24 V-Tolerant USB-C port using the TPS25810 and TPD1S514-1

Adam McGaffin, Darwin Fernandez, Catherine Camron

ABSTRACT

The TPS25810 is a USB Type-C Downstream Facing Port (DFP) controller that monitors the Type-C Configuration Channel (CC) lines to determine when a USB device is attached. If an Upstream Facing Port (UFP) device is attached, the TPS25810 applies power to VBUS. One concern in some USB Type-C applications is that a non-compliant DFP device that disregards the USB Type-C specification can be connected to the port controlled by the TPS25810. Such a device may apply a voltage to VBUS above the absolute maximum rating of the TPS25810 which could damage the part. During such an over-voltage event, it is important that the 5 V rail connected to the TPS25810 input not rise above 5.5 V. Some applications only need to protect against an overvoltage event when no sink has been detected. Other applications need to protect against an overvoltage event that occurs while connected to a sink device. This application note presents an integrated solution, using a Texas Instruments USB OVP switch, which is able to meet these requirements, even when connected to a sink device.

Contents

List of Figures

List of Tables

Trademarks

1 Introduction and Related Material

The focus of this application note is to showcase the combination of the TPS25810 and TPD1S514 for protecting a system if a high voltage is presented at VBUS on a Type-C port. There are two instances where this is possible. The first instance is if a sinking device was charging from a high voltage supply, then unplugged and quickly plugged into the Type-C port that is connected to the TPS25810. If this occurs, VBUS would not have had time to discharge. The second instance is if a non-compliant USB Type-C PD source controller is connected which may not follow proper protocol. Because a USB Type-C port is capable of power delivery, voltage levels from 5 V to 20 V are expected; however, there is a strict power negotiation protocol in order to achieve the delivery of these different voltage levels. Some non-compliant USB Type-C PD source controllers may ignore this negotiation and apply a high voltage on VBUS which is dangerous for a USB Type-C source controller. The OUT pin of the TPS25810 which connects to VBUS, is rated up to 7 V, meaning that exposure to a higher voltage would damage the TPS25810.

Another problem associated with having a non-compliant device present an unexpected 20 V is that potential for damage to other devices connected to the system 5 V rail, which powers the TPS25810. Within the TPS25810 is a FET that connects the IN pins to the OUT pins of the device. If the overvoltage presented on VBUS is not removed quickly, the system rail supplying power to the TPS25810 can rise to a voltage greater than 5 V. This will not only damage the TPS25810, but it has the potential to damage any other ICs connected to the rail if the voltage rises above a certain threshold. Industry requirements have changed necessitating the system 5 V rail does not rise above a certain threshold. Using the TPD1S514 in addition to the TPS25810 ensures that the system will not fail and the voltage stays under the industry-required threshold.

Throughout this application note, “compliant” and “non-compliant” are used to describe USB Type-C devices. A compliant UFP device is one that uses the CC line properly as defined in the Type-C and USB PD specification. A non-compliant DFP device is one that applies a voltage greater than 5 V without going through the proper power negotiation as defined in the Type-C and USB PD specification.

The TPS25810 datasheet (SLVSCR1), the TPD1S514 datasheet (SLVSCF6), and the USB Type-C documentation (http://www.usb.org/developers/usbtypec/) are good resources to have a general understanding of before reading this application note.

2 TPS25810 and TPD1S514-1 Protection Solution

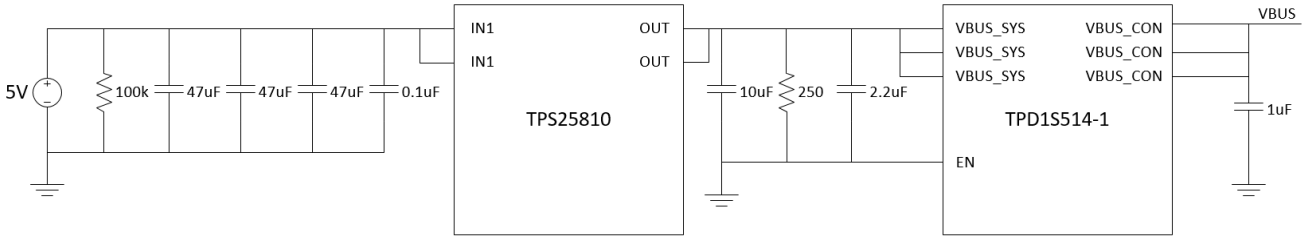

Figure 1. Overvoltage Protection Circuit

2.1 Circuit Operation

The TPD1S514 is a single chip solution used to protect the VBUS line of a USB connector. The NFET switch internal to the TPD1S514 ensures safe current flow in host mode while protecting the internal system circuits from any overvoltage conditions at the VBUS_CON pin. This device can handle overvoltage protection of up to 30 V. The device protects the pins of the TPS25810 from being exposed to a voltage higher than 5.9 V as specified in the TPD1S514 datasheet (SLVSCF6). The enable pin of the TPD1S514 is tied low in order to be enabled by default whenever the TPD1S514 is powered via VBUS_SYS.

