Texas Instruments

Application Report

SLVA741–November 2015

DRV3201 Boost Converter

Motor Drive Business Unit - Advanced Protection Motor Drivers

ABSTRACT

The DRV3201 boost converter is used to drive the external power MOSFETs. This type of converter allows the DRV3201 to continue full operation of the external bridges down to a lower voltage than other DC-DC converters. It is important to understand the requirements of the external components to power the boost to ensure proper operation. This application report describes the boost converter for the DRV3201.

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1 Boost Converter

The output current capability of the Boost Converter can be configured with the external *Rshunt_boost* resistor to 0.1 V/*Rshunt_boost* (please note that this resistor needs to be able to conduct the boost switching current). In this way, the output current capability can be dimensioned to the needed current determined by the PWM switching frequency and the gate-charge of the external power FETs. TI recommends choosing a coil having a current saturation level of at least 30% above the current limit level set with the resistor *Rshunt_boost* .

The operation principle of the Boost Converter is based on a burst-mode fixed-frequency controller. During the on-time, the internal low-side boost FET turned on until the current limit level is detected; the off-time is calculated proportionally from a 2.5-MHz time-reference by sensing the supply voltage (VS) and the output voltage (VBOOST). The formula for the calculated off-time is given in Equation 1, with f_{boost} = 2.5 MHz.

$$t_{off} = \frac{VS}{V_{BOOST} \times f_{BOOST}} \tag{1}$$

For steady-state, the current in the coil will look as illustrated in Figure 1.

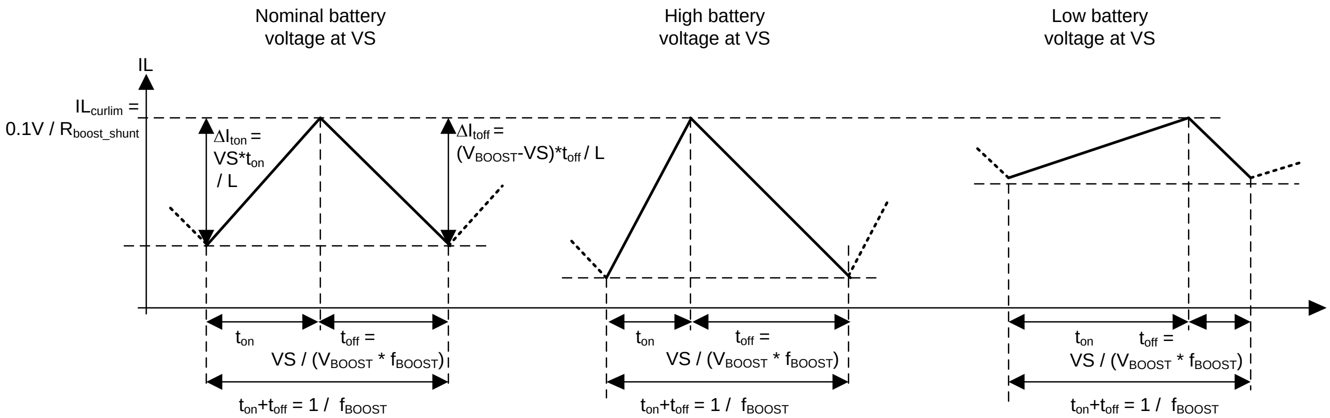

Figure 1. Coil Current Waveforms in Steady State for Nominal, High and Low Battery Voltage

From this figure, the ripple current and the boost output current can be calculated as follows:

$$IL_{ripple} = \frac{VS}{L \times f_{BOOST}} \times \left(1 - \frac{VS}{V_{BOOST}}\right) = \frac{(V_{BOOST} - VS) \times VS}{L \times f_{BOOST} \times V_{BOOST}} \tag{2}$$

$$I_{BOOST} = \frac{VS}{V_{BOOST}} \times IL_{curlim} - \frac{1}{2} \times \left(\frac{(V_{BOOST} - VS) \times VS}{L \times f_{BOOST} \times V_{BOOST}}\right) \tag{3}$$

$$f_{BOOST} = 2.5\text{ MHz}; \quad (V_{BOOST} - VS) = 15\text{ V}; \quad IL_{curlim} = \left(\frac{0.1\text{ V}}{R_{shunt\_boost}}\right) \tag{4}$$

