UM2191
User manual

STM32 Nucleo pack for USB Type-C™ and Power Delivery with the Nucleo-F072RB board and the STUSB1602

Introduction

The USB Type-C™ and Power Delivery Nucleo pack P-NUCLEO-USB002 includes:

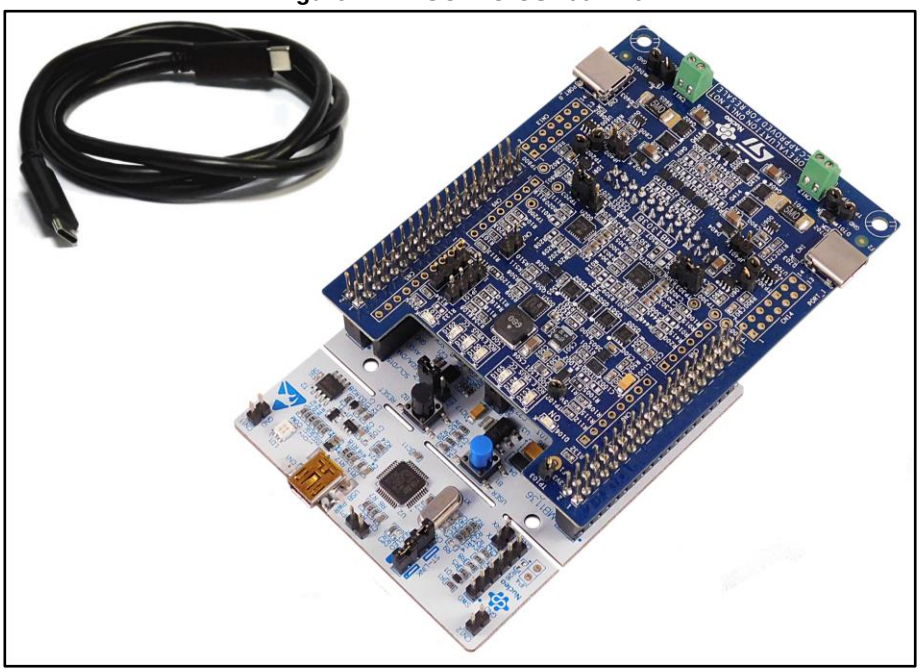
- the NUCLEO-F072RB board
- the P-NUCLEO-USB002 expansion board based on the certified STUSB1602 USB Type-C port controller with PD PHY and BMC driver
- a full-featured Type-C cable

These components, together with the X-CUBE-USB-PD certified STM32F0 USB Type-C PD middleware stack, form a platform for demonstrating USB Type-C and USB Power Delivery (USB PD) capabilities and facilitating solution development.

The new USB PD protocol expands USB functionality by providing up to 100 W power over the same cable used for data communication. Devices supporting the protocol are able to negotiate voltage and current over the USB power pins and define their roles as Provider or Consumer accordingly.

Once the platform is configured, the embedded demonstration firmware can signal cable status (attached or detached) and orientation information, as well as the role of each of the two ports.

Figure 1: P-NUCLEO-USB002 kit



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1 USB Type-C and Power Delivery

1.1 Overview

The USB Type-C™ and Power Delivery technologies simplify development and enhance user experience; the new reversible USB Type-C connector insertion is more intelligent and user friendly.

These technologies offer a smart connector able to carry all the necessary data (including video) as well as negotiate up to 100 W supply or charge connected equipment according to the Power Delivery protocol.

Less cables, less connectors and universal chargers are among the final objectives.

The USB Type-C connector supports up to 15 W (5 V at 3 A), which rises to 100 W (up to 20 V at 5 A) adopting the USB Power Delivery feature.

1.2 Main characteristics

The USB Implementer Forum (USB-IF) introduces these complementary specifications:

1. the USB Type-C™ receptacle, plug and cable specification rev. 1.2
2. the USB Power Delivery (PD) specification rev. 2.0 that allows two PD compliant entities to exchange up to 100 W during their negotiations.

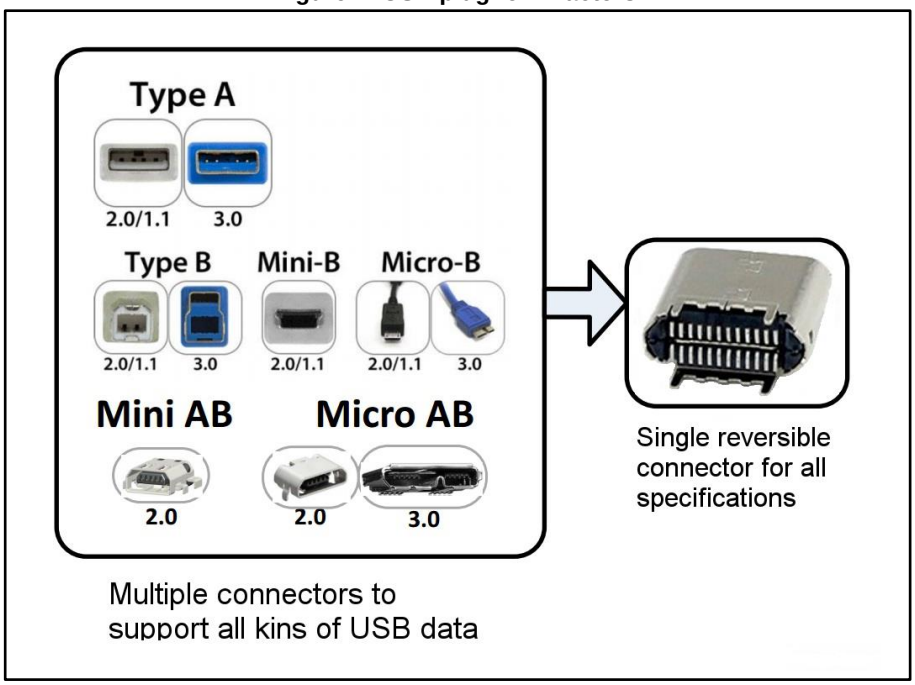
Any system embedding a USB Type-C receptacle or plug which is designed to implement a USB Power Delivery application such as a single port device, a multi-port hub or a simple cable is based on these specifications.

The connector is intended for a wide range of charging applications like computers, displays and mobile phones, with all the advanced features of PD:

- power role negotiation
- power sourcing and consumption level negotiation
- electronically marked cable identification
- vendor-specific message exchange
- alternate-mode negotiation, allowing different communication protocols to be routed onto the reconfigurable pins of the USB Type-C connectors.

The cables use the same male connector on both ends.

Figure 2: USB plug form factors



The new USB Type-C covers all the features provided by the previous generation USB plugs in a single connector, rendering USB usage easier and more flexible. It supports all protocols from USB2.0 onward, including power capability.

The USB Type-C connection allows ports to operate in host-mode only, device-mode only or dual-role. Both data and power roles can be independently and dynamically swapped using the USB PD protocol.

1.3 USB Type-C™ pin map

USB Type-C™ plugs and receptacles are 24-pin connectors with two groups of pin connections arranged so as to ensure pinout reversibility for any connection.

- The symmetrical connections: are
  - eight power pins: V_{BUS}/GND
  - USB2.0 differential pairs (D+/D-)
- The asymmetrical connections are:
  - two sets of Tx/Rx signal paths supporting USB3.1 data rates
  - two configuration channels (CC lines) for the discovery, configuration and management of USB Type-C power delivery features
  - two sideband use (SBU lines) signals for analog audio modes; may be used by alternate mode.

Figure 3: USB Type-C plug pinout

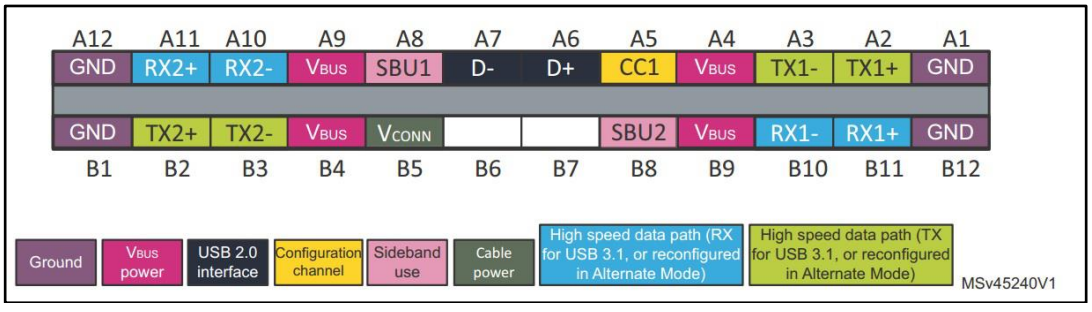


Figure 4: USB Type-C receptacle pinout

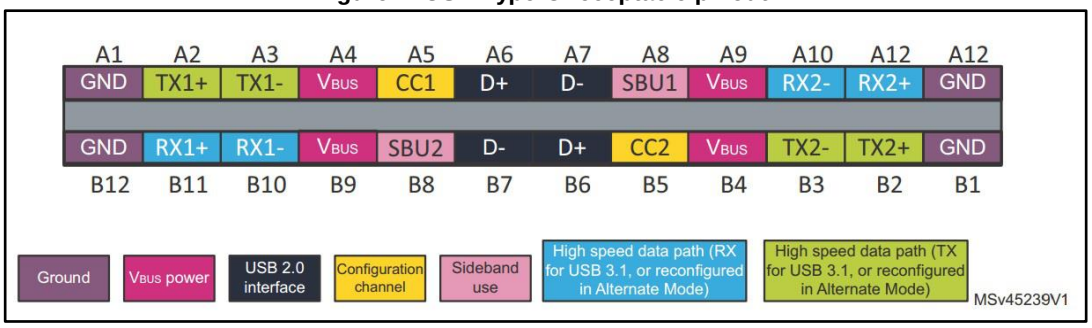


Table 1: USB Type-C pinout description

Pin	Receptacle signal	Plug signal	Description	Comment
A1	GND	GND	Ground return	Can be up to 5 A split into four pins
A2	TX1+	TX1+	USB3.1 data lines or Alternate	10-Gbyte TX differential pair in USB 3.1
A3	TX1-	TX1-		
A4	V_{BUS}	V_{BUS}	Bus power	Max power is 100 W (20 V at 5 A) split into four pins
A5	CC1 or V_{CONN}	CC	Configuration channel or power for active or electronically marked cable	In VCONN configuration, max. power is 1 W
A6	D+	D+	USB2.0 datalines	-
A7	D-	D-		-
A8	SBU1	SBU1	Sideband Use (SBU)	Alternate mode only
A9	V_{BUS}	V_{BUS}	Bus power	Max power is 100 W split into four pins
A10	RX2-	RX2-	USB3.1 datalines or Alternate	10-Gbyte RX differential pair in USB 3.1
A11	RX2+	RX2+		
A12	GND	GND	Ground return	Can be up to 5 A split into four pins
B1	GND	GND	Ground return	Can be up to 5 A split into four pins
B2	TX2+	TX2+	USB3.1 datalines or Alternate	10-Gbyte RX differential pair in USB 3.1
B3	TX2-	TX2-		
B4	V_{BUS}	V_{BUS}	Bus power	Max power is 100 W split into four pins
B5	CC2 or V_{CONN}	V_{CONN}	Configuration channel or power for active or electronically marked cable	In V_{CONN} configuration, max. power is 1 W
B6	D+	-	USB2.0 datalines	-
B7	D-	-		-
B8	SBU2	SBU2	Sideband Use (SBU)	Alternate mode only
B9	V_{BUS}	V_{BUS}	Bus power	Max power is 100 W split into four pins

Pin	Receptacle signal	Plug signal	Description	Comment
B10	RX1-	RX1-	USB3.1 datalines or Alternate	10-Gbyte RX differential pair in USB 3.1
B11	RX1+	RX1+		
B12	GND	GND	Ground return	Can be up to 5 A split into four pins

1.4 Port configurations

As stated in the USB Type-C™ and USB Power Delivery specifications, a data role (host or device) and a power role (source, sink or DRP) can be assigned to each port. Both data and power roles can be independently and dynamically swapped according to rules and procedures established by the specifications.

1.4.1 Downstream Facing Port (DFP)

The downstream facing port is associated with the flow of data in a USB connection. It is usually the port on a host or hub which devices connect to.

In its initial state, the DFP must be able to supply V_{BUS} and V_{CONN} and support data.

1.4.2 Upstream Facing Port (UFP)

The upstream facing port is associated with the data flow in a USB connection. It represents the port on a device or a hub that connects to a host or the DFP of a hub. In its initial state, UFP sinks V_{BUS} and supports data (e.g., display).

1.4.3 Source or provider

This port must source power over V_{BUS} (5 V to 20 V and up to 5 A), and most commonly belongs to a host or hub DFP. A provider must assert an Rp resistor (pull-up resistor, See *Figure 5: "USB power delivery architecture"*) on CC pins (configuration channel pins, see *Section 1.6: "CC pins: port termination characteristics"*).

1.4.4 Sink or consumer

This port is able to sink power over V_{BUS}, making use of power (from 5 V to 20 V and up to 5 A), most commonly embedded on a device or UFP. A Consumer must assert an Rd resistor (pull-down resistor: see *Figure 5: "USB power delivery architecture"*) on CC pins.

1.4.5 Dual Role Power (DRP)

A dual role power USB port can operate as a source or a sink. The initial role of the port may be fixed or may alternate between the two port states.

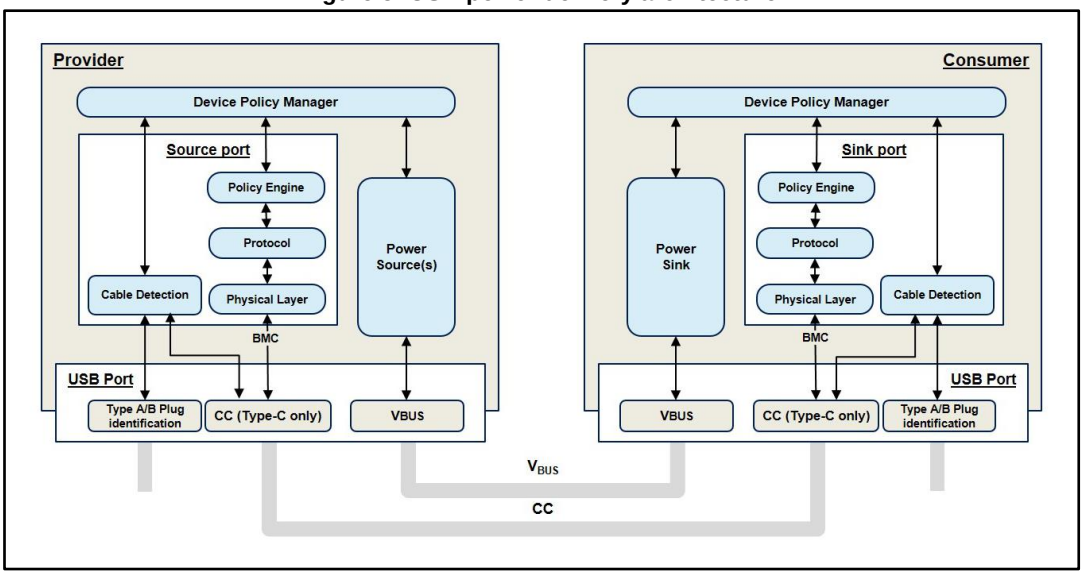
Initially, when operating as a source, the port also assumes the role of DFP; when operating as a sink, the port takes the role of UFP.

The port role may be changed dynamically to reverse power.

1.5 USB-C PD architecture

The USB Power Delivery specification defines the stack architecture with all its layers managing a PD device.

Figure 5: USB power delivery architecture



As per the USB Power Delivery protocol, a USB DFP is initially a Source and a USB UFP is initially a Sink. When these two entities are connected between them, they start to communicate by means of the configuration channel (CC), while the Source supplies the Sink through the V_{BUS} path. Although USB-PD enables the Source/Sink and the DFP/UFP, the roles may be swapped every time the application requests it.

1.5.1 Device Policy Manager (DPM)

The device policy manager deals with the USB Power Delivery resources used by one or more ports on the basis of the local device policy. It interacts with the policy engines and cable detection entities of the device to implement the local policies for each port.

1.5.2 Policy Engine (PE)

The policy engine interacts directly with the DPM to determine which local policy to apply. Its role is to drive the message sequences according to the sent message and its expected response.

It allows power negotiation by establishing an explicit contract for power exchange. The acceptance or the refusal of a request depends on the response of the DPM with respect to a specific power profile.

The PE also handles the flow of vendor defined messages, allowing the discovery, entry and exit of modes supported by the provider and consumer sides.

1.5.3 Protocol Layer (PRL)

The protocol layer drives message construction, transmission, reception and acknowledgment. It allows the monitoring of message flows and the detection of communication errors.

1.5.4 Physical layer (PHY)

The physical layer is responsible for sending and receiving messages across the CC wire. It consists of a transceiver that superimposes a BMC signal on the wire. It is responsible for managing data over the wire, avoiding collisions and detecting errors in the messages using a Cyclic Redundancy Check (CRC).

1.6 CC pins: port termination characteristics

The configuration channel (CC) pins are used in the discovery, configuration and management of connection across a USB Type-C™ cable, as well as a communication channel for the PHY layer of the USB Power Delivery.

There are two CC pins in each receptacle, but only one is connected through the cable to establish communication. The other pin can be re-assigned as the V_{CONN} pin for powering electronics in the USB Type-C™ plug of electronically-marked cables.

Specific Rd and Rp resistor values connected to CC pins allow single role or dual role system configuration. The attachment and orientation detection operations are carried out through CC lines through these resistors:

- a source must assert Rp pull-up resistors on both CC1 and CC2
- a sink must assert Rd pull-down resistors on both CC pins
- a dual role power (DRP) is equipped with both Rp pull-up resistors and Rd pull-down resistors on its CC pins and is able to dynamically assert the appropriate resistors when the role is fixed by the application according to the operated power role.
- A full-featured USB Type-C cable must assert Ra pull-down resistors on the V_{CONN} pin.

The following table provides the values to be used for Rp or current source.

