Implementing an Isolated Half-Bridge Gate Driver

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An isolated half-bridge driver’s function is to drive the gates of high-side and low-side N-channel MOSFETs (or IGBTs) with a low output impedance to reduce the conduction losses and a fast switching time to reduce the switching losses. The high-side and low-side drivers need very close matching of the timing characteristics to allow accurate and efficient switching. This reduces the deadtime from one switch of the half bridge turning off before the second switch turns on. A number of approaches have been used in the past, each involving the use of optocouplers to provide isolation; as this article describes, digital isolators integrated with gate drivers have significant benefits over these legacy approaches.

One such typical approach to implementing the isolated half-bridge gate drive function is to use an optocoupler for isolation, followed by a high voltage gate driver IC, as shown in Figure 1. One potential issue with this circuit is that there is only one isolated input channel, and it relies on the high voltage driver to have the needed matching in the timing between channels and the deadtime needed for the applications. Another concern is that high voltage gate drivers do not have galvanic isolation between the outputs and rely, instead, on junction isolation to separate the high-side drive voltage from the low-side drive voltage in the same IC. Parasitic inductance in the circuit can cause the output voltage, $V_{GS}$, to go below ground during a low-side switching event. When this happens, the high-side driver can latchup and become permanently damaged.

![Figure 1. High voltage half-bridge gate driver.](image)

**Optocoupler Gate Driver**

The next legacy approach, shown in Figure 2, avoids problems with high-side to low-side interactions by using two optocouplers to establish galvanic isolation between the outputs. The gate driver circuit is often included in the same package as the optocoupler, and it is most common for there to be two separate optocoupler gate driver ICs to complete the isolated half bridge, which makes for a larger solution size. It should be noted that optocouplers are manufactured as a discrete device, even if two are packaged together, so they will have limitations in channel-to-channel matching. This will increase the required deadtime between switching one channel off and turning the other channel on, reducing the efficiency. The speed of response of an optocoupler is also limited due to the capacitance of the primary side light emitting diode (LED), and driving the output to speeds up to 1 MHz will be limited by its propagation delay (500 ns max) and slow rise and fall time (100 ns max). To run an optocoupler to its maximum speed, the LED current needs to be increased to more than 10 mA, consuming more power, and reducing the lifetime and reliability of the optocoupler, especially in high temperature environments common in solar inverter and power supply applications.

![Figure 2. Optocoupler half-bridge gate driver.](image)

**Pulse Transformer Gate Driver**

Next, we will look at galvanic isolators that have a speed advantage over optocouplers due to lower propagation delays and more accurate timing. A pulse transformer is an isolation transformer that can operate at speeds often needed for half-bridge gate driver applications (up to 1 MHz). A gate driver IC can be used to deliver the high currents needed for charging the capacitive MOSFET gates. The gate driver in Figure 3 will differentially drive the primary of the pulse transformer, which has two windings on the secondary to drive each gate of a half bridge. An advantage of using a pulse transformer is that it does not require isolated power supplies to drive the secondary side MOSFETs. However, a potential problem in this application can occur when large transient gate drive currents flow in the inductive coils, causing ringing. This can potentially switch the gate on and off when not intended, leading to damage of the MOSFETs. Another limitation with pulse transformers is they may not work well in applications that require signals that have more than 50% duty cycle. This is because transformers can deliver only ac signals since the core flux must be reset each half cycle to maintain a volt-second balance. Finally, the magnetic core and isolated windings of the pulse transformer require a relatively large package. This combined with the driver IC and other discrete components creates a solution that may be too large for many high density applications.

![Figure 3. Pulse transformer half-bridge gate driver.](image)

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Digital Isolator Gate Driver

Now, we will look at the digital isolator approach to an isolated half-bridge gate driver. In Figure 4, the digital isolator uses a standard CMOS integrated circuit process with metal layers to form transformer coils separated by polyimide insulation. This combination achieves more than 5 kV rms (1 minute rating) isolation, which can be used in reinforced isolated power supply and inverter applications.

As shown in the circuit in Figure 5, the digital isolator eliminates the LED used in an optocoupler and its associated aging problems; this circuit also consumes far less power and is more reliable. Galvanic isolation is provided between the input and the output, and between the outputs, to eliminate high-side to low-side interactions. The output drivers deliver a low output impedance to reduce the conduction losses and a fast switching time to reduce the switching losses. Unlike an optocoupler design, the high-side and low-side digital isolators are integrated circuits with matching outputs for better efficiency. The high voltage gate driver integrated circuit (Figure 1) has added propagation delay in the level shifting circuit, so it cannot match channel-to-channel timing characteristics like the digital isolator can. This integration of the gate drivers in the digital isolator reduces the solution size down to a single package for a much smaller solution size. For isolated half-bridge gate driver applications, the digital isolator has been shown to offer numerous advantages over optocoupler and pulse transformer-based designs.