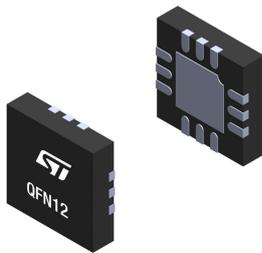


## USB-C overvoltage protection for VBUS and CC lines



| Product link and summary |  |
|--------------------------|--|
| Order code               | TCPP01-M12                               |
| Package                  | QFN12                                    |
| Packing                  | Tape and reel                            |
| Description              | PPS compliant USB Type-C port protection |

| Companion chip                       |  |
|--------------------------------------|--|
| USB Type-C                           | Any general purpose MCU (example: STM32 or STM8)               |
| USB Type-C with power delivery       | STM32 with UCPD support, example STM32L5, STM32G0, STM32G4     |
| Evaluation board                     | X-Nucleo-USBPDM1 with Nucleo-STM32G071RB or Nucleo-STM32G474RE |
| ST development board with TCPP01-M12 | NUCLEO-L552ZE-Q, STM32L562E-DK, STM32L552E-EV                  |
| ST reference design                  | USB-C power adaptor STEVAL-USBPD27S                            |

### Features

- VBUS overvoltage protection, adjustable from 5 V up to 22 V, with external N-channel MOSFET
- 6.0 V overvoltage protection (OVP) on CC lines against short-to-VBUS
- System-level ESD protection for USB Type-C connector pins (CC1, CC2), compliant with IEC 61000-4-2 level 4 ( $\pm 8$  kV contact discharge,  $\pm 15$  kV air discharge)
- Integrated gate driver and charge pump for an external N-channel MOSFET, (featuring lower  $R_{DS(ON)}$  than a P-channel MOSFET) for low BOM cost
- Null quiescent current when no USB charging cable is attached for battery-operated "consumer/sink" applications
- Integrated "dead battery" ( $R_D$  resistors)
- Over temperature protection (OTP)
- Operating junction temperature from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$
- Complies with the latest USB Type-C and USB power delivery standards
- Compliant with programmable power supply (PPS) for fast battery charging
- Open-drain fault reporting
- ECOPACK2 compliant
- USB-IF certification as power sinking device with TID: 3036 on X-Nucleo-USBPDM1 and Nucleo-STM32G071RB

### Applications

- Any USB Type-C device used in UFP/sink configuration using 5 V only or any PDO from USB power delivery, including PPS
- Power sinking devices: POS, gaming, healthcare, USB hub, IoT gateways
- Smart speakers, earphones, smart glasses, power tools, etc.

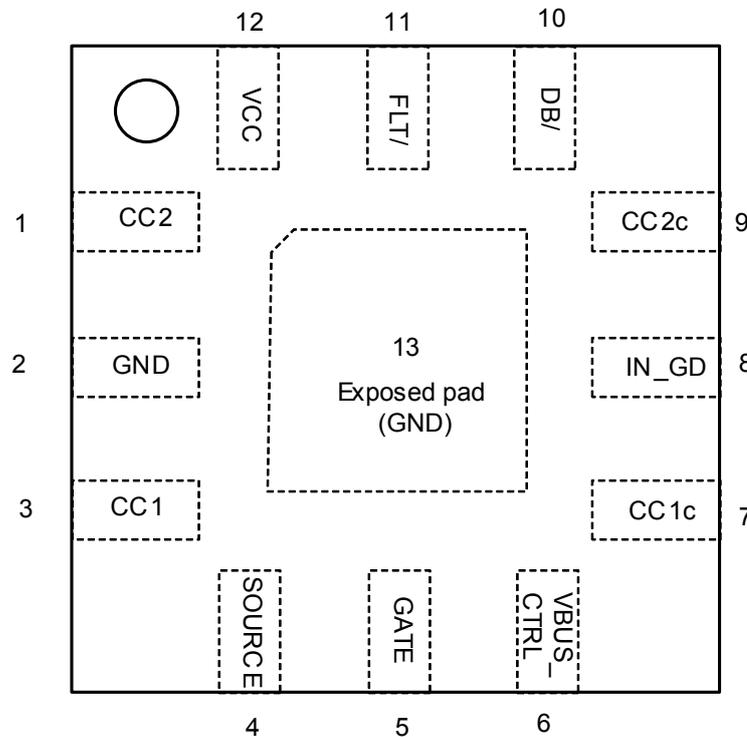
### Description

The TCPP01-M12 (Type-C port protection) is a single chip solution for USB Type-C port protection that facilitates the migration from USB legacy connectors type-A or type-B to USB Type-C connectors. The TCPP01-M12 features 22 V tolerant ESD protection as per IEC61000-4-2 level 4 on USB Type-C connector configuration channel (CC) pins. For a safe and reliable USB Type-C implementation, the TCPP01-M12 provides overvoltage protection on CC1 and CC2 pins when these pins are subjected to short circuit with the VBUS pin that may happen when removing the USB Type-C cable from its receptacle. For sink applications, TCPP01-M12 triggers an external N-MOSFET on VBUS line when a defective power source applies a voltage higher than selected OVP threshold. Also, the TCPP01-M12 integrates a "dead battery" management logic that is compliant with the latest USB power delivery specification. The power supply of the TCPP01-M12 for sink applications operated with a battery can be provided by an MCU 3.3 V GPIO in order to drop the power consumption in "cable not attached" condition down to 0 nA. This low power mode will extend the battery operating life when no source equipment is attached.

The TCPP01-M12 can also be used to protect source (provider) applications, and it can support programmable power supply feature from the USB-C power delivery specification.

# 1 Pinout and functions

**Figure 1. QFN12 pinout (top view)**



**Table 1. Pinout and functions**

| Name            | Pin # | Type           | Description  |
|-----------------|-------|----------------|--|
| CC2             | 1     | Input / Output | USB-PD controller side for the CC2 pin (configuration channel)   |
| GND             | 2     | Ground         | Ground   |
| CC1             | 3     | Input / Output | USB-PD controller side for the CC1 pin (configuration channel)   |
| SOURCE          | 4     | Power          | VBUS N-channel MOSFET's SOURCE   |
| GATE            | 5     | Output         | VBUS N-channel MOSFET's GATE   |
| VBUS_CTRL       | 6     | Input          | Input voltage setting the VBUS OVP threshold by external resistor bridge   |
| CC1c            | 7     | Input / Output | Connector side for CC1 OVP internal FET  |
| IN_GD           | 8     | Power          | VBUS N-channel MOSFET's DRAIN, input of the N-channel MOSFET gate driver   |
| CC2c            | 9     | Input / Output | Connector side for CC2 OVP internal FET  |
| DB/             | 10    | Input          | Dead battery resistors management, connected to 3,3 V MCU GPIO   |
| FLT/            | 11    | Output         | Fault reporting flag (open-drain), triggered by either OVP (overvoltage protection), OTP (overtemperature protection), or UVLO (undervoltage lockout) event. |
| V <sub>CC</sub> | 12    | Input          | 3.3 V power supply   |
| Exposed pad     | 13    | Ground         | Ground   |

## 2 TCPP01-M12 simplified internal block diagram

Figure 2. Block diagram

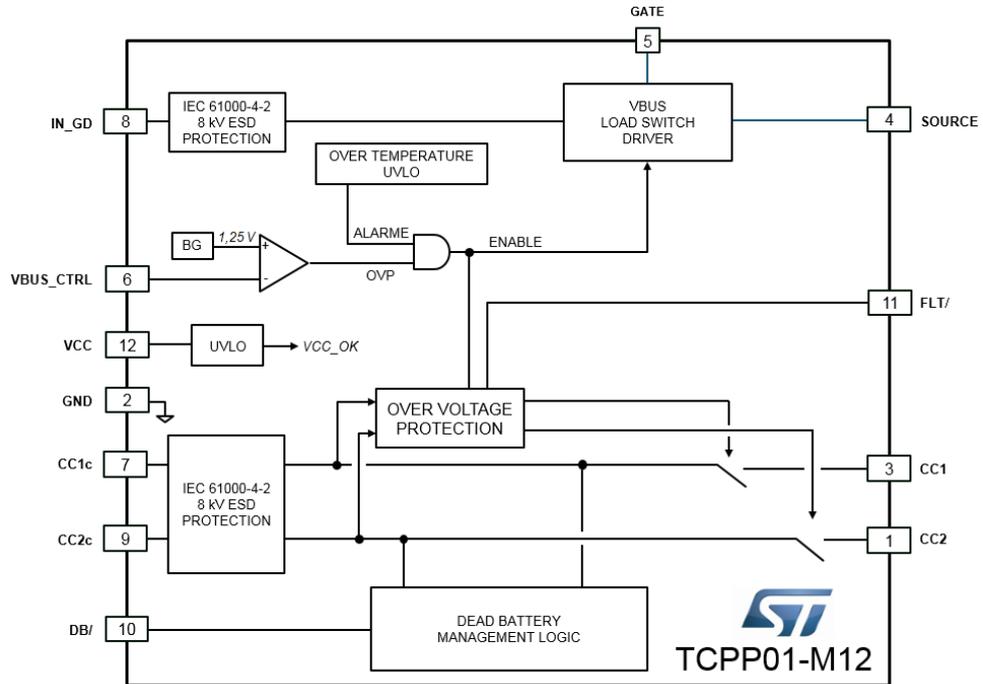


Figure 3. Typical schematic for battery-operated sink (UFP) power delivery application

