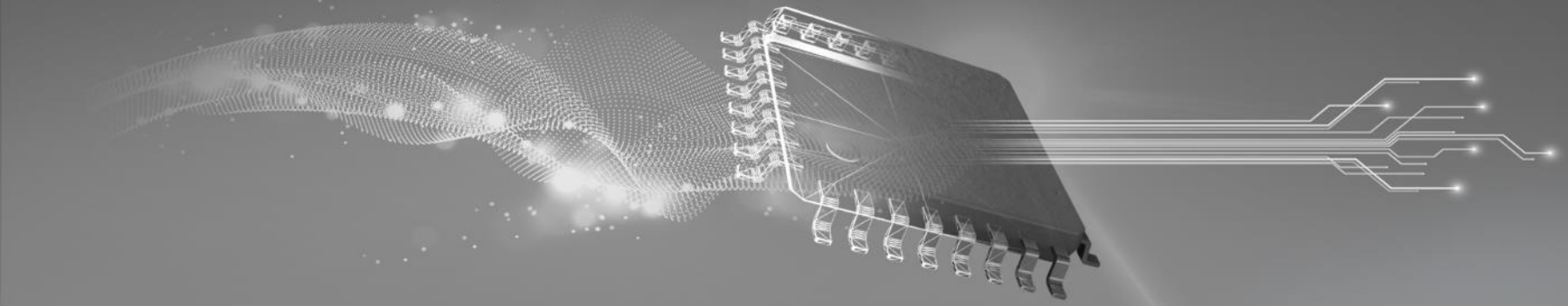
TI TECH DAYS



How to design your standalone USB Type-C™ PD charging solution

Steve Preissig

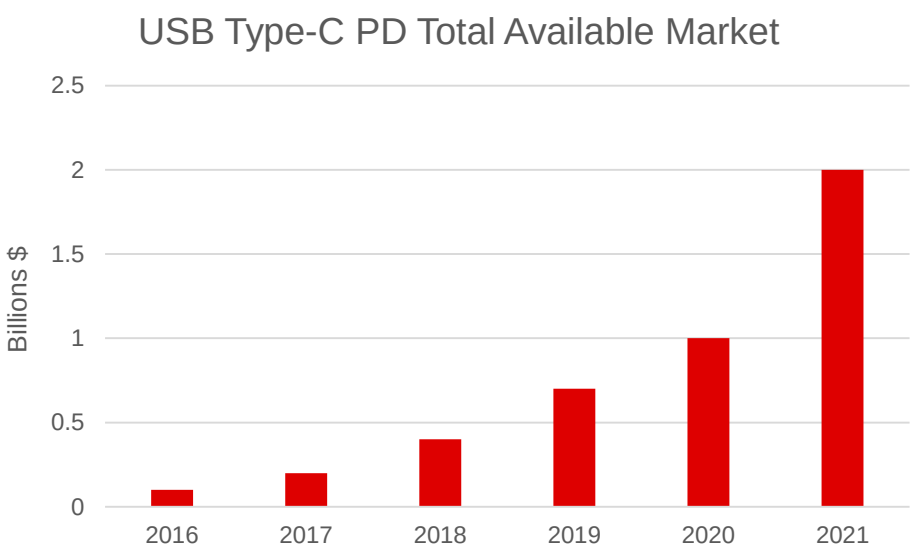
Texas Instruments

Agenda

- Overview of USB PD
- USB PD requirements for a charger IC
  - *Seamless transition among boost, buck-boost and buck operating modes*
  - *USB on-the-go (OTG) mode and back up mode*
- BQ25790 and BQ25792 overview
  - *High integration level to maximize power density and facilitate system design*
  - *Efficiency optimization*
  - NVDC power path management
  - Minimize battery quiescent current, ship mode and shutdown mode
  - Dual-input power mux driver to support two input sources
- TPS25750D + BQ25792 autonomous PD charging chipset
- TPS25750D + BQ25792 reference design
  - Simple configuration with binary vending machine

USB Type-C® PD market and applications

- New generation of personal electronics and industrial applications are employing USB Type-C PD charging
- Up to 100W of power can be delivered implementing USB Type-C PD charging



Why USB Type-C PD charging?

- **Before USB Type-C:**
  - Need multiple adapters to charge different applications

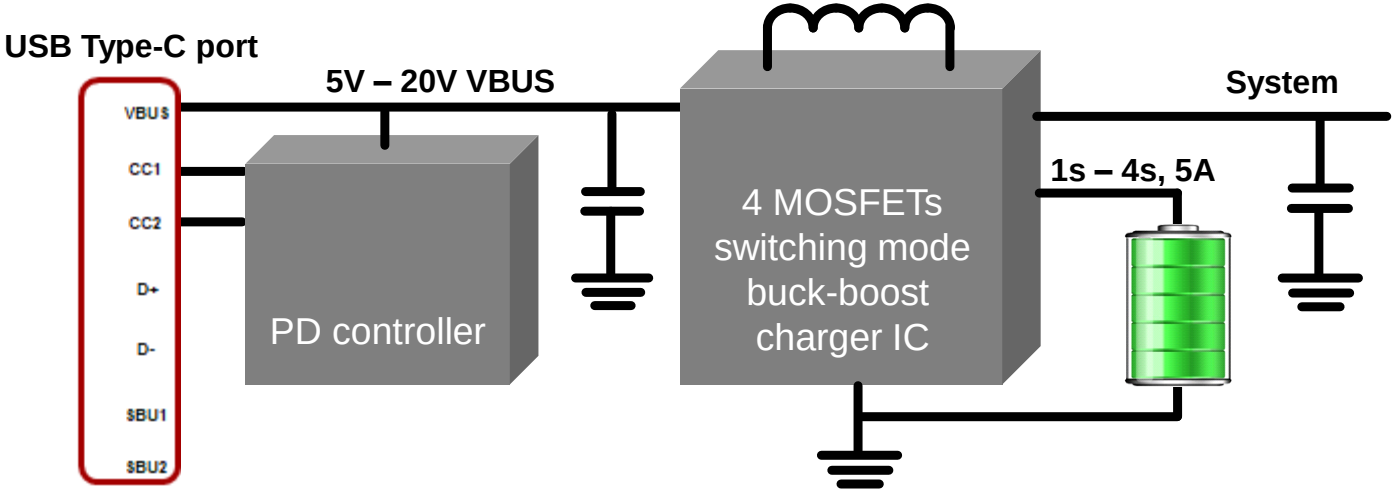
- **After USB Type-C:**
  - Single adapter can be used to charge different applications
  - Universal charging trend is growing very fast in the past couple years

USB Power Delivery (PD) over USB Type-C

Precedence	Mode of operation	Nominal voltage	Maximum current
Highest	USB PD	Up to 20 V	Up to 5 A
	USB Type-C current @ 3A	5 V	3 A
	USB Type-C current @ 1.5A	5 V	1.5 A
	USB BC1.2	5 V	Up to 1.5 A
	USB 3.1	5V	900 mA
Lowest	USB 2.0	5V	500 mA

- **What is USB Power Delivery (PD)?**
  - USB Power Delivery is a charging technology, which uses USB Type-C cables and connectors to deliver higher levels of power to your devices.
  - USB PD adapter normally outputs 5 V and is compatible with USB 5 V adapter. It increases output voltage from 5 V to 9 V / 15 V / 20 V after handshake with charger to provide high voltage charging.

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, 5V/3A, 9V/3A, 15V/3A, 20V/3A, 20V/5A

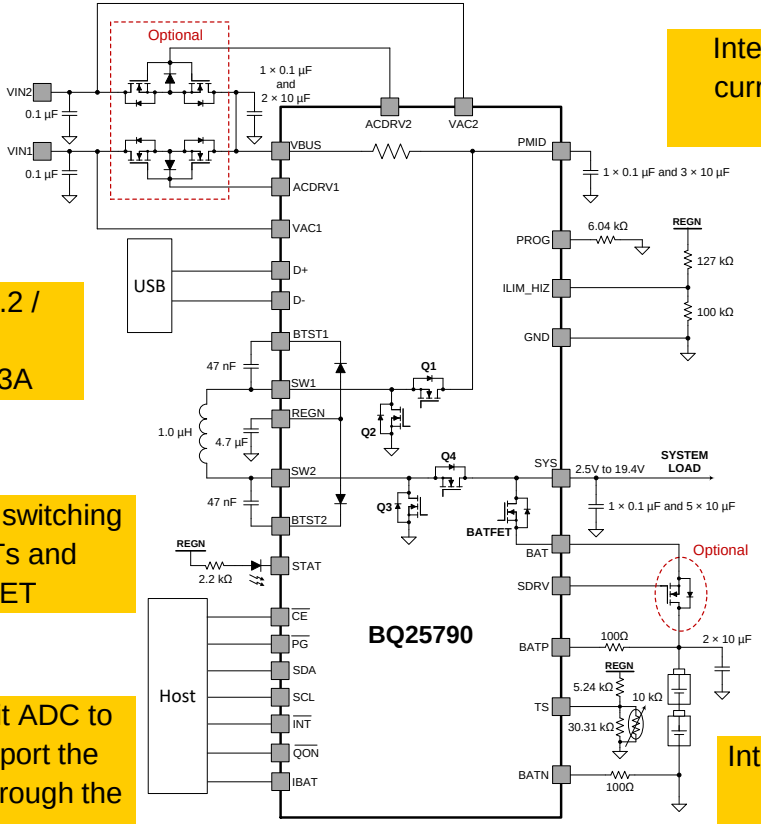
Fully integrated buck-boost charger: BQ25790

Dual-input power mux drivers to select adapter or wireless

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

Integrated 4 switching MOSFETs and BATFET

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



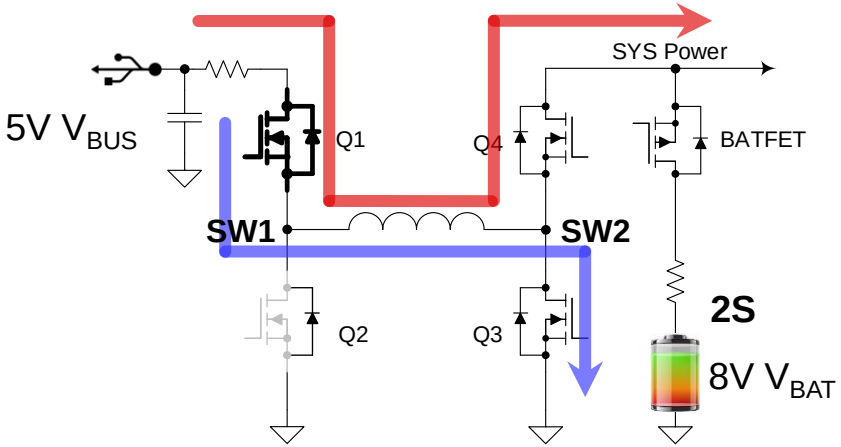
Integrated input current sensing circuitry

