USB Type-C™ and USB PD Demystified

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STMicroelectronics

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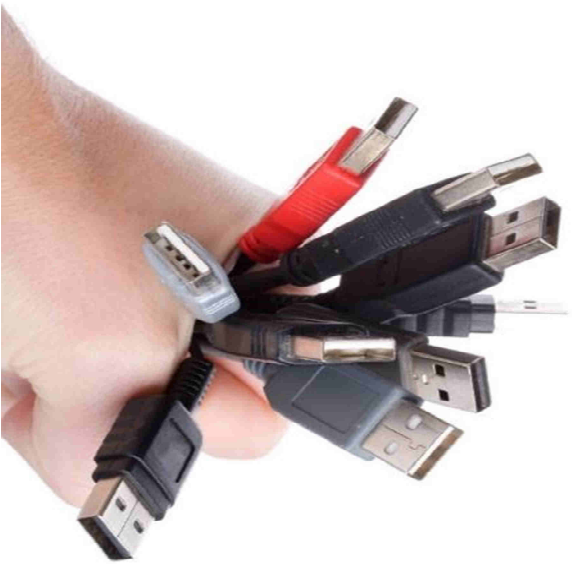
Technology Tour 2019
Vancouver, BC | September 24

Agenda

- USB Type-C and USB Power Delivery Benefits
- USB Type-C Technical Details
- ST Offer
- Evaluation Tools

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



USB Type-C

Power Delivery

USB Data

Alternate Mode

A smart and green technology

- More **flexibility** with a new reversible & thinner connector, more robust
- More **power** with USB Power Delivery (up to 100W)
- More **speed** with USB 3.1 (5/10Gbps) or USB 3.2 (20Gbps)
- More **protocols** (Display Port, HDMI, Thunderbolt 3, …)

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Power, Data & Display: All-in-One interface

Power management

High Speed Data
USB 2.0
USB 3.x

Display Connection
Video + Audio
(DisplayPort™ or HDMI™)

USB Type-C™
USB-C™

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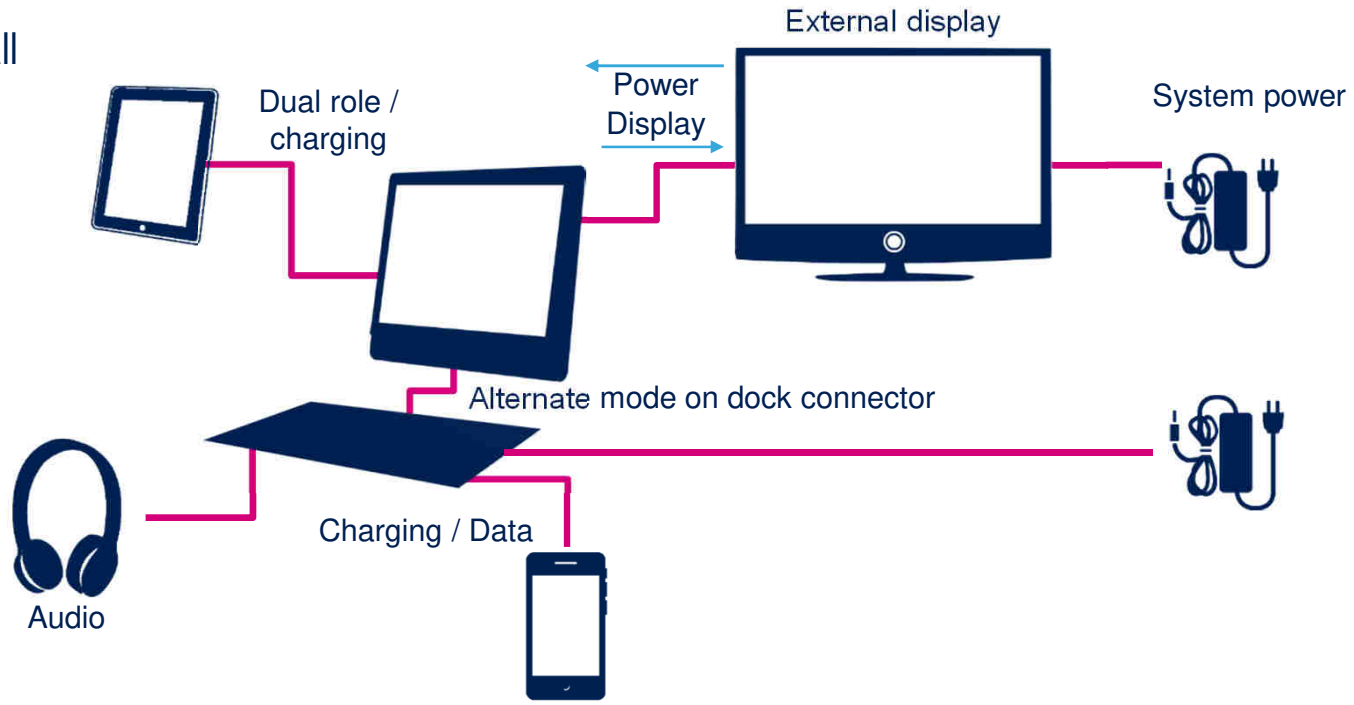
USB Type-C
and USB Power Delivery

Modifying the ecosystem.....enabling new scenarios!

USB Type-C:
One port to rule them all



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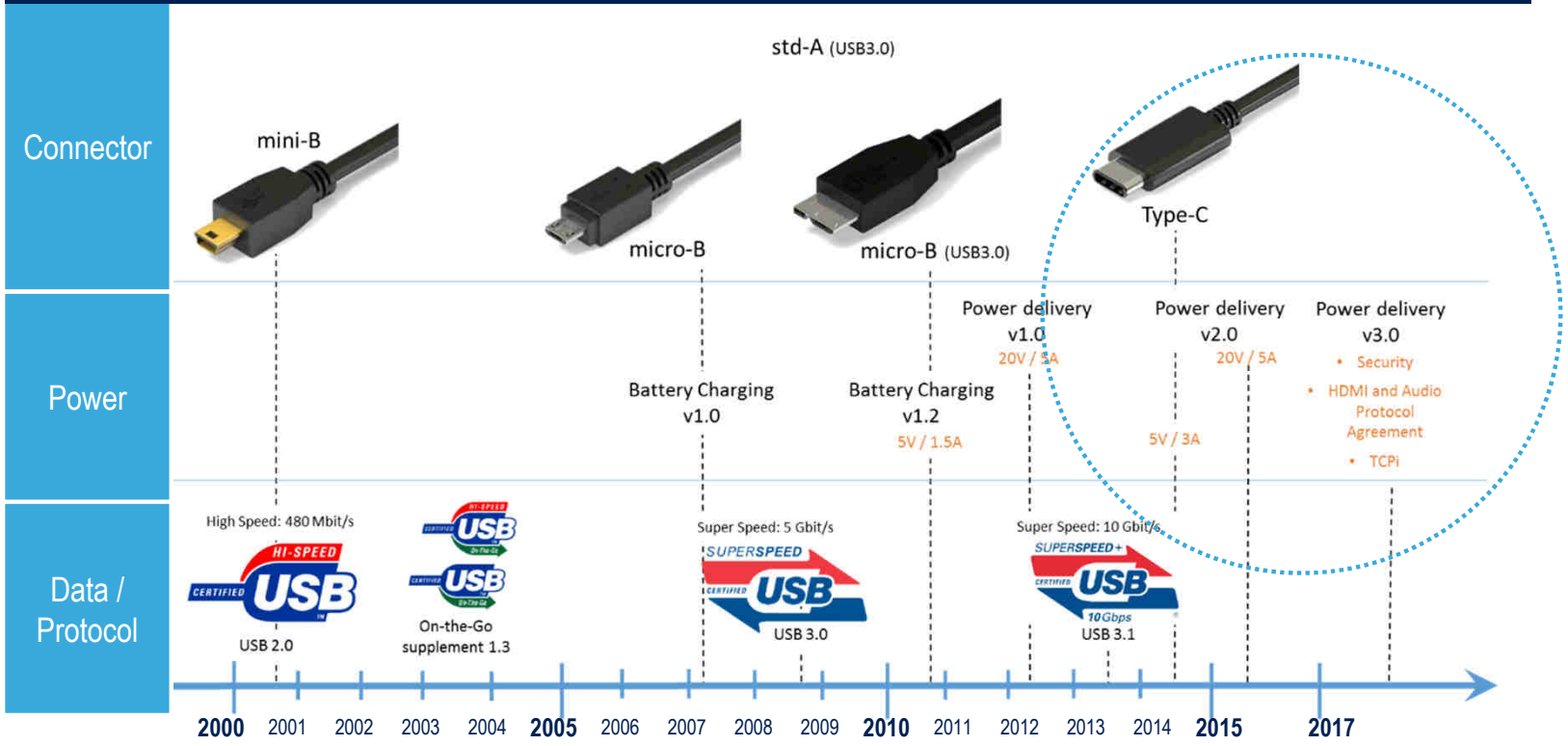
USB Global Evolution

