Application Note

Applying Non-Isolated Gate Drivers in Battery-Powered Tools and Appliances

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ABSTRACT

Non-isolated gate drivers are widely used in various appliance applications, especially in battery packs, chargers, and motors. This application note provides an overview of Texas Instrument's non-isolated gate drivers that can target the small home appliance and garden and power tool end equipments.

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Trademarks

1 Introduction

Appliances enable hobbies and more efficient task completion in homes and large-scale buildings alike. Whether using a blender for a morning smoothie or powering up garden tools to touch up landscaping, all battery-powered appliances must be designed to meet the following criteria:

- **Efficient:** Maximizing the usability of power drawn by appliances is crucial to reduce energy costs and verify long lasting operation. Whether extending the potential of a battery pack or optimizing the power received from an outlet, gate drivers help minimize switching losses in a system.
- **Reliable:** Owners of home tools want investments to last an extended period of time. Careful component selection and considering the physical environment the appliance operates in enable appliances to be built to last.
- **Affordable:** With many brands competing in this battery-powered tools market, appliance products are heavily scrutinized on price. To transfer savings to the consumer, engineers need to use cost optimized parts that do not compromise performance.

2 Gate Drivers in Small Home Appliances and Garden and Power Tools

The three main components that factor into the performance of an appliance system are the controller, the switch and the gate driver. The controller is the brains of the system, determining switching speed, duty cycle, and when the system is powered. A transistor is the component that performs the switching, handling the majority of the power transfer. Common examples of these power switches can be a MOSFET, IGBT, SiCFET or GaNFET. A gate driver is the in-between of the controller and the switch to efficiently control this transistor. The drive strength of the gate driver determines how fast the switch turns on or off, allowing for the optimization of system efficiency. Appliances systems operate across many power levels, making lower drive currents of LM2x0x or higher drive current of UCC273xx viable options. Features such as undervoltage lockout (UVLO) and overcurrent protection (OCP) help protect the switch from accidental damage and make the system more reliable. Selecting the best gate driver helps get the most out of the system while verifies high performance stays affordable.

TI has gate drivers that 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 switch 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 if 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 have a floating voltage. Selecting the right gate driver is determined by the type and characteristics of appliance subsystem being designed.

3 Battery Powered Appliance System Overview

Battery Charger

Many tools used around the home these days market themselves as cordless, enabling free usage wherever needed. To provide this feature, appliances implement battery packs to source the required power. These battery packs need to be charged from the wall, and once connected to the appliance, the power must be delivered to the motor or attached components. The following sections discuss these subsystems and why a gate drive is utilized.

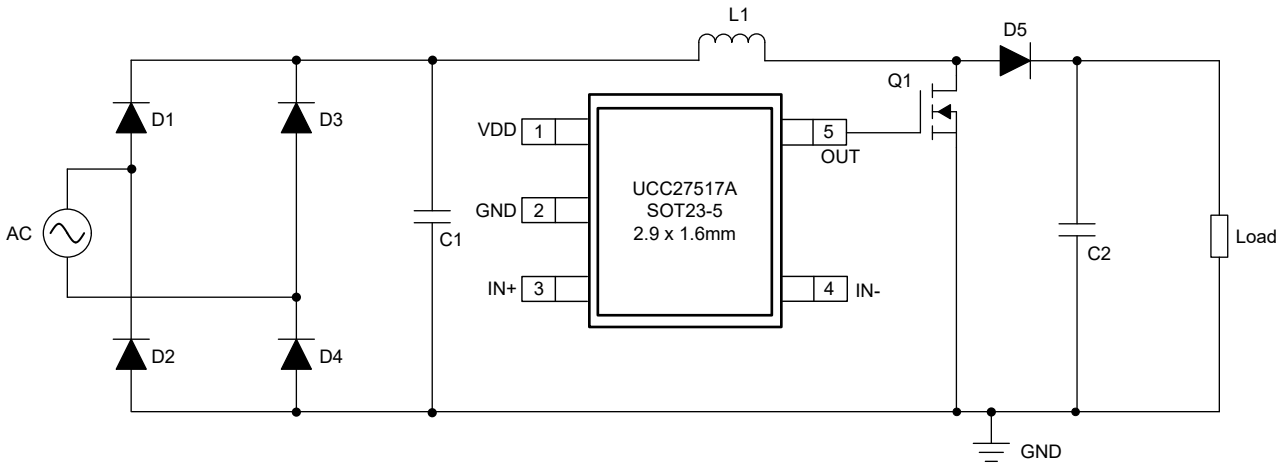

Figure 3-1. Battery Charger

AC voltage standards of America or Europe alike (100-120VAC, 220-240VAC respectively) are often rectified and boosted to 400V. The rectification is achieved via a Power Factor Correction (PFC) circuit. Shown is a typical boost PFC circuit, employing a low-side gate driver. This is a simple and cost-efficient approach, important to keep end-system costs low.

