Impact of an isolated gate driver

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With information exchange and urbanization rising at a global level, the need for power management is becoming more critical than ever.

Introduction

This affects high-efficiency and robust systems that require power electronics with sophisticated intelligence in order to meet the demands of power consumption. Several day-to-day applications that necessitate these requirements are data centers, telecommunications base stations, industrial automation, motor drives and grid infrastructure. Each has their own power-level requirements, topologies and appropriate choice of power switches.

For example, data centers and telecommunications applications use power metal oxide semiconductors (MOSFET) simply because these applications need to switch faster while increasing the system power density. On the other hand, industrial automation and motor drives typically deploy insulated bipolar gate transistors (IGBT) due to their high-voltage requirement and higher power levels. Grid infrastructure equipment such as solar inverters have the flexibility to choose any of the power switches, depending on the inverter type and power level.

Human machine interface (HMI) is involved in these applications. Additionally, intelligent systems such as controllers and communication peripherals need protection from the high-power and high-voltage circuitry. This is achieved through isolation. Also, integrating the isolation circuitry with the power transfer components helps to reduce system size cost. One key trend is to integrate the gate driver with an isolator (the device that performs the isolation function) known as the isolated gate driver. This is becoming a key trend that makes these system-level features attractive.

The focus of this paper is twofold. The first is to understand why an isolated gate driver has become so attractive, which is illustrated by walking through an application. The second is to identify the requirements of an isolated driver as a function of the power switch.

Why use an isolated gate driver?

Data center application

The demand and availability of information trans-action and retrieval is ubiquitous. Time is seldom wasted in using a smart device, for example. Check out what is in our social media, our messages or email. All this is happening in the cloud. This cloud is the workhorse of real-time connectivity across the globe. The cloud is physically located in a data center.

Information to and from the data center is transmitted through a line such as fiber or coax cable, or wireless through telecommunications base stations. Inside the data center is the power delivery unit, commonly referred to as the power supply. Information is stored in servers, known as cloud servers. These servers need power to store and retrieve information back and forth to the users. These power supply units are in the range of a few hundred to thousands of watts. They operate off the grid, which is the AC line voltage in the range of hundreds of volts. Hence, they are referred to as the high-voltage unit.

There are several low-voltage components such as controllers and communication components required to improve server efficiency. Moreover,

these servers are sold based on their efficiency ratings and therefore are becoming mandatory to maintain those ratings. In addition, there are humans involved in the cloud operation interacting with the servers through HMIs. It is important to avoid any breakdown and leakage of current from the high-voltage unit into the HMI as it could damage all the low-voltage components, such as controllers and communications.

Isolation is the answer

An isolation device, which is a semiconductor integrated circuit (IC), allows data and power to transfer between the high-voltage and low-voltage units, while preventing any hazardous DC or uncontrolled transient current flowing from the grid. One well-known example is a lightning strike. Isolation is a means to break the ground loops created in circuits that have high-energy flow. There are several methods of isolation. Of all, galvanic isolation is the one that provides protection for very large potential differences [1].

Day-by-day this demand for power continues to increase. Not only that, people expect to receive this information instantaneously. This means that data center capacity is growing by the day with increasing data demand, which means that power delivery systems need to supply more and more power. However, the data center has limited real estate constraints. Scaling them to a larger size is expensive and highly uneconomical.

One way to address this demand is to increase power density and provide isolation robustness. This can be done by significantly improving power supply efficiency and increasing the power transfer rate, also known as switching frequency measured in kHz. This improvement helps to make the power supply units smaller. Isolation robustness is realized by integrating the isolator with a key power component: the high-speed gate driver. This integrated device is known as the isolated gate driver.

Gate driver functionality

To further understand the value of such an integrated solution, first you need to understand how a gate driver is used. Gate drivers are implemented in a system that operates under switched-mode power where the power switch operates in an ON and OFF mode, thereby consuming zero power, ideally under high-switching frequencies. Two common power switches used are the power MOSFET and IGBT. Switched-mode power operates in a controller-based, closed-loop power topology. Controlling the ON/OFF status happens at the gate of these switches in order to regulate voltage and the flow of current through the switches. Take a power MOSFET, for example. **Figure 1** illustrates how the gate terminal works.
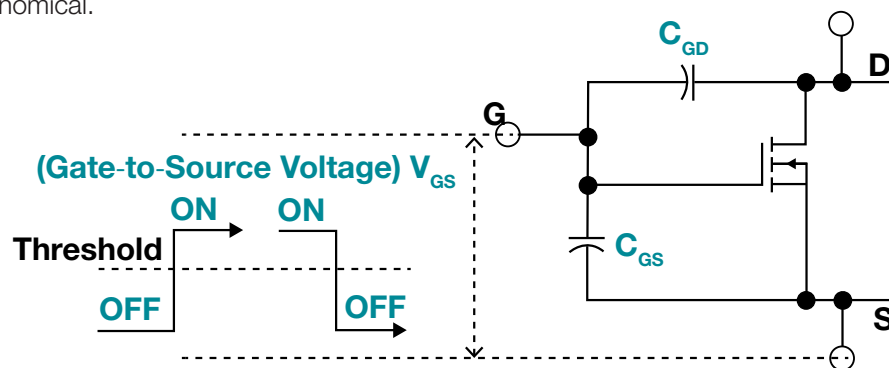

