Freescale EV/HEV Products and solution

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Main Content

- Freescale Overview & EV/HEV Market
- Freescale EV/HEV MCU Product & Solution
- Freescale EV/HEV Analog Product & Solution

A *Global Leader* in Microcontrollers and Digital Networking Processors

>50 Year Legacy

>5,500 Engineers

>6,000 Patent Families

Five Core Product Groups

- Microcontrollers
- Digital Networking
- Automotive MCU
- Analog & Sensors
- RF

Four Primary Markets

- Automotive
- Networking
- Industrial
- Consumer

50+ Year Heritage of Innovation

More than **6,000** patent families granted and pending worldwide

1952 — 3-amp power transistor

1960 — Si-base transistor

1975 — MC6800 1st microprocessor used in automotive application

1979 — 16-bit processor MC68000

1984 — 32-bit processor MC68020

1989 — MC68302 comms processor

1991 — PowerPC® (1) Alliance

1993 — 1st RF-LDMOS device for 1GHz cellular handset & infrastructure markets

1994 — 1st PowerPC® processor

1995 — MPC860 PowerQUICC

1996 — 500-700 Mhz, 65 W RF plastic package

1998 — 1st PowerQUICC II comms processor

2001 — MPC7455 SOI volume production

2003 — MXC 1st single-core modem: "smartphone-on-a-postage stamp"

2003 — Leading capacitive tire pressure MEMS

2004 — 1st 130 nm MCU with 2 MB eNVM

2005 — i.MX31 apps processor for mobile multimedia

2006 — MC9RS08KA2 ultra-low-power MCU with RS08 core

2006 — Multicore DSP for wireless & wireline infrastructure

2006 — One of industry's 1st commercial MRAM products

2007 — Flexis QE128 family: migration from to 8-bit to 32-bit MCUs

2008 — Debuts world's most powerful automotive MCU for 'green' engine design

2008 — Industry's most accurate Li-ion battery charging IC

2008 — Samples LED backlighting IC

2009 — Leader in 90 nm MCU with embedded flash

2009 — Breakthrough in power conversion tech for solar

2010 — Xtrinsic - smart sensor platform

2010 — Industry's most powerful auto MCU (MPC5674F)

2010 — Industry's 1st radar technology with integrated 77 GHz SiGe programmable transmitter & PLL

2010 — Founding member of Linaro software alliance

2010 — Kinetis - most scalable MCU portfolio based on ARM® Cortex™-M4 processor

2011 — QorIQ Qonverge: 1st scalable multimode MPU+DSP "base station on a chip"

2011 — QorIQ T series 24+-core multi-thread MPUs

2011 — Airfast #1 in RF power for more than 6 years

2011 — S12 MagniV MCUs: digital & high-voltage analog on a single die

2011 — PX series built on Power Architecture: controls 3+ comms & 6 motors simultaneously

2012 — Layerscape software-aware, core-agnostic development platform

2012 — Qorivva: 1st auto MCU with ISO 26262 functional safety certification

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Freescale patent total as of January 2013

(1) The "PowerPC" name is a trademark of IBM Corp. and is used under license.

Major Trends Shaping Our Future

Going **Green**

Health & **Safety**

Connected Intelligence

Why EV/HEV

- Consumer motivation switching from ICE to HEV/EV powered car (US)

- Innovative pricing models or lower price overall…… 71%
- Extended reach or range of the vehicles…….... 64%
- Convenience of usage or services…… 63%
- Availability of charging infrastructure…… 62%
- **SIGNIFICANTLY HIGHER OIL PRICES……..…. 51%**
- **Green image or sustainability concerns……..... 48%**
- **GOVERNMENT INCENTIVES OR REGULATIONS……..41%**
- Traffic congestion……26%

Source IBM, 2011

BOTTOM LINE: Consumers must perceive benefits from electric car ownership. Decision to buy is a matter of price, function and network externalities.

The Mileage Cost – Electric vs. Gas

	EMEA				US			
Energy Source	**kWh GM Volt**	**kWh Nissan Leaf**	**L/100km**	**L/100km**	**kWh GM Volt**	**kWh Nissan Leaf**	**mpg**	**mpg**
Battery capacity	16	24			16	24		
Mileage capability	40	100			40	100		
Yearly mileage average	25000	25000	25000	25000	16000	16000	16000	16000
Gas consumption average			6	7,5			24	35
Gas price (est. 1Q2012)			1,42 €	1,42 €			$3,85	$3,85
Electricity cost	0,08 €	0,08 €			$0,12	$0,12		
Annual Energy expense	**800 €**	**480 €**	**2 130 €**	**2 663 €**	**$768**	**$461**	**$2 567**	**$1 760**

Source: Freescale GSM

- The electric cost may vary by country.
- Gas price depends on tax rate by country
- High cost battery may be offset by subsidy and overall savings
- Within one year the savings factor is up to 4x for electric charge vs. gas vehicles

Cost estimates for the Li-ion batteries currently used in most vehicles, for instance, run in a range of $600 - $900 per kilowatt-hour; the U.S. Energy Department's goal is **to reduce battery prices to $250/kWh by 2020.**

Why not Move to EV/HEV quickly - EV/HEV in Review

- Batteries continue to be the weak link
  - Too heavy
  - Too Costly
  - Too little power for the weight/cost
  - Un-known lifetime performance

- Progress is being made in batteries
  - Lithium-ion could provide improvement

- Current market driven by early adopters
  - Next stage driven by cost/benefit trade-off
  - Strongly enabled by higher prices for gasoline