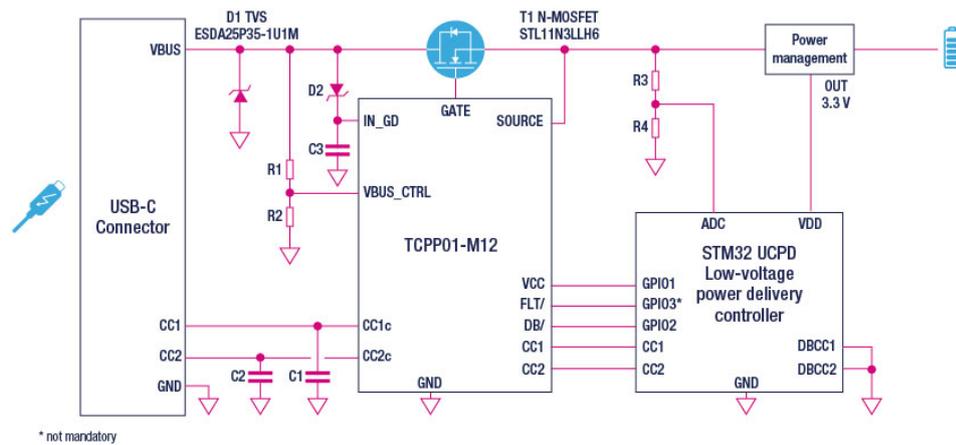


Table 2. Product characteristics

| Part number | USB Type-C application | Package |
|-------------|------------------------|---------|
| TCPP01-M12  | Sink, UFP, consumer    | QFN-12L |
| TCPP02-M18  | Source, DFP, provider  | QFN-18L |
| TCPP03-M20  | DRP, Dual Role Power   | QFN-20L |

### 3 Characteristics

**Table 3. Absolute maximum ratings ( $T_{amb} = 25^{\circ}\text{C}$ )**

| Symbol      | Parameter                              | Pin name                 | Value |      | Unit                        |
|-------------|--|--------------------------|-------|------|-----------------------------|
|             |  |                          | Min.  | Max. |                             |
| $V_{POWER}$ | Voltage for Power pins                 | VCC                      | -0.3  | 4    | $V_{DC}$                    |
|             |  | IN_GD                    | -0.3  | 22   | $V_{DC}$                    |
| $V_{IN}$    | Voltage for Input pins                 | VBUS_CTRL, DB/, CC1, CC2 | -0.3  | 4    | $V_{DC}$                    |
| $V_{OUT}$   | Voltage for Output pins                | FLT/, SOURCE             | -0.3  | 5.5  | $V_{DC}$                    |
|             |  | GATE                     | -0.3  | 27   | $V_{DC}$                    |
| $V_{I/O}$   | Voltage for CC1c, CC2c pins            | CC1c, CC2c               | -0.6  | 22   | $V_{DC}$                    |
| $R_{thj-a}$ | Junction-to-ambient thermal resistance |                          |       | 150  | $^{\circ}\text{C}/\text{W}$ |
| $T_J$       | Junction temperature                   |                          | -40   | +125 | $^{\circ}\text{C}$          |
| $T_{STG}$   | Storage temperature range              |                          | -55   | +150 | $^{\circ}\text{C}$          |

**Table 4. ESD ratings ( $T_{amb} = 25^{\circ}\text{C}$ )**

| Symbol      | Description  | Pins  | Value | Unit |
|-------------|--|---|-------|------|
| $V_{ESD_c}$ | System level ESD robustness on USB Type-C connector side   | IN_GD, CC1c, CC2c, VBUS_CTRL <sup>(1)</sup> | 15    | kV   |
|             | IEC61000-4-2 Level 4, air discharge                        |   | 8     |      |
|             | IEC61000-4-2 Level 4, contact discharge                    |   |       |      |
| $V_{HBM}$   | $V_{ESD}$ ratings Human body model (JESD22-A114D, level 2) |   | 2     | kV   |

1.  $VBUS\_CTRL$  ESD capability is guaranteed by the external resistor  $R1_{min} = 3.8\text{ k}\Omega$

(see Figure 18. Sink applications, without battery, PPS compliant).

Note: for more information on IEC61000-4-2 standard testing, please refer to AN3353.

**Table 5. Electrical characteristics – Power supply and leakage current,  $T_{amb} = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$** 

| Symbol        | Parameter                                   | Test condition                | Value |      |      | Unit          |
|---------------|---|-------------------------------|-------|------|------|---------------|
|               |   |                               | Min.  | Typ. | Max. |               |
| $V_{CC}$      | Allowable voltage input range               | -                             | 3.0   | 3.3  | 3.6  | V             |
| $I_{VCC}$     | $V_{CC}$ supply current                     | $V_{CC} = 3.0 - 3.6\text{ V}$ |       |      | 120  | $\mu\text{A}$ |
| VBUS          | Allowable voltage range                     |                               | 3.3   |      | 22   | V             |
| $I_{L\_VBUS}$ | VBUS Supply current at $VBUS = 22\text{ V}$ |                               |       |      | 2    | $\text{mA}$   |

**Table 6. Electrical characteristics – VBUS OVP control, T<sub>OP</sub> = -40 °C to +85 °C**

| Symbol                | Parameter                   | Test condition  | Value |      |      | Unit |
|-----------------------|-----------------------------|---|-------|------|------|------|
|                       |                             |   | Min.  | Typ. | Max. |      |
| V <sub>GS</sub>       | GATE to SOURCE voltage      | V <sub>CC</sub> = 3.0 - 3.6 V, VBUSc <sup>(1)</sup> = 4.0 V | 5.0   | 5.5  | 6.0  | V    |
|                       |                             | V <sub>CC</sub> = 3.0 - 3.6 V, VBUSc <sup>(1)</sup> = 3.3 V | 4.0   |      | 5.0  |      |
| t <sub>ON_VBUS</sub>  | Turn-on time on VBUS pin    | V <sub>CC</sub> = 3.0 - 3.6 V                               |       | 1    |      | ms   |
| V <sub>ovp_th</sub>   | OVP VBUS threshold voltage  | V <sub>CC</sub> = 3.0 - 3.6 V                               | 1.20  | 1.25 | 1.34 | V    |
| V <sub>hyst</sub>     | OVP VBUS voltage hysteresis | V <sub>CC</sub> = 3.0 - 3.6 V                               |       | 0.13 |      | V    |
| t <sub>ovp_VBUS</sub> | OVP VBUS response time      | Gate capacitance = 470 pF, V <sub>CC</sub> = 3.0 - 3.6 V    |       |      | 100  | ns   |

1. VBUSc is the VBUS voltage as seen from USB-C connector between VBUS and GND.

**Table 7. Electrical characteristics – DB/ pin and CC lines OVP, T<sub>OP</sub> = -40 °C to +85 °C**

| Symbol                | Parameter  | Test condition                | Value |      |      | Unit |
|-----------------------|--|-------------------------------|-------|------|------|------|
|                       |  |                               | Min.  | Typ. | Max. |      |
| R <sub>ON</sub>       | ON resistance of CC OVP FET  | V <sub>CC</sub> = 3.0 - 3.6 V |       |      | 1.2  | Ω    |
| R <sub>ON_FLAT</sub>  | ON resistance flatness   | 0 - 1.2 V                     |       | 5.0  |      | mΩ   |
| C <sub>ON_CC</sub>    | Equivalent ON capacitance  | 0 - 1.2 V, f = 400 kHz        | 40    |      | 100  | pF   |
| V <sub>CL_DB</sub>    | Dead battery clamp voltage   | I = 200 μA                    |       |      | 1.5  | V    |
| V <sub>TH_CC</sub>    | CC OVP threshold voltage   | V <sub>CC</sub> = 3.0 - 3.6 V | 5.6   | 6.0  | 6.4  | V    |
| V <sub>OVP_CC_H</sub> | CC OVP hysteresis  | V <sub>CC</sub> = 3.0 - 3.6 V |       | 10   |      | mV   |
| t <sub>ovp_cc</sub>   | OVP response time on the CC pins (internal FET)<br>(see Figure 12) | V <sub>CC</sub> = 3.0 - 3.6 V |       |      | 70   | ns   |
| BW_CCx                | Bandwidth on CCx pins at -3dB                                      | 0 - 1.2 V                     | 10    |      |      | MHz  |
| R <sub>DB_off</sub>   | Equivalent resistor when dead battery is OFF                       | V <sub>CC</sub> = 3.0 - 3.6 V | 170   | 300  | 460  | kΩ   |

**Table 8. Electrical characteristics – Fault reporting, T<sub>OP</sub> = -40 °C to +85 °C**

| Symbol           | Parameter                                      | Test condition                | Value |      |      | Unit |
|------------------|--|-------------------------------|-------|------|------|------|
|                  |  |                               | Min.  | Typ. | Max. |      |
| t <sub>pd</sub>  | Propagation time from OVP, OTP or UVLO to FLT/ | V <sub>CC</sub> = 3.0 - 3.6 V | -     | 5    | -    | μs   |
| R <sub>ON</sub>  | FLT/ pin resistance when active                |                               | -     | 250  | -    | Ω    |
| R <sub>OFF</sub> | FLT/ pin resistance when inactive              |                               | -     | 1    | -    | MΩ   |

## 4 Typical electrical characteristics curves

Note:  $T_{op} = 30\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 3.3\text{ V}$ , SOURCE = 5 V, SINK configuration, unless otherwise stated.

