EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

Safety Switches for xHEV and Autonomous Driving Vehicles

Dr. Massimo Venturi[1], Dirk Mandery[2], Christian Brosig[3]

[1,2,3] Eberspächer Controls Landau GmbH & Co.KG, Max-Planck-Str. 3, 76829 Landau, Christian.brosig@eberspaecher.com

Abstract

The automotive industry is facing two major challenges to cope with: environmental targets resulting from the 21st Conference of the Parties in Paris and safety requirements, in particularly for autonomous driving. The diesel gate is forcing the OEM´s to increase the powertrain electrification from xHEV to full battery vehicles to meet the stringent future environmental regulations.

Vehicle electrification and autonomous driving (AD) are challenging the electrical board net of all kind of vehicles. The need to safely disconnect the board net in these kind of vehicles requires certain component features, like fast switching, handling high currents and safe disconnection. These components have to be developed according to ISO 26262 and depending on the application, need to fulfill ASIL B, C or D. This paper describes the recent core development of Eberspaecher Automotive Electronics.

Keywords: autonomous, battery management, BEV, PHEV, safety

1 Introduction

With its innovative products and solutions, automotive supplier Eberspaecher is making an active contribution to environmentally sustainable, comfortable and safe mobility. In exhaust technology, fuel operated and electrical vehicle heaters, air-conditioning systems and automotive electronics, Eberspaecher is one of the sought-after innovation partners of the international automotive industry.

The Automotive Controls division has been established in 2014 and specializes in high-performance, reliable products for power distribution, energy management and comfort systems. Eberspaecher's contribution to autonomous driving in the vast range from sensors to actuators is safe and intelligent power distribution in terms of MOSFET based switches. The electronics specialists within the group of companies develop and manufacture products in Germany (Landau and Esslingen) as well as Canada (Toronto) for the global automotive market.

Vehicle electrification and autonomous driving are challenging the electrical board net of all kind of vehicles. The need to safely disconnect the board net in these kinds of vehicles requires certain component features, like fast switching, handling high currents, and safe disconnection. Eberspaecher develops tailor-made solutions for customer specific electrical board net architectures.

2 Vehicle architecture

Each OEM has its own electrical board net architecture. So, even if the main functions are almost equal, in detail they differ a lot in component requirements. Starting from the typical Start/Stop function, we can distinguish three main topologies:

- 1 battery topology Starter Current Control (SCC) (Fig. 1)
- 2 battery topology with switches (12 V/12 V micro-hybrid topology mHEV)
- 1 or 2 battery topology with switch in HEV or PHEV

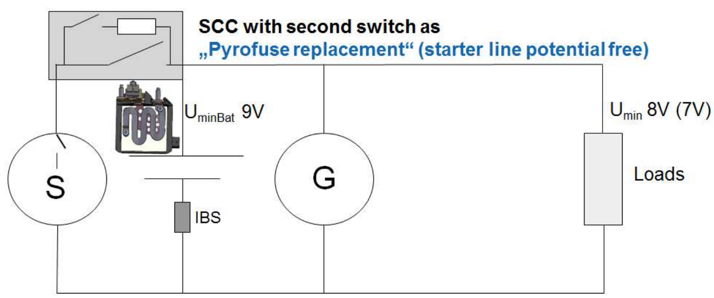

Fig.1: Typical 1 battery topology with Starter Current Control

Figure 2 shows a typical 12 V dual battery architecture, and Figure 3 a possible simplified hybrid configuration.

