

# Cascoding Two TPSI3050 Isolated Switch Drivers to Increase Gate Drive Voltage



TEXAS INSTRUMENTS

## ABSTRACT

This application note explains the importance of selecting the proper gate drive voltage for power transistors such as Si MOSFETs, IGBTs, and SiC MOSFETs. In addition, this application note introduces how to achieve higher gate drive voltage with TPSI3050 isolated switch driver. TPSI3050 device is an isolated switch driver that transfers power to the secondary side to create a 10-V gate drive voltage. TPSI3050 devices are paired with power switches to form a complete solid state relay (SSR) solution. This document includes bench measurements to show different operation modes to achieve different gate drive voltages.

The [design file package](#) contains all of the collateral listed in this application note.

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## Trademarks

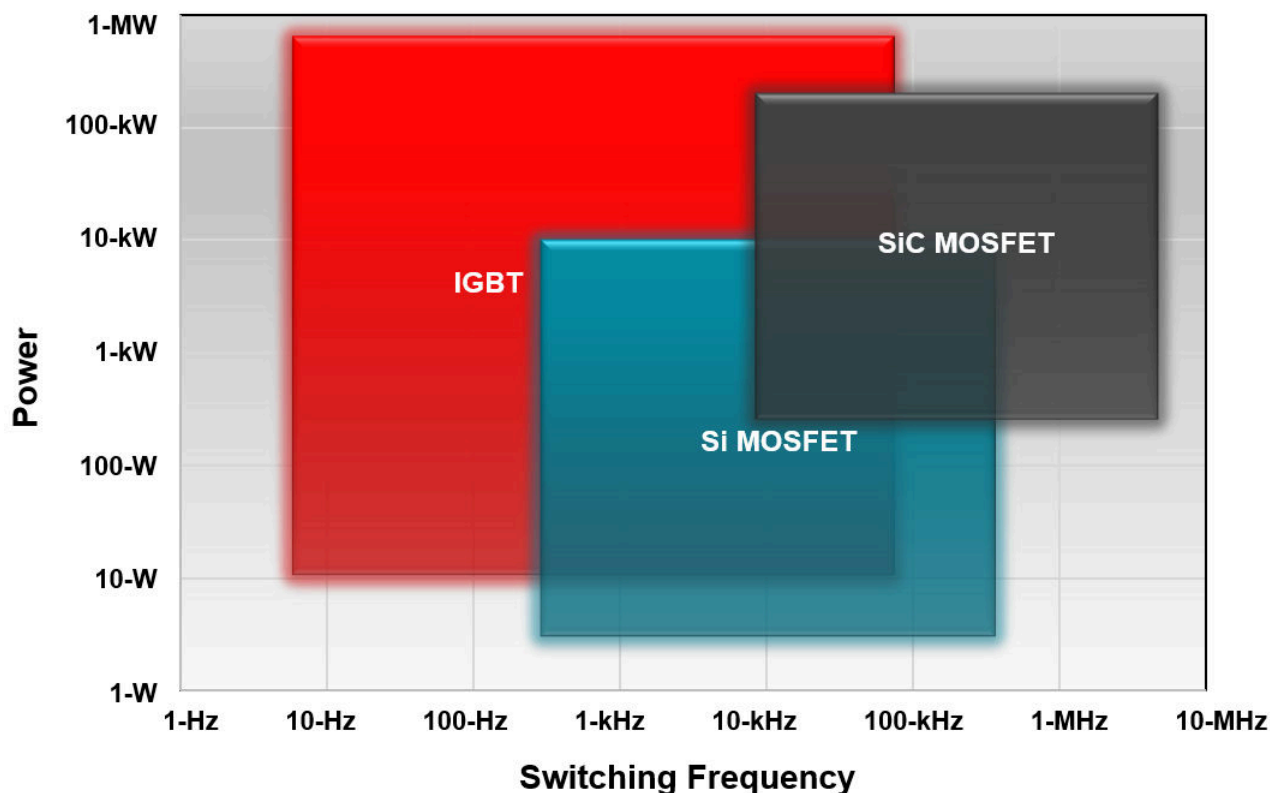
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## 1 Introduction

There are many options available for power transistors in high voltage circuit designs, such as Si MOSFETs, IGBTs and SiC MOSFETs. Different power transistor technologies can require different gate drive voltages. This application note shows how to use two isolated switch drivers to achieve higher efficiency when driving certain power transistors.