STMicroelectronics is a board member of USB-IF and USB 2.0 & USB 3.0 promoter



http://www.usb.org/developers/powerdelivery/

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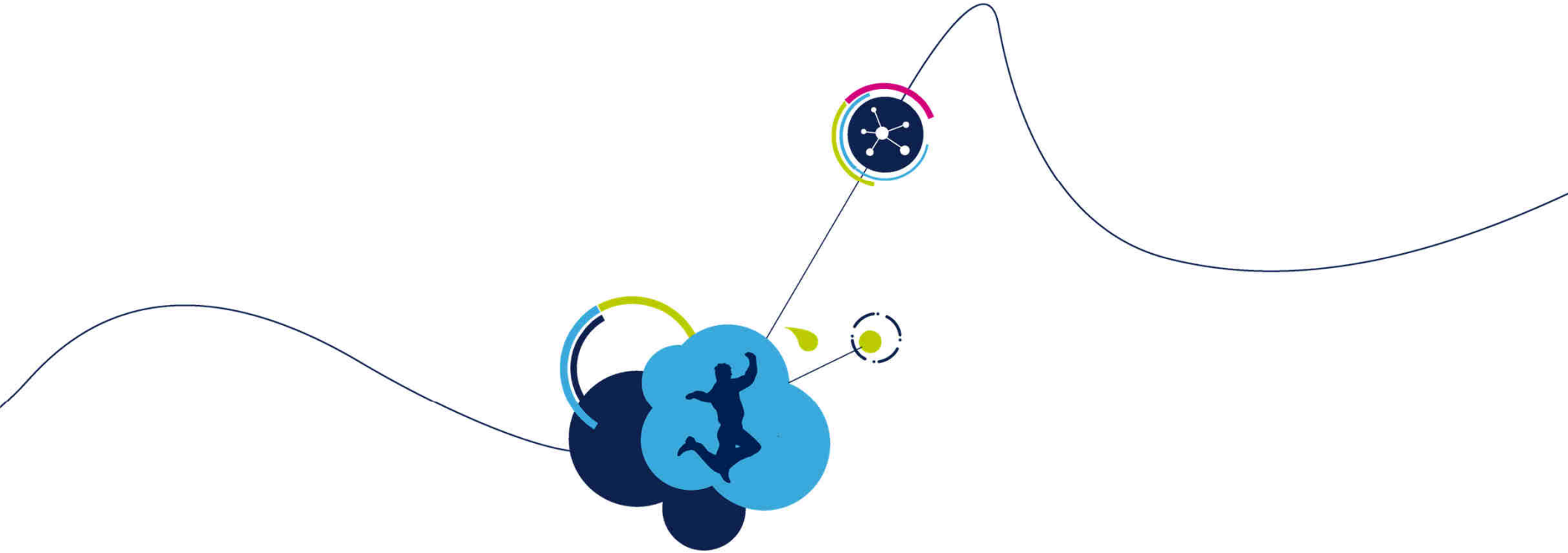

USB Type-C Technical Details

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USB Type-C Pinout Functions

Enhance ease of use

Receptacle

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1-	V_{BUS}	CC1	D+	D-	SBU1	V_{BUS}	RX2-	RX2+	GND
GND	RX1+	RX1-	V_{BUS}	SBU2	D-	D+	CC2	V_{BUS}	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_{BUS}	SBU1	D-	D+	CC	V_{BUS}	TX1-	TX1+	GND
GND	TX2+	TX2-	V_{BUS}	V_{CONN}			SBU2	V_{BUS}	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_{CONN} 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

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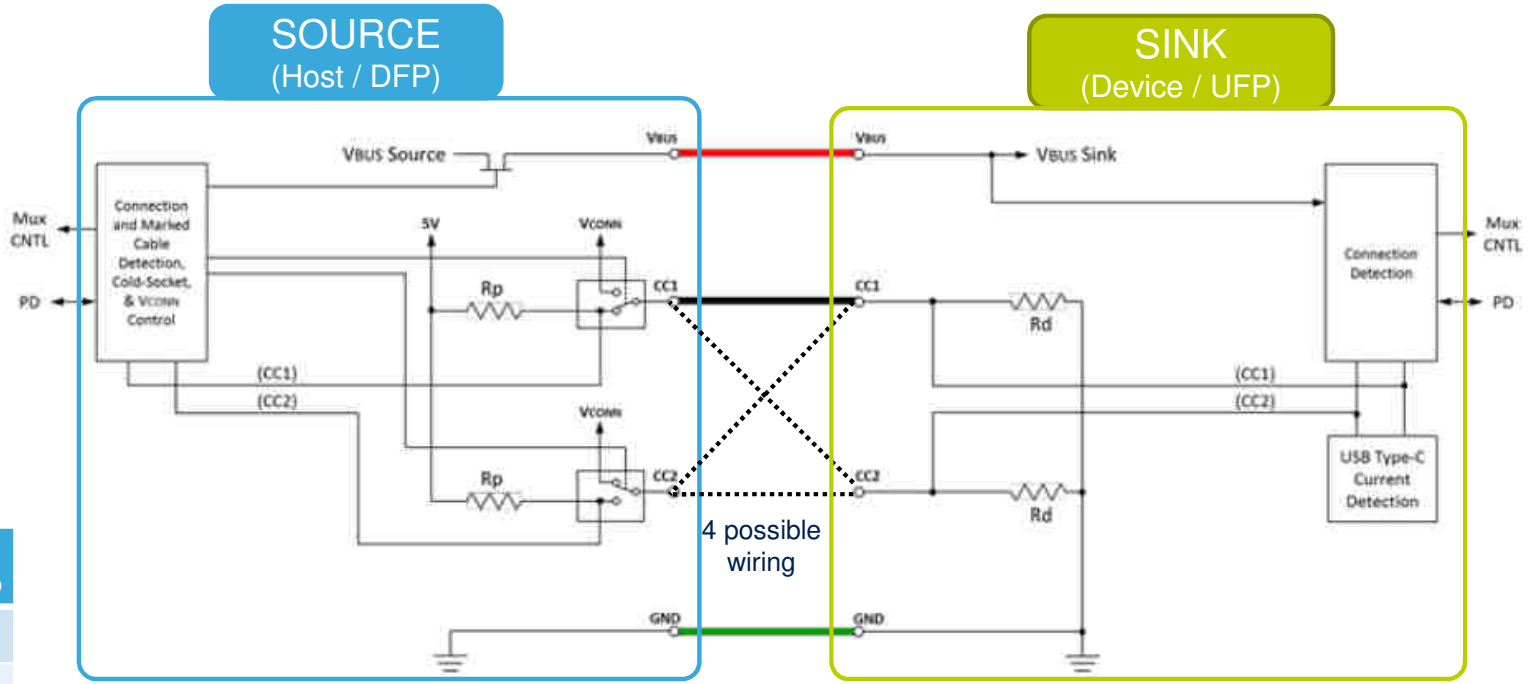
USB-C: Host-to-device Connection



Source Power	Rp pull-up
Legacy current	56 kΩ
1.5A @ 5V	22 kΩ
3A @ 5V	10 kΩ

1. By default: **VBUS is not powered** (cold socket)
2. At insertion detect, the Configuration Channel **(CC pin) is used to solve plug orientation (CC1 or CC2)**
   - HOST identified by Pull-up resistor / current source on its CC pin
   - Device identified by Pull-Down resistor on CC pin
3. After correct Host to Device connection, VBUS is supplied as well as Vconn on the unconnected CC pin
4. Optionally, USB PD, Alternate or Accessory Mode can be supported

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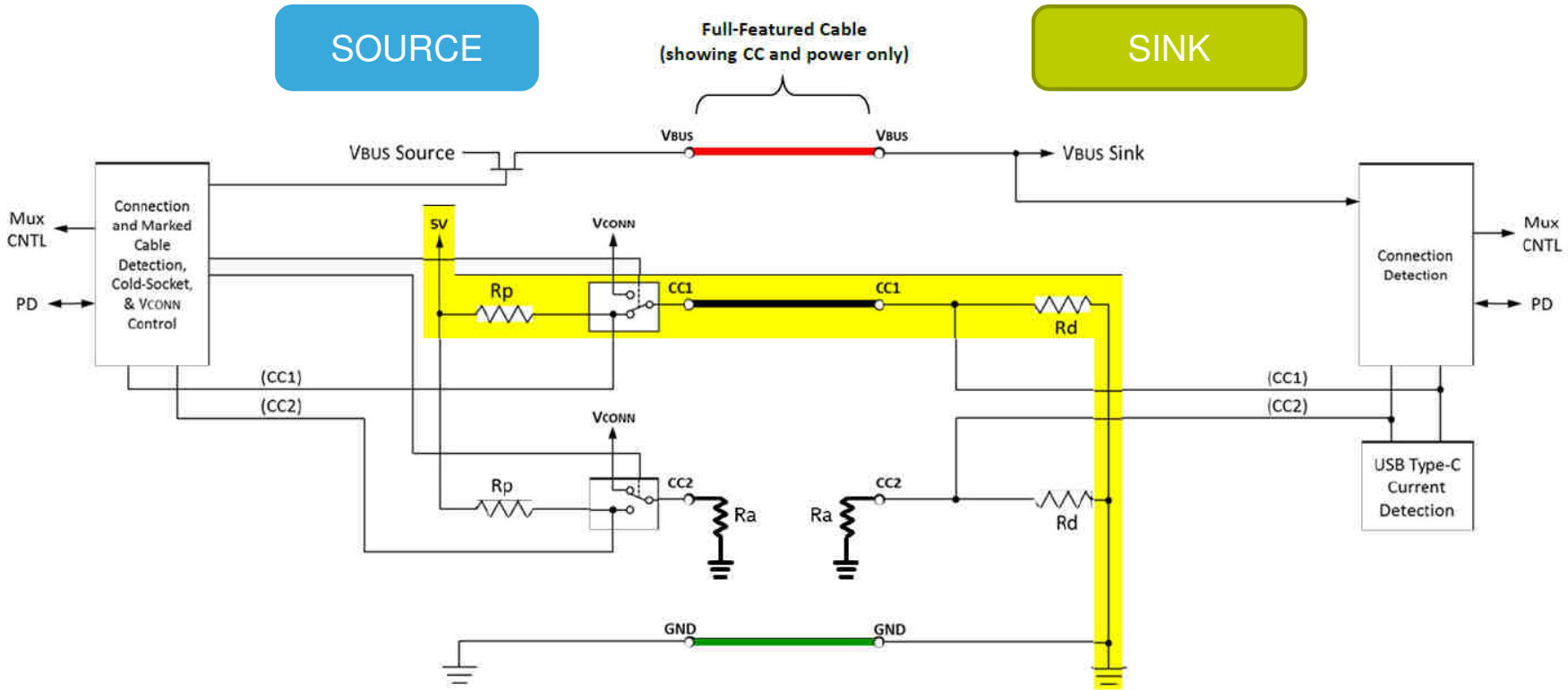
USB-C principle

