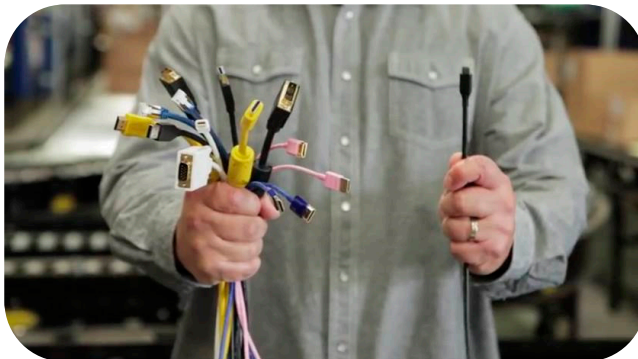
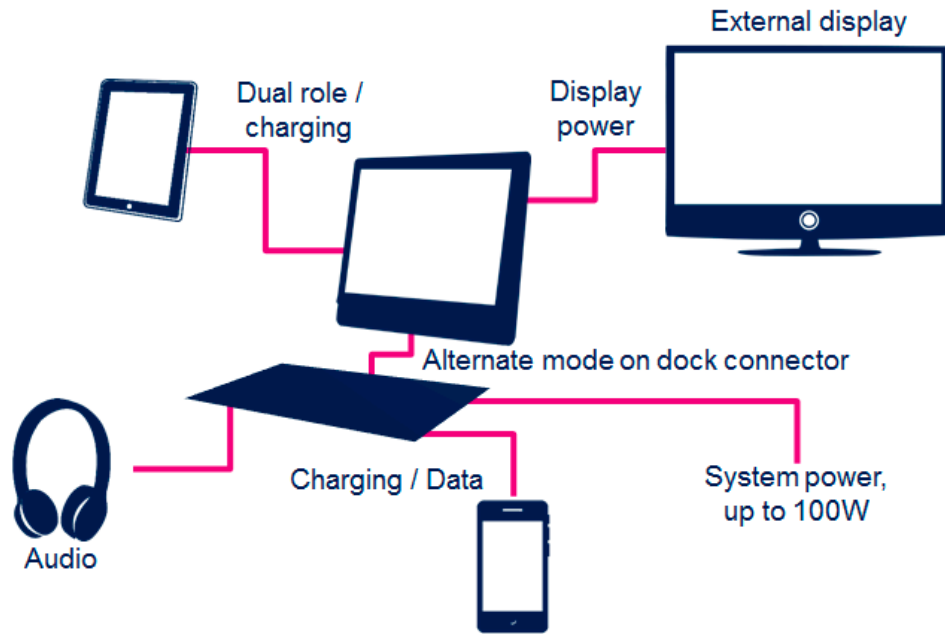


# USB Power Delivery and Type-C™



Flexible, robust  
solution for power  
and interconnect

Type-C & USB-PD  
Architecture  
Features

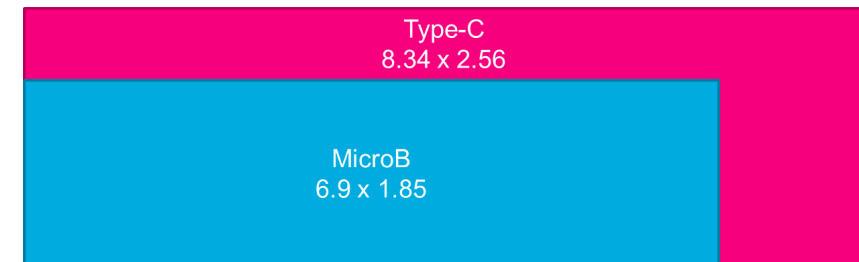
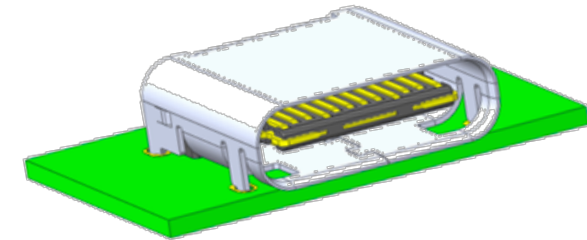
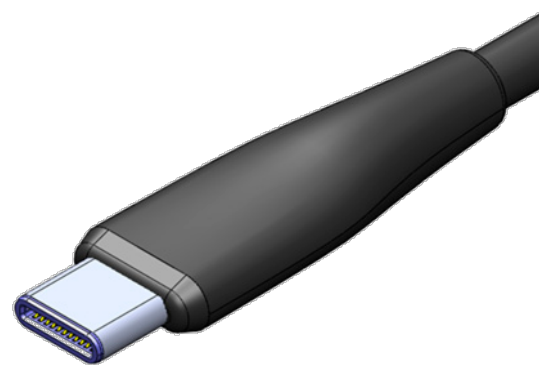
ST products for  
Type-C & USB-PD

Type-C & USB-PD  
Solution

# USB Type-C Overview

USB Power Delivery specification introduces USB Type-C receptacle, plug and cable; they provide a smaller, thinner and more robust alternative to existing USB interconnect. Main features are:

- Enable new and exciting host and device form-factors where size, industrial design and style are important parameters
- Work seamlessly with existing USB host and device silicon solutions
- Enhance ease of use for connecting USB devices with a focus on minimizing user confusion for plug and cable orientation



# USB Type-C with Power Delivery

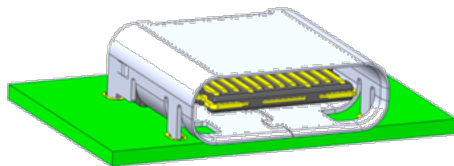
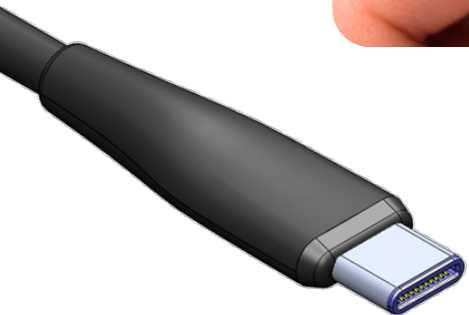


New USB Type-C receptacle, plug and cable;  
a smaller, thinner and more robust alternative to existing USB interconnect

Enables new and exciting host and device form-factors where size,  
industrial design and style are important parameters

Work seamlessly with existing USB host and device silicon solutions

Enhances ease of use for connecting USB devices  
Focus on minimizing user confusion for plug and cable orientation



# The Re-Evolution of USB

USB has evolved from a data interface capable of supplying limited power to a primary provider of *power* with a data interface



Power  
Delivery

More **Power** with USB Power Delivery (100W)



Type-C

More **Flexibility** with a new reversible USB-C connector



Alternate  
Mode

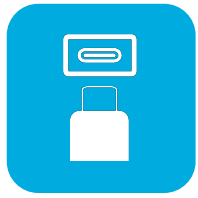
More **Protocols**  
(Display Port, HDMI, VGA, Ethernet...)



USB IF

More Speed with USB 3.1 (10 Gbit/s)

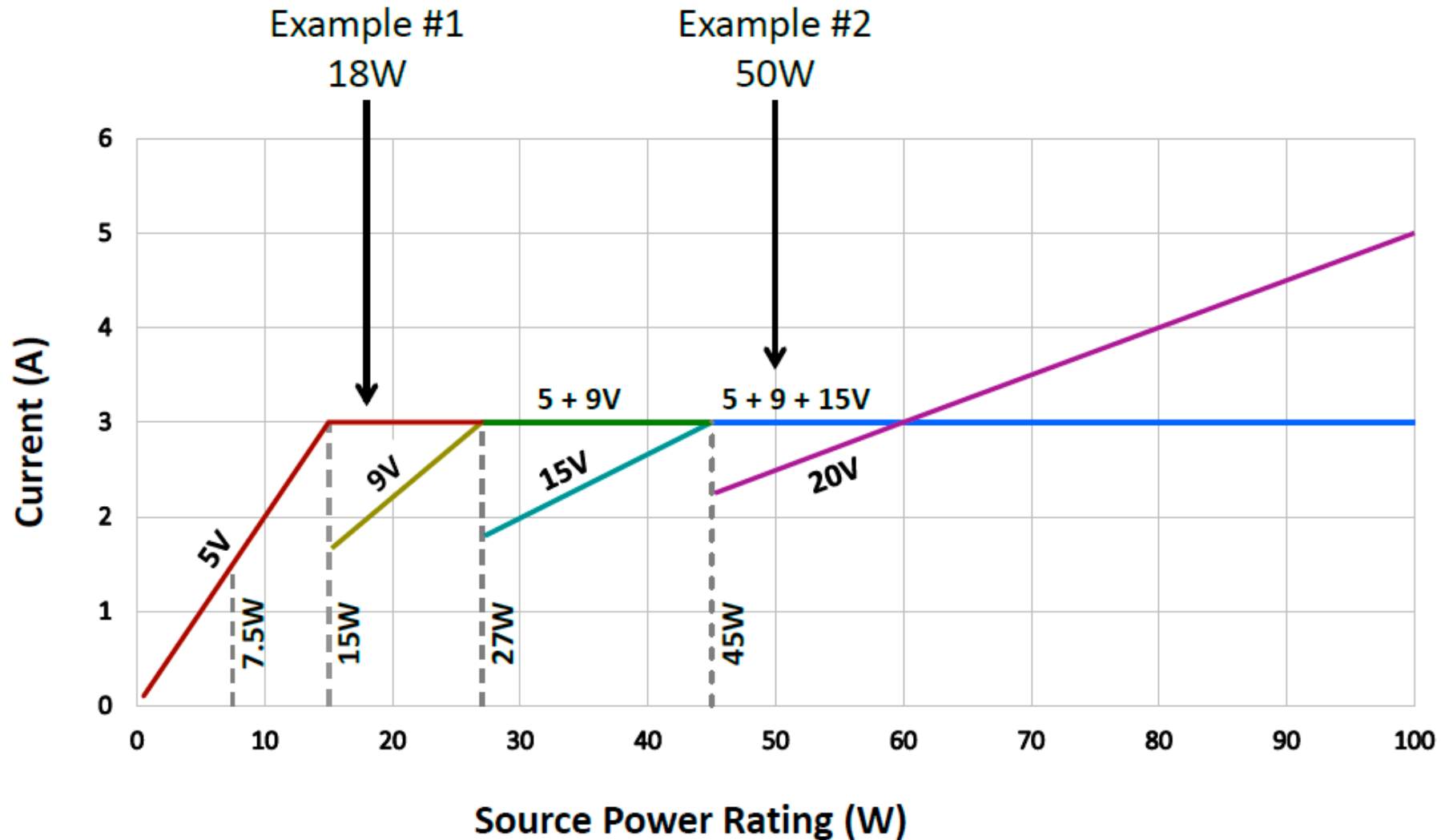




# USB Type-C: More Power Options

Mode of Operation	Nominal Voltage	Maximum Current	Notes
<b>USB 2.0</b>	5 V	500 mA	Default current, based on definitions in the base specifications
<b>USB 3.1</b>	5 V	900 mA	
<b>USB BC 1.2</b>	5 V	Up to 1.5 A	Legacy charging
<b>USB Type-C @ 1.5 A</b>	5 V	1.5 A	Supports high power devices
<b>USB Type-C @ 3.0 A</b>	5 V	3 A	Supports higher power devices
<b>USB PD</b>	Configurable up to 20 V	Configurable up to 5 A	Directional control and power level management