## 2 When Should You Cascode Two TPSI3050 Devices

In the automotive industry, electric vehicles (EV) and hybrid electric vehicles (HEV) are using up to 400-V or 800-V batteries. In industrial applications within grid infrastructure and power delivery, 120-Vac or 240-Vac control is commonly used. These are high voltage (HV) systems that require high voltage switching technologies. The most common solutions in this space are Si MOSFETs, IGBTs, and SiC MOSFETs [Figure 2-1](#). The [TPSI3050-Q1](#) offers 5 kV reinforced isolation and AEC-Q100 qualification for automotive applications while the [TPSI3050](#) offers 3 kV basic isolation for industrial applications.



**Figure 2-1. Power Switches Positioning Based on Capabilities**

[Figure 2-2](#) shows  $I_D$  vs  $V_{DS}$  (or  $V_{CE}$ ) curves for the three different power transistors. The  $R_{DS(ON)}$  for MOSFETs can be extracted from these curves; lower  $R_{DS(ON)}$  results in lower power dissipation in the transistor. The lowest  $R_{DS(ON)}$  can be estimated using the relation between  $I_D$ ,  $V_{DS}$ , and  $V_{GS}$ . For the same  $I_D$  current for different  $V_{GS}$  curves, the higher the  $V_{DS}$  drop, the higher the resulting  $R_{DS(ON)}$ . In the case of the IGBTs, the curves represent Collector-Emitter voltage drop ( $V_{CE}$ ). The higher the  $V_{CE}$ , the higher the power dissipation in the IGBT. Therefore, for a given collector current operation, it is helpful to operate the IGBT at a higher  $V_{GE}$  to achieve a lower  $V_{CE}$ , resulting in lower power dissipation.

For the Si MOSFET (left plot of [Figure 2-2](#)) when  $V_{GS}$  is greater than 7-V and the MOSFET is in the ohmic region,  $R_{DS(ON)}$  is at the lowest possible value. The ohmic region shows overlapping curves for  $V_{GS}$  greater than 7-V representing relatively constant  $R_{DS(ON)}$ . TPSI3050 generates a 10-V gate drive which is suitable for many Si MOSFETs. For IGBTs and SiC MOSFETs, the optimal operating condition might require higher  $V_{GS}$  voltage to obtain full enhancement.

IGBTs and SiC MOSFETs can have a higher dependence on the drive voltage as can be observed in the linear region (IGBTs) or ohmic region (MOSFETs) with different slopes in [Figure 2-2](#). If insufficient  $V_{GE}$  (IGBTs)/ $V_{GS}$  (SiC MOSFETs) is used for IGBTs or SiC MOSFETs power switches, then high conduction losses can occur. High conduction losses can lead to potential damage of the power switch. Care must be taken to ensure thermal considerations are understood as well as ensuring the device's safe operating area is not violated. For this IGBT (center plot of [Figure 2-2](#)),  $V_{GE}$  higher than 15-V is desired to obtain lower  $V_{CE}$  for lower power dissipation. For the case of the SiC MOSFET (right plot of [Figure 2-2](#)),  $R_{DS(ON)}$  is highly dependent on  $V_{GS}$  and 20-V would provide the lowest  $R_{DS(ON)}$ .

