Application Report
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# Loop Characteristic Evaluation and Optimization of TPS2583x-Q1

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**ABSTRACT**

TPS2583x-Q1 is a high integrated USB Type-C and BC1.2 charging port controller that includes a synchronous DC/DC converter. With cable droop compensation, the VBUS voltage remains constant regardless of load current, ensuring connected portable devices are charged at optimal current and voltage. Because the output of USB Type-C and BC1.2 is based on the 5 V, the voltage feedback resistors are integrated in the IC; also due to voltage compensation circuit, it is difficult to test and evaluate the loop characteristics of the system. This application report is mainly about TPS2583x-Q1 Loop Characteristic Evaluation and Design. The test hardware in this application report is based on http://www.ti.com/tool/TPS25831Q1EVM-062.

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# 1 Introduction

## 1.1 Loop Introduction of TPS2583x-Q1

TPS2583x-Q1 integrated a wide Vin buck DCDC to generate 5 V output. It is no different from the normal DCDC when it is without the cable compensation function (no Rsns, Rimon=0), as shown in Figure 1.

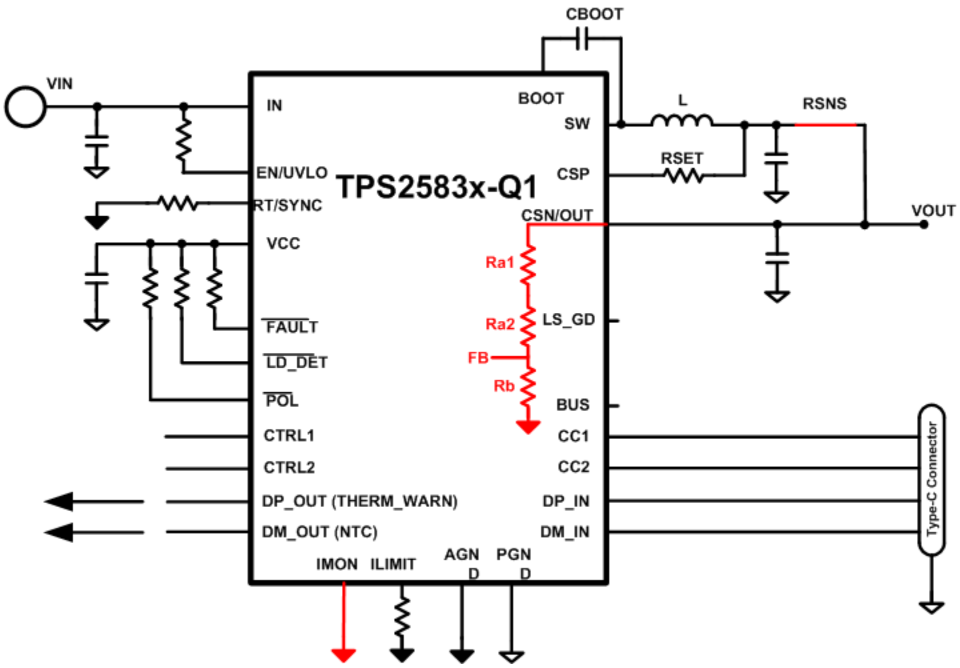


**Figure 1. TPS2583x-Q1 System Without Cable Compensation Function**

When it uses the cable compensation function, as shown in Figure 2, it adds another current feedback loop.

