USB-C VBUS voltage generation for multiple type-C ports in automotive vehicles with LITIX™ devices

About this document

This document explains how to generate USB-C VBUS voltage for multiple USB type-C ports in automotive vehicles.

Scope and purpose

The purpose of this application note is to inform about possible implementations of USB-C charging ports using Infineon LITIX™ devices. The devices covered by this application note are: TLD5501-2QV, TLD5190QU/QV and TLD5542-1QU/QV.

Intended audience

This application note is intended for designer engineers who want to have a clear view on how to generate VBUS voltage for USB-C applications.

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1 Introduction

Mobile devices like smartphones, tablets and laptops are part of our daily life.

In the last decade the functionalities of these devices have been enhanced drastically increasing the quality of the user experience.

On the other hand, with the increase of functionalities, the request of power from such devices is increasing, with the consequence that the battery needs to be charged more often than in the past. For this reason the market requires fast charging capabilities in order to reduce the time that the users need to wait for a fully charged device.

USB-C and USB power delivery (USB-PD) are one of the latest answers to the fast charging market request. USB-C standards enhance a USB type-C port to deliver up to 15 W (5 V, 3 A) over the USB type-C cable. The USB-PD standard enhances even more a port to deliver up to 100 W (20 V, 5 A) over specific versions of USB type-C cables.

Since the USB-C and USB-PD standards have been published, many smartphones, tablets and laptop OEMs have adopted USB type-C ports into their devices. One of the first implications is the need to offer USB-C chargers inside the automotive vehicles as well, to enable the fast charging user experience.

In this application note different solutions to implement automotive USB-C charging ports using Infineon LITIX™ devices are shown.

2 System overview

The number of USB type-C ports inside cars is increasing rapidly. Soon it will be possible to see USB type-C ports distributed all over the car (i.e. 2 on the rear seat, 2 inside the armrest/console and another 2 into the head unit and glove compartment).

In automotive applications, it is common to have the USB VBUS power generation on a dedicated control unit into the body compartment and then to distribute the voltage across remote USB type-C ports via a dedicated wire harness that can be up to several meters long.

For USB-C ports that do not implement USB power delivery, the voltage VBUS generation is limited to 5 V.

A good approach in order to save BOM costs is then to share the VBUS generation with a common central DC-DC converter that generates the VBUS for all the remote USB-C ports as depicted in Figure 1.

