

# **How to Improve an Eye Diagram With the TPS25840-Q1 Device Using a Long USB Cable**

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## ABSTRACT

This application report is description how to improve an eye diagram with the TPS25840-Q1 when using a long USB cable. TPS25840-Q1 device is a USB Type A (BC 1.2) charging solution that includes a synchronous DC/DC converter and USB 2.0 high-speed data line (DP and DM) switches.

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### Trademarks

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 Baidu CarLife is a registered trademark of Baidu Online Network Technology (Beijing) Co., LTD.  
 Android Auto is a registered trademark of Google LLC.

## 1 Introduction

Data communication is a very important function in the automotive USB port. Some applications like Apple CarPlay®, Android Auto®, and Baidu CarLife® are required in some automotive USB ports, so good signal integrity performance is very critical in the automotive USB port application. Several factors impact the data communication quality in the USB port such as the PCB layout, system parasitic resistance and capacitance, and a long data cable. This application report discusses the influence of the long data cable and how to improve the signal integrity quality in the long cable data communication.

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## 2 TPS25840-Q1 Device Overview

The TPS25840-Q1 device is a USB Type a (BC 1.2) charging solution that includes a synchronous DC/DC converter. With cable droop compensation, the  $v_{bus}$  voltage remains constant regardless of load current, ensuring connected portable devices are charged at optimal current and voltage even under heavy loads. The TPS25840-Q1 device includes high bandwidth analog switches for DP and DM pass-through. The tps25840-q1 also integrates short-to-battery protection on VBUS, DM\_IN and DP\_IN pins. These pins can withstand voltage up to 18 V.

The TPS25840-Q1 device has an internal high-bandwidth analog switch for the DP/M\_IN and DP/M\_OUT pin. The data sheet bandwidth is about 800 MHz, this high data bandwidth is good for signal integrity. Figure 1 shows the TPS25840-Q1 data transmission characteristics. Figure 1 shows the TPS25840-Q1 good eye diagram performance which is based on the TPS25840Q1EVM-079 evaluation board.



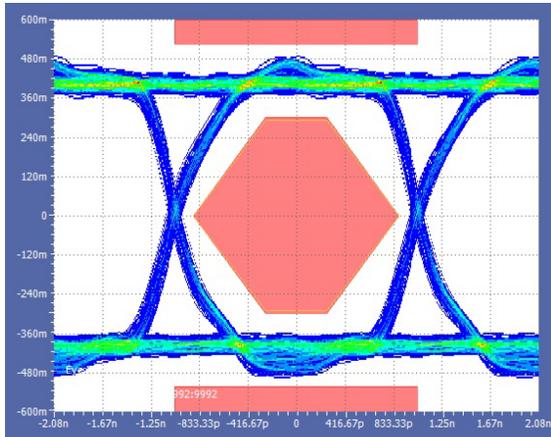
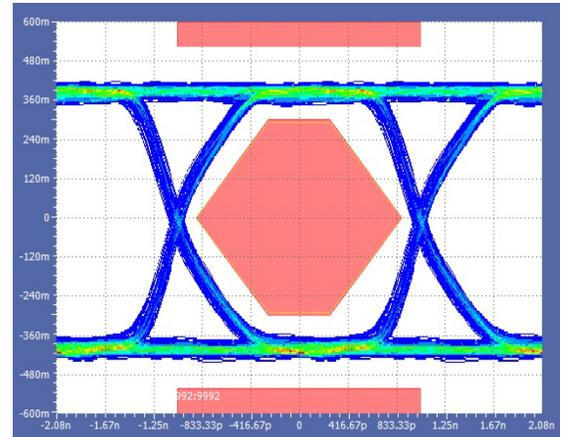
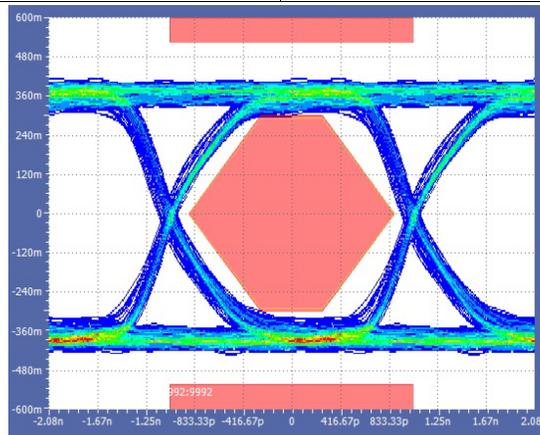
Figure 1. Data Transmission Characteristics vs Frequency

## 3 Data Communication With the Long Cable

In the automotive USB port application, the USB port in the armrest generally needs to communicate with the front-end head unit and the distance is about 1 to 1.5-m. In some car models, the USB port in the rear seat also needs to communicate with the front-end head unit and the distance may be above 3 meters. All this communication needs a long data cable, the length from 1 to 3-m. So, high signal bandwidth and good eye diagram performance is required for this long data cable communication.

