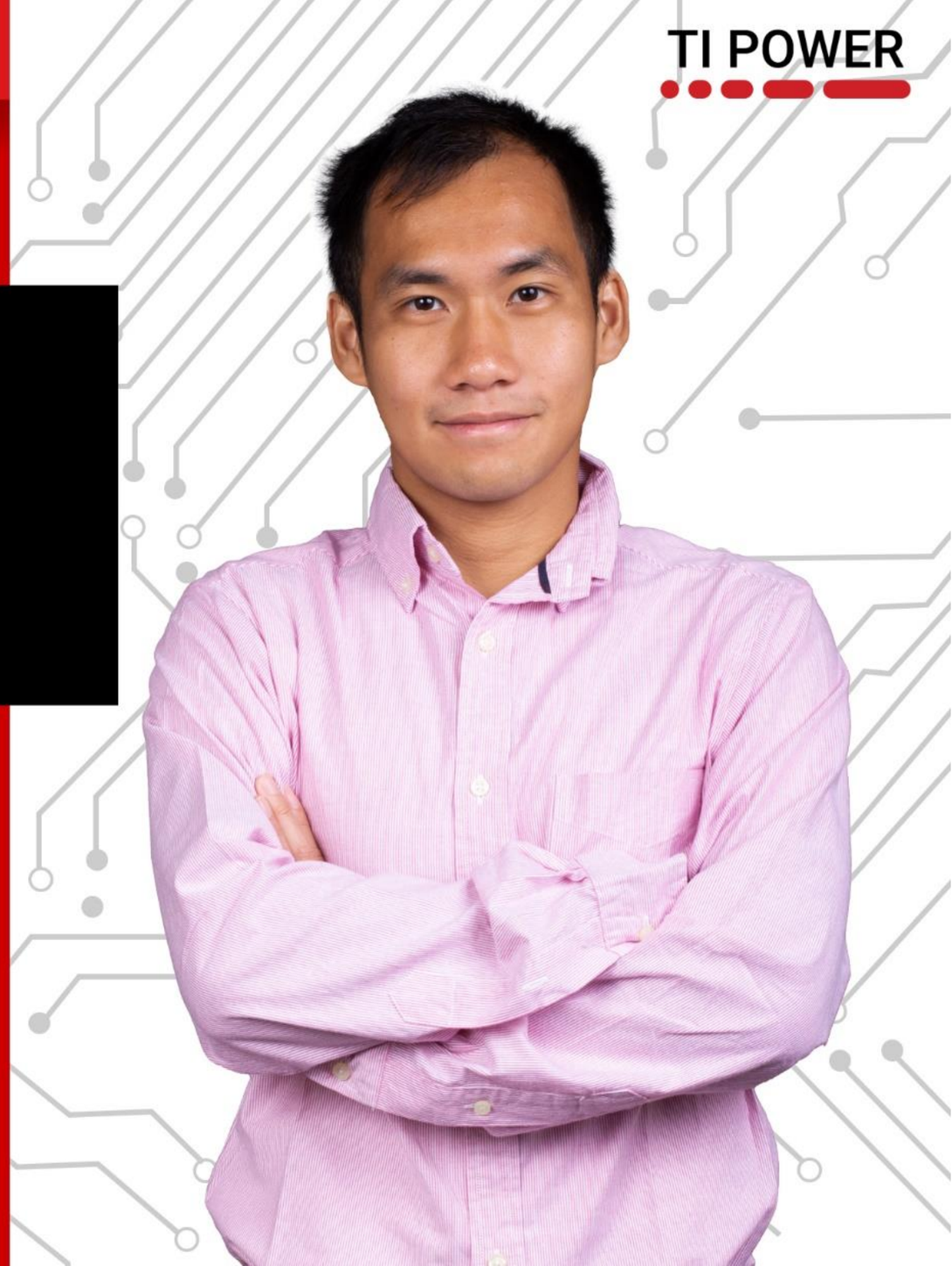
Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

PENGZHAO ZHU

IMPLEMENTING AUTONOMOUS USB TYPE-C® POWER DELIVERY FOR DUAL-ROLE CHARGING AND SOURCING



Agenda

- Overview of USB Type-C and power delivery (PD).
- Implementation of USB Type-C and PD.
  - Type-C sink-only solution for 1S (1 battery cell) and 2S (2 battery cells).
  - Type-C standalone dual-role-power (DRP).
  - Host controlled Type-C DRP (1S and 2S).
  - USB-PD DRP with integrated MOSFET chargers.
  - USB-PD DRP with high power controllers.
- Summary.

Overview of USB Type-C and PD

USB Type-C and PD

Precedence	Mode of operation	Nominal voltage	Maximum current
Highest	USB PD	Configurable	Up to 5 A
	USB Type-C current at 3 A	5 V	3 A
	USB Type-C current at 1.5 A	5 V	1.5 A
	USB BC 1.2	5 V	Up to 1.5 A
	USB 3.2 (Default Power)	5 V	900 mA
Lowest	USB 2.0 (Default Power)	5 V	500 mA

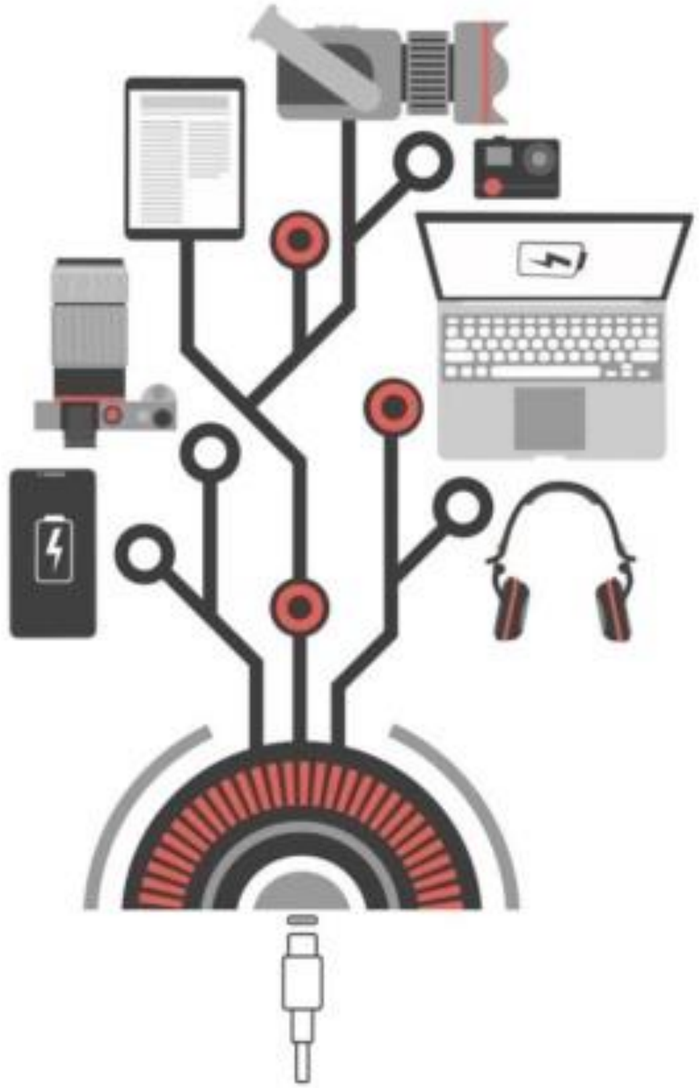
Reference: Release 2.1, universal serial bus Type-C cable and connector specification

What is USB Type-C and PD?

- USB Type-C is the newest version of the USB connector series.
  - A set of receptacle, plug and cables are defined to be used in the USB Type-C ecosystem.
  - The USB Type-C connection is a 24-pin connector that can be used for both power and data applications.
- USB PD is a power delivery protocol associated with the USB Type-C ecosystem.
  - The voltage range of the protocol is variable and range from 5 V up to 48 V with maximum defined current of 5A.

Why USB Type-C charging?

- **Before USB Type C:**
  - Need multiple different adaptors to charge different applications.
- **After USB Type C:**
  - Single adaptor could be used to charge different applications.
  - The universal charging trend is growing very fast.



USB Type-C and PD applications

- The new generation of personal electronics and industrial applications are employing USB Type-C charging.
- Up to 240 W of power can be delivered implementing USB Type-C PD.

