NX20P0477

USB Type-C CC smart protection

Rev. 1.0 — 3 February 2020 Product data sheet

1 General description

NX20P0477 is a single-chip USB Type-C (USB-C) port overvoltage protection solution integrating a corrosion prevention algorithm from moisture. CC1/CC2 pins in the system side are protected from 28 V short to VBUS.

USB-C allows VBUS voltage to increase up to 20 V through Power delivery protocol. CC1/2 pins can be shorted to VBUS due to mechanical twisting and sliding of the connector since USB-C connector contact pins are 25 % closer to each other than a micro USB connector. Moisture or fine dust may also cause the 20 V VBUS pin to be shorted to adjacent pins.

NX20P0477 enables CC pins to be more robust in even abnormal conditions. NX20P0477 is 28 V DC tolerant on CON_CC pins in connector side and quickly disconnects switches if the voltage is above overvoltage threshold, protecting CC pins in system side from high voltage.

USB PD standard requires 80 µA, 180 µA or 330 µA as Rp to detect sink device, but this Rp current accelerates USB-C connector pin corrosion when CC pins are contaminated with water, especially salt water. Furthermore, CC/PD controller may recognize this water impedance as detected sink, providing 5 V through VBUS pin, which accelerates corrosion.

NX20P0477 converts these USB standard Rp currents from CC/PD controller to ultra-low current source to prevent corrosion.

NX20P0477 integrates IEC 61000-4-2 ESD protection of +6 kV contact discharge and +8 kV air discharge on CON_CC1 and CON_CC2, which helps to reduce external BOM cost.

NX20P0477 CON_CC1 and CON_CC2 pins are designed to be protected from surge voltage up to +/-40 V.

NX20P0477 is offered with 0.5 mm pitch, 9 bumps, 1.49 mm x 1.49 mm x 0.555 mm WLCSP package.

2 Features and benefits

- USB Type-C CC1 and CC2 short protection to VBUS
- CON_CC1 / CON_CC2: 28V_{DC} AMR
- Rd clamp circuit in CON_CC1/CON_CC2 in dead battery condition
- Smart corrosion prevention scheme with low current source
- 250 mΩ Low R_{DSon} switch
- Robust ESD immunity for CON_CC1/CON_CC2
  - IEC 61000-4-2 contact discharge: 6 kV
  - IEC 61000-4-2 air discharge: 8 kV
- +/-40 V surge protection on CON_CC1/CON_CC2

- Low leakage current: 14 µA
- CC1 / CC2 leakage current: < 1 µA
- Fast OVP turn-off time: 60 ns

3 Applications

- Smartphone
- Tablet
- Laptop

4 Ordering information

Table 1. Ordering information

Type number	Topside marking	Package		
		Name	Description	Version
NX20P0477UK	N77	WLCSP9	wafer level chip scale package, 9 terminals, 0.5 mm pitch, 1.49 mm x 1.49 mm x 0.555 mm body (backside coating included)	SOT1385-2

4.1 Ordering options

Table 2. Ordering options

Type number	Orderable part number	Package	Packing method	Minimum order quantity	Temperature
NX20P0477UK	NX20P0477UKZ	WLCSP9	REEL 7" Q1 DP CHIPS	3000	T_{amb} = -40 °C to +85 °C

