Electric Mobility

"eMotion in Smart Cities"

25-26th September 2012, University of Bologna, Italy

"Semiconductors and Embedded Systems the muscles and brain of tomorrow's vehicles"

Reiner John
Infineon, Germany

ARTEMIS

eniac JOINT UNDERTAKING

Tomorrows vehicles....?
Tomorrows mobility....?

- Semiconductors today and tomorrow (enabling solutions)
  - Energy, Efficiency, Mobility, Connectivity,
  - Safety, Security, Convenience, Functionality
- Trends in semiconductors for electromobility
  - Powerdensity, Reliability, Integration, application driven voltage classes,
- Safety

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Mars 100% electromobility…..

- Mars is first planet with full e-mobility
  → Continent Europe the first on Earth with two digit % share of e-mobility in the fleet (new cars)?

Europe 2020:
1st continent with
two digit % e-mobility?

1st Generation e-mobility on Mars

2nd Generation e-mobility on Mars

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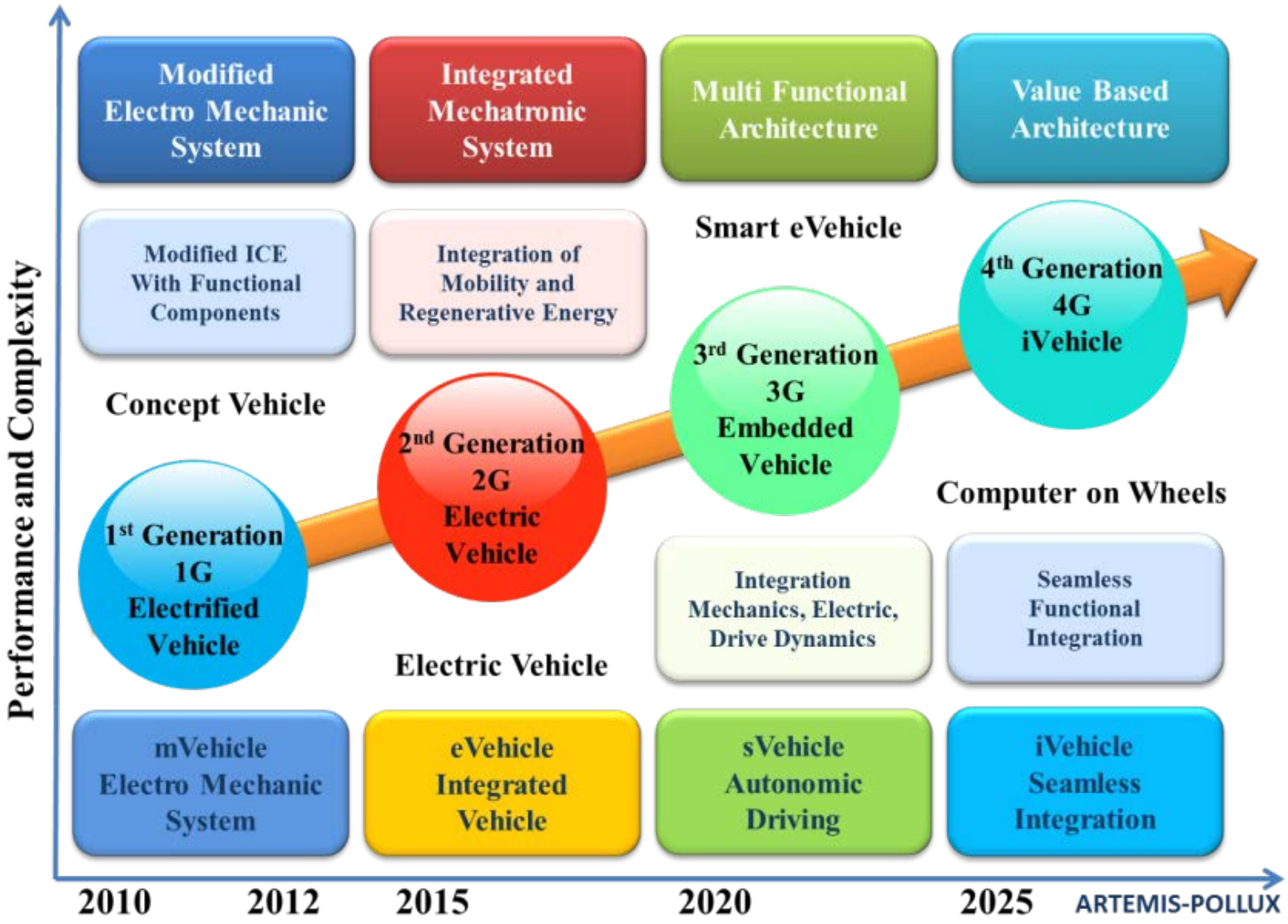
What we think will be…… roadmaps….



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New mobility….
New car……

- ……..Green (clean) is not enough (but is a must)
- Winning the customer is key
- Trends
  - Paradigm shifts
  - Growing population and Increase in Wealth
  - Gross world product
  - Expectations of different generations of driver

    User orientation, smart info, „ipad like“ as interface

    Info-tainment

    Driver assistence,

    networking…“someboding is braking ahead“

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Expected Paradigm shifts

Source: Elmar Frickenstein, BMW from
14. Fachkongress Automobilelektronik, Ludwigsburg

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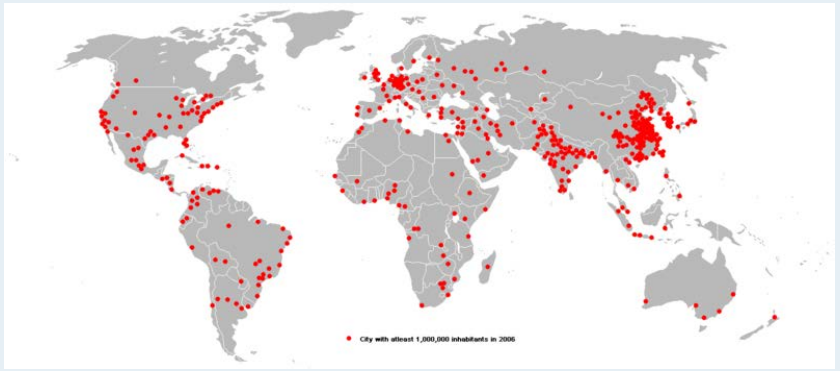
Growing population and Increase in Wealth



Growing population

- 1960 to 2010 doubled population
- Today we are 7 billion people

Megacities → Mega problems

- Beijing, Shanghai, Chongqing
- Seoul
- Tokyo
- New York, Mexico, San Paulo
- London, Paris

Pyramid of age & Parity M / W

- China: 1 child policy
- India: High birth rate
- Germany: Low birth rate

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Gross world product
-> environment protection & efficiency

Gross world products

- 1960 to 2010 produced value$ x45

Impact on the raw resources

- Air, Water, Soil
- Oil, Gas, Coal, …
- Wood, Minerals, Metals …
- Food: Cereals, Animals, …

Environment impact, Pollution

- During manufacturing
- Transport
- During product running life
- The goods after utilization

Urgent: manage product after life

- Second life
- Recycle

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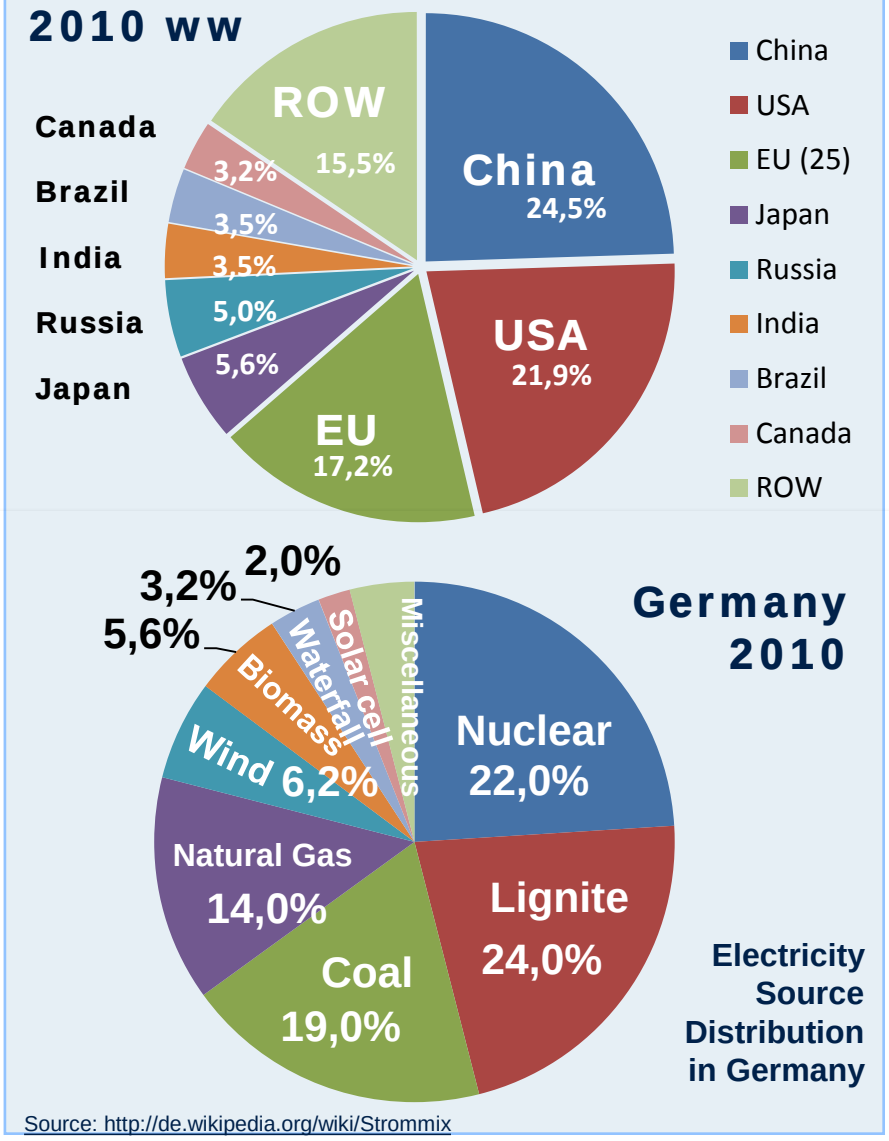
The world demand of electric energy



Source: http://de.wikipedia.org/wiki/Strommix

2010 Electricity demand

World	17 110 TWh/year
China	4 190 TWh/year
USA	3 741 TWh/year
EU(25)	2 950 TWh/year
Germany only	603 TWh/year
India	601 TWh/year

Source: http://en.wikipedia.org/wiki/List_of_countries_by_electricity_consumption

Growth of Electricity demand

- ww from 1970 to 2010 +250%
- ww from 2010 to 2035 +80%
- India from 2010 to 2035 +300%

Carbon footprint

- China 1 500 gCO2/kWh
- Germany 508 gCO2/kWh
- France 80% Nuclear

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What we knew today……..

