TPD4S201 USB Type-C® 20V SPR Port Protector: Short-to-VBUS Overvoltage and IEC ESD Protection

1 Features

- 4-channels of short-to-V_{BUS} overvoltage protection (CC1, CC2, SBU1, SBU2): 28V_{DC} tolerant
- 4-channels of IEC 61000-4-2 ESD protection (CC1, CC2, SBU1, SBU2)
- CC1 and CC2 overvoltage protection FETs for passing V_{CONN} power
- ± 35V surge protection on CC pins
- ± 35V surge protection on SBU pins
- CC dead battery resistors integrated for handling dead battery use case

2 Applications

- Desktop PC/motherboard
- Standard notebook PC
- Chromebook and WOA
- Docking station
- Port/cable adapters and dongles
- Smartphones

3 Description

The TPD4S201 is a single-chip USB Type-C port protection device that provides 28V short-to-V_{BUS} overvoltage and IEC ESD protection.

Since the release of the USB Type-C connector, many products and accessories for USB Type-C have been released that do not meet the USB Type-C specification. Another concern for USB Type-C is that mechanical twisting and sliding of the connector shorting pins due to the close proximity they have in this small connector. This mechanical twisting nad sliding of the connector causes 28V V_{BUS} to be shorted to the CC and SBU pins. Due to the proximity of the pins in the Type-C connector, there is a heightened concern of a short to the CC, SBU or USB2 pin to the the 28V V_{BUS} pin caused by debris and moisure.

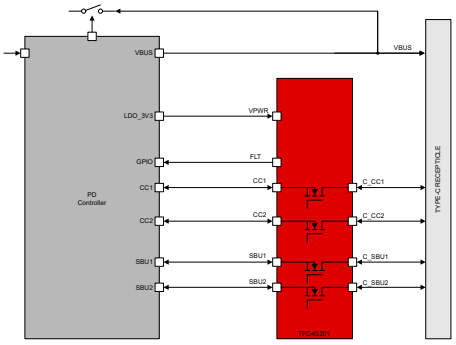
These non-ideal equipments and mechanical events make it necessary for the CC and other pins to be 28V tolerant, even though the pins only operate at 5V or lower. The TPD4S201 enables the CC and SBU or USB2 pins to be 28V tolerant without interfering with normal operation by providing overvoltage protection on the CC and SBU pins. The device places high voltage FETs in series on the SBU and CC lines. For systems not using alternate modes with SBU communication, the SBU pins of the TPD4S201 are available for to protect the USB2 data lines instead. When a voltage above the OVP threshold is detected on these lines, the high voltage switches are opened up, isolating the rest of the system from the high voltage condition present on the connector.

Finally, most systems require IEC 61000-4-2 system level ESD protection for external pins. The TPD4S201 integrates IEC 61000-4-2 ESD protection for the CC1, CC2, SBU1, and SBU2 pins, eliminating the need to place high voltage TVS diodes externally on the connector.

Package Information

PART NUMBER	PACKAGE(1)	BODY SIZE (NOM)
TPD4S201	RUK (WQFN, 20)	3mm × 3mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.



CC and SBU Overvoltage Protection

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4 Pin Configuration and Functions

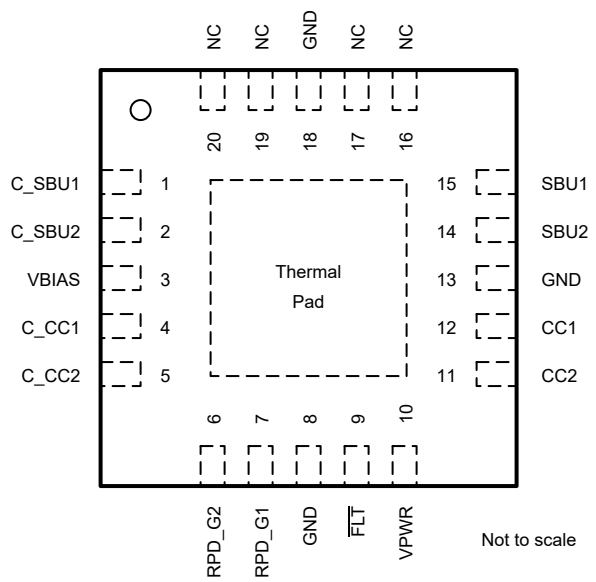


Figure 4-1. TPD4S201 RUK Package, 20-Pin QFN

Table 4-1. Pin Functions

PIN		TYPE[1]	DESCRIPTION
NO.	NAME		
12	CC1	I/O	System side of the CC1 OVP FET. Connect to either CC pin of the CC/PD controller.
11	CC2	I/O	System side of the CC2 OVP FET. Connect to either CC pin of the CC/PD controller.
4	C_CC1	I/O	Connector side of the CC1 OVP FET. Connect to either CC pin of the USB Type-C connector.
5	C_CC2	I/O	Connector side of the CC2 OVP FET. Connect to either CC pin of the USB Type-C connector.
1	C_SBU1	I/O	Connector side of the SBU1 OVP FET. Connect to either SBU pin of the USB Type-C connector. Alternatively, connect to either USB2.0 pin of the USB Type-C connector to protect the USB2.0 pins instead of the SBU pins.
2	C_SBU2	I/O	Connector side of the SBU2 OVP FET. Connect to either SBU pin of the USB Type-C connector. Alternatively, connect to either USB2.0 pin of the USB Type-C connector to protect the USB2.0 pins instead of the SBU pins.
15	SBU1	I/O	System side of the SBU1 OVP FET. Connect to either SBU pin of the SBU MUX. Alternatively, connect to either USB2.0 pin of the USB2.0 Phy when protecting the USB2.0 pins instead of protecting the SBU pins.
14	SBU2	I/O	System side of the SBU2 OVP FET. Connect to either SBU pin of the SBU MUX. Alternatively, connect to either USB2.0 pin of the USB2.0 Phy when protecting the USB2.0 pins instead of protecting the SBU pins.
7	RPD_G1	I/O	Short to C_CC1 if dead battery resistors are needed. If dead battery resistors are not needed, short pin to GND.
6	RPD_G2	I/O	Short to C_CC2 if dead battery resistors are needed. If dead battery resistors are not needed, short pin to GND.
9	$\overline{\text{FLT}}$	O	Open drain for fault reporting.
8, 13, 18	GND	GND	Ground
3	VBIAS	P	Pin for ESD support capacitor. Place a 0.1-µF capacitor on this pin to ground.
10	VPWR	P	2.7V to 4.5V power supply.
20	NC	-	No connect, leave floating or grounded

Table 4-1. Pin Functions (continued)

PIN		TYPE[1]	DESCRIPTION
NO.	NAME		
19	NC	-	No connect, leave floating or grounded
16	NC	-	No connect, leave floating or grounded
17	NC	-	No connect, leave floating or grounded
-	Thermal Pad	GND	Internally connected to GND. Used as a heatsink. Connect to the PCB GND plane

(1) I = input, O = output, I/O = input and output, GND = ground, P = power

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

			MIN	MAX	UNIT
V_I	Input voltage	VPWR	-0.3	5	V
		RPD_G1, RPD_G2	-0.3	28	V
V_O	Output voltage	$\overline{FLT}$	-0.3	6	V
		VBIAS	-0.3	28	V
V_{IO}	I/O voltage	CC1, CC2, SBU1, SBU2	-0.3	6	V
		C_CC1, C_CC2, C_SBU1, C_SBU2	-0.3	28	V
t_{rise}	Input voltage rise time (V_I > 36V)	CC1, CC2, SBU1, SBU2	400		ns
T_J	Operating junction temperature		-40	125	°C
T_{stg}	Storage temperature		-65	150	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

5.2 ESD Ratings—JEDEC Specification

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001	±2000	V
$V_{(ESD)}$	Electrostatic discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101	Charged-device model (CDM), per JEDEC specification JESD22-C101	±500	V

5.3 ESD Ratings—IEC Specification

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2, C_CC1, C_CC2	Contact discharge	±8000	V
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2, C_CC1, C_CC2	Air-gap discharge	±15000	V
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2, C_SBU1, C_SBU2	Contact discharge	±8000	V
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2, C_SBU1, C_SBU2	Air-gap discharge	±15000	V
$V_{(Surge)}$	Lightning and Surge	IEC 61000-4-5, C_CC1, C_CC2		±35	V
		IEC 61000-4-5, C_SBU1, C_SBU2		±35	V

5.4 Recommended Operating Conditions

			MIN	NOM	MAX	UNIT
V_I	Input voltage	VPWR	2.7	3.3	4.5	V
V_I	Input voltage	RPD_G1, RPD_G2	0		5.5	V
V_O	Output voltage	$\overline{FLT}$ Pull-up resistor power rail	2.7		5.5	V
V_{IO}	I/O voltage	CC1, CC2, C_CC1, C_CC2	0		5.5	V
		SBU1, SBU2, C_SBU1, C_SBU2	0		4.3	V
I_{VCONN}	V_{CONN} Current	Current flowing into CC1/2 and flowing out of C_CC1/2, $T_J \le 105$ °C			600	mA
I_{VCONN}	V_{CONN} Current	Current flowing into CC1/2 and flowing out of C_CC1/2, $T_J \le 85$ °C			1.25	A
T_J	Operating Junction Temperature		-40		125	°C

5.4 Recommended Operating Conditions (continued)

			MIN	NOM	MAX	UNIT
External Components[1]	External Components[1]	$\overline{FLT}$ Pull-up resistance	1.7		300	kΩ
		VBIAS capacitance [2]	0.04	0.1	0.14	µF
		VPWR Capacitance	0.3	1		µF
		VBUS_LV Capacitance		0.1		µF

(1) For recommended values for capacitors and resistors, the typical values assume a component placed on the board near the pin. Minimum and maximum values listed are inclusive of manufacturing tolerances, voltage derating, board capacitance, and temperature variation. Enable the effective value presented to be within the minimum and maximums listed in the table.