5 Functional diagram

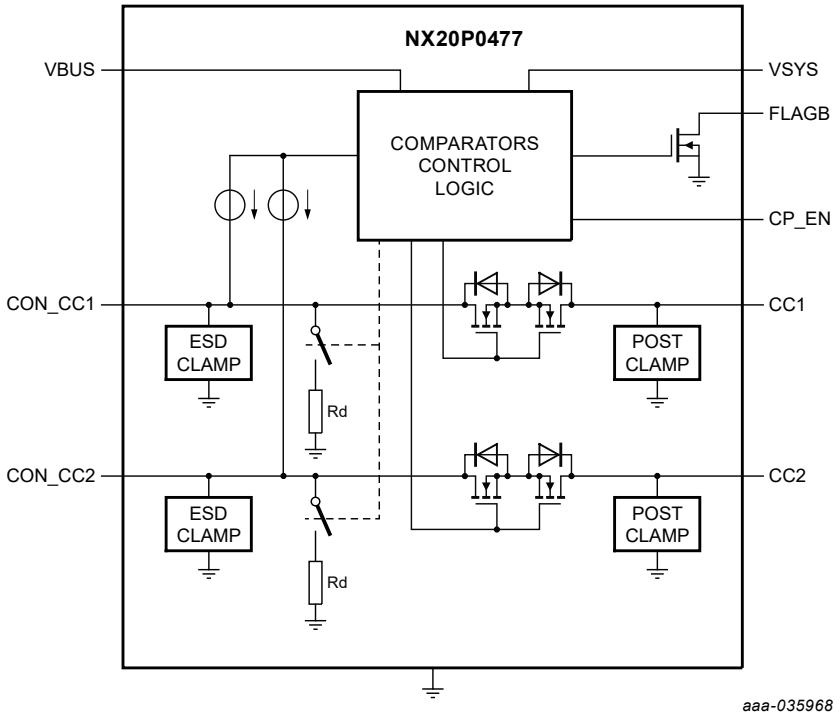

Figure 1. Functional diagram

6 Pinning information

6.1 Pinning

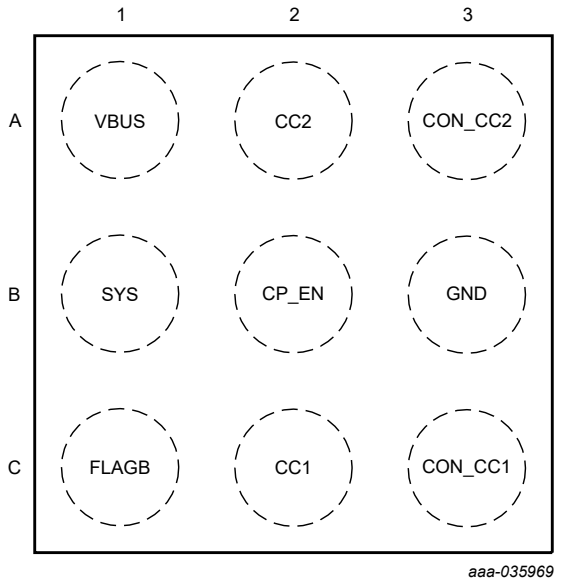

Figure 2. Pin map bump side down

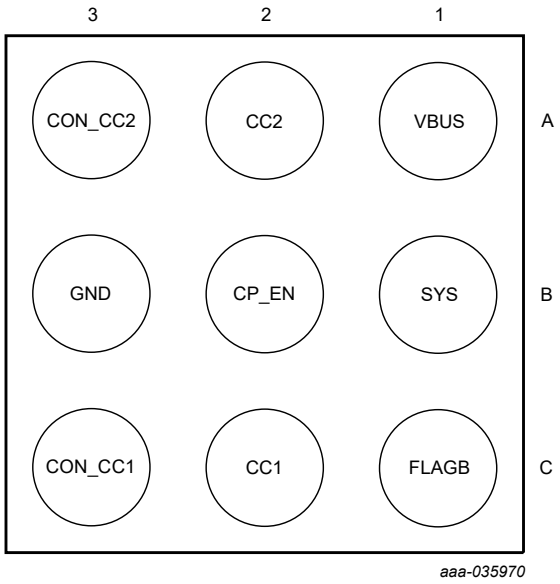

Figure 3. Pin map bump side up

6.2 Pin description

Table 3. Pin description

Symbol	Pin	Type	Description
CON_CC1	C3	P	USB-C connector side CC1. Connect CC1 of USB-C connector.
CON_CC2	A3	P	USB-C connector side CC2. Connect CC2 of USB-C connector.
CC1	C2	P	System side CC1. Connect CC1 of USB CC/PD controller.
CC2	A2	P	System side CC2. Connect CC2 of USB CC/PD controller.
VBUS	A1	AI	VBUS detection pin
VSYS	B1	P	Power supply input, connect System voltage and add 1 µF capacitor to GND.
FLAGB	C1	DO	Open-drain output indicating water detection. Low when water is detected. External 100 kΩ pull up resistor is required.
CP_EN	B2	DI	Corrosion protection Enable pin. It should be driven high to enable corrosion protection scheme. If it is low, CC switches are ON and acts as OVP switch.
GND	B3	GND	Ground

7 Functional description

NX20P0477 is placed between USB-C connector and CC/PD controller to protect CC pins in System side CC/PD controller from 20 V VBUS short, ESD and Surge voltage.

NX20P0477 has corrosion prevention feature, which can be enabled by driving CP_EN pin high. In this mode, the CC switch is off and Rp source from CC/PD controller is converted to low current source integrated in NX20P0477. CC switch is turned on only when true accessories are detected.

NX20P0477 has Rd clamp circuit on both CON_CC1 and CON_CC2 when VSYS is below UVLO threshold, known as dead battery condition. It allows USB-C adapter to detect SINK through the Rd clamp and start providing 5 V through VBUS. Main charger regulates system voltage from 5 V VBUS. Once VSYS comes up, NX20P0477 enables switchers and disconnects internal Rd clamp circuit from CON_CCx pins.

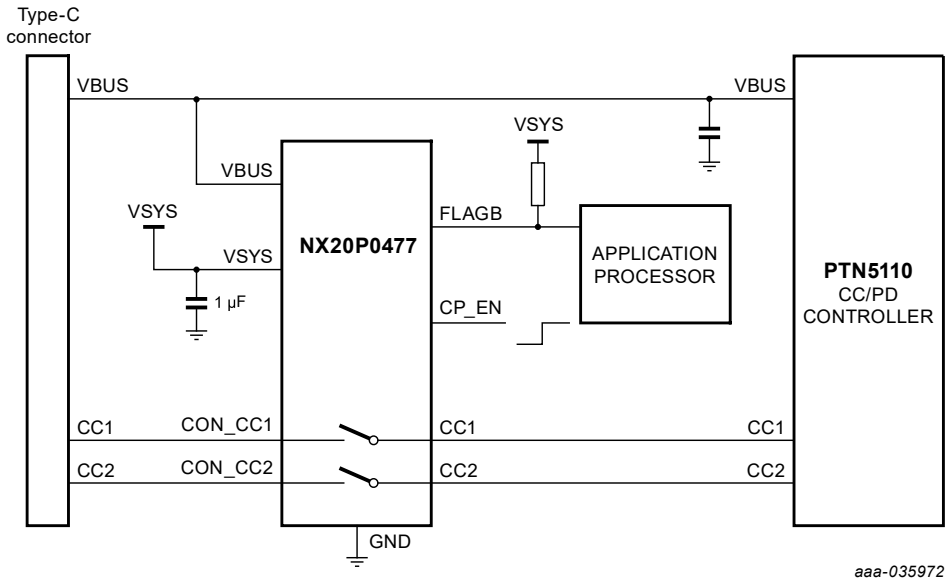

Figure 4. NX20P0477 application diagram

7.1 Internal block diagram

Figure 5 shows internal block diagram, where only one channel is shown. The other channel has the same circuit. CC switch is comprised with back-to-back MOSFET to truly isolate CC pin from CON_CC pin. There are four comparators in each CC channel. COMP1 on CC pin detects Rp or Rd by external CC/PD controller. COMP1 comparator output is used to enable internal Rd or Rp on CON_CC pin. COMP2 and COMP3 is used to detect accessory plugged in connector or moisture inside connector. COMP4 detects overvoltage on CON_CC pin.

