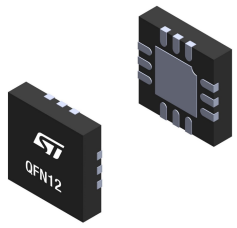
TCPP01-M12

Datasheet

USB Type-C™ and power delivery protection for sink application



Product labels

SUSTAINABLE TECHNOLOGY

LONGEVITY 10 YEARS COMMITMENT

Product link and summary	
Order code	TCPP01-M12
Package	QFN-12L
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, STM32U5
Evaluation board	X-NUCLEO-SNK1M1 with Nucleo-STM32G071RB or Nucleo-STM32G474RE
ST development board with TCPP01-M12	NUCLEO-L552ZE-Q, STM32L562E-DK, STM32L552E-EV, NUCLEO-U575ZI-Q, STM32U575I-EV
ST WIKI	Introduction to USB power delivery with STM32

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 (±8 kV contact discharge, ±15 kV air discharge)
- Integrated gate driver and charge pump for an external N-channel MOSFET (featuring lower R_{DSON} 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
- Compliant with all PDOs of USB Type-C™ power delivery specification
- Over temperature protection (OTP)
- Operating junction temperature from -40°C to 125°C
- Complies with the latest USB Type-C™ and USB power delivery standards
- Compliant with USB Type-C™ power delivery standard 3.1, standard power range (SPR), up to 100 W
- Open-drain fault reporting
- ECOPACK2 compliant
- USB-IF certification as power-sinking device with test ID: 5205 on X-NUCLEO-SNK1M1 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 the 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 MCU 3.3 V GPIO provides the power supply of the TCPP01-M12 for sink applications operated with a battery in order to drop the power consumption in “cable not attached” condition down to 0 nA. This low-power mode extends 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 a programmable power supply feature from the USB Type-C™ power delivery specification.

1 Pinout and functions

Figure 1. **QFN-12L pinout (top view)**

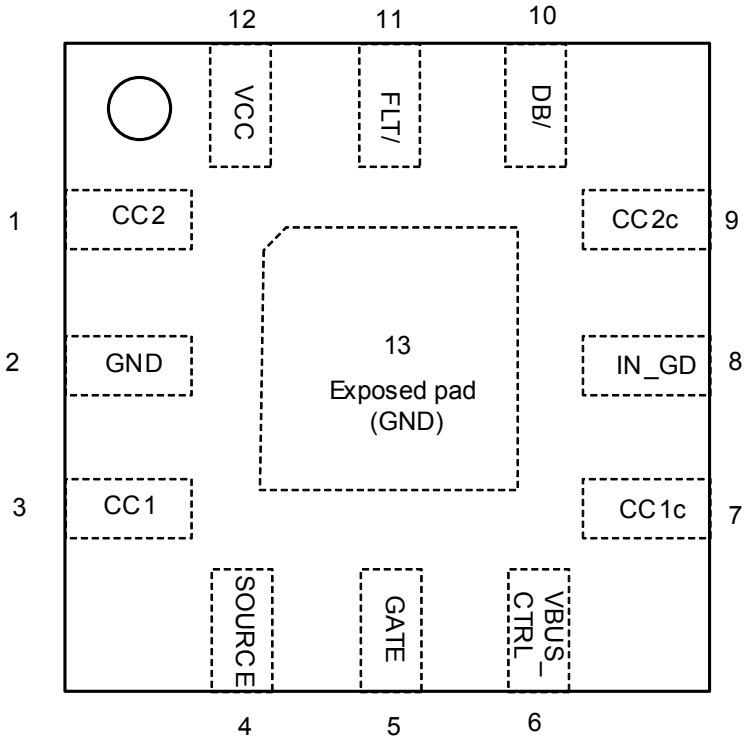


Table 1. **Pinout and functions**

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 the 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_{CC}	12	Input	3.3 V power supply
Exposed pad	13	Ground	Ground

2 TCPP01-M12 block diagram

Figure 2. TCPP01-M12 functional block diagram

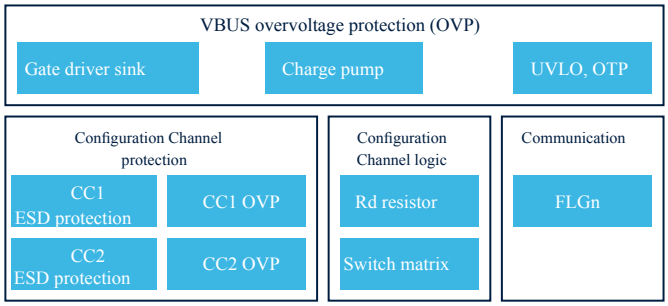


Figure 3. Internal block diagram

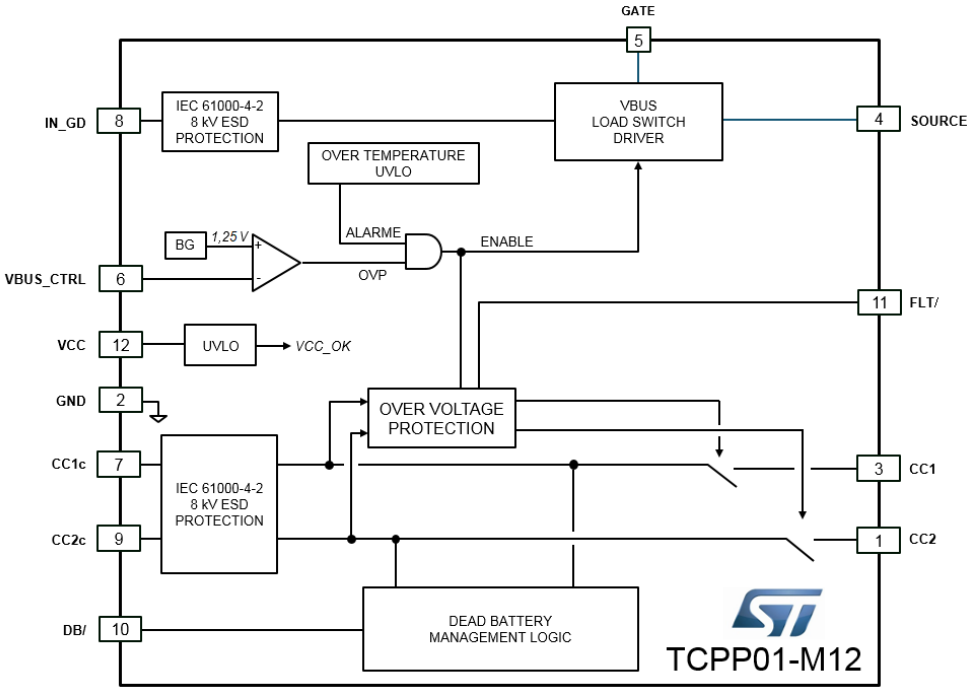
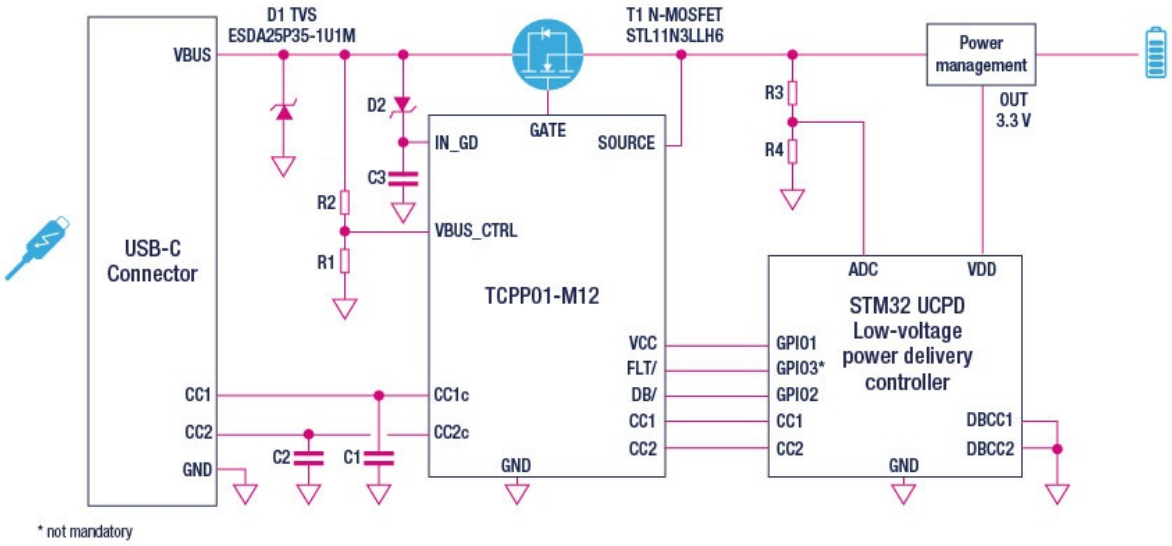