(2) The VBIAS pin requires a minimum 63-VDC rated capacitor. A 100-VDC rated capacitor is recommended to reduce capacitance derating.
See the VBIAS Capacitor Selection section for more information on selecting the VBIAS capacitor.

5.5 Thermal Information

THERMAL METRIC[1]		QFN 20 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	44.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	41.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	17.7	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	17.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	7.9	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.

5.6 Electrical Characteristics

over operating junction temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
CC OVP Switches						
R_{ON}	On Resistance of CC OVP FETs	CCx = 5.5V, $T_J \le 85$ °C		272	420	mΩ
C_{ON_CC}	Equivalent on Capacitance	Capacitance from CCx or C_CCx to GND when device is powered. Measure at V_{C_CCx}/V_{CCx} = 0V to 1.2V, f = 400kHz.	40	74	120	pF
RD_DB	Dead Battery Pull-Down Resistors (only present when device is unpowered)	V_{C_CCx} = 2.6V	4.1	5.1	6.1	kΩ
VTH_DB	Threshold voltage of the pull-down FET in series with RD during dead battery	I_{C_CCx} = 80µA	0.5	0.9	1.2	V
V_{OVPCC}	OVP Threshold on CC Pins	Place 5.5V on C_CCx. Step up C_CCx until $\overline{FLT}$ pin is asserted. Put 100mA load through the CC FET and see the FET shuts off.	5.6	5.9	6.2	V
V_{OVPCC_HYS}	Hysteresis on CC OVP	Place 6.5 V on C_CCx. Step down the voltage on C_CCx until the FLT pin is deasserted. Measure difference between rising and falling OVP threshold for C_CCx.		50		mV
BW_{ON}	On Bandwidth Single Ended (-3dB)	Measure the -3 dB bandwidth from C_CCx to CCx. Single ended measurement, 50-Ω system. Vcm = 0.1V to 1.2 V.		125		MHz
V_{STBUS_CC}	Short-to-VBUS tolerance on the CC pins	Hot-Plug C_CCx with a 1 meter USB Type C Cable, place a 30-Ω load on CCx			21.5	V
$V_{STBUS\_CC\_CLAMP}$	Short-to-VBUS System-Side Clamping Voltage on the CC pins (CCx)	Hot-Plug C_CCx with a 1 meter USB Type C Cable. Hot-Plug voltage C_CCx = 51 V. VPWR = 3.3 V. Place a 30-Ω load on CCx.		7		V

5.6 Electrical Characteristics (continued)

over operating junction temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SBU OVP Switches						
R_{ON}	On Resistance of SBU OVP FETs	SBUx = 3.6 V. –40°C ≤ TJ ≤ +85°C		4	6.8	Ω
C_{ON_SBU}	Equivalent on Capacitance	Capacitance from SBUx or C_SBUx to GND when device is powered. Measure at V_{C_SBUx}/V_{SBUx} = 0.3V to 4.0V.		6		pF
V_{OVPSBU}	OVP Threshold on SBU Pins	Place 3.6V on C_SBUx. Step up C_SBUx until $\overline{FLT}$ pin is asserted.	4.0	4.2	4.41	V
V_{OVPSBU_HYS}	Hysteresis on SBU OVP	Place 5 V on C_CCx. Step down the voltage on C_CCx until the FLT pin is deasserted. Measure difference between rising and falling OVP threshold for C_SBUx.		50		mV
BW_{ON}	On Bandwidth Single Ended (-3dB)	Measure the -3 dB bandwidth from C_SBUx to SBUx. Single ended measurement, 50Ω system. Vcm = 0.1V to 3.6V.	600	760		MHz
X_{TALK}	Crosstalk	Measure crosstalk at f = 1 MHz from SBU1 to C_SBU2 or SBU2 to C_SBU1. Vcm1 = 3.6 V, Vcm2 = 0.3 V. Terminate open sides to 50Ω.		-70		dB
V_{STBUS_SBU}	Short-to-VBUS tolerance on the SBU pins	Hot-Plug C_SBUx with a 1 meter USB Type C Cable. Put a 100-nF capacitor in series with a 40-Ω resistor to GND on SBUx.			21.5	V
$V_{STBUS\_SBU\_CLAMP}$	Short-to-VBUS System-Side Clamping Voltage on the SBU pins (SBUx)	Hot-Plug C_SBUx with a 1 meter USB Type C Cable. Hot-Plug voltage C_SBUx = 51V. VPWR = 3.3 V. Put a 150-nF capacitor in series with a 40-Ω resistor to GND on SBUx.		7		V
Power Supply and Leakage Currents						
V_{PWR_UVLO}	V_{PWR} Undervoltage Lockout	Place 1 V on VPWR and raise voltage until SBU or CC FETs turn-on.	2.1	2.3	2.6	V
$V_{PWR\_UVLO\_HYS}$	V_{PWR} UVLO Hysteresis	Place 3 V on VPWR and lower voltage until SBU or CC FETs turnoff; measure difference between rising and falling UVLO to calculate hysteresis.	70	100	130	mV
I_{VPWR}	V_{PWR} supply current	VPWR = 3.3 V (typical), VPWR = 4.5 V (maximum). –40°C ≤ T_J ≤ +85°C.		112	160	µA
$I_{C\_CC\_LEAK}$	Leakage current for C_CCx pins when device is powered	VPWR = 3.3 V, V_{C_CCx} = 3.6 V, CCx pins are floating, measure leakage current into C_CCx pins.			5	µA
$I_{C\_SBU\_LEAK}$	Leakage current for C_SBUx pins when device is powered	VPWR = 3.3 V, VC_SBUx = 3.6 V, SBUx pins are floating, measure leakage current into C_SBUx pins. Result should be same if SBUx side is biased and C_SBUx is left floating.-40°C ≤ T_J ≤ +85°C			3.2	µA
$I_{C\_CC\_LEAK\_OVP}$	Leakage current for C_CCx pins when device is in OVP	VPWR = 0 V or 3.3 V, V_{C_CCx} = 51 V, CCx pins are set to 0 V, measure leakage current into C_CCx pins.			1200	µA
$I_{C\_SBU\_LEAK\_OVP}$	Leakage current for C_SBUx pins when device is in OVP	VPWR = 0 V or 3.3 V, V_{C_SBUx} = 51 V, SBUx pins are set to 0 V, measure leakage current into C_SBUx pins.			720	µA
$I_{CC\_LEAK\_OVP}$	Leakage current for CC pins when device is in OVP	VPWR = 0 V or 3.3 V, V_{C_CCx} = 51 V, CCx pins are set to 0 V, measure leakage current out of CCx pins.			30	µA
$I_{SBU\_LEAK\_OVP}$	Leakage current for SBU pins when device is in OVP	VPWR = 0 V, V_{C_SBUx} = 51 V, SBUx pins are set to 0 V, measure leakage current into SBUx pins.	-1		1	µA
/FLT Pin						
V_{OL}	Low-level output voltage	IOL = 3mA. Measure voltage at $\overline{FLT}$ pin.			0.4	V
Over Temperature Protection						

5.6 Electrical Characteristics (continued)

over operating junction temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T_{SD_RISING}	The rising over-temperature protection shutdown threshold		150	175		°C
$T_{SD\_FALLING}$	The falling over-temperature protection shutdown threshold		130	140		°C
T_{SD_HYST}	The over-temperature protection shutdown threshold hysteresis			35		°C

5.7 Timing Requirements

		MIN	NOM	MAX	UNIT
Power-On and Off Timings					
t_{ON_FET}	Time from Crossing Rising VPWR UVLO until CC and SBU OVP FETs are on.		1.3	3.5	ms
$t_{ON\_FET\_DB}$	Time from Crossing Rising VPWR UVLO until CC and SBU OVP FETs are on and the dead battery resistors are off.		5.7	9.5	ms
dV_{PWR_OFF}/dt	Minimum slew rate for CC and FETs turn off during a power off.	-0.5			V/µs
Overvoltage Protection					
$t_{OVP\_RESPONSE\_CC}$	OVP response time on the CCx pins. Time from OVP asserted until OVP FETs turn off.		70		ns
$t_{OVP\_RESPONSE\_SBU}$	OVP response time on the SBUx pins. Time from OVP asserted until OVP FETs turn off.		80		ns
$t_{OVP\_RECOVERY\_CC}$	OVP recovery time on the CCx pins. Once an OVP has occurred, the minimum time duration until the CC FETs turn back on. Remove OVP for CC FETs to turn back on.		0.9	2.3	ms
$t_{OVP\_RECOVERY\_CC\_DB}$	OVP recovery time on the CCx pins. Once an OVP has occurred, the minimum time duration until the CC FETs turn back on and the dead battery resistors turn off. Remove OVP for CC FETs to turn back on.		5		ms
$t_{OVP\_RECOVERY\_SBU}$	OVP recovery time on the SBUx pins. Once an OVP has occurred, the minimum time duration until the SBU FETs turn back on. Remove OVP for SBU FETs to turn back on.		0.62		ms
$t_{OVP\_FLT\_ASSERTION}$	Time from OVP Asserted to /FLT assertion. $\overline{FLT}$ assertion is 10% of the maximum value. Set C_CCx or C_SBUx above the maximum OVP threshold. Start the time where it passes the typical OVP threshold value.		20		µs
$t_{OVP\_FLT\_DEASSERTION}$	Time from CC FET turn on after an OVP to $\overline{FLT}$ deassertion.		5		ms

