Application Report

Negative Input to Negative Output Step-Up Converter Design Using TPS61086

SW Lee

ABSTRACT

The TPS61086 device is a high-efficiency DC-to-DC converter with an integrated 2.0- A, 0.13-Ω power switch capable of providing an output voltage up to 18.5 V. The typical application for the TPS61086 is to reach higher level of positive output voltage from positive input voltage using the Boost topology. However, there are very few options for the engineer when it comes to creating negative voltage rails, and this application report introduces a solution to create a negative output voltage with a larger (more negative) amplitude from a negative input voltage using the TPS61086. By applying the proposed method, it would achieve a larger negative output voltage at a reasonable cost, and this report shows how well the initial design tests met to achieve negative input to negative output conversion using the TPS61086.

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1 Introduction

The Boost converter is used to *step-up* an input voltage to some higher level, and this characteristic is achieved by storing energy in an inductor and releasing it to the load at a higher voltage. The TPS61086 device that is specifically designed for Boost converter applications allows the use of small external inductors and capacitors with high switching frequency (1.2 MHz) and provides fast transient response.

Figure 1-1 shows the typical application circuit of the TPS61086 to get 12-V output from 3.3-V input. As shown in Figure 1-1, the typical application for the TPS61086 is to reach higher level of positive output voltage from positive input voltage using the Boost topology as it is the primary intended application. However, if a negative voltage is available in the system, it is necessary to use the negative voltage as the input for the converter, and it is beneficial to create more negative amplitude directly from the negative input voltage in non-isolated DC-to-DC solutions including point-of-load applications.

