Improving EV-HEV Safety, Performance and Reliability with Galvanic Isolation

Introduction

New advances in electric vehicle (EV) and hybrid electric vehicle (HEV) technology are propelling EV and HEV sales to new heights and accelerating the pace of innovation for this emerging automotive market. Electric and hybrid vehicles promise greater efficiency and reduced emissions and are rapidly approaching price and performance parity with gas-powered vehicles. To be competitive with existing vehicles, the batteries used in EV/HEVs must possess very high energy storage density, near-zero self-leakage current, and the ability to charge in minutes instead of hours. In addition, the battery management and associated power conversion system must be of minimal size and weight and be able to deliver large amounts of power to the electric motor efficiently. Finally, the system driving the electric motors, the traction inverter, needs to leverage cutting-edge semiconductor devices and control techniques to deliver maximum efficiency and torque from the motors.

Learn How

- Emerging requirements to improve performance, safety, and reliability in EV/HEVs influence car manufactures to select digital isolation over traditional optocoupler technology.
- Higher-operating voltages and currents and dissimilar voltages in electric vehicles systems emphasize the importance of electrical isolation for safety reasons.

EV/HEV Systems Typically Include Six Key System Components

Onboard Charger

Energy storage is provided by 800 V and greater lithium-ion battery packs charged by an onboard charger (OBC) consisting of an ac-to-dc converter with power factor correction (PFC) and supervised by a battery management system (BMS). This charger accommodates a variety of external charge sources ranging from 110 V single-phase ac to 380 V three-phase ac.

Climate Control

In electric vehicles the air conditioning and heating systems are electric. The air conditioning compressor runs off of an electric motor. To heat the vehicle, positive temperature coefficient (PTC) heaters are becoming common, as they are more efficient than a traditional resistive heater. Most PTC heaters, and even some compressors, run off of the high voltage rail and require isolation.

Auxiliary Inverters

Internal combustion engines use belts to drive engine accessories, such as air conditioner compressors and power steering pumps. EV/HEVs require auxiliary inverters to spin lower-power motors to drive similar vehicle components.

Battery Management System

Battery cells are monitored and managed by the battery management system (BMS) to ensure high efficiency and safety. The BMS controls the charge, state of health, depth of discharge, and conditioning of individual battery cells.

Traction Inverter

The true muscle of an electric vehicle, the traction inverter drives the high power, three phase electric motor. Traction inverters use advanced control algorithms and sophisticated power electronics to maximize efficiency, torque, and speed. They also convert the kinetic energy in braking into usable electricity in vehicles with regenerative braking.

DC-DC Converter

The dc-dc converter connects the high-voltage battery to the internal 12 Vdc or 48 Vdc network, which provides power to the accessories and bias to the local switching converters.

Galvanic Isolation

Modular EV/HEV circuit assemblies have combinations of fixed and floating grounds, dissimilar voltages between modules, and local (and potentially lethal) battery and power supply voltages. Given these factors, galvanic isolation is a necessity in the design of electric and hybrid vehicles.

What is galvanic isolation and what role does it play in electrical system design? Galvanic isolation insulates functional sections of electrical systems to prevent current flow between the sections while permitting information to be exchanged between them.

Figure 2 demonstrates this concept with a simple isolated data exchange example between Circuits A and B. Dedicated bias supplies VDD1 and VDD2 provide 5 V power on their respective sides of the isolator. The 5 V ground-referenced pulse train applied to the Circuit A input is faithfully transferred to the isolator output with no current passing between GND1 and GND2 at any time during the transaction. In other words, the impedance between GND1 and GND2 effectively creates an open circuit, and yet a successful data transaction is completed between the two insulated circuits as stated in the galvanic isolation definition.