As Equation 3 shows, the boost output current capability for a given *IL_curlim* is the lowest for the minimum supply voltage VS. So the boost output current capability needs to be dimensioned (by setting *IL_curlim* with external *Rshunt_boost*) such that the needed output current (based on PWM frequency and gate-charge of the external power FETs) can be delivered at the needed minimum supply voltage for the application. Equation 5 gives *IL_curlim* as a function of *IBOOST* and *VS*:

$$IL_{curlim} = I_{BOOST} \times \frac{V_{BOOST}}{VS} + \frac{1}{2} \times \left(\frac{V_{BOOST} - VS}{L \times f_{BOOST}}\right) \tag{5}$$

For setting the *IL_curlim*, the minimum application supply needs to be used in this equation and IBOOST according to Equation 5. The minimum application supply voltage which the DRV3201 can support is 4.75 V.

As shown by Equation 3, the boost output current capability increases for higher supply voltage VS. In case the boost output current capability is dimensioned such that it can deliver the necessary output current for the minimum supply voltage, it actually will deliver more current than needed for nominal supply voltage. This will cause the boost voltage to increase. Therefore, a hysteretic comparator (low-level VBOOST – VS = 14 V, high level VBOOST – VS = 16 V) determines starting/stopping the burst pulsing, as Figure 2 illustrates.

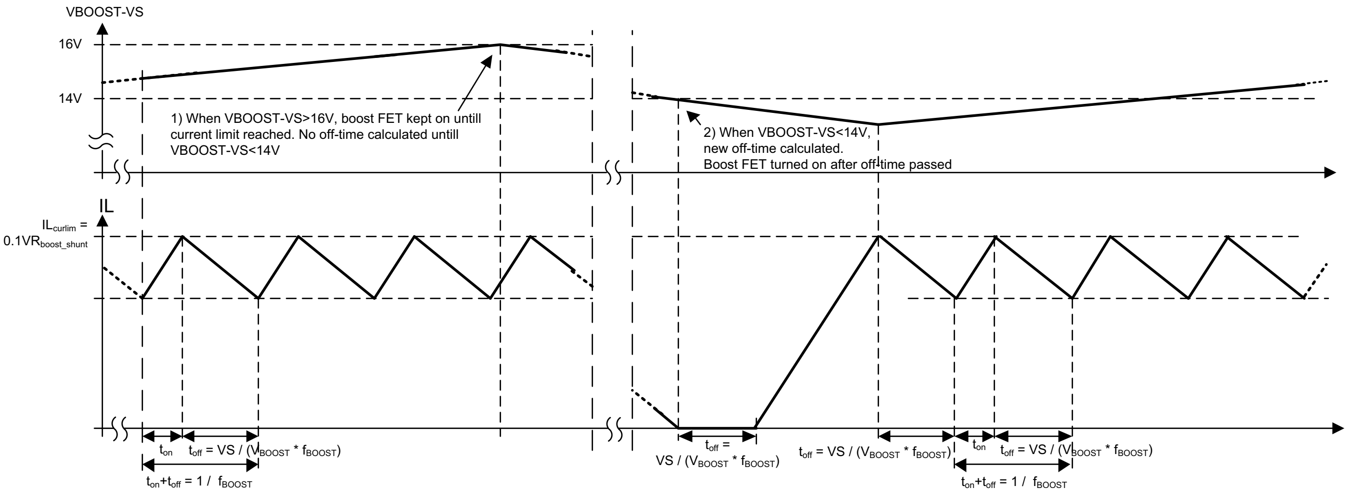

Figure 2. Boost Waveforms Showing Burst Pulsing Controlled by Hysteretic Comparator Levels

2 Application Circuit for Boost Converter

The recommended application for the Boost Converter is given in Figure 3. For the best performance a Schottky diode and a 22-µH coil is required. The current limit for the internal FET (and hence the maximum current in the coil) can be adjusted and is set to 0.1 V/0.33 Ω = 303 mA in the recommended application.

