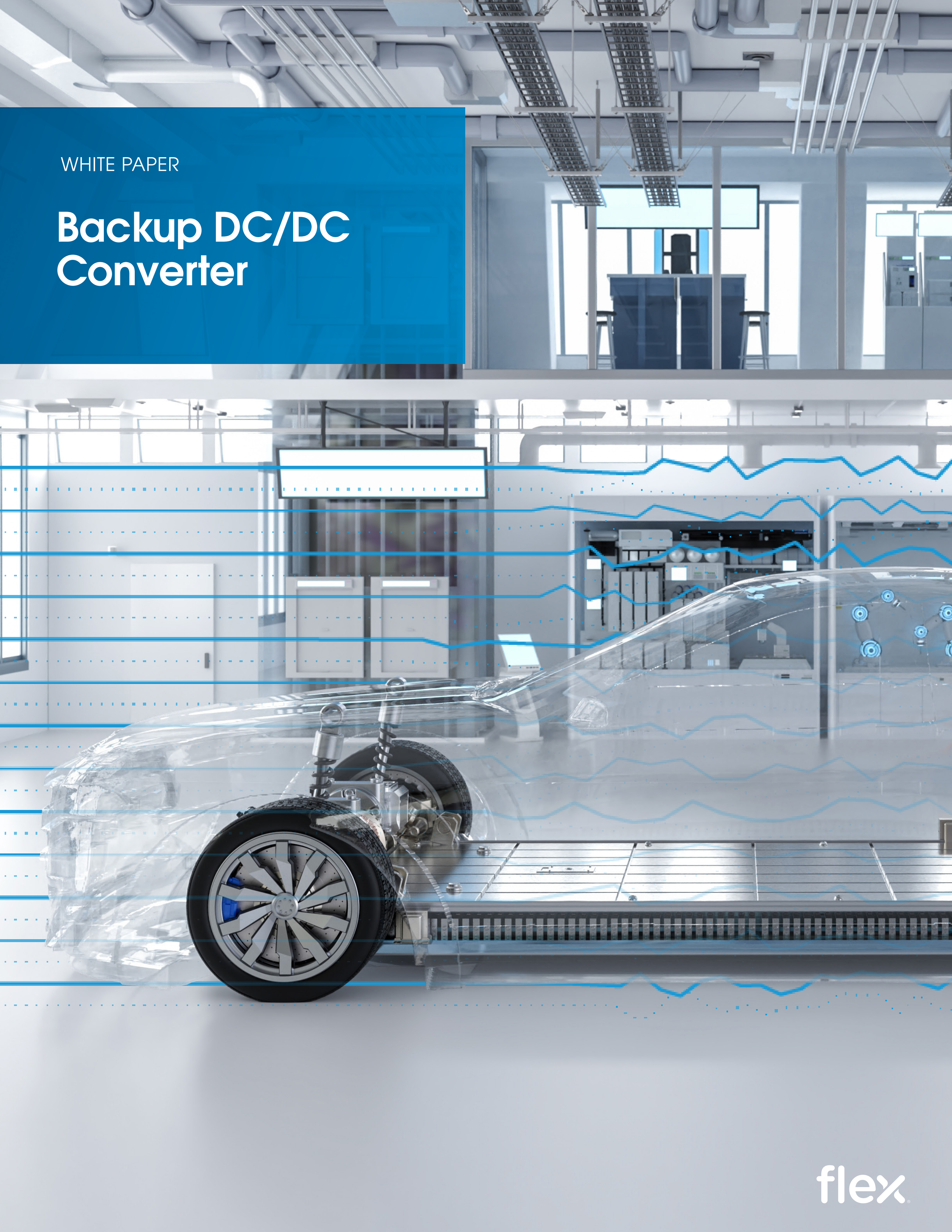
WHITE PAPER

Backup DC/DC Converter



flex

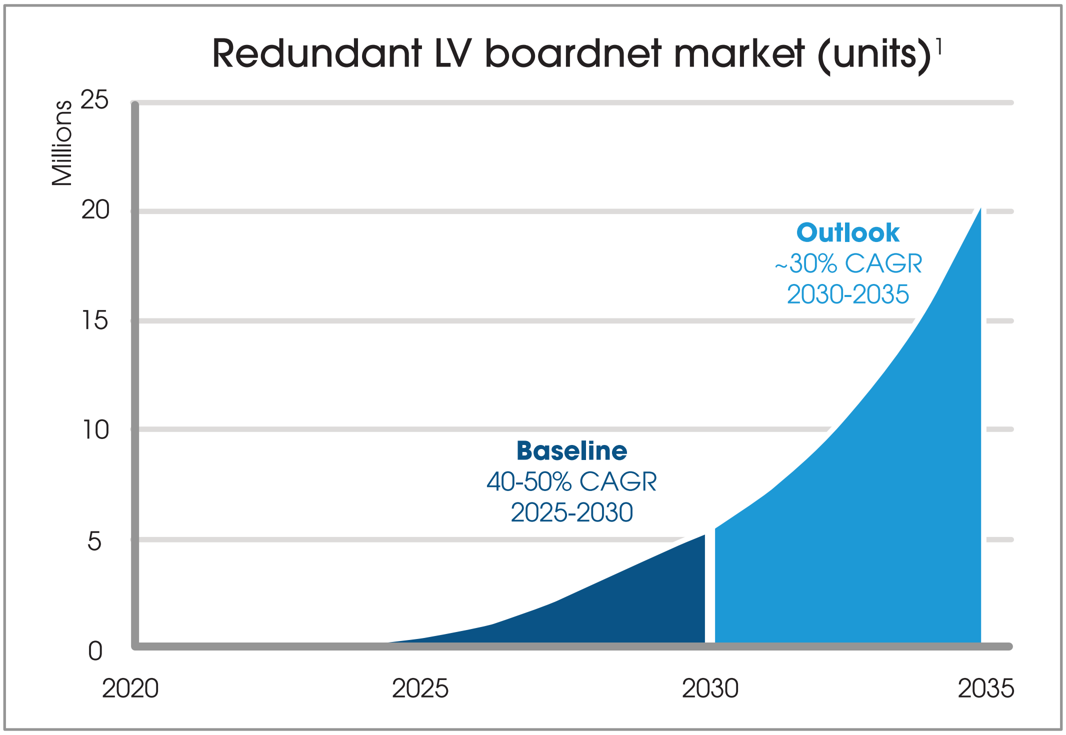
The expanding market for redundant power supplies

As modern vehicles become increasingly complex, the demands placed upon their safety systems and electrical architectures grow exponentially. The proliferation of advanced driver assistance systems (ADAS) and X-by-wire features are driving automakers to incorporate Automotive Safety Integrity Level (ASIL) critical low voltage (LV) loads. These systems require consistent and reliable power supplies for various LV auxiliaries, including during vehicle standby or sleep modes.

These needs have led the industry to adopt redundant board nets for core safety systems within their most advanced vehicles, which will then proliferate through the rest of their portfolios alongside the technologies that require them. This has positioned the redundant power supplies market on the brink of substantial growth, set to exceed the impressive mark of 500 million USD within the next five years[1]. Longer-term predictions indicate that this segment could evolve into a multi-billion-dollar market within the next decade, reflecting a dynamic shift in the automotive sector's demand for enhanced power solutions.

While early concepts have provided a temporary remedy, they do not address the evolving and more complex demands faced by the more robust electrical systems in future vehicles. Beyond the need for improved partial load efficiency, the growing requirements for ASIL compliant power availability, packaging, and weight optimization have become even more critical for developing effective technical solutions that leave a lasting impact. Notably, the costs associated with add-on features must also be closely monitored; any new vehicle concept must remain within acceptable cost targets to ensure market viability and widespread adoption.

To address these challenges, Flex proactively designed a new concept: a HV backup DC/DC converter aimed at catering specifically to the requirements of systems requiring a redundant power supply. This innovative design approach not only enhances power availability but also leverages significant advancements in packaging and weight reduction—achieving an impressive decrease of over 60% compared to existing state-of-the-art solutions. These transformations could yield substantial cost savings, enabling next-generation vehicle concepts to flourish.



