Application Report

SLUA169A–August 1995–Revised June 2018

IGBT DRIVE USING MOSFET GATE DRIVERS

ABSTRACT

Insulated gate bipolar transistors (IGBTs) are gaining considerable use in circuits requiring high voltage and current at moderate switching frequencies up to 100 kHz. Typically these circuits are in motor drive, Uninterruptible Power Supply (UPS), Solar and other similar inverter applications. Much of the IGBTs popularity stems from its simple MOSFET-like gate drive requirement. In comparison to bipolar transistors (BJTs) which were formally used in such designs, the IGBT offers a considerable reduction in both size and complexity of the drive circuitry as highlighted in Table 1. Modern IGBTs have the switching speed suitable for power supply applications, thus IGBTs will compete with MOSFETs for certain high voltage applications as well. Many designers have therefore turned to MOSFET drivers such as *UCC2753x* and *UCC53xx* for their IGBT drive requirements.

Table 1. IGBT comparison

Characteristic	BJT	FET	IGBT
Power Rating	<10 kW	<10 kW	>10 kW
Drive	20uA	7 - 12V	15 - 20V
Switching Speed	Slow	Fast	Medium

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1 IGBT drive requirements

IGBT drive requirements can be divided into two basic application categories: 1) Those that apply high dv/dt to the collector/emitter of the IGBT when it is off and 2) Those that do not. Examples of low dv/dt can be found in non-synchronous buck regulators and two switch forward converters, where only one switch is employed or multiple switches are activated synchronously in a bridge configuration. High dv/dt is applied during the off-state in most bridge circuits such as inverters and motor controllers, when opposing devices are turned on. Simultaneous cross conduction, or shoot through of opposing devices can occur in such bridge circuits, often with catastrophic results if proper gate drive and layout precautions are not followed. This behavior is caused by parasitic collector to gate (miller) capacitance, effectively forming a capacitive divider with the gate to emitter capacitance and thus inducing a gate to emitter voltage as illustrated in Figure 1. Further information on IGBT drive requirements can be found in, *SLUA618, Fundamentals of MOSFET and IGBT Gate Driver Circuits*.

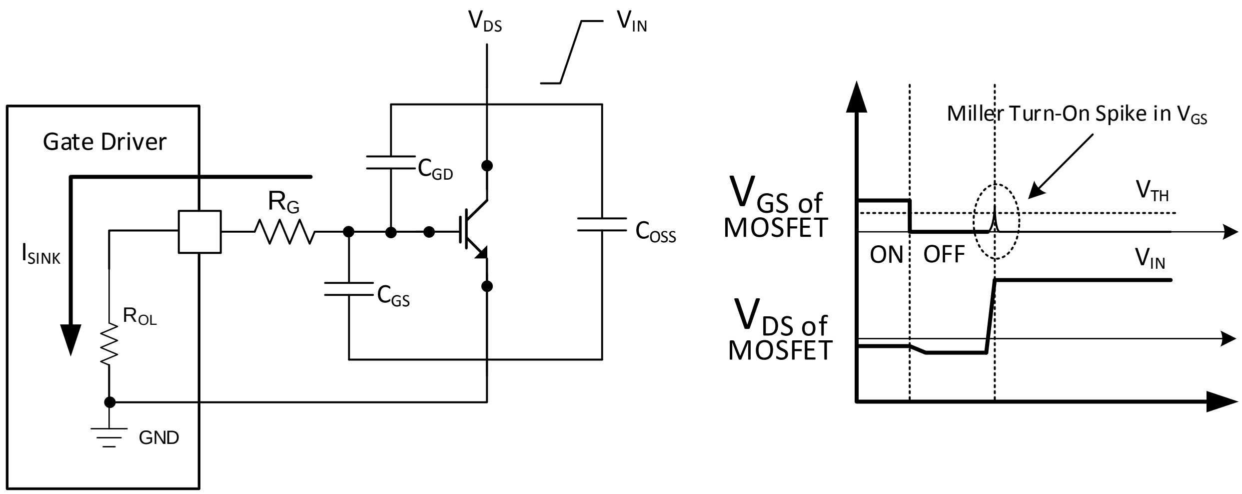

Figure 1. Miller Turn-On

When high off-state dv/dt is not present, the IGBT can be driven like a MOSFET using any of the gate drive circuits from switching power supplies. Normally 15V is applied gate to emitter during the on-state to minimize saturation voltage. The gate resistor or gate drive current directly controls IGBT turn-on, however turn-off is partially governed by minority carrier behavior and is less effected by gate drive.