- The race for CO2 efficiency and environment friendly vehicle is driving Powertrain toward electrification.
- Electric vehicle is a disruptive technology.
- New actors on the stage: Established players have to re-define their competencies.
- We have to proactively create the shift towards e-mobility cooperating along the value chain.
- The world is changing ..follow the trends

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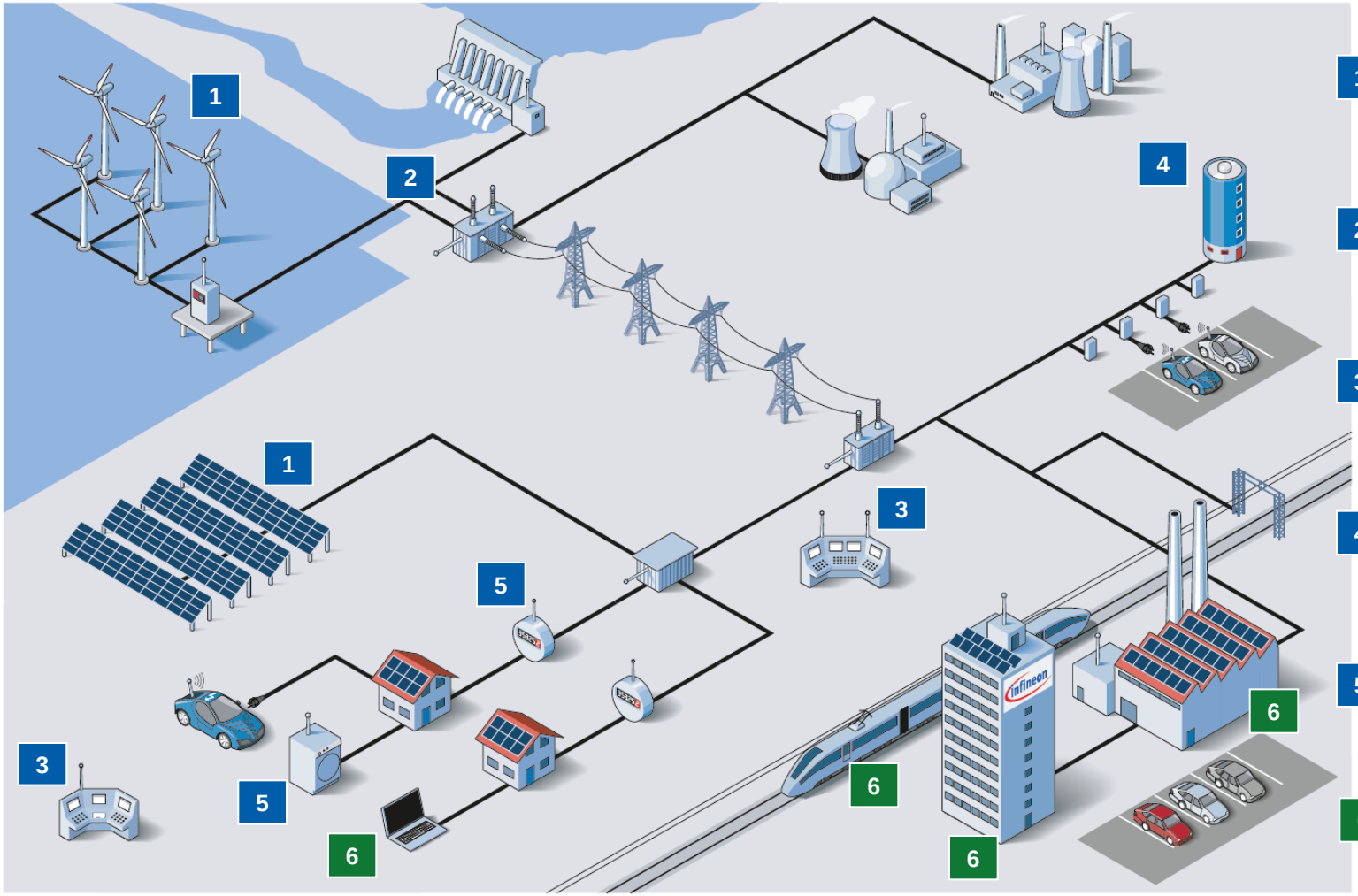
Scenario1: Smart Infrastructure & Grid: advanced power control, intelligence and communications V2x



1 Integration of renewable energy

2 Advanced transmission

3 Grid monitoring and control

4 Energy storage and EV-charging

5 Smart metering and appliances

6 Efficient consumption

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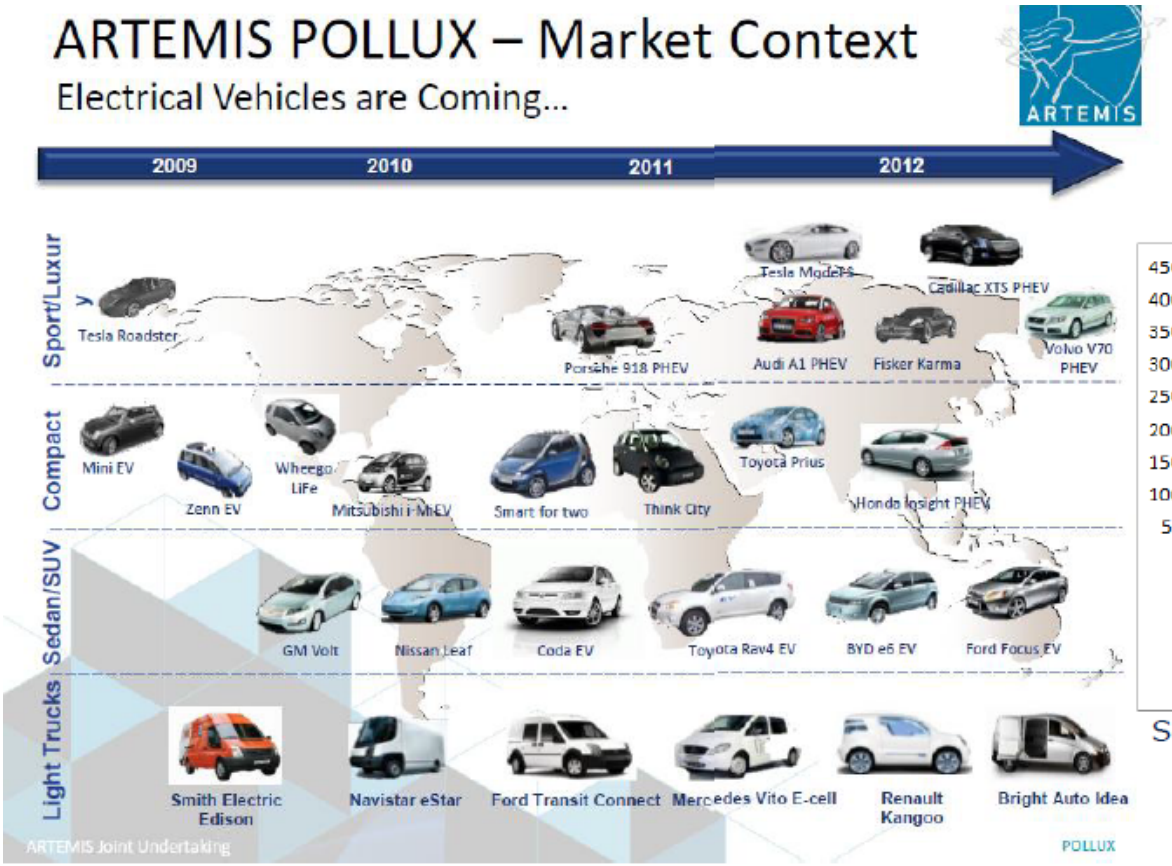
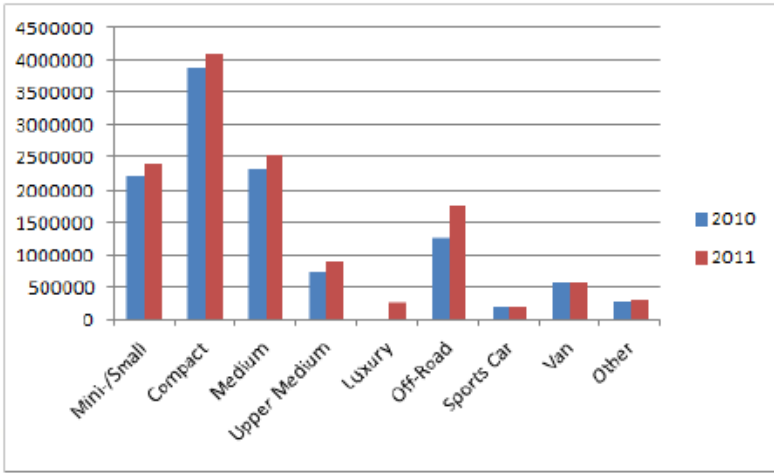
Scenario2: The world car demand



Source: Ovidiu Vermesan, Sintef, Artemis Project POLLUX

World automobile production of German manufacturers



Source: VDA, Germany

Key Message:
compact cars (e.g. Golf) will bring the volume IF the customers sees the added value!