Table 2: Source CC termination (Rp) requirements

Source Current Capability	Current Source to 1.7 V - 5.5 V	Rp pull-up to 3.3 V ±5%	Rp pull-up to 4.75 V - 5.5 V
Default USB power	80 µA ±20%	36 kΩ ±20%	56 kΩ ±20%
1.5 A at 5 V	180 µA ±8%	12 kΩ ±5%	22 kΩ ±5%
3.0 A at 5 V	330 µA ±8%	4.7 kΩ ±5%	10 kΩ ±5%

Rp resistors connected to both CC pins may be pulled-up to 3.3 V or 5 V. The resistor value is chosen on the basis the device port supplying capability. Moreover, if the source role is operated, the Rp resistors can be replaced by current sources.

The following table provides the values to be used for Rd or Sink CC termination.

Table 3: Sink CC termination (Rd) requirements

Rd setting	Nominal Value	Max Voltage on pin	Power Capability detection
±20% voltage clamp	1.1 V	1.32 V	No
±20% resistor to GND	5.1 kΩ	2.18 V	No
±10% resistor to GND	5.1 kΩ	2.04 V	Yes

Rd resistors may be implemented in multiple ways.

1.7 Power options

Regarding power exchange, every platform equipped with a Type-C™ connector but without power delivery must be able to support 5 V with one of the specific current capabilities. When power delivery is supported and the design is specifically optimized for managing high power loads, the same platform may support up to 20 V at 5 A (100 W).

Table 4: Power options

Mode of operation	Nominal voltage	Maximum current	Maximum power	Note
USB 2.0	5 V	500 mA	2.5 W	Default current based on specification
USB 3.1		900 mA	4.5 W	
USB BC1.2		up to 1.5 A	7.5 W	Legacy charging
USB Type-C™ current at 1.5 A		1.5 A		Support high power devices
USB Type-C™ current at 3 A		3 A	15 W	
USB PD	up to 20 V	up to 5 A	100 W	Directional control and power level management

1.8 Cable attachment and detachment detection and orientation

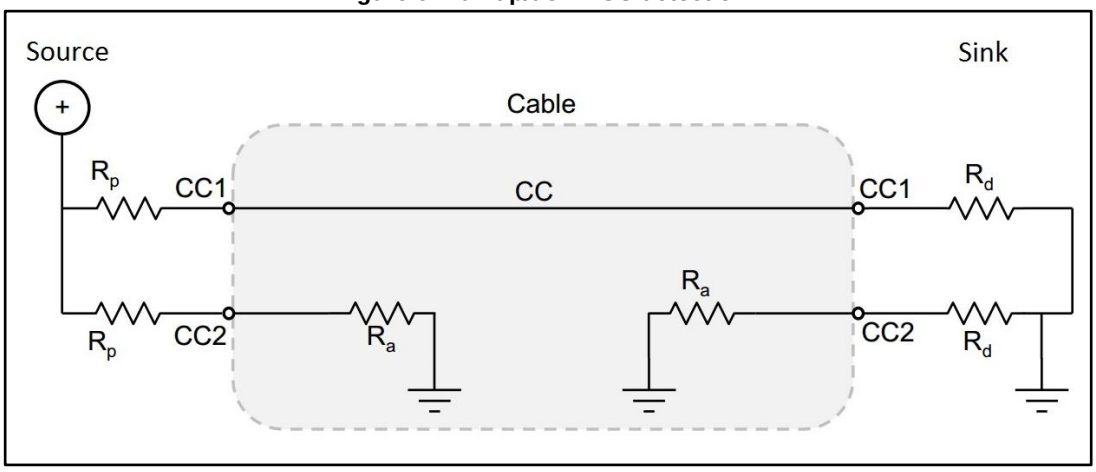
As stated in the USB Power Delivery specification, it is mandatory to determine the orientation of an attachment; i.e., when one of the two CC pins detects a valid Rp/Rd connection.

To detect an attachment, the source monitors both CC pins.

The pins are floating when nothing is attached, but when the sink is attached via the cable, one CC line of the source is directly pulled-down (through the sink Rd), signalling that a connection has been made (see *Figure 6: "Pull up/down CC detection"*).

Hence, once connection is established, a voltage divider is set between source pull-up resistor Rp and sink pull-down resistor Rd, fixing the voltage level on the CC line for the communication signals.

Figure 6: Pull up/down CC detection



At the same time, the orientation of the plug, and consequently of the cable, is defined according to which CC line (CC1 or CC2) detects a valid resistance after the attach event.

The figure above shows an unflipped cable orientation.

Moreover, the full-featured cable, exposing an Ra resistor, connects the V_{CONN} pins to ground.

1.9 Power negotiation

When a connection is made and the respective roles have been assigned, the source and the sink negotiate a contract for the power objects: the selected configuration channel (CC) allows them to establish communication and negotiate the power according to the protocol described in USB Power Delivery specification.

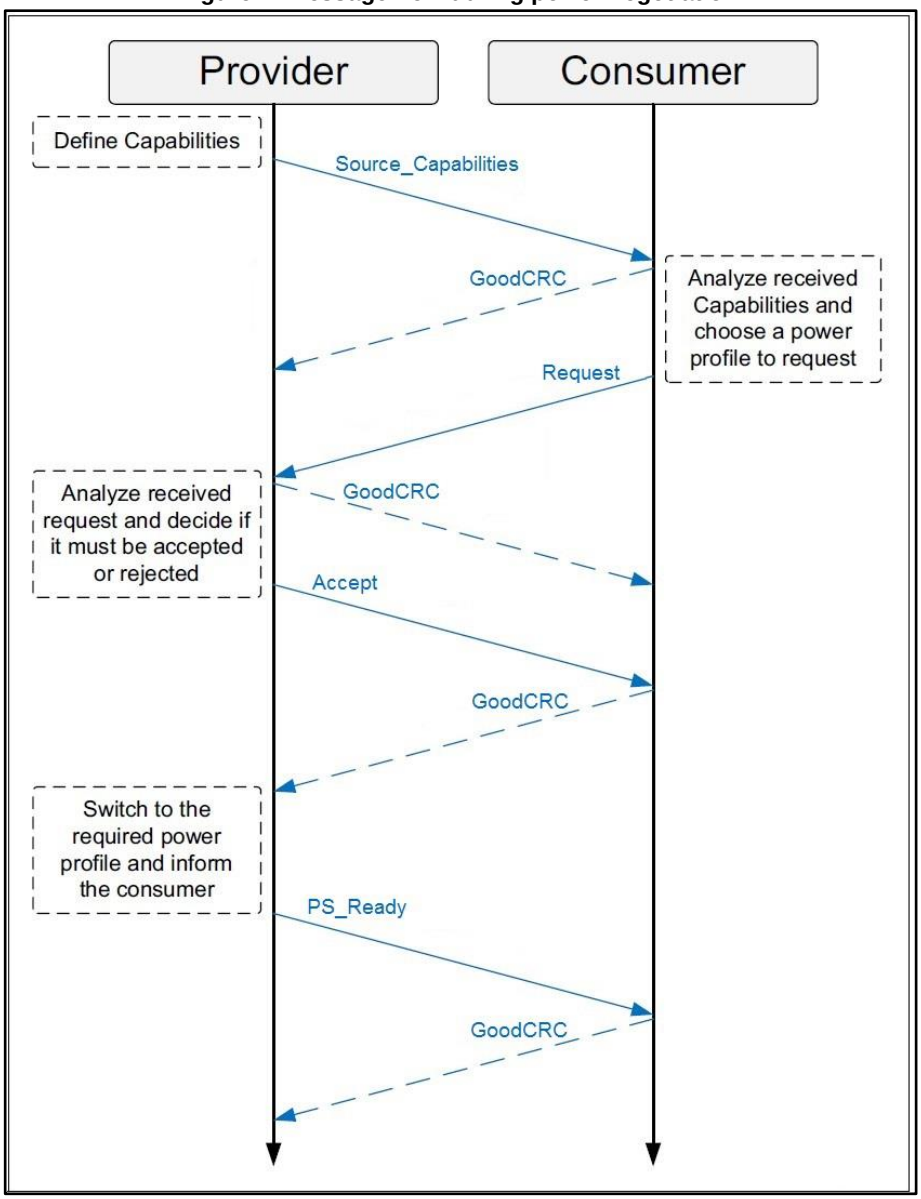
Originally, all the devices equipped with USB Type-C™ are able to provide up to 15 W (5 V and up to 3 A) power via the V_{BUS} path, but every subsequent request for delivering or receiving power from 15 W to 100 W (5 V at 3 A to 20 V at 5 A) must be negotiated according to the USB Power Delivery protocol.

The messages exchanged between a source (provider) and sink (consumer) are illustrated in *Figure 7: "Message flow during power negotiation"*.

1. Initially, the source dispatches a `Source_Capabilities` message to inform the port partner (sink) of its power capabilities.
2. The sink then sends a `Request` for one of the advertised power profiles.
3. The source accepts or rejects this request according to its power balance.
4. If confirmed, the source sends an `Accept` to the sink
5. The source then switches to the requested power profile and sends a `PS_Ready` confirmation message.

Each received message is acknowledged with a `GoodCRC` to confirm correct reception. Incorrect reception should be ignored and persistent communication errors should trigger a soft reset to reset protocol parameters and re-establish communication. If the error persists, a hard reset is performed.

Figure 7: Message flow during power negotiation



1.10 Full-featured Type-C™ cable and V_{CONN} supply

Full-featured Type-C™ cables are Type-C™ to Type-C™ cables that support USB2.0 and USB3.1 data operation, and include sideband use (SBU) wires.

All USB full-featured Type-C cables must be electronically marked and must provide 800 Ω to 1.2 kΩ impedance (Ra) that connects the assigned V_{CONN} pin to ground.

When a full-featured cable is attached to a source, the source must provide a V_{CONN} (5 V default) to supply it (valid voltage range is 3 V to 5.5 V).

Up to 1 W may be drawn from V_{CONN} to power the ICs in the plug, necessary to implement electronically-marked cables and V_{CONN}-powered accessories.

The V_{CONN} is systematically assigned to the free CC pin of the receptacle after a connection is established: the CC pins can be monitored to verify a valid Rp/Ra connection and then the V_{CONN} supply is routed by the source to the checked pin.

Since all the full-featured Type-C™ cables are reversible, both CC pins in the receptacle must be able to assume the role of CC and V_{CONN} on cable insertion.

1.11 Alternate modes and billboard device class

The USB Power Delivery specification supports alternate mode (Alt Mode) to transfer high-speed data over Type-C™ cables using protocols like:

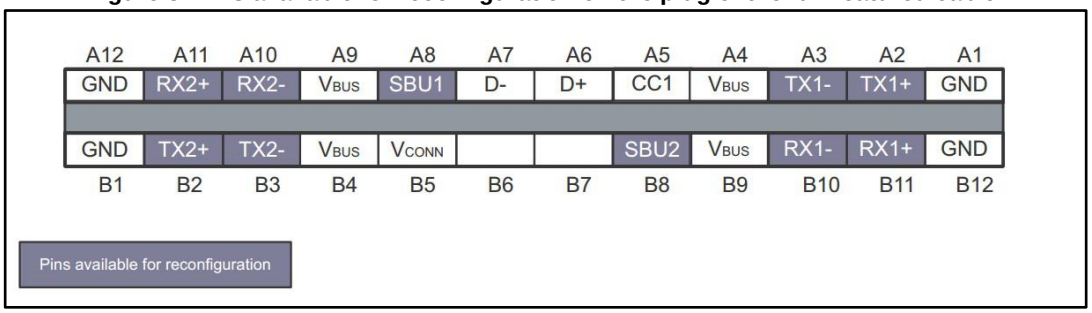
- High-Definition Multimedia Interface (HDMI)
- DisplayPort (DP)
- Peripheral Component Interconnect Express (PCI Express)
- Ethernet over twisted pair (Base-T Ethernet)
- Mobile High-Definition Link (MHL)

The adoption of alternate mode lets Type-C hosts and devices incorporate additional functionality, exploiting USB PD structured vendor defined messages (Structured VDMs) to manage typical display controller selection mechanisms: discover, enter and exit.

As alternate modes do not traverse the USB hub topology, they may only be used between a directly connected host and device.

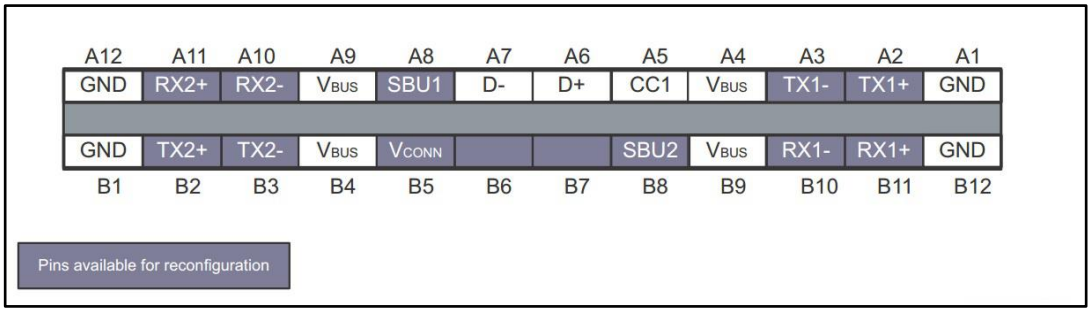
Structured VDMs may also be used for re-assignment of the pins that the USB Type-C connector exposes.

Figure 8: Pins available for reconfiguration on the plug of the full-featured cable



The following figure shows the pins available for reconfiguration with direct connect applications. There are three more pins because this configuration is not limited by the cable wiring.

Figure 9: Pins available for reconfiguration on the receptacle for direct connect applications



Where no equivalent USB functionality is implemented, the device must provide a USB interface exposing a USB billboard device class to identify the device. This is not required for non-user facing modes (e.g., diagnostic modes).

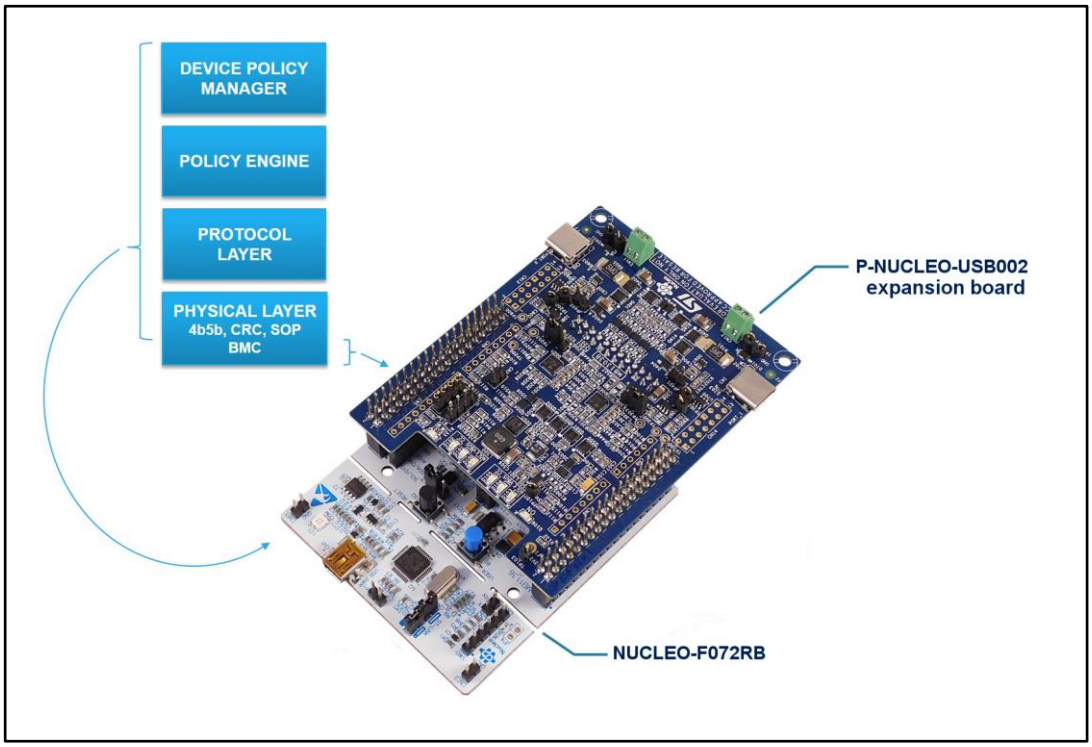
The USB billboard device class definition describes how to communicate the alternate modes supported by a device container to a host system, including string descriptors that provide supporting information in a human-readable format.

