MarSum Solutions: Next-Generation EV Powertrains: 800V Architectures and Wide-Bandgap Semiconductors (SiC, GaN)

Electric vehicle powertrain design is rapidly shifting from 400V-class battery systems toward 800V-class high-voltage architectures. The primary driver is simple: higher DC bus voltage enables high power transfer at lower current. That directly reduces current-related conduction losses, decreases copper mass in cabling and buswork, and expands the feasible operating envelope for high-power fast charging and high-performance traction inverters. In parallel, wide-bandgap (WBG) semiconductors are enabling higher-efficiency power conversion. Silicon carbide (SiC) is the primary WBG device family for 800V-class traction inverters today, while gallium nitride (GaN) is gaining relevance in chargers, auxiliary converters, and other high-frequency stages where voltage class and qualification requirements fit. This paper outlines the engineering motivations behind 800V platforms, the major architectural blocks that change at higher voltage, the practical role of SiC and GaN in traction inverters and chargers, and the design challenges that must be solved to ship a robust, compliant, automotive-grade system.

Why OEMs are moving from 400V to 800V

EV power levels have increased across vehicle classes. Faster DC charging, higher continuous traction power, and tighter efficiency targets all push the same constraint in 400V systems: current. As power rises, current rises proportionally for a fixed voltage, increasing conductor losses, connector heating, and cooling burden, while also expanding the volume and mass of copper in the HV distribution network.

800V-class architectures address this by raising the battery pack voltage, which reduces current at a given power level. In practice, the benefits show up across multiple subsystems:

- Faster DC charging: Higher bus voltage enables high charge power without extreme cable and connector current.
- Higher efficiency: Lower current reduces conduction losses in cabling, busbars, contactors, and power semiconductors.
- Reduced mass and material cost: Lower current allows reduced conductor cross-section, which can reduce harness mass and improve routing.
- Improved thermal margin: Lower distribution losses reduce localized heating at connectors and high-current junctions.

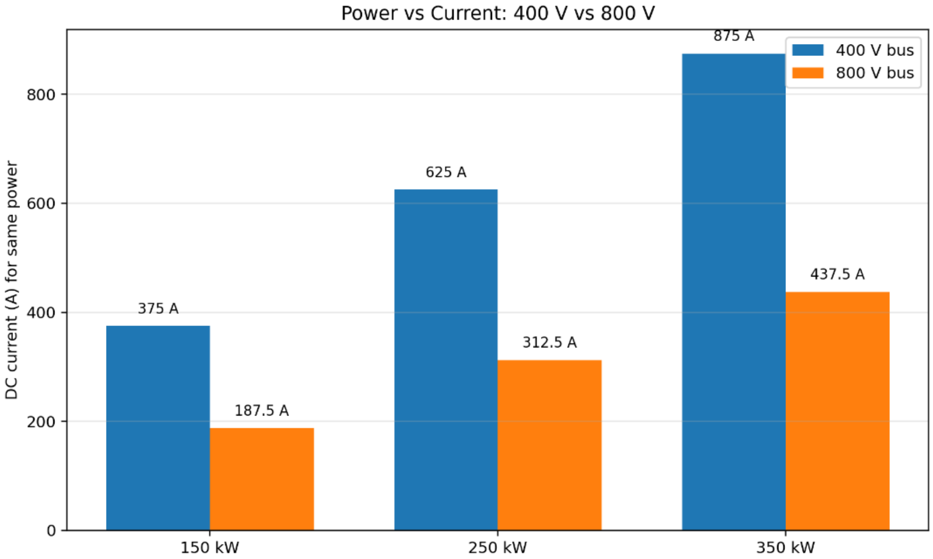

Figure 1: Power vs. Current Comparison

What “800V” means in real designs

“800V architecture” is shorthand. The actual pack voltage varies with chemistry, state of charge, temperature, and operating point. Most systems require margin for switching overshoot, charger and contactor transients, and bus ringing, as well as insulation coordination constraints. As a result, component voltage ratings, derating rules, and overvoltage protection strategy must be addressed early in the design, not corrected later as downstream issues.

800V platform architecture: the blocks that matter

An 800V EV platform is not just a higher-voltage battery. The voltage increase propagates through the vehicle's high-voltage powertrain and supporting energy-conversion systems. A practical way to frame the design is through the major functional blocks below.