Figure 4. **Typical application block diagram**



Note: VBUS path capacitive value should be included between 1 µF and 10 µF for a USB Type-C™ power delivery SINK port design.

Please refer to X-NUCLEO-SNK1M1 documentation (databrief, quick start guide, user manual, schematic and BOM) for detailed application usage of TCPP01-M12 and selection of external components.

The TA0357 provides an overview of USB Type-C™ and power delivery technologies.

Table 2. **USB Type-C™ port protection range**

Part number	USB Type-C™ application	Package	Nucleo expansion board	Expansion software
TCPP01-M12	Sink, UFP, consumer	QFN-12L	X-NUCLEO-SNK1M1	X-CUBE-TCPP
TCPP02-M18	Source, DFP, provider	QFN-18L	X-NUCLEO-SRC1M1	
TCPP03-M20	DRP, dual role power	QFN-20L	X-NUCLEO-DRP1M1	

3 Characteristics

Table 3. Absolute maximum ratings (T_{amb} = 25 °C)

Symbol	Parameter	Pin name	Value		Units
			Min.	Max.	
V_{POWER}	Voltage for power pins	VCC	-0.3	4	V_{DC}
		IN_GD	-0.3	24	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	24	V_{DC}
R_{thj-a}	Junction-to-ambient thermal resistance			150	°C/W
T_J	Junction temperature		-40	+125	°C
T_{STG}	Storage temperature range		-55	+150	°C

Table 4. ESD ratings (T_{amb} = 25°C)

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

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 °C to +85 °C

Symbol	Parameter	Test condition	Value			Unit
			Min.	Typ.	Max.	
V_{CC}	Allowable voltage input range	-	2.7	3.3	3.6	V
I_{VCC}	V_{cc} supply current	V_{CC} = 3.0 - 3.6 V			120	µA
VBUS	Allowable voltage range		3.3		22	V
I_{L_VBUS}	VBUS supply current at VBUS = 22 V				2	mA

Table 6. Electrical characteristics – VBUS OVP control, T_{OP} = -40 °C to +85 °C

Symbol	Parameter	Test condition	Value			Unit
			Min.	Typ.	Max.	
V_{GS}	GATE to SOURCE voltage	V_{CC} = 3.0 - 3.6 V, VBUSc[1] = 4.0 V	5.0	5.5	6.0	V
		V_{CC} = 3.0 - 3.6 V, VBUSc[1] = 3.3 V	4.0		5.0	
t_{ON_VBUS}	Turn-on time on VBUS pin	V_{CC} = 3.0 - 3.6 V		1		ms
V_{ovp_th}	OVP VBUS threshold voltage	V_{CC} = 3.0 - 3.6 V	1.20	1.27	1.34	V
V_{hyst}	OVP VBUS voltage hysteresis	V_{CC} = 3.0 - 3.6 V		10		%
t_{ovp_VBUS}	OVP VBUS response time	Gate capacitance = 470 pF, V_{CC} = 3.0 - 3.6 V			100	ns

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

Table 7. Electrical characteristics – DB/ pin and CC lines OVP, T_{OP} = -40 °C to +85 °C

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

Table 8. CC1 and CC2 typical clamping voltage after +8kV ESD (IEC61000-4-2)

CC line status	Applied ESD voltage IEC61000-4-2 level 4	Peak clamping voltage	Clamping voltage after 30ns
OFF	+8 kV	9.2 V	3.3 V
OFF	-8 kV	-7.7 V	-1.0 V
ON	+8 kV	14.8 V	6.3 V
ON	-8 kV	-11.8 V	-1.5 V

Note: Voltage measurement is done on CC lines using X-NUCLEO-SNK1M1 plugged on top of NUCLEO-G071RB.

Table 9. Electrical characteristics – Fault reporting, T_{OP} = -40 °C to +85 °C

Symbol	Parameter	Test condition	Value			Unit
			Min.	Typ.	Max.	
t_{pd}	Propagation time from OVP, OTP, or UVLO to FLT/	V_{CC} = 3.0 - 3.6 V		5		µs
R_{ON}	FLT/ pin resistance when active			250		Ω

Symbol	Parameter	Test condition	Value			Unit
			Min.	Typ.	Max.	
R_{OFF}	FLT/ pin resistance when inactive	V_{CC} = 3.0 - 3.6 V		1		MΩ

4 Typical electrical characteristics curves

Note: T_{op} = 30 °C, V_{CC} = 3.3 V, SOURCE = 5 V, SINK configuration, unless otherwise stated.

Figure 5. CC line bandwidth: V_{cm} = 0 V

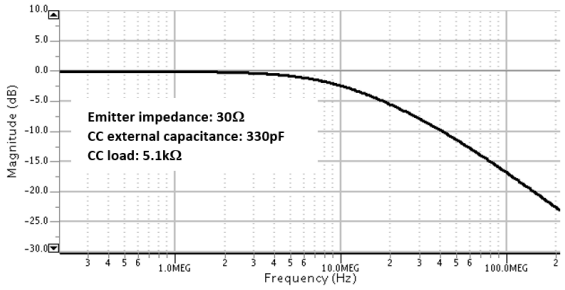


Figure 6. CC line bandwidth: V_{cm} = 1.2 V

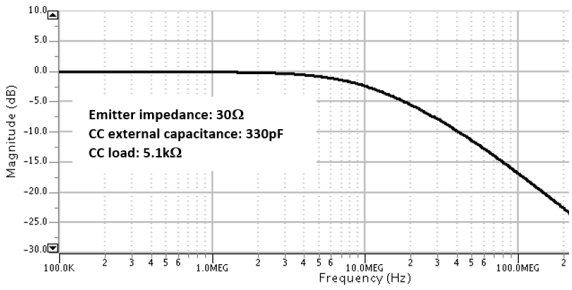


Figure 7. CC1c line short to VBUS (22 V) hot-plug via 1m of USB Type-C™ cable, sink configuration

