Driving a unipolar gate driver the bipolar way

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Question:

Do we need a specialised gate driver to deliver positive and negative voltages?

Answer:

No, a unipolar gate driver can be adapted to drive in a bipolar manner.

If a positive and negative gate drive is required for a particular power device, circuit designers don't need to search for a special gate driver that specifically handles bipolar operations. Use the following simple trick to make a unipolar gate driver deliver bipolar voltages:

When driving medium- to high-power MOSFETs and IGBTs, there is a risk of a Miller-effect-induced turn-on when there's high-rate voltage change across the device. Current is injected into the power device's gate through its gate-to-drain or gate-to-collector capacitance. If the current injection is large enough to rise the gate voltage above the device's threshold voltage, there may be a parasitic turn-on, lowering device efficiency or even leading to its failure.

The Miller effect can be mitigated via a very low impedance path from the power device's gate to its source or drain, or by driving the gate to a negative voltage with respect to the source or drain. The goal of Miller-effect turn-on mitigation techniques is to keep the gate voltage below a desired threshold when there's a current spike through the Miller capacitance.

Certain power devices even require a negative voltage to be fully off, necessitating a negative voltage coming from the gate driver; this is typically found in standard-silicon MOSFETs, IGBTs, SiC and GaN devices.

Unipolar and bipolar voltage drives

There are many isolated gate drivers that operate on a unipolar power supply on the secondary side (which drives the power device), but fewer gate driver devices that allow for explicit bipolar voltage drives. One method to overcome this is to offset the gate driver from the power device, thereby creating a negative gate drive relative to its source or drain, with the gate driver IC still only seeing a unipolar supply.

Unipolar and bipolar gate drive waveform examples are shown in Figure 1.

A schematic with ideal voltage sources is shown in Figure 2. In this example, the driver IC is powered by a voltage equal

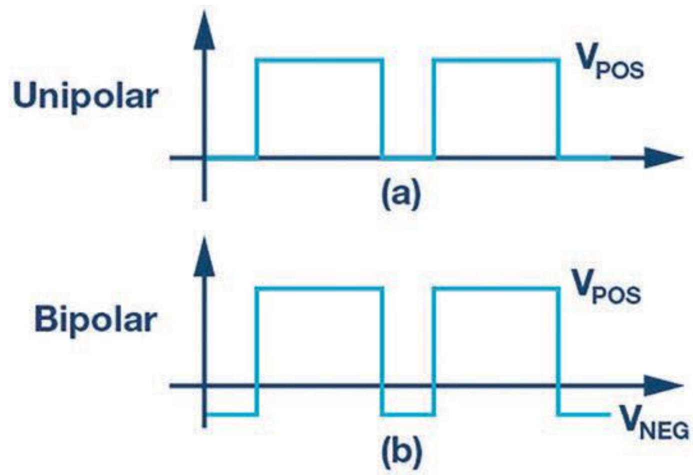

Figure 1: (a) Unipolar and (b) bipolar gate drive waveforms

to the sum of V1 and V2, whilst the MOSFET gate is driven to a +V1 in the ON state and a -V2 in the OFF state, relative to the MOSFET's source node.

Note that in this example, both voltage sources are decoupled with individual capacitors. The effective decoupling seen by the gate driver IC is a series combination of the capacitors, which is lower than the value of each individual capacitor. Additional decoupling can be added between V_{DD} and GND, if desired, but it is important to keep C1 and C2 as they provide low-impedance paths for the gate current during turn-on and turn-off separately.

Isolated gate driver ICs often come with an undervoltage lockout (UVLO) to prevent a power device from being driven weakly if the gate driver is driven with too low a gate voltage. When driving a unipolar gate driver as shown in Figure 2, care must be taken with the expected operation of the UVLO, which is usually referenced to the gate driver's ground.

Example

Consider a case where V1 = 15V, V2 = 9V and the gate driver UVLO is around 11V, common for IGBT operation. If V1 were to drop more than 4V, the UVLO would not trigger but the IGBT would be driven under 11V during the ON time, hence under-driving the IGBT.

