Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

ADAM MCGAFFIN & DERIC WATERS

USB TYPE-C PD3.1 EXTENDED POWER RANGE, AND THE BENEFITS OF TYPE-C + BQ SOLUTION

USB power supply options

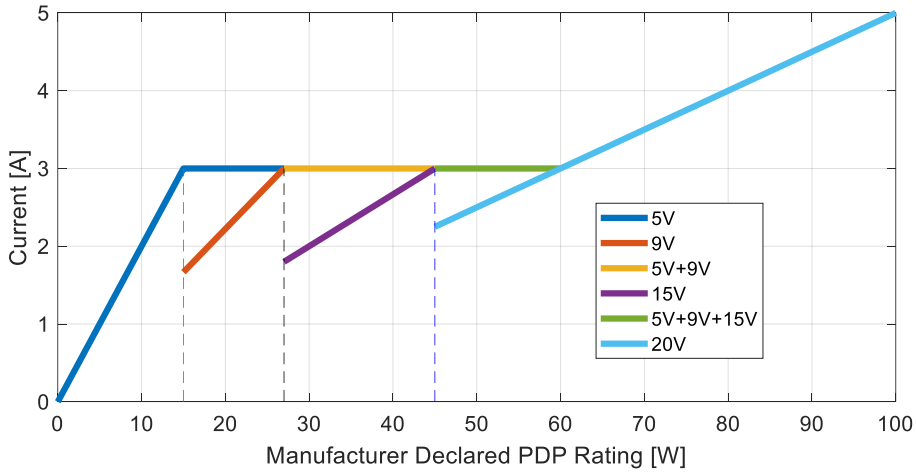
USB protocol	Nominal voltage	Maximum current	Power
USB Type-C	5 V	3 A	15 W
USB PD 3.0	Configurable up to 20 V	5 A	Up to 100 W
USB PD 3.1	Configurable up to 48 V	5 A	Up to 240 W

USB-PD Standard Power Range (SPR)

- USB-PD messages could negotiate 51.15 V and 10.23 A
  - 10-bit fields @ 50 mV and 10 mA
- Ch. 10 power rules put restrictions on the mechanism
  - ≤100 W, ≤20 V, ≤5 A
  - Sinks know <u>minimum</u> to expect from sources.
  - Single number sets customer expectation.
    - PDP = PD Power

Building a universal charging interface

SPR power rule summary



> 100W EPR applications

Docks/monitors	PC	Industrial	Automotive
Charging notebook • Deliver more power over single cable to PC's that need it	*Gaming/mobile workstation* • >100-W systems can move away from barrel jack *Notebook PC* • Faster battery charging • Source more power to peripherals	*Power tools* • 24-V and 40-V battery packs *EPOS* • 24-V power for thermal printers *AC/DC chargers* • USB-C can replace barrel jacks in more applications (universal charger)	• Most auto implementations are ≤60 W

Direction of adoption

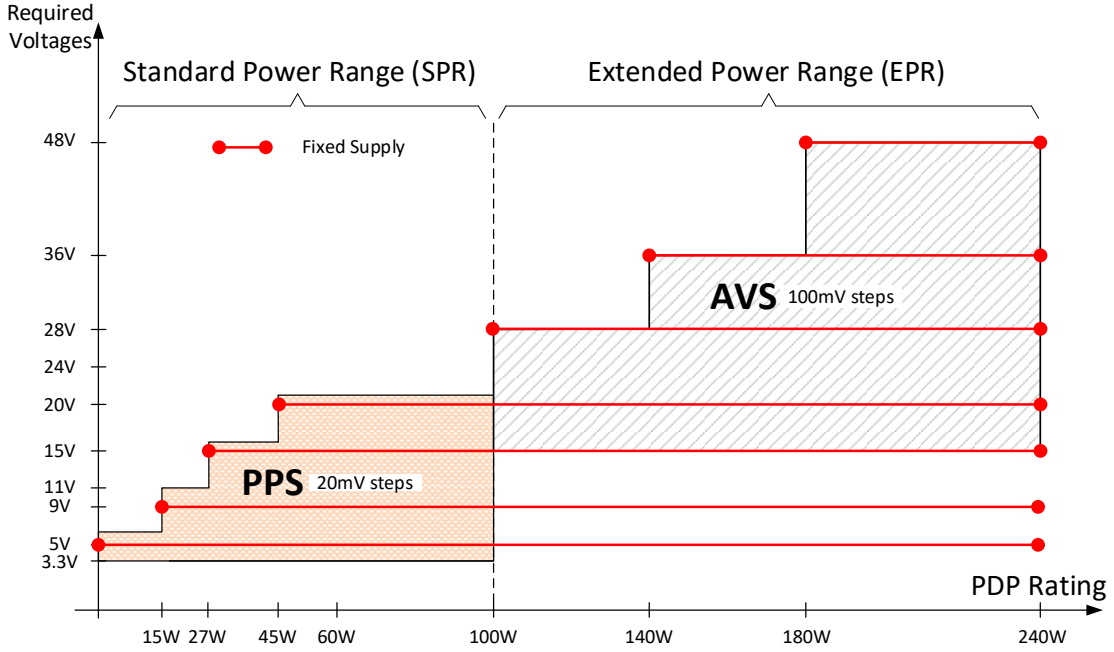
USB-PD Extended Power Range (EPR)

