

Riding the wave of non-isolated gate drivers in Light Electric Vehicles (LEVs)



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ABSTRACT

Bikes, motorcycles, and scooters are popular in areas where fuel is expensive or where the roads are packed tight. The electrification of vehicles such as sedans, trucks, and other consumer vehicles has also applied to 2-wheelers and 3-wheelers. Electric bikes, scooters, and other electric 2-3 wheelers are called light electric vehicles (LEVs). Non-isolated gate drivers are common in such end products and this application note provides an overview of Texas Instruments' non-isolated gate drivers that can target the battery pack, DC-DC converters, motor drives, and the on-board or off-board charger.

Table of Contents

1 Introduction	2
2 Gate Drivers in LEVs	2
3 Light Electric Vehicle System Overview	3
4 Hero Products	6
5 Summary	8
6 References	8

List of Figures

Figure 3-1. An Example Interleaved Boost PFC for an Off-Board Charger	3
Figure 3-2. Typical Battery Pack Topology	4
Figure 3-3. Typical 96V to 12V DC-DC Converter Topology	4
Figure 3-4. Typical 48V to 12V DC-DC Topology	5
Figure 3-5. Typical Motor Drive Stage Topology	5

List of Tables

Table 4-1. Hero Products of LEV Subsystems	6
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1 Introduction

As streets get more crowded and electrification gets more popular, light electric vehicles (LEVs) have become popular amongst consumers. When purchasing a new LEV, there are some qualities the LEV must have:

- **Power-Density:** LEVs have a small form factor that allow them to fit in narrow and congested roads. With a smaller vehicle, PCBs must optimize space. TI has gate drivers that use high drive current in small packages, allowing for efficiency and high-performance that is space-conscious.
- **Robustness:** Whether a user is riding in pouring rain or harsh sunlight, having an LEV that survives changing environments is a requirement. TI has a wide array of gate drivers have high VDD options and negative voltage handling contributing to robustness and reliability. This is all backed by strong customer support which helps provides confidence that TI gate drivers can be designed-in.
- **Affordability:** One of the major contributing factors to the rising amounts of LEVs is a lower cost compared to a traditional car. TI has gate drivers that bring high performance in a cost-optimized device and also can contain useful features that can reduce bill of material (BoM) cost and size. TI also has competitive web pricing that allows engineers to purchase high-quality devices at reasonable prices.

2 Gate Drivers in LEVs

There are multiple components that factor into the design of an LEV. Performance can depend on design choices in the DC-DC converter system, battery pack, or motor drive stage of the LEV. Each of these subsystems have power switches that gate drivers help drive. The switch is what is doing the actual switching, handling the majority of the power transfer and can be a MOSFET, IGBT, SiCFET or GaNFET. Finally, the gate driver is the in between of the controller and switch, the drive strength of the gate driver can determine how fast the switch turns on or off, reducing switching losses to make the system more efficient.

Low-side drivers are used when the power switch is referenced to ground. TI offers single or dual channel low-side drivers, referring to whether the gate driver can operate one or two ground referenced switches. Half-bridge drivers operate one switch referenced to ground, and another referenced to the *switch node* which has a floating voltage. Selecting the right gate driver is determined by the type and characteristics of the LEV battery voltage, system requirements, and other design elements.

TI's gate drivers come in non-isolated and isolated varieties. Isolated drivers provide a barrier for use across high voltage differentials, protecting both components and people. Non-isolated gate drivers are used when there is no such differential or along with external isolators to optimize the system. Depending on the placement of the power switch in the system (connected to ground or referencing a floating voltage) different types of TI gate drivers service these FETs.

The battery voltage of an LEV determines which half-bridge bus voltage is required, as many manufacturers enjoy headroom on the voltage supply. For 12V or 48V batteries, many design engineers want a half-bridge driver rated for 107V or 120V VHB such as the [LM2105](#) or [UCC27301A-Q1](#); for 96V batteries, a half-bridge driver rated at 230V VHB such as the [UCC27834-Q1](#) is required. Features such as UVLO and overcurrent protection help protect the switch from accidental damage, improve system efficiency, and make the system more reliable. Selecting the best gate driver for the system helps get the most out of each other component making sure high performance stays affordable.