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Car Cost depends on material (weight)
Car price is related to car class

Input Renault

Twizzy

Fahrzeugklasse	Typ	Gewicht von	Gewicht bis	Basispreis von	Basispreis bis
KompaktKlasse	A1	1.115	1.390	16.000	
Golfklasse	Golf VI	1.217	1.541	16.975	23.700
KompaktKlasse	BMW 1er	1.350	1.495	23.850	
Mittelklasse	A4	1.410	1.825	27.500	39.850
Obere MittelKlasse	A6	1.520	2.025	36.900	38.500
Elektro	Nissan Leaf	1.520		35.000	
Mittelklasse	3er	1.425	1.825	33.100	43.600
Elektro	Smart for 2	750		19.000	
Obere MittelKlasse	5er	1.625	1.790	42.500	49.000
LEV	Fahrad	18	20	300	900
Elektro	Mitsubishi MIEV	1.100		35.000	
Oberklasse	A8	1.870	2.130	69.600	137.000
Oberklasse	7er	1.935	2.250	74.400	147.200
Elektro	Tesla Roadstar	1.400		100.000	
LEV	Rennrad	13	15	1.500	2.000
LEV	Damenschuh elegant	0,700	1,000	50	350
LEV	Jogging Schuh	0,249	0,330	89,40	99,95
Aircraft	A380	560.000		230.769.231	

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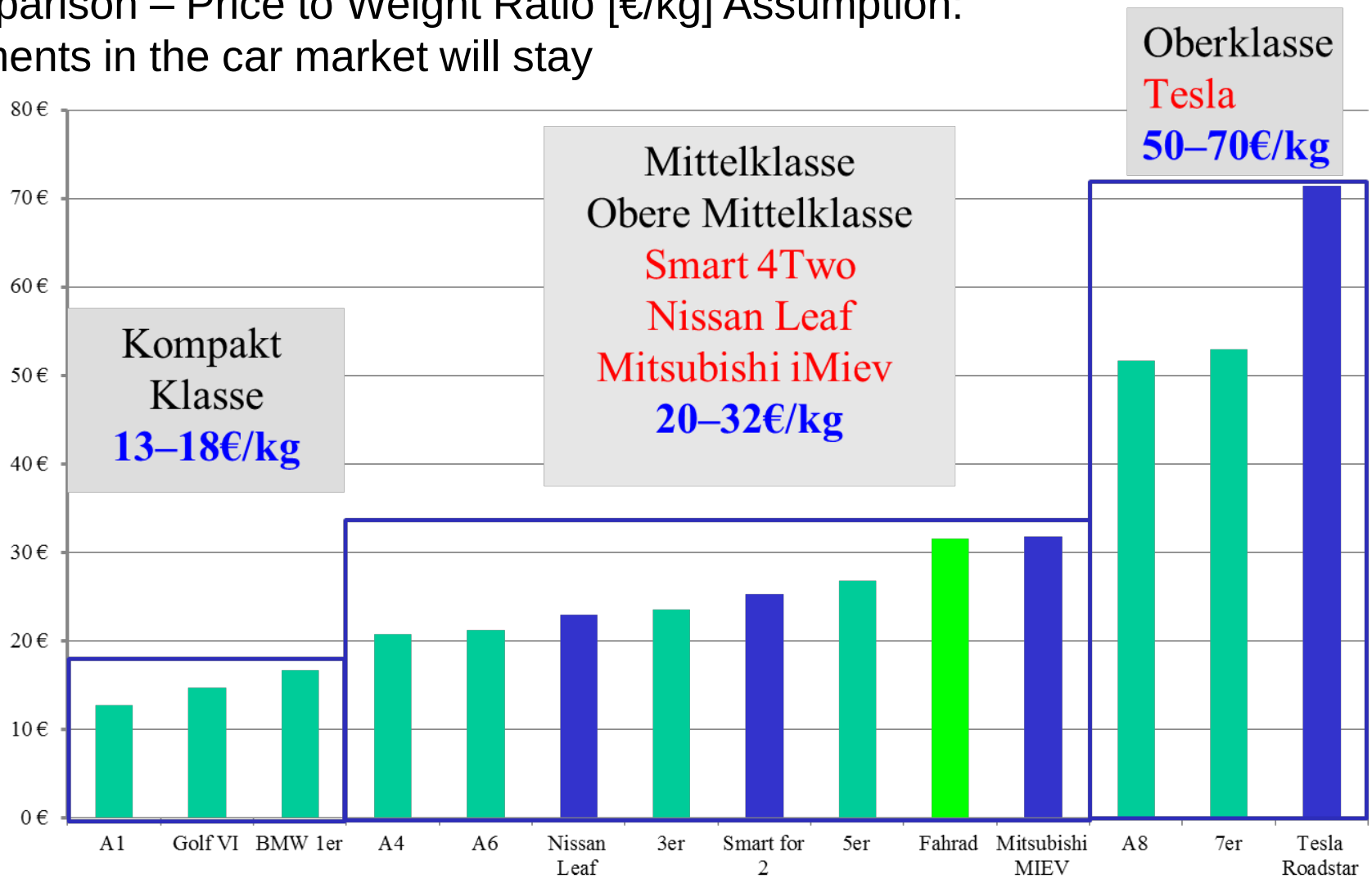
E-mobility - price regime 1-2 classes higher compared to established cars

Comparison – Price to Weight Ratio [€/kg] Assumption: segments in the car market will stay



Annahme: Zukünftige Fahrzeugtechnologien werden sich in in dieses Preisschema einpassen

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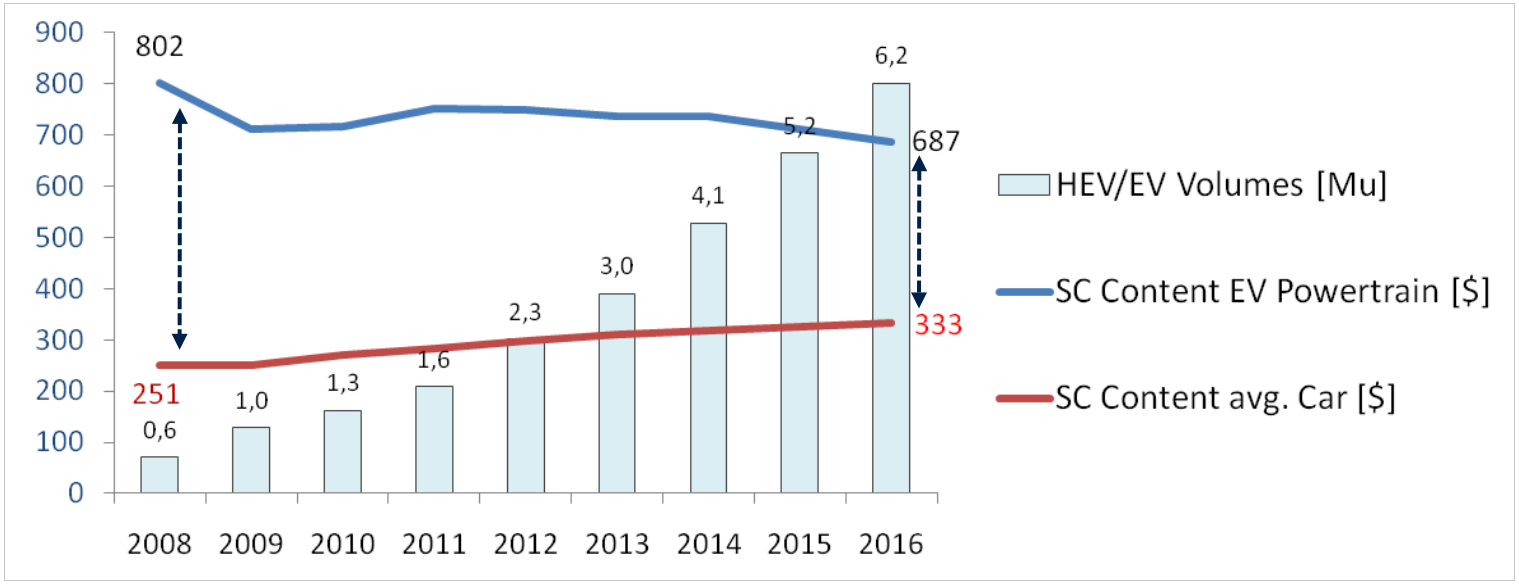
Our business: **Electric Vehicle architectures** drive demand for automotive power semiconductors

Auto vs. EV/HEV Semiconductor BOM*



- Powertrain semiconductor bill-of-material (BOM) of an **EV / HEV** is **approx. 2 times higher** than today´s total Auto SC BOM
- Even at the low end of market projections this becomes a **significant market for power semiconductors**

