4-CH OVER-VOLTAGE PROTECTION FOR CC/SBU PINS ON USB TYPE-C

Description

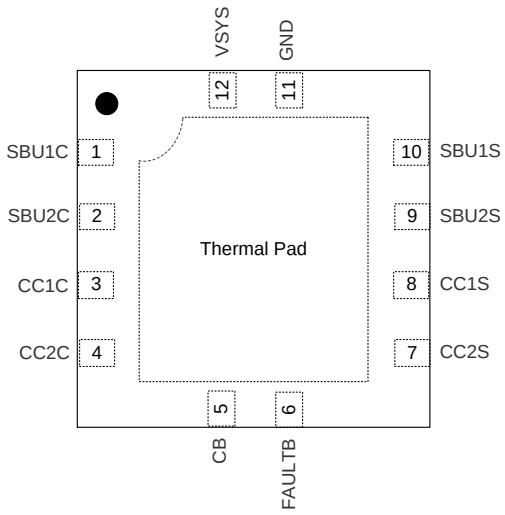
The DPO2036 provides 4 channels of over-voltage protection over the CC1/2 & SBU1/2 pins which are connected to the USB Type-C® connector. The 4 channels are divided into two pairs, one pair of channels protect the CC1 and CC2 pins from being shorted to the V_{BUS}, one pair of channels protect the SBU1 and SBU2 pins from being shorted to the V_{BUS}. Whenever the voltage threshold set for any of the two pairs of channels is reached, the exception condition becomes valid and the low-active flag FAULTB is subsequently asserted.

This device is designed to draw its operating voltage primarily from the system power, V_{VSYS}, which is either the always-ON 3.3V/5V existed within the system or the 1-cell battery inside the mobile system. Under the circumstance when the battery inside a mobile system is fully depleted, DPO2036 can obtain power from the external peripheral system connected to the USB Type-C connector. The DPO2036 supports the dead battery mode by having both of the CC1C and CC2C pins tied to the pull-down resistor R_D (resistor value per the USB Type-C Specification) embedded in the device.

The DPO2036 is housed in the low-profile and space-saving U-QFN2020-12 (Type B) package which is manufactured with environmental-friendly material.

Pin Assignments

(Top View)



U-QFN2020-12 (Type B)

Features

- Operating Voltage Range: 2.7V to 5.5V
- 4-Channel Over-Voltage Protection with Auto-Recovery
- $R_{DS(ON)}$ of OVP MOSFET for CC-Pin Protection: 350mΩ Typical
- $R_{DS(ON)}$ of OVP MOSFET for SBU-Pin Protection: 5Ω Typical
- C_{IN} of OVP MOSFET for CC-Pin Protection: 50pF
- C_{IN} of OVP MOSFET for SBU-Pin Protection: 5pF
- Dead Battery Support for CC Lines
- Built-In Over-Temperature Protection
- IEC61000-4-2 ESD Protection on CC1C, CC2C, SBU1C, SBU2C
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Applications

- Notebook/Desktop/AIO PCs, Tablets, Mobile Phones
- VR/AR Headsets
- Docking Stations, Universal & Multimedia Hubs
- FPTVs, PC Monitors
- Set-Top-Boxes, Residential Gateways, Storage Devices
- Universal AC/DC Chargers/Adapters

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Typical Application Circuit

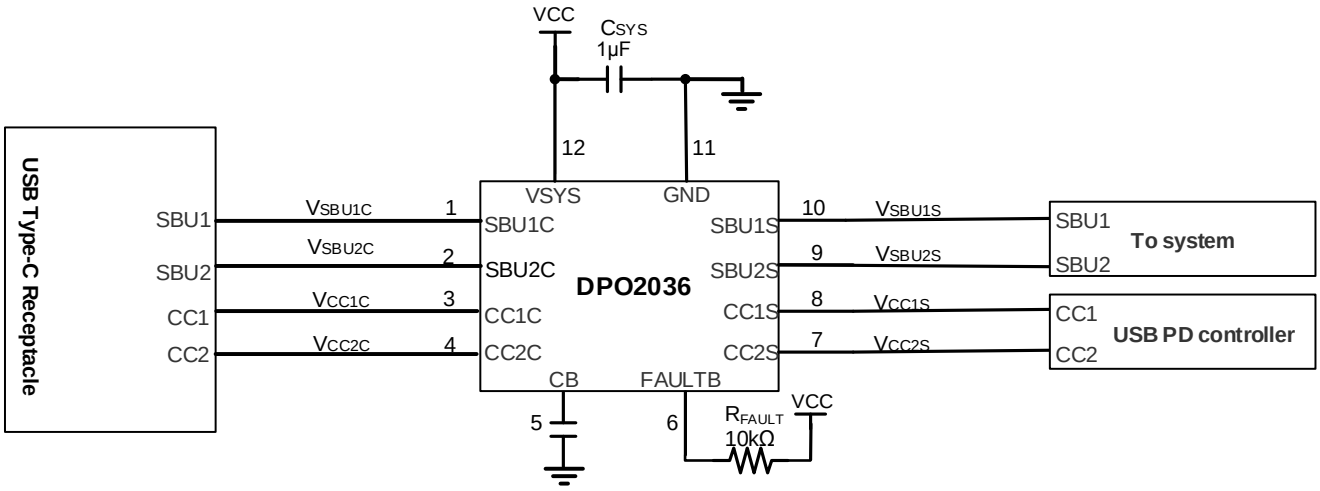


Figure 1. Typical Application Circuit

Pin Descriptions

Pin Number	Pin Name	Function
1	SBU1C	SBU1 connector side. This shall be connected to the SBU1 pin of the USB Type-C connector.
2	SBU2C	SBU2 connector side. This shall be connected to the SBU2 pin of the USB Type-C connector.
3	CC1C	CC1 connector side. This shall be connected to the CC1 pin of the USB Type-C connector.
4	CC2C	CC2 connector side. This shall be connected to the CC2 pin of the USB Type-C connector.
5	CB	Pin for ESD support capacitor. Place a 0.1µF capacitor on this pin to ground
6	FAULTB	Fault status. This is an active-low open-drain output.
7	CC2S	CC2 system side. This shall be connected to the CC2 pin of the component to be protected.
8	CC1S	CC1 system side. This shall be connected to the CC1 pin of the component to be protected.
9	SBU2S	SBU2 system side. This shall be connected to the SBU2 pin of the component to be protected.
10	SBU1S	SBU1 system side. This shall be connected to the SBU1 pin of the component to be protected.
11	GND	Ground.
12	VSYS	Power Input. This shall be connected to the 2.7 to 5.5V power source inside the system.
—	Thermal Pad	Need to connect pad to the PCB ground plane. It serves as a heatsink.