High-voltage battery system

- Cell configuration and pack topology for setting nominal and maximum voltage
- Contactor/precharge circuitry, fusing, and HV interlock loop (HVIL) strategy
- Isolated voltage and current sensing for monitoring, control, and fault detection
- Thermal management integration, especially where higher power throughput increases heat flux

Onboard charger (OBC) and HV DC-DC conversion

- AC to DC conversion stage topologies and switching frequency targets
- HV DC-DC conversion and low-voltage rail generation, including 12V and increasingly 48V subsystems
- Isolation, creepage, clearance, and transformer design constraints
- Bidirectional energy flow requirements for vehicle-to-everything (V2X) or regenerative support cases where applicable

Traction inverter and e-machine interface

- DC link capacitor selection and placement
- Power module selection, switching frequency target, and modulation strategy
- Current sensing approach (shunts, Hall, fluxgate) with isolation and bandwidth considerations
- Motor insulation and bearing current considerations caused by common-mode switching behavior
- Control loops: current regulators, torque control, field weakening, and real-time protection interlocks

High-voltage distribution and protection

- Cable and connector selection and temperature rise management
- EMI/EMC filtering placement and grounding strategy
- Surge protection, discharge paths, and safe de-energization behavior
- Diagnostic coverage and fault containment, especially for ISO 26262-aligned programs

A key implication of 800V systems is that integration discipline matters more. Power stage layout, sensor placement, HV isolation, and EMI containment are interdependent problems. Solving them independently often produces late-stage test failures or reliability issues.

Wide-bandgap semiconductors: what changes and why

WBG devices, primarily SiC MOSFETs and GaN HEMTs, enable meaningful performance improvement in high-voltage EV power conversion because they can switch faster with lower switching energy and can often operate at higher junction temperatures than comparable silicon devices. The practical value for EVs is typically not "more power at any cost," but the ability to improve efficiency, reduce thermal burden, and shrink package size at the same system power level.

Silicon IGBTs vs SiC MOSFETs (traction-centric view)

Legacy traction inverters used silicon IGBTs extensively due to cost and maturity. However, in 800V-class systems, especially where designers push switching frequency higher to improve control response or reduce passive component size, IGBT switching loss and diode reverse recovery behavior become increasingly punitive. SiC MOSFETs reduce switching loss and enable higher effective switching frequency without the same efficiency penalty. That can improve inverter efficiency across a wider range of torque-speed operating points and can reduce cooling demand.

Where GaN fits

GaN devices are commonly most attractive in 650V-class applications where very fast switching and high frequency allow smaller magnetics and higher power density. In EVs, this often maps to charger and auxiliary conversion stages more naturally than traction inverters. The industry is evolving quickly, but the engineering selection rule remains stable: pick the device technology that best fits voltage class, switching frequency, thermal design limits, cost targets, and qualification maturity.

Voltage class and headroom reality

An 800V battery does not imply 800V-rated semiconductors. Designers typically require headroom for switching overshoot, bus transients, and aging. This is why 1200V-class SiC devices are common in 800V traction inverters. That headroom is not a luxury. It is part of a robust design margin strategy.

Traction inverter design challenges at 800V with SiC

A traction inverter is the highest power-density and highest consequence block in the EV powertrain. Moving to 800V and WBG changes the design space. It does not remove constraints, it moves them.

Loss mechanisms and switching frequency strategy

Higher switching frequency can improve current-control response, reduce current ripple, and allow smaller passive components, but those benefits must be weighed against added loss, EMI, and insulation stress. Inverter losses include conduction loss, such as current-squared resistance losses (I^2R) and device on-state behavior; switching loss, which depends on energy per transition and switching frequency; and magnetic losses in filtering and motor components influenced by PWM patterns. SiC allows higher switching frequency at acceptable loss, but higher frequency is never “free.” It can increase EMI severity, tighten layout constraints, and increase stress on insulation systems. Selecting switching frequency becomes a system-level optimization:

- Efficiency targets across drive cycles
- Thermal capacity of the cooling system
- EMI/EMC compliance margin
- Acoustic and noise, vibration, and harshness (NVH) considerations related to PWM spectral content
- Control bandwidth and current ripple targets

Gate drive design and protection

WBG devices are fast. That speed is beneficial, but it amplifies sensitivity to parasitics, dv/dt coupling, and noise on control and sensing lines. Gate drive design typically becomes a primary design concern in 800V SiC systems.
Key gate drive considerations include:

- Isolated gate drive with high dv/dt immunity
- Miller effect management (gate-to-drain coupling) and the use of Miller clamps where appropriate
- Gate resistance selection to control di/dt and dv/dt without excessive switching loss
- Robust desaturation and overcurrent protection tuned to SiC short-circuit withstand behavior
- Soft shutdown and fault sequencing to avoid destructive overvoltage events

Power loop parasitics and overvoltage control

At high switching speed, stray inductance in the commutation loop produces voltage overshoot proportional to di/dt. This is why DC link capacitor placement, busbar design, and power module packaging are critical. Practical engineering focus areas include:

- Minimizing commutation loop inductance through physical layout
- Using laminated bus structures where applicable
- Kelvin source connections to decouple power current from gate reference
- Controlled snubbing strategy where needed to manage overshoot and ringing
- Measurement discipline: validating overshoot and ringing with proper probing to avoid false confidence

Thermal design, reliability, and lifetime

WBG power stages can reduce steady-state losses, but reliability is determined by thermal cycling and stress distribution over time, not a single peak efficiency datapoint.
Important reliability drivers include:

- Junction temperature swing during real duty cycles
- Thermal impedance stack from junction to coolant
- Thermal interface material (TIM) selection and lifetime stability
- Mechanical stress management in module attach and interconnect
- Derating behavior under high ambient and degraded cooling performance

For automotive programs, it is also essential to align electrical stress margins with manufacturing tolerances and aging. A design that passes early prototypes but lacks margin can fail in volume due to variation and drift.