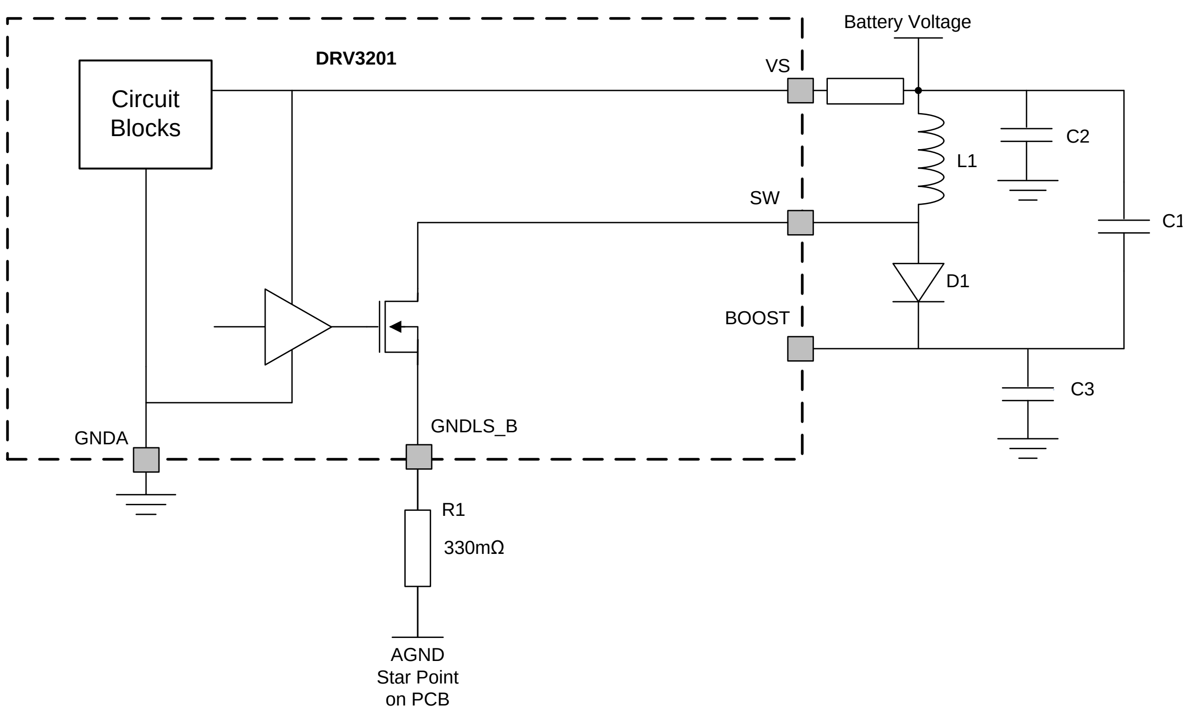

Figure 3. Recommended Application Circuit for Boost Converter

All capacitors must be appropriately sized to handle the boost voltage. The following list shows the part numbers for the primary components:

L1 = B82442A1223K000

D1 = SS28

C1 = 1 µF

3 Boost Converter Noise Reduction

In addition to the boost capacitor C1, two bypass capacitors, C2 and C3, are placed to reduce the ringing effect from the converter switching. Figure 4 shows the effect of adding two 0.1-µF bypass capacitors to the boost ripple. The red trace is the rising edge of the boost ripple while the converter is switching. The green trace shows the current sense output O1 to illustrate the possible coupling on the system. The first diagram is taken from our DRV3201EVM without any bypass components and shows the coupling from the converter switching to the boost output and the O1 current sense output. The addition of the bypass capacitors in the second diagram show a decrease in the transient spikes on the boost output, and show no coupling on the current sense output O1.

