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48V Hybrid Systems from Semiconductor Perspective

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Content

I. Market Drivers for 48V HEV
II. 48V Traction
III. 48V Boardnet DC/DCX
IV. 48V Auxiliary Inverters
V. Power Semiconductors for 48V
VI. Functional Safety / ISO26262 in 48V Hybrids
VII. Semiconductors for Functional Safety
VIII. Conclusion
Main Sources of CO2 emission

- Passenger Cars and Light Trucks: 17%
- Industry: 29%
- Commercial: 17.5%
- Residential: 17%
- Other Transportation: 11%
- Other: 1.5%
- Agriculture: 7%

*www.epa.gov/climatechange/emissions/usinventoryreport.html
*Electricity-related emissions, which represent 34% of U.S. GHG emissions, have been distributed to the end users.
Global CO₂ Targets

EU Legislative Resolution
Cars: 120 gCO₂/km beginning 2012
+10 g credit for biofuels, tires etc.....

CAFE & Clean Air Act: 35.5 mpg
2016  35.5mpg: Cars 39mpg, Trucks 30mpg
2025  54.5mpg: Cars 62mpg, Trucks 44mpg

Conversion table for regular gasoline engine

<table>
<thead>
<tr>
<th>gCO₂/km</th>
<th>155</th>
<th>140</th>
<th>130</th>
<th>120</th>
<th>110</th>
<th>100</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/100km</td>
<td>6.72</td>
<td>6.08</td>
<td>5.65</td>
<td>5.21</td>
<td>4.78</td>
<td>4.34</td>
<td>3.91</td>
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<tr>
<td>MPG</td>
<td>35.00</td>
<td>38.69</td>
<td>41.66</td>
<td>45.13</td>
<td>49.24</td>
<td>54.16</td>
<td>60.18</td>
</tr>
</tbody>
</table>
xEV Trends – 48V Major Growth Driver for Mild Hybrids

xEV vehicles – Total demand forecast

Mio. units


Pure EV
Any system whereby electric motors alone, powered from batteries, are used to propel the vehicle.

Plug-In Hybrid
Any system whereby one or more electric motors is used to provide brake recuperation and propulsive power to the vehicle, in conjunction with an internal combustion engine. A larger, plug-in rechargeable battery pack enables greater use of electric-only drive.

Full Hybrid
Any system whereby one or more electric motors >20 kW is used to provide brake recuperation and propulsive power to the vehicle, in conjunction with an internal combustion engine.

Mild Hybrid
Any system whereby one electric motor of <20 kW is used to provide brake recuperation and some torque assist to the vehicle, in conjunction with an internal combustion engine.

CAGR_{15-20} +20.2%

<table>
<thead>
<tr>
<th>Year</th>
<th>Pure EV</th>
<th>Plug-In Hybrid</th>
<th>Full Hybrid</th>
<th>Mild Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>002</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2014</td>
<td>003</td>
<td></td>
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<tr>
<td>2015</td>
<td>004</td>
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<td>2016</td>
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<td>2018</td>
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<td>2019</td>
<td>010</td>
<td></td>
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<tr>
<td>2020</td>
<td>011</td>
<td></td>
<td></td>
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<tr>
<td>2021</td>
<td>012</td>
<td></td>
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</tbody>
</table>

1: Source: Strategy Analytics Nov’14
2: Sources: Strategy Analytics Nov’14 (1) / (2)
Driving Forces behind 48V

World Trend to Reduce CO2

HEV Cost-Benefit-Ratio

Smooth / Stabilized 12V Boardnet

Additional Customer Features

12V Boardnet 12V + 48V Boardnet
### End Customer Price / Efficiency

<table>
<thead>
<tr>
<th>12V Start-Stop 2kW</th>
<th>12V BSG 5kW</th>
<th>48V BSG 10kW to 15kW</th>
<th>48V BSG + eBoost a</th>
<th>48V BSG + TM* FW or RW b</th>
<th>48V BSG + TM* c</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Customer Price</td>
<td>200€</td>
<td>500€</td>
<td>600-1000€</td>
<td>1300€</td>
<td>1500€</td>
</tr>
<tr>
<td>Fuel Efficiency</td>
<td>3%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>

**TM** Traction Motor, FW Front Wheel drive, RW Rear Wheel drive
48V Motor-Generator (μ & Mild Hybrid) System Block diagram

Infineon products

- **MOSFETs**
  - OPTIMOS-T, -T2 100V and 80V DPack, D2Pack, TOLL, SuperSO8

- **Drivers**
  - TLE9180 with 90V tech.