3 Light Electric Vehicle System Overview

There are different types of LEVs: electric bikes (e-bikes), electric scooters (e-scooters), and electric motorcycles (e-motorcycles). E-bikes have the lowest power levels and shortest ranges with a more compact design. This is followed by e-scooters with a moderate range and power with a bigger design, then proceeded by e-motorcycles with the largest range and power, but with the bulkiest design.

An LEV system consists of multiple stages: DC/DC converter, the motor drive stage, the battery pack, and on-board or off-board charger. Non-isolated gate drivers are located in all stages when higher drive current is needed compared to an integrated motor driver. Non-isolated gate drivers can alternatively be considered when driving a FET when discrete implementation is preferred compared to a smart motor driver.

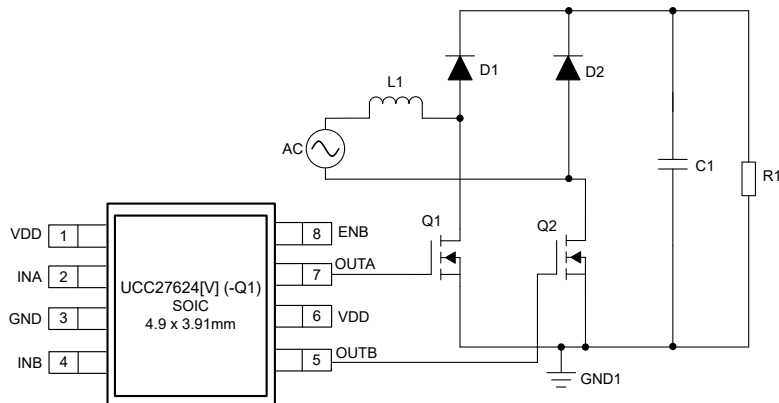


Figure 3-1. An Example Interleaved Boost PFC for an Off-Board Charger

For off-board charging, LEVs are seen paired with an external power conversion wall box or module. The power levels are higher for off-board chargers, sometimes exceeding over 1kW. An LEV fast charger takes an AC voltage from the grid (commonly from a garage wall charger or public charging rack/fast charger) and converts AC voltage into DC voltage within the charger to charge the batteries of the LEV. This voltage is regulated, maintained at a certain voltage, and power factor corrected to improve performance and efficiency. Non-isolated gate drivers such as the [UCC27624](#) are used for high-efficiency driving. LEV battery chargers also occasionally use automotive grade parts instead of industrial grade. TI has a non-isolated gate driver portfolio that boasts many devices in both industrial and automotive grade.

On-board chargers (OBC) are more common in lower battery voltages and power levels. These OBCs typically have a PFC stage and DC/DC conversion stage built somewhere on the LEV. For more details, see [Driving the Next xEV On-board Chargers and DC/DC Converters With High-Performing Non-isolated Gate Drivers](#).