- EPR = Higher voltage fixed supplies + Adjustable Voltage Supply (AVS)
  - AVS requires 100-mV steps from 15 V to the maximum voltage.
- More strict power rules for EPR than SPR (improving user experience)
  - Optional voltages are disallowed (just use AVS)
  - PDP limits max voltage. Ex. a 120-W EPR source shall NOT have >28 V
  - Requires supporting 5 A @ 20 V

	Max Current (A)							
	Fixed							AVS
PDP Rating (W)	5 V	9 V	15 V	20 V	28 V	36 V	48 V	
100 < x ≤ 140 W	3	3	3	**5**	PDP/28	**X**	**X**	Min(5 A, PDP limit)
140 < x ≤ 180 W	3	3	3	**5**	5	PDP/36	**X**	Min(5 A, PDP limit)
180 < x ≤ 240 W	3	3	3	**5**	5	5	PDP/48	Min(5 A, PDP limit)

Summary of USB-PD power rules

- Required current
  - $\frac{\sim\text{PDP rating}}{\text{voltage}}$
  - ≤ 5 A
  - Cable may limit to ≤ 3 A
  - 5-V, 9-V, & 15-V rails may be ≤ 3 A
- Optional
  - Extra current
  - Extra voltages in SPR
  - PPS



PPS = Programmable power supply
AVS = Adjustable voltage supply

Supply type comparison

	PPS	AVS	Fixed
Required for “USB Fast Charger” certification	Yes	No	No
Required for “USB Charger” certification	No	>100 W	Yes
Required if EPR supported	No	Yes	Yes
Minimum voltage	3.3 V	15 V	5 V
Maximum voltage (depends on PDP rating)	5.9 V, 11 V, 16 V or 21 V	28 V, 36 V or 48 V	5 V, 9 V, 15 V, 20 V, 28 V, 36 V or 48 V
Voltage step	20 mV	100 mV	N/A
Voltage tolerance	±5%	±5%	±5%
Dynamically switch between Constant-Current & Constant Voltage modes	Yes	No	No
Max voltage change at full load	±0.5 V	±1 V	N/A
Over/under shoot allowed	±0.1 V	±0.5 V	±0.5V

Implications of EPR for product safety

- New requirements to avoid fire hazards (IEC 62368-1)
  - SPR: Power > 15 W for >3 sec → Power Source Class 2 (PS2)
  - EPR: Power >100 W for >5 sec → Power Source Class 3 (PS3)
    - Requires V-1 (slow burning) material or performance equivalent
    - Additional safeguards since PS2 sinks or cables may be connected.
      - Entering EPR mode uses new USB-PD protocol:
        - » prevent a PS2 sink from negotiating >100 W erroneously.
        - » Cable check at every EPR mode entry. Not just a one-time check.
        - » Periodic “Keep Alive” messages to protect against fault scenarios
- For Electrical Energy Source Class 1 (ES1) ≤60 Vdc is required.
  - For 48-V nominal VBUS, the maximum expected DC is 50.4 V. This gives allowances for tolerances and fault conditions.

Ensuring safety through EPR mode entry process

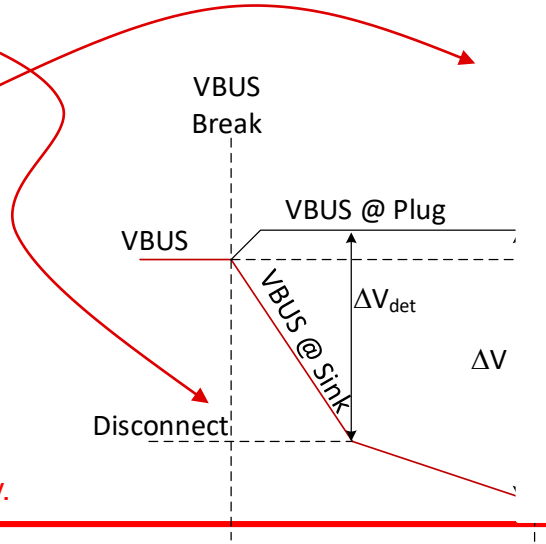
1. Negotiate an Explicit Power Contract in the Standard Power Range.
   - During this step, EPR-capable Sources and Sinks will declare their EPR capabilities through PDO and RDO exchanges.
   - This requires an EPR sink to understand new bit fields that a legacy sink would not process. 1
2. An EPR Sink, having discovered an EPR Source, can request EPR Mode entry.
   - This is a new message a legacy sink would not know how to formulate. 2
3. The EPR Source, upon receiving a EPR Mode entry request from the EPR Sink, will:
   - Send an ACK message to acknowledge the request
   - Verify the sink has declared itself EPR capable. 3
     - This requires the sink to properly set certain new bit fields differently from legacy sinks.
   - Confirm the cable is EPR capable. 4
     - This requires the cable to properly set certain new bit fields differently from legacy cables.
   - Send a message that EPR mode is entered successfully.
     - This requires the sink to understand a new message that a legacy sink would not process. 5
4. While in EPR Mode
   - The EPR Source sends EPR Capabilities (Fixed PDOs and an AVS APDO) to the EPR Sink which requires the Sink to evaluate and respond as appropriate to adjust the Explicit Power Contract.
   - The EPR Sink maintains a regular cadence of communications with the EPR Source to allow EPR Mode to continue.
   - If the source doesn't see any message for 1 second, it is treated as a fault condition.

