EV-INVERTER Pitch Pack

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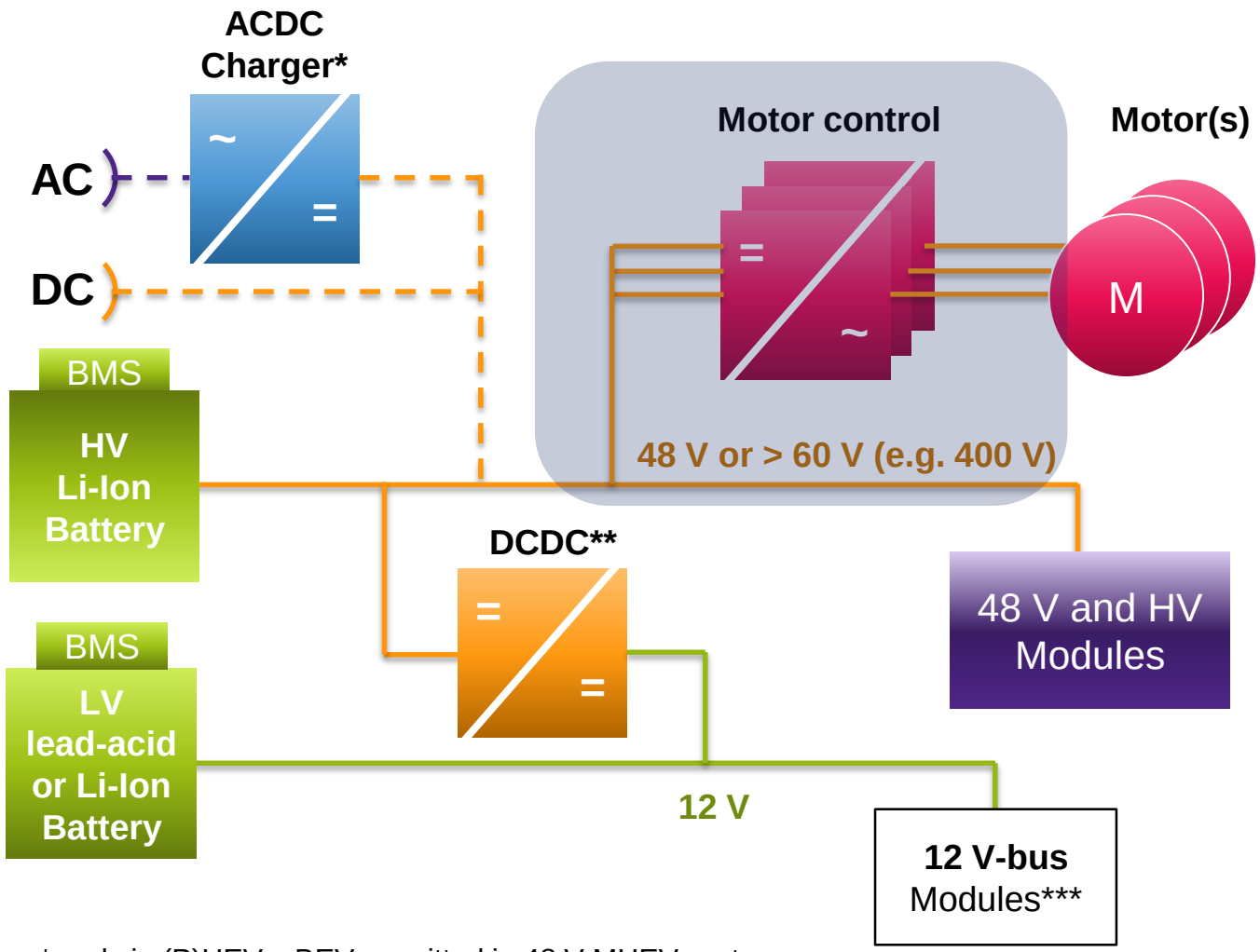
Agenda

- Target Market
- EV-INVERTER Description
- Key Differentiator
- Enablement
- Application Example
- Package Offering and Ordering

New Applications Driving Electrification Market Growth

Major components

- Battery management system
- Motor control (inverters, HCUs)
- 48 V eMachine (BSG, ISG, HVAC)
- DC/DC voltage domain converter
- On-board charger AC/DC converter



* only in (P)HEVs, BEVs, omitted in 48 V MHEV systems
** bidirectional in 48 V systems
*** as in exisiting ICE-based vehicles

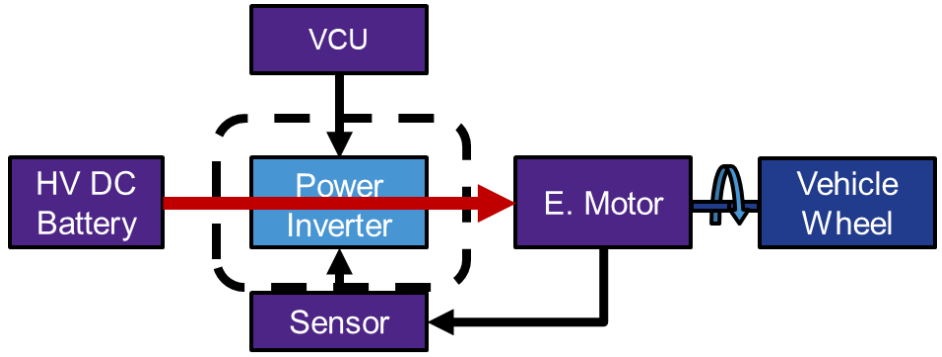
What is a HV Power Inverter for EV Traction Motor?

EV Traction motors requires high power (80 kW to 200+ kW) and high voltage (48 V to 400+ V).

EV range directly related to efficiency of the traction motor

Inverter output power & power density efficiency is critical with HV battery

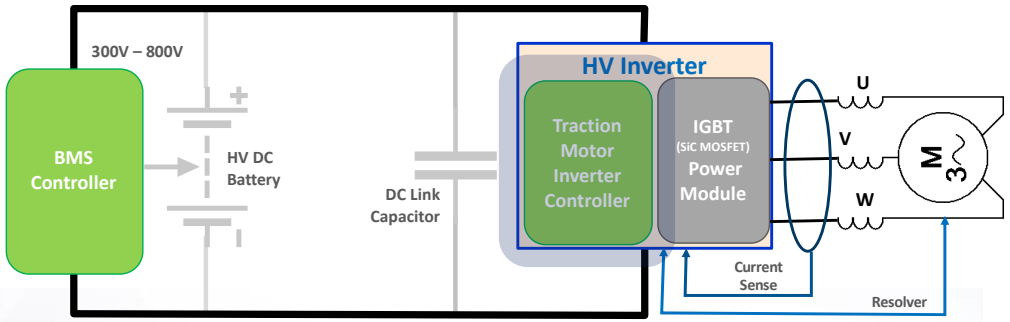
- The inverter converts DC power from HV battery to high current multi-phase AC power
  - i.e. converts high voltage, high current DC to AC and controls the traction motor, which is a 3-phase AC load
- The inverter drives electronics in the inverter key to efficiency of the traction motor
- The inverter electronics are required to:
  - Minimize switching losses & maximize thermal efficiency
  - Provide system protection
  - Withstand extremely high temperatures (125°C)
  - Withstand high voltages
  - Be as small and light as possible (better packaging or integration)
  - Typical functional safety requirement at ISO26262 ASIL-C/ ASIL-D

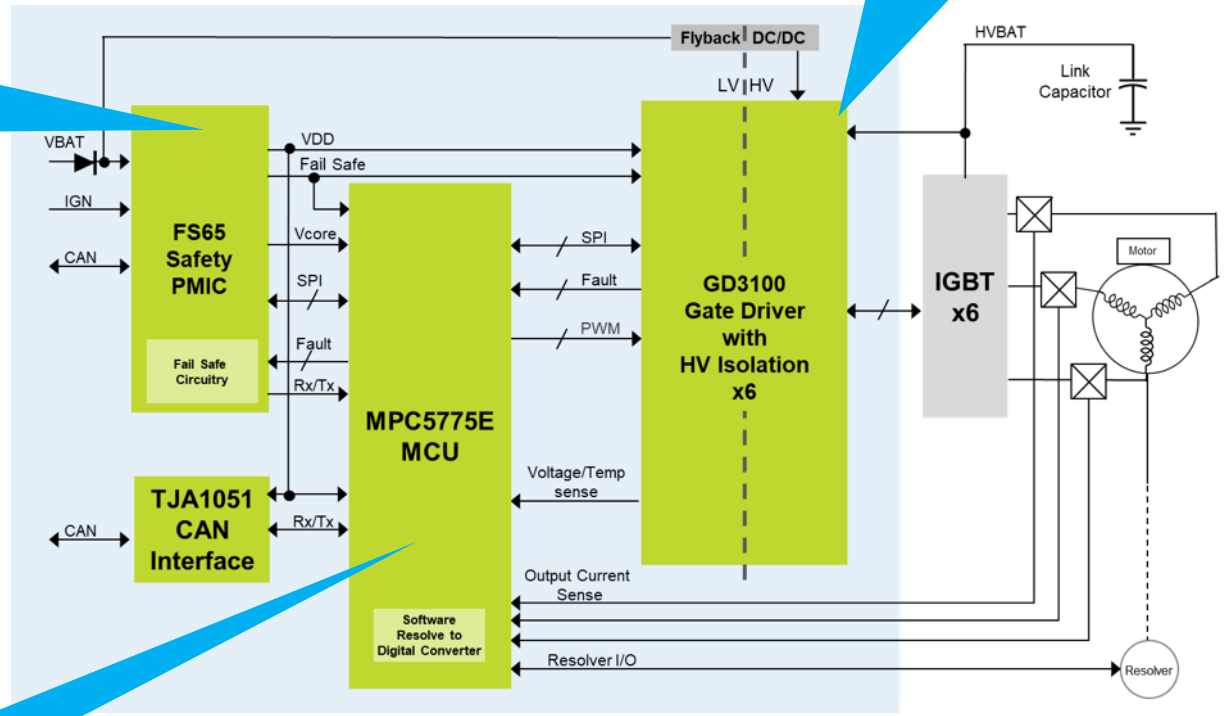


NXP EV-INVERTER Overview

- Independence (Phys & Elect) for ASIL D
- UV / OV monitoring
- Fail Safe State Machine
- Analog & Digital BIST
- Challenger watchdog

