# UM2050
# User manual

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

## Introduction

The USB Type-C™ and Power Delivery Nucleo pack (P-NUCLEO-USB001) is a development kit composed of a NUCLEO-F072RB board, the MB1257 expansion board and a full-featured Type-C cable. These components matched with the certified STM32F0 USB Type-C™ PD middleware stack X-CUBE-USB-PD and are needed for demonstrating the functionalities of the USB Type-C™ and USB Power Delivery technologies, facilitating the users to develop their solutions.

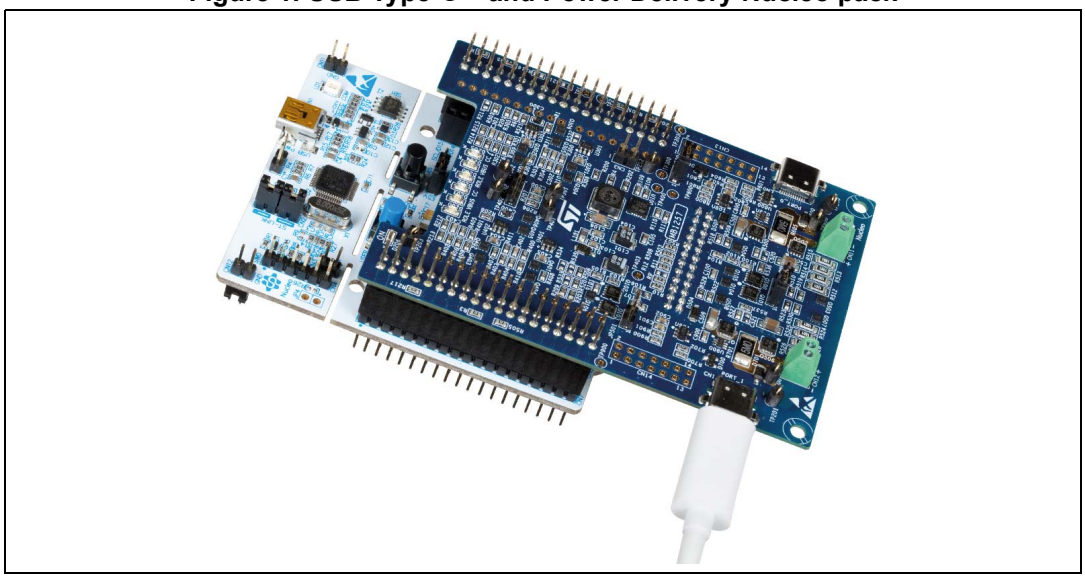
The USB PD is a brand-new protocol designed to enlarge USB capabilities, enabling the functionality of providing power delivery, ranging from 15 W up to 100 W, over the same cable used for the data communication. The devices supporting the PD protocol are able to negotiate voltage and current over the USB power pins and to define their roles as Provider or Consumer according to the requirements.

After introducing briefly the USB PD main characteristics and operations, this document describes the main components of the P-NUCLEO-USB001 pack and how to configure them to select the role.

Once configured the platform, the embedded demonstration allows showing the attach/detach cable and its orientation as well as the role of each one of the two receptacles: these are the most peculiar characteristics for automatically recognizing the configuration channel when the plug-flipping happens.

The *Figure 1* shows the assembled USB Type-C™ and Power Delivery Nucleo pack.

**Figure 1. USB Type-C™ and Power Delivery Nucleo pack**



1. Picture not contractual.

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# 1 Brief overview on USB Type-C and Power Delivery technology

The USB Type-C and the Power Delivery is certainly one of the most promising technology to simplify development and to enhance the consumer and mobile user experience. The new reversible USB Type-C connector makes the plug insertion more user friendly.

The technology offers a smart connector to carry all the necessary data (including video), and using Power Delivery protocol allows to negotiate up to 100 W to supply or charge the equipment connected to this USB port. Less cables, less connectors and universal chargers are the final objective.

Natively the USB Type-C connector supports up to 15 W (5 V at 3 A), extended to 100 W (up to 20 V at 5 A) with the optional USB Power Delivery feature. 15 W is far enough for most of the hundreds of millions of legacy USB powered devices actually on the market.

This first section introduces the two new standards: USB Type-C and USB Power Delivery.

## 1.1 USB Type-C in a nutshell

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

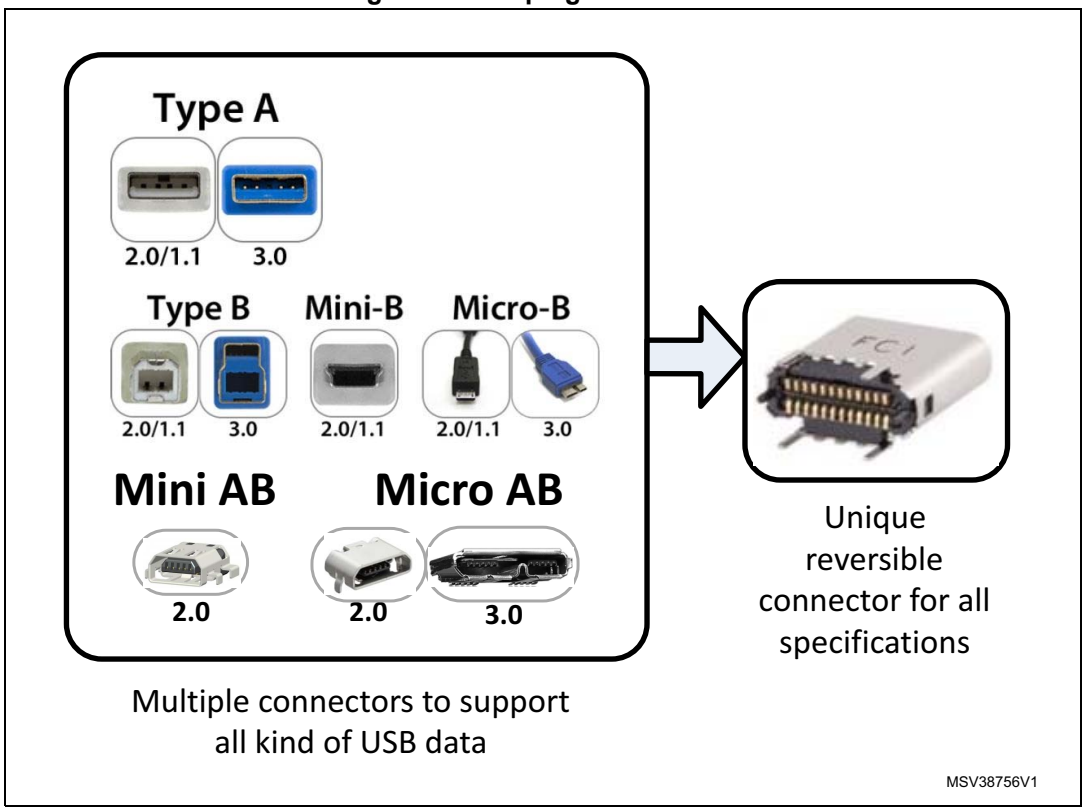
- The USB Power Delivery (PD) specification rev 2.0 (refer to *Section 7: References*) details how a link can be transformed from a 4.5 W power source (900 mA at 5 V on $V_{BUS}$) to a 100 W power or consumer source (up to 5 A at 20 V).
- The USB Type-C receptacle, plug and cable specification rev 1.2 (refer to *Section 7: References*) details a reversible, slim connector and more reliable solution to legacy cables and connectors, extending the USB 2.0 and USB 3.1 data signals with other features like the PD communication and the Alternate-Mode-communication signals.

The new connector is designed to be non-polarized and fully reversible, no matter which way it is inserted.

As such, this new reversible 24-pin USB Type-C plug is aimed to be an universal connector with all the advanced features proposed by PD:

- Negotiating power roles
- Negotiating power sourcing and consumption levels
- Performing active cable identification
- Exchanging vendor specific messaging
- Performing Alternate-Mode negotiation, allowing third-party communication protocols to be routed onto the reconfigurable pins of the USB Type-C cable.

**Figure 2. USB plug form factors**




The USB Type-C cables use the same male connector on both ends.

It is also important to mention that the USB Type-C supports all prior protocols from USB2.0 onward, including power capability.

The new connector is quite small as it is only 8.4 mm wide by 2.6 mm high.

As depicted in *Figure 2*, the new USB Type-C plug allows having single connector to cover all features provided by the previous plugs, which improves USB facility usage for all customers because of its flexibility in data and power role.

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

## 1.2 USB Type-C vocabulary

The terminology commonly used for USB Type-C system is:

- **Downstream Facing Port (DFP)**: associated with the flow of data in a USB connection, typically the ports on a host or on a hub to which devices are connected. In

its initial state, the DFP sources $V_{BUS}$ and $V_{CONN}$ and supports data. A charge only DFP port only sources $V_{BUS}$

- **Upstream Facing Port (UFP)**: associated with the flow of data in a USB connection. 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.
- **Dual-Role Port (DRP)**: refers to a USB port that can operate as either a source or a sink. The role of the port may be fixed to either source or sink or may alternate between the two port states. Initially when operating as a source, the port also takes role of a DFP and when operating as a sink, the port takes a role of a UFP. The port role may be changed dynamically either to reverse power or data roles.
- **Source**: port asserting Rp (pull-up resistor. See *Figure 5*) on CC (Configuration Channels pins, see *Section 1.6: CC pins*) pins and providing power over $V_{BUS}$ (5 V to 20 V and up to 5 A), most commonly a host or hub DFP. A USB Type-C PD port with Rp asserted on its CC wire and capable to source power over $V_{BUS}$ is called Provider.
- **Sink**: port asserting Rd (Pull down resistor. See *Figure 5*) on CC pins and consuming power from $V_{BUS}$ (5 V to 20 V and up to 5 A), most commonly a device. A USB Type-C PD port with Rd asserted on its CC wire and capable to sink power over $V_{BUS}$ is called Consumer.

## 1.3 Mapping of the USB Type-C connector pin

The 24-pin USB Type-C includes:

- Symmetric connections:
  - USB2.0 differential pairs (D+/D-)
  - Power pins: $V_{BUS}$/GND
- Asymmetric connections:
  - Two sets of Tx/Rx signal paths which support USB 3.1 data-speed
  - Configuration channels (CC lines) which handles discovery, configuration and management of USB Type-C power delivery features
  - Two Sideband Use (SBU lines) signals are present for analog audio modes and may be used by alternate mode

*Figure 3* and *Figure 4* show the receptacle and the plug pinouts and *Table 1* shows the pinout description.

**Figure 3. USB Type-C receptacle pinout**

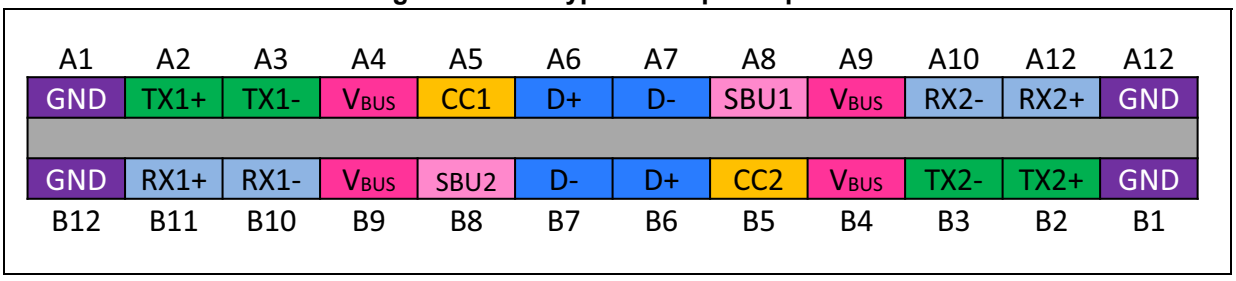


**Figure 4. USB Type-C plug pinout**

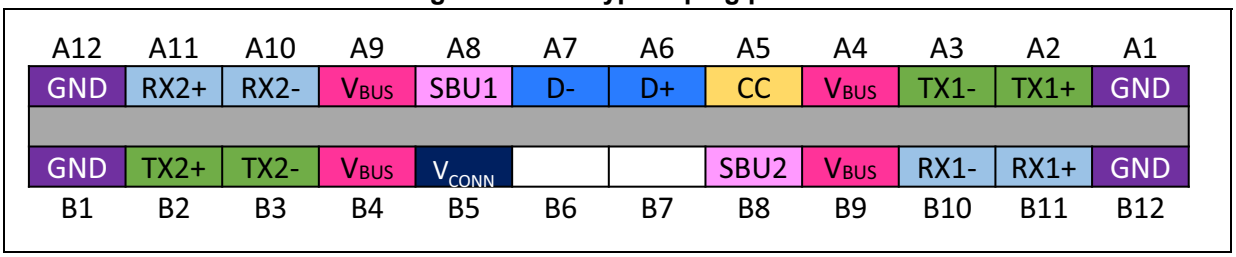



**Table 1. USB Type-C pinout description**

| 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 - 5 A) split into four pins |
| A5 | CC1 or $V_{CONN}$ | CC | Configuration channel or power for active or electronically marked cable | In $V_{CONN}$ configuration, min 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, min power is 1 W |
| B6 | D+ | - | USB2.0 datalines | |
| B7 | D- | - | | |
| B8 | SBU2 | SBU2 | Sideband use (SBU) | Alternate mode only |

Table 1. USB Type-C pinout description (continued)

| Pin | Receptacle signal | Plug signal | Description | Comment |
|---|---|---|---|---|
| B9 | $V_{BUS}$ | $V_{BUS}$ | Bus power | Max power is 100 W split into for pins |
| 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 Full-featured Type-C cable

Full-featured Type-C cables are Type-C to Type-C cables that support USB2.0 and USB 3.1 data operation, and include SBU wires. They are Electronically Marked Cable and use USB PD to provide the cable characteristics. Up to 1 W drawn from $V_{CONN}$ is requested to supply the electronics inside these cables.

## 1.5 $V_{BUS}$ power options

$V_{BUS}$ provides a path to deliver power between a host and a device and between a charger and a host/device.Power options available from a perspective of a device with a USB Type-C connector are listed in *Table 2*.

Table 2. Power supply options

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

## 1.6 CC pins

There are two CC pins in receptacle but only one CC pin is connected through the cable to establish signal orientation and the other CC pin is reused as $V_{CONN}$ for powering electronics in the USB Type-C plug.

On both CC1 and CC2, DFP must have Rp pull-up resistors, whereas UFP must have Rd pull-down resistors.

The full-featured cables have to provide impedance Ra to ground on $V_{CONN}$.

## 1.7 Plug orientation and cable twist detection

As USB Type-C plug can be inserted in the receptacle in either orientation, it is mandatory to first detect the orientation.

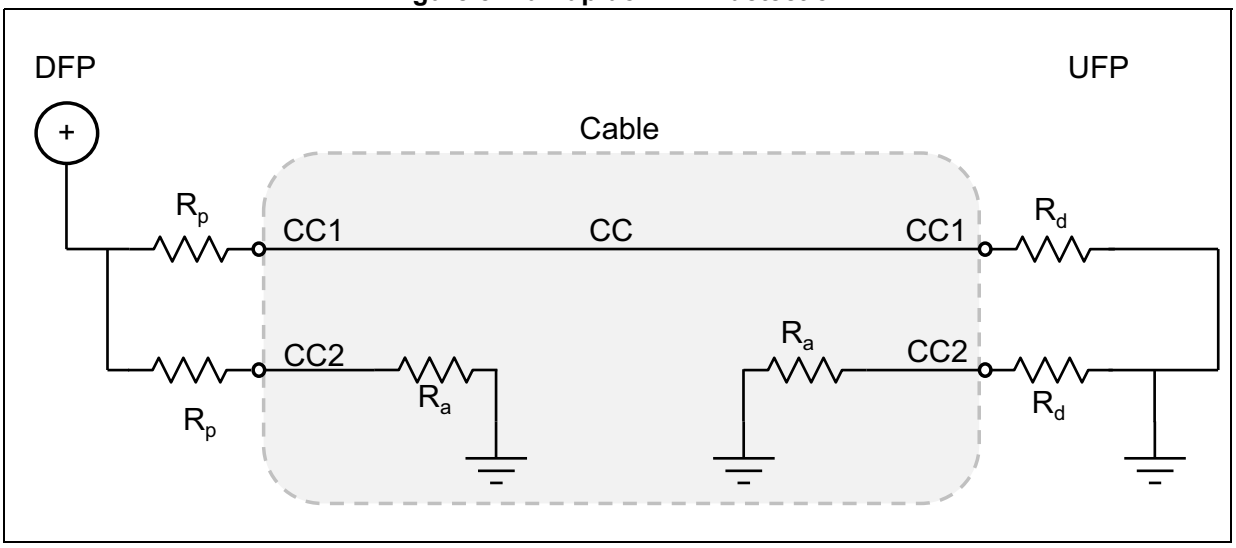
The detection is done through CC lines using Rp/Rd resistors.

Initially a DFP exposes Rp terminations on its CC pins and a UFP exposes Rd terminations on its CC pins.

To detect the connection, the DFP monitors both CC pins: when the cable is inserted it connects one CC line of the DFP to one CC line of the UFP.

Furthermore, if a full-featured cable is used, it will also expose a Ra resistor on UFP and DFP CC lines that are not directly connected together (see *Figure 5*).

**Figure 5. Pull-up/down CC detection**




## 1.8 Power capability detection and usage

Current supply capability of the port to the device depends on Rp pull-up resistor value on DFP. A 5 A capability can be negotiated using the USB PD protocol.

*Table 3* below shows the different possible values.