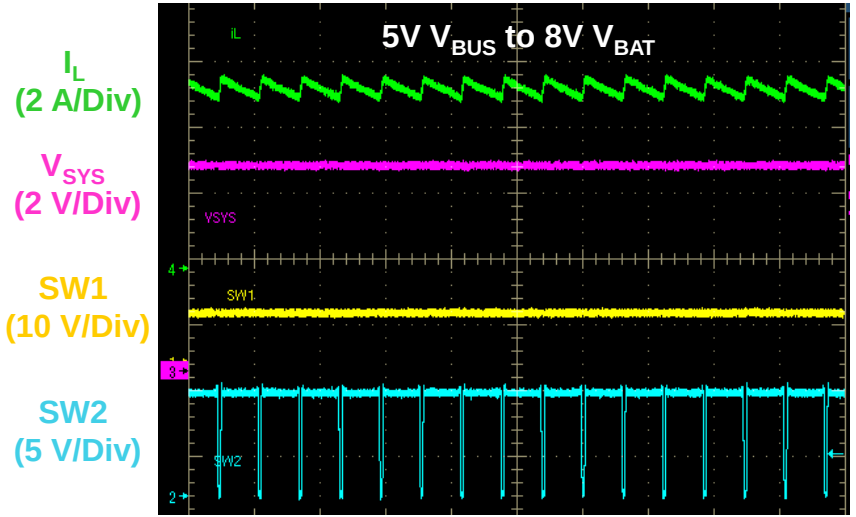
Integrated BATFET for NVDC power path management

Integrated ship FET driver for minimizing quiescent current

Integrated TS pin for NTC battery temperature sensing

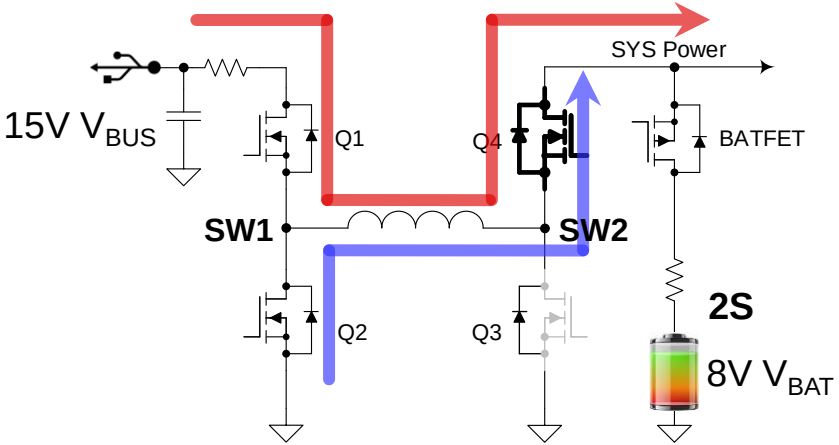
5 V charges 2S battery in boost mode

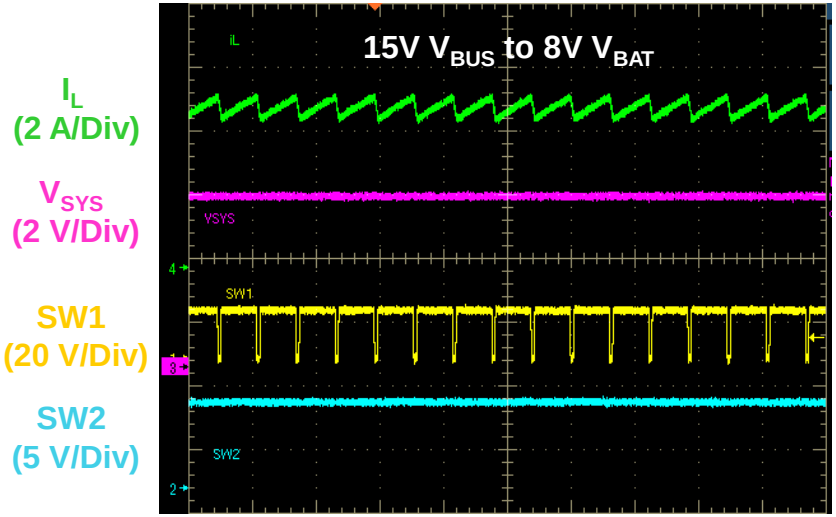




- Follows similar operation as a boost converter. Q2 is always off and Q1 is always on.
- In a single converter switching cycle, only two MOSFETs, Q3 and Q4, are switching.

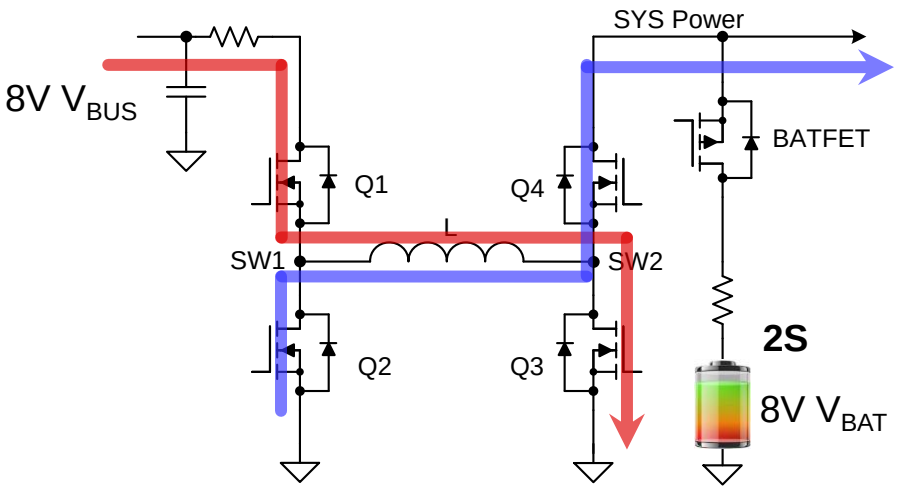
15 V charges 2S battery in buck mode

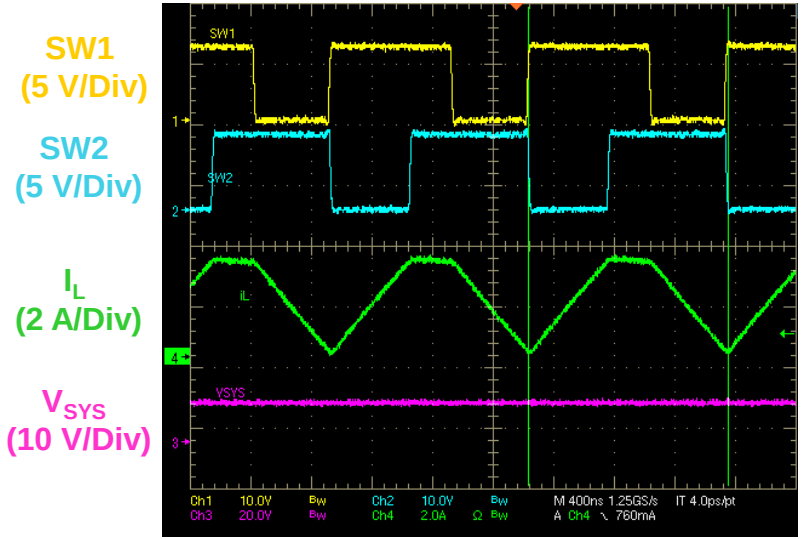




- Follows a similar operation as a buck converter. Q3 is always off and Q4 is always on.
- In a single converter switching cycle, only two MOSFETs, Q1 and Q2, are switching.

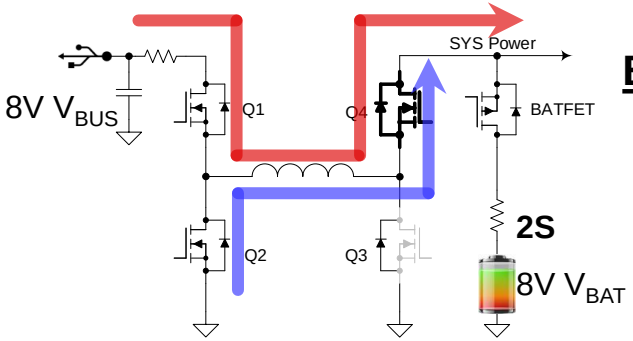
8 V charges 2S battery in buck-boost mode (traditional)



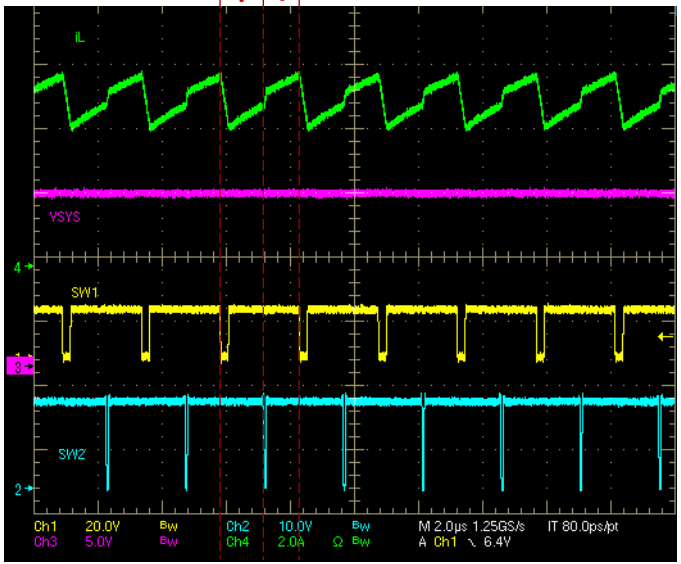


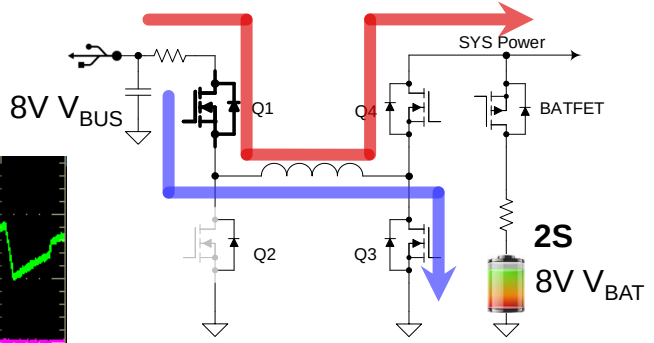
- All four MOSFETs are switching within a single switching cycle, resulting in a higher switching loss than the buck or boost mode operation.
- Larger inductor current ripples before the buck or boost operation, causing higher losses.