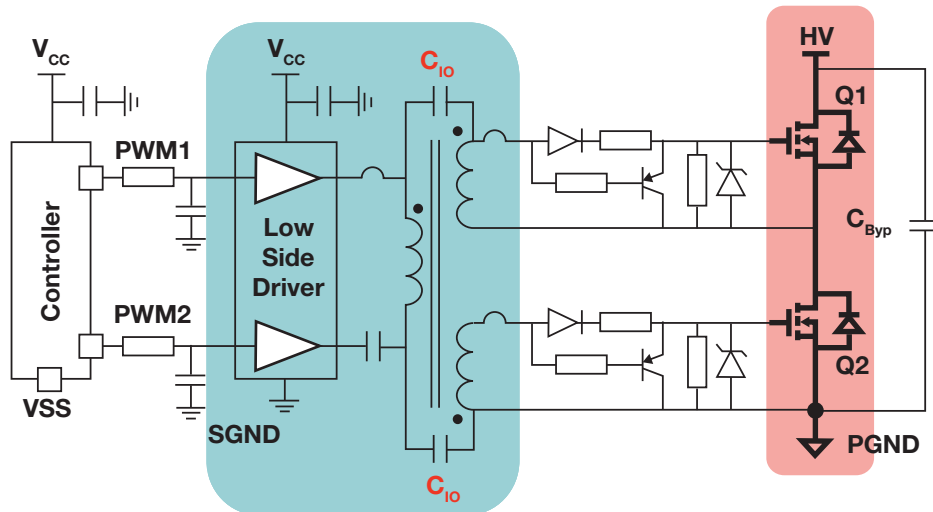
Figure 1. Control of a gate terminal in a power switch.

Figure 2a. *Transformer isolation drives both high-side, low-side switches in a phase leg.*
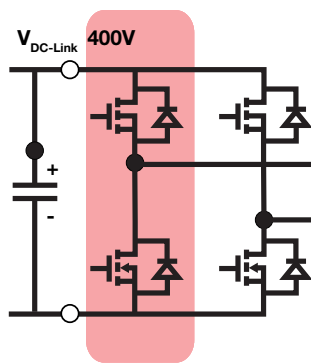

Figure 2b. *One phase leg of a full-bridge topology.*

First off, the GATE terminal controls a MOSFET's ON/OFF state. V_{GS} is the voltage between gate and source.

- To turn ON, apply a positive voltage, $V_{GS} >$ threshold level
- To turn OFF, reduce $V_{GS} <$ threshold level
- GATE is a capacitive input with a high-impedance.
- It has C_{GS}, C_{GD} as two parasitic capacitances residing in the MOSFET's internal structure

This is where the gate driver comes into play. It acts as a power amplifier that accepts a low-power input from the controller IC and produces the appropriate high-current gate drive for a power MOSFET to turn ON or OFF.

Isolated gate driver versus traditional transformer isolation

Depending on where the controller is positioned or placed, isolation is required between the controller and the driver for high-voltage applications such as data center power supplies. A traditional method for isolation is using a gate driver transformer. **Figure 2a** shows where the transformer is pulsed by a simple low-side, non-isolated gate driver to phase leg of a bridge topology (**Figure 2b**). This is referred to as Type A.