# USB Type-C Power Rules



# USB Type-C™ Pin Outs Functions

Enhance ease of use

Receptacle



A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1-	V <sub>BUS</sub>	CC1	D+	D-	SBU1	V <sub>BUS</sub>	RX2-	RX2+	GND
GND	RX1+	RX1-	V <sub>BUS</sub>	SBU2	D-	D+	CC2	V <sub>BUS</sub>	TX2-	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Two pins on the USB Type-C receptacle, CC1 and CC2, are used in the discovery, configuration and management of connections across the USB Type-C cable

Plug



A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2-	V <sub>BUS</sub>	SBU1	D-	D+	CC	V <sub>BUS</sub>	TX1-	TX1+	GND
GND	TX2+	TX2-	V <sub>BUS</sub>	V <sub>CONN</sub>			SBU2	V <sub>BUS</sub>	RX1-	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

On a standard USB Type-C cable, only a single CC wire within each plug is connected through the cable to establish signal orientation. The other CC pin is repurposed as V<sub>CONN</sub> for powering electronics  
Also, only one set of USB 2.0 D+/D- wires are implemented

High Speed Data Path  
(RX for USB 3.1, or reconfigured in Alternate Mode)

High Speed Data Path  
(TX for USB 3.1, or reconfigured in Alternate Mode)

USB 2.0 Interface

Cable Bus Power  
(from 5V up to 20V)

Sideband use

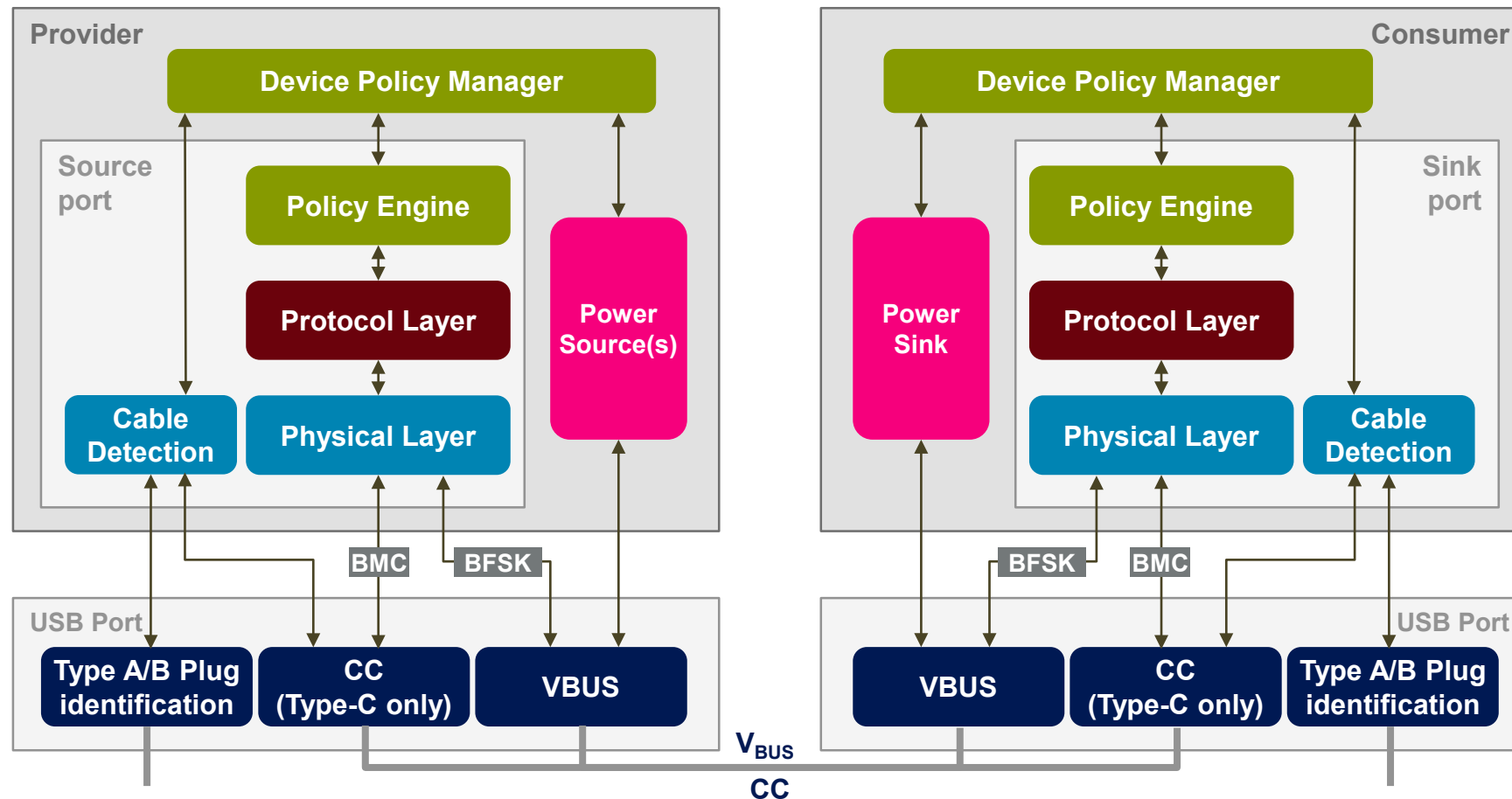
Cable Ground

Configuration Channel



# Architecture

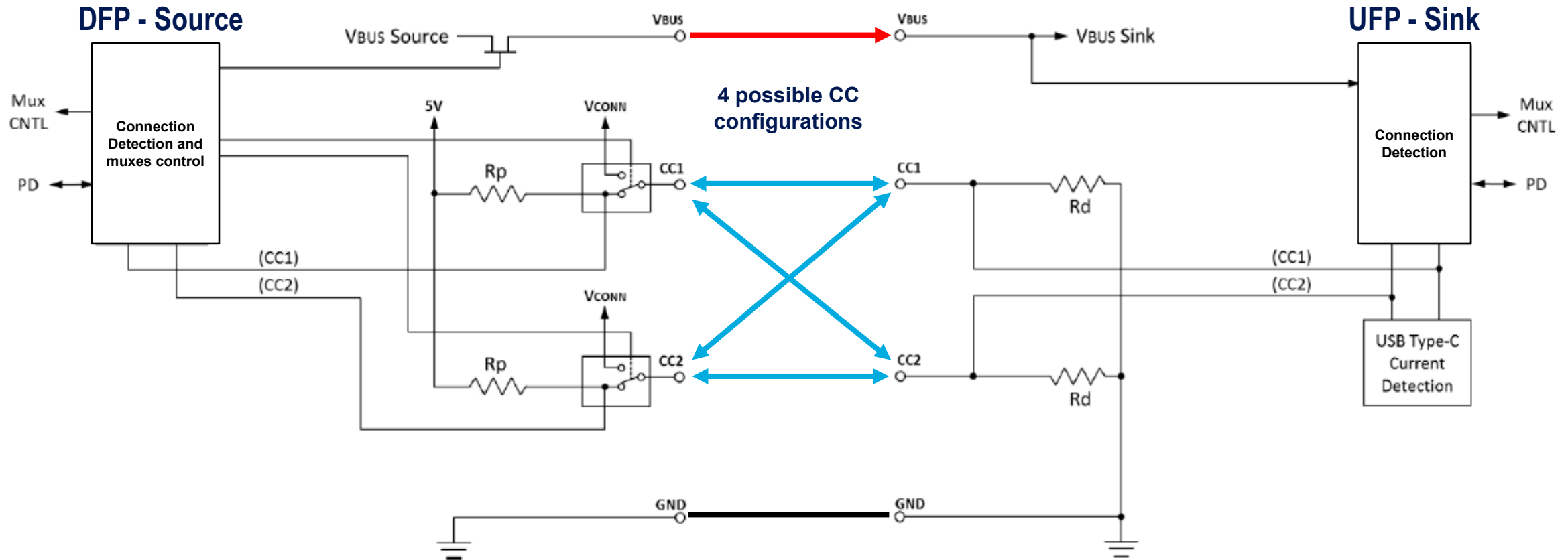
## Architecture and key words



Communication across the channel uses Biphase Mark Coding (BMC) over CC in Type C connector



# USB Type-C CC Connections



- Detect attach/detach of USB ports, e.g. a DFP to a UFP
- **Resolve cable orientation and twist connections** to establish USB data bus routing
- Establish DFP and UFP roles between two attached ports
- Discover and configure VBUS
- USB Power Delivery Communication

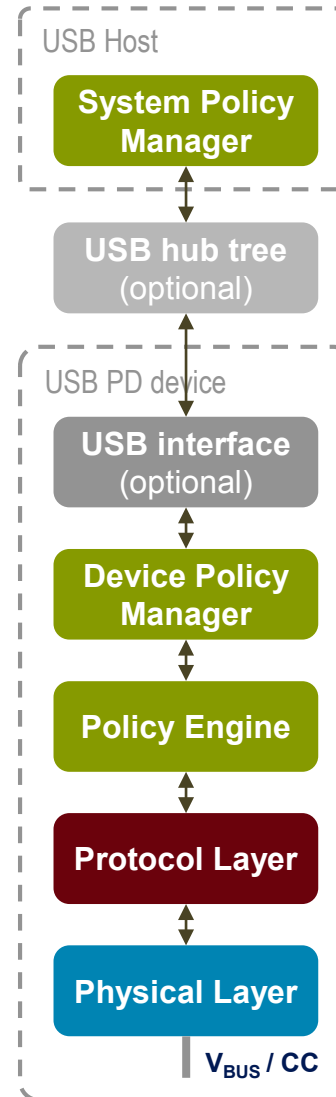
# USB PD Stack & Policy

## Policies

**System Policy Manager** (system wide) is optional. It monitors and controls System Policy between various Providers and Consumers connected via USB.

**Device Policy Manager** (one per Provider or Consumer) provides mechanisms to monitor and control the USB-PD within a particular Provider or Consumer. It enables local policies to be enforced across the system by communication with the System Policy Manager.

**Policy Engine** (one per Source or Sink Port) interacts directly with the Device Policy Manager in order to determine the present local policy to be enforced.



## Protocol Layer

**The Protocol Layer** forms the messages used to communicate information between a pair of ports. It receives inputs from the Policy Engine indicating which messages to send and indicates the responses back to the Policy Engine

## Physical Layer

It is responsible for sending and receiving messages across either the  $V_{BUS}$  or CC wire. It consists of a transceiver that superimposes a signal (BFSK on  $V_{BUS}$  or BMC on CC) on the wire.