Figure 4. CC line bandwidth:  $V_{cm} = 0\text{ V}$

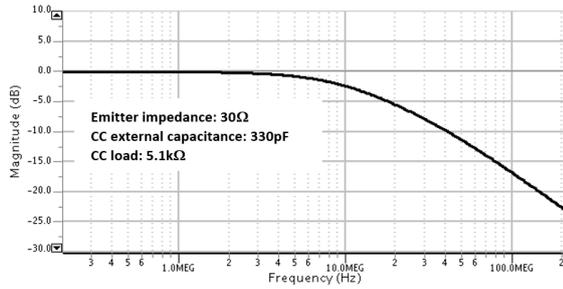


Figure 5. CC line bandwidth:  $V_{cm} = 1.2\text{ V}$

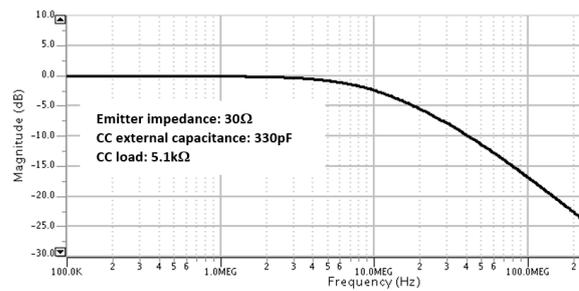


Figure 6. CCx digital communication (eye diagram performed on X-NUCLEO-USBPDM1 and NUCLEO-G071RB)

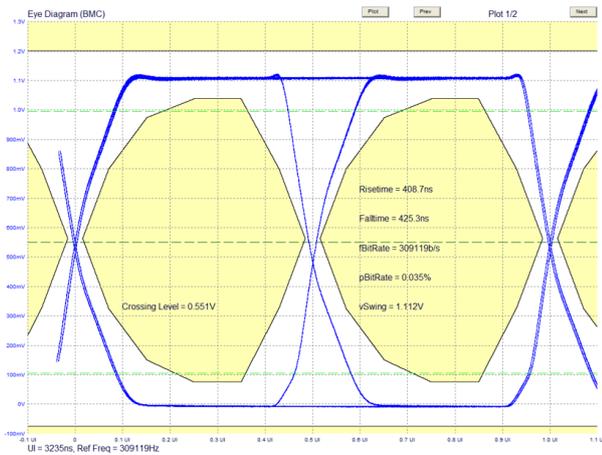


Figure 7. CC1c line short to VBUS (22 V) hot-plug via 1m of USB-C cable, sink configuration

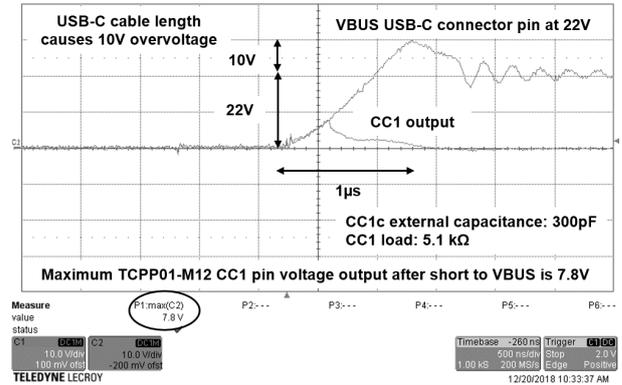


Figure 8. CC line leakage current vs ambient temperature at 5.5 V

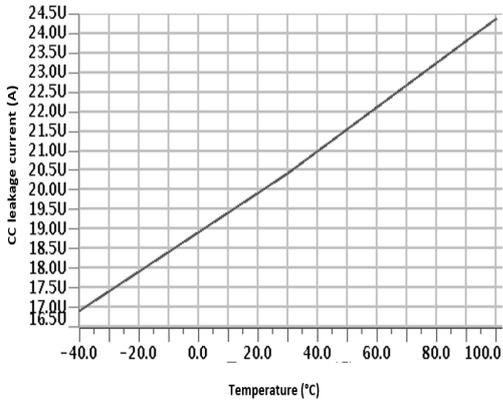


Figure 9. ON resistance of CC OVP FET vs ambient temperature

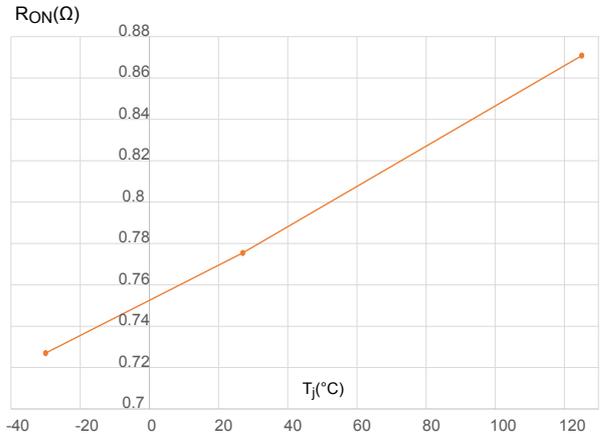


Figure 10. CC line attachment with 20 V source

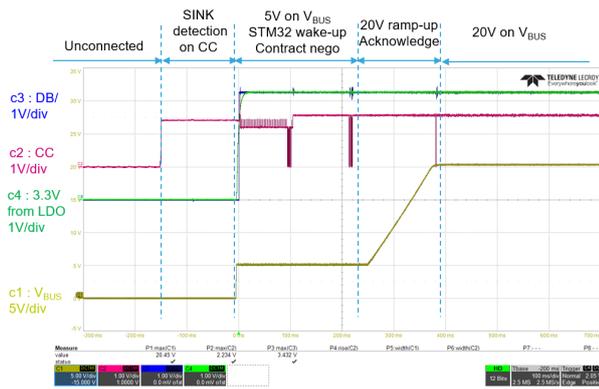


Figure 11. TCPP01-M12 start-up sequence

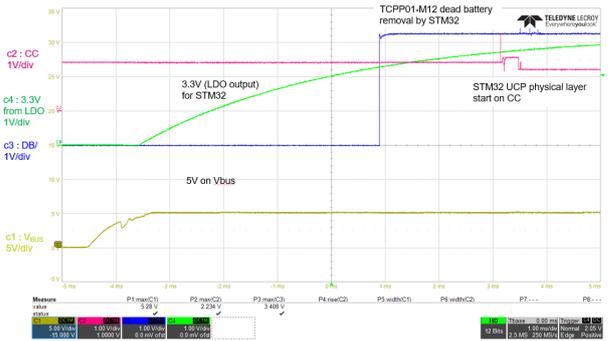


Figure 12. VBUS short to CC line

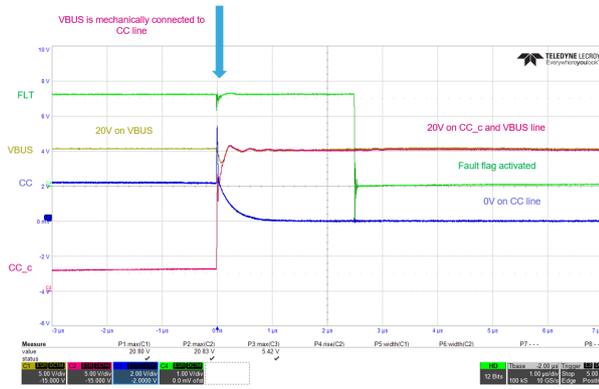


Figure 13. IEC61000-4-2 +8 kV ESD applied on CC1c, response on CC1 pin

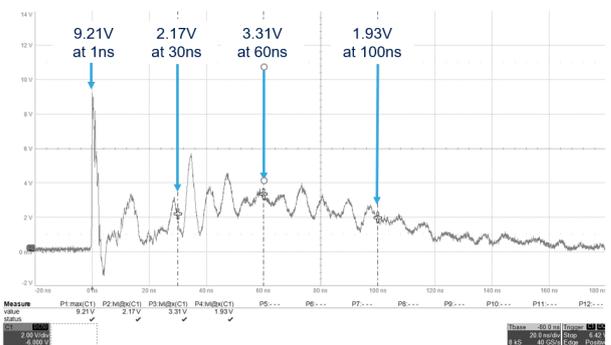


Figure 14. CCx line TLP curve (unpowered)

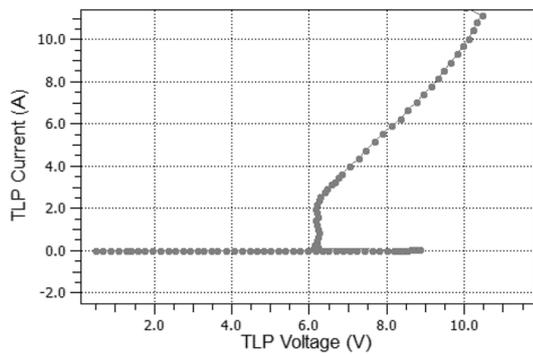


Figure 15. VBUS power-on at 5 V for a sink device

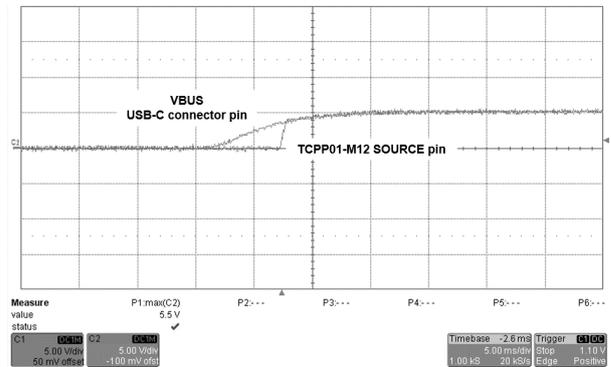
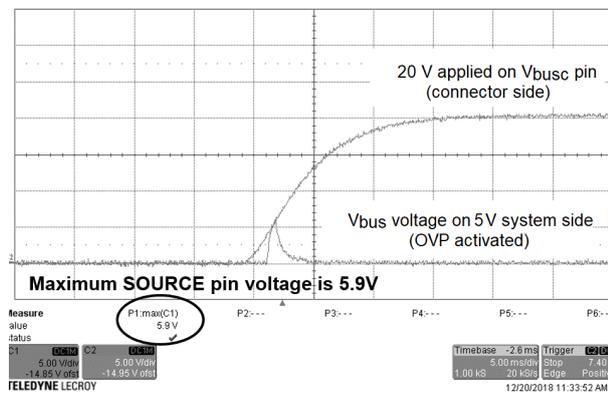


Figure 16. VBUS 5 V overvoltage protection (sink configuration, 20 V applied on VBUS)



## 5 TCPP01-M12 low power mode

---

### 5.1 What is TCPP01-M12 low power mode ?

TCPP01-M12 low power mode operation allows TCPP01-M12 to feature 0  $\mu$ A power consumption. This mode applies only for sink applications using the USB-C power delivery protocol.