- Fast short circuit protection
- High speed over current protection
- Integrated temp sense
- Integrated galvanic signal isolation





- Multi-core, ASIL-D MCU
- Programmable MC timers
- Software resolver
- Rich on-chip resources – communications, timer, ADC etc

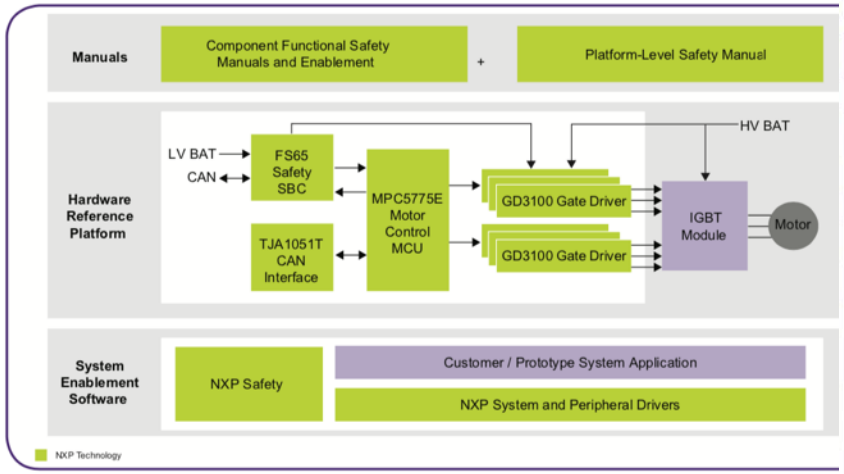
NXP EV-INVERTER Details

Small footprint ASIL-D 100 kW power inverter enablement

NXP Components

- **GD3100** isolated IGBT gate driver with <2us over-current protection
- **MPC5775E** advanced motor control ASIL-D MCU with software resolver
- **FS65** robust ASIL-D SBC with fail-silent and Grade 0 capabilities
- **TJA1042** redundant CAN bus interface with low power standby
- **System enablement software** with API and functional safety case

SYSTEM BLOCK DIAGRAM



Target Application:
EV motor power inverters
High voltage DC to DC boost circuits
High voltage on-board chargers

EVALUATION PROTOTYPE PERFORMANCE SUMMARY

Inverter Performance Summary		
Parameter	**Value**	**Units**
Operating Input Voltage Range	240-420	VDC
Maximum Output[1]	150	KVA
Nominal Voltage	340	VDC
Peak Current[2]	420	A, rms
Control Input Supply Voltage Range[3]	8.5 - 16	VDC
Motor Operating Speed	0-10,000	RPM
PWM Switching Frequency	3-12	kHz
Control Type	current/ speed/ torque	
Maximum Electrical Efficiency	98	%
Communication Interface	CAN	
Inverter Mechanical Envelope	28 x 28 x 15.43	cm
Power Devices	IGBT	1 module
Standby Power Consumption	<1	mA
HV Bus Capacitance	440	uF

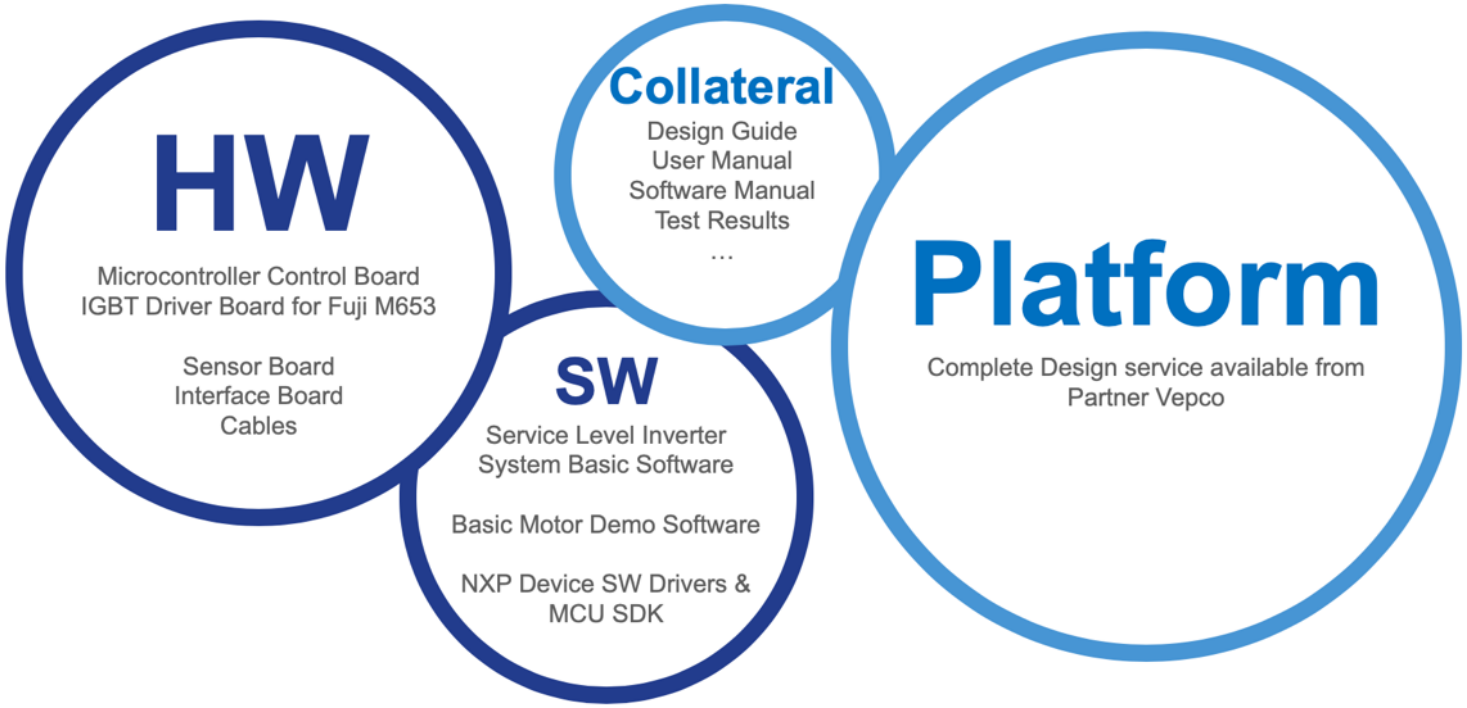
[1] Measurement conditions: HV bus capacitance of 440 uF, Fuji M653 IGBT module

[2] 1K - 3K RPM

[3] Range extension to 18 VDC is possible with hardware design update

NXP EV-INVERTER Key Differentiators

- **NXP EV Power Inverter Platform** provides a hardware reference design, system enablement software, and functional safety enablement to develop a complete ASIL-D compliant high voltage, high power traction motor inverter for electric vehicles.
- The Reference Platform demonstrates 196 kW peak output power and >96 % electrical efficiency operating from 320 V supply voltage.
- It is designed to interface to a Fuji M653 IGBT module rated for 800 A / 750 V operation (purchased separately from Fuji Electronics) and can drives up to ±15 A into a broad range of other IGBT & SiC power devices.



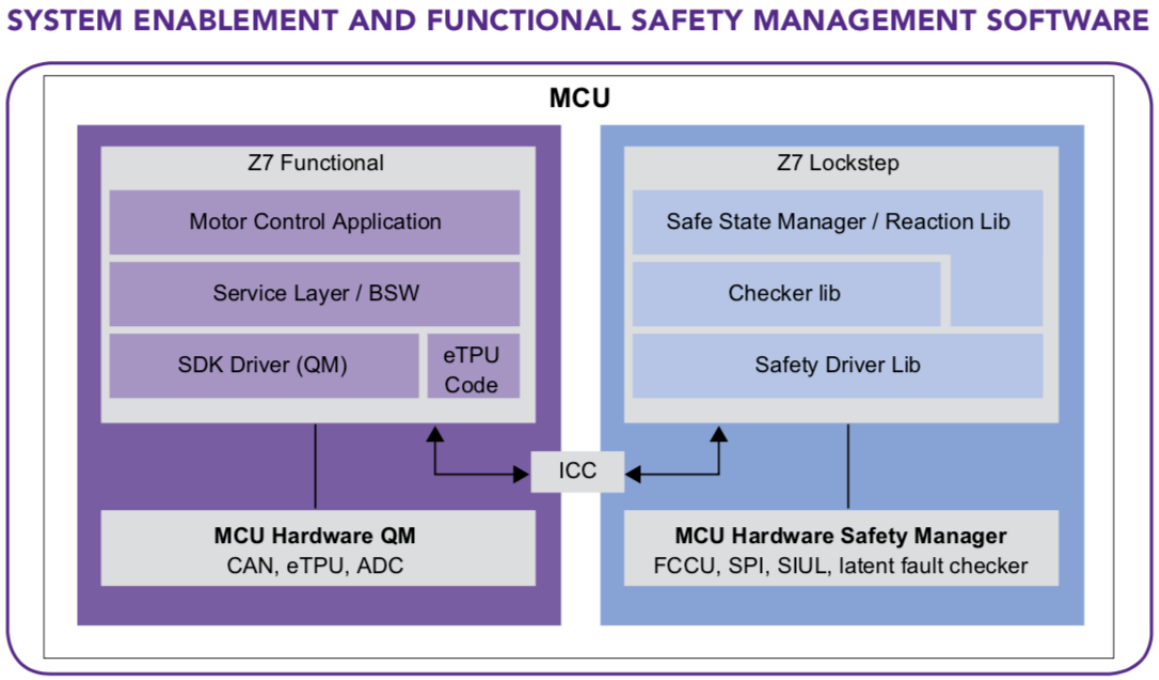
NXP EV-INVERTER SW Enablement

Functional Basic SW

- NXP SDK w/ production-ready SPCE/CMMI Class B and MISRA 2012 compliant drivers
- Peripheral drivers for FS65 & GD3100
- Special function drivers for SW RDC and eTPU advanced motor control timer
- Service layer w/ function calls for controlling platform motor control operations by functional application layer

Safety Basic Software (Coming Soon)