A DC/DC conversion is then needed to charge the battery pack at the proper voltage level. This is employed for a range of electrified appliances, from power tools to battery-powered riding mowers. A viable way to drive the half-bridge for this DC/DC conversion is with a push-pull circuit.

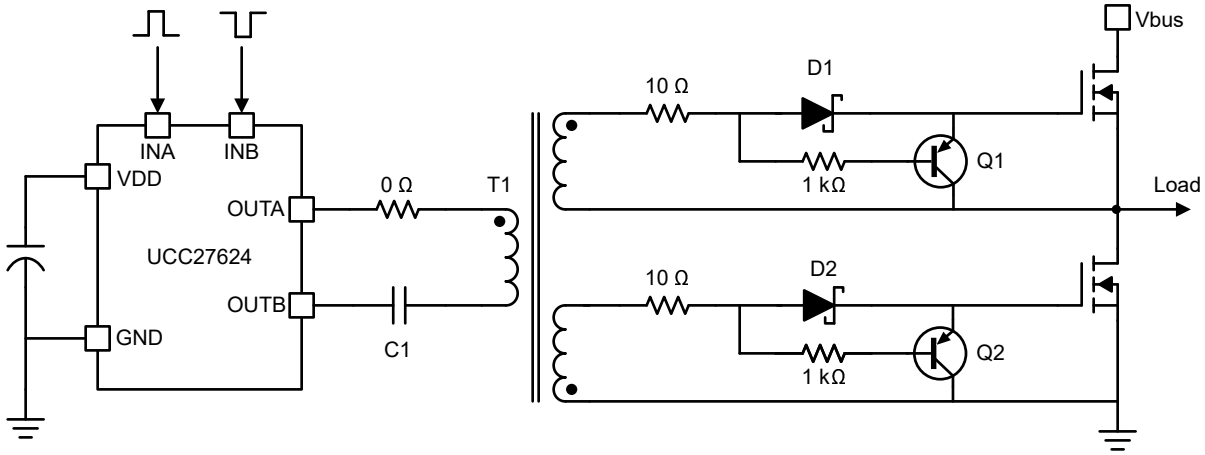

Figure 3-2. Pulse Transformer for DC/DC

This implementation can be seen fully illustrated in the following reference design and explained in detail in the following application note.

Battery Disconnect Switch

Battery disconnect switches are used as a mechanism to stop delivering power to a sub-component of an appliance. This can be a circuit break to shut off the motor or a way to stop power from being sent to an attachment.

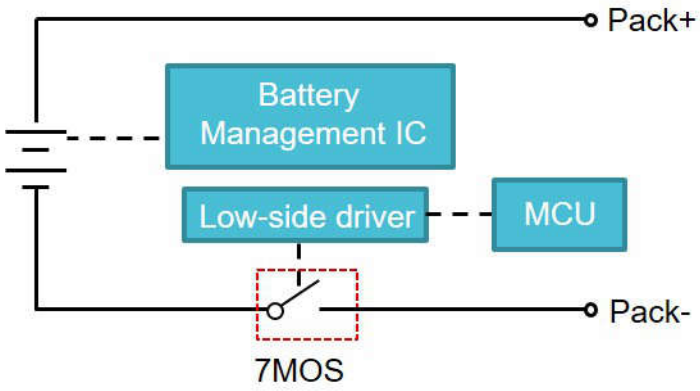

Figure 3-3. Battery Disconnect Switch

Some configurations have this *7th MOSFET* on the high-side of the circuit, rather than where it is shown above. See this application brief for a more detailed explanation of the advantages and differences of designing with *high-side* versus *low-side* configurations. If a high-side implementation is deemed preferable, this application report explains how this can be achieved with a half-bridge gate driver.

Motor Drive

Gate drivers are used for each winding on the motor, most often employing three total to support the 3-phases typical of a brushless DC motor.