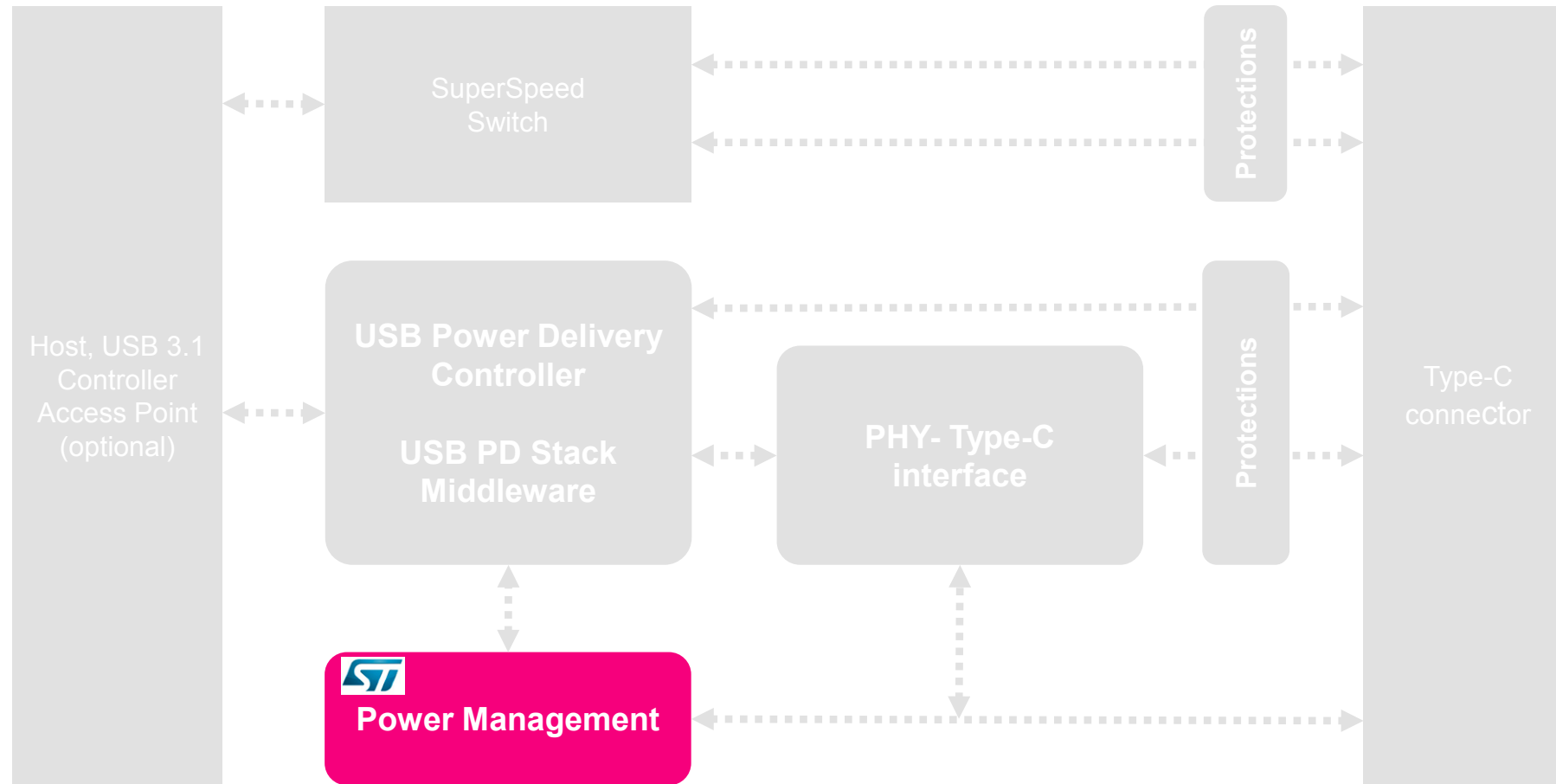
It is responsible for managing data on the wire and for collision avoidance and detects errors in the messages using a CRC

## ST Chipset: A flexible offer in the USB Type-C PD ecosystem



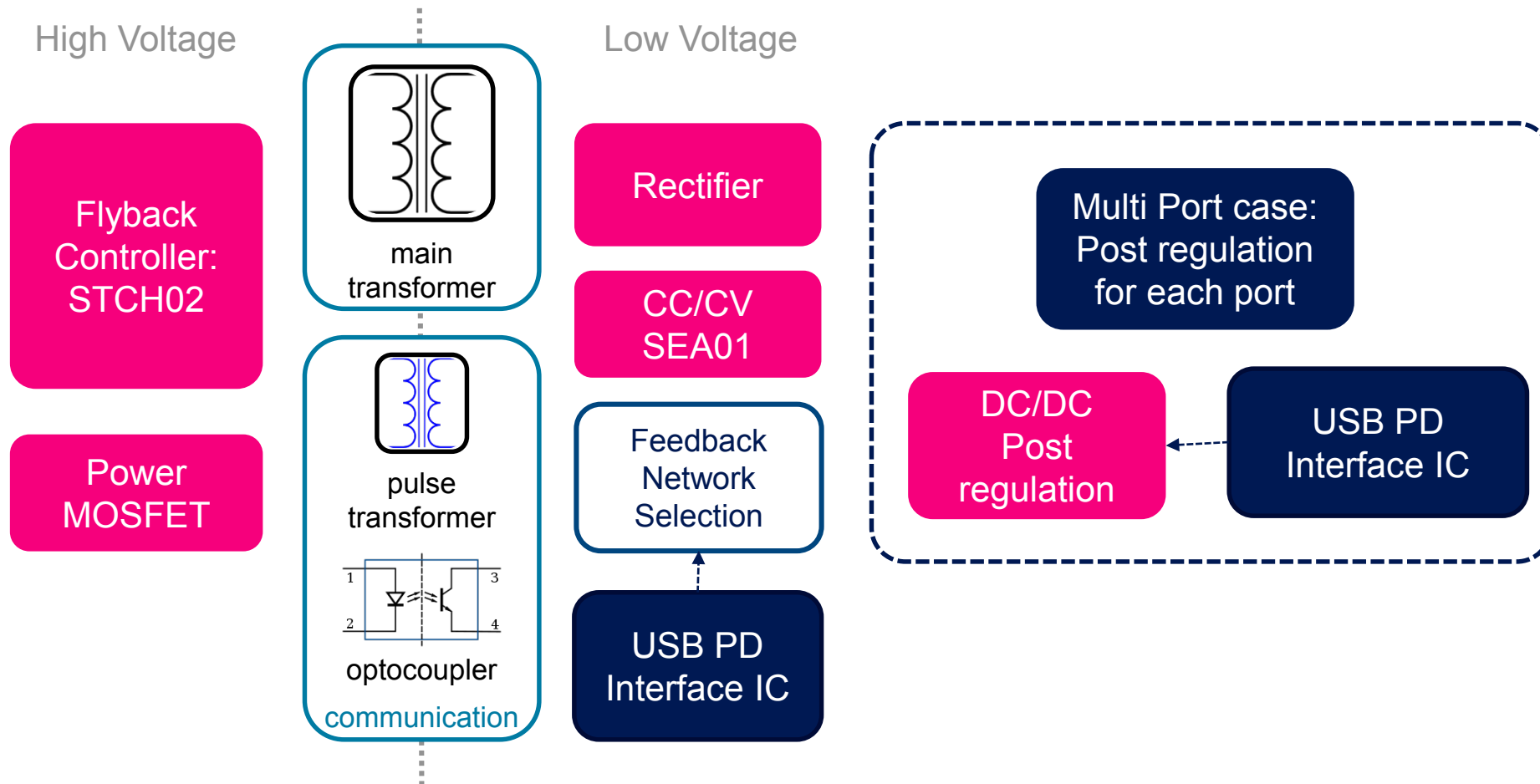
# Power Management

A complete offer to “lean in” USB PD Ecosystem



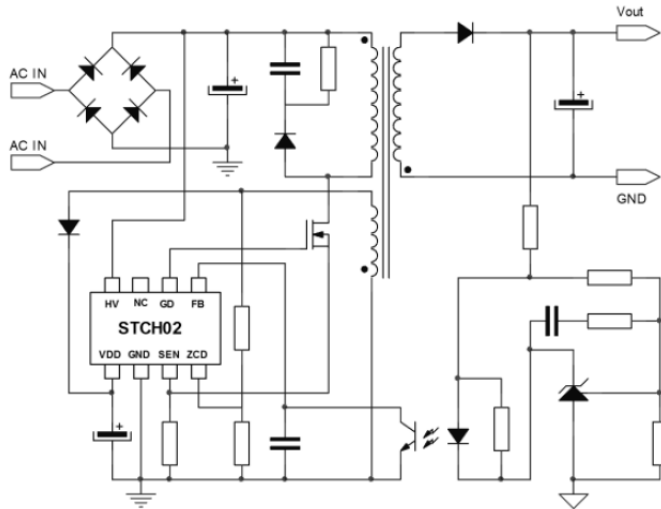
# Profile 1-2-3

## Power source building blocks



- It covers profile 1-2-3 from 5W to 45W
- High Efficiency
- Low EMI design: intelligent Jitter for EMI suppression

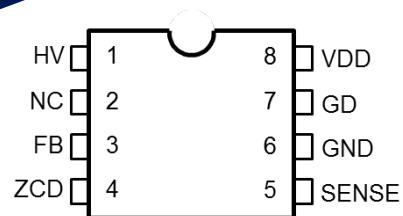
## Primary side controller: Adapters up to 45W



### Features

- Proprietary Constant current output regulation (CC) with no opto-coupler
  - 700V embedded HV start-up circuit
  - Quasi-resonant (QR) Zero Voltage Switching (ZVS) operation
  - Valley skipping at medium-light load and advanced burst mode operation at no-load for under 10mW consumption
  - Accurate adjustable output OVP
- Low part count. BOM reduction thanks to an extensive features integration
  - Exceeding 5 stars: No-Load power < 10mW
    - HV start-up zero power consumption
    - Advanced burst-mode operation
  - Flexibility: suitable for adapters from 5W to 40W
  - High Efficiency
  - Low EMI design: intelligent jitter for EMI suppression