**Table 3. DFP CC termination (Rp) requirements**

| $V_{BUS}$ power | Current source to 1.7 V - 5.5 V | Rp pull-up to 4.75 V - 5.5 V | Rp pull-up to 3.3 V +/- 5% |
|---|---|---|---|
| Default USB power | 80 µA +/- 20% | 56 kΩ+/- 20%(1) | 36 kΩ+/- 20% |
| 1.5 A at 5 V | 180 µA +/- 8% | 22 kΩ+/- 5% | 12 kΩ+/- 5% |
| 3.0 A at 5 V | 330 µA +/- 8% | 10 kΩ+/- 5% | 4.7 kΩ+/- 5% |

## 1.9 USB Power Delivery 2.0

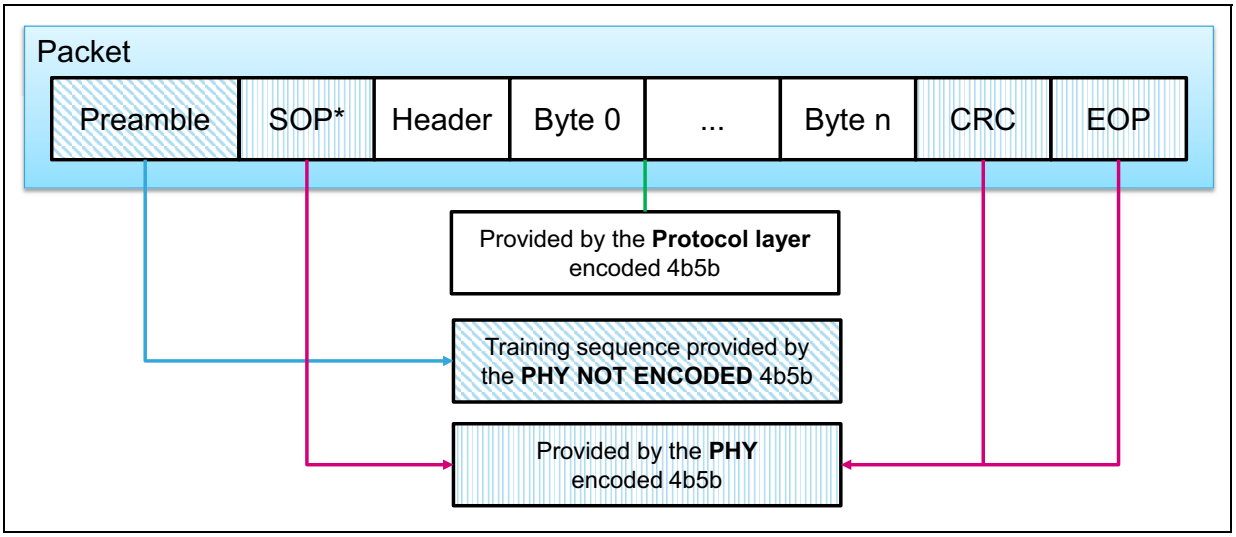
In USB PD 2.0, pairs of directly attached ports negotiate voltage, current and/or direction of power and data flow over the USB cable, using the CC wire as the communication channel using the Biphase Mark Coding (BMC).

This mechanism operates independently of other USB methods used to negotiate power.

## 1.10 Packet structure

The USB PD packet format is shown in *Figure 6*.

**Figure 6. USB PD packet format**

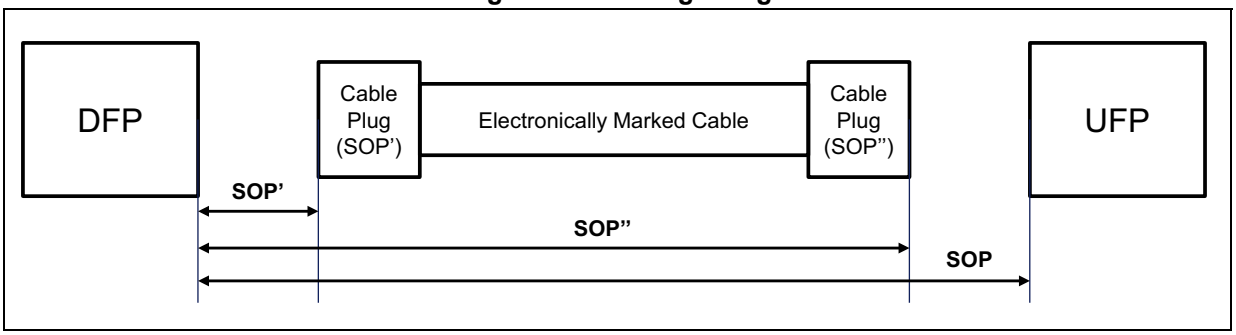



The main parts of the packet are:

- Preamble: 64-bit sequence of alternating 0s and 1s to sync up with transmitter.
- SOP* is the start of the packet. It can be SOP, SOP' (start of packet sequence prime) or SOP" (start of packet sequence double prime):
  - SOP packets shall be limited to PD capable DFP and UFP only
  - SOP' packets are used for communication with cable plug attached to the DFP
  - SOP" packets are used for communication with cable plug attached to the UFP
- Message data including message header which identifies type of packet and amount of data
- CRC: Error checking
- EOP (end of packet): unique identifier

A cable plug capable of SOP' or SOP" communication shall only detect and communicate with packet starting with SOP' or SOP", as reported in *Figure 7*.

**Figure 7. SOP* signaling**




## 1.11 Negotiating power

DFP is initially considered as a bus master.

The protocol layer allows the power configuration to be dynamically modified.

It is also possible to perform a Power Role swap to exchange the power supply roles such that the DFP receives power and the UFP supplies power. For a Type-C connector it is possible to perform a Data Role swap such that the DFP becomes the UFP and vice-versa and to perform a $V_{CONN}$ swap to change the partner supplying $V_{CONN}$ to the cable.

The default voltage on $V_{BUS}$ is always 5 V and can be reconfigured up to 20 V.

The default current capability is initially defined by Rp value and can be reconfigured up to 5 A. Current more than 3 A requires electronically marked USB PD Type-C cable.

The protocol uses start-of-packet (SOP) communications, each of which begins with an encoded symbol called K-code.

SOP communication contains a control or data message.

The control message has a 16-bit fixed size and is used to manage data flow.

The data message size varies depending on its contents. It provides information on data objects.

## 1.12 Alternate modes

All the hosts and devices (except chargers) using a USB Type-C receptacle shall expose a USB interface.

If the host or device optionally supports Alternate Modes:

- The host and device shall use USB PD Structured Vendor Defined Messages (Structured VDMs) to discover, configure and enter/exit modes to enable Alternate Modes.
- Where no equivalent USB functionality is implemented, the device shall provide a USB interface exposing a USB Billboard Device Class used to provide information needed to identify the device. A device is not required to provide a USB interface exposing a USB Billboard Device Class for non-user facing modes (e.g., diagnostic modes).

As Alternate Modes do not traverse the USB hub topology, they shall only be used between a directly connected host and device.

## 1.13 Alternate pins reassignment

In the *Figure 8*, pins highlighted in yellow are the only pins that shall be reconfigured in a full-featured cable.

**Figure 8. Pins available for reconfiguration over the full-featured cable**

| 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 |

*Figure 9* shows pins available for reconfiguration for direct connect applications. There are three pins more than in previous figure because this configuration is not limited by the cable wiring.

**Figure 9. Pins available for reconfiguration for direct connect applications**

| 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 |

## 1.14 Billboard

The USB Billboard Device Class definition describes the methods used to communicate the Alternate Modes supported by a Device Container to a host system.

This includes string descriptors that can be used to provide support details in a human-readable format.

For more details, refer to *USB Device Class Definition for Billboard Devices rev1.0a April 15, 2015*.

# 2 System architecture

The P-NUCLEO-USB001 is a development pack that permits to implement solutions based on the USB Type-C and the USB PD technologies. It is fully configurable for implementing and supporting several configurations like Provider, Consumer or Dual Role Port (DRP).

The P-NUCLEO-USB001, together with the USB-IF certified STM32F0 USB PD middleware stack (X-CUBE-USB-PD), permits to control two USB Type-C ports using a single STM32F0 32-bit Cortex®-M0 microcontroller. A simple Analog-Front-End PHY is required to interface the STM32F072RBT6 MCU with the Configuration Channels (CC lines) of the Type-C™ receptacles and allows communicating over those lines using the PD communication protocol.

STM32 USB PD middleware stack is compliant with the USB Type-C 1.2 and PD 2.0 specifications (refer to *Section 7: References*).

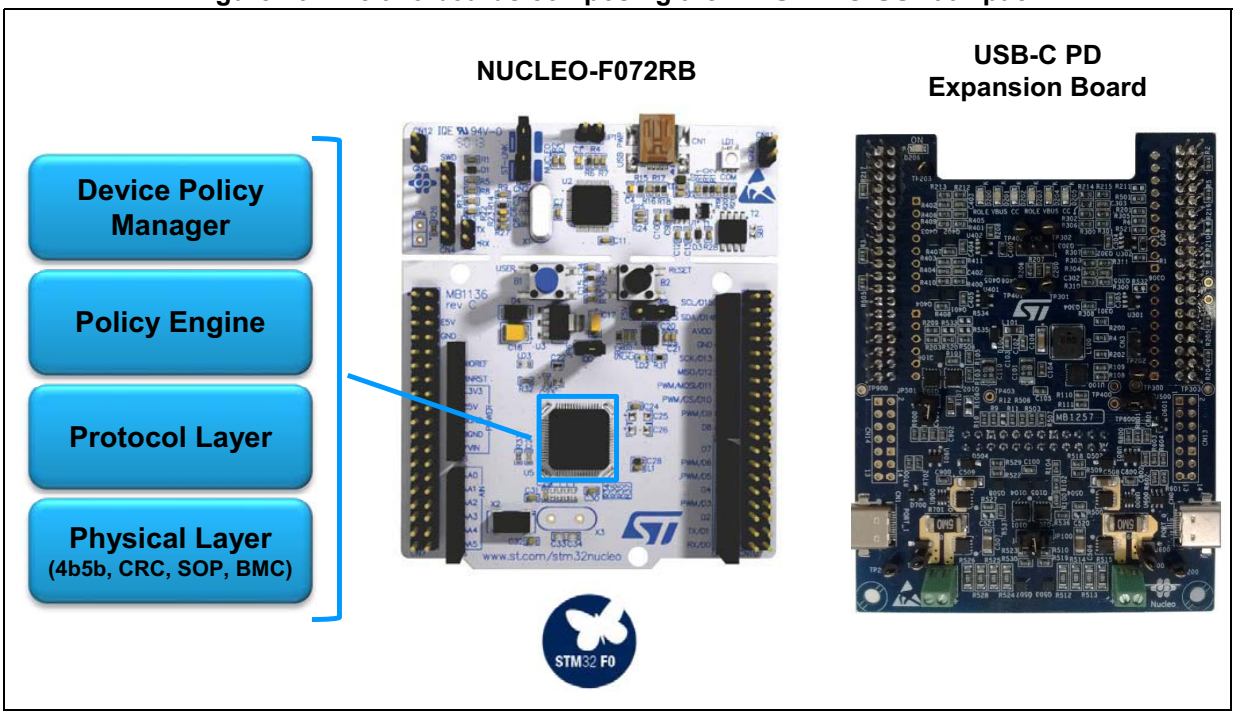
## 2.1 Hardware description

This section describes the hardware components of the pack (see *Figure 10*):

- A NUCLEO-F072RB Nucleo board specifically customized to exploit all the peripherals to serve the functions of the PD application: this represents the control block where the stack is running.
- The MB1257 expansion board implementing the USB Type-C interface.
- A USB Type-C full-featured cable.

The following sub-sections describe the individual components.

**Figure 10. The two boards composing the P-NUCLEO-USB001 pack**

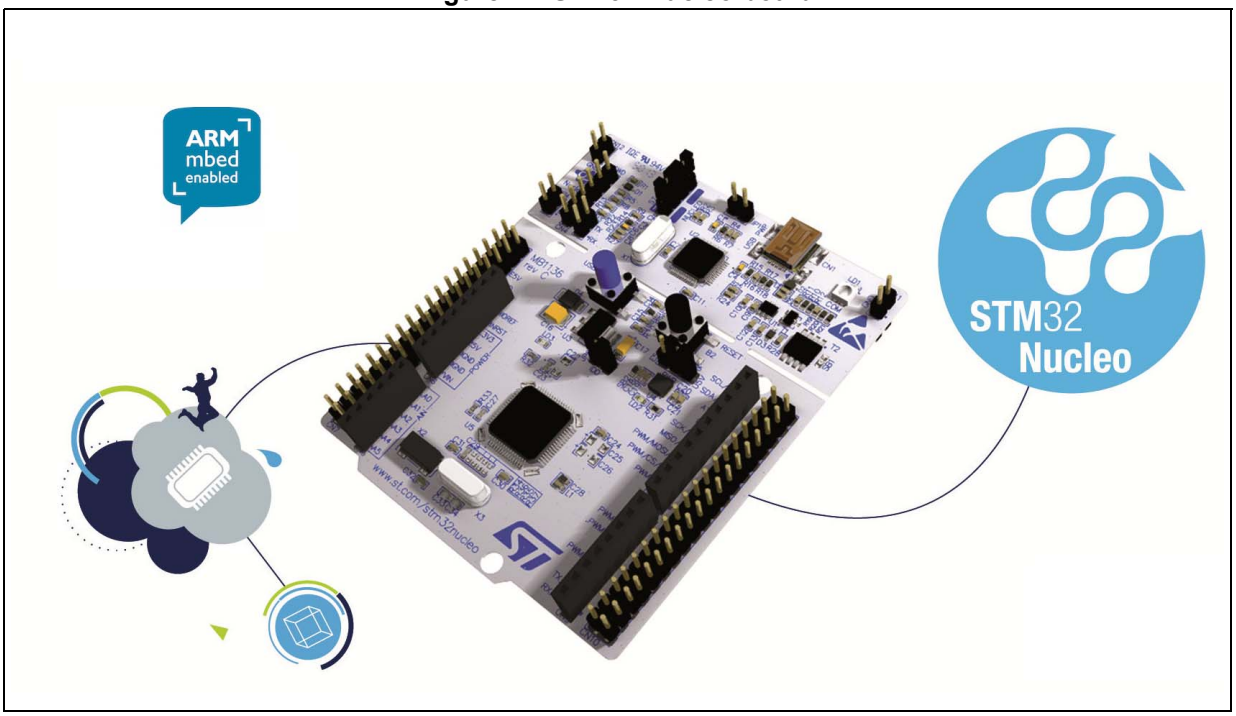


## 2.2 NUCLEO-F072RB board

The STM32 Nucleo board (see *Figure 11*) provides an affordable and flexible way for users to try out new ideas and build prototypes with any STM32 microcontroller lines. The Arduino™ connectivity support and ST morpho headers make it easy to expand the functionality of the STM32 Nucleo open development platform with a wide choice of specialized expansion boards. The STM32 Nucleo board does not require any separate probes as it integrates the ST-LINK/V2-1 debugger/programmer. The STM32 Nucleo board comes with the STM32 comprehensive software HAL library together with various packaged software examples.

Information about the STM32 Nucleo boards is available on st.com at the http://www.st.com/stm32nucleo webpage.

**Figure 11. STM32 Nucleo board**




The NUCLEO-F072RB Nucleo board embeds an STM32F072RBT6 MCU, a 32-bit microcontroller based on Cortex®-M0 with 128-Kbyte Flash memory, 16-Kbyte SRAM: these characteristics, together with its peripheral set, makes it eligible to run the appositely designed STM32 USB-C PD middleware stack (X-CUBE-USB-PD).

The STM32F072RBT6 is equipped with USB2.0 full-speed data interface as peripheral.

Moreover, The NUCLEO-F072RB board embeds the ST morpho extension pin headers for full access to all STM32 I/Os, and an on-board ST-LINK/V2-1 debugger/programmer with SWD connector able also to manage the serial communication with the application MCU (STM32F072RBT6).

Specifically for the USB PD application, the NUCLEO-F072RB Nucleo board contained in the P-NUCLEO-USB001 pack has been customized, modifying the solder bridges configuration characterizing the standard STM32 Nucleo board. So that the

STM32F072RBT6 microcontroller embedded in the board, is eligible to run the USB PD middleware stack X-CUBE-USB-PD in association with the USB-C PD expansion board MB1257.

The following *Table 4* reports the complete list of the solder bridges and resistances to be modified on the front side and on the back side of the NUCLEO-F072RB Nucleo board (see *Figure 12* and *Figure 13*).

For further information please refer to *STM32 Nucleo-64 boards* User manual (UM1724) available at the *www.st.com* website.

