Application Report

SLVA912–August 2017

Input Current Limit Solution for USB-Supplied Power System

Helen Chen

ABSTRACT

The maximum allowed output current from a USB rail is limited in a USB-powered system. A unit load is defined as 100 mA in USB 2.0. A device may draw a maximum of five unit loads (500 mA) from a port in USB 2.0. Most boost converters cannot limit input current to such a low value during start-up, especially in a high output capacitance application. This application note details an input current limit solution for a USB-powered system. With this solution, the designer can limit the input current well below the value set during start-up and normal operation conditions.

Contents

List of Figures

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

In a USB-powered application, the maximum supplied current must be limited below the maximum output current capability of the USB port; if not, the USB voltage drops, perhaps even to zero, due to overcurrent protection. This application note details an input current limit solution for a USB-powered system and contains a circuit design, test result, schematic, and bill of materials (BOM).

2 Design Process

2.1 Specification

Table 1 shows the specification of this application note. The maximum input current is limited below 200 mA during start-up and normal operation.

Table 1. Performance Specification Summary

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	—	4.75	5.00	5.25	V
I_{IN}	During start-up and normal operation	—	150	200	mA
V_{OUT}	V_{IN} = 5 V, 60-mF capacitive load	8.7	9.0	9.3	V

2.2 Schematic

Figure 1 shows the schematic of the input current limit solution. The U1 TLV61046 is a 28-V output voltage boost converter with power diode and isolation switch. The U2 INA138 is a high-side measurement current shunt monitor. U3 is an operational amplifier.

Resistor R5 and diode D1 are connected from the input to the output side. These components are used to charge up the output capacitance because the output voltage must be equal to the input voltage before enabling the TLV61046 integrated circuit (IC). If the output voltage is not equal to the input voltage, the input current rises to an uncontrolled high value while the V_{OUT} charges up to the V_{IN} stage, especially in the big output capacitance application. Enable the TLV61046 IC after the V_{OUT} finishes charging up to V_{IN} through R5 and D1.

The input current immediately rises up to the input current limit point after the boost converter has been enabled. The output voltage of the INA138 V_{O_INA138} jumps high and D4 conducts. V_{ADJ} is equal to $V_{O\_ INA138}$. The FB pin voltage V_{FB} immediately rises up to V_{REF}. So, the input current is immediately regulated and is well limited below the setting value. When the output voltage charges up to the target point, the input current goes low and D4 stops conducting.

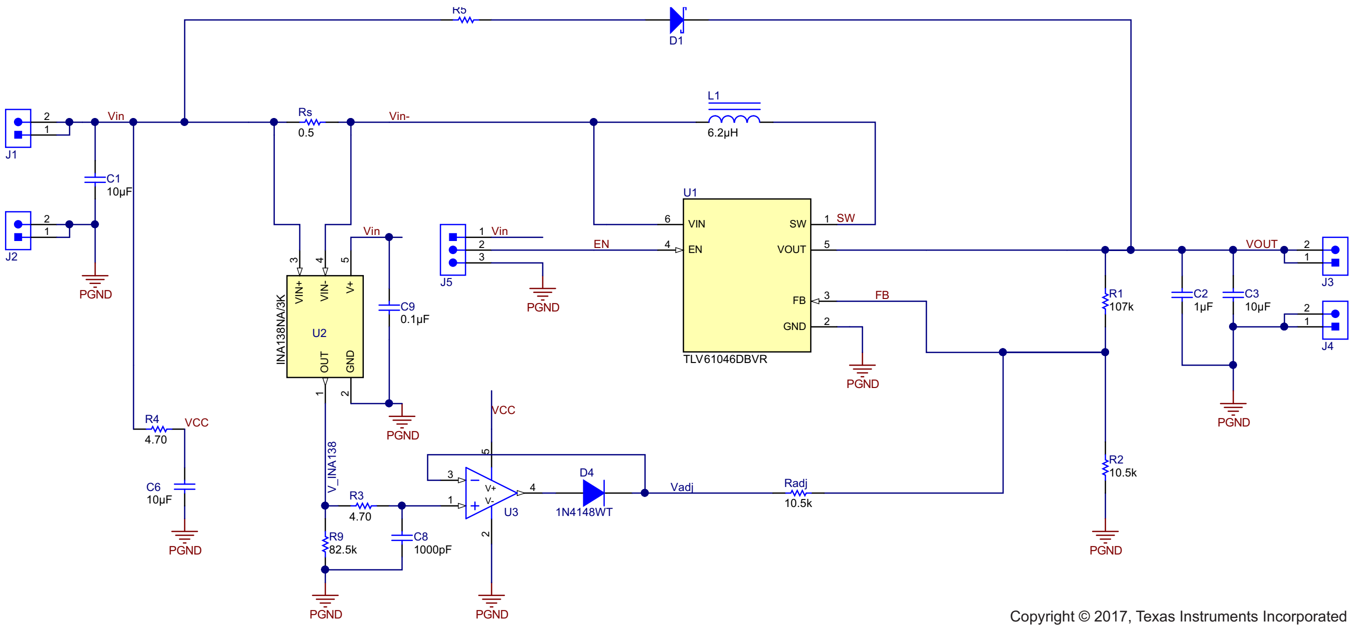

Figure 1. Schematic – Input Current Limit Solution

2.3 Component Selection

The maximum voltage drop across the precharge resistor R5 is 5 V, which happens at the V_{IN} = 5 V, V_{OUT} = 0 V condition. So a 499-Ω, 0603 resistor is chosen in this application.