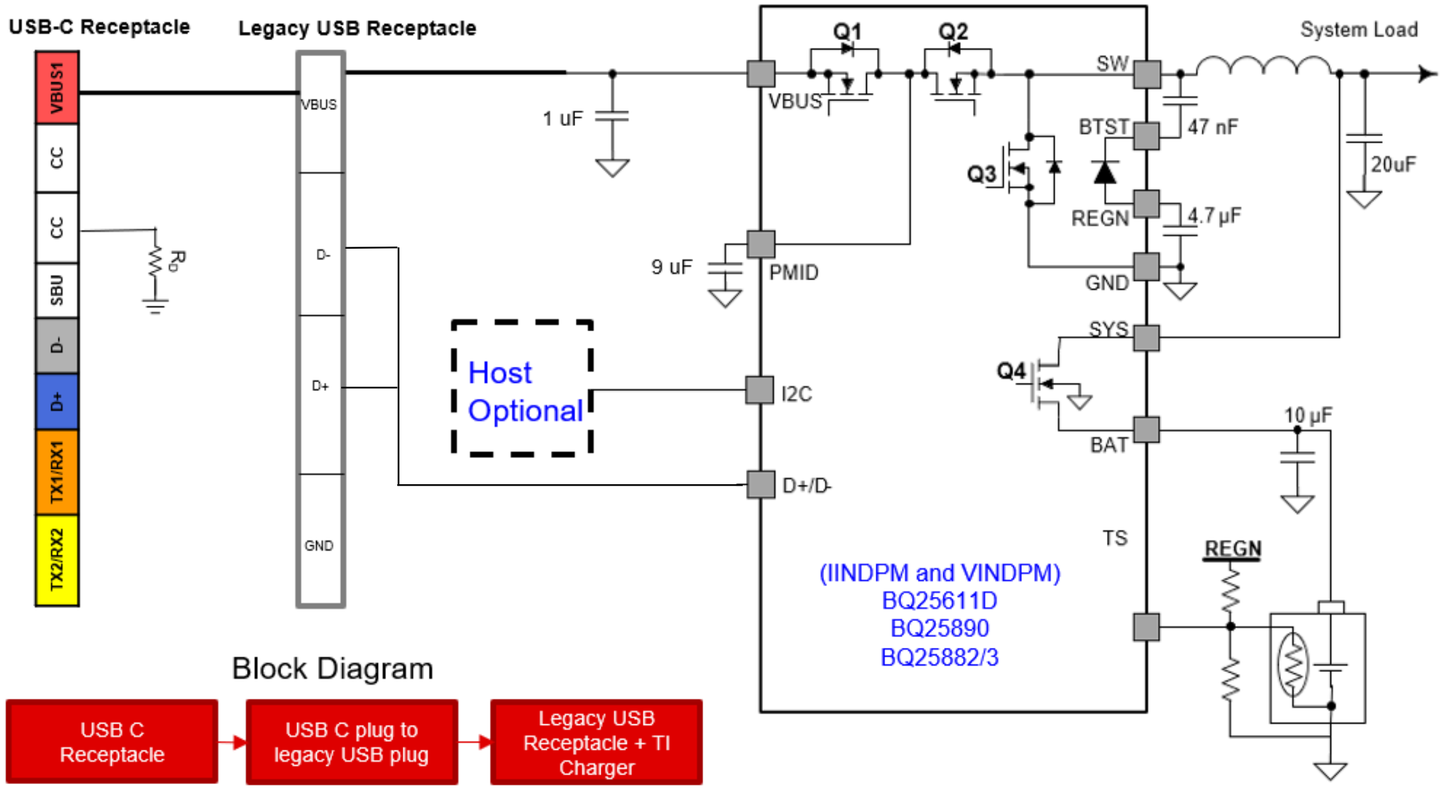
Type-C sink-only solution

Dynamic power path management to implement USB-C

- Input Current Dynamic Power Management (IINDPM) - limits the input current with the system load as the higher priority.
  - Used on input sources with ***known*** current capability.
  - Maximize the utilization of adaptor capability ***without*** overloading.

- Input Voltage Dynamic Power Management (VINDPM) - limits the input voltage with the system load as the higher priority.
  - Used on input sources with ***unknown*** current capability.
  - Maximize the utilization of adaptor capability ***with limited*** overloading.

Type-C sink only (1S and 2S)



Block Diagram

*Diagram corresponds to 1S chargers. Solution applies to 2S boost chargers such as BQ25882/3

*a set of cables are defined in the USB C spec to connect USB C systems to legacy systems

- Up to 3 A (15 W) sink.
- 1S/2S Li-ion charging from Type-C input.
- Charger IINDPM to control input current or VIINDPM to maximize adaptor capability.
  - Supports all non-PD type C inputs.
  - Supports all BC1.2 inputs.
- Simple solution to reduce BOM and solution size.

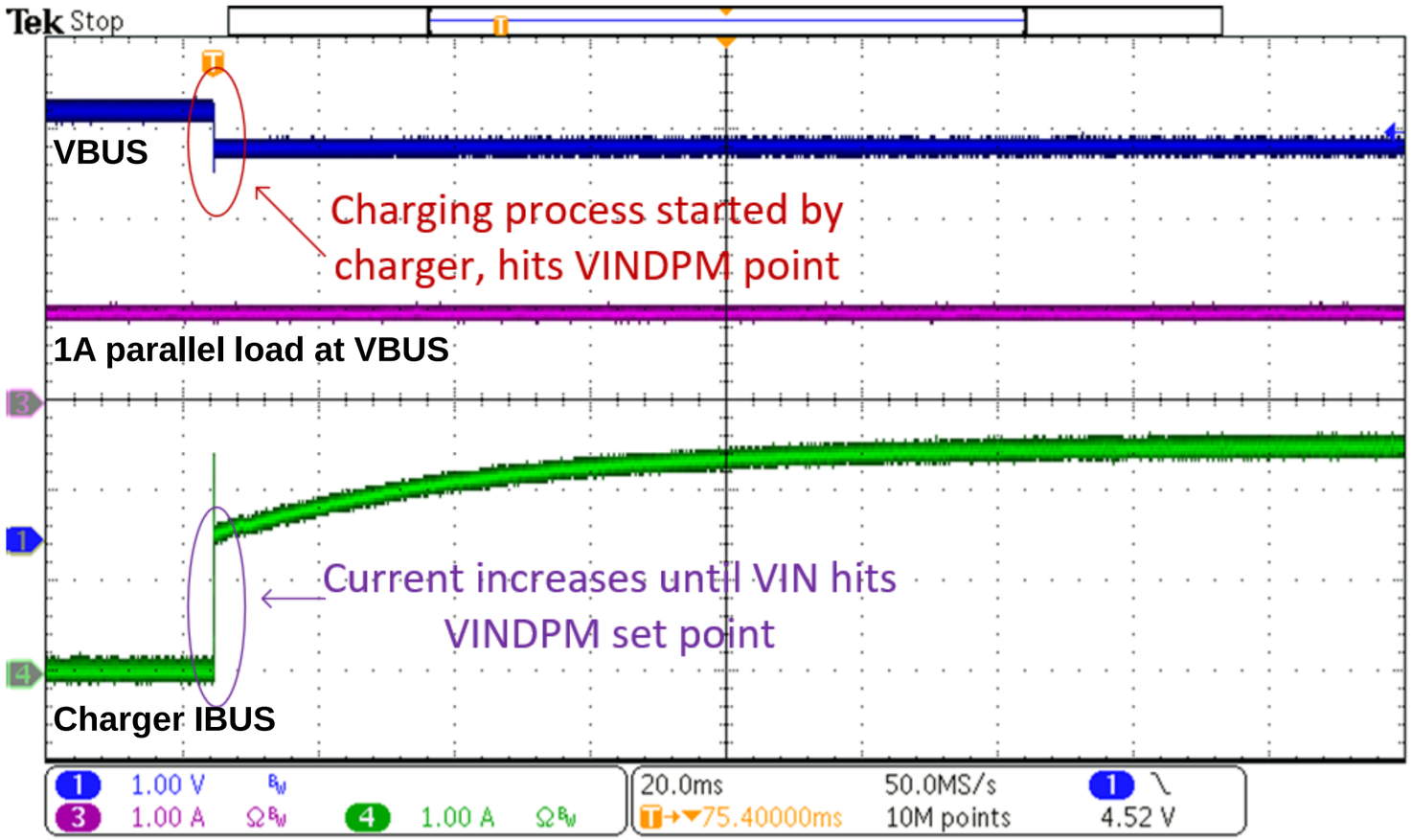
Type-C sink only (1S and 2S) - charger VINDPM