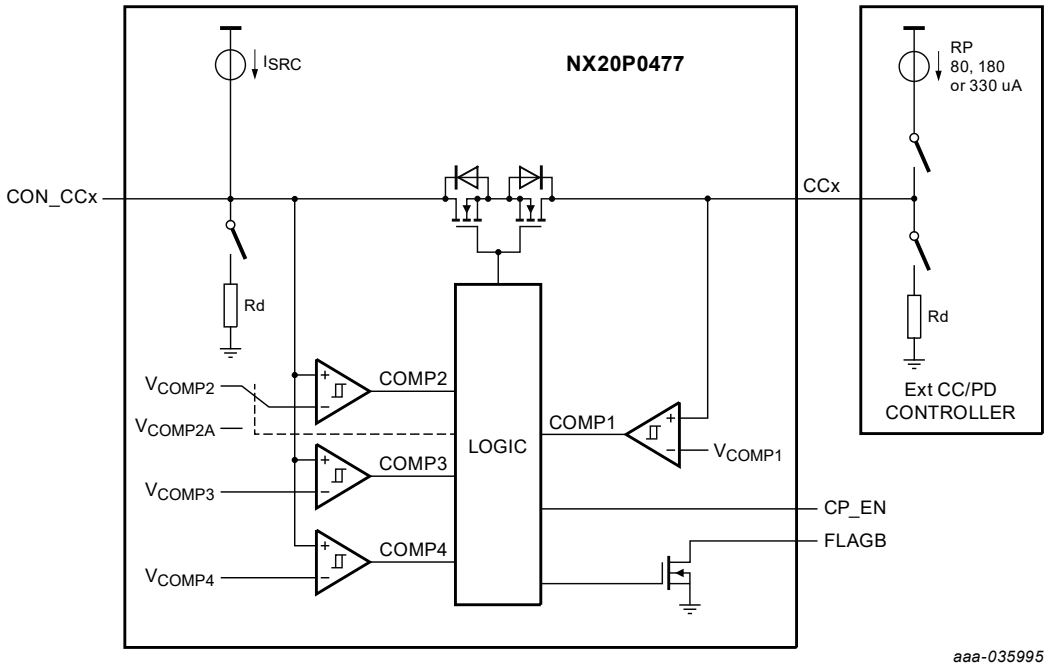

Figure 5. Internal block diagram – one channel only

7.2 Power status

When VSYS is below $V_{SYSUVLO}$, NX20P0477 stays in shutdown mode, where bias, switches and all comparators are disabled, but Rd clamp circuits on CON_CC1 and CON_CC2 are enabled. It allows USB-C adapter to detect the Rd and to supply 5 V through VBUS in dead battery condition. Table 4 lists NX20P0477 power states.

Table 4. Power state

Power state	VSYS	CP_EN	CCx	CON_CCx	FLAGB	CC Switch
Shutdown	VSYS < UVLO	X	X	Rd	Hi-Z	OFF
Wait.SRC	VSYS ≥ UVLO	H	L	Rd COMP2 = L	Previous status	OFF
Wait.SNK	VSYS ≥ UVLO	H	H	Isrc COMP3 = H	Hi-Z	OFF
Moisture.det	VSYS ≥ UVLO	H	H	Isrc COMP2 = H, COMP3 =L	L	OFF
Active	VSYS ≥ UVLO	H	-	Accessory detected	Previous status	ON
	VSYS ≥ UVLO	L	-	-	Previous status	ON

7.2.1 Shutdown state

When VSYS is below UVLO threshold, NX20P0477 enters Shutdown state, where both CC switches are turned off and Rd clamp circuit on CON_CC1 and CON_CC2 is enabled. Once VSYS is above OVLO, then NX20P0477 transitions to Active state by turning CC switch ON. If VBUS is not present for $t_{CC\_OFF\_VBUS}$ and CP_EN is high, it

transitions to Wait.SNK or Wait.SRC depending on CCx voltage. When CP_EN is low, NX20P0477 stays at Active state.

7.2.2 Wait.SNK state

When VSYS is above UVLO threshold and comparator1 (CP1) on CC1 and CC2 pins is high, NX20P0477 enters Wait.SNK state. Internal low current source is enabled on CON_CC1 and CON_CC2 by turning CC switches off. When CP1 is driven low by external CC/PD controller, the device transitions to Wait.SRC. If CP2 comparator on CON_CCx is low, it moves to Active state. if CP2 is high and CP3 is low, then it enters Moisture.det state. If FLAGB is driven low after detecting water on connector before, then FLAGB is cleared when CP3 is detected high in this state.

7.2.3 Wait.SRC state

When VSYS is above UVLO threshold and comparator1 (CP1) on CC1 and CC2 pins is low, NX20P0477 enters Wait.SRC state. Internal Rd is enabled on CON_CC1 and CON_CC2 by turning CC switches off. When CP1 is driven high by external CC/PD controller, the device transitions to Wait.SNK. If CP2 comparator on CON_CCx is high, it moves to Active state.

7.2.4 Moisture.Det state

NX20P0477 transitions to Moisture.DET state from Wait.SNK state when CP2 is high and CP3 is low, where FLAGB is driven low. The device transitions to Wait.SRC or Wait.SNK depending to CP1 status on CCx pins.

7.2.5 Active state

When either sink or source accessory is detected successfully, the device enters Active status where both CCx switches are turned on and internal current source or Rd is turned off. The rest of CC detection process is accomplished by external CC/PD controller. The device exits Active state in $t_{CC\_OFF\_VBUS}$ after removing VBUS. If CP_EN is driven low, the device remains in Active state.