- Source-Only meets Sink-Only



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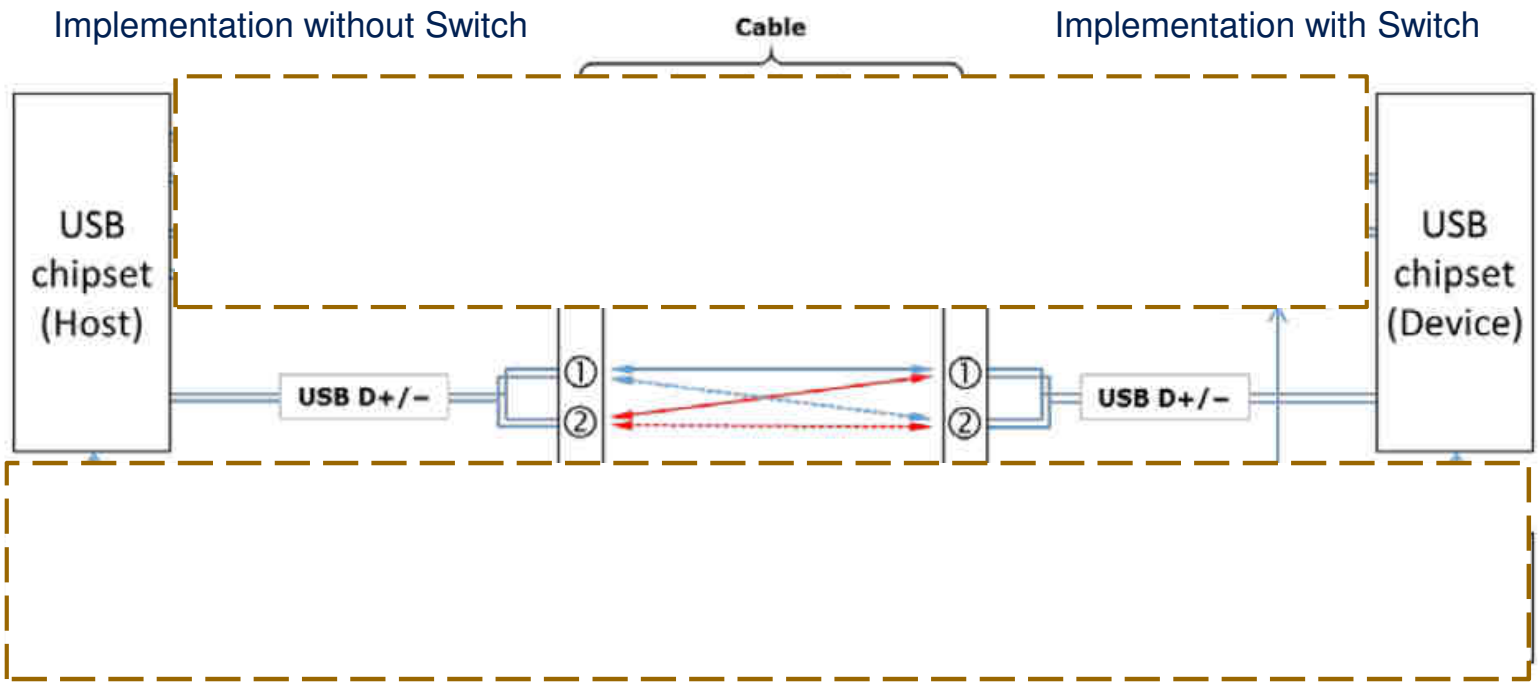
Host-to-device Connection

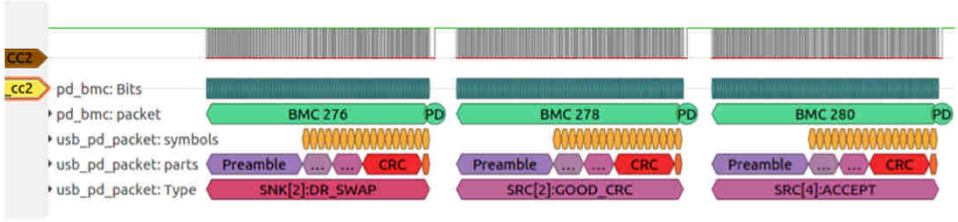
- Logical Model for Data Bus Routing



USB Power Delivery (USB PD)

Key Characteristics

- Voltage and Current values are **negotiated** (via CC pin)
  - Higher voltage and current: power up to 100W (20V / 5A)
- **Swapping** of power direction, data direction and source of VCONN
- Communication with USB Type-C Electronically Marked Cables (**EMC**)
- Support for **Alternate Modes** of operation (DP, MHL, Thunderbolt)
- Signaling :
  - 1-wire communication, bidirectional
  - Half duplex system
  - Biphase Mark Coding (BMC)
  - Bit rate : 300kbps
  - CRC-32 used to detect data corruption



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USB Type-C [vs] USB PD

- USB-C
  - Power: **15W** max
    - 5V/3A, 5V/1.5A, 5V/LegacyCurrent
    - Legacy USB2.0 power: 5V/500mA (after USB enumeration), 5V/100mA (no enumeration)
  - Power Role: Source, Sink, or Dual Role Power (DRP)

- USB-C Power Delivery
  - PD communication occurs on CC line
  - Power: **100W** max (20V@5A)
    - VBUS min= 5V ; max= 20V
    - Several power profiles possible (PDO). e.g.: [5V, 9V, 15V, 20V]
    - Power Role: Source, Sink, or Dual Role Power (DRP)
  - PD mode always starts after USB-C attachment is done (i.e. 5V is available on VBUS at this point)
  - Additional optional features:
    - Swap of Power Role, Swap of Data Role
    - Communicate with EMC cables, VDM, authentication, Alternate modes, Firmware update over CC, ...

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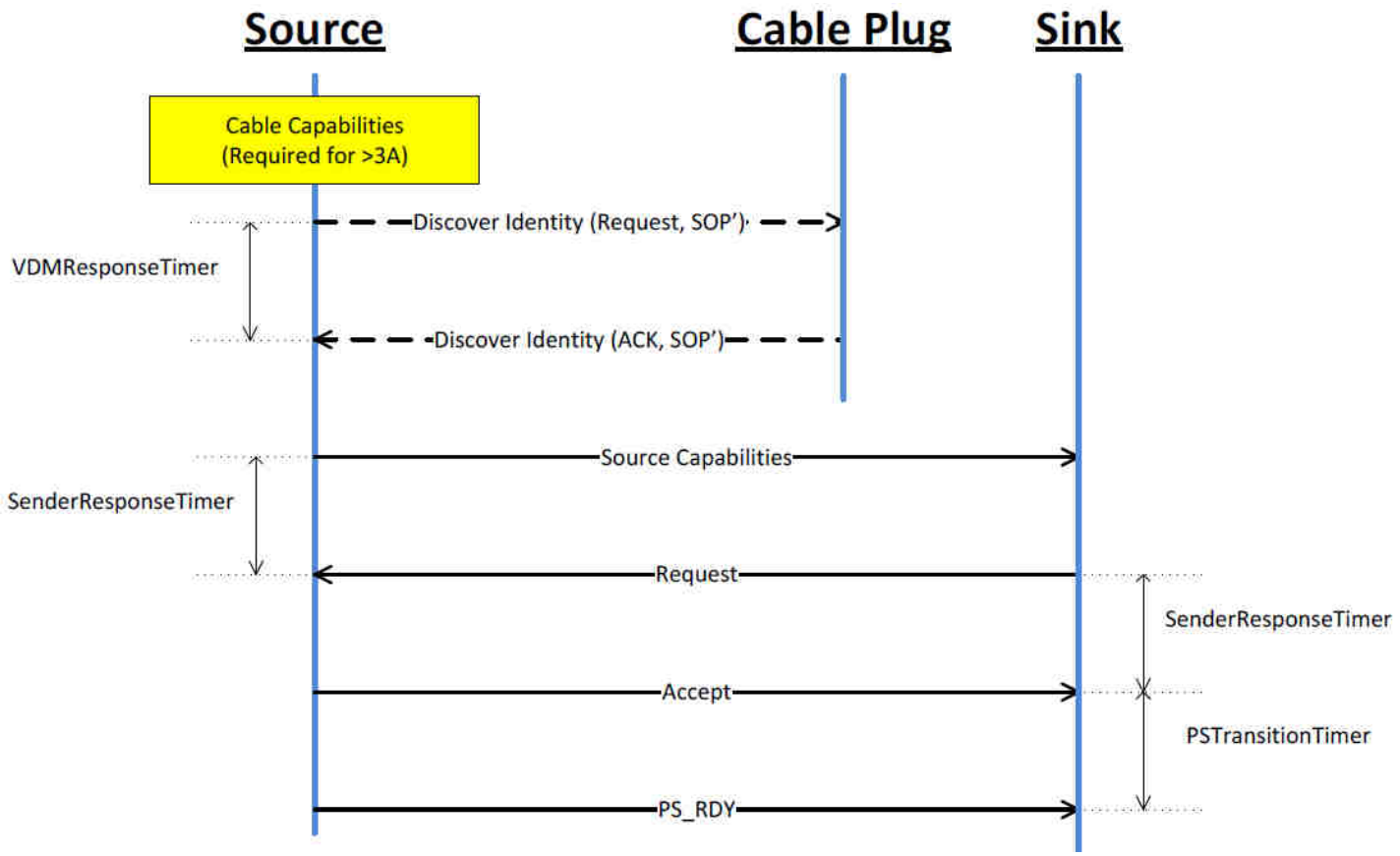
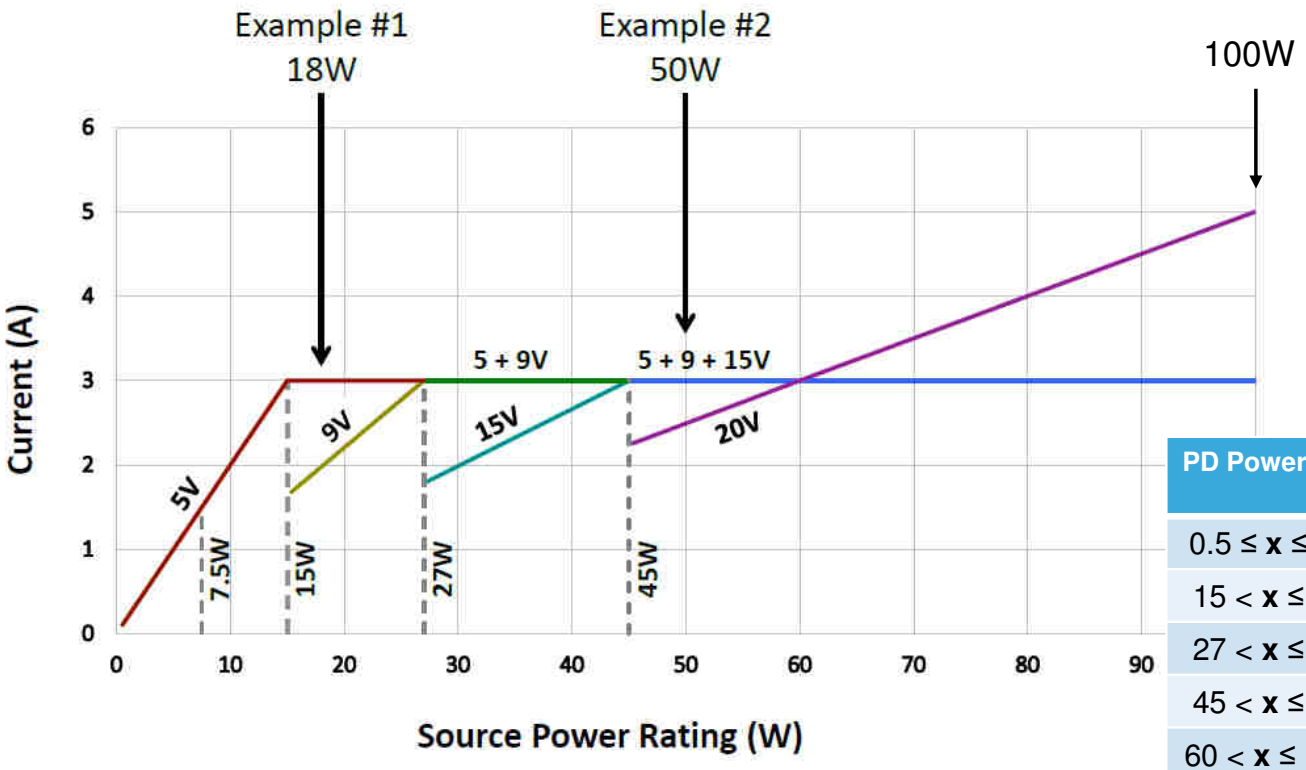
USB-PD: Power Negotiation Sequence