- IINDPM feature of the charger can be used to limit input current. If the current capability of the adapter is not known, VINDPM can be used to maximize power from adapter.
- Example implementation:

USB C Adaptor → C Plug to Legacy Plug → Legacy USB Receptacle →

BQ25883

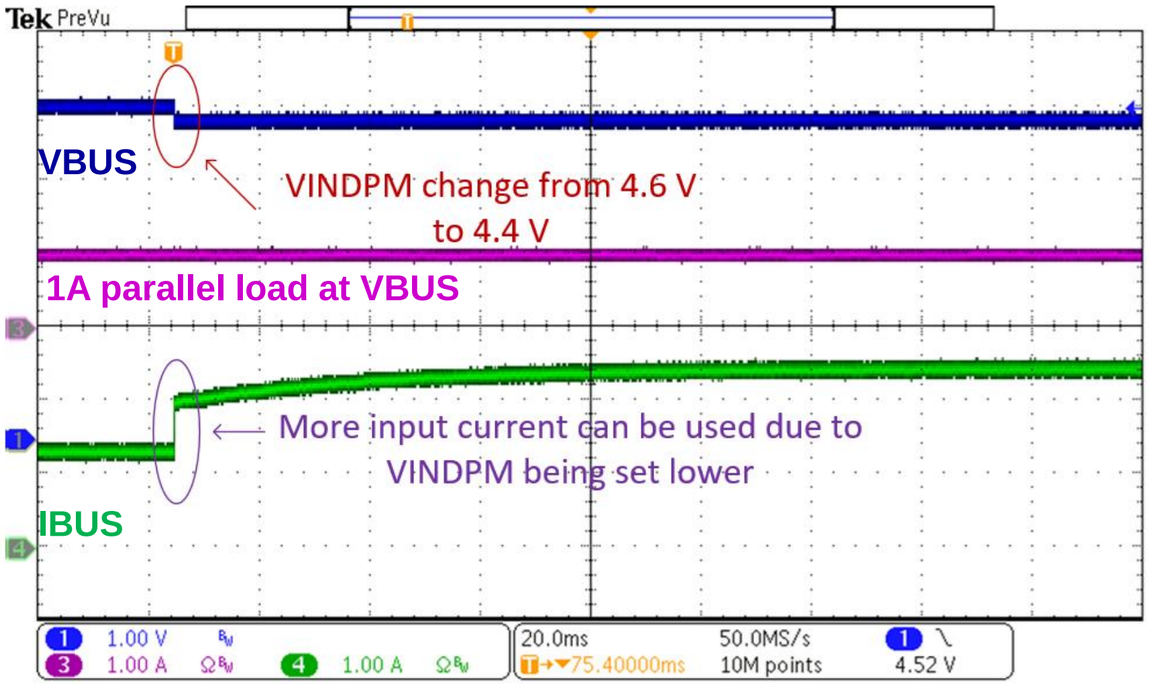
Type-C sink only (1S and 2S) - charger VINDPM



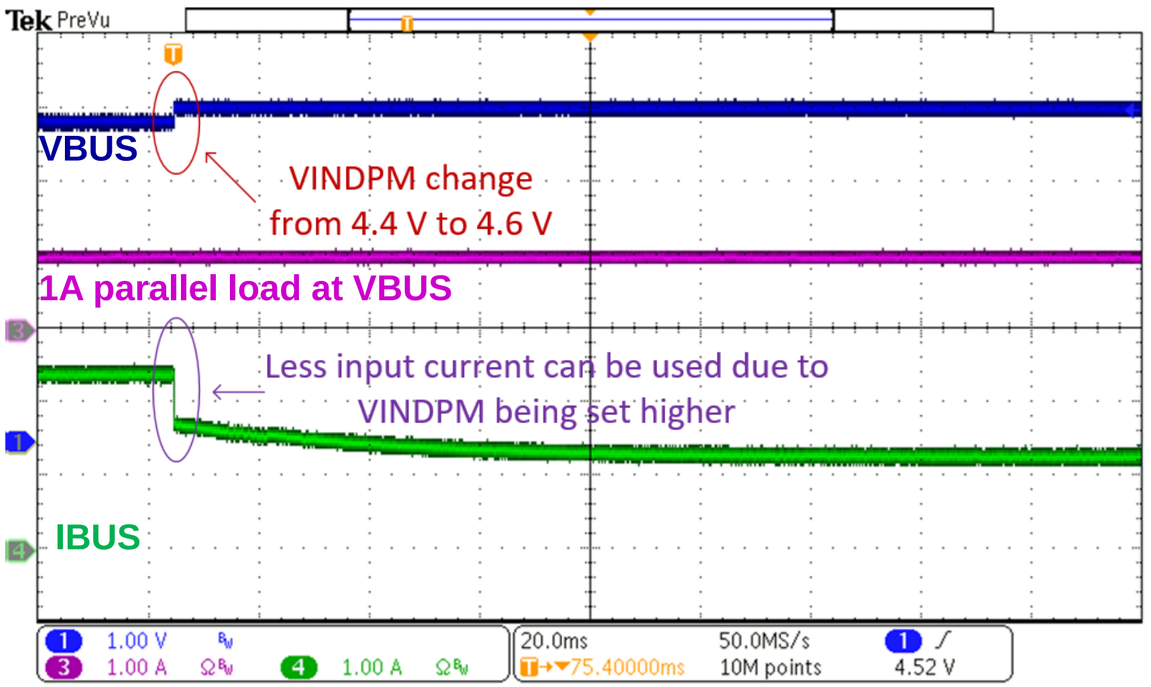
VINDPM = 4.4 V

- VINDPM - Limits the minimum input voltage and prevents overloading of the Type-C adaptor.