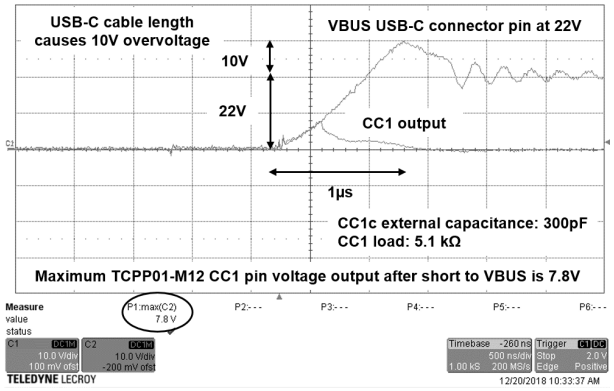


Figure 8. CC line leakage current vs ambient temperature at 5.5 V

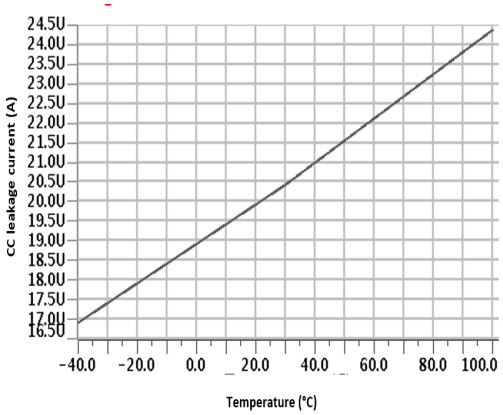


Figure 9. ON resistance of CC OVP FET vs ambient temperature

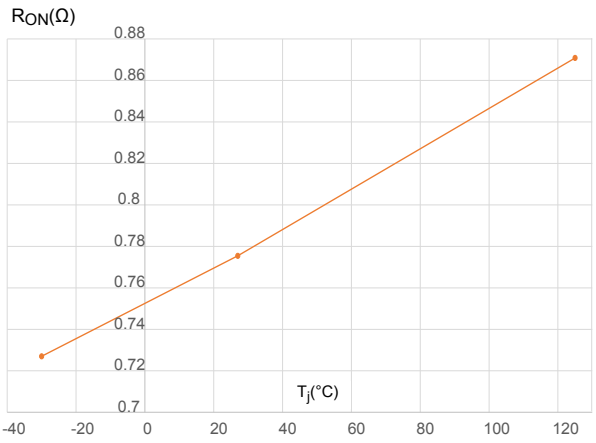


Figure 10. CC line attachment with 20 V source

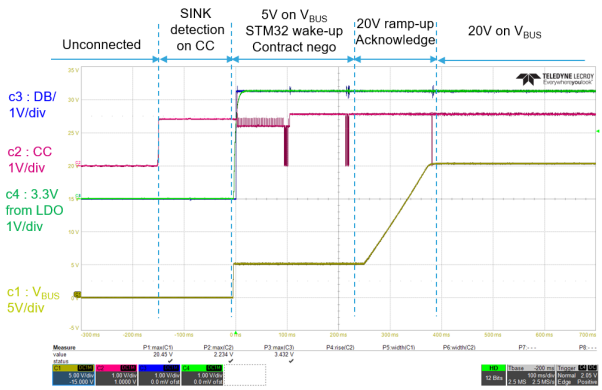


Figure 11. TCPP01-M12 start-up sequence

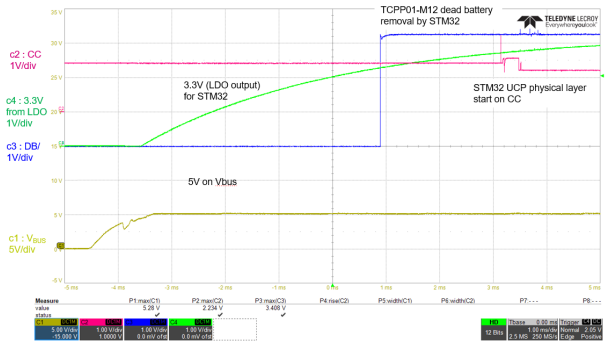


Figure 12. VBUS short to CC line

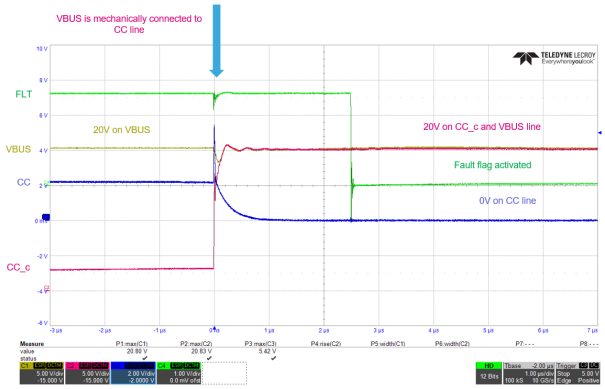


Figure 13. IEC61000-4-2 +8 kV ESD applied on CC1c, response on CC1 pin

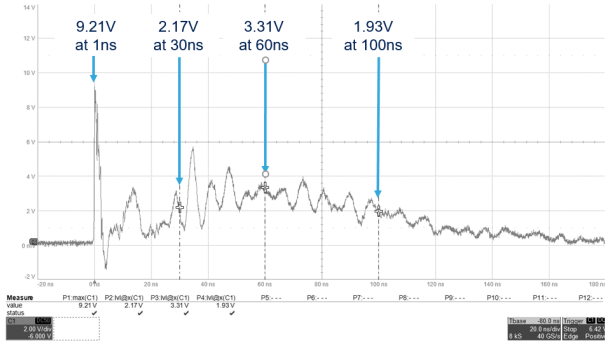


Figure 14. CCx line TLP curve (unpowered)

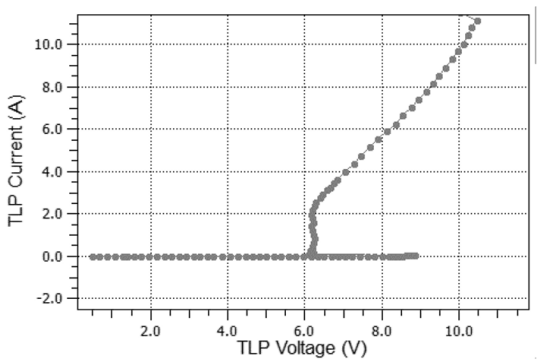


Figure 15. VBUS power-on at 5 V for a sink device

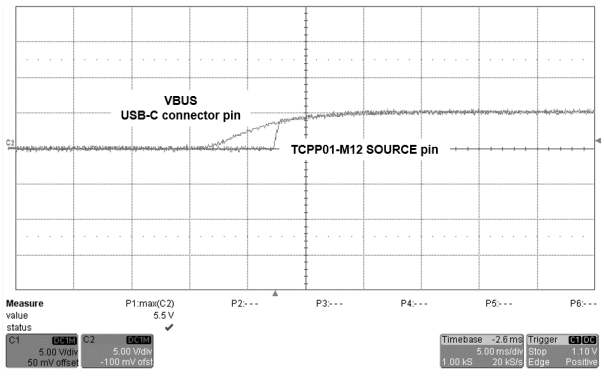
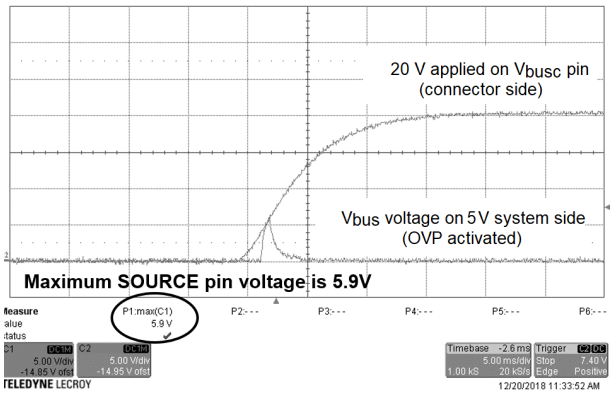


Figure 16. VBUS 5 V overvoltage protection (sink configuration, 20 V applied on VBUS)



5 TCPP01-M12 recommended use for low-power mode

5.1 What is TCPP01-M12 low power mode ?

TCPP01-M12 low-power mode operation allows TCPP01-M12 to feature 0 µA power consumption.

