USB Type-C™ and USB PD Demystified

Greg Gosciniak

Applications Engineer
USB Type-C and USB Power Delivery benefits

USB Type-C overview

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**: More flexibility with a new reversible & thinner connector.
- **Power Delivery**: More power with USB Power Delivery (100W).
- **Alternate Mode**: More protocols (Display Port, HDMI, VGA, Ethernet...).
- **USB IF**: More speed with USB 3.1 gen 2 (10 Gbps).

A smart and green technology.
USB Type-C
and USB Power Delivery

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

USB Type-C:
One port to rule them all

- Dual role / charging
- Display power
- Alternate mode on dock connector
- Charging / Data
- Audio
- External display

System power, up to 100W
USB Type-C Overview
STMicroelectronics is a board member of USB-IF and USB 2.0 & USB 3.0 promoter

http://www.usb.org/developers/powerdelivery/
USB Type-C Pin-Out Functions

Enhance ease of use

### Receptacle

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>A9</th>
<th>A10</th>
<th>A11</th>
<th>A12</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>TX1+</td>
<td>TX1-</td>
<td>VBUS</td>
<td>CC1</td>
<td>D+</td>
<td>D-</td>
<td>SBU1</td>
<td>VBUS</td>
<td>RX2</td>
<td>RX2+</td>
<td>GND</td>
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<tr>
<th>B12</th>
<th>B11</th>
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<th>B8</th>
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<th>B4</th>
<th>B3</th>
<th>B2</th>
<th>B1</th>
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<tbody>
<tr>
<td>GND</td>
<td>RX1+</td>
<td>RX1-</td>
<td>VBUS</td>
<td>SBU2</td>
<td>D-</td>
<td>D+</td>
<td>CC2</td>
<td>VBUS</td>
<td>TX2-</td>
<td>TX2+</td>
<td>GND</td>
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</tbody>
</table>

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

<table>
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<tr>
<th>A12</th>
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<td>D+</td>
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<td>VBUS</td>
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<td>TX1-</td>
<td>GND</td>
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<th>B11</th>
<th>B12</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>TX2+</td>
<td>TX2-</td>
<td>VBUS</td>
<td>VCONN</td>
<td>SBU2</td>
<td>SBU1</td>
<td>VBUS</td>
<td>RX1-</td>
<td>RX1+</td>
<td>GND</td>
<td></td>
</tr>
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</table>

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 VCONN for powering electronics. Also, only one set of USB 2.0 D+/D- wires are implemented.

### Pin Functions

- **USB 2.0 Interface**
- **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**
- **Configuration Channel**
- **Cable Ground**
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
# USB-PD 2.0(v1.2) & 3.0 Power Rules

## PDO: Power Data Object (Voltage, Current)

<table>
<thead>
<tr>
<th>Target Power (W)</th>
<th>Current (A) at 5V</th>
<th>Current (A) at 9V</th>
<th>Current (A) at 15V</th>
<th>Current (A) at 20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 ≤ x ≤ 15</td>
<td>x \div 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 &lt; x ≤ 27</td>
<td>3</td>
<td>x \div 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 &lt; x ≤ 45</td>
<td>3</td>
<td>3</td>
<td>x \div 15</td>
<td></td>
</tr>
<tr>
<td>45 &lt; x ≤ 60</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>x \div 20 (*)</td>
</tr>
<tr>
<td>60 &lt; x ≤ 100</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>x \div 20 (*)</td>
</tr>
</tbody>
</table>

(*) Requires a 5A cable
What to expect?

USB-C

A huge market...

- 2 billion+ units FORECAST to ship in 2019
  - 40% of Total Units
- Source: IHS (B. O’Rourke) as of Dec. 2015
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
USB Type-C and USB Power Delivery
AC / DC converters

ST Chipset: ultra-low standby and compact power supplies

High efficient and fully integrated AC-DC controllers enabling high efficiency and low EMI design AC-DC controllers

Wide Power MOSFETs product range with reduced switching losses, easy driving features and lower design complexity

Power Supplies  Power Hubs
ST Offer
Hard-Coded USB Type-C and USB PD Controllers

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>STUSB1600</td>
<td>USB Type-C interface&lt;br&gt;Less than 15W</td>
</tr>
<tr>
<td>STUSB1602</td>
<td>USB Type-C controller with PD PHY and BMC driver&lt;br&gt;15W to 100W</td>
</tr>
<tr>
<td>STUSB47xx</td>
<td>Power Delivery controller&lt;br&gt;Provider only&lt;br&gt;5W to 100W</td>
</tr>
</tbody>
</table>
Type-C & USB PD Controllers Certified Solutions