- **Smart Switches**
  - BTS50085, 6163, 452, 723
  - BTT6050

- **μC**
  - AUDO-MAX or AURIX, ASIL support

- **Sensors**
  - IGMR TLE 5012, future IAMR
48V Main Inverter Block Diagram

- 48V from Battery
- Filter + Protection
- AURIX 32-bit Microcontroller TC23x TC27x
- TLE9180 On-board 3-ph Driver IC
- TLF35584 DC/DC Buck
- SPI
- PWM
- TLE9180
- PWM Signal
- Feedback
- Current Signal
- H-Bridge Driver IC TLE6282
- ~3 Phase SM
48V Bordnetz

Heute

<table>
<thead>
<tr>
<th>12V</th>
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<tbody>
<tr>
<td>GEN</td>
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</table>

Speicher

Bordnetzerweiterung 48V

<table>
<thead>
<tr>
<th>12V</th>
<th>48V</th>
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</thead>
<tbody>
<tr>
<td>GEN</td>
<td></td>
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</tbody>
</table>

Speicher

**Gemeinsames Statement der OEMs**


- Die OEMs fordern alle Akteure - von Chip- und Batteriherstellern über Systeme bis hin zu Streifen- und Antriebsstrangherstellern - auf, aktiv an der Serienentwicklung teilzunehmen und diese konstruktiv zu unterstützen.
48V/12V DC/DC Converter
System Overview

- One DC/DC converter in every 48V car
- 1-3kW power, >95% efficiency
- Passive air cooling
- Scalable multiphase concept, 80-200kHz
- ASIL C (12V to 48V fail connection)

**Today**

- Jump-start
- 12V
- 

**48V Extension**

- Jump-start
- 12V
- DC/DC
- 48V
- no human access

- Safety
- Inverter
- M/G
- Motor / Generator
12V/48V DC/DC Converter

- Scalable: up to 3kW buck, up to 1 kW boost
- Modular: 9 phases/3 blocks
- Input: 36V...54V
  Output: 12V...16V
- Efficiency >95% (up to 97%)
- Compact: 1.3kW/l (210*165*60 mm)
- Passive air cooling
- Protection:
  - Overload;
  - Over-temperature;
  - Reverse battery 12V;
  - Short circuits (int./ext.);
  - Voltage de-rating;

![Efficiency vs. Power Graph](image)
48V/12V DC/DC Converter
3kW 9-Phase Concept

Three independent converter blocks, each with three phases
• 66% power available in case of failure

Three independent TLE9180 driver
• Pro SIL fail safe driver IC

Three independent polarity protection blocks
• protects the 12V against wrong polarity
• use as safety switch for the converter blocks

AURIX microcontroller
• Pro SIL high performance dual core controller

Dual fail safe supply
• for operation from 2 networks
• safe switch for protection of 12V

48V Input Filter
• reduction of noise @ 48V board net
48V Auxilliary Drives

- **Climate Compressor**: BLDC unidirectional, 4-5kW, 100A
- **Electric Charger (eTurbo)**: BLDC unidirectional, 2-4kW, 80A
- **Active Chassis Control**: BLDC bidirectional, 1-2kW, 40A
- **EPS**: BLDC bidirectional, 1-1.5kW, 30A
- **Engine Fan**: BLDC unidirectional, 1kW, 20A
- **HVAC Fan**: BLDC unidirectional, 0.5kW, 10A
xEV Solutions
Mapped to Power Semiconductors

- Start/Stop
- Coasting, Crawling
- Boosting

Power Semiconductor Devices

12V
- Start/Stop
- MOSFET(30...60)V

48V
- Coasting, Crawling
- Boosting
- MOSFET(60...100)V

(120-150)V
- Coasting, Crawling
- eDriveLight
- MOSFET (150...200)V
- CoolMOS™ (500...650)V
- IGBT (400...650)V

400V
- eDrive
- CoolMOS™ 650V
- IGBT 650V

(650-900)V
- eDrive
- CoolMOS™ 800V
- IGBT (850V,1200V)

Hybrid Types
- Plug-In Hybrid
- Full Hybrid
- BEV
- µ Hybrid
- Mild Hybrid

Log(Installed Power [kW])

- 10
- 1

Infineon
EVS 28
Possible MOSFET solution

- Discrete devices mounted on IMS
- Parallel connection of many MOSFETs necessary
- Good cooling conditions
- Flexible design – standard MOSFETs can be used

- Bare dies mounted on DCB
- Parallel connection of less devices
- Excellent cooling conditions
- No flexibility – bare dies is normally an ASIC
Functional Automotive Safety is a must for (H)EV Applications, Including 48V

All Components need to be considered in Safety Assessment

Compliance with ISO26262 to be proven with:
Safety Path, Redundancy, Diversity …

Semiconductors and especially the Microcontroller HW and SW as decision making part is a critical component in the system.
## Safe: Motor Position Sensing