### 5.2 How to activate TCPP01-M12 low power mode?

To activate low power mode operation, TCPP01-M12 pins  $V_{CC}$  and DB/ must be in OFF state: in this state, TCPP01-M12 presents its dead battery resistors ( $R_D$ ) on CC1 and CC2 lines.

### 5.3 When to activate TCPP01-M12 low power mode?

Low power mode activation may be done when no USB-C cable is attached. We recommend to activate TCPP01-M12 only when contract negotiation is required.

## 6 Application

### 6.1 General information

The sections below are not part of the ST product specification. They are intended to give a generic application overview to be used by the customer as a starting point for further implementations and customizations.

ST does not warrant compliance with customer specifications. Full system implementation and validation are under the customer's responsibility.

The TCPP01-M12 protects USB Type-C™ ports against over-voltage on VBUS and CC lines as well as electrostatic discharges on the connector pins, among other things. TCPP stands for Type-C port protection, and the TCPP01-M12 is unique because it works as a companion chip for our STM32 MCUs with built-in USB-C power delivery (UCPD) controllers on sink configurations. Moreover, using an STM32G0, STM32G4, or an STM32L5, and the TCPP01-M12 is significantly more cost-effective than competing solutions. The TCPP01-M12 also distinguishes itself thanks to a null quiescent current when unplugged and using the device in a sink configuration.

Engineers can separate the low voltage MCU domain and high voltage power path and benefit from all the protections needed. Additionally, the QFN12 package of the TCPP01-M12 can sit really close to the USB Type-C connector itself to maximize protection. Similarly, the fact that the device is compliant with programmable power supplies means that the sink device starts at 3.3 V and increases its request voltage by 20 mV increments until it matches the characteristics of the battery, thus offering quick charging capabilities while safeguarding the system. The TCPP01-M12 also improves the overall efficiency, compared to competing solutions, by offering a low  $R_{DSon}$  and a null quiescent current. The last feature is possible because the device receives power from the GPIO pin of the MCU rather than an internal low-dropout regulator. As a result, when the user unplugs a cable, the TCPP01-M12 doesn't consume any energy at all. This is particularly crucial for companies looking to create tiny products with particularly small batteries, and that must thus limit the system's consumption as much as possible. Many engineers may underestimate it, but when a product is as little as a pen, every microamp counts.

### 6.2 Electrical hazards related to USB Type-C

Applications using an USB Type-C connector must be protected against three kinds of hazards:

#### 6.2.1 CC lines short to VBUS

This happens when VBUS high voltage short circuit to the CC lines when hot unplug is done with a poor mechanical quality connector. Over voltage protection is needed on the CC lines because VBUS typical voltage can be as high as 20 V when CC pins are usually 5 V tolerant I/Os on low voltage USB-PHY controllers. TCPP01-M12 integrate this protection against CC lines short to VBUS thanks to an overvoltage protection (integrated FET).

#### 6.2.2 Defective charger

Until now, it was common to find the protection circuit inside a controller dedicated to USB-C power delivery. However, by supporting USB-C PD with an embedded module inside an MCU and a companion Type-C port protection device, we can lower the bill of material and facilitate the transition from micro-B devices, without requiring an expensive USB-C PD ASIC controller. One of the reasons the MCU and TCPP01-M12 bundle is such a compelling financial proposition is that the latter device integrates the VBUS gate driver, which enables the use of more affordable N-MOSFET, instead of the more expensive P-MOSFET.

This is an added value of TCPP01-M12, specially when VBUS line is compromised if a defective charger is stuck at a high voltage.

Overvoltage protection is always required on the VBUS line to prevent a voltage higher than negotiated is applied on the VBUS.

This use case can occur even when power delivery is not used i.e when VBUS voltage is 5 V.

#### 6.2.3 Electrostatic discharge (ESD)

Electrostatic discharges can be conducted by the USB Type-C connector and damage the electronic circuitry of the application.

The ESD surge waveform is modeled by the international electrotechnical commission in the specification IEC61000-4-2.

For more information on IEC61000-4-2 standard testing, please refer to STMicroelectronics application note [AN3353](#).

### 6.3 USB Type-C protection

Any application using an USB Type-C connector must use a Type-C port protection against above listed electrical hazards.

STMicroelectronics TCPP01-M12 (Type-C port protection housed in QFN12) is a single-chip cost effective solution to protect any application using a USB Type-C connector.

It is especially adapted to SINK (consumer) or SOURCE (provider) applications (see [Section 6.7 Typical USB-C source application](#) for specific usage in source applications).

The TCPP01-M12 provides 20 V short-to-VBUS over-voltage and system-level ESD protection on CC lines, as well as adjustable over-voltage protection for the VBUS line: an external N-channel MOSFET gate driver is integrated inside TCPP01-M12.

Also, TCPP01-M12 integrates dead battery management logic.

For consumer (sink) configurations, TCPP01-M12 features a null quiescent current thanks to TCPP01-M12 VCC pin being directly controlled by a MCU GPIO in this configuration.

TCPP01-M12 is the companion chip for:

- any general purpose MCUs (example: STM32, STM8) used for USB-C charging applications exposed to defective charger and electrostatic discharge.
- any low voltage USB power delivery controller (for example: STM32-UCPD like STM32G0, STM32G4 and STM32L5), exposed to short to VBUS, defective charger and electrostatic discharge.

## 6.4 How to handle dead battery (DB) condition with the TCPP01-M12

Dead battery use case happens when a battery-operated sink (consumer or UFP) application has its battery fully depleted. In this case TCPP01-M12 enters into dead battery operation.

Dead battery behavior is basically a pull down ( $R_D$ ) or a voltage clamp when a USB Type-C source voltage is applied to CC. It is interpreted as a request by the sink to receive VBUS. It thus facilitates the charging of equipment with a fully depleted battery:

- It must be present in most cases
- It must not be present in the case of a (pure) Type-C Source, for example a wall charger

The DB/ or 'dead battery resistor management' pin is a pulled-down active-low TCPP01-M12 input. The DB/ pin can be used in two ways:

- The DB/ pin is connected to VCC or
- The DB/ pin is driven by a 3,3 V MCU GPIO

As long as the DB/ pin is low or high-impedance (an internal 5 k $\Omega$  pull-down sets the level to '0'), the dead-battery resistors are connected and CC switches are open (OFF state).

When the DB/ pin is tied to VCC, the DB/ resistors are disconnected and CC OVP switches are closed (ON state).

DB/ usage in SINK (SNK) applications:

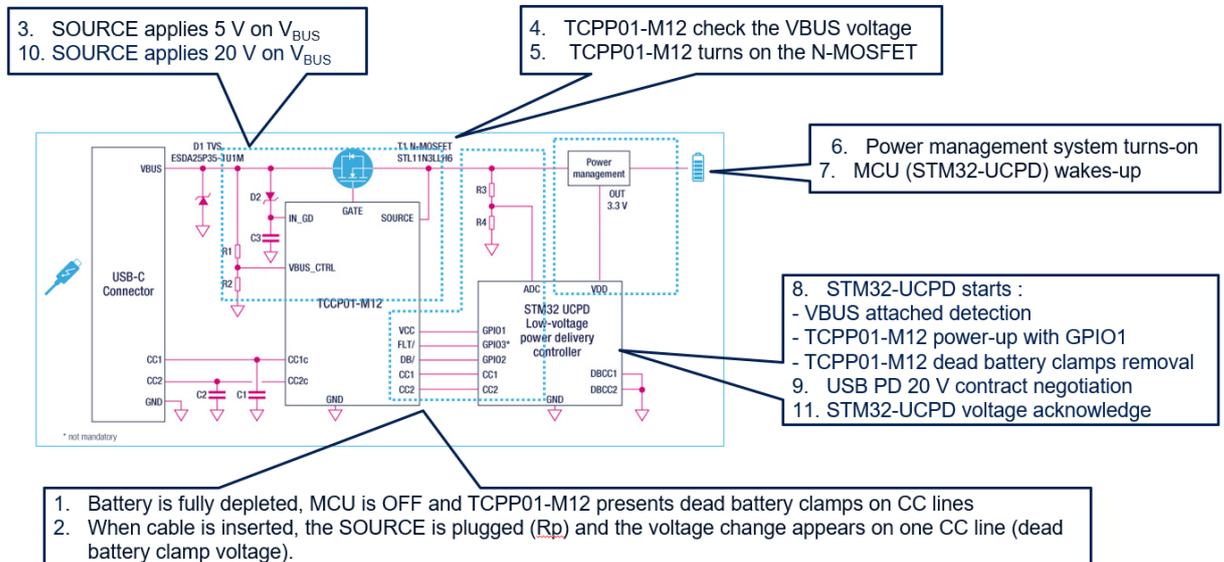
- After system power-up, the DB/ pin must be kept at 0. In this case  $R_D$  is enabled at TCPP01-M12 level.
- Once  $R_D$  is enabled in the UCPD (USB-C power delivery controller), the DB/ pin must be set to the logic level '1'

For DB/ usage in SRC or Source mode, the DB/ pin must be tied to  $V_{CC}$ .