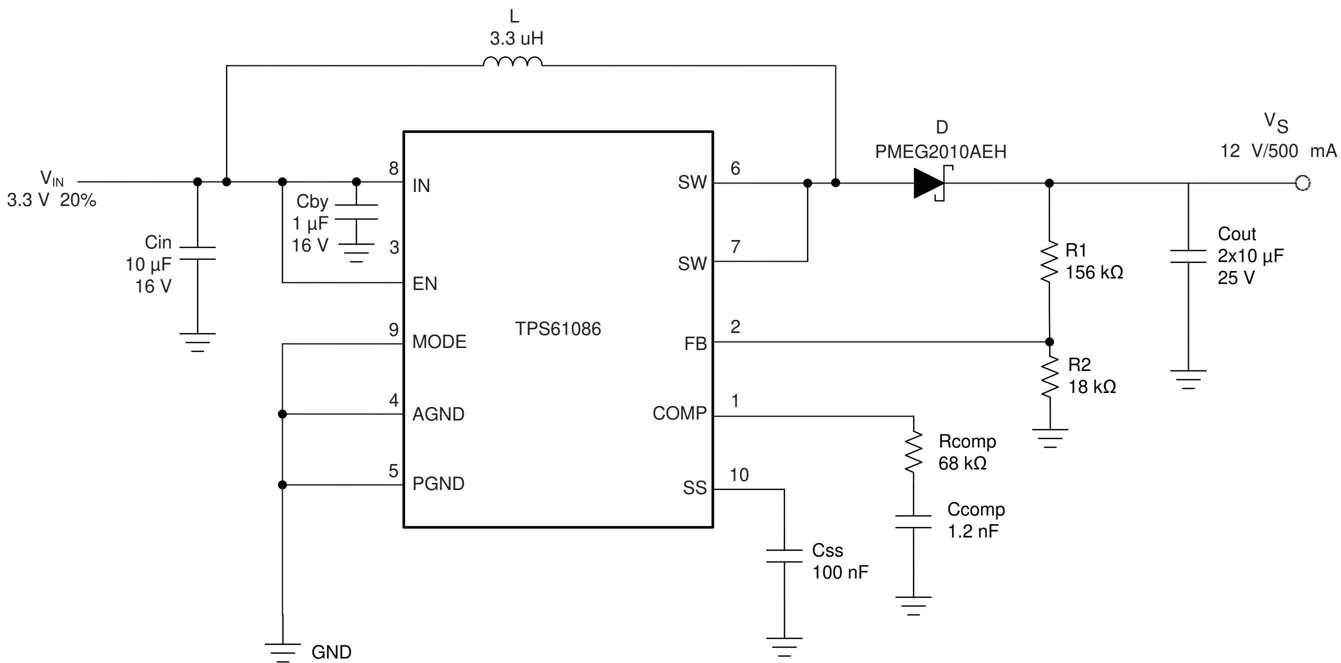

Figure 1-1. Typical Application Circuit of the TPS61086

It is certainly important to understand not only the internal construction of the TPS61086 itself but also switcher topologies themselves for the conversion across different topologies. There are many things to consider working on new configurations including voltage ratings of each pin, the feedback path, the ground connection and so on, and these are essential to get the desired results.

2 Proposed Circuit for Negative-to-Negative Boost Application

In non-isolated DC-to-DC applications, there are two input rails connecting to the DC source and two output rails connecting to the load. One rail is always shared between the input and the output, and this common rail is designated the