To introduce how the cable impacts the data communication, the following test results show difference eye diagram result with different cable length.

When applying the 1-, 1.8-, and 3-m cable, the eye diagram will become bad. The long cable creates the equivalent capacitance and resistance which makes the system bandwidth become narrow.


**Figure 2. Source Eye Diagram Without Cable**

**Figure 3. Eye Diagram With 1.8-m Cable**

**Figure 4. Eye Diagram With 3-m Cable**

## 4 How to Improve the Eye Diagram With a Long Cable

### 4.1 PCB layout

In the USB port, the DP and the DM make up the differential pair that carries out data transfers. To ensure signal integrity, both the DP and the DM signals should travel the same distance. If one trace is longer than the other, the timing of the signals could be affected resulting in data errors. Therefore, it is important to ensure that data trace lengths are matched. The recommended maximum allowed deviation between the DP and the DM trace lengths is just 150 mil.

Impedance control of the DP and the DM is another major concern. The tracking for these two should be matched on the printed-circuit board (PCB) to minimize signal reflections. The DP and the DM USB signals have a 90- $\Omega$  differential (45- $\Omega$  each to signal ground). The signals need to control the DP and the DM trace differential impedance to 90- $\Omega$  in the PCB board.

Care should also be taken not to add any stubs when putting voltage protection diodes and capacitors into the design. This will minimize data signal reflections. Also, the DP and DM signals should consistently be routed over a USB signal ground plane. Ideally, there should not be any splits in the plane directly under either DP or DM.

Basic circuit layout principles should always be followed, such as routing USB lines away from noisy power signals and clock circuitry components. Designers should also avoid the use of right-angled turns on USB signal traces. Using two 45° turns will prove far more beneficial than a single 90° turn.

### 4.2 Using Inductors and Capacitors

Figure 5 shows the LC network diagram used to improve the system eye performance. Figure 6 and Figure 7 show the 1.5-m cable eye diagram test results before and after connecting the LC network. In this test, it uses the 10-nH inductor and 4.7-pF for the LC network. This LC network can significantly improve the eye diagram in this application.