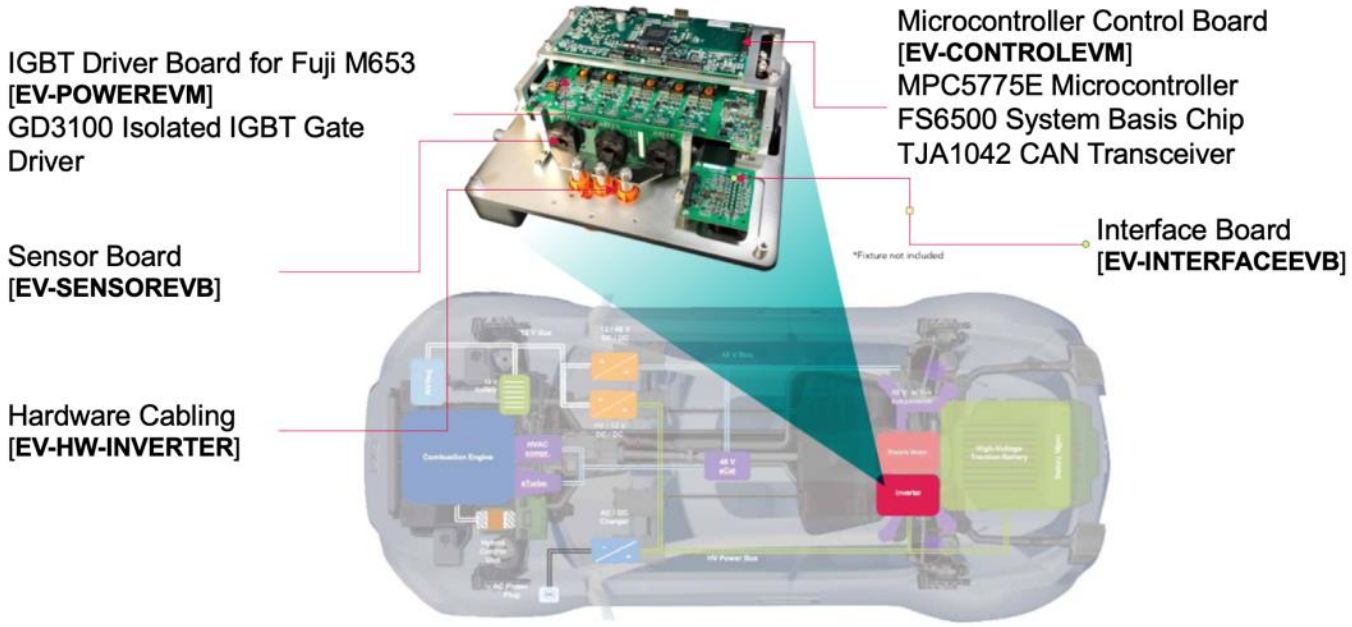
- Operates in lockstep core
- Transfers data with QM functional core via Inter-Core Communications mechanism
- Low level safety drivers interact with all platform HW safety mechanisms
- Checkers in safety services layer continuously monitor & verify status of critical safety mechanisms
- Safety libraries offer default Safe State & Reaction routines callable by safety manager application



NXP EV-INVERTER HW and Collateral Enablement

Reference design hardware kit

- Control board w/ MCU & SBC & CAN
- Driver board w/ GD3100
- Interface board w/ RDC I/F
- Sensor board w/ output current sensors
- PCB interconnect cables



Documentation

- Design Guide Application Note
- Enablement Kit User Manual (UM11298)
- Basic software user manuals (UM11317)
- Safety application package (coming soon)
- Hardware design package (schematics & layout)
- System proof-of-concept prototype test results

Vepco Engineering Services - Advanced development assistance

Power Inverter Platform

- Apply **NXP hardware, software and toolchains** to vehicle motor control
- **Setup** and **training** on the use of Platform
- Introduction on **Safety** concept of the Platform

Customization and advanced support

- Advance power inverter design principle to **different vehicle architecture and topology** needs
- Participate customer's **packaging design** and integration analysis
- Premium support over design of complete **eDrivetrain system**
- Facilitate customer ISO 26262 **functional safety** related activities in system design, development, validation and integration cycle
- Work with agencies on design and development process **certification**

Value-added services:

- **Calibration** and tools integration
- Application level **integration** with advanced auto **code generation** tools
- Engineering software and **tools**
- Dyno and Hardware-in-the-loop **testing**

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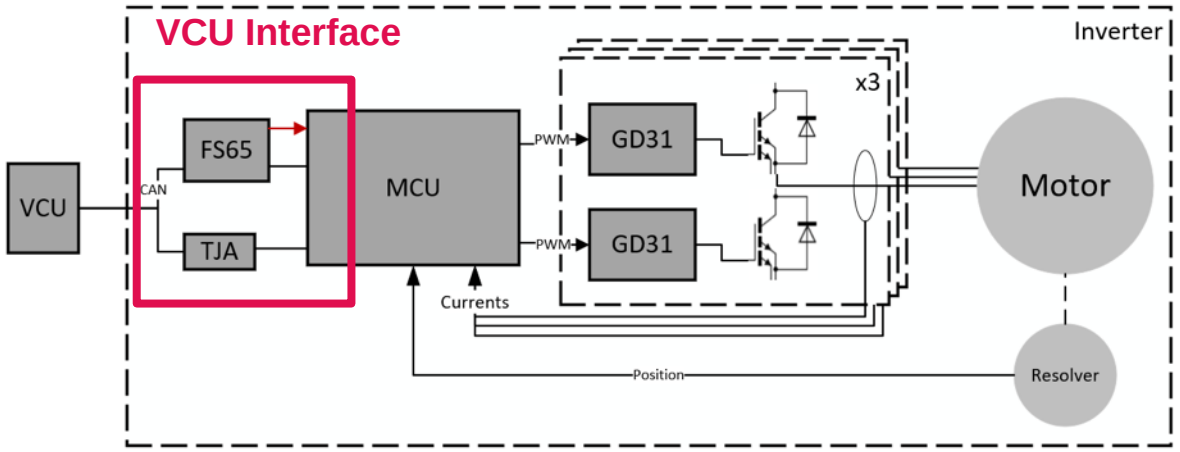
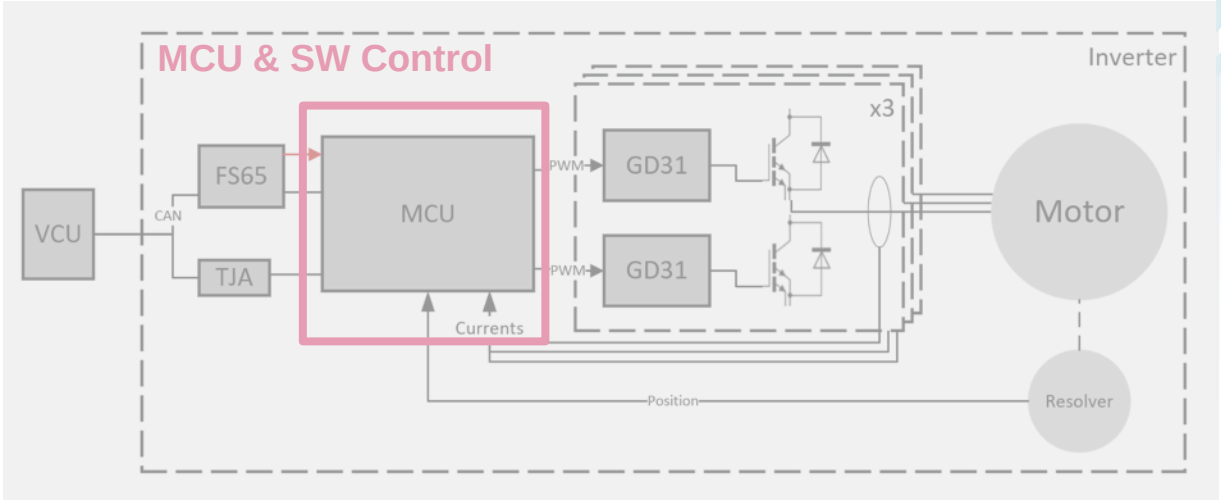
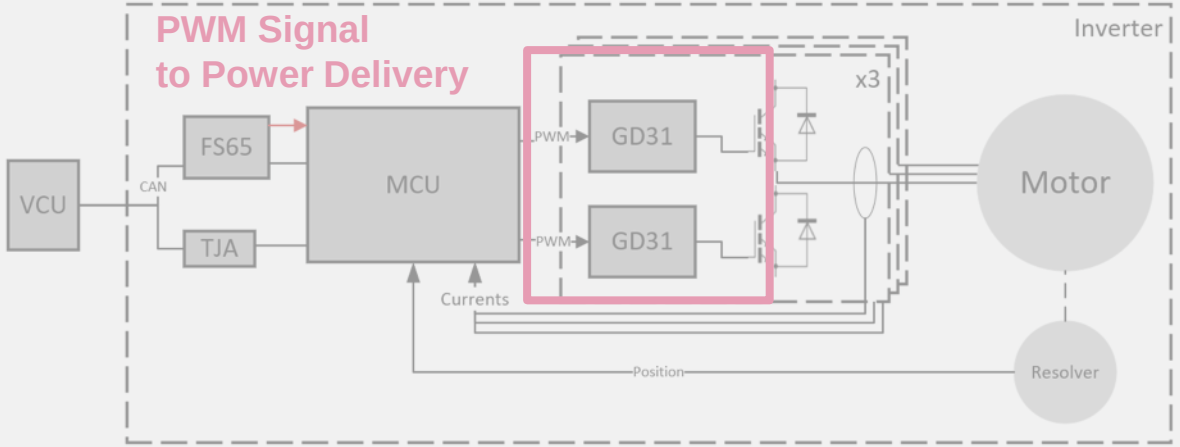
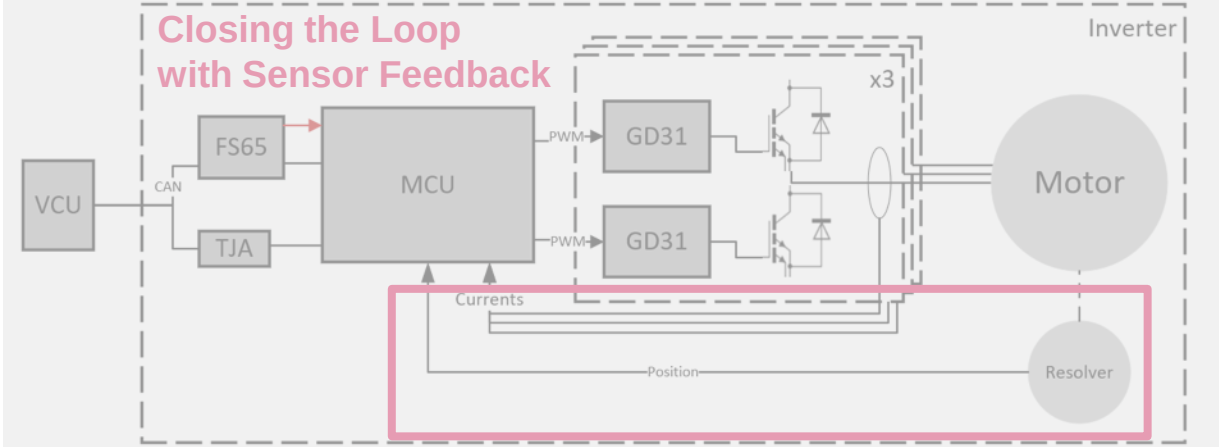
Application Example

