Technical Article

Reduce EV Cost and Improve Drive Range by Integrating Powertrain Systems

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When you can create automotive applications that do more with fewer parts, you'll reduce both weight and cost and improve reliability. That's the idea behind integrating electric vehicle (EV) and hybrid electric vehicle (HEV) designs.

What is powertrain integration?

Powertrain integration combines end equipment such as the onboard charger (OBC), high-voltage DC/DC (HV DCDC), inverter and power distribution unit (PDU). It's possible to apply integration at the mechanical, control or powertrain levels, as shown in Figure 1.

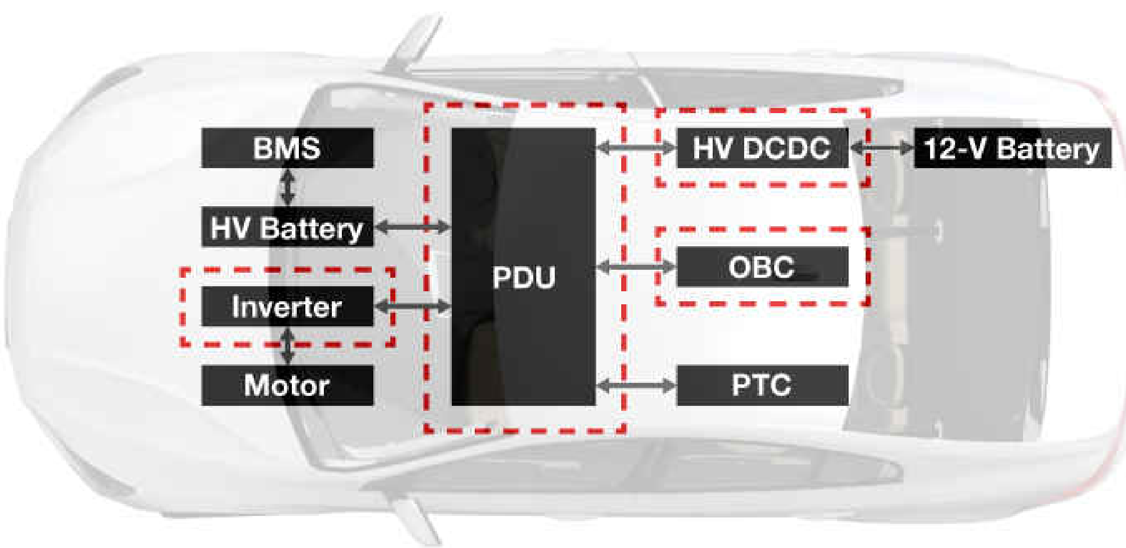


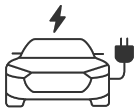
Figure 1. An overview of the typical architecture in an EV

Why is a powertrain integration great for HEV/EVs?

Integrating powertrain end-equipment components enables you to achieve:

- Improved power density.
- Increased reliability.
- Optimized cost.
- A simpler design and assembly, with the ability to standardize and modularize.

A High-Performance, Powertrain Integration Solution: the Key to EV Adoption



Read the white paper

TIDA-020040

Current applications on the market

There are many different ways to implement powertrain integration, but Figure 2 outlines four of the most common approaches (using an onboard charger and a high-voltage DC/DC integration as the example) to achieve high power density when combining the powertrain, control circuit and mechanics. The options are:

- Option No. 1 with independent systems; not as popular today as it was several years ago.
- Option No. 2 can be divided into two steps:
  - Share the mechanical housing of the DC/DC converter and onboard charger, but split the independent cooling systems.
  - Share both the housing and cooling system (the most common choice).
- Option No. 3 with control-stage integration is currently evolving to Option No. 4.
- No. 4 has the best cost advantage because there are fewer power switches and magnetic components in the power circuit, but it also has the most complex control algorithm.

