Application Note

Benefits of a Compact, Powerful, and Robust Low-Side Gate Driver

Ritesh Oza, Aaron Grgurich, Mamadou Diallo

ABSTRACT

The electrification of almost everything around us is happening at a rapid pace. Common industries and applications where most of this growth is occurring:

- Electric Vehicles
- Renewable Energy
- Telecom Systems
- Datacom / Server Systems
- Consumer Electronics
- Industrial Electronics

As the power demand of these applications continues to increase, the real estate available on the board continues to decrease. Miniaturization, power density, and efficiency are the new reality for today's power supply design engineers. Reliability over the lifetime of the converter is also of utmost importance. This means, the components designed into these converters need to be robust as well. The operating ambient temperature range of most of these converters is from -40C to 85C. Therefore, the printed circuit board (PCB) temperature and component temperatures can be even higher.

We will discuss design parameters to be considered while selecting a gate driver in switching power supplies and how they affect key performance metrics. Using test results in a DC-DC converter, we will show how UCC27614, TI's latest low-side gate driver, helps achieve higher efficiency, higher power density, and higher system robustness.

Table of Contents

List of Figures

Trademarks

All trademarks are the property of their respective owners.

1 Density

Modern power converter modules pack high power in a very small size. For example, power brick modules, such as 1/4 brick packs, supply in excess of 800W, eight brick packs in excess of 600W, and sixteen brick can pack more than 400W. Electronic components, such as gate drivers, need to match the trend of increased power density by offering small package sizes. A comparison of solutions sizes is shown in Table 1-1.

The UCC27614 gate driver helps minimize PCB area in the gate drive section of the board by using a smaller package (2mm x 2mm) while accomplishing the same or higher drive current (10-A) capability than most commonly available dual channel low-side gate drivers. Gate drivers are typically used in applications that require multiple MOSFETs to be driven, such as synchronous rectifiers. The solution size of using two UCC27614 is smaller than a single IC, dual channel solution. This solution size advantage allows designers to have increased drive strength, use less space, and optimize PCB layout.

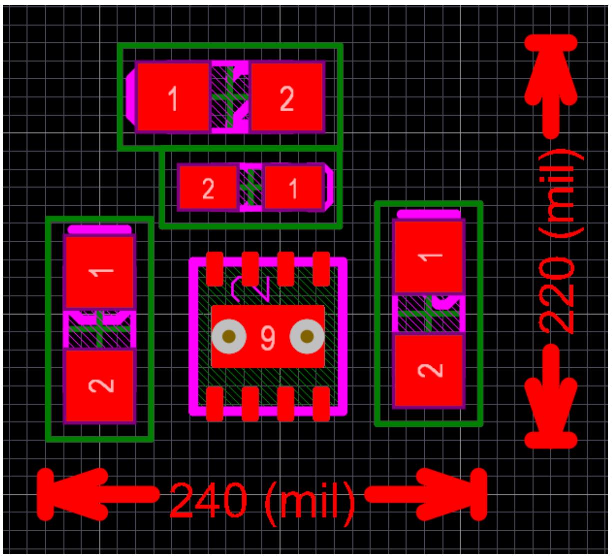

Figure 1-1. Layout Example of UCC27614 (2mm x 2mm)

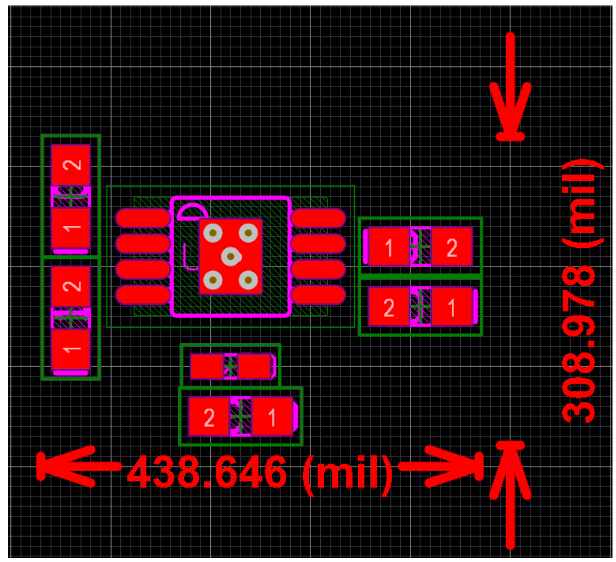

Figure 1-2. Layout Example of MSOP (5mm x 3mm) Driver

Note

240mil = 6.1mm, 220mil = 5.6mm, 438mil = 11.1mm, and 309mil = 7.85mm

Figure 1-1 and Figure 1-2 shows a PCB area comparison between UCC27614 and a commonly available MSOP (5mm x 3mm) dual channel low-side driver using a simplified gate drive circuit with a single gate resistor and 2 decoupling capacitors. Since synchronous rectification requires 2 channels, the UCC27614 solution uses 2 IC's for a total solution size of 68.13mm^2 while the dual channel solution results in 87.44mm^2. Total solution size is summarized in Table 1-1 where the 2 UCC27614 ICs results in 22.1% smaller solution size.