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

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
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)
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)**
<table>
<thead>
<tr>
<th>FEATURE</th>
<th>BENEFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• USB IF Certified silicon</td>
<td>• Proven solution</td>
</tr>
<tr>
<td>• Hard-wired</td>
<td>• <strong>NO NEED FOR MCU</strong>, Robust / Predictive</td>
</tr>
<tr>
<td>• Low Power consumption</td>
<td>• Contribution to Energy-saving Standards</td>
</tr>
<tr>
<td>• CC Short to Vbus protection</td>
<td>• Safe for users &amp; devices</td>
</tr>
<tr>
<td>• CC pins protected up to 22V</td>
<td>• <strong>No external LDO required</strong> – Low BOM cost</td>
</tr>
<tr>
<td>• Wide Supply Voltage range [3V; 22V]</td>
<td>• Contribution to Power Density</td>
</tr>
<tr>
<td>• High BOM Integration</td>
<td>• Easy customisation – Plug &amp; PLAY</td>
</tr>
<tr>
<td>• Internal NVM</td>
<td>• <strong>NO Software know-how required</strong></td>
</tr>
</tbody>
</table>
STUSB4700 Layout
High Integration/PCB Area Saving

USB PD - Fly Back Secondary side
- class 5 PCB
- clearance and track width: 150 μm / 5.905 mils
- Size could be reduced with further optimization
Using MCU-Based Solution

• Need dedicated DC-DC to get a 5V input
  • STUSB4700 is powered directly on VBUS (4 - 22V)
• Power consumption is much higher to run MCU ~7.5mA (Critical in low load conditions)
  • STUSB4700 is fully autonomous with 0.80mA Power consumption (0.05mA with No Load)
• Need external HV protections
  • STUSB4700 has 22V AMR protection on CC pins
  • STUSB4700 has 28V AMR for other HV pins
• Need external MOS for Discharge Path
  • STUSB4700 has integrated Discharge Path
• Need external Gate Drivers
  • STUSB4700 has integrated Gate drivers
• Potentially need External Vconn
  • STUSB4700 has integrated Vconn

MCU-based solutions are NOT effective for First Default protection
Features

- 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
**STUSB1602 vs USB PD r3.0**

IC compatibility versus standard

### 3.0 (optional)
- Application specific

### 3.0 (core)
- Long messaging (260 bytes)+extended msg chunk
- Fast Role SWAP without discharge (DRP only)
- Battery messaging
- Additional Alerts, capabilities, status
- SVDM update (v2.0)
- Non supported commands, EMCA communication
- Collision avoidance mechanism (Enhanced)
- Incremental Power Rules
- STUSB1602 is compliant with PDr3.0 core features

### 2.0 (core)
- Role SWAP
- Collision Avoidance
- PPS – VBUS min down to 3V instead of 5V
- Support for IEC 63002 power supply standards
- Authentication / Firmware Update applications
- Docking Stations, Computer
- Required for battery operated systems

**Supported**

**Not supported**

**Under Evaluation**
USB PD HW/SW partitioning with STUSB1602

USB PD stack

System Policy Manager
Device Policy Manager
Policy Engine
Protocol layer
4b5b, CRC, SoP
BMC encoder
USB PD RX/TX analog PHY
Type-C Interface
High Voltage Protections
I/F pins CC

USB PD features
- Packets signal conditioning for both RX / TX
- Packets encoding /decoding (BMC)

Type-C features
- Manage USB Type-C port connection
- Handle Dead Battery connection & system start-up
- Manage cable orientation
- Supply VCONN (programmable limit)

System/application features
- Enable the power path ➔ VBUS Gate drivers (PMOS)
- Manage voltage transitions ➔ VBUS discharge path
- Monitor the power path ➔ VBUS Monitoring
- Protects from High Voltage ➔ Short-to-VBUS protections (up to 28V)
- Protects Vconn ➔ OVP, OCP, OTP
STUSB1602 Suitable Applications in either PD r2.0 or r3.0

- **All SINK applications:**
  - including authentication (PDr3.0 option) and long messaging (PDr3.0)

- **SOURCE:**
  - Conventional chargers and AC/DC adapters
  - PPS fast charger (under evaluation)
  - DC/DC

- **DUAL ROLE**
  - All single port-supplied applications (smartphone, tablet)
  - Multi-port applications which do not require Fast Role SWAP
    - Set-top-box
    - TVs
### Integration Comparison

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits of STUSB16xx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vconn switch</td>
<td>Support Active cable &amp; mandatory for USB3.1 &amp; &gt;60W charging Application</td>
</tr>
<tr>
<td>Dead Battery</td>
<td>Mandatory for Battery powered consumer devices or Vbus powered devices</td>
</tr>
<tr>
<td>CC HV protection</td>
<td>Overvoltage protections on CC pins (up to 24V)</td>
</tr>
<tr>
<td>Vbus Discharge Path</td>
<td>High voltage discharge switch</td>
</tr>
<tr>
<td>Vbus Switch Driver</td>
<td>High voltage (up to 24V) switch</td>
</tr>
<tr>
<td>Vbus monitoring</td>
<td>Fast overvoltage detection, under voltage Lock out</td>
</tr>
<tr>
<td>Type-C PD phy</td>
<td>BMC &amp; Rx Tx drivers¹, Configurable Start-up profiles, Wide Supply voltage range (3 to 5.5V)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STUSB1600 Type-C Only (&lt; 15W)</th>
<th>STUSB1602 (1 port – DRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUSB47 (1 port Provider Only)</td>
<td>Vconn Switch Dead Battery CC HV Protect Discharge path Vbus Driver Vbus Monitor Type-C PD phy PD stack Current sensing</td>
</tr>
</tbody>
</table>