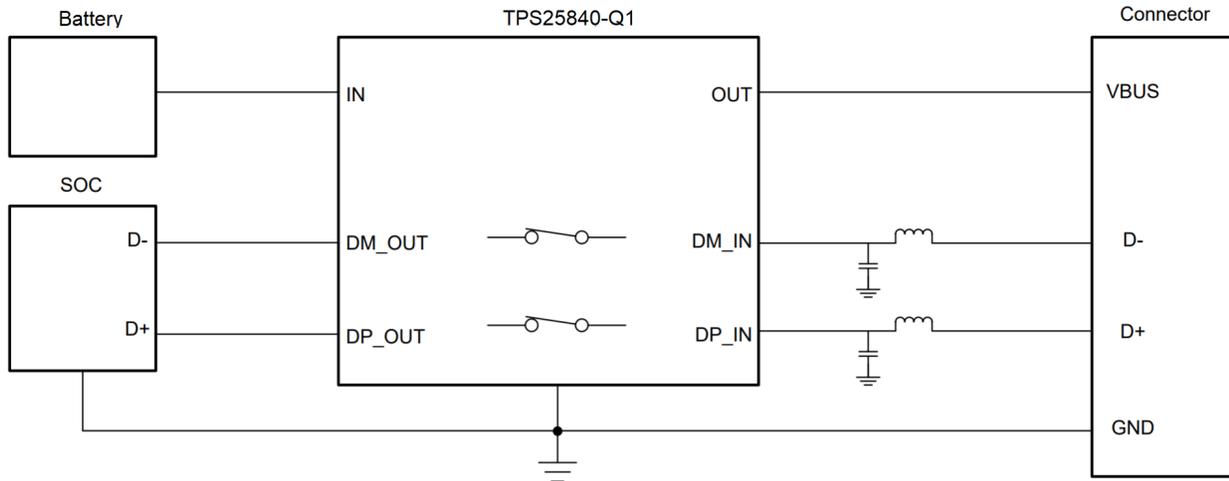


Figure 5. Add Inductor and Capacitance in Data Lines

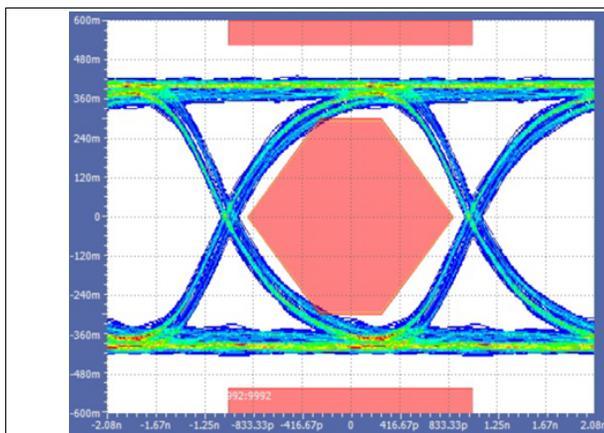


Figure 6. Without LC Network

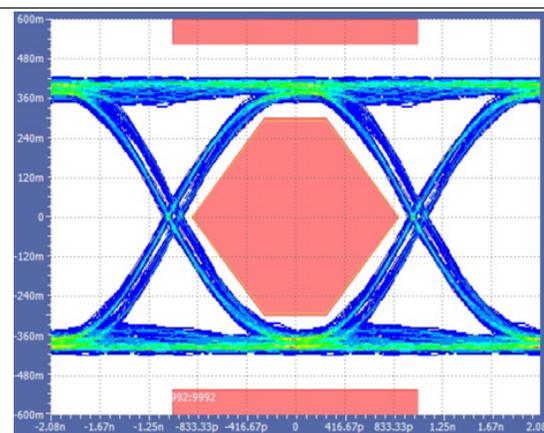


Figure 7. Add 10-nH and 4.7-pF LC Network

### 4.3 Add Signal Re-driver

To improve the eye diagram performance, the signal re-driver must be added to avoid signal attenuation. The PMP40544 is the reference design which uses the tps25840-Q1 device for USB Type A, BC 1.2 control and the TUSB217-Q1 device for signal boost. The PMP40544 can pass the USB 2.0 high-speed electrical near end eye compliance tests with a cable as long as 3-m.

Figure 8 shows the PMP40544 reference design schematic. This reference design uses the TPS25840-Q1 device for the USB Type A, BC 1.2 control. Since the TPS25840-Q1 device has 3.5-A loading capability, it can add additional loading in the output of the TPS25840-Q1. This design uses a low voltage LDO which receives power from the output of the TPS25840-Q1 and transfers it to 3.3 V for the TUSB217-Q1 power supply.

Figure 9, Figure 10, and Figure 11 Show the eye diagram with different length cable after the TPS25840Q1EVM-079 and PMP40544 designs. The PMP40544, which adds the signal re-driver TUSB217-Q1, helps the system pass the USB 2.0 high-speed electrical near end eye compliance tests.