* Source: IMS Research, Report on Hybrid and Electric Vehicles, 2010

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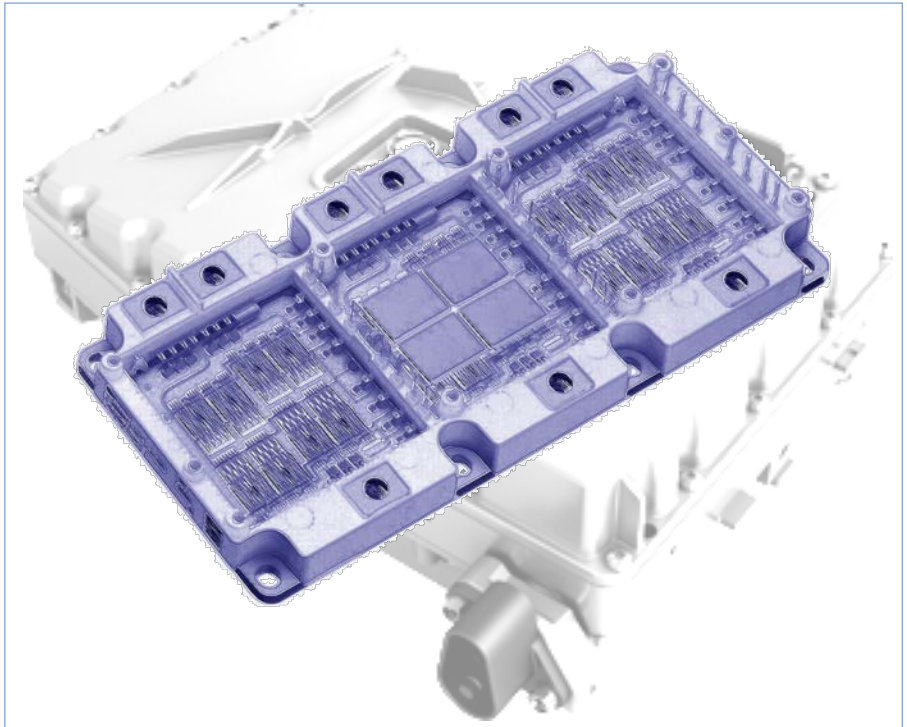
1st Paradigm Shift: IGBT's are the Injectors of Tomorrow

Today
Fuel Injectors in Combustion Engines

- Driver of vehicle performance: **Mechanical** components and subsystems
- Assisted by **semiconductors**
- On-board electrical power: ~1 kW

Tomorrow
IGBT's in Electrical Inverters



- Driver of vehicle performance: **Semiconductor** components and subsystems
- Assisted by **mechanicals**
- On-board electrical power: ~100 kW

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Innovative semiconductors are key enablers for leading-edge HEV/EV solutions

	What counts	Semiconductors
Inverter	▪ Highest power density ▪ High voltage and high current ▪ Temperature capability and cooling ▪ Lifetime in harsh environment ▪ Weight and size	▪ IGBTs ▪ Diodes (Si, SiC) ▪ HybridPACKs ▪ Gate drivers
DC/DC (Low Voltage)	▪ High power density ▪ Galvanic isolation ▪ High switching frequency (> 100kHz)	▪ MOSFETs ▪ CoolMOS ▪ Gate Driver ▪ EasyPACKs
Charger	▪ Efficient AC/DC conversion ▪ Handling of high currents (fast charging) ▪ High switching frequency (> 100 kHz) ▪ Safety and communication	▪ MOSFETs ▪ IGBTs ▪ Diodes (Si, SiC) ▪ EasyPACKs
Battery Mgmt.	▪ Extension of battery lifetime ▪ Monitoring and control of battery status by smart algorithms	▪ MOSFETs ▪ Battery management ICs

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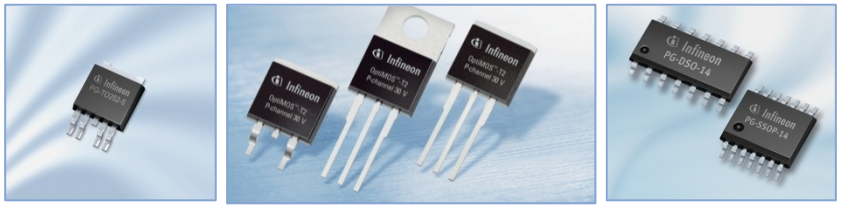
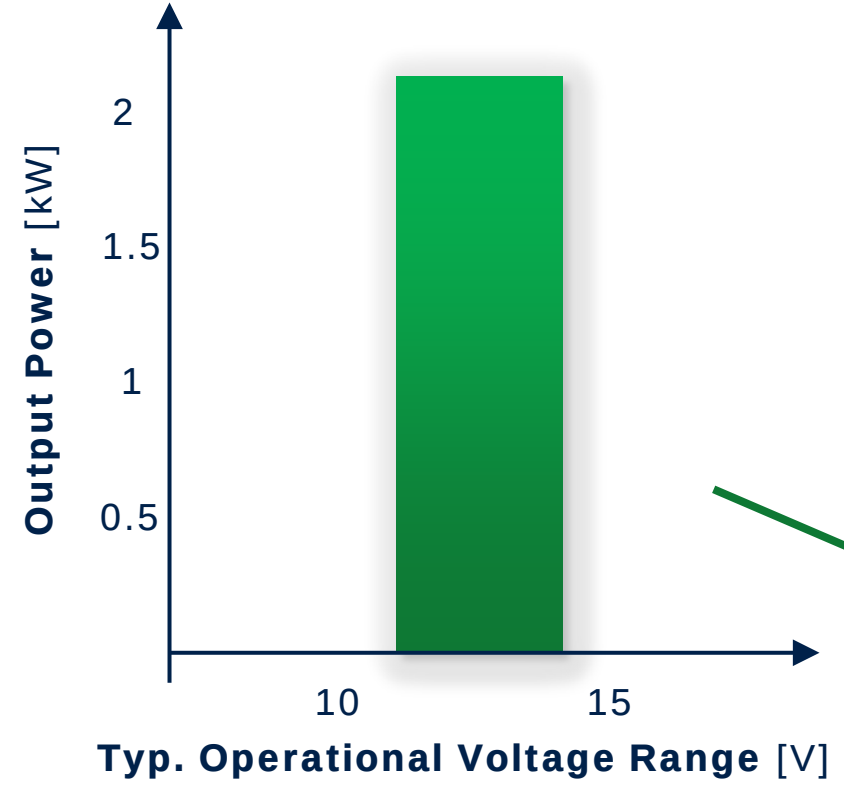
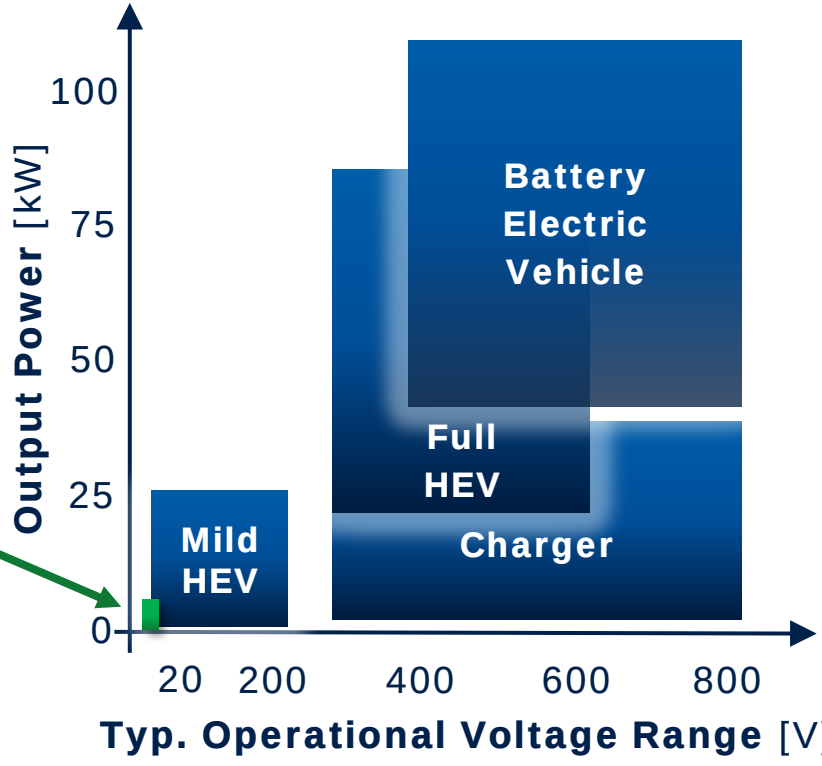
2nd Paradigm Shift: New Dimension of Power Semic. Performance

Power demand for ICE





Power demand for eMobility



ICE = internal combustion engine.

HEV = hybrid electric vehicle.