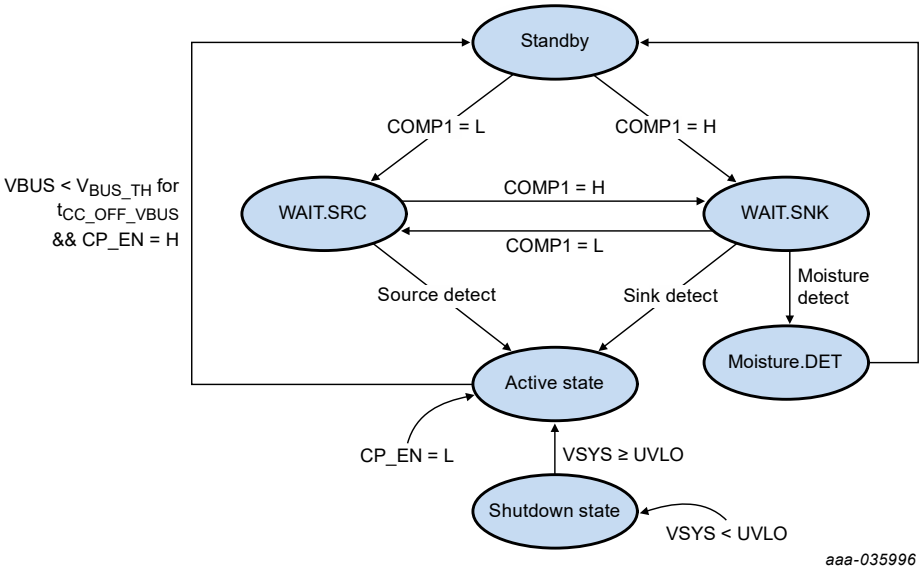

Figure 6. Simplified State diagram

7.3 Corrosion prevention feature

USB PD standard requires 80 µA, 180 µA or 330 µA as Rp to detect sink device. But it may accelerate corrosion when CC pins are contaminated with water, especially sea water. Furthermore, CC/PD controller may recognize this water impedance as sink detection, providing 5 V to VBUS pin and accelerating corrosion.

NX20P0477 isolates CC pin from CON_CC pin by turning CC switches off and imitating CC/PD controller behavior monitoring CC pin status. If CC/PD controller terminates CC pins with Rd, then NX20P0477 enables internal Rd on CON_CC pins. If the controller sources Rp current, it enables internal low current source. NX20P0477 can detect any accessory through connector with internal comparators synchronizing CC/PD Controller Rd/Rp timing.

7.4 Timing diagram

When CP_EN is driven high, CC switch is turned OFF and CON_CC pin follows CC pin status with logic delay, T_{CC_delay}.

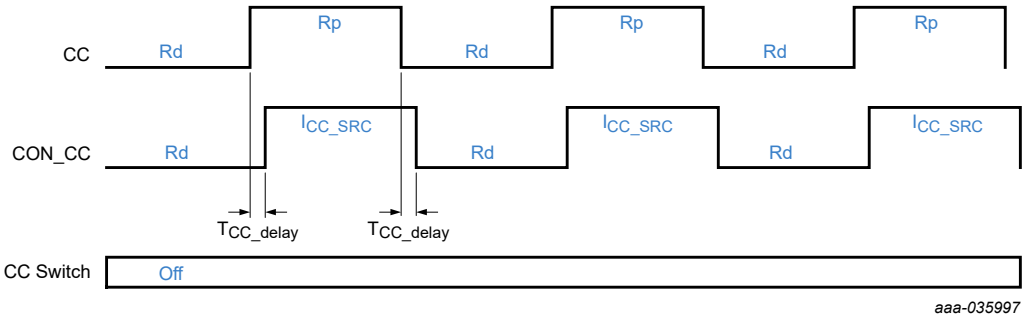

Figure 7. Standby Timing diagram

When source accessory (Rp) is plugged in, CON_CC voltage comes up above VCOMP2 from current source in source accessory. After debounce timer, T_{CC_deb}, NX20P0477

turns CC switch ON. Internal Rd is off after T_{Rd_off}, which is for Source accessory not to lose Rd during switch transition.

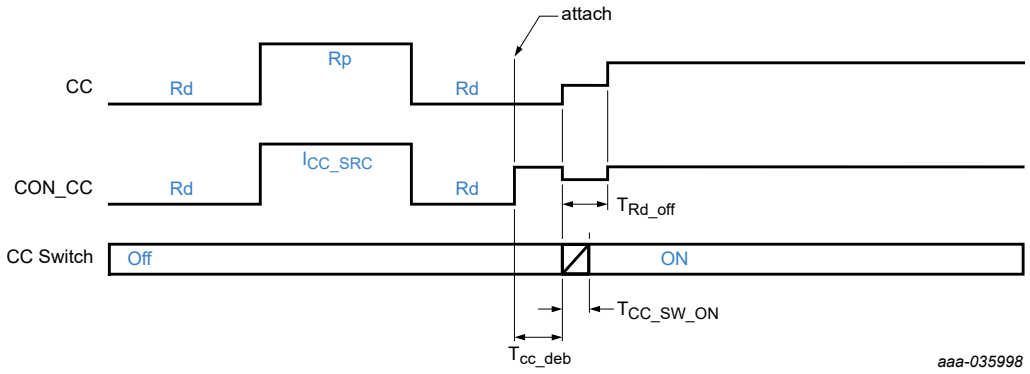

Figure 8. Source accessory detection Timing diagram

When Sink accessory (Rd) is plugged in, CON_CC voltage falls to Rd * I_{CC_SRC} which is below VCOMP3. NX20P0477 detects when something is plugged in and enables internal current source for T_{SRC_WAIT}, to discriminate Rd from water or dead battery. After T_{SRC_WAIT}, CON_CC voltage comes back to Rd * I_{CC_SRC}, which is below VCOMP2. After TCC_deb, NX20P077 detects as Sink accessory and turns on CC switch.