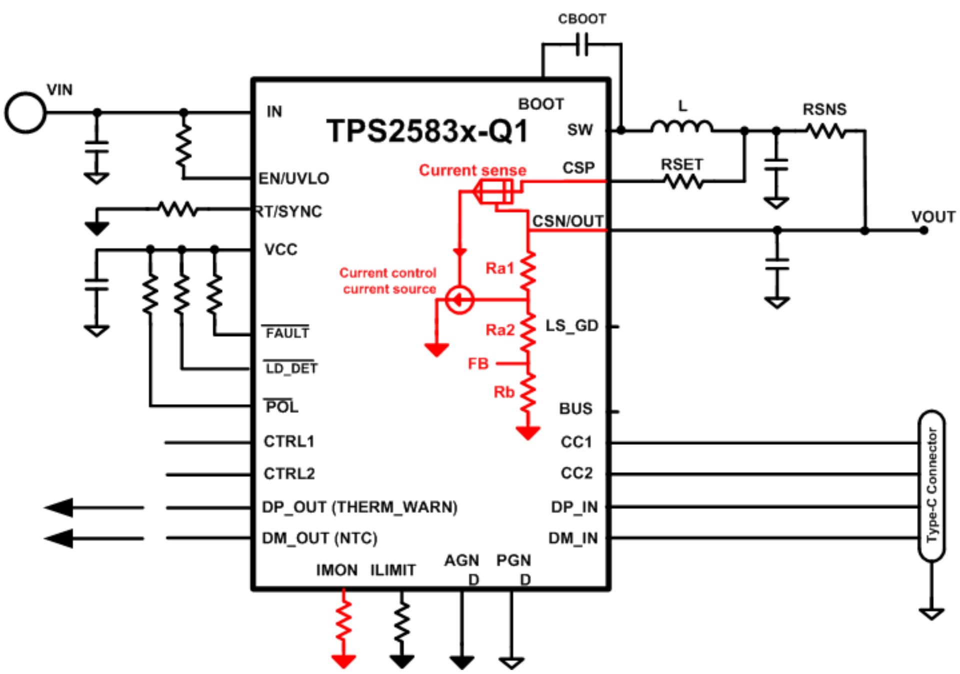


**Figure 2. TPS2583x-Q1 System With Cable Compensation Function**

# 2 Loop Test Method of TPS2583x-Q1

## *2.1 Test the Loop Characteristics Without Cable Compensation Function*

When the cable compensation function is disabled, the frequency response analyzer can be used to measure the loop characteristics of TPS2583x-Q1, setup as shown in Figure 3. You can get its crossover frequency, phase margin and gain margin. For this test, you need to do some modifications based on the TPS25831Q1EVM:

1. Change Rsns(R4) and Rimon(R16) to 0 Ω
2. Remove External FET Q1
3. Cut the wire between Vout and CSN/OUT, and add a 20 Ω resistor between it.