1. BMC & Rx Tx drivers denotes the ability for configuring start-up profiles.
Evaluation Tools
**STUSB4700 DEMO - 36W Fly-back**

**Target Applications**
- Universal or OEM Power Supplies and
- AC adapters for Computer, Tablets, STB etc...

**Key ST products**
- IPC : PWM controller (STCH02)
- IPC : CV controller (TLVH431)
- GPA : PD controller (STUSB4700)
- IPAD: ESD protection (ESDA25L-SMM4F24A)

**Description**
- AC/DC 36W Fly-back topology with CV
- Number of PDO: #3
- Voltage Select: Digital Output (Vsel_PDO)
- Fixed current

**STATUS**
**ORDER CODE:**
**AVAILABILITY:** On Request (limited quantities)

**TARGET APPLICATIONS**
- Universal or OEM Power Supplies and
- AC adapters for Computer, Tablets, STB etc...

**KEY ST PRODUCTS**
- IPC : PWM controller (STCH02)
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**DESCRIPTION**
- AC/DC 36W Fly-back topology with CV
- Number of PDO: #3
- Voltage Select: Digital Output (Vsel_PDO)
- Fixed current

**STEVIL STCH02 36W (EVAL-CHG-36W)**
Flyback – Primary side

**STUSB47 Dongle 36W**
Fly-back – Secondary side
**STATUS**

**AVAILABILITY:** On Request (limited quantities)

**Target Applications**
- Universal or OEM Power Supplies and
- AC adapters for Computer, Tablets, STB etc...

**Key ST products**
- **USB PD controller (STUSB4700)**
- PWM controller (STCH02)
- CV controller (TLVH431AICT)
- ESD protection (ESDA25L-SMM4F24A)

**Description**
- AC/DC 45W Fly-back topology with CV
- Number of PDO: #3
- Voltage Select: Digital Output (Vsel_PDO)
- Fixed current

---

STUSB4700

DEMO - 45W Fly-back

Top view

Side view

Diagram of STUSB4700 circuit with labeled components.
**Status**

**Order Code:** STEVAL-4710-BUCK

**Availability:** yes (tbc)

**Target Applications**
- Computer, Power Hub, Accessories,
- TV, Display, Set Top Box, Gaming, Industrial

**Key ST Products**
- IPC : DC/DC
  (ST1S14)
- GPA : PD controller
  (STUSB4700)
- IPAD: ESD protection
  (ESDA25L- SMM4F24A )

**Description**
- DC/DC 60W Buck Topology
- Number of PDO: #5
- Voltage Select: Analog Output (VVAR)
- Current regulation: ST1S14
STATUS

ORDER CODE: X-NUCLEO-1600
AVAILABILITY: yes (tbc)

Target Applications

- Computer, Power Hub, Accessories,
- TV, Display, Set Top Box, Gaming, Industrial

Key ST products

- GPA : Type-C controller (STUSB1600)
- IPAD: ESD protection (ESDA25L-SMM4F24A)

Optional NUCLEO board:
- MCD: MCU (STM32F072-NUCLEO)

Description

- STUSB1600 evaluation environment
- Suitable for SINK, SOURCE, DRP
- Dead Battery Support
- Vconn, Vsys, VDD
- Can run without Nucleo board (only required to access STUSB1600 I²C interface from the GUI)
STUSB1602
DEVELOPMENT – Dual Port STM32 Nucleo Pack

STATUS
ORDER CODE: P-NUCLEO-USB002
AVAILABILITY: yes (tbc)

Target Applications
- Computer, Power Hub, Accessories,
- TV, Display, Set Top Box, Gaming, Industrial

Key ST products
- GPA : PD controller (2 x STUSB1602)
- IPAD: ESD protection (ESDA25L- SMM4F24A )
- MCD: MCU (STM32F072 - NUCLEO)
- SMD: Authentication IC (STSAFE)

Description
- STM32 + STUSB1602 evaluation environment
- Type-C cable included
- Dual Port DRP system
- Dead Battery Support
- Vconn, Vsys, VDD support
- Requires dedicated SW environment
Key messages

• 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
  • USB PD & Type-C controller for DRP/DFP/UFP application as the perfect companion to Embedded Controller using the STUSB1602 supporting USB PD r3.0.

• Towards more features …
  • Using a Gen2 USB PD & Type-C Autonomous full HW controller supporting USB PD r3.0
  • Using a Gen2 TCPC controller including HV analog Front end
  • Using a new family of Power switches for Type-C & PD application.
  • Using STUSB1600Y, STUSB4700Y, STUSB1602Y for Automotive grade devices