Functional Block Diagram

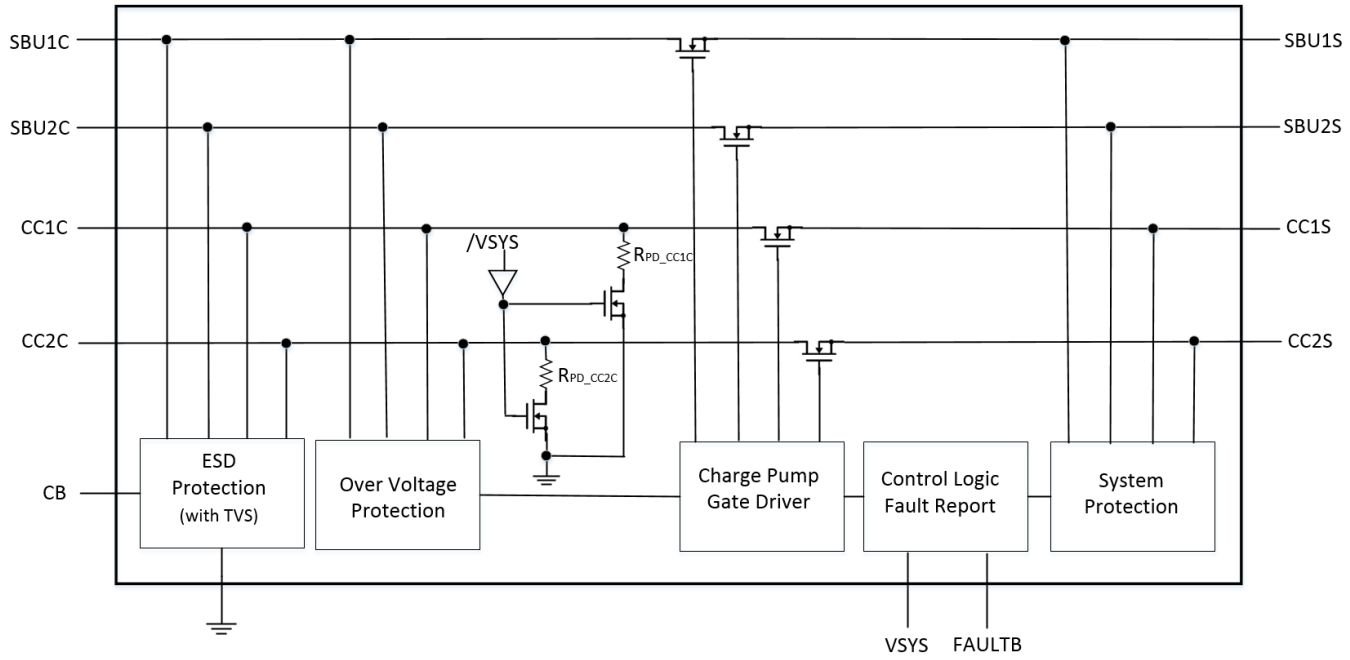


Figure 2. Internal Functional Blocks

Absolute Maximum Ratings (@ T_A = +25°C, unless otherwise specified.) (Note 4)

Symbol	Parameter	Rating	Unit
V_{VSYS}	Voltage Range of VSYS Pin	-0.3 to 6.0	V
V_{FAULTB}	Voltage Range of FAULTB Pin	-0.3 to 6.0	V
V_{SBUxS}, V_{CCxS}	Voltage Range of SBU1S, SBU2S, CC1S, CC2S Pins	-0.3 to 6.0	V
V_{SBUxC}, V_{CCxC}	Voltage Range of SBU1C, SBU2C, CC1C, CC2C Pins	-0.3 to 24.0	V
T_J	Operating Junction Temperature	-40 to +125	°C
T_L	Lead Temperature	+260	°C
T_{STG}	Storage Temperature	-65 to +150	°C
ESD	Human Body Model (HBM), JESD22-A114	±2.0	kV
	Charge Device Model (CDM), JESD22-C101	±0.5	

Note: 4. These are stress ratings only. Operation outside the absolute maximum ratings can cause device failure. Operation at the absolute maximum rating for extended periods can reduce device reliability.

Package Thermal Data (@ T_A = +25°C, unless otherwise specified.) (Note 5)

Symbol	Parameter	Rating	Unit
P_D	Power Dissipation	1.3	W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	96	°C/W
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case	26	°C/W

Note: 5. Device mounted on FR-4 substrate PC board, 2oz copper, with 1” × 1” copper pad layout.