Inverter Platform System Control Flow from Torque Command to Wheel Speed



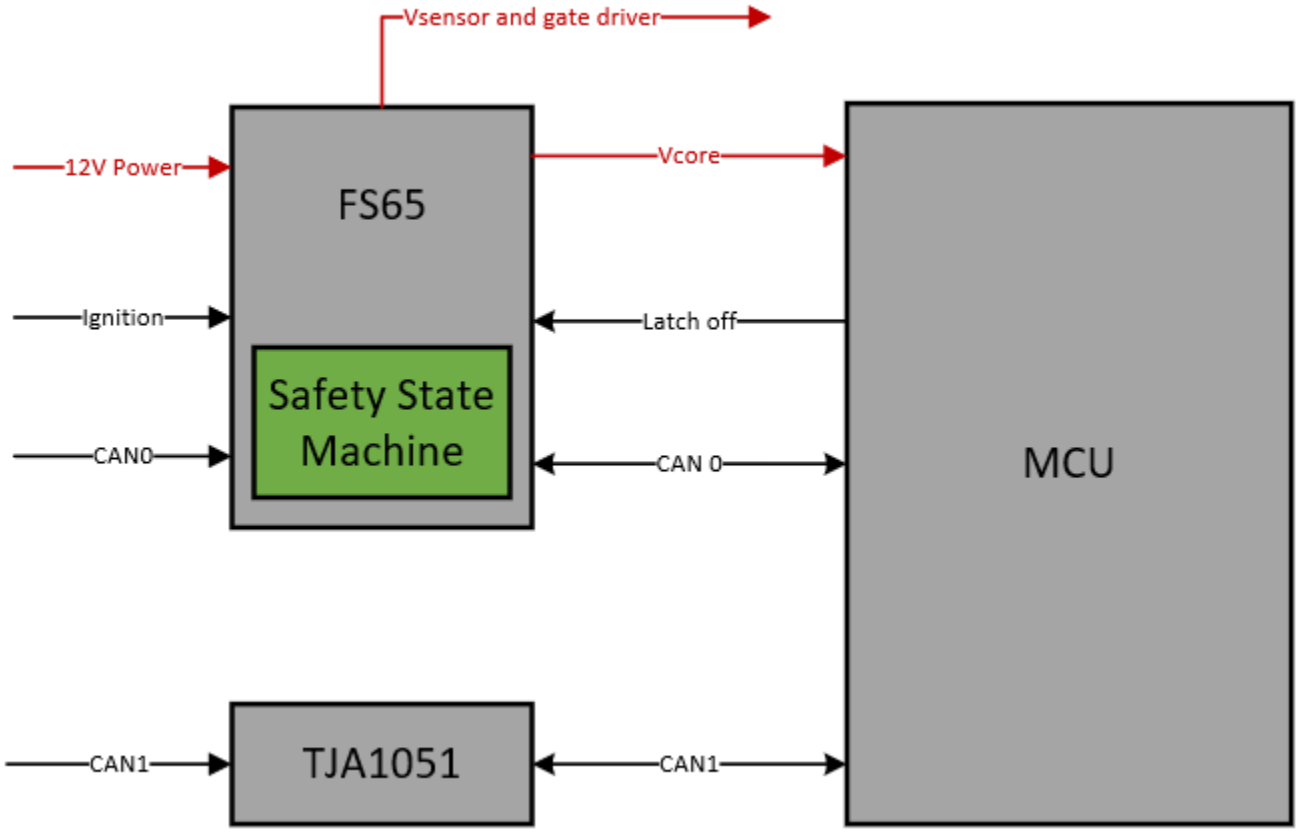






VCU Interface

System messaging, Safety and Power management



Dual CAN comm ports

- FS65 CAN transceiver
- TJA1051 NXP transceiver

FS65 functions

- Safe system power for all sensors, drivers, MCU, transceivers
- Key Safety Mechanism for MCU:
  - Check MCU, Clock, Power Supply
- System safe state assertion
- System latch-on / latch-off

