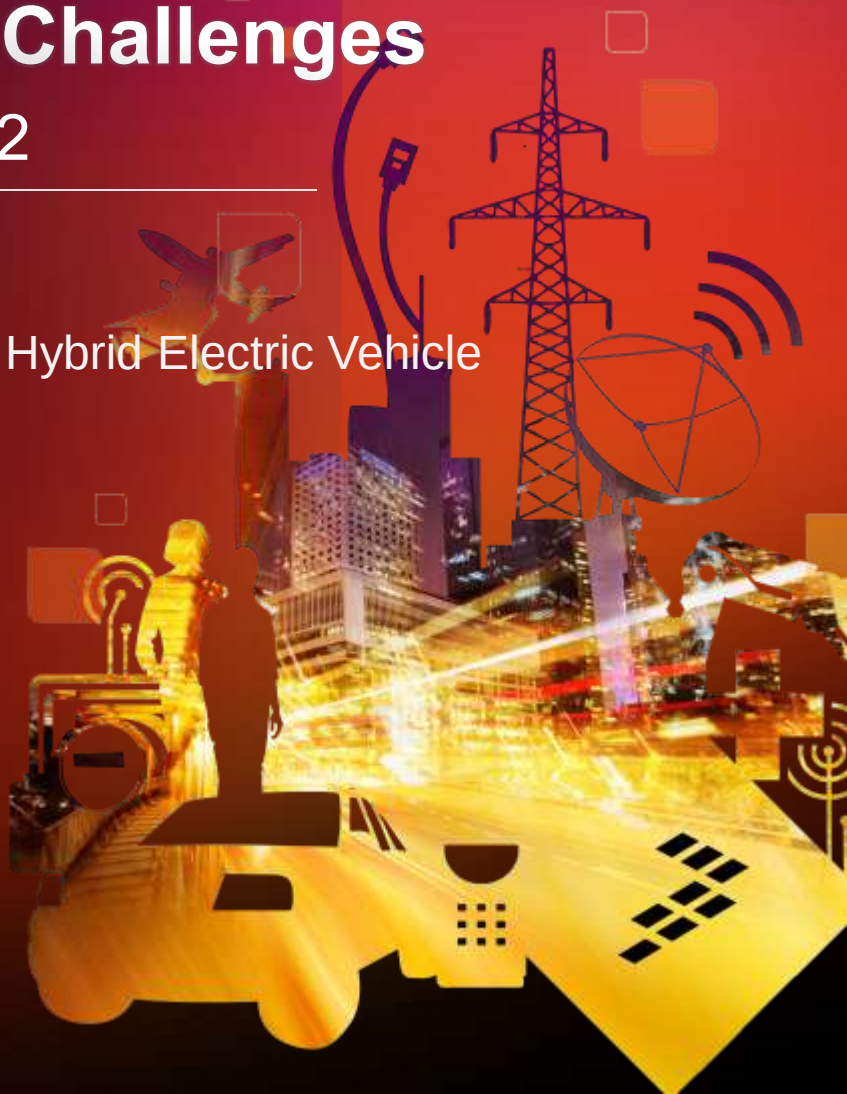
FTF | FREESCALE TECHNOLOGY FORUM POWERING INNOVATION

Electrification of the Car: Powertrain Challenges

FTF-AUT-F0042

Cherif Assad

Global Powertrain & Hybrid Electric Vehicle Marketing Manager



SAFE ASSURE by Freescale

June 2012

Agenda

- Automotive trends
- Electromobility – a societal issue
- Diversity of technology
- How Freescale is addressing the market
  - Internal combustion engine improvement
  - The Stop/Start function
  - Inverter for mild and full hybrid
  - Battery management
- Summary

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Automotive Trends

Automotive
Key Trends

Increased Efficiency
Electronic powertrain control key to fuel efficiency and lower emissions
Transition to hybrid and electric vehicles, overall electrification of multiple functions

Enhanced Safety
Zero vehicle-related fatalities
Seamless integration of active and passive safety systems
ISO26262 Standardization

SAFE ASSURE™ by Freescale

The Connected Vehicle
Car-to-car, Car-to-infrastructure, Car-to-cloud
The ultimate smart mobile device