2 Kelvin Connection

There are several techniques which can be employed to eliminate shoot through when high off-state dv/dt is present. The most important technique, which should always be employed, is a Kelvin connection between the IGBT emitter and the driver's ground. High di/dt present in the emitter circuit can cause substantial transient voltages to develop in the gate drive circuit if it is not properly referenced. The Kelvin drive connection also minimizes the effective driver impedance for maximum attenuation of the dv/dt induced gate voltage.

A Kelvin connection adds complication to driving multiple ground referenced IGBTs due to finite ground circuit impedance. Substantial voltages may develop across the ground impedance during switching. This ground bounce on power ground requires the gate driver to have a level shifter or isolation to reference the input signal properly allowing Kelvin drive circuit connections.

3 Negative Turn-Off Bias

A Kelvin connected unipolar driver may often be adequate at lower switching speeds, however negative gate bias must be applied during the off-state to utilize the IGBT at higher rates. This becomes apparent considering that the gate to emitter threshold voltage drops to approximately 1.4 V at high temperature due to negative temperature coefficient. With high dv/dt at the collector, a very low and impractical drive impedance is required to assure that the device remains off. By utilizing a negative turn-off bias, an adequate voltage margin is easily achieved, allowing the use of a more practical gate drive impedance. Fortunately most gate drivers have sufficient voltage capability to be used with bipolar power supplies. The UCC2753x shown in Figure 2 can sink up to 5 amps peak and is particularly suited to driving IGBTs. For added reliability during power sequencing a low VDD clamp turns off the output, actively sinking current when insufficient supply voltage is present. The positive supply, +Vcc, is normally 15 to 20 volts and the negative supply, -VEE, typically ranges between -5 and -15 volts depending on circuit conditions. Texas Instruments has the UCC2753x and UCC53xx families featuring strong sink current to defeat miller turn on and the ability to drive IGBTs or MOSFETs up to 35V max supporting negative turn off capability.

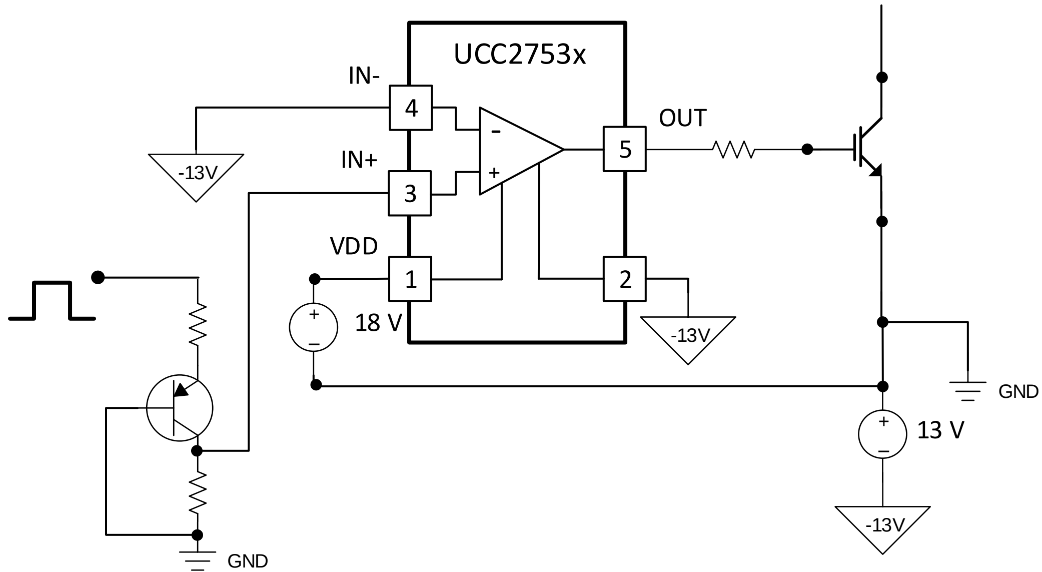

Figure 2. IGBT Bipolar Supply with Level Shifter

A PNP level shift circuit references the drive signal to ground. Opto-couplers are also commonly employed, and may be interfaced directly to the gate driver by referencing the signal to the negative supply. Note that high dv/dt is a very demanding application for optocouplers, and only devices rated for high CMRR should be used such as UCC53xx isolated gate drivers.

