Extending the Wide Output Voltage Capability of the TPS6108x Boost Converter

ABSTRACT

This application report explains how to extend the wide output voltage range capability of the TPS6108x by a factor of two using a discrete charge pump.

Introduction

In a normal circuit configuration, the TPS6108x is capable of providing an output voltage up to 27 V. This output range can be doubled with the addition of a charge pump consisting of only two additional diodes and two capacitors (see Figure 1). With the additional charge pump, the TPS6108x can provide output voltages up to 54 V. Figure 2 shows the discrete charge pump used to achieve this extended range of voltages.

Figure 1. Discrete Charge Pump Used to Extend the Voltage Range
Setting the Output Voltage

Typically, when a charge pump is tied to a converter to provide a secondary output, the charge pump output is unregulated. However, because the charge pump provides the primary output, the feedback circuitry in this application is tied to the charge pump output for better regulation. The same TPS6108x output voltage equation is valid for setting the output voltage with the charge pump configuration. For ease of finding resistors and for minimizing noise injection problems, the quantity R1 plus R2 should be kept less than 1 MΩ, which typically results in choosing R2 between 15 kΩ and 40 kΩ. These values vary slightly from the data sheet (SLVS644) recommendation because the output voltage range is different.

To set the output voltage, select the values of R1 and R2 according to Equation 1.

\[ R_1 = R_2 \times \left( \frac{V_{out}}{1.229 \text{ V}} - 1 \right) \]

(1)

The feedforward capacitor should be chosen by following the guidelines suggested in the data sheet by keeping the zero frequency between 1 kHz to 10 kHz.

\[ F_z = \frac{1}{2\pi R_1 \times C_1} \]

(2)

As stated in the data sheet, for high-output voltage, the zero and pole are further apart which makes the feedforward capacitor effective.

For this example, R1 and R2 were chosen to be 681 kΩ and 18.2 kΩ, respectively, to set a 48-V output voltage. Initially, the value for R2 was chosen to be 25 kΩ, but this value resulted in R1 and R2 being close to 1 MΩ. Therefore, the R2 value was decreased and the R1 value was recalculated. A value near 18.2 kΩ for R2 also would have been acceptable. A zero frequency of 2 kHz then was chosen to determine Cff (C1), which rounded to the nearest standard capacitor value, is 120 pF. Because a high-output voltage is being set, and R1 is much larger than R2, the zero and pole frequencies are further apart and the pole has little effect on the phase and gain at the crossover frequency.

Transient analysis or frequency analysis should be used to verify that the converter is operating with acceptable performance. In this example, frequency analysis was used and the plot shown in Figure 3 verifies that the components chosen for this application resulted in acceptable loop characteristics.
Figure 3. Open-Loop Gain and Phase of TPS6108x Boost Converter With an Attached Charge Pump, 48-V Output With 70 mA of Load.

Charge Pump Capacitor
The charge pump capacitor (C7) is recommended to be a 1-μF ceramic capacitor rated for a voltage greater than 1/2 the output voltage. In Figure 4, the difference between trace 4 and trace 3 shows the voltage across this capacitor, which is half the voltage of the 48-V output.

Output Capacitor
Because the charge pump is in a voltage-doubling configuration, the voltage on the OUT pin of the TPS6108x is approximately half of the output voltage. See Figure 4 for an example of voltage waveforms observed on a 48-V output boost/charge pump circuit. Although the user may opt to choose higher voltage-rated output capacitors tied to ground from both the TPS6108x OUT pin and from the discrete charge pump output, it is slightly more cost-effective, in this example, to stack lower voltage-rated capacitors (C5 and C4) on top of one another as shown in Figure 2. Neither configuration has a clear operational advantage over the other. The trade-offs, such as required voltage ratings and equivalent capacitances, in each configuration affect the overall cost. In either configuration, placing a 0.1-μF capacitor between the output of the charge pump and ground to filter out high-frequency switching spikes is recommended. For the output capacitors of the boost and charge pump, 4.7-μF or 10-μF ceramic capacitors are recommended. Figure 5 shows a typical waveform of the charge pump output ripple. Additional post regulation filtering may be required if lower output ripple is desired.

Circuit Waveforms
In Figure 4, channel 1 (C1) is the output waveform of the charge pump; channel 2 (C2) is the output waveform of the TPS6108x OUT pin; channel 3 (C3) is the positive referenced terminal of the charge pump capacitor; and channel 4 (C4) is the negative referenced terminal of the charge pump capacitor (see Figure 4).
Figure 5 shows a typical output ripple waveform of an ac-coupled, 48-V output at 70 mA of load. The output has two 4.7-μF output capacitors stacked on top of each other, shown in Figure 2, with an additional 0.1-μF capacitor tied from output to ground for high-frequency filtering.
Output Current Capability

The trade-off for extending the output voltage up to 2x the TPS6108x output voltage is reduced output current capability. Because the charge pump doubles the output voltage from the normal boost converter, the output current capability is approximately halved as compared to the boost converter output current capability. Although output current is halved, the output power remains the same. This reduction in output current is a result of the current-limiting protection of the internal MOSFET of the TPS6108x, which effectively sets a maximum output power capability. Therefore, the total output power capability is approximately equal to the normal boost converter. The actual output power capability in this configuration is typically reduced by 1% to 2%, due to additional power losses in the added diodes and capacitors. Actual losses depend on the specific characteristics of chosen components and operating parameters.

Conclusion

To increase the output voltage capability of TPS6108x family of switching converters, a charge pump attached to the switch node and output terminal of the IC can be used. This added circuitry is necessary for applications which require an output voltage going beyond the wide range of the TPS6108x. Although this added circuitry allows one to double the output voltage capability of the TPS6108x, it does not double the output power capability.
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