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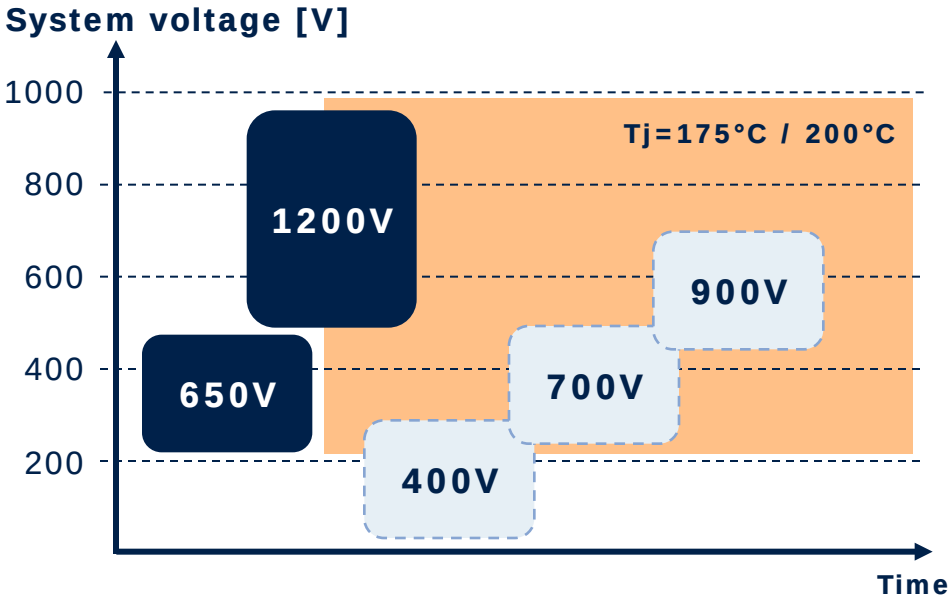
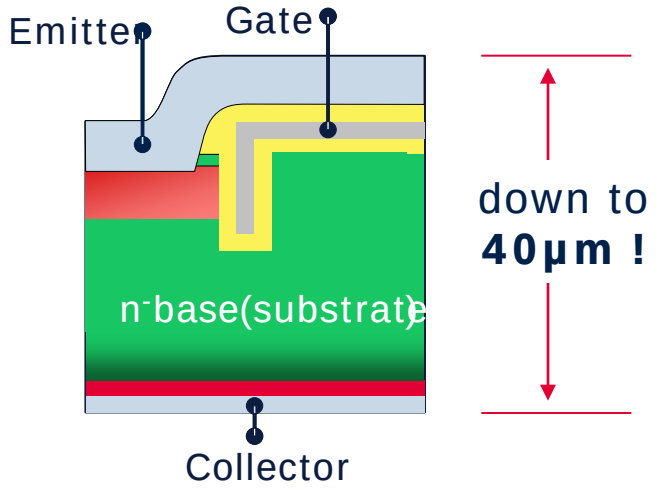
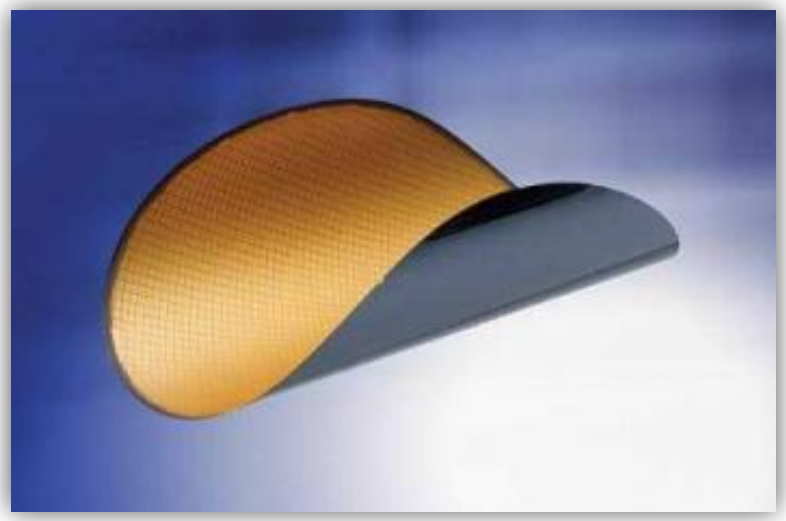
IGBTs - Silicon technology and manufacturing know-how enables optimized power density



Trench + Field-Stop Cell



- The **IGBT** is the preferred device for **higher currents** in typical inverter applications
- The **trench + field-stop** cell design enables **lower switching losses** and **high robustness**
- Increasing the **junction temperature** is the future road for **higher power density**



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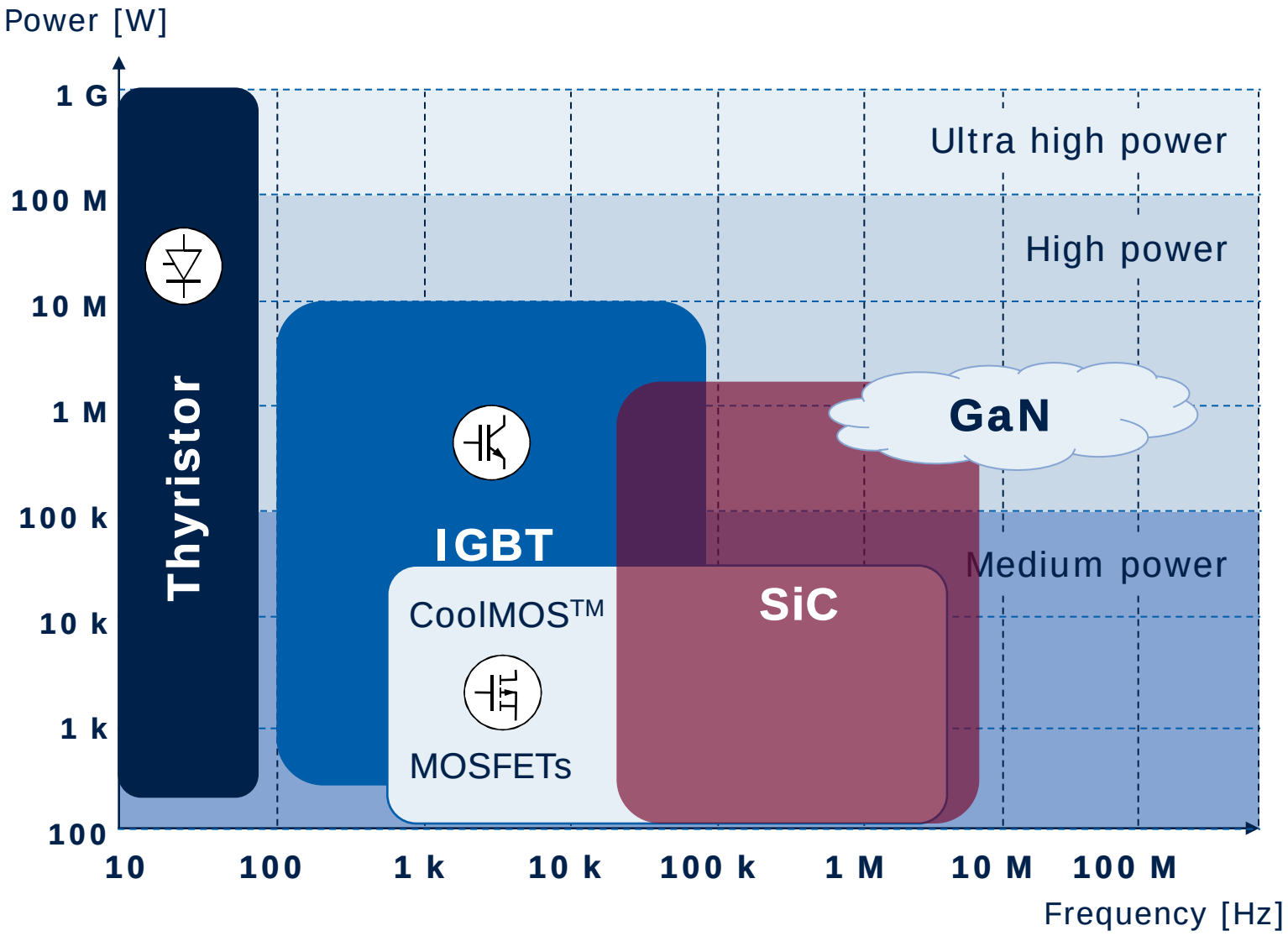
High Power Semiconductors - Overview
Infineon masters a comprehensive portfolio



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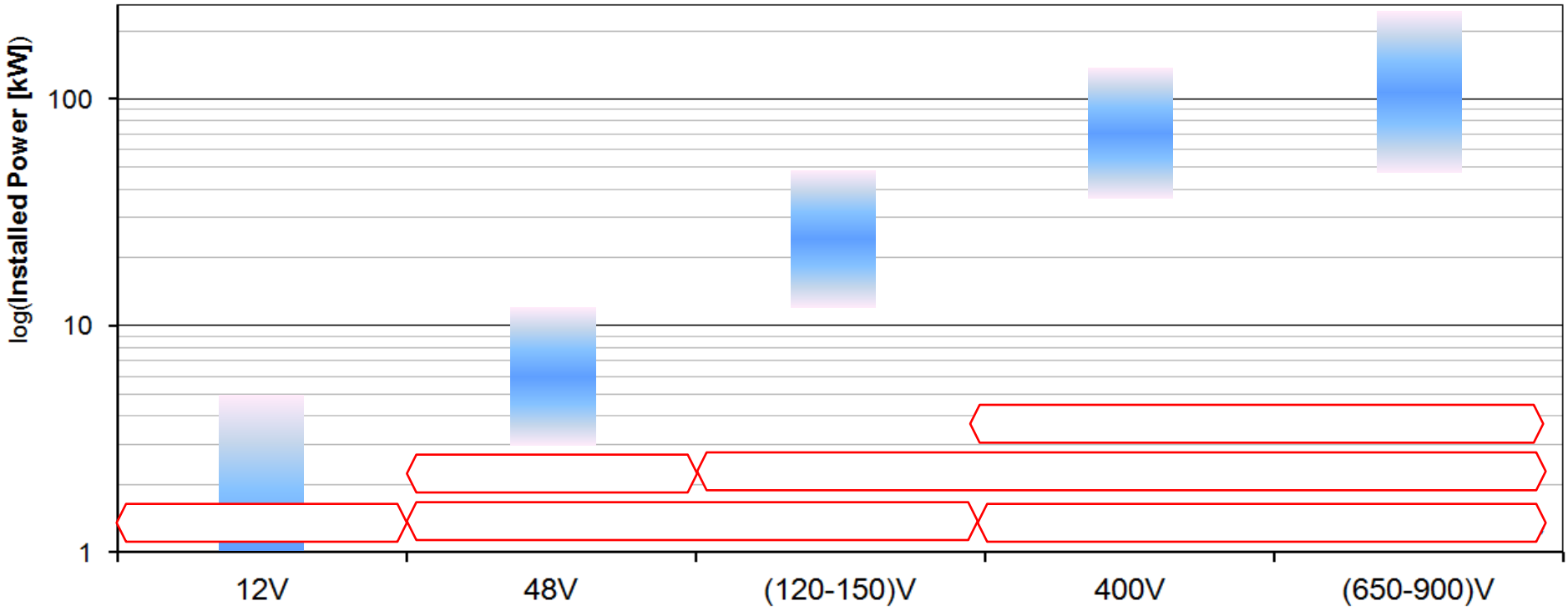
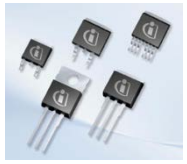
xEV Solutions
Mapped to Power Semiconductors