Challenges and Freescale Solution

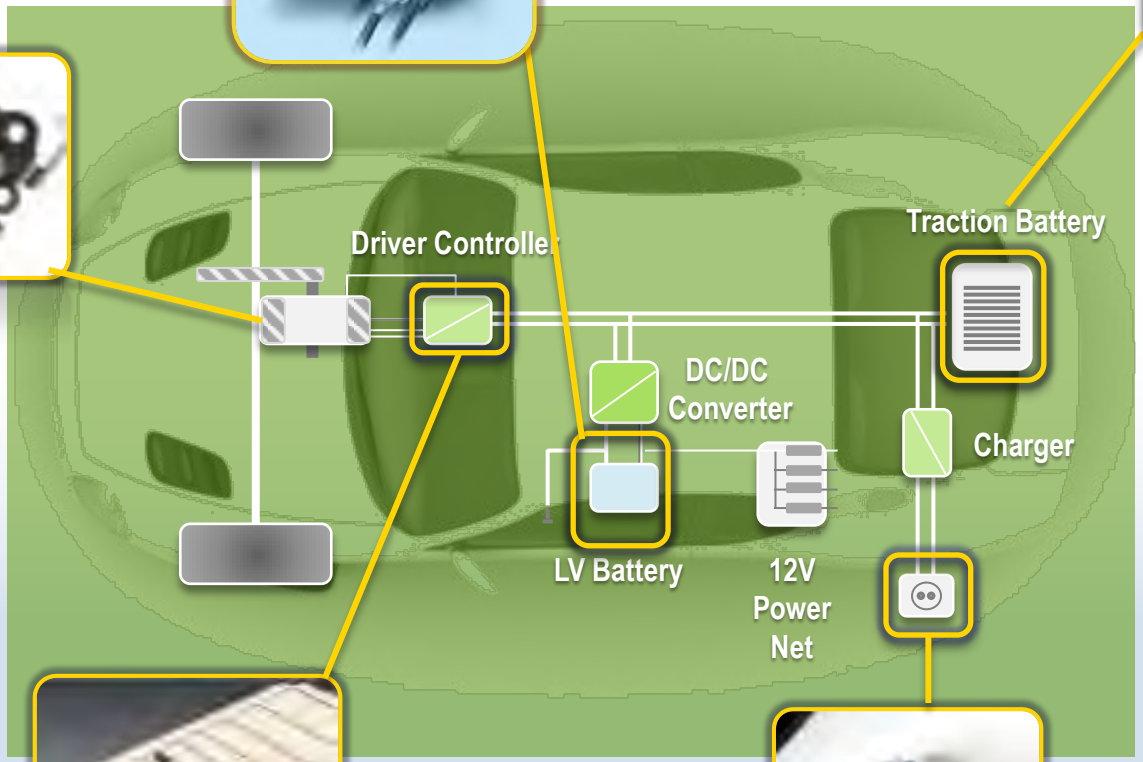
- Challenges (System level)
  - **Motor Control / Real time processing**
    - Precise, Fast, and Deterministic control timing
    - Execution performance and Code optimizations
  - **Complex Distributed System**
    - Synchronization of Multiple controllers
    - High communication availability (5ms response window)
  - **System costs**
    - Multiple controllers and sensors
    - Memory requirements for Flash and SRAM
    - Development costs for controller software

- Freescale Solutions (MCU level)
  - **Motor Control / Real time processing**
    - High Performance Power architecture
    - Sophisticated timer and triggering coprocessors
    - Optimized algorithms for Field Oriented Control
  - **Complex Distributed System**
    - Flexray for Deterministic and fast communications
    - Flexray or accelerated CAN
  - **System costs**
    - Sensorless control to eliminate expensive components
    - On-chip Resolver to digital decoding capability
    - Scalable roadmap of architecturally compatible devices
    - Optimized Software for Autosar and Motor Control Libraries
    - Extensive SW eco system

Freescale Uniquely Positioned To Address HEV/EV

Start Stop
- Drivers
- Re-Gen Braking
- Power Devices

LV Battery Monitoring
- MCU
- Voltage Monitoring
- Packaging



HV Battery Management
- MCU
- Charge Monitoring
- Charge Balancing
- Communications
- Isolation

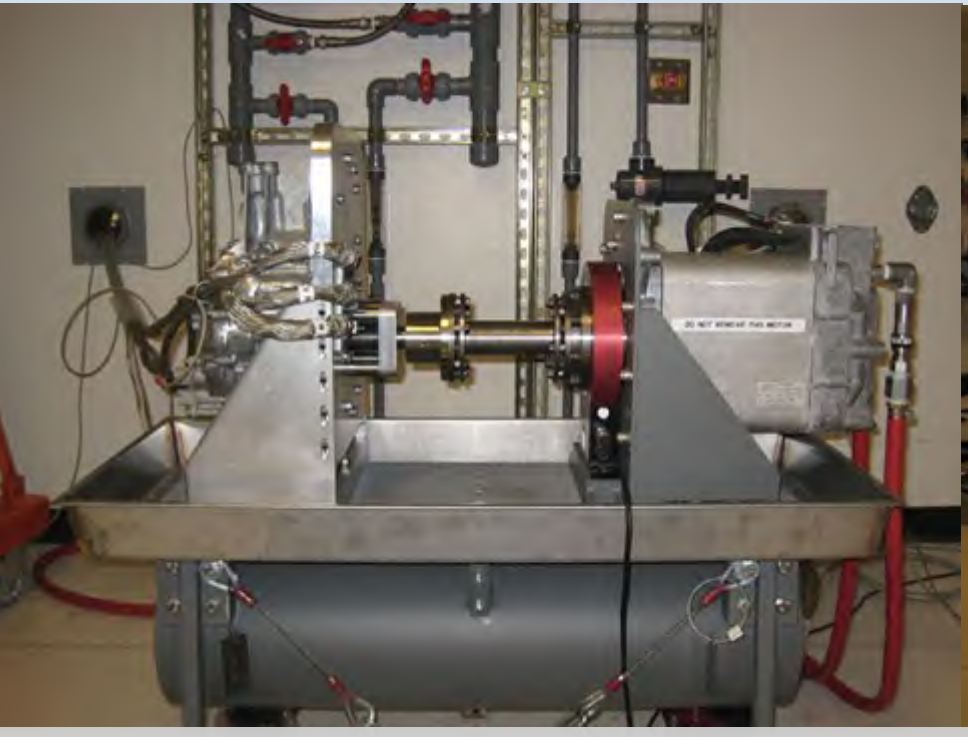
Inverter
- Control & Safing MCU
- Isolation
- Drivers
- Power Devices
- FOC Software
- Modeling and Simulation Tools

Charge Point
- MCU
- Communications

High Voltage Motor Dynamometer LAB in Phoenix

EV team in Phoenix with the necessary skills to do:

- Competitive analysis / existing product evaluation
- Validating new ideas / inventions IP & patents
- Define new potential products. Provide requirements / prototypes
- Help with evaluation of potential partners / acquisitions
- Integrate products / leverage ideas from across the Corporation
- Provide an environment for rapid prototyping
- Testing / making business case on new concepts