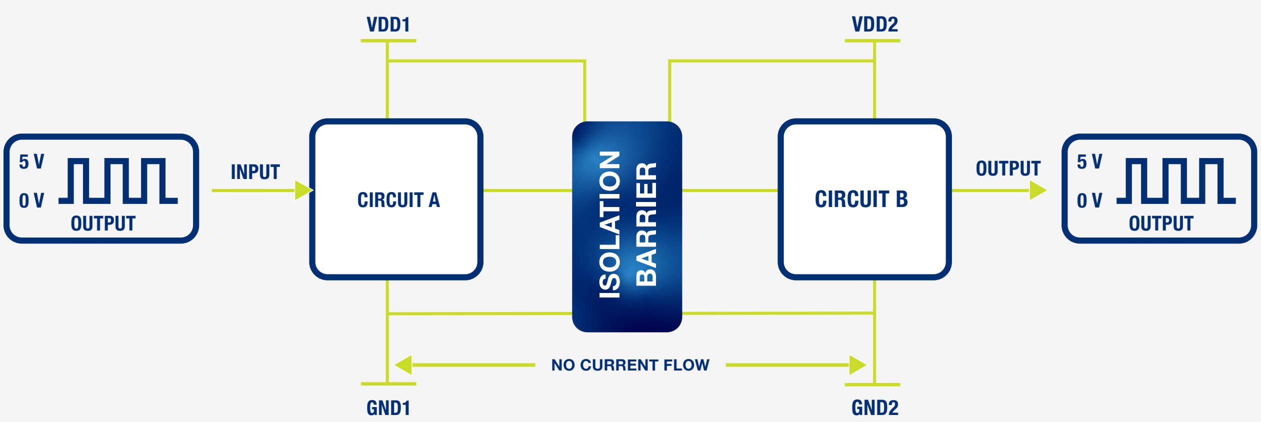


Figure 2 – Basic Isolator Behavior

Traditionally, optocouplers have been used to provide galvanic isolation. However, the demands of electric vehicles for performance and long-term reliability have led to the rapid adoption of digital isolation technology. Optocouplers use light from an LED and the analog output of a photo coupler to transmit data across the isolation barrier. Digital isolators, on the other hand, transmit digitally encoded signals across the isolation barrier using either capacitors or transformers. Digital signaling greatly improves the speed, propagation delay, and aging characteristics of the isolator. To learn more about the benefits of digital isolation, please see our "Isolator vs Optocoupler Technology" whitepaper.

The benefits of digital isolation can be used in various combinations to make EV/HEV electrical systems safer and more reliable. The main traction inverter block diagram in Figure 3 shows where isolation is used. Isolation provides safety isolation, level shifting and ground translation between the high-voltage motor drive and low-voltage controller in the phase current and voltage measurement circuits. Likewise, the isolated drivers provide these same functions between the driver and the high-voltage motor drive circuit. Silicon Labs Traction Inverter application page contains more details on traction inverters and the specific isolation components used.

An isolated dc-dc converter uses linear safety isolation in the feedback loop to ensure that no current flows between the primary and secondary sides of the supply, eliminating the possibility of high-voltage breakdown or leakage to low-voltage circuits. Lastly, isolators are used between sensors for safety, level shifting, voltage level translation and possibly ground loop mitigation. The DC-DC application page provides more details on isolation in an EV dc-dc converter.