Recommended Operating Conditions (@ T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Min	Max	Unit
V_{VSYS}	Input Supply Voltage at VSYS Pin	2.7	5.5	V
V_{FAULTB}	Power Rail for Pull-up on FAULTB Pin	2.7	5.5	V
V_{CCxC}, V_{CCxS}	I/O Voltage at CC1C, CC2C, CC1S, CC2S Pins	-0.25	5.5	V
V_{SBUxC}, V_{SBUxS}	I/O Voltage at SBU1C, SBU2C, SBU1S, SBU2S Pins	-0.25	4.2	V
I_{VCONN}	Output Current Flowing Into CCxS and out of CCxC, with $V_{CCxS} – V_{CCxC} \leq$ 250mV	—	600	mA

Electrical Characteristics (@ T_A = +25°C, V_{VSYS} = 4.2V, unless otherwise specified.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
CC OVP Switches						
$R_{DS(ON)\_CC}$	On Resistance of CC OVP FETs	V_{CCxC} = 5.5V, T_A ≤ +85°C	—	350	500	mΩ
		V_{CCxC} = 5.5V, T_A ≤ +105°C	—	350	520	mΩ
$R_{DS(ONFLAT)\_CC}$	On Resistance Flatness of CC OVP FETs	V_{CCxC} = 0.1V to 1.2V	—	—	5	mΩ
C_{ON_CC}	Equivalent ON Capacitance	Capacitance from CCxC or CCxS to GND when device is powered, (V_{CCxC} / V_{CCxS}) = 0V to 1.2V	—	50	—	pF
R_{PD_CCxC}	Dead Battery Pull-Down Resistance on CCxC Pin	V_{CCxC} = 2.6V	4.10	5.1	6.10	kΩ
$V_{TH\_RPD\_CCxC}$	Threshold Voltage of the Pulldown FET for in Series with R_{PD_CCxC}	I_{CCxC} = 100μA	1.2	1.4	1.6	V
$V_{TH\_OVP\_CCxC}$	OVP Threshold on CCxC Signal	—	5.6	6	6.25	V
$V_{TH\_OVP\_HYS\_CCxC}$	OVP Hysteresis on CCxC Signal	—	—	140	—	mV
BW_{ON_CC} (Note 6)	CC Line ON Bandwidth Single Ended (-3dB)	Measured from CCxC to CCxS, 50Ω system, V_{CM} = 0.1V to 1.2V	—	200	—	MHz
$V_{SHT\_CCxC\_MAX}$ (Note 6)	Short-to-VBUS Tolerance on the CCxC Pins	Hot-plug CCxC with a 1 meter USB Type-C cable, place a 30Ω load on CCxS	—	—	22	V
$V_{SHT\_CCxS\_CL}$ (Note 6)	Short-to-VBUS Clamping Voltage on the CCxS Pins	Hot-plug CCxC with a 1 meter USB Type-C cable, place a 30Ω load on CCxS. Hot plug voltage V_{CCxC} = 24V	—	7	—	V
SBU OVP Switches						
$R_{DS(ON)\_SBU}$	On Resistance of SBU OVP FETs	V_{SBUxC} = 3.6V, T_A = +85°C	—	5	—	Ω
		V_{SBUxC} = 3.6V, T_A = +105°C	—	5	—	Ω
$R_{DS(ONFLAT)\_SBU}$	On Resistance Flatness of SBU OVP FETs	V_{SBUxC} = 0.1V to 3.6V	—	—	1	Ω
C_{ON_SBU}	Equivalent ON Capacitance	Capacitance from SBUxC or SBUxS to GND when device is powered. V_{SBUxC} / V_{SBUxS} = 0V to 3.6V	—	5	—	pF
$V_{TH\_OVP\_SBUxC}$	OVP Threshold on SBUxC Signals	—	4.15	4.5	4.75	V
$V_{TH\_OVP\_HYS\_SBUxC}$	OVP Hysteresis on SBUxC Signals	—	—	110	—	mV
BW_{ON_SBU} (Note 6)	SBU Line ON Bandwidth Single Ended (-3dB)	Measured from SBUxC to SBUxS, 50Ω system, V_{CM} = 0.1V to 3.6V	—	600	—	MHz
$V_{SHTBUS\_SBUxC\_MAX}$ (Note 6)	Short-to-VBUS Tolerance on the SBUxC Pins	Hot-plug SBUxC with a 1 meter USB Type-C cable, place a 40Ω in series with 150nF to GND on SBUxS pin	—	—	22	V
$V_{SHTBUS\_SBUxS\_CL}$ (Note 6)	Short-to-VBUS Clamping Voltage on the SBUxS Pins	Hot-plug SBUxC with a 1 meter USB Type-C cable, place a 40Ω in series with 100nF to GND on SBUxS pin. Hot plug voltage V_{SBUxC} = 24V, V_{VSYS} = 3.3V	—	7	—	V
X_{TALK_SBUx} (Note 6)	Crosstalk between SBUx Lines	Measure crosstalk at f = 1MHz, from SBU1S to SBU2C or SBU2S to SBU1C. V_{CM1} = 3.6V, V_{CM2} = 0.3V, terminate open sides to 50Ω	—	-80	—	dB

Note: 6. Guaranteed by bench characterization.