8 V charges 2S battery in buck-boost mode (TI solution)



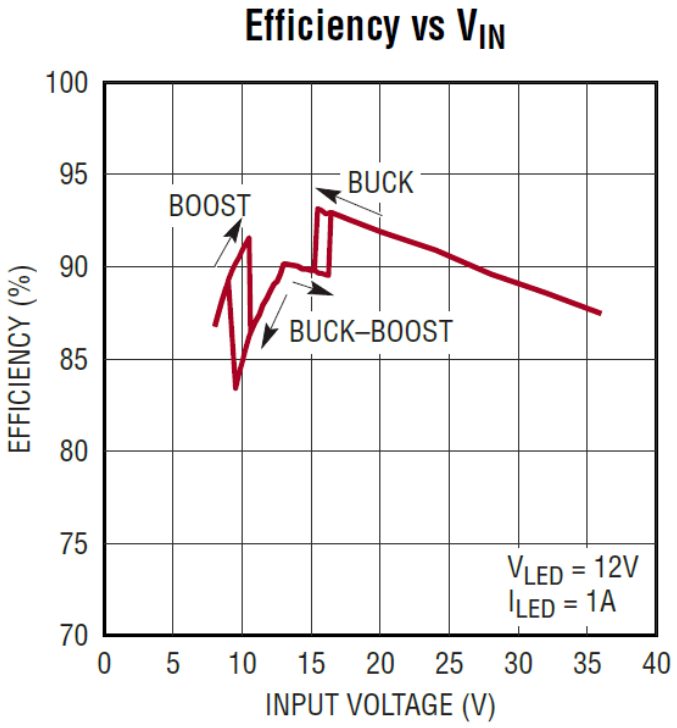
Buck **Boost**



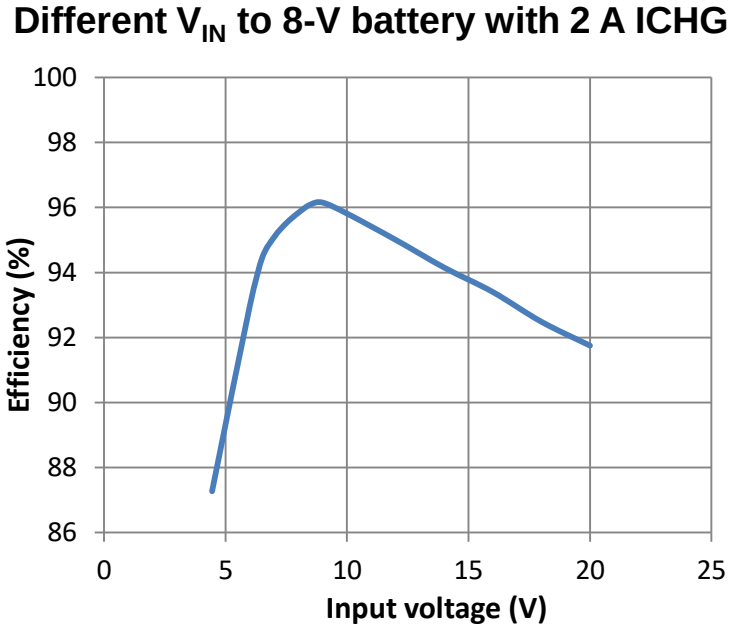


- The pure buck and boost mode are interleaving to achieve buck-boost operation.
- Equivalently, there are only two switching MOSFETs in one switching cycle.

Efficiency comparison

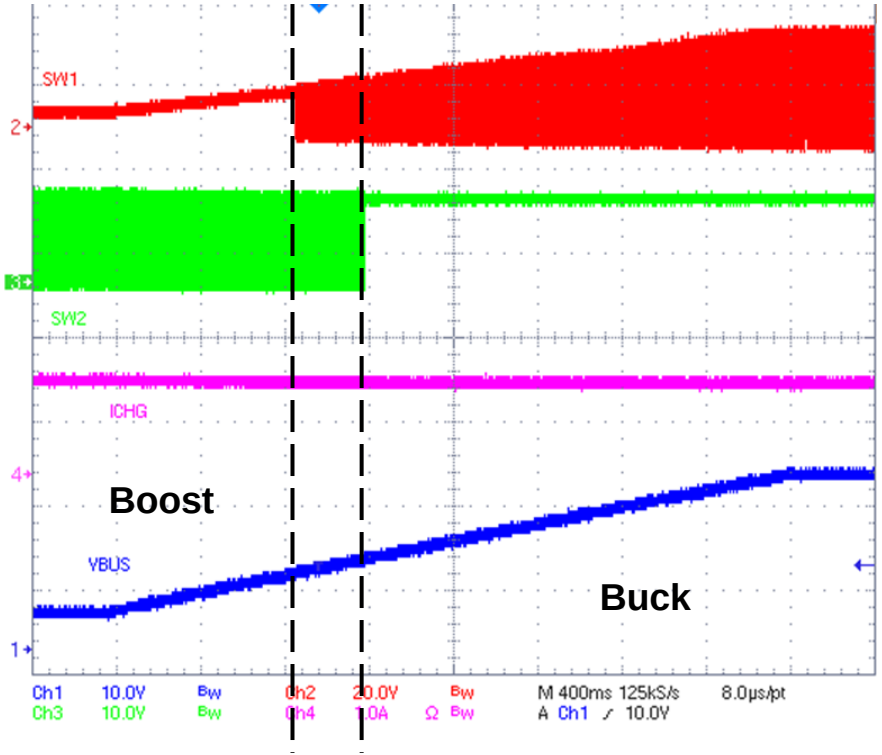


Traditional buck-boost operation



With a high efficiency buck-boost mode, there is no efficiency valley when V_{IN} is changed

Seamless transition across different operating modes

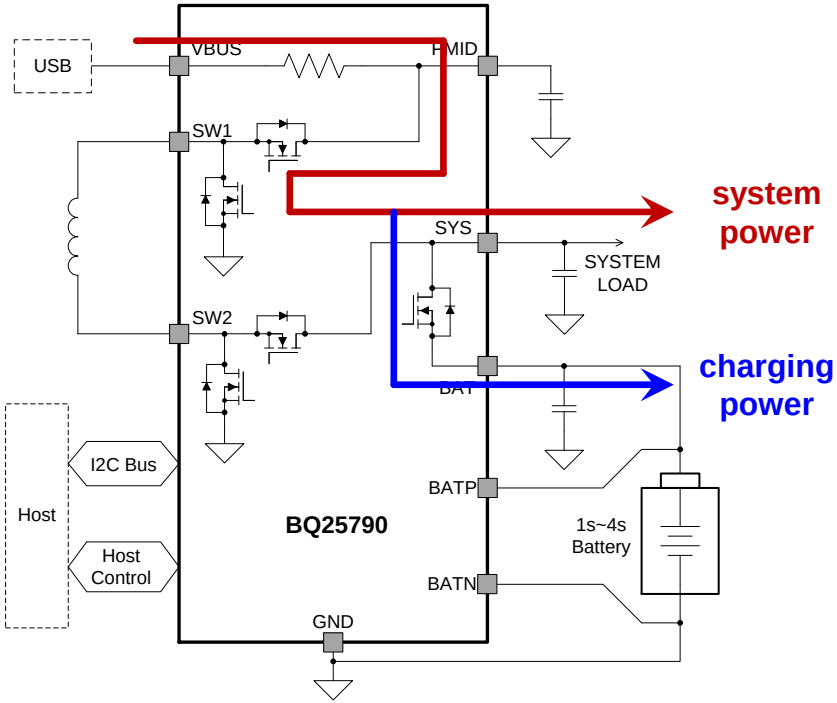


- Keep V_{BAT}=8 V, sweep V_{BUS} from 5 V to 20 V, charge is enabled with 1 A current
- The operating modes transient from boost, to buck-boost, then to buck mode
- The charging current is always kept at 1 A regardless of V_{BUS} voltage

No Dead Zone

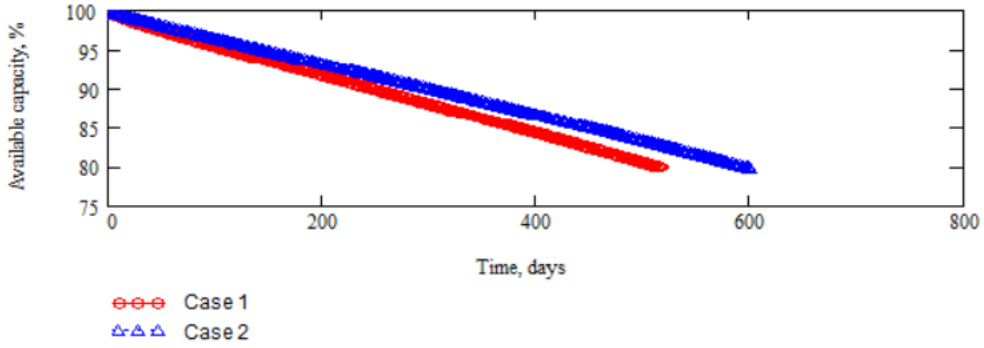
Integrated BATFET for NVDC power path management

- System can be powered from input source with deeply discharged battery
- System powered from the adapter through the buck-boost converter; charge current controlled by the BATFET
  - Extend battery life for applications with adapter attached for long period of time
- Separate charge current path from system current path, prioritize the system current with battery supplement the system when the adapter is overloaded
- Recommended topology when powering system and charging battery simultaneously



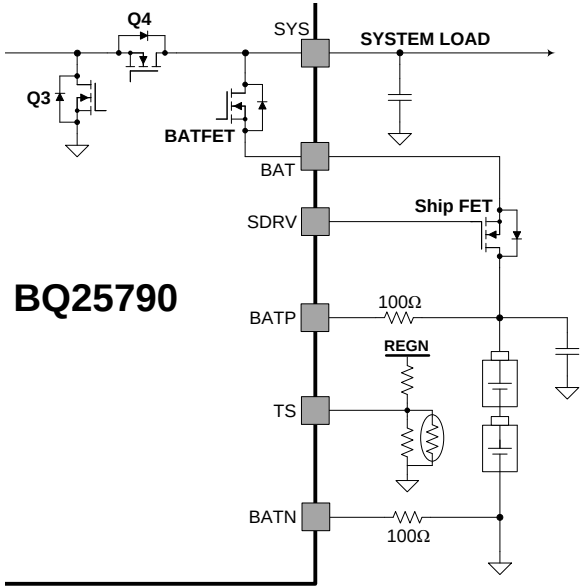
Extend battery life – 20% more operation time

- **Case 1:**
  - Charge from 0 to 100%.
  - No termination control. Charge is always enabled.
    - System load can discharge the battery below recharge threshold.
    - Battery is repetitively recharged before target time.
- **Case 2:**
  - Charge from 0 to 100%.
  - With Power Path control. Charge can be disabled while powering-up the system.
    - Battery is charged much less cycles before target time.