5.8 Typical Characteristics

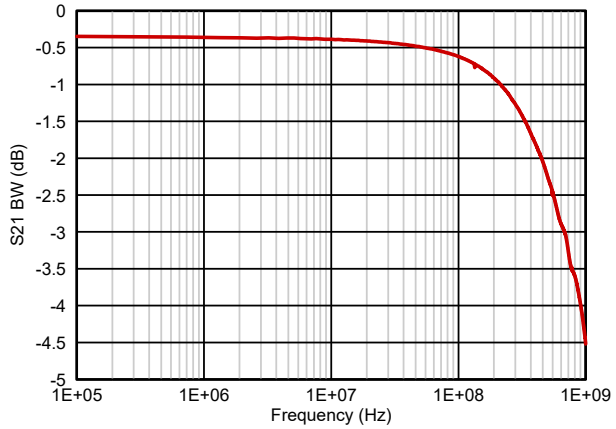


Figure 5-1. SBU Bandwidth

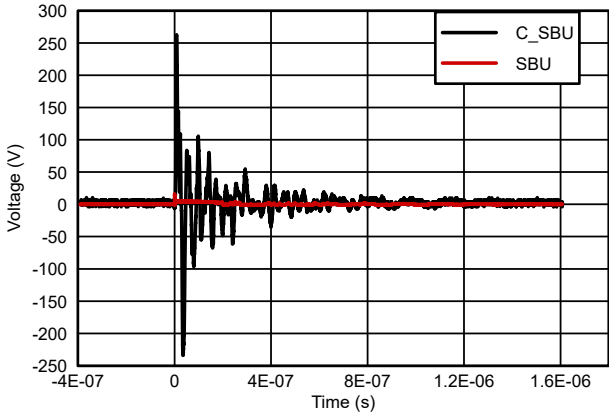


Figure 5-2. SBU IEC 61000-4-2 4kV Response Waveform

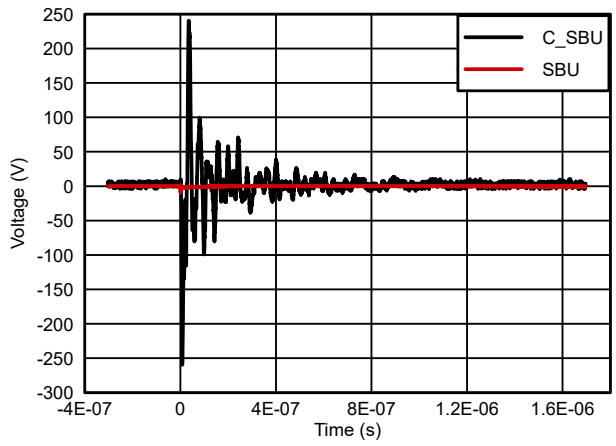


Figure 5-3. SBU IEC 61000-4-2 –4kV Response Waveform

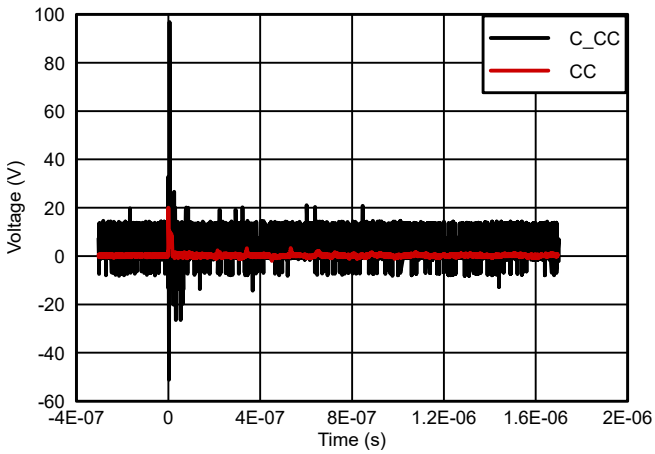


Figure 5-4. CC IEC 61000-4-2 8kV Response Waveform

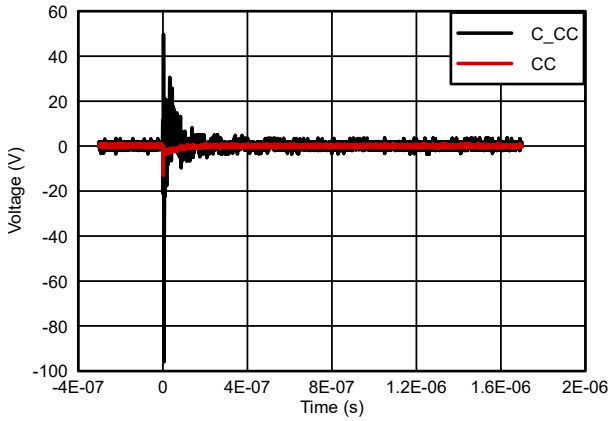


Figure 5-5. CC IEC 61000-4-2 –8kV Response Waveform

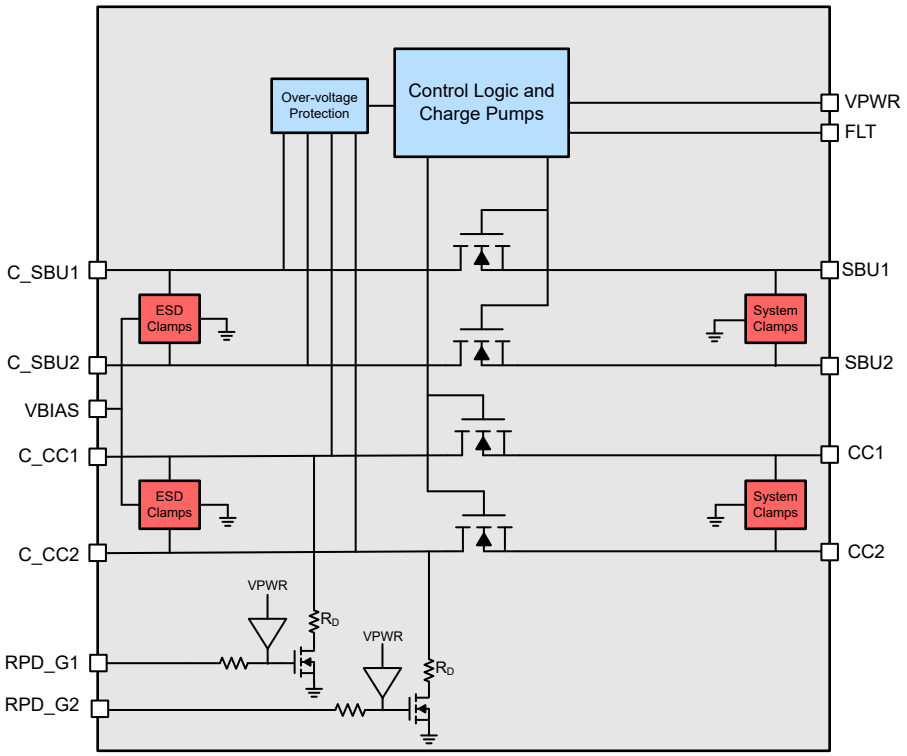
6 Detailed Description

6.1 Overview

The TPD4S201 is a single chip USB Type-C port protector that provides 28V short-to-V_{BUS} overvoltage and ESD protection. Due to the small pin pitch of the USB Type-C connector and non-compliant USB Type-C cables and accessories, the V_{BUS} pins short to the CC and SBU pins inside the USB Type-C connector. Because of this short-to-V_{BUS} event, the CC and SBU pins need to be 28V tolerant, to support protection on the full USB PD-SPR voltage range. The TPD4S201 integrates four channels of 28V short-to-V_{BUS} overvoltage protection for the CC1, CC2, SBU1, and SBU2 pins of the USB Type-C connector.

Additionally, IEC 61000-4-2 system level ESD protection is required to protect a USB Type-C port from ESD strikes generated by end product users. The TPD4S201 integrates four channels of IEC61000-4-2 ESD protection for the CC1, CC2, SBU1, and SBU2 pins of the USB Type-C connector, providing ESD protection for all of the low-speed pins on the USB Type-C connector in a single chip. Additionally, high-voltage ESD protection that is 21.5V DC tolerant is required for the CC and SBU lines to simultaneously support ESD and short-to-V_{BUS} protection. The TPD4S201 integrates a high-voltage ESD diode designed to work in conjunction with the overvoltage protection FETs inside the device.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 4-Channels of Short-to-V_{BUS} Overvoltage Protection (CC1, CC2, SBU1, SBU2 Pins or CC1, CC2, DP, DM Pins): 28-V_{DC} Tolerant

The TPD4S201 provides 4-channels of short-to-V_{BUS} Overvoltage Protection for the CC1, CC2, SBU1, and SBU2 pins (or the CC1, CC2, DP, and DM pins) of the USB Type-C connector. The TPD4S201 is able to handle $28V_{DC}$ on its C_CC1, C_CC2, C_SBU1, and C_SBU2 pins. This level of protection is necessary because according to the USB PD specification, with V_{BUS} set for 20-V operation, the V_{BUS} voltage is allowed to legally swing up to 21V and 21.2V on voltage transitions from a different USB PD V_{BUS} voltage. The TPD4S201 builds in tolerance up to $28V_{BUS}$ to provide margin above this 21.2V specification to support inductive rining that occurs during a short event.