**Table 4. 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 ST-LINK MCU, using flying wires between ST morpho connector and CN3.<br>SB13 and SB14 should be OFF. |
| SB63 | | |

Figure 12. STM32 Nucleo board (front view)

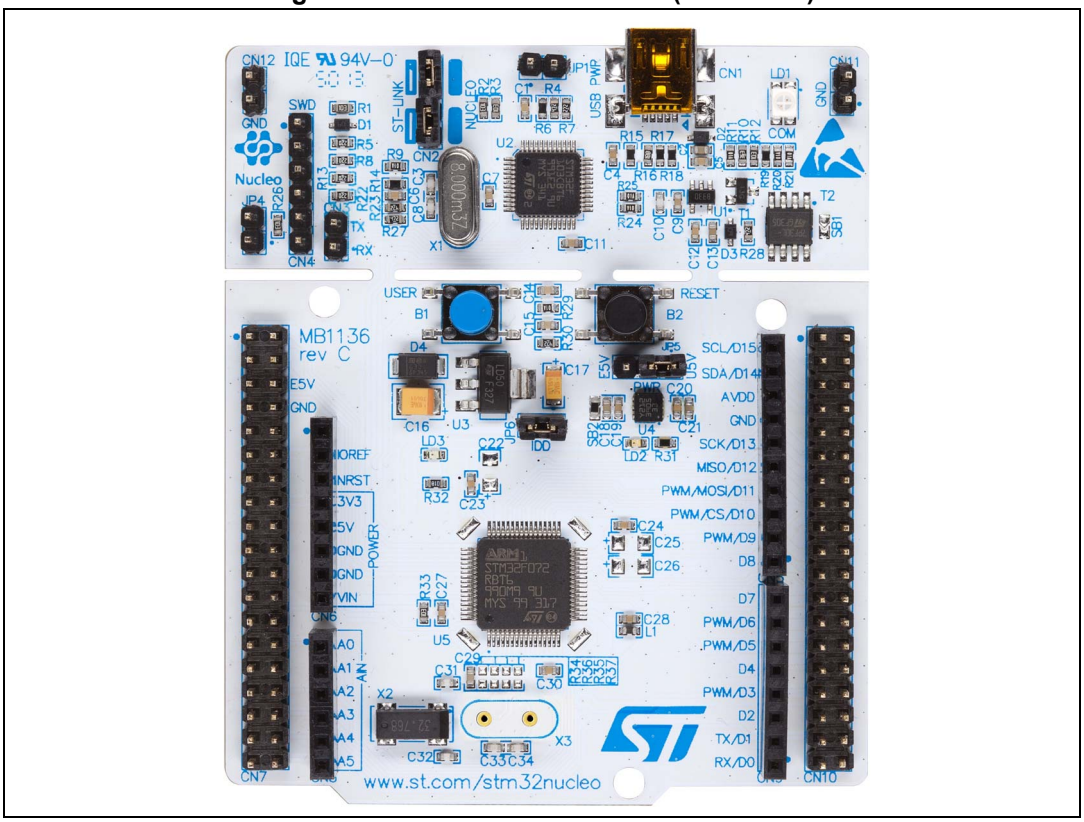
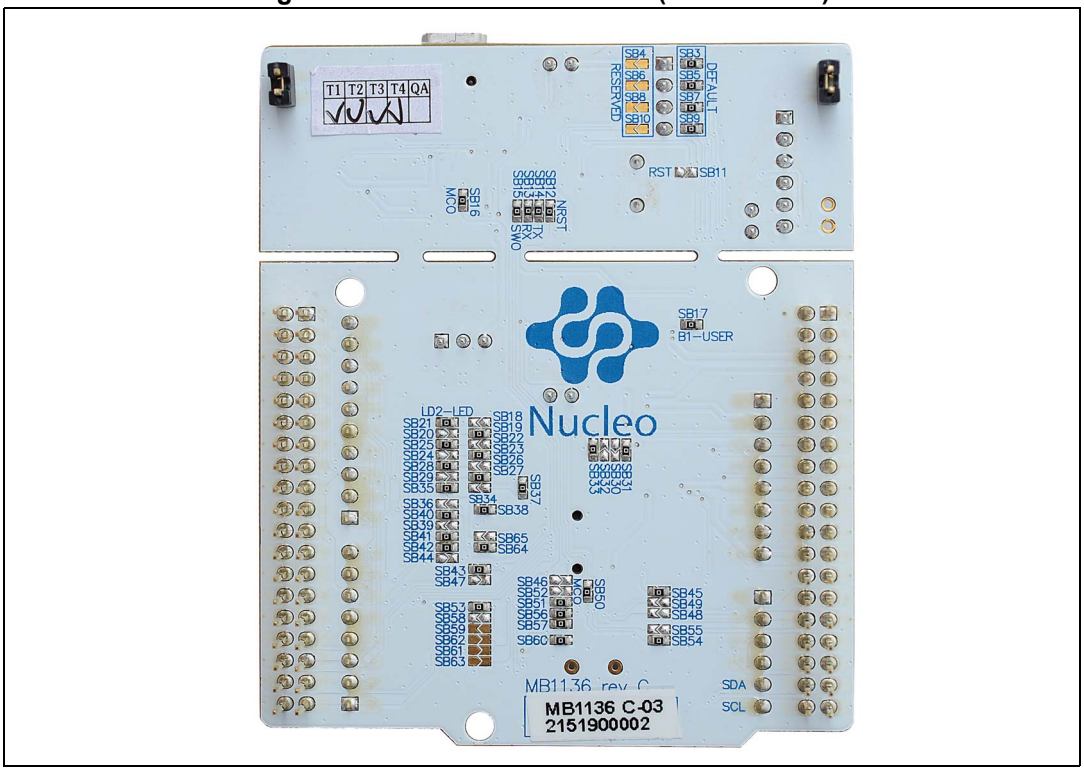



Figure 13. STM32 Nucleo board (bottom view)



## 2.3 MB1257 expansion board

The MB1257 expansion board embeds two Dual-Role Power USB Type-C ports with their relative discrete Analog-Front-End Physical Layer (PHY). This board permits to exploit the robustness of the digital receiver obtained by a discrete design and, at the same time, to guarantee the low-power operation.

To support the USB PD protocol and preserve the completeness, the application needs to exploit its entire flexibility, the MB1257 presents the following blocks and characteristics:

- USB Type-C certified receptacles
- CC discrete Analog-Front-End stages and $V_{CONN}$ switches
- $V_{BUS}$ port switch and discharge mechanism
- $V_{BUS}$ current and voltage sensing stages

The *Figure 14*, *Figure 15*, *Figure 16* and *Figure 17* show the MB1257 expansion board and its silkscreen layout, describing how the devices have been positioned on the board.

**Figure 14. MB1257 expansion board (top view)**

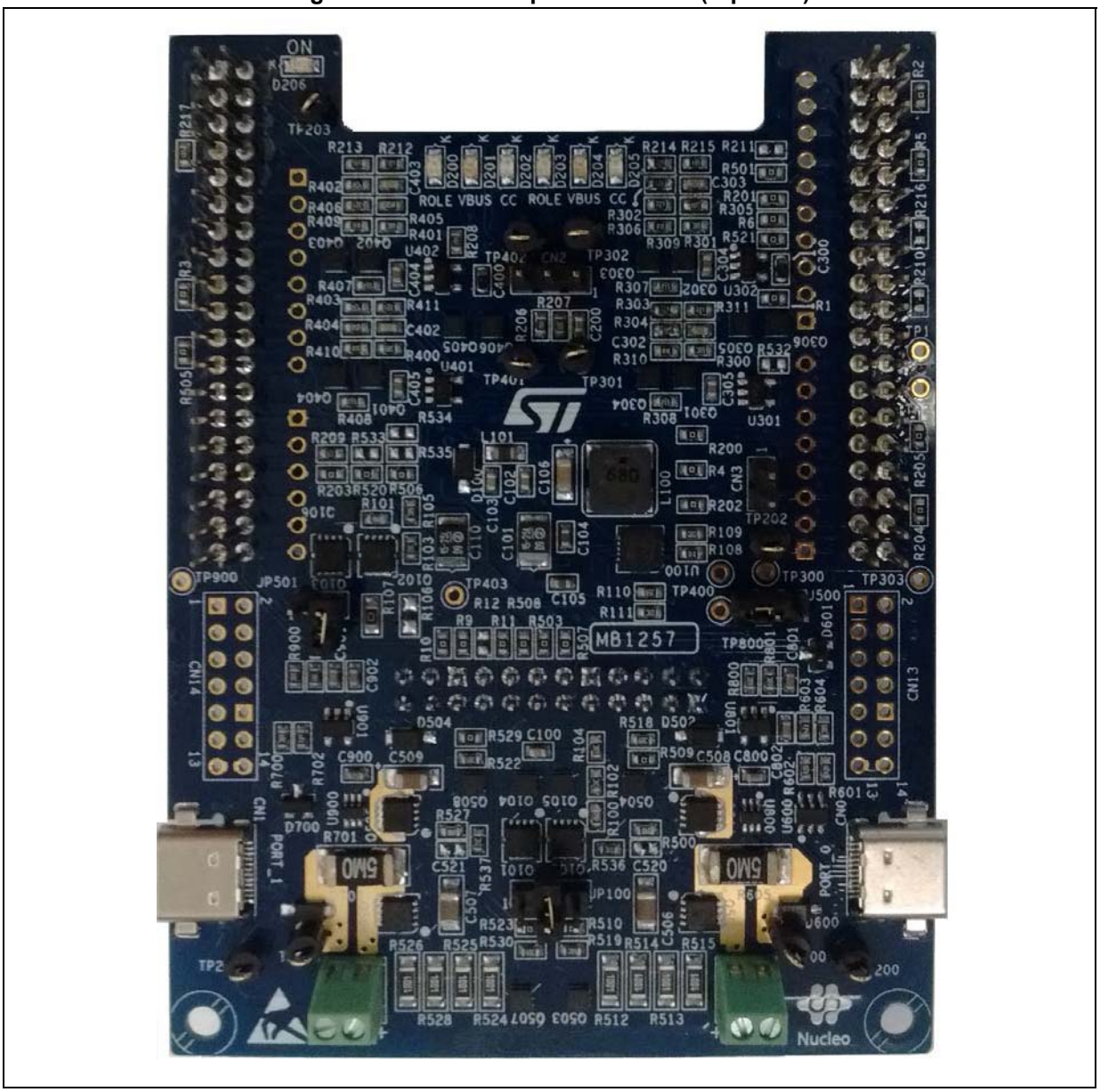


Figure 15. MB1257 expansion board (bottom view)

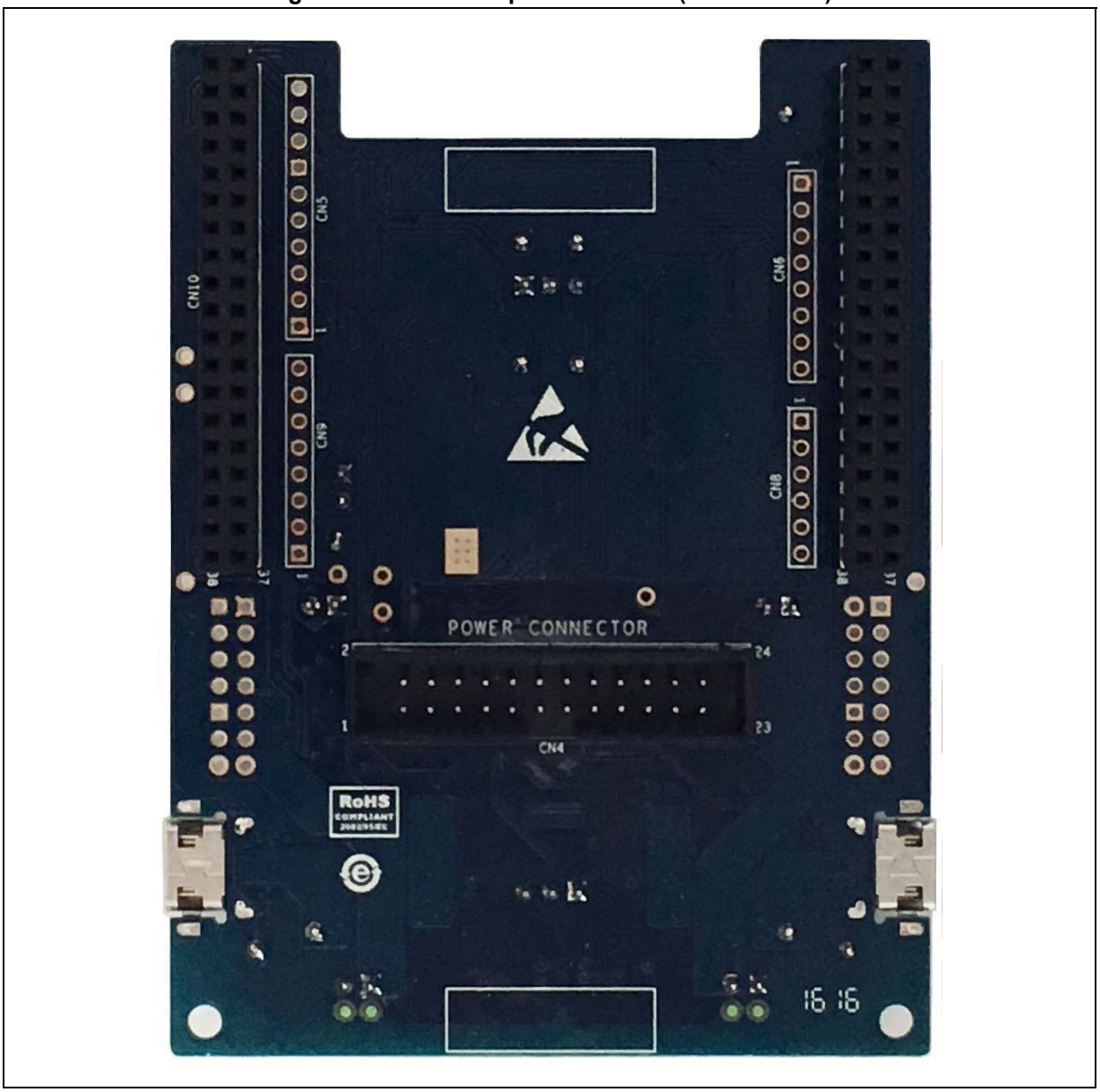


**Figure 16. MB1257 expansion board, silkscreen layout (top view)**

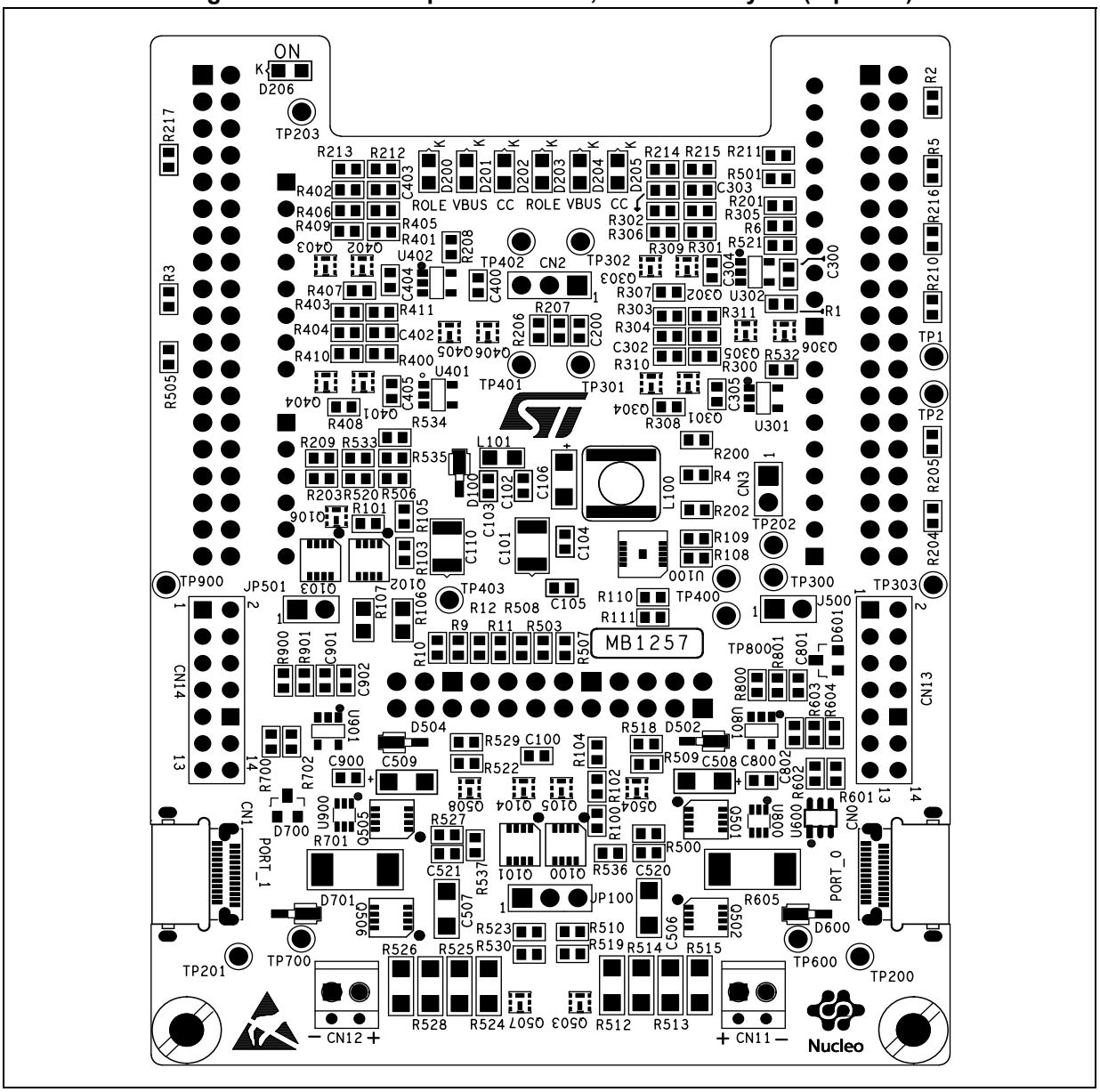
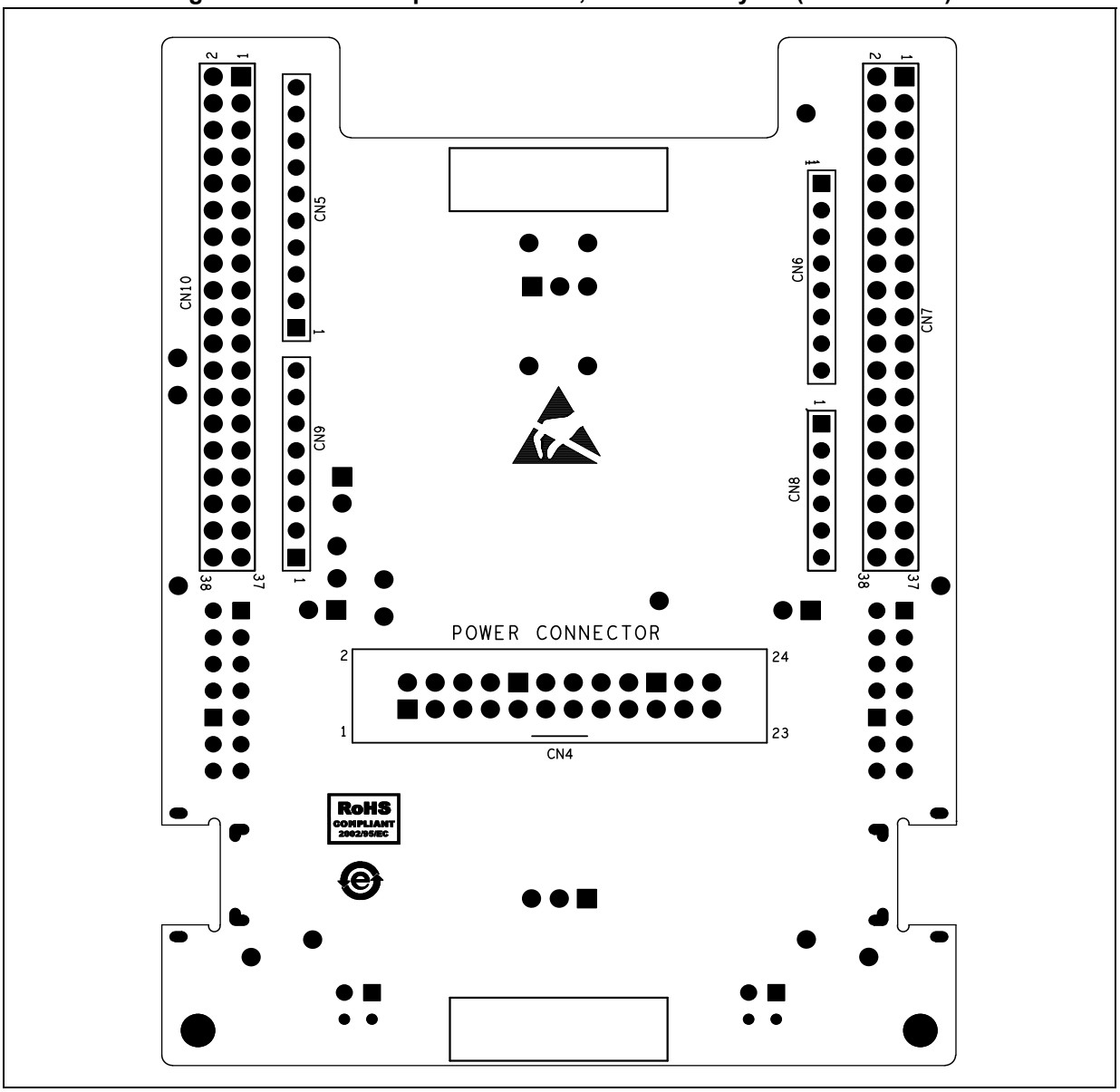


