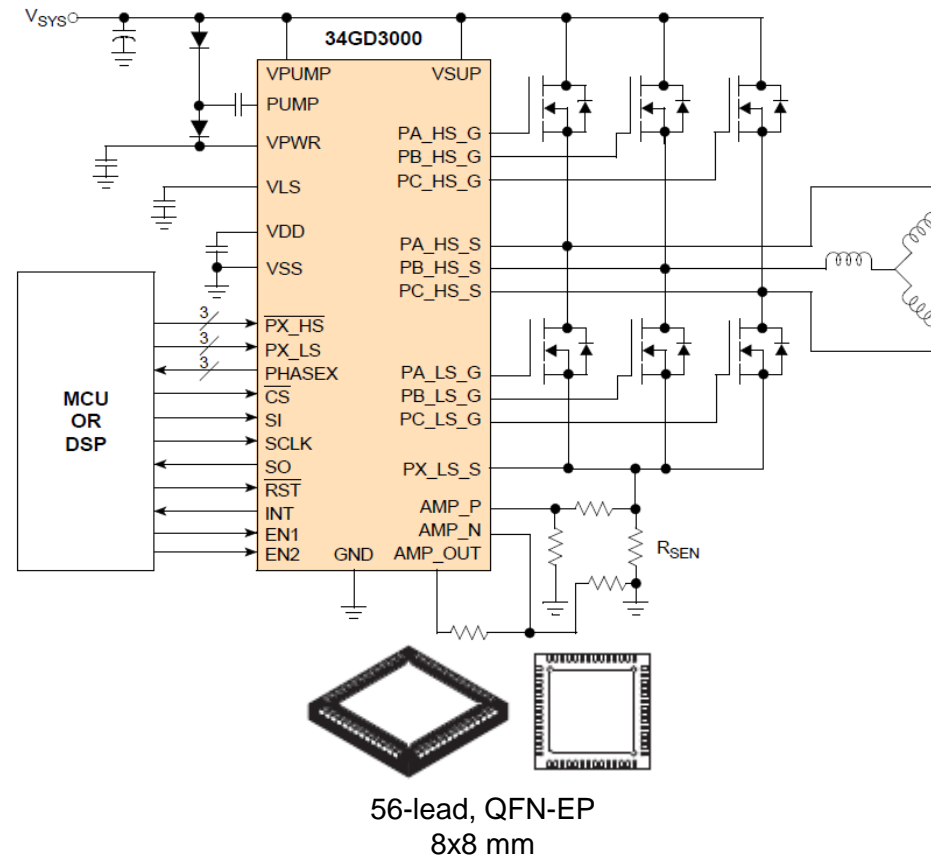| Setting	I_{LIM}	Short Circuit HS	Short Circuit LS	Units
00	5.4	11.9	10.9	A
01	7.0	13.5	12.5	A
10	8.8	15.3	14.3	A
11	10.7	17.2	16.2	A

Ilim Timing and Thermal response

GD3000 BRUSHLESS DC MOTOR MOSFET GATE DRIVER
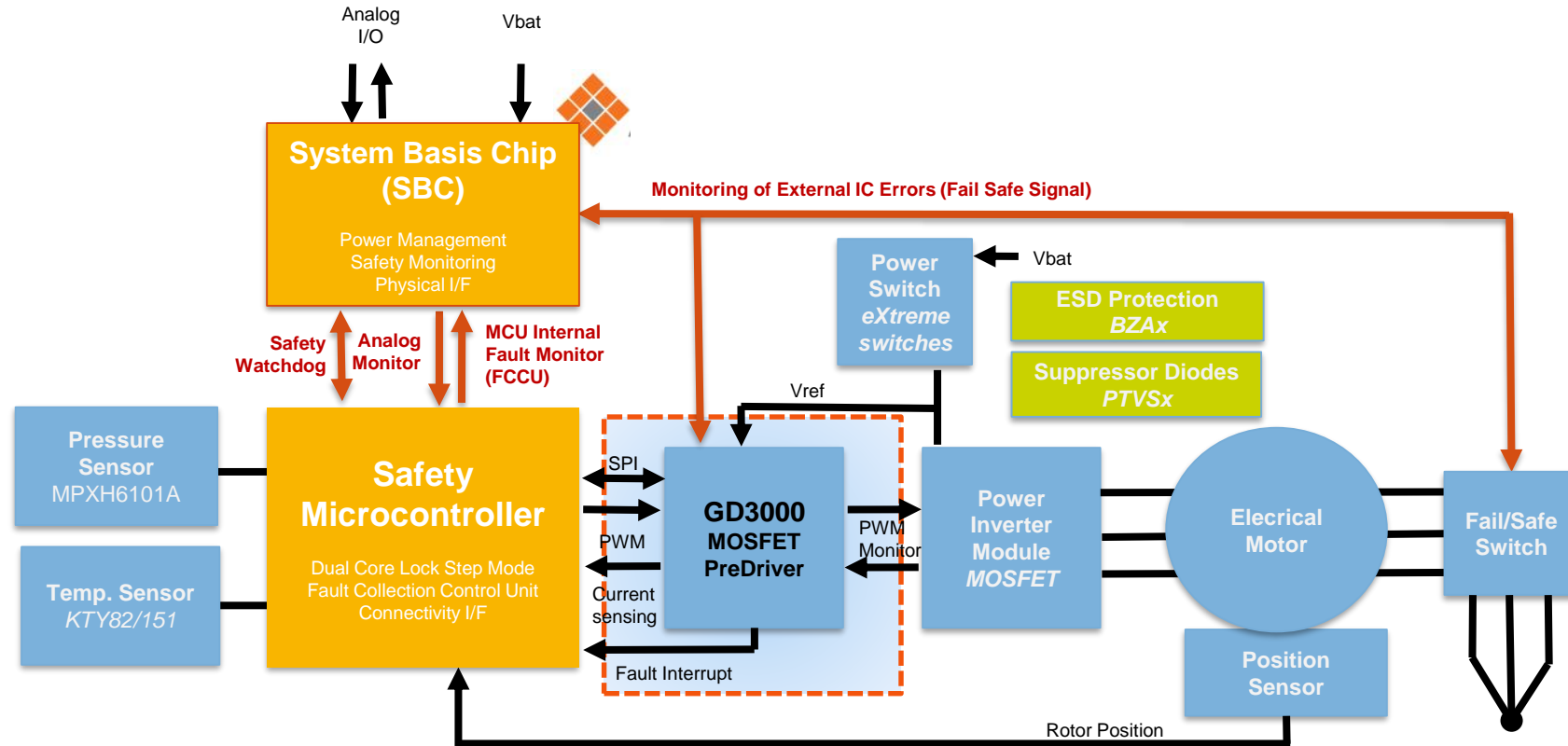
GD3000 Brushless DC Motor MOSFET Gate Driver

Features

- Small package: 8 x 8 mm with 6.75 x 6.75 mm exposed pad

- Up to 60 V operating voltage range

- PWM > 50 kHz

- 1.0 to 2.5A peak gate drive current

- Wide SPI programmable dead time

- Protection against transient spikes and reverse charge injection

56-lead, QFN-EP
8x8 mm

Base Part #	Temp Range (°C)	Package Footprint (LxW mm)	Release
MC33GD3000EP	-40 to 125	QFN 56 (8X8)	Now
MC34GD3000EP	-20 to 105	QFN 56 (8X8)	Now

Typical Applications

- Electronic Power Steering

- ABS / Water / Oil / Fuel Pumps

- Transmission Pumps

- Air Conditioning Compressors

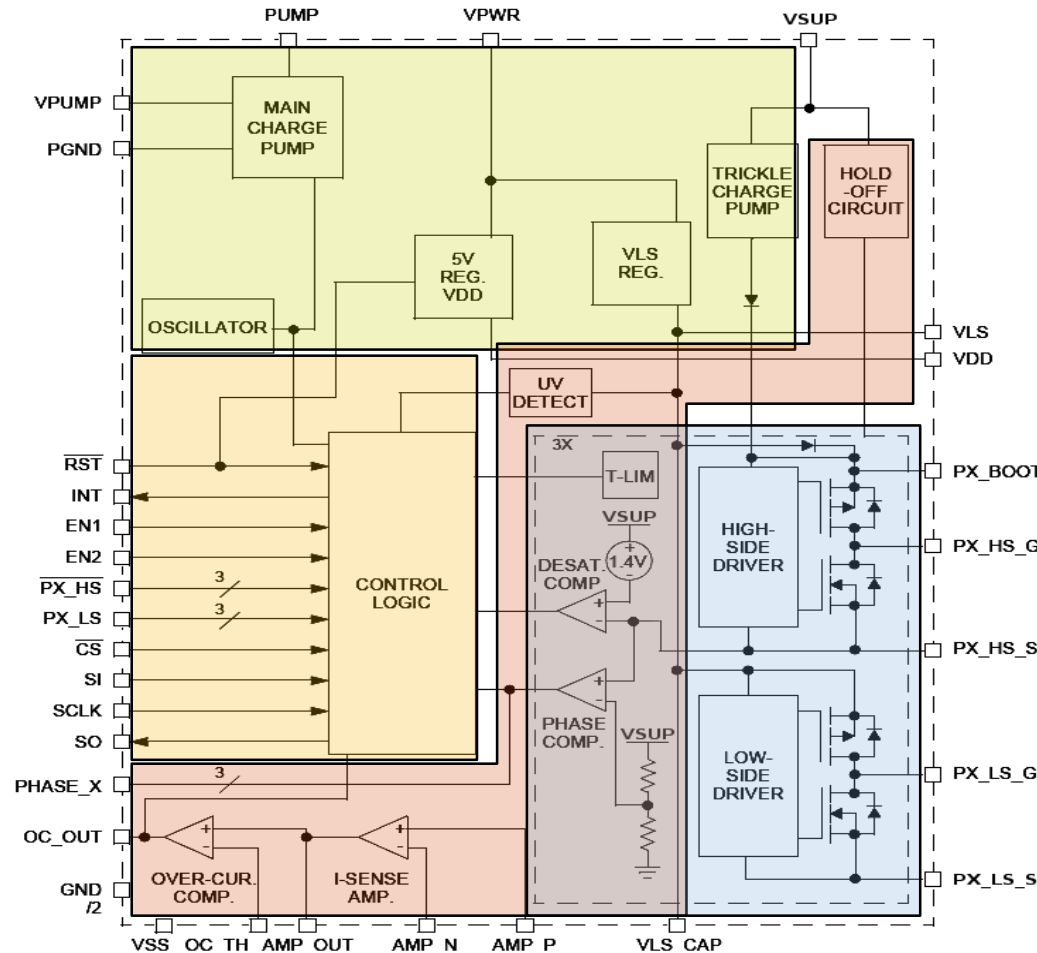- Fans

- Quadcopters / UAVs / Drones

MC33937/GD3000 Functional Block Diagram

Integrated Supplies
- 5 V regulator
- Main charge pump
- VLS regulator
- Trickle charge pump

Logic, Control, and Reporting
- Phase control
- SPI communication
- Dead time control
- Mode control
- Fault status and reporting
- Reset / Enable / Interrupt
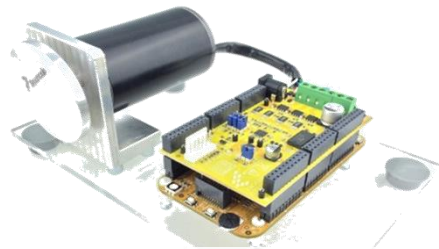- **Shoot-through protection / Cross conduction**

Sensing and Protection
- Differential current sense
- Over-current
- Phase-error
- Desaturation detect
- Over-temperature
- Under-voltage

External HS / LS Outputs x 3
- Large gate charge drive
- Robustness against dV/dt transients
- Voltage transient immunity

Motor Control HW & SW References

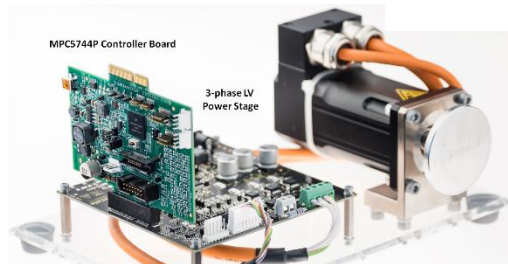PMSM & BLDC w/ S32K (sensorless)

PMSM w/ MPC5604P

Dual PMSM w/ MPC5643L

PMSM w/ MPC5643L

PMSM w/ MPC5743P (sensorless)

BLDC w/ MPC5604P

PMSM & BLDC w/ S12ZVM

BLDC w/ MPC5643L
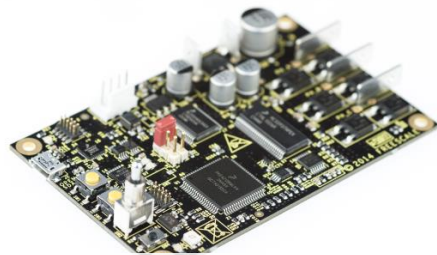
BLDC w/ KEA128

BLDC w/ MPC5606B

BLDC w/ S12G
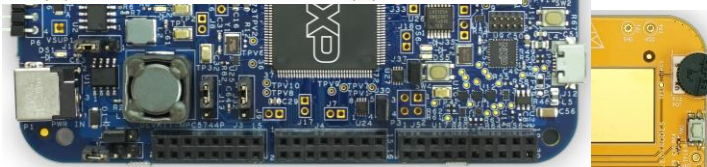
Dual BLDC w/ MPC5643L

GD3000 BDLC/PMSM Motor Control HW

ARM & PPC MCU

DEVKIT-MPC5748G

DEVKIT-MPC5744P

S32K144-EVB

FRDM-KEAZ128

FRDM-KEAZ64Q64

FRDM-KEAZN32Q64

Separate GD3000 and power MOSFET boards
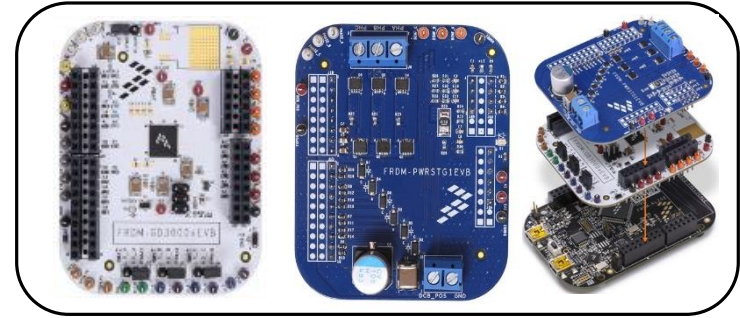
FRDM-GD3000EVB   FRDM-PWRSTG

or

GD3000 + MOSFET on one board
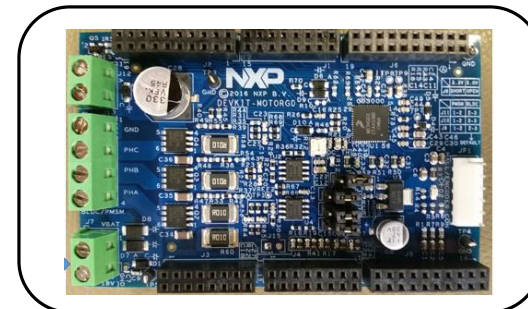
DEVKIT-MOTORGD
GD3000 Shield supports
S32K, KEA and MPC5744P