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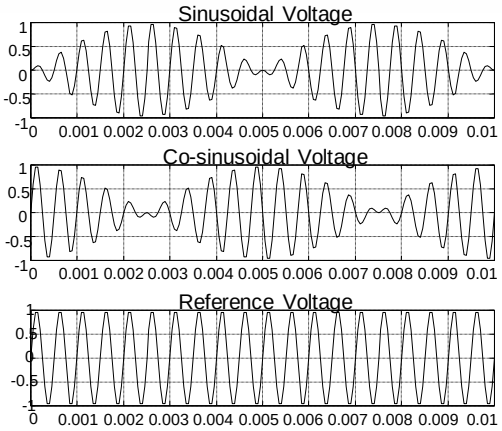
Continuing To Build On Our Real World Experience

Freescale Designed

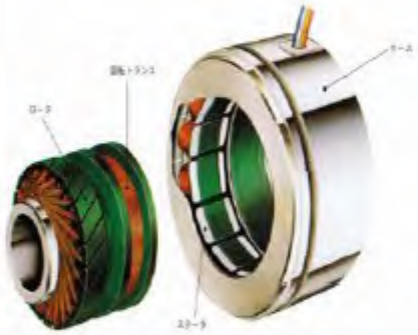
- Controller Board
- Gate Driver Board
- Common Mode Filter Board
- Motor Control Software
- Enclosure

65kW Prototype Inverter Developed for an Auto OEM

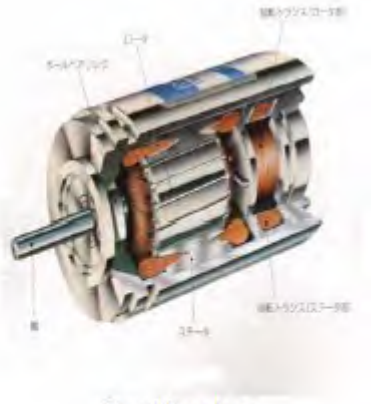
Resolver Interface



VR type



Built-in type



Brushless type

- Electro-magnetic induction type angle sensor
- Output voltage proportional to the rotational angle by alternating current excitation

- Develop hardware peripheral for reference generation, signal sampling, and sin/cos decoding
- Requirements shared with chassis & safety segment

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Battery Management

- Use existing multicore solutions for high throughput processing power
- Significant A/D resources required

- Functional safety (ASIL-C/D system level assessment)

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Microcontroller Solutions for EV/HEV – Overview

Aug. 2013

Addressing EV/HEV Needs: ***Power, Performance, Support***

- **Automotive highest performance MCU**
  - Multi-core designs allow lower power per MHz
  - Targeting >1400 DMIPS on 55nm
  - Qorivva e200z4 / z7 cores enhanced to run at 200MHz / 300MHz
  - On-chip DSP, SIPI and faster debug capabilities
- **Optimize HEV/EV designs using;**
  - FlexPWM
  - eTPU/GTM
  - Resolver
- **Enablement to support emerging markets**
  - Software code examples, engine reference designs and motor control libraries to speed development
  - eTPU function selector to autocode difficult engine parameters

Addressing Powertrain Needs: ***Safety & Security***

- ISO26262 (Functional Safety)
  - Qorivva supports ASIL-C and ASIL-D applications
    - Lockstep core and end to end ECC on all 55nm products

- Flash Reprogramming Detection and Prevention
  - Tamper detection and encryption options on all 55nm products
  - ECC, HSM, SB256 (secure boot 256bit encryption)

Advanced Architectures: Powertrain

Multicore Processing
(enhances throughput)

Lockstep Core
(safety)

I/O Processor
(offloads main cores)

Crossbar
(reduces delays in multicore memory access)

DSP Functionality

Local I-RAM / D-RAM
(instruction RAM, data RAM)
to maximize throughput

Embedded Flash / RAM

eTPU
FlexPWM
GTM

High-Speed A/D Converters

Reaction Channels
Decimation Filters

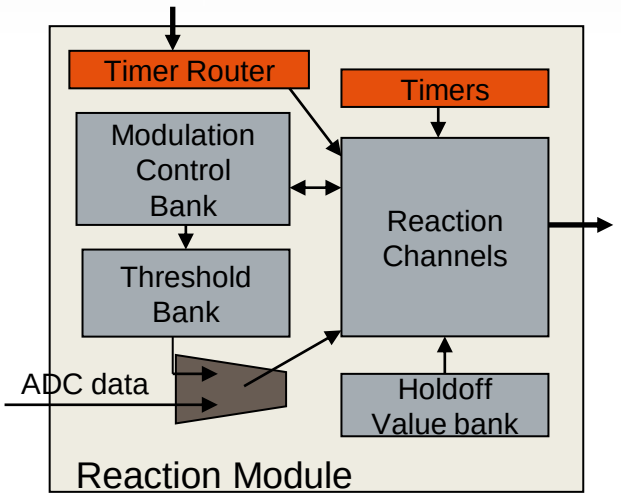
eTPU / FlexPWM

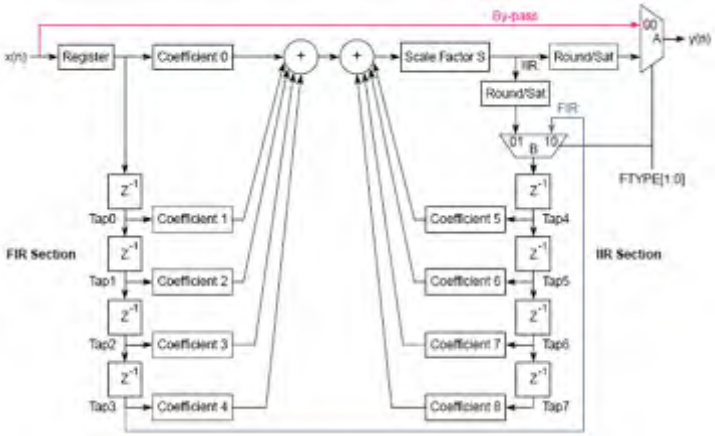
Key Market Characteristics

- Maintained for legacy customers
- Large eTPU code base, mature toolset
- FlexPWM for efficient inverter control

Key Technical Characteristics

- Upgrading design process for ASIL C/D
- Lockstep and safety designs
- Improved reaction channels for current control
- Decimation filters