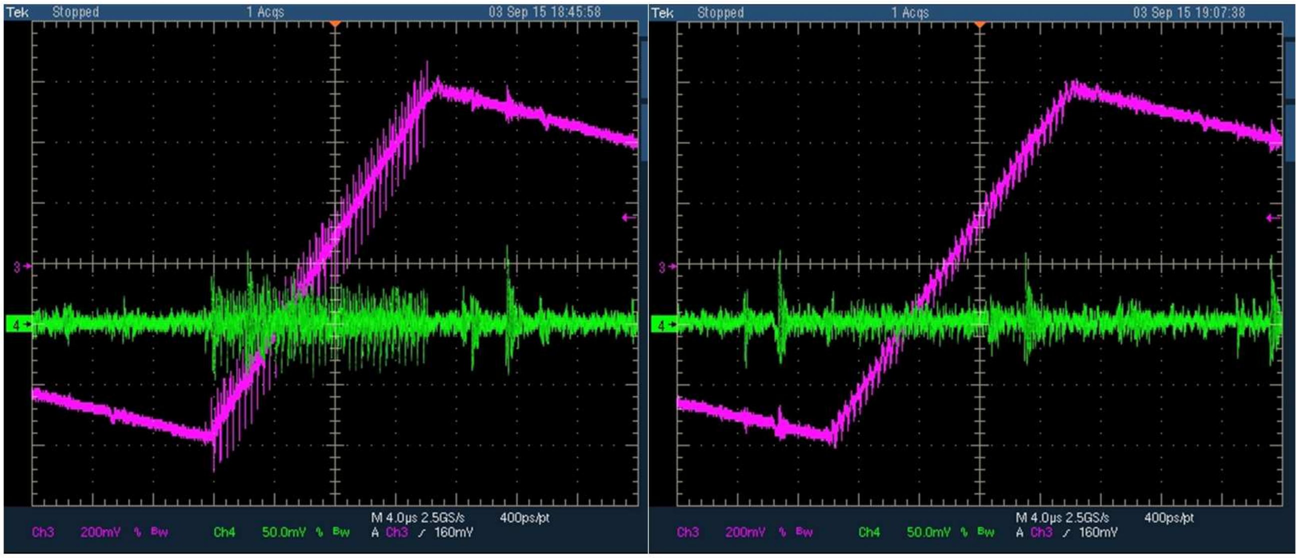

Figure 4. Boost Output and Current Sense O1 Output, Before and After Bypass Capacitor

The layout for the boost converter is critical to the device performance for both regulation and noise suppression. The most important consideration when laying out the boost converter is to keep all high current loops small. Figure 5 and Figure 6 show the high current paths during the on and off states of the boost MOSFET during regulation.