Motor Control Development Toolbox

- MATLAB™/Simulink™ model-based design environment for configuring and generating SW to execute motor control algorithms on NXP MCUs
- Software-in-the-loop (SIL) and processor-in-the-loop (PIL) support
- Auto code generation based on the Matlab Embedded Coder
- Bootloader support built in the tool
- Includes Automotive Math and Motor Control Library
- Integration with FreeMASTER for fine tuning

→ **Model-based design & auto code generation**
→ **Reduce development & prototyping time**
→ **Faster Time to Market**
→ **Support migration between platforms**

www.nxp.com/MCToolbox
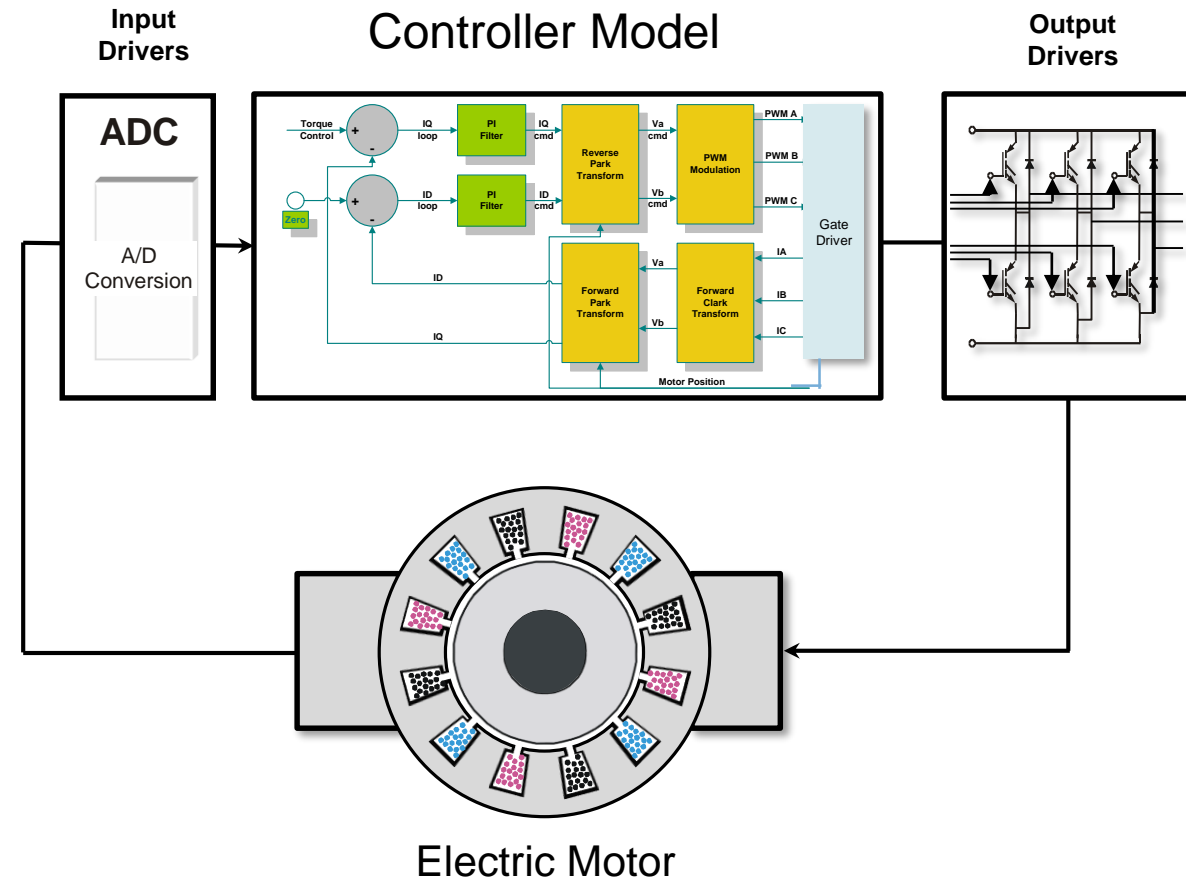
Spin Any Motor With MCAT Tool

- Graphical User Interface, plug-in for FreeMASTER

- It interfaces with the target MCU and allows the user to modify software variables during runtime to tune flashed motor control algorithms in real time (e.g. PI parameters of the current loop) to achieve desired control objectives

- Finally generates the header file with static configuration of the tuned parameters

→ **Simplifies tuning of the motor application (current / speed loops, sensorless algos)**

→ **Reduce development & prototyping time**

→ **Faster Time to Market**

www.nxp.com/MCAT

FreeMASTER – Run Time Debugging Tool

- User-friendly tool for real-time debug monitor and data visualization
  - Completely non-intrusive monitoring of variables on a running system
  - Display multiple variables changing over time on an oscilloscope-like display, or view the data in text form
  - Communicates with an on-target driver via USB, BDM, CAN, UART

http://www.nxp.com/FreeMASTER
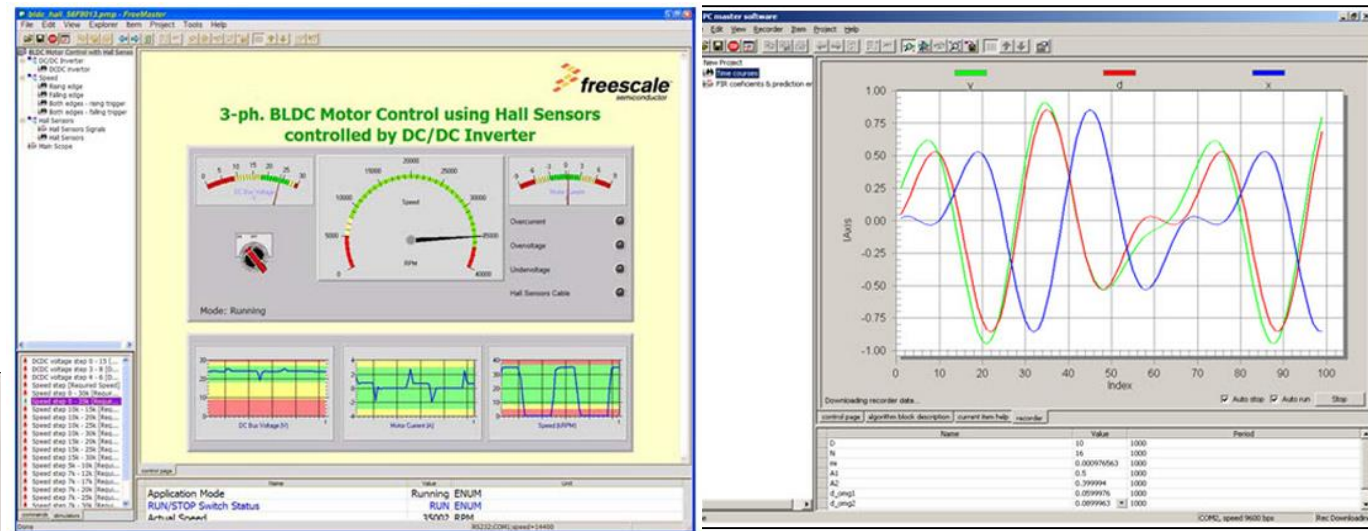
USB
BDM
CAN
UART
JTAG
Ethernet

Key URLs

www.nxp.com/AutoMCDevKits

NXP › Automotive Products › Microcontrollers and Processors › 32-bit Power Architecture › Ultra-Reliable MPC56xx 32-bit Automotive & Industrial Microcontrollers (MCUs)

MTRCKTDPS5643L: Dual 3-phase PMSM Development Kit with Freescale MPC5643L MCU

| Overview | Documentation | Downloads | Buy/Parametrics | Training & Support |

Jump To

Overview
Features
Jump Start Your Design
Supported Devices
Kit Contains

Overview

The MTRCKTDPS5643L motor control development kit is ideal for applications requiring two PMSM motors, like active suspension or electric powertrain. The kit is designed to enable rapid prototyping and evaluation of the motor control application without having to wait for the final hardware design. The kit includes a 32-bit NXP® MPC5643L based controller board and the 3-phase low-voltage power stage board.

An integral part of the automotive motor control development kit is the application software which provides a complete reference implementation of the PMSM motor control application and also takes advantage of the Automotive Math and Motor Control Library Set.

[Application Notes]   [🛒 Buy]

Motor Control Algorithm Concept

Motor Control Algorithm Concept

Automotive Motor Control Development Kits - Introduction
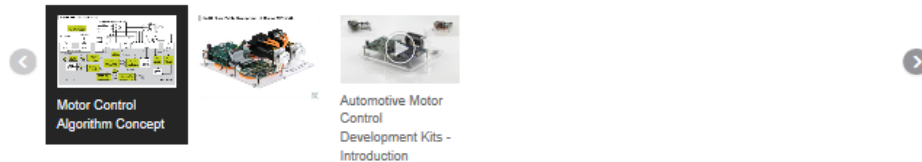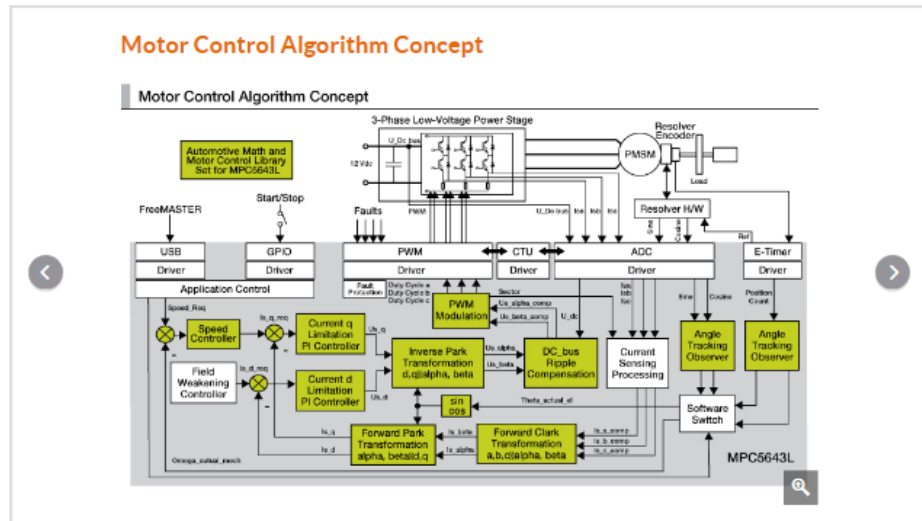
Features

The NXP® MTRCKTDPS5643L motor control development kit is ideal for applications requiring two PMSM motors, such as active suspension or electric powertrain.

- Designed to enable rapid prototyping and evaluation of the motor control application without having to wait for the final hardware design.
- Includes a 32-bit NXP MPC5643L based controller board and the 3-phase low-voltage power stage board.
- The application software is an integral part of the automotive motor control development kit as it provides a complete reference implementation of the PMSM motor control application and also takes advantage of the Automotive Math and Motor Control Library Set.

Kit Contains

- 3-phase low-voltage power stage based on SMARTMOS MC33397A pre-driver
- 32-bit NXP MPC5643L Dual Motor Controller Board (orderable separately as MTRCCBP5643L)
- AC/DC 24V Universal Power Supply Kit
- Two 3-phase PMSM low-voltage motors
- USB 2.0 A-A type cable, ribbon cables for power stage and controller board connection
- Fact sheet and quick start guide

Supported Devices

- MC33905: SBC Gen2 with High-Speed CAN and LIN
- MC33937: 3 Phase Field Effect Transistor Pre-driver
- MPC564xL: Ultra-Reliable Dual-Core 32-bit MCU for Automotive and Industrial Applications

🔲 Jump Start Your Design

Get Started With MTRCKTDPS5643L Dual 3-phase PMSM Development Kit

This collection of resources will help you to get started with the MTRCKTDPS5643L Dual 3-phase PMSM Development Kit with Qorivva MPC5643L MCU.

1. An overview about the product can be found in the fact sheet document.
2. Follow the quick start guide below to run the pre-programmed application and spin the PMSM motors using the FreeMASTER run-time debugging tool.