5 checks to ensure EPR mode is not entered "accidentally"

Maximum expected VBUS voltage

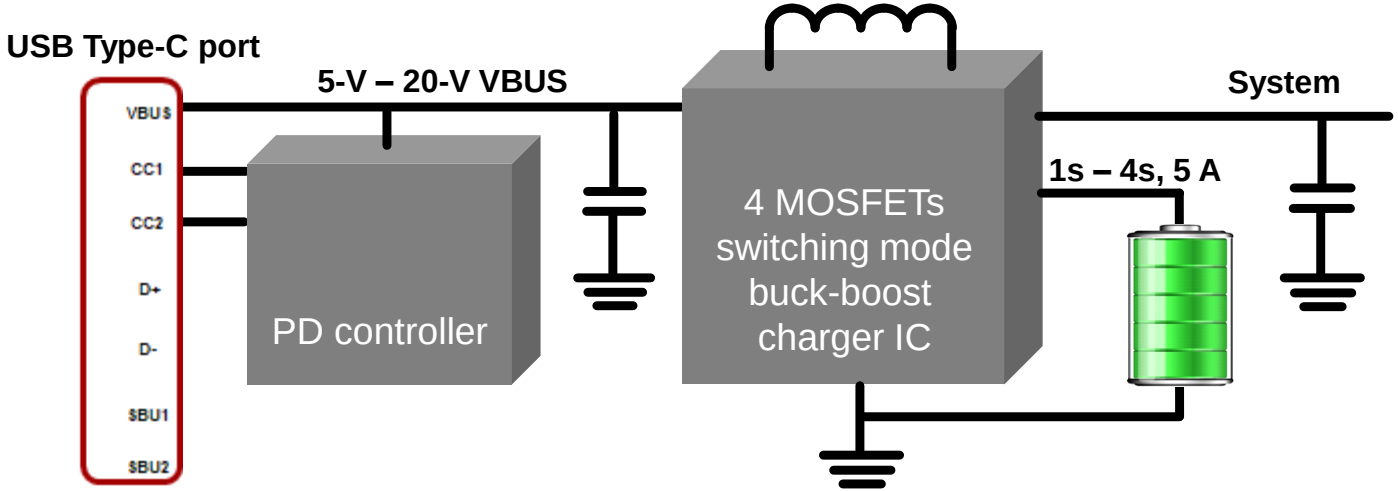
Nominal VBUS	20 V	28 V	36 V	48 V
VBUS (expected maximum)	21.5 V	29.9 V	38.3 V	50.9 V
ΔV_{det} (nominal)	16.9 V	24.1 V	31.3 V	42.1 V

- Sink detects VBUS voltage droop at Disconnect, takes action to reduce load.
- Fretting of contacts can lead to temporary reconnect during disconnect causing ringing.
- Protections to minimize Peak voltage:
  - Increase AbsMax of system VBUS
    - This is the most costly approach
  - Implement TVS dampening solution
    - TVS2200 for 20-V system
    - TVS3300 for 28-V system
  - Use early warning from CC voltage to prevent VBUS discharge.
    - TI's PD controllers provide this capability.



Benefits of implementing a Type-C + battery charger solution

Overview of USB-PD system with buck-boost charger



1 cell

2 cells

2~4 cells

4 cells

- With a step up/down buck-boost charger, the V_{IN} and V_{OUT} combination can be very flexible
- Wide input voltage 5 V ~ 20 V to charge multi-cell battery 1S ~ 4S
- Support up to 100 W power delivery, 5 V/3 A, 9 V/3 A, 15 V/3 A, 20 V/3 A, 20 V/5 A