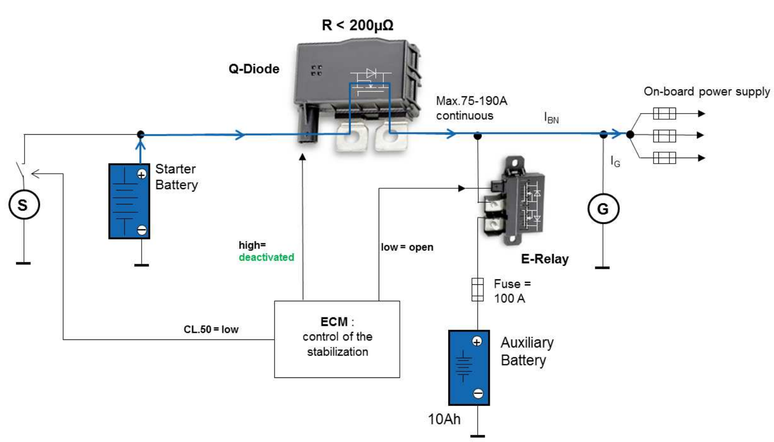

Fig. 2: Simplified dual battery topology (12 V/12 V micro-hybrid)

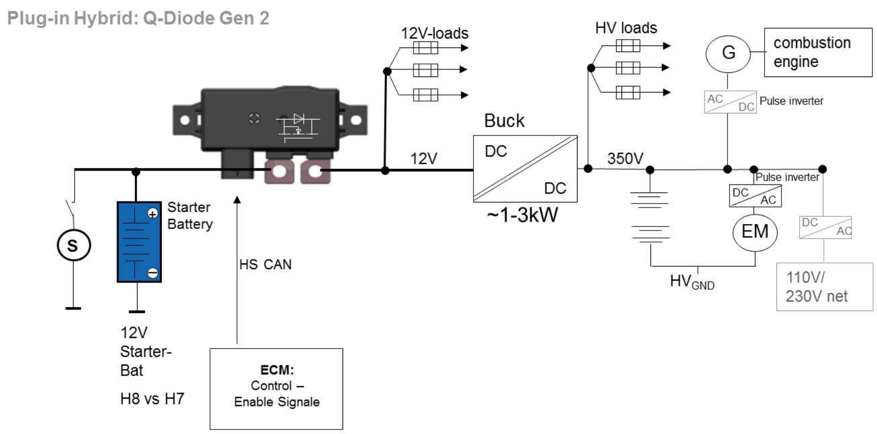

Fig. 3: Simplified hybrid architecture
The high voltage battery (eg: 350 V) can also be replaced by a 48 V battery

Autonomous driving requires a multiple battery topology to fulfill all the safety requirements. In this case a safety switch is absolutely necessary for separating and connecting these two power nets. Eberspaecher Automotive Electronics develops these products related to safety switches for different board net topologies.

The following represents the SAE nomenclature [1] for the autonomous driving levels:

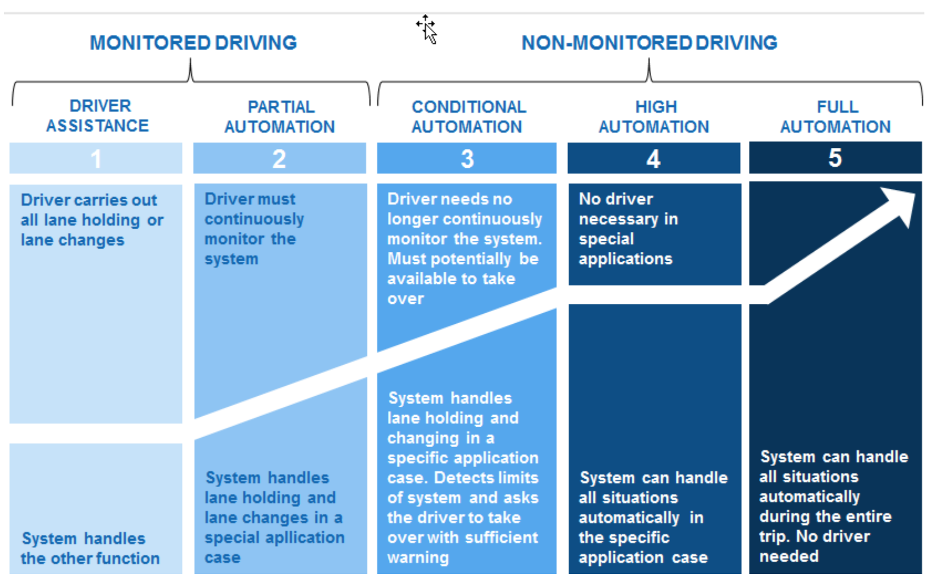

Fig. 4: Nomenclature for autonomous driving levels according to SAE

Depending on the level of autonomous driving the car is developed for, different technical solutions and requirements are needed.