Creating two separate voltage sources for this purpose requires using two isolated power supplies, although this can be costly. If a flyback topology is used, multiple winding taps could be applied to obtain multiple voltages relatively easily.

There are isolated voltage-source modules that provide isolated power, and some manufacturers offer voltages that support power device voltages. One example is Recom, which offers IGBT-targeted modules that produce isolated -9V and +15V rails. For such a large voltage swing, the gate driver must withstand a larger range than other devices.

Two gate drivers that work well with these voltages are ADI's ADuM4135 and ADuM4136 IGBT gate drivers with iCoupler technology, and a voltage range up to 30V. Both provide a dedicated ground pin on the output side, allowing the driver UVLO to be referenced against the positive supply rail. The ADuM4135 also includes an integrated Miller clamp, which further helps suppress the Miller-induced turn-on gate voltage bump.

A simple method for creating a bipolar supply from a single voltage source is to create a second voltage source using a biased Zener diode. Although gate drivers provide high current during device turn-on and turn-off, the average current needed from the power supply is relatively low – for most application it's often in the range of tens of mA.

The Zener diode can be placed to either regulate the positive or the negative voltage, and it should be chosen based on which rail requires greater accuracy.

The example in Figure 3 is set up to regulate the positive voltage more than the negative one. One reason is a tight tolerance on the gate voltage requirements, like with some GaN devices.

Also, regulating the positive supply has the added benefit of allowing the gate driver's UVLO to behave as expected, since any fluctuation in V3 will be attenuated by the Zener diode until it becomes too low to support the Zener voltage.

Using the Zener diode method to create two supplies out of a single one also saves on layout space. Not only do a Zener diode and a resistor effectively replace an entire isolated voltage source, but with a unipolar isolated gate driver, a six-pin device can be used, such as ADI's ADuM4120 with iCoupler technology, which saves even more space around the gate driver IC along the isolated creepage area.