Electrical Characteristics (@ T_A = +25°C, V_{VSYS} = 4.2V, unless otherwise specified.) (continued)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Power Supply and Leakage Current						
V_{UVLO}	V_{VSYS} Under Voltage Lockout	V_{VSYS} steps up from 2V until CC or SBU FETs turn ON	2.15	2.4	2.55	V
V_{UVLO_HSYS}	V_{VSYS} UVLO Hysteresis	V_{VSYS} steps down from 2.5V until CC or SBU FETs turn off. Measure difference between rising and falling UVLO to calculate	—	200	—	mV
I_{VSYS_ON}	V_{VSYS} Supply Current	—	—	190	—	µA
I_{LEAK_CCxC}	Leakage current for CCxC when device is Powered	V_{CCxC} = 3.6V	—	—	30	µA
I_{LEAK_SBUxC}	Leakage current for SBUxC when device is Powered	V_{SBUxC} = 3.6V	—	—	35	µA
I_{LEAK_CCxS}	Leakage Current for CCxS when device is Powered	V_{CCxS} = 3.6V	—	—	30	µA
I_{LEAK_SBUxS}	Leakage current for SBUxS when device is Powered	V_{SBUxS} = 3.6V	—	—	35	µA
$I_{LEAK\_OVP\_CCxC}$	Leakage current into CCxC pins when device is in OVP	V_{VSYS} = 0V, V_{CCxC} = 21V, V_{CCxS} = 0V	—	—	6	mA
		V_{VSYS} = 4.2V, V_{CCxC} = 21V, V_{CCxS} = 0V	—	—	150	µA
$I_{LEAK\_OVP\_SBUxC}$	Leakage current into SBUxC pins when device is in OVP	V_{VSYS} = 0V, V_{SBUxC} = 21V, V_{SBUxS} = 0V	—	—	200	µA
		V_{VSYS} = 4.2V, V_{SBUxC} = 21V, V_{SBUxS} = 0V	—	—	200	µA
$I_{LEAK\_OVP\_CCxS}$	Leakage current out of CCxS pins when device is in OVP	V_{VSYS} = 0V, V_{CCxC} = 21V, V_{CCxS} = 0V	—	—	1	µA
		V_{VSYS} = 4.2V, V_{CCxC} = 21V, V_{CCxS} = 0V	—	—	1	µA
$I_{LEAK\_OVP\_SBUxS}$	Leakage current out of SBUxS pins when device is in OVP	V_{VSYS} = 0V, V_{SBUxC} = 21V, V_{SBUxS} = 0V	—	—	1	µA
		V_{VSYS} = 4.2V, V_{SBUxC} = 21V, V_{SBUxS} = 0V	—	—	1	µA
FAULTB Pin						
V_{FAULTB}	Active-Low Output Voltage of FAULTB Pin	I_{OL} = 8mA	—	—	0.4	V
I_{LEAK_FAULB}	FAULTB Leakage Current	V_{FAULTB} = 4.2V	—	—	1	µA
$t_{FAULTB\_ASSERTION}$	FAULTB Assertion Time	—	—	—	300	µs
$t_{FAULTB\_DEASSERTION}$	FAULTB Deassertion Time	—	—	4	—	ms
Timing Requirements						
t_{ON}	Time from crossing rising V_{VSYS} UVLO until CC/SBU OVP FETs are on	—	—	—	2.5	ms
$t_{OVP\_RESPONSE\_CC}$	OVP response time on the CC pins, time from OVP asserted until OVP FETs turnoff	—	—	100	—	ns
$t_{OVP\_RESPONSE\_SBU}$	OVP response time on the SBU pins, time from OVP asserted until OVP FETs turnoff	—	—	100	—	ns
$t_{OVP\_RESPONSE\_CC\_1}$	OVP recovery time on the CC pins. Once an OVP has occurred, the minimum duration until CC FETs turn back on if OVP has been removed already	—	26	32	38	ms
$t_{OVP\_RESPONSE\_SBU\_1}$	OVP recovery time on the SBU pins. Once an OVP has occurred, the minimum duration until SBU FETs turn back on if OVP has been removed already	—	26	32	38	ms
$t_{OVP\_RESPONSE\_CC\_2}$	OVP recovery time on the CC pins. Time from OVP removal until CC FETs turn back on, if device has been in OVP > 40ms	—	—	1	—	ms
$t_{OVP\_RESPONSE\_SBU\_2}$	OVP recovery time on the SBU pins. Time from OVP removal until SBU FETs turn back on, if device has been in OVP > 40ms	—	—	1	—	ms
Thermal Shutdown and Hysteresis						
T_{SHDN}	Thermal Shut Down Theshold	—	—	+150	—	°C
T_{HSYS}	Thermal Shut Down Hysteresis	—	—	+20	—	°C

Performance Characteristics (@ T_A = +25°C, unless otherwise specified.)