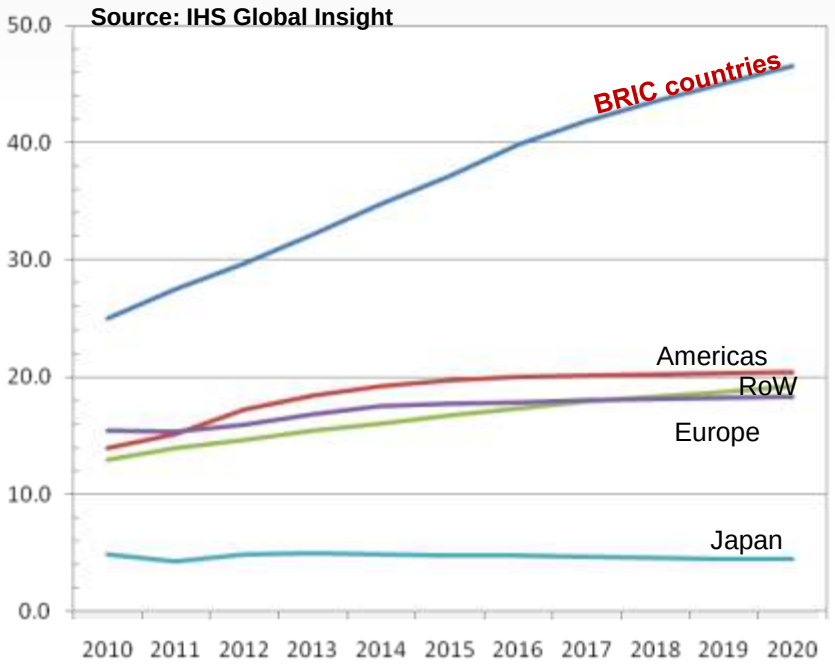
Mobility for Everyone
Cost efficient scalable products for an expanding global market.

freescale™

Mobility for Everyone

- **100M vehicles demand** forecasted before 2020, in addition to motorcycle and e-bike growth
- **35 mega cities** in 2030
  - Traffic jam, air pollution, parking issues
- Stringent r**egulations** foreseen
- 80% of automotive growth happening in BRIC markets after 2015
- Energy **source** alternatives
- **Infrastructure** set-up: grid, utilities, services

World Vehicle demand (MU), by major region



What do our customers need to succeed ?

- High-performance scalable MCU families: multicore, software, tools, etc.
- Low current consumption solutions
- Electrical motor control
- Battery management
- Efficient high power semiconductor solutions

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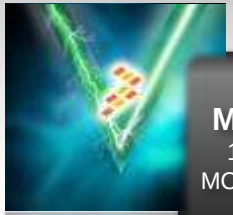
Technologies for Electromobility

- High-performance multicore processors in advanced NVM technologies
- System Basis Chip and power drivers
- MEMS Sensors and 77 GHz Radar Solutions
- CAN, Ethernet and FlexRay In-Vehicle Networking
- AUTOSAR standardized automotive software platform with ISO26262 capability
- Zero Defect Development Methodology and capability

Qorivva™
32-bit Automotive MCUs



MagniV™
16-bit Auto MCUs & analog

i.MX
Platform

Xtrinsic™
Automotive Sensors

freescale™

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A Societal Issue

Which Energy sources ?

- Peak oil in 2010's production as per IEA requires automobile to reconsider alternative to fossil energy

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 and 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
- Ratio Electric/Gas respected regardless the regions

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.**

Total Cost of Ownership

- Total Cost of Ownership over 5 years
  - Purchase Price
  - Vehicle depreciation
  - Local Government subsidy/incentive
  - Additional cost :
    - fuel cost or per-mile electric service contract,
    - insurance, taxes, credit cost
    - maintenance and repairs
  - Electric takes benefit of subsidy/incentive to offset high cost

ICE TCO benefit versus BEV remains significant ((> +20%) as of today. Therefore this could be mitigated upon business model on battery (buy or loan), oil price scenario, environmental constraint and electricity cost

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Diversity of Technologies

Technology Migration

Advanced ICE

- GDI, DDI
- Turbo Charger, Fuel Cell, HCCI
- Transmission and Gearbox

Micro Hybrid

- Modified Starter
- Battery monitoring
- Belt driven Alternator Starter
- Regenerative System

Auxiliaries

- Electric pumps
- HVAC compressor

Hybrid/Electric

- Mild Hybrid
- Battery Voltage >48V
- Full (Plug-in) Hybrid
- Series / parallel Mode

Fossil energy availability and battery technology remain key market enablers.

Electrification Ranges

	Micro Hybrid		Mild Hybrid	Full Hybrid	Plug-in Hybrid	Battery EV
Features	Start/Stop	Start/Stop Regenerative Braking	Start/Stop Regenerative Braking Power Assist	Start/Stop Regenerative Braking Power Assist Electric Drive	Start/Stop Regenerative Braking Power Assist Extended Electric Drive Plug-in Smart Grid Connectivity	Start/Stop Regenerative Braking Power Assist Extended Electric Drive Plug-in Smart Grid Connectivity
ICE	Conventional	Conventional	Downsized	Downsized	Downsized	None
Electric Power range (kW)	2 - 4	4 - 10	10- 20	25 - 60	30 - 80	30 - 150
Power Device Technology	Low Power (40V)	Low Power (65V)	Low/High Power (60 - 250 V)	High Power (> 400V AC)	High Power (> 400V AC)	High Power (> 400V AC)
MCU range	-	16 bit	16 / 32-bit	16 / 32-bit	16 / 32-bit	16 / 32-bit
Incremental cost (est.)	$ 500	$ 1000	$2,500	$ 5,000	$10,000	$15,000
CO2 reduction	Up to 5%	Up to 10%	Up to 30%	Up to 50%	Up to 70%	100%