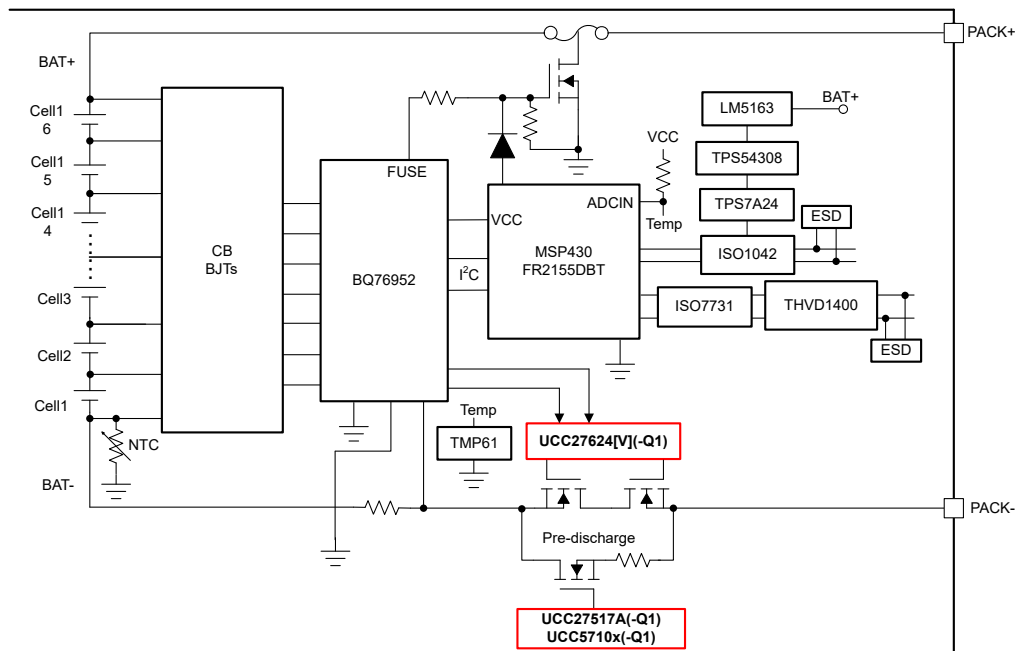


Figure 3-2. Typical Battery Pack Topology

The battery pack of an LEV helps power the motors, sometimes with the help of a DC-DC converter. These battery packs must be able to produce high enough voltages to the motor when accelerating, but also not overheat during elongated use or high environmental temperatures. Additionally, batteries must have large capacity to have a larger range, but the weight of the batteries must be taken into consideration. Thus, efficient yet power-dense batteries are a must, and non-isolated gate drivers help achieve this. Using a dual-channel low-side driver like the [UCC27624-Q1](#) to drive multiple FETs in a large battery. A small low-side driver like the [UCC27517A-Q1](#) helps minimize short-circuit or overcurrent response time by quickly switching the battery discharge FET. To learn more, see the TI [16s Battery Pack Ref. Des. W/ Low-Side MOSFET Control for Large Capacity Apps](#) reference design, which shows the UCC27524, but currently is pin-to-pin to the UCC27624, UCC27624V, UCC27624-Q1, and UCC27624V-Q1 shown in [Figure 3-2](#) Additionally, see the E2E forum post: [\[FAQ\] Which Battery Applications should I use Non-isolated Gate Drivers For?](#)

