

Driving Zero Emissions by SCALE-2

*A flexible and competitive solution for converter systems
of the class below 100kW*

CONCEPT has designed the most compact plug-and-play drivers on the market for the latest automotive IGBT modules from a range of manufacturers.

These designs demonstrate the outstanding capabilities of SCALE-2 technology in exploiting the full power of the challenging 650V IGBT modules dedicated to full electric and hybrid electric vehicles, and clearly show the high potential of future developments in custom-specific chipset and gate drivers.

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The potential for reducing carbon emissions by electrifying transportation has caught the attention of local and national government officials due to concerns about the contribution of transportation emissions to climate change. In 2009, the U.S. federal government highlighted electricity as a promising alternative to petroleum for transport purposes. An official domestic goal of putting one million electric vehicles on the road by 2015 was established, and a range of public policies to encourage electrification has been implemented by federal, state, and local governments [1]. In Asia-Pacific, there are various national-level initiatives and programs to promote the awareness of electric vehicles. China will be the largest Asia Pacific market for electric vehicles over the next five years, representing 53% of the region's total sales during that period. The vast majority of China's EV fleet will be full electric vehicles, driven by a strong push behind this category by the central government. In contrast, plug-in hybrid electric vehicles will be the largest category in Japan, which is expected to be the region's second-largest market for all EVs [2]. The enabling technologies for EVs include the gate drivers used in the related power converters since integration level and intelligent control substantially contribute to increasing power efficiency and reliability while offering the potential for reducing the total cost of the system.

CONCEPT - an independent and highly experienced gate-driver supplier
CT-Concept Technologie AG has over 25

years of experience as a technology and market leader in high-power IGBT gate driver electronics. Our SCALE-2 chipset [3] achieves the highest integration level seen on the market for 2- to 6-channel gate-drivers. It has a bidirectional transformer interface and integrated isolated DC-DC converters offering 2.5kV safe insulation, enhanced monitoring, increasing overall system efficiency by integrated Advanced Active Clamping, and various customization options by means of a single mask-programmable integrated analog and digital array. Since the start of series production in 2008, this chipset has been tried and tested in large quantities within a wide diversity of applications. The recently introduced technology demonstration platform for full electric vehicle gate drivers is a next step in the evolution of highly integrated gate drivers with the goal of further reducing costs while enabling highest flexibility to allow a rapid response to various customer demands.

Furthermore, CT-Concept Technologie AG contributes to increasing energy efficiency for power transmission and distribution by new technologies such as direct paralleling, master-slave operation, and Dynamic Advanced Active Clamping which have recently been introduced with the new high-voltage and high-power plug-and-play gate drivers.

The particular demands made on recent IGBTs and their gate drivers, such as advanced monitoring and maximum utilization of the IGBTs at the edges of the Safe

Operating Area (SOA), lead to a greater increase in complexity and development effort. Application specific integrated circuits (ASICs) are advantageous here because they reduce system complexity and therefore lower manufacturing costs while increasing reliability and system performance.

It is obvious that the best price-performance ratio can be achieved by choosing adequate technology and by large volume production. However, very few products reach this level of market demand. It is the inherent strength of CONCEPT as an independent and highly experienced gate-driver supplier to overcome the obstacles of monolithic integration in this highly specific market. Broad application coverage and a large combined quantity of drivers allow all common driver functions to be combined on a platform of dedicated ASICs.

Highly integrated SCALE-2 platform

The SCALE-2 driver chipset integrates the full functionality of a dual-channel gate driver core with a gate capability of 8A and 1W or even more per channel including control of isolated DC-to-DC conversion with a dedicated startup sequence, isolated bidirectional signal transmission by magnetic transformers, high-performance output stages as well as advanced protection, monitoring and interface functions. The fast signal processing combined with the low drift or divergence and jitter of propagation delay as well as all other relevant driver parameters also simplify the management of IGBTs in parallel or series connection.

Figure 1 shows the simplified topology of SCALE-2 Plug-and-Play drivers. The gate power and current can be easily increased by the use of external low-cost n-type DMOS which are directly controlled by the SCALE-2 chipset at a duty cycle from 0 to 100%. All our new automotive gate drivers use similar interfaces providing several operation modes, fault feedback, and NTC signalization including protection against insulation failure. The IGBTs can be operated in direct paralleling mode to combine the power of several phases of one or more modules.