In the system shown in Figure 1, the VBUS_SYS of the TPD1S514 is tied to the OUT pin of the TPS25810 such that if a compliant UFP device is detected, the OUT pin of the TPS25810, which is at a voltage below 5.9 V, powers the TPD1S514 and the switch opens allowing the system to function normally. When the TPS25810 does not detect a device, the OUT pin is at 0 V and the TPD1S514 is off which saves system power. If a non-compliant DFP applies a high voltage to the VBUS_CON pin of the TPD1S514, because the TPS25810 OUT pin is at 0 V and the TPD1S514 is off, the switch remains closed and the high voltage is blocked. With the TPD1S514 on, regardless of the state of the UFP pin on the TPS25810, if a high voltage is applied at VBUS, the TPD1S514 detects the high voltage and the switch is turned off protecting the USB Type-C system.

2.2 Component Selection

The TPS25810 (SLVUAI0) and TPD1S514 (SLVUA31) evaluation modules were used to test the solution shown in Figure 1. A 250 Ω (1/4 W) resistor on the output of the TPS25810 was selected to pull down the TPS25810 OUT pin voltage enough to stay within its ABS MAX rating due to reverse leakage from the TPD1S514-1 while 24 V is connected to VBUS_CONN. Also a 100 kΩ (100 mW) resistor imitates the quiescent current of the 5 V rail's system load.

3 Testing and Results

Testing was performed by simulating a non-compliant overvoltage event to evaluate the response of the system. Figure 2 shows the test setup, the locations of the oscilloscope probes, and the corresponding channels associated with each probe. A 24 V power source was used to imitate a non-compliant USB adapter. A 10 Ω series resistor was added as a system-level consideration for additional current limiting during the 24 V hotplug event. After the system shown in Figure 1 was powered on, the separate power supply was hot plugged to VBUS_CON.