When a short-to-V_{BUS} event occurs, ringing happens due to the RLC elements in the hot-plug event. Ringing up to twice the settling voltage appears on the connector if the resistance is low in the RLC circuit. Ringing of more than twice the DC level is generated if any capacitor on the line derates in capacitance value during the short-to-V_{BUS} event. This behavior means that more than 38V is seen on a USB Type-C pin during a short-to-V_{BUS} event. The TPD4S201 has built in circuit protection to handle this ringing. The diode clamps used for IEC ESD protection also clamp the ringing voltage during the short-to-V_{BUS} event to limit the peak ringing to approximately 28V. Additionally, the overvoltage protection FETs integrated inside the TPD4S201 are 28V tolerant, therefore being capable of supporting the high-voltage ringing waveform that is experienced during the short-to-V_{BUS} event. The TPD4S201 handles short-to-V_{BUS} hot-plug events with hot-plug voltages as high as 21.5V_{DC} because of the well-designed combination of voltage clamps and 28V tolerant OVP FETs.

The TPD4S201 has an extremely fast turnoff time of 70ns typical. Furthermore, additional voltage clamps are placed after the OVP FET on the system side (CC1, CC2, SBU1, SBU2) pins of the TPD4S201, to further limit the voltage and current that are exposed to the USB Type-C CC/PD controller during the 70ns interval while the OVP FET is turning off. The combination of connector side voltage clamps, OVP FETs with extremely fast turnoff time, and system side voltage clamps all work together to enable the level of stress seen on a CC1, CC2, SBU1, or SBU2 pin during a short-to-V_{BUS} event to be less than or equal to an HBM event.

The SBU OVP FETs are designed to be able to optionally protect the DP, DM (USB2.0) pins in lieu of the SBU pins. Some systems designers also prefer to protect the DP, DM pins from short-to-V_{BUS} events due to the potential for moisture/water in the connector to short the V_{BUS} pins to DP, DM pins. This protection is applicable in cases where the end equipment with a USB Type-C connector is trying to be made water-proof. If desiring to protect the DP, DM pins on the USB Type-C connector from a short-to-V_{BUS} event, connect the C_SBUx pins to the DP, DM pins on the USB Type-C connector, and the SBUx pins to the USB2.0 pins of the system device being protected from the short-to-V_{BUS} event.

6.3.2 CC1, CC2 Overvoltage Protection FETs 600-mA Capable for Passing VCONN Power

The CC pins on the USB Type-C connector serve many functions; one of the functions is to be a provider of power to active cables. Active cables are required when desiring to pass greater than 3 A of current on the V_{BUS} line or when the USB Type-C port uses the super-speed lines (TX1+, TX2–, RX1+, RX1–, TX2+, TX2–, RX2+, RX2–). When CC is configured to provide power, it is called VCONN. VCONN is a DC voltage source in the range of 3V to 5.5V. If supporting VCONN, enable the VCONN provider to have the capability to provide 1.5 W of power to a cable; this translates into a current range of 273mA to 500mA (depending on the VCONN voltage level).

When a USB Type-C port is configured for VCONN and using the TPD4S201, this VCONN current flows through the OVP FETs of the TPD4S201. Therefore, the TPD4S201 has been designed to handle these currents and have an RON low enough to provide a specification compliant VCONN voltage to the active cable.

6.3.3 CC Dead Battery Resistors Integrated for Handling the Dead Battery Use Case in Mobile Devices

An important feature of USB Type-C and USB PD is the ability for this connector to serve as the sole power source to mobile devices. With support up to 240W, the USB Type-C connector supporting USB PD powers a whole new range of mobile devices not previously possible with legacy USB connectors.

When the USB Type-C connector is the sole power supply for a battery powered device, enable the device to charge from the USB Type-C connector even when its battery is dead. In order for a USB Type-C power adapter to supply power on V_{BUS}, expose RD pulldown resistors on the CC pins. These RD resistors are typically included inside a USB Type-C CC/PD controller. However, when the TPD4S201 is used to protect the USB Type-C port, the OVP FETs inside the device isolate these RD resistors in the CC/PD controller when the mobile device has no power. When the TPD4S201 has no power, the OVP FETs are turned off to provide overvoltage protection in a dead battery condition. Therefore, the TPD4S201 integrates high-voltage, dead battery RD pull-down resistors to allow dead battery charging simultaneously with high-voltage OVP protection.

If dead battery support is required, short the RPD_G1 pin to the C_CC1 pin, and short the RPD_G2 pin to the C_CC2 pin. This short connects the dead battery resistors to the connector CC pins. When the TPD4S201 is unpowered, and the RP pull-up resistor is connected from a power adapter, this RP pull-up resistor activates

the RD resistor inside the TPD4S201, and enables V_{BUS} to be applied from the power adapter even in a dead battery condition. Once power is restored back to the system and back to the TPD4S201 on its VPWR pin, the TPD4S201 turns ON its OVP FETs in 3.5ms and then turns OFF its dead battery RD. The TPD4S201 first turns ON its CC OVP FETs fully, and then removes its dead battery RDs to make sure the PD controller RD is fully exposed before removing the RD of the TPD4S201.

If desiring to power the CC/PD controller during dead battery mode and if the CC/PD Controller is configured as a DRP, it is critical that the TPD4S201 be powered before or at the same time that the CC/PD controller is powered. It is also critical that when unpowered, the CC/PD controller also expose its dead battery resistors. When the TPD4S201 gets powered, it exposes the CC pins of the CC/PD controller within 3.5ms, and then removes its own RD dead battery resistors. Once the TPD4S201 turns on, present the RD pull-down resistors of the CC/PD controller immediately in order to maintain a connection. If the power adapter does not see RD present, the V_{BUS} disconnects. This event removes power from the device with its battery still not sufficiently charged, which consequently removes power from the CC/PD controller and the TPD4S201. Then the RD resistors of the TPD4S201 are exposed again, and connects the V_{BUS} of the power adapter to start the cycle over.

If the CC/PD Controller is configured for DRP and has started to DRP toggle before the TPD4S201 turns on, this DRP toggle is unable to maintain a connection with a power adapter. If the CC/PD controller is configured for DRP, the dead battery resistors of the PD controller need to be exposed as well, and that the resistors remain exposed until the TPD4S201 turns on. This behavior is typically accomplished by powering the TPD4S201 at the same time as the CC/PD controller when powering the CC/PD controller in dead battery operation.

If dead battery charging is not required in your application, connect the RPD_G1 and RPD_G2 pins to ground.

6.4 Device Functional Modes

The Device Mode Table describes all of the functional modes for the TPD4S201. The "X" in the below table are "don't care" conditions, meaning the value present maintains functional mode and is within the absolute maximum ratings of the data sheet.

Table 6-1. Device Mode Table

Device Mode Table		Inputs					Outputs		
MODE		VPWR	C_CCx	C_SBUx	RPD_Gx	T_J	$\overline{FLT}$	CC FETs	SBU FETs
Normal Operating Conditions	Unpowered, no dead battery support	<UVLO	X	X	Grounded	X	High-Z	OFF	OFF
	Unpowered, dead battery support	<UVLO	X	X	Shorted to C_CCx	X	High-Z	OFF	OFF
	Powered on, SPR mode	>UVLO	<OVP	<OVP	X, forced OFF	<TSD	High-Z	ON	ON
Fault Conditions	Thermal shutdown	>UVLO	X	X	X, forced OFF	>TSD	Low (Fault Asserted)	OFF	OFF
	CC over voltage condition	>UVLO	>OVP	X	X, forced OFF	<TSD	Low (Fault Asserted)	OFF	OFF
	SBU over voltage condition	>UVLO	X	>OVP	X, forced OFF	<TSD	Low (Fault Asserted)	OFF	OFF
	IEC ESD generated over voltage condition(1)	>UVLO	X	X	R_D ON if RPD_Gx is shorted to C_CCx	<TSD	Low (Fault Asserted)	OFF	OFF

(1) This row describes the state of the device while still in OVP after the IEC ESD strike which put the device into OVP is over, and the voltages on the C_CCx and C_SBUx pins have returned to their normal voltage levels.

7 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

The TPD4S201 provides 4-channels of short-to-V_{BUS} overvoltage protection for the CC1, CC2, SBU1, and SBU2 pins of the USB Type-C connector. The TPD4S201 provides adequate system protection as well as insuring that proper system operation is maintained. The following application example explains how to properly design the TPD4S201 into a USB Type-C system.