Table 1-1. UCC27614 Solution Size Advantage vs. Traditional Dual Channel Drivers

	UCC27614	Dual Channel Low-Side Driver
Total IC's	2	1
IC Package	2mm x 2mm	5mm x 3mm
Max Operating Voltage	30 V	26 V
Peak Pulsed Current	10 A	5 A
Solution Size	2 x 6.1mm x 5.6mm	1 x 11.1mm x 7.85mm
Total Solution Size	68.32mm^2	87.14mm^2

The layout plays an important role in optimally driving the switching power device such as MOSFETs. When the gate driver is placed far from the MOSFET, the value of the parasitic elements, such as loop inductance, increases. This increased loop inductance causes high frequency noise. Due to this high frequency noise, the system might need additional snubber components or a larger EMI filter. In worst case, this high frequency noise might cause excess stress and damage on the components. Because of its small size, UCC27614 can be placed extremely close to the power MOSFETs and helps avoid most layout related issues.

2 Wide Supply Voltage Range

The wide supply voltage range of the UCC27614, (4.5 V to 26 V) is optimized to source/sink high peak current to drive high gate charge MOSFETs as shown on Figure 2-1 and Figure 2-2. The UCC27614's wide drive voltage and high peak current can also be beneficial to drive IGBTs, which have higher threshold voltages and larger gate capacitance than Si MOSFETs. The 26 V maximum recommended operating voltage provides sufficient margin against transients resulting from high di/dt in the gate drive loops coupled with parasitic inductance from PCB traces in fast switching applications.

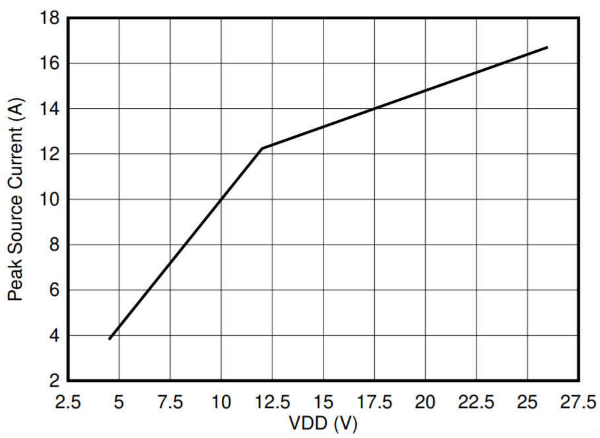

Figure 2-1. Peak Source Current vs V_{DD}

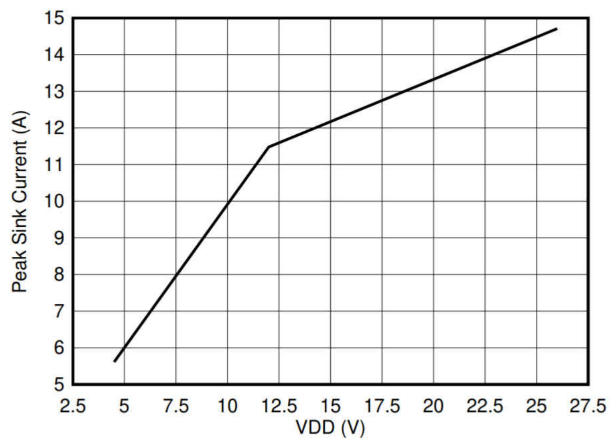

Figure 2-2. Peak Sink Current vs V_{DD}

3 Gate Drive Critical Loops

As explained earlier, gate drivers need to be placed as close as possible to the switching power devices, such as MOSFETs, for optimum performance. These switching power devices are generally operated at significantly higher temperature than ambient, and often close to their limits, such as 140C. Therefore, the gate driver must also be capable of operating at these higher ambient operating temperatures.

Lower ON resistance of the output stage and the thermal pad of the UCC27614 help it achieve wide thermal operation window of -40C to 150C . The UCC27614 not only provides great switching performance at very high switching frequencies, such as 6MHz, but also stays well within the recommended junction temperature range as shown in Figure 3-1.

