Application Note

Driving the Next xEV On-board Chargers and DC/DC Converters With High-Performing Non-isolated Gate Drivers

TEXAS INSTRUMENTS

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ABSTRACT

Non-isolated gate drivers are widely used in various automotive applications, especially in on-board chargers and DC/DC converters (together known as OBC/DC-DC). This application note provides an overview of Texas Instrument's non-isolated gate drivers that can target the OBC/DC-DC end applications.

Table of Contents

1 Introduction.....2
2 Gate Drivers in xEV On-Board Chargers/DC-DC Converters.....2
3 On-Board Chargers/DC-DC Converters System Overview.....3
4 Hero Products.....4
5 References.....4

List of Figures

Figure 3-1. A Typical OBC/DC-DC Subsystem.....3

List of Tables

Table 4-1. Hero Products of OBC/DC-DC Subsystems.....4

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1 Introduction

Looking at the latest car models, so many are now toted as electric vehicles (xEVs) boasting the larger ranges than other combustion engine counterparts. As technology continues to progress, xEVs continue to be more accessible to more and more people. When purchasing a new xEV, there are some qualities the xEV need to have:

- **Reliability:** Whether it be a quick trip to the grocery store or a long road trip, having a vehicle that is dependable is an absolute must. TI's gate drivers have high VDD options and negative voltage handling contributing to robustness and reliability. This is all backed by TI's customer support to fully maximize these robustness features.
- **Affordability:** Buying any vehicle, especially xEVs, can be a barrier to entry. TI's gate drivers not only bring high performance in a cost-optimized device, but also can contain useful features that can reduce bill of material (BoM) cost and size.
- **Power-Density:** xEVs are powerful machines, but too big and they can become harder to operation. TI's gate drivers pack high drive current in small packages, allowing for efficiency and high-performance that does not need to take up excessive space.

2 Gate Drivers in xEV On-Board Chargers/DC-DC Converters

The three main components that factor into the performance of an onboard-charger / DC-DC converter system are the OBC power factor correction (PFC) stage, the OBC DC-DC stage, and the high-voltage to low-voltage (HV-LV) DC-DC stage. Each of these subsystems have 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 GaN. 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 making the system more efficient. The power level of an OBC/DC-DC system generally requires drive strength of >4A such as in the UCC27624-Q1 or UCC27301A-Q1. Features such as UVLO and overcurrent protection help protect the switch from accidental damage and make the system more reliable. Choosing the best gate driver for the system helps get the most out of each other component making sure high performance stays affordable.

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 in order to optimize the system. Depending on the switch's placement in the system- connected to ground or referencing a floating voltage – different types of TI Gate Drivers best service these FETs.

Low-side drivers are utilized 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" that has a floating voltage. Choosing the right gate driver is determined by the type and characteristics of the xEV OBC/DC-DC system.

3 On-Board Chargers/DC-DC Converters System Overview

An OBC/DC-DC system consists of three main stages: the OBC PFC stage, the OBC DC-DC stage, and the HV-LV DC-DC stage. Non-isolated gate drivers are primarily located in the OBC PFC stage and the secondary side of the HV-LV DC-DC side of the system due to the requirement of isolation in other parts of the system.