7.2 Typical Application

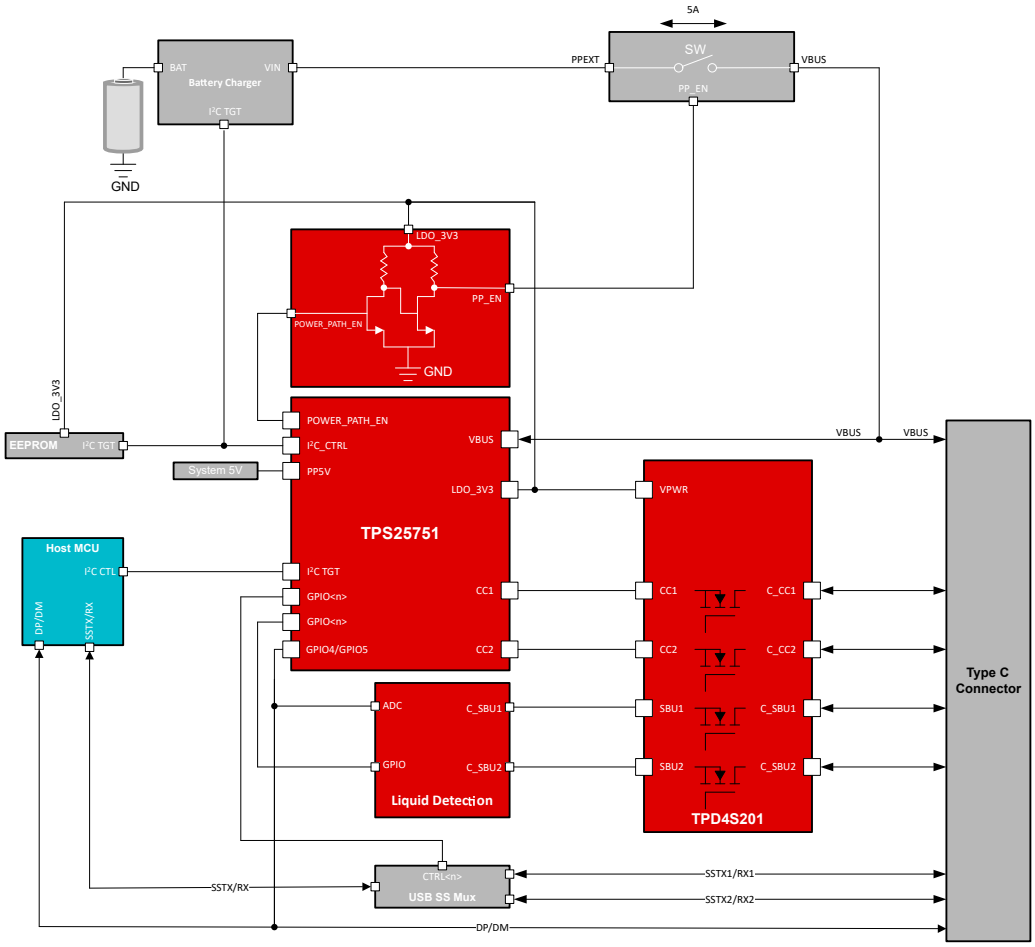


Figure 7-1. TPD4S201Typical Application Diagram

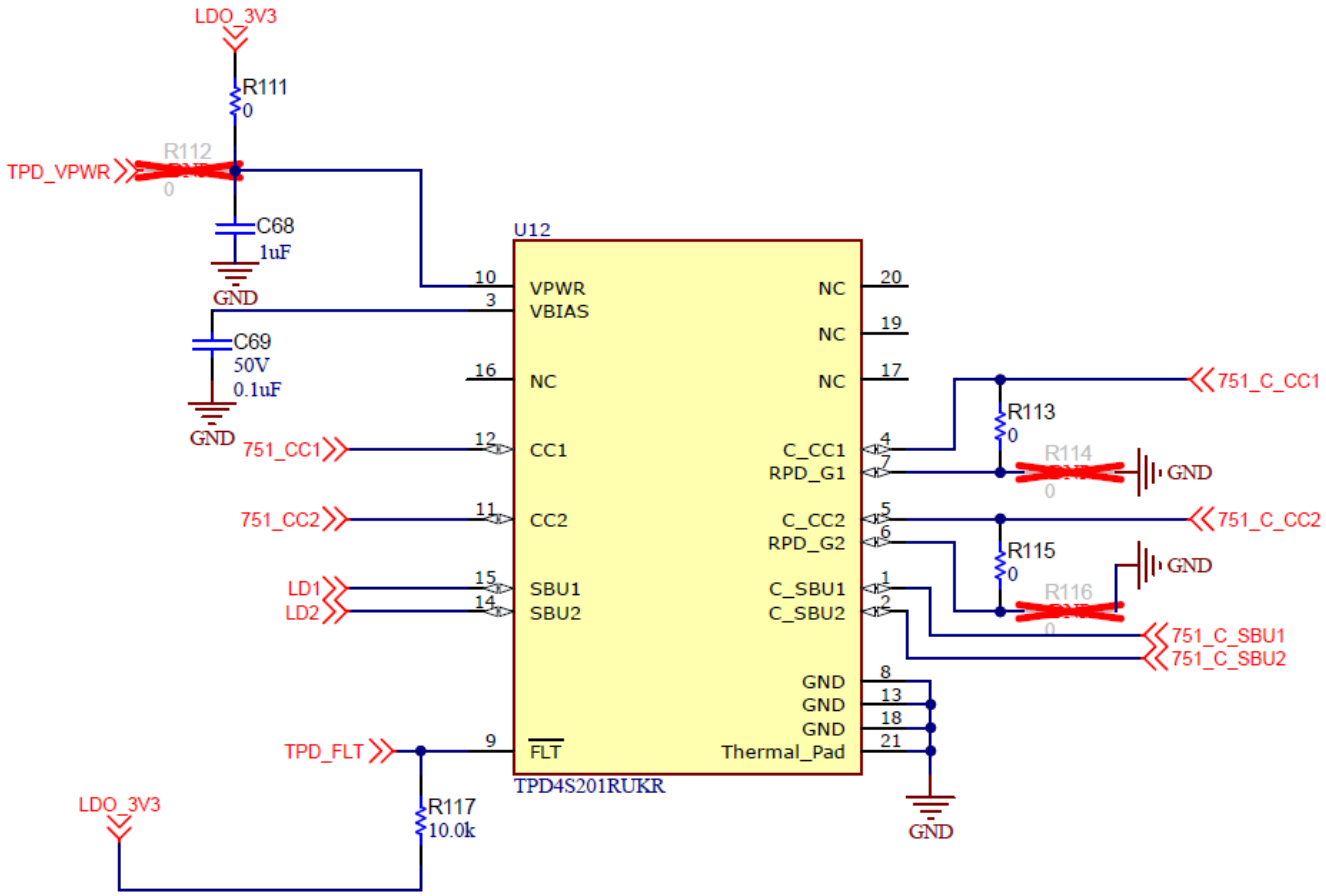


Figure 7-2. TPD4S201 Reference Schematic

7.2.1 Design Requirements

In this application example we study the protection requirements for a USB Type-C DRP Port, fully equipped with USB-PD, and 100W charging. The TPS25751 is used to easily enable a DRP port. Both the CC and SBU pins are susceptible to shorting to the V_{BUS} pin. With 100W charging, V_{BUS} operates at 20V, requiring the CC and SBU pins to tolerate 20V $_{DC}$. With these protection requirements present for the USB Type-C connector, the TPD4S201 is used.

Table 7-1 lists the TPD4S201 design parameters.

Table 7-1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{BUS} nominal operating voltage	20V
Short-to-V_{BUS} tolerance for the CC and SBU pins	28V
VBIAS nominal capacitance	0.1µF
Dead battery charging	100W
Maximum ambient temperature requirement	85°C

7.2.2 Detailed Design Procedure

7.2.2.1 VBIAS Capacitor Selection

As noted in the *Section 5.4* table, a minimum of 28V $_{BUS}$ rated capacitor is required for the VBIAS pin, and a 50V $_{BUS}$ capacitor is recommended. The VBIAS capacitor is in parallel with the central diode clamp integrated inside the TPD4S201. A forward biased hiding diode connects the VBIAS pin to the C_CCx and C_SBUx pins. Therefore, when a short-to-V_{BUS} event occurs at 21V, 21V $_{BUS}$ minus a forward biased diode drop is exposed to the VBIAS pin. Additionally, during the short-to-V_{BUS} event, ringing almost doubles the settling voltage of 21V, allowing a potential 42V to be exposed to the C_CCx and C_SBUx pins. However, the internal diode clamps limit the voltage exposed to the C_CCx and C_SBUx pins to around 28V. Therefore, at least a 28V capacitor is required to avoid the destruction of the VBIAS capacitor during short-to-V_{BUS} events.

A 50V, X7R capacitor is recommended to further improve the derating performance of the capacitors. When the voltage across a real capacitor is increased, the capacitance value derates. The more the capacitor derates, the larger the ringing in the short-to-V_{BUS} RLC circuit. The 50V X7R capacitors have great derating performance, allowing for the best short-to-V_{BUS} performance of the TPD4S201.

7.2.2.2 Dead Battery Operation

For this application, we want to support 100W dead battery operation. When the device is out of battery, dead battery mode is entered. During dead battery mode, enable the USB PD Controller to receive power and apply the maximum charging conditions of 20V and 5A. The TPS25751 has a built in LDO to supply the TPS25751 power from V_{BUS} in a dead battery condition.