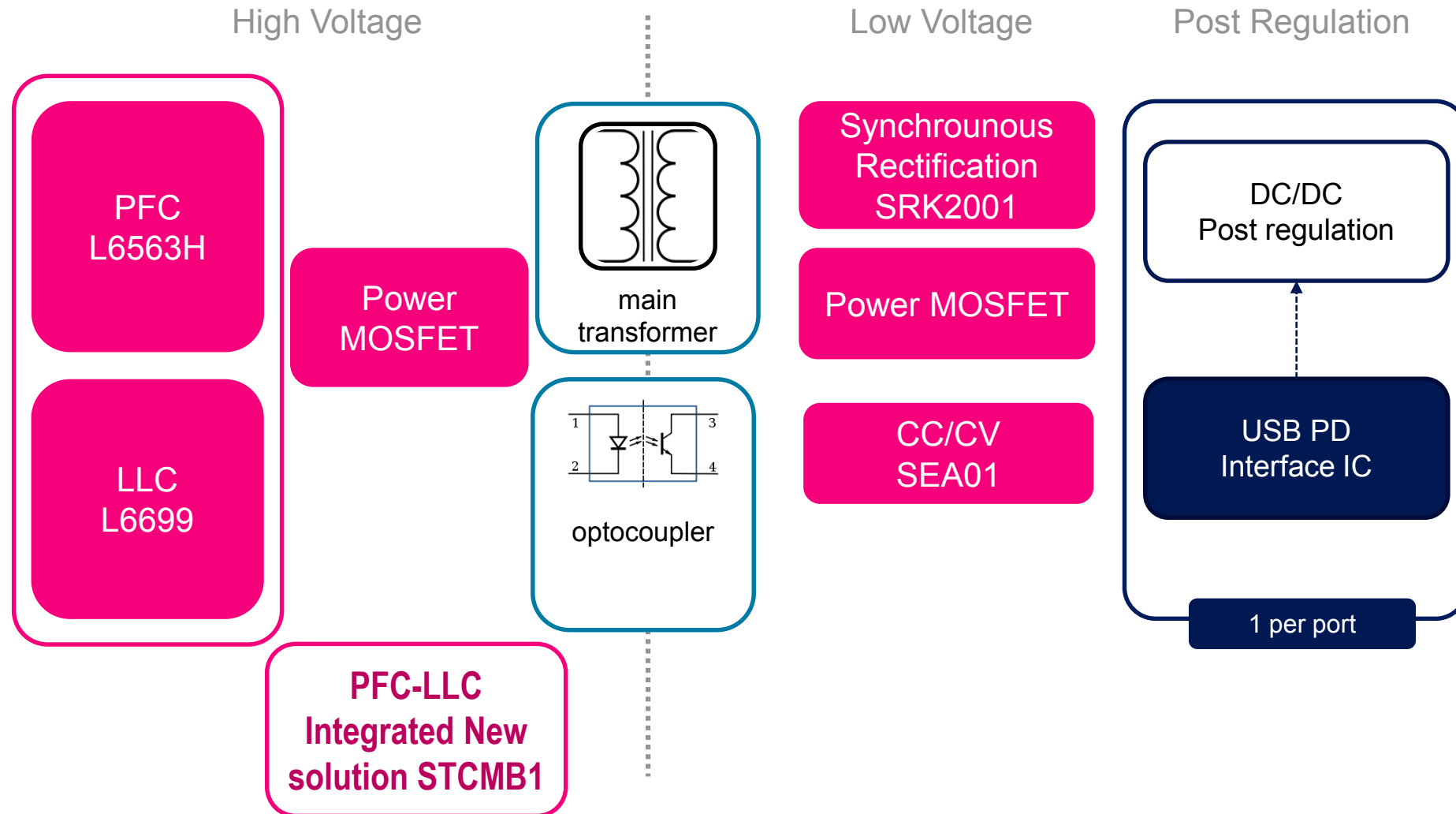
e.s. available



SO8

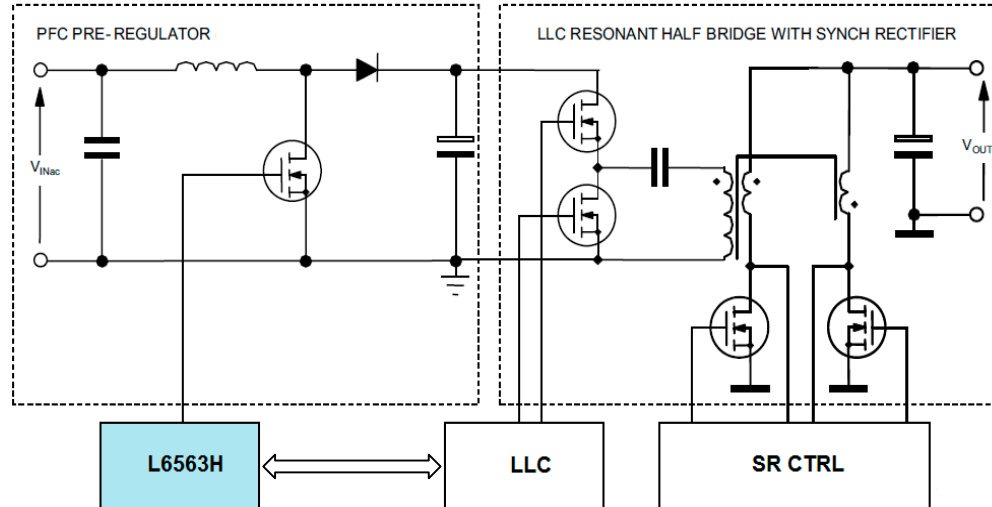
# Profile 4, 5

## Power source building blocks



# L6563H

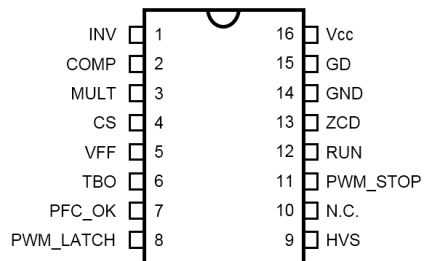
## Transition mode PFC controller



**Datasheet : available on [www.st.com](http://www.st.com)**

### Features

- 700V High Voltage Start-up circuit
- Fast bidirectional input voltage feed-forward
- Adjustable OVP
- AC Brownout Detection
- Tracking boost function
- Inductor saturation protection
- Proprietary THD optimizer circuit
- Interface for cascaded converters
- -600mA/+800mA gate driver



**SO16**

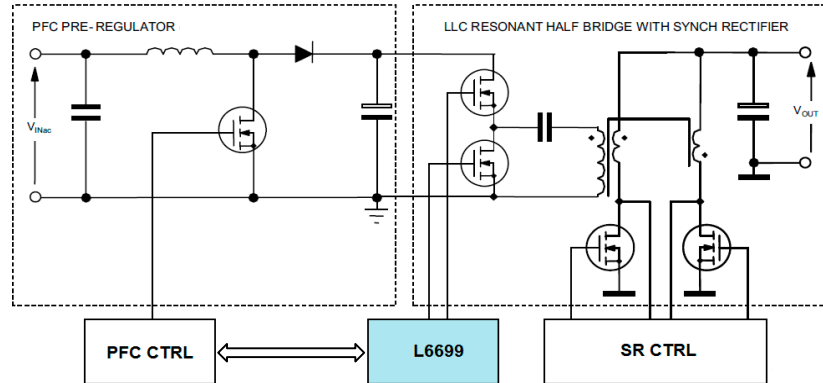
- Low steady state ripple and current distortion with limited under- or overshoot of the pre-regulator's output thanks to new input voltage feed-forward implementation
- Reduced THD of the current
- High reliability thanks to a full set of protections
- HV start-up significantly reduces consumption compared to standard discrete circuit solutions
- Facilitated cooperation with cascaded DC-DC converter thanks to several power management & housekeeping functions



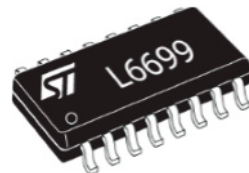
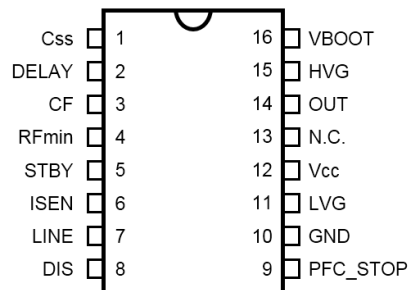
# L6699

## High power adapters 90W to 250W

### Series-resonant half-bridge topology



**Datasheet : available on [www.st.com](http://www.st.com)**



**SO16N**

### Features

- Self adjusting adaptive dead time
- Anti-capacitive mode protection
- Two-level OCP: Frequency shift and Immediate shutdown
- Safe-start procedure
- Burst-mode operation at light load
- Brown-out protection
- Interface with PFC controller

- High efficiency:
  - Reduced internal consumption ( $I_q=1\text{mA}$ )
  - Adaptive dead time allows design optimization to achieve ZVS with lower magnetizing current
- Improved reliability and lifetime thanks to anti-capacitive protection and smooth start-up circuit
- Reduced audible noise when entering burst-mode operation thanks to smooth restart feature

# USB-PD

## Power MOSFET product families

800V-1500V

K5

600V-650V

M2

Price/Performance

M6

Premium efficiency

40-120V

F7

Flyback

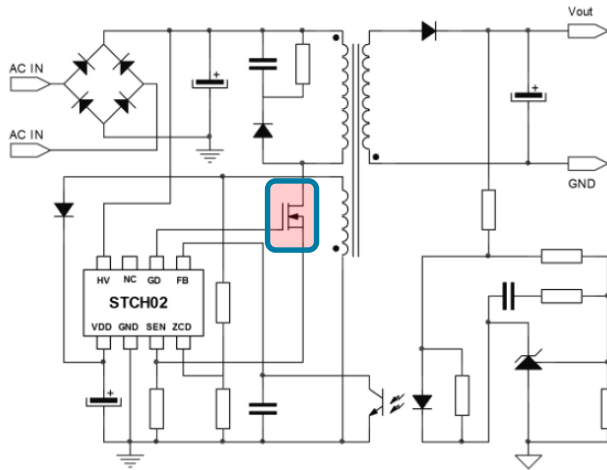
Flyback/PFC/LLC

Synch Rec

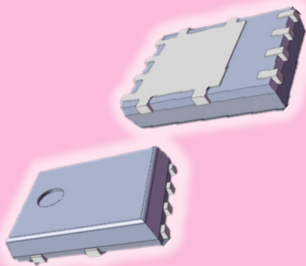


# VHV Power MOSFETs

Flyback Architecture



Outstanding Form Factor



**STL8N80K5**

800V, 950mOhm, 13nC  
PowerFLAT5x6

## Features

- Unmatched  $R_{DS(on)}$  at very high  $B_{VDS}$  - 800-950V-1050V
- Ultra-Low  $Q_G$  and high switching speed
- Extremely low thermal resistance
- High quality & reliability

## Benefits

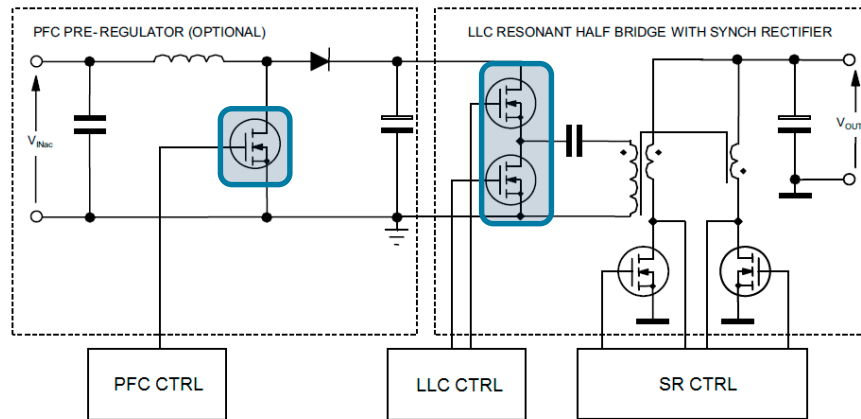
- Lower on-state conduction losses
- Best switching losses
- High efficiency with lower design complexity
- Ultra small Form factor