This mode applies only for sink applications using the USB Type-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 Type-C™ cable is attached.

We recommend to activate TCPP01-M12 only when contract negotiation is required.

6 Application

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.

Please refer to X-NUCLEO-SNK1M1 documentation (databrief, quick start guide, user manual, schematic and BOM) for detailed application usage of TCPP01-M12 and selection of external components.

The TA0357 provides an overview of USB Type-C™ and power delivery technologies.

6.1 General information

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.The TCPP01-M12 is unique because it works as a companion chip for our STM32 MCUs with built-in USB Type-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 from the high-voltage power path and benefit from all the protections needed. Additionally, the QFN-12L 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 from battery overheat.

The TCPP01-M12 also improves the overall efficiency, compared to competing solutions, by offering a low R_{DSon} and a null quiescent current when no cable is attached.

6.2 Electrical hazards related to USB Type-C

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

6.2.1 CC lines short to VBUS

USB Type-C™ standard specifies a pitch of 0.5 mm between connector pins (see figure 3-1 USB Type-C™ receptacle interface dimensions in USB Type-C cable and connector specification).

VBUS pin being adjacent to the CC pins, when removing the USB Type-C™ plug from the connector, VBUS can be shorted to CC lines and apply a voltage higher than specified for CC lines.

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).

When the voltage on the CC line goes above V_{TH_CC}, the OVP on CC line turns-on in less than 60ns (T_{OVP_CC} typical value) and FLGn pin goes to '0' state.

When the OVP event disappears, the OVP on the CC line is turned-off and the FLGn pin goes back to 'Hi-Z' state.

6.2.2 Defective charger

When the absolute maximum rating of the power management IC is below 20 V, an OVP is required on VBUS to protect the power management IC against a defective charger or cable that could apply a VBUS voltage higher than negotiated and damage the power management IC.

Until now, it was common to find the protection circuit inside a controller dedicated to USB Type-C™ power delivery. However, by supporting USB Type-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 Type-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 a 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 can occur even if 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 international electrotechnical commission modelize the ESD surge waveform in the specification IEC61000-4-2.

The TCPP01-M12 integrates ESD protection for CC1 and CC2 lines up to +8 kV contact discharge, associated with an external 100 nF - 50 V capacitor on C_{BIAS} pin.

Please refer to AN4871 USB Type-C™ protection and filtering to apply a required protection to comply with the IEC61000-4-2 specification.

For more information on IEC61000-4-2 standard testing, please refer to the STMicroelectronics application note AN3353.

6.3 USB Type-C protection

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

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

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 a MCU GPIO directly controlle the TCPP01-M12 VCC pin in this configuration.

TCPP01-M12 is the companion chip for:

- any general purpose MCUs (example: STM32, STM8) used for USB-C power sinking 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 FLT/ pin description

FLT/ pin is an output pin, open-drain, triggered by either OVP (overvoltage protection), OTP (overtemperature protection), or UVLO (undervoltage lockout) event.

FLT/ pin is at '1' in normal operating condition and goes to '0' when a protection event is triggered.

It goes back to '1' when the normal operating condition is recovered.

6.4.1 VBUS OVP

When a VBUS OVP event is triggered, FLT/ pin stays Low until the VBUS voltage goes below the V_{OVP_th}-V_{hyst}.

6.4.2 OTP

The embedded over temperature protection ensures the thermal protection for TCPP01-M12.

It features a typical turn-on at 145 °C and a typical turn-off at 125 °C.

When a VBUS OVP event is triggered, FLT/ pin stays low until OTP turns off.

6.4.3 CC lines OVP

When a CC line OVP event is triggered, FLT/ pin stays Low until the the CC line voltage goes below V_{TH_CC} - $V_{OVP\_CC\_H}$.

6.4.4 VBUS under voltage lock-out

This block continuously monitors VBUS voltage.

OVP_VBUS and consumer gate driver are enabled once the VBUS voltage reaches VBUS_UVLO voltage level (2.4 V typ.).

FLT/ pin stays Low until the the VBUSc voltage goes above VBUS_UVLO.

6.5 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.

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 kΩ 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.

DB/ usage in SINK (SNK) applications:

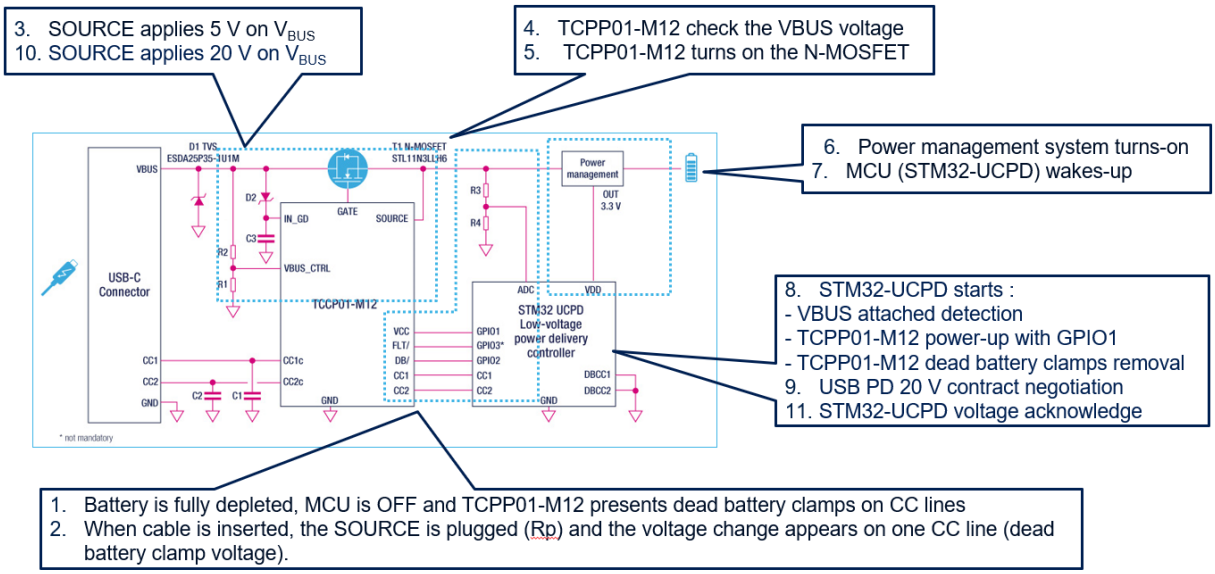
- After system power-up, the DB/ pin is kept at 0. In this case R_D is enabled at TCPP01-M12 level.
- Once R_D is enabled in the STM32-UCPD (USB-C power delivery controller), the DB/ pin is set to the logic level '1'

Table 10. Dead battery logic states

TCPP01-M12 VCC	TCPP01-M12 DB/	TCPP01-M12 DB clamp present	TCPP01-M12 CC1/CC2 OVP FET state	TCPP01-M12 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 advertised by 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) 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*
- *STM32-UCPD starts PDO contract negotiation*

6.6 Application example for USB Type-C power delivery for sink, PPS compliant

6.6.1 ESD capacitor (C3)

The system-level ESD capability of the TCPP01-M12 depends on this capacitor. It must feature 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 11. Example of ESD capacitor reference

Capacitor size	Part number
0603	CC0402KRX7R9BB104
0402	GRM188R71H104KA93D

6.6.2 Transient voltage suppressor on VBUS

The D1 diode ESDA25P35-1U1M is use to comply with the international electrotechnical commission specification IEC61000-4-5 on the VBUS power line when it is subject to switching and lightning transients.These electrical over stress (EOS) surges are defined in 8/20 µs waveform.