2 System architecture

The P-NUCLEO-USB002 USB Type-C™ and power delivery kit includes:

1. a NUCLEO-F072RB development board acting as the control board running the stack
2. a P-NUCLEO-USB002 expansion board acting as a Type-C and Power Delivery interface, with two STUSB1602 Type-C PD controllers
3. A full-featured and certified USB Type-C cable

Figure 10: The two boards composing the P-NUCLEO-USB002 kit



The P-NUCLEO-USB002 USB Type-C and Power Delivery expansion board is equipped with:

- two DRP USB Type-C™ ports managed by two STUSB1602 Type-C port controllers
- optional V_{BUS} current sensing (and discrete voltage monitoring)
- dedicated power connector to interface with an external power supply (not included) to provide different profiles as well as VCONN (5V), if necessary
- on-board power management able to provide internal supply voltages
- six status-control LEDs for USB-PD port purposes, a user LED and a power LED
- USB 2.0 interface capability available on both Type-C portsthere is only one USB 2.0 controller, which can be mapped to either port or in pass-through configuration.
- RoHS compliant
- PCB type and size:
  - PCB material: FR4
  - four-layer architecture
  - copper thickness: 35 µm

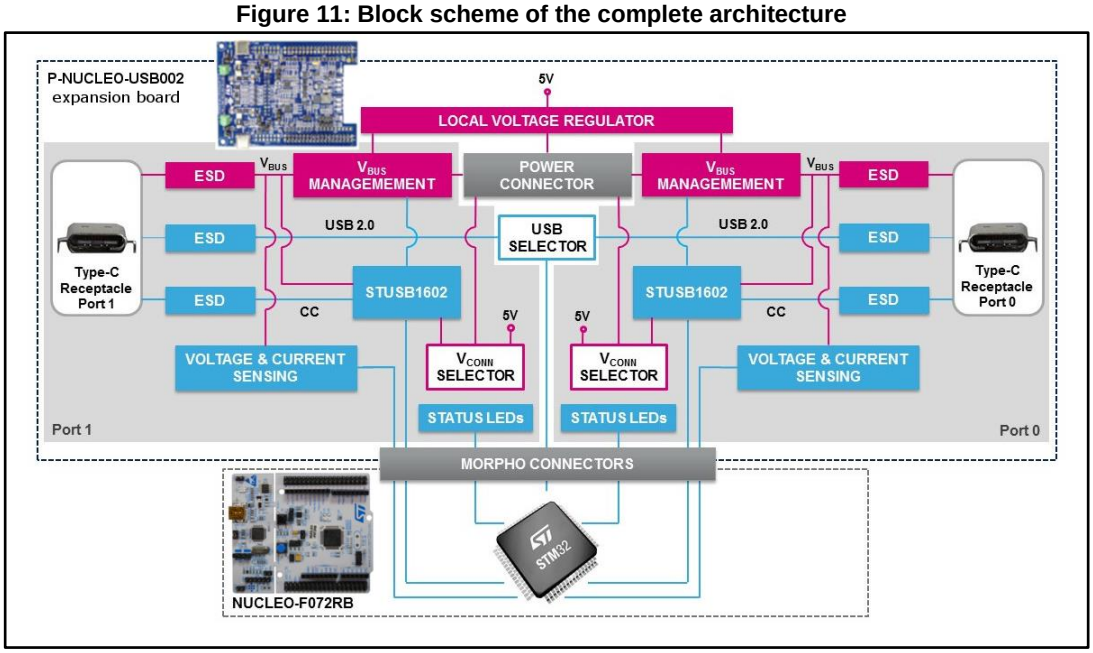
The NUCLEO-F072RB board includes:

- an STM32F072RBT6 32-bit microcontroller based on ARM® Cortex®-M0 with 128-Kbytes of Flash memory, 16-Kbytes of SRAM and a USB 2.0 full speed data interface in a LQFP64 package
- extension resources:
  - Arduino Uno revision 3 connectivity
  - ST morpho extension pin headers for full access to all STM32 I/Os
- on-board ST-LINK/V2-1 debugger/programmer with SWD connector:
  - selection-mode switch to use the kit as a standalone ST-LINK/V2-1
- flexible board power supply:
  - USB VBUS on Type-B connector or external source
  - Power management access point
- LEDs:
  - USB communication (LD1)
  - user LED (LD2)
  - power LED (LD3)
- push buttons:
  - USER
  - RESET
- USB re-enumeration capability; interfaces supported on USB:
  - Virtual Com port
  - Mass storage
  - Debug port
- Supported by various integrated development environments (IDEs):
  - IAR™
  - Keil®
  - GCC-based IDEs

The NUCLEO-F072RB included in the kit has a different solder bridge configuration with respect to the default one (see *Table 5: "NUCLEO-F072RB solder bridges and resistors to be modified"*)

2.1 System block scheme

Figure 11: Block scheme of the complete architecture



2.2 NUCLEO-F072RB STM32 Nucleo board

The STM32 Nucleo board provides an affordable and flexible way for solution and prototype development with any of STM32 microcontroller lines.

The board STM32F072RBT6 32-bit microcontroller is based on the ARM® Cortex®-M0 with 128 Kb Flash memory and 16 Kb SRAM.

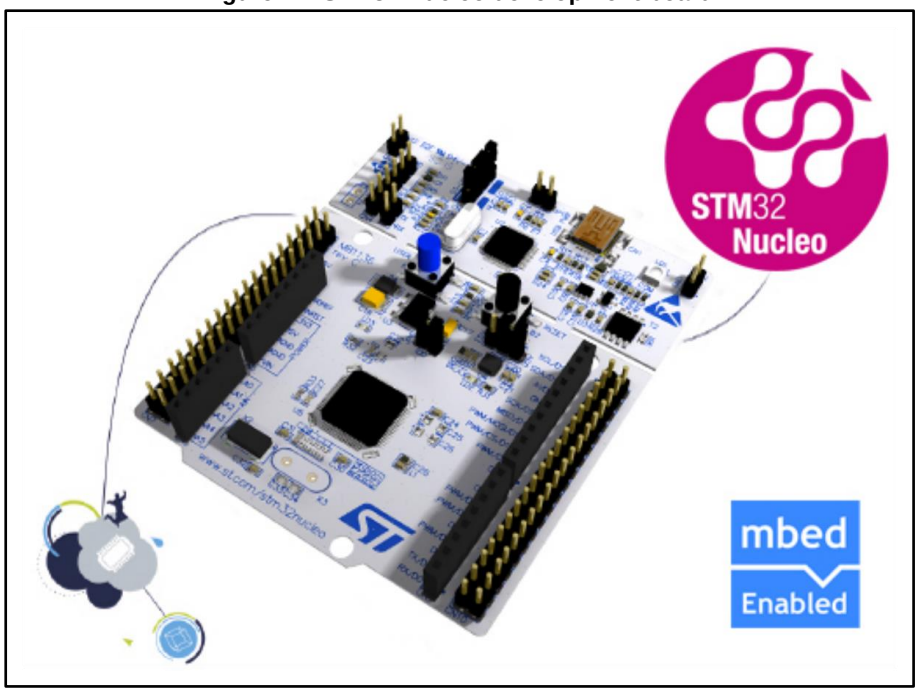
The Arduino™ connectivity support and ST morpho headers make it easy to expand with a wide range of specialized expansion boards.

Separate probes are not required as it integrates the ST-LINK/V2-1 debugger/programmer.

The STM32 Nucleo board comes with the comprehensive STM32 HAL software library together with various packaged software examples.

Visit *http://www.st.com/stm32nucleo* for more information.

Figure 12: STM32 Nucleo development board



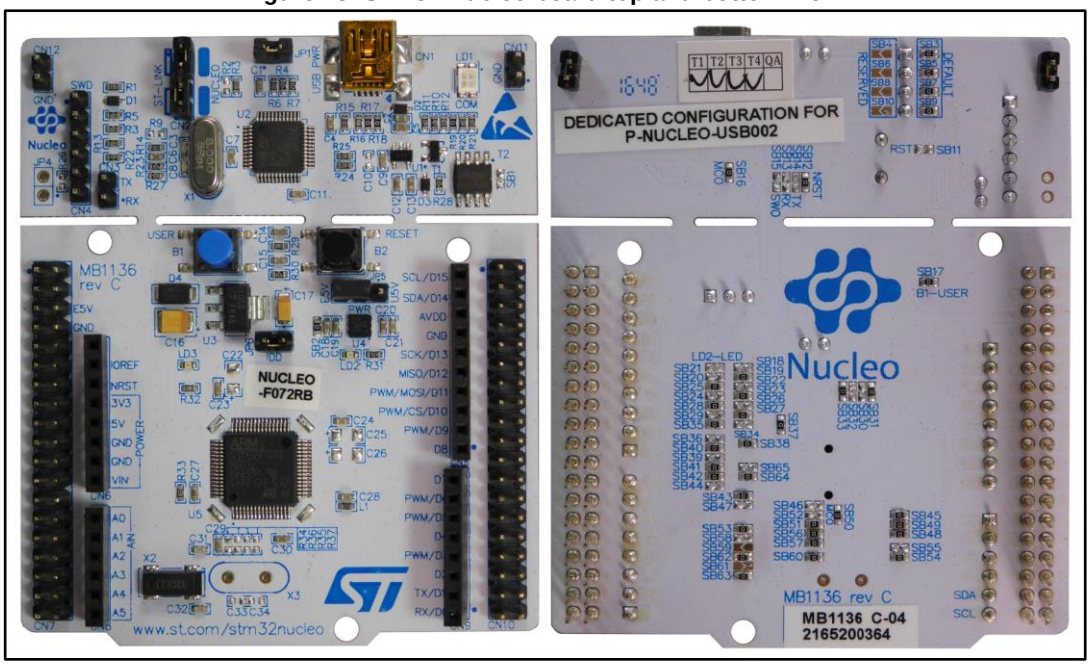
The solder bridge configuration on the NUCLEO-F072RB Nucleo board is customized to support USB PD applications (see *Table 5: "NUCLEO-F072RB solder bridges and resistors to be modified"* and *Figure 13: "STM32 Nucleo board top and bottom view"*).

For further information, please refer to user manual *UM1724 STM32 Nucleo-64 boards* on www.st.com.

Table 5: NUCLEO-F072RB solder bridges and resistors to be modified

Bridge reference	State	Description
SB13	OFF	PA2 and PA3 on STM32F103CBT6 (ST-LINK MCU) are disconnected from PA3 and PA2 of the STM32F072RBT6 MCU.
SB14		
SB15	OFF	The SWO signal is not connected to PB3 on STM32F072RBT6 MCU.
SB21	OFF	Green user LED LD2 is not connected to PA5 on STM32F072RBT6 MCU.
R34	OFF	LSE not used: PC14 and PC15 used as GPIOs instead of low speed clock.
R36		
SB48	ON	
SB49		
SB62	ON	To connect another USART (not the default USART2) to STLINK MCU, using flying wires between ST morpho connector and CN3. SB13 and SB14 should be OFF.
SB63		

Figure 13: STM32 Nucleo board top and bottom view



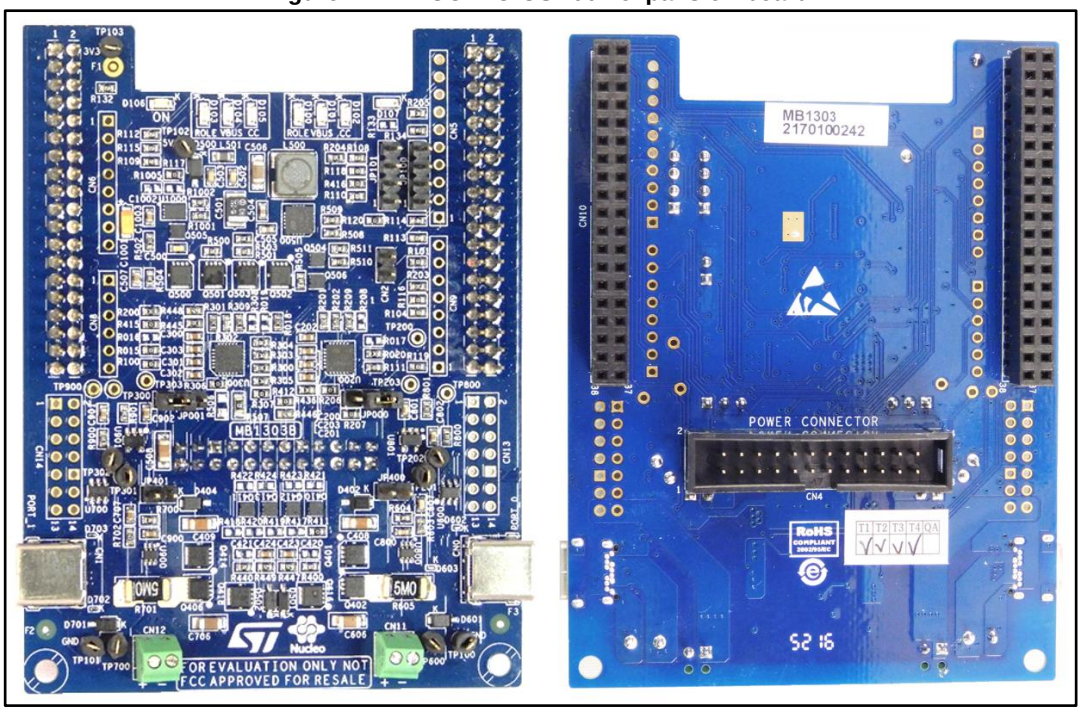
2.3 P-NUCLEO-USB002 expansion board

The P-NUCLEO-USB002 expansion board consists of different stages for specific aspects of the power delivery protocol. It embeds two USB Type-C™ ports, each containing the following functional blocks:

- an STUSB1602 Type-C port controller
- V_{BUS} management stage
- voltage and current measurement circuitry
- a V_{CONN} selector
- status LEDs
- ESD protections

The P-NUCLEO-USB002 expansion board local voltage regulator interacts with both of V_{BUS} management blocks.

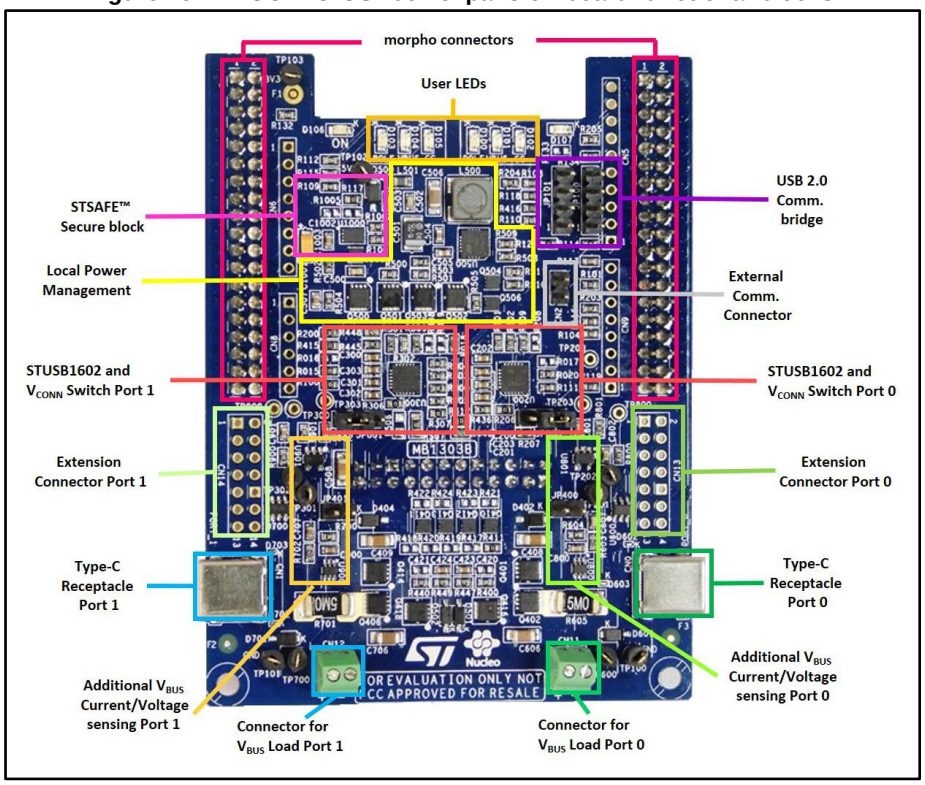
Figure 14: P-NUCLEO-USB002 expansion board



The USB selectors (JP100, JP101) allow use of the USB2.0 peripheral provided by the microcontroller, alternately on port 0 and on port 1, as well as allowing a pass-through topology connecting the USB pins of the two Type-C ports.

The main functional blocks regarding USB-C PD applications are shown below

Figure 15: P-NUCLEO-USB002 expansion board functional blocks



The connectors and jumpers regarding USB-C PD applications are shown below.

Figure 16: P-NUCLEO-USB002 expansion board connectors and jumpers

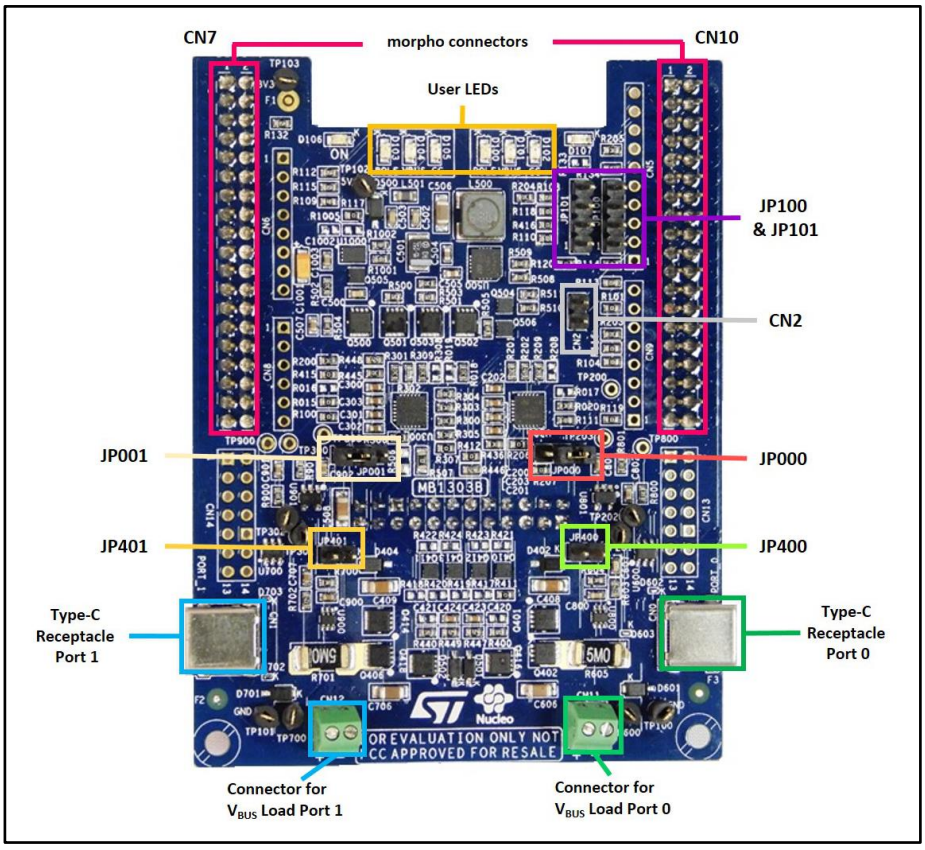
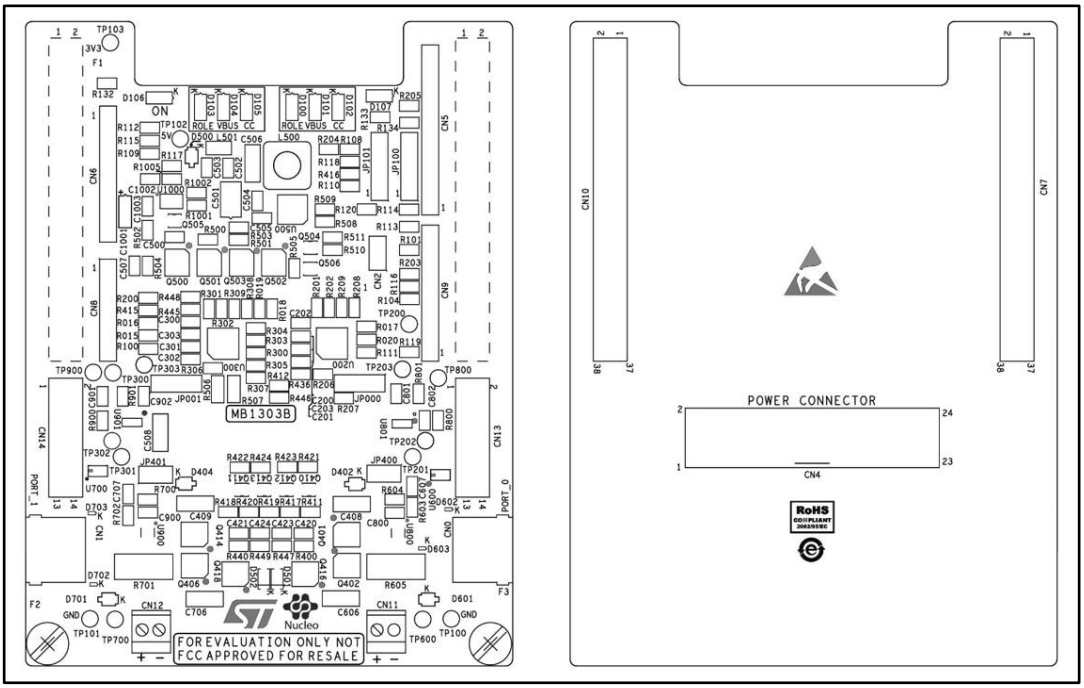


Figure 17: P-NUCLEO-USB002 expansion board silkscreen



2.3.1 P-NUCLEO-USB002 expansion board: USB Type-C connectors, voltage and current sense stage

The two USB Type-C™ CN0 and CN1 connectors on the P-NUCLEO-USB002 expansion board represent port 0 and port 1 respectively.