MPC5777C Cobra 55
8M Flash, 512k SRAM
2CC + 1LS, 264MHz
FlexRay, 3xeTPU2+

MPC5746R Rainier
4M Flash, 320k SRAM
2CC + 1LS, 200MHz
FlexRay, 2xeTPU2+

MPC5742F Fuji
Up to 2M Flash, 160k SRAM
1CC + 1LS, Up to 200MHz
1xeTPU2+

Core Legend
CC = Computational Core
IO = I/O Processor
LS = Lockstep Core

GTM Introduction

Key Market Characteristics

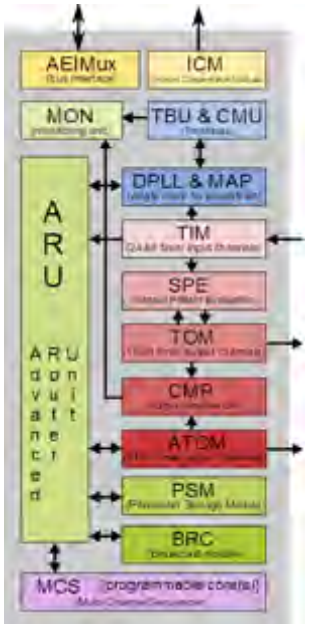
- Defined and developed by Bosch
- Continental is close follower
- Developed for “standard” timer from multiple sources

Key Technical Characteristics

- Multicore architectures
- Data flow driven design concept
- Configurable dedicated hardware sub-modules
- Central routing unit managing all internal data movement between sub-modules.
- Internal programmable RISC-like cores
- Qual Q1 2014

Drawbacks

- Reliance on Bosch by Freescale and non-Bosch Tier 1s
- Weakness for motor control



MPC5777M Matterhorn
8M Flash, 596k SRAM
2CC + 1LS 300MHz, 1IO 200MHz
FlexRay & Ethernet, GTM

MPC5746M McKinley
4M Flash, 320k SRAM
2CC + 1LS 200MHz, 1IO 200MHz
FlexRay & Ethernet, GTM

MPC5744K K2
2.5M Flash, 176k SRAM
2CC + 1LS 160MHz, 1IO 80MHz
FlexRay & Ethernet, GTM

MPC5726L Lavaredo
1.5M Flash, 64k SRAM
1CC 80MHz
Ethernet, GTM

Core Legend
CC = Computational Core
IO = I/O Processor
LS = Lockstep Core

MPC5746R Rainier 4M Block Diagram

Key Functional Characteristics

- Two independent 200 MHz Power Architecture z4 computational cores
  - Single 200 MHz Power Architecture z4 in lockstep
- eDMA – *64 channels (w/ lockstep DMA)*
- 4M Flash with ECC
- 320k total SRAM with ECC
  - 256k of system RAM (incls. 32k of standby RAM)
  - 64k of tightly coupled data RAM
- 3 ΣΔ ADC converters – *12 channels*
- 4 SAR converters – *52 channels*
- Cross Triggering Unit
- Ethernet (MII-lite/RMII)
- DSPI – *5 channels (2 supporting µSec channel)*
- LINFlex - *5 channels (2 supporting µSec channel)*
- FlexCAN – *4 channels*
- SENT – *6 channels*
- 2 eTPU2+ timers – *64 channels*
- 1 eMIOS – *32 channels*
- Reaction module – *10 channels*

Key Electrical Characteristics

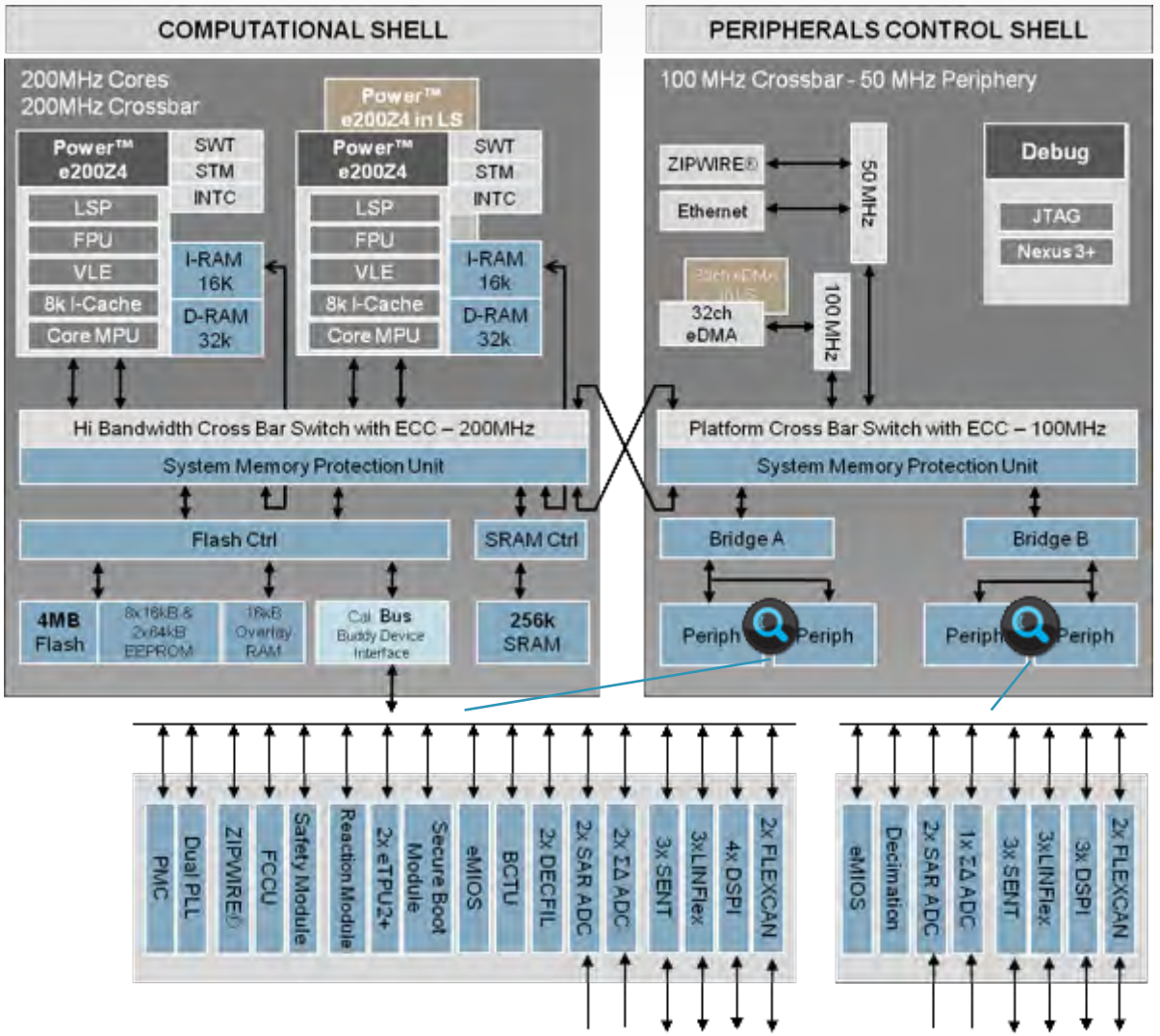
- -40 to +125 °C (ambient)
- Single 5v power supply

