Application Report
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Ground Shift Phenomenon Recommendation of TPS2583x

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ABSTRACT

The TPS2583x-Q1 and TPS2584x-Q1 is the USB Type-C or Type-A charging controller, which is widely used in the automotive USB charging application. In the application report, the customer sometimes meets the problem that data is disconnected or the charging current is small. Ground shift issues may be one a cause for this phenomenon.

This application report has an introduction of ground shift phenomenon. And introduce how ground shift disrupts data communication and also reduce the charging current. Some suggestions are given to avoid or reduce ground shift phenomenon.

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Trademarks

1 Introduction

Ground shift problems involve the current through a trace or wire causing voltage shift due to resistance of trace wire or USB cable, which appears on the ground according to Ohm's Law. The ground voltage shift not only increases the VBUS voltage drop that leads to the lower current charging and boosts the data signal voltages at the downstream port terminal, which causes the data communication disruption.

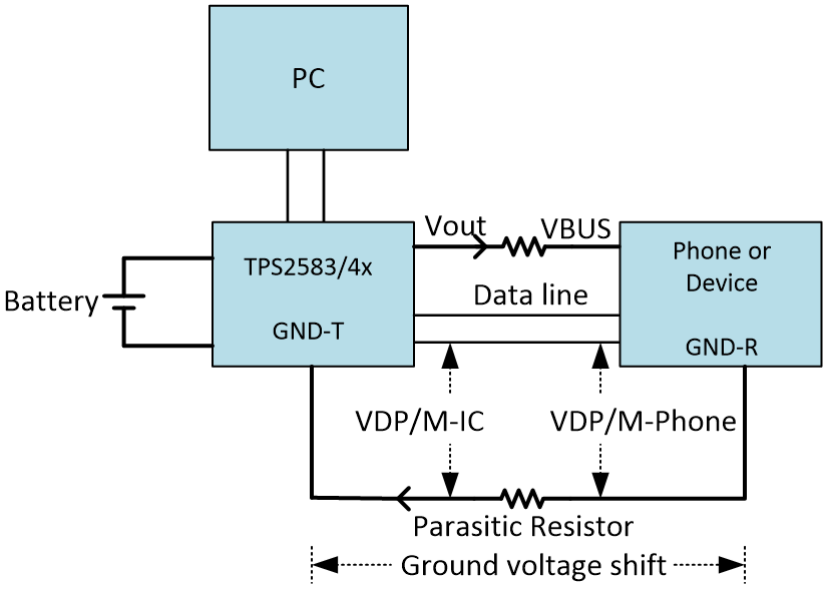


Figure 1. Simplified Block Diagram for Ground Shift of TPS2583/4x-Q1

As indicated in Figure 1, due to the existence of parasitic resistor on ground line, TPS2583x/4x-Q1 side data line(DP,DM) voltage will be higher than Phone side DP DM voltage. According to USB2.0 specification, the maximum voltage drop for all cables between upstream and downstream on GND is 125 mV [1].

Table 7-7 in the USB2.0 spec indicates that high speed disconnect detection threshold is from 525 mV to 625 mV. Table 7-1 also provides the disconnect envelop detector. Disconnection must be indicated when the amplitude of the differential signal at the downstream facing driver's connector ≥ 625 mV, and it must not be indicated when the signal amplitude is ≤ 525 mV. So for ground shift voltage, it's better to be controlled below 125 mV.

Based on USB battery charging 1.2 compliance plan [2], test item 7.14, the common mode test for high speed data communication will apply a maximum voltage of 375 mV offset to UUT ground. Then, check whether the enumeration is succeeded or not.