When a port acts as a power provider, it can supply an external device connected via a USB Type-C™ cable; the same port can receive power if it is set as a consumer.

Figure 18: P-NUCLEO-USB002 expansion board USB Type-C receptacle and current sensing (port 0) schematic view

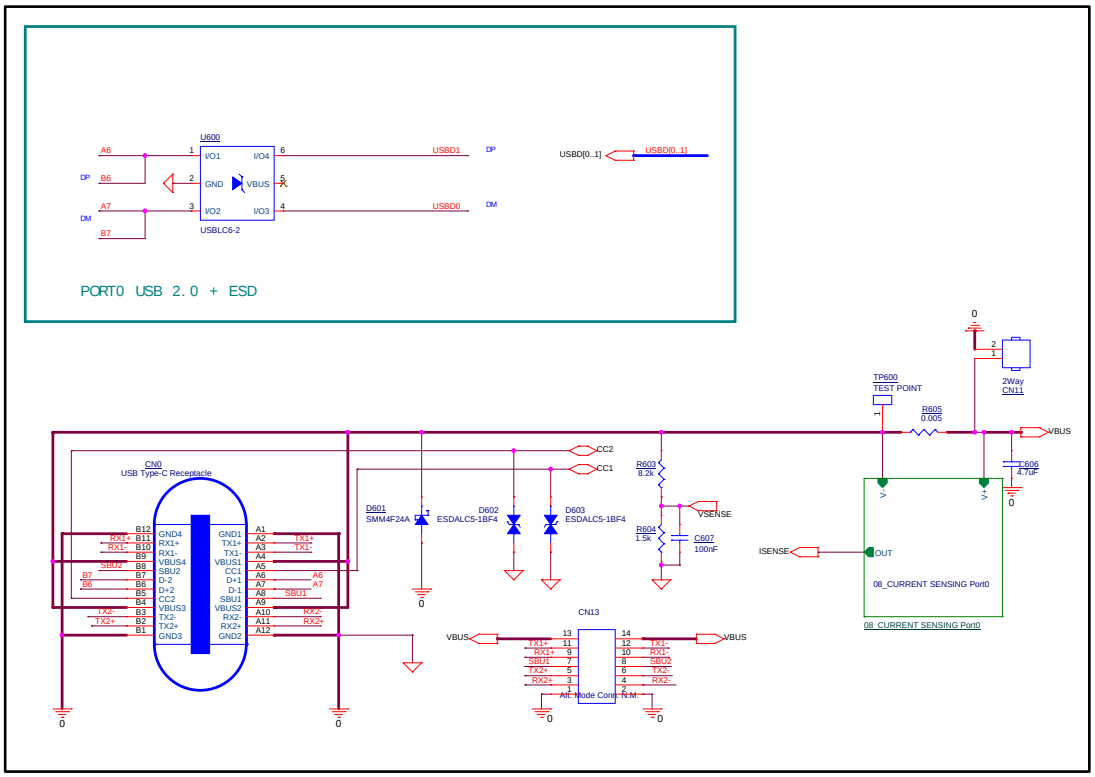
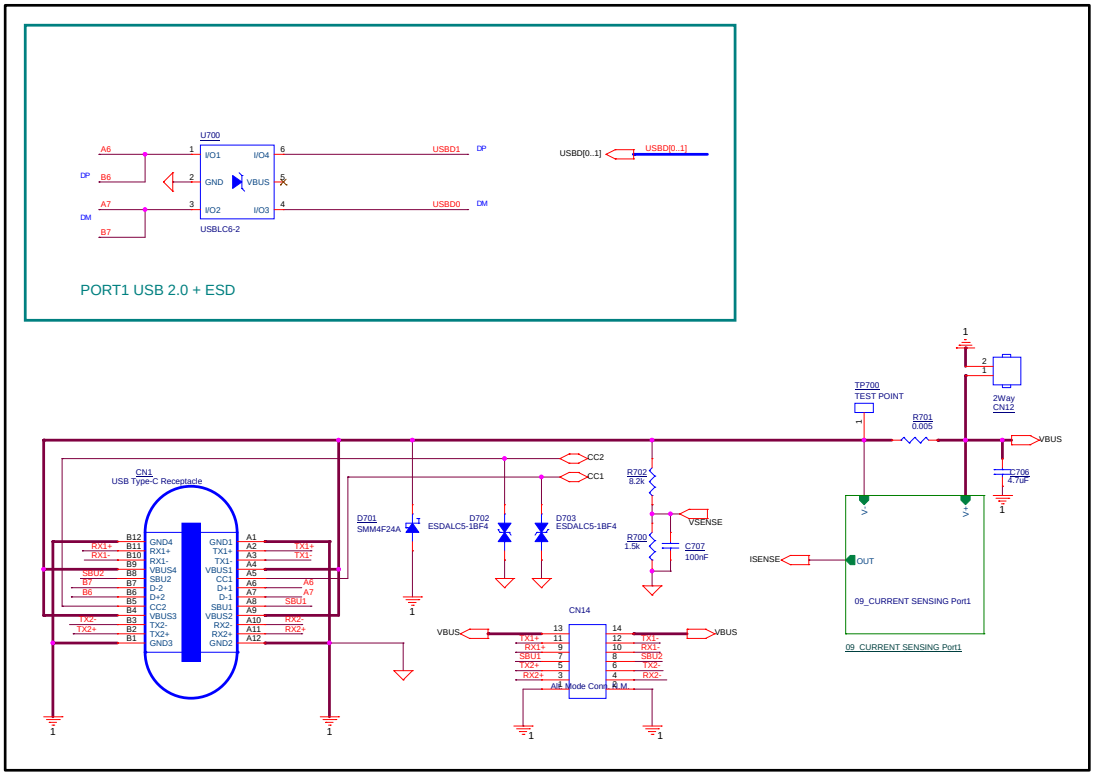


Figure 19: P-NUCLEO-USB002 expansion board USB Type-C receptacle and Current sensing (port 1) schematic view



The STUSB1602 monitors the V_{BUS} voltage on the USB Type-C receptacle via its VBUS_SENSE input pin and alerts the MCU if an undervoltage or overvoltage condition is detected.

The V_{BUS} operating range is defined by a high and a low voltage threshold above and below the nominal V_{BUS} target value. Valid V_{BUS} voltage and operating thresholds can be changed via the I²C interface.

Each port is also equipped with a dedicated current-sensing stage.

Figure 20: P-NUCLEO-USB002 expansion board Port 0 Current sensing stage schematic view

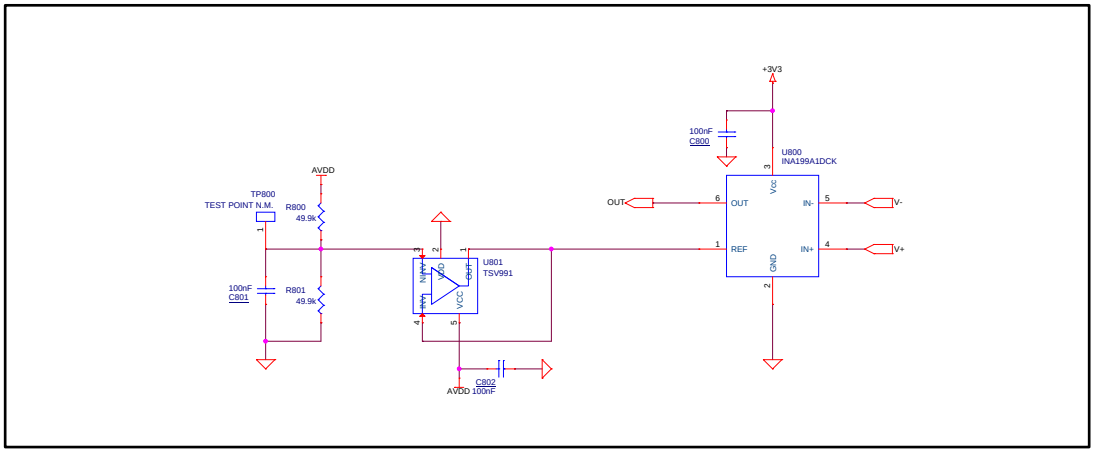
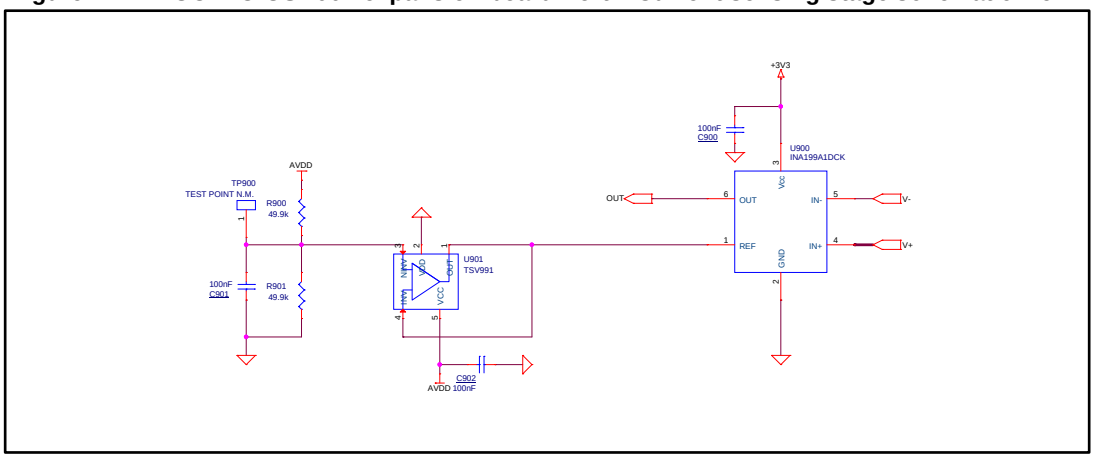


Figure 21: P-NUCLEO-USB002 expansion board Port 1 Current sensing stage schematic view



Although the STUSB1602 monitors the V_{BUS} voltage, a resistive voltage divider for voltage sensing managed by the STM32F072RBT6 ADC peripherals, has been added. This option, matched with the current sensing stage, provides the alternative of measuring power with the microcontroller.

2.3.2 P-NUCLEO-USB002 expansion board: STUSB1602 USB Type-C controller

The STUSB1602 device is a 20 V technology USB Type-C™ controller IC, designed to establish and manage the connection between two USB Type-C ports, according to the configured power role (source, sink or dual role power).

It is fully compatible with:

- USB Power delivery specification (rev2.0)
- USB type-C™ cable and connector spec (rev1.2)

Each STUSB1602 device interfaces with a Type-C port and interacts with the V_{BUS} management block and the microcontroller.

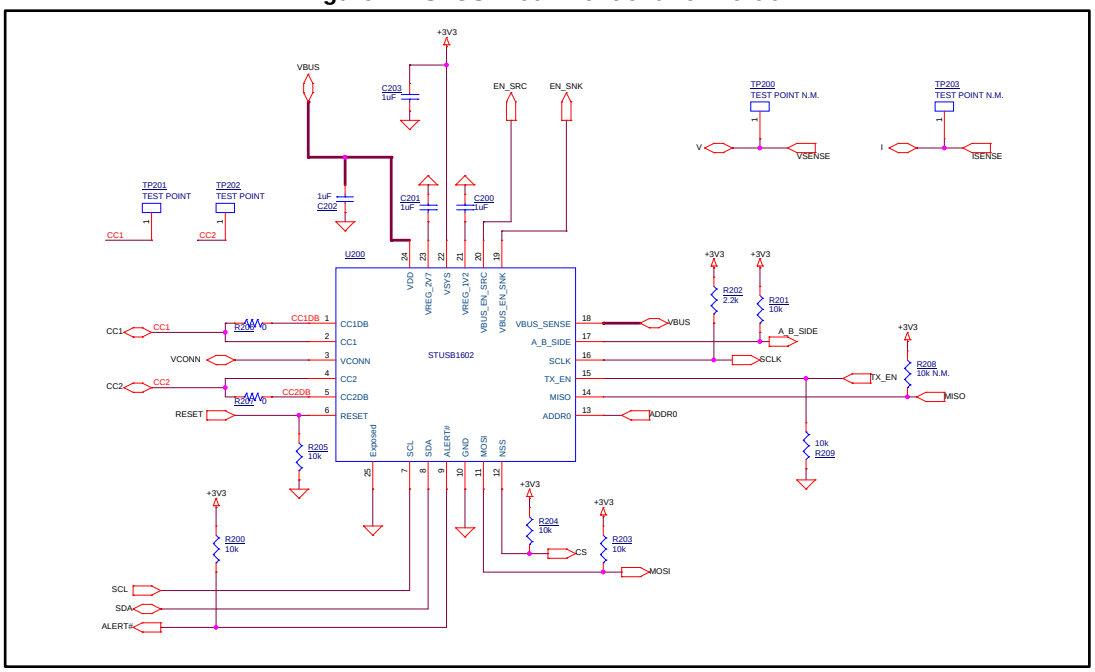
The Type-C port interface allows implementation of the lower level functions of the PD firmware stack, including:

- detecting the connection between two USB Type-C ports (attach detection)
- managing BMC coding and decoding
- establishing a valid source-to-sink connection
- determining the attached mode: source, sink or accessory
- resolving cable orientation and twist connections to establish USB data routing (mux control)
- configuring and monitoring the V_{BUS} power path
- managing the V_{BUS} power mode: USB Default, Type-C Medium or Type-C High current mode
- configuring V_{CONN} when required

It also supports dead battery and low power standby modes as well as providing high voltage protection and debug accessory support.

For further information, see the STUSB1602 datasheet on *www.st.com*.

Figure 22: STUSB1602 front end for Port 0



This circuit description uses port 0 for reference (see *Figure 22: "STUSB1602 front end for Port 0"*), but the same applies to port 1.

The STUSB1602 device interacts with the STM32F072RBT6 microcontroller embedded in the NUCLEO board via the following communication buses:

1. **I²C bus**: is used by the MCU to configure and control status of the device. This bus is shared by both STUSB1602 devices, according to their I²C addresses (ADDR0). Additionally, the STUSB1602 start-up profile can be fully customized by accessing its integrated non-volatile memory via I²C.
2. **SPI peripheral**: is reserved for USB-PD messages. The BMC transceiver on the STUSB1602 means that messages exchanged between the MCU and STUSB1602 are 5B coded (except the Preamble, as per the USB-PD specification).

The following MCU GPIOs are used for specific functions for each STUSB1602 device:

1. **TX_EN** is a control signal from the MCU to STUSB1602. It enables the BMC control logic that will transfer data from the MCU serial interface, encode in BMC format and drive the connected CC line.
2. **ALERT** signals specific events regarding CC detection, monitoring and fault condition groups to the microcontroller. Each of these groups of events can be masked configuring specific I²C registers.
3. **A_B_SIDE** pin provides cable orientation; this is also provided by an internal I²C register.
4. **RESET** allows resetting of the device; this can be also accomplished via a specific I²C register.

CC1 and CC2 configuration channel pins are for connection and attachment detection, plug orientation and system configuration management across the USB Type-C cable.

CC1DB and CC2DB are for dead battery mode when the STUSB1602 is configured in the sink power role or dual power role. This mode allows systems powered by a battery to be supplied by V_{BUS} when the battery is fully discharged.

This mode is enabled by connecting CC1DB and CC2DB respectively to CC1 and CC2. Thanks to this connection, the pull-down terminations on the CC pins are present by default even if the device is not supplied.

When an STUSB1602 device configured in dead battery mode is connected to source, it is supplied via its VDD pin connected to V_{BUS} on the USB Type-C receptacle side. The STUSB1602 may establish the source-to-sink connection by enabling the power path on V_{BUS}.

When the STUSB1602 assumes the sink power role, the VBUS_EN_SNK pin allows the enabling of the incoming V_{BUS} power when the connection to a source is established and V_{BUS} is in the valid operating range. Similarly, in the source power role, the VBUS_EN_SRC pin allows the enabling of the outgoing V_{BUS} power when the connection to a sink is established and V_{BUS} is in the valid operating range.

In both cases, the open drain output of the VBUS_EN_SNK and VBUS_EN_SRC pins allow the direct driving of a PMOS transistor. The logic value of these pins is also advertised in a dedicated I²C register bit.