	12V	48V	(120-150)V	400V	(650-900)V
	Start/Stop	Coasting, Crawling Boosting	Coasting, Crawling eDriveLight	eDrive	eDrive
Power Semiconductor Devices	MOSFET(30…60)V	MOSFET(60…100)V	MOSFET (150…200)V CoolMOS™ (500…650)V IGBT (400…650)V	CoolMOS™ 650V IGBT 650V	CoolMOS™ 800V IGBT (850V,1200V)



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Power density improvement of **power modules** by more than 180% since 1995

IFX long term experience in power modules

IGBT2

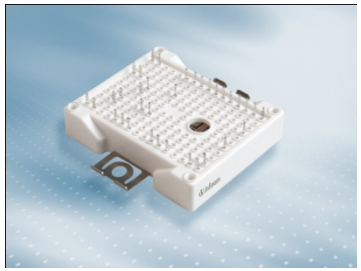
- 34mm module
- 1200 V
- 45 kW
- **0.46 kW/cm²**
- Tj=125 °C

1995

IGBT3

- EconoPACK™2
- 1200 V
- 37.2 kW
- **0.89 kW/cm²**
- Tj=125 °C

2001



IGBT4

- EasyPACK2B
- 1200 V
- 31.3 kW
- **1.16 kW/cm²**
- Tj=150 °C

2007

IGBT4.XT

- PrimePACK™2
- 1200 V
- 600 kW
- **1.31 kW/cm²**
- Tj=175 °C

2013

- **2010:** Yearly power module production for industrial applications is **~10 Mio.** pcs. **HybridPacks** for automotive solutions are ramped up.

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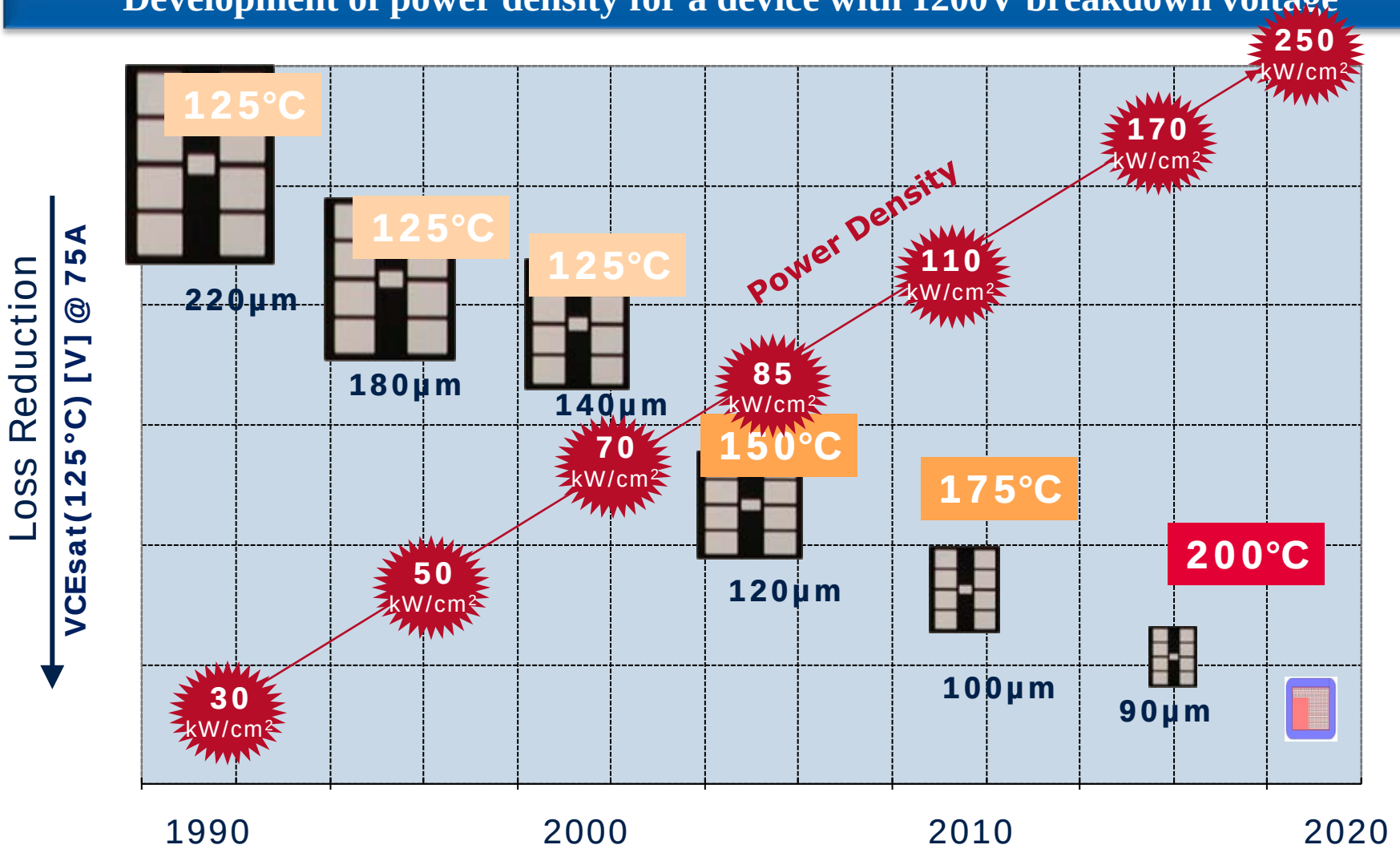
"Infineon's Law" for IGBTs: Double Power Density Every 10 Years!

Development of power density for a device with 1200V breakdown voltage



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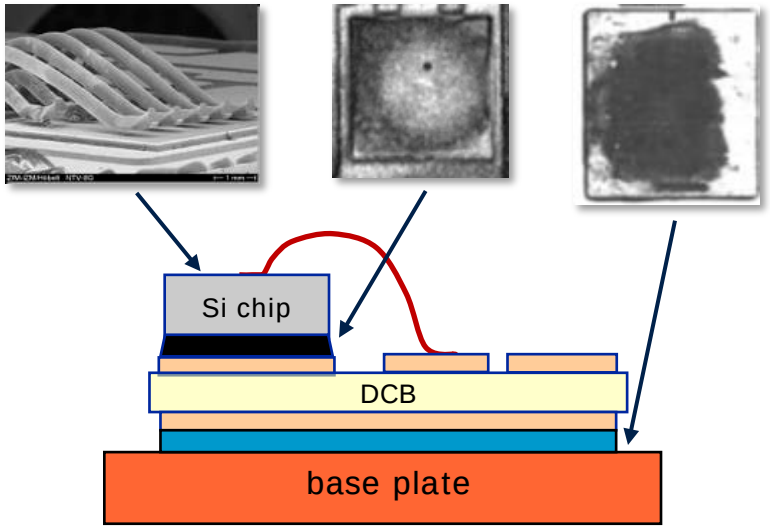
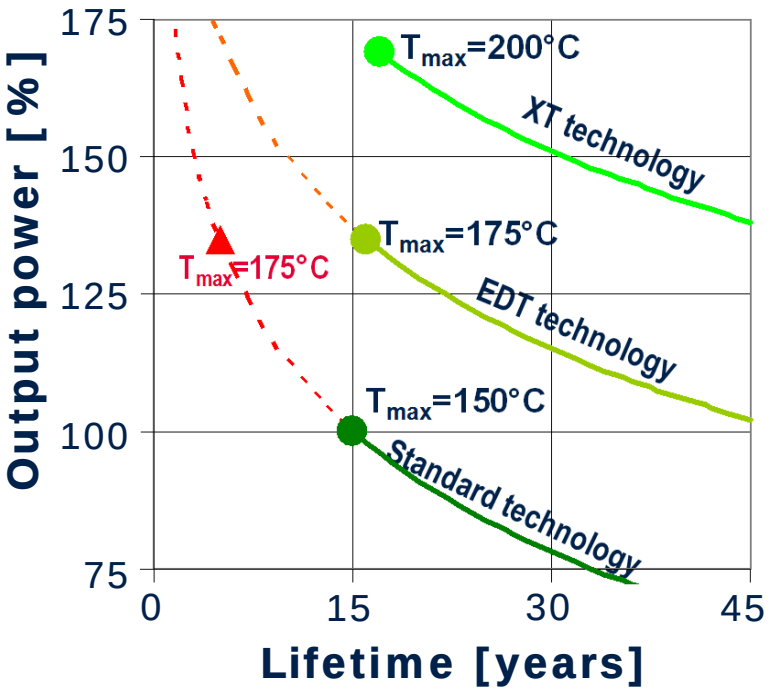
Advanced XT technology enables **higher thermal capability**

Improved **thermal capability**

- Higher **output power**
- Longer **lifetime**
- Reduced **system costs**

Wear out mechanism of **standard technologies**





Innovative solutions for **200°C**

- **Copper wire** bonding
- **Diffusion** soldering
- High reliability **system solder**

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A problem has been detected and Windows has been shut down to prevent damage to your computer.

If this is the first time you've seen this Stop error screen, restart your computer. If this screen appears again, follow these steps:

Check to be sure you have adequate disk space. If a driver is identified in the Stop message, disable the driver or check with the manufacturer for driver updates. Try changing video adapters.

Check with your hardware vendor for any BIOS updates. Disable BIOS memory options such as caching or shadowing. If you need to use safe mode to remove or disable components, restart your computer, press F8 to select Advanced Startup options, and then select safe mode.