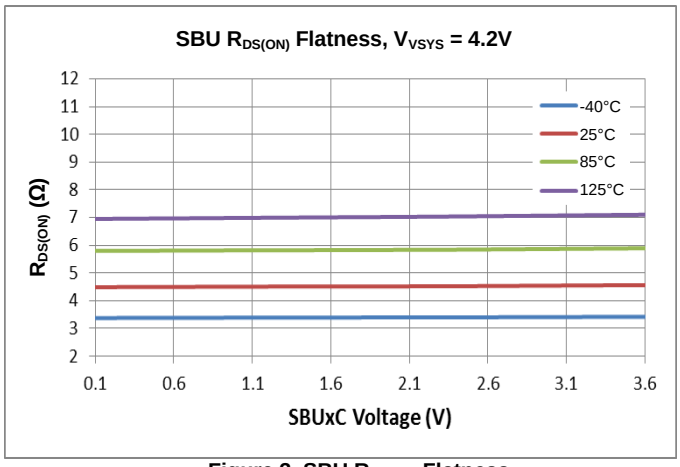


Figure 3. SBU $R_{DS(ON)}$ Flatness

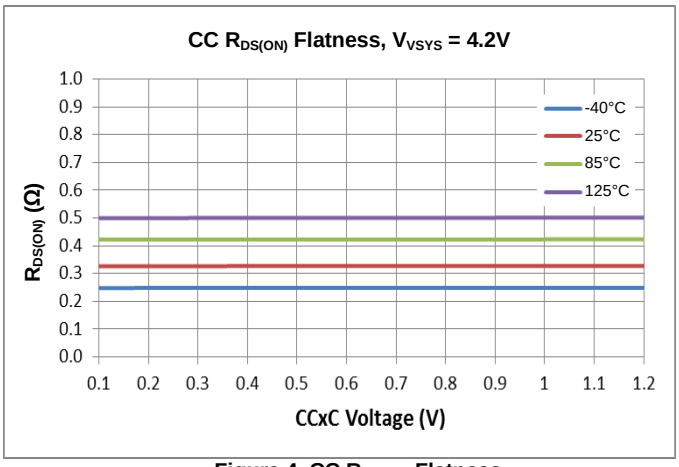


Figure 4. CC $R_{DS(ON)}$ Flatness

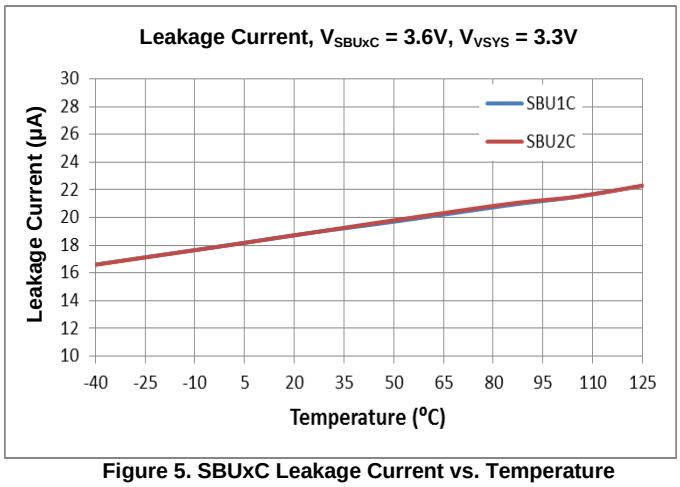


Figure 5. SBUxC Leakage Current vs. Temperature

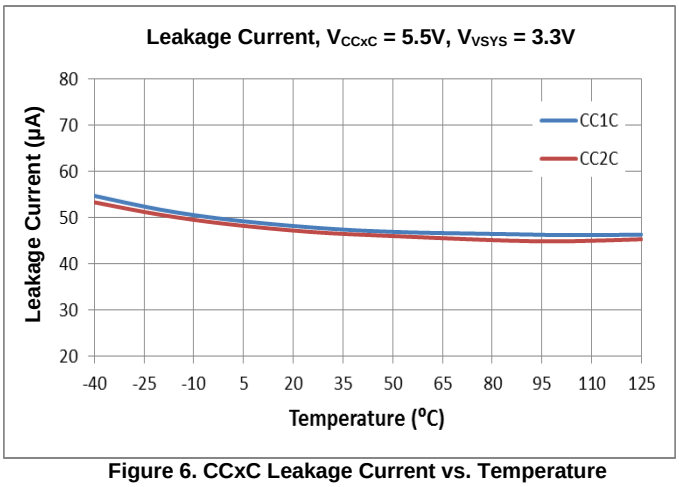


Figure 6. CCxC Leakage Current vs. Temperature

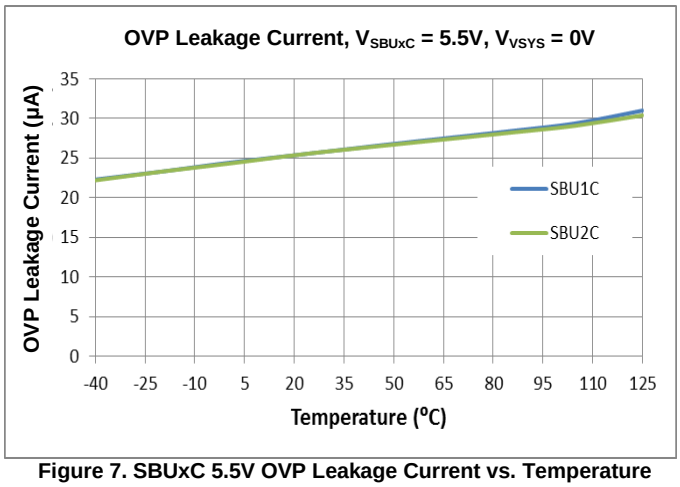


Figure 7. SBUxC 5.5V OVP Leakage Current vs. Temperature

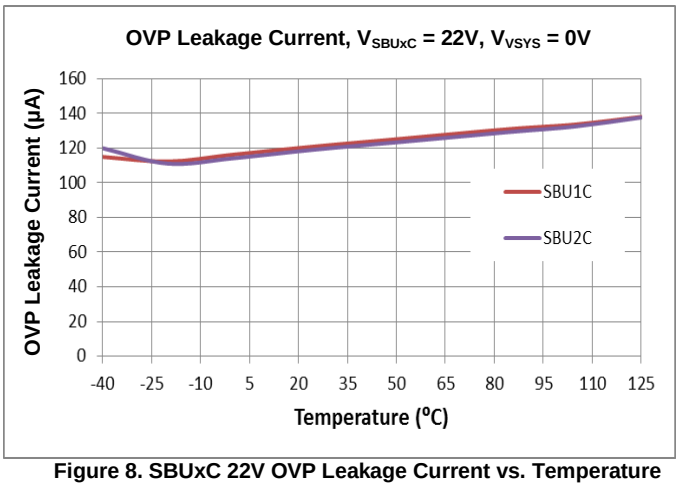


Figure 8. SBUxC 22V OVP Leakage Current vs. Temperature

Performance Characteristics (@ T_A = +25°C, unless otherwise specified.) (continued)