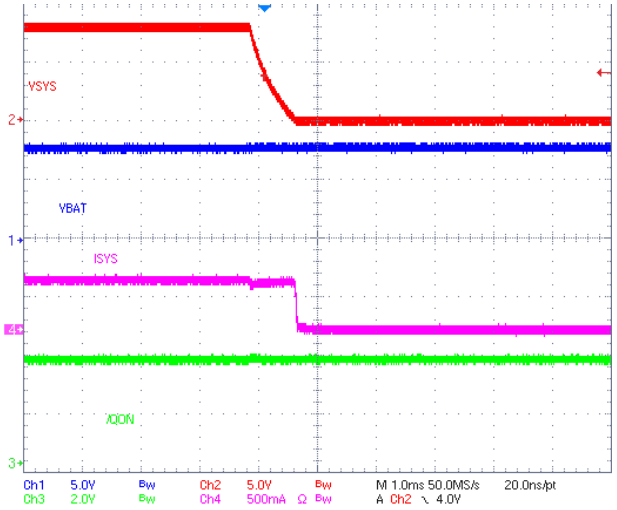
Swollen battery

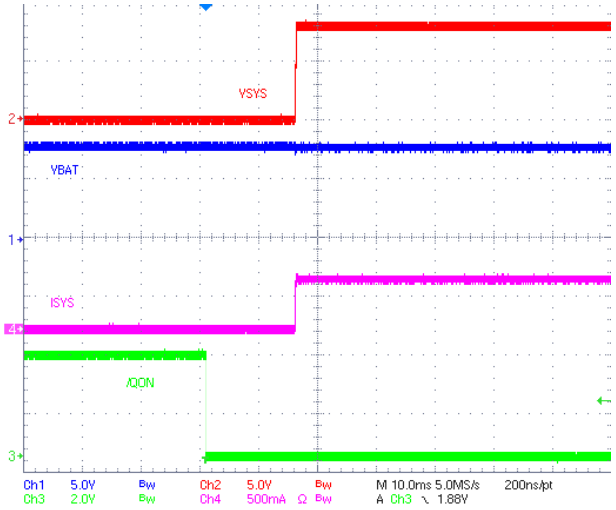
Minimize battery quiescent current, ship and shutdown mode



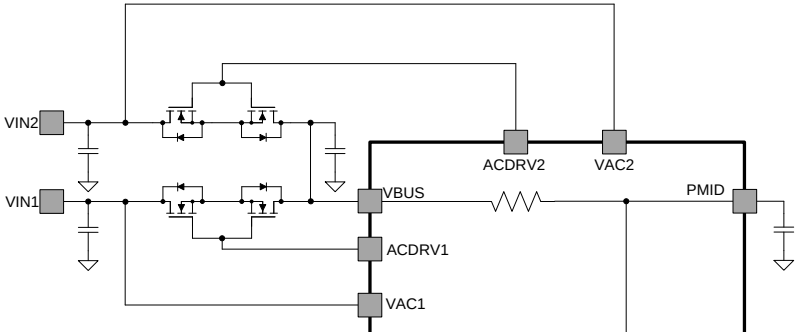
- Ship mode, 12 uA Iddq
- Shutdown mode, 600 nA Iddq

- The integrated BATFET is only one-directional blocking
- SDRV to drive the external ship N-FET, cut off the leakage current from battery to system
- Ship FET is optional, provides design flexibility

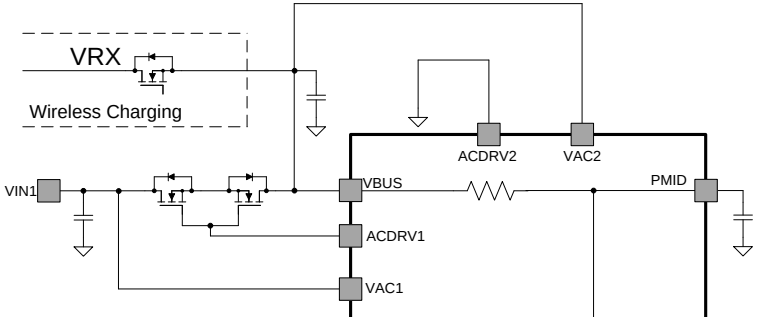




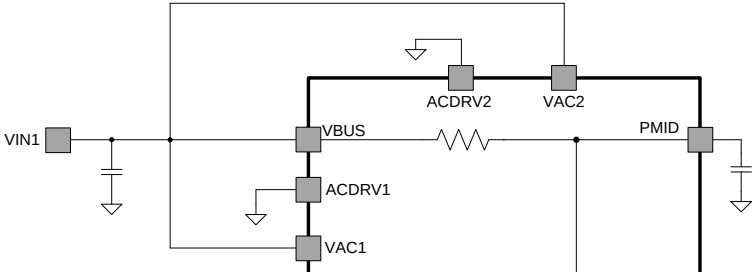
Dual-input power mux for sources selection



Dual-input application with 4 NFETs



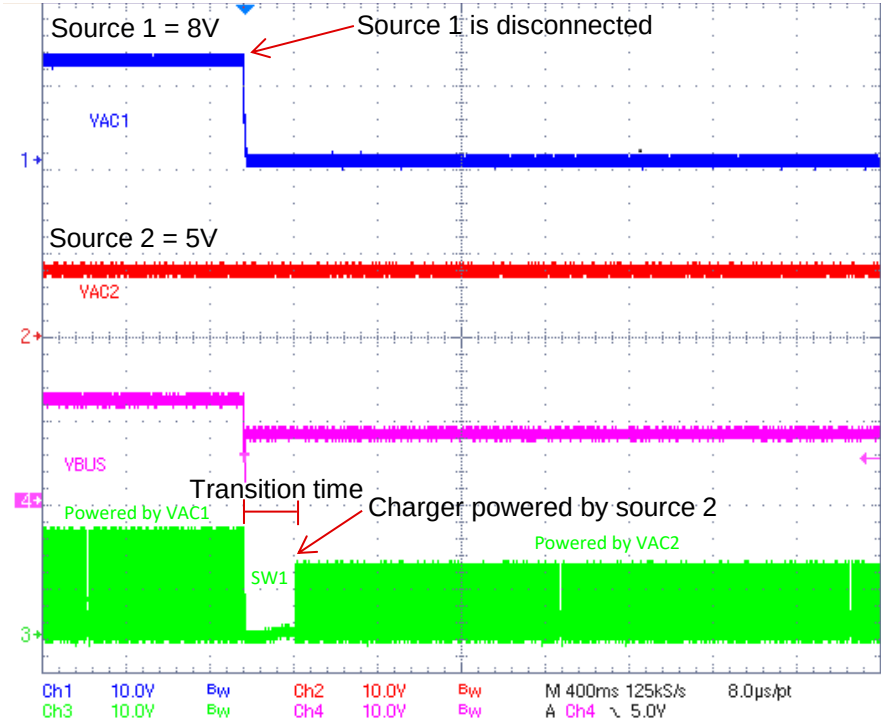
Dual-input application with 2 NFETs

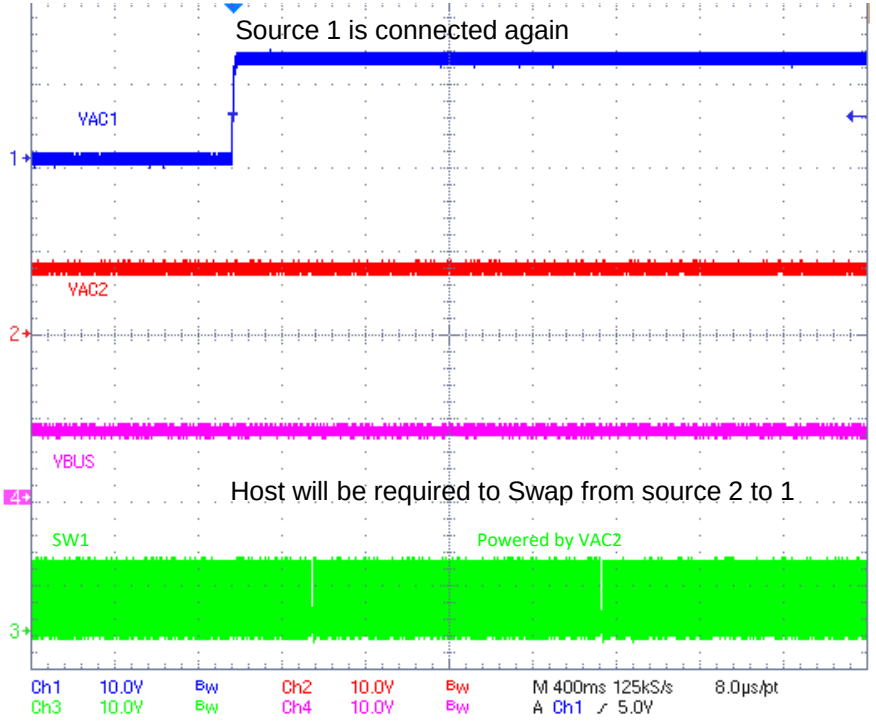


Single input application

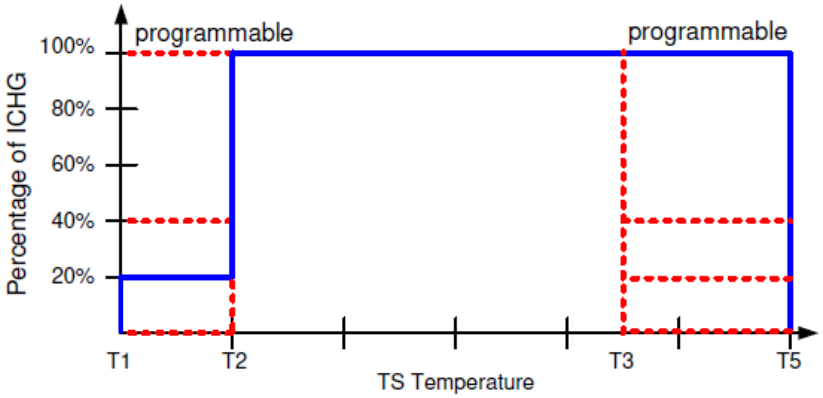
- At POR, charger detects the NFETs to determine which configuration it would be
- The first connected input source V_{IN} will be selected, and if two connected at the same time, selected input 1
- The host manages via I2C to swap between the two inputs
- When both inputs are present, if the selected input becomes invalid, the mux will swap the selected source to the other one automatically