**Table 9. Dead battery logic states**

| TCPP01-M12<br>VCC | TCPP01-M12<br>DB/ | TCPP01-M12<br>DB clamp present | TCPP01-M12<br>CC1/CC2 OVP FET<br>state | TCPP01-M12<br>DB function state |
|-------------------|-------------------|--------------------------------|--|---------------------------------|
| 0                 | 0                 | Yes                            | Open                                   | Activated                       |
| 0                 | 1                 | Yes                            | Open                                   | Activated                       |
| 1                 | 0                 | Yes                            | Open                                   | Activated                       |
| 1                 | 1                 | No                             | Closed                                 | Inactivated                     |

*Note:* When STM32-UCPD boots,  $R_D$  seen on CC lines are coming from TCPP01-M12. When STM32-UCPD has wake-up,  $R_D$  from TCPP01-M12 are disconnected and STM32-UCPD set  $R_D$  on CC lines from UCPD IP

**Figure 17. Wake-up sequence in dead battery condition**


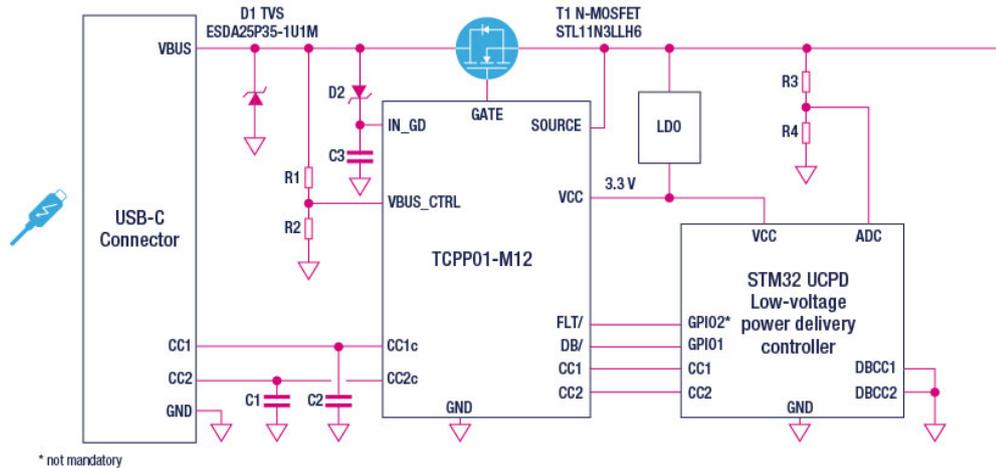
**Note:** In dead battery condition the sequence below applies:

- TCPP01-M12 dead battery present clamp (1.1 V) on CC1 and CC2 lines
- The source detects the clamp presence and applies 5 V on VBUS
- The N-channel MOSFET (T1: STL11N3LLH6) switches to ON state and supplies the application's power management with 5 V
- The MCU wakes-up and applies 3.3 V on GPIO1: this wakes up the TCPP01-M12
- The TCPP01-M12 removes its clamp on the CC lines so that ADC1 or ADC2 can sense the SOURCE power capability with the voltage across R5 or R6 (both resistors are needed)

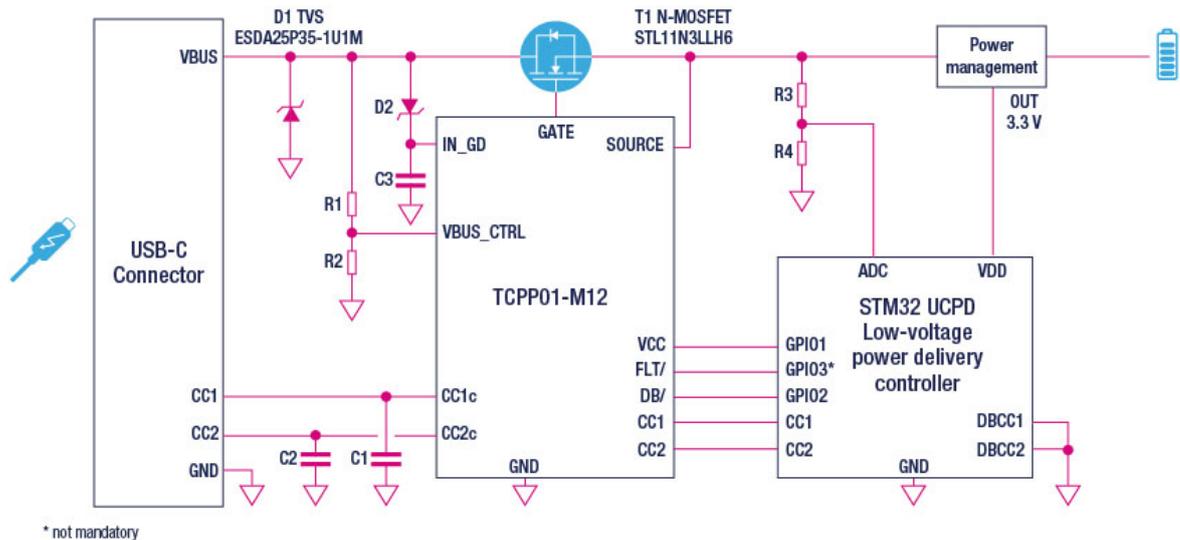
## 6.5 Application example for USB Type-C power delivery for sink (consumer), PPS compliant

In this application case, the system is solely powered via the USB-C connector.

**Figure 18. Sink applications, without battery, PPS compliant**



**Figure 19. Power sinking device PD3.0 application, with battery**



### 6.5.1 ESD capacitor (C3)

The system-level ESD capability of the TCPP01-M12 depends on this capacitor. The two constraints about it is a minimum of 35 V DC rated voltage and an ESL (equivalent serial inductance) as low as possible.

A 50 V X7R 100 nF capacitor is strongly recommended to improve the derating performance (X7R capacitance decreases as it voltage increases). ST recommends to choose a capacitor size equal or lower than 0603.

**Table 10. Capacitance specification**

| Capacitor size | Part number        |
|----------------|--------------------|
| 0603           | CC0402KRX7R9BB104  |
| 0402           | GRM188R71H104KA93D |

### 6.5.2 Transient Voltage suppressor on VBUS

In the [Figure 18](#), the D1 diode ESDA25P35-1U1M is used to comply with the international electrotechnical commission specification IEC61000-4-5 on the VBUS power line when it is subjected to switching and lightning transients. These surges are defined in 8/20 μs waveform. For more information, please refer to [AN4275](#): IEC61000-4-5 standard overview.

### 6.5.3 CC line capacitance (C1, C2)

USB PD has a specification for the total amount of capacitance for proper operation on CC lines. This specification is given here after.

**Table 11. USB Type-C power delivery specification**

| Description             | Min.   | Max.   |
|-------------------------|--------|--------|
| CC receiver capacitance | 200 pF | 600 pF |

Therefore, the capacitance added by the TCPP01-M12 and by the MCU or low voltage controller must fall within these limits. The next table shows the analysis involved in choosing the correct external capacitor for the system.

**Table 12. CC line capacitance budget analysis**

| CC capacitance                    | Min.   | Max.   | Comment   |
|-----------------------------------|--------|--------|---|
| CC line target capacitor          | 200 pF | 600 pF | From USB PD Specification Section 5.8.6                         |
| TCPP01-M12 CC1c, CC2c capacitance | 40 pF  | 100 pF |   |
| MCU capacitance                   | 60 pF  | 90 pF  | Typical value. To be adapted following the exact reference used |
| Proposed capacitance C1, C2       | 120 pF | 390 pF | 25 V DC min. of rated voltage 0402 or smaller recommended       |

### 6.5.4 Sense resistor (R1, R2)

VBUS OVP triggers when VBUS\_CTRL pin rises above 1.25 V typical. Choose R1 from any value between 5 kΩ and 10 kΩ and calculate R2 as follows:

$$R2 = \frac{R1}{\frac{VBUScMAX}{VBUS\_CTRL} - 1}$$

With:

- R1 = arbitrary resistor between 5-10 kΩ
- VBUScMAX = desired VBUS OVP threshold level
- VBUS\_CTRL = 1.25 V (typical)

**Table 13. R2 values when R1 = 10 kΩ**

| Power Delivery | VBUS maximum voltage | R2 normalized value in ohm (Ω) when R1 = 10 kΩ |
|----------------|----------------------|--|
| 15 W           | 6 V                  | 2.7 k  |
| 27 W           | 10 V                 | 1.5 k  |
| 36 W           | 13 V                 | 1.1 k  |
| 45 W           | 17 V                 | 820  |
| 100 W          | 22 V                 | 620  |

### 6.5.5 VBUS detect

R3 and R4 are used to sense the VBUS voltage. Recommended values are R3 = 200 kΩ and R4 = 40.2 kΩ.

As per USB-C PD specification, if the VBUS voltage is lower than 3.0 V, FLT/ pin will go to low state.

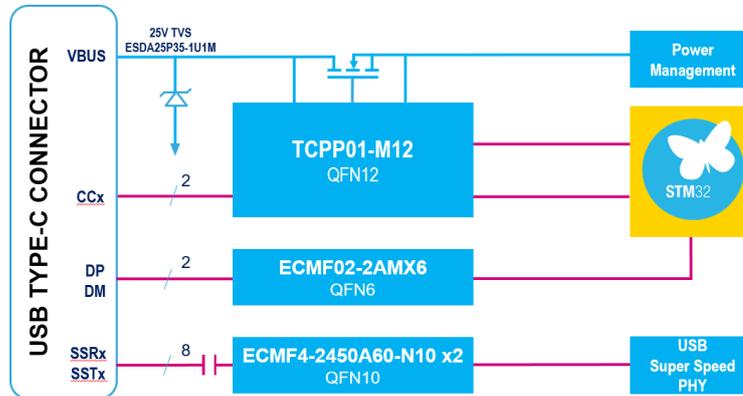
#### 6.5.6 N-channel MOSFET

The TCPP01-M12 ensures a  $V_{GS}$  voltage between 5 V and 6 V when the N-channel MOSFET is ON: choose a N-channel MOSFET fully specified (for example: STL11N3LLH6) with 5 V of  $V_{GS}$ . Maximum current in USB-PD applications can raises up to 5 A.