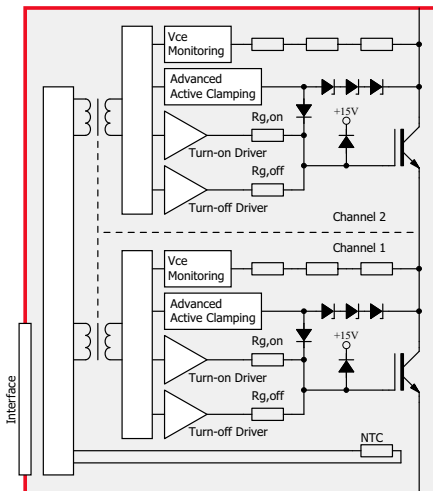


Figure 1: Simplified topology of SCALE-2 Plug-and-Play IGBT drivers

There is no need for synchronization or balancing of load inductances. It is only necessary to apply a common input signal to the gate drivers. Short-pulse command suppression is also available to achieve extreme EMI immunity. The UL-compliant design easily scales up to 1200V, meeting the requirement for 2.5kV safe insulation (to EN 50178 and IEC 60664) and can be adapted to different module types and customer requirements.



Figure 2: Six-channel Plug-and-Play driver 6SP0110T engineering sample made for Infineon HybridPACK™ 1

Six-channel IGBT driver 6SP0110T for Infineon HybridPACK™ 1

The extreme cost saving capability of ASIC integration is demonstrated in the design of the new 6SP0110T six-channel Plug-and-Play IGBT driver, see Figure 2, left. It is adapted for the HybridPACK™ 1 from Infineon, which is a power module designed for Mild Hybrid Electrical Vehicle applications for a power range up to 30 KW and is rated up to 400A/650V.

The gate capability of 8A and 1W per channel is fully assured by the chipset without the need for external active components.

The overall component count is reduced by about 50 % compared to a SCALE driver based on the previous chipset, which allows single-sided assembly.

The DC-DC and signal transformers have been optimized to minimize costs while still maintaining superior performance as regards long-term reliability, thermal stability, coupling capacitance and signal integrity.

The costs of the 6SP0110T or similar custom-specific gate drivers are very competitive, thanks to the very high integration level achieved with the SCALE-2 chipset.

Moreover, the chipset has been developed on the basis of two independent semiconductor processes while retaining full functional and parameter compatibility. Its competitive advantages of exceptional cost performance and long-term availability options will strongly impact its make-or-buy analysis.



Figure 3: Six-channel Plug-and-Play driver 6SP0235T engineering sample made for Infineon HybridPACK™ 2

Six-channel IGBT driver 6SP0235T for Infineon HybridPACK™ 2

Figure 3 shows a similar gate driver adapted to the HybridPACK™ 2 from Infineon. This is a power module designed for Full Hybrid Electrical Vehicle applications for a power range up to 80 KW. It is designed for directly water-cooled inverter systems.

AD

Figure 4 shows the results of turn-off control by Advanced Active Clamping. This advanced methodology allows the switching frequency of the gate driver to be increased by factor of ten or more, compared with simple active clamping. Current designs achieve maximum DC link voltages of 450V at twice the nominal collector current at a junction temperature of 150°C. Particular optimization or other dedicated control such as V_{ce}/dt or dI_c/dt feedback could also be considered.

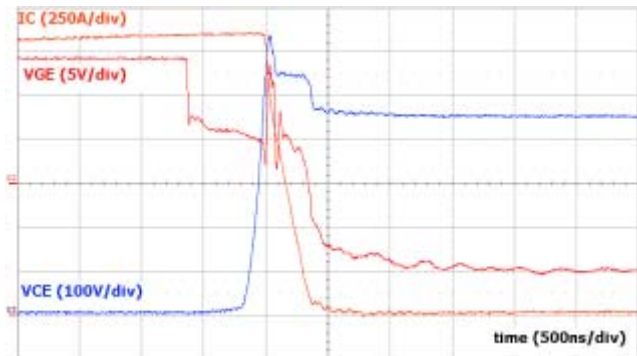


Figure 4: Turn-off of Infineon HybridPACK™ 2 by six-channel Plug-and-Play driver 6SP0235T