The maximum differential input voltage for the INA138 is 0.5 V and the recommended value is 0.1 V; therefore, choose R_S = 0.5 Ω in this application. When I_{IN} = 0.2 A, the sensed voltage is just 0.1 V.

The highest input current occurs when the TLV61046 is enabled. As Equation 1 shows, the initial output voltage is equal to:

$$V_{O\_INI} = V_{IN} = 5\ \text{V} \tag{1}$$

To effectively limit the input current during start-up, the superposition voltage at the FB pin must be equal to the feedback voltage V_{REF} at this time (see Equation 2).

$$V_{O\_INI} \times \left(\frac{R_{P1}}{R_{P1} + R_1} \right) + V_{ADJ} \times \left(\frac{R_{P2}}{R_{P2} + R_{ADJ}} \right) = V_{REF} \tag{2}$$

where,

- $R_{ADJ} = 10.5\ \text{k}\Omega$ *initially,*
- $R_{P1} = \dfrac{R_{ADJ} \times R_2}{R_{ADJ} + R_2}, \quad R_{P2} = \dfrac{R_1 \times R_2}{R_1 + R_2},$
- $V_{REF} = 0.807\ \text{V}.$

Using the calculation from Equation 2 results in the following Equation 3:

$$V_{ADJ} = \frac{V_{REF} - V_{O\_INI} \times \left(\dfrac{R_{P1}}{R_{P1} + R_1} \right)}{\dfrac{R_{P2}}{R_{P2} + R_{ADJ}}} \tag{3}$$

V_{ADJ} = 1.203 V; therefore, the output voltage of the INA138 device is also equal to 1.203 V.

Calculate Equation 4 using the specifications from the INA138 data sheet:

$$V_{O\_INA138} = I_S \times R_S \times (200\ \mu A/V) \times R_9 \quad (4)$$

Calculate R9 using the following formula in Equation 5:

$$R_9 = \frac{V_{O\_INA138}}{I_S \times R_S \times (200\ \mu A/V)} \quad (5)$$

where,

- R_S = 0.5 Ω.

The designer must leave some margin during the theoretical calculation to limit the input current below 200 mA. When leaving a 25% margin, let I_{IN} = 150 mA, then R9 = 82.5 kΩ.

2.4 Test Result

Figure 2 and Figure 3 show the start-up waveforms of the V_{IN}, I_{IN}, V_{ADJ}, and V_{FB} pins with a 60-mF electrolytic capacitor at the output side.

The input current increases immediately when the IC is enabled. The voltage V_{ADJ} jumps up from 0.45 V to 1.2 V, which makes the V_{FB} immediately jump up to V_{REF}. So the TLV61046 device can regulate the input current immediately at the time in which it is enabled. Thus the input current is well limited below 200 mA during start-up at the big output capacitance condition.