MCU can still close the MOSFET with a MCU GPIO connected to VBUS\_CTRL: in this case, normal mode (i.e TCPP01 overvoltage protection active on VBUS) is ensured with GPIO in HighZ. To close the MOSFET, MCU GPIO must be set at '1'.

**6.5.7 Complementary products for USB dataline protection for pins DP, DM, SSRX, SSTX**

For applications requiring USB dataline protection, STMicroelectronics recommends the implementation shown in picture below:

**Figure 20. USB dataline ESD protection for pins DP, DM, SSRX, SSTX**

**Table 14. Product recommendations**

| Part Number           | Description                                       | USB-C connector pin                              | Protection features  |
|-----------------------|---|--|--|
| TCPP01-M12            | Type-C port protection                            | VBUS, CC1, CC2                                   | ESD protection as per IEC61000-4-2 Level 4<br>Overvoltage on VBUS<br>CC lines short to VBUS                        |
| ESDA25P35-1U1M        | Power line transient voltage suppressor (TVS)     | VBUS   | ESD protection as per IEC61000-4-2 Level 4<br>IEC61000-4-5 (8/20µs surge waveform)                                 |
| ECMF02-2AMX6          | Common mode filter with integrated ESD protection | D+, D-   | ESD protection as per IEC61000-4-2 Level 4<br>RF antenna desense due to high speed differential link EMI radiation |
| ECMF4-2450A60N10 (x2) | Common mode filter with integrated ESD protection | TX1+, TX1-, RX1+, RX1-<br>TX2+, TX2-, RX2+, RX2- | ESD protection as per IEC61000-4-2 Level 4<br>RF antenna desense due to high speed differential link EMI radiation |

For more information on USB Type-C protection for datalines, please refer to [AN4871](#), USB Type-C protection and filtering.

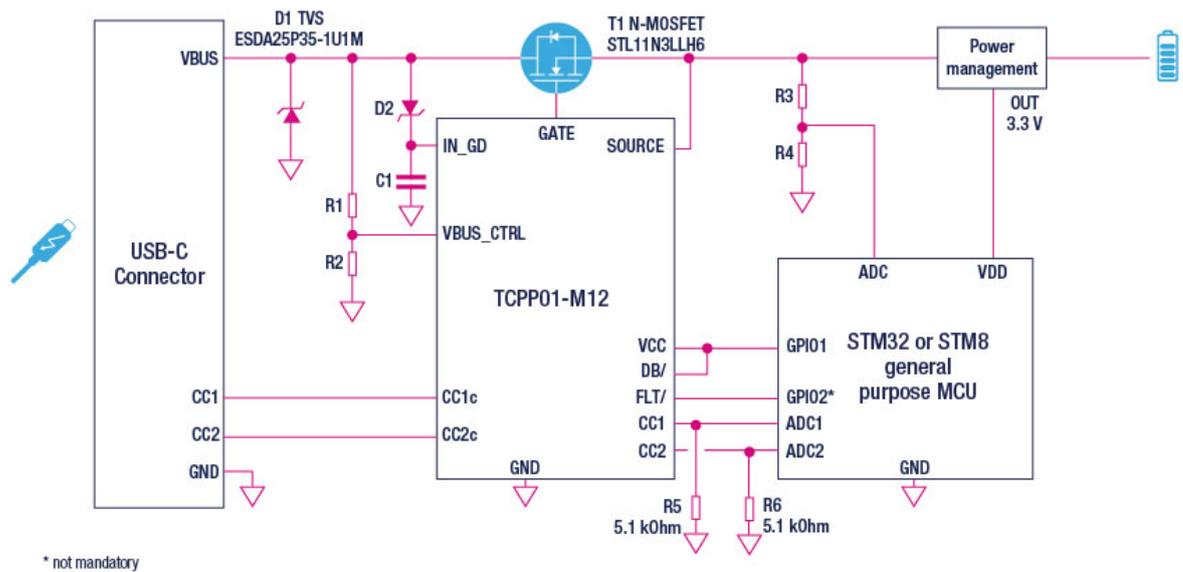
For more information on RF antenna desense due to high speed differential link EMI radiation, please refer to [AN4356](#), Antenna desense on handheld equipment.



### 6.6.2 USB-C using 5 V only (without power delivery)

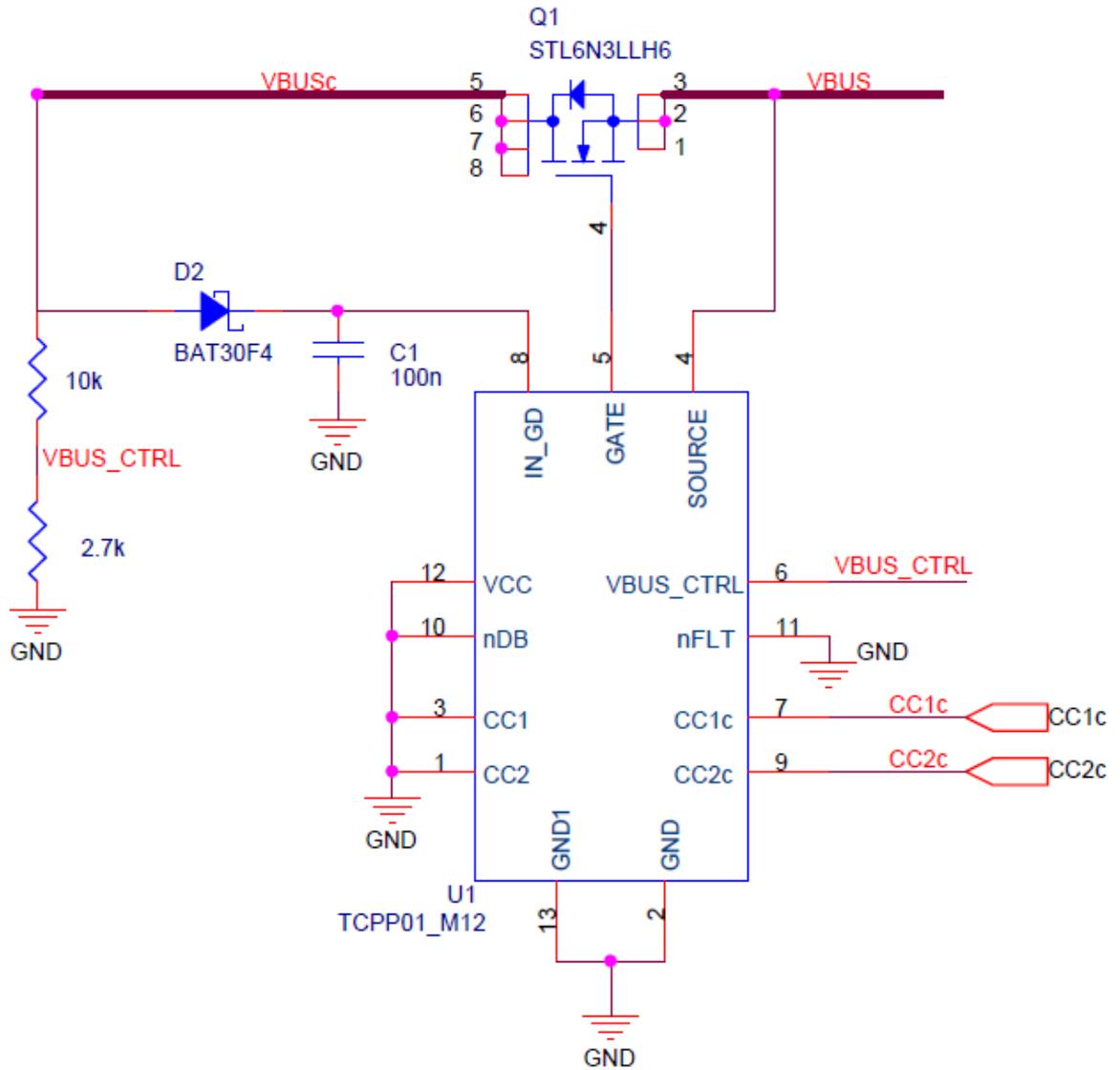
In case 5 V only is used with USB-C connector, i.e without power delivery, an overvoltage protection on VBUS is still required as a protection against defective chargers or cables that could allow a voltage higher than 5 V on a USB-C device. Also ESD protection as per IEC61000-4-2 Level 4 is required for the pins CC1, CC2 and VBUS. This is why TCPP01-M12 can be used on USB-C devices operating at 5 V only without power delivery.

**Figure 22. 15 W sink applications, with battery and general purpose MCU (for example: STM32 or STM8)**



When the power delivery protocol is not used, the TCPP01-M12 is used for protection against defective charger, ESD protection and dead battery management. The MCU can be an STM8 or any STM32 featuring at least 3 ADCs. The power profile is defined by the pull-down resistors on CC lines on the Sink side and pull-up resistors on the Source side. Cf p:47/56 of AN5225 "USB Type-C power delivery using STM32xx series MCUs and STM32xxx series MPUs".(AN5225).

**Figure 23. Schematic example for USB-C at 2.5 W with TCPP01-M12**



At 2.5 W, USB Type-C is used at 5 V, 0.5 A. Therefore capacitors on CC lines are not needed anymore (they are needed only for power delivery) . Also TCPP01-M12 VBUS OVP is set at 6 V with the resistor bridge on VBUS\_CTRL.

In this configuration, TCPP01-M12 internally presents the  $R_D$  resistors because the DB/ pin is tied to GND.