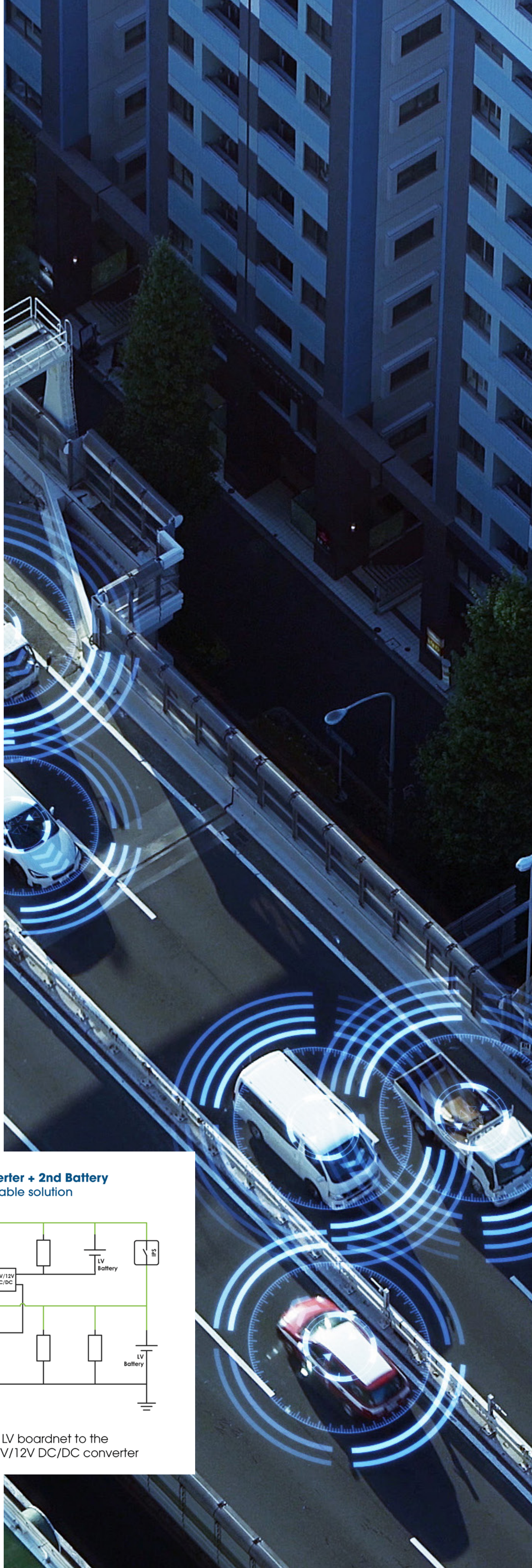
[1] Flex analysis based on data from S&P Global Mobility, TechInsights, and customer conversations

New technologies expand automotive safety requirements

With the advancement of software-defined vehicle technologies leading to the advent of Level 3 autonomous vehicles and the gradual introduction of X-by-wire systems, ASIL-D functional safety requirements have been imposed onto the low-voltage automotive board net that supplies these safety critical systems.

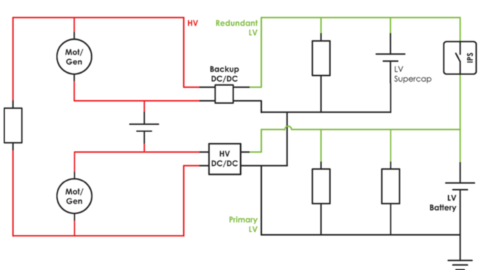
One example of a safety-critical system is steer-by-wire. The system has no mechanical linkage to the steering wheel and therefore no mechanical backup, but it must still be operational even in the event of failure of the main power supply, relying entirely on electrical backup power. Another example can be found in autonomous driving vehicles, where again, in case of a power supply failure the availability of the main ADAS ECUs, which perform processing of key sensor data, must be ensured for a specified amount of time after the failure allowing the human driver to take control of the vehicle.

Modern Level 3 equipped vehicles address the ASIL-D board net requirement by incorporating two independent-but-identical power supplies and dual independent board nets to achieve the associated functional safety goals. This type of redundancy ensures that in the event of a power system failure, critical vehicle functions are not compromised, allowing enough time for the driver to take control of the vehicle and perform a safety maneuver. This is a reliable strategy, but early approaches have treated the two systems as near-identical, rather than two bespoke systems functioning under drastically different operational parameters.