MTRCKTDPS5643L Fact Sheet
Provides an overview and look and feel about the content of the Dual 3-phase PMSM Development Kit with Qorivva MPC5643L MCU.
Type: Fact Sheets   Format: pdf   Size: 240.0 kB

MTRCKTDPS5643L Quick Start Guide
Provides an overview of the hardware, step-by-step instructions for running the out-of-box demo application and jumper settings quick reference table.
Type: Quick Reference Guides   Format: pdf   Size: 988.5 kB

AN4518, Dual 3-Phase PMSM Development Kit with MPC5643L
Provides the 3-phase PMSM Development Kit with Qorivva MPC5643L MCU system concept and software implementation details. Covers both single and dual motor control implementations.
Type: Application Notes   Format: pdf   Size: 7.7 MB

MC DevKits documentation

MTRCKTDPS5643L Application Software
Complete motor control application software package.
Type: Apps   Software vendor:

MC DevKits example SW

MPC5643L Dual Motor Controller Board User Guide
Complete reference for the hardware design and features of the MPC5643L dual motor controller board.
Type: Users Guides   Format: pdf   Size: 3.5 MB

3-Phase BLDC/PMSM Low Voltage Power Sta... User Manual
Complete reference for the hardware design and features of the 3-phase low-voltage power stage.
Type: Users Guides   Format: pdf   Size: 2.3 MB

MC DevKits Hardware

Less ▲

FUNCTIONAL SAFETY VALVE CONTROL

Valve Controller SoC family – System Architecture Overview

Actual Architecture

ECU

MCU → Valve controls, Pump control, Diagnostic, Configurable, Supervision

⟶ Valves

⟶ Motor Pump

NXP Valve Controller SoC

ECU

MCU ⟷ SPI

Valve Controller SoC

Valve controls	Pump control
Diagnostic	Safety features
Configurable	Supervision
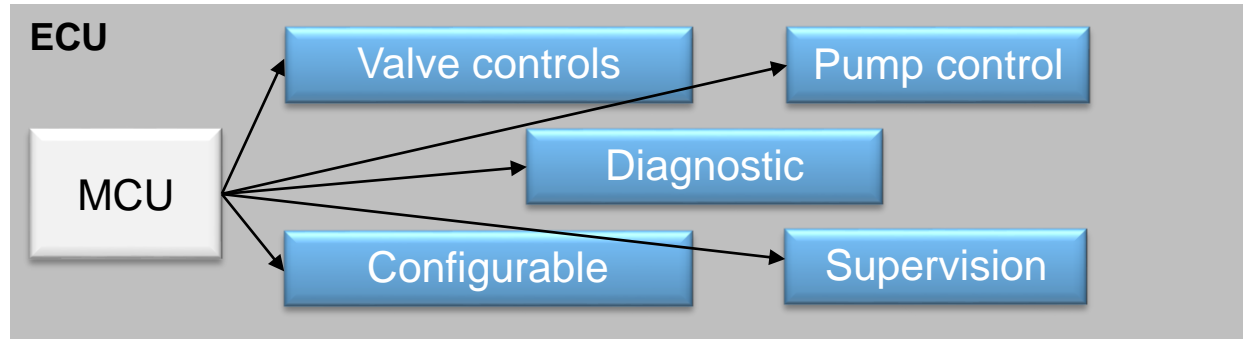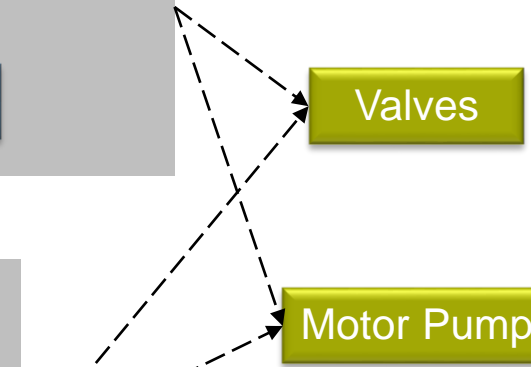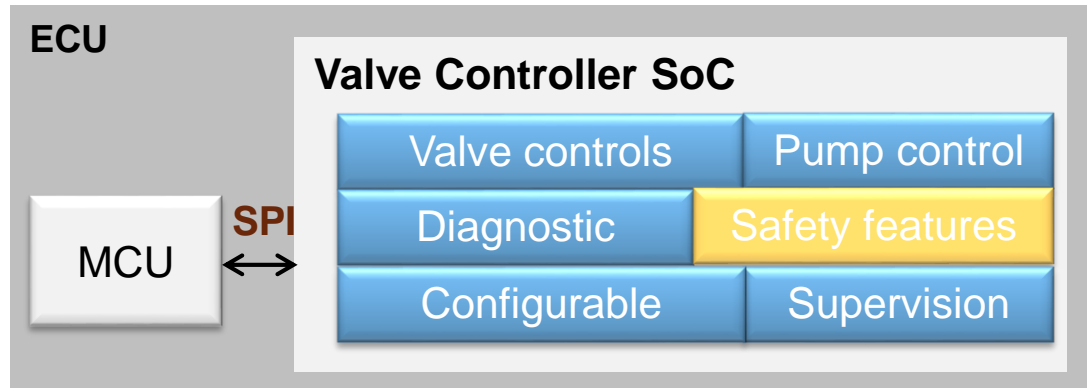
- One single analog device to manage the overall Hydraulic / Pneumatic system (Valves + Motor Pump) with safety features
  - ✓ BOM cost reduction
  - ✓ Design-in simplicity thanks to SPI interface to speed time to market
  - ✓ Safe switching off mode for safety and robustness

MC34SB0410/0800 Valve Controller SoC Solution

> **Unique system solution to manage Hydraulic or Pneumatic systems (valves, DC motor pump control) with safety features, SPI interface, watchdog and PWM capability**

Differentiation

- Fully integrated solution **replacing discrete** solutions for digital and proportional valves control for BOM **cost reduction**
- Best thermal efficiency due to exposed pad (<2°/W) and low Rds(on) (<300mΩ)
- Design-in simplicity thanks to **SPI** interface
- **Real-time** valve **current regulation**
- Robust and secure solution thanks to **safe MOSFET** switching off all the valves in case of issue

Features

- **5.3V to 36V** continuous operation, 40V transient
- **8x valve drivers**
  - **4x** current regulated **+/- 2%** up to 2.25A (300mΩ)
  - **4x PWM** up to 5 kHz, 5A (225mΩ)
- Integrated valve protection including **HS pre-driver**
- Integrated **DC pump motor pre-driver** controller 500Hz PWM
- MC34SB0800 in LQFP64 package / MC34SB0410 in LQFP48 package
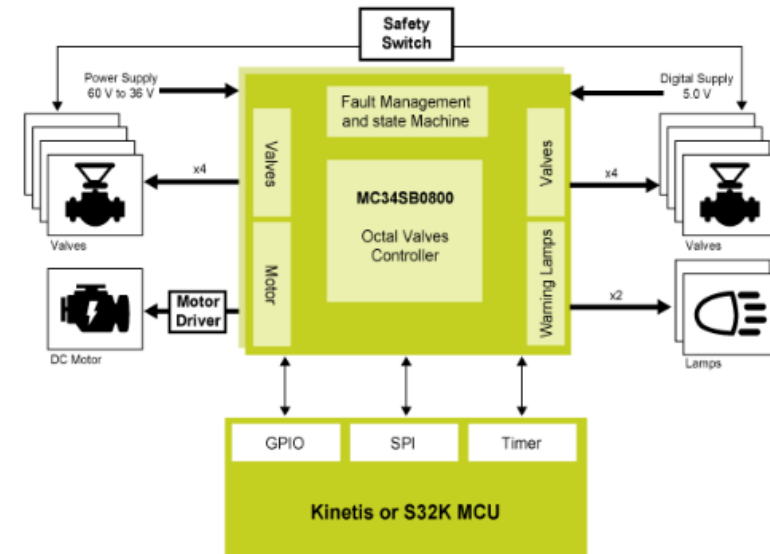
Applications

- Heavy Equipment and Construction Machinery
- Forklifts
- Water control system for irrigation
- Food control in animal farms
- Hydraulic Press
- Petrol Pump dispenser
- ATM

http://www.nxp.com/products/automotive-products/discretes-and-logic/low-side-switches/hydraulic-pneumatic-valves-controller-system-with-safety-and-monitoring:VALVE-CONTROLLER-SYSTEM?fsrch=1&sr=2&pageNum=1#featuresExpand

TYPICAL APPLICATIONS

- **Medical**
  - Oxygen concentrators
  - Medical test equipment
  - Dialysis machines
  - Blood pressure monitoring

- **Commercial**
  - 3D printers
  - Soda dispensers
  - High end showers and baths: water temperature control

- **Industrial**
  - Heavy Equipment and Construction Machinery
  - Forklifts
  - Water control system for irrigation (connected to farm tractors)
  - Food control in animal farms
  - Cooling systems
  - Hydraulic Press
  - ATM
  - Petrol pump dispenser

Valves Controller SoC: MC34SB0800 / MC34SB0410

Thermally efficient, Valve Controller with SPI for driving compressor motors, PWM & proportional valves leveraging integrated Safe Assure functional safety features
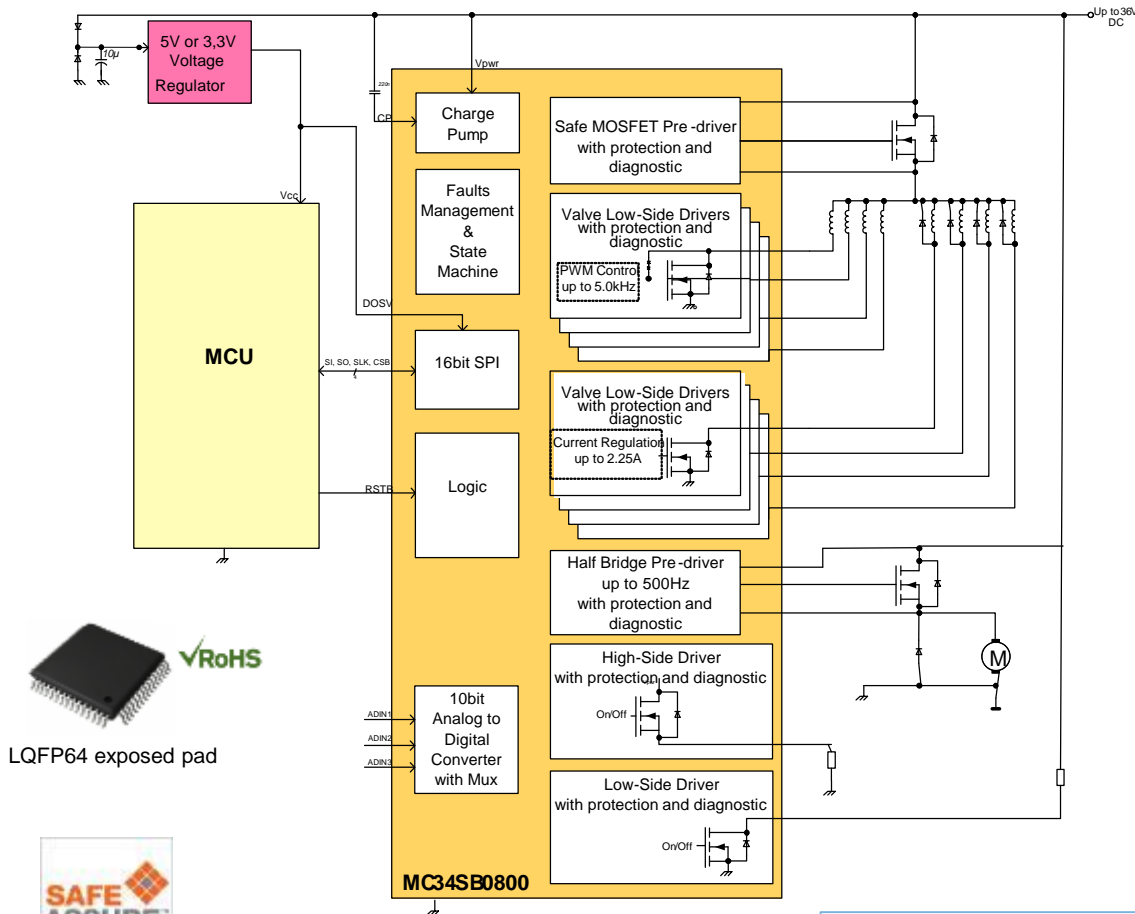
Typical Application Diagram

Samples: Available
EVM: Available
Production: Now
TWR-SB0800-36EVB: Now
TWR-SB0410-36EVB: Now

LQFP64 exposed pad

Differentiating Points

- Best thermal efficiency due to exposed pad (<2°/W) and low Rds(on) (<300mΩ)

- Design-in simplicity thanks to **SPI** interface

- **Real-time** valve **current regulation**

- Robust and secure solution thanks to **safe MOSFET** switching off all the valves in case of issue

Key Characteristics

- **8x valve drivers**

  - **4x** current regulated **+/- 2%** up to 2.25A (300mΩ)

  - **4x PWM** up to 5 kHz, 5A (225mΩ)

- Integrated valve protection including **HS pre-driver**

- Integrated **DC pump motor pre-driver** controller 500Hz PWM

- Self protected high-side driver (1.0Ω)

- Self protected low-side drivers (14Ω)

- Die temperature warning

- Fault management & State Machine

- **5.3V to 36V** continuous operation, 40V transient

- **10-bit A**nalog-to-**D**igital **C**onverter

- 16-bit **SPI interface with watchdog & challenger (octal only)**

- **MC34SB0800**: **LQFP64** package

- **MC34SB0410**: **LQFP48** package

Protection - Embedded Supervision overview

CONFIDENTIAL AND PROPRIETARY
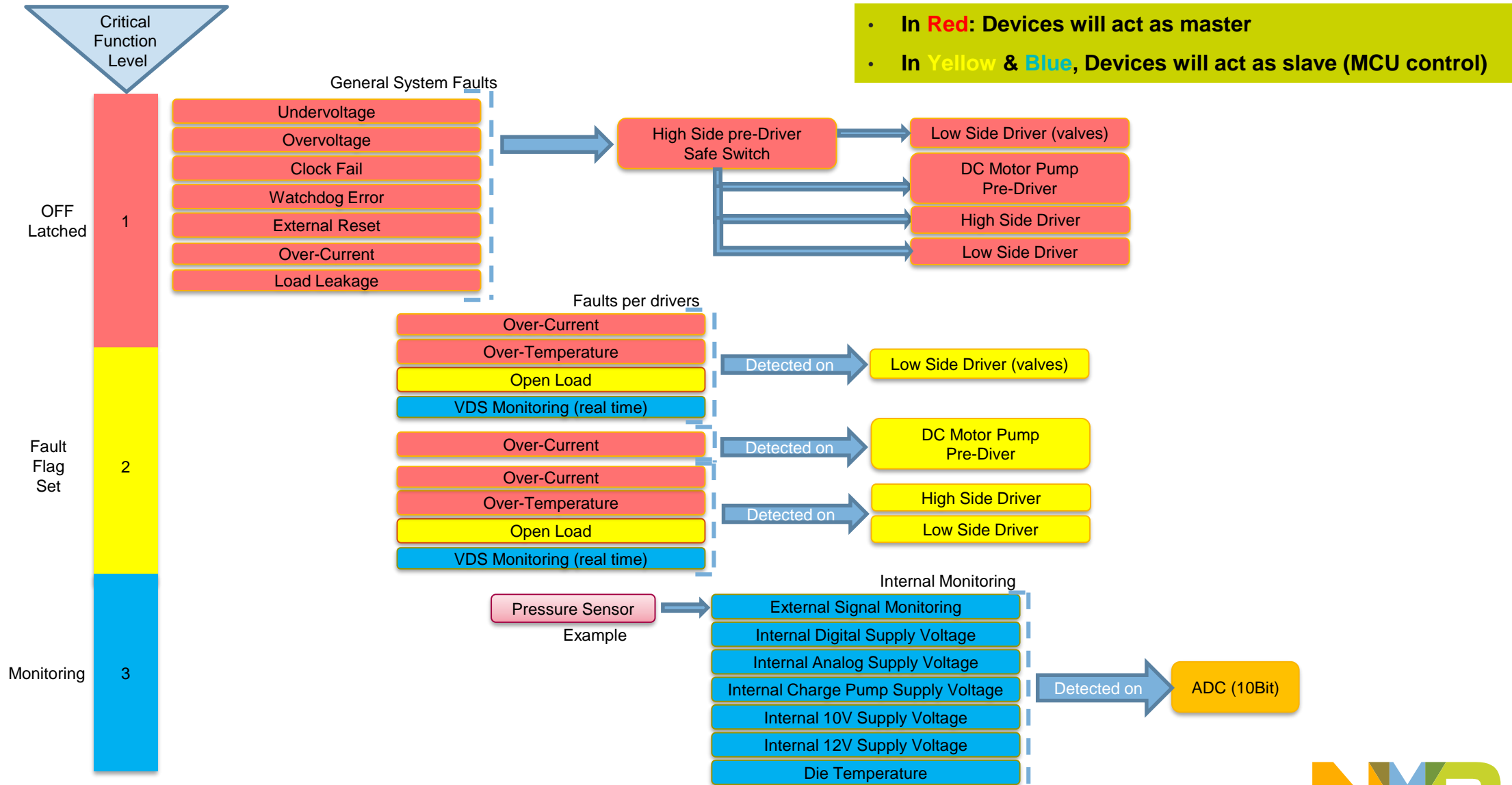
MC34SB0800/0410: Accurate Current Regulated Valves Drivers (x4Ch) (1/2)