USB-PD 2.0 & 3.0 Power Rules



PDO : Power Data Object
(Voltage, Current)

PD Power (W)	Current (A) at 5V	Current (A) at 9V	Current (A) at 15V	Current (A) at 20V
0.5 ≤ **x** ≤ 15	**x** ÷ 5			
15 < **x** ≤ 27	3	**x** ÷ 9		
27 < **x** ≤ 45	3	3	**x** ÷ 15	
45 < **x** ≤ 60	3	3	3	**x** ÷ 20
60 < **x** ≤ 100	3	3	3	**x** ÷ 20 (*)

(*) Requires a 5A cable

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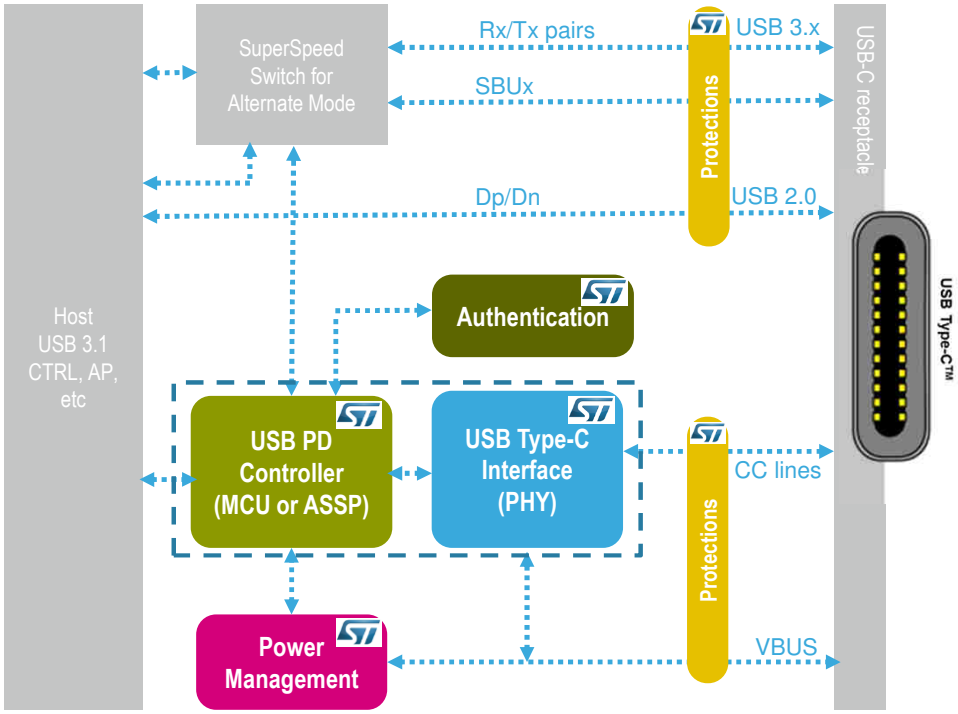
USB Type-C
and USB Power Delivery-enabled subsystems

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



Scalable offer for USB-PD controller and USB Type-C interface: from STM32 general purpose MCU to hard-coded solution to fit different use cases and power ratings

Large product portfolio for protection and filtering covering all the application needs

Highly secure solution using STSAFE secure element family for strong authentication needs

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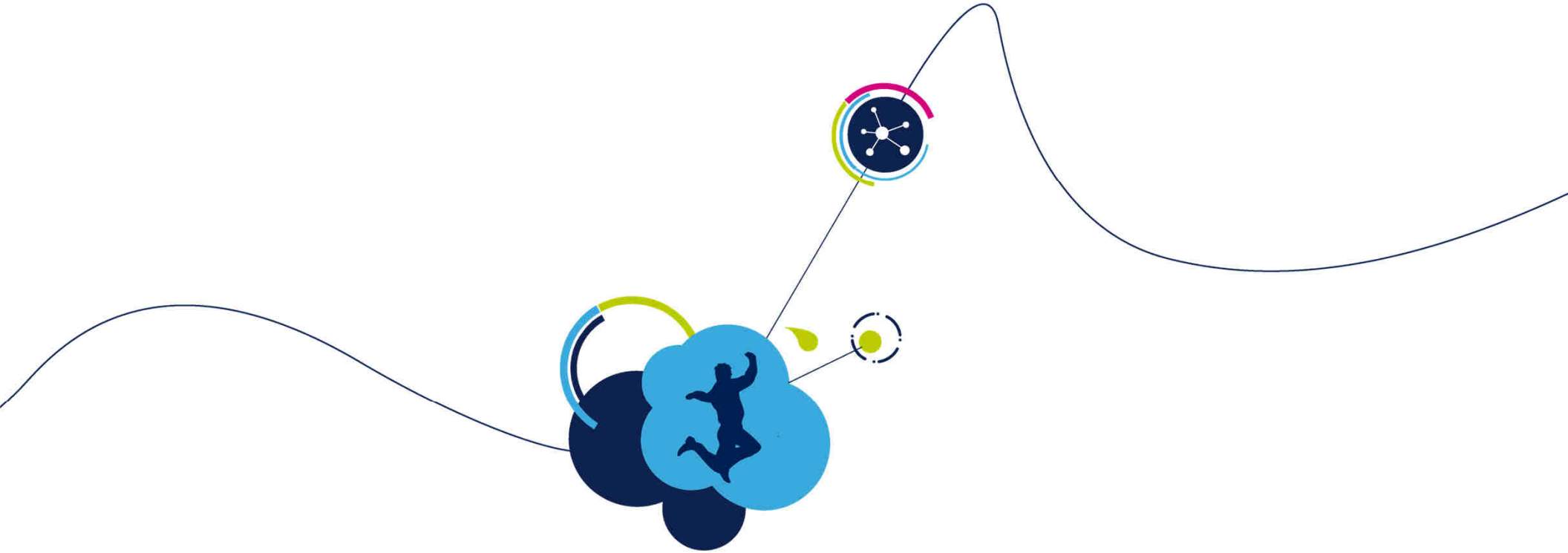

ST Offer

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ST Product family

USB-C PD Controllers

Covering all use cases from Type-C to full-feature Power Delivery

PD stack running in SW

Standalone

		STUSB1600	STUSB4500	STUSB47xx	STUSB1602 + µC	STM32Gx with UCPD interface
		USB Type-C controller Sink / Source / DRP	Power Delivery controller SINK only	Power Delivery controller SOURCE only	USB Type-C controller with USB PD PHY Sink / Source / DRP	Embedded USB PD controller Sink / Source / DRP
USB Type-C	≤ 15W					
+ Power Delivery	15-60W 60-100W					
+ Alternate Mode	Any power					

USB Type-C & PD Controllers

Certified Solutions

Offer to designers the flexibility to enable the needed optimization of stack partitioning and BOM