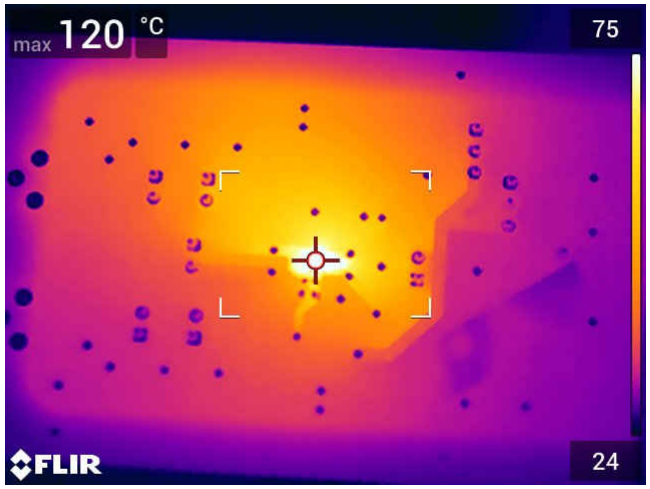

Figure 3-1. Case Temperature with C_{Load} = 1.8nF, V_{DD} = 12V, and f_{sw} = 6MHz

4 Efficiency and Switching Performance

For example, if a MOSFET with gate charge of 156nC needs to be turned ON and OFF within 20ns, then the gate driver needs to supply 7.8 A of peak source and sink current, as shown in Equation 1.

$$\frac{dQ}{dt} = C \times \frac{dV}{dt} = Ipk = \frac{152nC}{20ns} = 7.6A \quad (1)$$

UCC27614 is capable of delivering 10A even at junction temperature of 150C, which is confirmed in Figure 4-1. The high drive strength across temperature range allows the driver IC to consistently deliver fast and stable rise/fall times, ensuring minimum losses on the FETs regardless of the junction temperature.

Because power MOSFETs in these applications operate at high case temperatures, the gate driver needs to supply sufficient drive current regardless of temperature so that rise and fall times of the switching MOSFET can be minimized. Faster rise and fall times allows the MOSFET to be in the ohmic region for less time and get into the saturation region sooner, which results in less resistive losses in the transistor. The gate driver's propagation delay should also be minimized, so that the dead time can be optimized, which results in lower losses and higher efficiency.

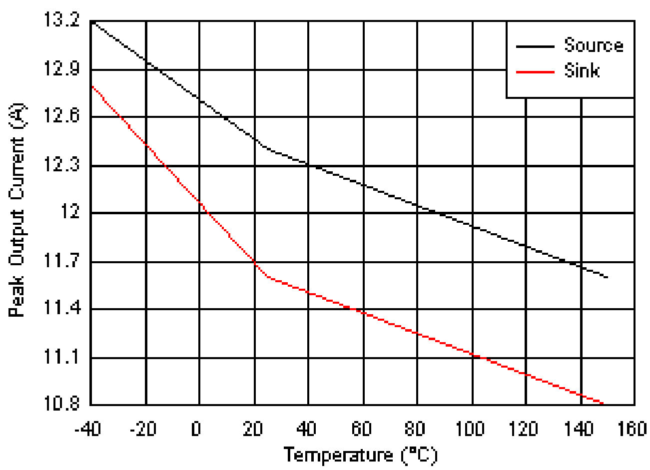

Figure 4-1. Source and Sink Current at 12 V and 100nF Load Across Temperature

5 UCC27614 in a 400V to 12V DC-DC Converter

Figure 5-1 shows a simplified block diagram of the PSFB circuit where MOSFETs Q1, Q2, Q3 and Q4 form the phase shifted full-bridge on the primary side of the transformer T2. Q1 and Q4 are switched at 50 % duty and 180 degrees out of phase with each other. Similarly, Q2 and Q4 are switched at 50 % duty and 180 degrees out of phase with each other. The PWM signals for the half-bridge Q2 – Q3 are phase shifted with respect to those for second half-bridge Q1 – Q4. The amount of this phase shift dictates the amount of overlap between diagonal FETs, which in turn determines the amount of energy transferred.