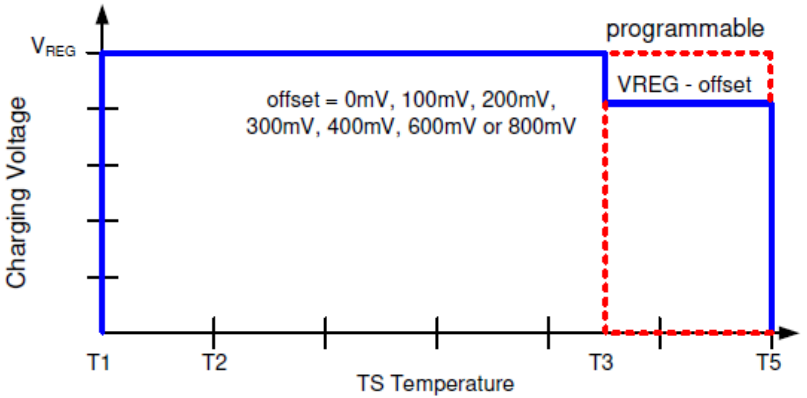
Input source transition from port 1 to port 2





Programmable JEITA protection



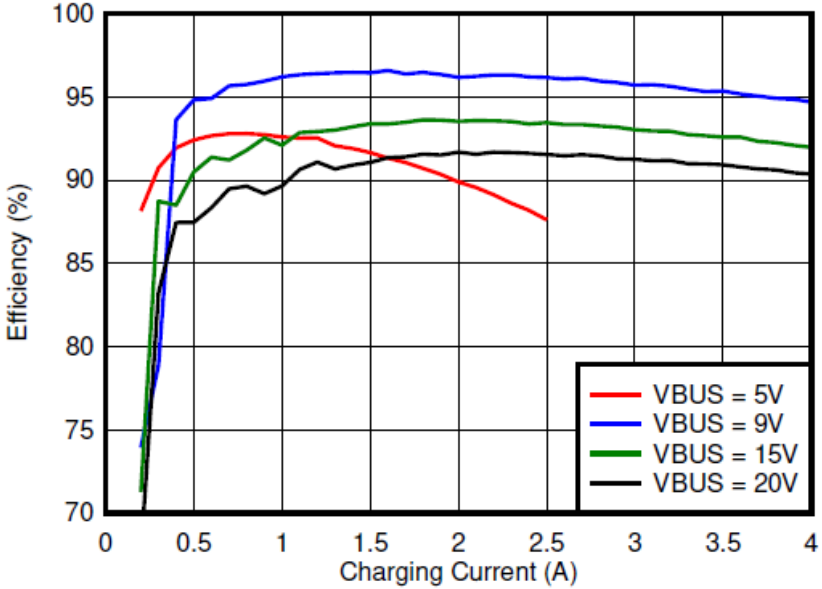


With one set of resistor divider (5.24kΩ + 30.31kΩ) as an example:

T_{COLD} (°C)	T_{COOL} (°C)	T_{WARM} (°C)	T_{HOT} (°C)
0	5, 10(default), 15, 20	40, 45(default), 50, 55	60

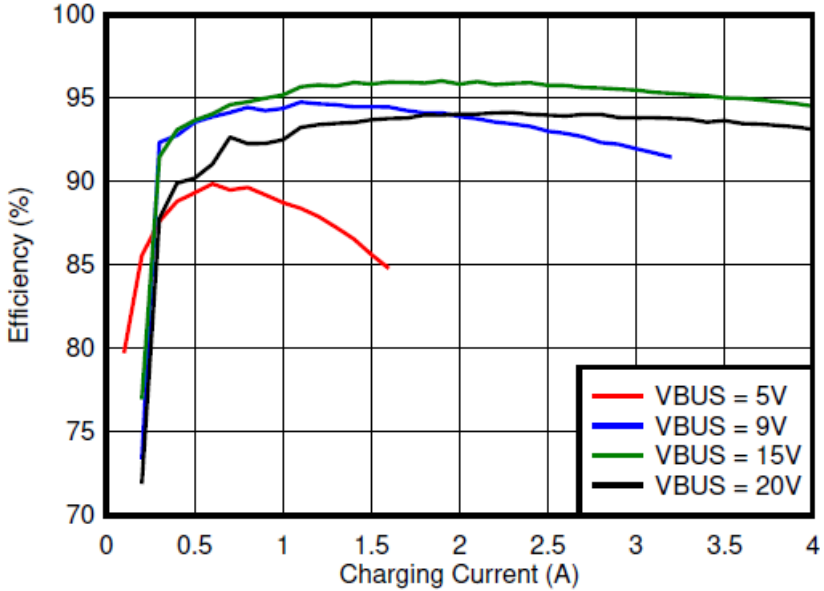
- Multiple temperature settings to program the COOL and WARM temperature for custom JEITA requirements
- Flexibility to set the V_{BAT} voltage to V_{BAT} (800 mV to 100 mV) to ensure safe charging of battery in warm conditions

BQ25790 charging efficiency summary



VBAT = 8V, Fsw = 1.5MHz with L1 = 1µH, PFM disabled

Figure 1. 2s Battery Charge Efficiency vs. Charge Current

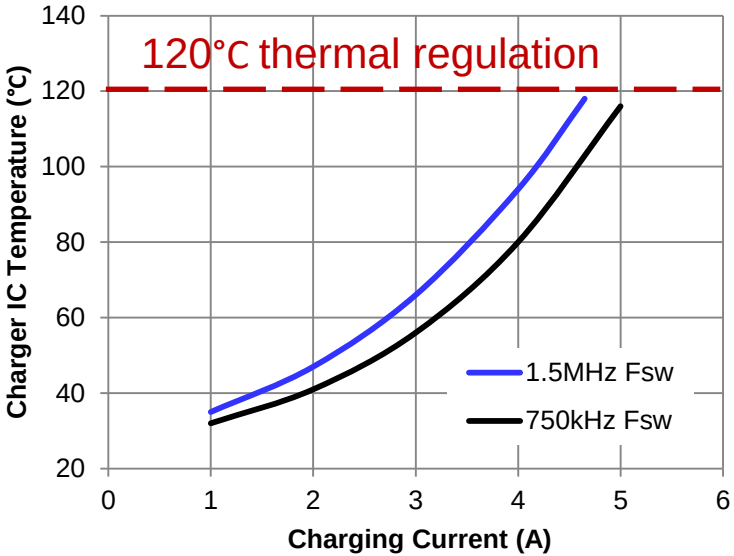


VBAT = 12V, Fsw = 1.5MHz with L1 = 1µH, PFM disabled

Figure 2. 3s Battery Charge Efficiency vs. Charge Current

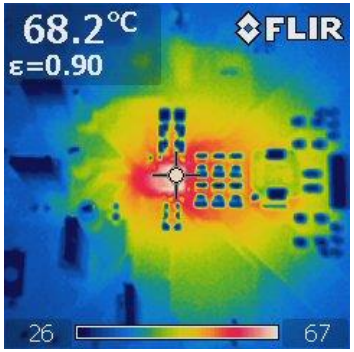
Charger IC temperature at heavy load conditions

15 V_{BUS} charges 8 V_{BAT} with different current

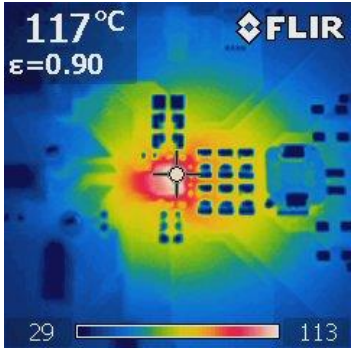


The integrated solution can handle up to 45 W of charging power

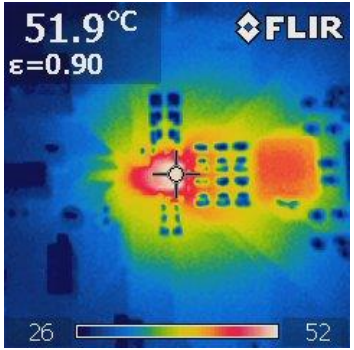
1.5MHz, 3A ICHG



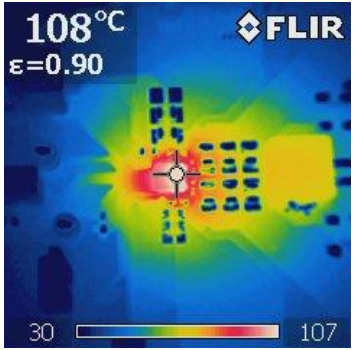
1.5MHz, 4.6A ICHG



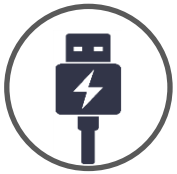
750kHz, 3A ICHG



750kHz, 5A ICHG



BQ25790, BQ25792 features overview



Integrated USB source detections

D+/D- and ICO to set input maximum current limit upon adapter plug in.

1s-4s Li-ion autonomous charging

Configurable battery voltage to charge from 3.6 V – 24 V input for full temperature range spec (-40 to 125° C).

Power path management

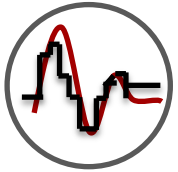
Dedicated charge control while powering up system. Termination control extends battery life time.

USB on-the-go

Boost up the battery voltage to the input port and provides regulated 2.8 V – 22 V output.

Flexible JEITA

Programmable temperature ranges, battery voltage and charge current.

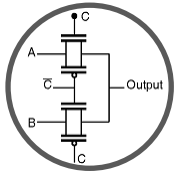


16-bit ADC

High performance 16-bit Sigma Delta ADC integrated to monitor VBUS, IBUS, VBAT, IBAT, VSYS, TS, etc.

Ship mode and shutdown mode

0.6uA shut down mode current enables longer shelf battery life for better user experience.

