Application Report
SLVA981–July 2018

Charging Supercapacitor Banks from USB Type C Port With Boost Converter

Helen Chen — *Boost Converter and Controller Solutions*

ABSTRACT

The maximum allowed output current from the USB type C port is 5V3A by default. Most of the boost converter cannot limit the input current below 3A when charging big capacitance. Because when charging a big capacitance, it will take a relatively long time before the output voltage reaches the input voltage. The boost converter works with maximum duty. So the input current is uncontrollable and will rise to a very high value during this period. This application note gives out a simple, reliable and low cost solution for the big capacitance charge circuit. It is especially fit for the USB type C port supplied system as the input current can be well limited below 3A. The charging speed can be adjusted by using different fly-back transformers. It is also fit for some critical applications where the input current need to be limited below 200-500mA by choosing a small current rating boost converter.

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1 Introduction

There are various methodologies on how to charge a big cap like super capacitor (SC). Constant current and constant voltage (CICV) is one of the most commonly used and preferred solution. At the beginning of the charging cycle, the charging device charges the SC with a constant current. When the SC is charged to the target value, constant voltage loop becomes active and prevent the SC from over charging. This kind of charging IC, especially the boost charging IC is less common and much expensive than the normal boost converter.

This application note delivers a very simple and low cost solution on how to charge the SC banks from a USB type C port. By choosing an appropriate boost converter and connecting it in the fly-back topology, the input current can be effectively limited below 3A. The maximum charge current into the SC banks is also limited below a certain value, which can reduce the heat generation and extend the life of SC.

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2 Device Overview

2.1 Specification

Table 1 shows the specification of this application report. The maximum input current is limited below 3A during the startup and during the normal operation.

Table 1. Performance Specification Summary

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input Voltage		4.5	5.0	5.5	V
I_{IN_peak}	Peak Input Current	Anytime during charging the SC banks	3			A
V_{SC_target}	The voltage across the SC banks after fully charged	V_{IN}=5V	13.5			V