- ## Current Regulated Valves (x4Ch)

  - Solenoid driver composed by low-side switch which is **controlled by SPI**

  - Low-side driver (300mΩ max Rds(on) for SB0800 and 225mΩ max Rds(on) for SB0410 @ 150°C) either **as current regulator or as digital**

  - Accurate current regulation up to 2.25A

  - Configurable PWM frequency up to 5.0kHz

  - PWM duty-cycle resolution 0.1%

  - External freewheeling diode needed

- ## Diagnostic and Protection per Driver

  - Openload detection in off-state

  - Drain-to-source state monitoring

  - Over-current shutdown (5.0A min)

  - Over-temperature shutdown

  - Error current regulation
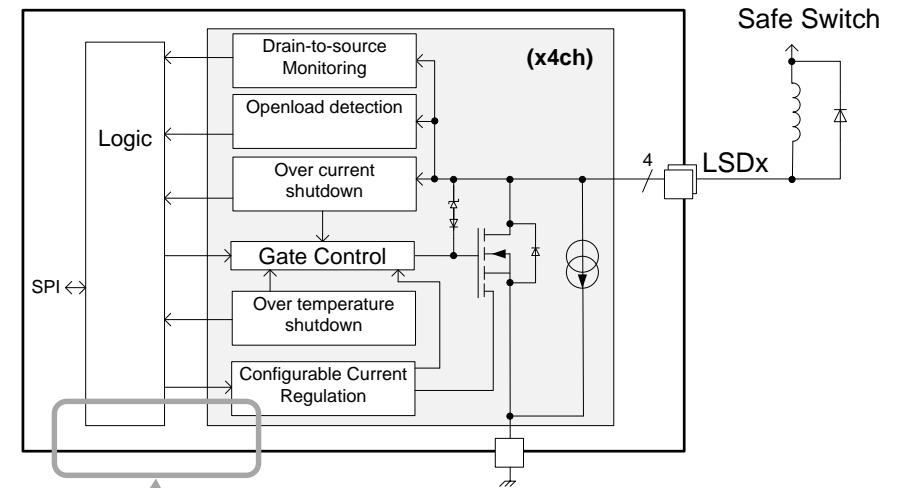
Thanks to configurable digital PI-controller (proportional-integral) for all the valves, the response time for current regulation can be optimized:

$$\frac{KI}{(z-1)} + KP$$

MC34SB0800/0410: Accurate Current Regulated Valves Drivers (2/2)

The current regulation is based on Ton/2 current measurement (through the low-side)

Nominal Operation

Precision (%) vs. Current Targeted

Note: LSD in regulation mode with calibration at 1 A @ +25 °C

Openload event
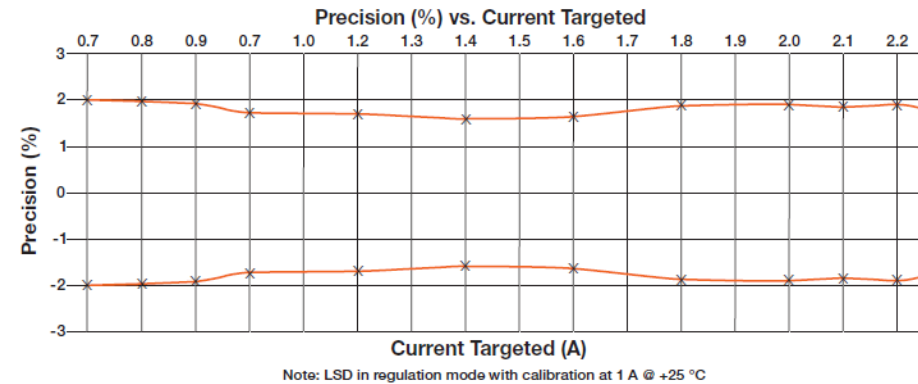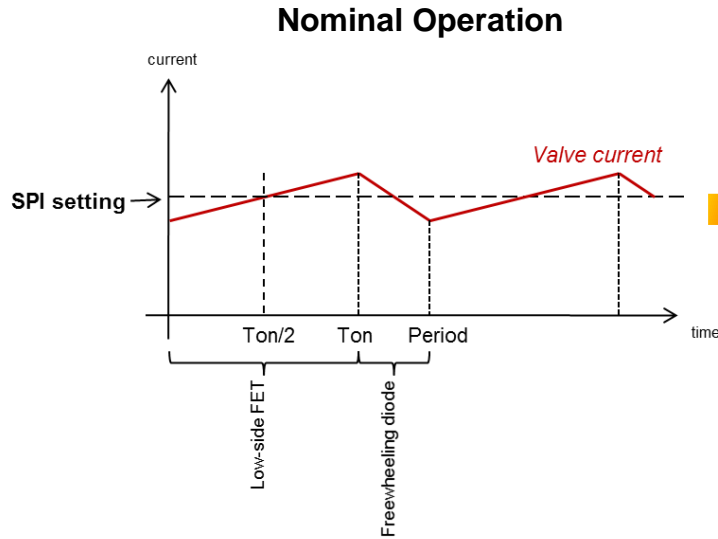
- Precision +/- 2%
- Current Regulation Error reporting +/- 50mA
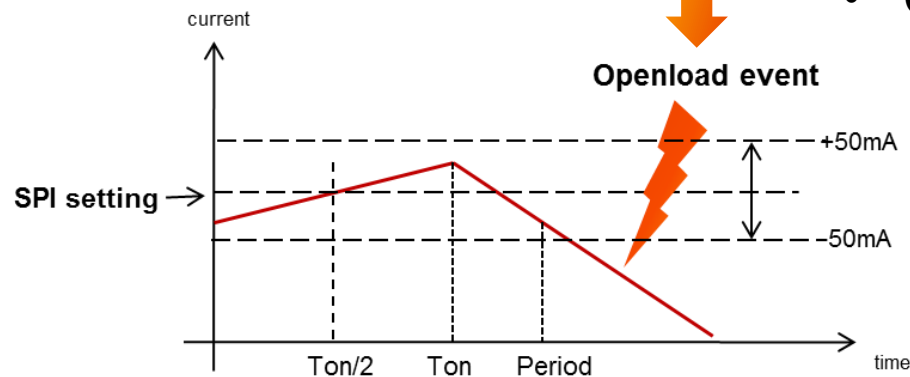
Current regulation error will be reported if the valve current does not reach +/-50mA of expected SPI value

VALVE DRIVER: SW COMPONENT OVERVIEW

MC34SB0800
MC34SB0400

Now

34SB0800
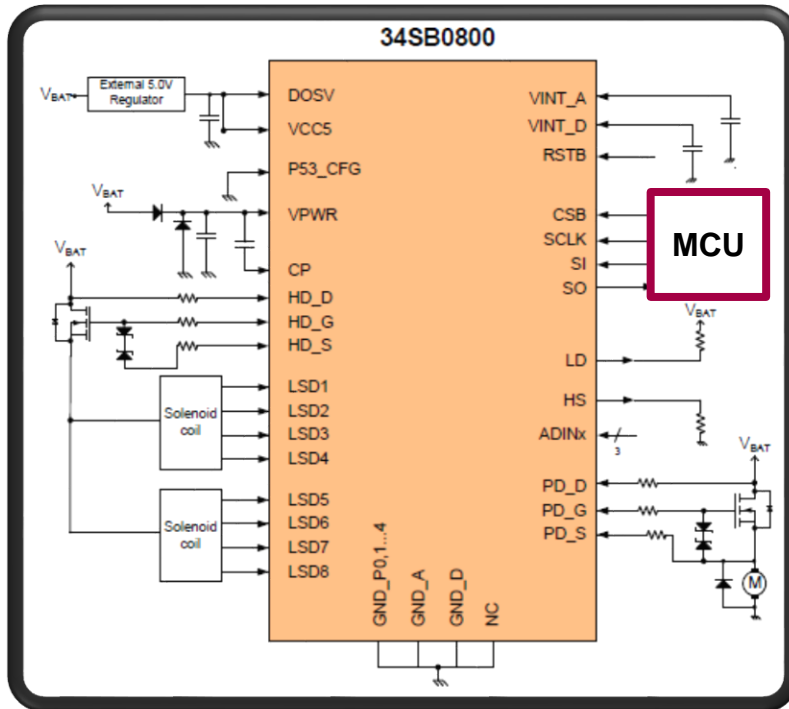
- Direct Valves Controller **MCU agnostic** Analog software component
  - Supported technology: Processor Expert – AML (KSDK 2.0, S32K SDK)

- MCU **cross-sell enablement** tools
  - KL25Z CW10.6 project examples
  - KL25Z, KL43Z Freemaster project examples
  - KL25Z, K20, KV31, KL43Z KDS project examples
  - KL25Z IAR project example
  - Compatible with KV10, K64, K22, K70
  - Projects Compatible with TWR-SB0800-36EVB & TWR-SB0410-36EVB

- Fast & Easy customer **complex system enablement**
  - Control and monitoring up to 12 outputs
  - Safety features (watchdog w/ challenger, protections & diagnostics)
  - Flutter frequency to prevent valves friction

NXP

Method	Description
Init	Initializes the device with predefined values.
Deinit	Deinitializes the device. It sets reset pin (RSTB) to LOW. Valve controller consequently clears all registers of valve controller device.
WriteRegister	This method writes a value to selected SI register. It allocates SPI bus and calls internal function VC_write_register.
ReadRegister	This method reads a value from selected SO register. It allocates SPI bus and calls internal function VC_read_register.
GetControllerStatus	Gets selected status information. It reads content of two selected device registers and returns them. Then you can check possible faults.
ClearDriverFault	Clears selected fault flags. This method handles only faults related to driver modules (all lowside drivers, highside driver, pump motor predriver). It is not intended to clear faults of supervision module (i.e. RST_WD, RST_ALU, RST_EXT, RST_CLK, VINT_UV, VCC5_UV, DOSV_UV, OT, GND_LOSS, VPWR_UV, VPWR_OV).
SetDriverState	This method sets selected driver output value. It handles driver either by SPI bit (SPI control mode) or directly by output of the MCU (Direct control mode). In case of PWM control, "dsON" stands for predefined PWM duty, "dsOFF" means 0 percent duty.
SetPDPWMDuty	This method sets PWM duty cycle for pump motor predriver. It is available only when property "Input Control" of pump motor predriver is set to "PWM".
SetLSDPWMDuty	This method sets PWM duty cycle for selected lowside driver (LSD) for inductive loads. An error is returned when the selected LSD is not in PWM mode. It also reports an error when the PWM duty converted to target current is above limit (see property "Maximum Current").

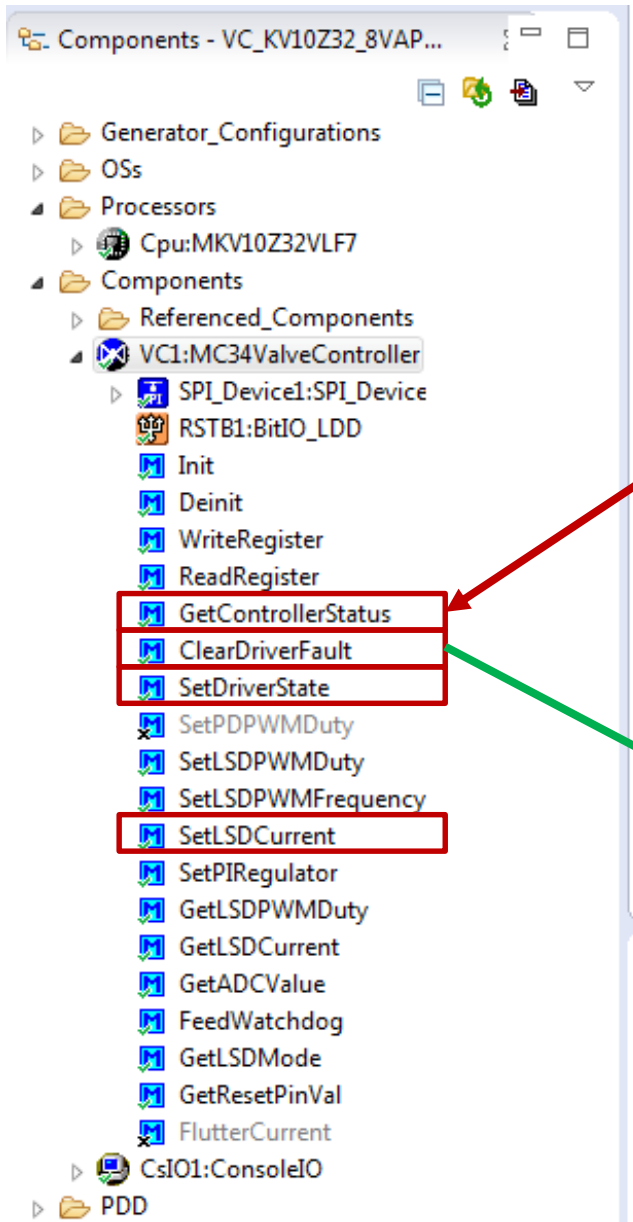|	
SetLSDPWMFrequency	This method sets PWM frequency for selected lowside driver (LSD) for inductive loads.
SetLSDCurrent	This method sets current target for selected lowside driver for inductive loads (LSD). This method is blocking. When the lowside driver is in PWM mode the software PI regulation is utilized to reach current target. An error is returned when the current target is above limit (see property "Maximum Current").
SetPIRegulator	This method sets parameters of PI regulator.
GetLSDPWMDuty	This method returns PWM duty cycle for selected lowside driver for inductive loads (LSD). It can be used only when selected LSD is in current regulation mode.
GetLSDCurrent	This method returns current value for selected lowside driver for inductive loads. It can be used only when selected LSD is in PWMed mode.
GetADCValue	This method gets and interprets selected ADC value from a valve controller register.
FeedWatchdog	This method handles watchdog of valve controller. It sends MCU monitoring result computed for LFSR output received from the device.
GetLSDMode	This method returns mode for selected lowside driver for inductive loads (LSD).
GetResetPinVal	This method returns value of reset pin. When the pin is LOW the valve controller is in fault state. You can use method Init for recovery.
FlutterCurrent	This method checks whether to adjust the current of lowside driver and sets new current target to create sinusiodal current curve. Call this method as often as possible.