system ground which is the ground for the power stage. The ground of the TPS61086 may not always be connected to the system ground if the TPS61086 is being used in a way other than its primary intended application.

Figure 2-1 shows the proposed circuit for negative-to-negative boost application, and the ground of TPS61086 is not connected directly to the system ground. In this case, the sensing point for the feedback is not direct from the actual load since the feedback voltage always needs to be referenced to the ground of the TPS61086.

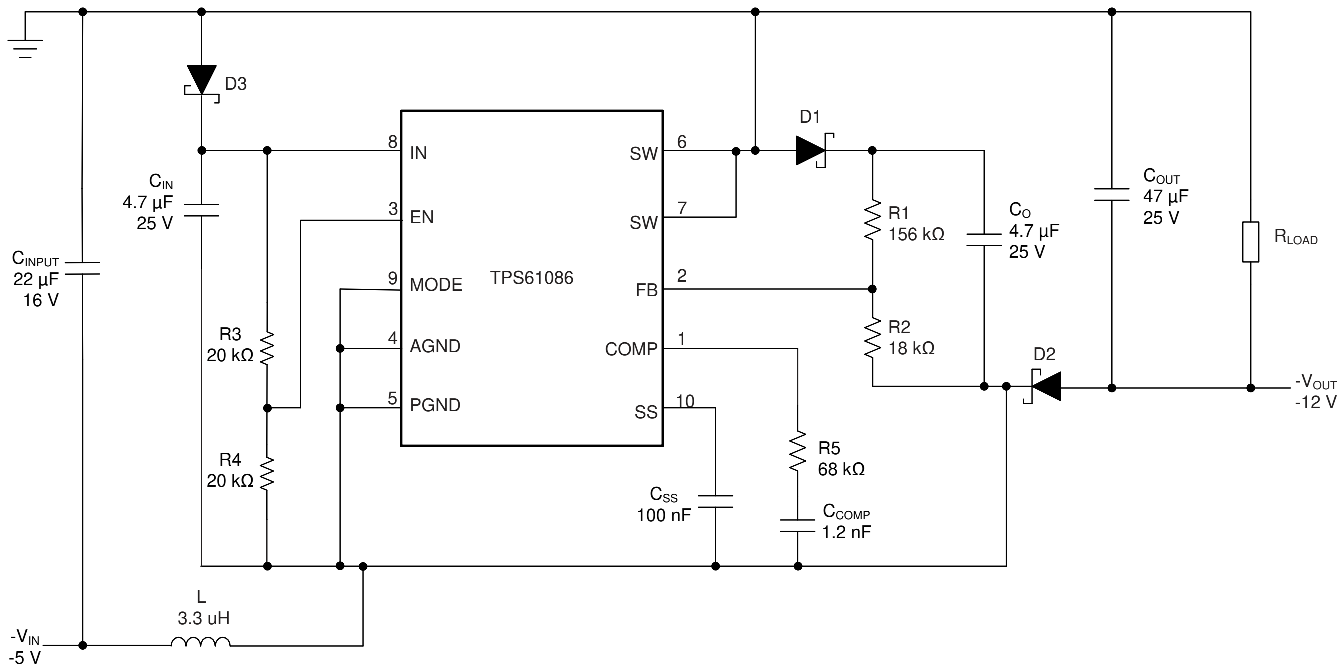

Figure 2-1. Negative-to-Negative Boost Converter

The regulator loop can be compensated by adjusting R5 and Ccomp connected to COMP pin which is the output of the internal transconductance error amplifier.