Package

- 176 LQFP, 252 BGA
- 292 BGA eCal package (incls. RAM buddy chip) for emulation/debug

Enablement

- Software : AutoSAR drivers
- Tools : Debugger (Lauterbach), multicore compiler (Wind River and Green Hills)



MPC5746M McKinley 4M Block Diagram

Key Functional Characteristics

- Two independent 200 MHz Power Architecture z4 computational cores
  - Single 200 MHz Power Architecture z4 core in delayed lockstep for ASIL-D safety
- Single I/O 200 MHz Power Architecture z4 core
- eDMA controller – *64 channels*
- 4M Flash with ECC
- 320k total SRAM with ECC
  - 128k of system RAM (incls. 64k standby on 292 PBGA pac kage)
  - 192k of tightly coupled data RAM
- 6 ΣΔ & 8 SAR converters – *60 channels on 292 MAPBGA, 48 channels on 176 LQFP*
- Ethernet (MII/RMII)
- DSPI – *7 channels (2 supporting µSec ch.)*
- LINFlex - *5 channels (2 supporting µSec ch.)*
- MCAN-FD/TTCAN – *3x modules/1x module*
- GTM – *120 timer channels*

Key Electrical Characteristics

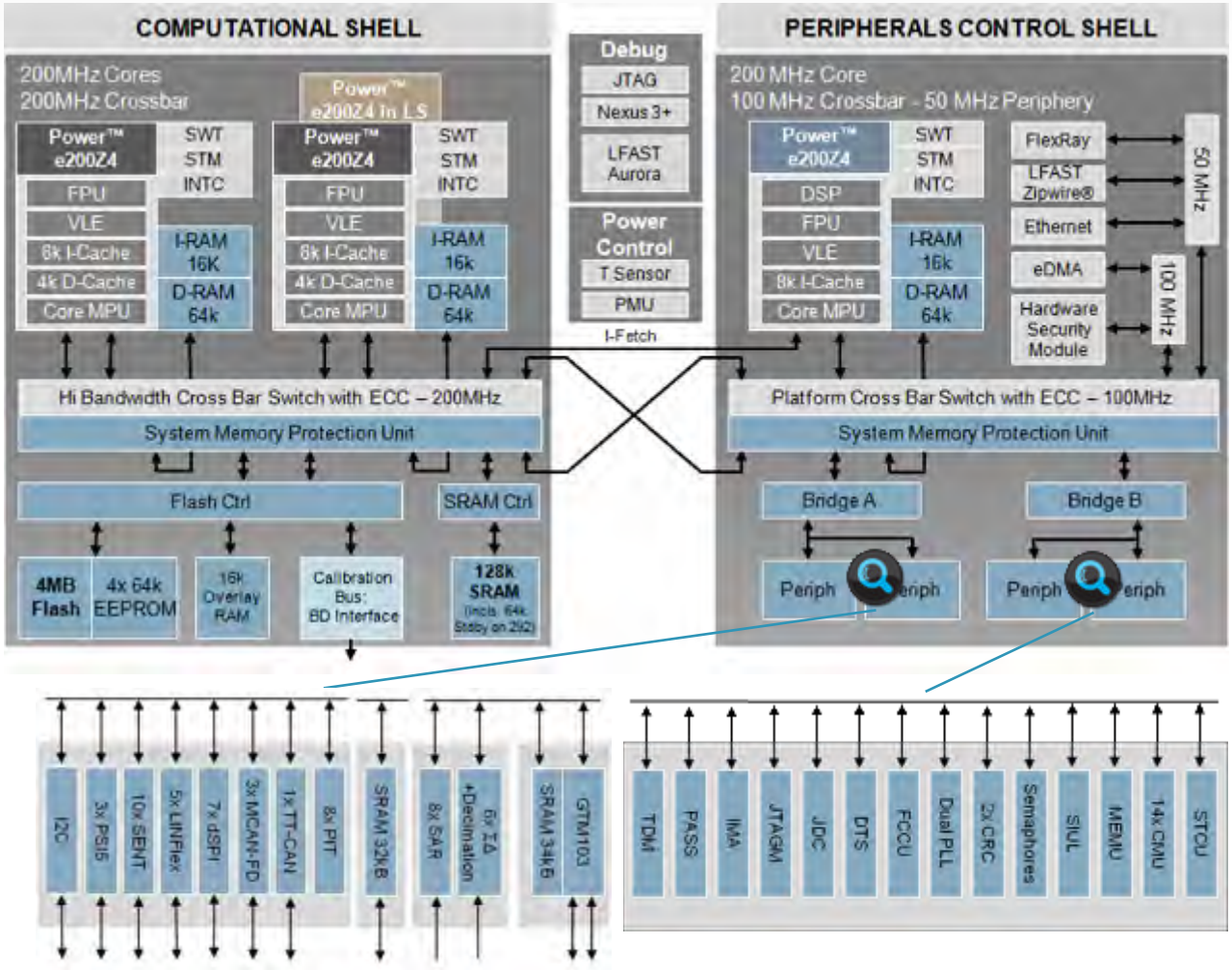
- -40 to +125 °C (ambient)
- 165 °C junction for KGD
- 1.26V Vdd, 5.0V I/O, 5V ADC

Package

- 176 LQFP / EP, 292 PBGA
- eCal emulation device for each package

Enablement

- Software: AutoSAR drivers
- Tools
  - Debugger: Green Hills, Lauterbach and PLS
  - Multicore compiler: HighTec, GCC, Wind River, GHS
  - Simulation tools