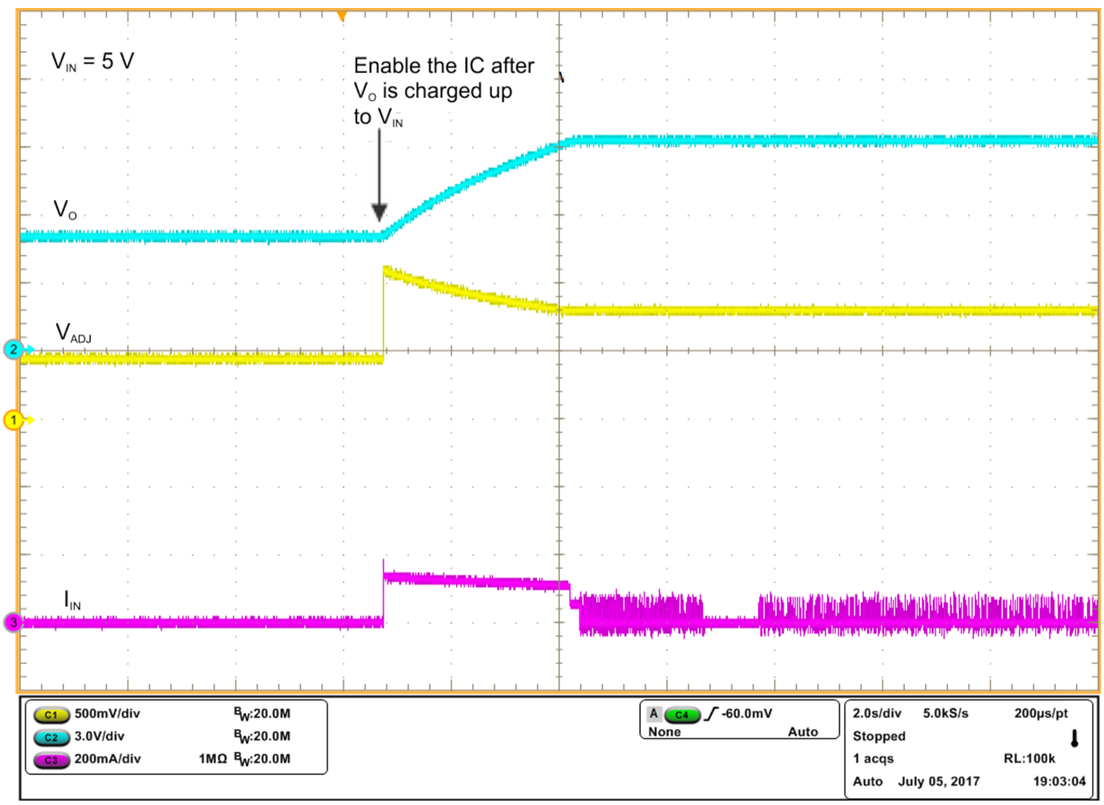

Figure 2. Start-Up Waveforms of V_{IN}, I_{IN}, V_{ADJ}

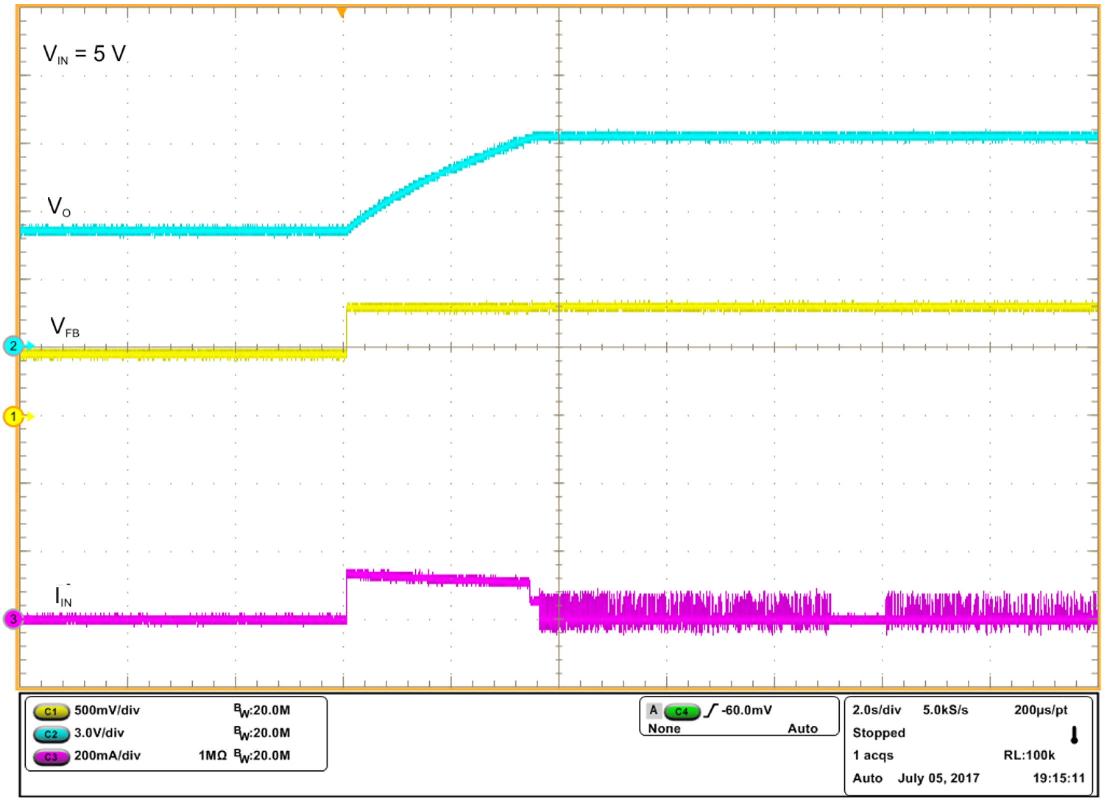

Figure 3. Start-Up Waveforms of V_{IN}, I_{IN}, V_{FB}

3 Conclusion

This application note describes an input current limit solution for the boost converter TLV61046 in a USB-powered application. This solution is realized by a high-side measurement current shunt monitor INA138 and a single low-voltage rail-to-rail output operational amplifier LMV321. The input current can be well limited below the setting point after start-up. When the output voltage rises up to the target value, the input current goes low and the current limit circuit stops working and ceases to affect the normal operation.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265