Source: Freescale GSM

Semiconductor Demand outlook

Micro Hybrid

- HEV/EV does not include Stop/Start
- Product dominated by medium power devices (HDTMOS6, 25V/400A)
- EMEA driving the market, wide adoption to all OEMs before 2020 (next wave after Airbag, ABS, ESP, TPMS,…)
- Micro Hybrid may migrate to Mild Hybrid system including eAssist function

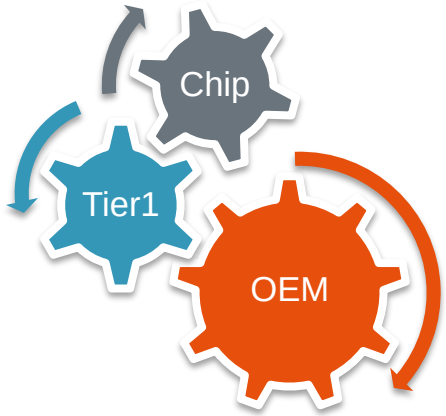
Source: Strategy Analytics

HEV/EV Market Outlook

Source: Strategy Analytics

GLOBAL VEHICLES (KU)

	2011	2012	2013	2014	2015	2016	2017	2018
Mild Hybrid	518	1 032	1 501	2 006	2 519	3 055	3 557	4 044
Full Hybrid	604	957	1 199	1 378	1 602	1 803	1 969	2 130
Plug-In Hybrid	20	62	120	171	201	237	290	357
Pure EV	69	155	322	497	624	780	937	1 086
Total	**1 211**	**2 206**	**3 141**	**4 051**	**4 948**	**5 876**	**6 753**	**7 617**



SEMICONDUCTOR DEMANDS (MU)

	2011	2012	2013	2014	2015	2016	2017	2018	CAAGR 2010-15
MCU	4,6	8,3	11,9	15,3	18,4	21,8	25,0	28,2	34%
Power	49	87	125	162	195	230	265	299	34%
Non-power Analog	43,3	78,0	112,4	145,2	176,3	208,9	240,1	271,0	35%
Sensors	24	43	61	79	96	114	131	148	34%
Other	3	6	9	12	14	17	20	22	37%
Total	**124**	**222**	**320**	**413**	**500**	**592**	**680**	**768**	**34%**

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Freescale Solutions: Addressing the Market

Automotive Sessions at FTF on HEV/EV

Session	Title
FTF-AUT-F0018	Open source, Off the Shelf Powertrain Platform: Four-Cylinder Reference Design
FTF-AUT-F0022	Automotive Software - AUTOSAR is Just the Beginning
FTF-AUT-F0098	How to Use and Program the New MC33816 High-Performance Fuel Injector Driver Circuit
FTF-AUT-F0144	Modular High-Power Inverter System with Freescale IGBTs and Qorivva MCU Motor Control Hardware and Software
FTF-AUT-F0170	Panel: The Future of the Hybrid Car and How to Make it Commercially Feasible Given the Technical Challenges
FTF-AUT-F0177	Pushing Performance in Powertrain MCUs
FTF-AUT-F0196	Small Engine Control Systems Using a New System-in-Package Solution
FTF-AUT-F0197	Smart Actuator Control in Powertrain Systems
FTF-AUT-F0206	The NASCAR Engine Revolution of 2012
FTF-AUT-F0306	AUTOSAR and ISO 26262
FTF-AUT-F0308	Dual-Core Programming Using Qorivva MPC5676R MCUs
FTF-AUT-F0352	Unlocking the Performance of the Latest Qorivva 32-bit MCU for Powertrain

Advanced Architectures: Powertrain

Contributes to fuel savings and emissions control

Multicore Processing
(enhances throughput)
300 EEMBC automark ®

Lockstep Core
(safety)

I/O Processor
(offloads main cores)

DSP Functionality

Advanced protection against hacking

Crossbar
(reduces delays in multicore memory access)

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

MC33816 – Revolutionary Fuel Injector Driver

Contributes to fuel savings and emissions control

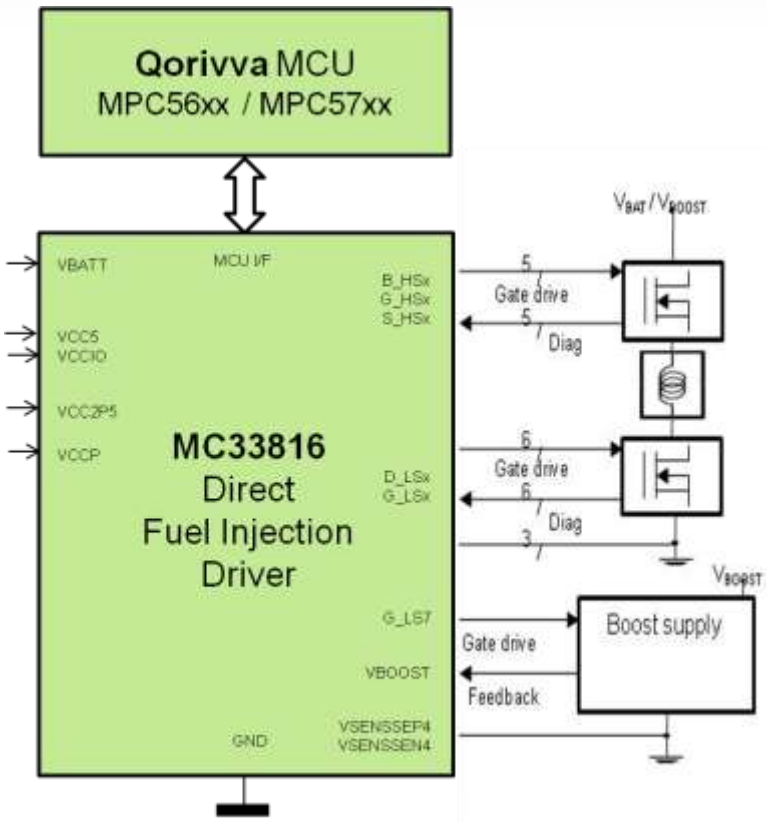
MC33816:

- IC for engine injection and electric valve control
- Provides a highly flexible smart gates driver for reduced fuel consumption and improved emission control
- Automotive (12V) , Truck and Industrial application (24V)

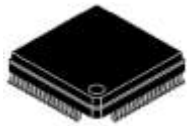
Key Features

- Integrated Power Supplies and monitoring, charge pump and high voltage DC-DC converter pre-drivers, lowering external parts
- Multi-injection cycles without MCU intervention,
- 4 independent sequencers including ALU and associated memory
- protected code is ensured by cipher encryption

Up to 6 Cylinder Engine Management

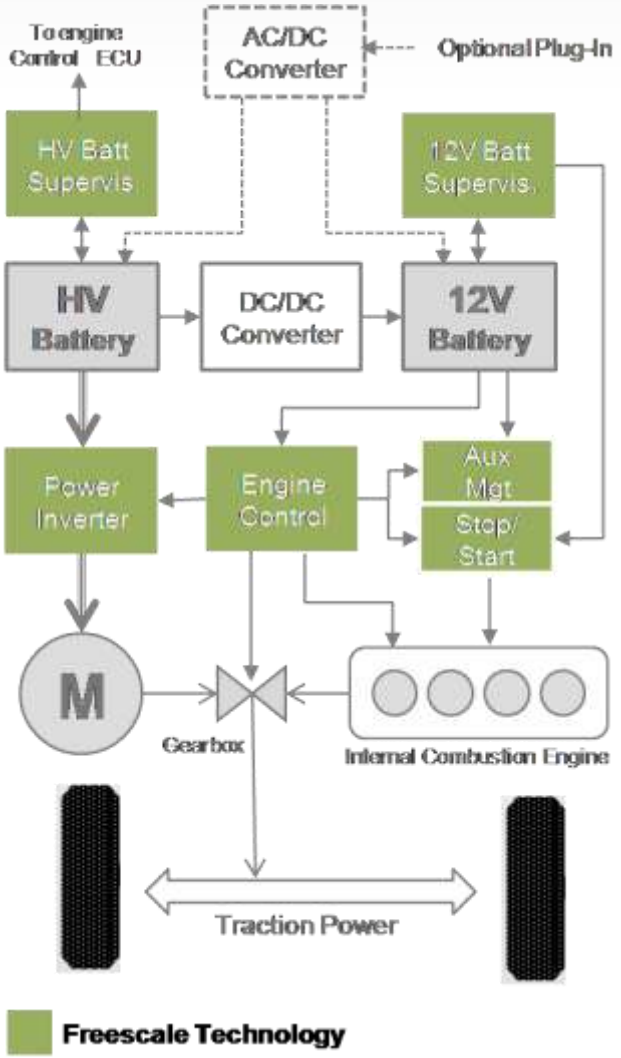


Samples available
64-pin LQFP EP



Vehicle Electrification Solutions

- Freescale is providing a portfolio of solutions for **car electrification** and fuel consumption reduction
- Internal Combustion Engine **performance improved** and **reduced emissions** thanks to Qorivva MCU, Analog Mixed Signal ICs and Xtrinsic pressure sensor
- Micro Hybrid combines our **HDTMOS power MOSFET** with Xtrinsic **battery sensors**. Additional fuel savings thanks to electrification of the auxiliaries
- High Voltage **Battery Management** including pack and cell control
- **Electric Motor Control expertise** and adapted technology



Analog and Power Overview for HEV/EV

- Freescale is investing in Automotive Power solutions for EV/HEV to complement Analog and Digital solutions and enable system level optimization.