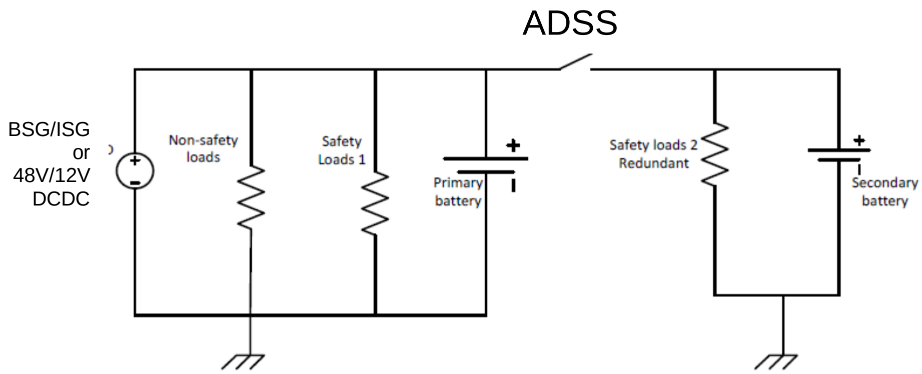

Fig. 5: Simplified Level 3/4 AD EE Architecture of mHEV (12 V or 48 V)

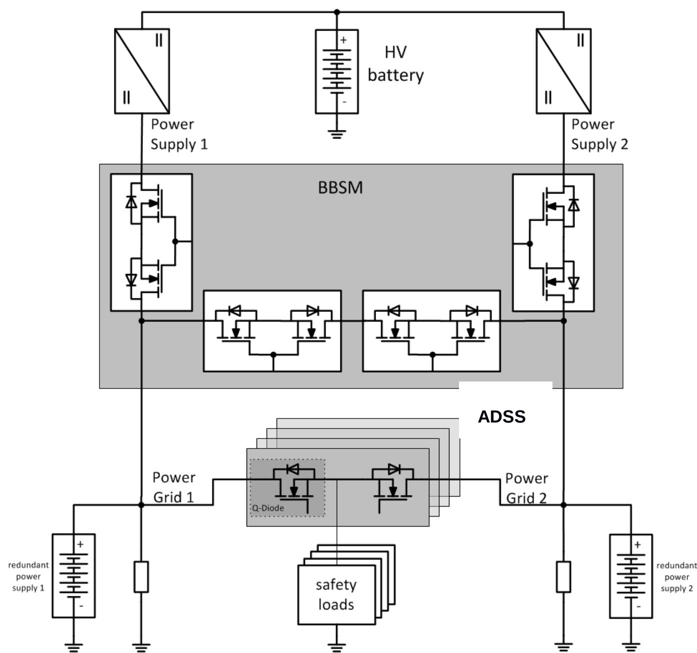

Fig. 6: Simplified Level 5 Autonomous Driving E/E Architecture of BEV

Figure 5 shows simplified 12V dual battery architecture for level 3 and 4 assisted and highly automated driving. Figure 6 shows a possible redundant HV-LV board net of a BEV designed for level 5 Autonomous Driving. In both configurations Eberspaecher’s ADSS (Autonomous Driving Safety Switch) is shown; additionally figure 6 shows the BBSM (Battery and Boardnet Safety Switch). Typical safety loads are actuators like brakes, electrical power steering (front and rear), sensors (e. g. camera, lidar, radar) and the Domain ECU in charge of firewall, eHorizon, Map and Object fusion.