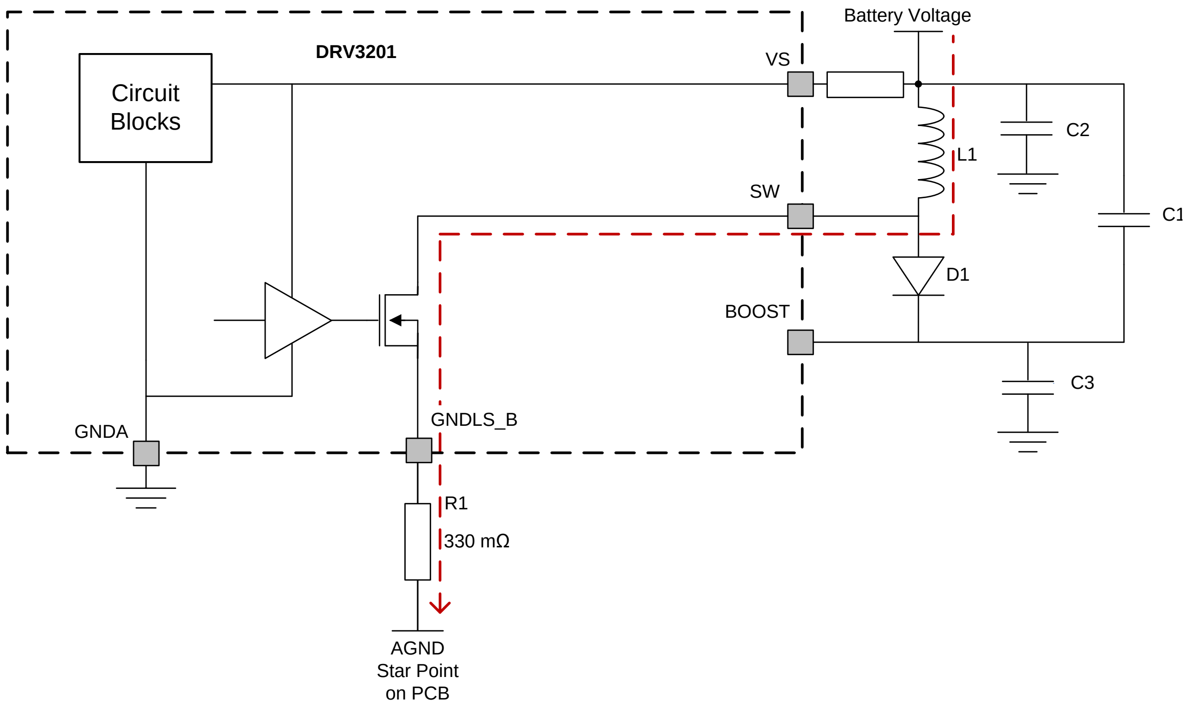

Figure 5. High Current Path During Boost FET 'On' State

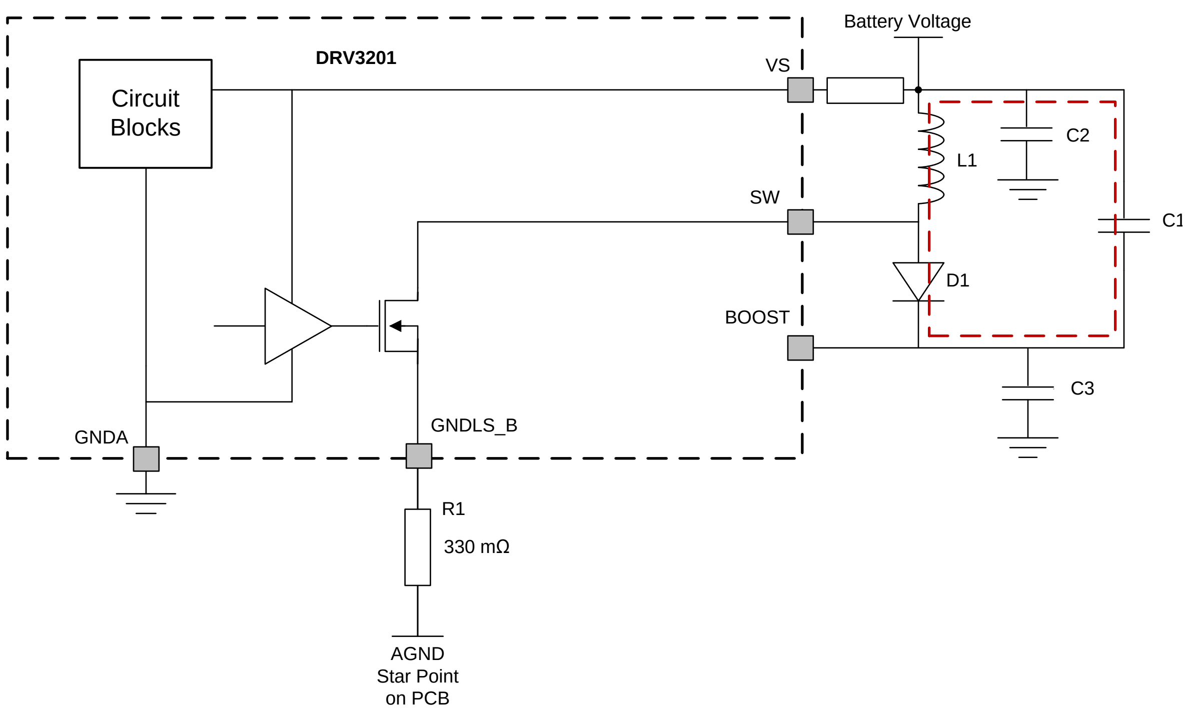

Figure 6. High Current Path During Boost FET 'Off' State

In addition to these high current paths, the loops for high current transients must be kept small. Figure 7 illustrates the high current transient loops that exist when at the instant the boost FET is switched on or off.