Product range example

Part Number	$B_{VDS}$	$R_{DS(on)}$	$I_D$
STB13N80K5	800V	0.45Ω	12A
STD8N80K5	800V	0.95Ω	6A
STD9N80K5	800V	0.90Ω	7A

# Power MOSFET

## PFC & LLC architecture



### Product range example

PFC	$V_{DSS}$	$R_{DS(on)}$	$I_D$
STF24N60M2	600V	0.190Ω	18A
STF25N60M2-EP	600V	0.188Ω	18A
STF20N60M2-EP	600V	0.278Ω	13A

### PFC Performance

LLC	$V_{DSS}$	$R_{DS(on)}$	$I_D$
STF9N60M2	600V	0.750Ω	5.5A
STF15N60M2-EP	600V	0.378Ω	11A
STF11N60M2-EP (e.s.available)	600V	0.595Ω	8.0A

### LLC Performance

LLC	$V_{DSS}$	$R_{DS(on)}$	$I_D$
STF9N60M6	600V	0.750Ω	ES April '16
STF10N60M6	600V	0.600Ω	ES April '16
STF13N60M6	600V	0.380Ω	ES April '16

### LLC Premium

### Features

- Up to 30% lower  $Q_G$  vs main competition (equivalent die size)
- 400 – 700V  $BV_{DSS}$  rated
- Back-to-Back G-S Zener protected

### Benefits

- Reduced switching losses
- Enhanced immunity vs ESD & Vgs spikes
- Technologies dedicated to specific topology

### Product range example

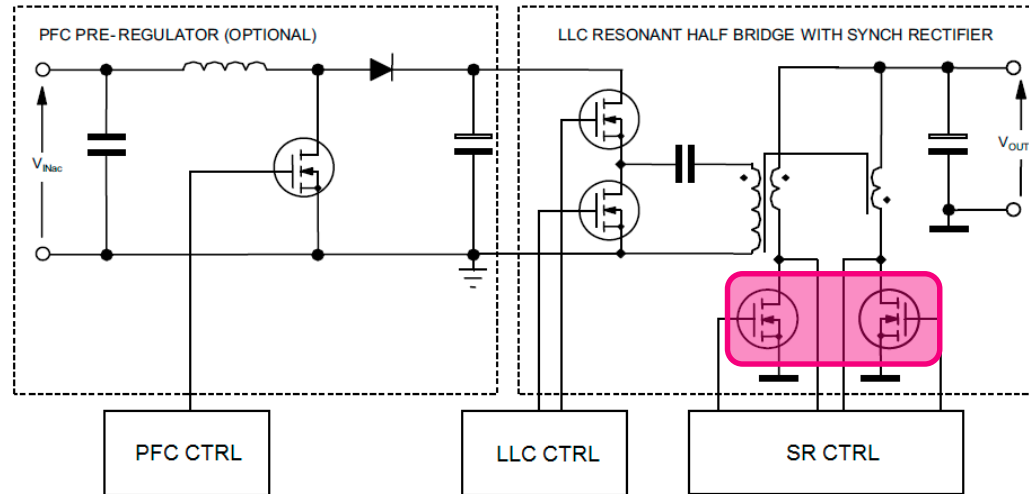


**STL24N60M2**

600V, 210mΩ, 28nC  
PowerFLAT8x8

# Power MOSFETs

## Synchronous rectification



Part Number	Voltage	Ron	Current
STL260N4LF7	40V	<1.1mΩ	5.5A
STL200N45LF7	40V	<1.8mΩ	11A

### Features

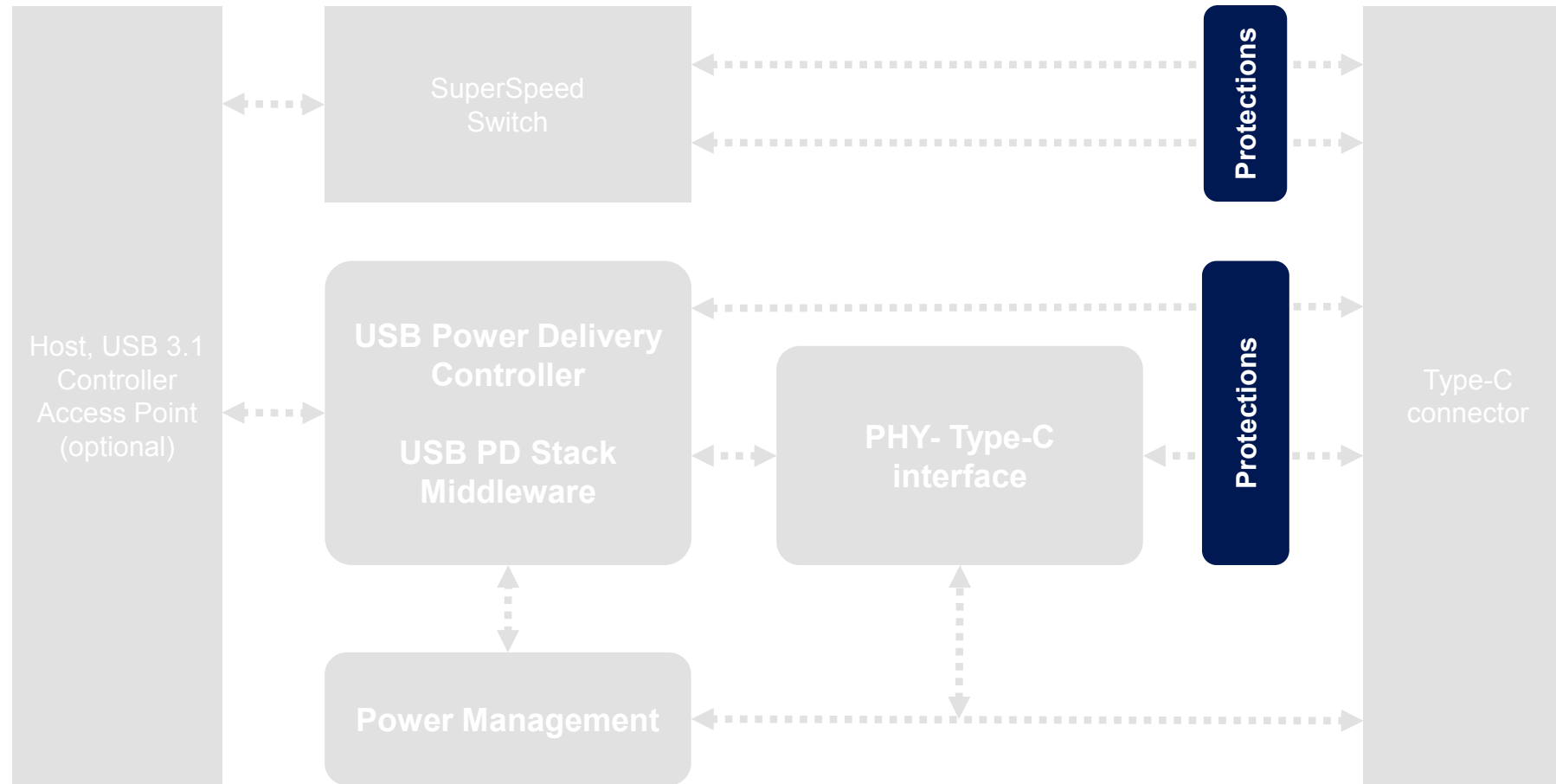
- Very low  $R_{DS(on)}$
- Proper  $C_{OSS}$
- Low  $V_{SD}$  and  $Q_{RR}$  with soft recovery body-drain diode
- LL  $V_{th}$

### Benefits

- Efficiency improvement due low conduction losses and to static and dynamic diode ones, minimized switching noise and Vds spike at turn OFF
- Easy driving features

# Protections

A complete offer to “lean in” USB PD Ecosystem



# Protections

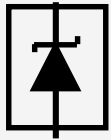
## ESD/CMF/ECMF

High flexibility for the Designers needs to find best compatibilities



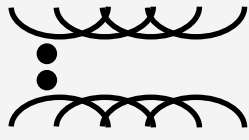
**ESD Protection**

- Robustness: Surge capability up to 25kV and low clamping
- Flexibility & Integration: Single or multi lines products
- Transparency: High bandwidth for high speed signals



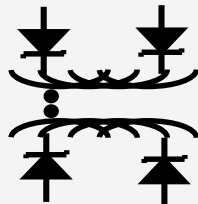
**ESD**

+



**CMF**

- High quality of protection
- Unique filtering shape capabilities
- Serial Interface: USB2.0/3.0, MIPI, DP, HDMI
- Filters radiated noise and limits antenna de-sense.