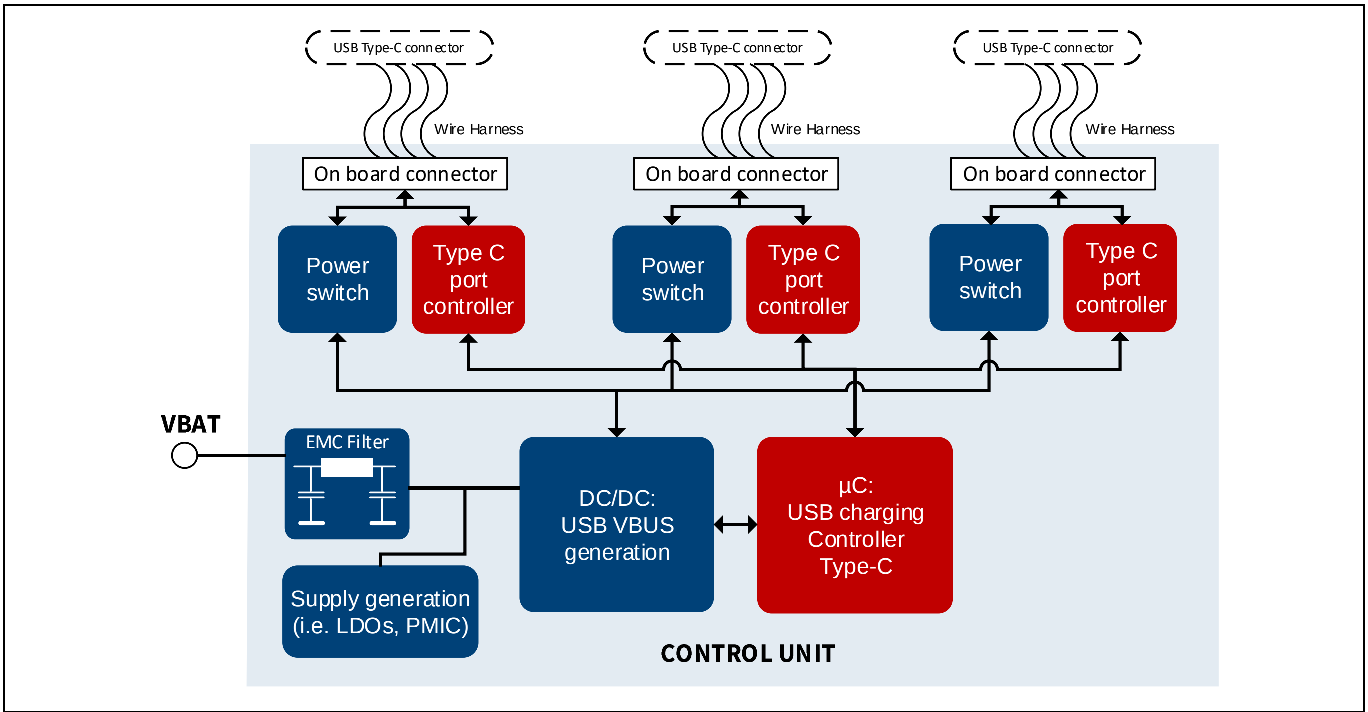

Figure 1 Automotive USB-C system architecture example

The maximum current that can be offered by a USB type-C port, without considering the further USB power delivery enhancement, is increased according to the USB type-C standard up to 3 A.

With the increasing number of USB ports available inside a car the output power that needs to be delivered by the DC-DC will also increase rapidly. For instance, considering the 6 ports scenario described at the beginning of this section, the output power of the DC-DC can be up to 90 W (5 V, 18 A).

For these reasons, a highly efficient synchronous DC-DC approach is the right choice to suitably handle the requested power with the aim to reduce the PCB space and to avoid the need to have big heat sinks to cool down the DC-DC components, bringing in both the cases a cost reduction value.

Infineon offers a wide portfolio of high efficient synchronous DC-DC control ICs. In the following sections the implementation of a USB-C system will be described with:

- TLD5501-2QV: dual channel synchronous buck DC-DC controller with SPI
- TLD5190QU/QV: synchronous H-Bridge DC-DC controller
- TLD5542-1QU/QV: synchronous H-Bridge DC-DC controller with SPI

3 Control unit hardware implementation with LITIX™ devices

3.1 TLD5501-2QV

In the first scenario the following requirements are considered:

- 6 USB Type-C Ports (i.e. 2 on the rear seat, 2 inside the armrest/console and another 2 into the head unit and glove compartment)
- 5 V fixed output voltage as specified into the USB Type-C specifications
- battery voltage functional range: 8 V to 16 V

With such requirements a buck controller is the perfect selection to generate the needed output voltage (max value of 5.5 V).

The total amount of power is 90 W (5 V, 18A) so a synchronous buck DC-DC would help to improve the system efficiency.

Moreover, due to the relative high current output demand of up to 18 A, a multiphase buck DC-DC controller would be the perfect choice in order to split the output current between two inductors and then relax the requirements for the inductors and the switching elements.

Indeed a multiphase design allows significant flexibility for output inductor choice, which is extremely important in small form factor applications because it allows to select a device with a smaller saturation current with the consequence that smaller inductor sizes can be selected.

Another benefit of the multiphase design is to reduce the output voltage ripple by a factor *n*, where *n* is the number of phases, without the need to increase the output filter capacitance.

Moreover a multiphase design improves also the EMC performances of the DC-DC with the consequence that BOM cost can be saved by designing smaller filters.

Infineon offers the right choice for a buck multiphase voltage regulator: the TLD5501-2QV.