Table 1. Common Mode Test – High Speed [2]

Test Setup	Test Setup 4. UUT is a PD. PET simulates a SDP
Pre-conditions	This test should be performed with a good battery in order to minimize extra current flowing in the cable ground, as the PET provides the ground offset itself
Purpose	This test verifies that a UUT is able to communicate with a charging downstream port at high-speed when cable ground is dropping Imax_bc x 0.25 Ω + 5 mV
Description	This test will apply a maximum of 375 mV offset to UUT ground, and then verify UUT enumerates and works successfully. PET simulates an SDP to reduce the risk that the UUT itself draws a significant current.
Parameters	
Checklist	PD33
Pass Criteria	Step 5: UUT enumerates successfully Step 6: UUT functions as expected

The USB battery charging 1.2 compliance plan also includes test item 9.6, CDP ground offset test for the high speed signal, which also validates the ground shift influence for charging and data communication.

Table 2. CDP Ground Offset Test – High Speed [2]

Test Setup	Test Setup 5. UUT is an CDP, PET simulates a PD.
Pre-conditions	When running this test, ensure that an isolated computer is used for the tester host (for example, laptop).
Purpose	To verify that charging downstream port fulfills USB2.0 specification common mode voltage requirements at high speed.
Description	Insert specified command voltage offset and check UUT can enumerate reference device and operate well.
Parameters	
Checklist	CDP11
Pass Criteria	Step 9: Enumeration is successful.

2 Data Communication Issue Caused by Ground Shift

In order to validate the ground shift influence for USB data communication, the bench shown in Figure 2 was built.

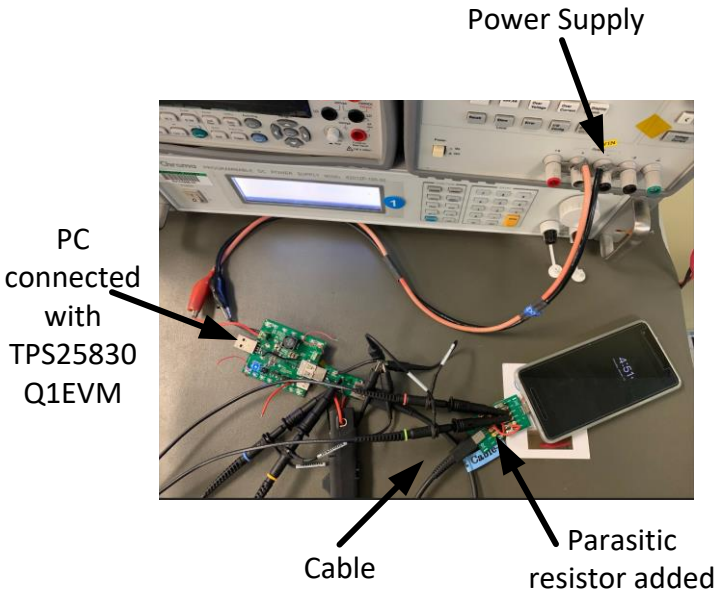


Figure 2. Bench Setup for Ground Shift Test

Figure 3 shows the data communication and charging waveforms without additional resistor added.

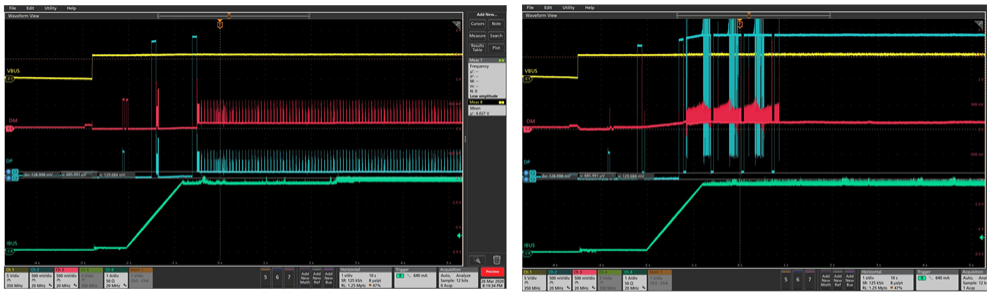
- Condition:

  In CDP mode, without cable compensation, pixel2 phone, and parasitic resistor not added, only USB cable and connector wire.