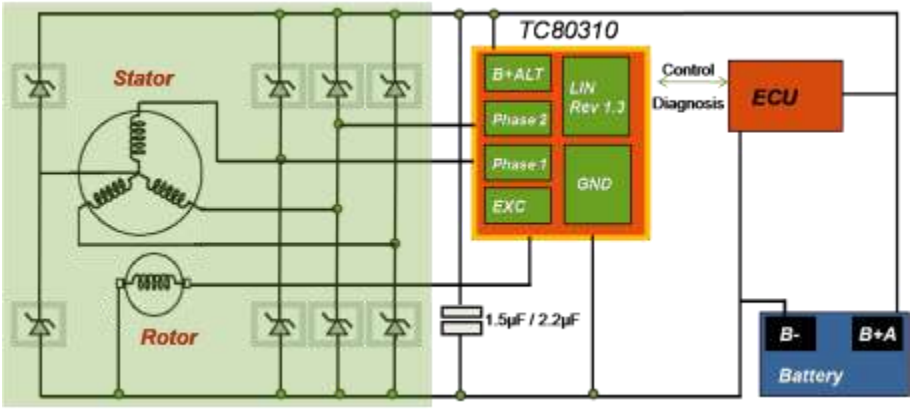
- Opportunity for partnership to assess the technical merits of various options (GaN Vs. Si-IGBT Technology Vs. Inverter Power)

- **Current Status as of June 2012**
  - In high volume production for micro-hybrid (HDTMOS)
  - Sampling LFET-based prototypes for Mild Hybrid
  - Sampling IGBT Modules
  - GaN switch process development resulting in working prototypes

- Roadmap to push these solutions forward

LIN Alternator Regulator System-on-Chip

- Thermal protection and compensation
- Robust **LIN 1.3 INTERFACE**
- Self-start operation available (in case of LIN disconnection)
- Multiple adjustments capability for loop regulation (internal ramp, digital filter)
- Die Chip
- Easy evaluation Start



Alternator

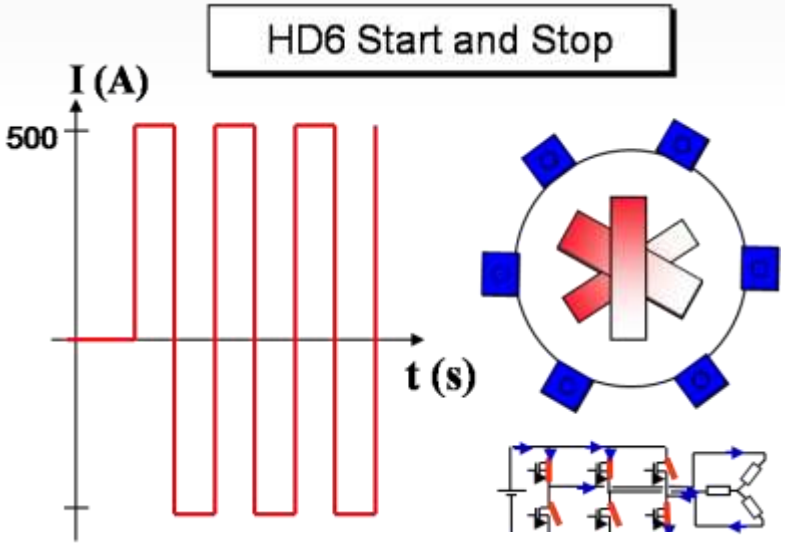
The TC80310 is a complete **System On Die** solution to manage electrical parameters of an **Alternator** with rotor excitation current **up to 8A**, using high side excitation technology combined with free wheeling diode.

HDTMOS for Micro Hybrid

- HDTMOS Technology advantages in avalanche mode
  - **Multiple MOSFET** at higher frequency to control Motor in multiple phases configuration
  - **"Sub-mW"** devices , **0.6 mΩ at 550A**
  - **Reverse mode using body diode at 400A**
  - **Repetitive UIS : 60M cycles at 400A**

- Freescale production started 2010 and will be above 10M pieces run rate in 2012

- Stop Start using HDTMOS



Source Valeo

Mild Hybrid Requirements

Mild Hybrid system, 3rd generation of alternator/starter which will bring:

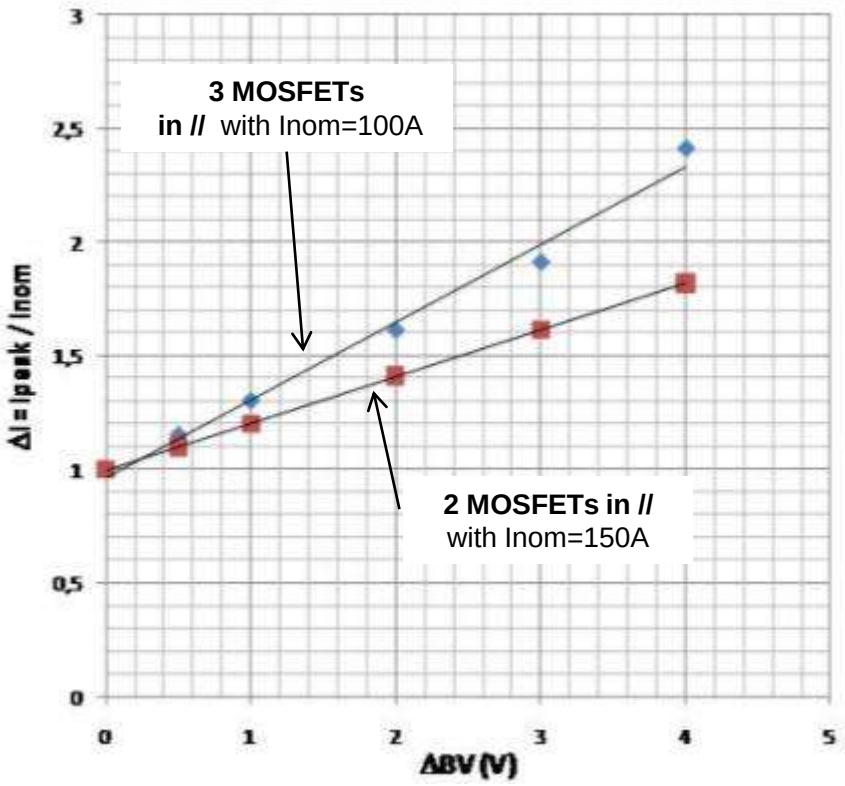
- Start/stop,
- Regenerative braking ,
- Torque assist functions