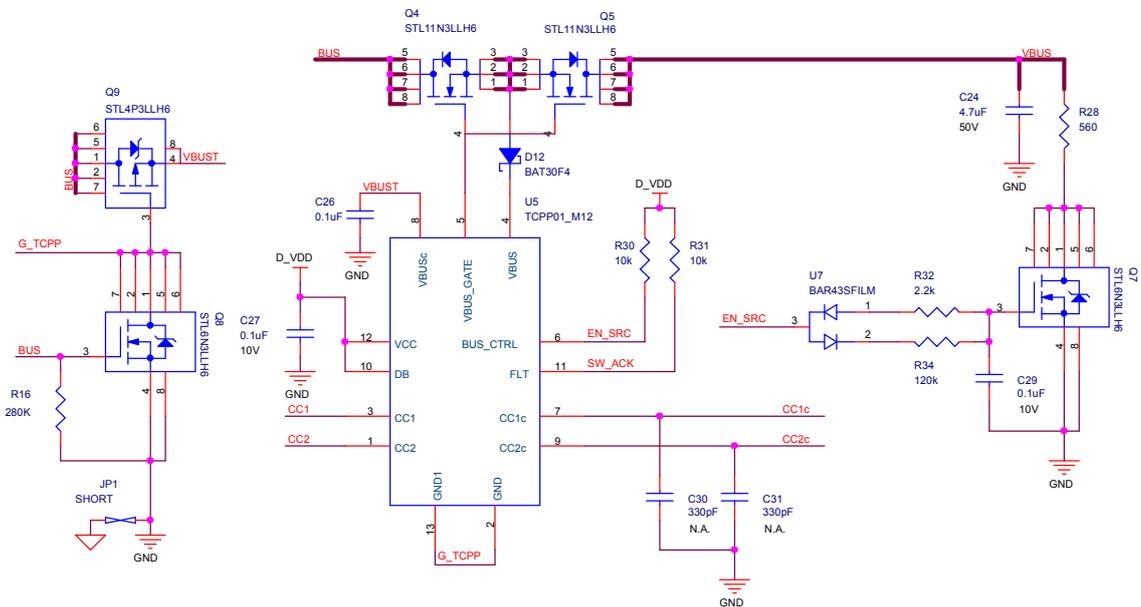
## 6.7 Typical USB-C source application

When using TCPP01-M12 in SOURCE application, the following changes applies compared with SINK application:

- TCPP01-M12 dead battery function is no more needed, it must be disabled. It is done by connecting the TCPP01-M12 DB/ signal to V<sub>CC</sub>.
- Now, it is the MCU which detects an attachment condition and controls the VBUS turn ON / turn OFF.
- Finally, an over-current protection is mandatory on VBUS as required by the USB-PD specification (not represented in the picture below). Refer to STEVAL-USBPD27S for full schematic.

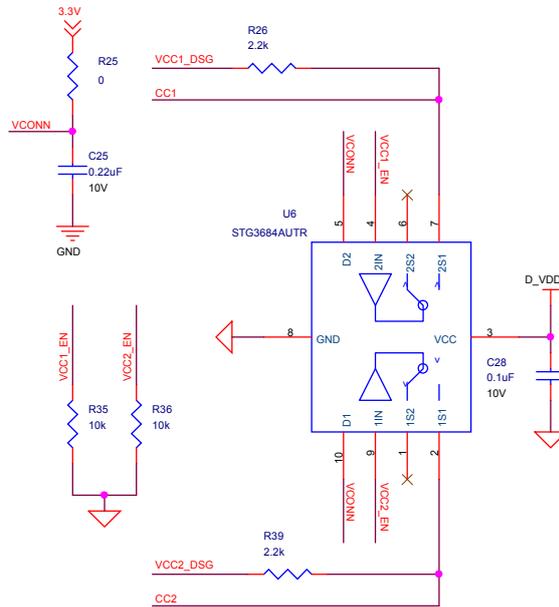
Note that the proposed design does not provide V<sub>CONN</sub> switches. As a consequence, it can handle low speed, full speed, high speed, super speed USB data rate. Also SOURCE current is limited to 3 A (no active cable support).

Figure 24. Bus control and protections



- Q7 : VBUS discharge
- Q8 : Disconnect pull-down resistors when no BUS
- Q9 : To remove link through BUS GND
- D12 : To avoid VBUS and BUS charge by CC lines

Figure 25. CC lines



- U6 : power mux for VCONN

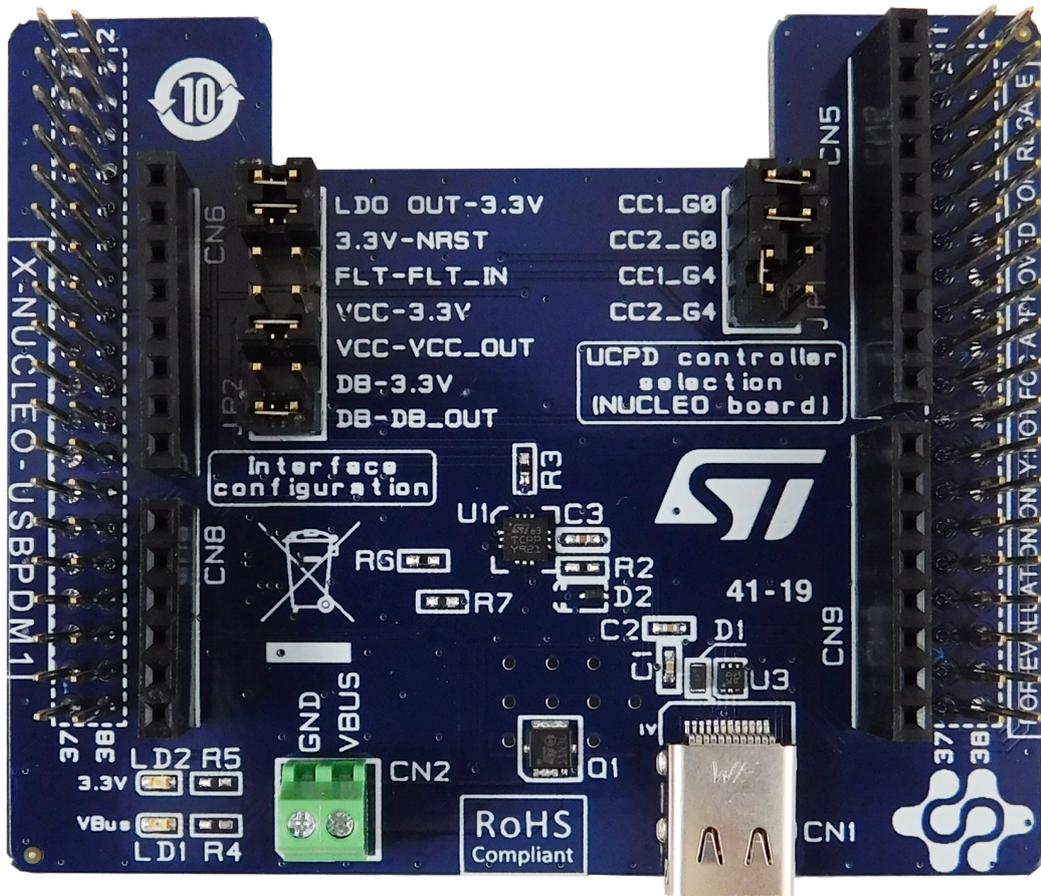
## 6.8 Development tools

The X-NUCLEO-USBPDM1 is an expansion board for the NUCLEO-G071RB and NUCLEO-G474RE development boards. It provides a straightforward means for evaluating USB Type-C power delivery in SINK mode based on TCPP01-M12.

The X-Nucleo-USBPDM1 associated with the Nucleo-G071RB have been certified by the USB-IF (TID: 3036) as a power sinking device, up to 100 W, with programmable power supply (PPS).

The USB Type-C connector can supply the STM32 Nucleo development board thanks to a 3.3 V LDO. Quick start guide and HW/SW prerequisites are listed [here](#).

Figure 26. X-Nucleo-USBPDM1 picture





## 8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of **ECOPACK** packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

### 8.1 QFN12 package information

**Figure 29. QFN12 package outline**

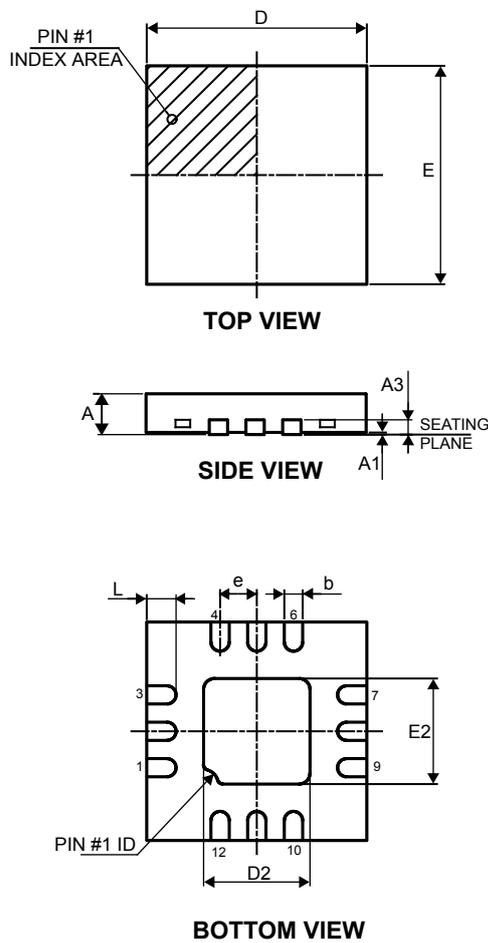


Table 15. QFN12 package mechanical data

| Ref. | Dimensions  |      |      |
|------|-------------|------|------|
|      | Millimeters |      |      |
|      | Min.        | Typ. | Max. |
| A    | 0.80        | 0.90 | 1.00 |
| A1   | 0.00        | 0.02 | 0.05 |
| A3   |             | 0.20 |      |
| b    | 0.18        | 0.25 | 0.30 |
| D    | 2.95        | 3.00 | 3.05 |
| E    | 2.95        | 3.00 | 3.05 |
| D2   | 1.30        | 1.45 | 1.55 |
| E2   | 1.30        | 1.45 | 1.55 |
| e    |             | 0.50 |      |
| K    | 0.20        |      |      |
| L    | 0.30        | 0.40 | 0.50 |