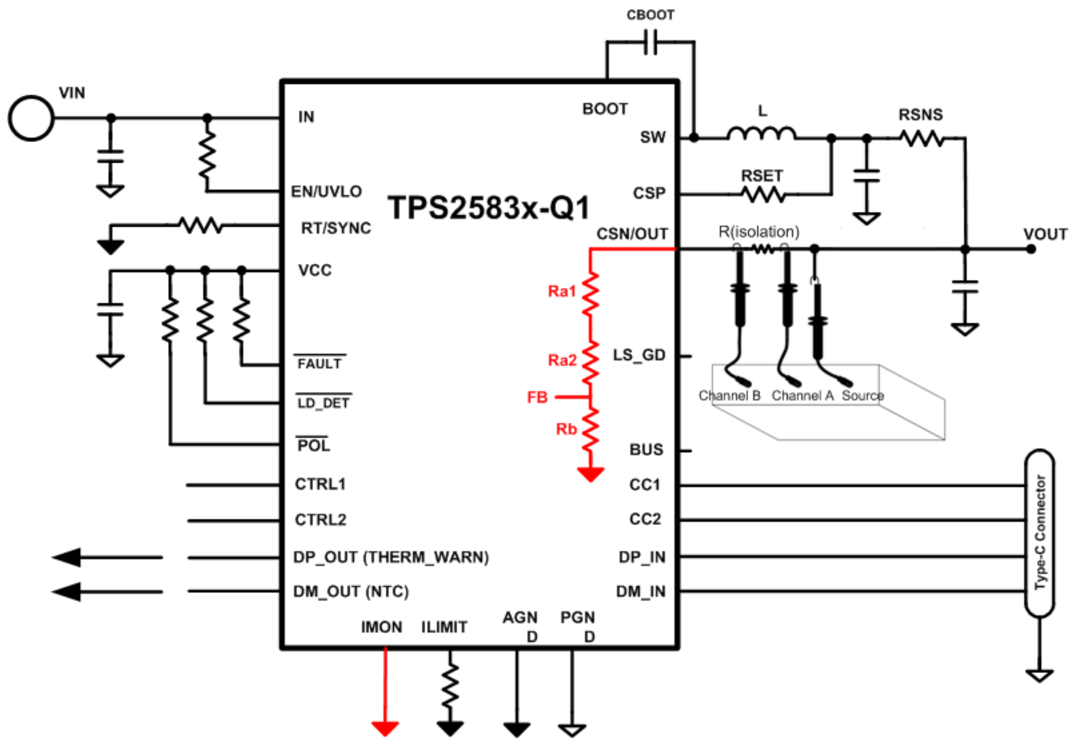


**Figure 3. Setup of Loop Test**

Figure 4 shows the test result. The crossover frequency is 39.25 kHz, phase margin is 44.914°, gain margin is 13.52dB.

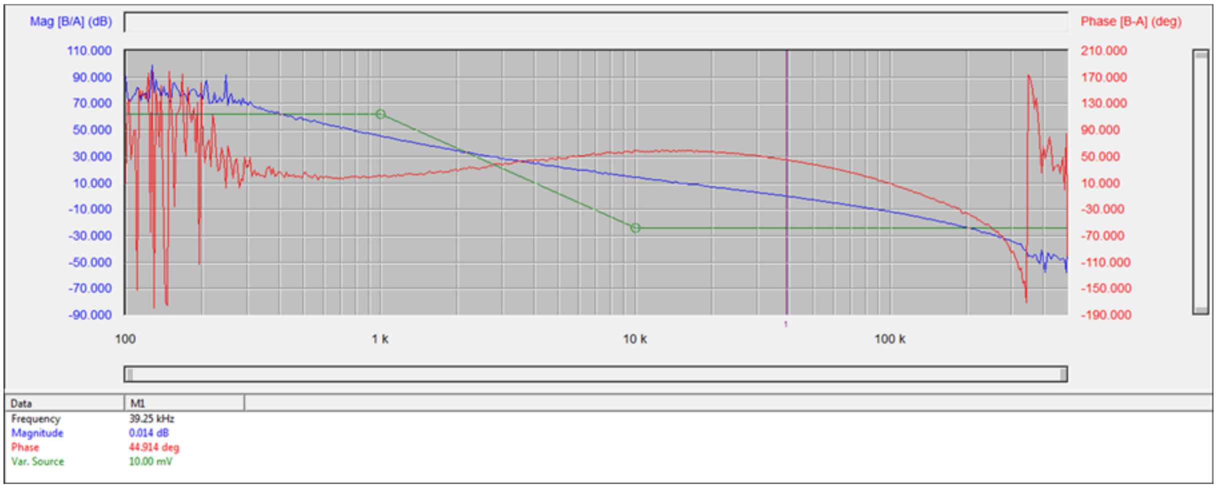


**Figure 4. Loop Result of TPS2583x-Q1 System Without Cable Compensation**

## 2.2 *Evaluating Loop Characteristics With Cable Compensation Function*

When the cable compensation function is used, the setup shown in Figure 3 cannot cut off the loop completely. This method cannot measure the loop characteristic correctly when the cable compensation function is enabled. For this case, fast load transient is used to evaluate loop characteristics. Generally speaking, when the phase margin is greater than 45 °, the overshoot of the load transient will be smaller, and the overshoot callback will be smooth [1]. For poor loop design, its overshoot of load transient will be higher, and the overshoot callback may have ringing. The load transient performance of TPS2583x-Q1 is compared with and without cable compensation function. Figure 5 is the load transient result of no cable compensation function. Figure 6 is the load transient result with cable compensation function. The overshoots and undershoots are summarized in Table 1.