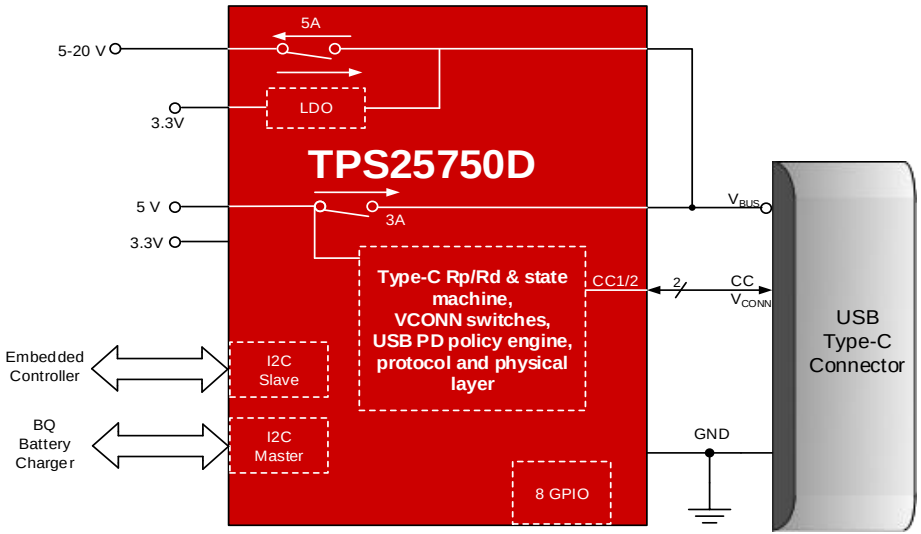
TPS25750D: Single USB Type-C DRP USB-PD controller

Features

- Controls one Type-C Power Delivery port
- Integrated 5-A,18-m Ω bidirectional power path
- Integrate 5-V source power path
- Configurable as source/sink or sink only power roles
- Configurable data role and power role preference
- Comprehensive power path management
- Comprehensive power path protection
- I2C control for BQ25790 and BQ25792 devices
- GPIOs for external USB3 mux and fault detection
- Dead-battery Rd
- 4x6 QFN (0.4-mm pitch)
- External I2C EEPROM required to store configuration data
- Configuration options selected via “Binary Vending Machine” GUI

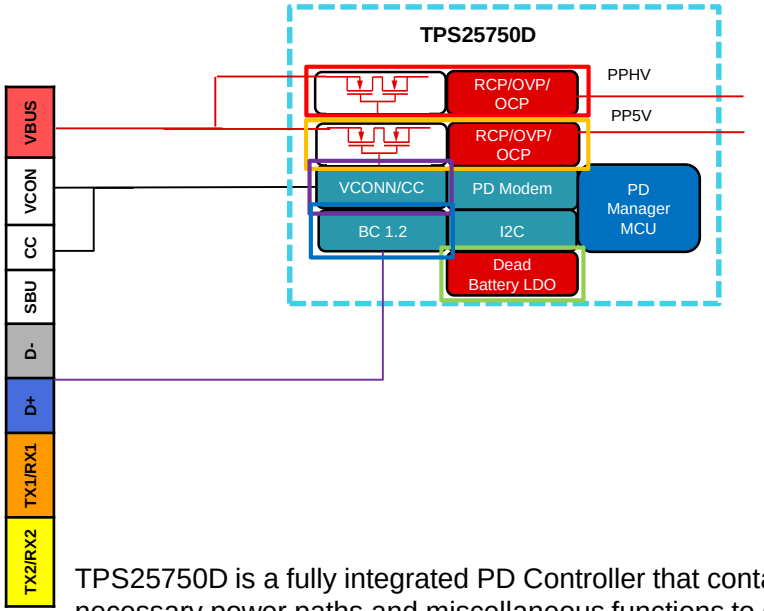
Benefits

- Fully Integrated USB Type-C and PD solution
  - No additional discrete IC’s needed for full CC function
  - UL certification
- Compliant to the USB Type-C 1.x and USB PD 3.x specifications
- Industry’s smallest solution size



TPS25750D vs. competition PD controllers

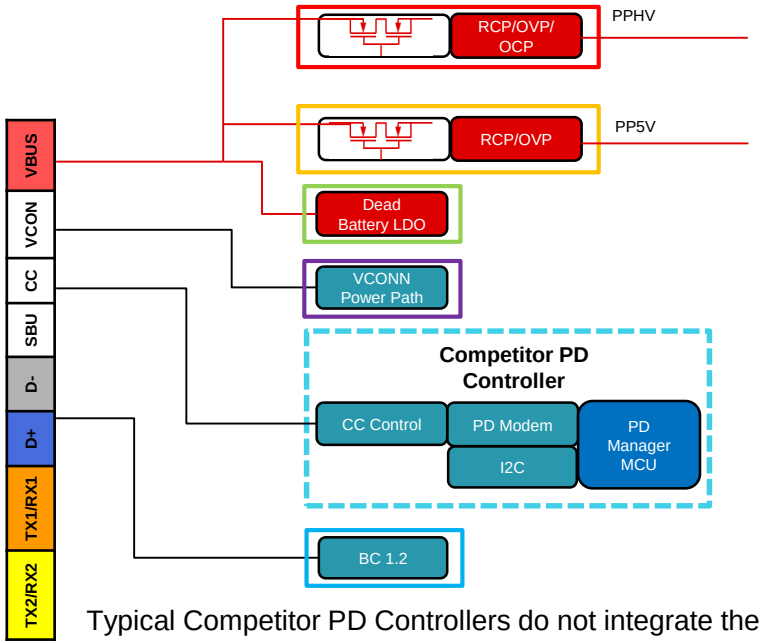
TPS25750D solution



TPS25750D is a fully integrated PD Controller that contains all the necessary power paths and miscellaneous functions to design a USB Type-C PD System.

