Application Report
SNAA137A–February 2012–Revised April 2013

AN-2218 Precision Current Limiting with the LMP8646 and LM3102

ABSTRACT

This application report discusses how to design the Texas Instruments LMP8646 with the LM3102 voltage regulator and a supercap load application.

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1 Overview

The LMP8646 is a precision current limiter used to improve the current limit accuracy of any switching or linear regulator with an available feedback node. Many regulators might have an internal current limiter, but its output accuracy is often as high as 30%. The output accuracy of the LMP8646 can be as low as 3%, making it a preferred current limiter for many regulator applications. The SuperCap application with LM3102 regulator and LMP8646 precision current limiter is shown in Figure 1.

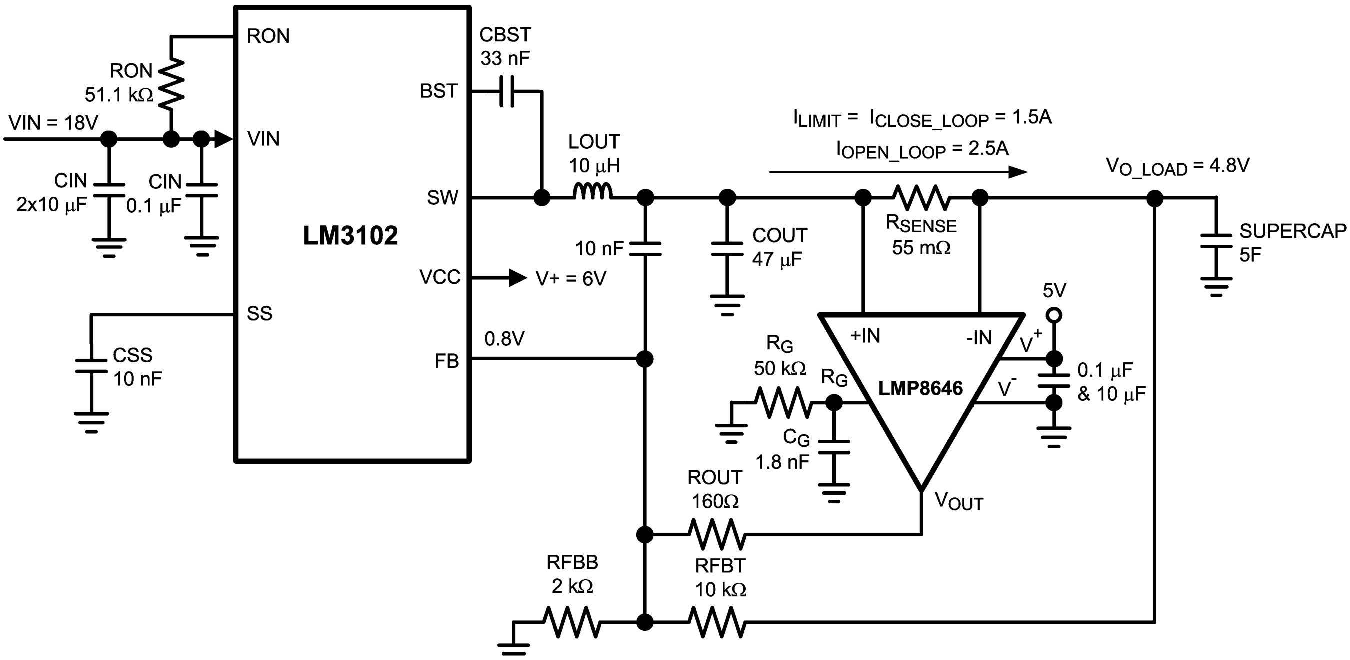

Figure 1. SuperCap Application with LM3102 Regulator and LMP8646 Precision Current Limiter

2 Example

A supercap application requires a very high capacitive load to be charged. This example assumes the output capacitor is 5F with a limited sense current, I_{LIMIT}, at 1.5A. The LM3102 provides the current to charge the supercap, and the LMP8646 monitors this current to make sure it does not exceed the desired 1.5A value.

This is done by connecting the LMP8646 output to the feedback pin of the LM3102, as shown in Figure 1. This feedback voltage at the FB pin is compared to a 0.8V internal reference. Any voltage above this 0.8V means the output current is above the desired value of 1.5A, and the LM3102 will reduce its output current to maintain the desired 0.8V at the FB pin. The following steps show the design procedures for this supercap application. In summary, the steps consist of selecting the components for the voltage regulator, integrating the LMP8646 and selecting the proper values for its gain, bandwidth, and output resistor, and adjusting these components to yield the desired performance.

Step 1: Choose the components for the Regulator.

To select the appropriate components for the LM3102 voltage regulator, see *AN-1646 LM3102 Demonstration Board Reference Design* (SNVA248).

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Step 2: Step 2: Choose the sense resistor, R_{SENSE}

R_{SENSE} sets the voltage V_{SENSE} between +IN and -IN and has the following equation:

$$R_{SENSE} = V_{OUT} / [(I_{LIMIT}) \times (R_G / 5kOhm)] \quad (1)$$

In general, R_{SENSE} depends on the output voltage, limit current, and gain. To choose the appropriate R_{SENSE} value, see the Selection of the Sense Resistor, R_{SENSE} section in *LMP8646 Precision Current Limiter* (SNOSC63). Typically, R_{SENSE} is a power resistor in the mOhm range. In this example, we will use 55 mOhm.