32 bit MCU Summary

- **Qorivva MCUs** cover the **MPC55xx (130nm), MPC56xx (90nm)** families, and **MPC57xx (55nm)** families.
- 90nm 32-bit MCU in Qorivva:
  - MPC563xM, 564xA for Powertrain and VCU/HCU
  - MPC560xP and MPC564xL, for Safety and Motor control
  - MPC560xB/C, for VCU/HCU and gateway and high end body control.
- 55nm 32-bit MCU in Qorivva:
  - MPC570xB, 574xG, 574xF for VCU/HCU and Battery Control
  - MPC574xR/M 577xC, for VCU/HCU and Motor control (MCU)

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Analog Solutions for EV/HEV – Overview

Aug. 2013

Power Management & P/L Market Dynamics

Energy Efficiency

•Government regulations to reduce CO2 emissions (impact is 20% Power saving target on each ECU)
•New E/E architecture preparing transition to EV-HEV
•New CAN standard for energy saving

Functional Safety

•ISO26262 Standardization for Auto and IEC61508 for Industrial
•Functional Safety requiring system approach
• MCU Attach solutions offering Freescale leardership in growing markets and value

Connectivity EveryWhere

• 100M# vehicles at horizon 2020
• 1,7B# CAN and 1,0B# LIN
• Standardization of EMC and ESD certification requirements
• CAN partial networking and Flexible data new innovations
• Trends in Ethernet penetration for both Auto and Industrial markets

Simplify Complexity

•Acceleration of Computing capabilities (32bit market growth)
•Needs for Plug and Play and **Attach compatible** solutions
•Professional Eco system
•Demonstrators

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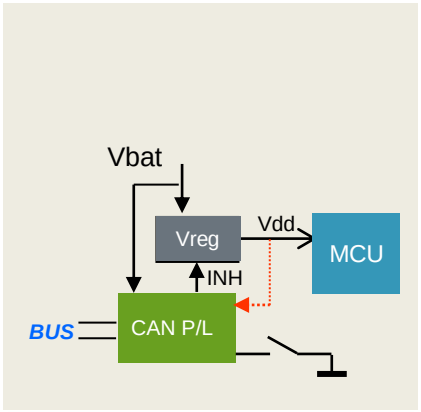
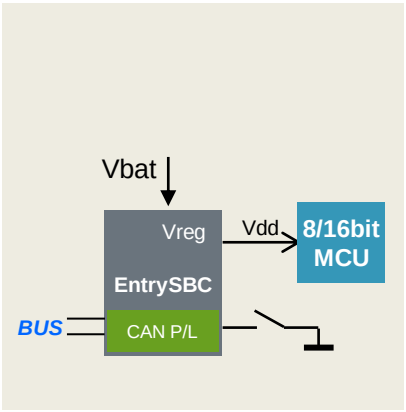
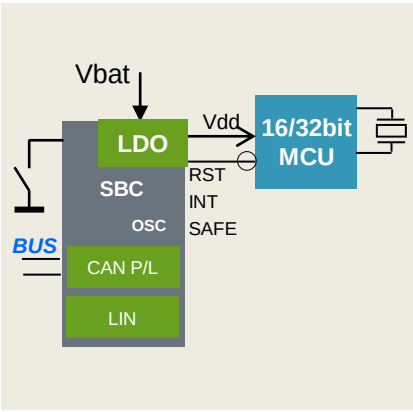
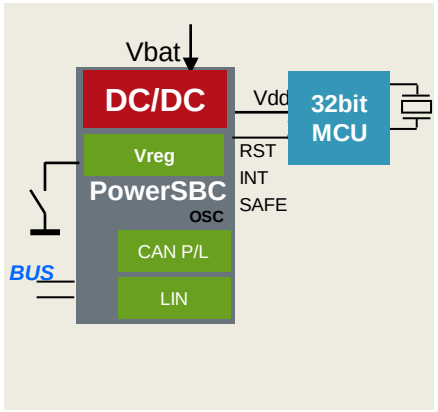
Freescale SBC Segmentation

Different Standard Solutions for Different System Needs

Physical Layer	*entrySBCs*	*SBCs*	*PowerSBCs*
			
High Robustness EMC/ESD **Design for Cost** **CAN Partial Networking** Selective Wake up	**Simple Low Power Modes** **Robustness** **Design for Cost**	**Ultra Low Power Modes** **Flexible Power Management** **Medium Functional Safety**	**Energy Efficient (>85%)** **High Current (up to 2.0A)** **High Functional Safety** (fit for ASILD applications)

KEY VALUES

MC33907/8 Safe SBC with Buck/Boost Regulator

System Basis Chip (SBC) family providing energy efficient DC/DC power conversion and low voltage operation with advanced functional safety mechanisms

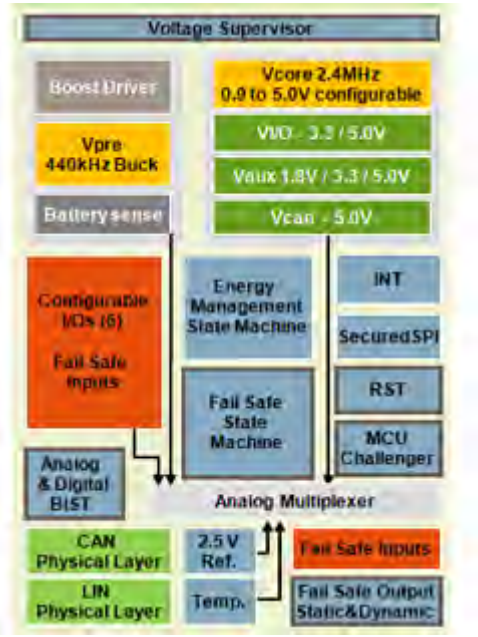
Differentiating Points

- **Availability** : Ultra low voltage operation **down to 2.7V**
- **Efficiency** of a Dual DC/DC converter topology
- **Safety :** Innovative architecture allowing **independent** monitoring of safety critical parameters
- **Scalable** family of products supporting a wide range of MCU and power segmentation architectures

Product Features

- Flexible DC/DC Buck pre regulator with optional Boost to fit with **LV124**
- Multiple supplies up to **1.5 A**
- Low Power Modes (**25µA**), -50% versus competition
- Analog Multiplexer & Battery sensing
- **Independent fail safe state machine** supporting functional safety standards
- Secure SPI interface
- Robust physical layers with superior EMI/ESD performance