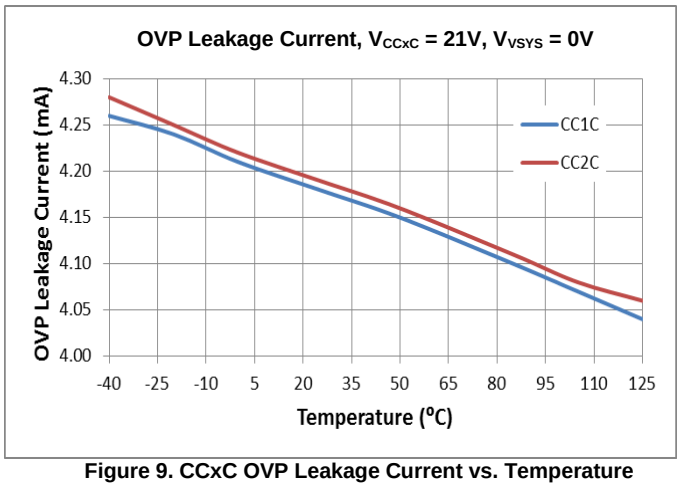


Figure 9. CCxC OVP Leakage Current vs. Temperature

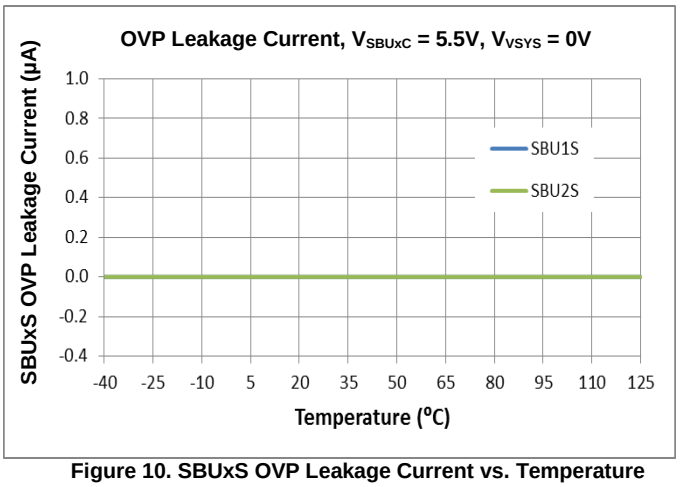


Figure 10. SBUxS OVP Leakage Current vs. Temperature

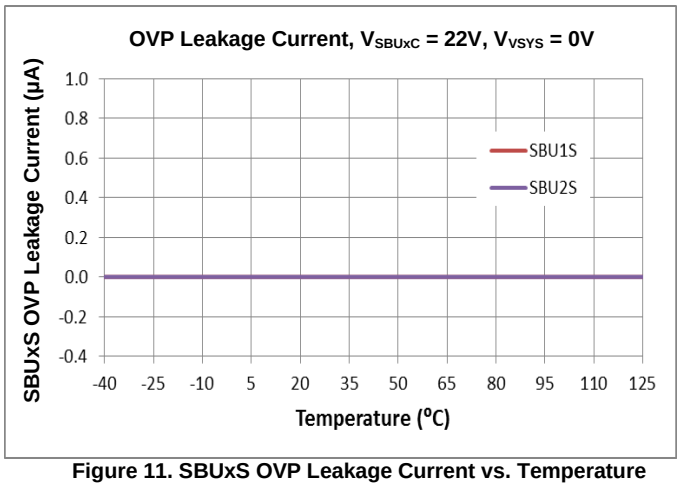


Figure 11. SBUxS OVP Leakage Current vs. Temperature

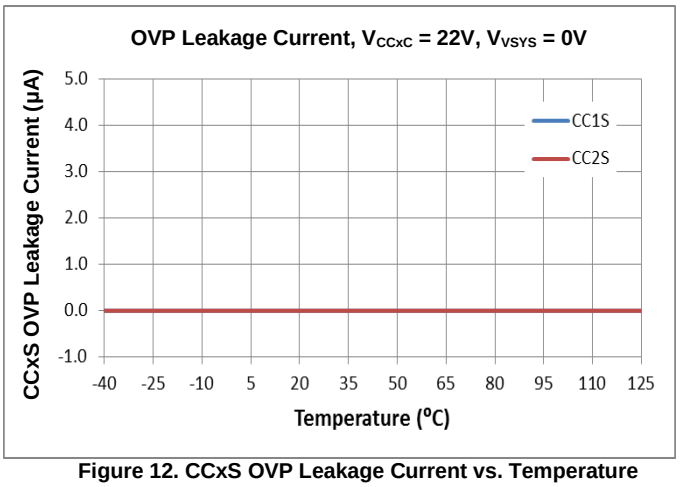


Figure 12. CCxS OVP Leakage Current vs. Temperature

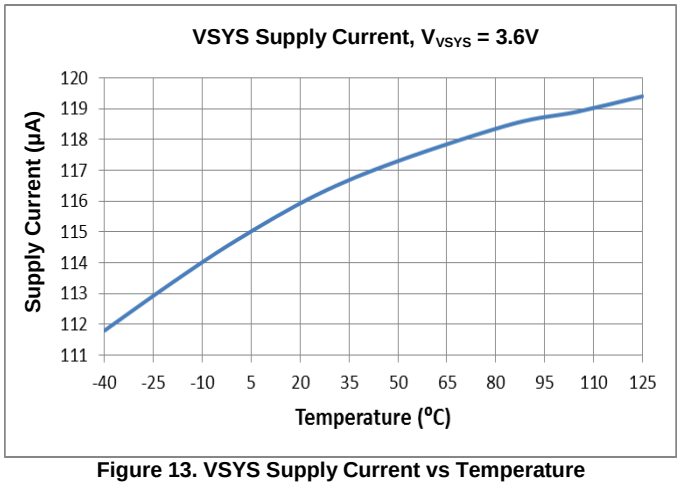


Figure 13. VSYS Supply Current vs Temperature

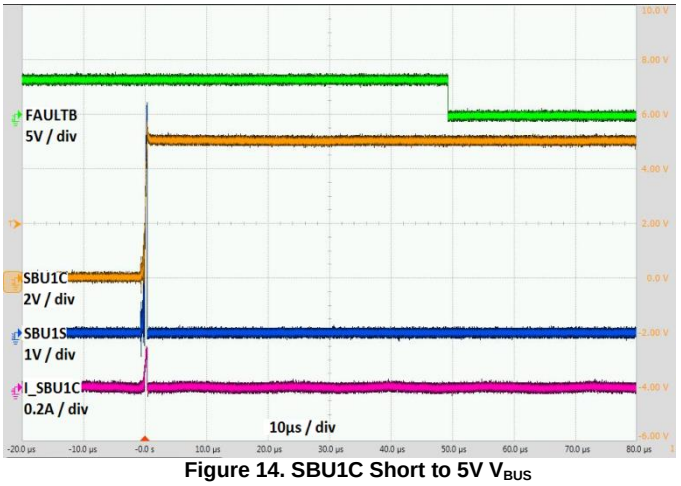


Figure 14. SBU1C Short to 5V V_{BUS}

Performance Characteristics (@ T_A = +25°C, unless otherwise specified.) (continued)