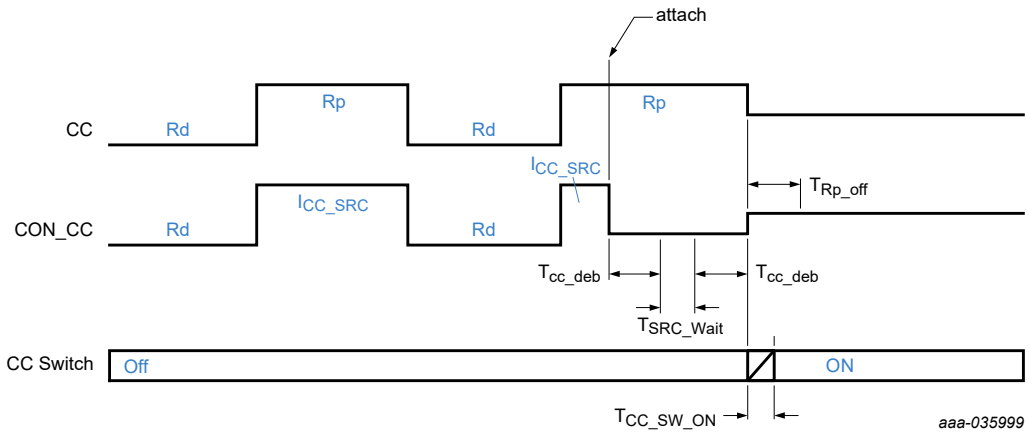

Figure 9. Sink accessory detection Timing diagram

When Dead battery accessory (Rd Clamp) is plugged in, CON_CC voltage is clamped from Rd clamp circuit in accessory which is below VCOMP3. NX20P0477 detects when something is plugged in and enables internal current source for T_{SRC_WAIT}. Unlike Rd accessory, CON_CC voltage doesn't fall below VCOMP2 due to clamp circuit after T_{SRC_WAIT}. NX20P0477 enables internal current source for T_{CC_deb}, to discriminate Dead battery accessory from water. NX20P0477 then turns I_{CC_SRC} off and turns Rd on. Since there is no source, CON_CC voltage falls below VCOMP2. After TCC_deb, NX20P077 detects as Dead battery accessory and turns on CC switch.

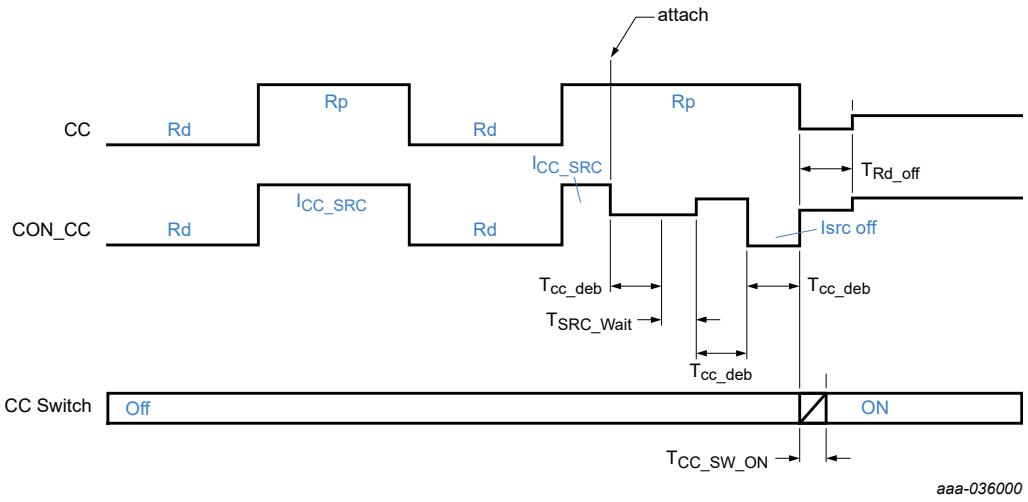

Figure 10. Dead battery accessory detection Timing diagram

Water impedance can be simply modeled with resistance and capacitance. Tap water and purified water show a few hundred kΩ and a few hundred nF capacitance. Sea water has a few tens kΩ and around 1 µF capacitance. NX20P0477 utilizes this characteristic to detect water from normal accessory.

When water comes into contact with a USB-C connector pin, CON_CC voltage drops due to water impedance which is below VCOMP3. NX20P0477 detects a change and enables internal current source for T_{SRC_WAIT}, and then enables the current source for T_{CC_deb}. During this time, CON_CC voltage increases above VCOMP3 in case of tap water, it detects as water, where CC switch stays off and FLAGB is pulled low. In case of sea water, the voltage doesn't go over VCOMP3 even if enabling internal current source for T_{CC_deb}, after then NX20P0477 turns off internal all current source and enables Rd. CON_CC voltage doesn't fall below VCOMP2 due to water capacitance.