Type-C sink only (1S and 2S) - charger VINDPM



VINDPM: 4.6 V to 4.4 V

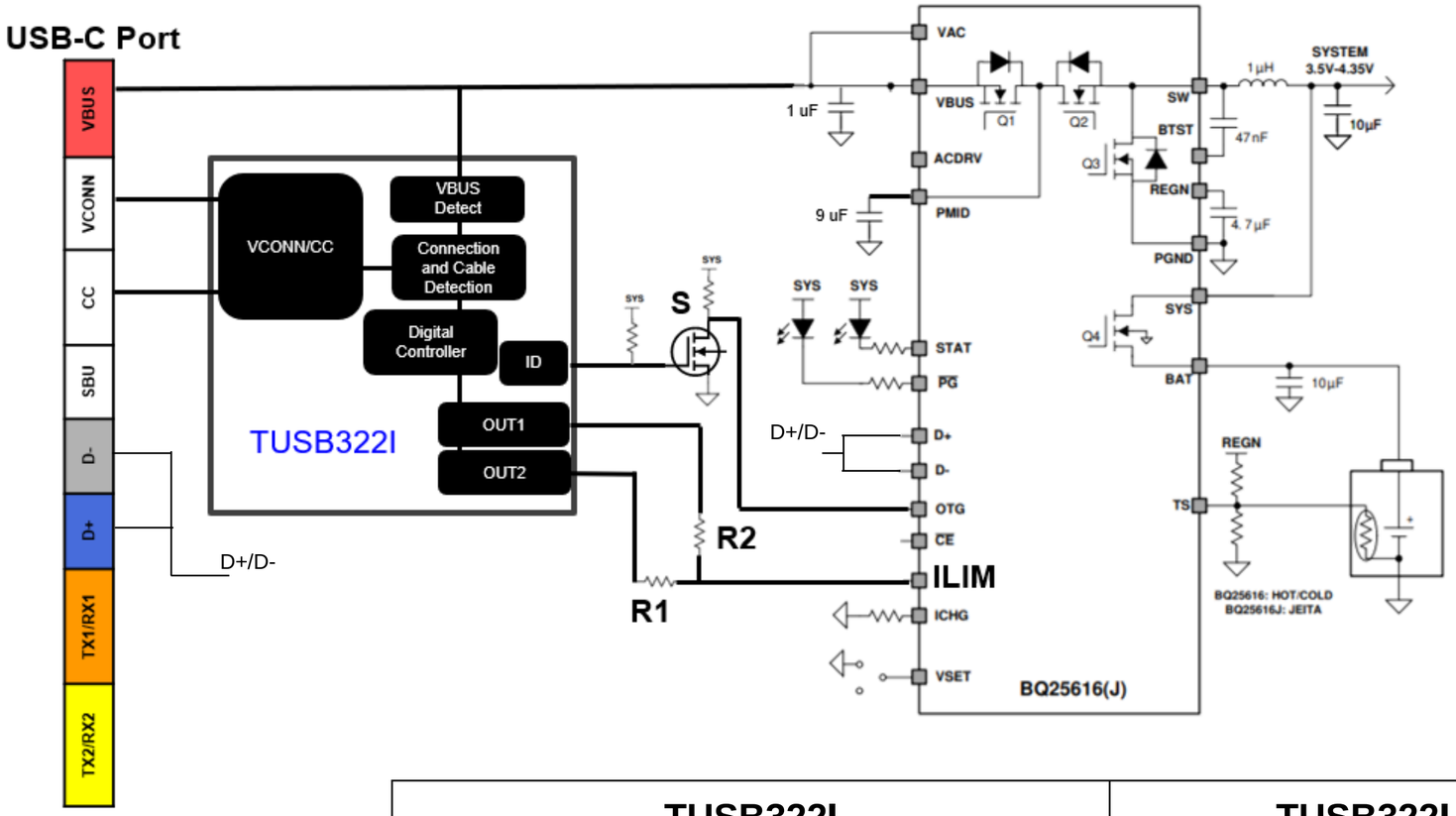


VINDPM: 4.4 V to 4.6 V

- VINDPM
  - –Different input current limit can be achieved with different VINDPM settings.
  - –Fast dynamic response.

Type-C standalone DRP

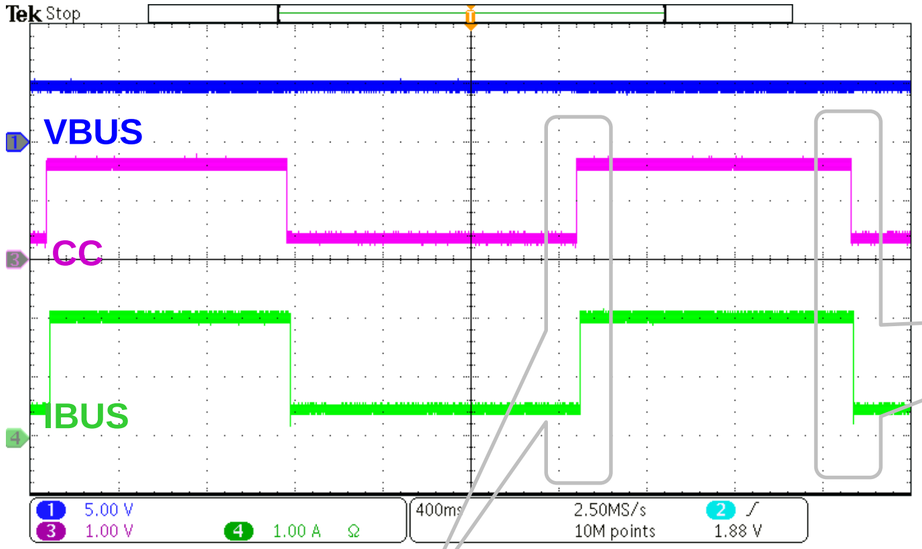
Type-C standalone DRP

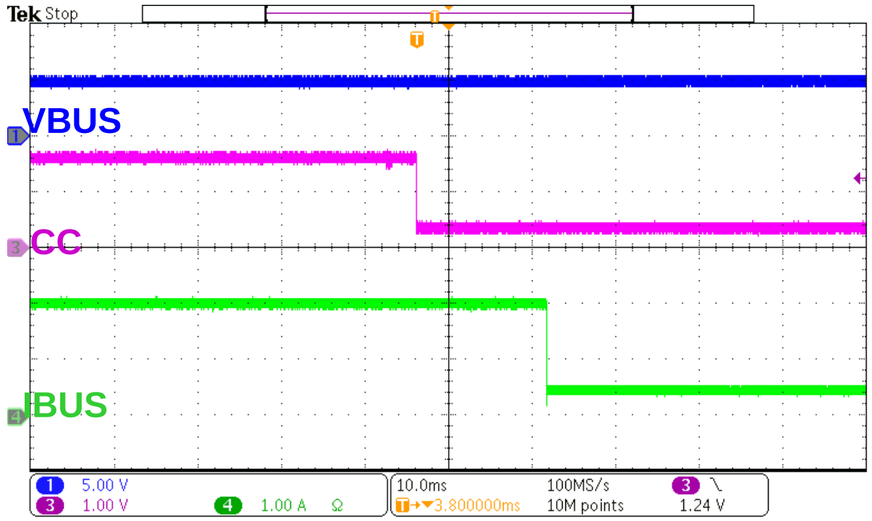


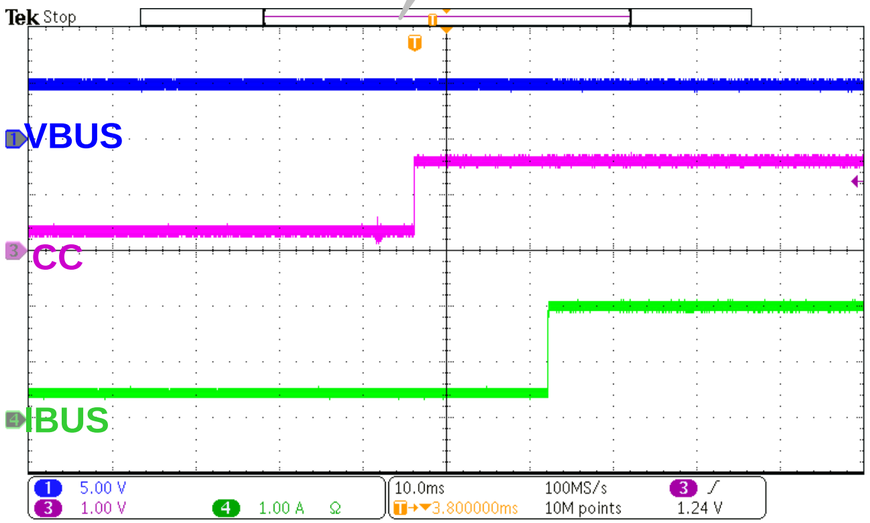
- Standalone DRP implementation without the need for host control.
- Capable of 900 mA as source.
- 1S Li-ion charging from Type-C input.
- Simple solution to reduce BOM and solution size.

TUSB322I	TUSB322I		BQ25616 or BQ25616J	
State Description	**OUT1**	**OUT2**	**R_ILIM**	**IBUS (A)**
Default current in attached state	H	L	R1	**0.9**
Medium current in attached state	L	H	R2	**1.5**
High current in attached state	L	L	R1 // R2	**2.4**

Type-C standalone DRP – sink dynamic behavior







Advantages:

- Simple implementation without host control.
- ILIM pin on the charger controls the input current with fast response.

Limitations:

- 500 mA, 1.5 A, and 2.0 A.
- 900 mA, 1.5 A, and 2.4 A.

Host controlled Type-C DRP (1S and 2S)

Host controlled Type-C DRP (1S and 2S)