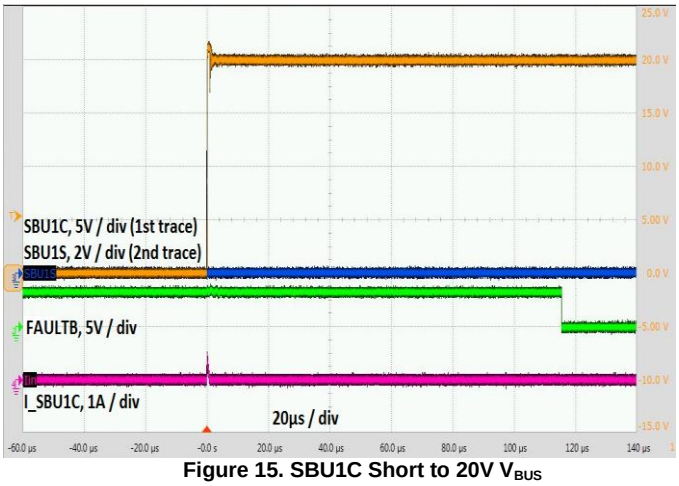


Figure 15. SBU1C Short to 20V V_{BUS}

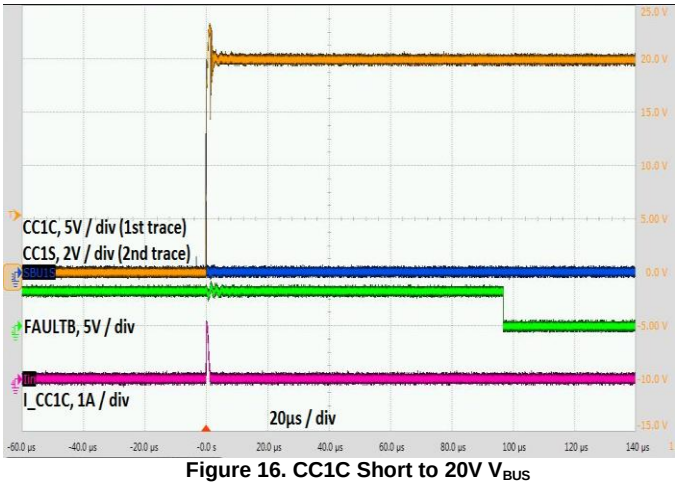


Figure 16. CC1C Short to 20V V_{BUS}

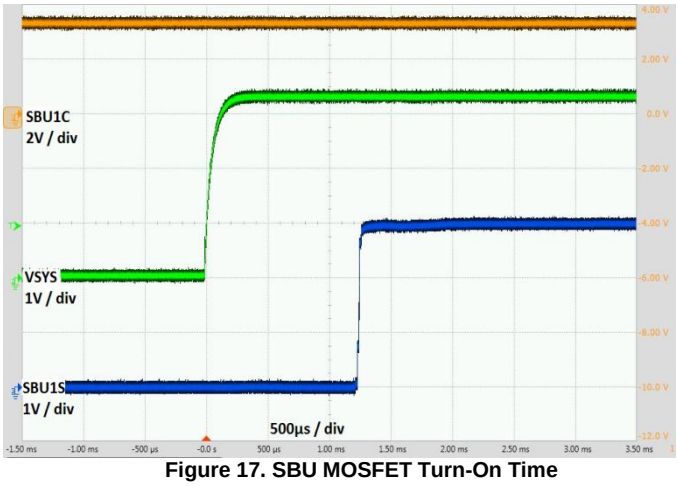


Figure 17. SBU MOSFET Turn-On Time

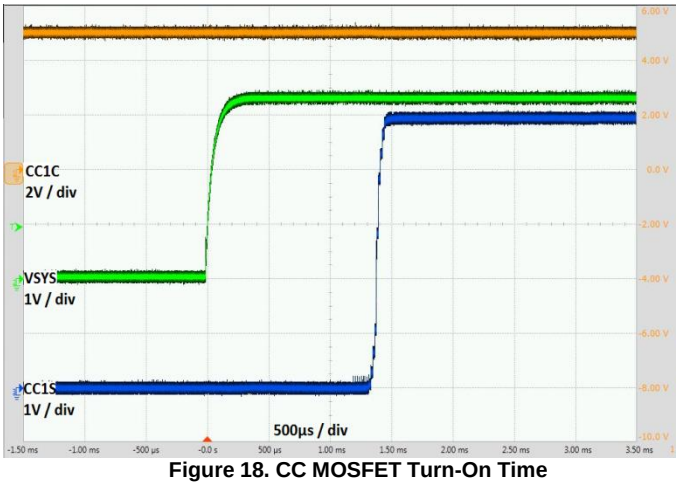


Figure 18. CC MOSFET Turn-On Time

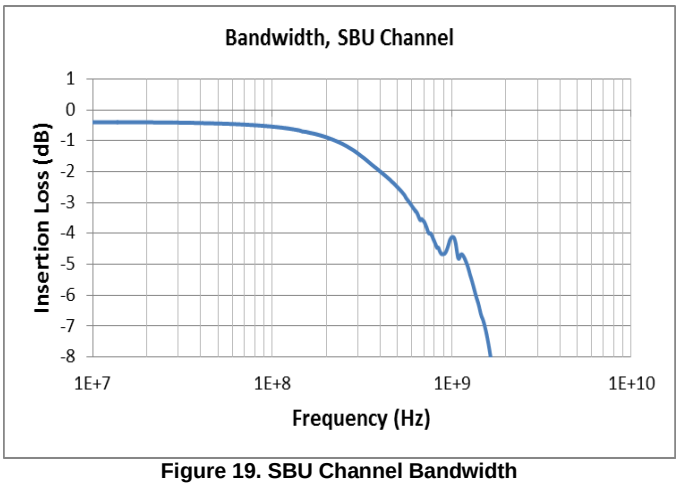


Figure 19. SBU Channel Bandwidth

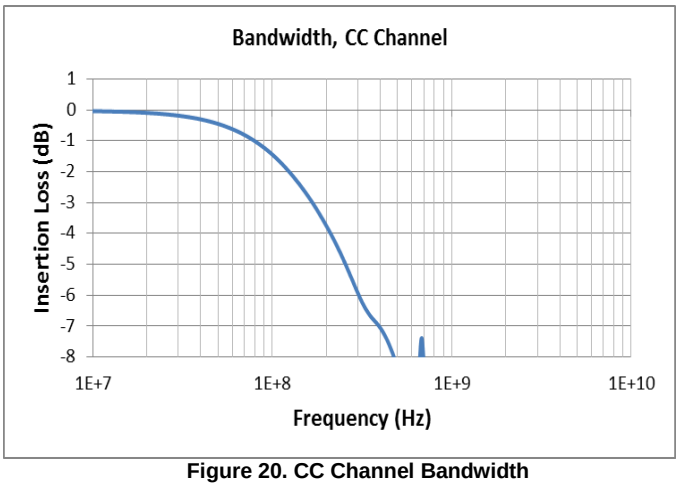


Figure 20. CC Channel Bandwidth

Performance Characteristics (@ T_A = +25°C, unless otherwise specified.) (continued)

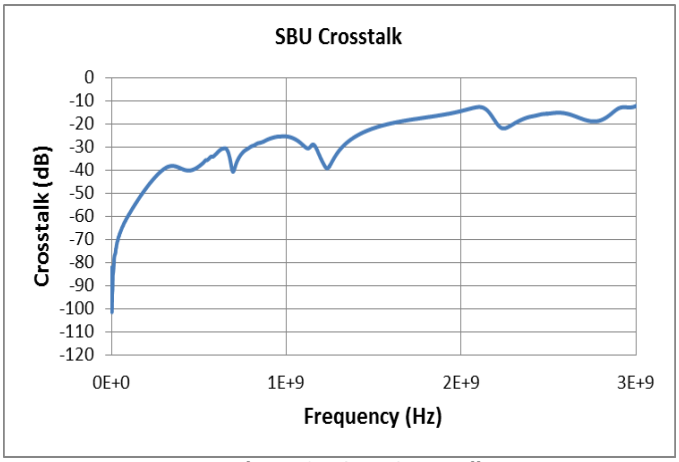


Figure 21. SBU Crosstalk

Application Information

General Description

The DPO2036 is a USB port protection device designed to work with USB Type-C connector, cable and USB PD to form a system that enables signal management and power delivery in a compact package. It provides short to VBUS protection for the CC and SBU pins over the USB Type-C connector, and supports the dead battery mode of operation in an end system / product where the embedded battery is fully depleted.

Short to VBUS Protection

The DPO2036 is a 4-channel uni-directional power switch with over-voltage protection. This is used to prevent the components inside a system which adopts the USB Type-C connector from being damaged by unexpected hazard. On the USB Type-C connector, the CC and SBU pins are located in the close proximity of the VBUS pin. If ever the CC and/or the SBU lines are short to the VBUS line either at the USB-C connector or at the cable end, the components (mostly ICs manufactured on the various sub-micron process nodes) behind the USB Type-C connector can easily be damaged by the resulting EOS. The damage, if occurred, is likely non-recoverable especially given that the voltage level on the VBUS line can go up to 20V or slightly higher. The DPO2036 