6.6.3 Sink capacitance

As per USB-C specification a 2,2 µF 50 V should be added on VBUS.

6.6.4 CC line capacitance (C1, C2)

C1 and C2 are EMI capacitors specified in the USB-C power delivery specification.

USB PD has a specification for the total amount of capacitance for proper operation on CC lines. This specification is given in Table 12:

Table 12. 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 13. 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

6.6.5 R1, R2: voltage divider resistance bridge for externally adjustable VBUS OVP threshold

Refer to X-NUCLEO-SNK1M1 user manual for proper selection of OVP sense resistors.

6.6.6 VBUS detect

An external voltage divider resistance bridge is used to monitor the VBUS voltage (CF R6, R7 in the X-NUCLEO-SNK1M1 User Manual, chapter 1.2.5) using an ADC channel of a MCU.

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

6.6.7 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 with 5 V of V_{GS}. Maximum current in USB-PD applications can raise up to 5 A.

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

Example of ST N-channel MOSFET are provided in the user manual of the X-NUCLEO-SNK1M1 (page:5, table1).

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

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

Figure 18. USB data line ESD protection for pins DP, DM, SSRX, SSTX

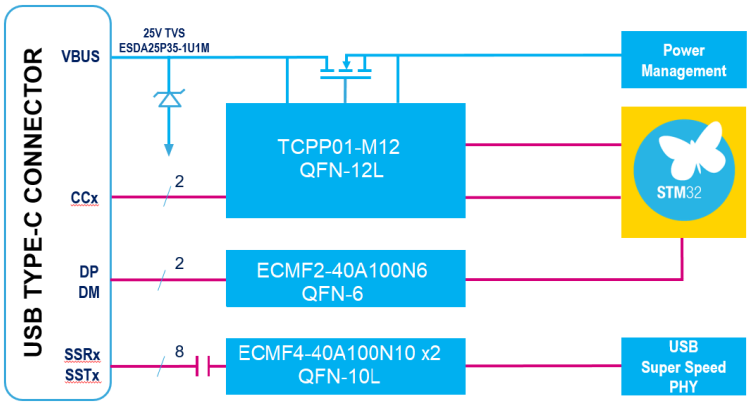


Table 14. Product recommendations

Part number	Description	USB Type-C™ connector pin	Protection features
TCPP01-M12	Type-C port protection	VBUS, CC1, CC2	ESD protection as per IEC61000-4-2 level 4 Overvoltage on VBUS CC lines short to VBUS
ESDA25P35-1U1M	Power line transient voltage suppressor (TVS)	VBUS	ESD protection as per IEC61000-4-2 level 4 IEC61000-4-5 (8/20µs surge waveform)
ECMF2-40A100N6	Common mode filter with integrated ESD protection	D+, D-	ESD protection as per IEC61000-4-2 level 4 RF antenna desense due to high-speed differential link EMI radiation
ECMF4-40A100N10	Common mode filter with integrated ESD protection	TX1+, TX1-, RX1+, RX1- TX2+, TX2-, RX2+, RX2-	ESD protection as per IEC61000-4-2 level 4 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.

6.7 Typical USB Type-C™ using 5 V only (without power delivery)

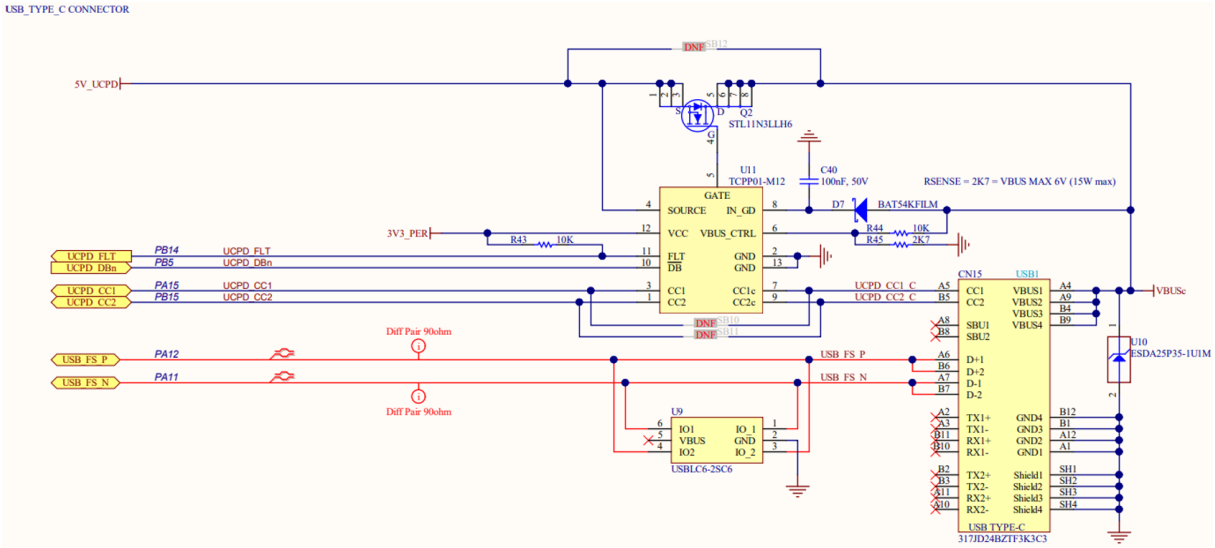
Thanks to its simple implementation and system compliancy with both legacy USB charging (using 5 V only) and the latest USB power delivery specification, USB Type-C™ applications using the TCPP01-M12 can simply migrate from legacy USB charging (see Figure 2) to USB power delivery charging by simply swapping the STM32 from general purpose (for example: STM32L0) to general purpose + UCPD. Empty PCB footprints can be planned earlier in the design to allow this hardware system scalability.

In this application use case, the system is typically powered by embedded batteries and the USB Type-C™ connector is used to recharge them.

Compared to the previous case, the TCPP01-M12 is now powered via GPIO1: This is possible thanks to the very low TCPP01-M12 biasing current (120 µA worst case). In this configuration, the TCPP01-M12 consumes power only during USB attachment. An attachment condition is detected via resistors R3 and R4.

Once a source has detected a SINK attachment, it releases automatically 5 V / 0.5 A on the VBUS. TCPP01-M12 detects this voltage and it turns on the N-channel MOSFET T1 (needed power is drawn from the IN_GD pin). As the VBUS voltage increases, the attachment is detected through the ADC.