2.1 Vehicle typical requirements

By having so many different board net architectures, decomposing the vehicle board net in vehicle single component requirements is not an easy task. In the past several years' competences have been built up in order to identify if and when modular approach is feasible or requires too much customization. In general, the key vehicle requirements for this kind of board net can be synthetized as follows:

- System ASIL rating B to D
- Redundant supply of components critical to safety (steering, brakes …)
- Failures in the board net must not influence the supply of components critical to safety
- Secure emergency stop (after critical incident within 30 seconds)

2.2 Key component requirements

The key component requirement that can be considered as "common" is the capability to safely disconnect the board net in certain defined cases. Functional safety requirements, the current at different temperature and the maximum current are some of the values that determine the basic design of the switch. In addition to hardware requirements and its technical implementation, different software content makes the switch more or less "intelligent". Both hardware and software requirements need to be developed according to the safety vehicle requirements, which can result in a different ASIL classification, from typically B to D. The typical and essential base requirements are as follows:

- Secure open by command or autonomously (e. g. open after reaching a certain threshold)
- Secure no unintended switching
- Low switching time
- Secure opening of switch under load
- Secure open in case of a voltage failure of the board net
- Secure open in case of a short circuit
- Voltage and current measurements of the board net
- Secure diagnostics of the health state of the switch

Depending on application, several different base components have been developed. Figure 7 shows the relevant existing products.

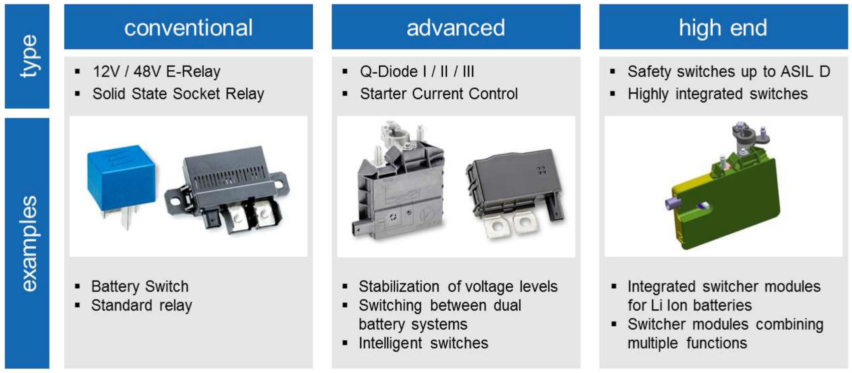

Fig. 7: Typical switches for different applications. From a simple start / stop in single and dual battery configuration up to a HV Hybrid configuration.

2.3 Key test results

Derived from the key requirements the following main items are an evidence of the reliability of Eberspaecher's components.

- High life endurance represented by high switching cycles (T_{amb} = 125°C, I_{switch} = 200A)

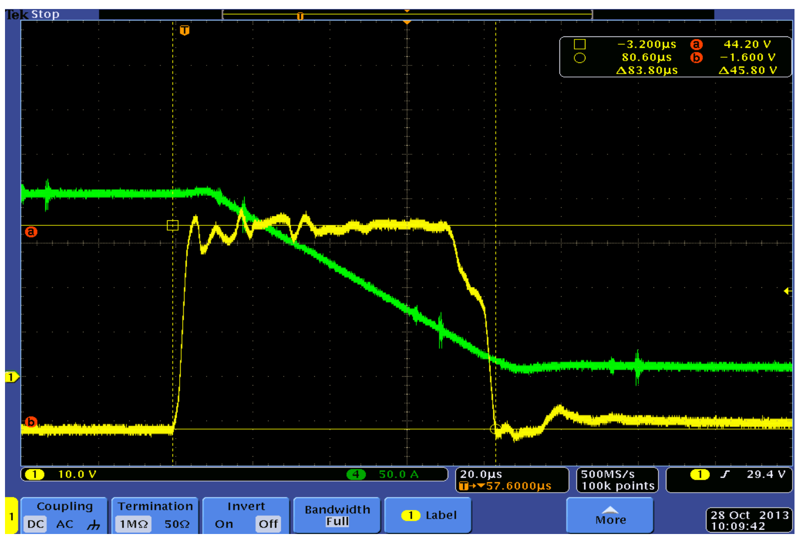

Fig. 8: Avalanche Pulse at typical life endurance test. Test end at 1,2 Million switching cycles without wear out

- Robustness in typical external failure cases

Switches in high current path cannot be protected against overload with temperature sensors. Therefore another smart protection solution is necessary.