**Figure 17. MB1257 expansion board, silkscreen layout (bottom view)**

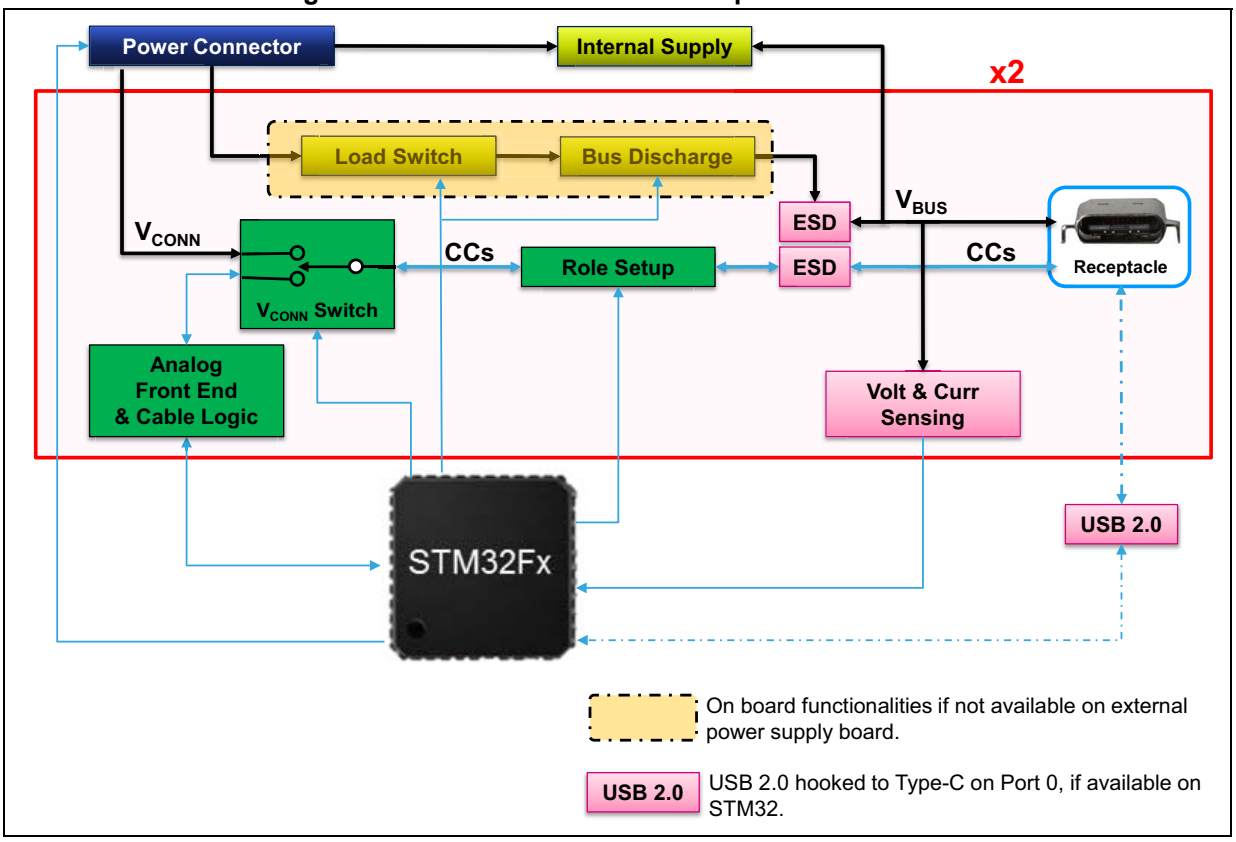



In the MB1257 board, a USB Type-C port is a subsystem composed by different stages, each one accomplishing a specific feature of PD protocol. The most peculiar blocks implementing a port are:

- The USB Type-C receptacles
- The Current-Sense stage
- The Analog-Front-End stage
- CC signal management
- The $V_{CONN}$ switch blocks
- The $V_{BUS}$ Port switch
- The $V_{BUS}$ discharge mechanism

The *Figure 18* depicts the block scheme of the complete architecture, including all the main interactions between the STM32F072RBT6 MCU and the main functional blocks outlined so far.

**Figure 18. Block scheme of the complete architecture**




All these main functional blocks characterizing the USB-C PD application, comprising of its connectors and jumpers (highlighted also in the *Figure 19* and *Figure 20*), will be briefly described in the following sub-sections. The description of the block will refer to PORT_0 as example, but all the assumptions are the same for the other port.

Figure 19. MB1257 main connectors and jumpers for setting

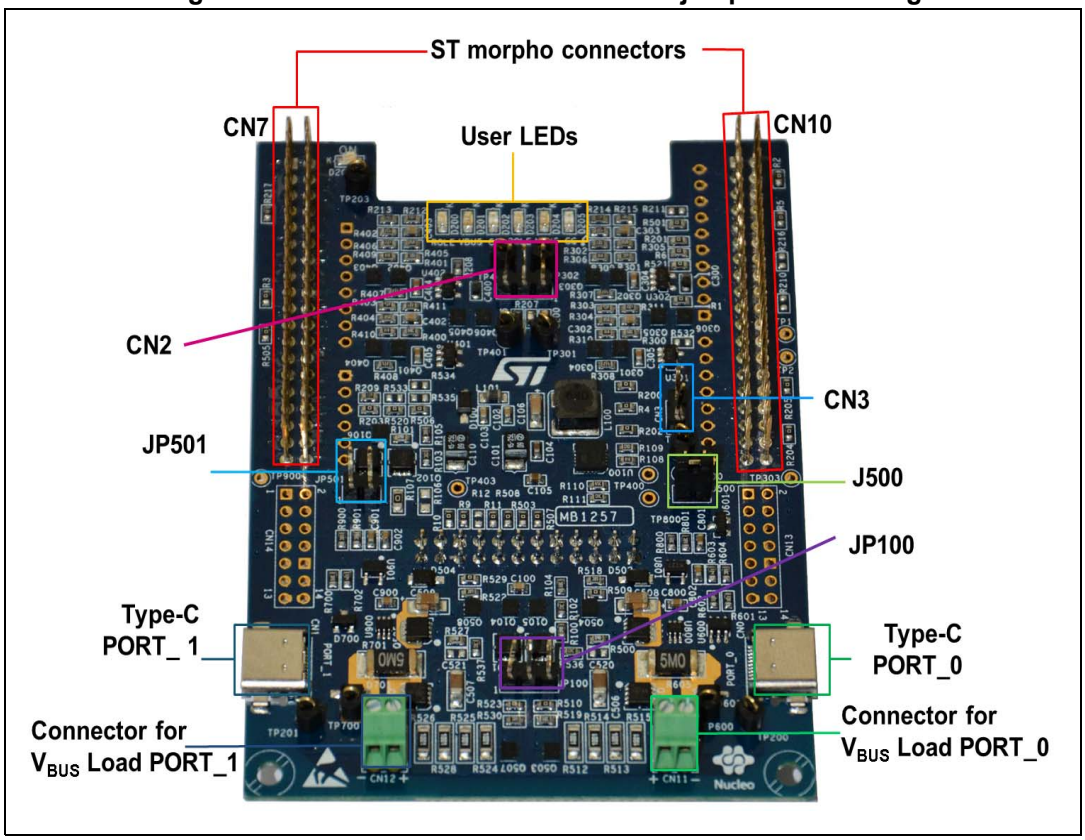
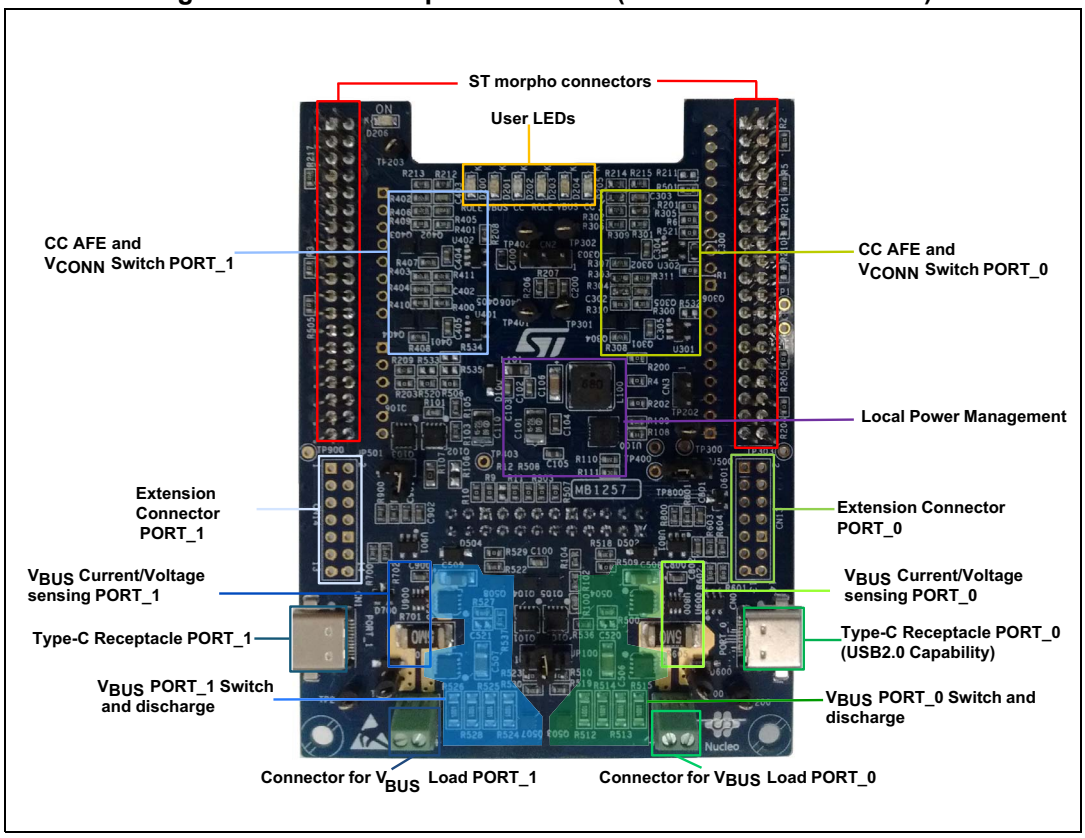


Figure 20. MB1257 expansion board (view of the main blocks)

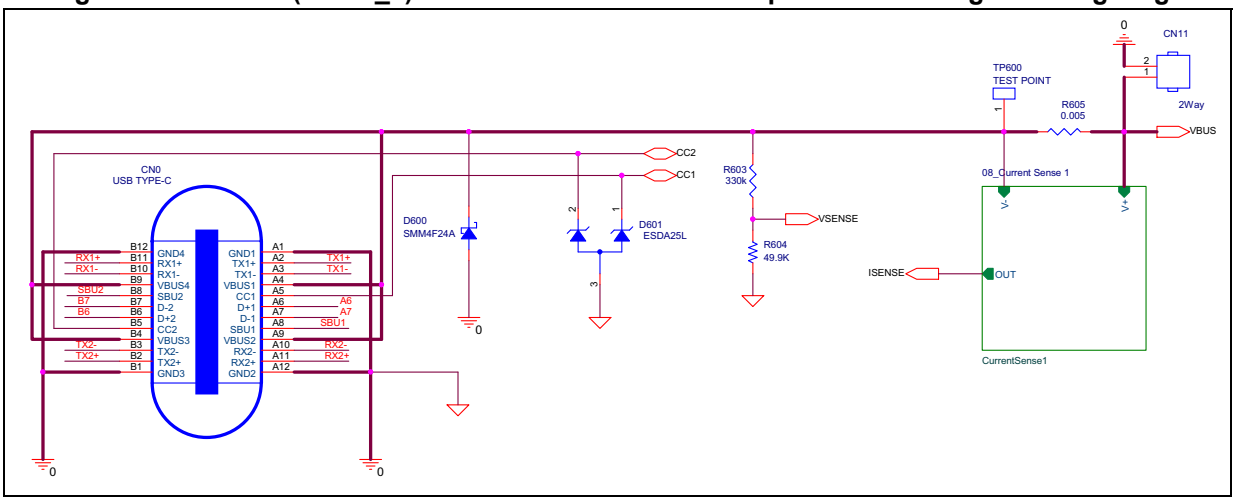



## 2.4 MB1257: USB Type-C receptacle and current-sense stage

Two USB Type-C certified receptacles CN0 and CN1 are present on the MB1257 board, representing respectively the PORT_0 and PORT_1. Both ports are eligible to supply another platform plugged by a USB Type-C cable when they are configured as Provider or, otherwise, to be supplied in case of Consumer configuration.

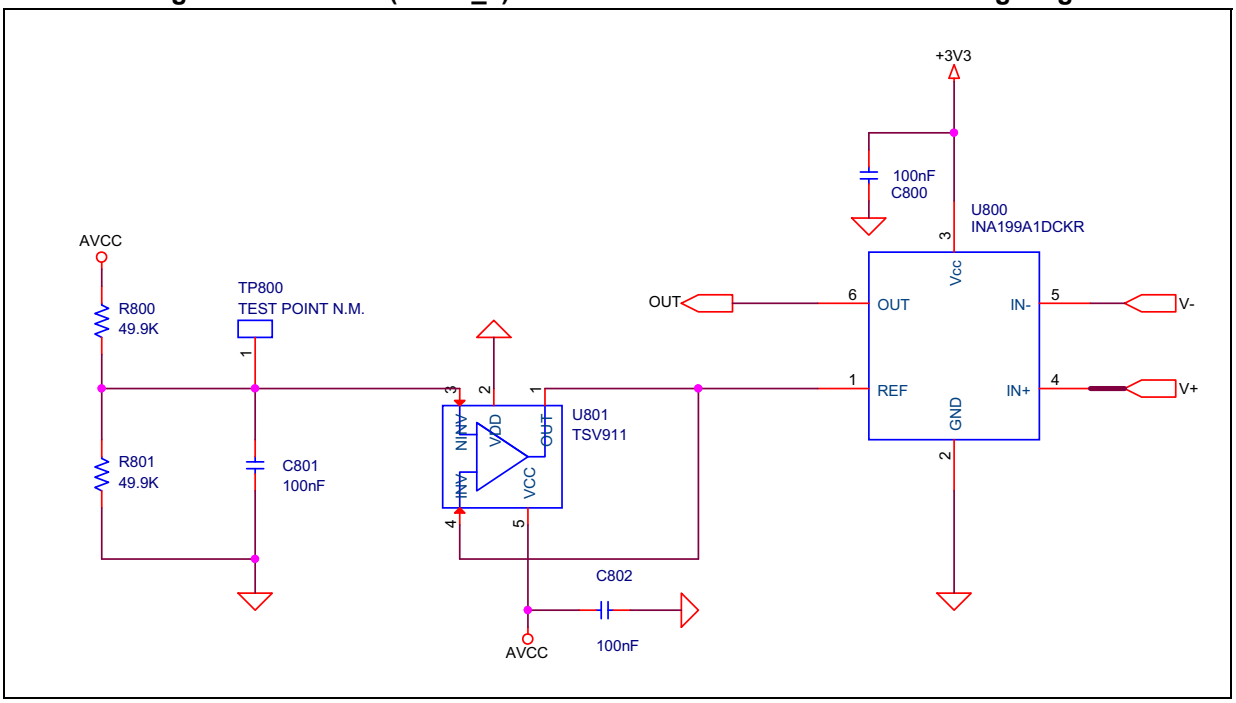
The *Figure 21* shows the USB Type-C receptacle pinout on the MB1257 schematic (also see *Figure 3*).

**Figure 21. MB1257 (PORT_0): schematic view of the receptacle and voltage-sensing stage**




As represented in *Figure 21*, each port is equipped by a current-sensing stage, shown in *Figure 22*, that, matched with the voltage sensing carried by the STM32F072RBT6 ADC peripherals, is able to monitor the right power level applied on the port $V_{BUS}$.

**Figure 22. MB1257 (PORT_0): schematic view of the current-sensing stage**




## 2.5 CC Analog Front-End and CC management

As described by the USB-C PD specification, the role assignment of a port (i.e. Provider or Consumer) depends, at hardware level, on the voltage level (related to a resistance value) exposed to the other system connected by the USB Type-C cable. Therefore, the STM32F072RBT6 MCU is eligible to manage the configuration of the Analog Front-End

block, to select the assigned role: the *Figure 23* and *Figure 24* show the main stages which this function carries out.