2.2 Schematic

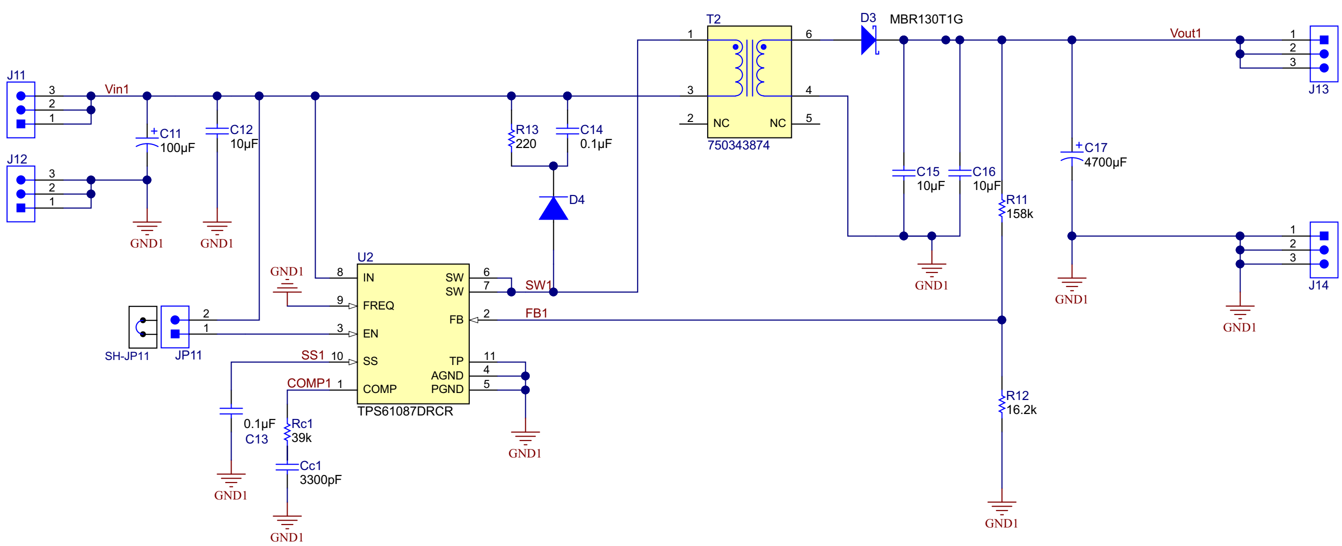

Figure 1. Application Schematic

Figure 1 shows the schematic for this application report. The circuit is of fly-back topology. The boost converter, TPS61087, always works at the current-limit mode during start-up before the output voltage reaches the target value. The peak primary inductor current is limited at the peak current limit point of TPS61087, which is around 4A. Accordingly, the peak secondary inductor current is limited at the primary current times the transformer turns ratio. After the output capacitor is fully charged, the TPS61087 device works in the skip mode.

2.3 Parameter Calculation

The maximum allowable turns ratio NP/NS is determined by the input voltage (V_{IN}), output voltage (V_O), and the maximum switch node voltage (V_{SWmax}).

$$N_{max} = \frac{N_P}{N_S} = \frac{V_{SWmax} - V_{IN}}{V_O} \quad (1)$$

where

- V_O=13.5V
- V_{IN}=5V

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If we set the maximum switch node voltage V_{SWmax} at 14V, which is 70% of the absolute maximum rating voltage, then the maximum turns ratio N_{max}= 0.65. So the turns ratio of the flyback transformer should be lower than this value to meet the design target. Larger inductance means larger inductor size. In AN SLVA981, TPS61087 works in the DCM and CCM boundary when the output voltage reaches the target value. So the inductance will be neither too large nor too small.

If NP/NS=0.25, the maximum duty cycle D_{max1} can be calculated with Equation 2.

$$D_{max1} = \frac{0.25 \cdot V_O}{0.25 \cdot V_O + ɧ \cdot V_{in}} \approx 0.44$$

where

- ɧ is the conversion efficiency, ɧ=0.85 (2)

If NP/NS=0.6, the maximum duty cycle, D_{max2}, can be calculated with Equation 3.

$$D_{max2} = \frac{0.6 \cdot V_O}{0.6 \cdot V_O + ɧ \cdot V_{in}} \approx 0.66 \tag{3}$$

As the TPS61087 works in the current limit mode, so the maximum average input current under different duty cycle is different. The typical current limit value I_{LIM} of TPS61087 is 4A according to the datasheet. So the maximum average input current under different turns ratio can be calculated by the following equation:

$$I_{IN\_1} = I_{LIM} \cdot \frac{D_{max1}}{2} = 0.88A \tag{4}$$

$$I_{IN\_2} = I_{LIM} \cdot \frac{D_{max2}}{2} = 1.32A \tag{5}$$

The current limit value I_{LIM} has ±20% tolerance, so the average input current will also has ±20% tolerance.

The secondary current is determined by the primary current limit I_{LIM} times the turns ratio. So the maximum charge current under different turns ratio is:

$$I_{charge\_sup1} = I_{LIM} \cdot 0.25 = 1A \tag{6}$$

$$I_{charge\_sup2} = I_{LIM} \cdot 0.6 = 2.4A \tag{7}$$

So the transformer turns ratio can be chosen according to the maximum current rating of the supercapacitor.

3 Test Results

Figure 2 and Figure 3 show the waveforms of the output voltage VO and the input current IIN during charging a 70mF cap. When the turns ratio is 0.25, the charging period is around 2.2 seconds; when the turns ratio is 0.6, the charging period is around 1.2 seconds.

Figure 4 and Figure 5 show the waveforms of the current flowing into the output cap during charging up. The charging current is larger with a larger turns ratio transformer as shown in these waveforms.