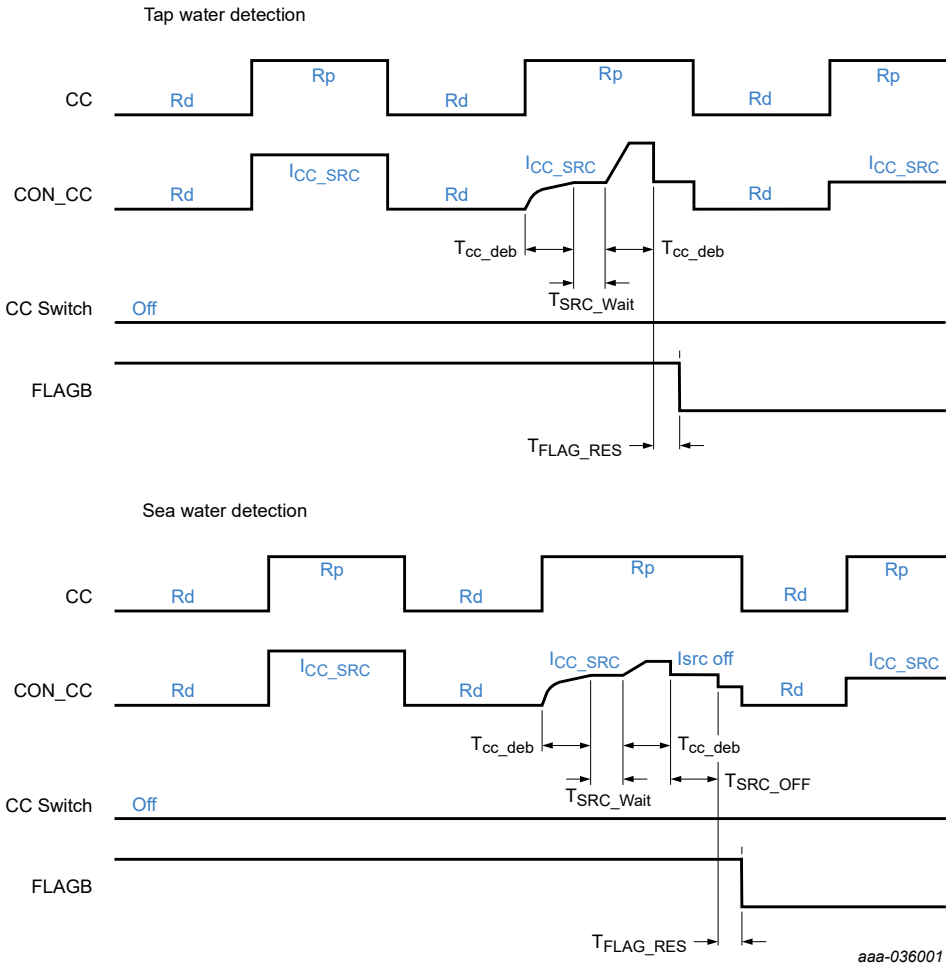

Figure 11. Tap/sea water detection Timing diagram

7.5 Overvoltage protection

NX20P0477 has overvoltage protection of CON_CC1 and CON_CC2 up to 28 V. CC switch overvoltage threshold is V_{OVPCC} to guarantee 5 V VCONN power supply, which is maximum 5.5 V by USB USB-C spec.

Once overvoltage on either channel is detected, the switch is quickly turned off within t_{OVP_res}, to prevent passing overvoltage to system side. If the voltage of the channel triggered OVP comes down below overvoltage threshold for t_{OVP_Deb}, NX20P0477 CC switch turns back on.

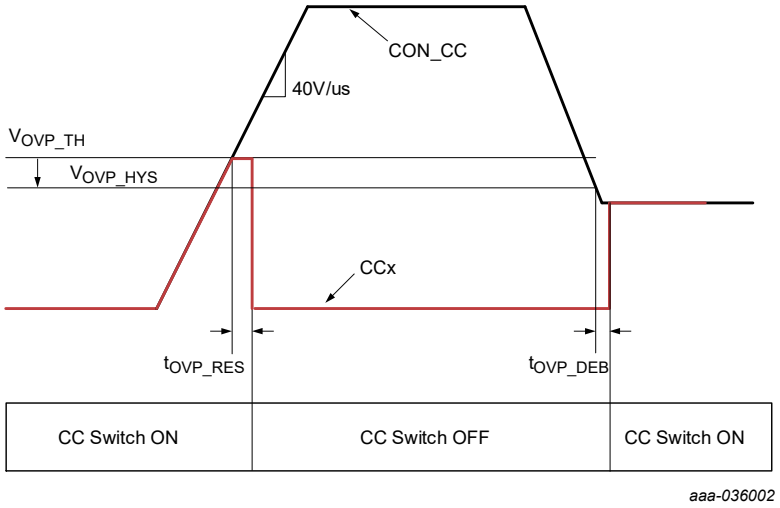

Figure 12. Overvoltage protection timing in Active state

7.6 CP_EN

CP_EN pin is a control pin that enables the corrosion prevention feature.

When CP_EN pin is driven high, corrosion prevention circuit is enabled. If CP_EN pin is driven low, corrosion prevention circuit is disabled and enters active state by turning CC switches on, where NX20P0477 acts as an overvoltage protection switch.

7.7 VBUS

VBUS pin detects VBUS presence and uses this signal to turn off CC switch. Whenever an accessory is detected, VBUS comes up according to USB USB-C specification. When accessory is removed, VBUS disappears. NX20P0477 turns off CC switch 2.5 sec after VBUS is removed.

7.8 FLAGB

FLAGB pin is an open drain output to indicate moisture condition on USB-C connector pins to application processor. When NX20P0477 detects water, such as tap or sea water, it drives FLAGB low. If both CON_CC1 and CON_CC2 voltages exceed V_{COMP3} in Wait.SNK state, it is regarded as dry condition on connector and FLAGB gets High-Z. When VSYS voltage falls below UVLO threshold, FLAGB gets High-Z.

8 Limiting values

Table 5. Limiting values

Absolute Maximum Ratings

Explanation	Pin	Conditions	Min	Max	Unit
Voltage range (with respect to GND)	CON_CC1, CON_CC2		-0.5	+28	V
	CC1, CC2		-0.5	+6	V
	VSYS		-0.5	+6	V
	FLAG, CP_EN		-0.5	+6	V
	VBUS		-0.5	+28	V
Output Current	CON_CC1, CON_CC2, CC1, CC2	Tj < 105 °C	-350	+350	mA
Junction temperature			-40	+135	°C
V_{ESD} Electrostatic discharge voltage	All pins for HBM and CDM specs	HBM (JESD22-001)	-2	+2	kV
		CDM (JESD22-C101E)	-500	+500	kV
	CON_CC1, CON_CC2 for IEC specs	IEC 61000-4-2 contact discharge	-6	+6	kV
		IEC 61000-4-2 air discharge	-8	+8	kV
P_{tot}	Total power dissipation[1]			1.35	W

[1] The (absolute) maximum power dissipation depends on the junction temperature Tj. Higher power dissipation is allowed in conjunction with lower ambient temperatures. The conditions to determine the specified values are T_{amb} = 25 °C and the use of a two-layer PCB