Extract of the MC34ValveController.pdf
Pages 3 and 4.

MC34SB0800 Safety Methods overview (2)
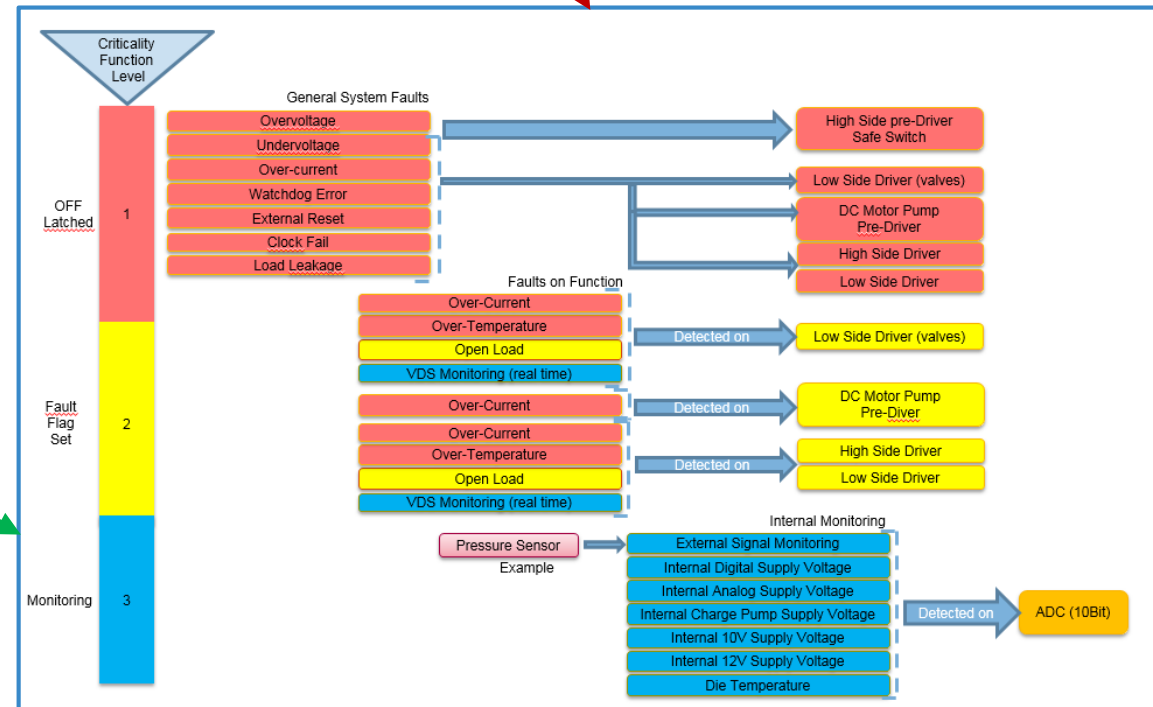
Scalable Valves Controller Offer

	SB0421	SB0420	SB0410	SB0800	SB1200
Regulated Valves Driver	NA	NA	X4 +/-2% accuracy up to 2.25A- 300mΩ With external Freewheeling diode (Mode 1)	X4 +/-2% accuracy up to 2.25A – 300mΩ With external Freewheeling diode	X8 +/-1.5% accuracy up to 2.25A – 200&300mΩ - High side for recirculation integrated.
PWM Valves Driver	X2 up to 5kHz up to 5A- 160mΩ - 56mJ capable	X4 up to 5kHz up to 5A- 160mΩ - 56mJ capable	X4 up to 5kHz up to 5A- 225mΩ - 40mJ capable (Mode 2)	X4 up to 5kHz up to 5A- 225mΩ - 40mJ capable	X4 up to 10kHz up to 5A- 300mΩ - 40mJ capable
Motor Control	X1 Up to 500Hz	X1 Up to 500Hz	X1 Up to 16kHz	X1 Up to 500Hz	X1 Up to 16kHz with active recirculation
High Side Safe switch	X1	X1	NA	X1	X1
PMIC	NA	NA	NA	NA	X1 DCDC buck 440kHz configurable 1.2 to 3.3V up to 1.0A X1 LDO 5V up to 200mA X1 LDO 3.3V up to 200mA X1 LDO 5V external up to 100mA with short to VBAT protection
CAN Physical Layer	NA	NA	NA	NA	X2 chokeless capable up to 36dBm
ADC	X1 10bits 3 inputs	X1 10bits 3 inputs	X1 10bits 3 inputs	X1 10bits 3 inputs	X1 10bits 3 inputs
SPI	X1 16bits with Challenger watchdog	X1 16bits with Challenger watchdog	X1 16bits	X1 16bits with Challenger watchdog	X1 32bits with challenger watchdog and CRC
Safety	All hardware monitoring (OV,UV,overtemp, overcurrent)	All hardware monitoring (OV,UV,overtemp, overcurrent)	Safe Assure All hardware monitoring (OV,UV,overtemp, overcurrent)	Safe assure All hardware monitoring (OV,UV,overtemp, overcurrent)	Safe assure All hardware monitoring (OV,UV,overtemp, overcurrent) LBIST & ABIST

- - - Will be derivated from BM   - - - One mode possible

Motorcycle Braking SoC

Differentiation

- HW & SW compatible solution for 1W & 2W
- Low system BOM w/ integrated safety functions
- Small footprint 7x7mm 48 pin QFN package
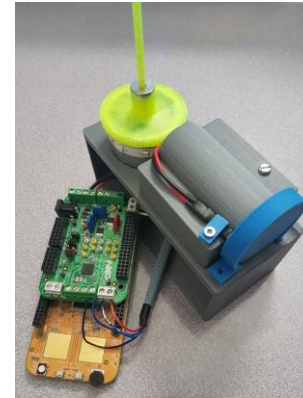
Motorcycle Braking Demo
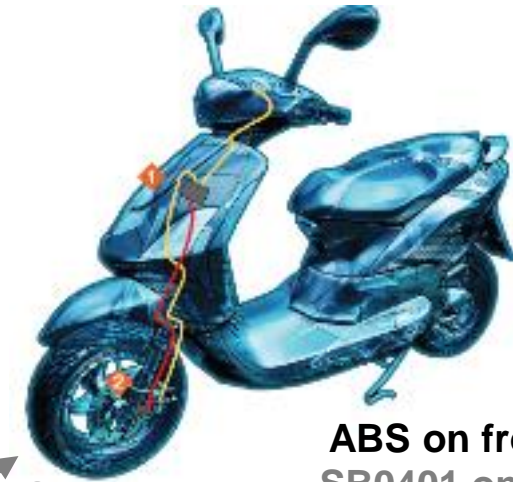
ABS on front wheel only
SB0401 one channel ABS

x2

ABS adoption driven by regulatory mandates in Europe, America, & Asia

x4
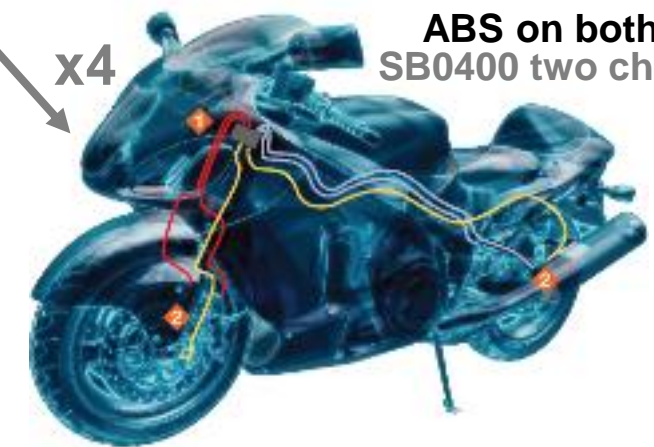
ABS on both wheels
SB0400 two channel ABS

SoC Block Diagram

VBAT → UJA1169 or FS45xx SBC

UJA1169 or FS45xx SBC --VDD--> S32K or MPC574x MCU

TX,RX between SBC and MCU

- Safe Switch Pre-Driver → Mosfet
- 2/4 valves Low side (PWM) → /4 → Solenoid valve
- Warning lamp driver → Lamp
- 2 Wheel speed sensor → /2 → KMI23 Wheel Speed Sensor
- Motor pump driver (500 Hz) → Brake oil pump
- K-line → Diagnostic system

SPI interface, System & Fault management

ADC, Vehicle speed output

VSO_IN

SPI

WSO

TX,RX

/2

Highly Integrated Motorcycle Braking SoC

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
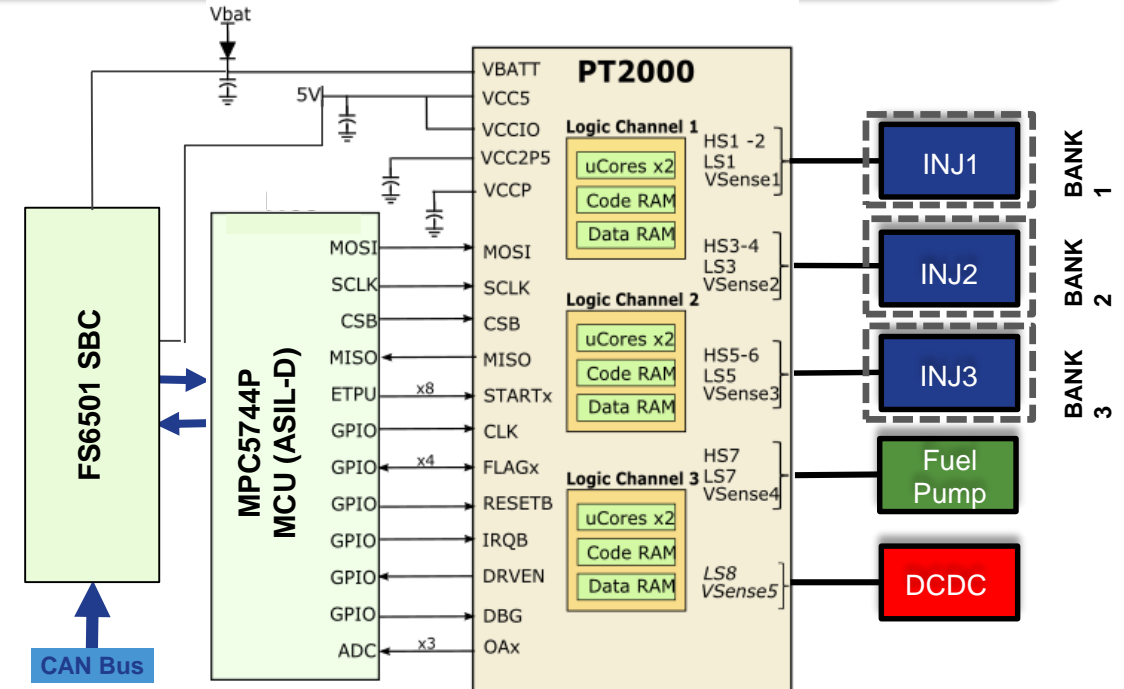
Typical Applications

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

FUNCTIONAL SAFETY BATTERY MANAGEMENT SYSTEM

Battery Cell Controllers - Portfolio Overview

Scalable system solution addressing all battery management applications – maximizing reuse

Controller Performance

Premium
+ **Synchronized current measurement**
+ **Coulomb counter**
+ **O/U Temp**

Advanced
+ **Cell Balancing**
+ **O/U Temp**

Basic
+ **Precision voltage measurement**
+ **Cell OV/UV**
+ **4 Mbps SPI**

Entry
+ **MC3377xyTC**

Intelligent Battery Sensor (IBS)

1xV 1xI 1xT | MCU | SBC

Battery Cell Controller (BCC6)

6xV 1xI 4xT | Digital | MCU | SBC

Battery Cell Controller (BCC14)

14xV 1xI 7xT | Digital | MCU | SBC

Battery Cell Controller (N x BCC14)

14xV 1xI 7xT | Digital | MCU | SBC

CO_2 -20%

CO_2 -100%

Level of Electrification

Start-Stop 12V Pb Battery

Advanced Start-Stop 14V Li-ion Battery

48V Mild Hybrid 48V Li-ion Battery

(Engine not mounted)

EV/PHEV High Voltage Li-ion Battery

Intelligent Battery Sensors MM912J637 / MM9Z1J638

**Precision battery monitoring solution enabling lower system power consumption
with operating redundancy for mission-critical applications up to 52 V**

Differentiating Points

- LIN conformance and ESD/EMC robustness

- Configurable ADC **HW filters reduce Software complexity**

- Input voltage flexibility to address variety of applications
  Operating voltage redundancy with 3 ADC paths