Typical Block Diagram



Typical Applications

- Power management
- Functional safety integration
- Safety Critical Motor Control

MC33907/8 Safe SBC with Buck/Boost Regulator

Features Table Overview

Part Number	PC33907 PowerSBC10	PC33908 PowerSBC20
Pre-regulator (6.5V) 5%	2A (B-B_440kHz)	2A (B-B_440kHz)
MCU core supply VCore / 2%	0.8A (B_2.4MHz)	1.5A (B_2.4MHz)
MCU A/D ref. voltage supply VCCA /1%	100 mA (int) +/-1% Or 300mA (ext. PNP) +/-3%	100 mA (int) +/-1% Or 300mA (ext. PNP) +/-3%
Auxiliary ECU supply Vaux / 3%	*Up to 300 mA* *Tracker / Auxiliary*	*Up to 300 mA* *Tracker / Auxiliary*
Can_5V Supply – VCAN (dedicated to internal CAN physical layer)	100mA	100mA
CAN Interface	1	1
IOs	6 (incl. F/S inputs)	6 (incl. F/S inputs)
Watchdog	Challenger	Challenger
Stdby mode - LPOFF	25µA	25µA
AMUX & Battery Sense	Yes	Yes
Fail Safe	Independant I&O	Independant I&O
Package	LQFP48eP	LQFP48eP

MC33907/8 Safe SBC with Buck/Boost Regulator

Product Differentiation

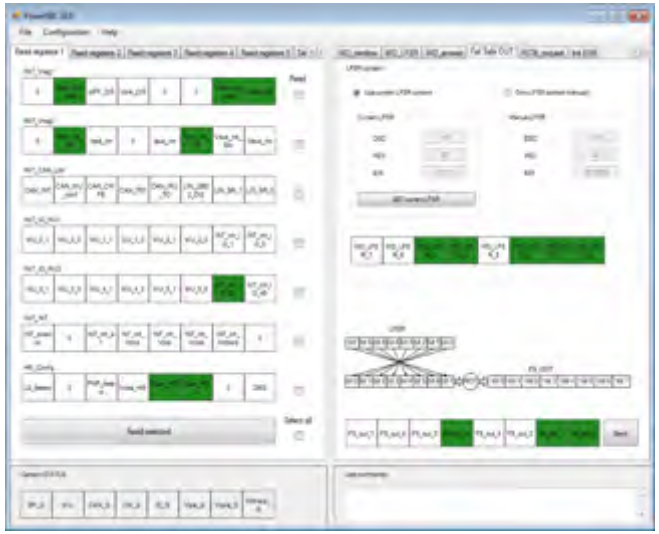
New generation of System Basis Chip, ideal companion solution of Qorriva MCUs, offering scalable and energy efficient DC/DC solution, support lowest operating voltages standards and combine advanced functional safety mechanisms

Efficiency & Availability	Fit for ISO26262 Functional Safety	Power Scalability Qorriva Attach strategy
Combination of the efficiency of a standard DC/DC with unique low voltage operation down to 2.7V Vsup. **Energy Efficient Solution ™**	Innovative IC architecture allowing independent monitoring of safety critical parameters, ideal for stringent safety needs **SafeAssure Solution ™**	Scalable set of products that help customer to design a platform solutions with various MCU and Power segmentation.
• Innovative DC/DC PMICs solutions to improve energy utilization	• Fit for purpose of ASILD application, combined with MCUs like MPC5643L	• Ideal Power Supply for large range of Freescale 32bit Qorivva MCUs
• Low Current consumption during low power mode. combined wake-up strategy	• Advanced HW Safety to allow external MCU verification through independent fail safe state machine.	• Combined ecosystem to simplify MCU and PowerSBC interaction
• Sustain Class A during 3.5V battery voltage during cranking pulse, (2.7V Vsup, called LV124 specification)	• Safe Documentation to support ISO26262 system certification	• Pin-to-pin compatible products allowing OEMs to design one board platform for multiple vehicle

Enhanced EVB : eEVB

MC33907 (PowerSBC10) + MPC5643L (Leopard)

- Complete solution using FSL Power supply unit and MCU
- Easy to use (using GUI)
- Low Level Drivers available and delivered with kit
- Fit with ASILD application requirements
- Fault injection validation
- Speed-up customer development



Intelligent Precision Battery Sensors

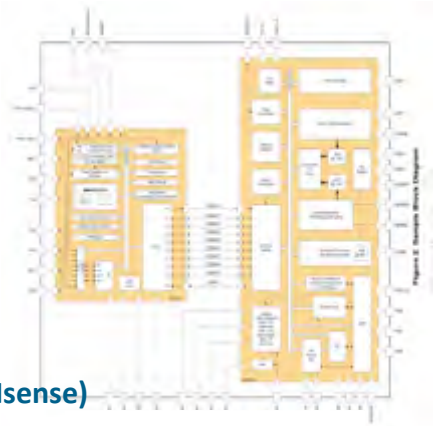
Freescale's Intelligent Precision Battery Sensors - Overview

EDN INNOVATION AWARD 创新奖
2011 Leading Product
Mixed Signal Category

AECQ100 Qual

MM912J637 – 12V Pb (LIN)

MCU S12 (16-bit)
Flash 96k/128k
Data Flash 4k
RAM 6k



Mixed-Signal Chip
LIN Physical Layer (ESD 15kV)
Watchdog
Standby Current <100µA (1sec Isense)
Vreg capability 50mA
Operating Voltage 3.5..28V
RAM Contents Guaranteed :2.5...3.5V
3x ADC (2nd Order Sigma Delta) 16bit
Current Measurement
- Relative Accuracy <0.5%

Voltage Measurement
- Relative Accuracy <0.2%

Temperature Measurement
- Relative Accuracy <2K

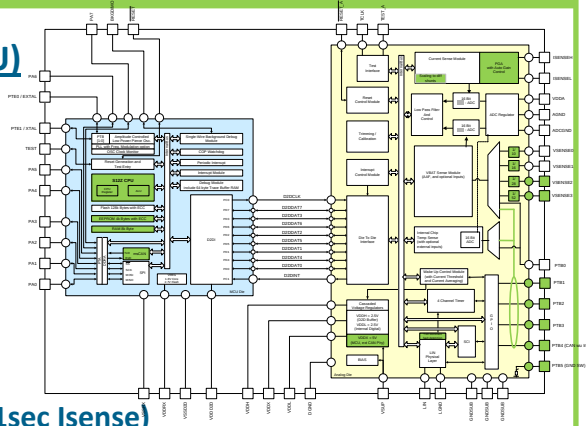
Operating Temperature -40°C<Ta<125°C

48ld 7x7 QFN
w/ wet-able flanks

AECQ100 Qual

MM9Z1J638 – Multi Applications (LIN, msCAN)