- Results:

  With secondary detection finished (CDP mode), enumeration starts and also the phone draws current. With a process of recognition from full speed to the high speed signal, data communication starts successful. The ground voltage shift is about 129 mV. Voltage at the terminal of IC is about 5 V . Current draw by the phone is about 3A.

Per the USB2.0 spec, the maximum voltage drop for all cables between upstream and downstream on GND is 125 mV. Although the data communication is normal, after you plug and unplug the phone several times, the phone data communication fails., see Figure 3.



(a) (b)

Figure 3. (a) Without Additional Resistor Added (b) Without Additional Resistor Added but Pug and Unplug Phone Several Times

Figure 4 shows related waveforms with parasitic resistor added.

- Condition:

  In CDP mode, without cable compensation, pixel2 phone, and 20 mΩ parasitic resistor added on ground line.

- Results:

  The ground voltage shift is about 347 mV. The data signal voltage is about 400 mV + 347 mV = 747 mV, which is far out of the range of 625 mV. Current drawing is about 2.6A due to VBUS voltage drop. Data communication also fails. As shown in Figure 4, too high parasitic resistor on the ground line leads to too high ground voltage shift, which will boost the data signal voltage out of threshold causing data communication failure and VBUS drops with low charging current.

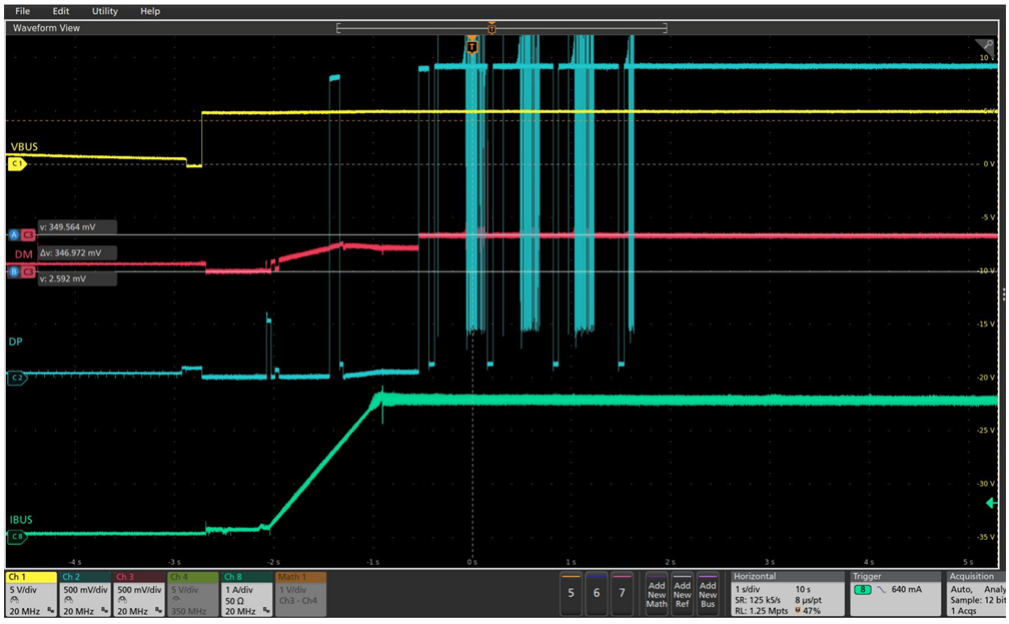


Figure 4. Charging and Data Communication Waveforms With Parasitic Resistor Added

3 Charging Current Issue Caused by Ground Shift

Apple spec provides the provision of port voltage requirements for lightning accessories and non-lightning accessories. No matter lightning or non-lightning accessories, the accessories port voltage should not be below specific threshold. If below specific port voltage, with lower terminal voltage, charging current will be smaller.