- 70% stop duty cycle operation

- 20% lower system current consumption

*EDN INNOVATION AWARD 创新奖
2011 Leading Product
Mixed Signal Category*

Product Features

- **Integrated MCU**, Flash, RAM, communication

- **3x 16-bit** ADC for **Current, Voltage** and **Temperature**

- Low-power features

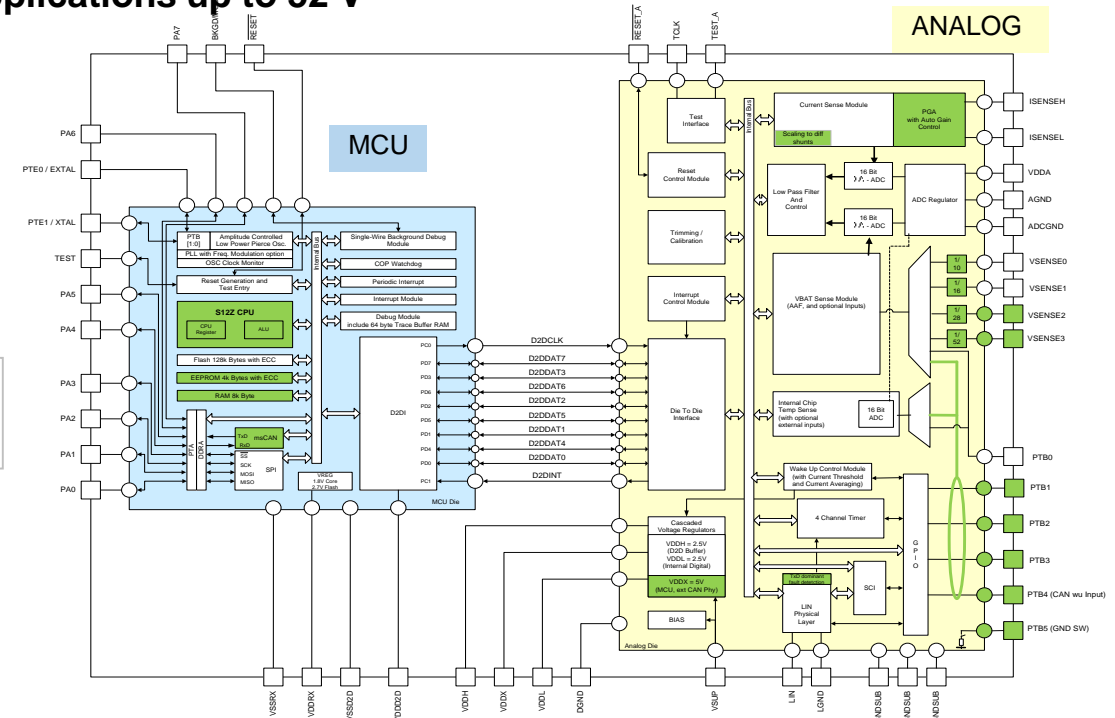- **Multiple wake-up** features (Current, temp, etc)

- Configurable HW filters (voltage and current SD ADC)

- Robust LIN physical layer

- MM912J637: 16-bit MCU targeting **lead acid battery management** over LIN interface

- MM9Z1J638: High-end 16-/32-bit MCU targeting a **wide range of battery applications** over **CAN** or LIN interface

Typical Applications

- Automotive
  - 12 V Lead Acid, 14 V Li-Ion
  - 48 V HV BMS, Battery Junction Box
- Trucks & Utilities
  - 24 V Lead Acid
- Industrial
  - Energy Storage Systems (ESS), UPS
  - Industrial Automation precision monitor
  - Cordless tools & appliances

MC33771 - 14 Cell Li-ion Battery Cell Controller

Scalable, reliable, safe and BOM optimized Li-ion cell control with low-cost, robust, high-speed Isolated communication

Differentiation

- Scalable platform from 14V to > 1000 V
- 0.5% current sensors w/ 300mA cell balancing FETs
- 2 mV voltage measurement accuracy
- 65µs one shot synchronized impedance acquisition
- Fast data acquisition: 3.6 ms/96 cells, 4.5 ms/112 cells
- ASIL-C functional safety compliant

Features

- Single chip 48 V battery control scalable to > 1000 V
- 3750V isolated 2 Mbps differential or 4 Mbps SPI comm
- 9.6 V ≤ VPWR ≤ 61.6 V operation, 70V transient
- 14x differential + stack voltage measurement
- 7x ADC + GPIO + temperature sensor Inputs
- Low power modes
- 64 pin QFP package
- Low-level drivers for simplified SW development

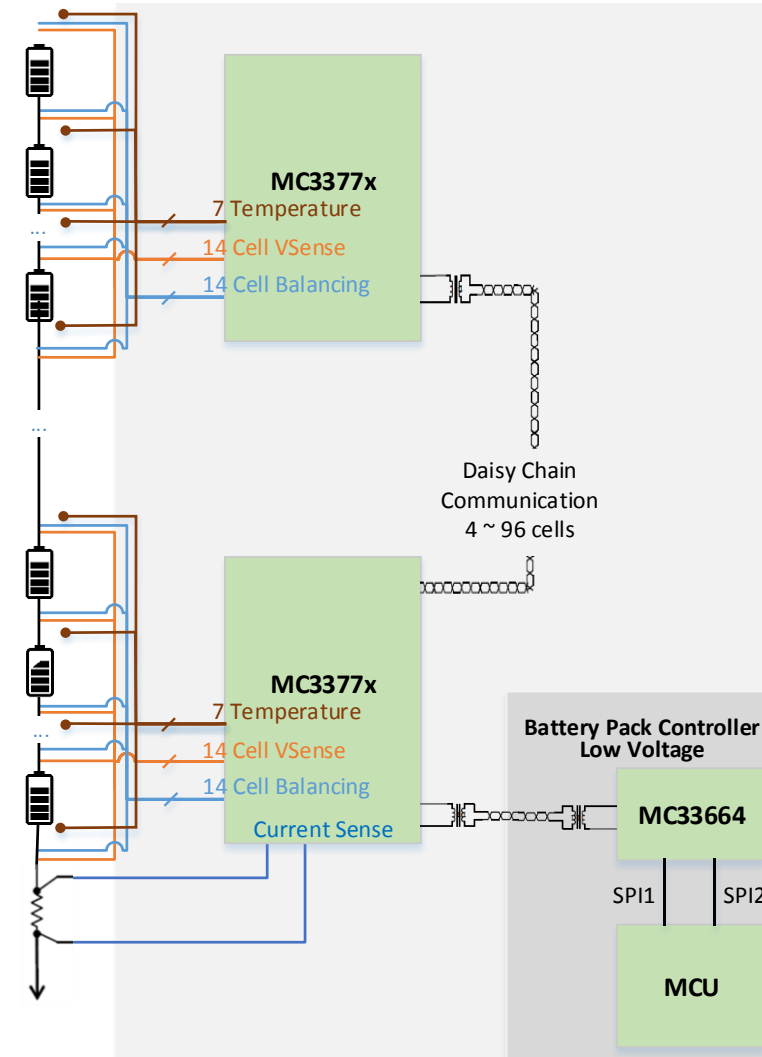# MC33771 – 48V Li-ion Battery Cell Controller

Scalable, reliable, safe and BOM optimized Li-ion cell control with low-cost, robust, high-speed Isolated communication

Differentiation

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- 2 mV voltage measurement accuracy
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Features

- Single chip 48 V battery control scalable to > 1000 V
- 3750V isolated 2 Mbps differential or 4 Mbps SPI comm
- 9.6 V ≤ VPWR ≤ 61.6 V operation, 70V transient
- 14x differential + stack voltage measurement
- 7x ADC + GPIO + temperature sensor Inputs
- Low power modes
- 64 pin QFP package
- Low-level drivers for simplified SW development

System solution with BCC, IsoPHY, MCU, SBC

NXP BCC Solution

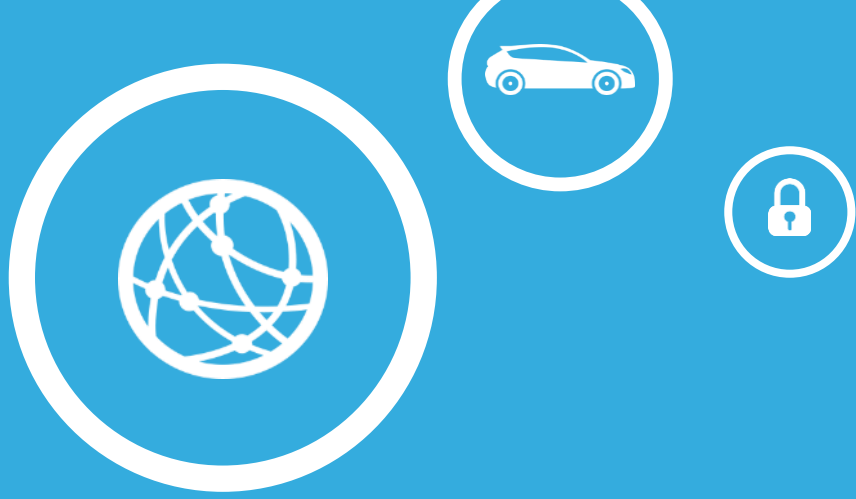*NXP BCC offers state-of-the-art diagnostics & functional safety => safety guarantee*

Differentiating Points

- Battery topology flexibility
- High integration
- High measurement accuracy
- Fast data acquisition and communication
- Superior daisy chain communication
- System diagnostics and functional safety supporting ISO26262 w/ single chip

Best diagnostics in the market (ISO26262)
Single chip ASIL C capable (Easy ASIL D)

Safety feature	Normal mode	Sleep mode	Diagnostic mode	Fault detected	Method and action
VPWR OV/UV	X	X	X	VPWR overvoltage and undervoltage	VPWR_OV_FLT or VPWR_UV_FLT flag activated, FAULT pin activated, bus wake-up
Cell OV/UV detection	X	X	With on demand conversion	Cell overvoltage and undervoltage	CT_OV_FLT or CT_UV_FLT error flag activated, FAULT pin activated, bus wake-up
OT/UT detection	X	X	With on demand conversion	External over/undertemperature	AN_OV_FLT or AN_UV_FLT error flag activated, FAULT pin activated, bus wake-up
FAULT pin heart beat	X	X	X	FAULT pin in stuck at 0 or 1.	FAULT pin toggles if no fault; FAULT pin stuck at logic 1 if fault is present
CTx OV/UV functional verification			MCU control	Fault on digital comparators used for OV/UV detection	If no fault, then CTx_OV_FLT or CTx_OV_FLT activated; else missing activation. FAULT pin activated
CTx open detection			MCU control	Open path from a cell to a CT pin	MCU checks cell voltages after diagnostic switch positioning. A value close to 0V means open line
CTx open detection functional verification			MCU control	Broken switch of CTx Open Detection safety mechanism	MCU checks cell voltages against expected results to detect a latent fault.
CTx leakage test			MCU control	MCU verifies the input structures on the CTx pins have not degraded by measuring the input leakage	If the MCU detects leakages exceeding the OV/U safety margin
Cell voltage channel functional verification			MCU control	Lack of integrity of level-shifters embedded in the Analog Front End	MCU checks voltages of diagnostic Zener diodes against voltage of the reference Zener diode
ADC1-A, ADC1-B functional verification (precision reference to ADC)	X	X	With on demand conversion	ADC out of compliance due to band-gap deviation or other error	ADC1_A_FLT or ADC1_B_FLT error flag activated. FAULT pin activated, bus wake-up
Oscillator clock monitoring	X	X	X	Low frequency clock failure	OSC_ERR_FLT flag activated, FAULT pin activated
Cell balance shorted load protection/ detection	X	X	X	Overcurrent condition on CB switches	CB_SHORT_FLT error flag activated, FAULT pin activated, bus wake-up
Cell balance open detection	X	X	MCU Control	Open cell balance circuit	CB_OPEN_FLT error flag activated. FAULT pin activated
End of time CB notification (EOT_CBx)	X	X	X	Expiration of a cell balance timer	EOT_CBx flag activated. FAULT pin activated, bus wake-up
ISENSE ± precision reference			MCU Control	Current measurement out of compliance due to PGA or ADC2 or digital processing failure	Conversion of a known reference at the input of the PGA. MCU checks for an expected value
ISENSE ± open detect			MCU control	Open circuit on ISENSE ± input pins	CPin current injection. IS_OL_FLT error flag. FAULT pin activated
ISENSE ± overcurrent fault		X		Overcurrent condition during sleep mode	I_OC_FLT error flag. FAULT pin activated, bus wake-up

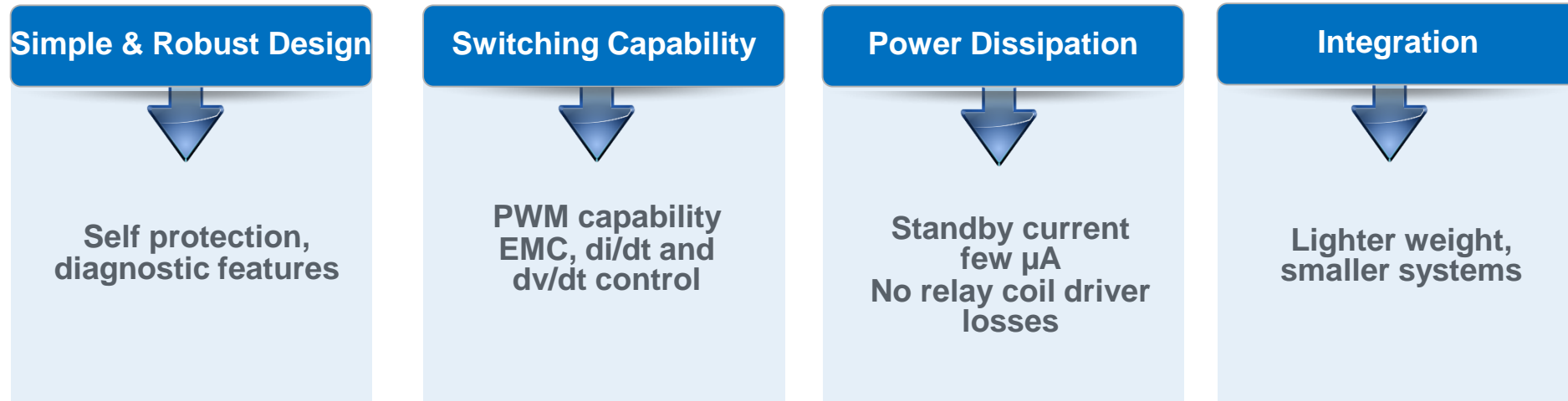| Safety feature	Normal mode	Sleep mode	Diagnostic mode	Fault detected	Method and action
Coulomb counter overflow	X		X	Overflow on the coulomb count registers	CC_OVR_FLT error flag. FAULT pin activated
VCOM short/UV protection detection	X	X	X	Undervoltage on the VCOM power supply	FAULT pin activated
VANA short/UV protection detection	X	X	X	Undervoltage on the VANA power supply	VANA_UV_FLT flag, FAULT pin activated, bus wake-up
VANA short/OV protection detection	X	X	X	Overvoltage on the VANA dpower supply	VANA_OV_FLT error flag. FAULT pin activated, bus wake-up
GPIO short detection protection	X	X	MCU control	GPIO opposite of the commanded state	GPIO_SH_FLT error flag. FAULT pin activated, bus wake-up
GPIO open detection			MCU control	Disconnected analog input	AN_OPEN_FLT error flag. FAULT pin activated
Onboard temperature protection mode	X	X	X	Overtemperature of the silicon	FAULT pin activated: bus wake-up and IC_TSD_FLT error flag activated when normal temperature resumes
Exit diagnostic mode safety timer			X	Unauthorized permanence in diagnostic mode.	Trace left in the PREVIOUS_STATE upon timer expiration
Idle mode fault (init to idle)				Indicator the device has entered idle mode without being programmed	FAULT pin activated for time period
Loss of ground detection has a fault bit and can generate a wake-up. No activation of output	X	X	X	Loss of ground on DGND and AGND pins	FAULT pin activated, bus wake-up
TAG ID for conversion data	X		X	Wrong sequencing of the requested conversions	MCU detects incorrect TAG ID in the message
Register address identification in message frame	X		X	Faulty decoder of data register addressing	MCU detects an incorrect physical address
Eight Bit CRC with non-zero seed	X		X	Corrupted communication frame	MCU/33771 detect incorrect CRC
Unique identifiable start-of-message and end-of-message	X		X	Wrong message delimitation	MCU/33771 detect incorrect message frame
Communication confirmation architecture	X		X	R/W register bits stuck at 0/1	MCU checks received data content after a write command
Communication loss fault	X		X	Stopped or slow communication from the MCU to the IC	COM_LOSS_FLT flag. FAULT pin activate
Communication error register overflow	X		X	Incorrect number of bits of the frame, incorrect clock phase	COM_ERR_FLT fault flag. FAULT pin activated
I²C error fault (init mode)				Error when trying to load EEPROM data into memory mirror	I2C_ERR_FLT error flag. FAULT pin activated
ECC check		X		Corrupted calibration data. A double error has been detected (and only one corrected)	DED_ERR_FLT error flag. FAULT pin activated

FUNCTIONAL SAFETY LOAD DRIVERS

Energy Distribution with SmartPower

SmartPower device is a Power IC with some digital content.