FS65 Safety SBC Safety Monitoring Capabilities

Robust fit for ASIL-D with fail-silent and Grade 0 capabilities

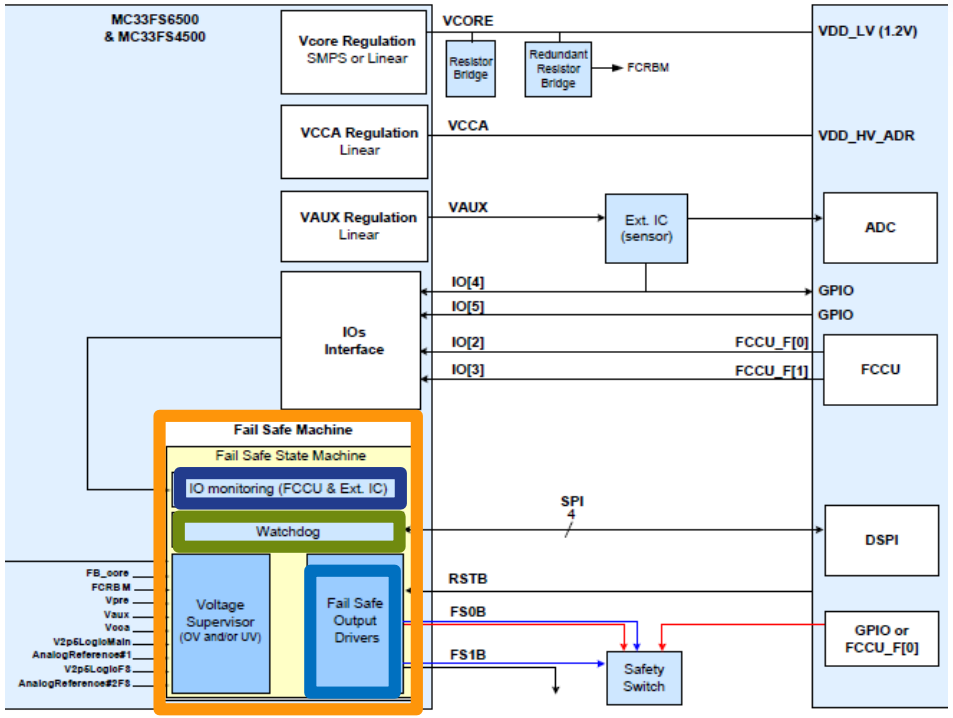
Independent Fail Safe State Machine

- 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



HW Redundancy

- Vcore external monitoring

MCU Monitoring

- FCCU: fault collection control unit
- Monitor dual-core lock-step modes

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

Application Example

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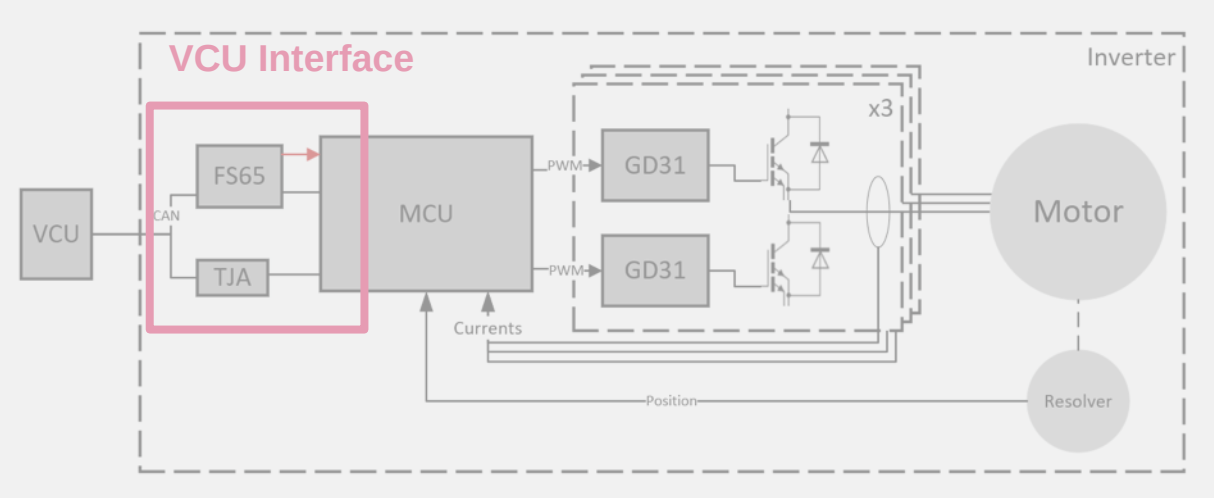
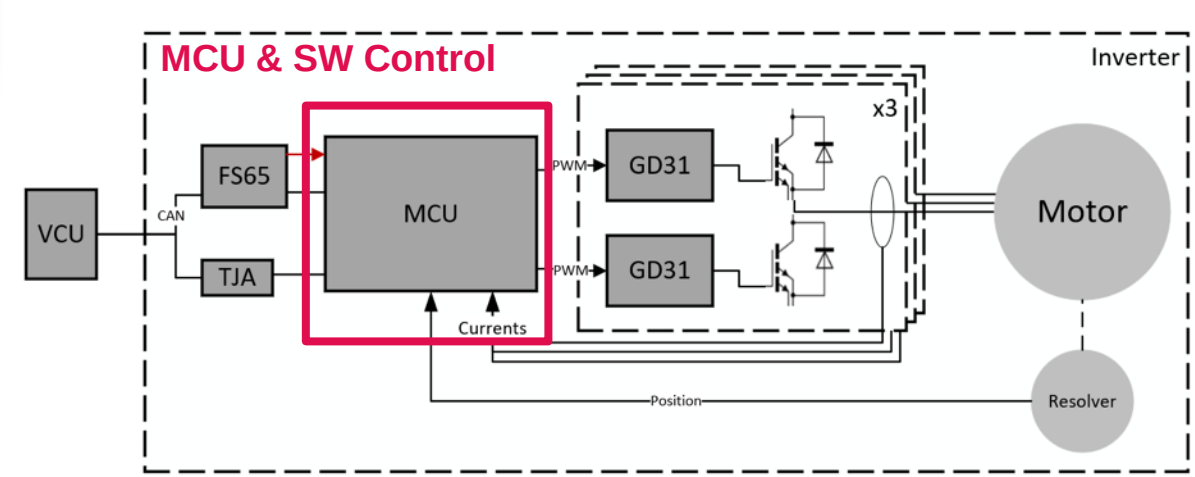
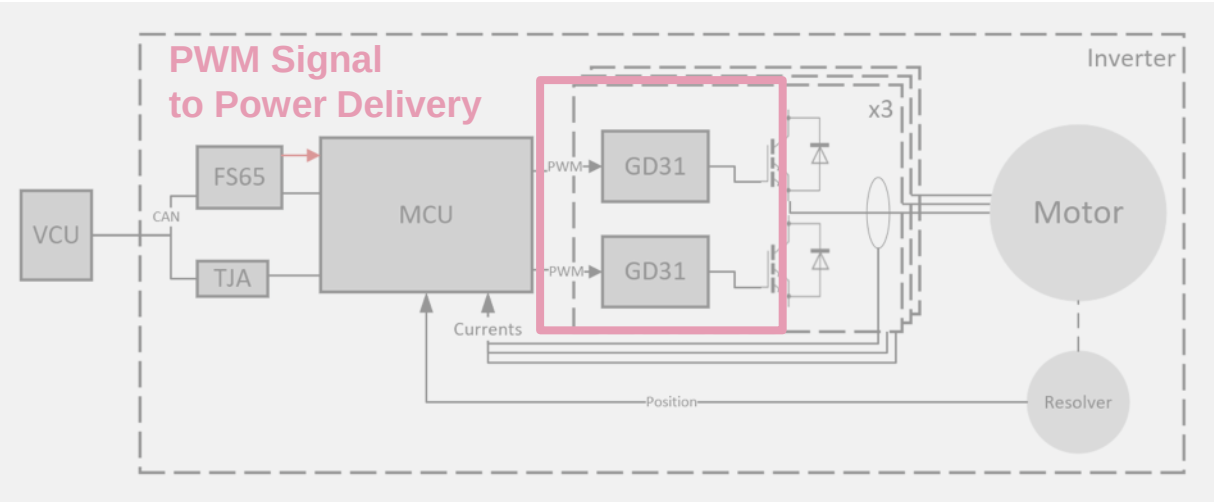
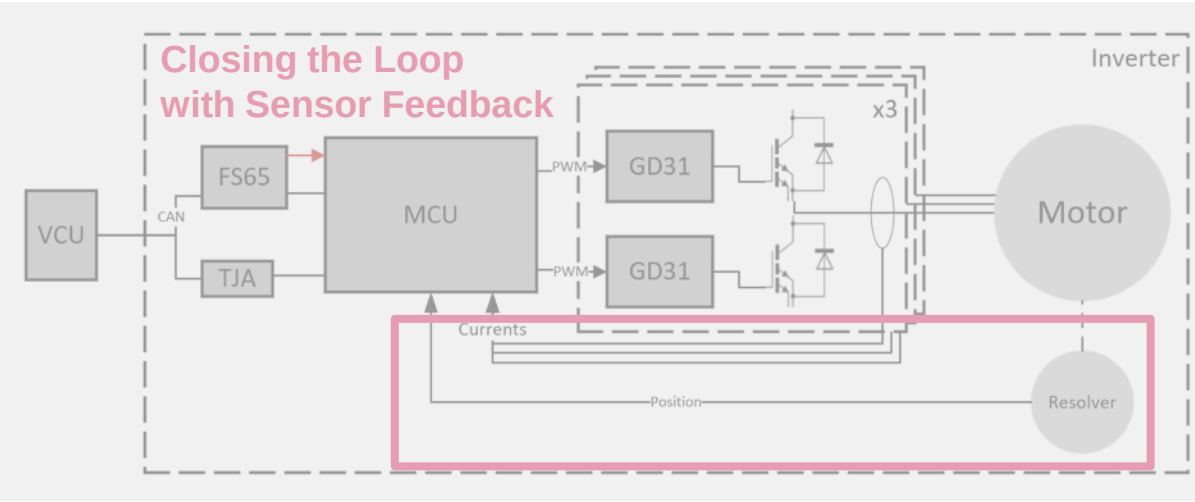


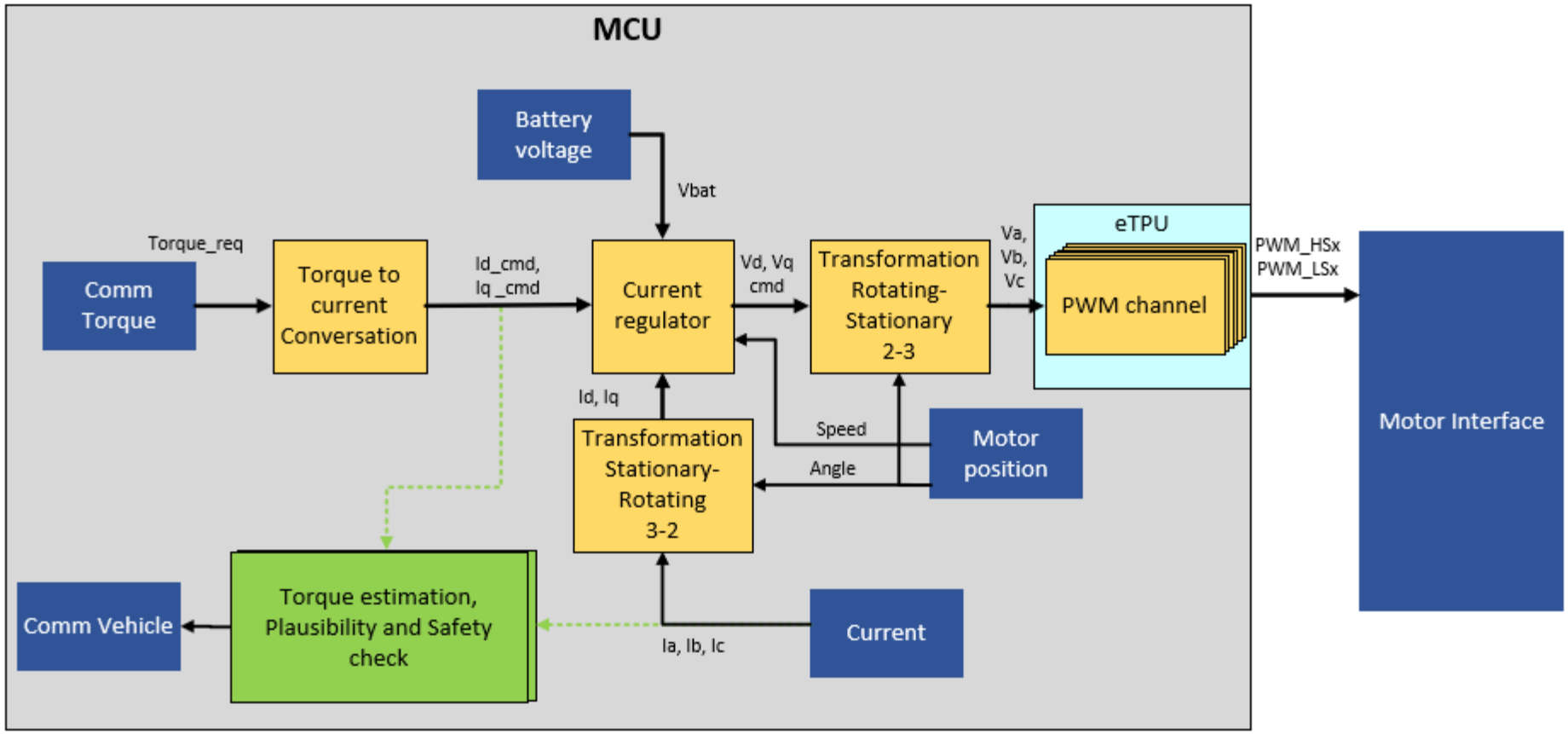






Field Oriented Control (FOC) Processing Block Diagram

Typical customer application functionality supported by the platform



MPC5775E

Advanced traction motor power inverter MCU

Cores
Z7 Functional core (QM)
Z7 Safety Core (lockstep)