**Figure 23. MB1257 (PORT_0): schematic view of the Analog Front-End**

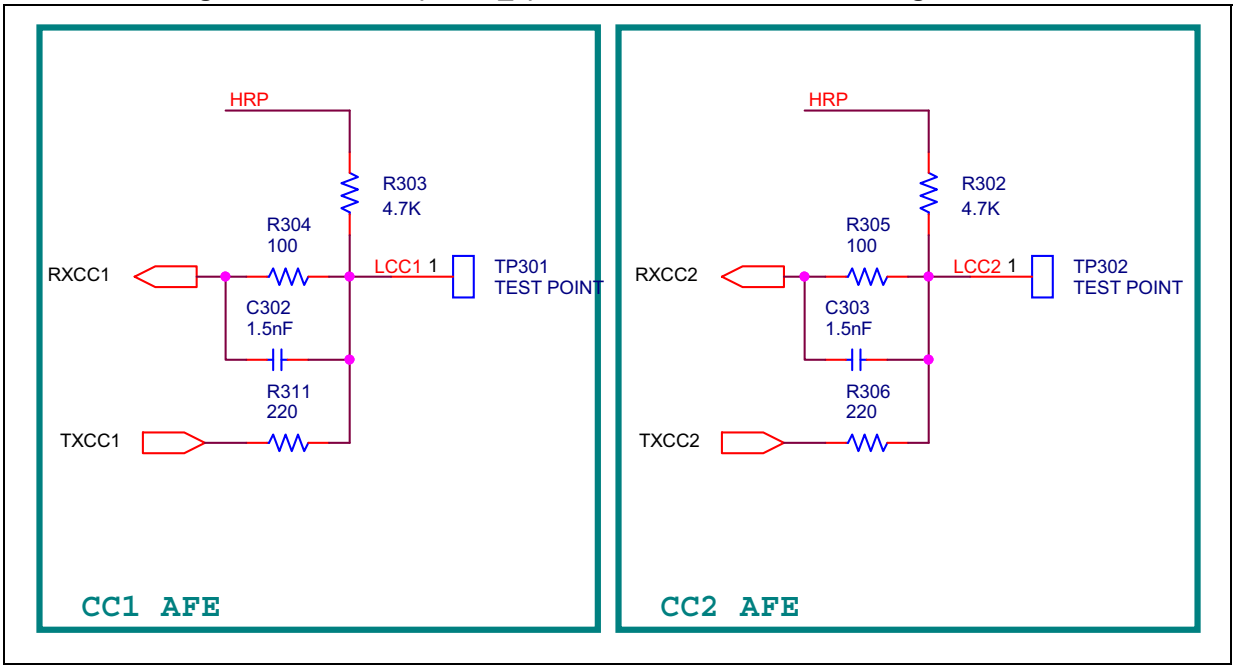
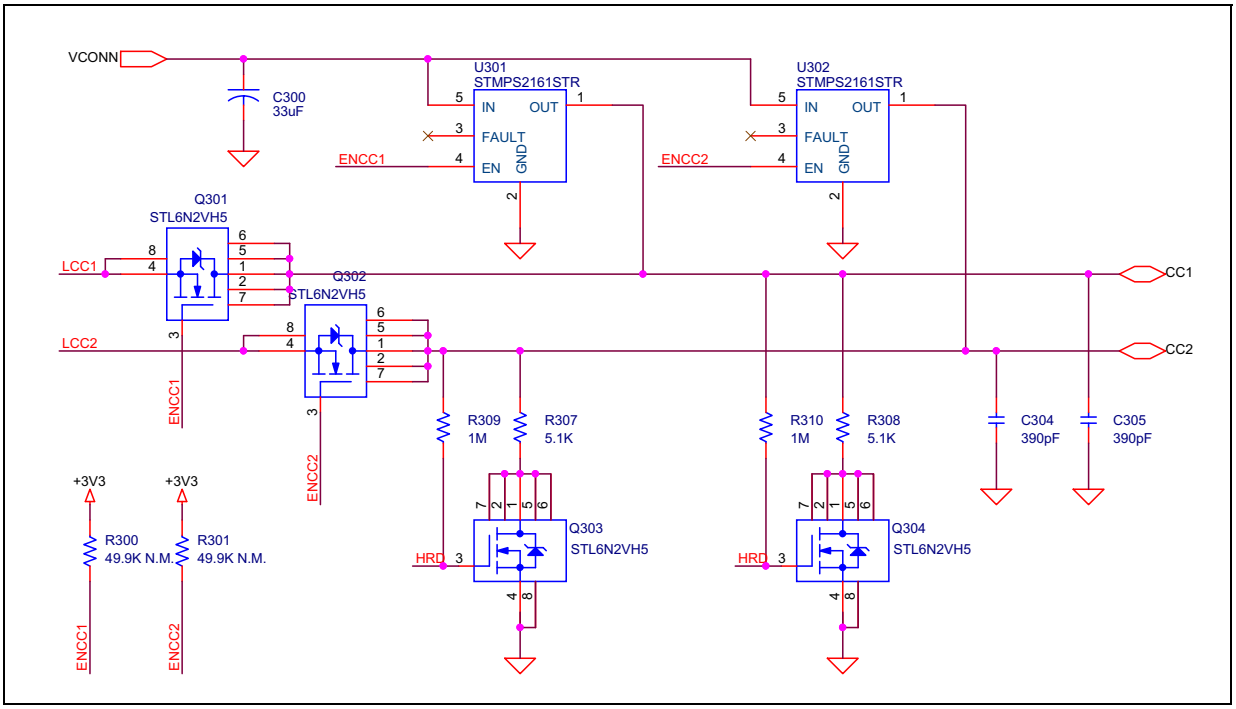



**Figure 24. MB1257 (PORT_0): schematic view of the CC management**



For the role assignment:

- When the designated port must be configured as Provider, the STM32F072RBT6 MCU sets high the HRP function (*Figure 23*) and, contemporary, sets high the CC enable command (labelled as ENCC1 or ENCC2 in *Figure 24*). In this way, a pull-up with 4.7 kΩ Rp resistance (R303 for the CC1 line or R302 for the CC2 line) is exposed on the CC lines.
- If the designated port acts as Consumer, the STM32F072RBT6 MCU sets HRP in High Impedance for releasing the Rp resistance in the CC line Analog Front-End stage, and sets high the HRD pin (related to the Q303 and Q304 MOSFETs in *Figure 24*). This operation exposes the 5.1 kΩ Rd resistance on CC lines (R308 for the CC1 line or R307 for the CC2 line).

The CC line selection is first mechanically-driven by the cable insertion in the receptacle and then managed by the STM32F072RBT6 MCU, through the Cable Attach/ Detach mechanism.

In fact, the STM32F072RBT6 MCU sets high the ENCC1 e ENCC2 pins on Q301 and Q302 (*Figure 24*), and then it checks the voltage on LCC1 and LCC2 (*Figure 23*) by its ADC peripherals, identifying the CC line selected for the communication.

About the communication aspect, the STM32F072RBT6 MCU enables the transmission on the CC lines managing the resistor divider on R311 (CC1) or R306 (CC2), and the ENCC1 or ENCC2 pins for selecting CC lines.

For the reception, the STM32F072RBT6 MCU always acts on ENCC1 or ENCC2 to connect the CC lines to the relative analog path, by mean of RXCC1 (R304) e RXCC2 (R305): these nets are connected to the STM32F072RBT6 MCU pins internally hooked to comparators and ADC peripherals.

A further peculiar aspect of this stage is the management of the Dead Battery condition: this case is verified when a Consumer is not powered and unable to expose the Rd resistors on its CC lines and needs the Provider interaction to start up.

When the two entities are plugged by mean of the USB Type-C cable, the MOSFET related to the linked CC line (Q303 or Q304) will turn-on by effect of the self-biasing through R309 or R310 resistors: so Rd is exposed on the selected CC line establishing the connection (*Figure 24*).

## 2.6 MB1257 $V_{CONN}$ switch

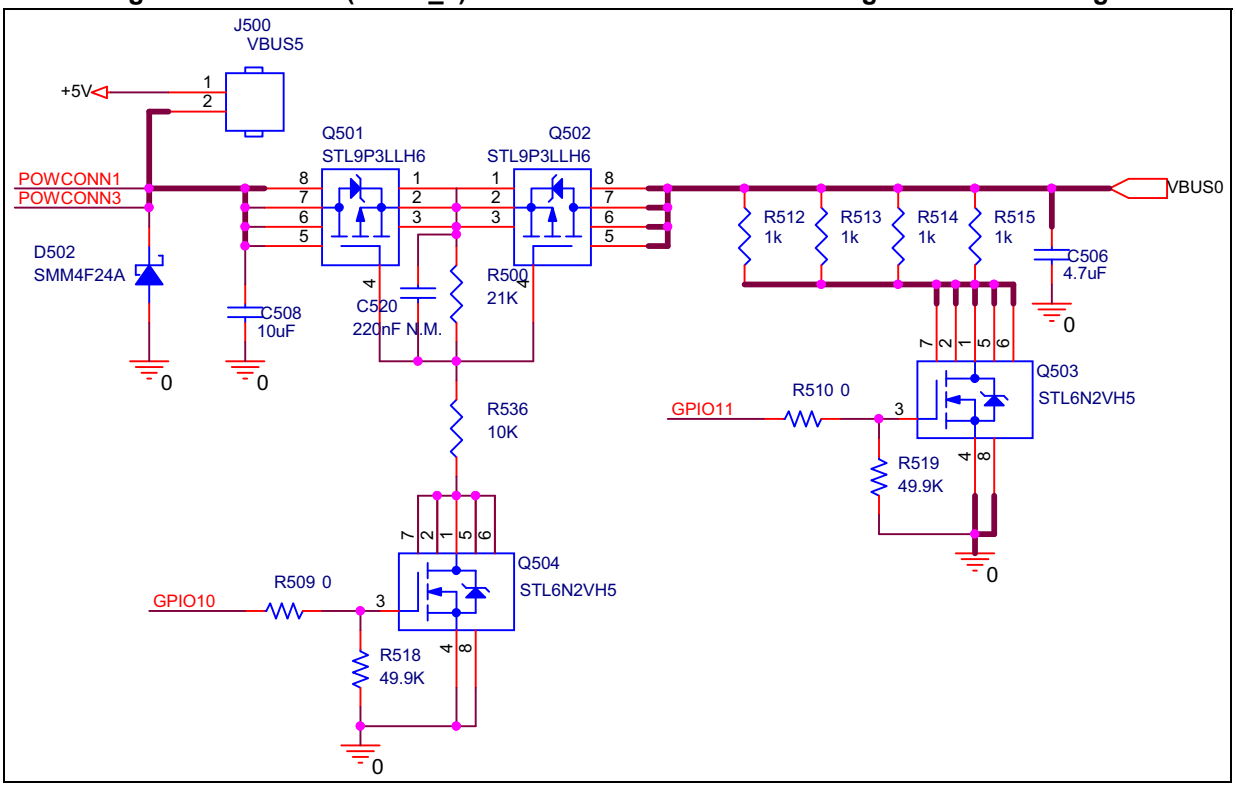
When the full-featured cable is connected to one of the ports, the $V_{CONN}$ is directly managed by the STM32F072RBT6 MCU by mean of the ENCC1 or ENCC2 and the load switches U301 and U302 (*Figure 24*).

The STMPS2161 switches (U301 and U302) are controlled by the same signals ENCC1 and ENCC2 driving the MOSFETs Q301 and Q302 but, differently from these ones, they are active-low: then, U301 and U302 work in opposition to the MOSFETs. So that, when a CC line is selected for the communication, the other one is eligible to provide the $V_{CONN}$.

## 2.7 MB1257 $V_{BUS}$ management and discharge mechanism

The *Figure 25* describes the $V_{BUS}$ management and discharge mechanism.

**Figure 25. MB1257 (PORT_0): schematic view of the discharge mechanism stage**




This block is eligible to manage different $V_{BUS}$, as described by USB PD specification (see *Section 7: References*), for supplying other platforms as Provider, or to be supplied as Consumer. In this way the Q501-Q502 MOSFETs are set in back-to-back configuration to protect and isolate the $V_{BUS}$ supplying path on both directions.

If the Provider is matched with an external power supply through the power connector CN4, the $V_{BUS}$ is on the supply path by mean of the discrete load switch (Q501-Q502) driven by the MCU (GPIO10).

**If an external power supply is connected on CN4, the jumpers J500 and JP501 must be left open.**

If no external power supply is available, fitting the jumper J500 allows to use the 5 V from the NUCLEO-F072RB board as $V_{BUS}$, and only for Provider role. **This is used mainly for demonstration purpose**.

*Note: The integrated Rp value is 4.7 kΩ at 3.3 V to advertise current capability of 3 A at 5 V. User has to change it according to the power supply capabilities.*

For the Consumer case, the same $V_{BUS}$ path is managed by the STM32F072RBT6 MCU enabling the discrete load switch.

Moreover, the $V_{BUS}$ path presents a discharge mechanism implemented by the MOSFET Q503 and an RC filter.

## 2.8 MB1257 $V_{BUS}$ load connectors

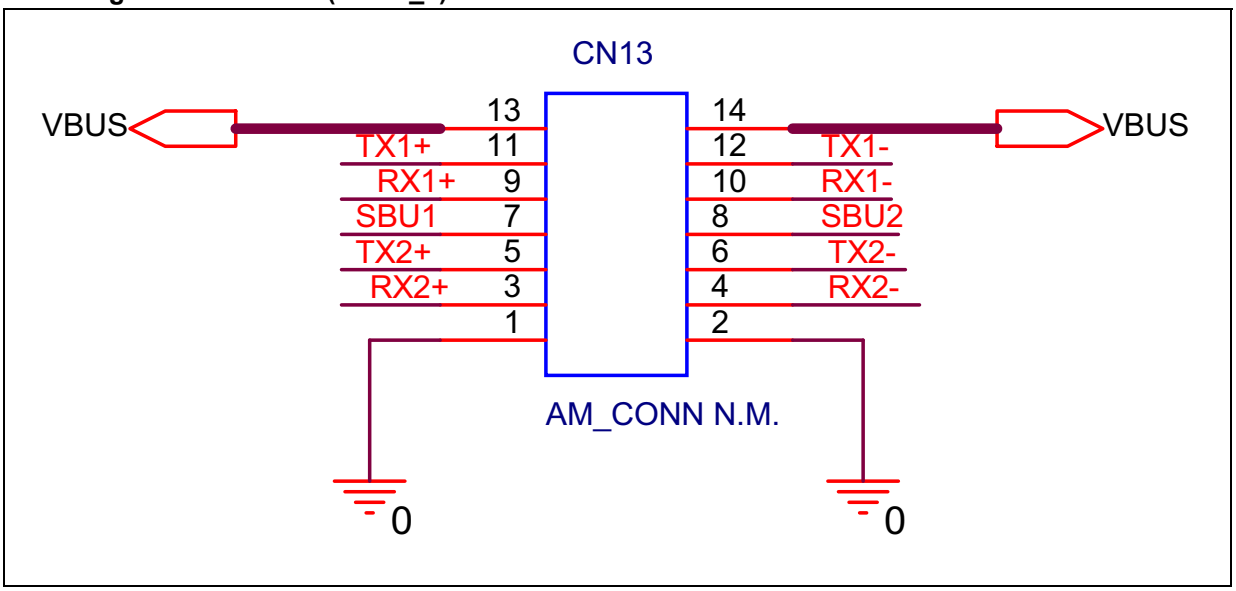
The two connectors CN11 and CN12, respectively associated to PORT_0 and PORT_1, are able to provide externally the $V_{BUS}$ supplying any load connected to them.

## 2.9 MB1257 extension connectors

As anticipated, both ports support the USB PD and the USB Type-C specification (refer to *Section 7: References*) including the Alternate-Mode capability that enables the multi-purposing of the designated pins in the connector: concerning this last option, two dedicated connectors (CN13 and CN14) have been inserted to expose all the main pins and facilitate the design of the application related to this topic.

The *Figure 26* reports the pins exposed on the Alternate-Mode connector CN13, related to the PORT_0.

**Figure 26. MB1257 (PORT_0): schematic view of the alternate-mode connector CN13**




## 2.10 MB1257 USB2.0 capability

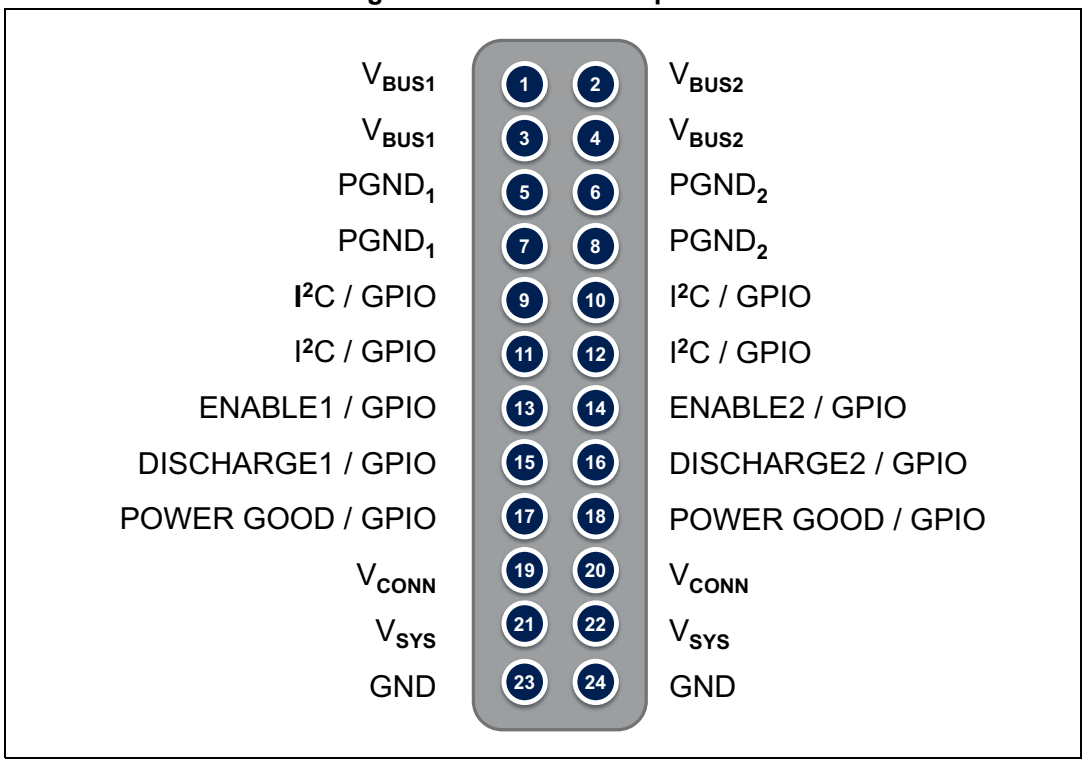
Finally, the PORT_0 supports the USB 2.0 capability too, embedding the USBLC6-2 protection (U600), so that it is able to act as UFP.