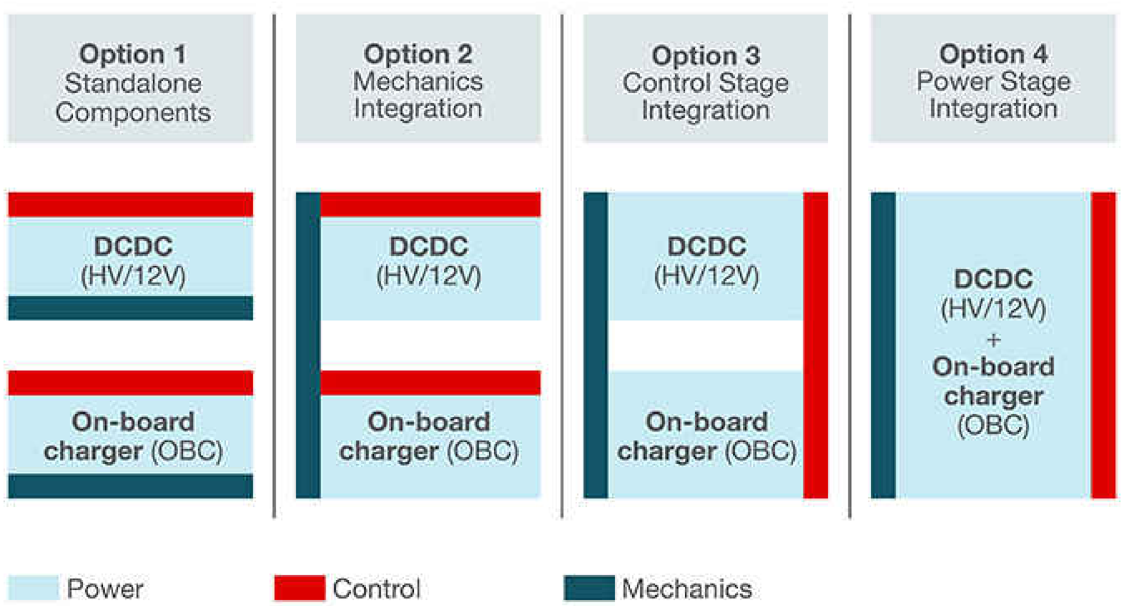


Figure 2. Four of the most common options for a OBC and DC/DC integration

Table 1 outlines integrated architectures on the market today.

Table 1. Three successful implementations of powertrain integration

High-voltage three-in-one integration of OBC, high-voltage DC/DC and PDU optimizing electromagnetic interference (EMI) (option No. 3)	Integrated architecture integrating an onboard charger plus a high-voltage DC/DC converter (option No. 4)	43-kW charger design integrating an onboard charger plus a traction inverter plus a traction motor (option No. 4)
• 6.6-kW onboard charger • 2.2-kW DC/DC • Power distribution unit *Third party data reports that designs such as this can achieve approximately a **40% weight and volume reduction** and a **40% boost in power density**	• 6.6-kW onboard charger • 1.4-kW DC/DC • Magnetic integration • Shared power switches • Shared control unit (one microcontroller [MCU] control power factor correction stage, one MCU control DC/DC stage and one high-voltage DC/DC)	• AC charging power high, up to 43 kW • Shared power switches • Shared motor windings

C2000™ real-time microcontrollers, such as the newly released TMS320F280039C-Q1 MCU, enables EV and HEV powertrain designers to employ both discrete and integrated architectures for OBC-PFC, OBC-DCDC, and high-voltage-to-low-voltage DC/DC applications. In addition, TMS320F280039C-Q1 reduces powertrain size and cost by managing the real-time control for multiple power stages using a single MCU. There are multiple reference designs that highlight how to achieve integration of multiple powertrain subsystem using a single MCU.

Table 2 shows which C2000 MCU product families can help designers achieve various discrete and integrated powertrain topologies.

Table 2. C2000 microcontrollers recommended for differing levels of powertrain integration

Design need	OBC PFC	OBC DC/DC	HV-LV DC/DC
Lowest Isolation Cost	F28002x	F28003x	F28003x
Modular Development	F28004x / F28003x		F28003x
	F28002x	F28004x / F28003x	
Integrated Real-Time Control	F2837x / F2838x		

Block diagrams for powertrain integration

Figure 3 depicts a powertrain block diagram implementing an architecture with power-switch sharing and magnetic integration.