Technical information:

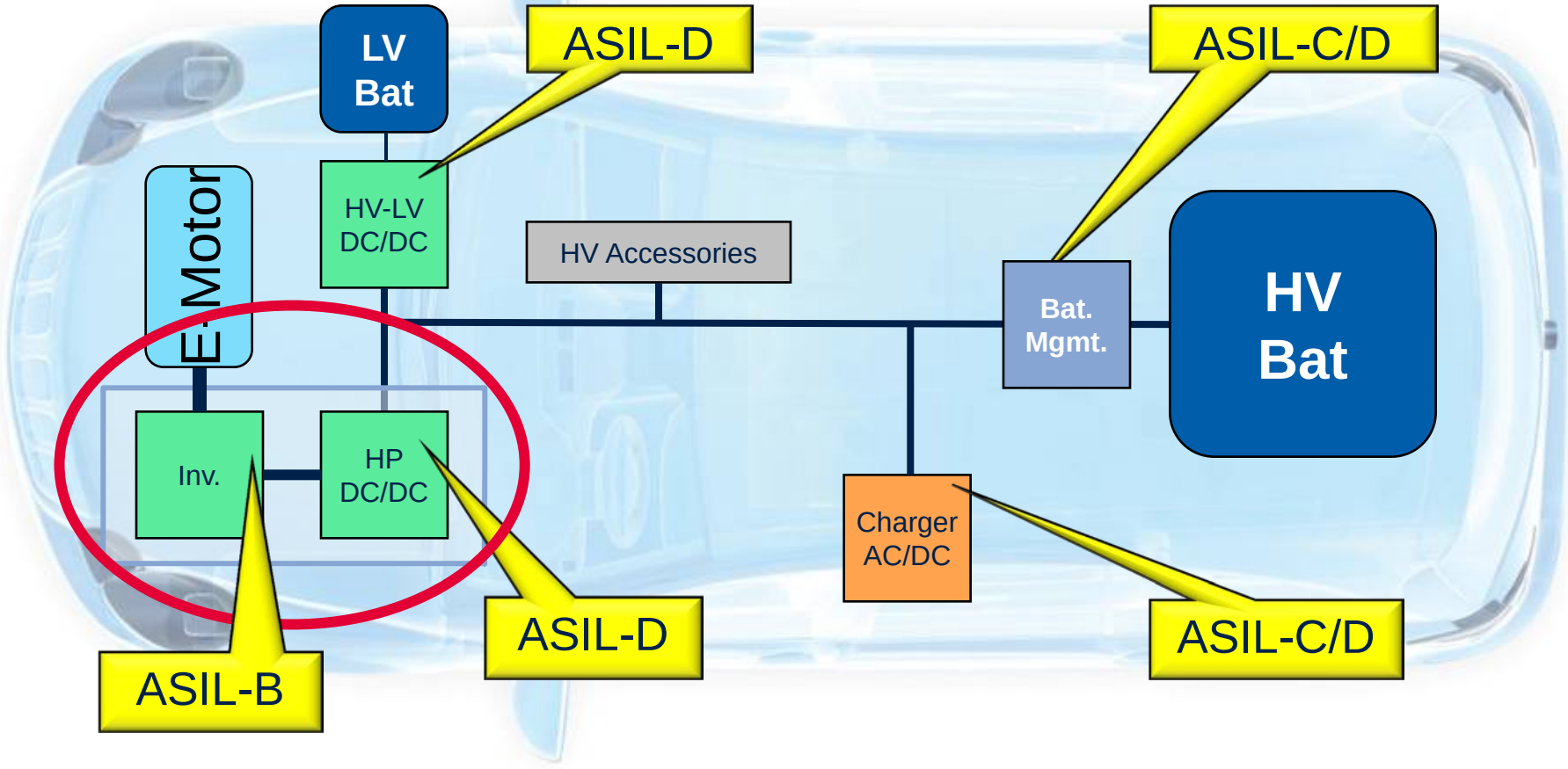
*** STOP: 0x00000024 (0x001902FE, 0xF791E94B, 0xF791E644, 0xBA6805CC)

*** Ntfs.sys – Address BA6805CC base at BA645000, Datestamp 41107EEA

Beginning dump of physical memory

Physical memory dump complete.
Contact your system administrator or technical support group for further assistance.

E-Mobility Architecture
Safety Levels



- E-Mobility is an X-by-Wire system that requires the most stringent safety integrity care
- ISO 26262 is classifying application according to Severity, Exposure, Controllability
- Most sub applications (inverter, battery management, DC/DC HV-LV) are ASIL-D

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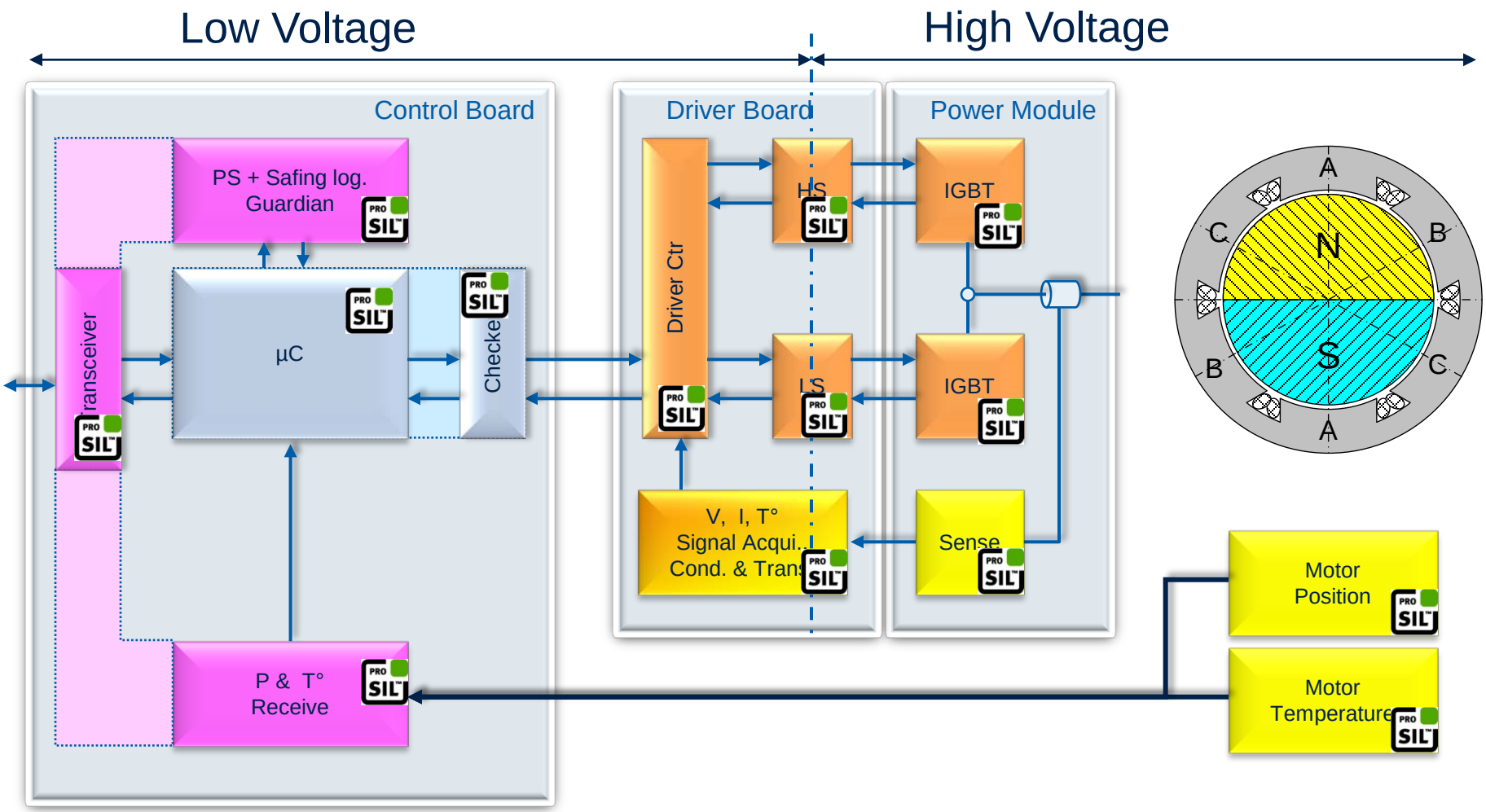
Inverter Architecture



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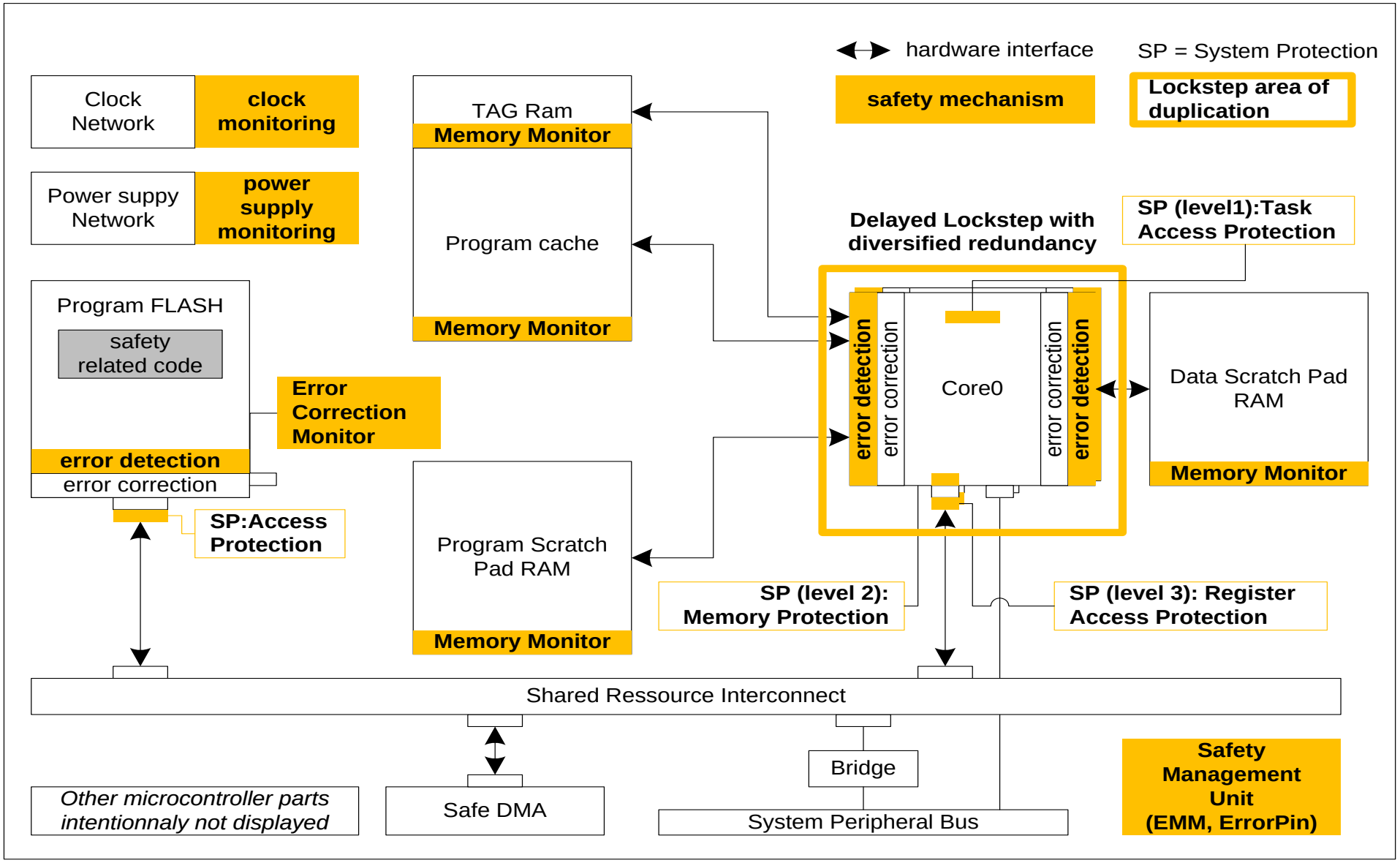
Safety Functions in a Modern 65nm Microcontroller