## 2.11 MB1257 local-power management stage

About the power aspects, the MB1257 is equipped with a dedicated power connector, tagged CN4 and located on the bottom side of the board. This allows to connect the board to a selectable power supply that provides the right power objects (voltage and current couples) supporting the USB PD application.

The CN4 connector is a kind of interface with the external power supply: its pinout is reported in the *Figure 27*.

**Figure 27. MB1257: CN4 pinout**




Through CN4, the MB1257 is able to provide the $V_{BUS}$ directly coming from the external board to its two Type-C™ receptacles CN0 and CN1. Moreover, two couples of CN4 pins can be used for acting on the power supply and selecting the right power requested by the application: particularly, the CN4 pins 9 and 11 are connected to two GPIO pins on the STM32F072RBT6 MCU which can be configured also as an $I^2C$ channel to act on smart power supplies.

Enable pins and discharge pins can be used for controlling the load switches on the power supply if available. Another couple of pins called POWER GOOD have been inserted in order to check when the power supply is ready with the right power range to be provided. Finally there is also the possibility to receive the $V_{CONN}$ voltage from the external power supply through the related pin.

$V_{SYS}$ is a voltage between 5 V and 20 V to be used as supply voltage for the overall system. It can be used as voltage input of the embedded DC-DC.

Relatively to the PD feature, the MB1257 board has been designed to provide power to the connected platforms either starting by an external power supply board, or by the standard USB port through the connector CN1 present on the NUCLEO-F072RB board. Then, while in the first case an external power supply may guarantee also considerable power ranges, in the second case, the maximum power availability is limited to the standard 5 V, 500 mA related to the standard PC USB current offer.

Only in this last case, the jumpers J500 and JP501 enable the standard USB 5 V over $V_{BUS}$ on the USB Type-C receptacles CN0 and CN1 (if the ports are configured as Provider). Two options are available:

- If the external power supply is plugged to the power connector CN4, J500 and JP501 must be left open: the $V_{BUS}$ will be one of the voltage levels offered by the external power supply board.
- If the system is supplied by the standard USB port through the connector CN1 (without any other source on the power connector), J500 and JP501 must be closed and the $V_{BUS}$ will be only 5 V, coming from U5V of NUCLEO-F072RB board.

The MB1257 embeds also a local power management stage mainly composed by two sets of load switches respectively implemented by the MOSFETs STL9P3LLH6 (Q100-Q101 and Q102-Q103) driven by the STM32F072RBT6 MCU (by means of DRP and /DRP), and the DC-DC converter L6984 (U100).

These two parts are respectively showed in *Figure 28* and *Figure 29*.

**Figure 28. MB1257: schematic view of the load switches of the local power management**

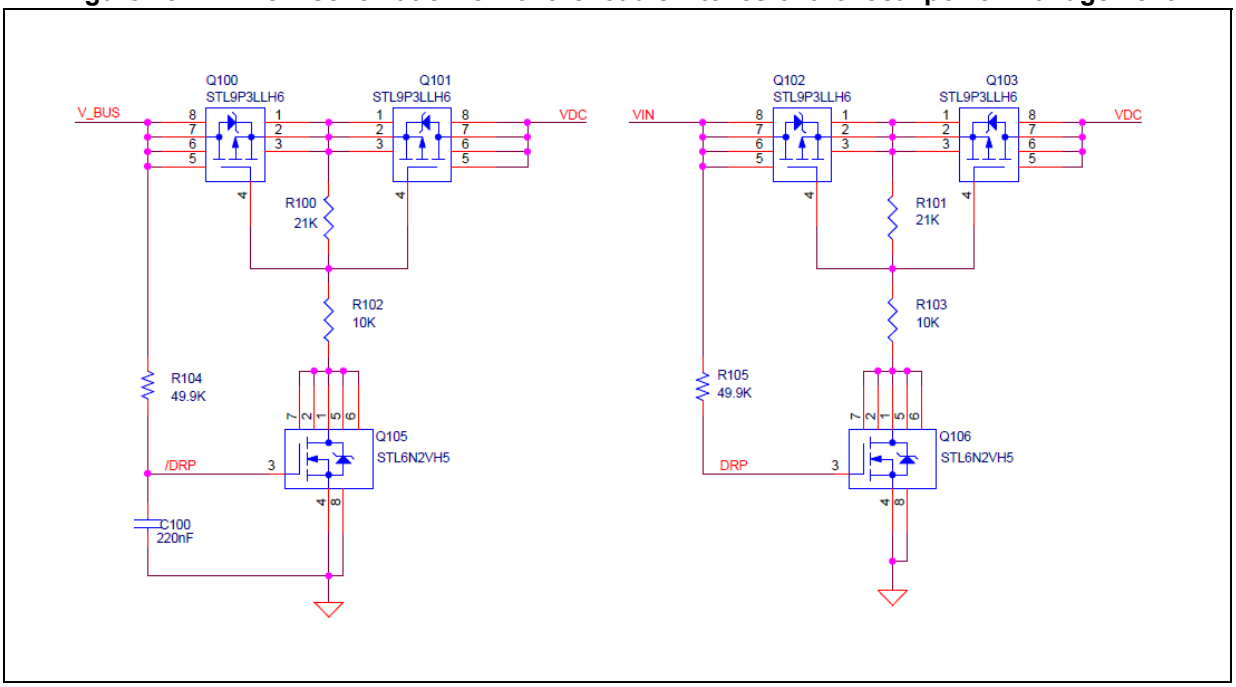
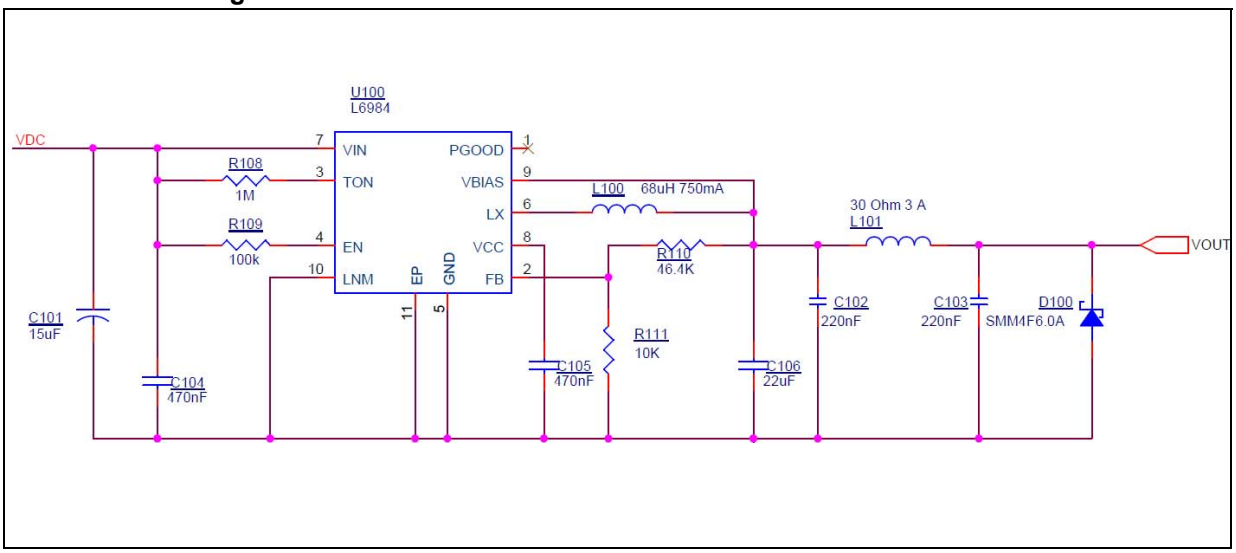


**Figure 29. MB1257: schematic view of the local DC-DC converter**




As supported by the USB PD specification, this stage is able to manage different power ranges, to supply the system. The Q100-Q101 and Q102-Q103 are set in back-to-back configuration and permit isolation on both directions of the supplying path.

In fact, it is possible to supply the platform starting from the $V_{BUS}$ delivered from a Provider connected to one of the ports, or alternatively from the $V_{IN}$ provided by mean of the power connector (CN4): the two power paths are independent, exclusive and controlled directly by the STM32F072RBT6 MCU through the DRP and /DRP functions.

In particular, when the platform is in Consumer role and receives the $V_{BUS}$ on one of the two ports, the jumper JP100 permits to set the PORT_0 (fitting the 2-3) or the PORT_1 (fitting the 1-2) in order to deliver $V_{BUS}$ to the Q100-Q101 load switch and then supply the system by the DC-DC converter.

## 2.12 MB1257 user LEDs

For each port, three LEDs permit to identify the operative conditions when the application runs: the following *Table 5* describes the LEDs blinking functionalities.

**Table 5. LEDs blinking meaning**

| LED | Port | Function label | Color | Comment |
|---|---|---|---|---|
| D203 | 0 | ROLE | Blue | The ROLE LEDs blinking mode provides information on the PORT ROLE connected to the cable:<br>“one blink” means the Port connected is a Provider;<br>“two blinks” means the Port connected is a Consumer; |
| D200 | 1 | | | |
| D204 | 0 | $V_{BUS}$ | Green | When the $V_{BUS}$ LED blinks, the $V_{BUS}$ is applied on the connected port.<br>When the $V_{BUS}$ LED is ON --> the connected port has established explicit contract. |
| D201 | 1 | | | |

Table 5. LEDs blinking meaning (continued)

| LED | Port | Function label | Color | Comment |
|---|---|---|---|---|
| D205 | 0 | CC | Orange | The CC LEDs blinking mode provides information on the CC Line connected for the communication:<br>“one blink” means CC Line #1 is connected<br>“two blinks” means CC Line #2 is connected |
| D202 | 1 | | | |

## 2.13 MB1257 serial communication connectors

For implementing a serial communication able to send commands or reach data from the application, the MB1257 board embeds a connector CN3 exposing the USART1 peripheral of the STM32F072RBT6 MCU, when the expansion board is plugged upon the NUCLEO-F072RB. The connector CN3 is useful to implement the serial communication through the ST-LINK, connecting the application MCU with the STM32F103CBT6 (ST-LINK MCU) by its respective CN3 connector.

Moreover, the connector CN2 exposing the STM32F072RBT6 I2C peripheral has been put to add a further communication capability to the wide-range communication peripheral set the platform already has.

## 2.14 Full-featured Type-C cable

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

# 3 System setup

This chapter describes how to set up the platform in two different configurations.

In each configuration the MB1257 board must be stacked on the NUCLEO-F072RB board through the ST morpho connector, paying attention to the mounting verse of the two boards. The MB1257 board must be stacked on the NUCLEO-F072RB board through the ST morpho connector. There is only one position allowed for this connection, the one where the stacked board MB1257 does not cover the two blue and black push-buttons on the NUCLEO-F072RB board (see the blue button B1 and black button B2 in the *Figure 12*).

## 3.1 Provider configuration

The Provider role can be managed with two different supply options that correspond to two configuration settings:

- The Provider is supplied by the on-board NUCLEO-F072RB voltage regulator, by mean of a USB Type-A to Mini-B cable plugged to the CN1 connector and then to a PC. This setting is similar to the one used for the demonstration showed in the *Getting started with the STM32 Nucleo pack* User manual (UM2051). For USB Type-C and PD:
  - On NUCLEO-F072RB board (see *Figure 12*), verify that the jumper JP1 is open, JP5 (PWR) closed on U5V (fitting the pins 1-2), and JP6 (IDD) closed.
  - On MB1257 expansion board (see *Figure 14*), close the jumper related to the port chosen as Provider, between J500 for PORT_0 and JP501 for PORT_1.

This setting will permit to manage the $V_{BUS}$ on the selected port, starting from the NUCLEO-F072RB USB PWR voltage (CN1 connector).

- The Provider is equipped with an external board by the power connector CN4:
  - On the NUCLEO-F072RB board (see *Figure 12*), the following jumper settings must be guaranteed: JP1 closed, JP5 (PWR) closed on E5V (fitting the pins 2-3), and JP6 (IDD) closed.
  - On the MB1257 expansion board (see *Figure 14*), the jumpers JP100, J500, JP501 must be left open.

This setting configuration will permit to the external power board to supply the entire system and, particularly for the USB PD application, to offer a voltage level for the $V_{BUS}$ of the port.

## 3.2 Consumer configuration

The system can manage two supply options for the Consumer configuration.

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. when a Consumer is supplied by the Provider by mean of its $V_{BUS}$).

Both configurations correspond to two different settings, too (see *Figure 12*):

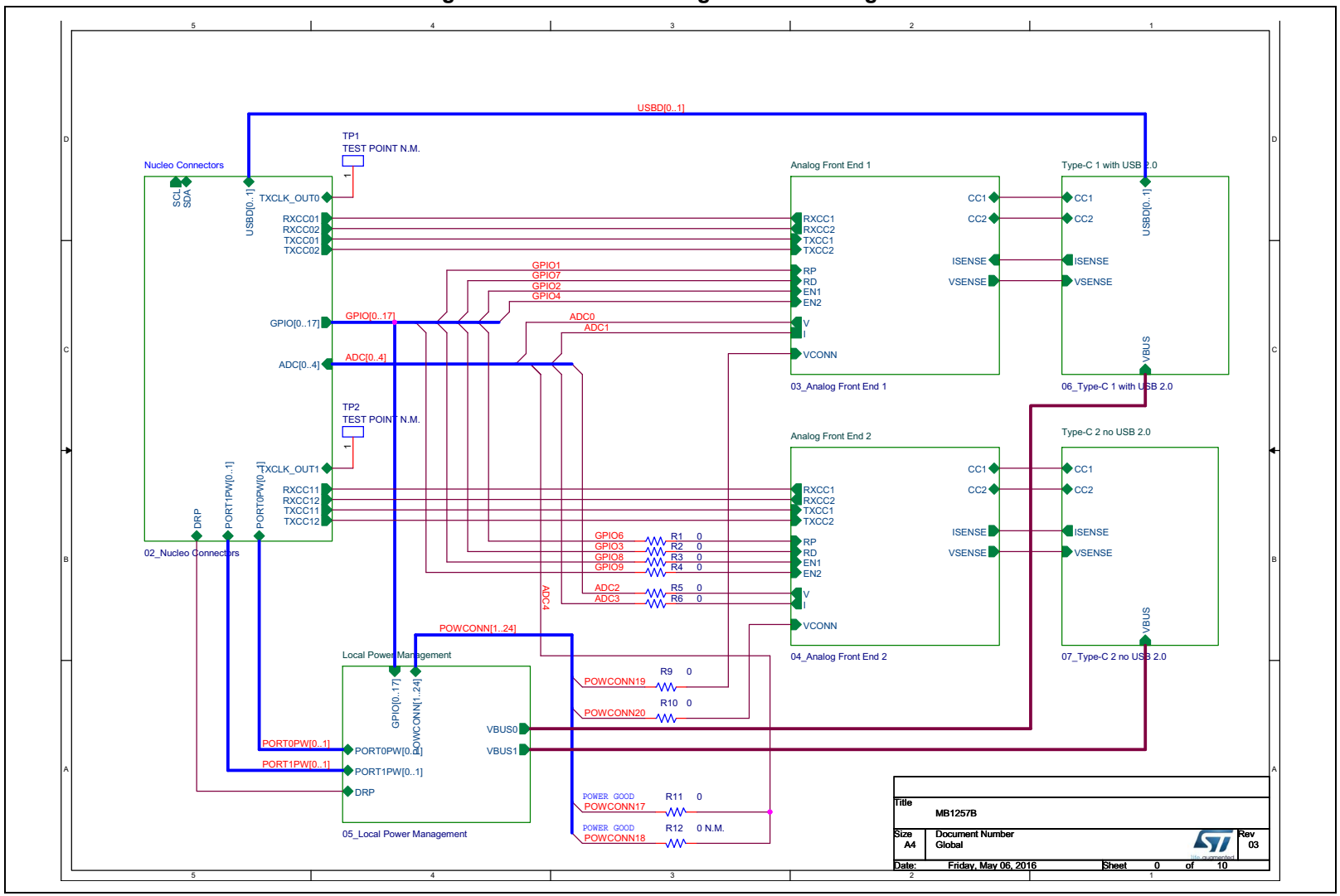
- If the Consumer is supplied by the NUCLEO-F072RB voltage regulator, the system setting is the following one:
  - On NUCLEO-F072RB board (*Figure 12*), verify that the jumper JP1 is open, JP5 (PWR) closed on U5V (fitting the pins 1-2), and JP6 (IDD) closed.
  - On MB1257 expansion board (*Figure 14*), open the jumpers JP100, J500, JP501.
- If the Consumer is supplied by the $V_{BUS}$ delivered by the connected Provider through the USB Type-C cable, the system setting is the following one:
  - On the NUCLEO-F072RB board (*Figure 12*), the jumper JP1 must be closed, JP5 (PWR) closed on E5V (fitting the pins 2-3), and JP6 (IDD) closed.
  - On MB1257 expansion board (*Figure 14*), while the jumpers J500, JP501 are opened, the jumper JP100 must be set according to the port chosen for supplying the system (fit 2-3 for PORT_0 or 1-2 for PORT_1).