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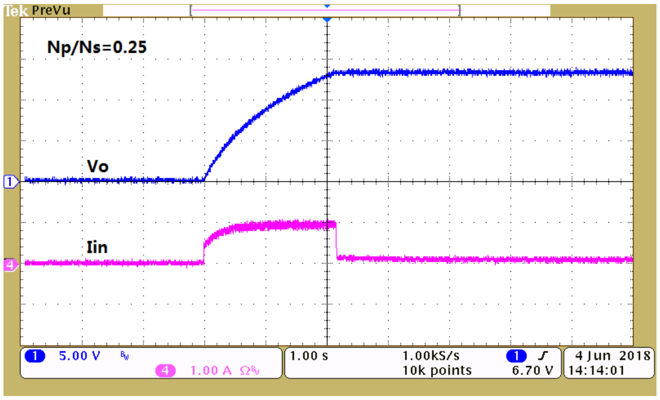

Figure 2. Waveforms of V_O, I_{IN} at NP/NS=0.25

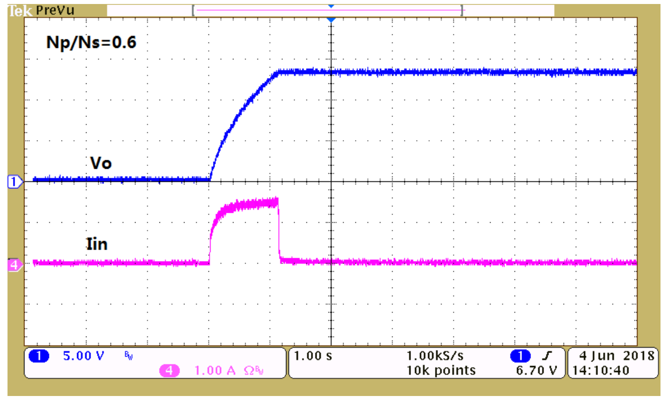

Figure 3. Waveforms of V_O, I_{IN} at NP/NS=0.6

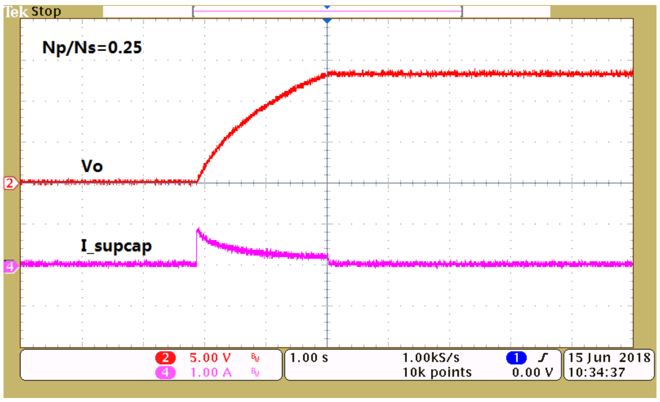

Figure 4. Waveforms of V_O and the Charge Current into the Supercapacitor (NP/NS=0.25)

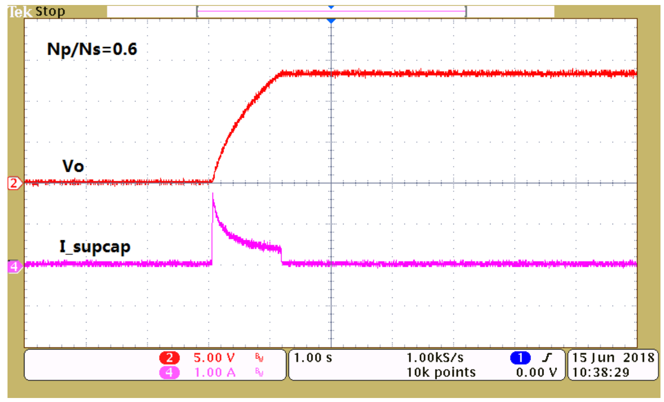

Figure 5. Waveforms of V_O and the Charge Current into the Supercapacitor (NP/NS=0.6)

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