- Only external component required is an I2C EEPROM for storing configuration and FW Patch information.

Competitor solution



Typical Competitor PD Controllers do not integrate the Power Paths required in a USB Type-C PD System. These need to be added to the system by either designing a discrete power path, or purchasing a 5-V or HV load switch.

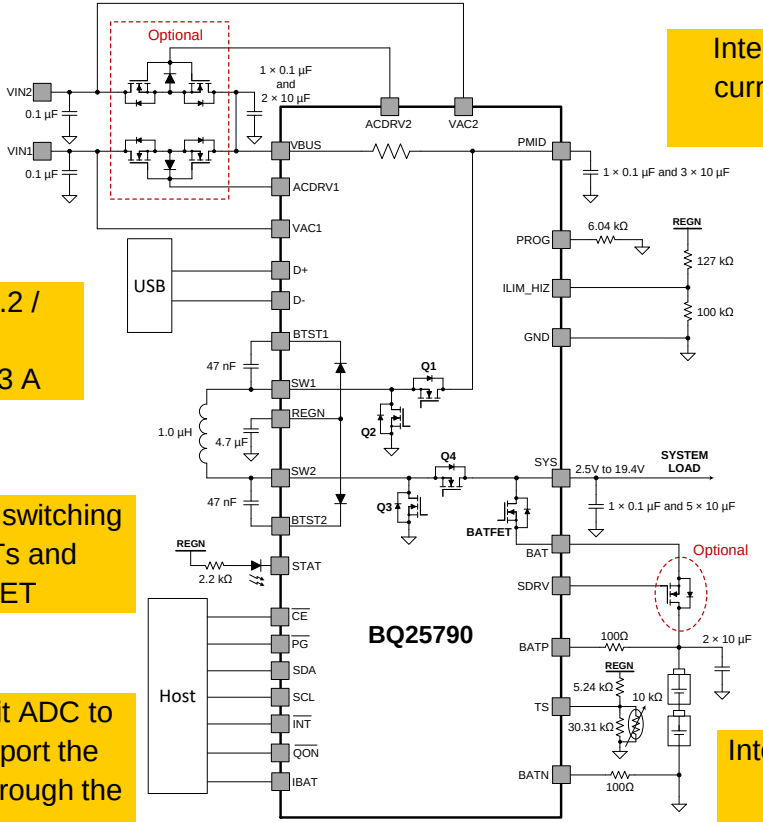
Fully integrated buck-boost charger: BQ25790

Dual-input power mux drivers to select adapter or wireless

D+/D- supports BC1.2 / HVDCP
IINDPM = 0.1 A – 3.3 A

Integrated 4 switching MOSFETs and BATFET

Integrated 16-bit ADC to monitor and report the system status through the I2C bus



Integrated input current sensing circuitry

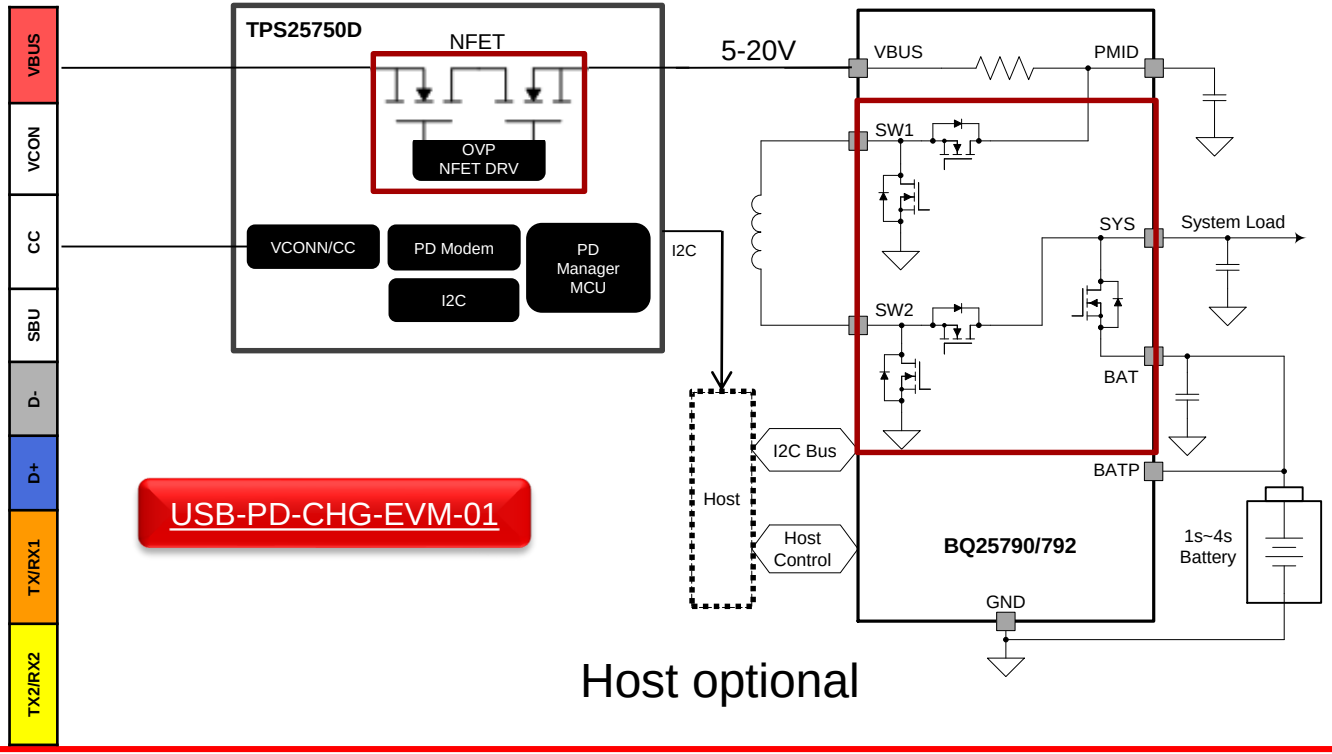
Integrated BATFET for NVDC power path management