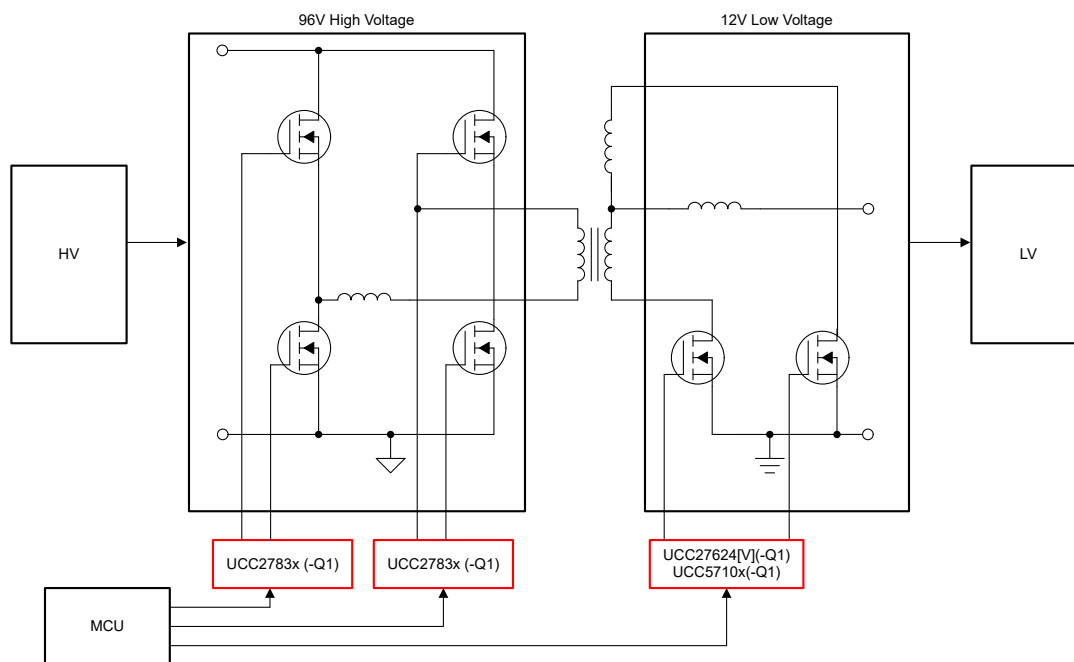


Figure 3-3. Typical 96V to 12V DC-DC Converter Topology

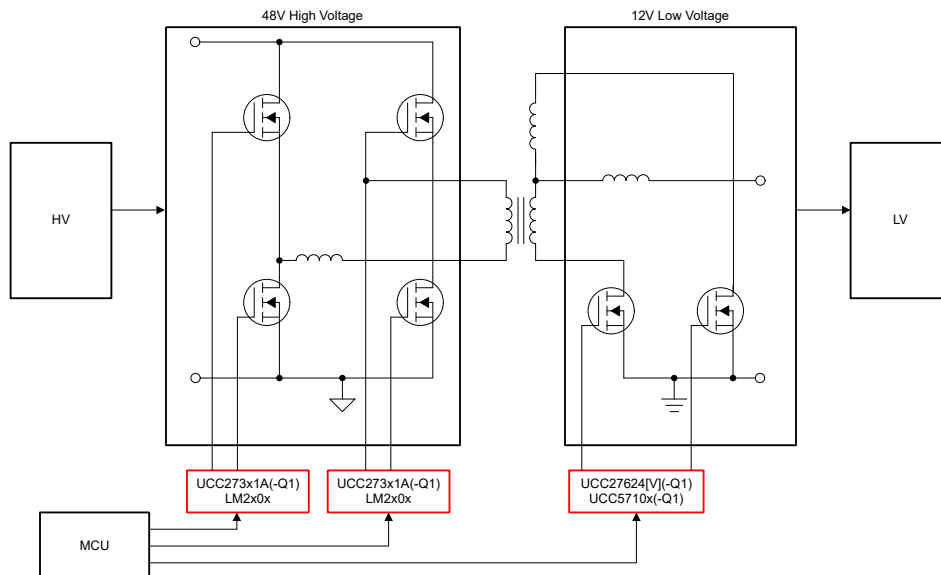


Figure 3-4. Typical 48V to 12V DC-DC Topology

The DC-DC subsystem contains the high-voltage to low-voltage DC-DC conversion, typically stepping down that higher-voltage battery of 96V, 72V, or 48V down to 12V for lighting, horns, or other smaller electrical components. In this stage, high power density, reliability, and efficiency are key factors to what components are chosen. Another consideration is the voltage of the bootstrap supply pin on the high-side of a half-bridge gate driver, as this needs to provide ample headroom on the voltage – typically double of the battery voltage. Switching the FETs quickly in the appropriate battery level is critical for a gate driver, and TI's [UCC27834-Q1](#) has a 230V VHB for 96V and 72V systems and the [UCC27301A-Q1](#) or [LM2105](#) have a 120V VHB and 107V VHB respectively for a 48V battery system.

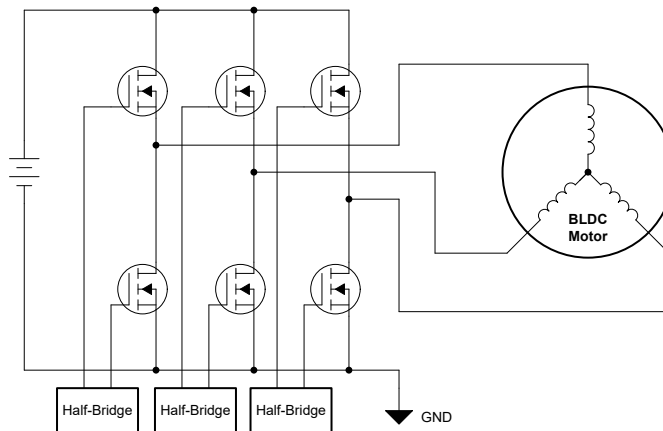


Figure 3-5. Typical Motor Drive Stage Topology

The motor driver stage of the LEV takes the electrical energy from the battery pack for the motor, which turns the wheels of the LEV. One of the most common topologies seen in an LEV is a BLDC motor. In this topology, gate drivers drive the two FETs that drive the phases a 3-phase brushless motor to either ground or the supply voltage. Using three half-bridge drivers such as the [LM2105](#) or [UCC27301A-Q1](#) can help minimize noise by allowing placement of the drivers as close to the FET as possible. Additionally, small packages such as the 2 × 2mm package of the [LM2105](#) shrinks the PCB size, allowing for optimized designs. To learn more, see [How to Choose a Gate Driver for DC Motor Drives](#).