2.3.3 P-NUCLEO-USB002 expansion board: V_{CONN} switch

The V_{CONN} input power pin of STUSB1602 is connected to pins CC1 and CC2 across independent subscript for CONN power switches. The V_{CONN} voltage provided to the STUSB1602 device can be supplied via the power connector or the local voltage regulator according to the JP000 and JP001 jumper settings below.

Table 6: P-NUCLEO-USB002 expansion board VCONN settings

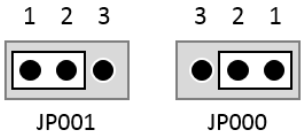
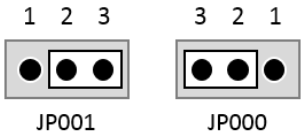
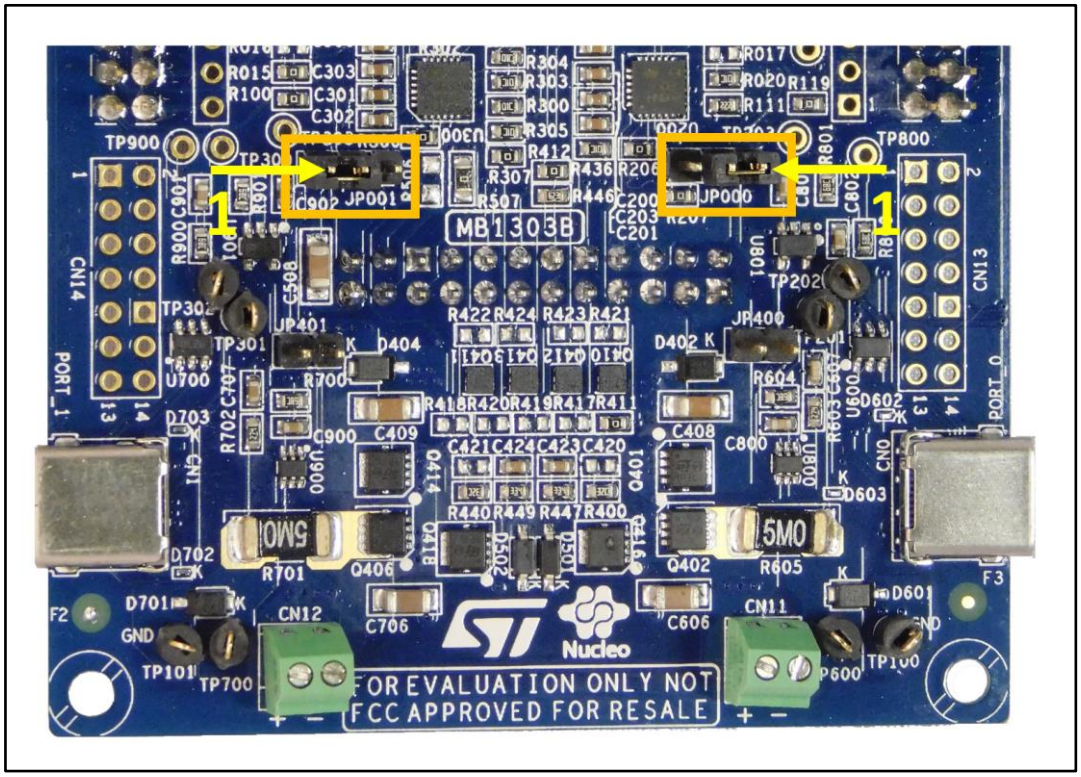
	V_{CONN} is provided by the local voltage regulator
	V_{CONN} is provided by the power connector

Figure 23: P-NUCLEO-USB002 expansion board: JP000 and JP001 jumper settings to provide VCONN through the local voltage regulator



The V_{CONN} voltage is only applied to the CC pin that is not connected to the CC wire after:

- the device is configured in source power role or dual role power (DRP)
- V_{CONN} power switches are enabled
- a valid connection to a sink is achieved
- Ra is detected on the unwired CC pin
- a valid power source is applied on the VCONN pin with respect to a pre-defined UVLO threshold.

V_{CONN} discharge is automatically managed by STUSB1602.

V_{CONN} protections can be configured via a dedicated control register (see STUSB1602 datasheet on *www.st.com*).

2.3.4 P-NUCLEO-USB002 expansion board: VBUS management

Figure 24: P-NUCLEO-USB002 expansion board Port 0 schematic view of the VBUS management mechanism

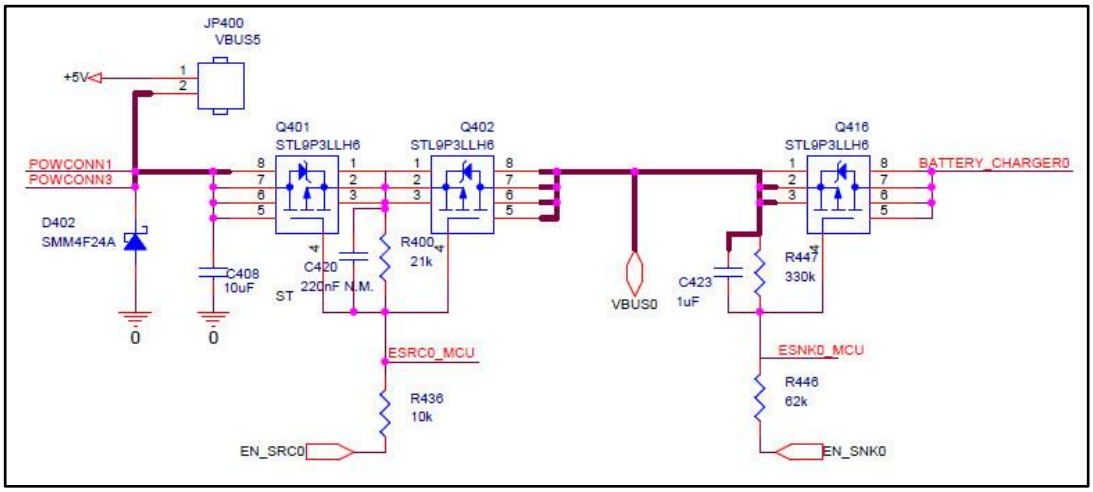
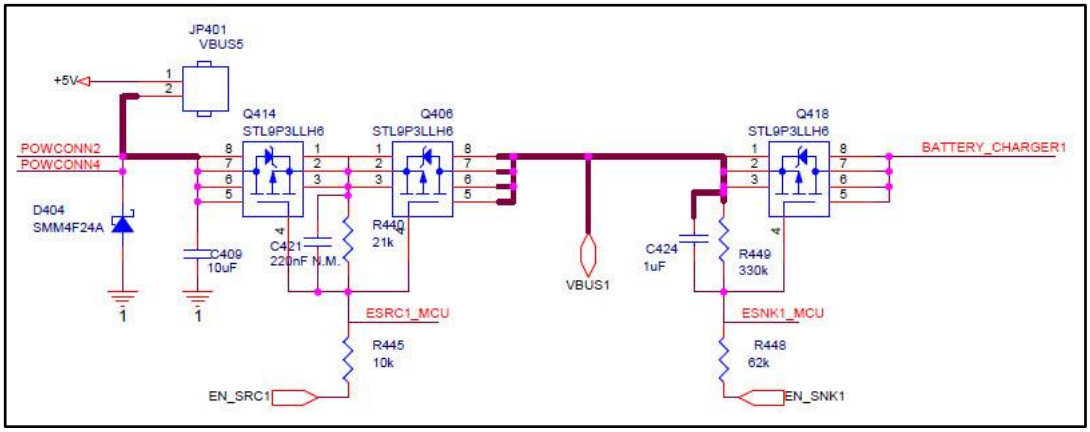


Figure 25: P-NUCLEO-USB002 expansion board Port 1 schematic view of the VBUS management mechanism



This circuit description uses port 0 for reference, but the same applies to port 1.

The V_{BUS} management block can manage different V_{BUS}, as described by USB PD specification. It provides energy if the STUSB1602 is set as a provider and supplies energy when it is a consumer.

Transistors Q401 and Q402 are set in back-to-back configuration to protect and isolate the V_{BUS} supplying path in both directions.

When the port acts as a provider, the V_{BUS} power can be supplied via power connector CN4 (jumper JP400 must be left open). V_{BUS} is put on the supply path via the discrete load switch (Q401-Q402), driven by the STUSB1602 VBUS_EN_SRC pin.

If no external power supply is available, closing jumper JP400 allows using the 5 V from the NUCLEO-F072RB board as V_{BUS} in the provider role only. This is mainly used for demonstration purposes.

When the port is a consumer, the same V_{BUS} path is managed by the VBUS_EN_SNK pin of the STUSB1602 device that enables the discrete load switch Q416.

The STUSB1602 monitoring block handles the internal V_{BUS} discharge path connected to the VBUS_SENSE input pin. The discharge path is activated on a detach event or when the device enters the error recovery state, regardless of the power role.

The V_{BUS} discharge to 0 V path is enabled by default over a time interval that can be modified via dedicated I²C registers.

The exposed Rp value that advertises the current capability may be set on the STUSB1602 by registers (i.e., SINK_POWER_STATE).

2.3.5 P-NUCLEO-USB002 expansion board: local power management stage

This stage does not contain any power blocks to derive multiple voltage profiles from a single input voltage source. To implement such a solution, the user must connect appropriate external circuitry, under their own responsibility, to the P-NUCLEO-USB002 expansion board CN4 power connector.

The P-NUCLEO-USB002 expansion board is designed to provide power to the connected platforms via:

1. An external power supply: this may supply high power levels. If the external power supply is connected to connector CN4, JP400 and JP401 must be open; V_{BUS} will be a voltage level offered by the external power supply board
2. The standard USB port through connector CN1 on the NUCLEO-F072RB board. The maximum available power is the 5 V 500 mA currently offered by the standard PC USB; jumper JP400 or JP401 or both must be closed

The local power management stage consists of the following sets of load switches implemented by the MOSFETs transistor:

1. Q500-Q501 enabled by Q505
2. Q502-Q503 enabled by Q506

Similarly, the STM32F072RBT6 MCU can act on DRP and /DRP lines enabling the DC-DC converter L6984 (U500).

Figure 26: P-NUCLEO-USB002 expansion board: schematic view of the load switches of the local power management

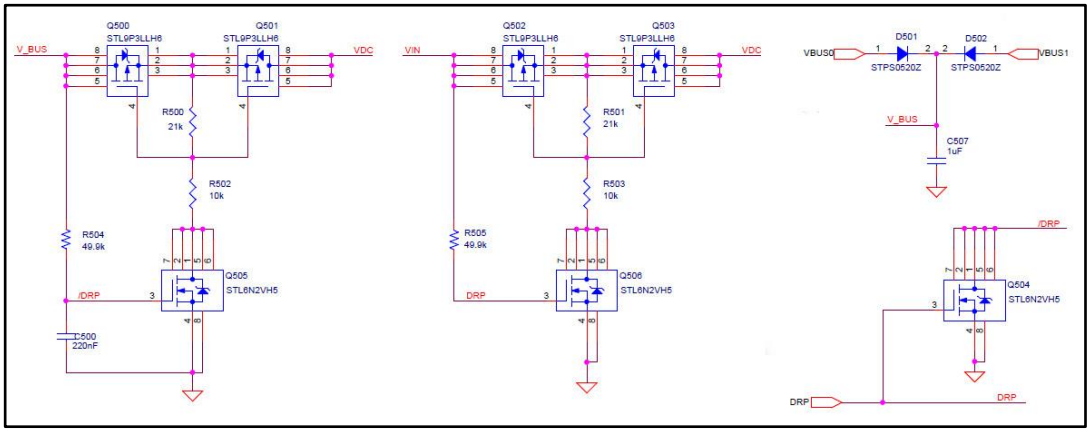
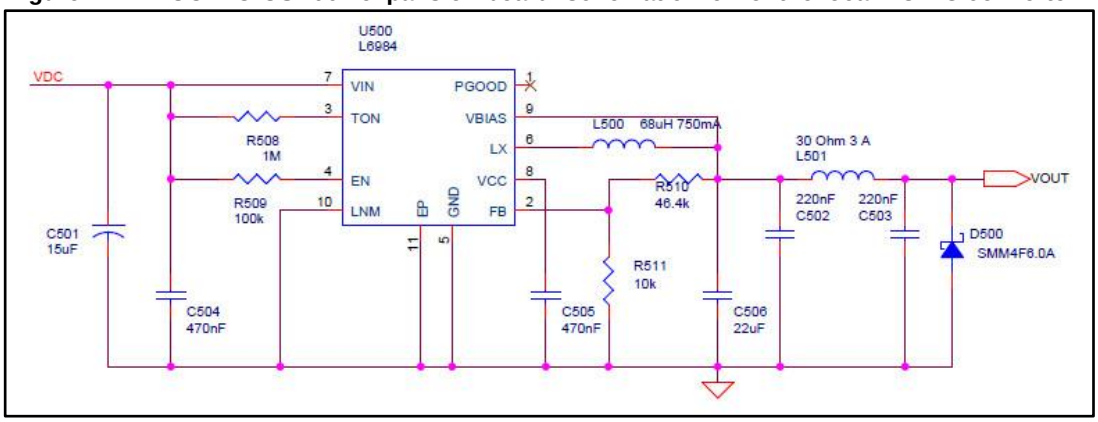


Figure 27: P-NUCLEO-USB002 expansion board: schematic view of the local DC-DC converter



This stage is able to supply different voltage levels to the system according to the USB PD specification. Q500-Q501 and Q502-Q503 are set in back-to-back configuration and permit isolation in both directions of the supplying path.

It is indeed possible to supply the platform from V_{BUS} via a provider connected to one of the ports or from V_{IN} via power connector CN4: the two independent power paths are directly controlled by the STM32F072RBT6 MCU through the DRP and /DRP functions.

When the platform is the consumer and receives V_{BUS} on one of the two ports, diodes D501 and D502 deliver V_{BUS} to the Q500-Q501 load switch and then supply the DC-DC converter, and hence the system.

2.3.6 P-NUCLEO-USB002 expansion board: STSAFE secure device

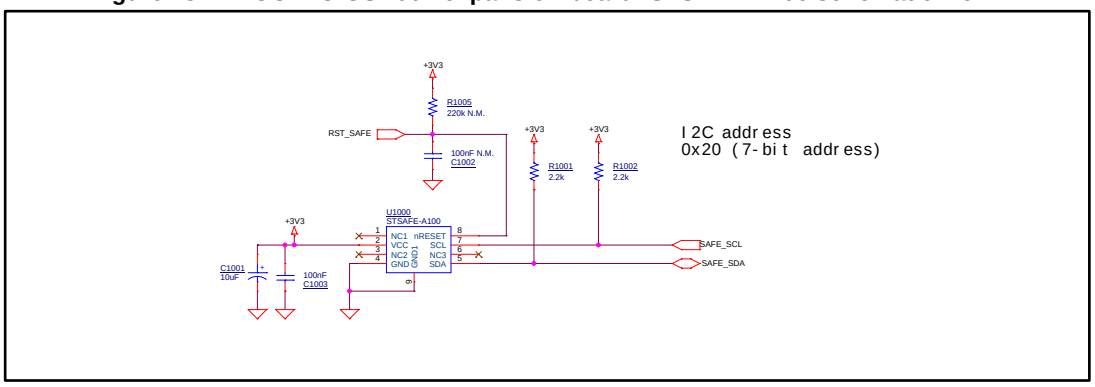
The STSAFE™-A100 device on the P-NUCLEO-USB002 expansion board provides authentication and secure data management services.

It is mounted on a device that authenticates a remote host or on a peripheral that authenticates the local host itself, legitimating communication between the two entities.

As the STSAFE-A100 is provided with a host library that can be ported to a wide range of microcontrollers, there is an exclusive I²C link between the device in P-NUCLEO-USB002 expansion board and the MCU in the NUCLEO-F072.

The STSAFE capabilities can therefore authenticate single port communication or ensure the integrity of the whole platform (dual port solution).

Figure 28: P-NUCLEO-USB002 expansion board: STSAFE-A100 schematic view

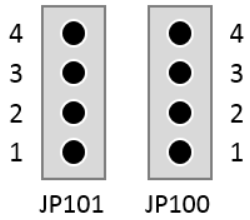
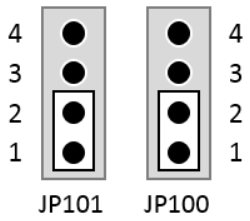
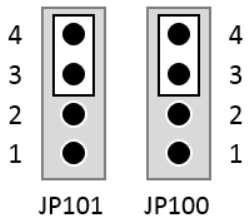


Refer to STSAFE-A100 databrief at *www.st.com*.

2.3.7 P-NUCLEO-USB002 expansion board: USB2.0

The P-NUCLEO-USB002 expansion board enables different USB2.0 configurations via jumpers JP100 and JP101.