TLD5501-2QV is a dual channel synchronous buck DC-DC controller explicitly designed for high power applications. The two channels can work independently or in multiphase operations. It implements an SPI interface to control and retrieve the status of the DC-DC. The switching frequency is adjustable in the range of 200 kHz to 700 kHz. It can be synchronized to an external clock source. A built in programmable Spread Spectrum switching frequency modulation and the forced continuous current regulation mode improve the overall EMC behavior. Furthermore, the current mode regulation scheme provides a stable regulation loop maintained by small external compensation components. The adjustable soft start feature limits the current peak as well as voltage overshoot at start-up.

The control unit hardware implementation with the TLD5501-2QV is then shown in Figure 2.

In Figure 3 the application diagram of the TLD5501-2QV as voltage supply in multiphase operation is shown.

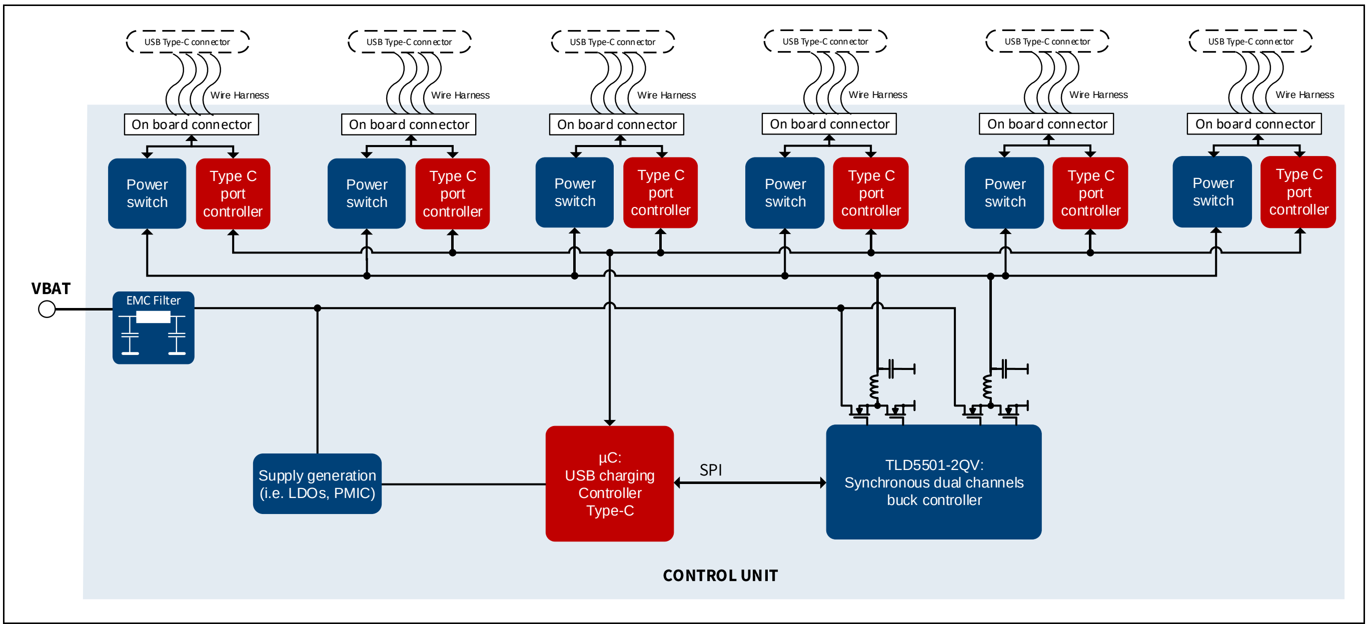

Figure 2 Automotive USB-C system hardware implementations with TLD5501-2QV

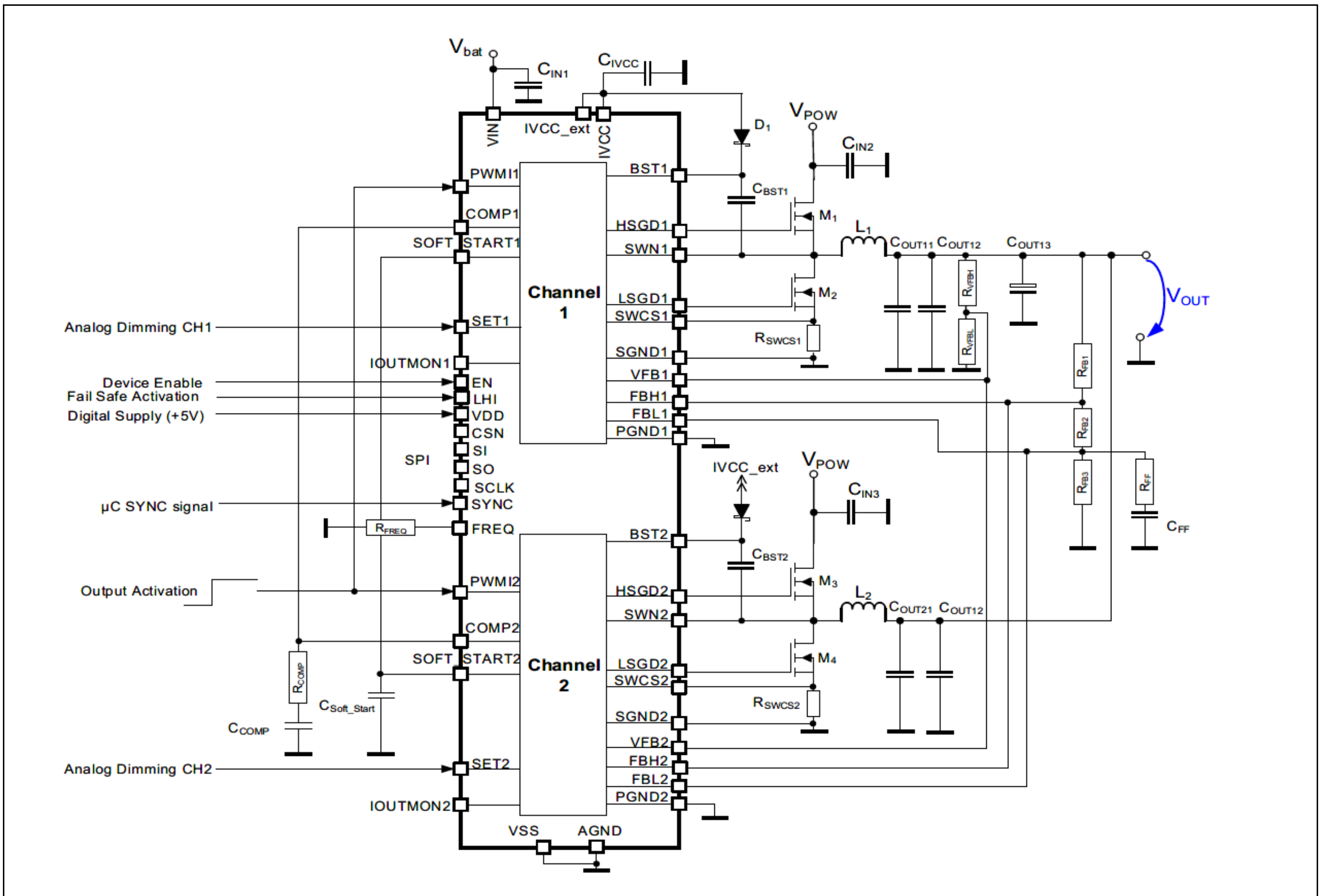

Figure 3 Application diagram of TLD5501-2QV as buck voltage regulator in multiphase operation

3.2 TLD5190QU/QV or TLD5542-1QU/QV

In the second scenario the following requirements are considered:

- 4 USB Type-C Ports (i.e. 1 on the rear seat, 2 inside the armrest/console and another 1 into the head unit and glove compartment)
- 5 V fixed output voltage as specified into the USB Type-C specifications
- battery voltage functional range: 8 V to 16 V

The total amount of power in this case is 60 W (5 V, 12 A) and again a synchronous DC-DC controller would help to improve the system efficiency.