Now consider using an isolator IC instead of a transformer located between the controller and a high-side, low-side driver (**Figure 3**). This is referred to as Type B.
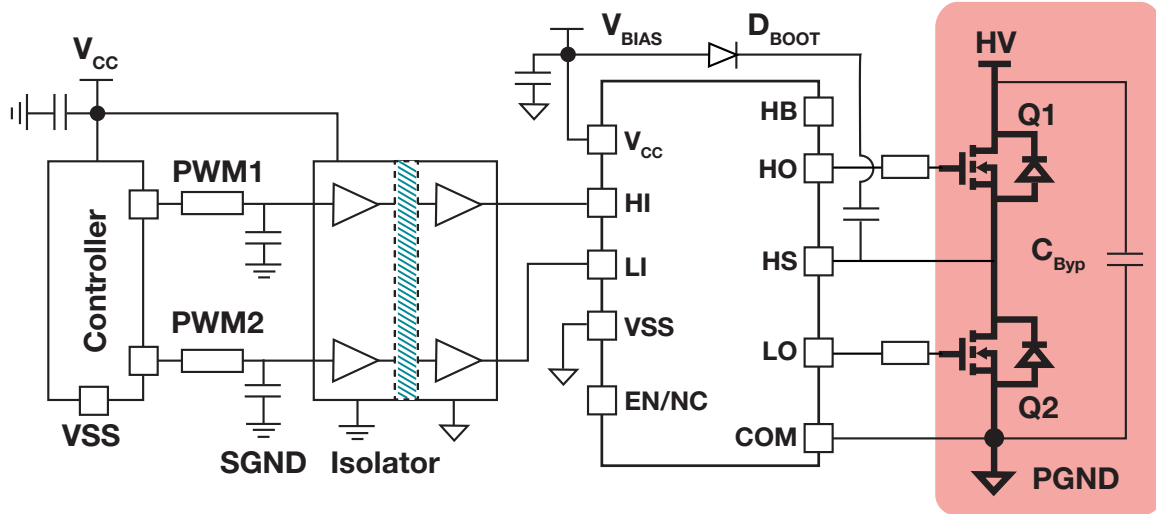
Figure 3. An isolator and a gate driver configuration highlighting a phase leg.

Table 1 shows a typical comparison between Type A and Type B.

Specifications	Type A	Type B
TProp	≈20 ns	≈100 ns
Bias power	NO	Yes
C_{I0}	≥10 pF	≤1 pF
Parasitics	Large (LLK)	Very small
Overshoot	Large	Small
Size	Bulky	Small

Table 1. Type A versus Type B comparison

Note that the size of the isolator and gate driver combination is small compared to the transformer isolation. However, the propagation delay, a key metric for high-power density applications, is significantly higher for Type B.

Now consider the isolator and the driver integrated into one IC or a multi-chip module as shown in **Figure 4**. This is referred to as Type C. This solution is the isolated gate driver.
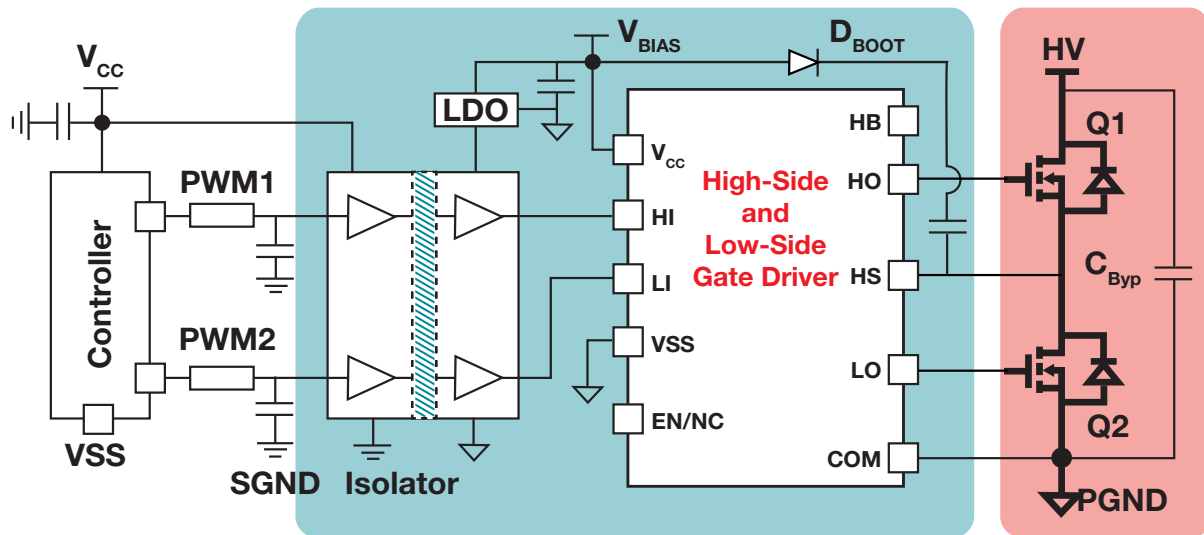
Figure 4. An integrated solution where an isolated gate driver drives a phase leg.

Type C gives a propagation delay similar to or better than a discrete transformer solution while it also gives a significant area reduction greater than 50 percent. Furthermore, Type C can be tailored to deliver common-mode transient immunity (CMTI) greater than 100 V/ns, a number significantly higher than that achievable by the Type A solution. CMTI is a key parameter that determines the robustness of a gate driver.