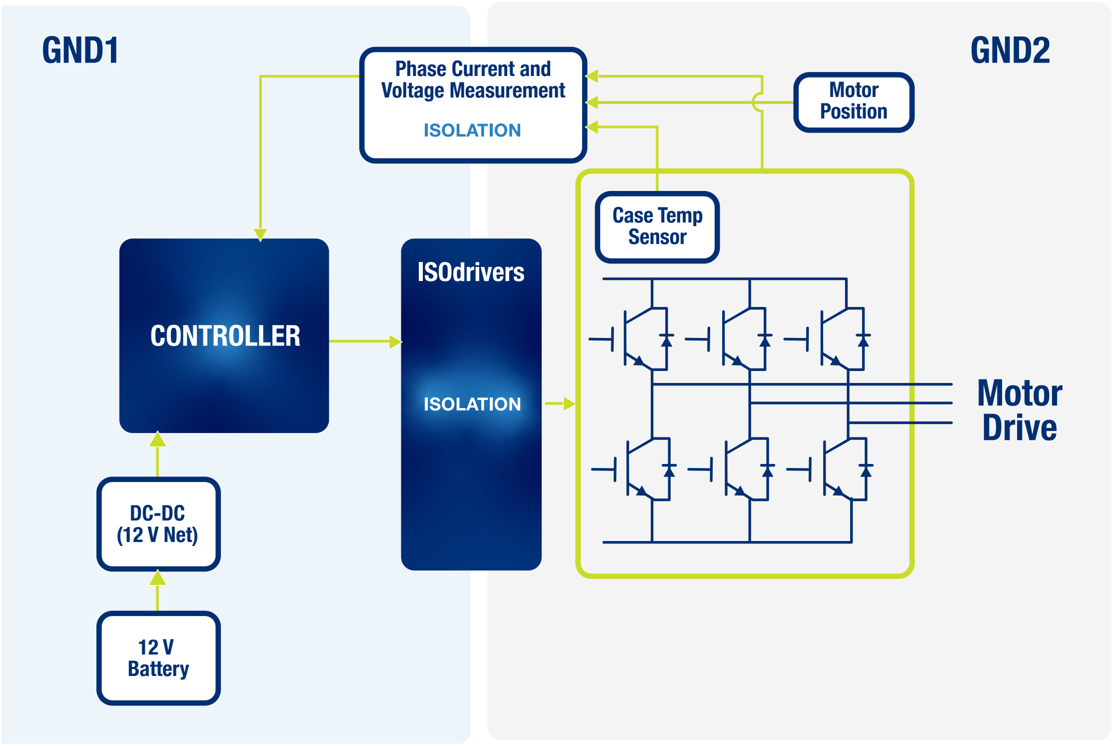


Figure 3 – Isolation in the Traction Inverter

Switched Mode Power Conversion in EV/HEVs

Switched mode power converters are an important part of EV/HEV systems and are used in the onboard charger, battery management system, and 12 or 48 V network dc-dc converter. These converters transform voltage and current to meet the requirements of the devices they power and use isolation for safety and level shifting.

Figure 4 shows a block diagram of the battery charger's internal ac-to-dc converter in which the input voltage is provided by external infrastructures, such as a charging spot. As shown, the charger's ac input is immediately converted to dc by the input rectifier and filter and conditioned by the power factor correction (PFC) circuit. The conditioned dc voltage is then "chopped" into pulses by the primary side switching circuit and applied to the transformer primary. The transformer "scales" the voltage and current pulses to meet the output requirements of the charger. Secondary-side circuits rectify and filter the high-frequency pulses, converting them to dc.