Integrated ship FET driver for minimizing quiescent current

Integrated TS pin for NTC battery temperature sensing

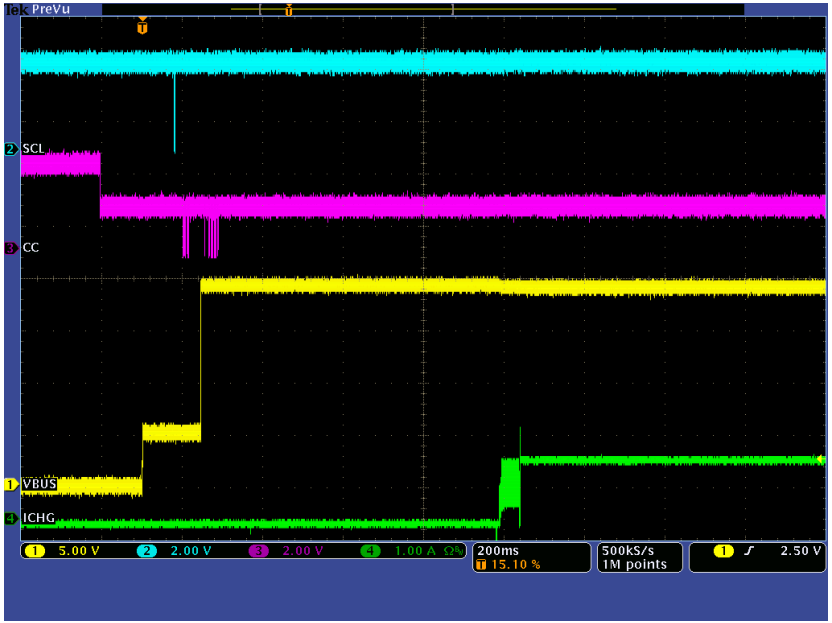
Low power optimized charging solution for 1-4S battery

USB Type-C port

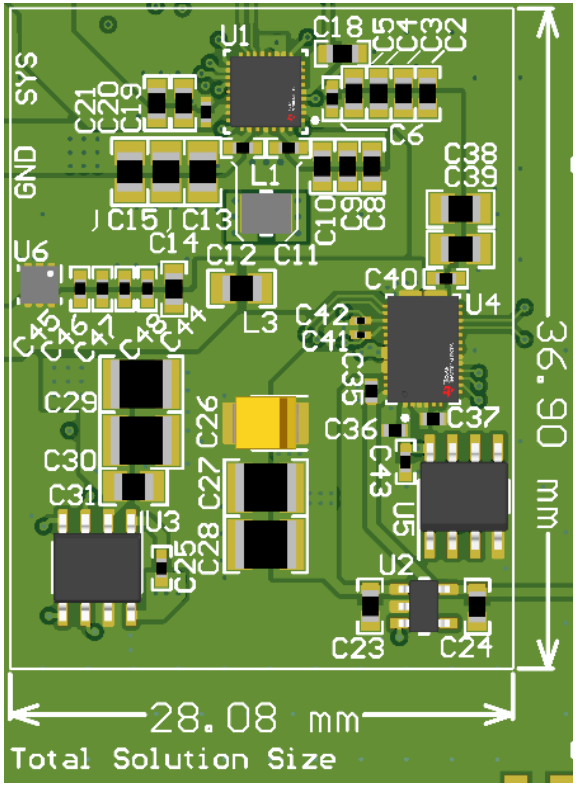


- Options 45-W, 27-W and 15-W source and sink settings
- Options to select preferred power role and preferred data role
- MCU optional
- 1-4S Li-ion charging from 5-20-V input
- Fully integrated solution to reduce BOM material and solution size