This conversion belongs to the family of indirect energy transfer converters, and the power process involves an energy-storing phase and energy-release phase. During the on time, the inductor stores energy, and the output capacitor alone powers the load. When the internal power switch of the TPS61086 closes, V_{IN} immediately appears across the main inductor (L), and the inductor current reaches a peak value as it is defined by Equation 1.

$$I_{peak} = I_a + \frac{V_{IN}}{L} \times t_{on} \tag{1}$$

I_a represents the condition for t=0. In the case of the discontinuous conduction mode case, it can be zero, or a certain value for continuous conduction mode operation. Figure 2-2 shows the situation where the load and the output capacitor are left alone while the power switch closes, and the output capacitor voltage will decrease during this on time.

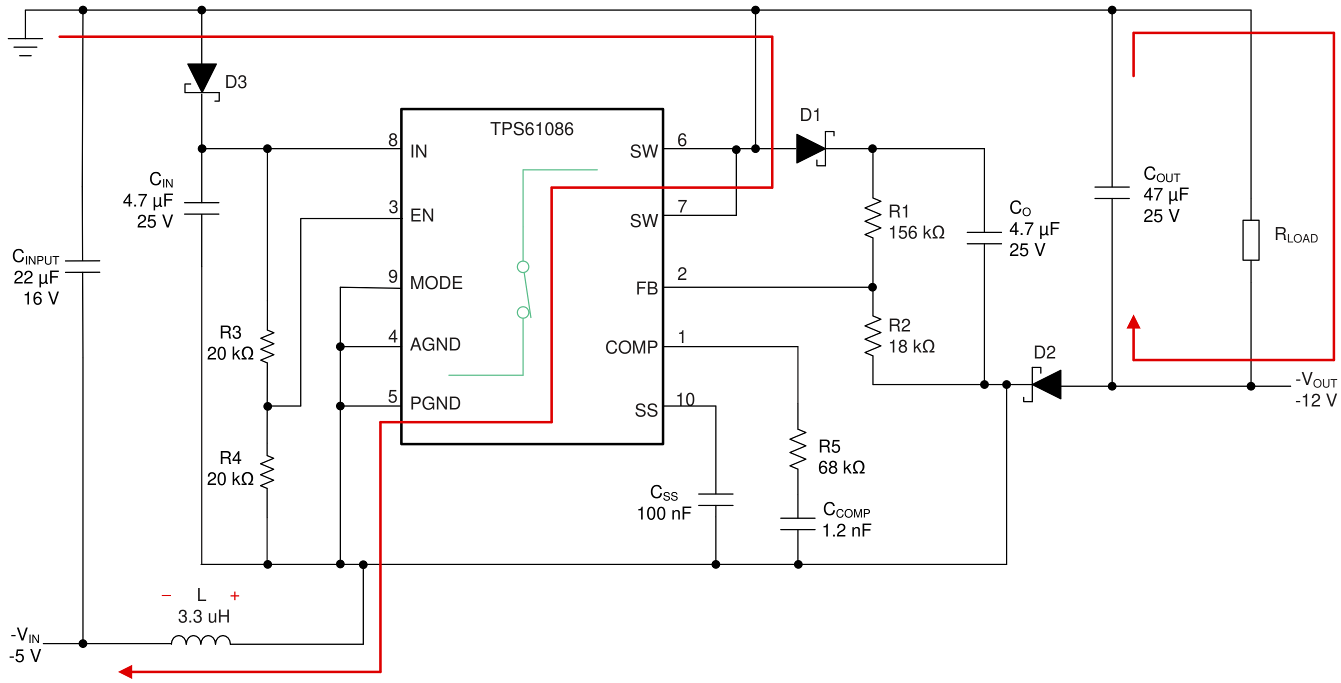

Figure 2-2. The Internal Power Switch of the TPS61086 is On

Figure 2-3 shows the status when the internal power switch of the TPS61086 turns off, and the inductor current must find a circulating path in this case. At the power switch opening, the stored inductor energy appears in series with the input source (V_{IN}) and contributes to supply the output. Also, the inductor voltage reverses trying to keep the ampere-turns constant, and this voltage comes in series the input voltage.