Step 3: Choose the gain resistor, R_G, for LMP8646

R_G is chosen from the limited sense current. As stated in Equation 1, since $V_{OUT} = V_{FB} = 0.8V$, the limited sense current is 1.5A and R_{SENSE} is 55 mOhm, R_G can be calculated as:

$$R_G = (V_{OUT} \times 5\ kOhm) / (R_{SENSE} \times I_{LIMIT})$$

$$R_G = (0.8 \times 5\ kOhm) / (50\ mOhm \times 1A) = 50\ kOhm\ (approximate) \quad (2)$$

Step 4: Choose the Bandwidth Capacitance, C_G.

The product of C_G and R_G determines the bandwidth for the LMP8646. To see the range for the LMP8646 bandwidth and gain, see the Typical Performance Characteristics plots in *LMP8646 Precision Current Limiter* (SNOSC63). Since each application is very unique, the LMP8646 bandwidth capacitance, C_G, needs to be adjusted to fit the appropriate application.

Bench data has been collected for the supercap application with the LM3102 regulator, and we found that this application works best for a bandwidth of 500 Hz to 3 kHz. Operating outside of this recommended bandwidth range might create an undesirable load current ringing. We recommend choosing a bandwidth that is in the middle of this range and using the equation:

$$C_G = 1/(2 \times pi \times R_G \times Bandwidth) \quad (3)$$

to find C_G. For example, if the bandwidth is 1.75 kHz and R_G is 50 kOhm, then C_G is approximately 1.8 nF.

After selecting an initial C_G value, capture the plot for I_{LIMIT} and adjust C_G until a desired load current plot is obtained.

Step 5: Calculate the Output Accuracy and Tolerable System Error

Since the LMP8646 is a precision current limiter, the output current accuracy is extremely important. This accuracy is affected by the system error contributed by the LMP8646 device error and other errors contributed by external resistances, such as R_{SENSE} and R_G.

In this application, $V_{SENSE} = I_{LIMIT} \times R_{SENSE} = 1.5A \times 55\ mOhm = 0.0825V$, and $R_G = 50\ kOhm$. From the LMP8646 Electrical Characteristics Table, it is known that $V_{OFFSET} = 1\ mV$ and Gm_Accuracy = 2%. Using the equations in Figure 2, the output accuracy can be calculated as 3.24%.

$$\text{Output Accuracy} = \left| \frac{V_{OUT\_THEO} - V_{OUT\_CAL}}{V_{OUT\_THEO}} \right| \times 100(\%)$$

$$\text{where } V_{OUT\_THEO} = (V_{SENSE}) \times \frac{R_G}{1/Gm}$$

$$\text{and } V_{OUT\_CALC} = \frac{(V_{SENSE} + V_{OFFSET}) \times R_G}{1/[Gm\ (1 + Gm\_Accuracy)]}$$

Figure 2. LMP8646 Output Accuracy Equation

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Step 6: Choose the Output Resistor, ROUT

At startup, the capacitor is not charged yet and thus the output voltage of the LM3102 is very small. Therefore, at startup, the output current is at its maximum (I_{MAX}). When the output voltage is at its nominal, then the output current will settle to the desired limited value. Because a large current error is not desired, ROUT needs to be chosen to stabilize the loop with minimal initial startup current error. Follow the equations and example below to choose the appropriate value for ROUT to minimize this initial error.

Assume that the tolerable current error, I_{ERROR}, is 5%, where $I_{ERROR} = (I_{MAX} - I_{LIMIT})/I_{MAX}$ (%). Therefore, the maximum allowable current is calculated as:

$I_{MAX} = I_{LIMIT}\ (1+ I_{ERROR})$ = 1.5A × (1 + 5/100) = 1.575 A.

Next, use the following formula to calculate for ROUT:

$$ROUT = \frac{(I_{MAX} * R_{SENSE} * Gain - V_{FB})}{\frac{V_{FB}}{RFBB} - \frac{(V_{O\_REG\_MIN} - V_{FB})}{RFBT}} \quad (4)$$

For example, assume the minimum LM3102 output voltage, $V_{O\_REG\_MIN}$, is 0.6V, then ROUT can be calculated as:

ROUT = [1.575A × 55 mOhm × (49.9k / 5k) - 0.8] / [(0.8 / 2k) - (0.6 - 0.8) / 10k] = 153.6 Ohm.

Populate ROUT with a resistor that is as close as possible to 153.6 Ohm (this application uses 160 Ohm). If the current exceeds 1.575A at any point in time, then adjust this ROUT value to obtain the desired limit current. We recommend that the value for ROUT is at least 50 Ohm.

Step 7: Adjusting the Components

Capture the output current and output voltage plots and adjust the components as necessary. The most common components to adjust are C_G to decrease the current ripple and ROUT to get a low current error. An example output current and voltage plot can be seen in Figure 3.

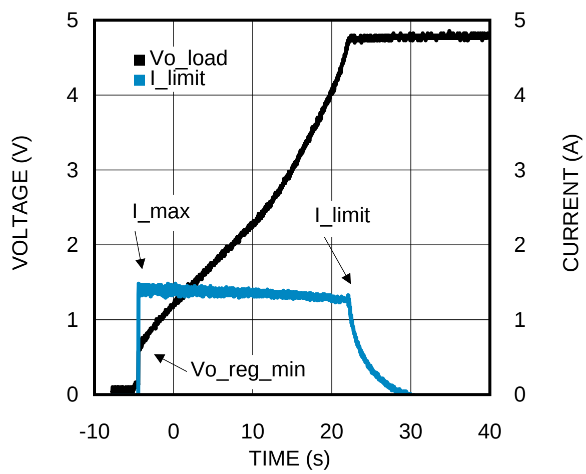

Figure 3. SuperCap Application with LM3102 Regulator Plot

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