As explained in the data center application, system solutions are becoming smaller in size. This translates into a power supply with higher power levels and smaller board space. Integrating as many components as possible is vital, which is why this is the trend in power solutions. An isolated gate driver (Type C) is the answer to this trend. Galvanic isolation technology is typically capacitive, optical and inductive. Additionally, the isolation level (such as reinforced, basic and functional) depends on the application.

Isolated driver as a function of power switch

Isolated driver functionalities are very similar to a non-isolated gate driver such as:

- Propagation delay
- Common-mode transient immunity (CMTI)
- Rise time/fall time
- Maximum driver-side supply voltage
- UVLO
- Channel-to-channel delay
- Protection schemes
- Dead time control and overlap
- Enable/disable features

The importance of a specification parameter is dictated by the application. For example, power supplies used in data center servers and telecommunications infrastructure operate at high-switching frequencies above 20 kHz.

For such applications where a power MOSFET is used, minimizing switching loss is key. This makes parameters such as rise time/fall times and propagation delay very important. Alternatively, applications like motor drives and high power (> 5 kW) solar inverters operate at switching frequencies in the range of 5 to 20 kHz. For such high-power applications where IGBT is used, you need to have good protection schemes and high driver-side supply voltages to ensure that your design can tolerate the harsh environments in these applications.

One unique parameter of the isolated gate driver is CMTI [2], which is important to consider when operating the system at higher switching frequencies. CMTI is the ability of an isolator in the gate driver IC to tolerate high-slew-rate voltage transients between its two grounds without corrupting signals passing through it. The higher the CMTI is implies that the isolated gate driver can be used in high-switching frequency applications. Also, with the advent of wide bandgap switches such as gallium nitride (GaN) and silicon carbide (SiC), CMTI is becoming perhaps the most important parameter for isolated gate drivers.

In particular, SiC MOSFET, due to its superior material properties, has emerged as the disruptive solution in power electronics—resulting in energy efficient, robust and compact systems in high-voltage, high power applications. These applications are increasingly becoming of interest with the advent of electric vehicles and renewable energy power systems—making the gate driver requirements for SiC very critical. TI recently introduced the industry's first family of isolated gate drivers, UCC217xx, with fast, integrated sensing for SiC MOSFETs. Utilizing TI's capacitive isolation technology, the UCC217xx family maximizes insulation barrier lifetimes while providing high reinforced isolation ratings, fast data speeds and high density packaging.

Power switch	MOSFET	IGBT
Switching frequencies	High (>20 kHz)	Low-to-medium (5 to 20 kHz)
Number of channels	Single- and dual-channels	Single-channel
Protection	No	Yes – Desaturation, Miller clamping
Max V_{DD} (power supply)	20 V	30 V
V_{DD} range	0 to 20 V	-10 to 20 V
Operating V_{DD}	10 to 12 V	12 to 15 V
UVLO	8 V	12 V
CMTI	50 to 100 V/ns	<50 V/ns
Propagation delay	Smaller the better (<50 ns)	High (not critical)
Rail voltage	Up to 650 V	>650 V
Typical applications	Power supplies: Server, data communications, telecommunications, factory automation, onboard and offboard chargers, solar u-inverters and string inverters (<3 kW), 400-12 V DC/DC, automotive	Motor drives (AC machines), UPS, solar central and string power inverters (>3 kW), automotive traction inverters

Table 2. *Comparison between MOSFET and IGBT isolated gate drivers.*

This stems from TI's capacitive barrier and industry's highest dielectric strength insulator, SiO2. Each capacitive barrier is built using TI proprietary technology with strength exceeding 12.8 kV of isolation surge-voltage protection and a specified isolation voltage of 5.7 kV to ensure strengthened system-level reliability. In addition, fast short-circuit protection and quick response time enhance system protection.

Table 2 compares MOSFET and IGBT isolated gate drivers and summarizes the differences explained earlier.

Summary

High-power density and robustness are becoming increasingly important in power management applications such as power supplies, solar inverters and HEV/EV DCDC converters. With increasing power levels, it is important to protect HMI and intelligent systems. Therefore, isolated gate drivers are becoming the preferred solutions for these

applications. In this paper I compared the value of the isolated gate driver to the traditional transformer method. Key requirements for this driver are highlighted and explained as a function of the power switch and application. TI offers several isolated gate drivers for these power switches. These include isolated gate drivers such as the UCC21710-Q1, UCC21732-Q1, UCC21750, UCC21520, ISO5451/5452, UCC5350 and UCC21220 family for several applications such as power supplies, motor drives, solar inverters and automotive electrification systems to name a few.

References

1. Kamath, Anant. Pushing the envelope with high performance, digital-isolation technology, Texas Instruments Analog Applications Journal, 4Q 2015

2. Common-mode transient immunity for isolated gate drivers, Texas Instruments Analog Applications Journal, 4Q 2015