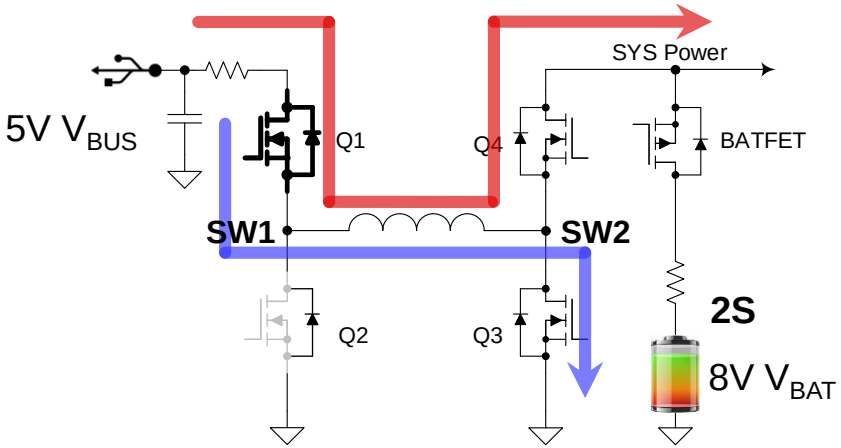
TPS25750 + BQ25792 power bank (no microcontroller)

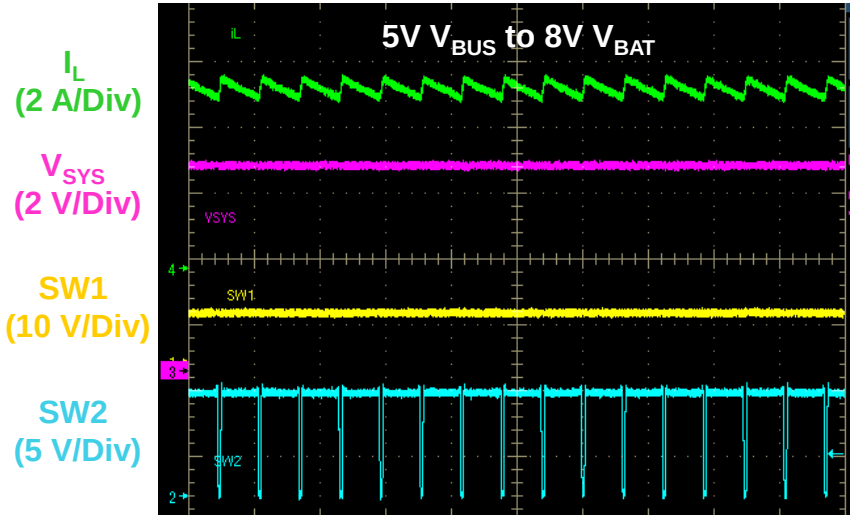


TPS25750 controls BQ25620 to charge battery from 20-V adapter



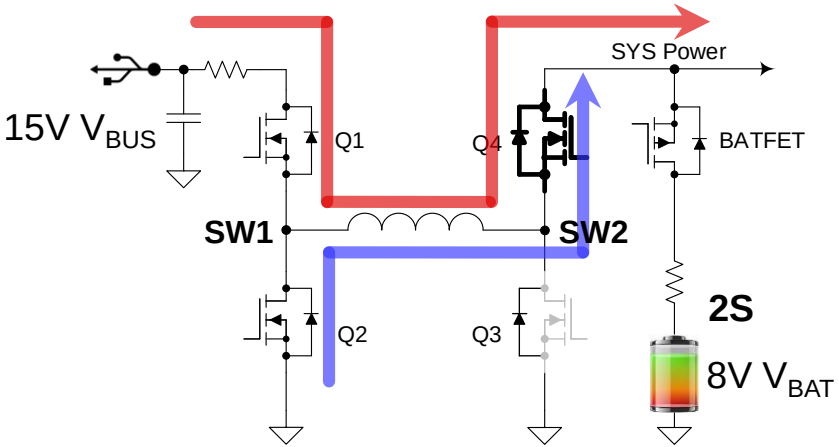
5 V charges 2S battery in boost mode

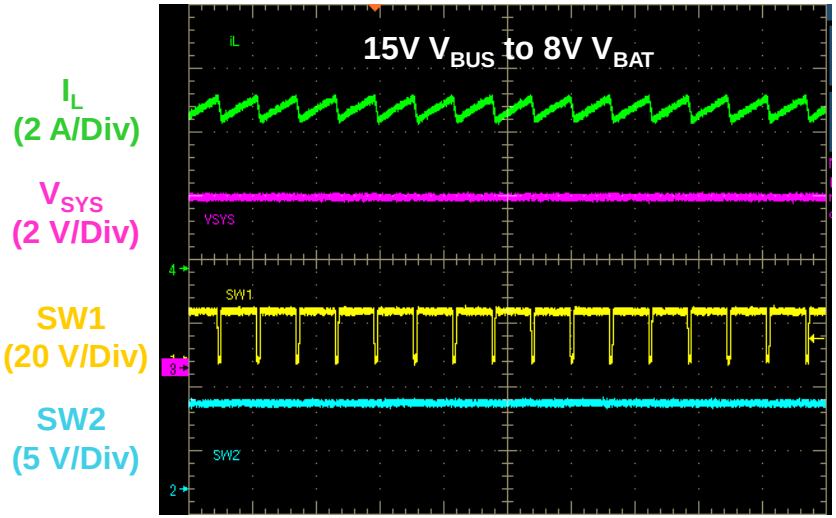




- Follows similar operation as a boost converter. Q2 is always off and Q1 is always on.
- In a single converter switching cycle, only two MOSFETs, Q3 and Q4, are switching.