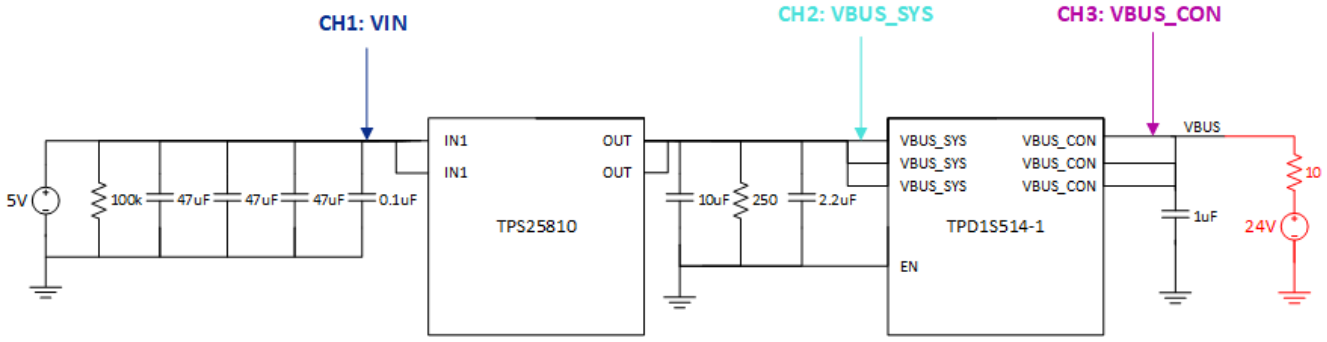

Figure 2. Test Configuration

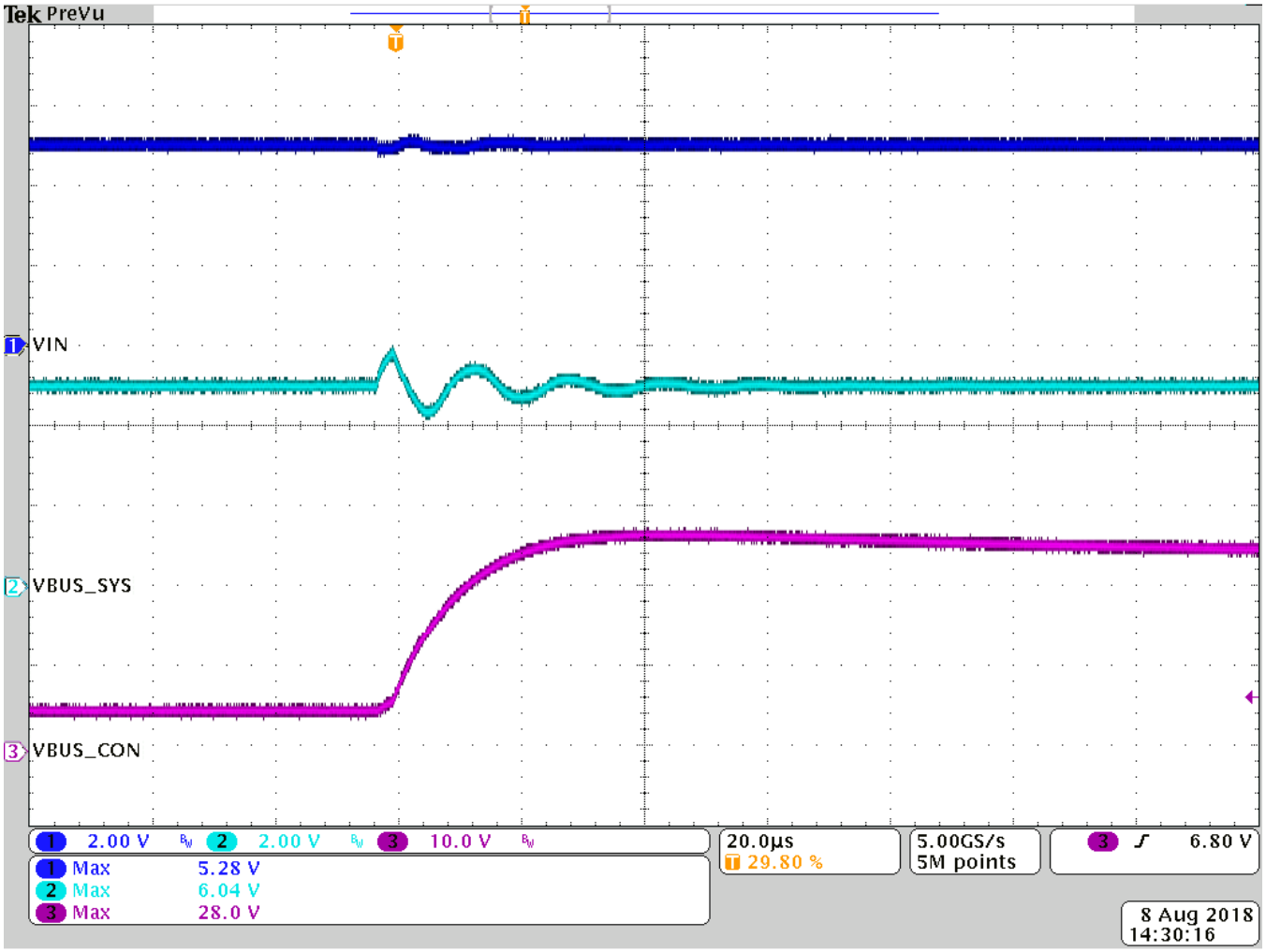

Figure 3. TPS25810 Input Protection during a 24 V VBUS Hotplug

As shown in Figure 3, when an external power source of 24 V is applied to VBUS_CON, the supply voltage going to the TPS25810 does not rise to a level that would collapse the 5 V system rail. While the external supply increases to a peak of 28 V, the connection between the TPS1S514 and TPS25810 peaked at 6.04 V, and the voltage spike at VIN rose only to 5.28 V. These results are within a 10% tolerance range, which most integrated circuits are capable of handling.

It should also be noted that the TPD1S414 can also be used in replacement of the TPD1S514. The TPD1S414 will still be able to protect the internal 5 V rail supplying power to the TPS25810, but has a higher threshold voltage so the voltage spike will be slightly larger than if the TPD1S514 is used.

4 Summary

There are many solutions to blocking non-compliant DFP adapters from being used in USB Type-C systems that employ the TPS25810. Using a USB OVP switch, such as the TPD1S514 ensures that the entire system is protected from damage and not just the TPS25810.

5 References

- Protecting the TPS25810 from High Voltage DFPs (SLVA751)

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

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