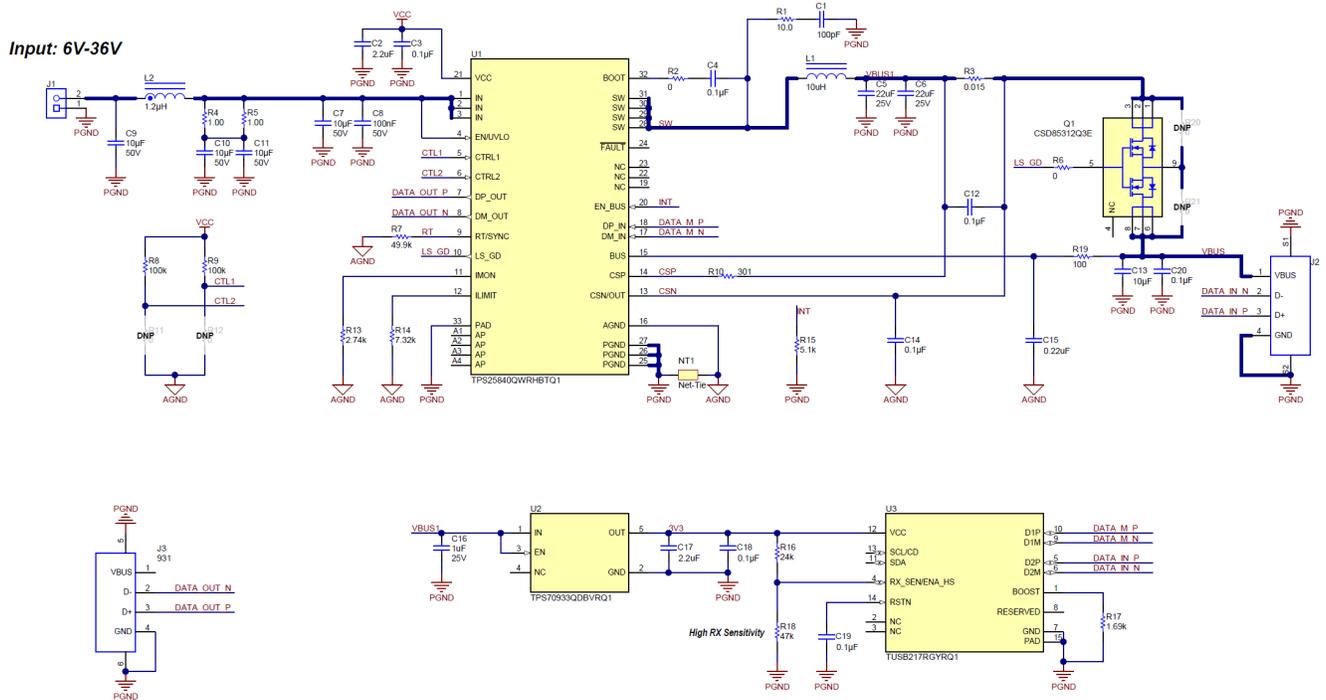


Figure 8. PMP40544 Schematic

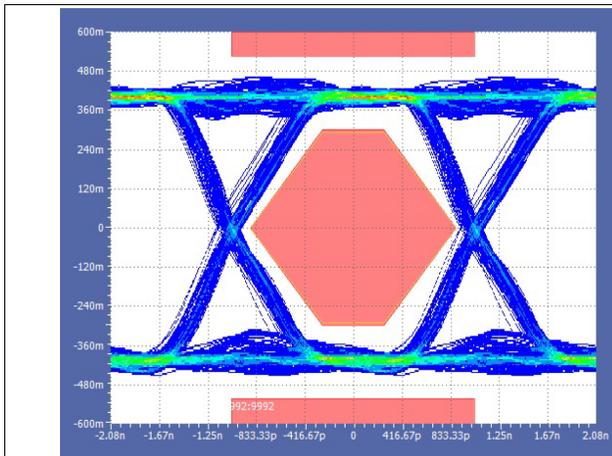


Figure 9. PMP40544 Eye Diagram With 1-m Cable

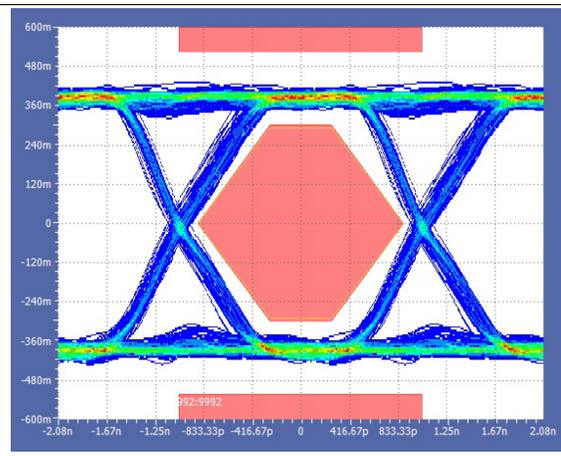


Figure 10. PMP40544 Eye Diagram With 1.8-m Cable

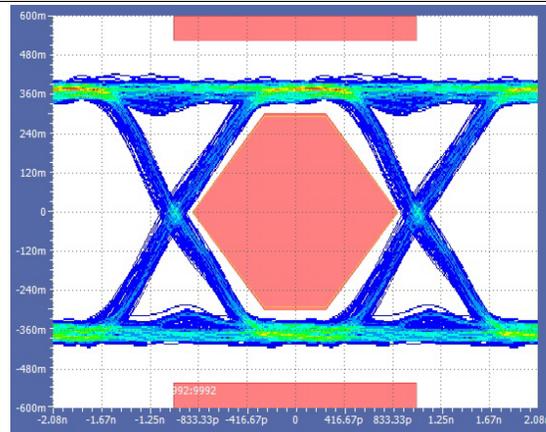


Figure 11. PMP40544 Eye Diagram With 3-m Cable

## 5 Summary

The long data cable will create the equivalent capacitive, inductance, and resistance which will decrease the signal amplitude and narrow the data way bandwidth. The system must care about the PCB layout and do the DP/M signal trace differential impedance control. The PMP40544 reference design can improve the signal quality for the long data cable application. This is a good solution which can help the system pass the USB 2.0 high-speed electrical near end eye compliance tests.

## 6 References

- Texas Instruments, [TPS2584x-Q1 USB Type-A and BC1.2 5-V 3.5-A Output, 36-V Input Synchronous Step-Down DC/DC Regulator with Cable Compensation Data Sheet](#)
- 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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