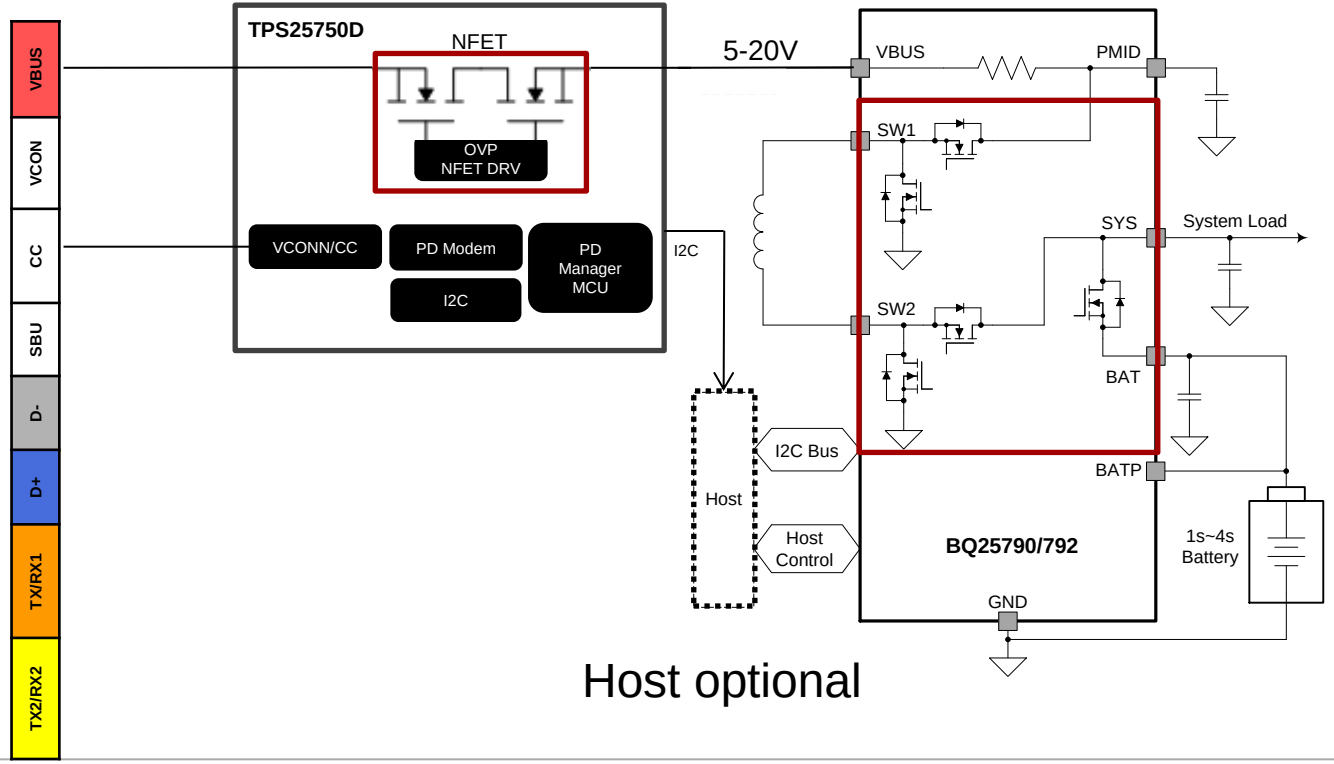


Dual-input mux

Dual input power mux control to support priority based selection.

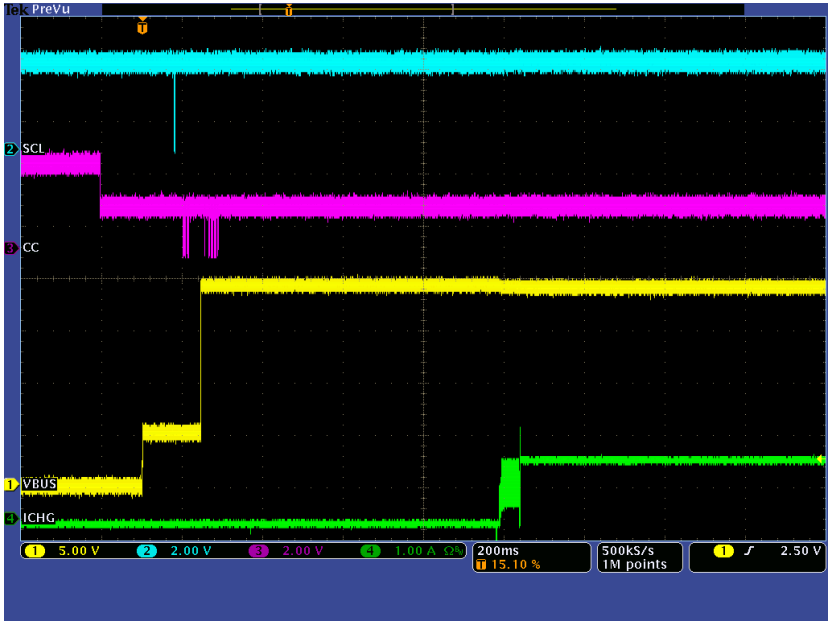
Low power optimized charging solution for 1-4S battery

USB Type-C port

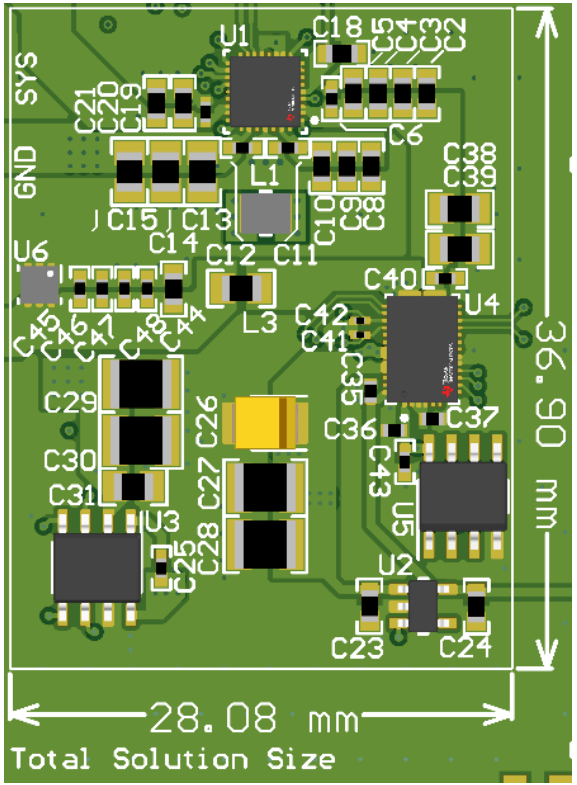


- Options 45 W, 27 W and 15W source and sink settings
- Options to select preferred power role and preferred data role
- MCU optional
- 1-4S Li-ion charging from 5- 20-V input
- Fully integrated solution to reduce BOM material and solution size

TPS25750 + BQ25792 power bank (no microcontroller)

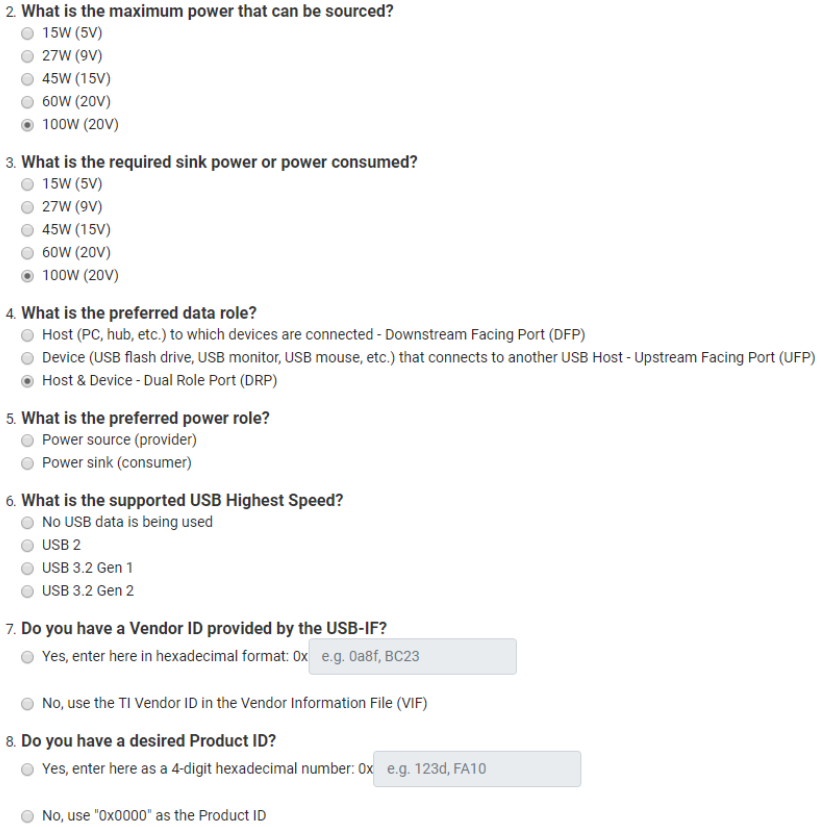


TPS25750 controls BQ25620 to charge battery from 20-V adapter



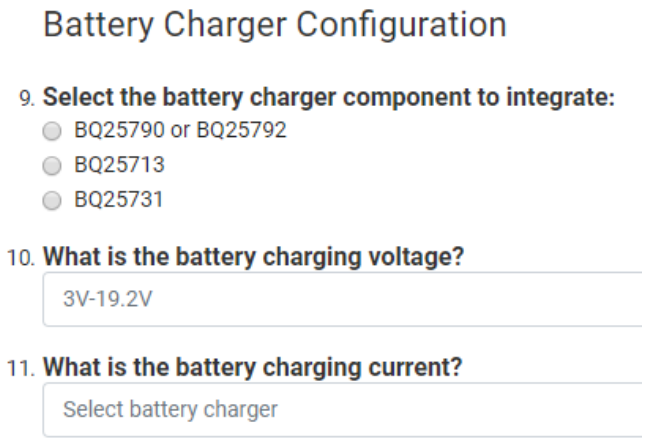
TPS25750: How to configure + program step 1