Electrical machine to replace the conventional alternator with a specific power inverter, Supercap or medium voltage Li-ion Battery

Parameters from customers to be determined:

- Vbat <60V, 100V, >100V
- Power (8 - 15 kW)
- Rms current & Peak current
- 100V / 2 mΩ MOSFET

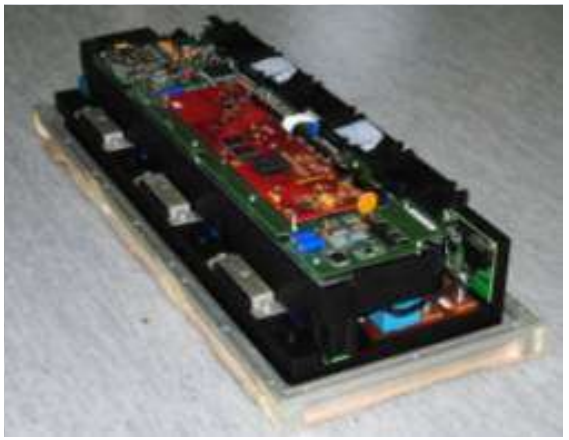
Higher integration (Size, system cost, reliability)

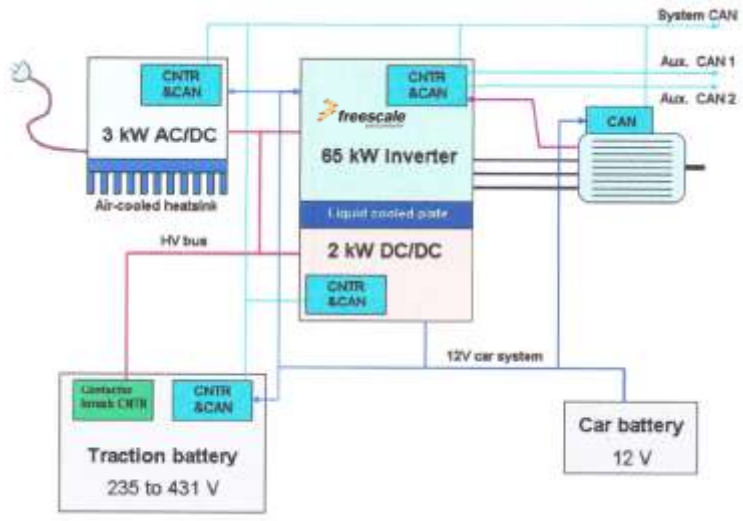


R & D Inverter

INVERTER

- Kick off program in 2010
- First prototype test completed by Freescale
- First inverter samples
- Validated hardware with Freescale control commands
- Additional manufacturing inverters completed
- Test bench in 2012





Electric Motor Drivers - Key Features

- Wide operating range
  - Down to 5V reduced performance (Crank)
  - Normal operation from 8V to 28V
- Automatic current regulation
- Current limit fold back at high die temperatures

Wide H-bridge family:

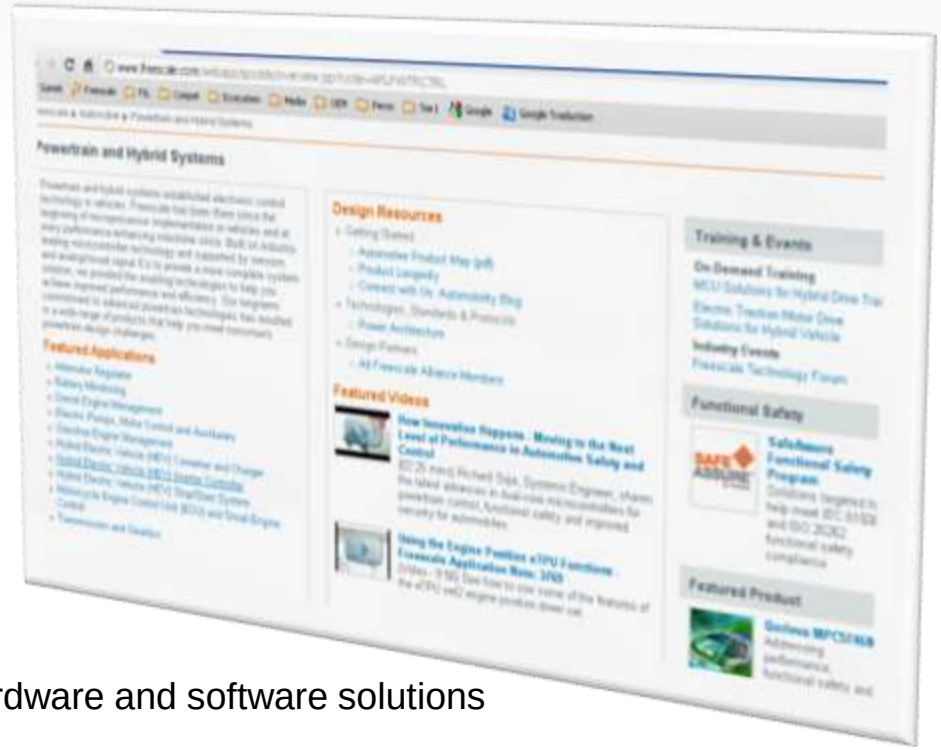
- Ultra-low current sleep mode
- Slew rate selection configurability (depending on device)
- Current Sense Feedback
- From basic to highly integrated feature set in the product family
- SPI based configurability (MC33899)

- Currently available devices
- 5 Ampere H-Bridge Family
  - MC33886
  - MC33887
  - MC33926
  - MC33931 (New!)
  - MC33932 (New!)
- Programmable H-Bridge
  - MC33899
- Three Phase Pre-Driver
  - MC33937A (up to 24V!)

Online Available Tools

Application Page

- Block Diagram
- Product portfolio
- Apps Notes
- Design resources
- software



Comprehensive Software Enablement

Integrated, differentiated, production-ready hardware and software solutions

Freescale Runtime Software

AUTOSAR
MCAL & RTOS

Development Tools

CodeWarrior

Market Solutions

FlexRay

Software Tools for Electric Motor Application

Software tools include:

- Run-time software
- Customization services

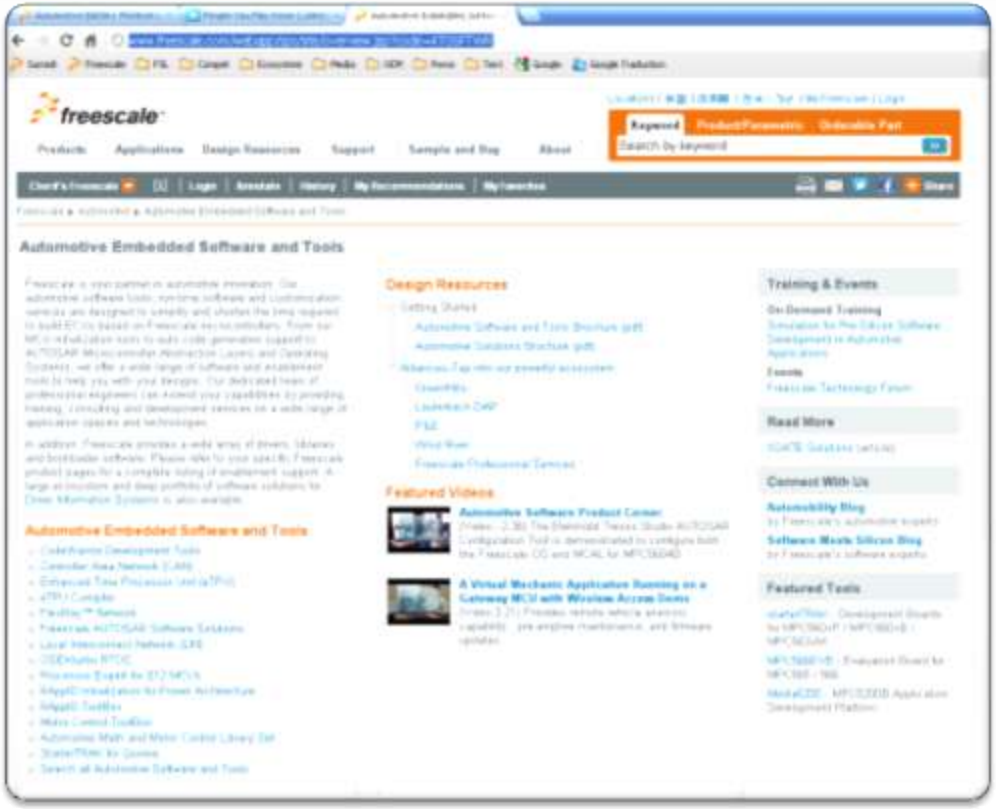
MCU initialization tools:

- Wide array of drivers
- Libraries
- Bootloader software

Auto code generation support

Microcontroller Abstraction Layers

Operating Systems



Battery Management

Various format and Chemistries:

Prismatic, Pouch, cylindrical

Cell value from 2.3V to 3.8V

Li-Ion and Electrode material

Prismatic

A123 cylindrical

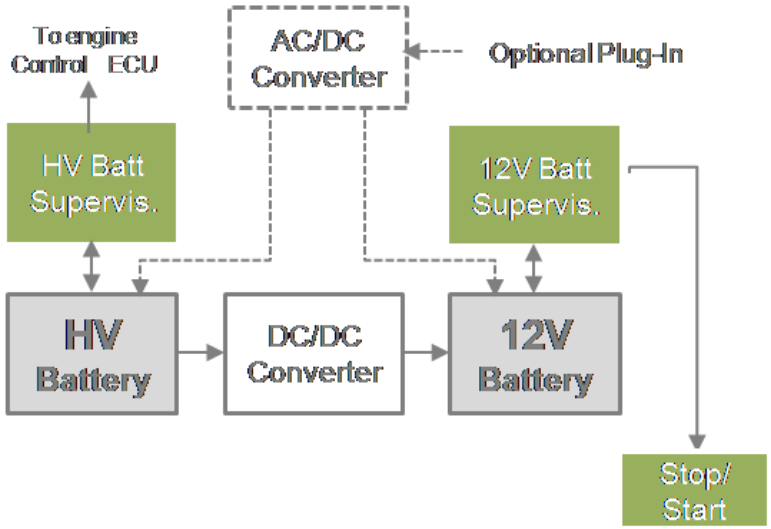
Pouch

Challenges:

- Damages on burst, safety
- Charge / discharge cycling (1,500 cycles)
- Lifetime sustainability
- Monitor temperature, voltage and current
- Cost over time

Benefits:

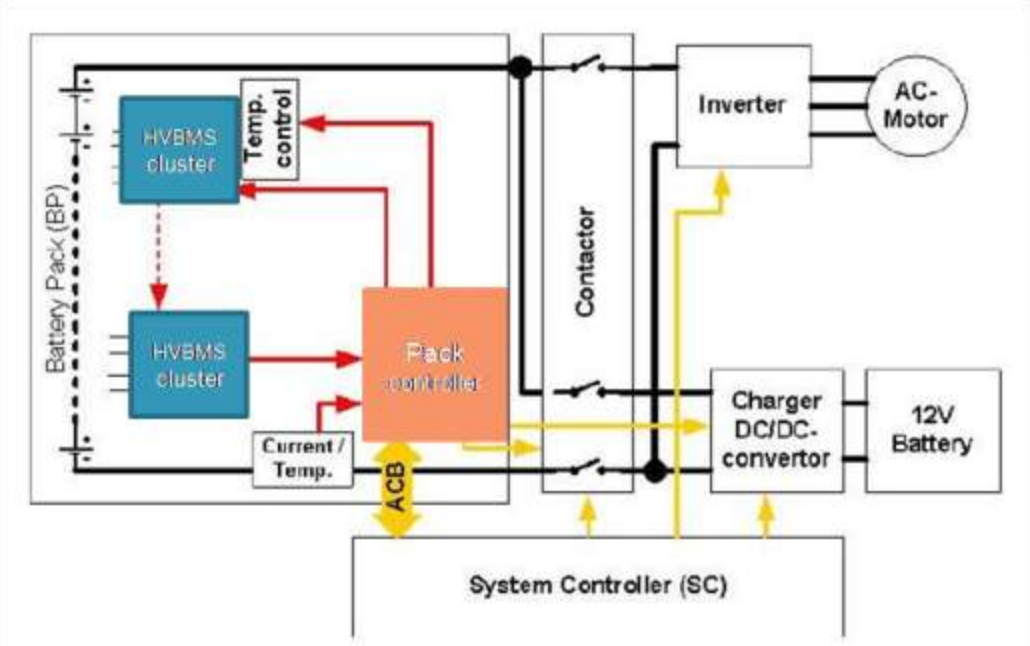
- High Power / High Energy density
- Low self discharge
- No lost of capacity over time
- No voltage depletion



Battery Management Architecture

The HVBMS cluster

- Detects cell **OV/UV/OT**
- Measures and reports cell **voltage, current, temperature.**
- Cell balancing actuation
- All related diagnostics.



The HV management unit (Pack controller)

- Manages cell balancing
- Monitors, classify and reports pack voltage, current, temperature.
- Calculates and reports SOC, SOH, and SOF
- Contactor control

Cell Balancing:
To prevent a cell to be overcharged due to different characteristic (process/aging)

The full system is ASILD

freescale™

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

Electromobility Summary

Summary	
MARKET:	- Growth upon regulations and scenarios - Start/Stop deployment before 2018 - Mild Hybrid might mitigate electrification cost - Analysts foresee HEV/EV at 10% total car production by 2020
ASSETS:	- Wide Portfolio to address motor control applications - Value our expertise in Centers of Excellence - Alignment of Freescale technologies for Electromobility
PARTNER:	- Re-inventing partnership with OEM and Tier1 - Elaborate standards of the future
CHALLENGES:	- Technology enablement in capability and cost - System engineering in processing, power technology, packaging, integration

Q&A

- Thank you

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