### Functional Safety Concept at Sensor Stage

<table>
<thead>
<tr>
<th></th>
<th>Today</th>
<th>Next Generation for Functional Safety Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discrete</td>
<td>Redundancy in Package</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Two or more sensors within a single IC Package.</td>
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<tr>
<td></td>
<td>• Sensor chips on both sides of a leadframe.</td>
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</table>

System architecture determines best fitting option.
AURIX HW measures supporting safety

- **A**: Redundant, spatial separated peripherals
- **B**: Bus Monitoring Unit
- **C**: Safe DMA
- **D**: Safe SRI
- **E**: SRAM ECC (DECTED with enhancements to detect multi bit failures)
- **F**: Flash ECC (SECDED with enhancements to detect multi bit failures)
- **G**: Lockstep core
- **H**: CPU self tests (90% Latent Fault Metric)
- **I**: Memory protection core
- **J**: Memory protection peripherals
- **K**: Safe Interrupt Processing
- **L**: Flexible CRC Engine (FCE)
- **M**: IO Monitor
- **N**: Clock Monitoring
Safe:
Safety Documentation and Support

• One safety case for the complete family
• Best in class safety requirement tracking
• Development in close cooperation with ISO26262 accreditation bodies like Exida and TÜV
• AURIX is developed following ISO26262
  – Infineon's process will be assessed by independent instance
• AURIX is documented following ISO 26262
  – Safety Case
  – Safety Manual
  – FMEDA (internal document, available for safety audits)
  – Safety Concept (internal document, available for safety audits)
  – Infineon's documentation will be assessed by independent instance
• Safety Application Guides
• Safety Support
TLF35584 System Supply for Safety-Relevant Applications - Overview

**Power Management**

**Pre-Regulator**
- Synchronous Buck
- Optional Asynchronous Boost
- Enable & Wake/INH
- External Core-Voltage Supply
- Timer
- State Machine

**Post-Regulator**
- μC-Supply
- Communication-Supply
- Sensor-Supply
- Voltage-Reference
- Standby-Supply
- Internal Supply, Bandgap, Clock

**Functional Safety**

- Window-Watchdog
- Functional-Watchdog
- Safe State Controller
- Electrical Isolation
- Voltage Monitoring
- Reset/Interrupt Generator
- Built In Self Test
- Bandgap, Clock
- Safe State Control
- Built In Self Test

**μC-Interface**
- SPI

**Diagram**

- Logic Buck-Regulator
- Feedback
- µP Supply
- LDO1: 3.3V (5V)
- Communication Supply
- LDO2: 5.0V
- Sensor Supply Tracker 1: 5.0V
- Tracker 2: 5.0V
- Internal Supply
- Timer
- Clock
- SPI
- Enable & Wake/INH
- Internal Supply, Bandgap, Clock
- Functional - Watchdog & Window-Watchdog
- Safe State Control
- Optional Asynchronous Boost
- Enable & Wake/INH
- External Core-Voltage Supply
- Timer
- State Machine
- Pre-Regulator
- Post-Regulator
- μC-Supply
- Communication-Supply
- Sensor-Supply
- Voltage-Reference
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- Safe State Controller
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- Built In Self Test
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**TLF35584**
TLF35584 System Supply
Functional Safety

**μC-Interface**
- SPI

**Functional Safety**
- Window-Watchdog
- Voltage Monitoring
- Functional-Watchdog
- Reset/Interrupt Generator
- Safe State Controller
- Built In Self Test
- Electrical Isolation
- Bandgap, Clock

**μC: Clocks and Interrupts**
- RO (μC)
- Interrupt
- CHIP SELECT
- CLOCK
- DATA_IN
- DATA_OUT
- Trigger
- /ErrorPin
- Safe State 1
- Safe State 2 (signal delayed)

**Internal Supply**
- Clock
- Bandgap 1

**Pre-Regulator**
- Bandgap 2

**Post-Regulator**
- Voltage Monitoring/Reset Generator
- Window Comparator

**Standby Regulator**
- Interrupt Generator
- Safe State Control

**External Core-Supply**
- Functional-Watchdog
- Window-Watchdog

**Integrated Functions**
- Internal Supply
- Pre-Regulators
- Post-Regulators
- Standby Regulator
- External Core-Supply
TLE9180 – ISO 26262 Relevant Bridge Driver

Optimized Feature set
2 or 3 OpAmps
Basic/Enhanced Features

Suitable for a wide range of applications

Demoboard/kit available

LQFP-64 package available

Worldwide success
48V Systems
TLE9180 - next Generation Driver IC

Power Supply
incl. Diagnostic & Safety Functions

SPI Interface

Direct Input Control
Input Logic
Shoot Through, Dead Time

Diagnostics
Failure Detection
Diagnostic Test(s)
and Error Logic

Floating HS driver
incl. diagnostics

Floating LS driver
incl. diagnostics

Current Sense Block
(OpAmps for GND-related shunt measurement)