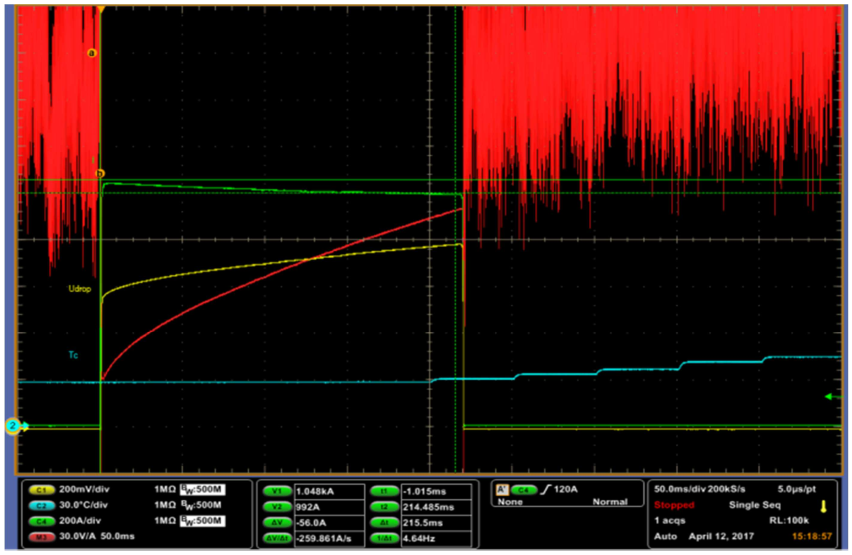

Fig. 9: Short circuit/overcurrent protection of a power MOSFET (overcurrent 1000A);
goal: switch off before reaching maximum temperature Tj.
C1: Udrop = voltage over Drain-Source; C2: Tc = Case temperature MOSFET; C4: I = current; M3: Tj = junction temperature MOSFET

Also in case of current flow through the intrinsic diodes of a power MOSFET it is not sufficient to only protect the MOSFET with temperature sensors. Thus a short circuit/overcurrent was developed.

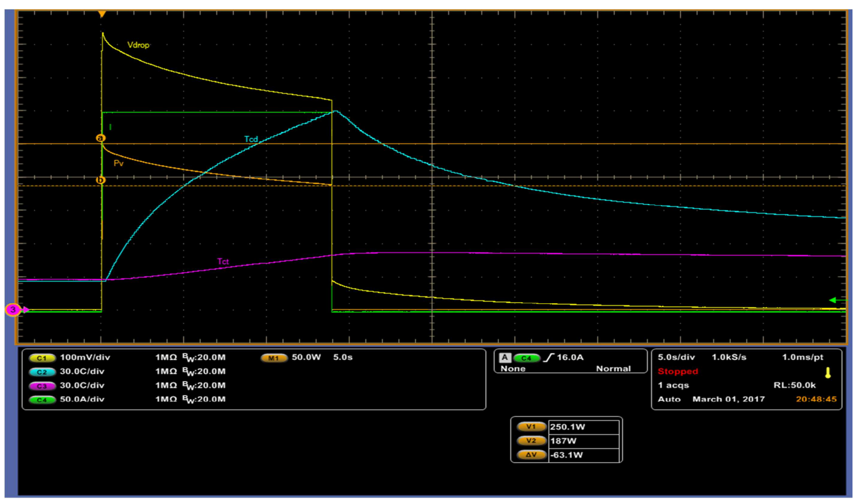

Fig. 10 short circuit/overcurrent protection of a power MOSFET (overcurrent 300A over the intrinsic diodes); goal: switch of the MOSFET as long as they can.
C1:U_{drop} = voltage over Drain-Source; C2: T_{cd} = silizium diode voltage MOSFET; C3: T_{ct} = temperature tab MOSFET; C4: I = current; M1: P_v = power dissipation bodydiode