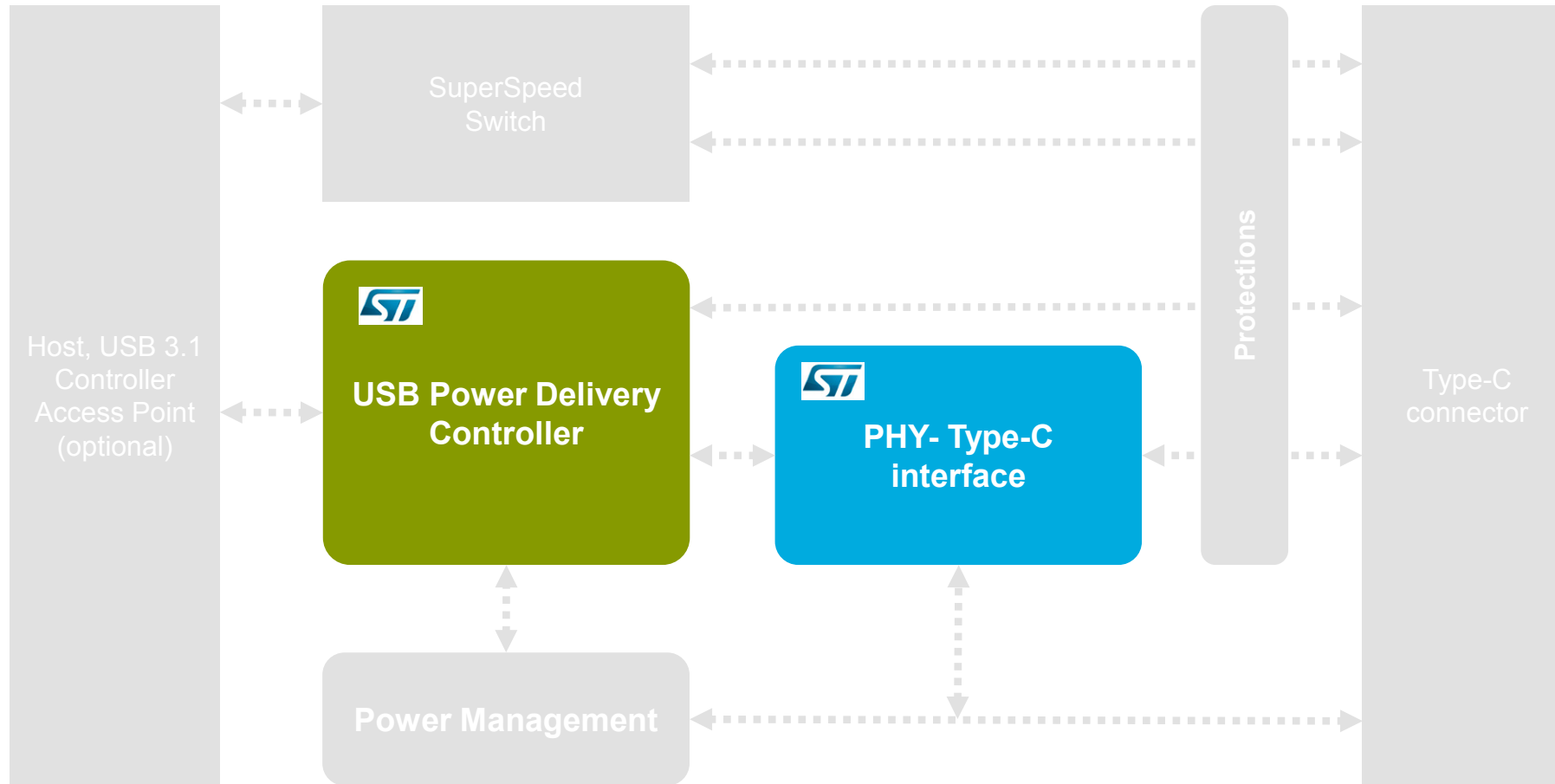


**ECMF = ESD + CMF integrated**

- High quality of protection
- High integration: 1mm<sup>2</sup> / 2 differential lines
- Serial Interface: USB2.0/3.0, MIPI, DP, HDMI
- Filters radiated noise and limits antenna de-sense

# Type-C and USB PD Controller

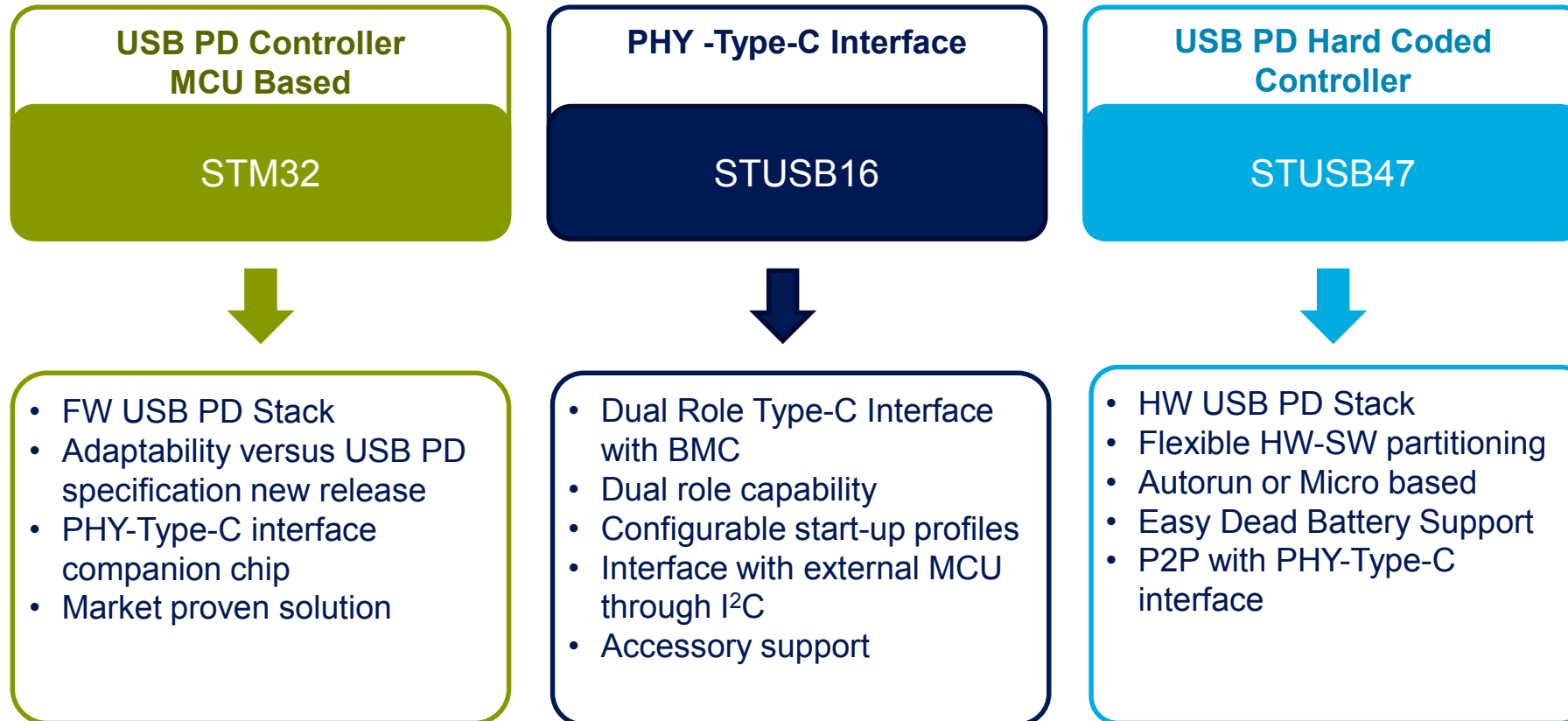
A complete offer to “lean in” USB PD Ecosystem





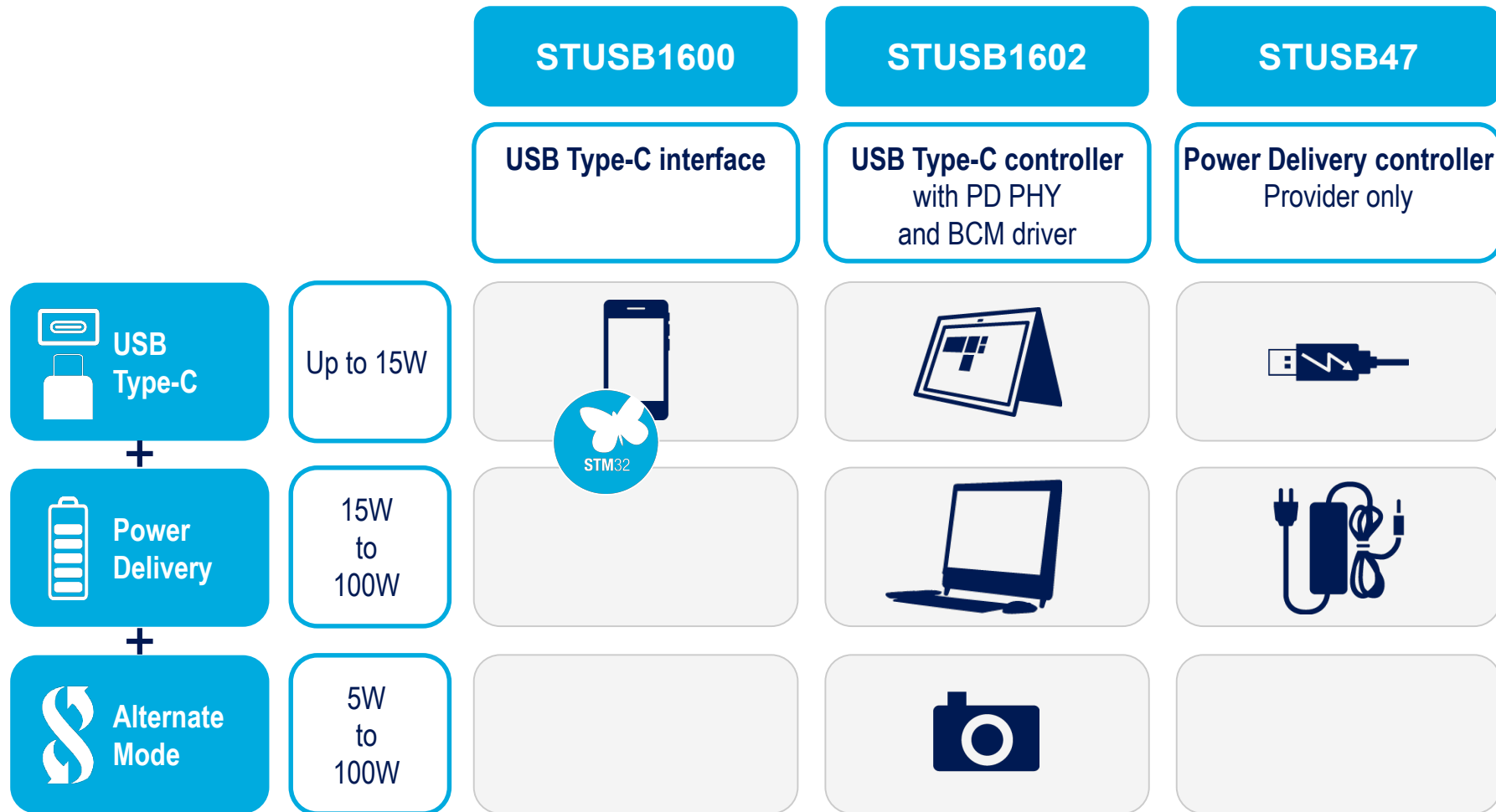
# Controller & Interface

Offering flexible and scalable solutions for designers



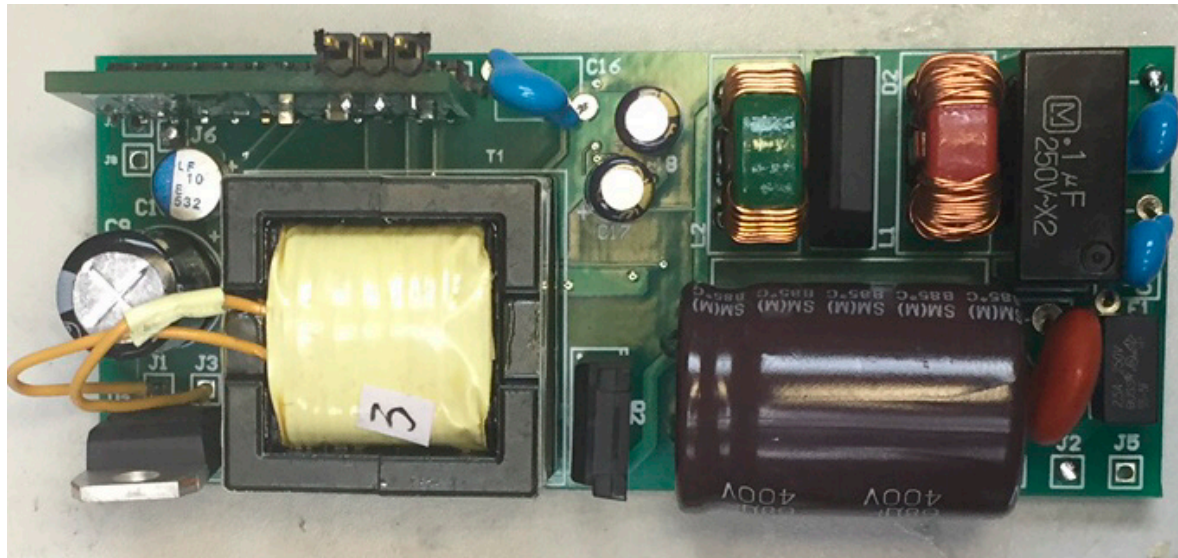
# USB Type-C™ and USB PD Controller

STUSB Family: from USB Type-C Interface to 100% HW Power Delivery Controllers



# USB-PD Provider Solution

- AC/DC Multi-output 45W Converter
  - Based on STCH02 QR controller
  - Multiple Output voltages (5V, 9V, 12V)
- STUSB4700 hard coded controller
  - to interface with USB-C connector
  - to handle the USB Power Delivery protocol
  - No software, better reliability