9 Recommended operating conditions

Table 6. Recommended Operating Conditions

Explanation	Pin	Conditions	Min	Max	Unit
Voltage range (with respect to GND)	VSYS		2.5	+5.5	V
	VBUS		0	+22	V
	FLAG, CP_EN		0	+5.5	V
	CC1, CC2, CON_CC1, CON_CC2		0	+5.5	V
CC current	CON_CC1, CON_CC2, CC1, CC2		-200	+200	mA
Ambient temperature			-40	85	°C

10 Thermal characteristics

Table 7. Thermal characteristics

Symbol	Parameter	Conditions		Typ	Unit
Rth(j-a)	thermal resistance from junction to ambient		[1] [2]	72.3	°C/W

[1] The overall Rth(j-a) can vary depending on the board layout. To minimize the effective Rth(j-a), all pins must have a solid connection to larger Cu layer areas e.g. to the power and ground layer. In multi-layer PCB applications, the second layer should be used to create a large heat spreader area right below the device. If this layer is either ground or power, it should be connected with several vias to the top layer connecting to the device ground or supply. Try not to use any solder-stop varnish under the chip

[2] This Rth(j-a) is calculated based on JEDEX2S2P board. The actual Rth(j-a) value may vary in applications using different layer stacks and layouts.

11 Electrical characteristics

11.1 Static characteristics

Table 8. Static characteristics

Unless otherwise specified, VSYS = 3.6 V, VBUS = 5 V, C_{VSYS} = 1 µF, T_{amb} = -40 °C to +85 °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supply current / Leakage current						
$V_{SYSUVLO}$	VSYS Under Voltage Lockout	Falling, 100 mV hysteresis	2.14	2.27	2.40	V
I_{SYS_STDBY}	Standby current	V_{SYS} = 3.6 V, CCx = 5.1 kΩ, CON_CCx floating, CP_EN = H		13	20	µA
I_{SYS_STDBY}	Standby current	V_{SYS} = 3.6 V, CCx = 3.6 V, CON_CCx floating, CP_EN = H		13	20	µA
I_{SYS_ACTIVE}	Active Current	V_{SYS} = 3.6 V, CCx = 5.1 kΩ, CON_CCx floating, CP_EN = L		44	60	µA
I_{VBUS}	VBUS leakage current	V_{SYS} = 3.6 V, VBUS = 5.0 V		4	10	µA
I_{CC_Leak}	Leakage current for CC1, CC2	V_{SYS} = 3.6 V, CCx = 3.0 V, CON_CCx floating, V_{SYS} > VCCx + 0.6 V. Switch OFF		0.5	2	µA
	Leakage current for CC1, CC2	V_{SYS} = 3.6 V, CCx = 3.6 V, CON_CCx floating, Switch OFF		0.5	5	µA
CC switcher						
R_{on_CC}	On resistance	V_{SYS} = 3.6 V, CCx = 5.5 V, I_{CON_CCx} = 200 mA, Switch ON	-	230	400	mΩ
R_{on_Flat}	On resistance flatness	Sweep CC voltage between 0 V and 3.6 V, I_{CON_CCx} = 200 mA		2	10	mΩ
V_{CLAMPH}	CON_CCx clamping voltage	External 330 µA, VSYS = 0 V	0.9	1.4	2.13	V
V_{CLAMPM}	CON_CCx clamping voltage	External 180 µA, VSYS = 0 V	0.5	0.8	1.2	V
V_{CLAMPD}	CON_CCx clamping voltage	External 80 µA, VSYS = 0 V	0.3	0.7	1.2	V
Rd	Rd resistance on CON_CCx	VSYS = 3.6 V, VCCx = 0 V, CP_EN = H		5.1		kΩ
$Rd_{\_STR}$	Strong Rd resistance on CON_CCx	VSYS = 3.6 V, VCCx = 0 V		150		Ω
V_{OVP}	OVP threshold on CON_CCx	V_{SYS} = 3.6 V, Rising	5.6	5.8	6.0	V
V_{OVP_hys}	OVP threshold hysteresis			100		mV

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
C_{on_cc}	Equivalent on capacitance	Capacitance between CCx/ CON_CCx and GND when Powered up. V_{CCx} = 0 V to 1.2 V, f = 240 MHz		25		pF
BW_{CC}	3dB Bandwidth	Single ended, 50 Ω termination, V_{CCx} = 0.1 V to 1.2 V		100		MHz
Detection						
V_{COMP1}	Comparator 1 threshold	VSYS = 3.6 V	1.28	1.6	1.92	V
V_{COMP2}	Comparator 2 threshold	VSYS = 3.6 V, VCCx > 2.0 V	40	50	60	mV
V_{COMP2}	Comparator 2 threshold	VSYS = 3.6 V, VCCx < 1.0 V	160	200	240	mV
V_{COMP3}	Comparator 3 threshold	VSYS = 3.6 V, VCCx > 2.0 V	1.44	1.8	2.16	V
I_{CC_SRC}	Current source	VSYS = 3.6 V, VCCx > 2.0 V V_{CON_CCx} = 2 V	2	2.5	3.125	µA
V_{VBUS_th}	Valid VBUS detection threshold	Falling	2.6	2.8	3.0	V
$V_{VBUS\_th\_Hys}$	VBUS detection hysteresis			500		mV
FLAGB						
V_{OL}	Output low voltage	I_{OL} = 5 mA			0.3	V
I_{OH}	High level leakage current	V_{FLAG} = 5.5 V, VSYS = 5.5 V			1	µA
CP_EN						
V_{IH}	Valid input high		1.5			V
V_{IL}	Valid input low				0.4	V
I_{IH}	Input leakage current	VSYS = 3.6 V, V_{CP_EN} = 3.6 V			1	µA
Over Temperature						
T_{OTP}	Over temperature			125		°C
T_{OTP_hys}	Over temperature hysteresis		-	10	-	°C