- Self-Diagnostic:

Whether coasting, start/stop or autonomous driving, Eberspaecher Automotive Electronics detects with patented self-diagnostics, the switch to be closed, opened or defect (low or high ohmic), with a 100% reliability.

switch open switch closed switch defect

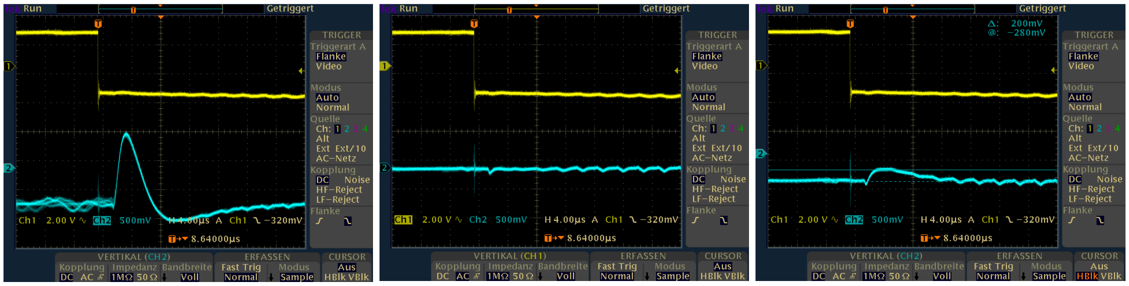

Fig. 11: Patented self-diagnostic proofs 100% detection of low and high ohmic short circuits of MOSEFT

3 Conclusions

The youngest division of the Eberspaecher Group is leader in safe switching of high currents based on PCB's technology. From less complex products for start-stop functions in different kind of E/E-architectures, the team is evolving the product portfolio to high performance safety switches and systems for autonomous driving vehicles. A no wear-out component for safety application is certainly an obvious gain. Mastering high currents with high switching frequency and in parallel controlling the thermal behavior is the core competence of the development team. With this key knowledge it is possible to transform the product portfolio from start-stop to automated driving. Several new products are currently under development in co-operation with leading car makers. The fulfillment of customer requirements by maintaining a higher degree of concept modularity is a challenge. If automated driving is taking place at the announced pace, it is necessary that more standardized requirements or standards will be agreed by the car makers to drive the costs down.

Acknowledgment

The authors acknowledge S. Wandres for his creativity and commitment to search for innovative solutions in PCB based switches.

Nomenclature

OEMs – Original Equipment Manufacturer

BEV – Battery Electric vehicle

HEV – Hybrid Electric vehicle

mHEV – Mild Hybrid Electric vehicle

PHEV – Plut-in Hybrid Electric vehicle

ASIL B, C or D – Automotive Safety Integrity Level (Levels A to D)

ADSS – Autonomous Driving Safety Switch

BBSM – Battery and Boardnet Safety Switch

MOSFET – metal oxide semiconductor field-effect transistor

E/E architectures – electrical / electronic architecture

PCB – printed circuit board

References

1	SAE International	Society of Automotive Engineers
2	Haus der Technik	E/E-Architekturen zukünftiger Stopp-Start-Systeme (Brosig; 2012)

Authors

Dr. Massimo Venturi

is General Manager and Head of BU Automotive Electronics bringing long experience in transforming organizations from start-up to fully automotive compliance. He drives innovation and process implementation to stabilize development and production.
For about 10 years he was leading a fuel cell company bringing technology maturity on the road.
He is author of several papers.

Christian Brosig

is Director Sales, Key Account and Product Management of BU Automotive Electronics and Special ECU. With more than 12 years automotive E/E experience in leading roles he has a deep market insight in automotive electric board nets and electronics. Market trends, acquisition of new products and entering new markets are his speciality.

Dirk Mandery

is Director Research & Development of Eberspaecher Controls Landau. Working in the industry in leading positions for 13 years he brings lots of experience in processes and is pushing innovations which help the company facing new market challenges.
He has worked in the development of several patents.