Figure 19. Schematic example (extracted from NUCLEO-L552ZE-Q, STM32 Nucleo-144 development board with STM32L552ZE MCU)

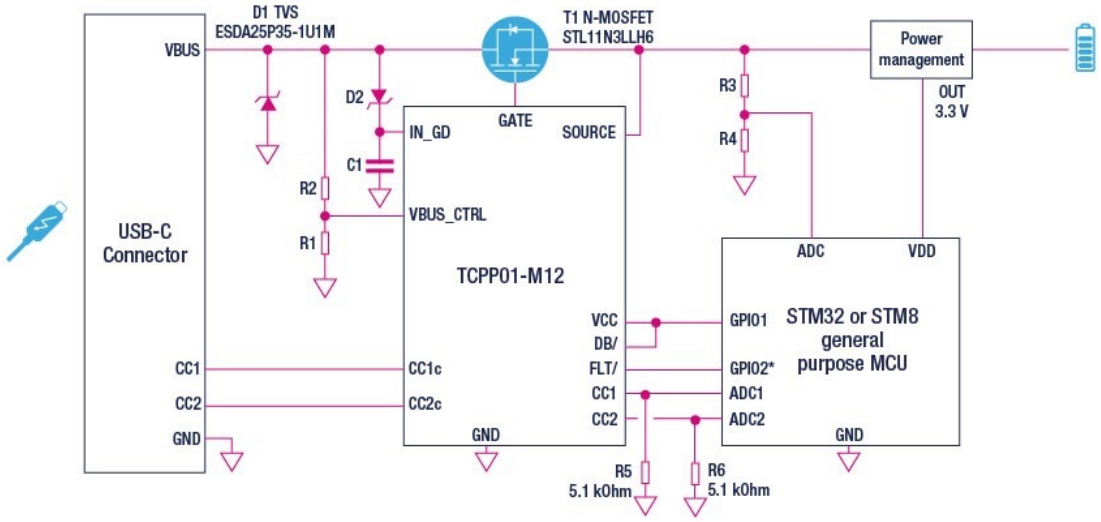


Please refer to AN5225 for more information related to USB Type-C™ power delivery using STM32xx series MCUs and STM32xxx series MPUs.

For more information on EMI filtering and ESD protection of USB datalines, please refer to AN4871: USB Type-C™ protection and filtering.

In case 5 V only is used with a USB Type-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 Type-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 Type-C™ devices operating at 5 V only without power delivery.

Figure 20. 15 W sink applications, with battery and general purpose MCU (for example: STM32 or STM8)



Note: The VBUS voltage monitoring from resistor bridge R3 and R4 is optional.

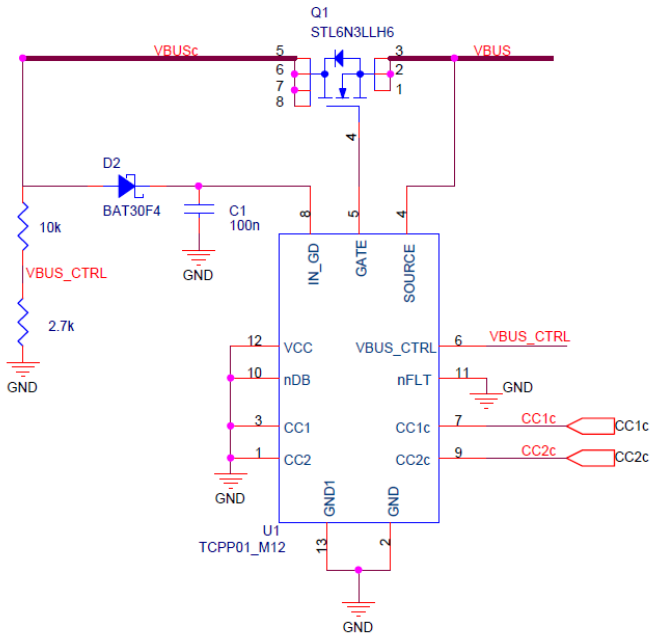
When the power delivery protocol is not used, the TCPP01-M12 is used for protection against defective charger, ESD protection and, dead battery management. The MCU can be an STM8 or any STM32. The pull-down resistors on the CC lines on the Sink side and the pull-up resistors on the Source side define the power profile. Cf p:47/56 of AN5225 “USB

Type-C™ power delivery using STM32xx series MCUs and STM32xxx series MPUs”.(AN5225).

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.

Figure 21. Schematic example for USB Type-C™ at 2.5 W with TCPP01-M12



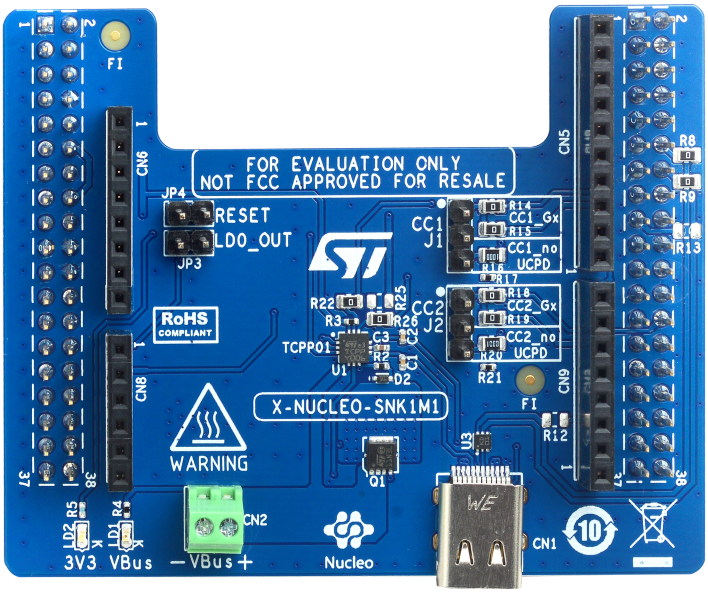
6.8 Development tools

The X-NUCLEO-SNK1M1 is an expansion board for the NUCLEO-G071RB and NUCLEO-G474RE Nucleo-64 boards. It provides a straightforward way to evaluate USB Type-C™ power delivery in SINK mode based on TCPP01-M12 along with X-CUBE-TCPP, the free software expansion code for all the TCPP boards.

The USB-IF (TID: 5205) certify the X-NUCLEO-SNK1M1 associated with the NUCLEO-G071RB 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.

Figure 22. X-NUCLEO-SNK1M1 picture



6.9 STM32 ecosystem tools for USB Type-C™

Table 15. ST companion chips for USB Type-C™ - Protection

USB Type-C™ application	Microcontroller	USB Type-C™ Power / Data role	Type-C port Protection (TCPP)	TCPP USB Type-C™ features and protections	STM32 Nucleo-64 expansion board	STM32 Nucleo-64 expansion software
	STM32		ST PROTECT	LONGEVITY 10 YEARS COMMITMENT	STM32 Nucleo	STM32 CubeExpansion
USB Type-C™ at 15 W maximum (5 V – 3 A max.)	Any MCU	Sink / Device	TCPP01-M12	V_{BUS}, CC OVP ESD protection	X-NUCLEO-SNK1M1 USB-IF TID: 5205	X-CUBE-TCPP also in STMicroelectronics GitHub
		Source / Host	TCPP02-M18	V_{BUS} OCP, CC OVP ESD protection, current sense	X-NUCLEO-SRC1M1	
USB Type-C™ power Delivery(1) Any PDO up to 100 W (20 V / 5 A) PPS-compliant	STM32 with UCPD(2) STM32G0, STM32G4, STM32L5, STM32U5	Sink / Device	TCPP01-M12	V_{BUS}, CC OVP ESD protection	X-NUCLEO-SNK1M1 USB-IF TID: 5205	
		Source / Host	TCPP02-M18	V_{BUS} OCP, CC OVP ESD protection, current sense	X-NUCLEO-SRC1M1	
		DRP: Dual role Power DRD: Dual role data	TCPP03-M20	V_{BUS}, CC OVP + OCP ESD protection, current sense	X-NUCLEO-DRP1M1 USB-IF TID: 6408	

1. *Compliant with USB power delivery 3.1 SPR (standard power range) specification. PPS: Programmable power supply.*
2. *UCPD: USB Type-C™ power delivery controller, embedded in STM32 microcontrollers.*

Note: OVP: Over voltage protection
OCP: Over Current protection
Click here to access the list of STM32 integrating UCPD.