Table 7: P-NUCLEO-USB002 expansion board JP100 and JP101 settings

	USB2.0 functionality not used
	USB2.0 functionality to Type-C™ port 0
	USB2.0 functionality to Type-C port 1

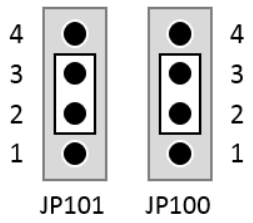
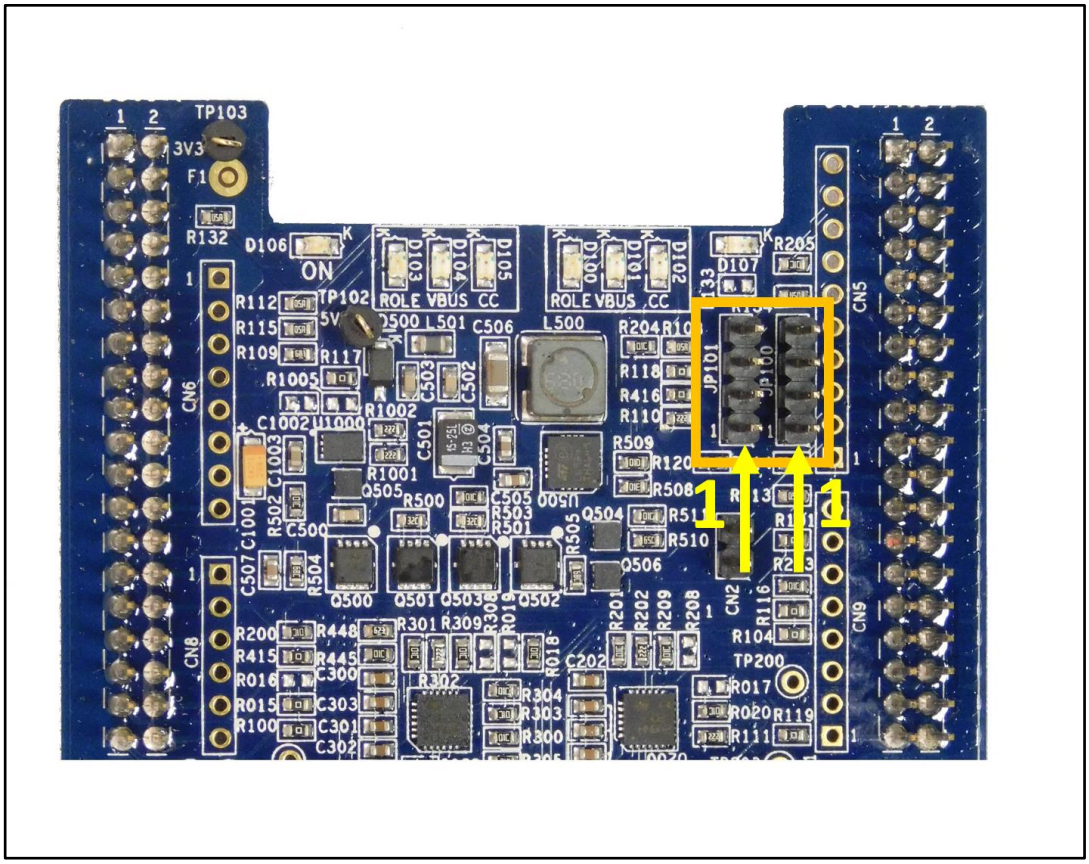
	USB2.0 bridge between port 0 and port 1

Figure 29: P-NUCLEO-USB002 expansion board: JP100 and JP101 connectors for USB 2.0 configurations



2.3.8 P-NUCLEO-USB002 expansion board: ESD protections

The P-NUCLEO-USB002 expansion board features USB protections on:

1. V_{BUS}: each port is protected by an SMM4F24A Transil, designed to protect sensitive equipment against electro-static discharges
2. CCx lines: each CC line is connected to an ESDALC5-1BF4 providing low clamping, low capacitance, bidirectional, single line ESD protection
3. USB2.0 pins: the USB pins of both ports are connected to a USBLC6-2 ESD protection for high speed interfaces (USB 2.0, Ethernet links and video lines) with high integrity while still protecting sensitive chips against the worst ESD strikes

2.3.9 P-NUCLEO-USB002 expansion board: connectors

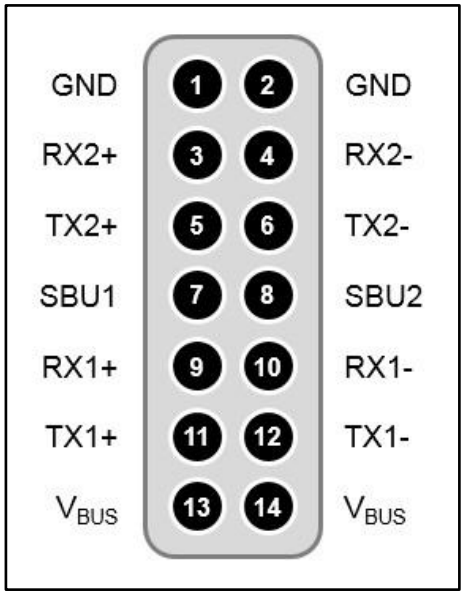
2.3.9.1 VBUS load connectors

Connectors CN11 and CN12 for port 0 and port 1 are able to supply V_{BUS} externally to power any load connected to them.

2.3.9.2 Extension Connectors

Both ports support the USB PD and the USB Type-C™ specification, including the alternate-mode capability. For this reason, connectors CN13 and CN14 for port 0 and port 1 are available to expose all the main pins and facilitate the design of applications using this mode.

Figure 30: P-NUCLEO-USB002: CN13 and C14 connector pinout



2.3.9.3 Power connector

The P-NUCLEO-USB002 power connector CN4 on the rear of the board connects the expansion board to a selectable power supply with appropriate voltage and current couples for the USB PD specification.

The pairs 1 and 3 as well as 2 and 4 can externally supply the V_{BUS} management circuits from a power board to the two Type-C™ receptacles CN0 and CN1.

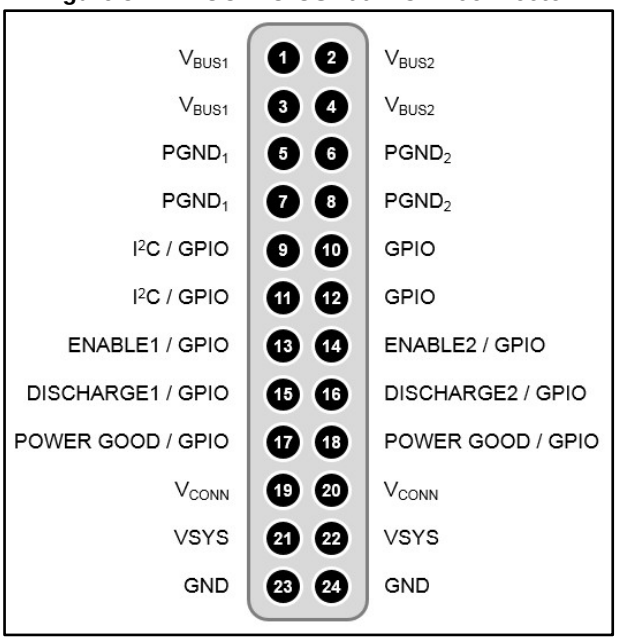
Pairs 9 and 11 as well as 10 and 12 can select the external power requested by the application. In particular, the default GPIO functionality assigned to pins 9 and 11 can be changed to I²C SDA and I²C SCL respectively if the external power board acts as smart power supply.

Enable and discharge pairs 13 and 15 as well as 14 and 16 can control any external power supply board load switches available. A pair of POWER GOOD pins check whether the power supply is ready to provide the requested power range.

Power connector CN4 is also able to provide the V_{CONN} voltage if the external power supply board supports that functionality.

Finally, the V_{SYS} system supply voltage be the voltage input for the embedded DC-DC converter.

Figure 31: P-NUCLEO-USB002: CN4 connector



2.3.9.4 Serial communication connector

The P-NUCLEO-USB002 expansion board embeds the CN2 connector that exposes the USART1 peripheral of the STM32F072RBT6 MCU when the expansion board is plugged to the NUCLEO-F072RB board.

This allows exploiting the serial communication to send commands to the NUCLEO-F072 MCU or access to the application data.

Since the ST-LINK contained in the NUCLEO-F072 board may be used as a Virtual COM port, accessible by the CN3 connector, the expansion board CN2 connector can be connected to the NUCLEO-F072 CN3 connector via two female wires (included in the blister). It is also possible to retrieve the application data through a serial/TCP terminal.

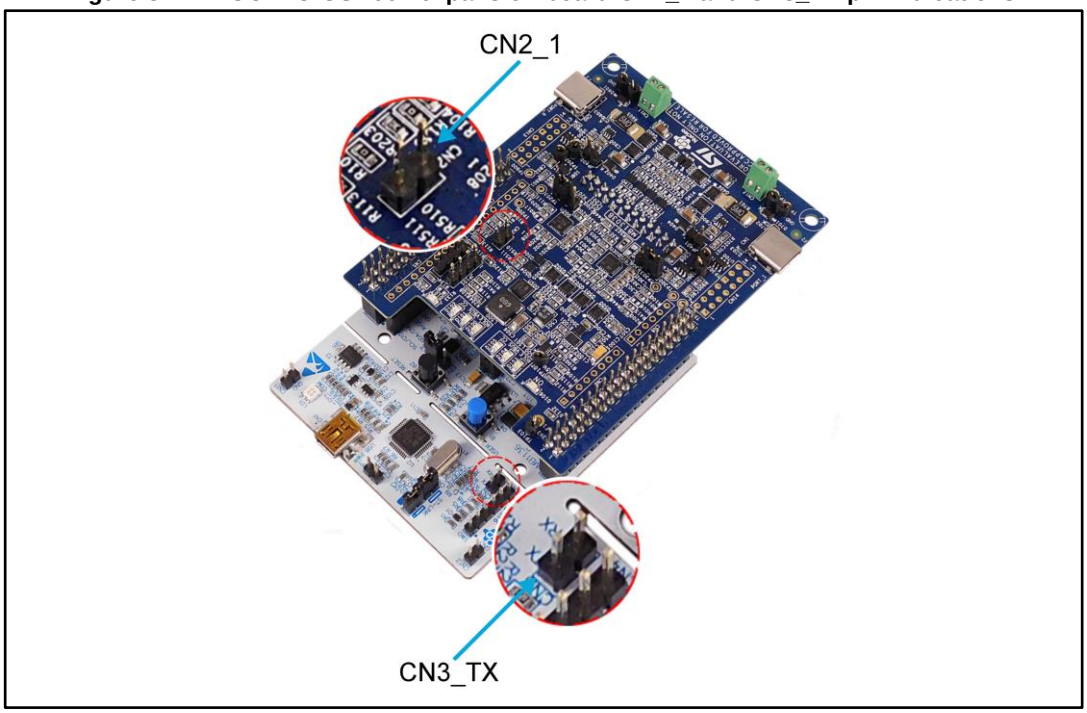
The following table and the figure below provide more information on how to set up the serial communication connection.[a]

Table 8: P-NUCLEO-USB002 expansion board serial communication connection

Transmit/receive	ST-LINK	P-NUCLEO-USB002 expansion board
TX	CN3_TX	CN2_1
RX	CN3_RX	CN2_2

[a] Refer to UM2205, "Getting started with the STM32 Nucleo pack for USB Type-C™ and Power Delivery with the Nucleo-F072RB board and the STUSB1602", available at www.st.com.

Figure 32: P-NUCLEO-USB002 expansion board CN2_1 and CN3_TX pin indications



2.3.10 P-NUCLEO-USB002 expansion board: test points

Table 9: P-NUCLEO-USB002 expansion board test points

Test Point	Description
TP100, TP101	GND
TP102	+3.3V
TP103	E5V
TP201	CC1 port 0
TP202	CC2 port 0
TP200 (N.M.)	V sense port 0
TP203 (N.M.)	I sense port 0
TP301	CC1 port 1
TP302	CC2 port 1
TP300 (N.M.)	V sense port 1
TP303 (N.M.)	I sense port 1
TP600	VBUS port 0
TP700	VBUS port 1
TP800 (N.M)	Reference voltage of port 0 current sensing circuit
TP900 (N.M)	Reference voltage of port 1 current sensing circuit

2.3.11 P-NUCLEO-USB002 expansion board: jumpers

Table 10: P-NUCLEO-USB002 expansion board jumpers

Jumper	Description
JP000	Port 0 VCONN selector
JP001	Port 1 VCONN selector
JP100	USB DP line selector
JP101	USB DM line selector
JP400	Port 0 VBUS selector. If closed, VBUS is provided by the standard USB port through connector CN1 of the NUCLEO board (without any other source on the power connector)
JP401	Port 1 VBUS selector. If closed, VBUS is provided by the standard USB port through connector CN1 of the NUCLEO board (without any other source on the power connector)

2.3.12 P-NUCLEO-USB002 expansion board: user LEDs

Table 11: P-NUCLEO-USB002 expansion board LED signaling

LED	Port	Function	Color	Comment
D100	0	ROLE	Blue	- **one** blink: port is a **Provider** - **two** blinks: port is a **Consumer** - **three** blinks: port is **DRP**
D103	1			
D101	0	VBUS	Green	- **blinking**: the VBUS is **supplied** (when Provider) **or sunk** (when Consumer) by the port. - **ON**: the two connected ports have established an **explicit contract**
D104	1			
D102	0	CC	Orange	- **one** blink: **CC Line #1** is connected - **two** blinks: **CC Line #2** is connected
D105	1			

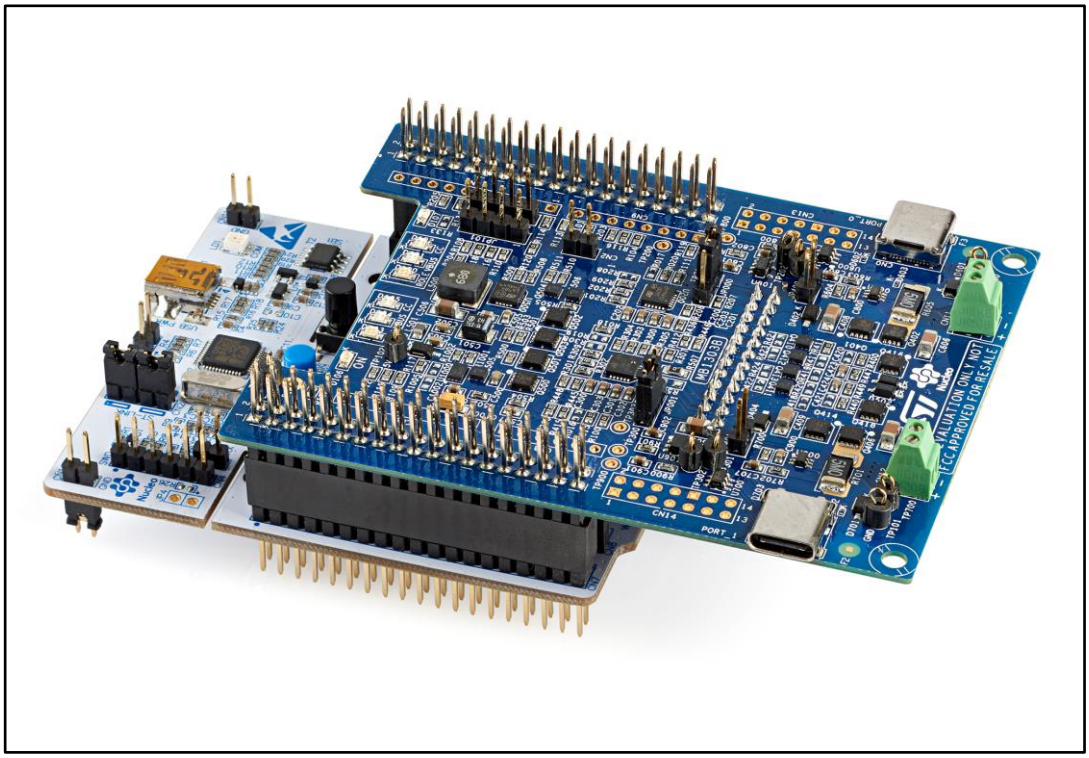
2.4 Full-featured Type-C cable

A certified USB full-featured Type-C™ cable is provided with the pack.

3 System setup

For each configuration, the P-NUCLEO-USB002 expansion board must be stacked on the NUCLEO-F072RB board through the ST morpho connector, paying attention to the mounting direction and alignment of the two boards, as per the following figure.

Figure 33: P-NUCLEO-USB002 mounting orientation



3.1 Source power role configuration

3.1.1 Using the NUCLEO-F072 on-board voltage regulator

When the P-NUCLEO-USB002 kit is connected to a PC or a standard USB power supply via a USB Type-A to Mini-B cable plugged to CN1 connector, the on-board NUCLEO-F072RB voltage regulator supplies the entire system and provides (5 V) V_{BUS}.

To deliver the V_{BUS} on the selected port from the NUCLEO-F072RB USB PWR voltage (CN1 connector):

- on NUCLEO-F072RB board:
  - JP1 open
  - JP5 (PWR) closed on U5V (fitting pins 1-2)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - JP400 and JP401 (relative to PORT_0 or PORT_1) closed

3.1.2 Using an external power supply

If an external power board is connected to the P-NUCLEO-USB002 expansion board power connector CN4, the provider can offer different V_{BUS} voltage profiles. The Provider configuration is:

- on NUCLEO-F072RB board:
  - JP1 closed
  - JP5 (PWR) closed on E5V (fitting pins 2-3)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - JP400 and JP401 (relative to PORT_0 or PORT_1) open

Once configured, if a full-featured cable is used, verify that on the selected port the VCONN jumpers (JP000 and JP001) on the P-NUCLEO-USB002 expansion board are configured according to the preferred voltage delivery mode:

- fit pins 1-2 of JP000 and JP001 to select VCONN provided by the +5 V generated by NUCLEO-F072RB board
- fit pins 2-3 of JP000 and JP001 to select the VCONN provided by the external power supply through the CN4 power connector

3.2 Sink power role configuration

In the Consumer configuration, the system may manage two supply options.

The first one is supplied by the NUCLEO-F072RB board, while the second configuration is more interesting from the application point of view, since it implements a specific feature of the USB PD solutions, i.e. the Dead Battery mode (when a Consumer is supplied by the Provider by mean of its VBUS). Both configurations correspond to two diverse settings, too:

3.2.1 Using the NUCLEO-F072RB on-board voltage regulator

When the P-NUCLEO-USB002 kit is connected to a PC or a USB power supply by NUCLEO-F072RB CN1 connector, the on-board voltage regulator supplies the system.

In this case, the system setting:

- on NUCLEO-F072RB board:
  - JP1 open
  - JP5 (PWR) closed on U5V (fitting pins 1-2)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - V_{BUS} jumpers JP400 and JP401 open
  - V_{CONN} jumpers JP000 JP001 open

3.2.2 Using an external provider

This configuration allows applications to implement a specific feature of the USB PD solutions: the Dead Battery mode.

If the Consumer is supplied by the V_{BUS} delivered by the connected Provider through the USB Type-C™ cable, the system setting is:

- on NUCLEO-F072RB board:
  - JP1 closed
  - JP5 (PWR) closed on E5V (fitting pins 2-3)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - V_{BUS} jumpers JP400 and JP401 open
  - V_{CONN} jumpers JP000 JP001 open

3.3 Dual Role Power configuration

The DRP configuration setting ensures operation as both provider and consumer.

As the provider configuration setting ensures the correct V_{BUS} and V_{CONN} management, the DRP configuration setting is the same as described for the Provider.