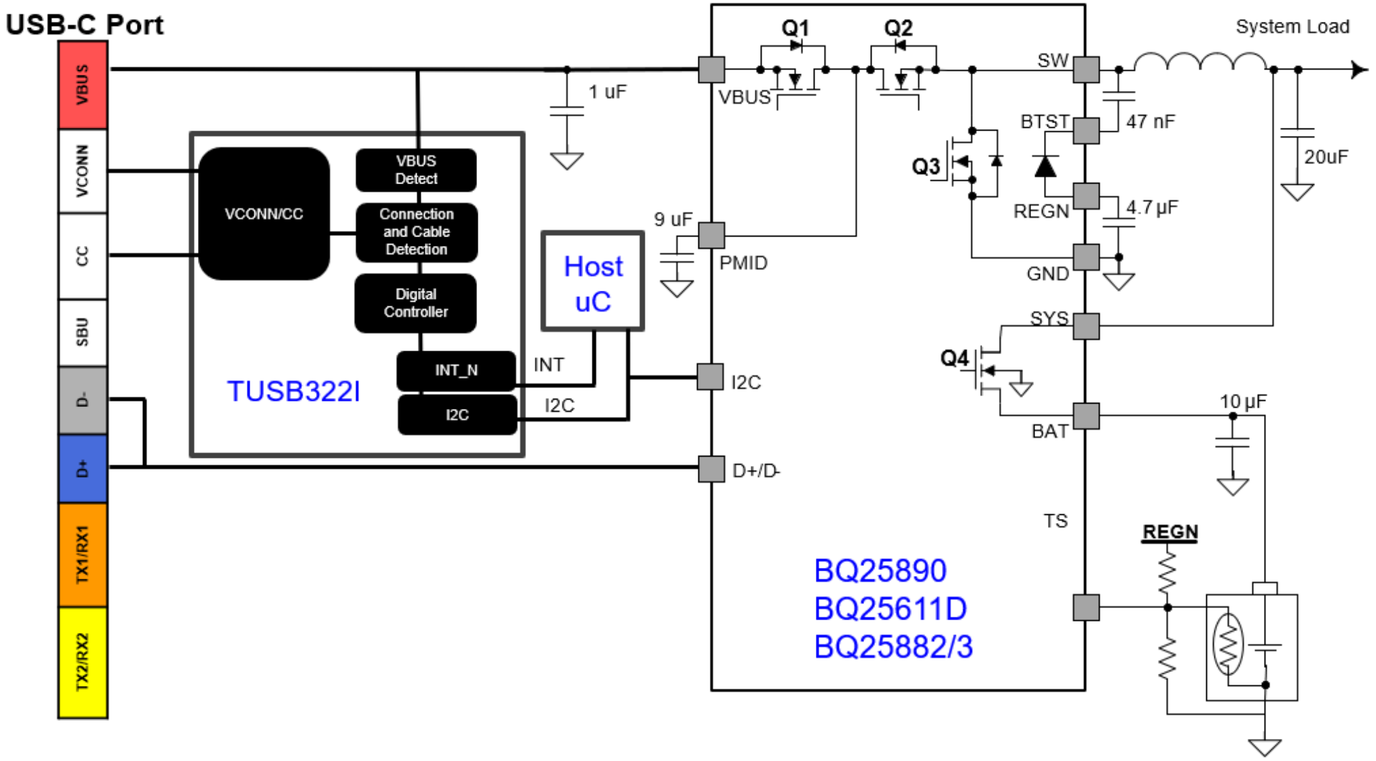
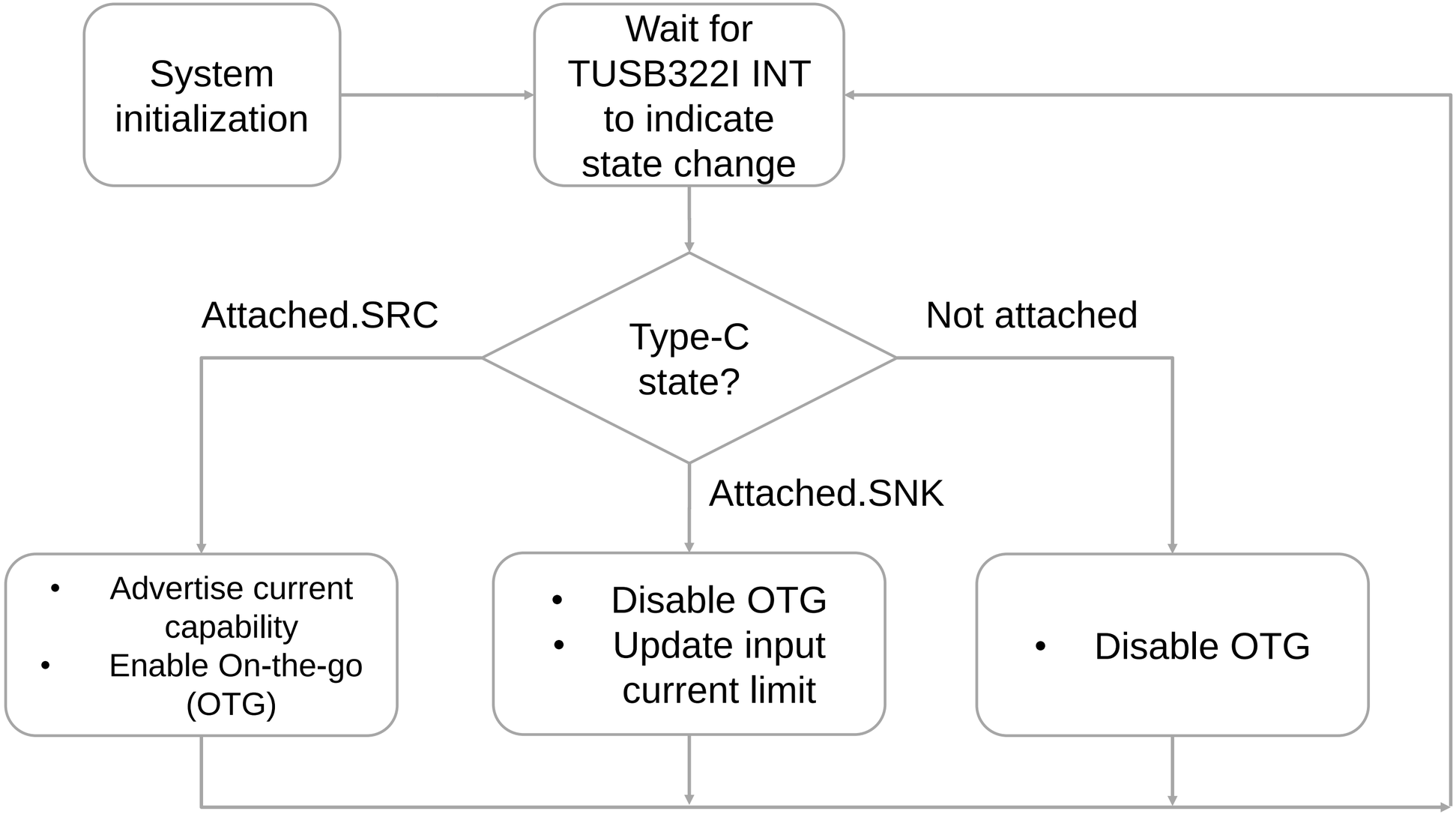


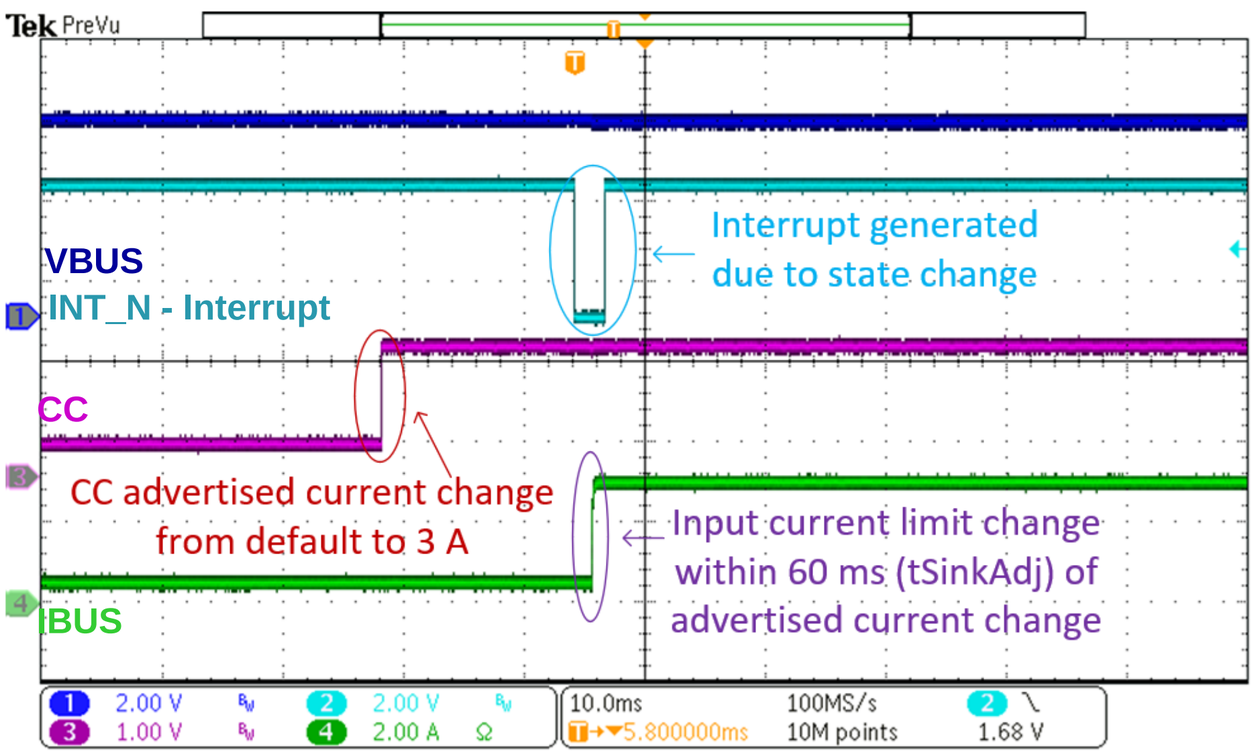
*Diagram corresponds to 1S chargers. Solution applies to 2S boost chargers such as BQ25882/3