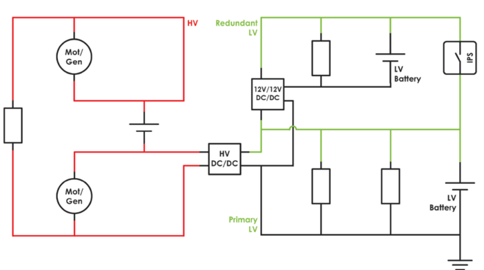
Redundant LV boardnets for L3 ADAS & drive-by-wire

Backup DC/DC Converter
Our purpose-built solution



Connects the redundant LV boardnet to the HV boardnet with a HV Backup DC/DC Converter

12V/12V DC/DC Converter + 2nd Battery
Today's best available solution



Connects the redundant LV boardnet to the primary LV boardnet with a 12V/12V DC/DC converter

Today's leading approach: Backup lead-acid battery + 12V/12V DC/DC converter

Some Level 3 vehicles out in the market today address the ASIL-D challenge with a backup lead-acid battery which is connected to a secondary or backup board net via a 12V/12V buck-boost DC/DC converter. The buck-boost converter has two key functions; firstly, it provides a stable output voltage regardless of the backup battery voltage ensuring the safety critical loads receive a nominal voltage. Secondly, it ensures that the backup lead-acid battery is at a sufficient state of charge and has enough stored energy (including a safety margin) to satisfy the mission profile requirements in case of a failure of the primary board net.

An additional power distribution switch controls the current flow from the primary to the secondary board net and vice versa as required. The switch itself also must be designed according to ASIL-D functional safety requirements.

While this solution leverages proven technology, it has some drawbacks inherent to the lead-acid battery. Lead-acid batteries have notoriously low lifetimes (approximately 3-5 years) due to their low number of discharge cycles. This short lifespan is not ideal for safety-critical systems, where an uninterrupted power supply is crucial. Subsequently, the vehicle owner could potentially have to replace the backup lead-acid battery 3-5 times over the vehicle's expected 15-year operational life – increasing the total cost of ownership of the solution. Another disadvantage of this solution is the low power density, which is a result of both the volumetric size and weight of the lead acid battery.

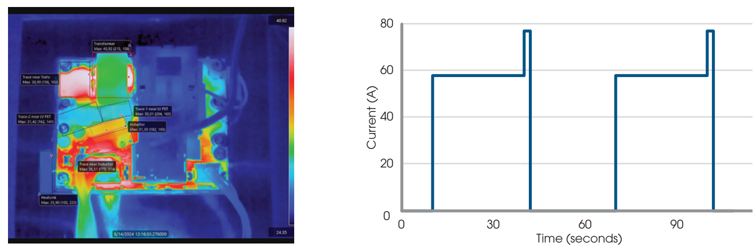
A purpose-built solution: HV/LV Backup DC/DC converter