Interconnect Isolation
Cross bar with end to end ECC
MPU for isolation

Memory
4M Flash
512K RAM

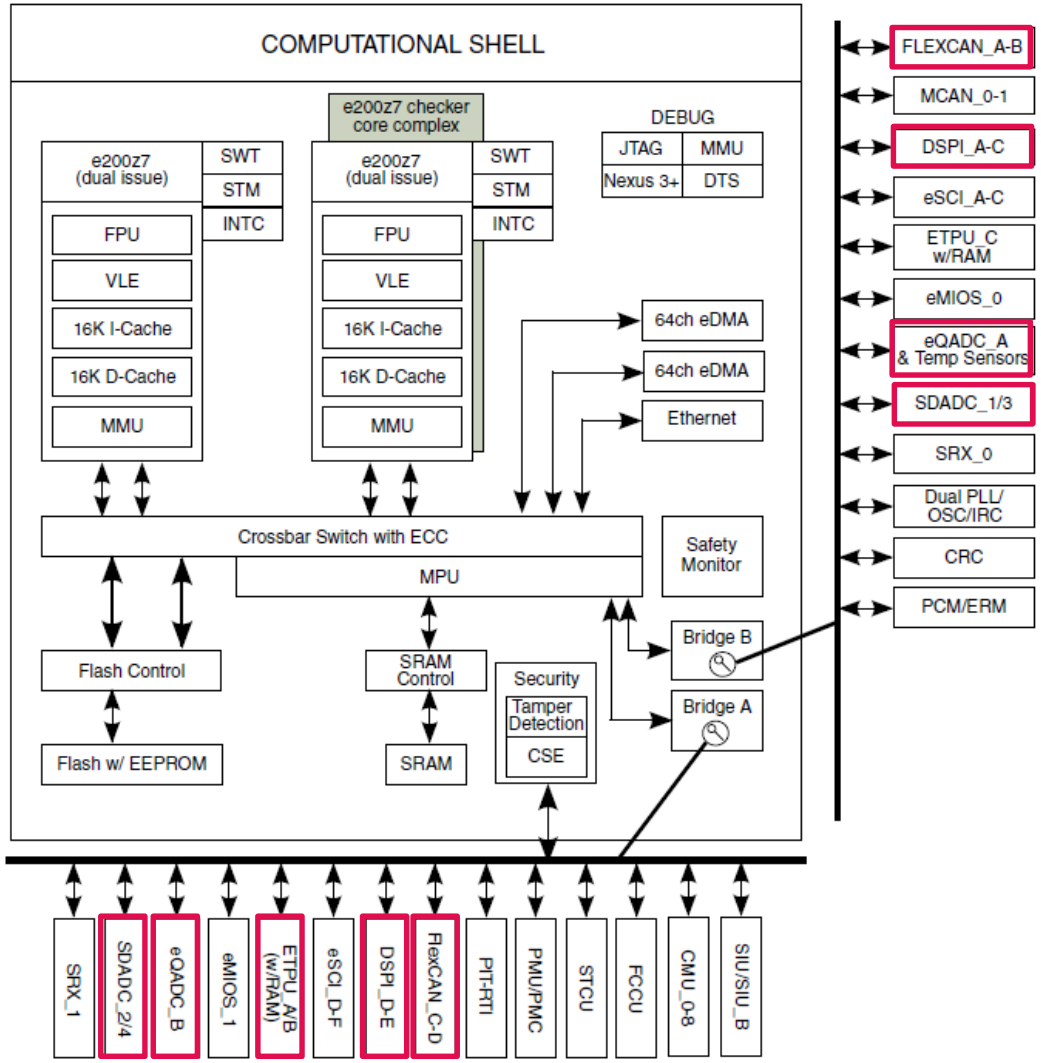


Figure 2-1. MPC5775E block diagram

Peripherals
FlexCAN (4) + CRC
SPI for gate driver and FS65
ETPU A/B for:
- CA-PWM + ADC Trigger
- SW Resolver and diag

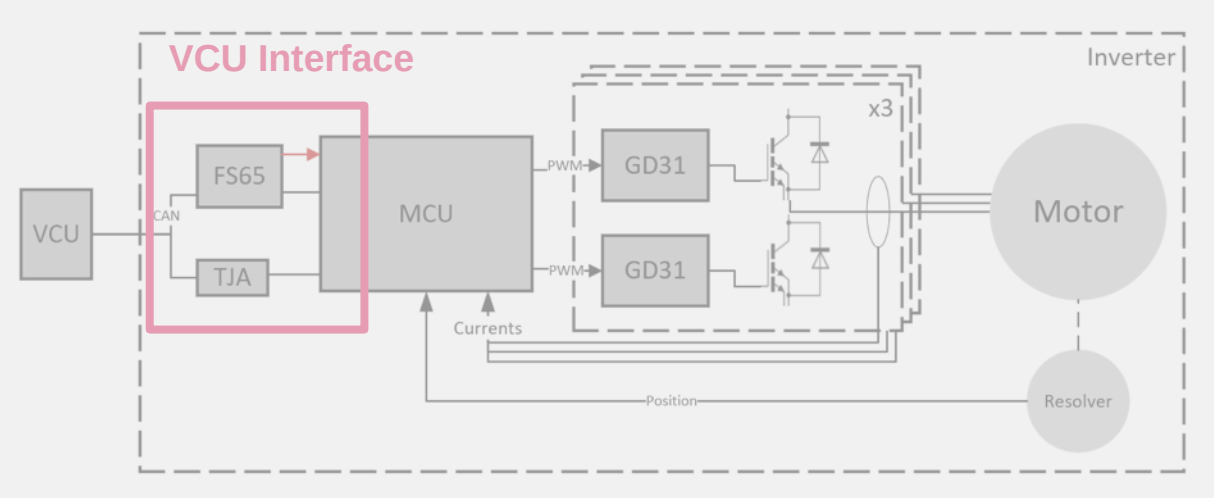
eQADC
SD ADC (for resolver)

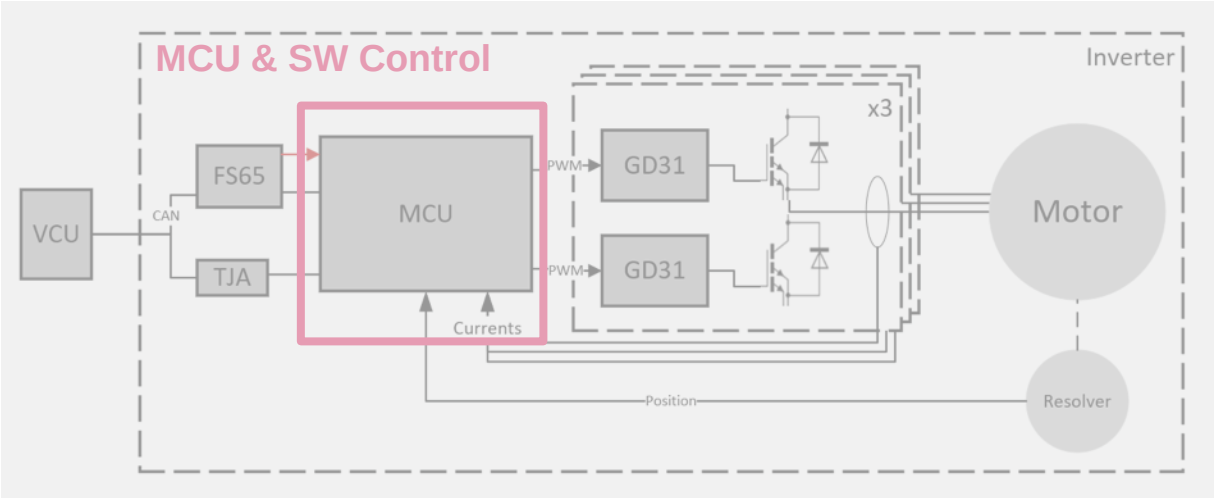
Safety
FCCU, ECC, SWT, Lockstep
CMU PMU…
And Latent fault check (BIST, ECC Fault Injection)

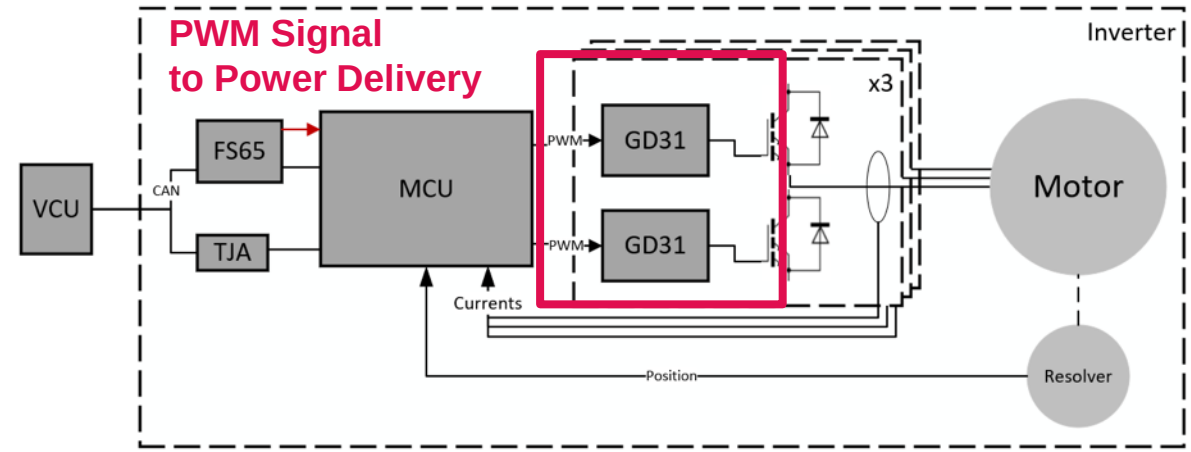
Security
Crypto Security Engine
For OTA Update