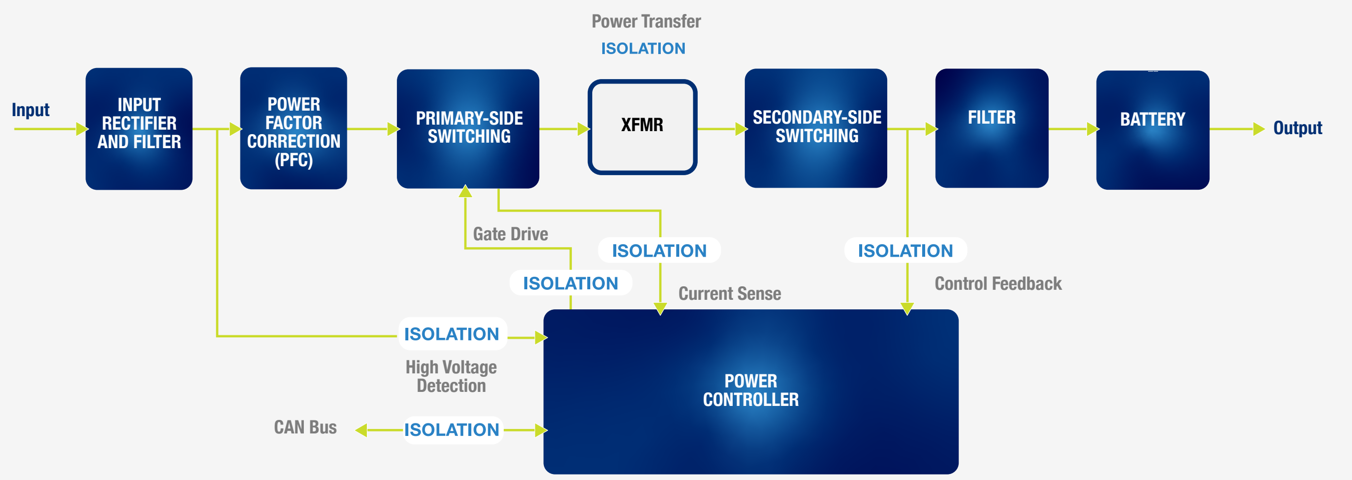


Figure 4 – DC-DC (12 V Network) Converter

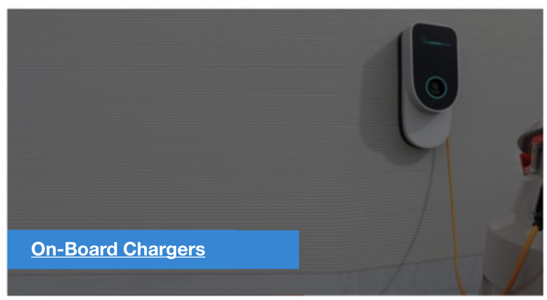
The power controller supervises the closed-loop operation and monitors the amount of power transferred to the battery until the battery is fully charged. Isolation components provide several important functions in this example: the transformer isolates power transfer between the primary and secondary sides of the converter; the isolated current and voltage sensors provide safety isolation for high-voltage detection and feedback control signals, and digital isolators provide safety isolation for the controller area network (CAN) bus interface. By leveraging the capabilities of modern digital isolators, the system is safe, efficient, and reliable for the lifetime of the vehicle. Further details on battery chargers can be found on the [Silicon Labs On-Board Charger application page.](#)

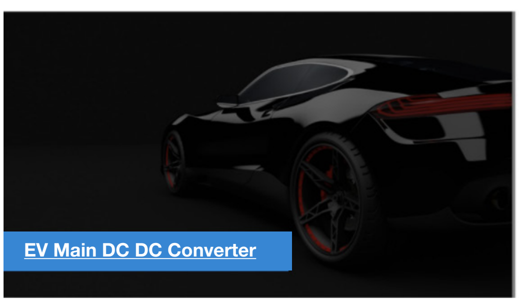
HEVs present a more difficult technical challenge due to the added complexity of the small internal combustion engine (ICE), typically located in the drivetrain. This addition complicates both the mechanical drivetrain and electronics. However, most HEVs have the same main electrical systems found in an EV with the same need for isolation. The ICE is managed by a dedicated engine control module (ECM), which includes an isolated CAN bus to safely communicate with the high-voltage electric portion of the vehicle. Many of the system sensors are also isolated from the HV ECU to ensure safety and voltage level compatibility. Just like in an EV, the traction and auxiliary inverters, onboard charger, and 12 V network dc-dc converters are all isolated from one another wherever different ground potentials or high voltages are present.