# 4 Ordering information

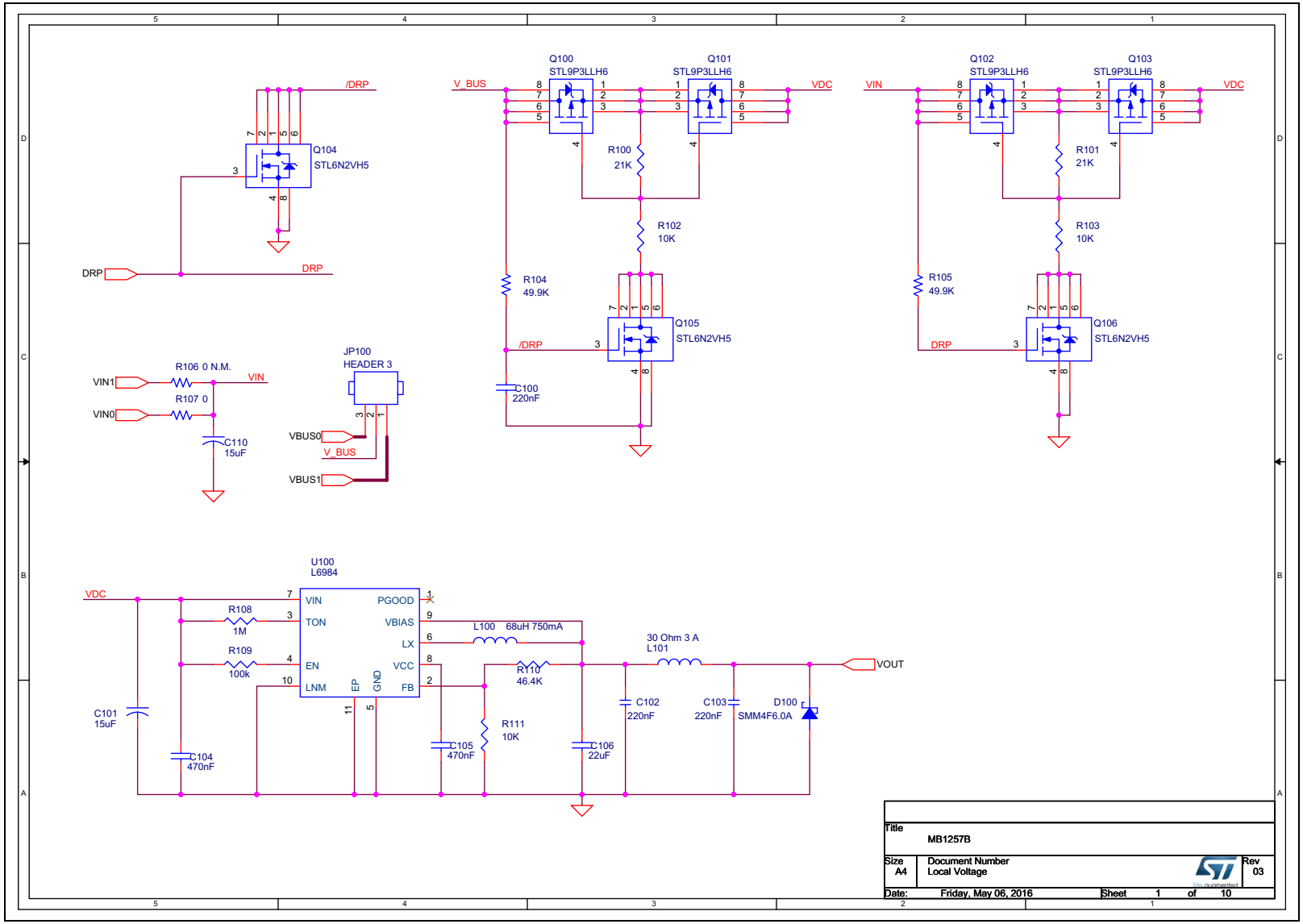
To order the USB Type-C™ and Power Delivery Nucleo pack based on the NUCLEO-F072RB board, the MB1257 expansion board and the USB full-featured Type-C Cable, use the order code: P-NUCLEO-USB001.

# 5 Electrical schematics

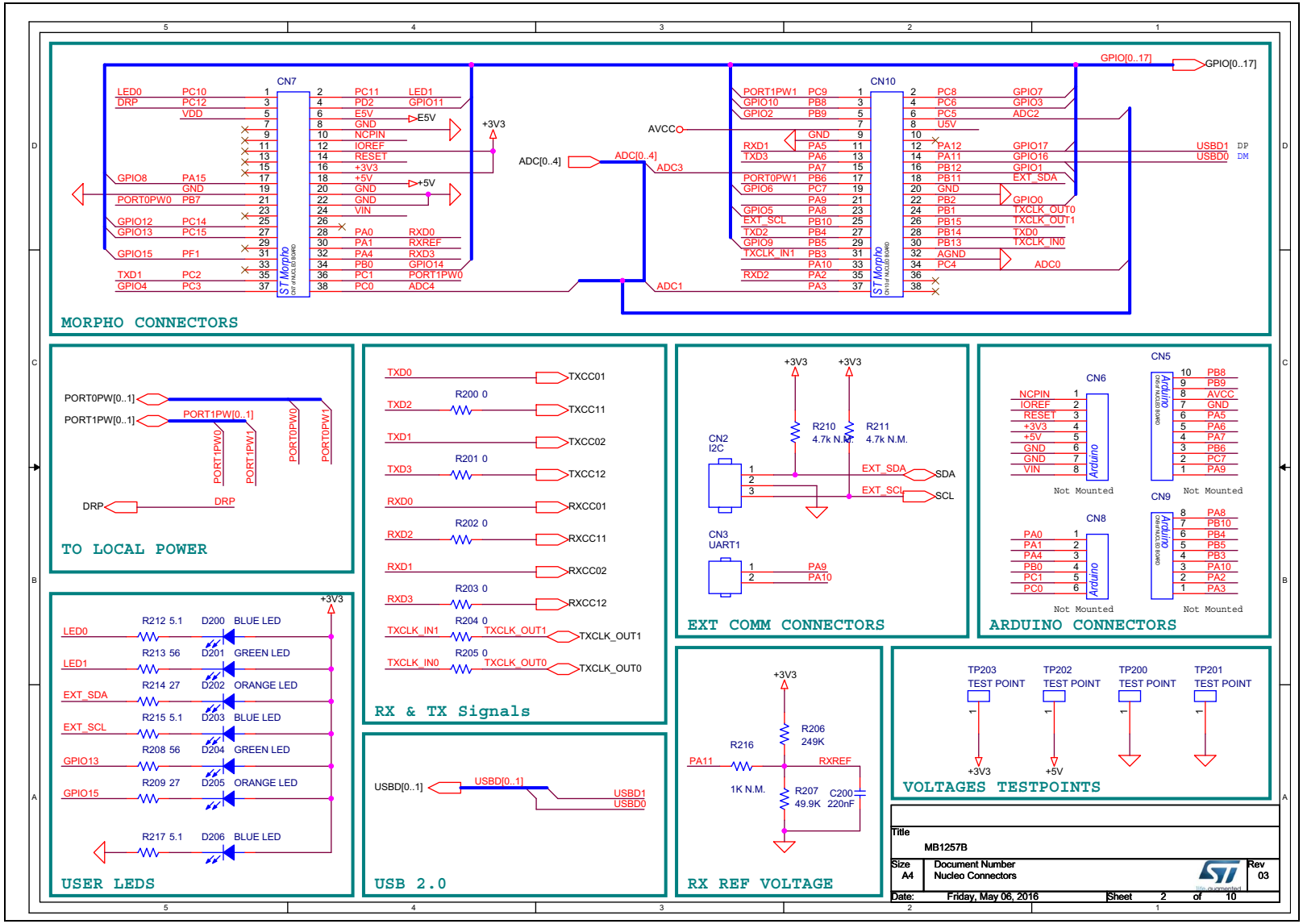
**Figure 30. MB1257 board: global block diagram**



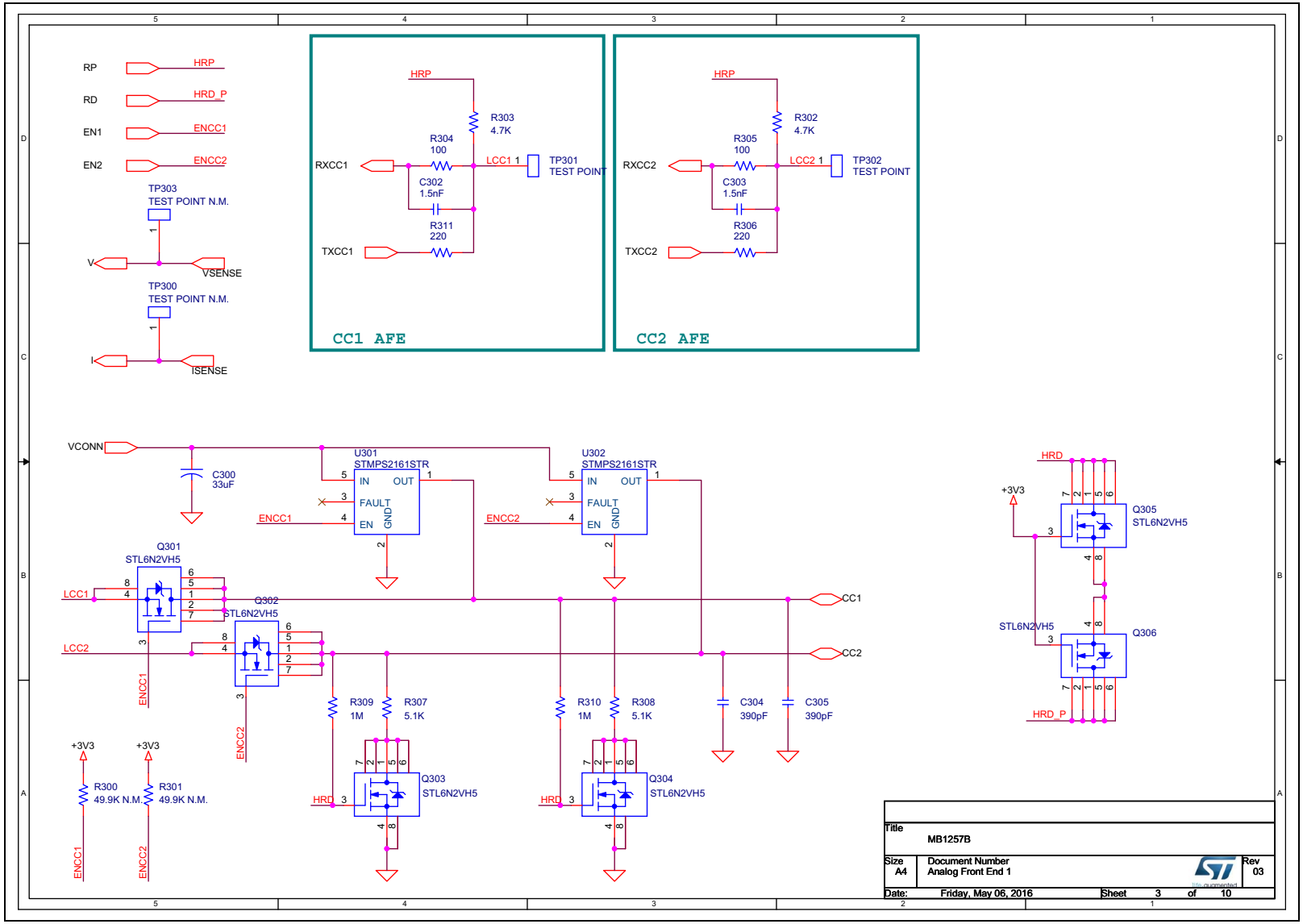
## Figure 31. MB1257 board: local voltage management



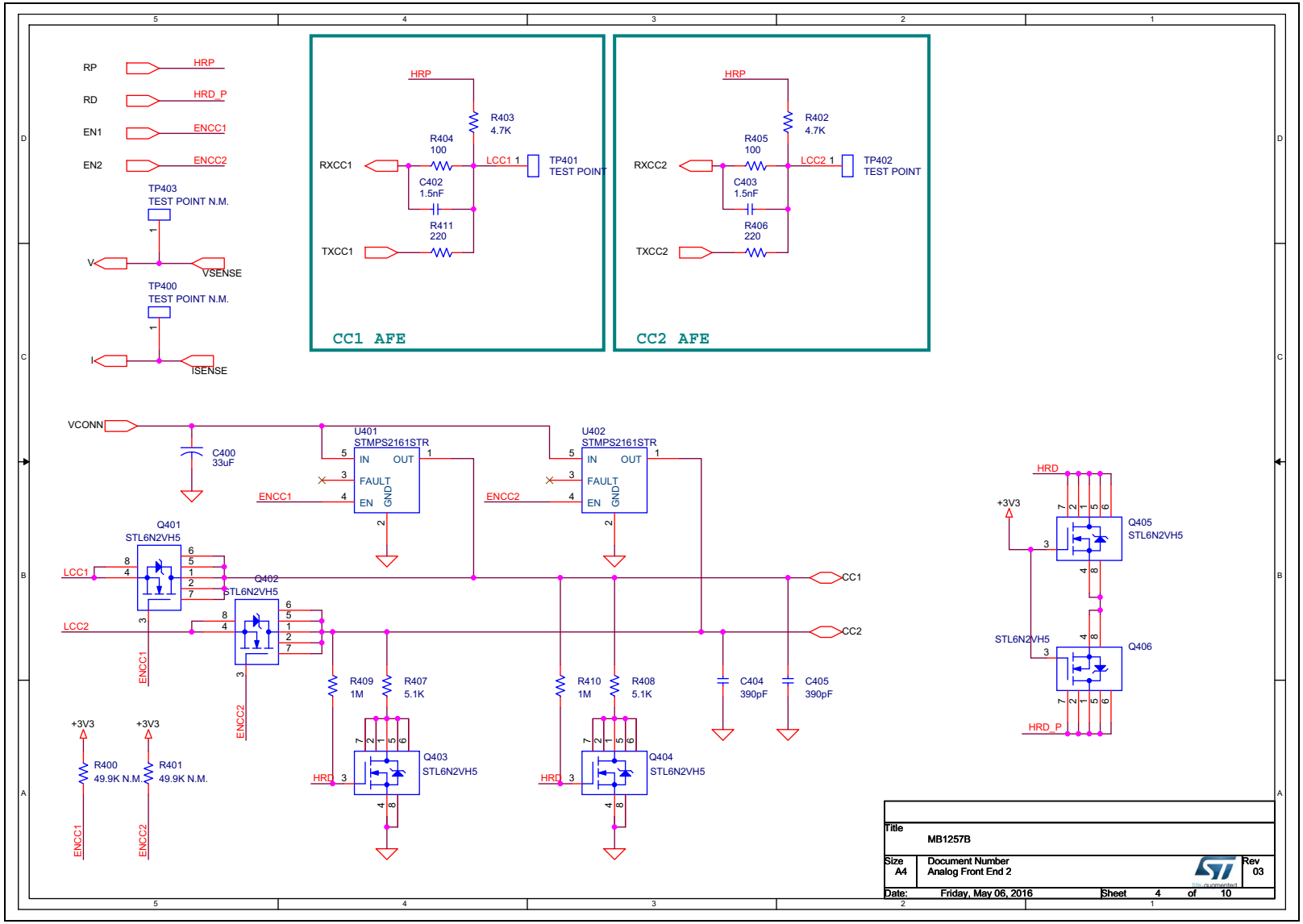
## Figure 32. MB1257 board: main connectors and operations