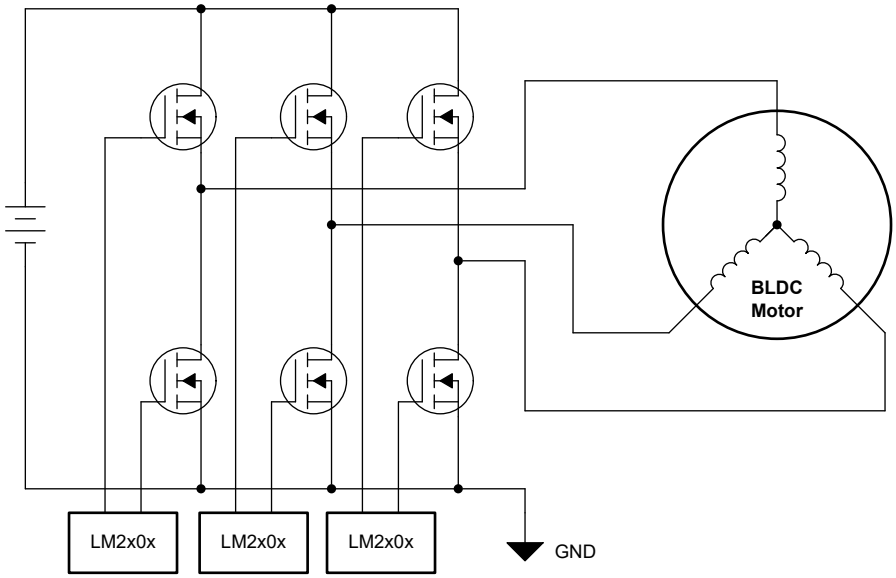

Figure 3-4. Three-Phase Motor Drive

To select a gate driver for motor drive systems, it is important to consider the voltage level of the system. Smaller products such as power tools or vacuums typically operate on 48V or less, making a 120V half-bridge optimal. For larger equipment such as professional tools or riding lawn mowers, multiple batteries can be stacked to operate at 80V or greater, meaning a 220V half-bridge or even 700V can be required to provide sufficient headroom for noisy signals.

4 Hero Products

Table 4-1. Hero Products of Battery-Powered Appliance Subsystems

Subsystem	Implementation	Configuration	Generic Part Number	Description
Battery Charging	PFC	MOSFET	UCC27517A	20V 4A/4A single-channel low-side driver with 5V UVLO
		IGBT	UCC57148	30V 3A/3A single-channel low-side driver with 8V UVLO and OCP protection
	DC/DC	MOSFET	UCC27624	30V 5A/5A dual-channel low-side driver with 4V UVLO
Battery Disconnect Switch	Low-side disconnect	MOSFET	UCC27517A	20V 4A/4A single-channel low-side driver with 5V UVLO
	High-side disconnect	MOSFET	LM2005	107V half-bridge gate driver with 8V UVLO,integrated bootstrap diode, and 2x2mm package option
			UCC27884	230V half bridge gate driver with 8V UVLO
Motor Drive	Lower Voltage (48V or less)	MOSFET	LM2105	107V low-current half-bridge gate driver with 5V UVLO, integrated bootstrap diode, and 2x2mm package option
			UCC27301A	120V mid-current half-bridge with 8V UVLO, integrated bootstrap diode, and interlock
	Higher Voltage (72V+)	IGBT	UCC27834	230V half bridge gate driver with 8V UVLO and interlock

5 Summary

TI has a wide variety of gate drivers that can be implemented to optimize the design of battery powered tools. Whether the design emphasizes cost optimization or high-end perfomance, the robust portfolio of drivers and available resources enables designers to develop power management and motor drive subsystems for many appliances.

6 References

- Texas Instruments, *Power Factor Correction design for On-Board Chargers in Electric Vehicles Driver Needs*, application report.
- Texas Instruments, *7-MOSFET for Cordless Power Tools*, application brief.
- Texas Instruments, *Implementing a Battery Disconnect Switch Using 100-V Half-Bridge Gate Drivers*, application report.
- Texas Instruments, *Why use a Gate Drive Transformer?*, application report.
- Texas Instruments, *Phase-Shifted Full Bridge DC/DC Power Converter*, reference design.
- Texas Instruments, *LM2x0x: TI's First 2mm by 2mm Half-Bridge Gate Driver*, product overview.
- Texas Instruments, *Low-side drivers overview*, product page.
- Texas Instruments, *Half-bridge drivers overview*, product page.

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