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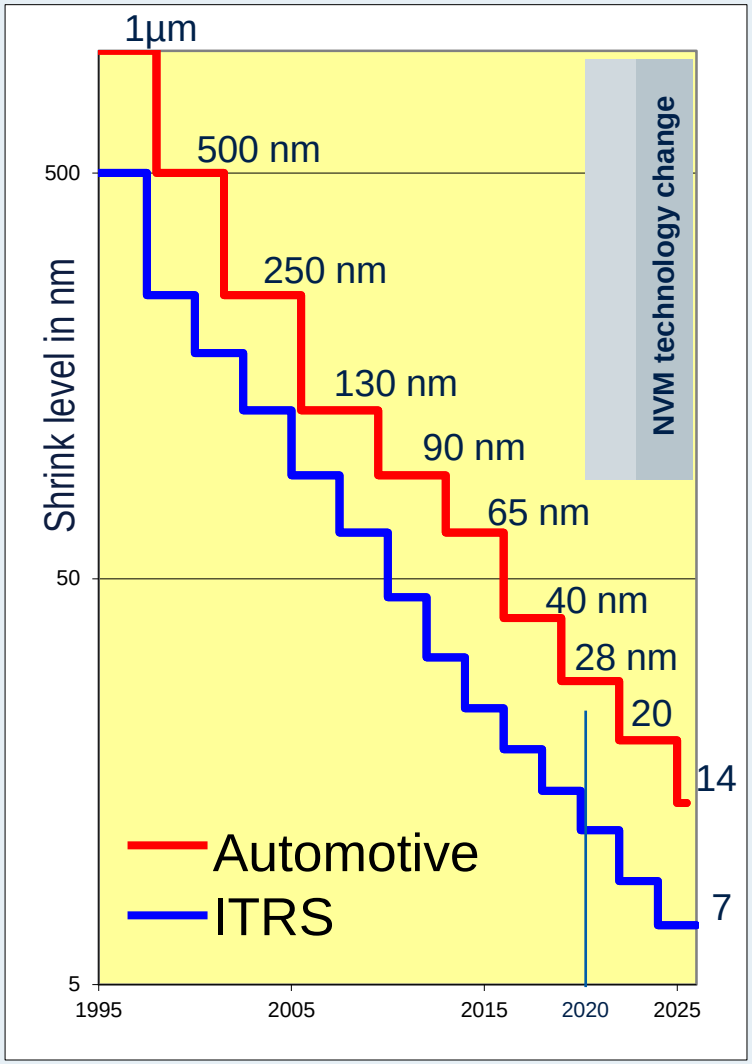
Microcontroller technologies



1- ITRS

International Technology Roadmap of Semiconductors (ITRS): MPU roadmap

2- Automotive

Challenges for automotive µC technology when going lower in shrink level

- Processed wafer cost
- More expensive is mask cost
- More sensitive to radiation
- Higher leakage current
- Analoge does not shrink at same rate (Flash, ADC, Pad…)
- Need to change to new NVM
- Automotive quality challenges

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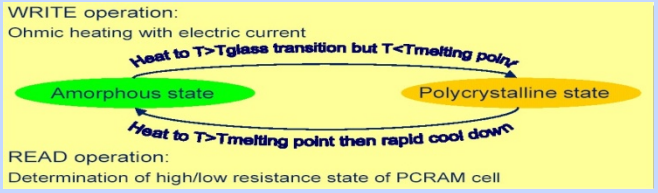
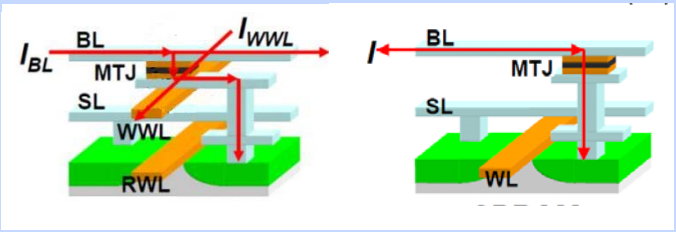
Future NVM (Non Volatile Memory)

PCRAM: Phase Change RAM

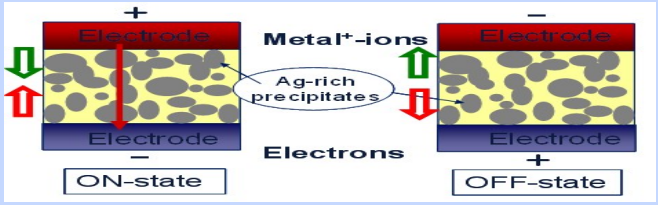


MRAM: Magneto Resistive RAM

Stoner Wohlfahrt (SW-MRAM)
Spin Torque Transfer (STT-MRAM)



CBRAM: Conductive Bridging RAM



	small module size	process simplicity	w/e speed	read speed	retention	endurance	Temp° behavior	Low power	shrinkability	maturity
Nano Crystal	+	0	0	0	-	0	0	0	+	++
FeRAM	-	+	+	-	0	+	0	++	--	++
PCRAM	+	+	0	0	0	0	-	0	++	+
SW-MRAM	-	++	++	+	+	+++	+	-	-	+
STT-MRAM	++	++	++	+	+	+++	+	0	++	-
CBRAM	++	++	++	0	-	+	--	++	++	-
RRAM	+	+	+	-	-	0	-	++	++	---

This table compares the NVM options to replace today's Flash

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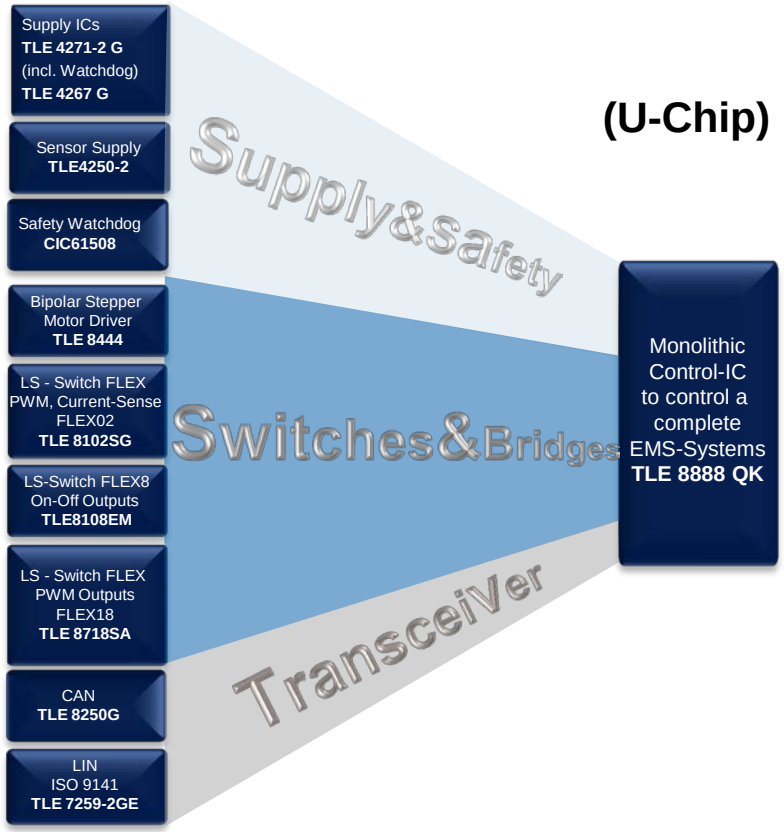
Integration example of Gasoline Port Injection System

Integration

- The Engine management ECU for entry segment MPI has the size of a credit card with mainly 2 components on it: the µC + the U-Chip



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Summary

- The race for CO2 efficiency and environment friendly vehicle is driving Powertrain toward diversity of energy carriers.
- Optimizing the “Driving mission” will require a complete coherence between the car systems and the infrastructure.
- Infineon is working to supply cost effective, safe, secure, and reliable component solutions.
- The race for performance and integration is the differentiating factor of the semiconductor industry.

Thank you!

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