## Figure 33. MB1257 board: Analog Front-End 1 (PORT_0)



## Figure 34. MB1257 board: Analog Front-End 2 (PORT_1)



## Figure 35. MB1257 board: local power management

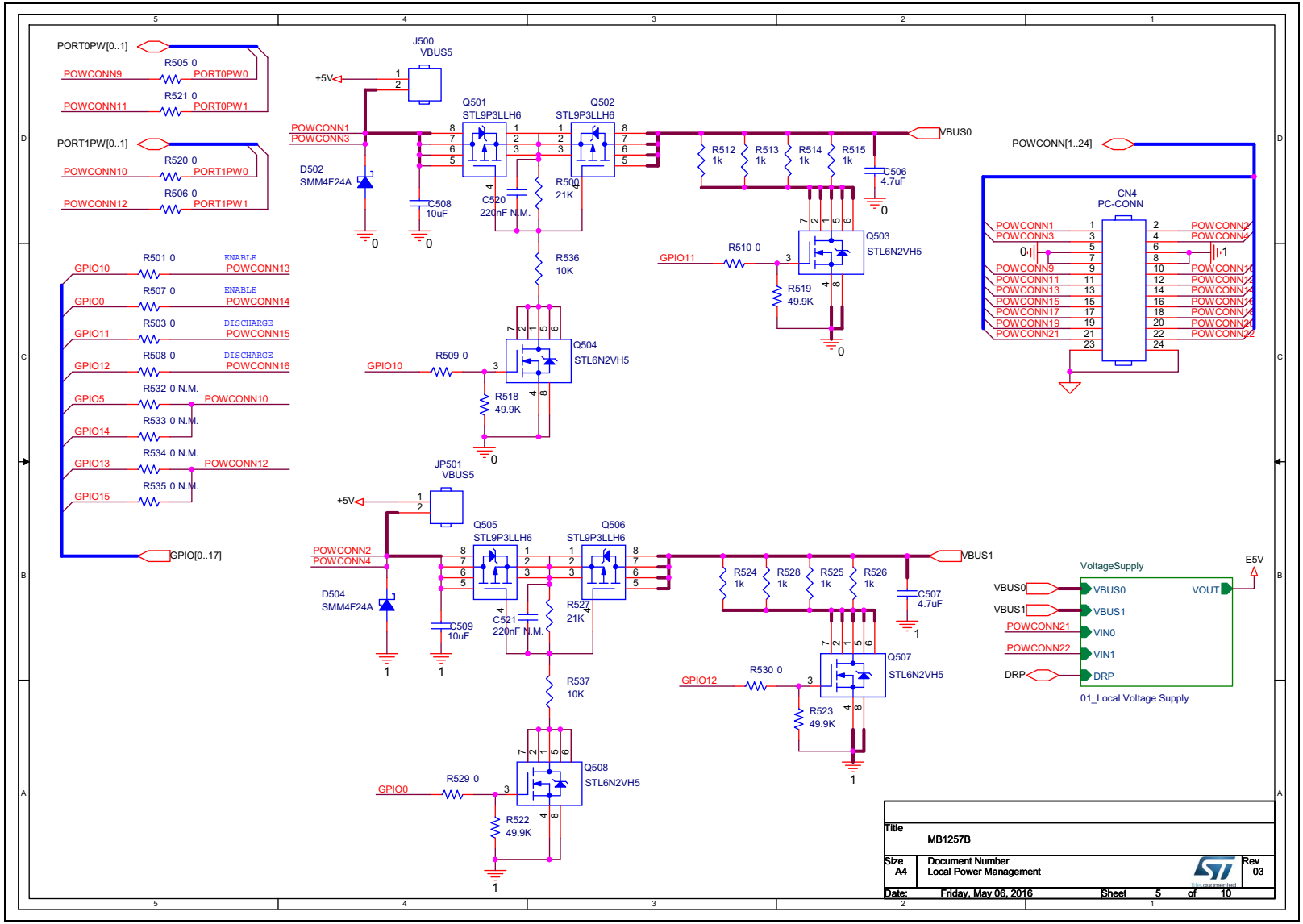
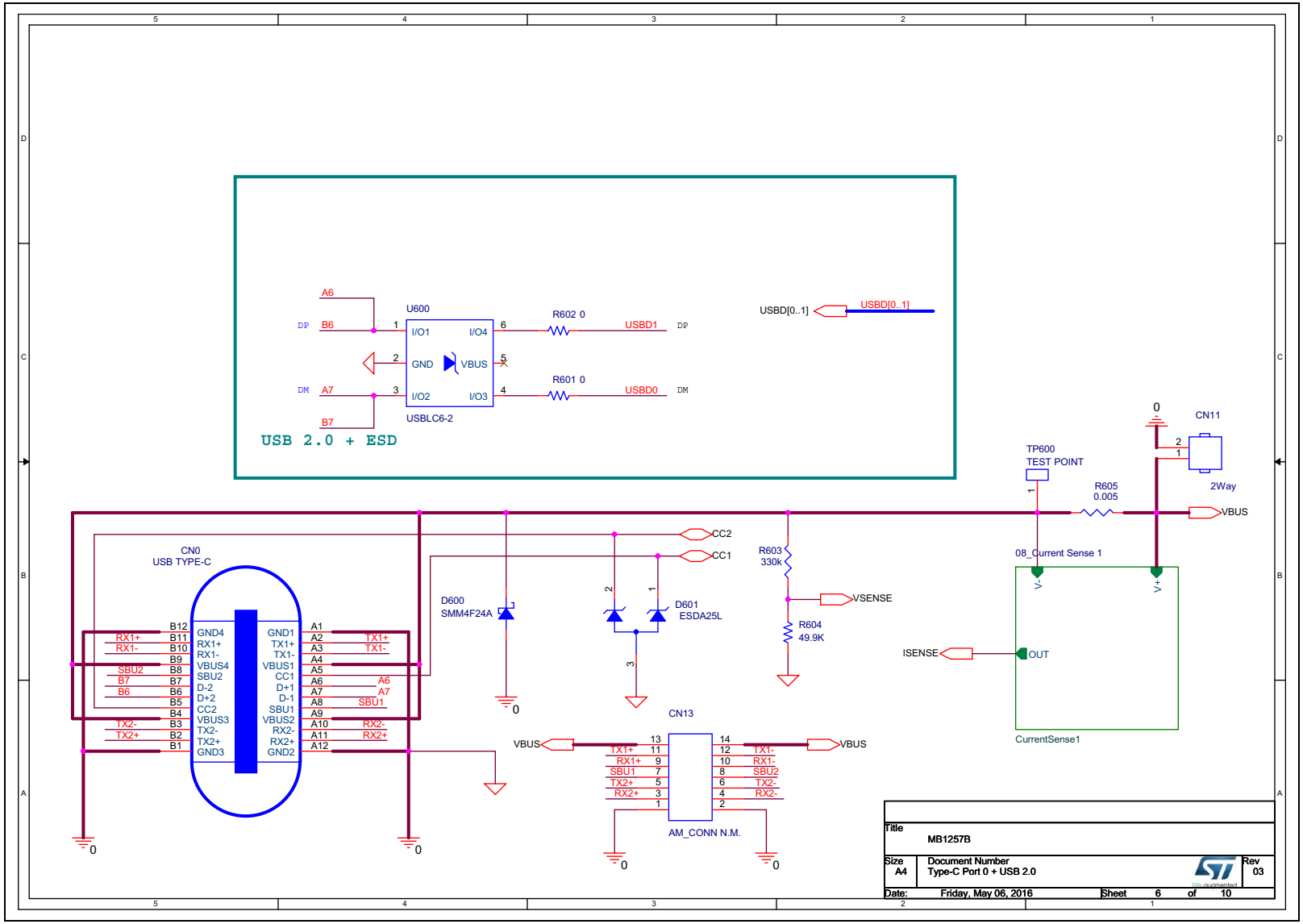


**Figure 36. MB1257 board: Type-C PORT_0 and USB 2.0**



## Figure 37. MB1257 board: Type-C PORT_1

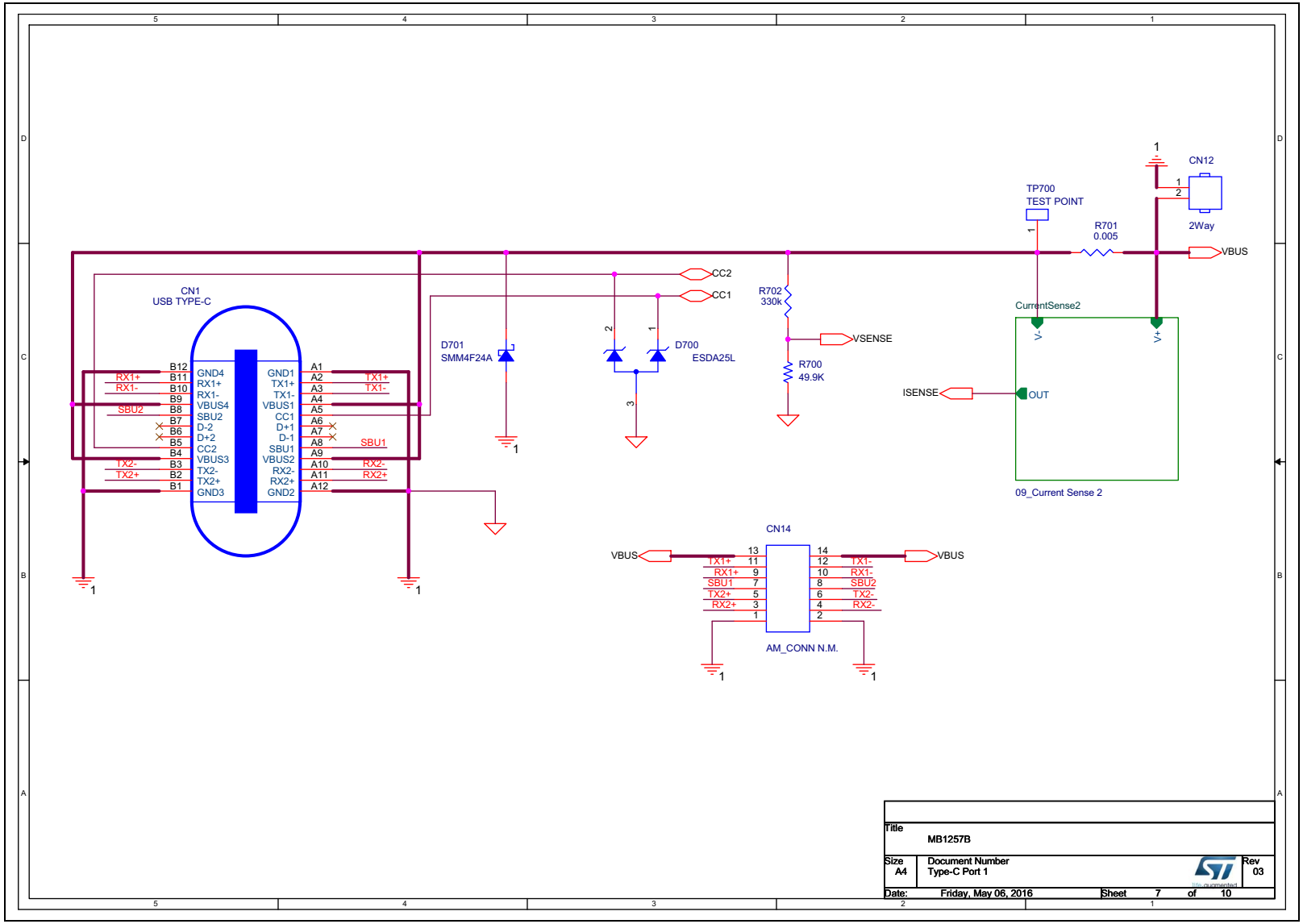
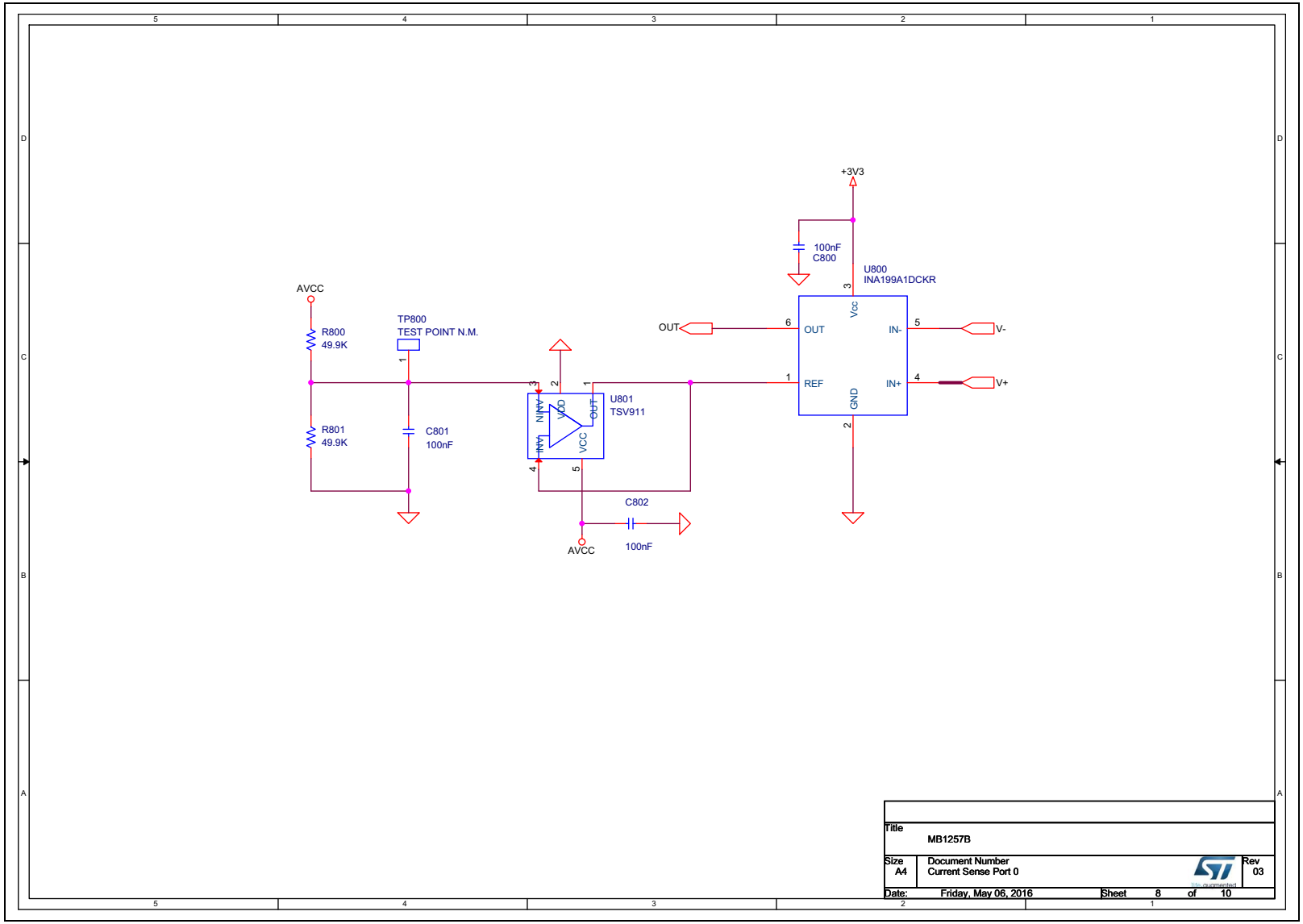
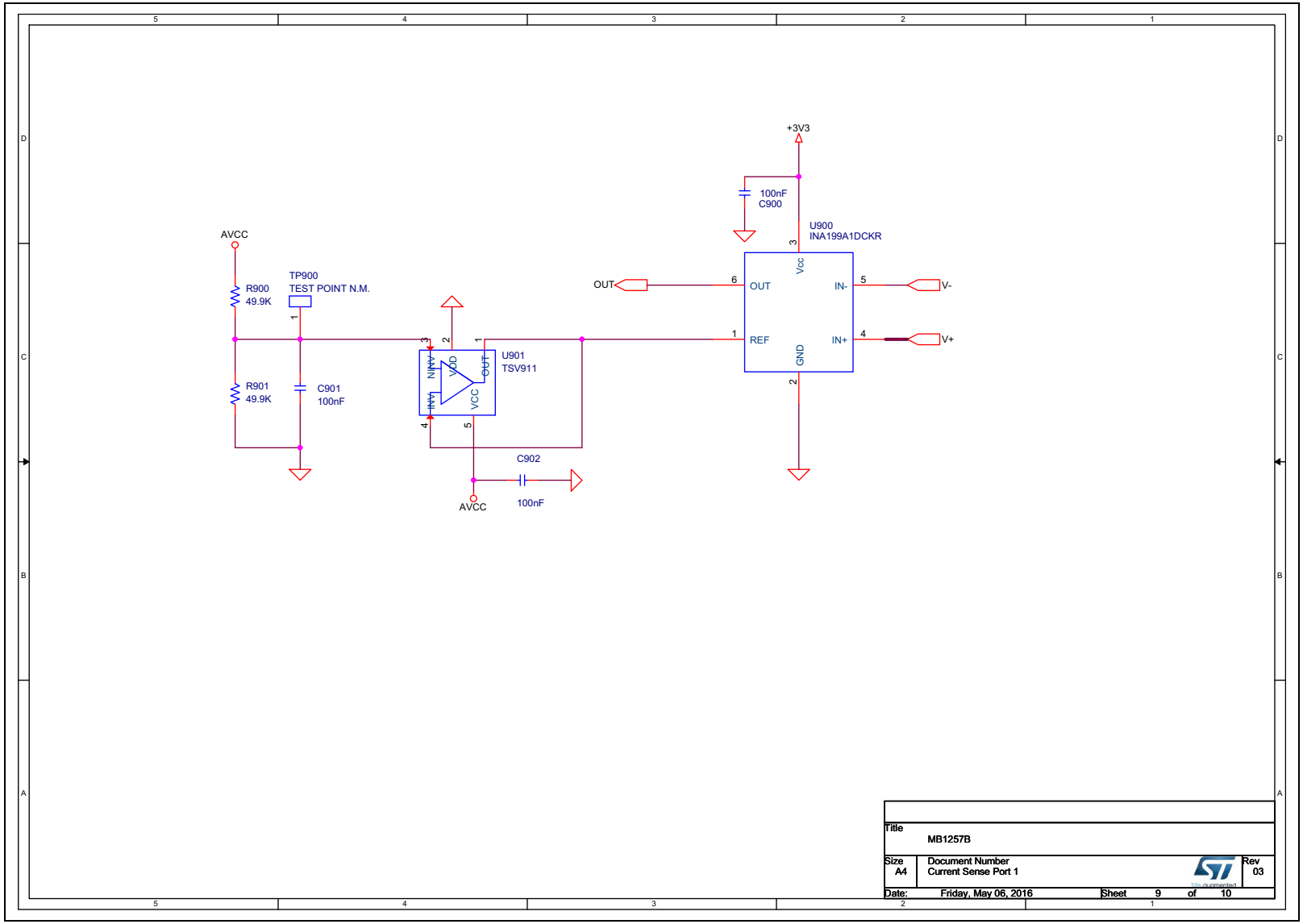


**Figure 38. MB1257 board: current sense PORT_0**



## Figure 39. MB1257 board: current sense PORT_1



# 6 Acronyms and abbreviations

**Table 6. Acronyms and abbreviations**

| Acronym | Description |
|---|---|
| BMC | Biphase Marked Coding |
| DFP | Downstream Facing Port |
| EMC | Electronically Marked Cable |
| MCU | Microcontroller Unit |
| PD | Power Delivery |
| PHY | Physical Layer |
| UFP | Upstream Facing Port |
| USB | Universal Serial Bus |
| USB OTG | USB On-The-Go |

# 7 References


- USB2.0 Universal Serial Bus Revision 2.0 Specification
- USB3.1 Universal Serial Bus Revision 3.1 Specification
- USB Type-C Cable and Connector Specification Revision 1.2
- USB PD USB Power Delivery Specification Revision 2.0, August 11, 2014
- USB BC Battery Charging Specification Revision1.2 (including errata and ECNs through March 15, 2015), March 15, 2012
- USB BB USB Device Class Definition for Billboard Devices rev1.0a April 15, 2015
- *Getting started with the STM32 Nucleo pack* User manual (UM2050) available from the *www.st.com* website

# 8 Revision history

Table 7. Document revision history

| Date | Revision | Changes |
|---|---|---|
| 07-Jun-2016 | 1 | Initial version |