The OVP FETs of the TPD4S201 remain OFF when unpowered to provide protection in dead battery or unpowered situations. However, when the OVP FETs are OFF, this isolates the TPS25751s dead battery resistors from the USB Type-C ports CC pins. A USB Type-C power adapter is required to sense the RD pull-down dead battery resistors on the CC pins to provide power on V_{BUS}. Since the dead battery resistors of the TPS25751 are isolated from the USB Type-C connector CC pins, connect the dead battery resistors of the TPD4S201. Short the RPD_G1 pin to the C_CC1 pin, and short the RPD_G2 pin to the C_CC2 pin.

Once the power adapter sees the dead battery resistors of the TPD4S201, 5V is applied on the V_{BUS} pin. The pin provides power to the TPS25751, turning the PD controller on, and allowing the battery to begin to charge. However, this application requires 100W charging in dead battery mode, so V_{BUS} at 20V and 5A is required. USB PD negotiation is required to accomplish this, so the TPS25751 needs to be able to communicate on the CC pins. To expose the PD controller to the CC lines, turn on the TPD4S201 in dead battery mode. To turn on the device, the TPD4S201 is powered by the internal LDO of the TPS25751, the LDO_3V3 pin. When the TPS25751 receives power on V_{BUS}, the TPD4S201 is turned on simultaneously.

The dead battery resistors of the PD controller also need to be present so the PD controller properly boots up in dead battery operation with the correct voltages on the CC pins.

Once this process has occurred, the TPS25751 can start negotiating with the power adapter through USB PD for higher power levels, allowing 100W operation in dead battery mode.

For more information on the TPD4S201 dead battery operation, see the *CC Dead Battery Resistors Integrated for Handling the Dead Battery Use Case in Mobile Devices* section of the data sheet.

7.2.2.3 CC Line Capacitance

USB PD has a specification for the total amount of capacitance that is required for proper USB PD BMC operation on the CC lines.

Table 7-2. USB PD cReceiver Specification

NAME	DESCRIPTION	MIN	MAX	UNIT	COMMENT
cReceiver	CC receiver capacitance	200	600	pF	The DFP or UFP system have capacitance within this range when not transmitting on the line

When USB PD is in use, keep the capacitance of the CC lines between 200pF and 600pF. The combination of capacitances added to the system by the TPS25751, the TPD4S201, and any external capacitor need to fall within these limits.

7.2.2.4 Additional ESD Protection on CC and SBU Lines

If additional IEC ESD protection is desired to be placed on either the CC or SBU lines, it is important that high-voltage ESD protection diodes be used. The maximum DC voltage sensed on the CC or SBU lines in USB PD SPR is 21V, with 21.5V allowed during voltage transitions. To prevent the diode from breaking down during a short-to-V_{BUS} event, use an ESD protection diode that has a reverse stand off voltage higher than 21.5V.

The short-to-V_{BUS} event applies a DC voltage to the CC and SBU pins, do not use a deep-snap-back diode unless its minimum trigger voltage is above 42V. During a short-to-V_{BUS} event, RLC ringing of up to twice the settling voltage is exposed to CC and SBU, allowing for up to 42V to be exposed to the CC and SBU lines. Greater ringing can occur if any capacitor derates on the CC or SBU line. Since this ringing is hard to bound, it is recommended to not use deep-snap-back diodes. If the deep-snap-back diode triggers during the short-to-V_{BUS} hot-plug event, it begins to operate in its conduction region. With a 21V V_{BUS} source present on the CC or SBU line, this allows the diode to conduct indefinitely.

7.2.2.5 $\overline{FLT}$ Pin Operation

Once a short-to-V_{BUS} occurs on the C_CCx or C_SBUx pins, the $\overline{FLT}$ pin is asserted in 20µs (typical) to quickly notify the PD controller. If V_{BUS} is being shorted to CC or SBU, it is recommended to respond to the event by forcing a detach in the USB PD controller to remove V_{BUS} from the port. The TPD4S201 provides protection from these shorting events, but does not protect the other device connected through the USB Type-C Cable or any active circuitry in the cable. Although shutting the V_{BUS} off through a detach does not always stop the other device or cable from being damaged, it mitigates any high current paths from causing further damage after the initial damage. Additionally, even if the active cable or other device does have proper protection, the short-to-V_{BUS} event is capable of corrupting a configuration in an active cable or in the other PD controller, so it is best to detach and reconfigure the port.

7.2.2.6 How to Connect Unused Pins

If either the RPD_Gx pins are unused in a design, connect them to GND.

7.2.3 Application Curves

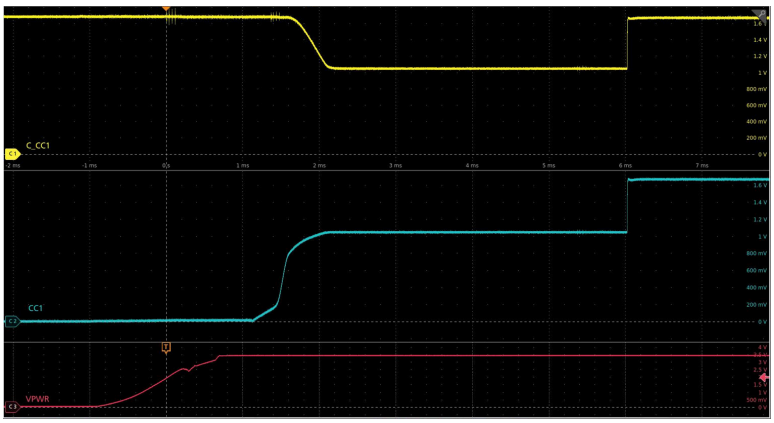


Figure 7-3. TPD4S201 Turning On in Dead Battery Mode with $R_D$on CC1

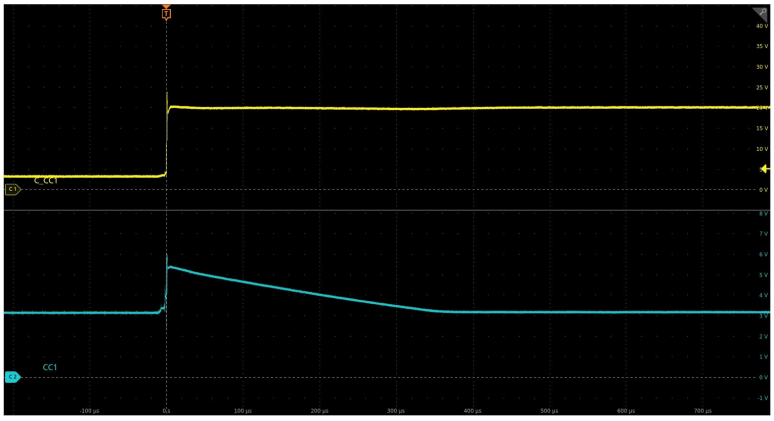


Figure 7-4. TPD4S201 Protecting CC during a Short-to-V_{BUS} Event

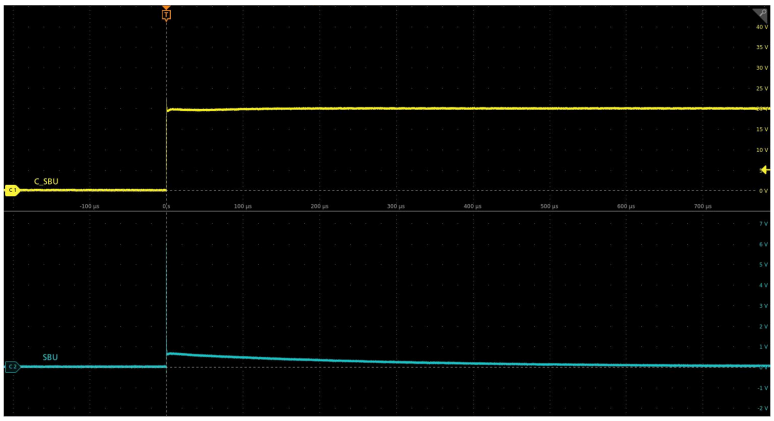


Figure 7-5. TPD4S201Protecting SBU during a Short-to-V_{BUS}Event

7.3 Power Supply Recommendations

The V_{PWR} pin provides power to all the circuitry in the TPD4S201. It is recommended a 1-µF decoupling capacitor is placed as close as possible to the VPWR pin. If USB PD is desired to be operated in dead battery conditions, it is critical that the TPD4S201 share the same power supply as the PD controller in dead battery boot-up (such as sharing the same dead battery LDO). See the *CC Dead Battery Resistors Integrated for Handling the Dead Battery Use Case in Mobile Devices* section for more details.

7.4 Layout

7.4.1 Layout Guidelines

Proper routing and placement is important to maintain the signal integrity the SBU and CC line signals. The following guidelines apply to the TPD4S201:

- Place the bypass capacitors as close as possible to the V_{PWR} pin, and ESD protection capacitor as close as possible to the V_{BIAS} pin. Attach capacitors to a solid ground to minimize voltage disturbances during transient events such as short-to-V_{BUS} and ESD strikes.
- Route the SBU lines as straight as possible and minimize any sharp bends.