- 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



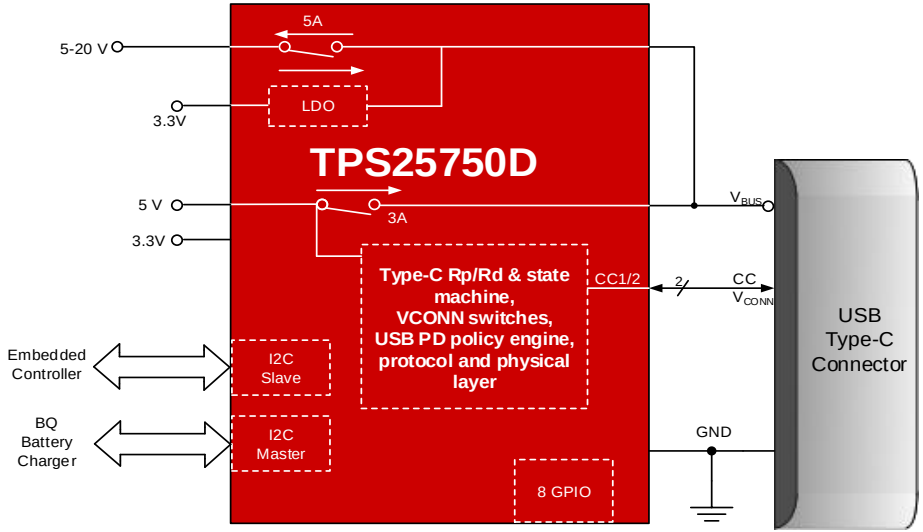
TPS25750D: Single USB Type-C DRP USB-PD controller

Features

- Controls one Type-C Power Delivery port
- Integrated 5 A 18m 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 (0.4mm pitch)
- External I2C EEPROM required to store configuration data
- Configuration options selected via “Binary Vending Machine” GUI

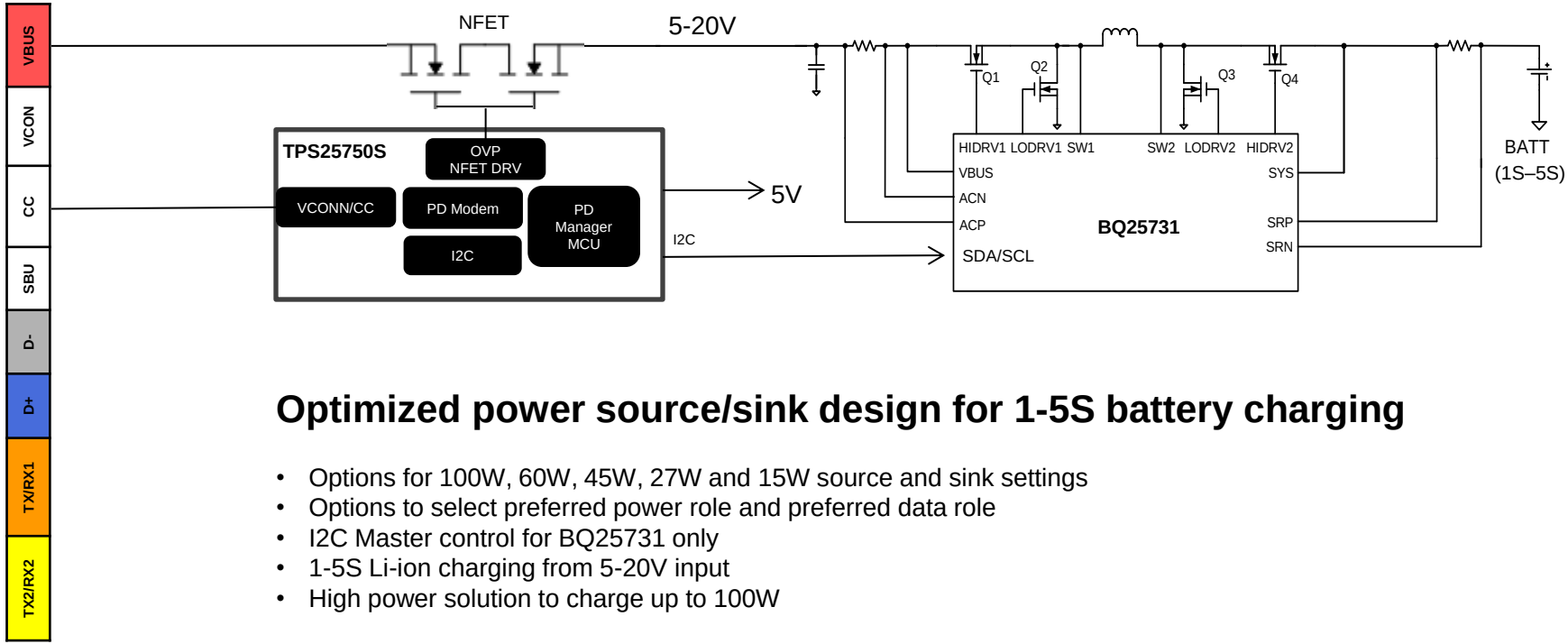
Benefits

- 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



High power optimized charging solution for 1-5S battery

USB Type-C port



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

- Options for 100W, 60W, 45W, 27W and 15W source and sink settings
- Options to select preferred power role and preferred data role
- I2C Master control for BQ25731 only
- 1-5S Li-ion charging from 5-20V input
- High power solution to charge up to 100W

BQ25731 buck-boost charger controller for 1s~5s battery without power path

Features

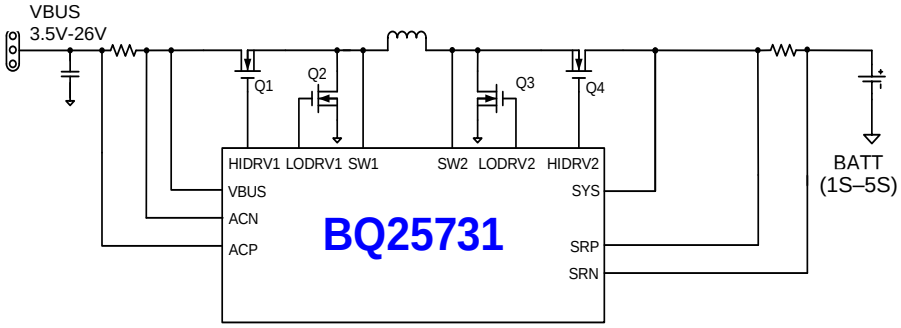
- Buck boost charger for 1s-5s battery
  - Seamless transition among buck, buck-boost and boost modes
  - Unique buck-boost operation to achieve high efficiency
- USB power delivery wide input range from 3.5V to 26V
  - Input current setting up to 10A/6.4A with 100mA/50mA step
- USB OTG output fully compatible with PD 3.0 PPS
  - Adjustable 3V to 24V VOTG with 8mV output resolution
  - IOTG regulation up to 12.8A/6.4A with 100mA/50mA step size
- Programmable 400kHz/800kHz switching frequency with dithering feature to improve EMI
- Support both 5mohm &10mohm input and charging sensing resistor
- Package: 32-pin 4x4 mm QFN

Applications

- Vacuum robots, home automation applications, medical applications
- Handheld terminals, power tools

Benefits

- Integrated ADC for voltage/current/power monitoring
- Bidirectional converter offer forward charge and OTG modes
- I2C communication provides flexibility for different applications
- No BATFET needed to save BOM



BQ25731 Samples available now

Texas Instruments

Buck-boost charger solution for applications >45W

Features

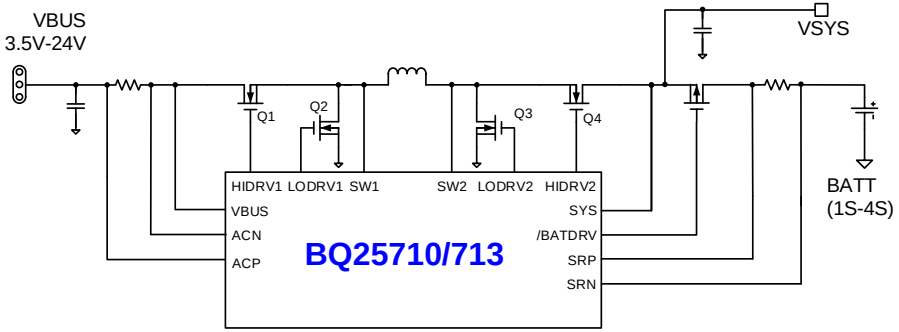
- Buck boost charger for 1-4 cell battery
  - Seamless transition among buck, buck-boost and boost modes
  - Unique buck-boost operation to achieve high efficiency
- Wide input range from 3.5V to 24V
  - Input current setting up to 6.4A with 50mA step size
  - Max power tracking with input voltage and current regulation to optimize adapter output power
- USB OTG with adjustable output from 3V to 20.8V
  - 8mV VOTG step size compatible with USB-PD 3.0
  - IOTG regulation up to 6.4A with 50mA step size
- V_{MIN} active protection (VAP) to prevent system crash
- Programmable 800kHz/1.2MHz switching frequency
- Pass through mode for efficiency/thermal improvement

Applications

- Ultrabook and 2-in-1 tablets
- Handheld terminals, power banks
- Industrial and medical equipment

Benefits

- OTG current regulation with uninterrupted OTG power source
- Instant-on with no battery or depleted battery
- Integrated ADC for voltage, current and power monitoring
- Battery supplements system when adapter is fully-loaded
- 710 SMBus / 713 I2C port for system optimization and status reporting
- Package: 32-pin QFN 4x4x0.75mm (RSN)