These are examples where cascoding two TPSI3050 devices would provide optimal gate drive to reduce conduction losses. TPSI3050 generates a floating secondary supply of 10-V and when two devices are cascoded, these can be combined to obtain higher voltage levels. Two TPSI3050 devices allow for gate drive voltages up to 20-V. In addition, it can be configured to provide other options such as -5-V to 15-V. [Figure 3-1](#) shows how to configure two TPSI3050 devices to obtain voltages from -5-V to 15-V and 0-V to 20-V.

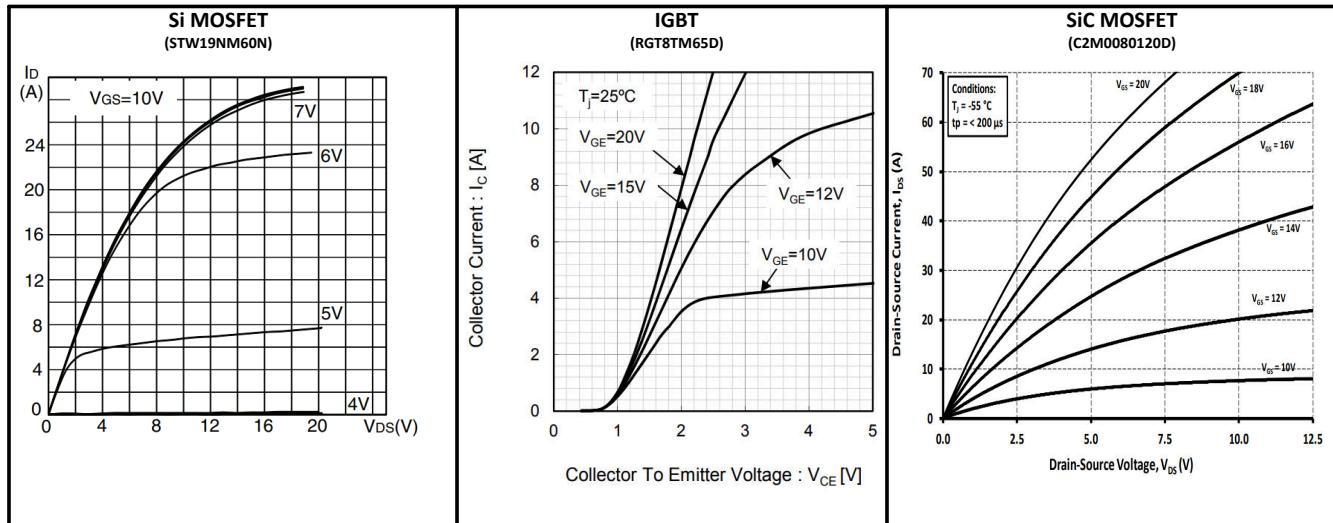


Figure 2-2.  $I_D$  vs  $V_{DS}$  Curves

### 3 How to Properly Cascode Two TPSI3050 Devices

TPSI3050 has a floating secondary supply and because of this feature it can bootstrap another TPSI3050 device using VDRV signal. To achieve a gate drive voltage from 0-V to 20-V, connect VSSS of the bottom TPSI3050 device to the source of the power transistor and VDRV of the top TPSI3050 device to the gate of the power transistor. To create a voltage drive from -5-V to 15-V, connect VDDM of the bottom TPSI3050 device to the source of the power transistor. Scope captures in [Figure 3-3](#) show the results of the two different configurations.



## 4 Summary

When selecting the driver for the power transistor, it is important to ensure that proper gate drive voltage is provided to fully enhance the power switch and minimize power losses. The most popular choices for power transistors in HV systems are Si MOSFETs, SiC MOSFETs and IGBTs. Typically IGBTs and SiC MOSFETs require higher gate drive voltage than Si MOSFETs to fully enhance the device. While one TPSI3050 device can provide sufficient gate drive voltage for Si MOSFETs, two TPSI3050 devices can provide different gate drive voltage options to optimize power dissipation in IGBTs and SiC MOSFETs.

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