Electrification of the auxiliary accessories in Electric Drive Vehicles (EDV’s)

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**EDVs growth driven by power semiconductors**

**Average EDVs semiconductor content by degree of electrification**

<table>
<thead>
<tr>
<th>48 V</th>
<th>HEV / PHEV</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ICE</strong></td>
<td><strong>total</strong></td>
<td><strong>total</strong></td>
</tr>
<tr>
<td>Adder for DCDC and starter / generator</td>
<td>$414</td>
<td>$709</td>
</tr>
<tr>
<td>$338</td>
<td>$29</td>
<td>$60</td>
</tr>
<tr>
<td>$47</td>
<td>$76</td>
<td>$15</td>
</tr>
<tr>
<td>Gate Drivers and Power switches (Si, SiC, GaN?)</td>
<td></td>
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</tr>
</tbody>
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**2020: 1.6m* **
- high growth for 48V (not even including 48V auxiliaries nor mild hybrid)

**2020: 3.5m HEVs* 1.9m PHEVs**
- PHEV to overtake HEV after 2020, especially in Europe

**2020: 1.4m EVs**
- strong growth driven by Chinese OEMs and Tesla

*Source: IHS Alternative Propulsion Forecast - Jan 16, expected number of vehicles
System level trends and drivers

What are the system trends and drivers in the market?

- **Tougher CO2 and emission regulations**
  - 2020: EU 95gCO2/km, Japan: 105gCO2/km
  - 2025: China: 95gCO2/km, USA: 54.5 mpg (≈109 g CO2/km)
  - EURO 6c >2017: Real Driving Emission (RDE)

- **Interference with other frequency bands used in vehicles accentuate EMC challenges**
  - Increased power density
  - Switching of high currents (>400A) with high frequencies (6-20kHz), DCDC up to 100kHz

- **New battery technology and lower cost/kWh enabling competitive vehicle prices**
  - Battery cost and performance is a big lever and has direct impact of vehicle price
  - Inverter efficiency plays a role: SiC switches may improve efficiency

- **Need for Power and range**
  - Average user likes to have same or better acceleration and power than combustion cars.
  - Range of EDVs should approach that of a combustion car, need for high battery capacity (50kWh and up).

Electrification of the drivetrain

Increased EMC requirements

HV battery price drops

High battery capacity and low weight.
Auxiliary Application on EDVs: from mechanical to electrical solution HV drivers are needed

Electrification takes away loads that used to be branched the traction motor shaft, like HVAC, oil/water pumps, fans and brings more flexibility by decentralizing these actuators without the use of gears or belts.
Automotive gate driver portfolios for HV applications

**Level-Shift**

- Junction Isolation (JI)
  - Monolithic solution with guard ring (red) to separate input side from output side and to allow high voltage swings (600 V/1200 V) at output section of the chip.
  - Level-shifting circuitry (purple) inside guard ring to transmit switching information between input and output and diagnostics in the opposite direction.

**Galvanic Isolation**

- Coreless Transformer (CT)
  - Two isolated chip ensures galvanic isolation.
  - Isolation allows very large voltage swings (±1200 V or more).
  - Coreless transformers are used for transmitting switching information between input chip and output chip.
Block Schematic of an High Voltage system

- **Battery (250V-450V)**
- **Main inverter 50-100 kW**
- **HVAC 1 - 3kW**
- **Main HV bus**
- **Secondary HV bus**
- **Oil pump < 500W**
- **Fans, Water pump < 500W**
- **DC/DC from HVbus to 12V 2-3kW**
- **Isolated driver**
- **HVJI driver**
High Voltage ICs & Drivers
Explanation of segmentation

› Gate drivers for IGBT’s and SIC/MOSFET’s for EDV high voltage applications.

› Segmentation parameters
  – Non isolated drivers
  – Isolated drivers

› Isolated drivers
  – Used mostly (or only so far) in the main inverter drive for traction in (H)EVs, the main task of these devices is to drive properly and protect the large size IGBTs (200A, 10x10mm or more) used in this application. Isolation is needed for safety and functional reasons, protections and programmability of switching parameters is also needed, via SW or HW. Request to develop these devices according to ISO26262. Certification of the inverter system to ASIL C or D is required.