MCU S12Z (32-bit ALU)
Flash 96k/128k
EEPROM 4k
RAM 8k
msCAN



Mixed-Signal Chip
LIN Physical Layer
Watchdog
Standby Current <100µA (1sec Isense)
Vreg capability 150mA
Operating Voltage 3.5..28V (Vs3:52V)
RAM Contents Guaranteed :2.5...3.5V
3x ADC (2nd Order Sigma Delta) 16bit
Current Measurement
- Relative Accuracy <0.5%

Voltage Measurement
- Relative Accuracy <0.15%

Temperature Measurement
- Relative Accuracy <2K

Operating Temperature -40°C<Ta<125°C

48ld 7x7 QFN
w/ wet-able flanks

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Freescale Intelligent Battery Sensors - Feature Comparison

MM912J637AM2

- Application
  - 12V PB Battery (LIN)
- Communication
  - LIN, SCI, SPI
- Just Enough MCU Performance
- Features
  - Cranking mode
  - 2nd Vsense
  - External Temp sense
- Full Temp Range
  - 40C.. 125C

PPAP completed
SOP: 1Q13

MM9Z1J638AM2

- Applications
  - 12V Pb Battery (Lin, CAN), 14V Li-ion Battery, Multi-battery apps, HV Battery Junction Box
- Communication
  - msCAN,LIN,SCI,SPI
- Higher MCU Performance
- Features
  - Cranking mode
  - 4 attenuated Vsense and 4 direct Voltage Pins
  - 4 External Temp sense
- Full Temp Range
  - -40C.. 125C

Final Silicon, PPAP: 4Q13,
SOP: 3Q14

Summary for Products by Freescale in HEV

Qorivva MCUs:

Specific features required for complex algorithms in motor control and battery management:

- DMA, DSP functions, Flex PWM, msCAN, Memories, HAL, SW tools
- Single/Multicore MCU
- Multicore MCU

PowerSBC – MCU companion with Safety approach

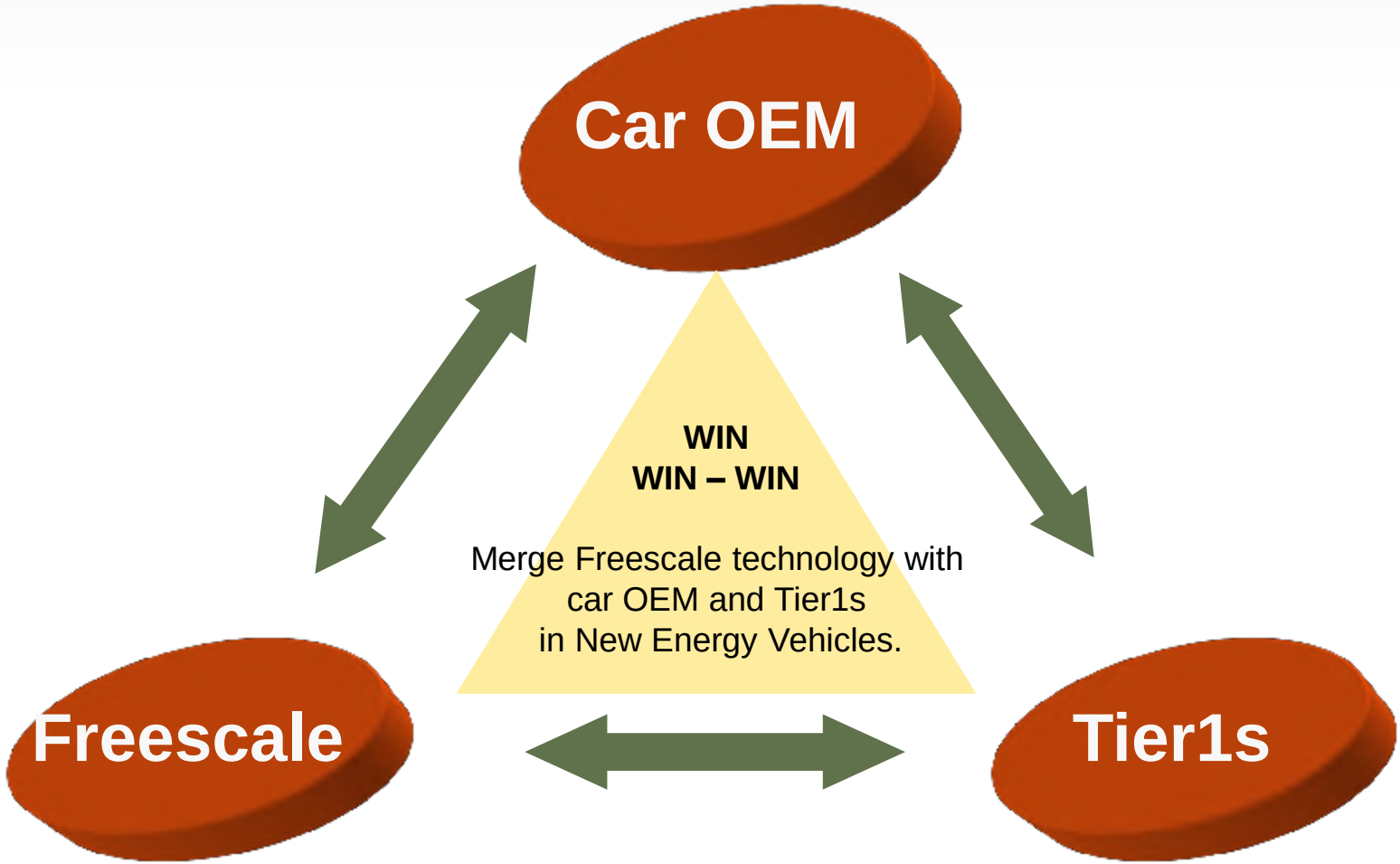
HDTMOS / LFET 90V

Xtrinsic battery sensor and derivatives

Electric pump applications – **MagniV Technology**

Functional Safety – Freescale SafeAssure

Business Model



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