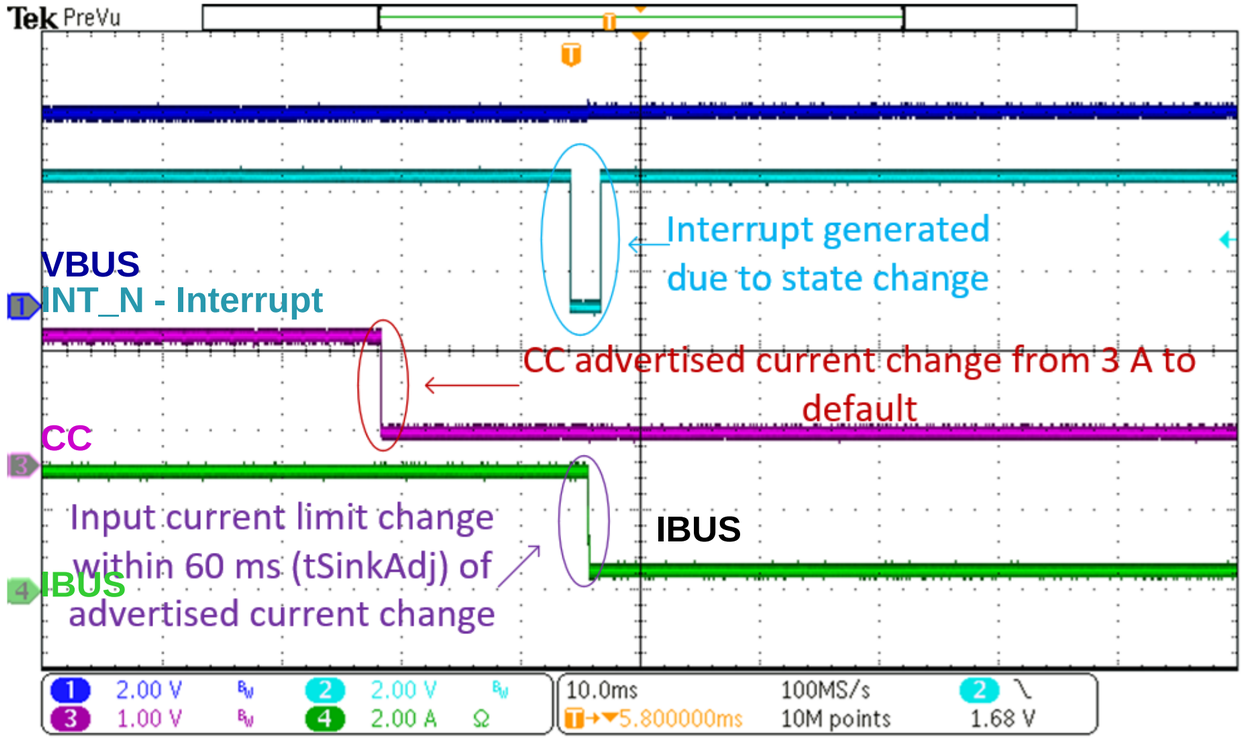
- 3 A (15 W) sink and 1.5 A (7.5 W) source.
- Options to select preferred Type-C role (Try.SRC and Try.SNK).
- 1S and 2S charging from Type-C input.
- Integrated solution to reduce BOM and solution size.