3.3.1 Using the NUCLEO-F072RB on-board voltage regulator

When the P-NUCLEO-USB002 kit is supplied by the on-board NUCLEO-F072RB voltage regulator, via a USB Type-A to Mini-B cable plugged to the NUCLEO board CN1 connector and then to a PC or a standard USB power supply.

The system setting is:

- on NUCLEO-F072RB board:
  - JP1 open
  - JP5 (PWR) closed on U5V (fitting pins 1-2)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - JP400 and JP401 (relative to PORT_0 or PORT_1) closed

3.3.2 Using an external power supply

Connect an external power board to the P-NUCLEO-USB002 power connector CN4 so the system can offer different VBUS voltage profiles.

In this case, the system configuration is:

- on NUCLEO-F072RB board:
  - JP1 closed
  - JP5 (PWR) closed on E5V (fitting pins 2-3)
  - JP6 (IDD) closed
- on P-NUCLEO-USB002 expansion board:
  - JP400 and JP401 (relative to PORT_0 or PORT_1) open

Once configured, if a full-featured cable is used, verify that on the selected port the VCONN jumpers (JP000 and JP001) on the P-NUCLEO-USB002 expansion board are fit according to the preferred voltage delivery mode:

- fit pins 1-2 of JP000 and JP001 to select VCONN provided by the +5 V generated by NUCLEO-F072RB board
- fit pins 2-3 of JP000 and JP001 to select the VCONN provided by the external power supply through the CN4 power connector

4 Ordering information

To order the USB Type-C™ and Power Delivery Nucleo pack, use the order code:

- **P-NUCLEO-USB002**

5 Electrical schematics

Figure 34: P-NUCLEO-USB002 expansion board circuit schematic - global view

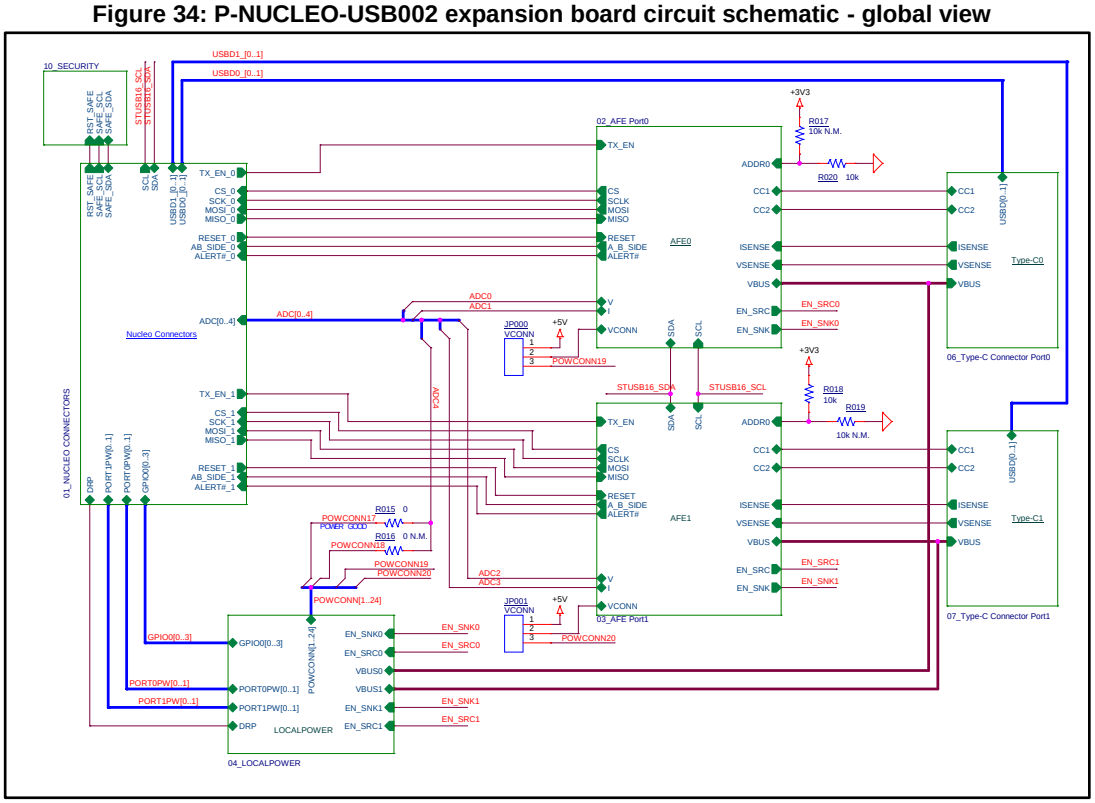


Figure 35: P-NUCLEO-USB002 expansion board circuit schematic - MCU interface

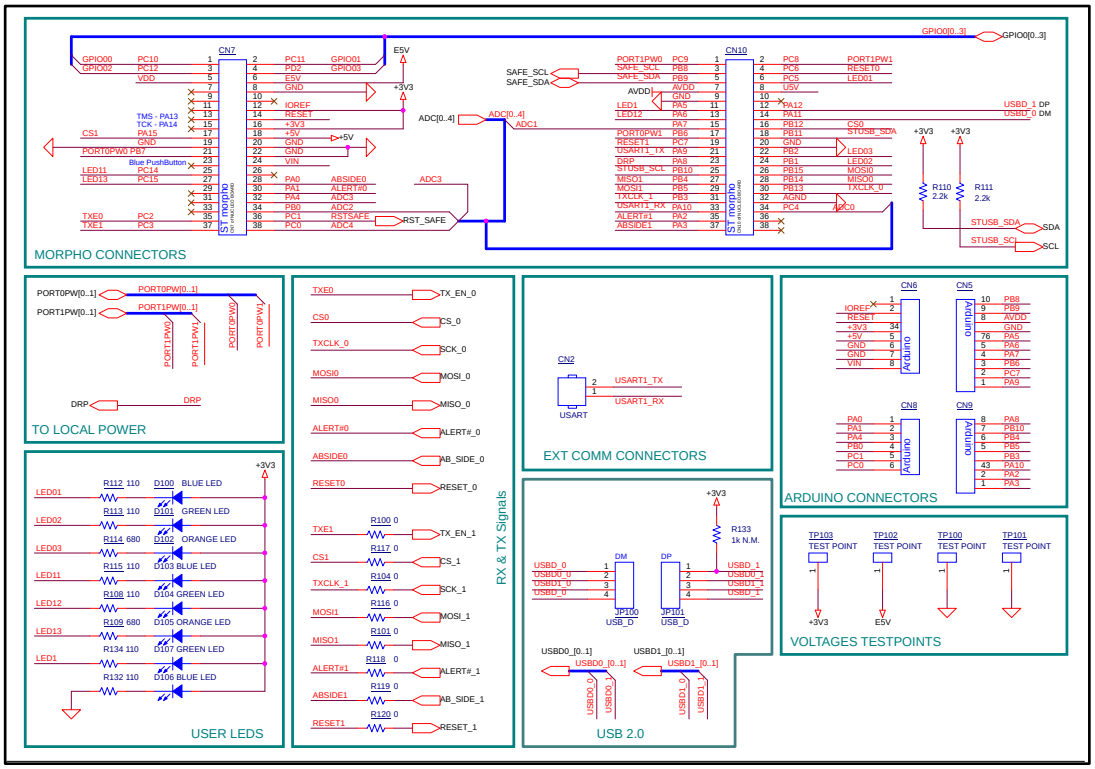


Figure 36: P-NUCLEO-USB002 expansion board circuit schematic - STUSB1602 front end Port0

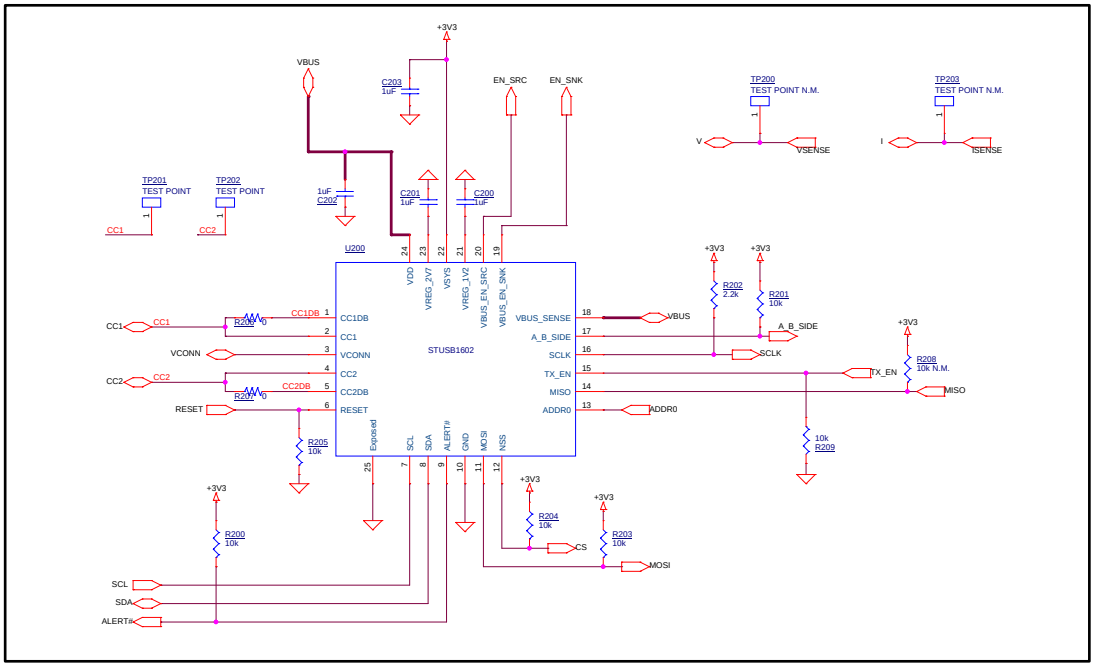


Figure 37: P-NUCLEO-USB002 expansion board circuit schematic - STUSB1602 front end Port1

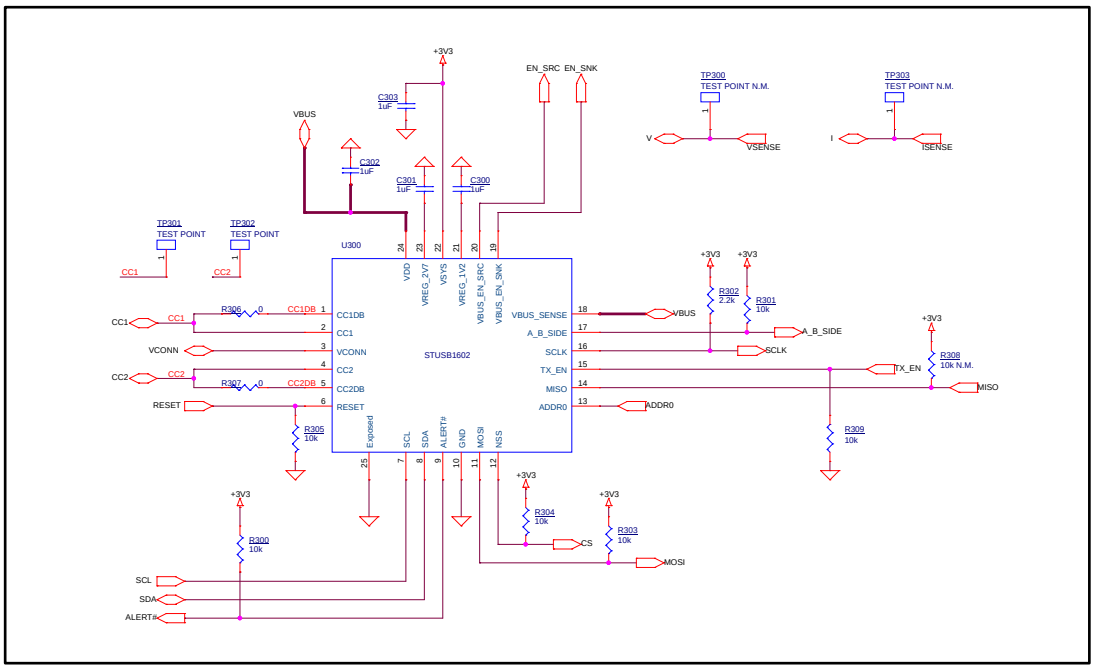


Figure 38: P-NUCLEO-USB002 expansion board circuit schematic - local power

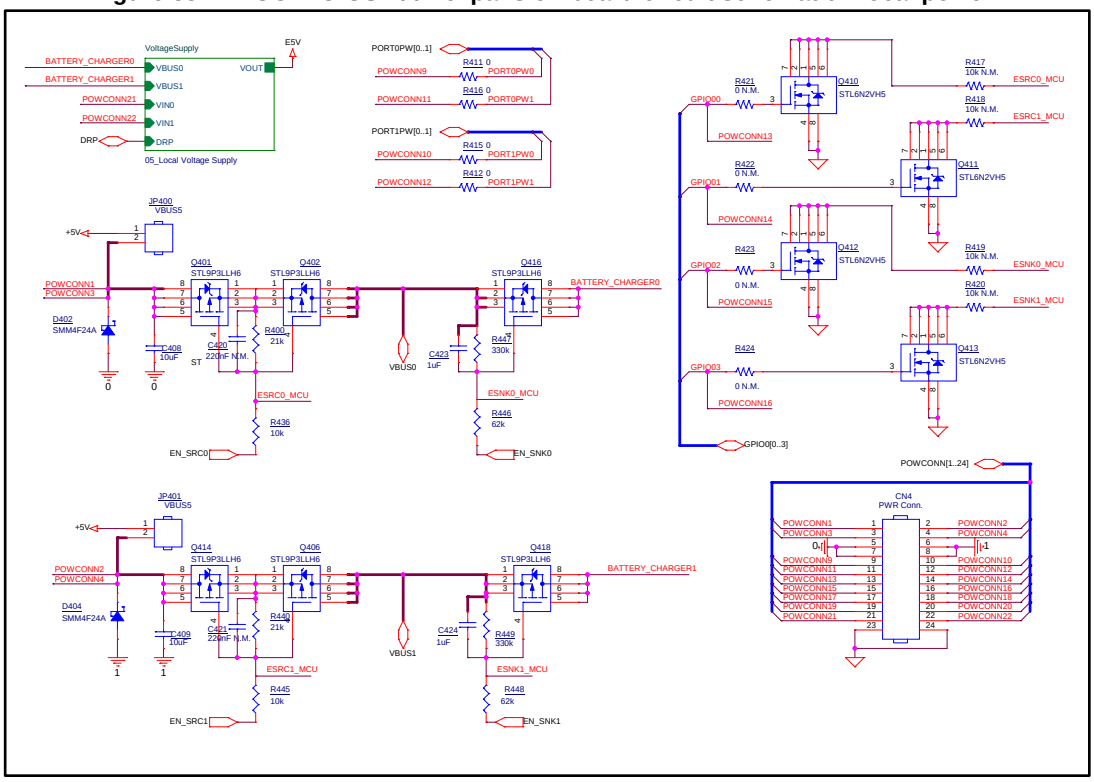


Figure 39: P-NUCLEO-USB002 expansion board circuit schematic - local voltage supply

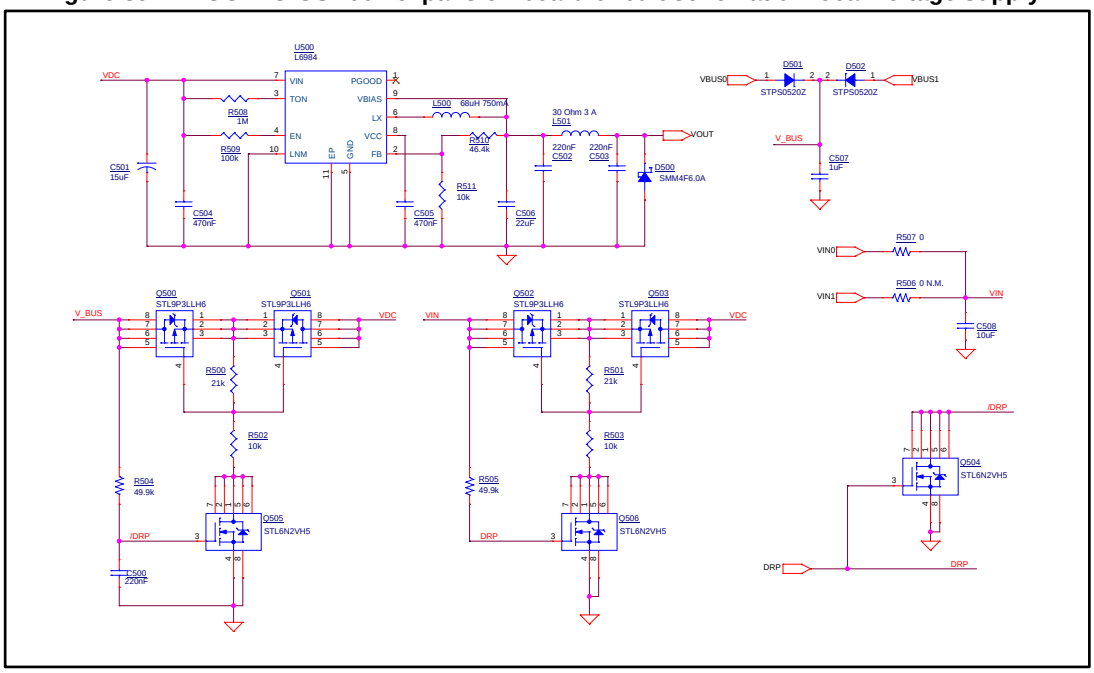


Figure 40: P-NUCLEO-USB002 expansion board circuit schematic - Type-C Connector 0