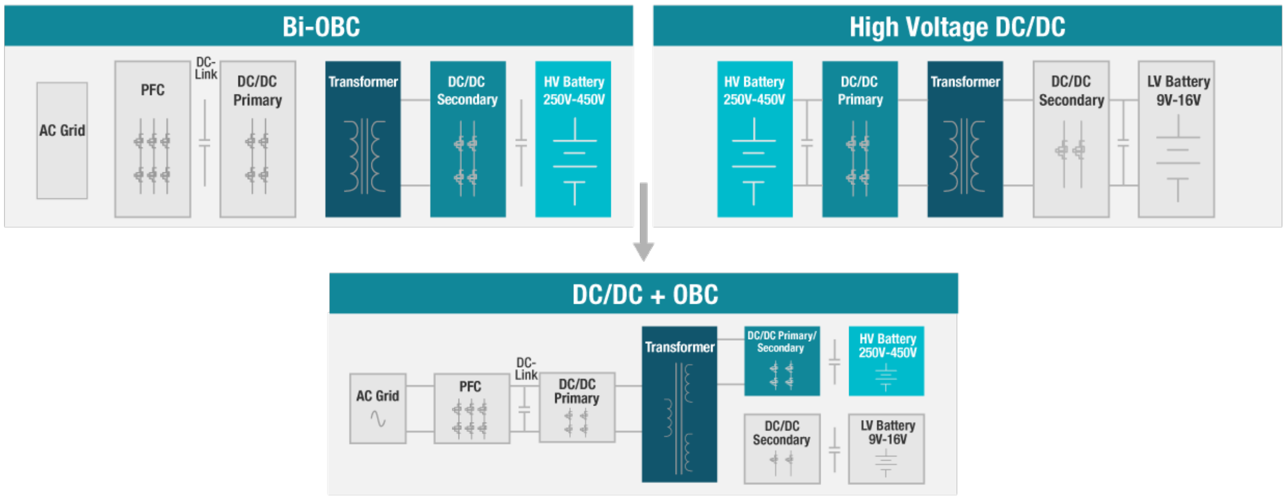


Figure 3. Power switch and magnetic sharing in a integrated architecture

As shown in Figure 3, both the OBC and high-voltage DC/DC converter are connected to the high-voltage battery, so the rated voltage of the full bridge is the same for the onboard charger and the high-voltage DC/DC. This enables power-switch sharing with the full bridge for both the onboard charger and the high-voltage DC/DC.

Additionally, integrating the two transformers shown in Figure 3 achieves magnetic integration. This is possible because they have the same rated voltage at the high-voltage side, which can eventually become a three-terminal transformer.

Boosting performance

Figure 4 shows how to build in a buck converter to help improve the performance of the low-voltage output.

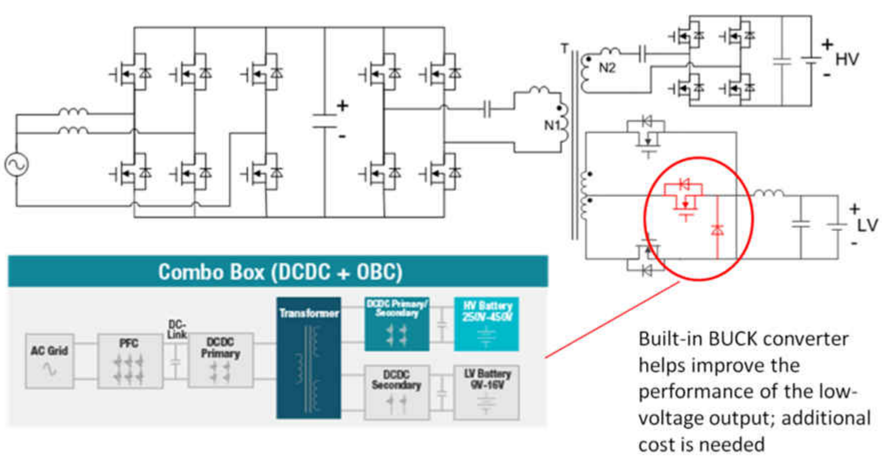


Figure 4. Improving the performance of the low-voltage output

When this integrated topology is working in the high-voltage battery-charging condition, the high-voltage output will be controlled accurately. However, the performance of the low-voltage output will be limited, since the two terminals of the transformer are coupled together. A simple method to improve the low-voltage output performance is to add a built-in step-down converter. The trade-off, however, is the additional cost.