Due to the reduced request of maximum current compared to the previous scenario, a one stage synchronous DC-DC controller would be the perfect choice to reduce the BOM costs.

Infineon offers the right choices: the TLD5190QU/QV or TLD5542-1QU/QV.

TLD5190QU/QV is a synchronous H-Bridge DC-DC controller with built in protection features. This concept is beneficial for high power application with maximum system efficiency and minimum number of external components. The switching frequency is adjustable in the range of 200 kHz to 700 kHz. It can be synchronized to an external clock source. A built in Spread Spectrum switching frequency modulation and the forced continuous current regulation mode improve the overall EMC behavior. Furthermore the current mode regulation scheme provides a stable regulation loop maintained by small external compensation components. The adjustable soft start feature limits the current peak as well as voltage overshoot at start-up.

TLD5542-1QU/QV enhances the TLD5190QU/QV by adding an SPI interface to control and retrieve the status of the DC-DC.

The control unit hardware implementation with the TLD5190QU/QV or TLD55421-1QU/QV is then shown in Figure 4.

In Figure 5 the application diagram of the TLD5190QU/QV has voltage regulator is shown.

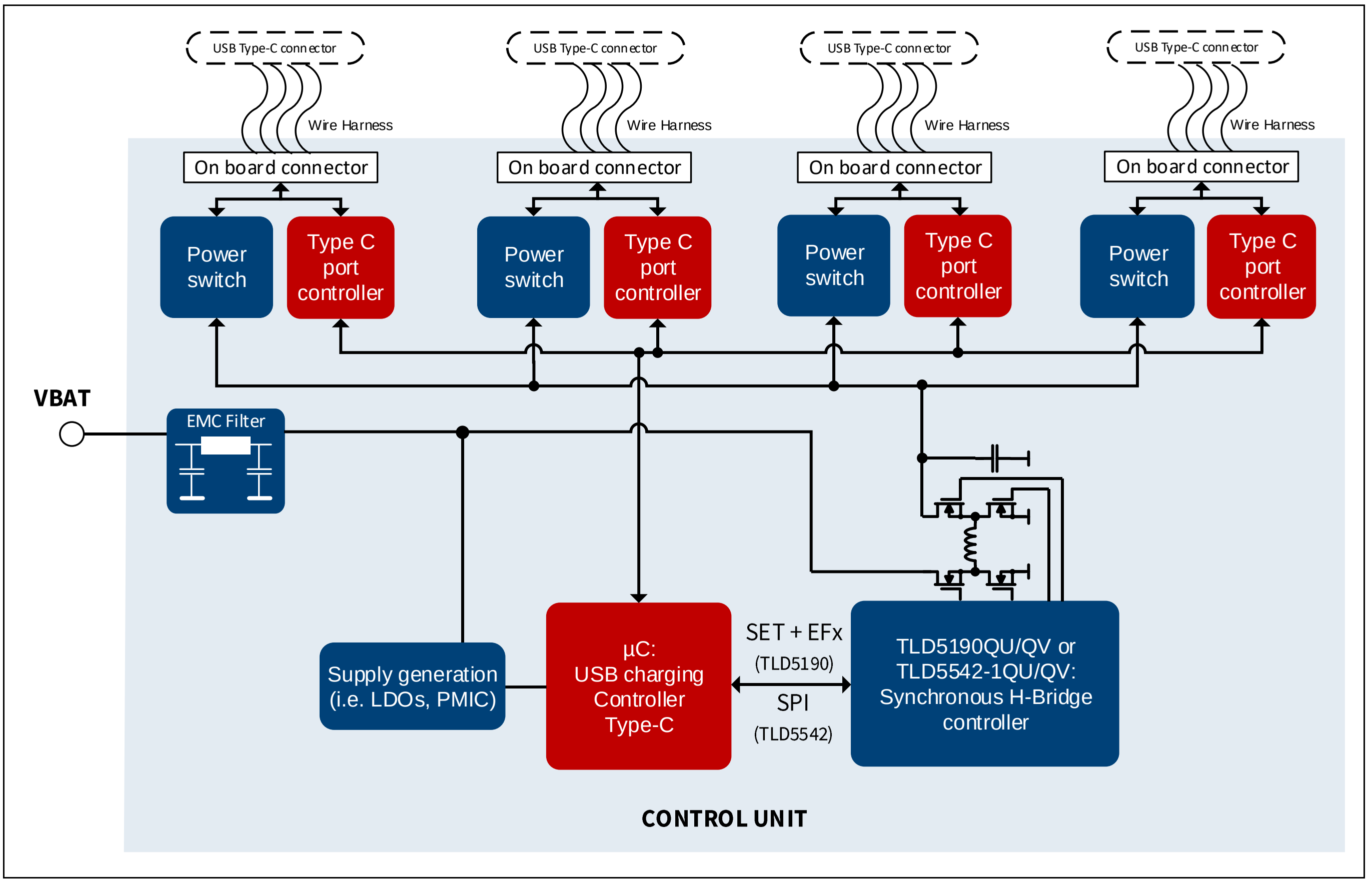

Figure 4 **Automotive USB-C system hardware implementations with TLD5190QU/QV or TLD5542-1QU/QV**