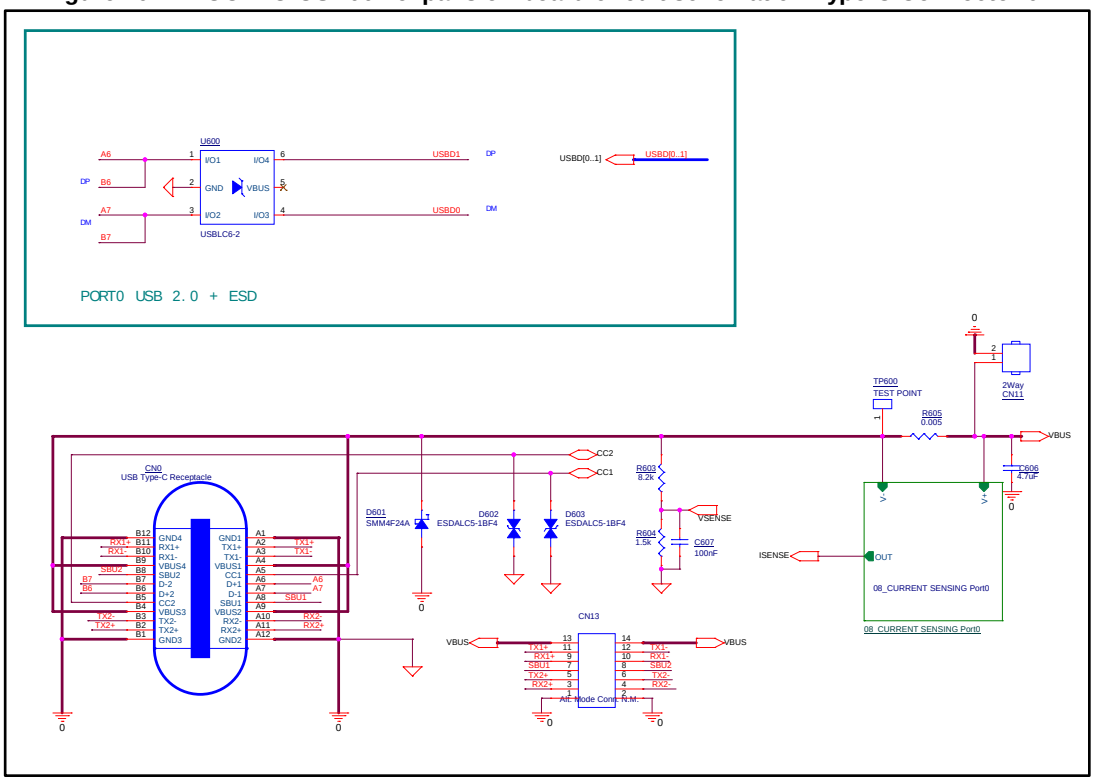


Figure 41: P-NUCLEO-USB002 expansion board circuit schematic - Type-C Connector 1

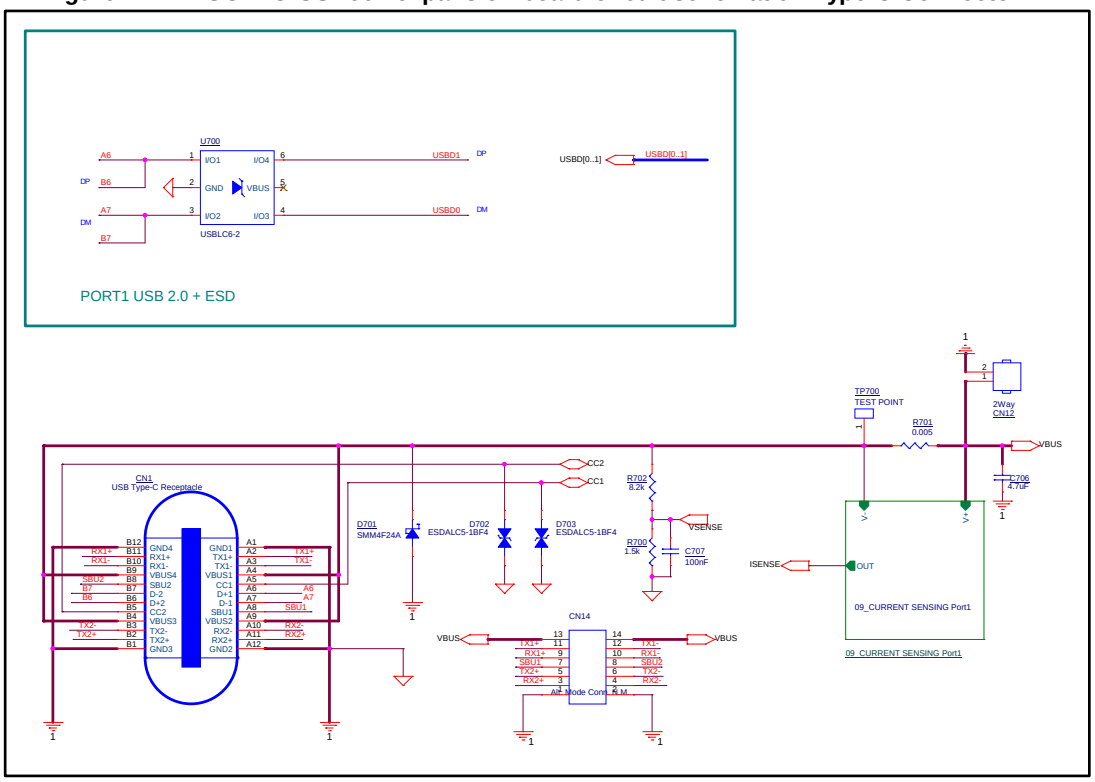


Figure 42: P-NUCLEO-USB002 expansion board circuit schematic - Current Sensing C0

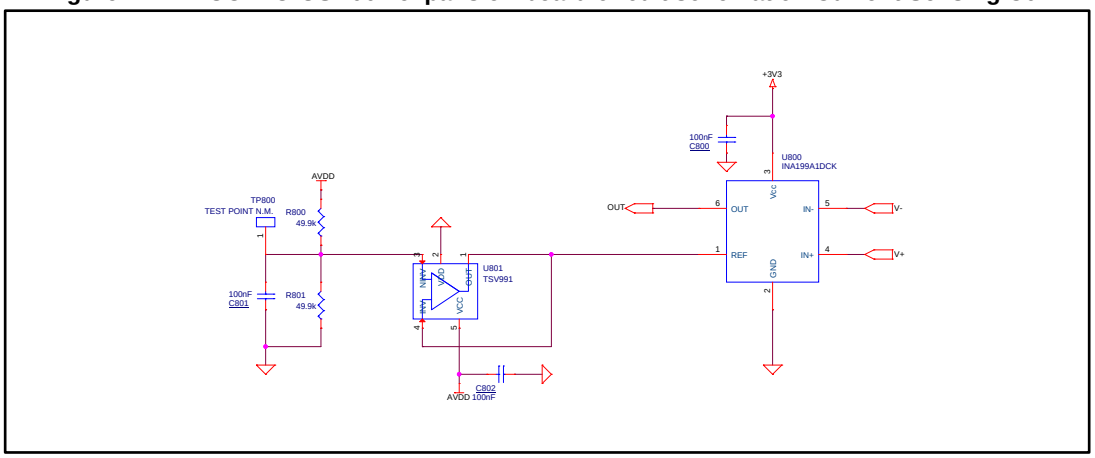


Figure 43: P-NUCLEO-USB002 expansion board circuit schematic - Current Sensing C1

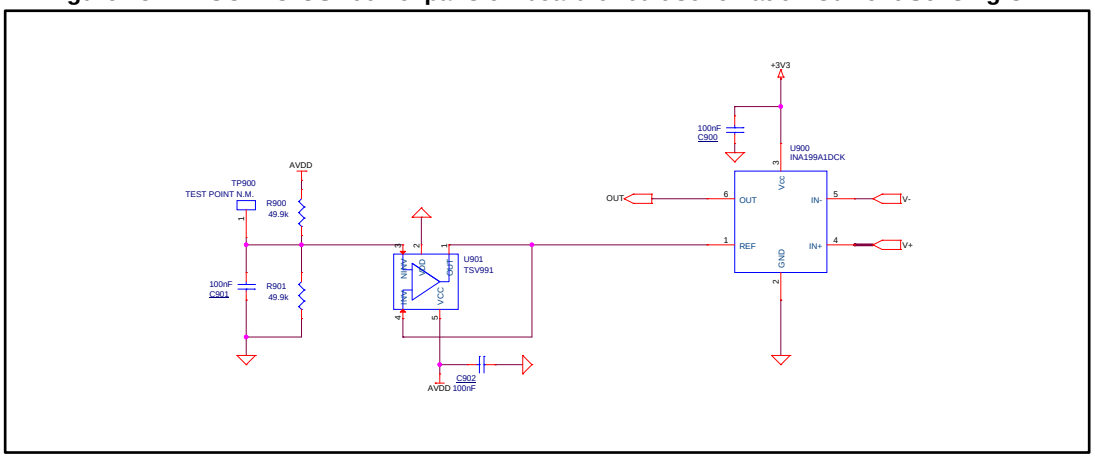
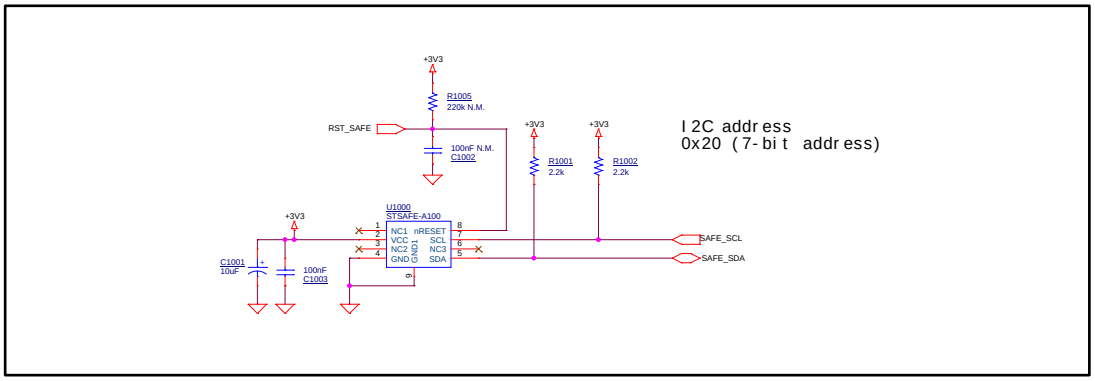


Figure 44: P-NUCLEO-USB002 expansion board circuit schematic - security



6 Bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	2	CN1,CN0	USB Type-C Receptacle	Type-C Receptacle	JEM	121U-3CST-01CR
2	1	CN2	UART Connector	HEADER	ANY	
3	1	CN4	PWR Conn.	HEADER	AMPHENOL	T821124A1S100CEU
4	1	CN5	ARDUINO_10x1 N.M.	HEADER	SAMTEC	SSQ-110-03-F-S
5	2	CN6,CN9	ARDUINO_8x1 N.M.	HEADER	SAMTEC	SSQ-108-03-F-S
6	2	CN7,CN10	ST_MORPHO_19x2	HEADER	SAMTEC	ESQ-119-24-T-D
7	1	CN8	ARDUINO_6x1 N.M.	HEADER	SAMTEC	SSQ-106-03-G-S
8	2	CN11,CN12	2Way	HEADER	Phoenix Contact	1725656
9	2	CN13,CN14	Alt. Mode Conn. N.M.	HEADER	ANY	
10	11	C200,C201, C202,C203, C300,C301, C302,C303, C423,C424, C507	1µF 50V ±10%	Ceramic X5R	ANY	
11	3	C408,C409, C508	10µF 35V ±10%	Ceramic X5R	MURATA	GRM31CR6YA106KA12L
12	2	C420,C421	220nF N.M. 50V ±10%	Ceramic X5R	ANY	
13	3	C500,C502, C503	220nF 50V ±10%	Ceramic X5R	ANY	
14	1	C501	15µF 25V ±10%	Tantalium	VISHAY	293D156X9025B2TE3
15	2	C504,C505	470nF 50V ±10%	Ceramic X5R	TDK	C1608X5R1H474K080AB
16	1	C506	22µF 16V ±20%	Ceramic X5R	AVX	1206YD226MAT2A
17	2	C606,C706	4.7µF 100V ±10%	Ceramic X7S	AVX	12061Z475KAT2A
18	9	C607,C707, C800,C801, C802,C900, C901,C902, C1003	100nF 25V ±10%	Ceramic X5R	ANY	
19	1	C1001	10µF 6.3V ±10%	Tantalium	AVX	TAJR106K006RNJ

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
20	1	C1002	100nF N.M. 25V ±10%	Ceramic X5R	ANY	
21	3	D100,D103, D106	BLUE LED 3.2V	LED	Kingbright	KP-2012PBC-A
22	3	D101,D104, D107	GREEN LED 2.2V	LED	Kingbright	KP-2012SGC
23	2	D102,D105	ORANGE LED 2.5V	LED	Kingbright	KP-2012SEC
24	4	D402,D404, D601,D701	SMM4F24A 24V	Transil	ST	SMM4F24A-TR
25	1	D500	SMM4F6.0A 6V	Transil	ST	SMM4F6.0A-TR
26	2	D501,D502	STPS0520Z 30V	Diode Schottky diode	ST	STPS0520Z
27	4	D602,D603, D702,D703	ESDALC5-1BF4	TVS diode	ST	ESDALC5-1BF4
28	2	JP001,JP000	VCONN	HEADER	ANY	
29	2	JP100,JP101	USB_D	HEADER	ANY	
30	2	JP400,JP401	VBUS5	HEADER	ANY	
31	1	L500	68uH 750mA ±30%	Inductor	Wurth Elektronik	744053680
32	1	L501	30Ω 3 A	Bead	Wurth Elektronik	74279206
33	10	Q401,Q402, Q406,Q414, Q416,Q418, Q500,Q501, Q502,Q503	STL9P3LLH6	PMOS	ST	STL9P3LLH6
34	7	Q410,Q411, Q412,Q413, Q504,Q505, Q506	STL6N2VH5	NMOS	ST	STL6N2VH5
35	17	R015,R100, R101,R104, R116,R117, R118,R119, R120,R206, R207,R306, R307,R411, R412,R415, R416	0 ±1%	RESISTOR	ANY	
36	5	R016,R421, R422,R423, R424	0 N.M. ±1%	RESISTOR	ANY	
37	8	R017,R019, R208,R308, R417,R418, R419,R420	10k N.M. ±1%	RESISTOR	ANY	

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
38	19	R018,R020, R200,R201, R203,R204, R205,R209, R300,R301, R303,R304, R305,R309, R436,R445, R502,R503, R511	10k ±1%	RESISTOR	ANY	
39	6	R108,R112, R113,R115, R132,R134	110 ±1%	RESISTOR	ANY	
40	2	R109,R114	680 ±1%	RESISTOR	ANY	
41	6	R110,R111, R202,R302, R1001, R1002	2.2k ±1%	RESISTOR	ANY	
42	1	R133	1k N.M. ±1%	RESISTOR	ANY	
43	4	R400,R440, R500,R501	21k ±1%	RESISTOR	ANY	
44	2	R446,R448	62k ±1%	RESISTOR	ANY	
45	2	R447,R449	330k ±1%	RESISTOR	ANY	
46	6	R504,R505, R800,R801, R900,R901	49.9k ±1%	RESISTOR	VISHAY	CRCW060349K9FKEA
47	2	R604,R700	1.5k ±1%	RESISTOR	ANY	
48	1	R506	0 N.M. ±1%	RESISTOR	ANY	
49	1	R507	0 ±1%	RESISTOR	ANY	
50	1	R508	1M ±1%	RESISTOR	ANY	
51	1	R509	100k ±1%	RESISTOR	ANY	
52	1	R510	46.4k 50V ±1%	RESISTOR	MULTICOMP	MC0063W0603146K4
53	2	R603,R702	8.2k ±1%	RESISTOR	ANY	
54	2	R605,R701	0.005 ±1%	RESISTOR	Panasonic	ERJM1WSF5M0U
55	1	R1005	220k N.M. ±1%	RESISTOR	ANY	
56	10	TP100,TP101,TP102,TP103,TP201,TP202,TP301,TP302,TP600,TP700	TEST POINT	TEST POINT	Vero Technologies	20-2137
57	6	TP200,TP203,TP300,TP303,TP800,TP900	TEST POINT N.M.	TEST POINT	Vero Technologies	20-2137

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
58	2	U200,U300	STUSB1602	USB Type-C interface	ST	STUSB1602
59	1	U500	L6984	DCDC	ST	L6984TR
60	2	U600,U700	USBLC6-2	ESD protection	ST	USBLC6-2SC6
61	2	U800,U900	INA199A1DCK	Current shunt monitor	TEXAS INSTRUMENTS	INA199A1DCKR
62	2	U801,U901	TSV991	Rail to rail op-amp	ST	TSV991AILT
63	1	U1000	STSAFE-A100	Authentication device	ST	STSAFE-A100
64	3	JUMPER		Female 2.54mm jumper		
65	1	USB Type-C Cable		CABLE USB C-MALE TO C-MALE 1M		
66	2	UART wires		Female to Female 2.54mm 0.1 in Jumper Wires F/F		

7 Acronyms and abbreviations

Table 12: List of acronyms

Acronym	Description
USB	Universal Serial Bus
PD	Power Delivery
CC	Configuration Channel
DRP	Dual Role Power
SBU	Sideband Use
EMC	Electronically Marked Cable
MCU	Microcontroller Unit
DFP	Downstream Facing Port
UFP	Upstream Facing Port
USB OTG	USB on-the-go
PHY	Physical layer
BMC	Biphase Marked Coding
IDEs	Integrated Development Environments
VDM	Vendor Defined Messages
HDMI	High-Definition Multimedia Interface
DP	DisplayPort
PCI Express	Peripheral Component Interconnect Express
Base-T Ethernet	Ethernet over twisted pair
MHL	Mobile High-definition Link
CRC	Cyclic Redundancy Check

8 References

1. USB2.0 Universal Serial Bus Revision 2.0 Specification.
2. USB3.1 Universal Serial Bus Revision 3.1 Specification.
3. USB PD USB Power Delivery Specification Revision 2.0, Version 1.3, January 12, 2017.
4. USB Type-C Cable and Connector Specification Revision 1.2.
5. USB BC Battery Charging Specification Revision1.2 (including errata and ECNs through March 15, 2015), March 15, 2012.
6. USB BB USB Device Class Definition for Billboard Devices rev1.0a April 15, 2015.

9 Revision history

Table 13: Document revision history

Date	Version	Changes
26-May-2017	1	Initial release.
19-Jun-2017	2	Minor text and formatting changes Updated *Table 11: "P-NUCLEO-USB002 expansion board LED signaling"* Inserted note in *Section 2.3.5: "P-NUCLEO-USB002 expansion board: local power management stage"*

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