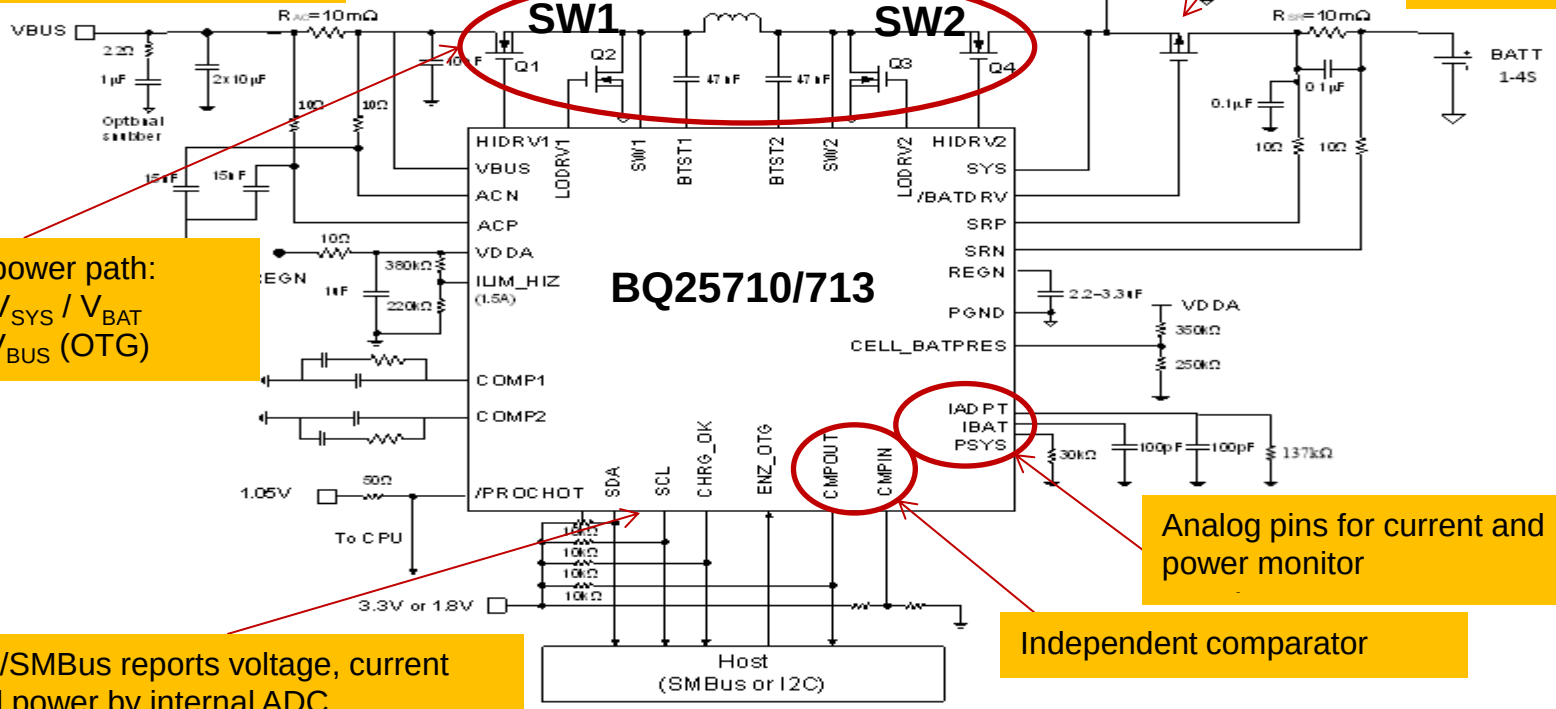
BQ25710, BQ25713 application diagram

VBUS: 3.5V-24V
OTG: 3V to 20.8V with 8mV step
(BQ25710, BQ25713)

Ext. FETs for efficiency optimization, fitting different power levels

Power path with BATFET

V_{BAT} 1-4 cell



Bidirectional power path:
1. V_{BUS} to V_{SYS} / V_{BAT}
2. V_{BAT} to V_{BUS} (OTG)

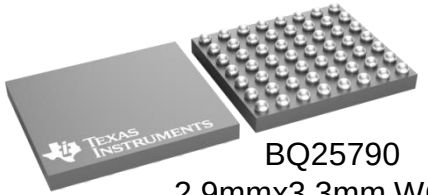
Analog pins for current and power monitor

Independent comparator

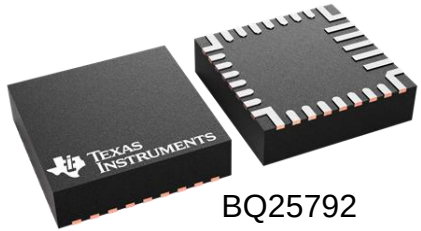
I2C/SMBus reports voltage, current and power by internal ADC

Resources

Switch-mode buck-boost battery chargers supporting USB Type-C PD	Flash and switched-cap chargers supporting USB Type-C PD	USB Type-C and PD controller IC	USB Type-C and PD short-to-V_{BUS} protection IC
BQ25790, WCSP package	BQ25871	TPS25750S/D	TPD6S300A
BQ25792, QFN package	BQ25970		



BQ25790
2.9mmx3.3mm WCSP



BQ25792
4mmx4mm QFN

Training content:

- Technical article "Universal and fast charging – a future trend for battery-powered applications"
- Technical article "Maximize power density with buck-boost and USB Type C™ Power Delivery"
- Video "What could you achieve with universal and fast charging?"
- White paper "USB Type-C and USB power delivery power path design considerations"
- USB Type-C and USB Power Delivery overview page https://www.ti.com/interface/usb/type-c-and-power-delivery/overview.html

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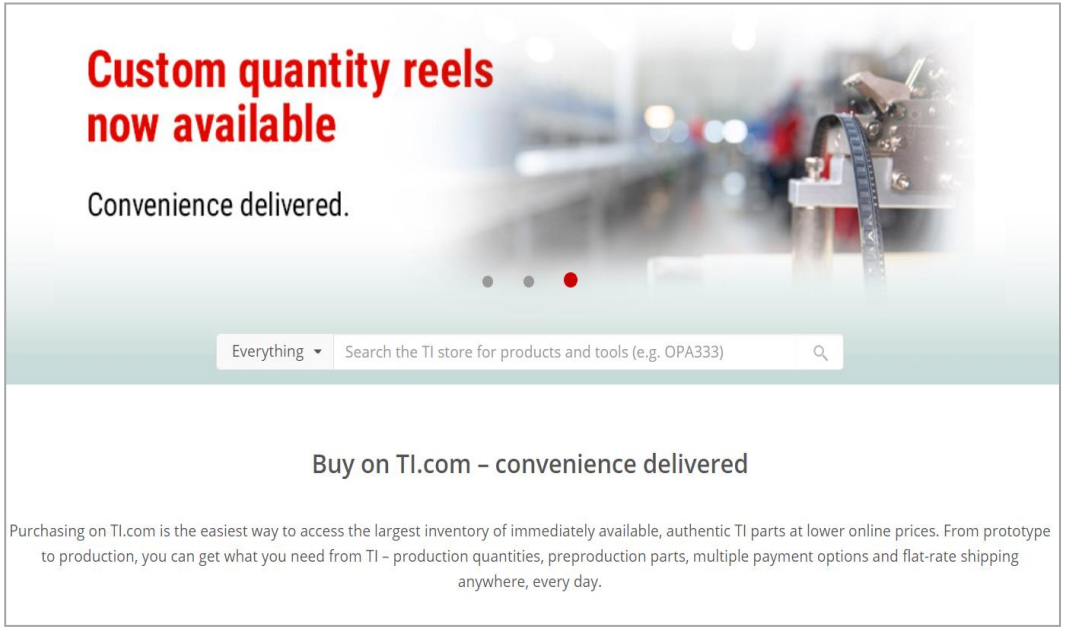

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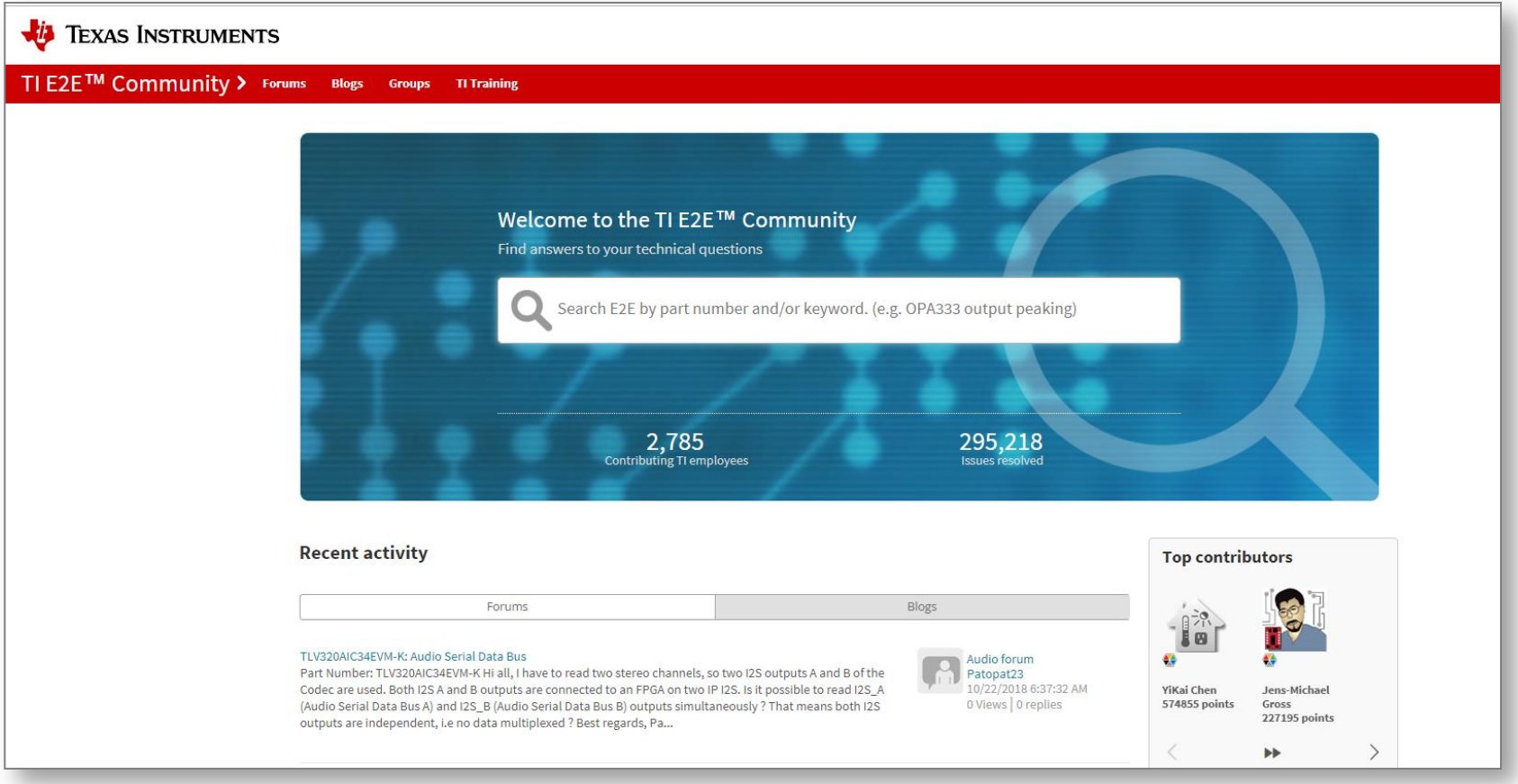
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TLV320AIC34EVM-K: Audio Serial Data Bus
Part Number: TLV320AIC34EVM-K Hi all, I have to read two stereo channels, so two I2S outputs A and B of the Codec are used. Both I2S A and B outputs are connected to an FPGA on two IP I2S. Is it possible to read I2S_A (Audio Serial Data Bus A) and I2S_B (Audio Serial Data Bus B) outputs simultaneously ? That means both I2S outputs are independent, i.e no data multiplexed ? Best regards, Pa...
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