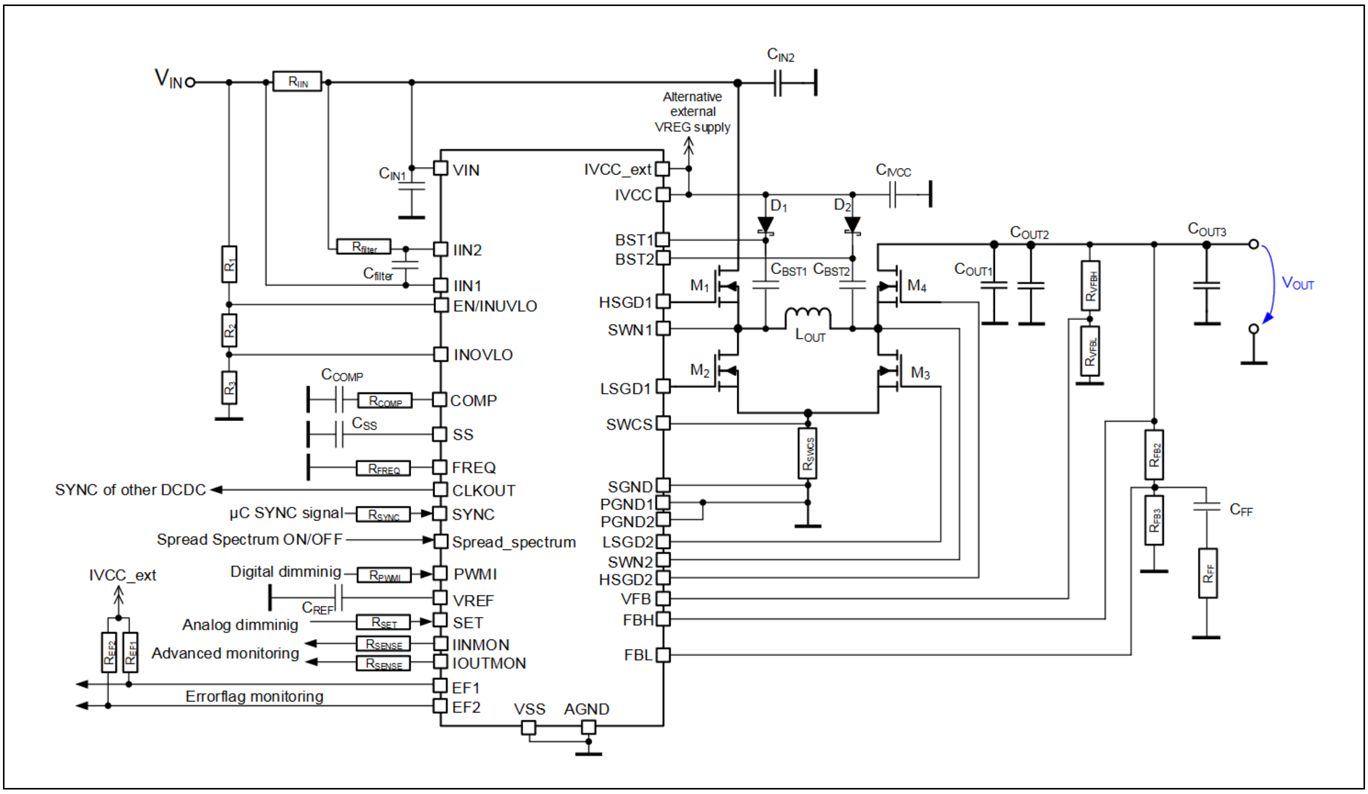

Figure 5 **Application drawing of TLD5190QU/QV as voltage regulator**

4 USB-C specific requirements

4.1 Cable drop compensation

The cable drop compensation is one of the challenges for a USB-C system implementation in automotive. As described in Figure 1, the power from the central unit is delivered to the USB-C connector via the wire harness that may be up to several meters long.

The USB-C standard requests to provide a regulated VBUS voltage at the connector. Considering the presence of the long cable between the DC-DC and the remote USB connector at high charging currents, the cable equivalent resistance can cause an unwanted voltage drop.

For instance considering a 2 meters internal cable specification, the following cable equivalent resistance is obtained:

VBUS cable resistance [mΩ]	GND cable resistance [mΩ]	Total cable resistance [mΩ]
112	84	196

The USB standard requests to have a VBUS voltage of minimum 4.75 V on the connector. With the considered cable example, a DC-DC generating a fixed output supply voltage needs to limit the maximum current in order to avoid the USB VBUS specification violation:

Fixed output supply [V]	5	5.1	5.2	5.3
Maximum current [A]	1.28	1.78	2.3	2.8

To allow cable length design flexibility without the need to limit the output current a cable drop compensation is needed. Infineon LITIX™ devices proposed in this application note offer the analog dimming feature: it allows to adjust the output voltage to compensate the cable drop for different charging current levels.

For TLD5501-2QV and the TLD5542-1QU/QV the analog dimming feature is a programmable 8-bit register to adjust the internal reference of the devices to control the output voltage, as is depicted in Figure 6.

Alternatively, via SPI it is possible to program these devices to use the SET pin to perform the analog dimming feature as shown in Figure 7.

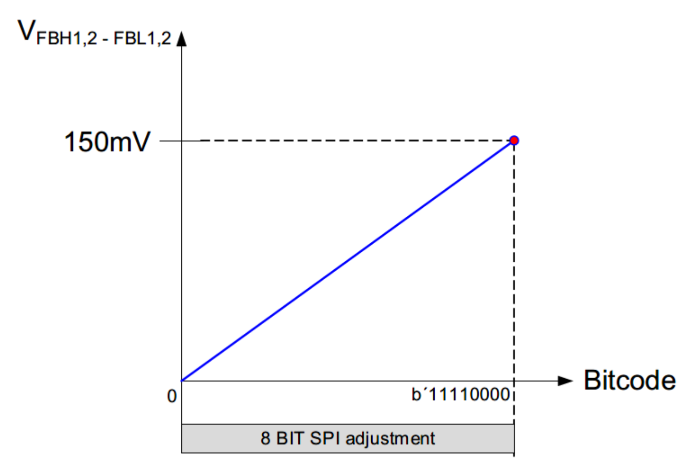

Figure 6 TLD5501-2QV and TLD5542-1QU/QV analog dimming overview

For the TLD5190QU/QV the analog dimming feature is controlled via the SET pin as is depicted in Figure 7.