Figure 30. QFN12 recommended footprint

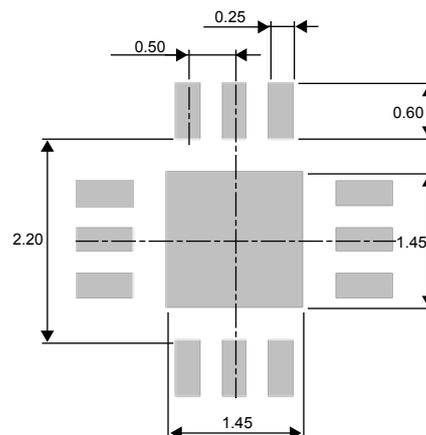
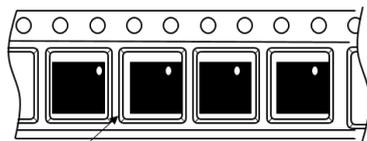


Figure 31. Package orientation in reel



Pin 1 located according to EIA-481

Note: Pocket dimensions are not on scale  
Pocket shape may vary depending on package

Figure 32. Tape and reel orientation

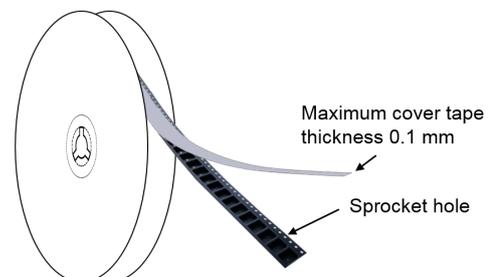


Figure 33. Reel dimensions (mm)

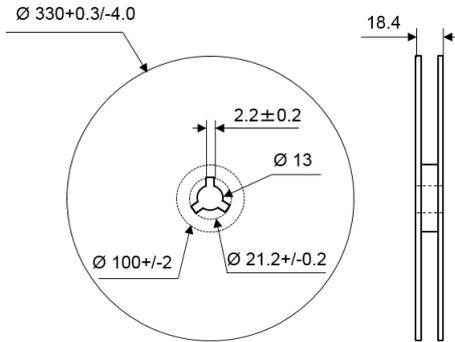


Figure 34. Inner box dimensions (mm)

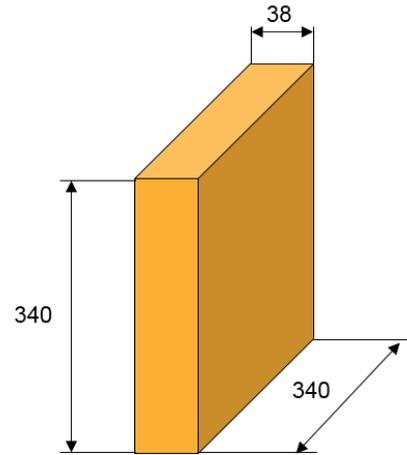
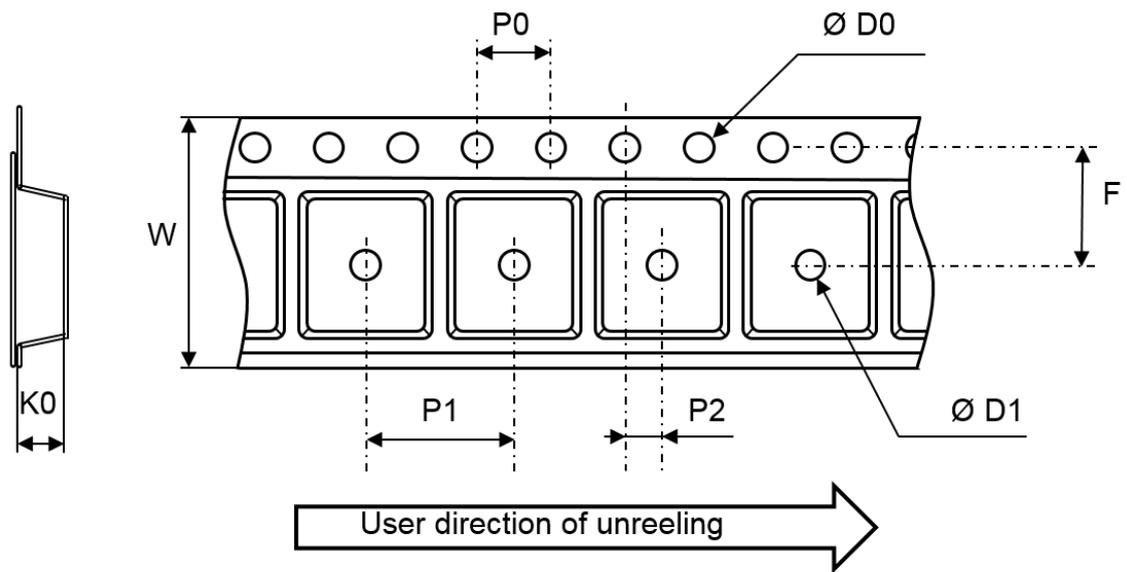


Figure 35. Tape and reel outline



Note: Pocket dimensions are not on scale  
Pocket shape may vary depending on package

**Table 16. Tape and reel mechanical data**

| Ref. | Dimensions  |       |       |
|------|-------------|-------|-------|
|      | Millimeters |       |       |
|      | Min.        | Typ.  | Max.  |
| D0   | 1.50        | 1.55  | 1.60  |
| D1   | 1.50        |       |       |
| F    | 5.45        | 5.50  | 5.55  |
| K0   | 1.00        | 1.10  | 1.20  |
| P0   | 3.90        | 4.0   | 4.10  |
| P1   | 7.90        | 8.00  | 8.10  |
| P2   | 1.95        | 2.00  | 2.05  |
| W    | 11.70       | 12.00 | 12.30 |

## 9 Ordering information

Table 17. Ordering information

| Order code | Marking | Package | Weight | Base qty. | Delivery mode |
|------------|---------|---------|--------|-----------|---------------|
| TCPP01-M12 | TCPP    | QFN12   | 23 mg  | 3000      | Tape and reel |

## Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Pinout and functions</b> .....  | <b>3</b>  |
| <b>2</b> | <b>TCPP01-M12 simplified internal block diagram</b> .....                              | <b>5</b>  |
| <b>3</b> | <b>Characteristics</b> .....   | <b>6</b>  |
| <b>4</b> | <b>Typical electrical characteristics curves</b> .....                                 | <b>7</b>  |
| <b>5</b> | <b>TCPP01-M12 low power mode</b> .....   | <b>9</b>  |
| 5.1      | What is TCPP01-M12 low power mode ? .....  | 9         |
| 5.2      | How to activate TCPP01-M12 low power mode? .....                                       | 9         |
| 5.3      | When to activate TCPP01-M12 low power mode? .....                                      | 9         |
| <b>6</b> | <b>Application</b> .....   | <b>10</b> |
| 6.1      | General information .....  | 10        |
| 6.2      | Electrical hazards related to USB Type-C .....   | 10        |
| 6.2.1    | CC lines short to VBUS.....  | 10        |
| 6.2.2    | Defective charger .....  | 10        |
| 6.2.3    | Electrostatic discharge (ESD).....   | 10        |
| 6.3      | USB Type-C protection.....   | 11        |
| 6.4      | How to handle dead battery (DB) condition with the TCPP01-M12 .....                    | 12        |
| 6.5      | Application example for USB Type-C power delivery for sink (consumer), PPS compliant . | 14        |
| 6.5.1    | ESD capacitor (C3).....  | 14        |
| 6.5.2    | Transient Voltage suppressor on VBUS .....   | 15        |
| 6.5.3    | CC line capacitance (C1, C2) .....   | 15        |
| 6.5.4    | Sense resistor (R1, R2).....   | 15        |
| 6.5.5    | VBUS detect .....  | 15        |
| 6.5.6    | N-channel MOSFET .....   | 16        |
| 6.5.7    | Complementary products for USB dataline protection for pins DP, DM, SSRX, SSTX.....    | 17        |
| 6.6      | Typical USB-C battery powered application.....   | 18        |
| 6.6.1    | Power sinking device using PD3.0 .....   | 18        |
| 6.6.2    | USB-C using 5 V only (without power delivery) .....                                    | 19        |
| 6.7      | Typical USB-C source application.....  | 21        |
| 6.8      | Development tools .....  | 23        |
| <b>7</b> | <b>PCB design recommendations</b> .....  | <b>24</b> |

---

|          |                                   |           |
|----------|-----------------------------------|-----------|
| <b>8</b> | <b>Package information</b> .....  | <b>25</b> |
| 8.1      | QFN12 package information .....   | 25        |
| <b>9</b> | <b>Ordering information</b> ..... | <b>29</b> |
|          | <b>Contents</b> .....             | <b>30</b> |
|          | <b>Revision history</b> .....     | <b>32</b> |

## Revision history

**Table 18. Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 06-Sep-2019 | 1        | Initial release.  |
| 29-Jun-2020 | 2        | Updated Section Product status / summary, Section Features, Figure 3, Figure 9, Figure 23 and Section 5.5.4 .<br>Added Figure 10, Figure 11, Figure 24, Figure 16, Figure 18 and Figure 21.<br>Added Table 12 and Table 14. |
| 29-Sep-2020 | 3        | Updated , Section 5.1 , Section 5.2.1 , Section 5.2.2 , Section 5.5.5 and Section 5.8 Development tools.  |
| 18-Dec-2020 | 4        | Added <a href="#">Figure 9</a> and <a href="#">Section 5</a> .  |

**IMPORTANT NOTICE – PLEASE READ CAREFULLY**

STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST’s terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers’ products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, please refer to [www.st.com/trademarks](http://www.st.com/trademarks). All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2020 STMicroelectronics – All rights reserved