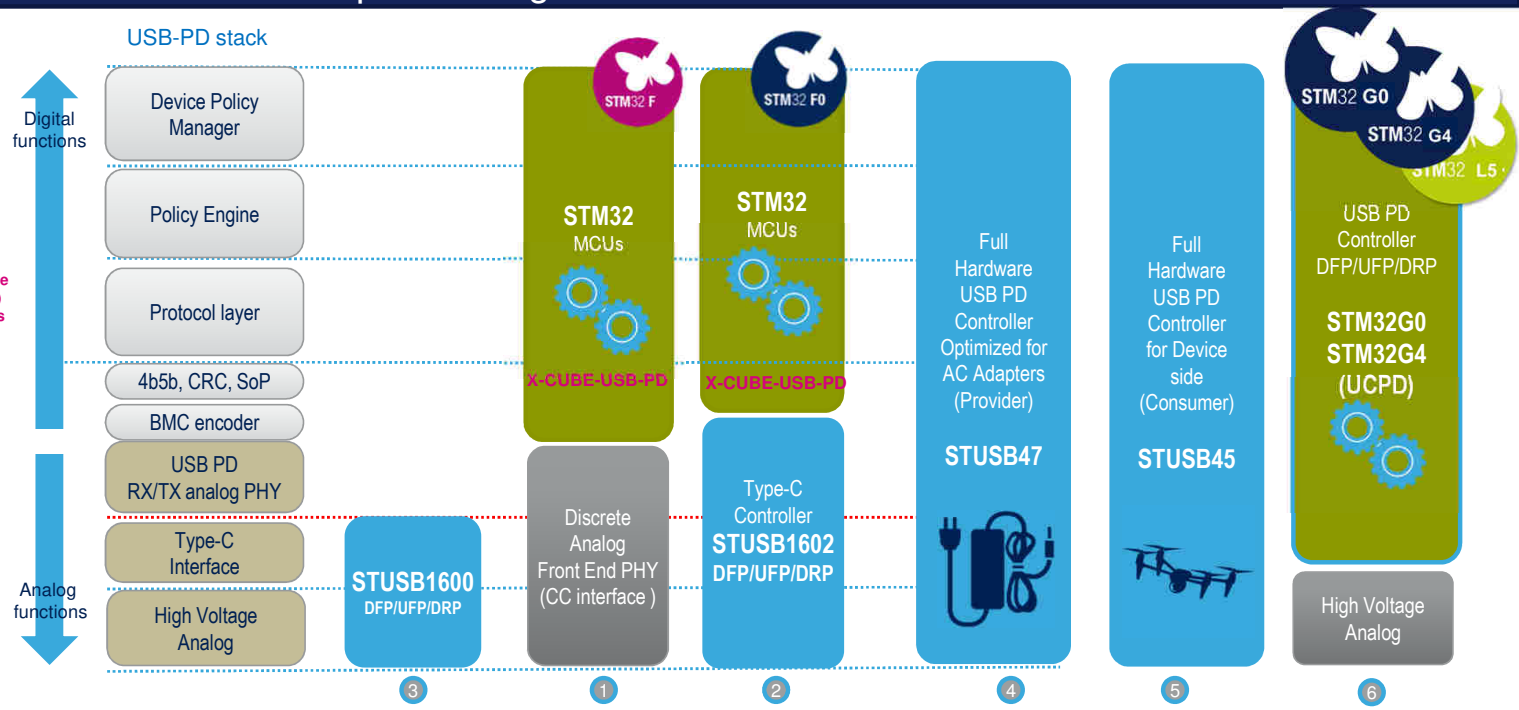
CERTIFIED USB CHARGER 45W

Highest **flexibility** and **adaptability** with GP STM32 MCU for **multi ports** management +

Embedded Software (X-CUBE-USB-PD) & Low level drivers for USB1602

+

Highest **integration** with High Voltage USB-C and PD controllers (STUSBXX)



1. Market proven FW solution on STM32F0 with discrete Analog Front End to control two DRP Type-C
2. More integration with STUSB1602 Type-C PD Controller including PD PHY and BMC line driver
3. Full HW solution with STUSB47 PD controller optimized for AC adapters (1 Port Provider)
4. Standalone Type-C interface STUSB1600 up to 15W

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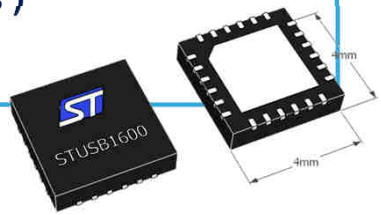
STUSB1600

USB Type-C controller – Source / Sink / DRP

Features

- **Transition any USB Type-A/Micro-B to USB Type-C**
- Performs USB Type-C detection including port attach & cable orientation
- Supports legacy, 1.5A & 3A USB Type-C charging profiles
- Embeds
  - VCONN power switch (OVP,OCP,OTP)
  - Vbus Monitoring & Discharge Path
  - Dead Battery Support
  - PMOS Gate drivers
  - **High Voltage Protections (CC pins & Vbus)**



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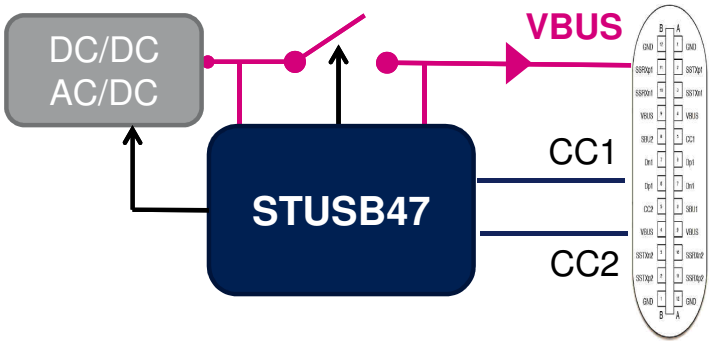
STUSB47xx - SOURCE

Standalone USB Power Delivery Controller - SOURCE

Provider
- all USB PD profiles supported up to 100W
- Suitable for AC/DC and DC/DC

- Auto-run / Plug & Play
- Dead Battery Support
- Up to 5 PDO profiles
- Short to VBUS Protections
- Power sharing capable thru MCU



Certified

CERTIFIED USB CHARGER

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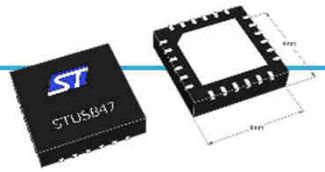
STUSB4710

Autonomous Type-C & USB PD controller

Features

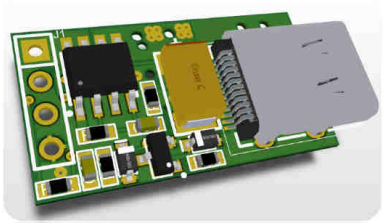
- **Full HW USB-PD stack** for safe USB PD r2.0 negotiation
- Single Role, **Provider Only** (Source)
- Performs USB Type-C detection including port attach & cable orientation
- Establish Safe & valid Host to Device Connection
- Offers up to 5 programmable PDOs
- Offers very low power consumption
- Embeds
  - Vbus Monitoring & Discharge Path
  - PMOS Gate drivers
  - **High Voltage Protections (CC pins & Vbus)**



SO-16

QFN-24
4x4 mm²

QFN-16
3x3 mm²



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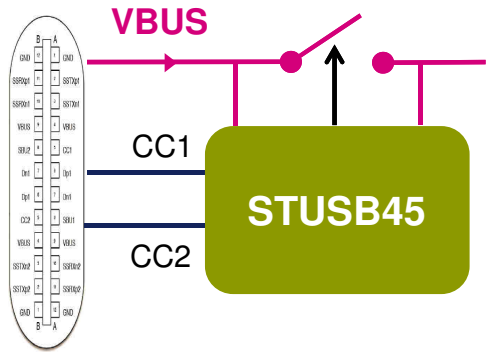
STUSB4500 - SINK

Standalone USB Power Delivery Controller - SINK

Consumer
- all USB PD profiles supported up to 100W
- Fast migration to USB PD

- Auto-run / Plug & Play
- Dead Battery Support
- Up to 3 SINK PDO profiles
- Short to VBUS Protections
- PCB area saving



Certified

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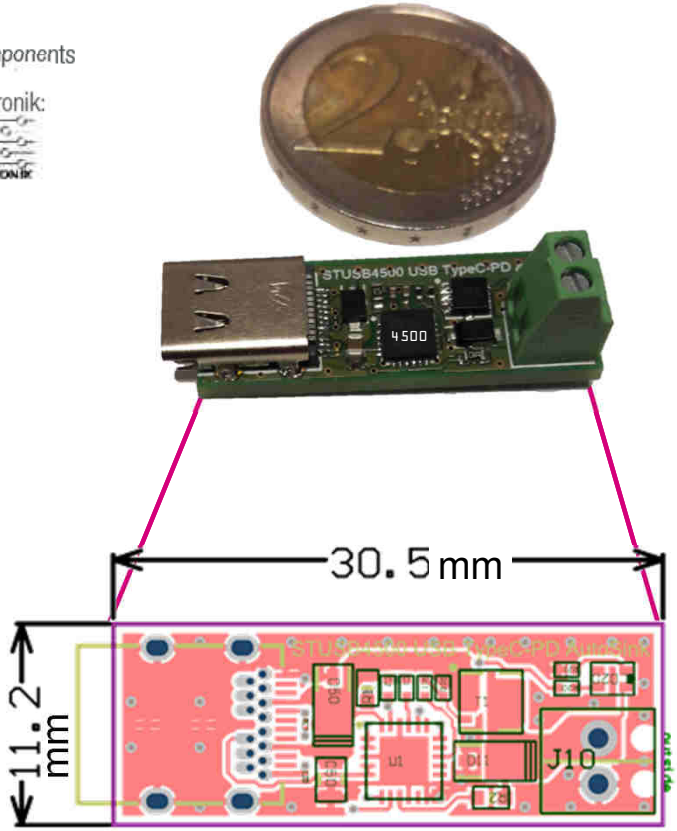
STUSB4500 Footprint

DEMO BOARD – USB Type-C/PD SINK

Passive components supplied by Würth Elektronik:



Power any 100W (or less) device with USB PD!
It's:

- Tiny,
- Safe,
- Certified,
- Plug-Play
- Customizable

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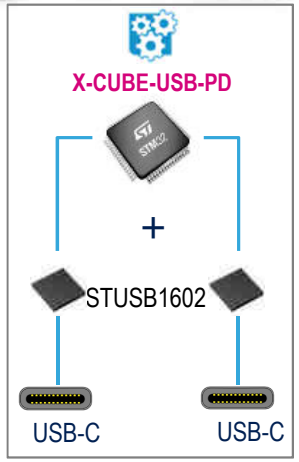
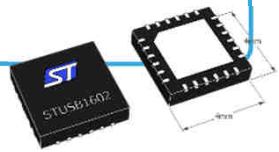
STUSB1602

Type-C & USB PD controller – DRP/Source/sink

Features

- Analog Front End
- **Integrates the USB PD r2.0 PHY + BMC encoding**
- **Compatible with USB PD r3.0**
- Perfect companion chip to EC to manage USB Type-C port
- Performs USB Type-C detection including port attach & cable orientation
- Embeds
  - VCONN power switch (OVP,OCP,OTP)
  - Vbus Monitoring & Discharge Path
  - Dead Battery Support
  - PMOS Gate drivers
  - High Voltage Protections (CC pins & Vbus)
- Solves **Security & safety** concerns