EMI/EMC and insulation coordination at 800V

The transition to 800V and fast-switching devices increases the importance of electromagnetic interference and electromagnetic compatibility (EMI/EMC) engineering, as well as high-voltage insulation design. These are frequently the schedule and cost drivers when systems move from lab functionality to production readiness.

Why EMI gets harder with WBG

Fast voltage transitions increase high-frequency spectral content. That increases common-mode currents and can trigger resonant behavior in wiring harnesses, housings, and grounding structures. The inverter, motor, and HV harness often behave as a coupled RF system. EMI issues commonly show up as:

- Conducted emissions exceeding limits on power lines
- Radiated emissions from harnesses and enclosures
- Sensor signal corruption due to common-mode coupling
- Communication faults and intermittent resets driven by ground bounce and dv/dt injection
- Bearing currents and motor insulation stress driven by common-mode voltage

EMI mitigation is not a single filter problem - it is a system-level architecture challenge

High-performance designs typically combine multiple mitigation strategies:

- Switching edge control via gate drive tuning
- Physical separation and shielding strategy for sensitive signals
- Correct filter topology, placement, and grounding approach
- Common-mode choke and differential-mode filter design aligned to the inverter and harness behavior
- Housing bonding and return path control so high-frequency currents flow where intended

Insulation coordination at higher voltage

Higher voltage increases requirements for creepage and clearance distances, insulation system selection, and contamination management. At high dv/dt, partial discharge risk becomes relevant in specific geometries, especially where sharp edges, voids, or field concentration exist.
Important insulation topics include:

- Creepage and clearance targets that match the maximum expected voltage and environment
- Connector selection and HV cable insulation rating
- Coating, potting, and encapsulation strategy tradeoffs
- Validation testing aligned to expected operating environment and life requirements

A recurring theme with 800V systems is that electrical, mechanical, and manufacturing decisions intersect here. Layout geometry and assembly processes can determine whether insulation margins are robust or fragile.

How MarSum supports 800V EV powertrain and wide-bandgap semiconductor programs

MarSum Solutions supports EV power electronics and high-voltage powertrain development with an engineering-first approach focused on performance, robustness, and manufacturability. We typically engage in the areas where 800V programs encounter the highest hidden risk—where small early decisions can create late-stage efficiency shortfalls, thermal margin loss, EMI/EMC failures, or durability problems that are expensive to correct after hardware is frozen.

Our work commonly includes high-voltage architecture definition and feasibility support, including 400V-to-800V tradeoff studies, subsystem voltage-rating selection, and margin strategy across switching transients, parasitics, and insulation coordination. For traction inverters and high-power conversion stages, we support power-stage selection and design refinement—spanning gate-drive strategy, switching behavior verification, loss and thermal modeling, and the physical layout decisions that determine commutation-loop inductance and influence overvoltage stress.

We also provide controls and embedded support for high-voltage power stages, where stability and protection behavior are inseparable from performance. This includes current regulation and torque-control interfaces, fault detection and protection sequencing, real-time monitoring, and estimator development when sensor availability, bandwidth, or noise requires it. Because wide-bandgap devices often increase dv/dt and common-mode noise, we frequently support system-level EMI/EMC engineering as well—mitigation planning, filter and grounding strategy, shielding and return-path control, and test-readiness preparation aligned with program timelines.

Finally, we help teams move from “it works on the bench” to production readiness through validation and qualification planning. That includes derating strategy, failure-mode reviews, test plan development, and risk-focused debug support for prototype and pre-production builds—targeting the issues that most often delay compliance and volume release.

Engagement models

We support customer teams through several engagement models depending on program phase and internal resourcing. This can range from focused technical consulting—architecture reviews, design audits, and risk reduction plans—to deeper co-development support from concept through prototype bring-up and refinement. We also provide targeted debug and performance improvement efforts when programs encounter efficiency, thermal, instability, or EMI/EMC issues, and we support validation readiness by aligning design decisions with compliance expectations and production constraints.

800V-class EV architectures and wide-bandgap semiconductors are enabling higher power density, improved efficiency, and expanded fast-charging capability. However, they also introduce new design constraints that must be addressed intentionally: switching behavior, parasitic-driven overvoltage, gate drive robustness, EMI containment, and insulation coordination. The most successful 800V programs treat these topics as core architecture decisions rather than downstream fixes. A disciplined, system-level engineering approach reduces late-stage test failures and supports a faster path from prototype performance to production readiness.

Selected sources: Infineon wide-bandgap semiconductor materials; Wolfspeed 1200 V SiC MOSFET application materials; Texas Instruments GaN-versus-SiC technical overview.

Contact us today to scope your 800V EV powertrain or wide-bandgap semiconductor power electronics project!