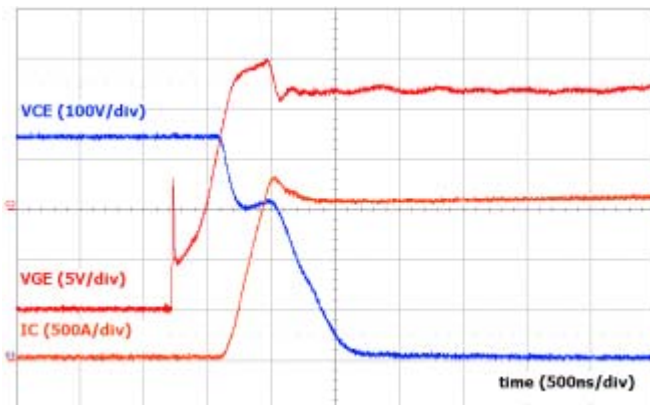


Figure 5: Turn-on of Infineon HybridPACK™ 2 by six-channel Plug-and-Play driver 6SP0235T

Figure 5 shows a turn-on of the Infineon HybridPACK™ 2 by the six-channel Plug-and-Play driver 6SP0235T. The dV_{ce}/dt may also be increased upon customer request.

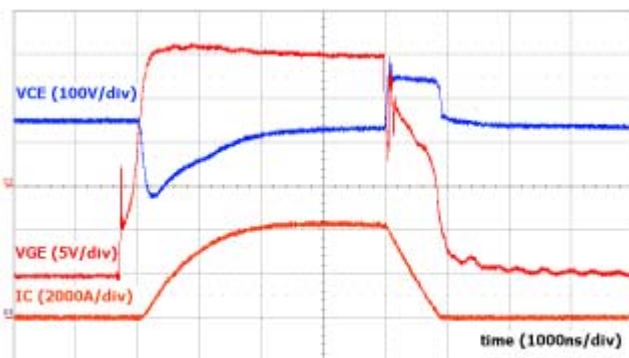


Figure 6: Short-circuit turn-off of Infineon HybridPACK™ 2 by six-channel Plug-and-Play driver 6SP0235T

Figure 6 shows a short-circuit turn-off of the Infineon HybridPACK™ 2 by the six-channel Plug-and-Play driver 6SP0235T. The response time is very short to comply with the particular SOA requirements.

Six-channel IGBT driver 6SP0108T for Fuji 6MBI400VN-065V

Figure 7 shows the six-channel Plug-and-Play driver 6SP0108T made for the Fuji 6MBI400VN-065V. The driver has been divided into two parts which are stacked to achieve a minimum footprint. The design could be further optimized to omit one part.



Figure 7: Six-channel Plug-and-Play driver 6SP0108T engineering sample made for Fuji 6MBI400VN-065V

Custom-specific developments

The gate drivers are designed for a maximum switching frequency of 16kHz for an ambient temperature range of -40 to 85°C under industrial or traction conditions, thus achieving highest reliability for use with full electric vehicles.

Upon request, an in-system qualification will clarify the available margin and design flexibility since the specified operating life time can be reduced according to typical automotive demand.

Since the specified temperature coolant for the HybridPACK™ 2 is 75°C, there is some potential for cooling the driver via the IGBT baseplate since thermal conduction can be provided by the electrical interfaces on top of the module. Furthermore, upon request, the ASICs are also available in QFN packages to enhance their thermal conductivity. Also, the cooling of gate resistors could be improved by several means.

Summary and outlook

It has been demonstrated that SCALE-2 drivers are also a flexible and competitive solution for converter systems of the class below 100kW. Samples of the new automotive gate drivers are available from Q3 2011. Ongoing research based on this technology demonstrator platform, followed by custom-specific developments focuses on further increasing the integration level of future chipsets.

www.IGBT-Driver.com

[1] http://www.indiana.edu/~spea/pubs/TEP_combined.pdf

[2] <http://www.pikeresearch.com/newsroom/electric-vehicle-sales-in-asia-pacific-to-total-1-4-million-by-2015>

[3] J. Thalheim, H. Rüedi: Universal Chipset for IGBT and Power-MOSFET Gate Drivers, PCIM Europe, 2007