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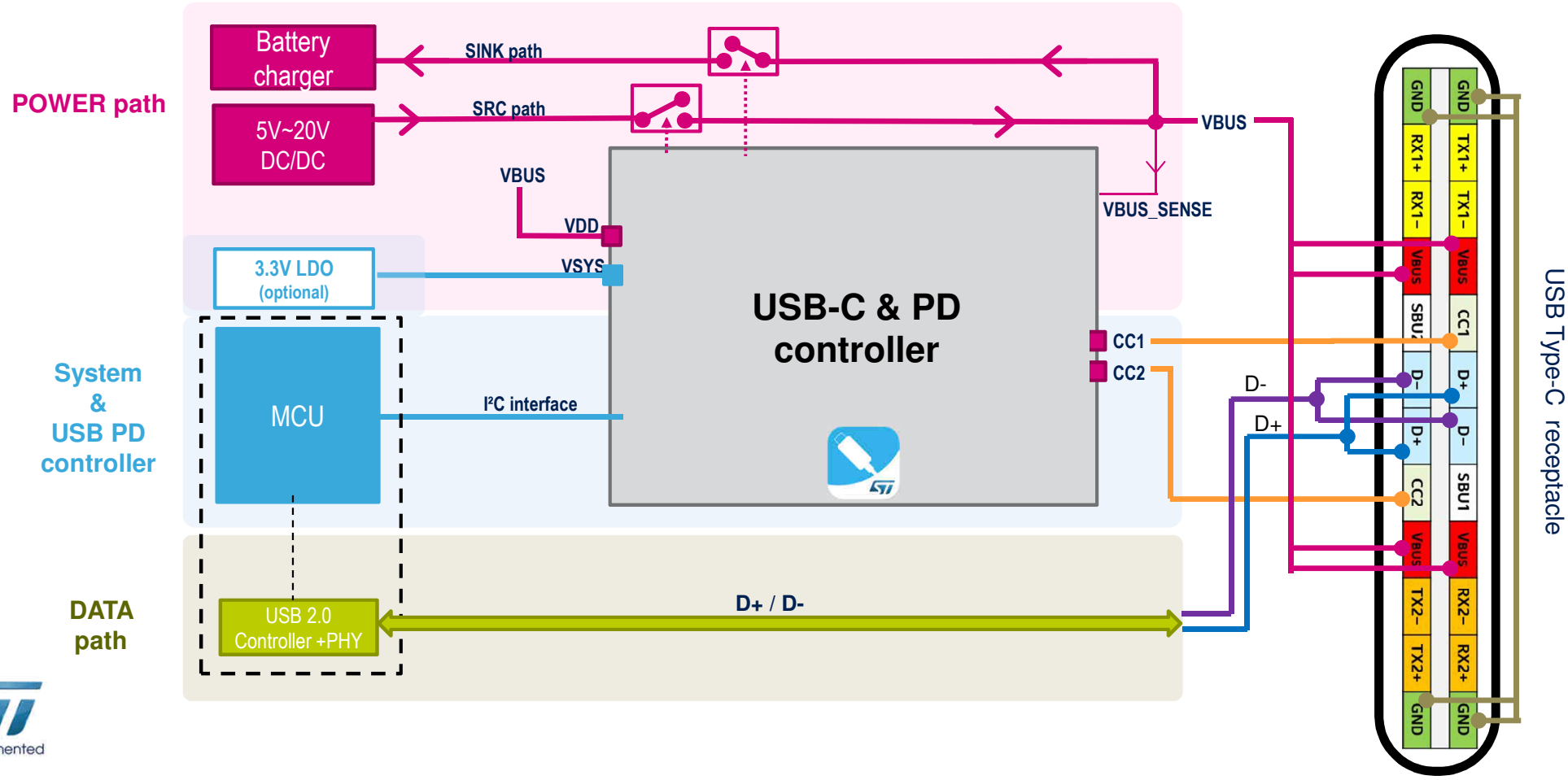
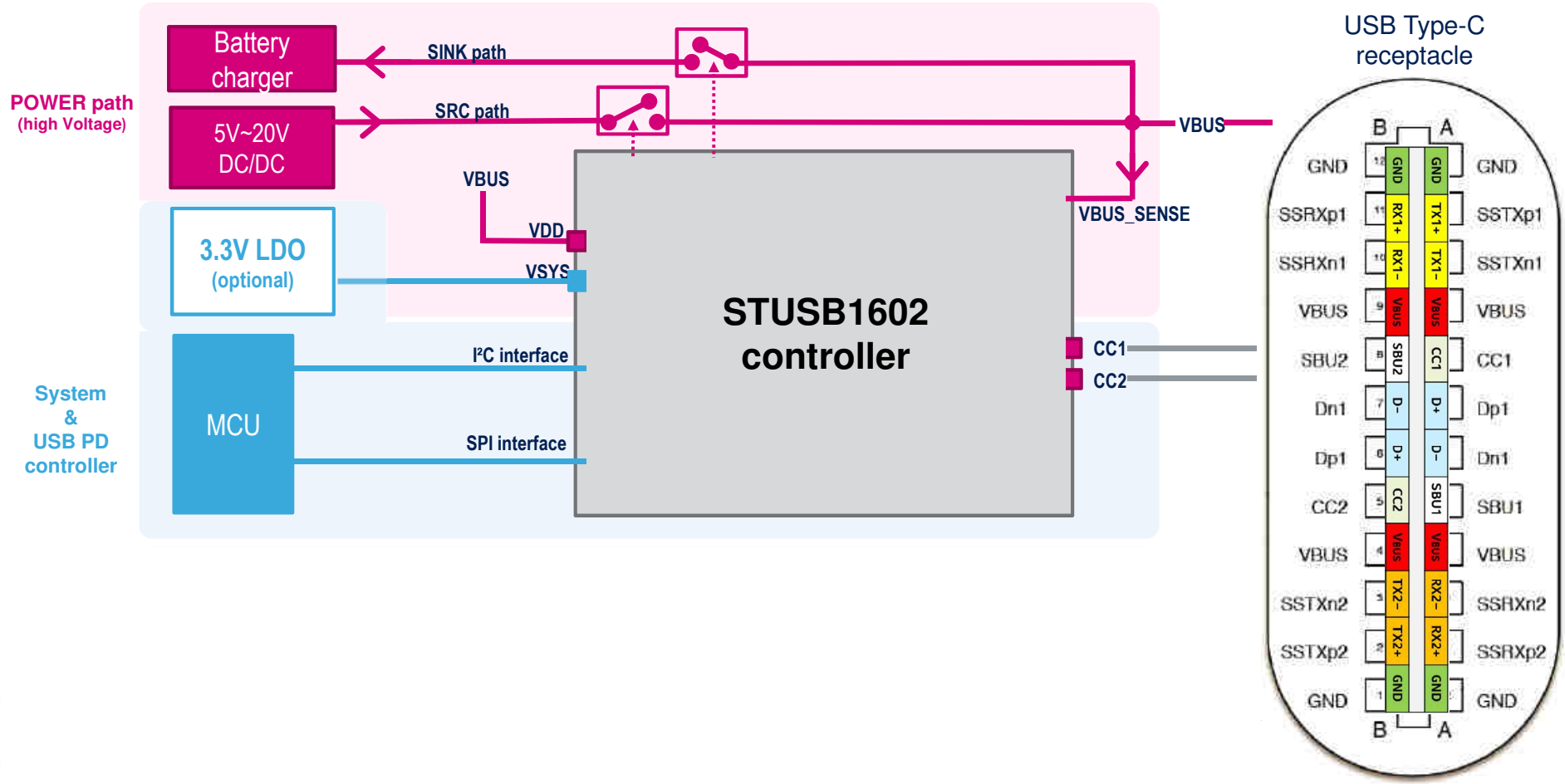
USB Type-C + USB 2.0

HW implementation in DRP mode



STUSB1602 Dual-Role Power (DRP)

Implementation example



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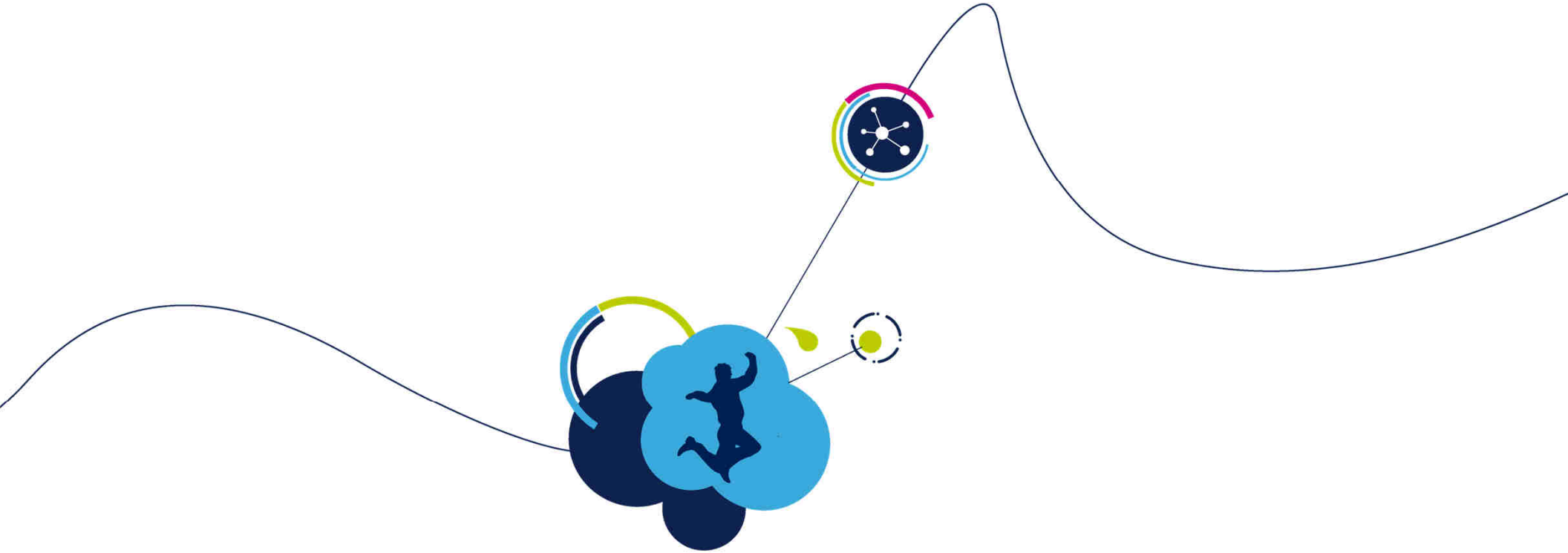