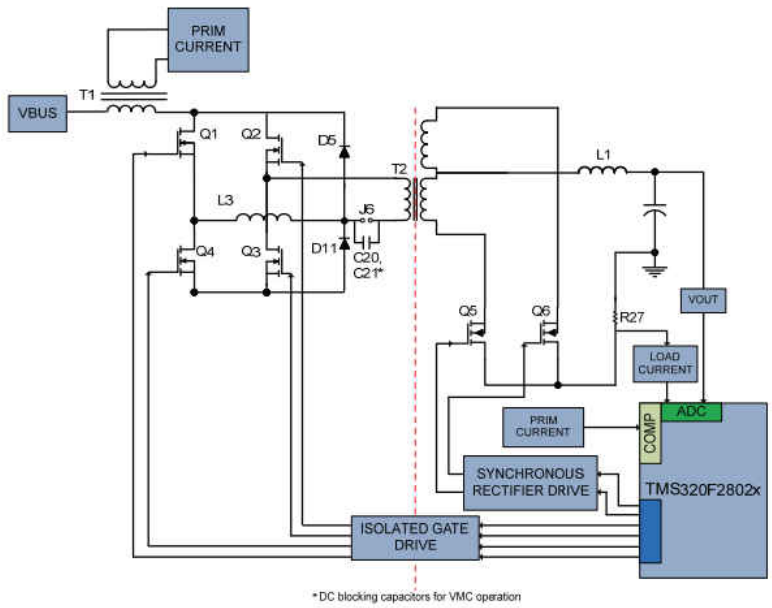

Figure 5-1. Simplified Phase Shifted Full Bridge Converter with Secondary Side Synchronous Rectification

Synchronous rectification is used for high output current isolated DC-DC to converters, where output diodes are replaced with MOSFETs to replace diode forward conduction losses with MOSFET conduction losses. This is because the voltage drop across a MOSFET, $R_{DS(on)}$, is significantly smaller than the diode forward voltage drop and therefore results in lower losses and higher efficiency.

Figure 5-2 shows the converter input (400VDC), output (12VDC) using the UCC27614 outputs (CH4_U5_OUT) driving the synchronous rectification MOSFET to achieve efficient V_{DS} switching times (CH1). Figure 5-3 shows the converter's output voltage and current with a gate drive voltage of 12V to drive the synchronous rectification MOSFET.

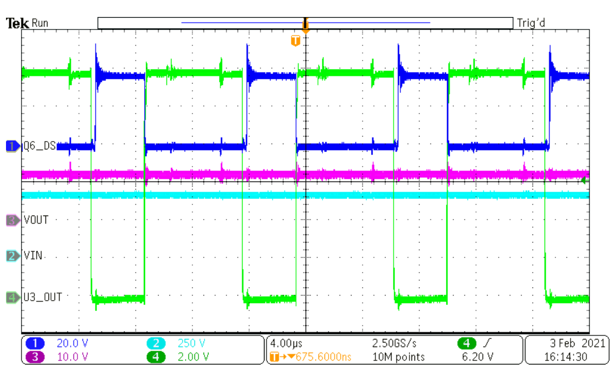

Figure 5-2. Converter Input, Converter Output, Gate Drive Waveform, and MOSFET Drain to Source Voltage

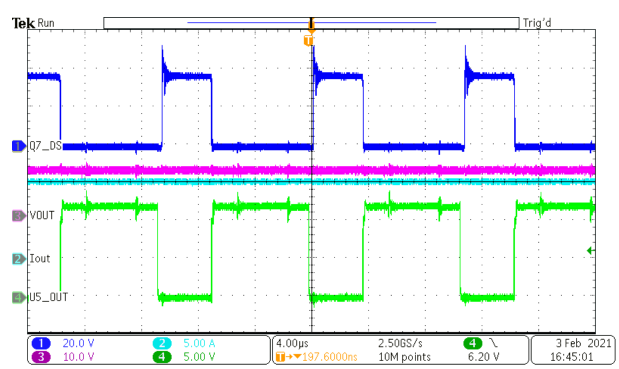

Figure 5-3. Converter Voltage Output, Converter Current Output, Gate Drive Waveform, and MOSFET Drain to Source Voltage

6 Summary

The small size (2mm x 2mm) of UCC27614 helps achieve denser power solutions. 10A of peak current across the entire temperature range helps achieve lower losses and therefore higher efficiency. Small propagation delay furthers the cause of higher efficiency. 150C junction temperature capability, 30V absolute maximum supply voltage , and better high frequency noise handling capability of the UCC27614 improves the system robustness.

7 References

- Texas Instruments, *Gate Drivers* products
- Texas Instruments, *UCC27614 30-V, 10-A Single Channel Low Side Gate Driver with -10V Input Capability* data sheet
- Texas Instruments, *UCC27614* product folder