It interfaces between an MCU and a load.

"**eXtreme Switch**" is NXP's brand name for high-current "SmartPower".

Why use SmartPower devices instead of relays?

Simple & Robust Design	Switching Capability	Power Dissipation	Integration
Self protection, diagnostic features	PWM capability EMC, di/dt and dv/dt control	Standby current few µA No relay coil driver losses	Lighter weight, smaller systems

eXtreme Switch composition

SMARTMOS™

❑ **Protection and diagnostic**
- Over temperature (175°C)
- Over current shutdown
- Over/under voltage
- Short circuit
- Reverse battery
- Loss of ground/Vbat
- Energy discharge protection

❑ **SPI Interface**
- Easy connection to the uP
- Programmability
- Daisy chain using SPI
- Programmable over current trip level
- Watchdog
- Embedded PWM module
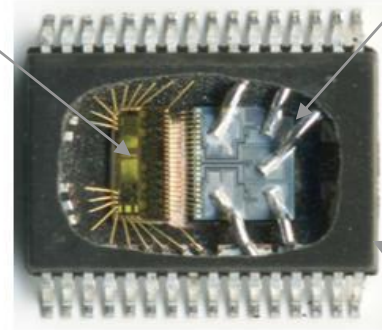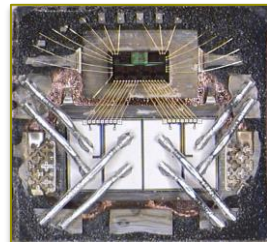
Vertical Power Stage

❑ **Best-in-class technology**
- Planar HDTMOS and TrenchFet LFET
- 45V & 65V BV

❑ **Protection in the power stage**
- Temperature sensor
- Current sensor
- Voltage sensor (Gen4)

Power Package

❑ **PQFN low cost power package**
- 0.5 mm thick lead frame
- Die soldered attached
- Rthj-c < 0.5°C/W
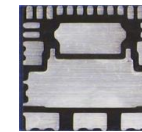
❑ **SOICeP32 and 54**
- Designed for high power
- Large al wire capability
- Pb-free compliancy

12V Automotive eXtreme Switches

12V multiple HSS

Family	Part Number	Outputs # and On-Resistance	Total Outputs #	Operating Voltage (V)	Max continuous current (A)	Max PWM frequency	Package	Pin to Pin Compatibility	SW Compatibility
MC12XS3	MC07XS3200EK	Dual 7mΩ	2	6-20	21	800Hz	32-pin SOICEP	-	
	MC10XS3425EK	Dual 10mΩ, Dual 25mΩ	4	6-20	19-9	800Hz	32-pin SOICEP	-	
	MC10XS3412DHFK	Dual 10mΩ, Dual 12mΩ	4	6-20	19	1kHz	24-pin PQFN	√	√
	MC10XS3435DHFK	Dual 10mΩ, Dual 35mΩ	4	6-20	19-9	1kHz	24-pin PQFN		
	MC15XS3400DHFK	Quad 15mΩ	4	6-20	19	1kHz	24-pin PQFN		
	MC35XS3400DHFK	Quad 35mΩ	4	6-20	9	1kHz	24-pin PQFN		
	MC09XS3400AFK	Quad 9mΩ	4	6-20	21	800Hz	24-pin PQFN		
MC12XS3	MC10XS3535HFK	Triple 10mΩ, Dual 35mΩ	5	7-20	12-6	400Hz	24-pin PQFN	√	√
	MC35XS3500HFK	Penta 35mΩ	5	7-20	6	400Hz	24-pin PQFN		
	MC06XS3517AFK	Triple 6mΩ, Dual 17mΩ	5	7-20	17-9	400Hz	24-pin PQFN		
MC12XS6	MC07XS6517BEK	Triple 7mΩ, Dual 17mΩ	5	7-18	18-9	400Hz	54-pin SOICEP	√	√
	MC17XS6500BEK	Penta 17mΩ	5	7-18	9	400Hz	32-pin SOICEP		
	MC40XS6500EK	Penta 40mΩ	5	7-18	6	400Hz	32-pin SOICEP		
	MC08XS6421BEK	Dual 08mΩ, Dual 21mΩ	4	7-18	18-9	400Hz	32-pin SOICEP		
	MC17XS6400BEK	Quad 17mΩ	4	7-18	9	400Hz	32-pin SOICEP		
	MC25XS6300EK	Triple 25mΩ	3	7-18	8	400Hz	32-pin SOICEP		
	MC10XS6325EK	Dual 10mΩ, Single 25mΩ	3	7-18	16-8	400Hz	32-pin SOICEP		
	MC10XS6200EK	Dual 10mΩ	2	7-18	16	400Hz	32-pin SOICEP		
	MC10XS6225EK	Single 10mΩ, Single 25mΩ	2	7-18	16-8	400Hz	32-pin SOICEP		

Main Switches

Family	Part Number	Outputs # and On-Resistance	Total Outputs #	Operating Voltage (V)	Max continuous current (A)	Max PWM frequency	Package	Pin to Pin Compatibility	SW Compatibility
MC12XS2	MC33981ABHFK	Single 4mΩ	1	6-27	75	60kHz	16-pin PQFN	-	-
	MC33982CHFK	Single 2mΩ	1	6-27	41	1kHz	16-pin PQFN	√	√
	MC33984CHFK	Dual 4mΩ	2	6-27	21	1kHz	16-pin PQFN		
	MC33988CHFK	Dual 8mΩ	2	6-27	10.5	1kHz	16-pin PQFN		

Customer challenges for power distribution

- ✓ **CO2 savings:**
  - Weight savings.
  - PCB space saving

- ✓ **Cost and Quality**:
  - Simple design with few external components and high integration density.

- ✓ **Flexibility:**
  - reuse for different platform

- ✓ **Safety** :
  - Overall system protection

- ✓ **Robustness** :
  - Power dissipation
  - Current consumption
  - fully protected switches with high reliability with embedded protection

Power Board

Control Board
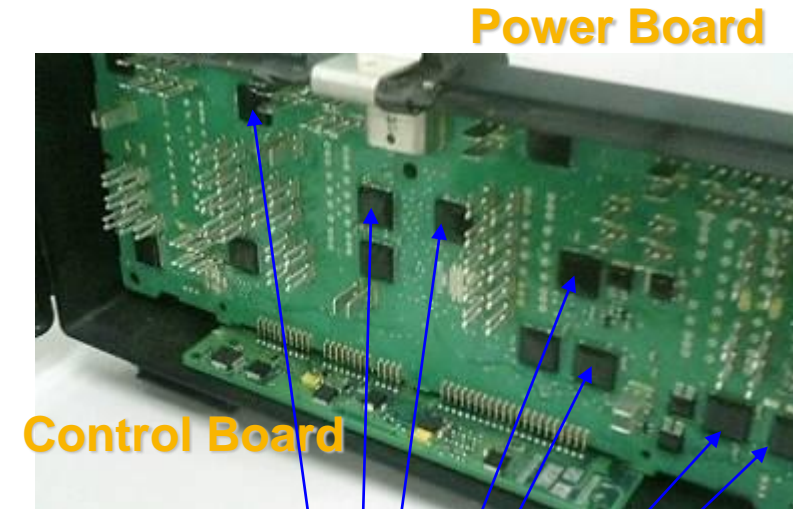
Junction Box using MC33982 (2mOhm) & MC33984 (4mOhm) eswitch

7 to 10 eSwitches

MC12XS6 –Gen4 eXtreme Switches

Latest generation of programmable high-side switches with wide range diagnostic current sensing and lowest RDSon for up to 30% smaller PCB

Differentiating Points

– **Robustness:** Unique over-current latch-off protection, full digital and analog diagnostics, and protection features

– **Integration:** 7 mΩ / 8 mΩ / 10 mΩ / 17 mΩ / 21 mΩ / 25 mΩ / 40 mΩ outputs in, Penta/ Quad/ Triple/ Dual configurations

– **Accuracy**: Advanced accurate current monitoring from 25mA to 22A

– **Flexibility:** Xenon / LED / Halogen from 25 Hz to 400 Hz

– **Scalability:** Pin and SW driver compatible family

Product Features

– Operating voltage range from 6 - 18 V with sleep current < 5.0 μA

– 5.0 MHz 16-bit daisy chainable SPI control

– Enhanced output current sense with programmable synchronization signal, ±5°C temperature and ± 1% battery voltage feedback

– Full diagnostic and protection including over-current profiles, output-ON and –OFF open load detections, thermal shut-down, pre-warning, and fault reporting

– Individually programmable external PWM signals with 8 bit duty cycle control (Phase, prescaler, duty cycle, slew rate per channel)

– Watchdog and failsafe mode

– External smart power switch control
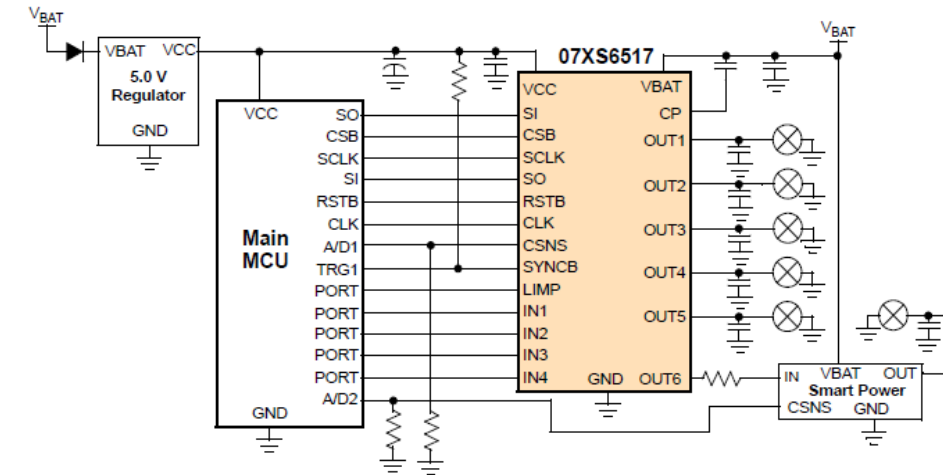
Typical Applications
Automotive
○ 12V Lighting from High beam to LEDs
○ Valves

54 & 32-pin eSOIC package

MC24XS4 eXtreme Switches
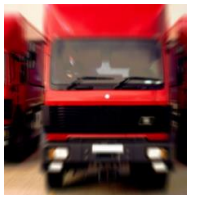
Scalable, programmable family of 24A/36V SPI-driven, dual-channel, smart high-side switches with lowest RDSon for up to a 30% board reduction

Differentiating Points

- **Robustness:** Unique over-current latch-off protection, full digital & analog diagnostic and protection features
- **Integration:** 6 mΩ / 10 mΩ / 20 mΩ / 22 mΩ / 50 mΩ outputs in Dual configuration
- **Accuracy:** 5X better current sensing accuracy with unique accurate temperature sensing capability
- **Flexibility:** lighting or DC motor mode up to 1kHz
- **Scalability:** SW driver compatible family & pin compatibility

Product Features

- Normal operating range: 8 -36 V, (ext range: 6 -58 V) Sleep mode current < 10 µA
- 3.3 V and 5.0 V compatible 16-bit Daisy chainable SPI control
- Parallel output operating modes
- Full diagnostic and protection including programmable over-current profiles, output-ON and –OFF open load detections, thermal shut-down, pre-warning, and fault reporting
- ±5°C temperature and synchronous / asynchronous current (±10%) sensing
- Individually programmable internal/external signals with 8 bit duty cycle control & slew rate
- Watchdog and failsafe mode
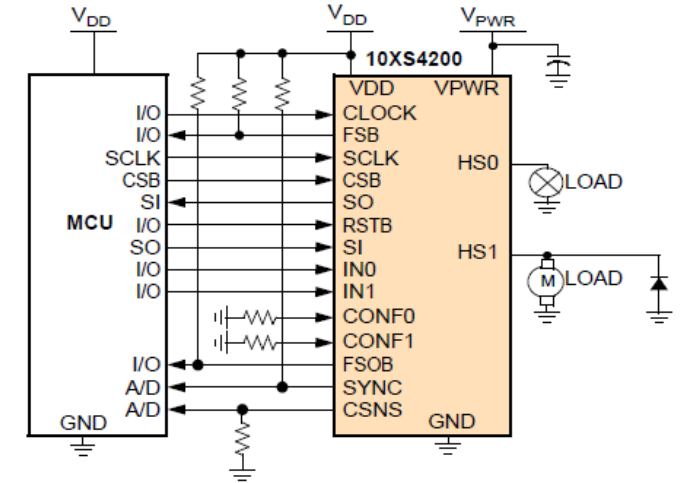
Typical Applications
Transportation 12 / 24V
- o 24V Lighting and capacitive loads
- o Valves
- o DC motors
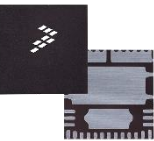
24-pin PQFN package
32-pin eSOIC package

eXtreme switch - EcoSystem

- ## Evaluation kits

- ## Reference design

  - Lighting reference design 4 eXtreme Switch devices (Gen4), MCU: S12G SBC: 33903

  - Light Control Module 1 eXtreme Switch device (Gen3) MCU: KEA

  - 16-bit MCU S12G, 4 eXtreme Switch devices, CAN Physical Layer, 5V regulator
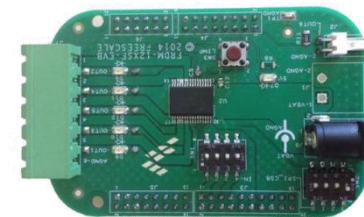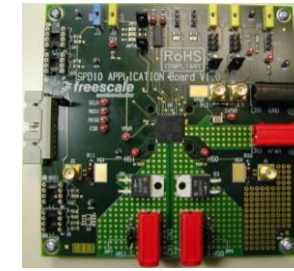
- ## Freedom board

  - FRDM-12XSF-EVB: MC17XSF500, Freedom shield PeX component/ Freemaster GUI /Spigen compatible.