Evaluation Tools

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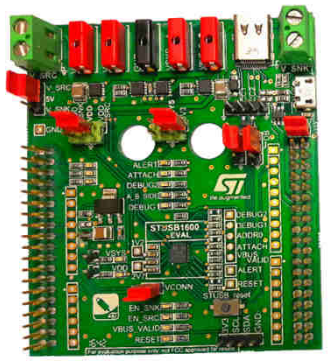
STUSB1600A - DRP

Standalone USB Type-C Controller



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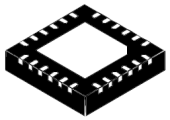

QFN-24 - EP
4x4 mm²

- Dual Role, provider, consumer
- Fast migration to Type-C <15W

- Configurable start-up profiles
- Dead battery support
- Short to VBUS Protections

Ideal solution for <15W charging (1.5A @5V / 3A@5V) with or without USB DATA

CERTIFICATION

- Certified according to:
  - USB type-C™ (rev1.2 + ECN)
  - TID: 1000100

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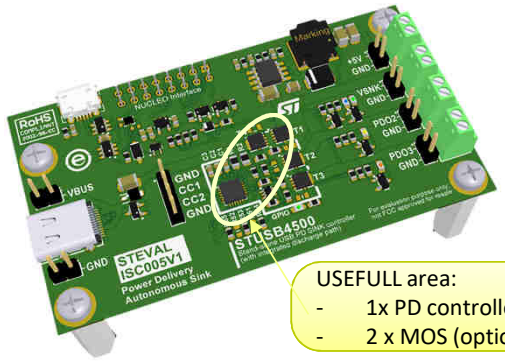
STUSB4500 - SINK

Standalone USB PD Controller - SINK



USEFULL area:
- 1x PD controller
- 2 x MOS (optional)

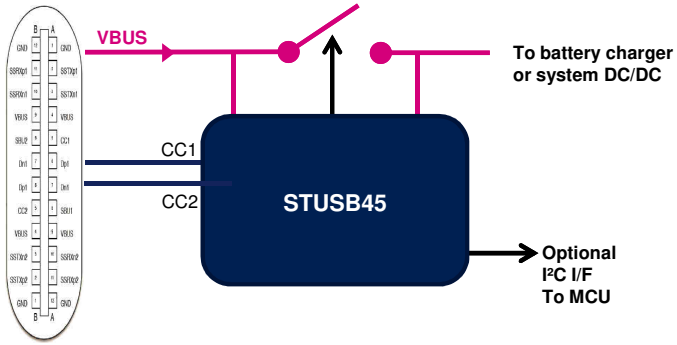
STEVAL_ISC005V1

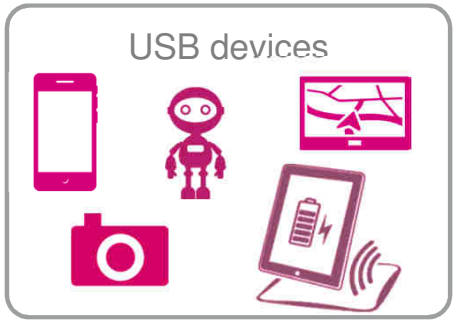
QFN-24 - EP
4x4 mm²

WLCSP-25
(2.6x2.6x0.5)

Consumer
- all USB PD profiles supported up to 100W
- Fast migration to USB PD

- Auto-run / Plug & Play
- Dead Battery Support
- Up to 3 SINK PDO profiles
- Short to VBUS Protections
- PCB area saving





CERTIFICATION
- Certified according to:
  - USB type-C™ (rev1.2)
  - USB PD (rev2.0)
  - TID: 1000133
- Compliant with USB PD (rev3.0)

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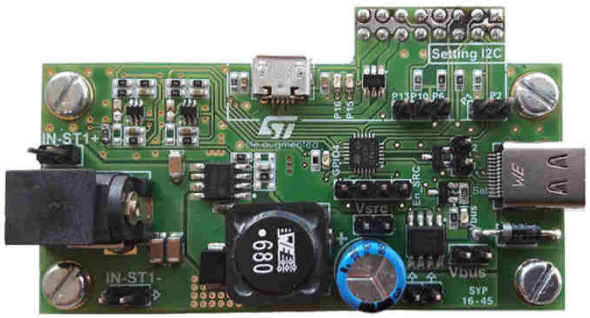
STUSB47xx - SOURCE

Standalone USB PD Controller - SOURCE



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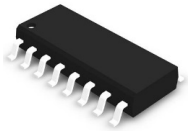
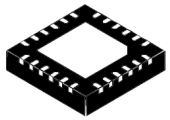


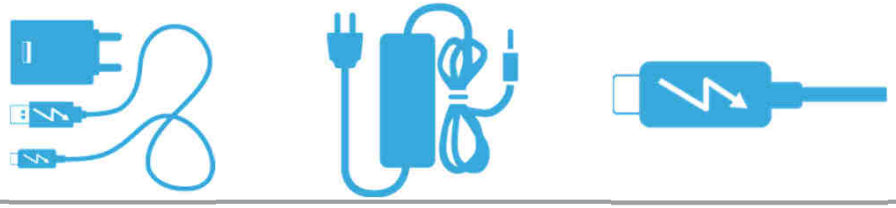
SO-16



QFN-24
4x4 mm²

QFN-16
3x3 mm²

AC adapters & Power supplies



Provider
- all USB PD profiles supported up to 100W
- Suitable for AC/DC and DC/DC

- Auto-run / Plug & Play
- Dead Battery Support
- Up to 5 PDO profiles
- Short to VBUS Protections
- Power sharing capable thru MCU

CERTIFICATION
- Certified according to:
  - USB type-C™ (rev1.2)
  - USB PD (rev2.0)
  - TID: 1000125 / 1030023
- Compliant with USB PD (rev3.0)

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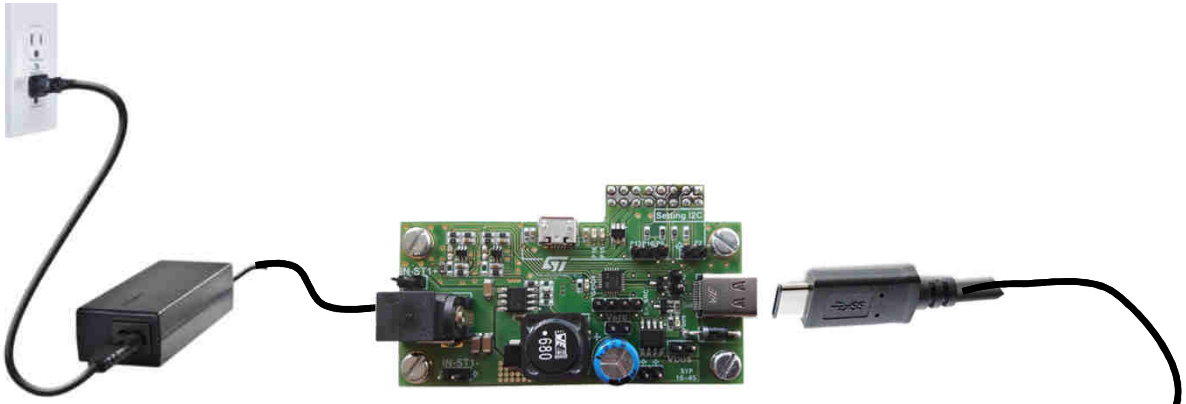
STUSB47 meets STUSB45

Stand-alone controllers for SOURCE and SINK applications



PROVIDER: STUSB47
SOURCE - Autorun

Passive components supplied by Würth Elektronik:

CONSUMER: STUSB45
SINK - Autorun

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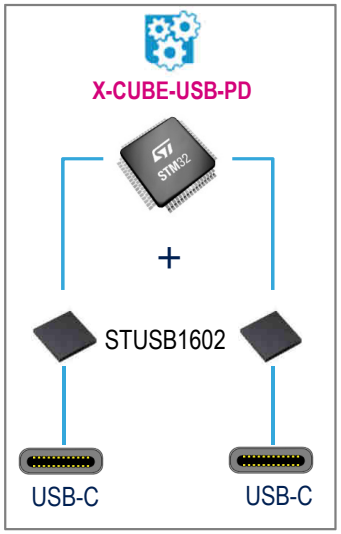
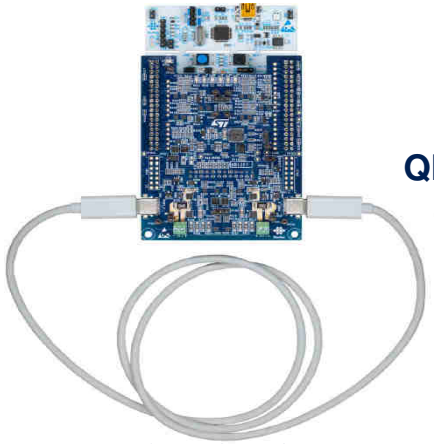
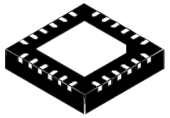
STUSB1602 - DRP

USB Type-C controller with PD PHY





P-NUCLEO-USB002



QFN-24 - EP
4x4 mm²

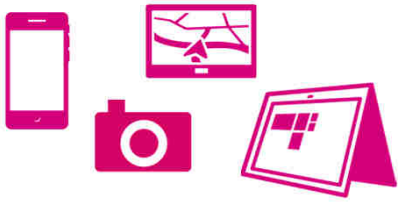
- Dual Role: DFP/UFP/DRP
  USB PD PHY + BMC (PD support)

- Interconnects with STM32
- Development tool available (P-NUCLEO-USB00X)

Dual port USB devices

Universal chargers (source)