Simplified software flowchart



Host controlled Type-C DRP - sink behavior



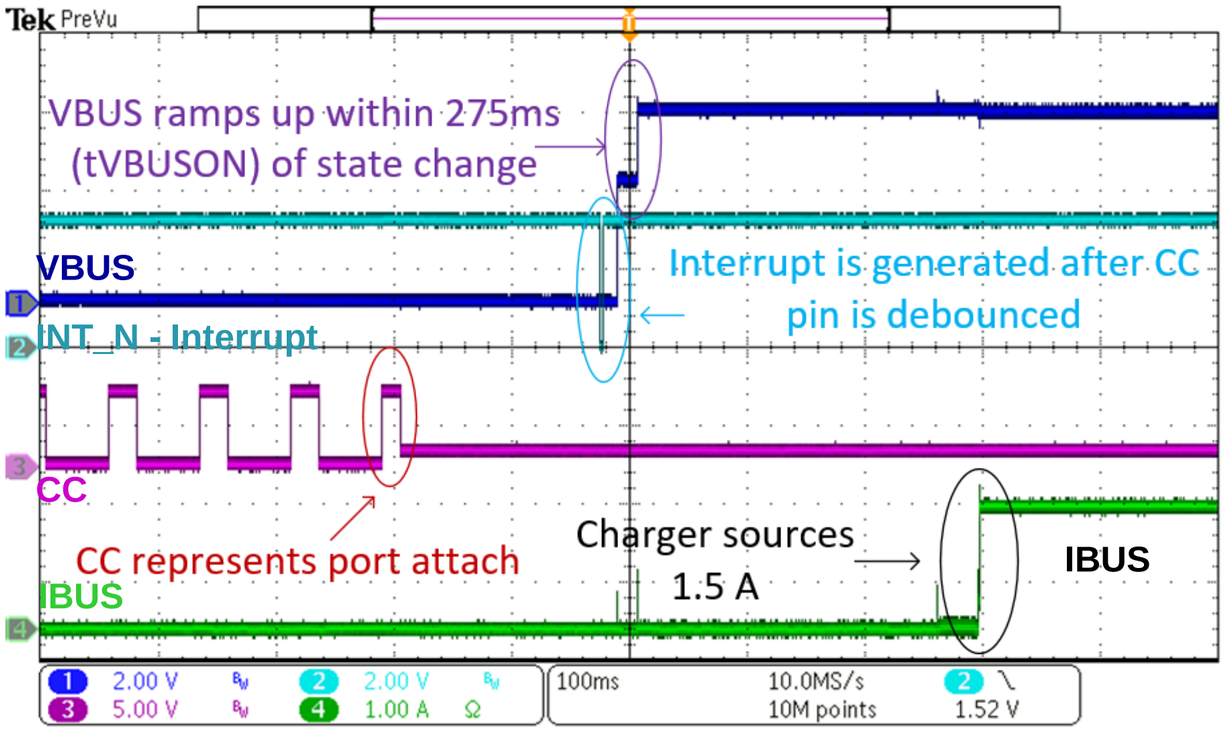


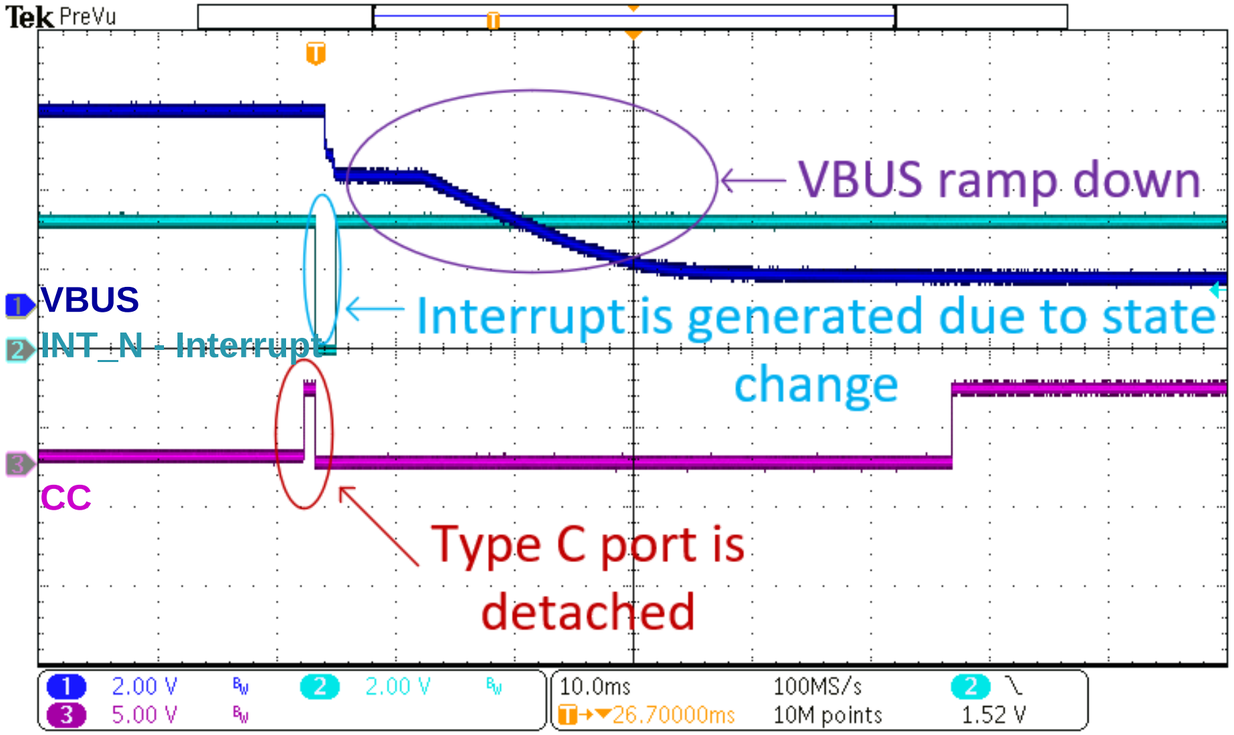
CH1=VBUS, CH2=INT_N, CH3=CC, CH4=IBUS

*BQ25890 waveforms

CC current advertisement changes → TUSB322I generates interrupt to processor → processor adjusts charger IINDPM to limit input current.

Host controlled Type-C DRP - source behavior





CH1=VBUS, CH2=INT_N, CH3 = CC, CH4=IBUS

*BQ25890 waveforms

CC represents attach/detach → TUSB322I generates interrupt to processor → processor enables/disables OTG.

USB-PD DRP with integrated MOSFET chargers

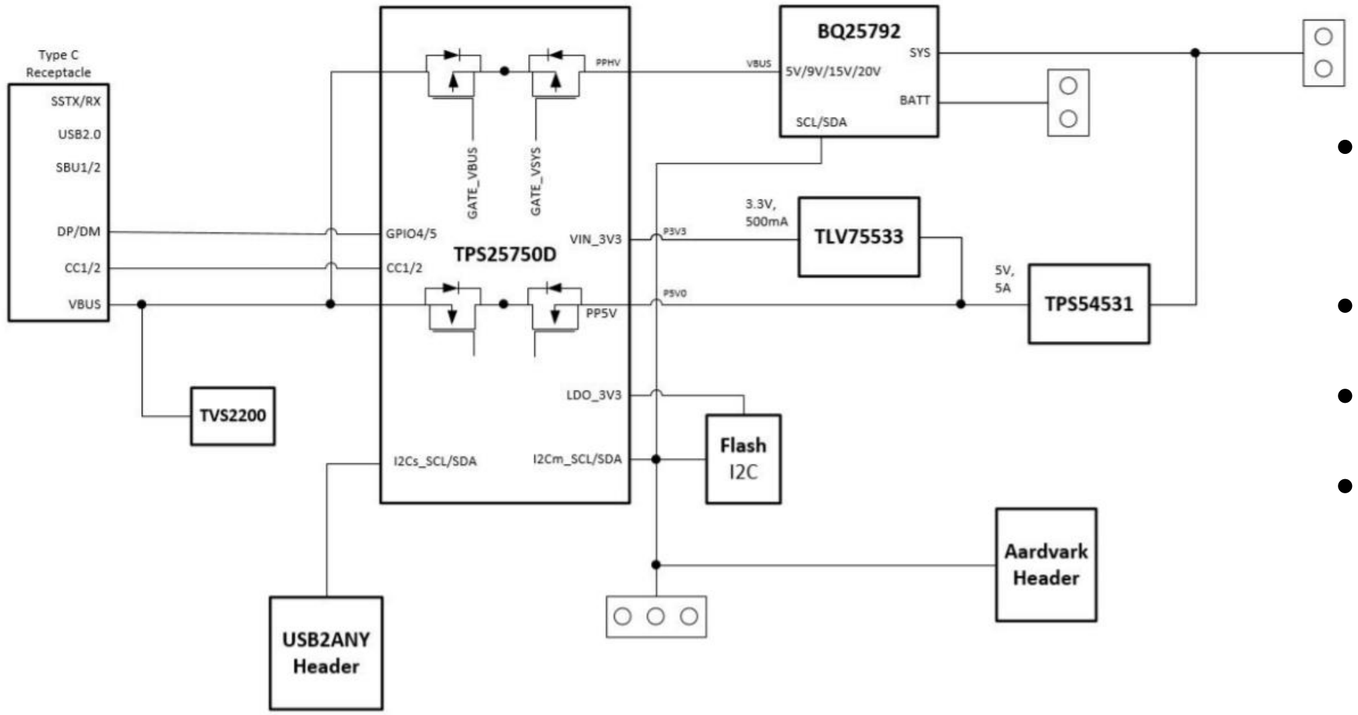
USB-PD DRP with integrated MOSFET chargers

- The TPS25750D is a stand-alone USB Type-C and PD controller.
  - Upon cable detection, it communicates on the CC wire using the USB PD protocol.
  - After USB PD negotiation, the controller enables the appropriate power path depending on the contract negotiation and configuration.

- The BQ25792 is a switched-mode, fully-integrated, buck-boost charger with 3.6 V-24 V input voltage for 1-4S batteries.

	Charging		**OTG**	
	Max	**Resolution**	**Max**	**Resolution**
Current	5.0 A	10 mA	3.32 A	40 mA
Voltage	18.8 V	10 mV	22.0 V	10 mV

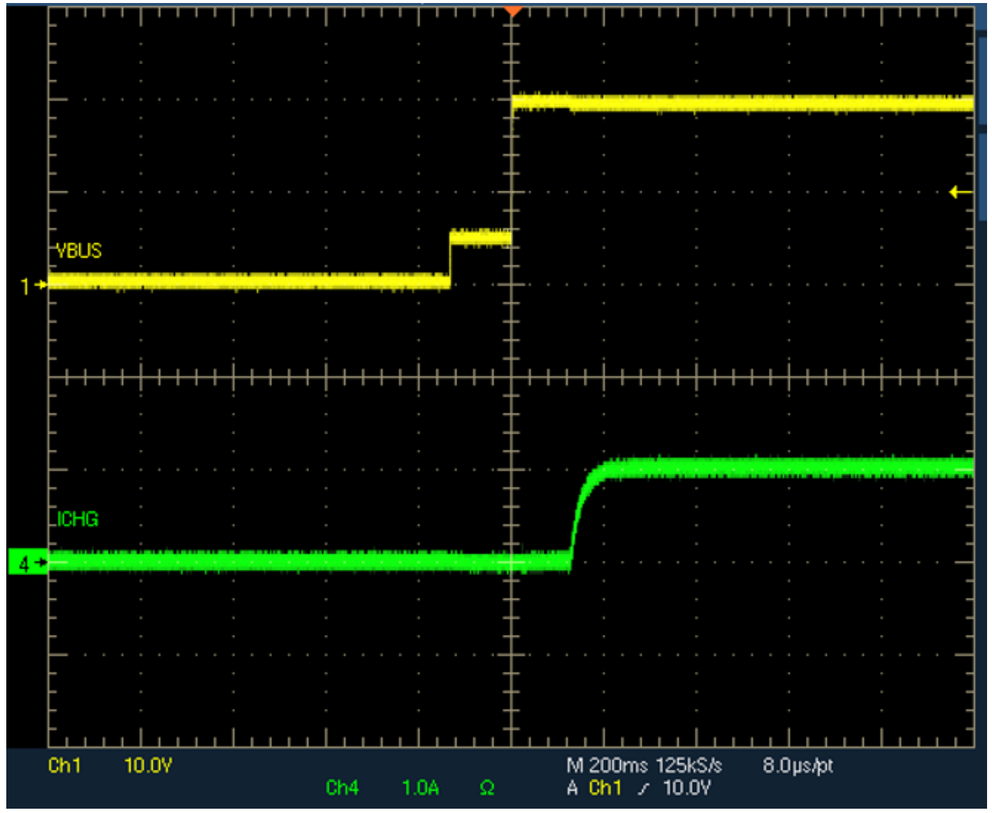
USB-PD DRP with integrated MOSFET chargers