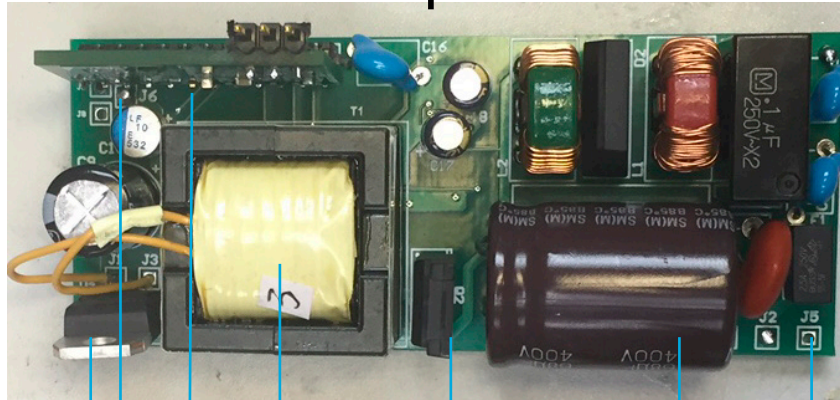


# ST 45W Adapter for ST USB-PD

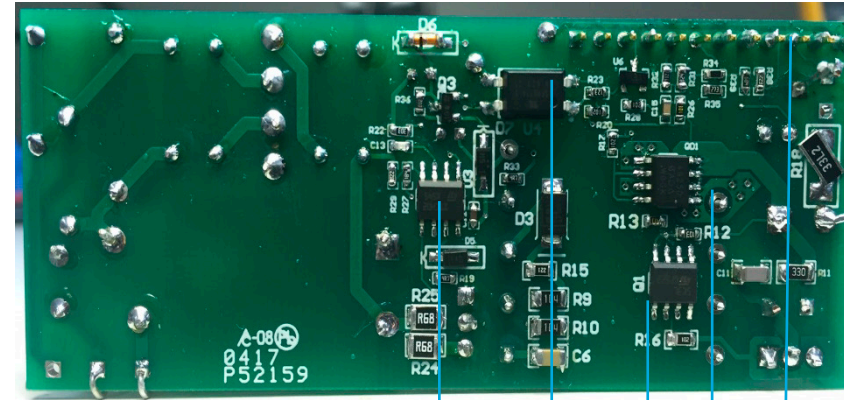
28

Board Layout: dimensions: L=3.47in, W=1.42in, H=0.95in

Top view



Bottom view



AC Input

FERD20H100S

STF10LN80K5

HF XFRM\*

Bulk Cap 68uF, 400V

Control Board with STUSB4700 and TS391

Connection for Captive Cable: Vbus, GND, CC line

Opto

STCH02

Stripline Conn for Control Board

DSCH Switch

Load Switch

\*RM10 Core Replaced EFD20



# USB PD 2.0 Vs. USB PD 3.0

29

USB 3.0 ensures full compatibility with respect to USB 2.0 and requires some additional optional and mandatory features

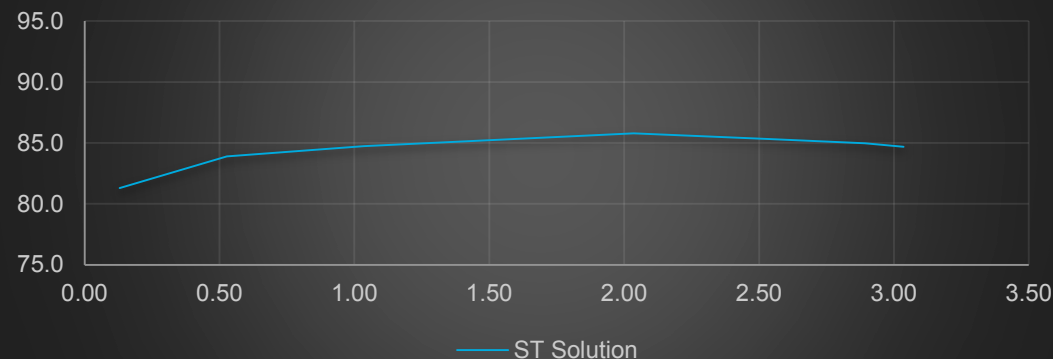
New mandatory features in USB PD 3.0	Enables
Battery status data message (Required for systems with batteries)	Reporting of the battery state of charge
Battery capabilities extended message (Required for systems with batteries)	Reporting of the battery design capacity and last full charge capacity
Tighter control on communication to the cable (Required)	Only the $V_{\text{CONN}}$ source to communicate to the cable plug e-marker
Source-coordinated collision avoidance (Required)	A more robust mechanism to avoid collisions caused when both source and sink want to send messages beyond the typical power negotiation. USB PD 2.0 has a collision-avoidance mechanism, but with the many new optional messages that may be sent in USB PD 3.0 a more robust method was needed
Not supported control message (Required)	A way to inform a port partner that a particular message is not supported. This is meant to help in the future as USB PD 3.0 expands to include more options and features.

- The voltages required by the new “Power Rules” are 5V, 9V, 15V, and 20V.
- USB PD 3.0 new features are not necessary in all application
- A simple Source device may not need USB PD 3.0 new features

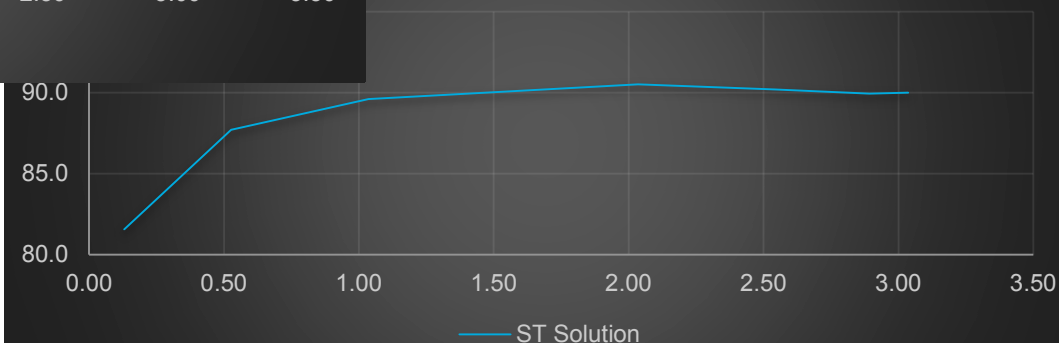
## Efficiency: 120VAC Input Voltage

- Power measured at output capacitor
- Tested at 5V and 15V; Load current swept from 0.1A to 3A
- ST Nucleo USB-PD board connected as a host
- Input Power Measured with Yokogawa WT200
- Output current and Voltage measured with Fluke True RMS Digital Multimeters
- Efficiency measured at room temperature after 20 min operation at full power
- No cable drop compensation

### Efficiency 5V, 120Vac



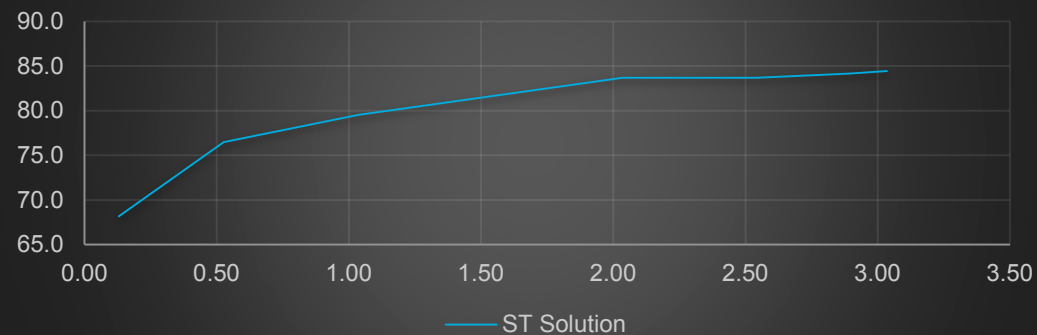
### Efficiency at 15V, 120Vac



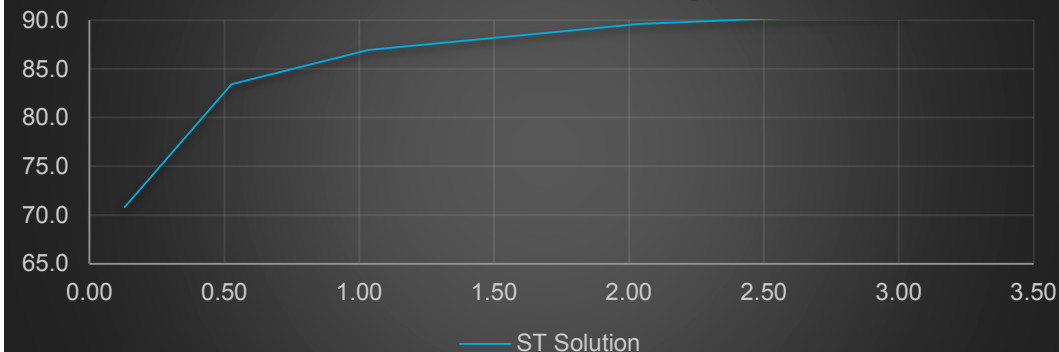
## Efficiency: 230VAC Input Voltage

- Power measured at output capacitor
- Tested at 5V and 15V; Load current swept from 0.1A to 3A
- ST Nucleo USB-PD board connected as a host
- Input Power Measured with Yokogawa WT200
- Output current and Voltage measured with Fluke True RMS Digital Multimeters
- Efficiency measured at room temperature after 20 min operation at full power