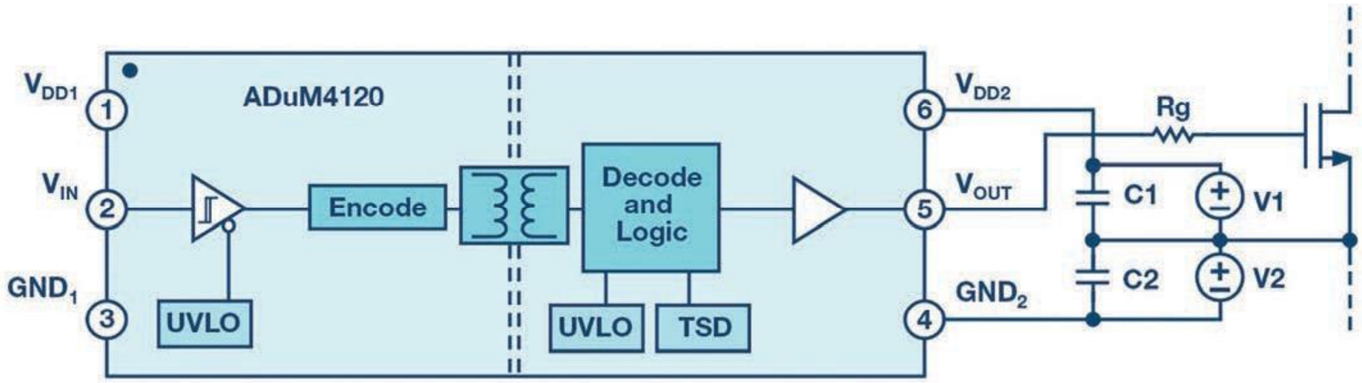

Figure 2: Example bipolar supply setup

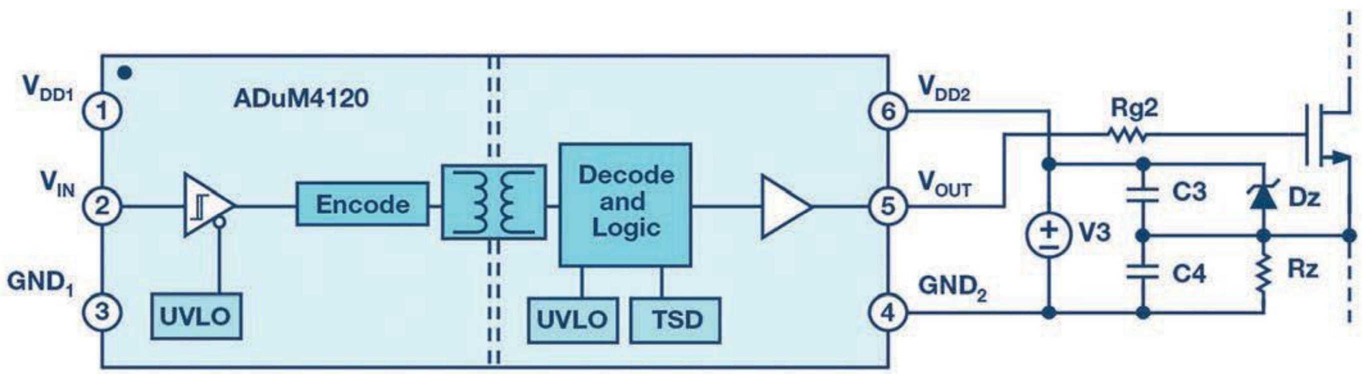

Figure 3: Zener diode example

A reference example of the Zener diode bipolar setup was created using ADI's ADuM4121 and GaN Systems's GS66508T to create a half bridge. The example was designed to have a +5V and -4V drive referenced to the device source. The example can easily be adapted to have +6V and -3V drive by using a different Zener diode, and the same 9V isolated power supply. A large deadtime is used to separate the Miller bump from other turn-off transients, but, in practice, the ADuM4121 allows for much shorter deadtimes, in the range of tens of nanoseconds, an important spec for high-efficiency GaN designs.

Creating a negative-gate volt-drive that can mitigate a Miller effect parasitic turn-on doesn't have to be complicated. Many existing gate drivers that are unipolar in operation can easily drive a gate negative voltage with minimal external circuitry. There are some implications to consider, such as the effective UVLO voltage, but the benefits are worth it. EW

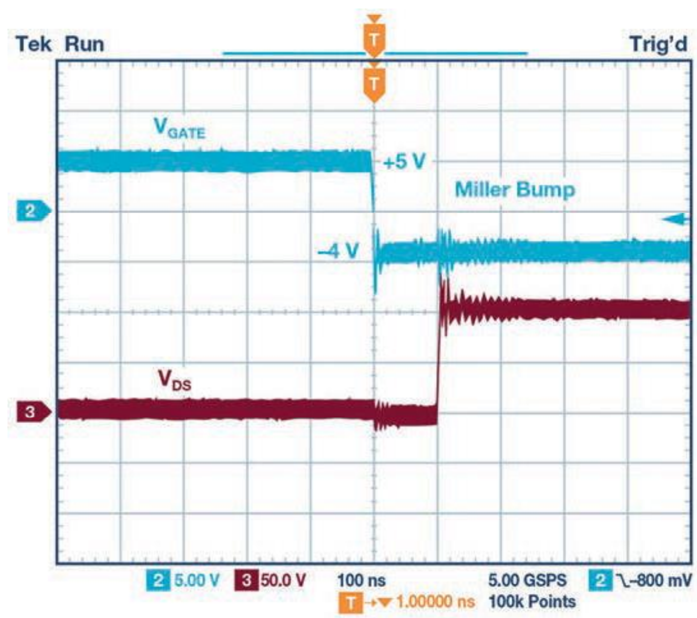

Figure 4: ADuM4121 and GS66508T experimental results