During the off time, the energy stored in the inductor during the on time depletes to a rate described by Equation 2.

$$I_a = I_{peak} - \frac{V_{OUT} - V_{IN}}{L} \times t_{off} \tag{2}$$

The diode (D1) routes the inductor current to the capacitor (C_O) for the feedback path to regulate the output voltage (V_{OUT}) since the feedback voltage always needs to be referenced to the ground of the TPS61086. Also, the diode (D2) routes the inductor current to the capacitor (C_{OUT}) and the output load (R_{LOAD}), and this will help dump the stored inductor energy into C_{OUT} and R_{LOAD}. When the new cycle occurs, the internal power switch of the TPS61086 closes again as shown in Figure 2-2.

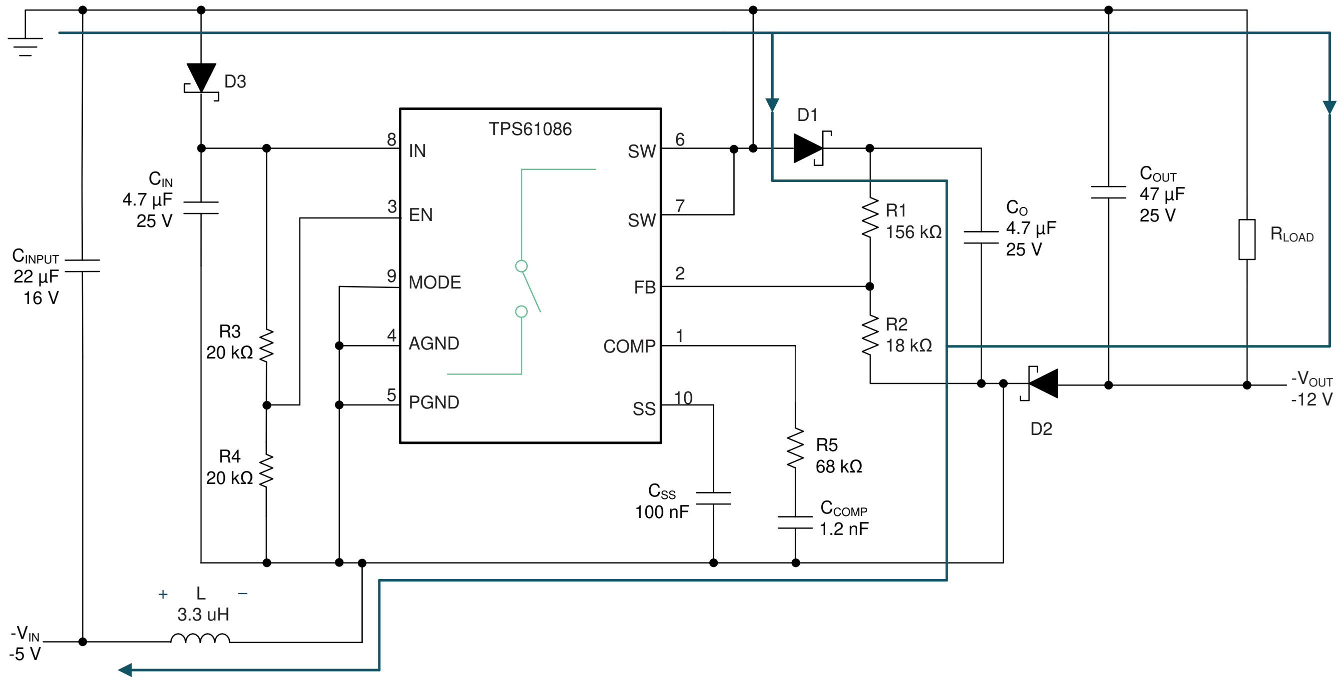

Figure 2-3. The Internal Power Switch of The TPS61086 is Off

3 Simulation and Experimental Results

To verify the operation and performance of the proposed application method, the critical waveforms including the output voltage and the inductor current are measured as shown in the figures from Figure 3-1 to Figure 3-3. The results shown in Figure 3-1 and Figure 3-2 have been obtained by PSpice simulation, and it can be seen that the TPS61086 operates properly for negative-to-negative boost applications.

Figure 3-1 shows -12 V output voltage in red starting up with -5 V input voltage in green.

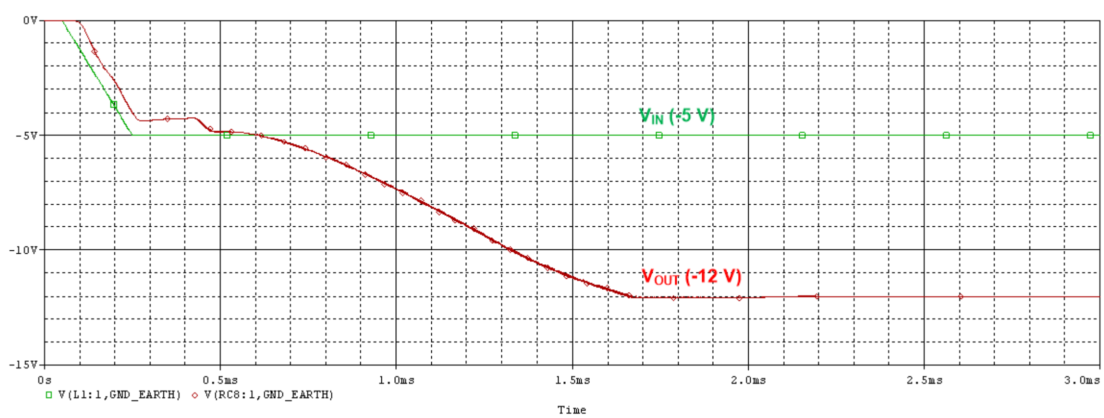

Figure 3-1. PSpice Simulation Result at Startup

Figure 3-2 shows the inductor current, the output voltage and the switching node of the inductor at steady state activating the internal power switch on and off, and the output current is 200mA. As shown in Figure 3-2, when the internal power switch is on, the switching node of the inductor goes up to the system ground. On the opposite, when the internal power switch is off, this will help dump the stored inductor energy into C_{OUT} and R_{LOAD}.