Standard ESD recommendations apply to the C_CC1, C_CC2, C_SBU1, C_SBU2:

- The optimum placement for the device is as close to the connector as possible:
  - EMI during an ESD event couples from the trace being struck to other nearby unprotected traces, resulting in early system failures.
  - The PCB designer minimizes the possibility of EMI coupling by keeping any unprotected traces away from the protected traces which are between the TPD4S201 and the connector.
- Route the protected traces as straight as possible.
- Eliminate any sharp corners on the protected traces between the TVS and the connector by using rounded corners with the largest radii possible.
  - Electric fields tend to build up on corners, increasing EMI coupling.

7.4.2 Layout Example

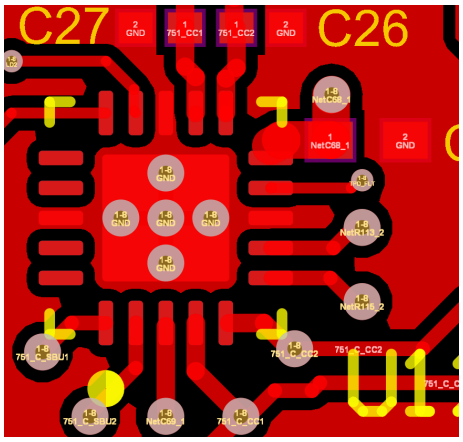


Figure 7-6. TPD4S201 Top Layer Routing

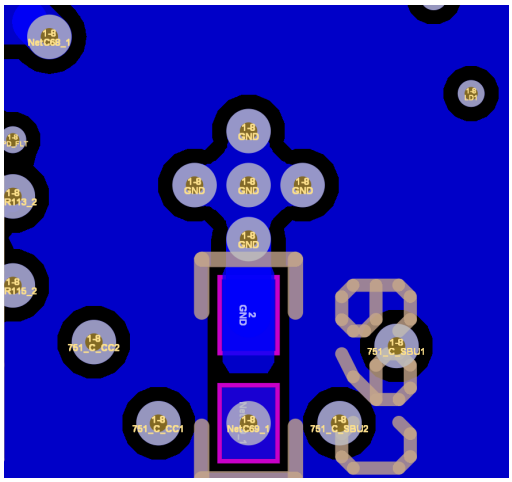


Figure 7-7. TPD4S201 Bottom Layer Routing

8 Device and Documentation Support

8.1 Documentation Support

8.1.1 Related Documentation

For related documentation see the following:

TPS25751 USB Type-C® and USB PD Controller With Integrated Power Switches Optimized for Power Applications

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

8.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.
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8.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.6 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
July 2025	*	Initial Release

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPD4S201RUKR	Active	Production	WQFN (RUK) | 20	5000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 105	4S201

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

OTHER QUALIFIED VERSIONS OF TPD4S201 :

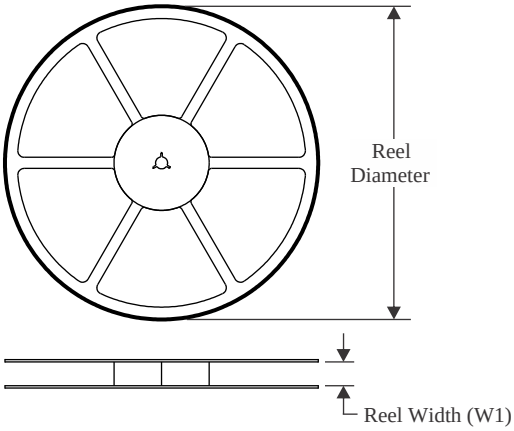
- Automotive : TPD4S201-Q1

NOTE: Qualified Version Definitions:

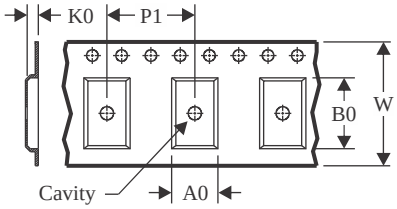
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

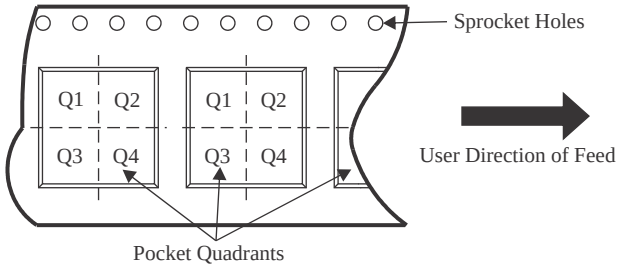


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

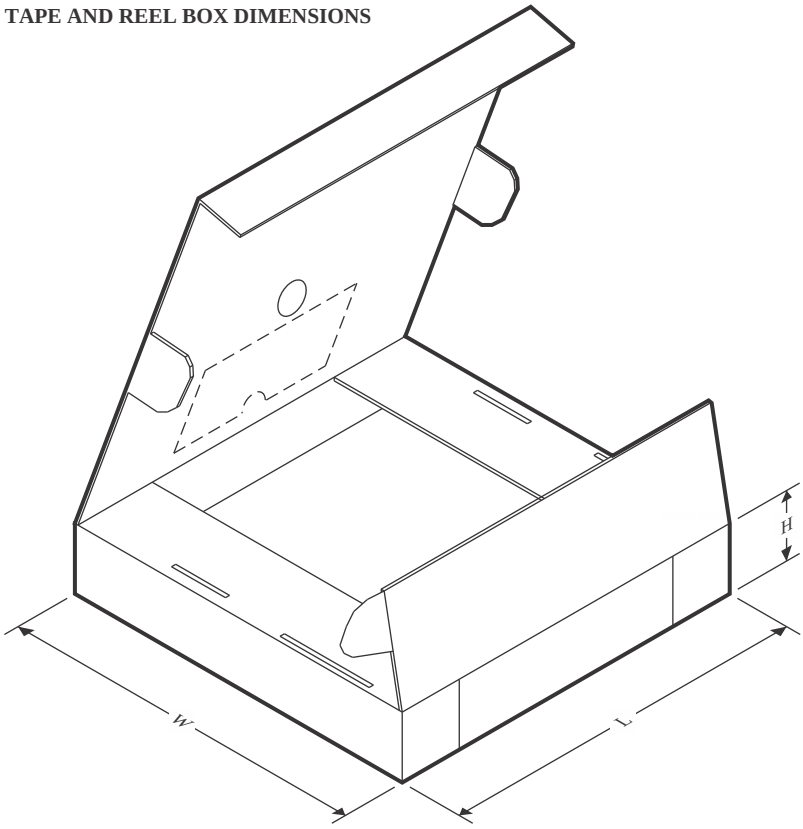
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPD4S201RUKR	WQFN	RUK	20	5000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPD4S201RUKR	WQFN	RUK	20	5000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPD4S201RUKR	WQFN	RUK	20	5000	367.0	367.0	35.0
TPD4S201RUKR	WQFN	RUK	20	5000	346.0	346.0	33.0