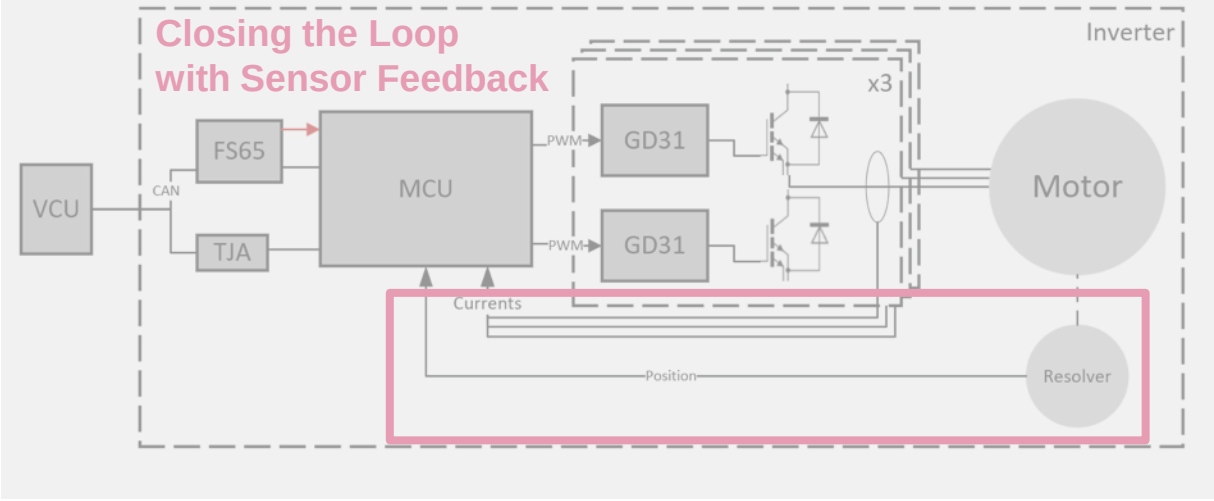
Application Example

Inverter Platform System Control Flow from Torque Command to Wheel Speed







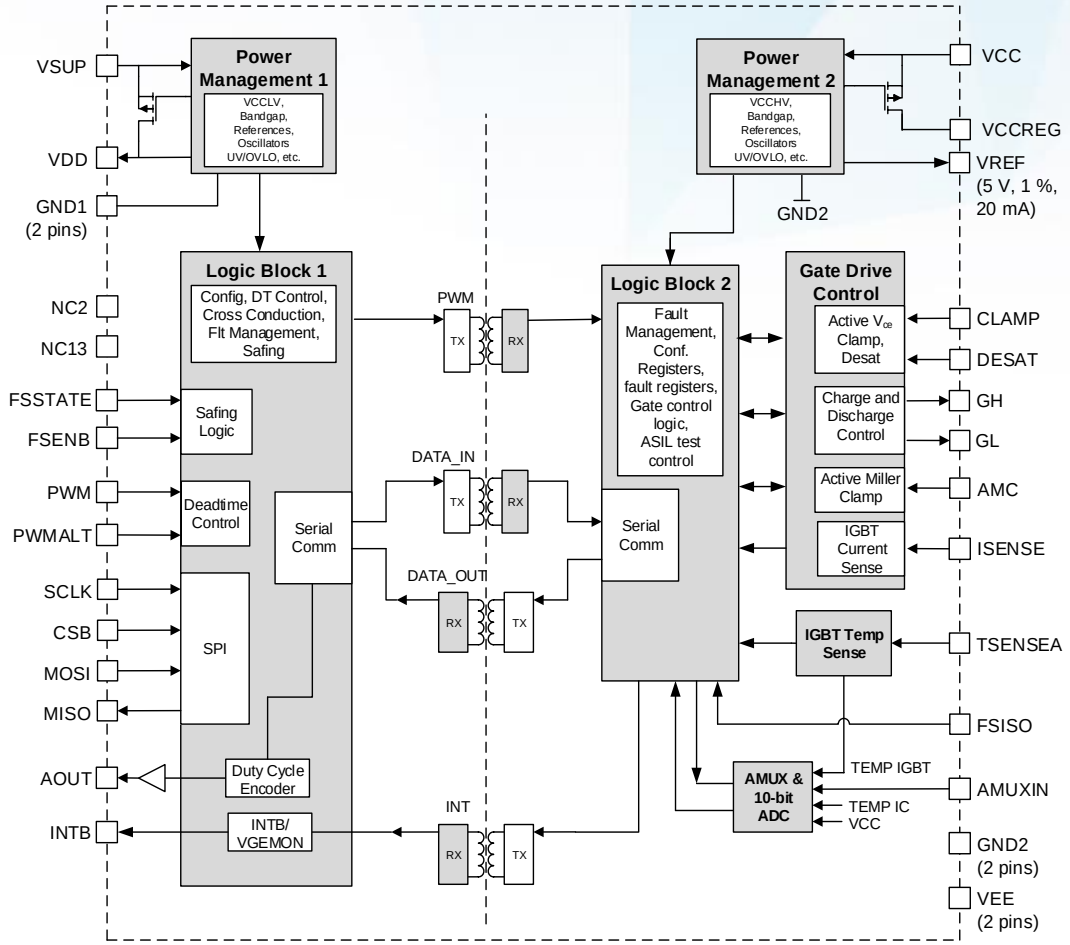


GD3100 IGBT Gate Driver with High Voltage Isolation

ASIL C/D ISO26262 compliant advanced gate driver for high voltage power IGBTs with integrated high voltage isolator, high speed current sense interface and robust functional safety mechanisms

Features:

- 5 kV galvanic signal isolation compatible with 1700V IGBTs
- High 15 A peak gate current source/sink capability
- <2 us short circuit protection via IGBT i-Sense direct feedback
- Programmable Desaturation Detect level, Two Level Turn off
- Redundant PWM gate control signal paths
- IGBT Vge monitoring for IGBT gate control verification
- Active Miller Clamp (AMC) reduces need for turn off assist
- Temperature sense soft shutdown for system protection
- Compact 10 x 18 mm SOIC package for reduced PCB area



Application Example

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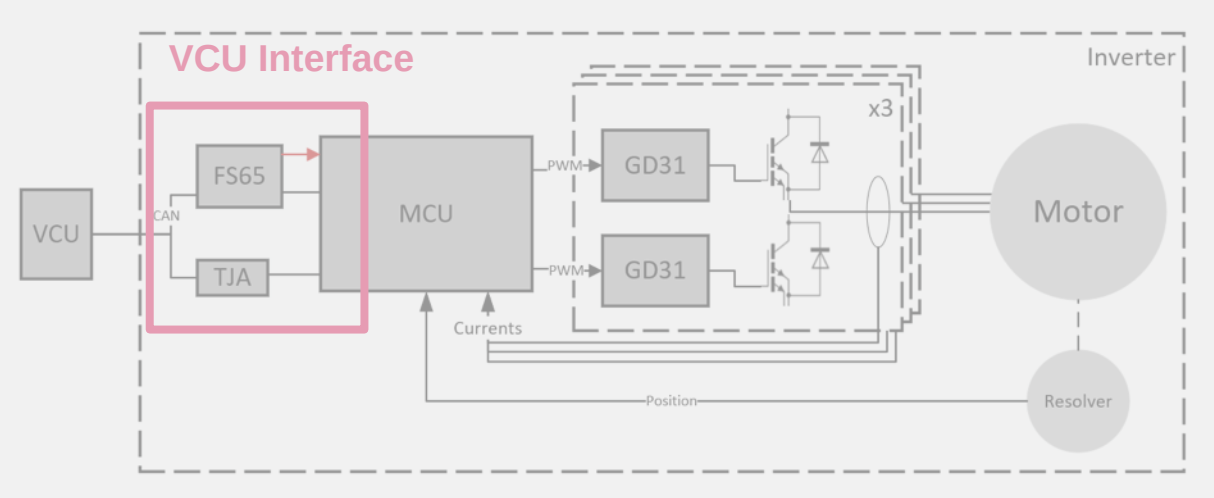
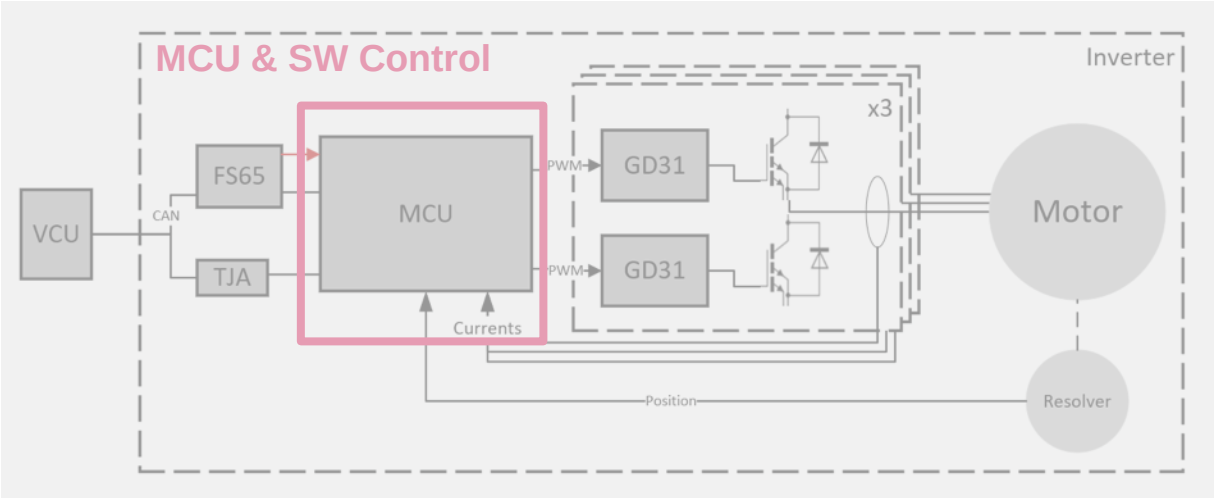
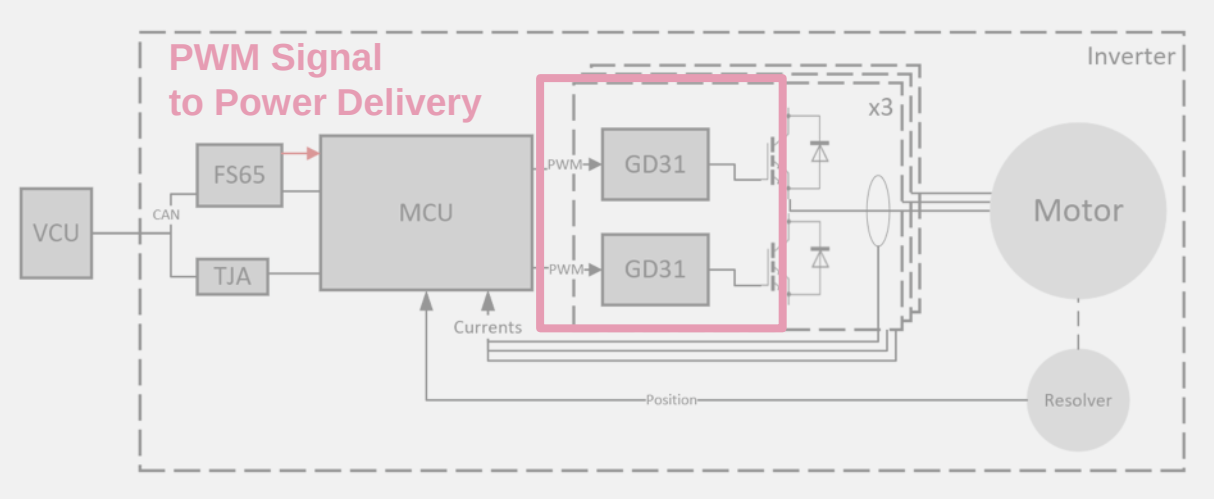
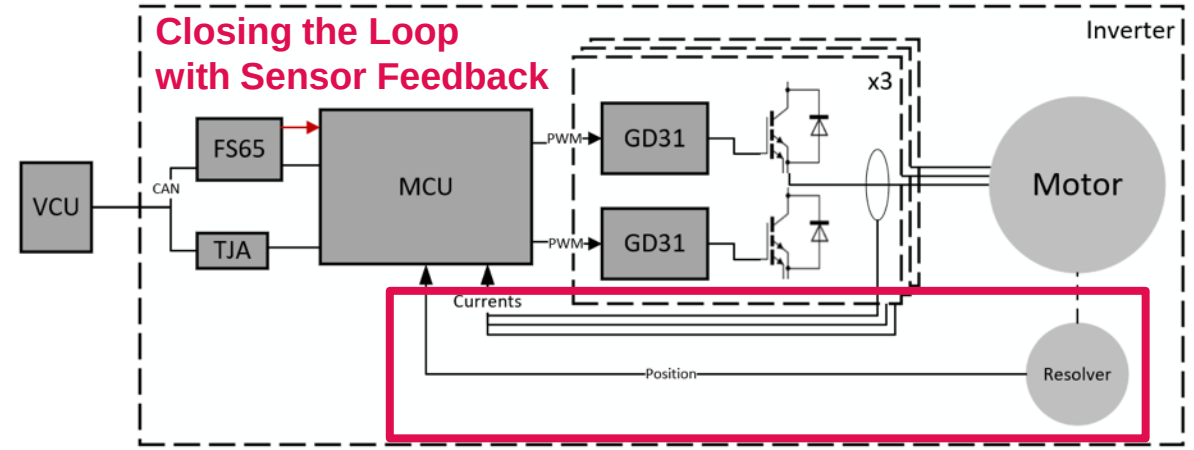