4 Hero Products

Table 4-1. Hero Products of LEV Subsystems

Subsystem	Configuration	Switch Type	Generic Part Number	Description
Battery Pack	Low-side 2-channel	MOSFET	UCC27624-Q1	30V 5A/5A dual-channel low-side driver with 4V UVLO
		IGBT	UCC27624V-Q1	30V 5A/5A dual-channel low-side driver with 8V UVLO
		MOSFET	UCC27444-Q1	20V 4A/4A dual-channel low-side driver with 4V UVLO
	Low-side 1-channel	MOSFET	UCC27517A-Q1	20V 4A/4A single-channel low-side with 5V UVLO
		SiC	UCC57102-Q1	30V 3A/3A low-side gate driver with 12V UVLO and DESAT protection
DC-DC Converter Stage	Low-side 2-channel	MOSFET	UCC27624-Q1	30V 5A/5A dual-channel low-side driver with 4V UVLO
		IGBT	UCC27624V-Q1	30V 5A/5A dual-channel low-side driver with 8V UVLO
	Low-side 1-channel	MOSFET	UCC27614-Q1	30V 10A/10A single-channel low-side driver with 4V UVLO
	Half-Bridge	IGBT	UCC273x1A-Q1	120V, 3.7A/4.5A half-bridge with interlock option, integrated bootstrap diode, and 8V UVLO
			LM2005	107V 0.5A/0.8A half-bridge gate driver with 8V UVLO and integrated bootstrap diode
			UCC278x4-Q1	230V, 3.5A/4A Half Bridge Gate Driver with 100V/ns Noise Immunity
		MOSFET	LM2105	107V 0.5A/0.8A half-bridge gate driver with 5V UVLO and integrated bootstrap diode

Table 4-1. Hero Products of LEV Subsystems (continued)

Subsystem	Configuration	Switch Type	Generic Part Number	Description
Motor Drive	Low-side 1-channel	SiC	UCC57102-Q1	30V 3A/3A low-side gate driver with 12V UVLO and DESAT protection
	Half-Bridge	MOSFET	LM2105	107V 0.5A/0.8A half-bridge gate driver with 5V UVLO and integrated bootstrap diode
		MOSFET	UCC27302-Q1	120V, 3.7A/4.5A half-bridge with interlock option, integrated bootstrap diode, and 5V UVLO
		IGBT	UCC273x1A-Q1	120V, 3.7A/4.5A half-bridge with interlock option, integrated bootstrap diode, and 8V UVLO
			UCC278x4-Q1	230V, 3.5A/4A Half Bridge Gate Driver with 100-V/ns Noise Immunity
On-board/Off-board charger	Low-side 2-channel	MOSFET	UCC27624-Q1	30V 5A/5A dual-channel low-side driver with 4V UVLO
	Low-side 1-channel	SiC	UCC57102-Q1	30V 3A/3A low-side gate driver with 12V UVLO and DESAT protection
	Half-Bridge	IGBT	UCC273x1A-Q1	120V, 3.7A/4.5A half-bridge with interlock option, integrated bootstrap diode, and 8V UVLO
			UCC2773x-Q1	700V Half-Bridge with 3.5A/4A drive strength and upto 200V/ns Noise Immunity

5 Summary

Non-isolated gate drivers are commonly found in many LEV designs. Thus, it is important that the gate driver selected has the best package, voltage range, drive current, and feature support for any specific design. Texas Instruments has a wide portfolio of non-isolated gate drivers that can target key end products in LEVs.

6 References

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- Texas Instruments, [UCC27311A-Q1](#), product page.
- Texas Instruments, [UCC27301A-Q1](#), product page.
- Texas Instruments, [UCC27712-Q1](#), product page.
- Texas Instruments, [UCC27734-Q1](#), product page.
- Texas Instruments, [UCC27834-Q1](#), product page.
- Texas Instruments, [UCC57102-Q1](#), product page.

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