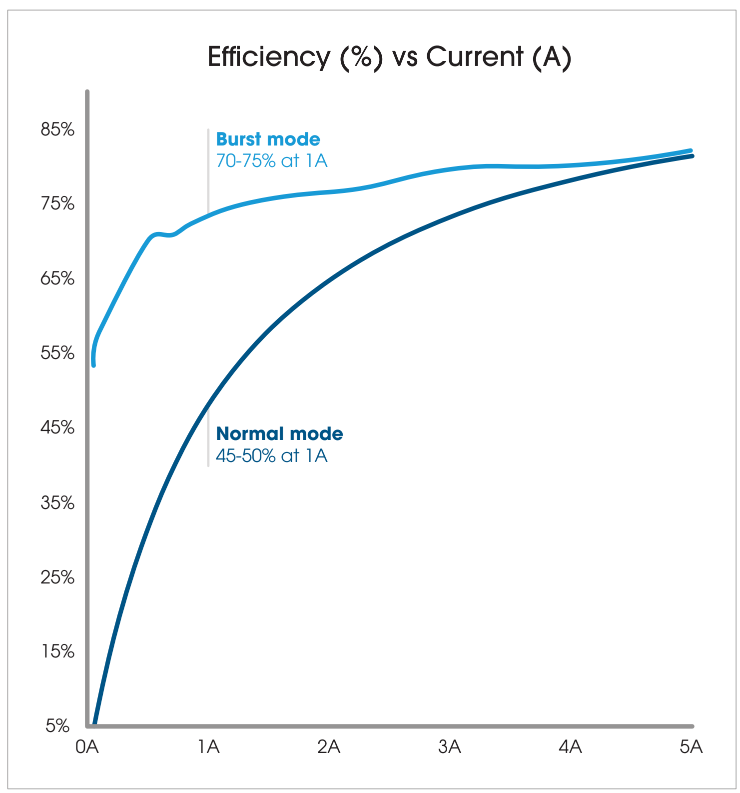
An alternative solution gaining traction in the automotive community for addressing the functional safety challenges of low-voltage board nets—particularly in PHEVs and BEVs where an additional energy storage on the HV side is already available — is to use a high-voltage-to-low-voltage (HV/LV) backup DC/DC converter directly connected to the main battery pack. This configuration also has a secondary backup board net with its own dedicated power distribution network and power switches.

This solution addresses the limitations of the previously discussed approach while offering several distinct advantages. Its most significant benefit is an extended operational lifetime of up to 15 years, compared to the 3-5 year lifespan of lead-acid batteries, making it well-suited for safety-critical systems that demand long-term reliability. Moreover, its performance is generally unaffected by the ambient temperature and state of charge, factors that often pose challenges for battery-based solutions.

The higher power density of the backup DC/DC converter results in a compact size and low weight, providing OEMs with greater flexibility in deciding where to place the module within the vehicle.

Effective thermal management at peak load



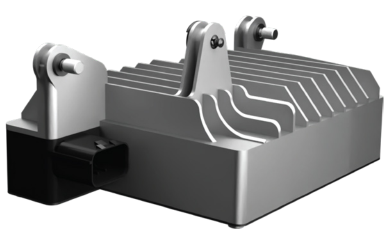


Depending on the current slew rate requirements of the specified load profiles, a smaller backup supercapacitor or battery module may be necessary to handle steep current transients and maintain the voltage within specified limits – avoiding undervoltage on the board net during a failure event. Since the backup energy storage module would only need to provide short bursts of power to handle the large but brief load transients, it would not need to store significant amounts of energy – making it more compact and cost-effective than in the first solution.

Another key consideration is the normal operation of a device like a backup DC/DC converter. Typically, the mission or load profiles require support for continuous output power in the range of 300W to 500W, with peak output current pulses of up to 100A lasting several seconds. However, a backup board net will rarely function under those profiles and will instead spend the vast majority of its lifetime in a very low power and low load environment. Therefore, focusing on improved low-load efficiency must be a key consideration of a backup DC/DC converter; it must be effective in critical, life-saving moments while remaining as efficient as possible in between those moments.