› Non isolated drivers
  – These products are mostly used in the auxiliary inverters, like for compressors, fans, pumps and SMPS. In this market, galvanic isolation is normally not needed at the drivers level. Protections are necessary, however no programmability is usually requested. These drivers are usually mainly analog, made in a high voltage but not very sophisticated technology (HVJI or SOI).
  – These drivers (at 100V/200V) are also most suitable for the 48V application, in DC/DC and auxiliary drives.
Main inverter drive

Usually uP/DSP board and power board are physically separated;

Cost of uP board is not low and it makes sense to avoid damaging it in case of failures in the power switches and drivers section.

Picture from Bosch web site
Auxiliary Drives – High Voltage HVAC

Application

- Replaces belt driven compressor
- 6 IGBTs + 3 driver ICs
- Power levels ≤ 3-5kW
- Three phase inverter topology for PMDC motors

HV Semiconductor chipset

- IGBTs for relevant power levels
- Easy Modules
- Gate driver ICs

Market Drivers

- Classic 3 phase inverter
- Lifetime
- Switching frequency
- Driver protection features

Galvanic Isolation
 Auxiliary Drives – Oil and water pumps, Fans

Application

- Replaces belt driven fan and pumps
- 6 IGBTs/Mosfets + 3 driver ICs
- Power levels ≤ 0.8 kW
- Mostly Three phase inverter topology in future

HV Semiconductor chipset

- IGBTs/Mosfets for relevant power levels
- Easy Modules
- Gate driver ICs

Market Drivers

- Classic 3 phase inverter
- Lifetime
- Switching frequency
- Driver protection features

Galvanic Isolation
DC-DC Converter

Application

- Wide input voltage range (200V - 450V)
- 14V output up to 3kW
- 4 – 10 MOSFETs or Fast IGBTs
- Future user of SiC
- 2x or 4x HV drivers
- 2x Synch Rectification drivers

HV Semiconductor chipset

- HV MOSFET or ultra Fast IGBT
- LV MOSFET for sync. rectification
- SiC Mosfets
- EASY modules
- Fast gate driver IC

Market Drivers

- Different topologies
- Total efficiency
- System cost driven
- Switching frequency

Galvanic Isolation
On Board Charger (AC/DC)

**Application**
- PFC + DC-DC
- Output voltage 250-450V
- Output power from 3 kWh to 40 kWh

**HV Semiconductor chipset**
- HV MOSFET or ultra Fast IGBT
- EASY modules
- Fast gate driver IC
- HV Diodes
- SiC Mosfets

**Market drivers**
- Different topologies
- System trade-off driven
- Switching frequency
- Universal input

**Diagram**
- PFC + DC-DC
- Output voltage 250-450V
- Output power from 3 kWh to 40 kWh
- HV MOSFET or ultra Fast IGBT
- EASY modules
- Fast gate driver IC
- HV Diodes
- SiC Mosfets
- Galvanic Isolation
- Universal input
- 2ph or 3ph 110V/220V/380V AC input
- HV Li Batt
PTC Heater
Emerging application needed in EDVs

**Application**

- Uses 2-4 IGBTs
- 3-4 Gate drivers
- Uses 600V/1200V IGBTs
- Output power from 2 kWh to 6 kWh

**HV Semiconductor chipset**

- Slow speed IGBTs
- EASY modules
- Gate driver ICs

**Market Drivers**

- Need to warm-up the cabin!
- Cost sensitive application
- No major technical challenges (very low frequency application)
EDVs growth driven by power semiconductors

Average EDVs drivers content by family

Vehicle electrification is a proven path to meet CO2 legislation

Considering the market forecast for number of electric vehicles in the next 6 years and the average number of IC drivers needed by each system, as shown in the previous sides, the graph here above highlights the expected market grow (in volumes) of the isolated and non isolated switch drivers.

*Source: IHS Alternative Propulsion Forecast - Jan 16, expected number of e-vehicles
Conclusions

- Electrification, it's not just about the powertrain: there are several other mechanical axes and systems in the car that will be supplied by the HV battery in the future;
- These systems include HVAC, Oil and water pumps, OBC, DC/DC and PTC-Heater;
- The semiconductor content in a EDV is expected to be more than double what is used in an ICE car;
- Electrification allows flexibility: the motor/actuator can now be located where needed and doesn’t have any more a mechanical connection to the ICE, gears and belt are reduced;
- Auxiliary axis at 12V will move to higher voltage allowing loss and cost reduction. Main benefit is for high power systems like the HVAC, Power steering and PTC-heater;
- Power Electronic companies like electrification: the market for HV switches, modules, gate drivers and motors will grow with a high pace rate in the next 6 years and onwards.
THANK YOU!

Part of your life. Part of tomorrow.