### Efficiency 5V, 230Vac



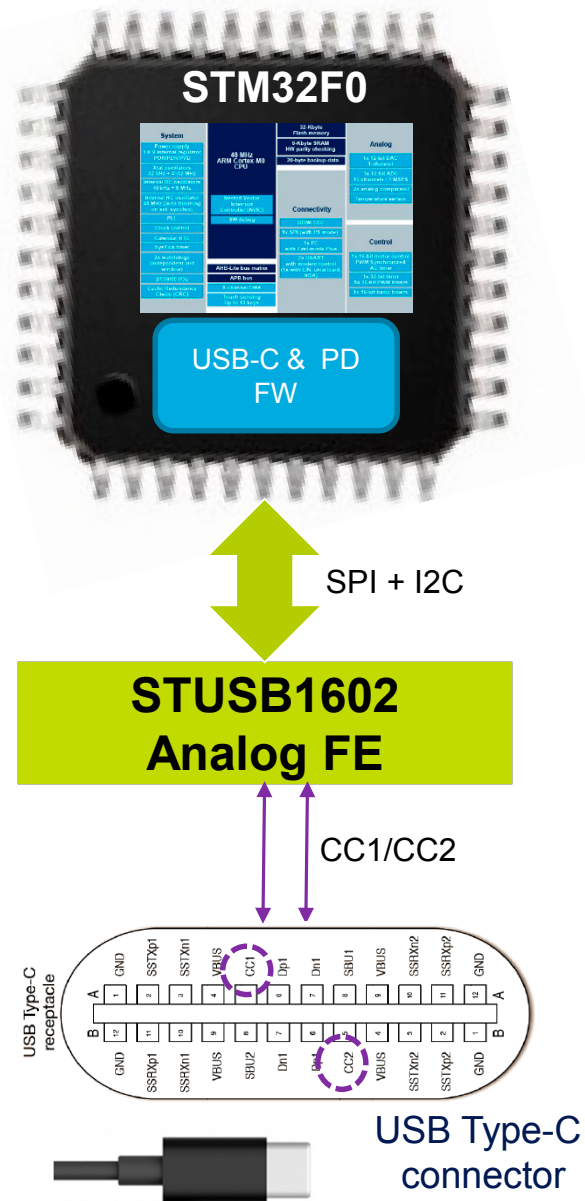
### Efficiency 15V, 230Vac





# USB-PD Dual Role Solution

## MCU + Analog Front-End overview



- STM32 Embedded Software Solution + STUSB1602 AFE
  - Provide Flexibility
  - Possibility to customize the software

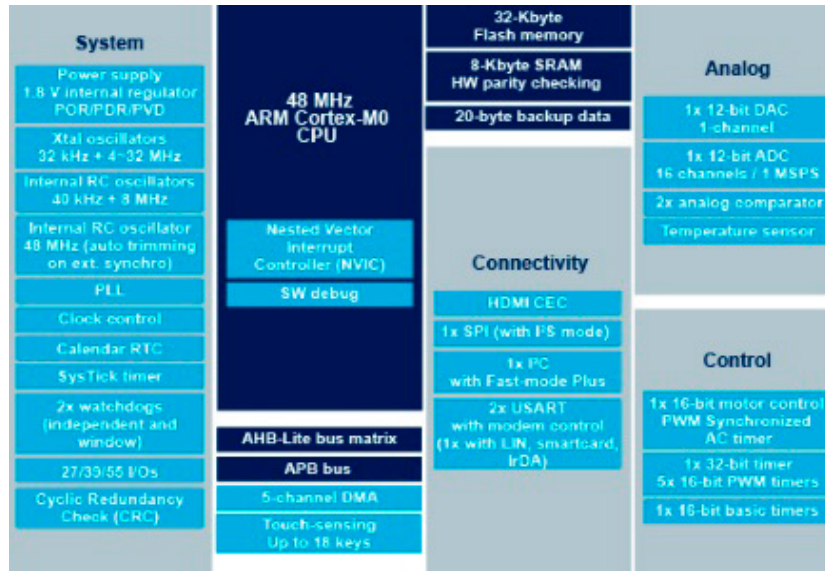
- Hardware : Entry level Cortex-M0 based STM32F0 microcontroller series with simple discrete Analog Front End PHY
- Embedded Software : USB-C & PD Middleware

Best device for 2 ports management : STM32F051 in 48 pin package  
Best device for 1 port management : STM32F051/31 in 20/32 pin package

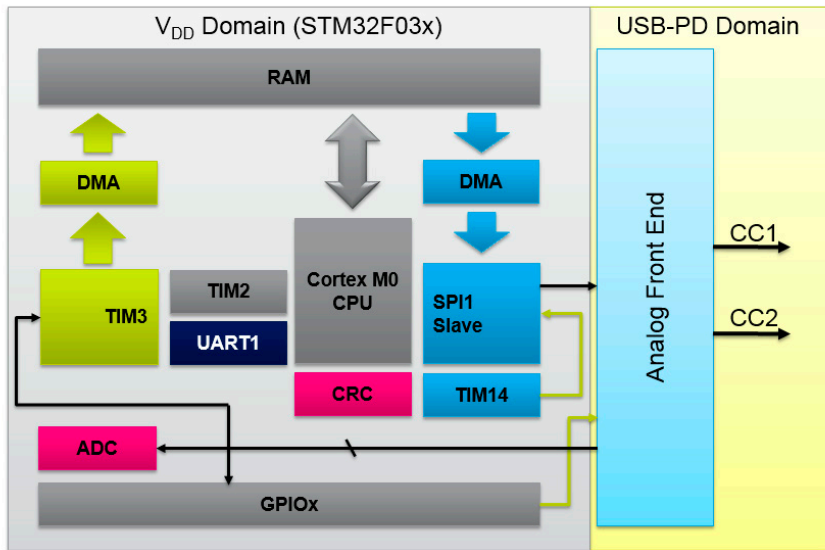


# MCU Overview

## STM32F0 HW resources



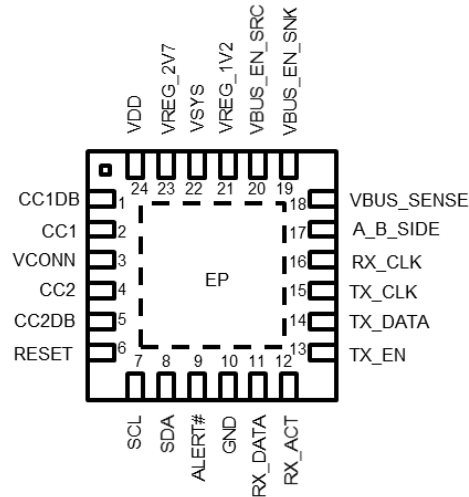
- Transmission uses : **TIM14, SPI1, DMA, GPIO**
- Reception uses : **TIM3, DMA, 1 comparator**
- **TIM2** is used to time-schedule tasks
- Embedded **ADC** to detect device on the CC bus and perform power measurements
- **CRC** to evaluate message's CRC
- Standard GP I/Os to control Vconn, Load switch, Vbus discharge switch, Vout selection (primary feedback...



Project	Flash Memory	RAM Memory
Provider only	25.5 kB	4.4 kB
Provider only (RTOS)	29.0 kB	7.3 kB
Provider/Consumer DRP (RTOS)	30.2 kB	7.3 kB

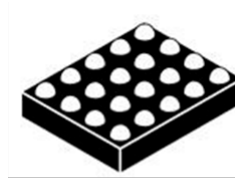
# USB-PD Interface

## STUSB16xx



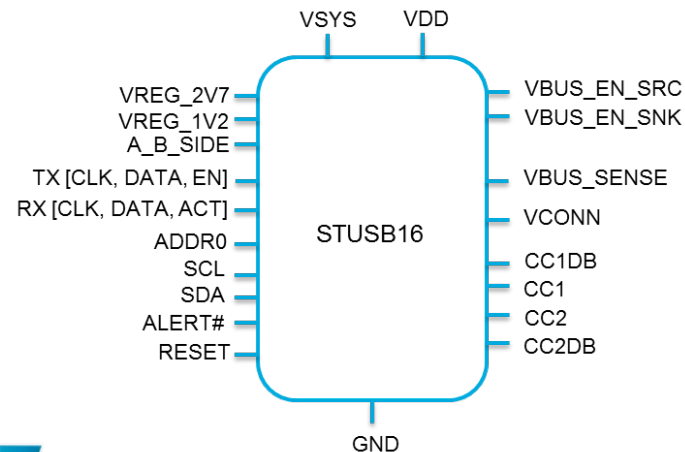
QFN-24 (4x4 mm)

Pin to pin compatible with STUSBxx family



2 x 1.6 mm<sup>2</sup> - 400um  
2.5 x 2 mm<sup>2</sup> - 500um

CSP



### Features

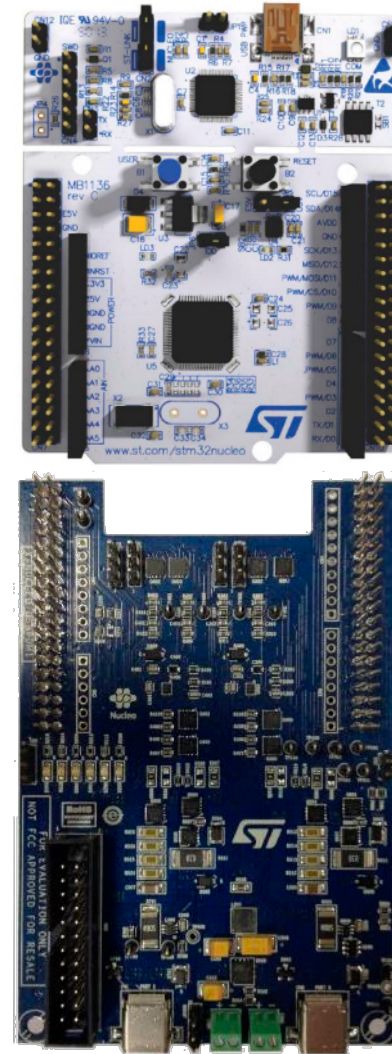
- Dual Role Type-C Interface with BMC
- Dual role capability
- Configurable start-up profiles
- 600mA VCONN
- 120uA Idle current measured
- Interface with external MCU through I<sup>2</sup>C+Interrupt
- Integrated Voltage monitoring
- Integrated V<sub>BUS</sub> discharge path
- Accessory support
- Dual Power supply:
  - V<sub>SYS</sub> = 3.3V,
  - V<sub>DD</sub> [4.6V; 22V] (from V<sub>BUS</sub>)

### Benefits

- Low Pin count
- Integrated BMC transceiver
- Simple, Robust
- Configurable, Flexible
- Optimized for Portable applications
- P2P with STUSB4x

# X-NUCLEO-USBPDM1

- USB-C Power Delivery expansion board with two USB Type-C connectors for two port management
- Main features:
  - Two Dual Role Port
  - Dedicated Power Connector to interface with external Power Supply board providing different profiles (up to 20V and 5A) and  $V_{\text{CONN}}$
  - On-board Power management able to provide internal needed voltages from  $V_{\text{BUS}}$
  - Six debug LEDs
  - USB 2.0 interface capability available on one port
  - Compatible with STM32 Nucleo boards
  - Equipped with ST morpho connectors



# X-NUCLEO-USBPDM1

## Board details