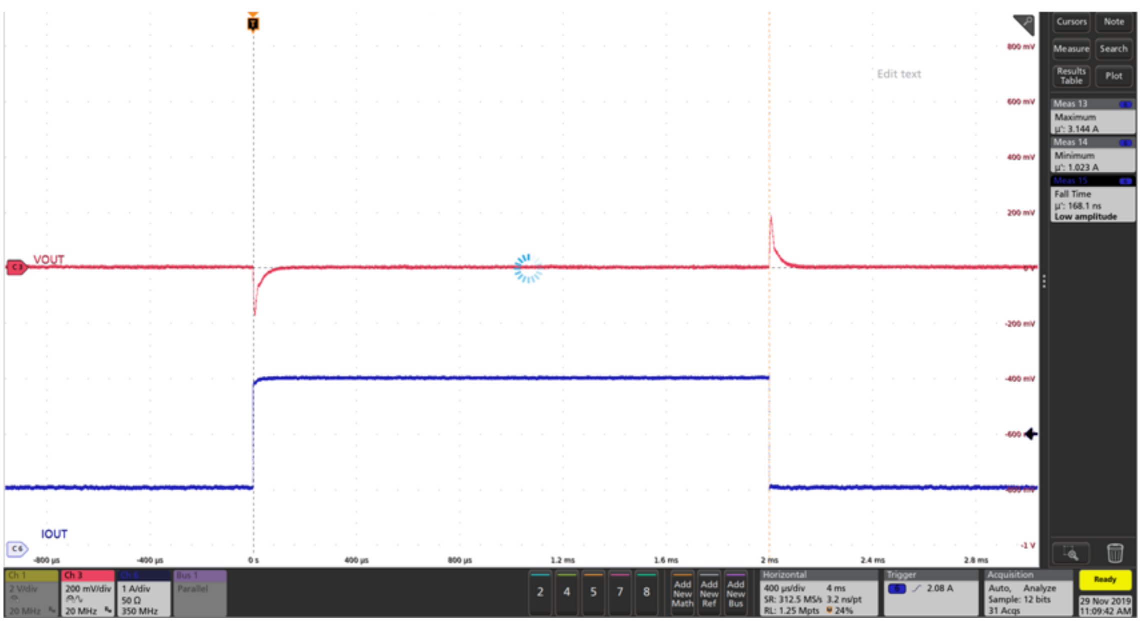


**Figure 5. Load Transient Result of TPS2583x-Q1 Without Cable Compensation**

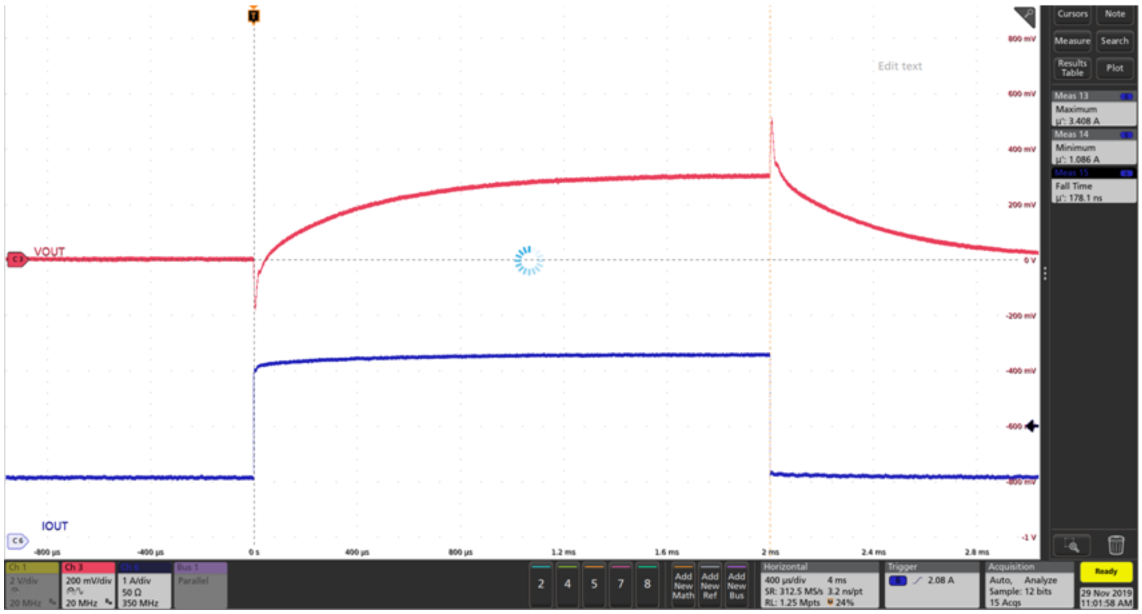


**Figure 6. Load Transient Result of TPS2583x-Q1 With Cable Compensation**

**Table 1. Overshoot and Undershoot Result**

| | Overshoot (mV) | Undershoot (mV) |
|---|---|---|
| No cable compensation | 192.2 | 175.6 |
| With cable compensation | 201.2 | 183.6 |

## 3 How to improve the loop characteristic of TPS2583x-Q1

Usually, 45° phase margin is enough to ensure the stable of system, but some customer want to have higher phase margin. To improve the phase margin, there two options:

- Reducing the power inductor is a specific way to improve the phase margin, but as we all know that reduce the power inductor will increase the inductor current ripple, customer need trade off those two performance. When the inductor decreases to a certain extent, we need to increase the frequency to keep low current ripple of the inductance. Table 2 is the loop test result of different inductor under 400 kHz and 2.2 MHz of TPS2583x-Q1 without cable compensation.

**Table 2. Loop Result vs Inductor**

| Vin(V) | I_load(A) | Cout (µF) | Fsw (kHz) | Inductor(uH) | Fcross(kHz) | Phase Margin(°C) | Gain Margin(dB) |
|---|---|---|---|---|---|---|---|
| 13.5 | 3 | 66 | 400 | 10 | 39.3 | 44.9 | -13.52 |
| | | | | 8.2 | 41.9 | 50.4 | -14.22 |
| | | | | 6.8 | 38.9 | 53.2 | -14.65 |