Multi cell USB devices



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CERTIFICATION

- Certified according to:
  - USB type-C™ (rev1.2)
  - USB PD (rev2.0)
  - TID: DRP 1000117 / Source 1000118 / Sink 1000119
- Compliant with USB PD (rev3.0)

USB-C STM32 Ecosystem

STM32G071B-DISCO
- USB-C analyzer (Sink)

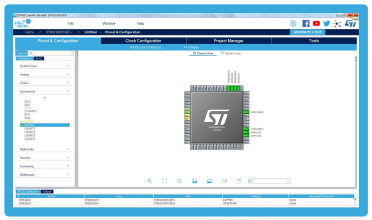
STM32G081B-EVAL
- 1 Port DRP (45W)
- 1 port Sink (AM)

B-G474E-DPOW1
- 1 port Sink + USB data

STM32G474E-EVAL
- 1 Port DRP (15W) + USB data

NUCLEO-L552ZE-Q
- 1 Port Sink + USB data

STM32L552E-EVAL
- 1 Port Sink + USB data



STM32 CubeMX
UCPD configuration

STM32 CubeMonitor-UCPD
Debug tool

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STM32G0 USB-C Discovery

Promotional kit and tool to learn and discover USB-C port capabilities. It offers 3 operating modes :

1. "**Standalone**" mode: Discover and display power / data / Alternate Mode capability of any USB-C host (source/DRP).
2. "**Sniffer + USB PD meter**" mode: Display current direction, power information (V_{bus} voltage, I_{bus} current) between two USB-C enabled devices.
3. "**Advanced User**" mode: Debug, configure, inject USB PD3.0 packet using "STM32CubeMonUCPD".

Ordering info :

RPN :STM32G071B-DISCO

POS/RRP : 65$

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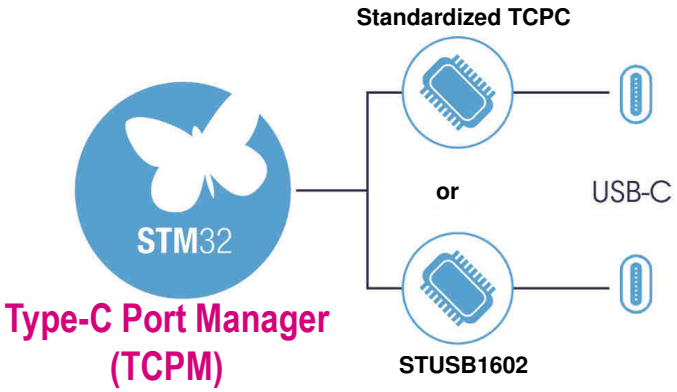
X-CUBE-USB-PD Software Pack

Enables any STM32 to handle USB-C and Power Delivery



TCPM stands for Type-C Port Manager
TCPC stands for Type-C Port Controller

- X-CUBE-USB-PD complies with :
  - ✓ USB-C 1.3 and **USB PD 3.0** specifications
  - ✓ Type-C Port Controller Interface specification (TCPC*i*)
- Hardware architecture supported
  - Any STM32 as **TCPM** with standardized **TCPC** from 3rd parties

(Our stack has been tested with ON Semiconductor® FUSB307B, a USB-PD 3.0 v1.1-certified TCPC)

  - Or STM32F0 with STUSB1602 Type-C interface
- Single-or multi-port supported (Sink, Source, Dual Role Power)
- Optional features such as Programmable Power Supply (PPS), Authentication messages and Fast Role Swap (FRS) are supported

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STEVAL-USBC2DP:
USB Type-C to DisplayPort adapter

Key Features:

- The USB Type-C to DisplayPort Adapter expands a USB Type-C laptop screen onto a monitor or projector equipped with DisplayPort
- Based on the Alternate Mode Functional Extension of the USB Type-C & Power Delivery to enables the DisplayPort interface

DisplayPort

Advantages

- Type-C Alternate Mode demo in a compact PCB design (5.5 x 2.3 mm)
- Full ST BOM for a cost-effective solution based on Discrete AFE approach
- Including the DFU feature

Key Products

STM32F072: the high-performance ARM® Cortex®-M0 32-bit RISC core operating at up to 48 MHz frequency, high-speed embedded memories and with USB 2.0 data interface.

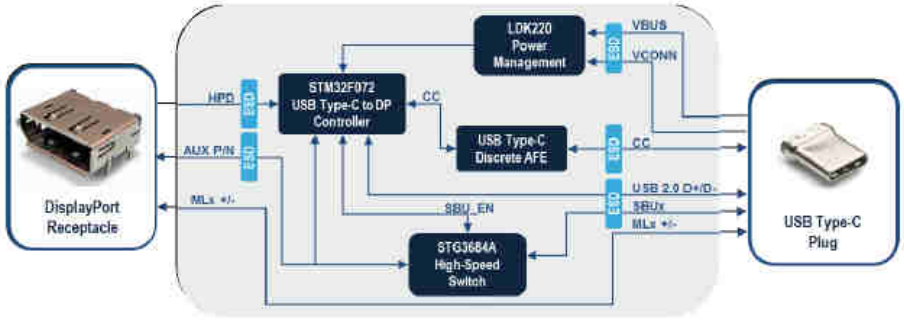
LDK220: 200 mA low quiescent current and low noise LDO.

STG3684A: Low Voltage 0.5 Ohm Max Dual SPDT Switch with Break-Before-Make

ESDALC5-1BF4: Low clamping and low capacitance bidirectional single line ESD protection

STPS0520Z: Power Schottky rectifier

X-CUBE-USB-PD: STM32 USB-PD package consisting of libraries and application examples for STM32F0 devices acting as USB-PD controllers



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Summary

- USB Docs: **www.usb.org/documents**

- ST is strongly involved in USB Type-C & PD controllers
  - Member of the USB-IF consortium / Member of USB PD working groups
- Certified Solutions available
  - Type-C only for an **easy & Safe transition from Std-A to Type-C** using the STUSB1600
  - USB PD & Type-C **Autonomous full HW** controller for Provider Only application using the STUSB4700, or Consumer only with STUSB4500
  - USB PD & Type-C controller for DRP/DFP/UFP application as the perfect companion to Embedded Controller using the STUSB1602+STM32 supporting USB PD rev3.0.
  - Microcontrollers embedding UCPD interface : STM32G0, STM32G4, STM32L5
- Automotive
  - Using STUSB1700Y, STUSB4700Y, STUSB1702Y for **Automotive grade** devices

Thank You

Visit **www.st.com/usb-type-c**

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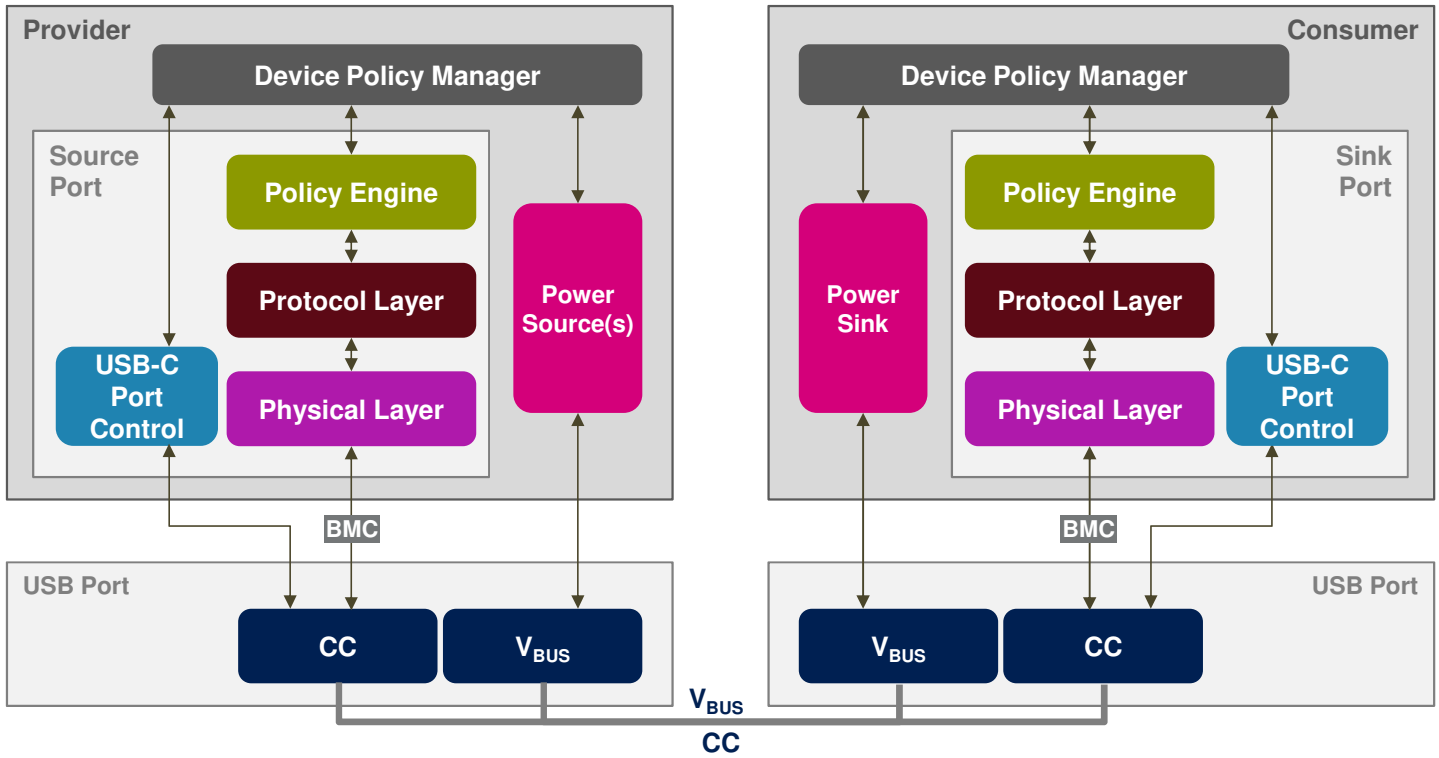
USB Type-C™ and USB Power Delivery

High level architecture

The different layers can be implemented in different topologies HW / SW



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

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