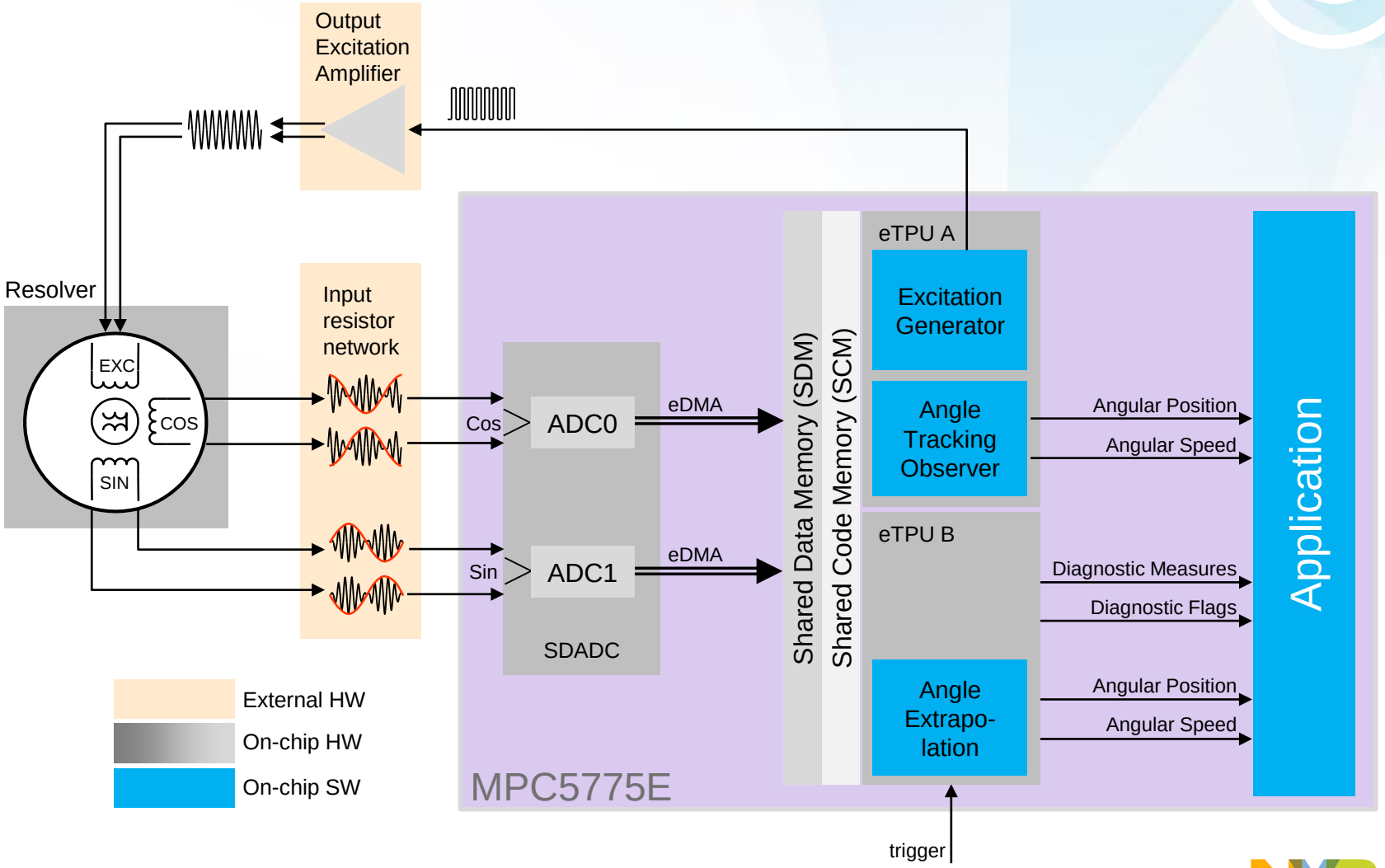




eTPU-Based SW Resolver to Digital Converter

Block diagram and performance specifications

Parameter	Value
Output Resolution	2^{24}
Accuracy	±0.1º
Max angular acceleration (bandwidth dependent)	
Phase delay Output response time	±0.12º / 10k min^{-1} 2 µs
Tracking rate	300,000 min^{-1}
Settling time w/ 180º step input (bandwidth dependent)	4.8 ms @ 0.2 kHz BW 0.38 ms @ 2.5 kHz BW
Start-up time	25 ms
Algorithm Type	Angle tracking observer w/ error calc after demod
Output form	24-bit fractional
Diagnostics	Signal Loss (LOS) Signal Degradation (DOS) Tracking Loss (LOT) Signal Disconnects Signal Shortcuts



Package Offering and Ordering

Inverter Platform Enablement Kit: $5000

KIT INCLUDES

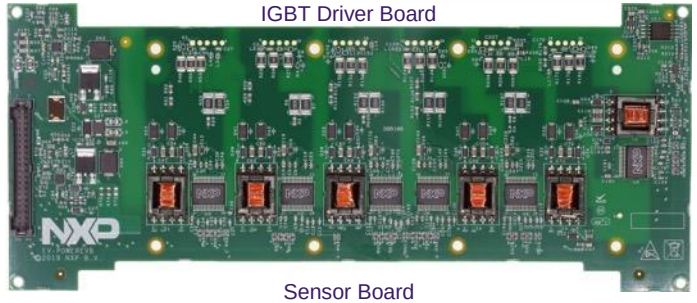
Offerings	Type	Offering Packages	
		Inverter Platform Enablement Kit	Inverter Platform Safety Kit *
Hardware design package (schematics & layout)	DOC	DL	
NXP device datasheets	DOC	DL	
NXP device functional safety documents	DOC	DL	
NXP device software drivers (GD3100 & FS65)	SW	DL	
Reference design enablement kit including control, driver, RDC interface, & sensor boards	HW	X	
BSW with service level, SDK, driver & GUI software	SW	DL	
Reference design enablement kit user manual	DOC	DL	
Design guide application note	DOC	DL	
BSW user manual	DOC	DL	
System proof-of-concept prototype test results	DOC	DL	
Safety basic software & safe-state library	SW		DL
Basic safety software user manual	DOC		DL
Inverter safety concept manual			
Analysis & fault reaction matrix	DOC		DL

DL = downloadable from NXP

* Available by end of 2019

Microcontroller Control Board

IGBT Driver Board



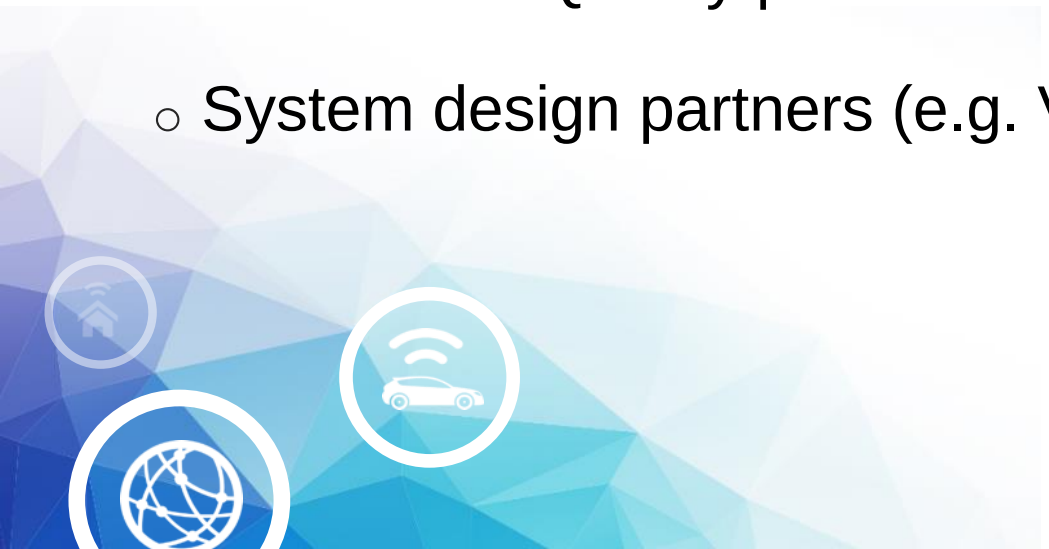
Sensor Board

Interface Board

NXP EV-INVERTER Reference Platform Summary

Reference Platform

- Open system IP with hardware, Basic SW enablement and Safety concept
- Optimized BOM solution targeting ASIL-D
- System safety concept based on NXP’s Safety IC and ISO26262 methodology
- Automotive Quality proof-of-concept prototype available for Dyno Testing
- System design partners (e.g. Vepco) to reduce customer engineering efforts



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