4 Isolated IGBT Driver

A bipolar IGBT gate driver with isolated bias supply can be implemented using the UCC53xx isolated gate driver as featured in *UCC5390SCDEVM-010* shown in Figure 3. The UCC53xx transmits the gate drive signal across the isolation barrier and SN6505B transmits power across a push pull transformer, thereby achieving low cost and high voltage isolation in a compact solution. An additional transformer winding develops a negative voltage, providing a bipolar supply for the UCC53xx. The UCC53xx can also be used for circuits which do not require negative turn-off bias by simply eliminating the negative supply and using a positive isolated bias to drive the IGBT gate.

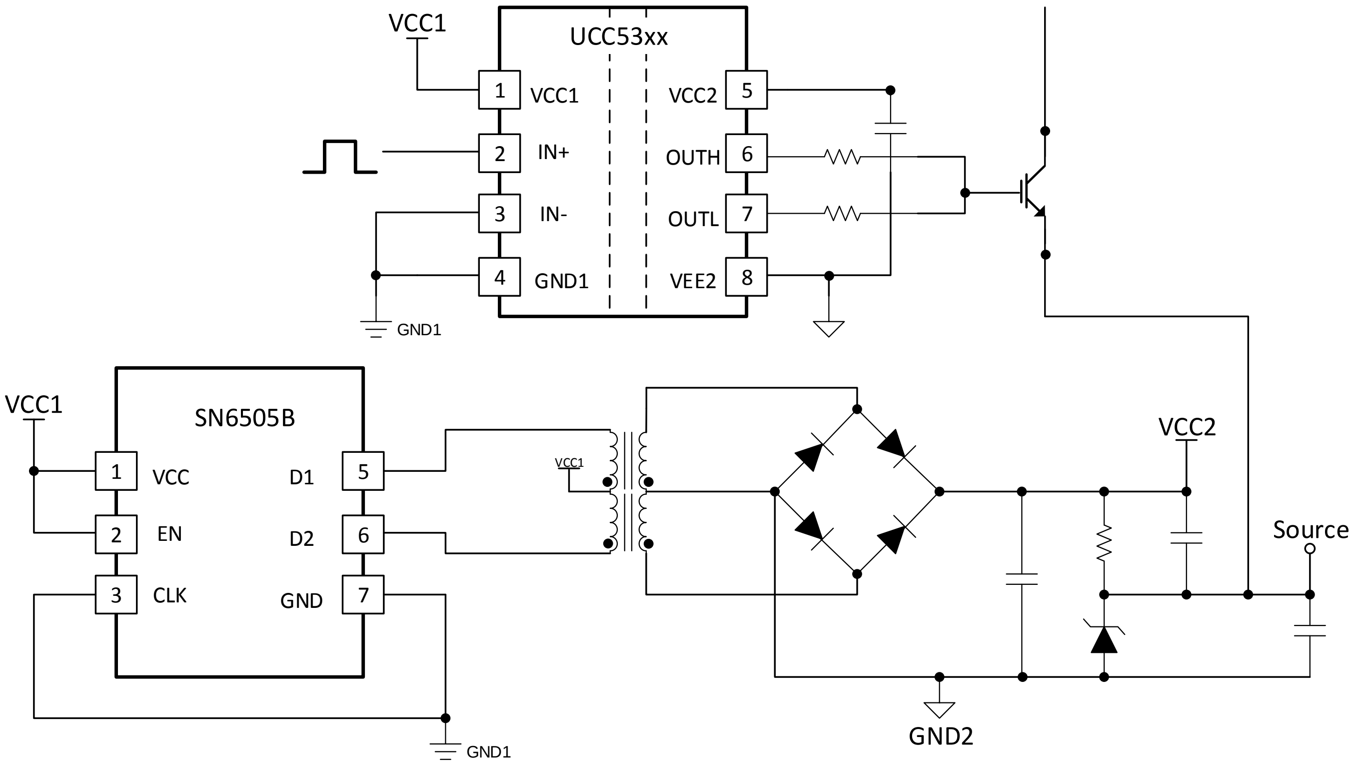

Figure 3. UCC5390SCDEVM-010 Simplified Schematic

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from original Revision (March 2013) to A Revision **Page**