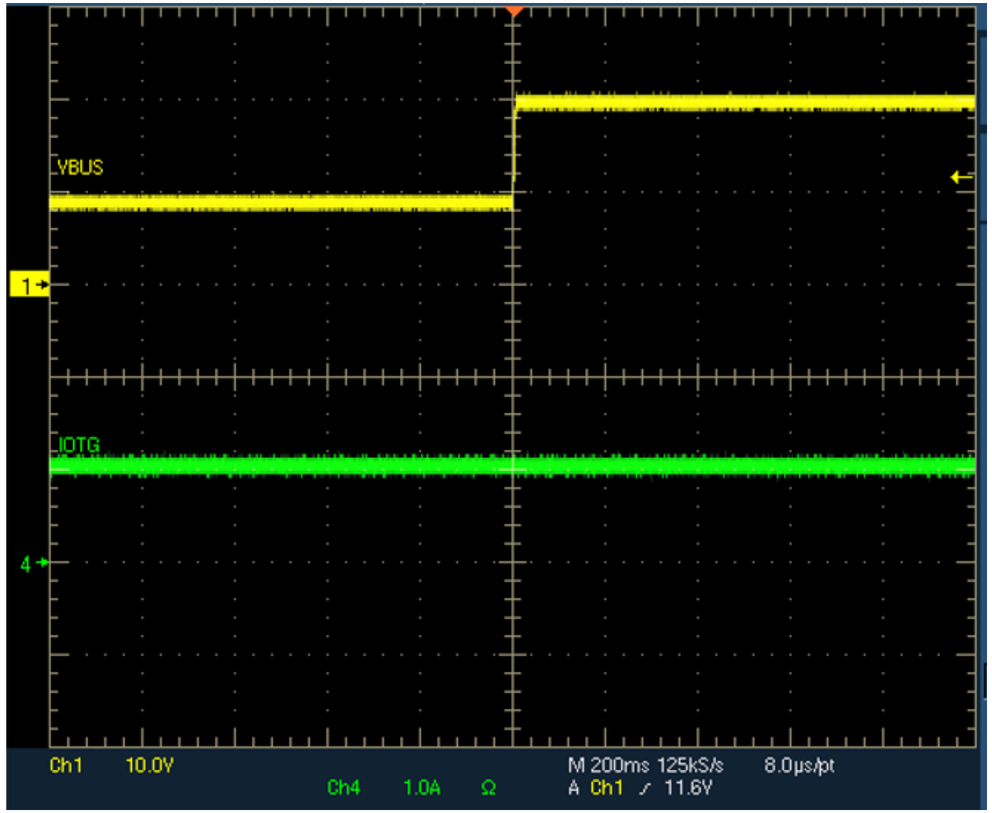
- Charge current up to 5 A and source capability up to 45 W.
- I2C Master control for BQ25792.
- 2-4S Li-ion charging from 5 V-20 V input.
- **Total integrated solution to reduce BOM material and solution size.**

Reference design
USB-PD-CHG-EVM-01

TPS25750D + BQ25792 - sink and source



1 A charge current with 20 V input

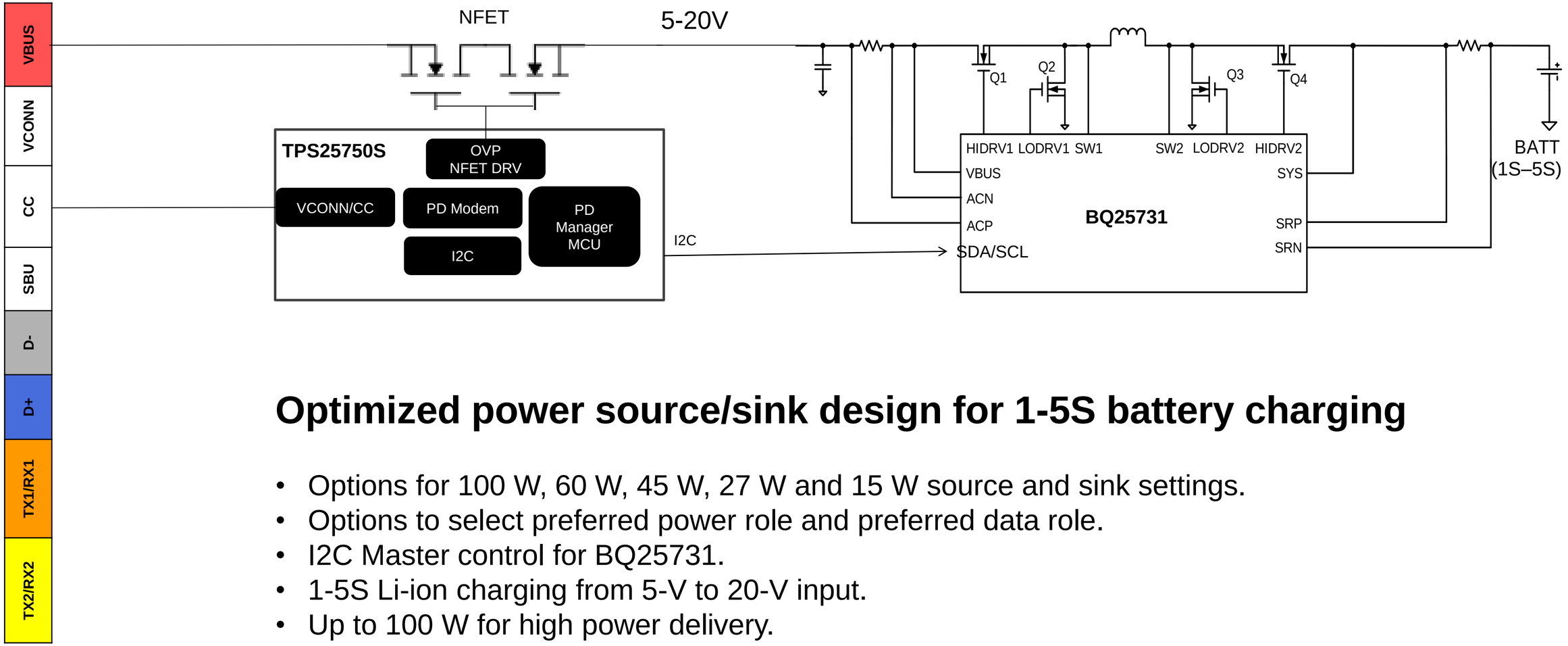


Sourcing 20 V at 1A in OTG Mode

USB-PD DRP with high power controllers

USB-PD DRP w/ high power controllers (under development)

USB Type-C port



Optimized power source/sink design for 1-5S battery charging

- Options for 100 W, 60 W, 45 W, 27 W and 15 W source and sink settings.
- Options to select preferred power role and preferred data role.
- I2C Master control for BQ25731.
- 1-5S Li-ion charging from 5-V to 20-V input.
- Up to 100 W for high power delivery.

Solution summary

Solutions	Battery	Controller	Charger	Sink	Source
Type-C Sink only	1S	NA	BQ25890 BQ25611D	Up to 3 A	NA
	2S	NA	BQ25882/3	Up to 3 A	NA
Type-C standalone DRP	1S	TUSB322I	BQ25616/616J	Up to 2.4 A	0.9 A
Host Controlled Type-C DRP	1S	TUSB322I	BQ25890 BQ25611D	0.5 / 0.9 / 1.5 / 3.0 A	1.5 A 0.9 A
	2S	TUSB322I	BQ25882/883	0.5 / 0.9 / 1.5 / 3.0 A	1.5 A
Full USB-PD	2-4S	TPS25750D	BQ2579x	Up to 20 V at 3.3 A	Up to 45 W
	1-5S (under development)	TPS25750S	BQ25731	100 W, 60 W, 45 W, 27 W & 15 W	100 W, 60 W, 45 W, 27 W & 15 W

Summary

- USB Type-C and PD overview.
  - Type-C: solution for both data and power applications.
  - Universal charging solution for different devices.

- USB Type-C and PD implementation.
  - Type-C sink only, Type-C DRP, Type-C PD solutions implemented and demonstrated.
  - Complexity of USB Type-C scales with power level and functionalities.

- Texas Instruments provides different solutions optimized for different power requirements.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), 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, regulatory 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 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.

TI objects to and rejects any additional or different terms you may have proposed.

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