7 PCB design recommendations

When routing the TCPP01-M12, please respect the following recommendations:

- Place the circuit as close as possible of the USB connector
- Place the ESD capacitor as close as possible of the TCPP01-M12

An example of routing with two layer board is shown here after.

For more information on ESD protection layout and placement, please refer to AN576: PCB layout optimization.

Figure 23. Layer board for sink mode

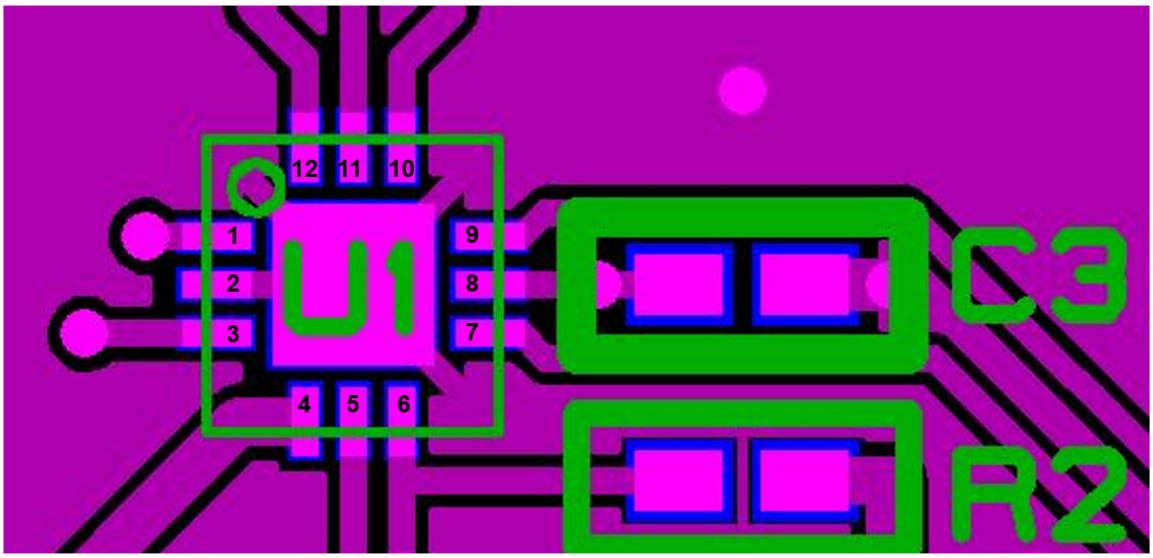
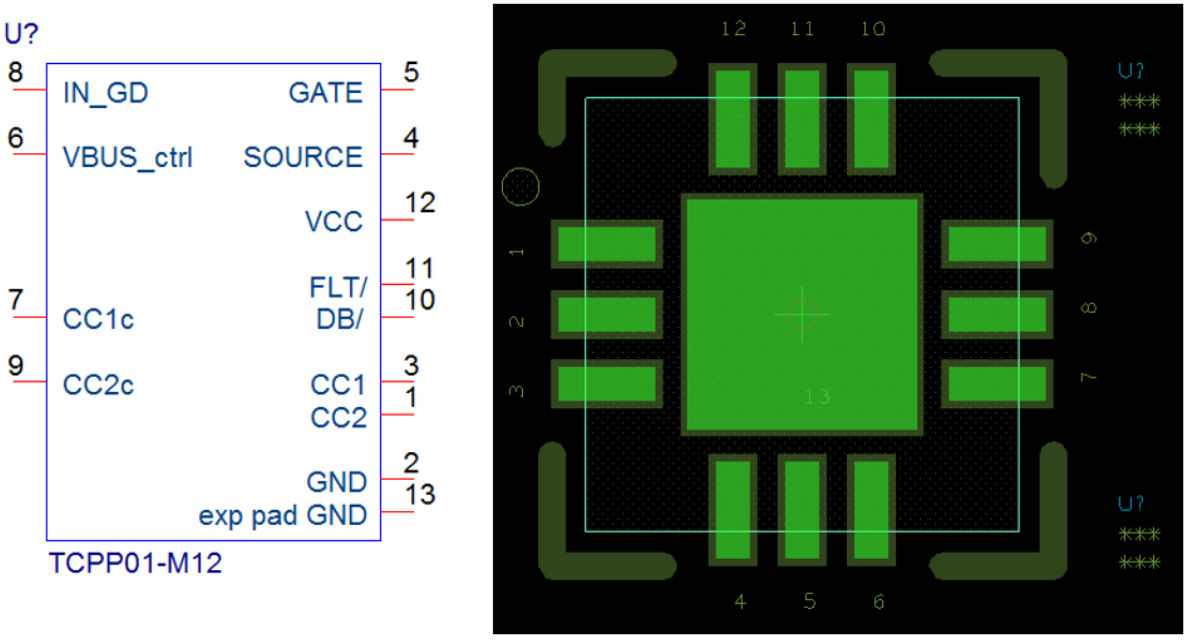


Figure 24. TCPP01-M12 symbol and footprint



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. ECOPACK is an ST trademark.

8.1 QFN-12L package information

Figure 25. **QFN-12L package outline**

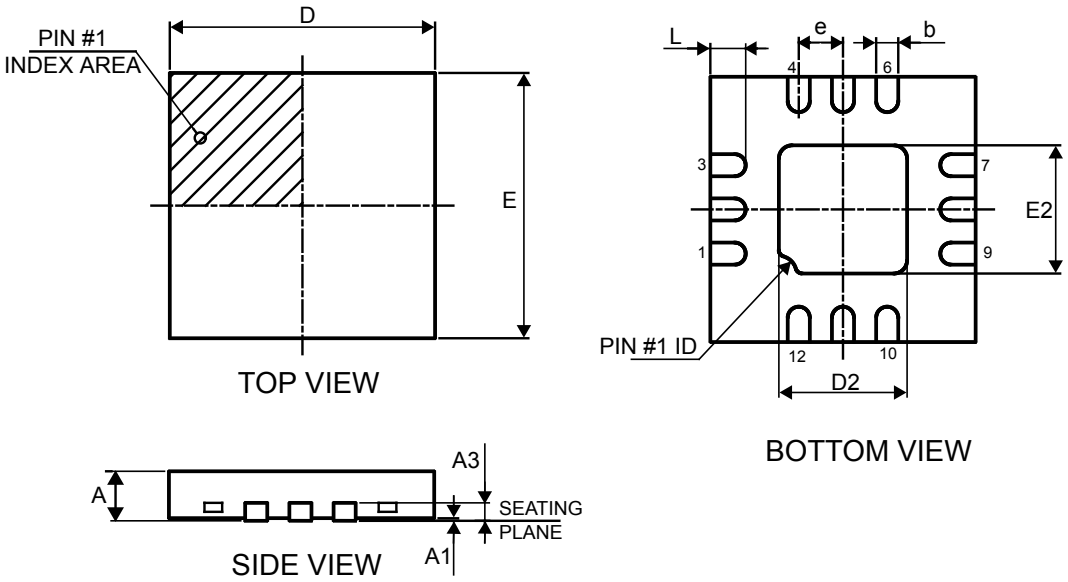


Table 16. **QFN-12L package mechanical data**

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 26. **QFN-12L recommended footprint**