  - FRDM-32XSF-EVB: MC17XSG500 (30V version). Freedom w/ Arduino compatibility (Resale through PremierFarnell Element14). Launch in Q1 2017

- ## Tower board

  - TWR-MC36XSDEVB: Tower System for 36VeXtreme Switch

- ## Application Notes and tools

  - Application notes
  - Training package
  - Microsoft Excel© Thermal Calculator
  - Cadence Orcad© Behavioral models
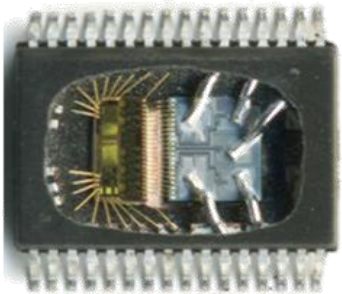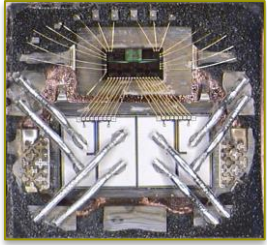
eXtreme Switch reference designs
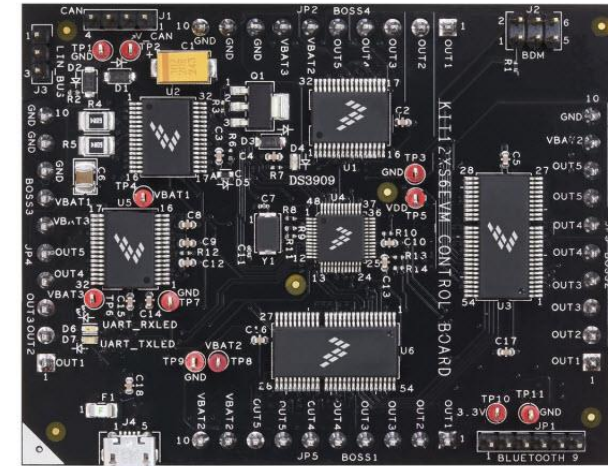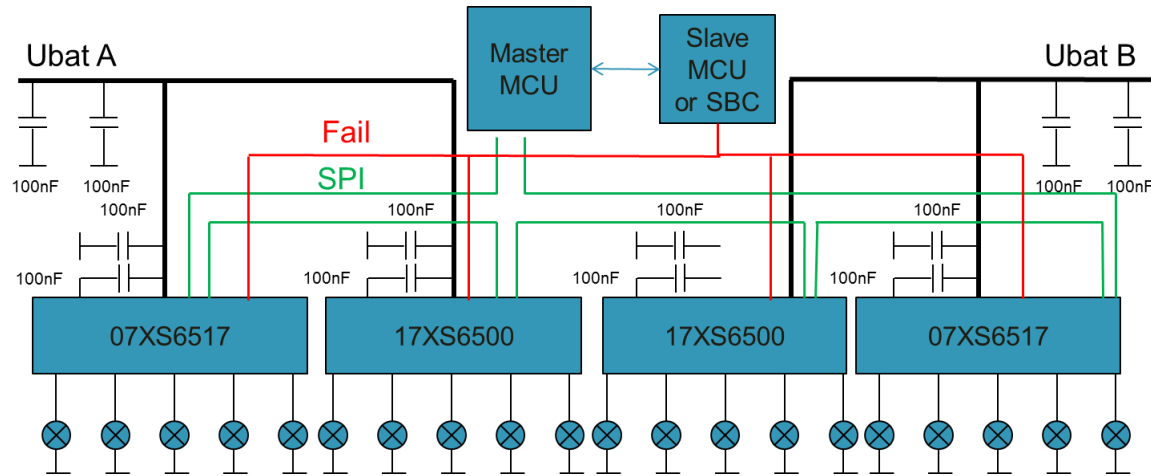
KIT12XS6EVM reference design
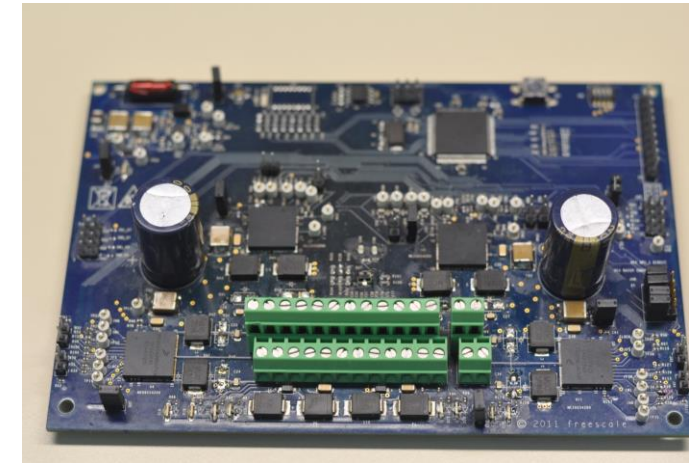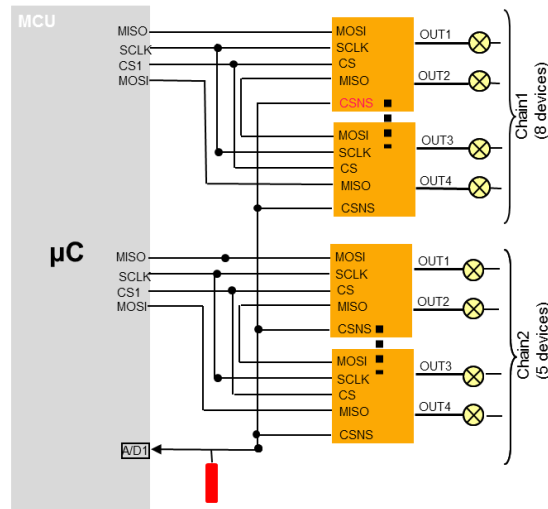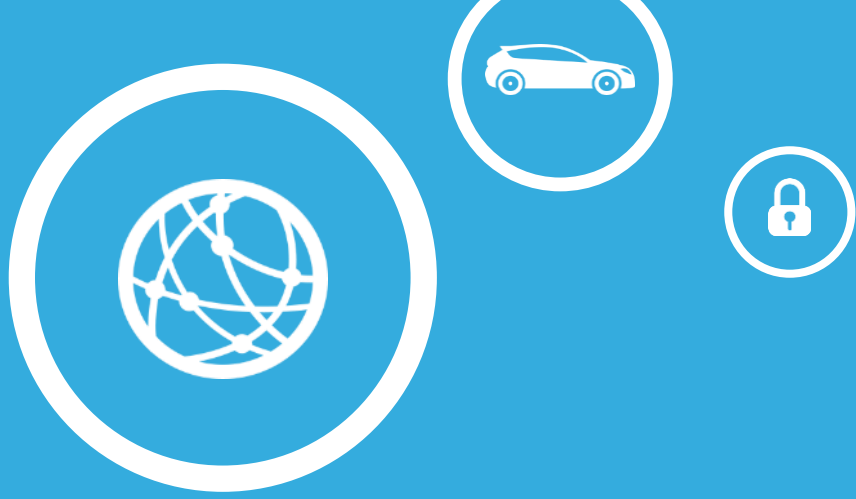

SPDxx reference design

Top reasons to choose eXtreme Switch:

- **Robustness:** unique diagnostic and protection features with embedded failsafe mode

- **Flexibility:** to accommodate with the large variations of modules (SPI, CSNS accuracy)

- **Diagnostics:** able to support ASIL B/C designs thanks to embedded protections, diagnostics, failmode

- **Accuracy:** very accurate current sensing over temperature and supply voltage range

- **Integration:** multiple configurable channels "Daisy-chainable SPI control" per package with low Rdson

- **Expanding product roadmap:** Q100 family, next gen ultra low RDSon, 48V family, smart low RDSon switches ….

- **Automotive expertise:** highly skilled technical development & support teams

Driving total system cost reduction (HW, SW…)

ADD-ON
WIRELESS CLOUD
CONNECTIVITY

SIGFOX Use Cases: Unleashing The Full Potential of the IoT

The Power of Low Energy & Low Cost

Examples:

- Smart Building management

- Smart Agriculture

- Industry 4.0

- Asset Track & Trace

OL2385 - System-on-Chip Sigfox Solution

System-on-Chip Sigfox Solution with best RF performances, low BOM cost and ultra low-power

Differentiation

- Best in class **RF performance** and **low BOM cost**
  - -128 dBm FSK sensitivity @ 600 bps
  - Excellent Phase Noise allows easy add-on of external PA
  - Good blocking performance and strong image rejection (**no** SAW filter)
  - Reference design **not** requiring TCXO
- Ultra **low-power**
  - Tx current at 14 dBm: **29 mA /** receive mode: 10 mA

Features

- **System-on-Chip** HW and SW solution
  - **Pre-loaded Sigfox modem** SW with ID & PAC numbers
  - 16-bit RISC integrated µC & DSP core
  - Multiple ISM zones support (ETSI, FCC, LATAM, JPN,…)
- Sigfox approved **reference design**
- HVQFN48 package; temperature range: -40 °C to + 85 °C
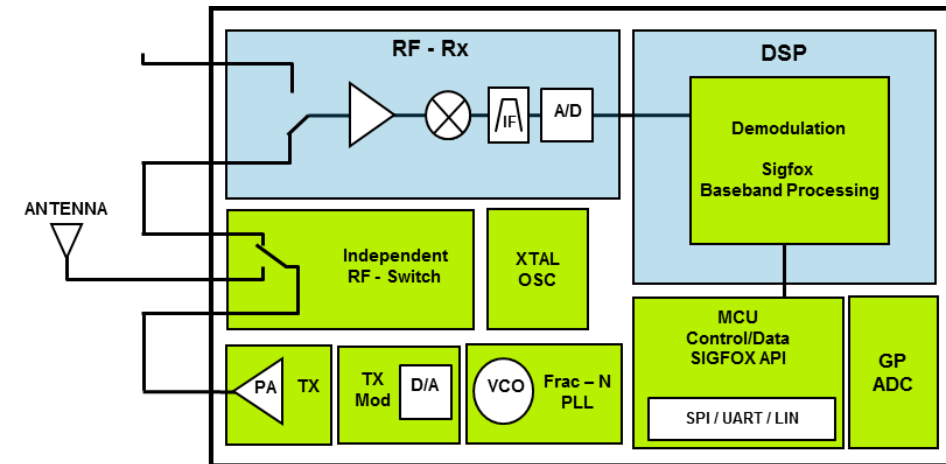
Applications

- Water metering, electricity metering, smart building management, renewable energy monitoring
- Automotive & fleet management
- Smart irrigation, weather stations, wind monitoring
- Road side management, parking slot monitoring
- Home alarm system, smoke detector
- Smart button, connected defibrillators

OM2385: SIGFOX Development Kit with KL43Z MCU

- Orderable on-line for $99 at nxp.com
  order here

- Kit Contains
  - OL2385 Arduino shield board
  - Freedom KL43Z MCU board *(pre-loaded with demo application SW sending accelerometer sensor data, temperature and illuminance)*
  - Quick reference card *(how to activate kit)*
  - USB A-to-MiniB cable
  - Antenna

- On-line ressources
  - Instructions to activate Sigfox account with ID and PAC (two years pre-paid Platinum subscription)
  - Hardware and software user guides
  - Downloadable example demo code to be used with Kinetis Design Studio IDE tool (KSDK2.0) and example code for LPC8xx (free)
  - REST HTML5 demo for data display from Sigfox back-end server
  - Printed Circuit Board, bill of material and design files
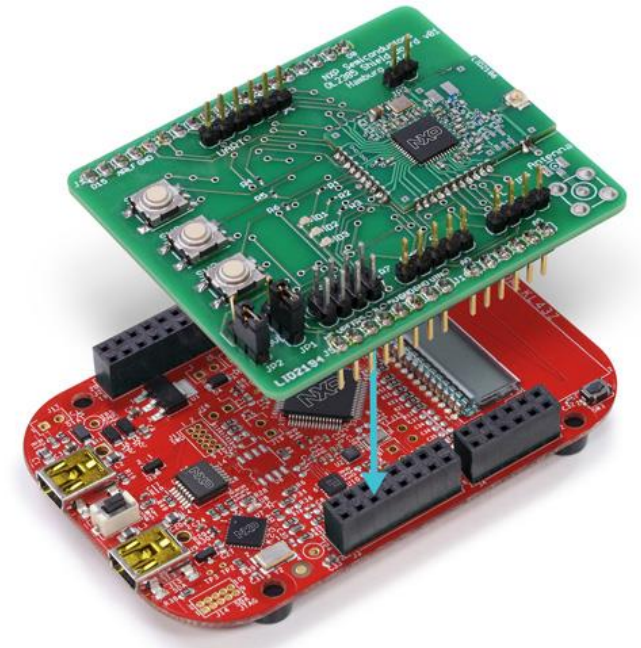
🛒 Buy

Agenda

- Market needs for safety
- Functional safety foundations
- Safe Assure solutions
- Safety system solution
- Evolution of functional safety

LEADING THE INDUSTRY TOWARDS ZERO ACCIDENTS

CONCLUSION

- ✓ Functional safety is about **RISK** assessment, prevention, protection

- ✓ Car OEMs set risk of **HAZARD** and **SAFETY GOALS** at System Level

- ✓ There are market driven reasons that mean that functional safety is a requirement for the future of **EVERY** automotive development

- ✓ ISO 26262 process and ASIL definition provide the **FRAMEWORK** and **EVIDENCES** to demonstrate that safety objectives are met

- ✓ Safety Requirements and Standard will continue to evolve as the industry moves towards full autonomous drive