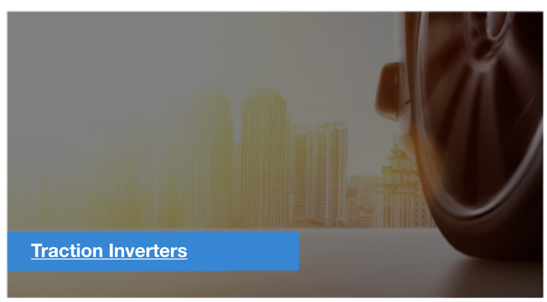
Driving EVs Into the Future

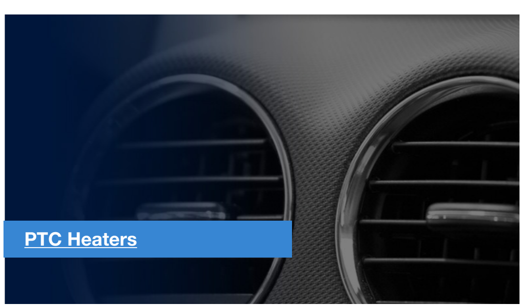
To continue expanding market share, electric and hybrid vehicle designs must reduce vehicle weight, improve range, and reduce charging time, all while achieving lower costs. These advancements will in turn require innovation in electric vehicle systems, such as battery charging, dc-dc conversion, and traction inverter design. Modern digital isolation devices are ready to meet the needs of these future systems with gains in performance, integration, and gate drive capability unheard of with older optocoupler technology. At the same time, digital isolation offers designers improved reliability and safety. For example, The Silicon Labs Si86xxT family of digital isolators offers speeds up to 150 Mbps with a 10 kV surge rating, and the Si88xx family integrates an isolated dc-dc converter into the device. Silicon Labs isolated gate drivers safely and efficiently drive silicon, IGBT, GaN, and SiC devices, empowering designers to use the latest in power device technology. The Si892x and Si893x (pre-production) isolated analog and ADCs ensure safe and precise measurements for controlling advanced EV systems. As EVs and HEVs gain a greater share of the automotive market, isolation devices will be a critical part in more vehicles on the road, providing safe vehicle operation and enabling innovation that will drive EVs into the future.

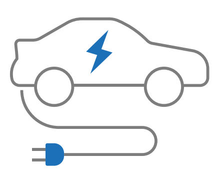
The Silicon Labs Si86xxT family of digital isolators offers speeds up to 150 Mbps with a 10 kV surge rating











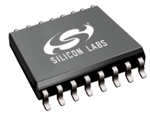
[Si8600AB-AS](#)

2.5 kV 2-ch Dgtl Isolator

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)



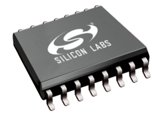
[Si88321EC-AS](#)

3.75 kV 2ch dc-dc Dgtl Isolator

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)



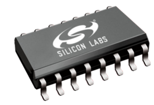
[Si8230AB-AS](#)

2.5 kV 5 V Iso Gate Driver

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)



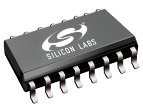
[Si82390AD-AS](#)

5 kV 6 V Dual Iso Gate Driver

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)



[Si823H6BB-AS1](#)

2.5 kV Dual Drivers

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)

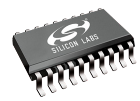
[Si8271AB-AS](#)

Hi CMTI Single Isolated Driver

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)



[Si8285CC-AS](#)

Isolated IGBT Driver

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)

[Si8920A-AP](#)

Isolated Analog Amplifier

[Datasheet](#)

[Tech Docs](#)

[Software & Tools](#)

Rudye McGlothlin is the director of marketing for Silicon Labs' Power products. Rudye has worked in the semiconductor industry for more than 15 years and joined Silicon Labs in 2011. He has experience in highly integrated, CMOS-based isolation products as well as high-precision analog components. Prior to joining Silicon Labs, Rudye served as a product marketing engineer for analog products at Texas Instruments, where he managed marketing activities for a variety of product families. Rudye has written several articles on usage and performance of various isolation devices. He holds a Bachelor of Science degree in physics from the University of Texas.

Interested in learning more about how Silicon Labs' automotive solutions can help your business?

Contact us today.

[Learn More](#)