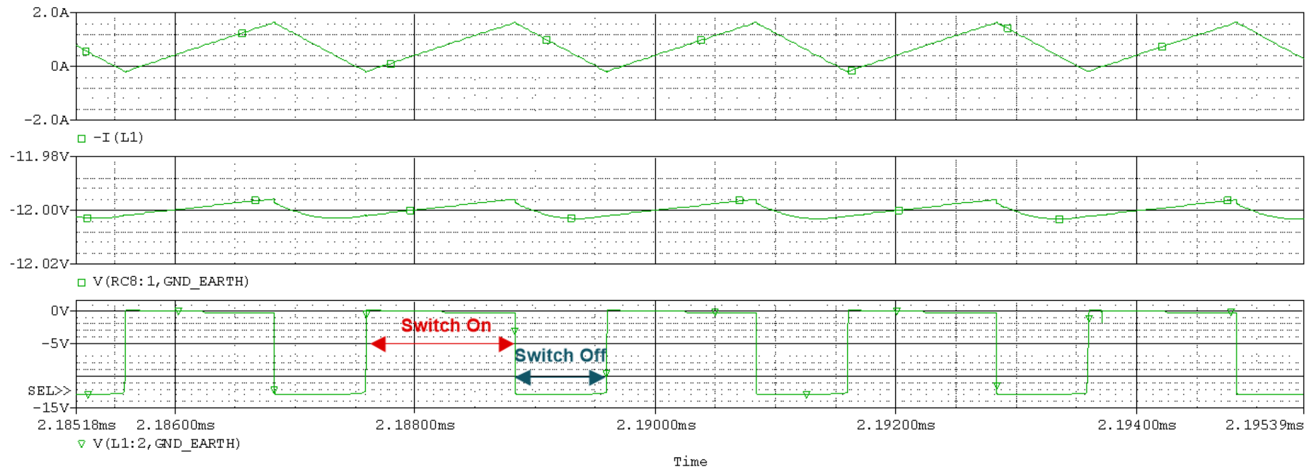

Figure 3-2. PSpice Simulation Result at Steady State

Figure 3-3 shows an experimental result to create -12 V output (Ch2 in light blue, 2 V/div) from -5 V input (Ch1 in blue, 2 V/div). As shown in Figure 3-3, the test waveform matches the simulation result well, and the actual input voltage range is from -2.9 to -6 V for the proper regulation on the output (-12 V).

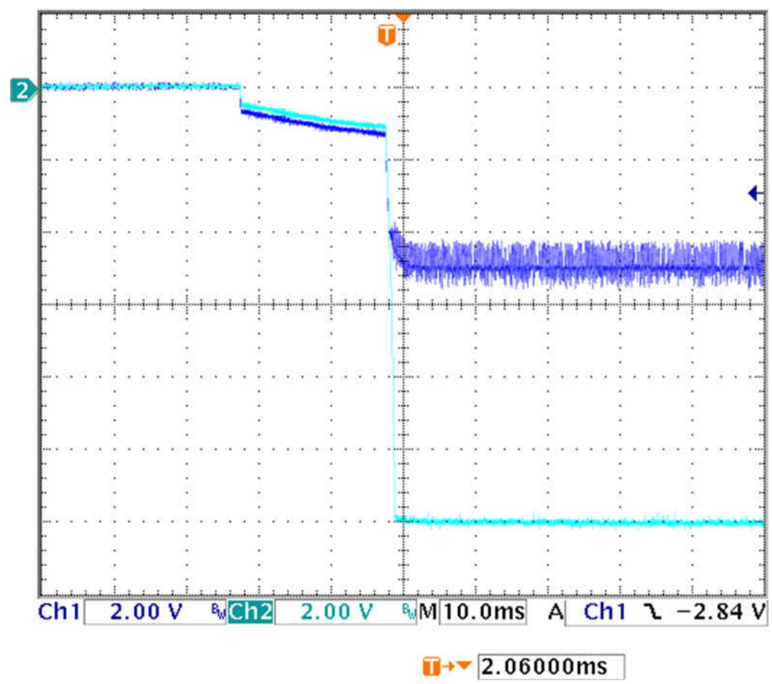

Figure 3-3. Test Waveform from -5 V Input to -12 V Output

It is important to note that this kind of new configurations might have different voltage levels on each pin of the TPS61086 compared to its primary intended application, and the desired operation can be successfully achieved by complete understanding on the both the internal construction of the TPS61086 and the power stage topologies.

4 Summary

A practical approach to create a negative output voltage with a larger (more negative) amplitude from a negative input voltage using the TPS61086 is proposed in this application report. As it has been confirmed with the actual application case (V_{IN} =-2.9 V~-6.0 V, V_{OUT} =-12 V, L=3.3uH) by PSpice simulation and experimental results, the solution operates properly. The ground of TPS61086 is not connected directly to the system ground with the new configuration. In this case, the sensing point for the feedback is not direct from the actual load since the feedback voltage always needs to be referenced to the ground of the TPS61086, and the new configuration should be carefully reviewed in terms of voltage ratings, current waveforms, the feedback path, PCB layout and so on to get the desired results.

5 References

- Texas Instruments, *TPS61086 18.5-V PFM – PWM Step-Up DC – DC Converter With 2.0-A Switch* data sheet.
- Texas Instruments, *TPS61086EVM-526 User's Guide*.