Gen2 in development with significant improvements

Backup DC/DC Converter
Gen1



Automotive News
PACE
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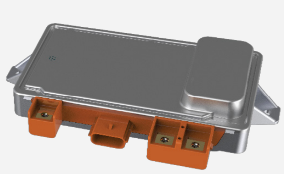
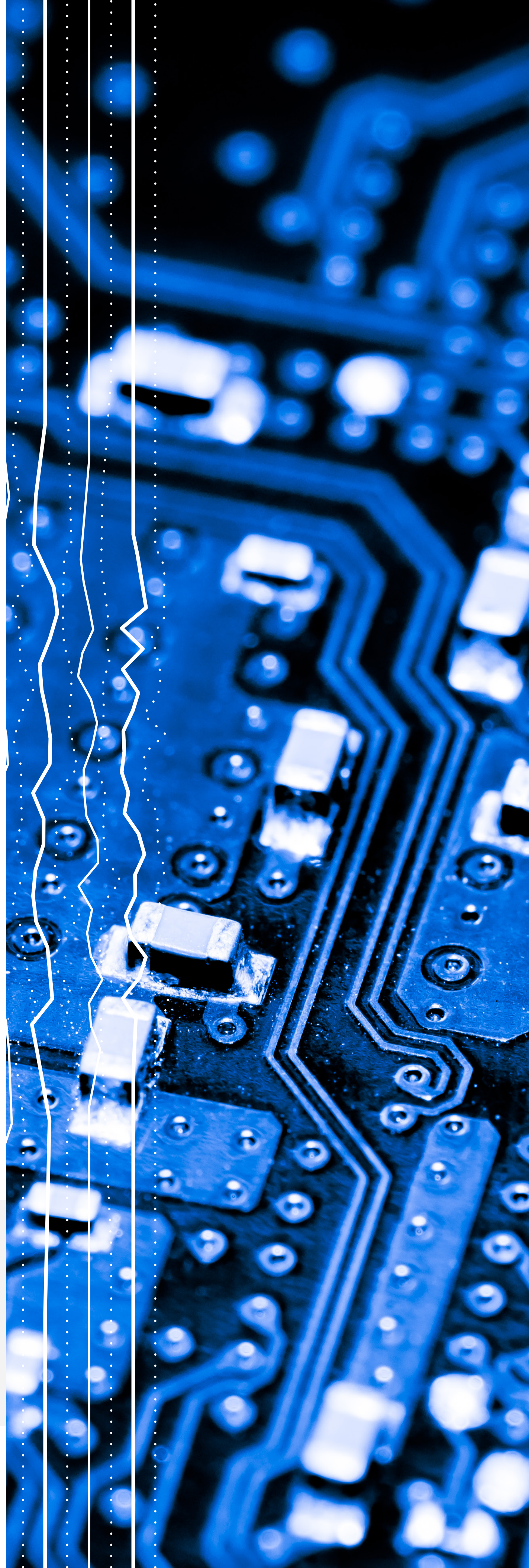
2025 WINNER

Backup DC/DC Converter
Gen2



2x higher power density
50% smaller volume
20% reduced BOM
NEW liquid cooling option
NEW IP6k9k waterproofing



Tangible benefits above and beyond the market standard

Flex's backup DC/DC converter has been successfully implemented in a next-generation BEV platform for a major global automaker with the following device specifications:

- Support for both 400V and 800V platforms
- >300W continuous power,
  >1 kW/L (peak) power density
- Peak efficiency ~94%
- Stand-by power losses of 2W
- Air-cooled solution
- Operational lifetime of 15 years

Flex's backup DC/DC converter is designed for high efficiency, high power density and reliability. It employs a shifted-phase bridge topology with zero voltage switching and a dynamic switching frequency, allowing the converter to adapt to varying loads, and thereby minimizing switching losses and improving overall conversion efficiency. Additionally, the use of SiC MOSFETs on the high voltage stage further reduces both conduction and switching losses.

As a result of its high efficiency and the burst mission profile, Flex's backup DC/DC converter is passively air-cooled, removing the need for a liquid cooling system and further reducing system cost and design complexity.

The first generation of these advanced designs is scheduled to enter production in 2026, generating great anticipation within the industry. Furthermore, plans for subsequent generations, expected to begin production in 2028 and beyond, aim to achieve further reductions in power densities and costs. These developments herald a new era for redundant power solutions, allowing automakers to comply with stringent safety regulations while maintaining the efficiency and performance that modern consumers expect.

Advancing power electronics innovation with STMicroelectronics

The pace of change in the automotive industry, driven by rapid advancements in electrification and software-defined vehicles, creates the need for an increasingly collaborative environment where automakers and their networks of suppliers contribute their respective strengths to address increasing technology complexity and accelerate innovation.

Flex has been collaborating with global semiconductor company STMicroelectronics on next-generation power electronics for BEVs. This includes the adoption of STMicroelectronics products to power Flex's High-Voltage (HV) Combo Units, which combine a primary DC/DC converter and onboard charger to provide an all-in-one power conversion solution for BEVs.

Flex is also leveraging ST's SiC MOSFET technology and Stellar automotive microcontrollers – both of which are vital for the efficient and safe operation of power converters – in our backup DC/DC converter.

Combined with Flex's advanced manufacturing capabilities, the HV combo units and backup DC/DC converters aim to enable automakers to accelerate EV development.

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