| | | | 2200 | 2.2 | 37.25 | 67.923 | -16.868 |

- Increasing output capacitance. According to our test results, the phase margin of TPS2583x system can be increased by appropriately increasing the capacitance.

- Table 3 is the test result of different output capacitance values.

**Table 3. Loop Result vs Cout**

| Vin(V) | I_load(A) | Inductor (µH) | Fsw (kHz) | Cout(uF) | Fcross(kHz) | Phase Margin(°C) | Gain Margin(dB) |
|---|---|---|---|---|---|---|---|
| 13.5 | 3 | 8.2 | 400 | 44 | 55.4 | 41.8 | -13.32 |
| | | | | 66 | 41.9 | 50.4 | -14.22 |
| | | | | 88 | 30.6 | 56.4 | -16.59 |

## 4 Summary

- The loop characteristic of TPS2583x-Q1 EVM is crossover frequency is 39.25 kHz, phase margin is 44.914°, gain margin is 13.52dB.
- The loop characteristic of TPS2583x-Q1 with and without cable compensation function is almost the same, so you can evaluate the loop characteristics by measuring the loop characteristic of TPS2583x-Q1 without cable compensation function.
- The loop characteristic can be improved by decreasing the power inductor and increasing the output capacitance; however, it should be noted that the switching frequency needs to be increased to ensure that the inductance current is within a reasonable range when the inductor is too small.

## 5 References

1. Boost E, Dampled R . Switch-Mode Power Supplies Spice Simulations and Practical Designs P.197[J]. Eetimes Com, 2014.

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