GENERIC PACKAGE VIEW

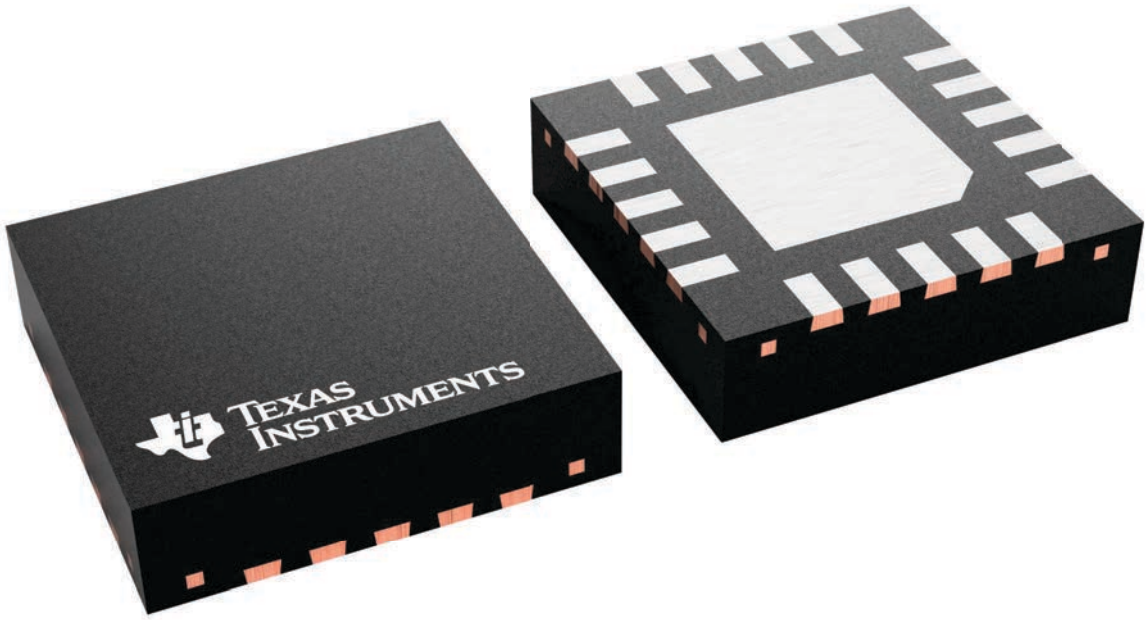
RUK 20

WQFN - 0.8 mm max height

3 x 3, 0.4 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



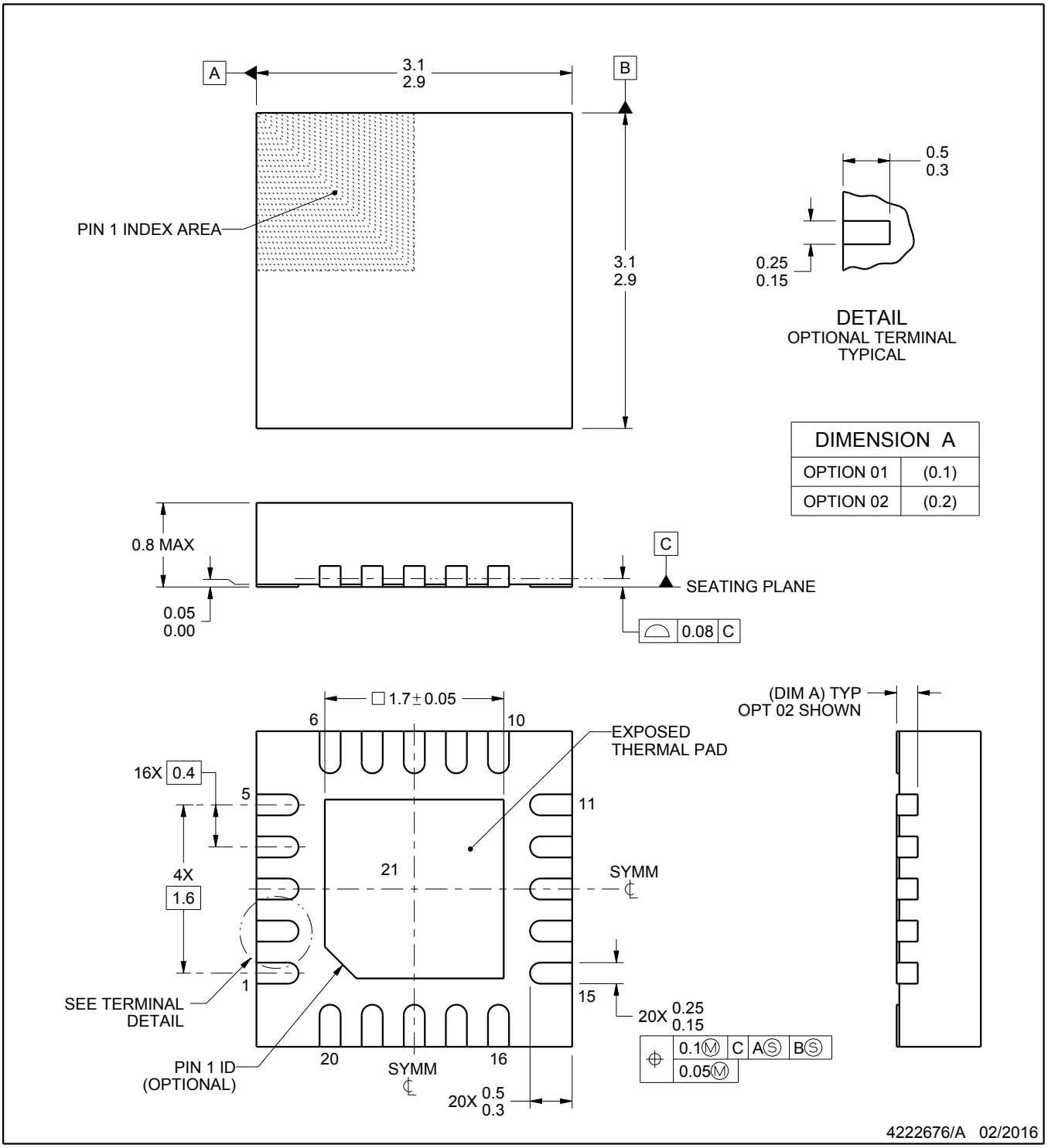
4229651/A

PACKAGE OUTLINE

RUK0020B

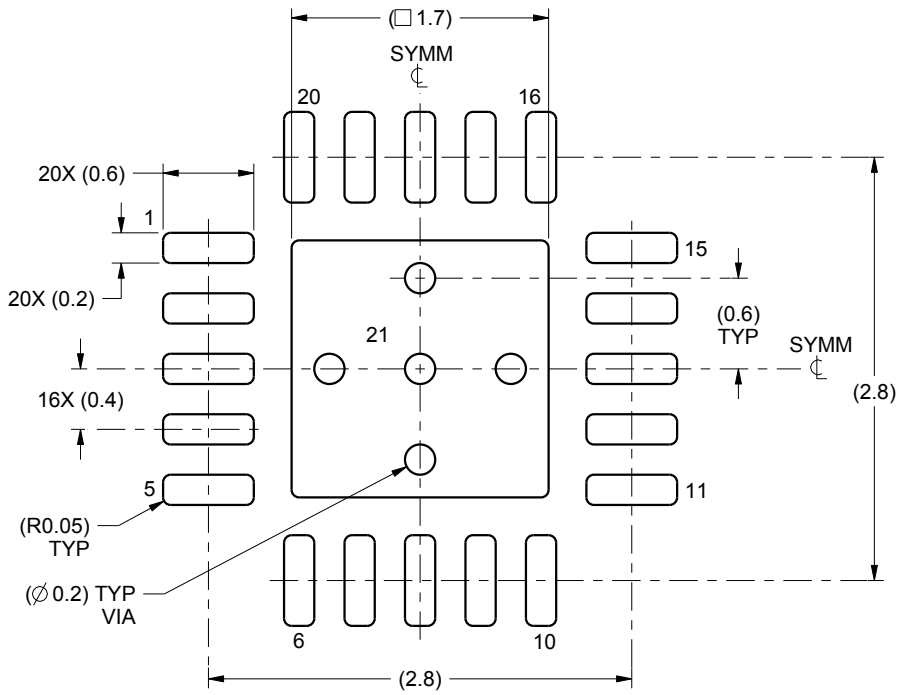
WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

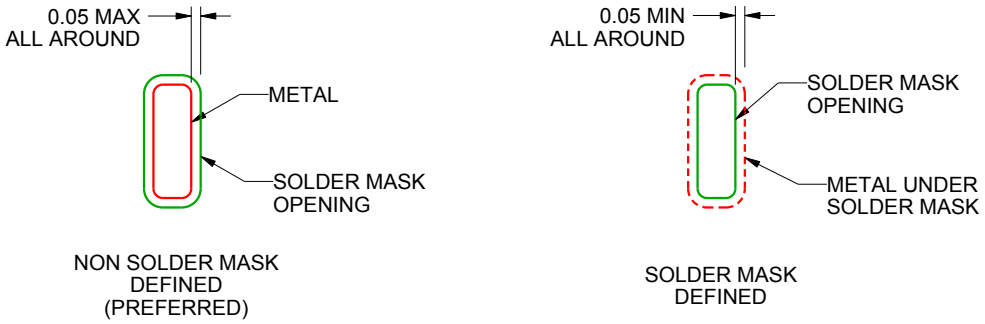


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
SCALE:20X



SOLDER MASK DETAILS

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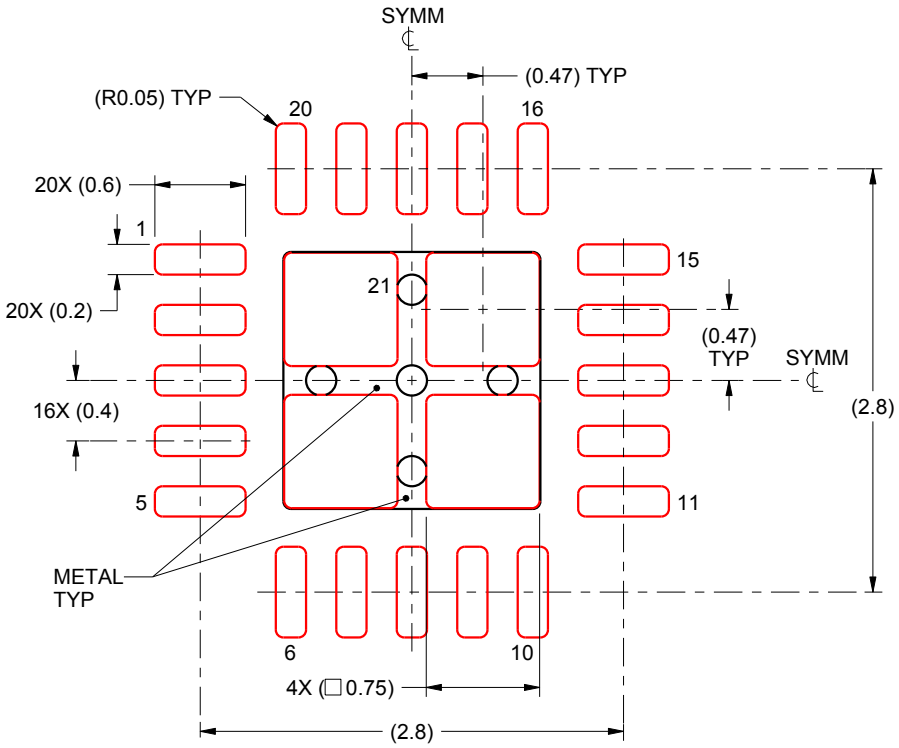
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD 21:
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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Last updated 10/2025