Sharing components

Like the OBC and high-voltage DC/DC integration, the voltage rating of the power factor correction stage in the onboard charger and the three half bridges is very close. This allows power-switch sharing with the three half bridges shared by the two end-equipment components, as shown in Figure 5, which can reduce cost and improve power density.

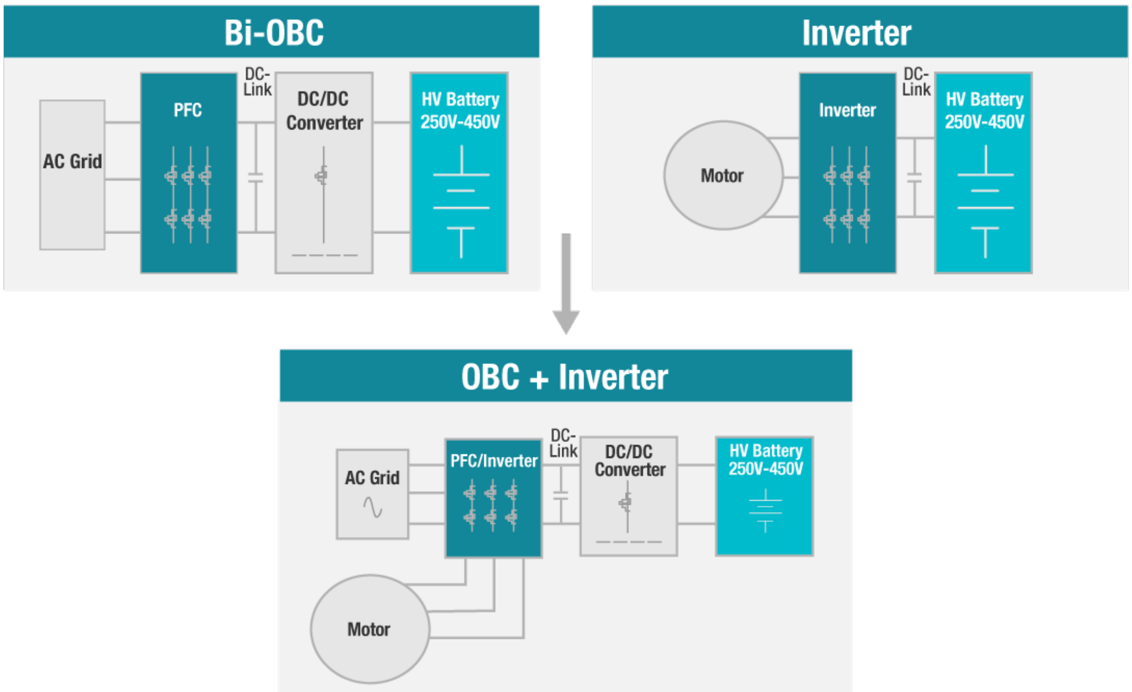


Figure 5. Sharing components in a powertrain integration design

Since there are normally three windings in a motor, it is also possible to achieve magnetic integration by sharing the windings as the power factor corrector inductors in the OBC which also lends to the cost reduction and power-density improvement of this design.

Conclusion

The integration evolution continues, from low-level mechanical integration to high-level electronic integration. System complexity will increase as the integration level increases. However, each architecture variant presents different design challenges, including:

- The need for careful design of the magnetic integration in order to achieve the best performance.
- The control algorithm will be more complex with an integrated system.
- Designing the high-efficient cooling system to dissipate all of the heat within smaller systems.

Flexibility is key with powertrain integration. With so many options, you can explore this design at any level.

Additional resources

- Read the 98.6% Efficiency, 6.6-kW Totem-Pole PFC Reference Design for HEV/EV Onboard Charger.
- Explore the GaN-based, 6.6kW, bidirectional onboard charger reference design.
- Check out the ASIL D safety concept-assessed high-speed traction, bi-directional DC/DC conversion reference design.

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