15 V charges 2S battery in buck mode

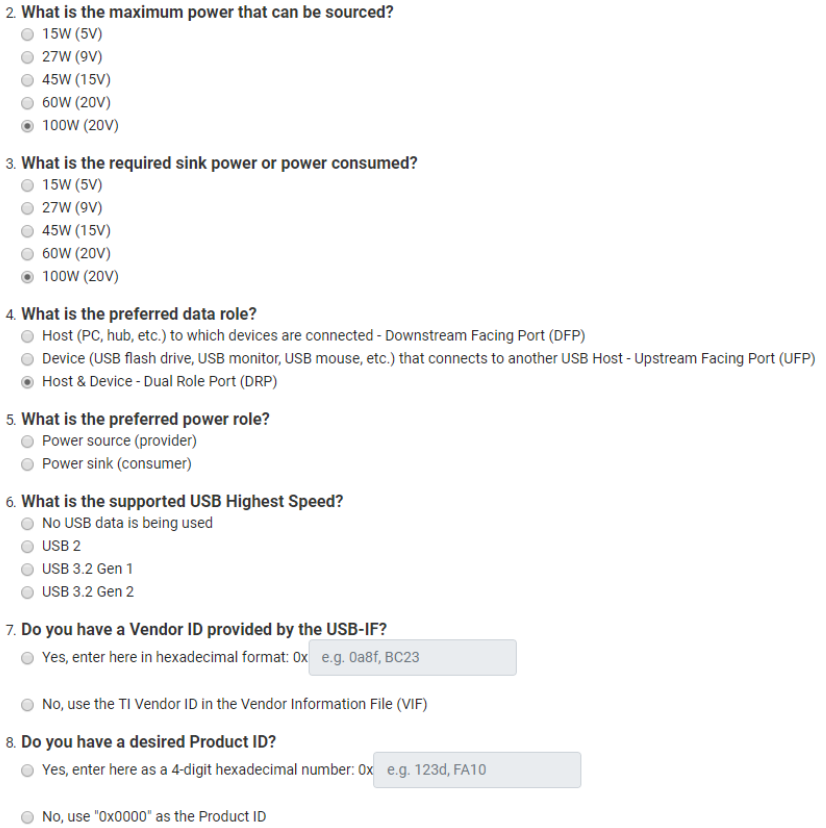




- Follows a similar operation as a buck converter. Q3 is always off and Q4 is always on.
- In a single converter switching cycle, only two MOSFETs, Q1 and Q2, are switching.

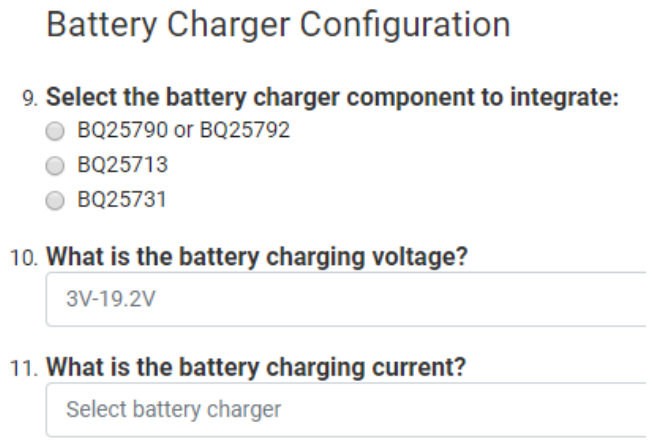
TPS25750: How to configure + program step 1

- The questions to the right are related to the PD controller functionality
- These questions are seen after selecting which architecture your system is using (See previous slide)
- Some questions may not be valid based on the architecture you have selected:
  - For example: When selecting a Sink-Only architecture, the questions for Source Capabilities will not be selectable
- The questions displayed should be answered per your system requirements.
- The web-based GUI will have “Help Me” messages that will be displayed when hovering over the question



TPS25750: How to configure + program step 2

- When using the TPS25750 with a BQ257xx battery charger, some additional questions are available in the TPS25750 GUI tool
- The questions shown on the right are specifically related to the battery charger settings when using TPS25750 with a BQ257xx charger device
  - The battery charger component is selectable
  - The battery charge voltage is configurable
  - The battery charge current is configurable



Future of Type-C PD + Battery Charger

- TI is currently designing and evaluating a PD3.1 EPR solution
- Will pair our next generation PD3.1 PD controller with a next generation battery charger
- If interested, reach out to your local TI representative to stay informed on the latest

USB PD3.1 EPR Demo

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