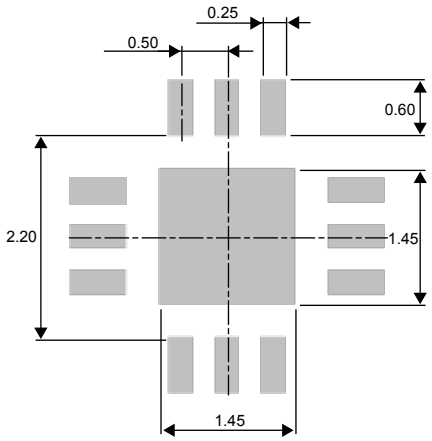
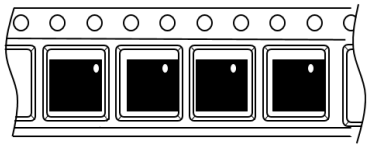


Figure 27. **Package orientation in reel**



Pin 1 located according to EIA-481

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

Figure 28. **Tape and reel orientation**

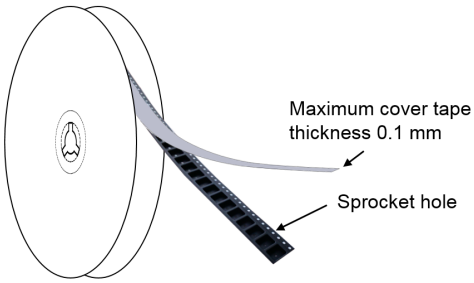


Figure 29. **Reel dimensions (mm)**

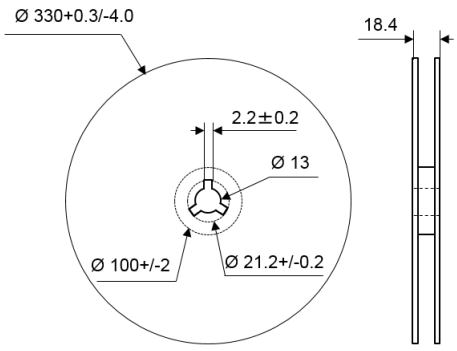


Figure 30. **Inner box dimensions (mm)**

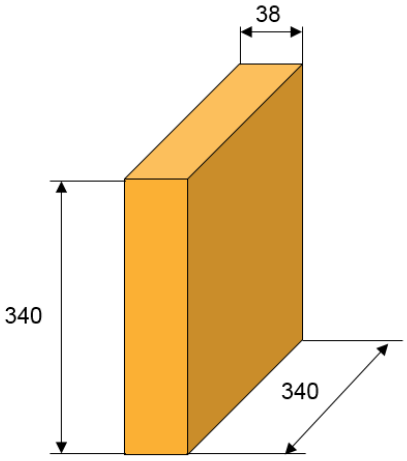
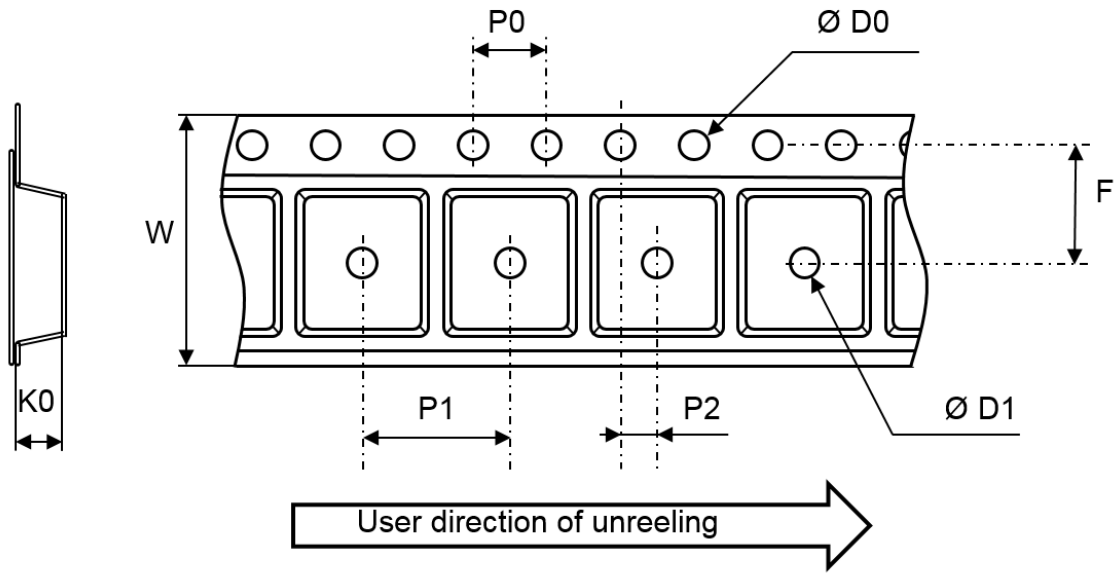


Figure 31. **Tape and reel outline**

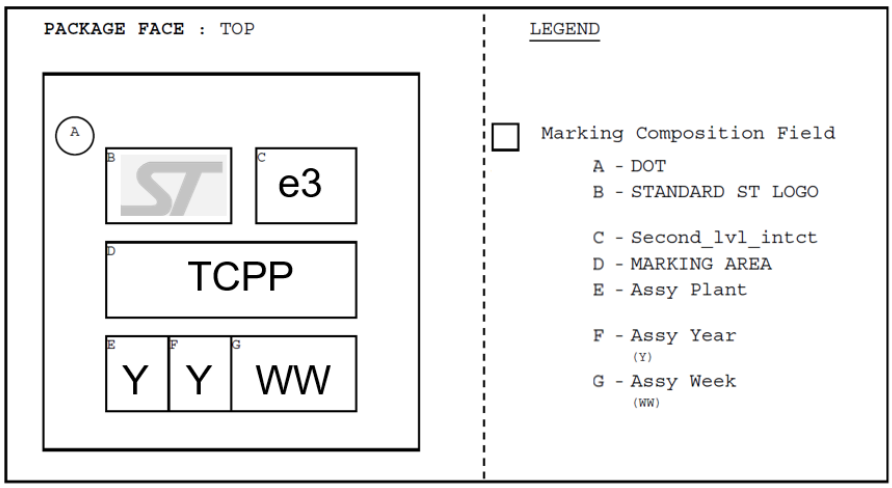


Note: Pocket dimensions are not on scale
Pocket shape may vary depending on package

Table 17. **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

Figure 32. **TCPP01-M12 marking**



9 Ordering information

Table 18. **Ordering information**

Order code	Marking	Package	Weight	Base qty.	Delivery mode
TCPP01-M12	TCPP	QFN-12L	23 mg	3000	Tape and reel

Contents

Revision history

Table 19. **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 . Added Figure 10, Figure 11, Figure 24, Figure 16, Figure 18 and Figure 21. 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 Figure 10 and Section 5.
25-May-2022	5	Updated Features, Table 3, Table 5, Table 6, Table 8, Section 6.1 , Section 6.2.1 , Section 6.2.2 , Section 6.6.4 , Section 6.6.5 , Figure 18, Table 14, Section 6.8 and Figure 22. Removed figure "CCx digital communication (eye diagram performed on X-NUCLEO-USBPDM1 and NUCLEOG071RB)" and "Typical USB-C source application" chapter. Added Section 6.4 , Section 6.6.3 and Section 6.9 . Minor text changes.
15-Jul-2022	6	Removed figure Type-C receptacle (CN1) and ESDA25P35-1U1M TVS diode (D1) and figure TCPP01-M12 protection (U1) driving the STL11N3LLH6 MOS (Q1). Added Figure 4. Updated Table 15.