USB2.0 specification also makes provisions that the related ports voltage cannot be out of specific range [2].

Comparing Figure 3 with Figure 4, without and with additional resistor added, the charging current falls from 3A to 2.6A due to the voltage drop.

TPS2583x-Q1 and TPS2584x-Q1 integrate cable compensation function that can compensate the port voltage of accessories to required range [3].

4 Suggestions for Ground Shift Issue

1. Shorten and widen the ground trace as layout to reduce the parasitic resistor.

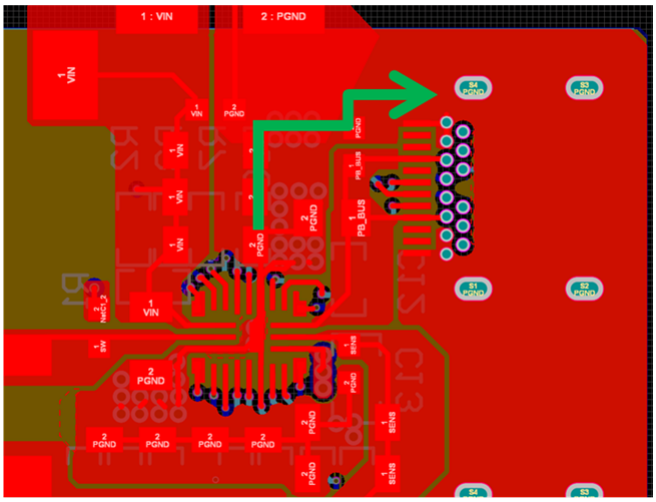


Figure 5. PGND Layout Example

As shown in Figure 5, it is an good layout example of ground connection.

With the green path indicated, the ground connection is connected by a big wide copper ground pin and a very short to connector ground pin. The wider trace and shorter trace means smaller parasitic resistor, as well beneficial to heat dissipation. Another benefit of wider and shorter trace have smaller parasitic inductance and capacitor which is better to signal integrity. It is also a good practice to add more vias at PGND to reduce the parasitic resistor and better thermal performance.

2. Use standard USB cable that has lower parasitic resistor than non-standard USB cable.

   For standard or good USB cable, it adopts better conductive medium such as much thicker copper wire and also use advanced shielded wire for signal transmission integrity. Better and thicker conductive medium have smaller wire resistance which mean smaller heat consumption and minor ground shift issue.

   LCR meter is sure can being used to measure the cable resistance precisely. Some simple methods can also be adopted to measure the resistance. You can force a small current on the cable and measure the voltage difference of the cable. According to Ohm's Law, the cable resistance can be easily acquired.

3. Use chips with cable compensation function for high charging current such as TPS2583x-Q1.
4. Better to have single point GND connection, not only beneficial to ground shift issue but also to reduce ground bounce issue.
5. Increasing the host side voltage level is as well one optional method to solve ground shift issue.

6. USB interface contact resistance is also one big influence factor which leads to ground shift. The contact resistance is relatively high. It is suggested to adopt USB terminal with low contact resistance. Widen the contact trace is also beneficial to reduce the contact resistance.
7. There are two ways to identify whether it's the ground shift issue or not.

   Firstly, you can change control mode from CDP to SDP. As SDP mode allows smaller charging current which means smaller ground shift voltage. If the data communication resumed after mode change, it may be ground shift issue.

   Secondly, you can charge the phone to full charging capacity, which means smaller charging current. Then as you attach phone, if the data communication resumed after mode change, it may be ground shift issue.

5 References

1. Universal Serial Bus Specification Revision 2.0
2. USB Battery Charging 1.2 Compliance Plan
3. Texas Instruments: *TPS2583x-Q1 USB Type-C and BC1.2 5-V 3.5-A Output, 36-V Input Synchronous Step-Down DC/DC Regulator with Cable Compensation Data Sheet*

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