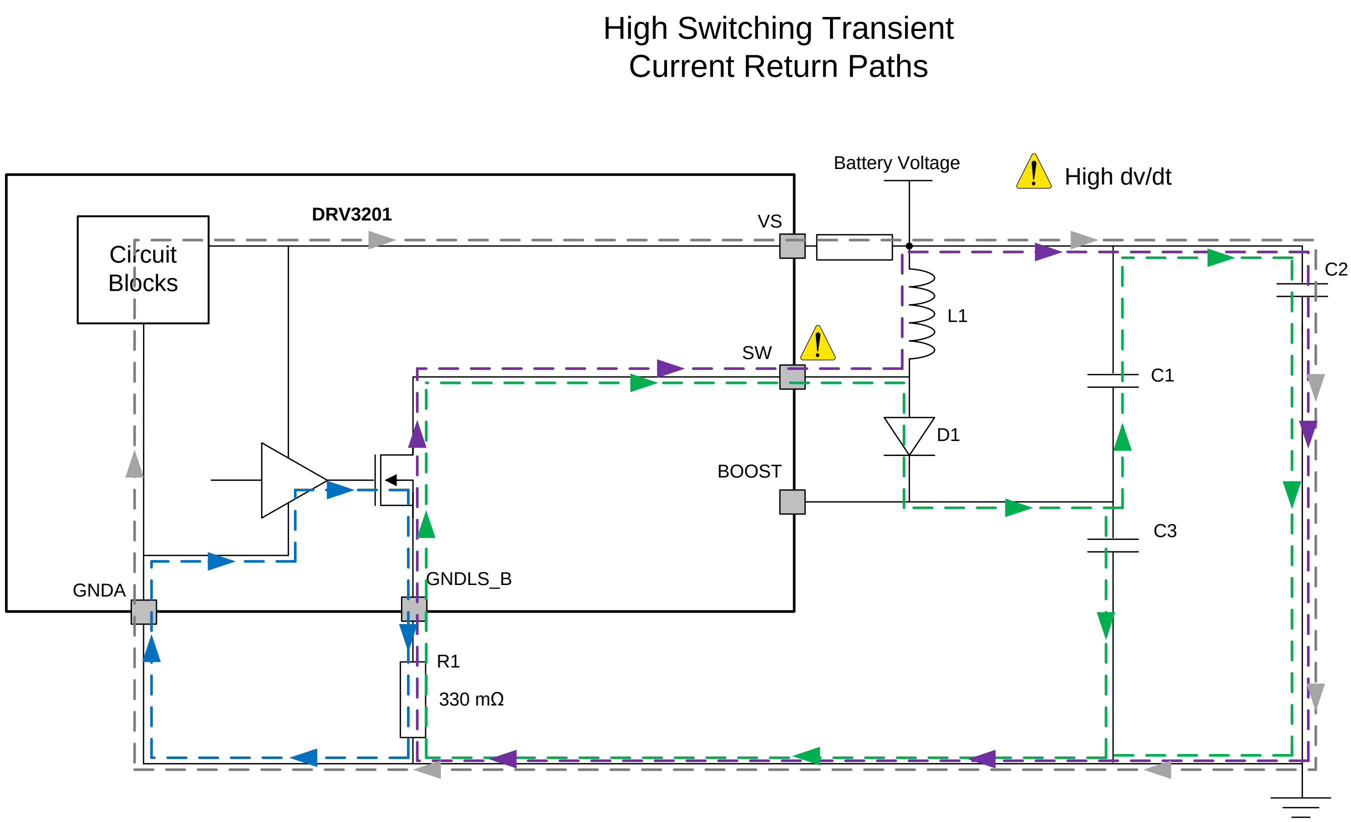

Figure 7. High Switching Transient Current Return Paths

If required, an additional series RC snubber circuit can be added to the switch pin to further reduce noise due to the effects of parasitic inductance and capacitance. For additional details on selection of snubber components, refer to *Minimizing Ringing at the Switch Node of a Boost Converter* (SLVA255).

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