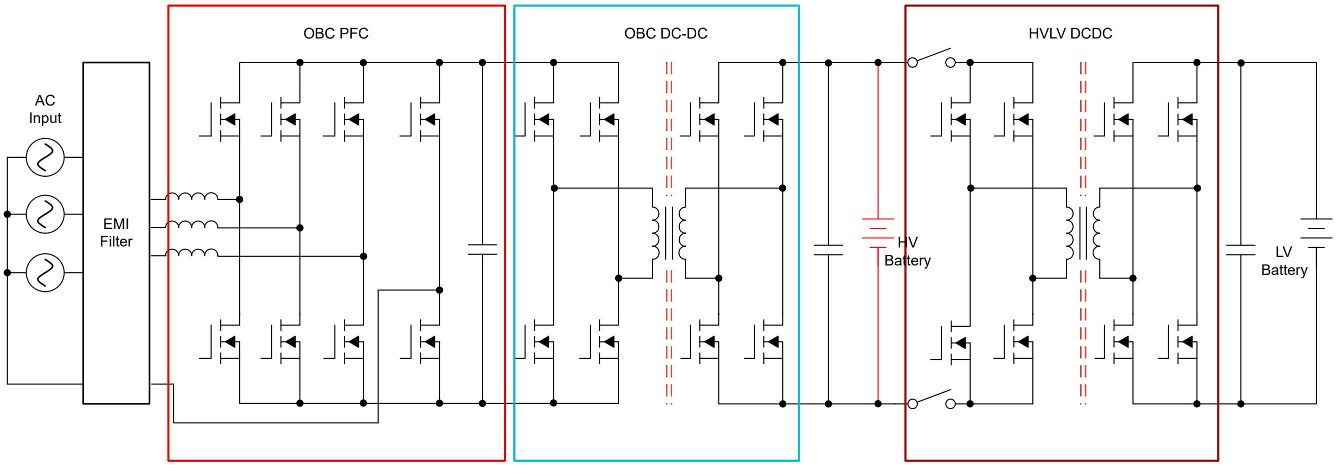

Figure 3-1. A Typical OBC/DC-DC Subsystem

An OBC takes an AC voltage from the grid (commonly from a garage wall box charger or public xEV charging station plug) and converts it into DC voltage to charge the xEV's batteries during the PFC stage. This voltage is regulated, maintained at a certain voltage, and power factor corrected to improve performance and efficiency.

There are multiple ways to implement a PFC stage on an xEV. A boost PFC is popular implementation which uses a high-efficiency gate driver like the UCC27614-Q1 to drive a FET. An interleaved boost PFC provides even higher efficiency at the tradeoff of complexity and additional components. Typically, a dual channel gate driver like the UCC27624-Q1 is used to accommodate for the additional FET used. To explore other PFC topologies like totem-pole or bridgeless, see *Review of Different Power Factor Correction (PFC) Topologies' Gate Driver Needs*. To learn more about the PFC design in xEVs, see *Power Factor Correction design for On-Board Chargers in Electric Vehicles*.

The OBC DC-DC converter stage takes the DC voltage from the PFC stage and converts it into a high-voltage battery, commonly 400V or 800V. These typically require isolation to prevent noise or voltage spikes on the high-voltage side from affecting the low-voltage side, so a gate driver like the UCC21550-Q1 can fulfill isolation requirements as well as high-voltage ratings.

The last section of the OBC/DC-DC subsystem is the high-voltage to low-voltage DC-DC conversion, typically stepping down that high-voltage battery to 12V or 48V for use in car outlets, motors, lighting, and other smaller components. In this stage, high power density, reliability, and efficiency are key factors to what components are chosen. Switching the FETs quickly in harsh environments is critical for a gate driver, and TI's UCC27624-Q1 has 30V VDD absolute maximum and 5A/5A drive current for DC-DC converter needs.

4 Hero Products

Table 4-1. Hero Products of OBC/DC-DC Subsystems

Subsystem	Configuration	Swith Type	Generic Part Number	Description
OBC PFC 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	UCC27712-Q1	700V half bridge gate driver with 8V UVLO and interlock
HV to LV 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 half-bridge with interlock option, integrated bootstrap diode, and 8V UVLO
			UCC27712-Q1	700V half bridge gate driver with 8V UVLO and interlock

5 References

- Texas Instruments: *Power Factor Correction design for On-Board Chargers in Electric Vehicles*
- Texas Instruments: *Why use a Gate Drive Transformer?*
- Texas Instruments: *Challenges and Solutions for Half-Bridge Gate Drivers in Bidirectional DC-DC Converters*
- Texas Instruments: *Improving Efficiency of DC-DC Conversion through Layout*
- Texas Instruments: *Review of Different Power Factor Correction (PFC) Topologies' Gate Driver Needs*
- TIDM-BIDIR-400-12 product page
- TIDM-BIDIR-400-12 product page
- UCC27624-Q1 product page
- UCC27614-Q1 product page
- UCC27311A-Q1 product page
- UCC27301A-Q1 product page
- UCC27712-Q1 product page