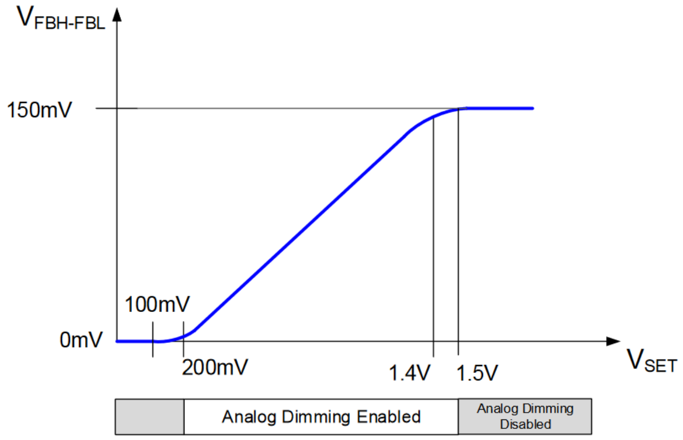

Figure 7 TLD5190QU/QV analog dimming overview

4.1.1 TLD5501-2QV analog dimming design example

An example of analog dimming design in order to allow voltage drop compensation with the TLD5501-2QV is shown below:

The output voltage of the application diagram shown in Figure 3 is defined by the following equation:

$$\mathrm{VOUT} = \left(I_{FBH} + \frac{V_{FBH} - V_{FBL}}{R_{FB2}}\right) * R_{FB1} + \left(\frac{V_{FBH} - V_{FBL}}{R_{FB2}} - I_{FBL}\right) * R_{FB3} + V_{FBH} - V_{FBL}$$

In order to allow the capability to increase the output voltage with the analog dimming feature, it is suggested to set 5V output voltage regulation for 80% of analog dimming value:

$$V_{FBH} - V_{FBL} = 0.8 * 150mV = 120mV$$

It suggested to use the high side sensing by selecting R_{FB1} = 0 ohm. It turns out that the output voltage at 80% of analog dimming capability is set then by:

$$\mathrm{VOUT} = \left(\frac{120mV}{R_{FB2}} - I_{FBL}\right) * R_{FB3} + 120mV$$

I_{FBL} in case of high side current sensing has a typical value of 30µA.

By selecting R_{FB2} = 120 ohm and R_{FB3} = 5.1K ohm, VOUT is equal to 5.067V at 80% of analog dimming.

VOUT can be increased up to 6.372V at 100% of analog dimming.

4.2 Output overcurrent protection

Another important aspect for any charging port is to protect itself from any destructive event (i.e. output short to ground) that would cause an overcurrent demand from the output.

4.2.1 TLD5501-2QV

The TLD5501-2QV implements a protection mechanism to limit the maximum current flowing into the inductor and then to the output load.

The inductor current is sensed via the $R_{SWCS1,2}$ resistors, as is shown in Figure 3, and in case it exceeds the TLD5501-2QV overcurrent threshold ($V_{SWCS1,2\_buck}$) the device reduces the duty cycle in order to bring the switches current below the imposed limit.

4.2.2 TLD5190QU/QV and TLD5542-1QU/QV

The TLD5190QU/QV and TLD5542-1QU/QV implements the same mechanism of the TLD5501-2QV to limit the current flowing into the inductor, moreover these devices also have the input current limiter feature to limit the output current flowing into the load.

The input current is sensed via a shunt resistor placed between the IIN1 and IIN2 pins, as is shown in Figure 5.

The control loop reduces the duty cycle when the voltage across the shunt resistor reaches the input current sense threshold ($V_{IIN1-IIN2}$) to keep the input current below the maximum set value and then to limit the output current as well.

5 Conclusions

In this application note different solutions to implement USB-C charging ports with the LITIX™ devices have been proposed.

Two scenarios with different requirements have been analyzed, in both cases Infineon devices offer the best fit for the requirement fulfilment in the harsh automotive environment.

Revision history

Major changes since the last revision

Page or Reference	Description of change
2020-01-10	Rev. 1.00 - First release

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Edition 2020-01-10

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

Z8F67775974