11.2 Dynamic characteristics

Table 9. Dynamic characteristics

Unless otherwise specified, VSYS = 3.6 V, VBUS = 5 V, C_{VSYS} = 1 µF, T_{amb} = -40 °C to +85 °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Switch Dynamic Characteristics						
t_{pwrup}	Power up time from Valid power source of VSYS			2	4	ms

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{OVP_res}	OVP response time	Time from OVP trip to 80 % of the trip voltage after OVP FET turn-off; Load 50 Ω to GND on CCx; CON_CCx voltage slope is 40 V		60		ns
t_{OVP_deb}	Minimum time to exit OVP shutdown	CON_CCx voltage should be lower than OVP threshold for this time		50		µs
$t_{CC\_SW\_ON}$	CC switch enable time after accessory detected	90 % of V_{CON_CCx}, V_{CON_CCx}=2 V, I_{CC}=330 µA		500	800	µs
$t_{CC\_OFF\_VBUS}$	CC switch OFF time after VBUS is removed		1.6	2.5		sec
t_{OTP_deb}	Minimum time to exit Over Temperature	[1]		30		µs
t_{FLAG_RES}	Time to FLAG assertion from water impedance detected	[1]		20		µs
t_{CC_delay}	Logic delay to transfer CCx voltage to CONN_CCx				100	µs
t_{CC_deb}	Debounce time for comparators			2		ms
t_{Rd_OFF}	Rd off time after CC switch is turned on			2		ms
t_{SRC_WAIT}	Wait time to check comparator at source mode			1		ms
t_{Rp_OFF}	I_{CC_SRC} off time after CC switch is turned on			2		ms
$t_{Rd\_STR\_ON}$	Rd_STR ON time after transition to Wait.SRC			3		ms
t_{SRC_OFF}	I_{SRC} off time			1		ms

[1] No production test, guaranteed by design

12 Package outline

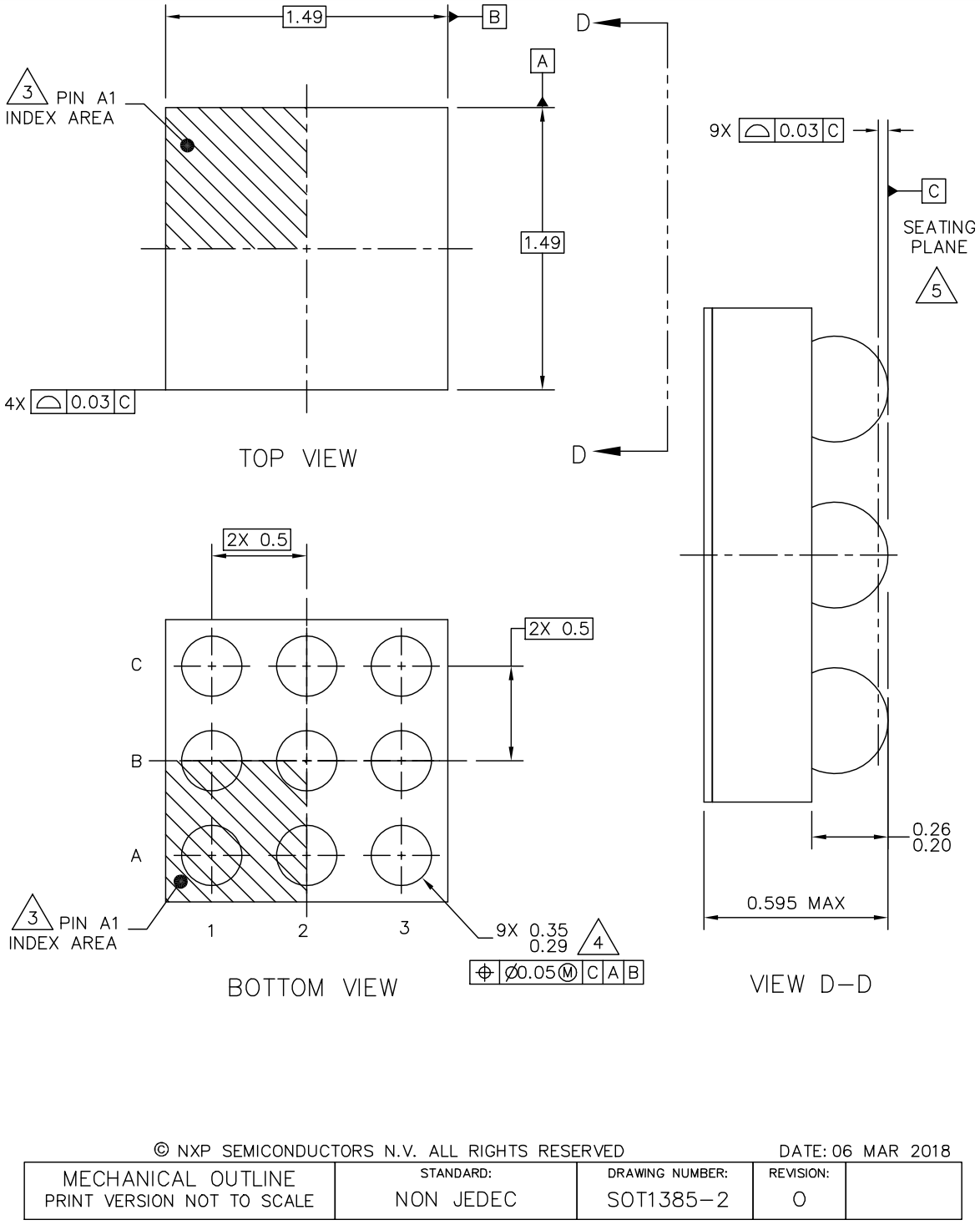

Figure 13. Package outline SOT1385-2 (WLCSP9)

13 Revision history

Table 10. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
NX20P0477 v.1.0	20200203	Product data sheet	-	-

14 Legal information

14.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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Tables

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