integrates four series over-voltage FETs to protect the system side CC and SBU lines. When either line on the Type-C connector side CC1C, CC2C, SBU1C or SBU2C is shorted to VBUS line, the DPO2036 will turn off the over-voltage FETs in less than 100ns window to isolate the system side CC and SBU lines from the over-voltage connector side. When shorted to VBUS line is detected, the open-drain FAULTB will output low to indicate a fault condition.

Dead Battery Charging and Power Delivery

In a battery-powered system, the pull-down resistors embedded inside DPO2036 are turned ON and connected to the CC1C/CC2C pins whenever the battery is depleted. Subsequently, the battery-powered system shall receive power through the USB Type-C connector from the external device connected. As soon as the embedded battery is sufficiently recharged to power the system and DPO2036, the pull-down resistors shall be disconnected from the CC1C/CC2C pins.

Signal Operation Range

Table 1 and Table 2 show the signal operation range and output status:

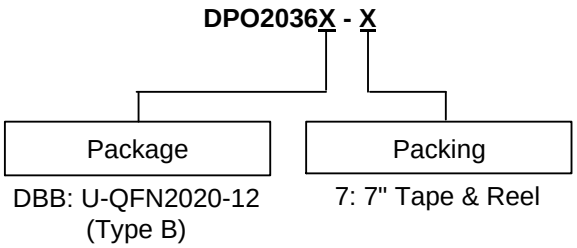
0V to UVLO (Invalid)	0V to 5.85V	OFF: Dead Battery R_{PD} Inserted
	5.85V to 20V	OFF: Dead Battery R_{PD} Inserted
2.7V to 5.5V (Valid)	0V to 5.85V	ON
	5.85V to 20V	OFF: FAULTB Asserted (OVP detected)

Table 1. Signal Operation Range for CCx

0V to UVLO (Invalid)	0V to 4.35V	OFF
	4.35V to 20V	OFF
2.7V to 5.5V (Valid)	0V to 4.35V	ON
	4.35V to 20V	OFF: FAULTB Asserted (OVP detected)

Table 2. Signal Operation Range for SBUx

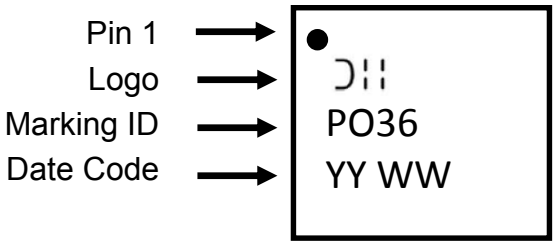
Ordering Information (Note 7)



Part Number	Marking ID	Reel Size (inches)	Tape Width (mm)	7" Tape and Reel	
				Quantity	Part Number Suffix
DPO2036DBB-7	PO36	7	8	3,000/Tape & Reel	-7

Note: 7. For packaging details, go to our website at https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information

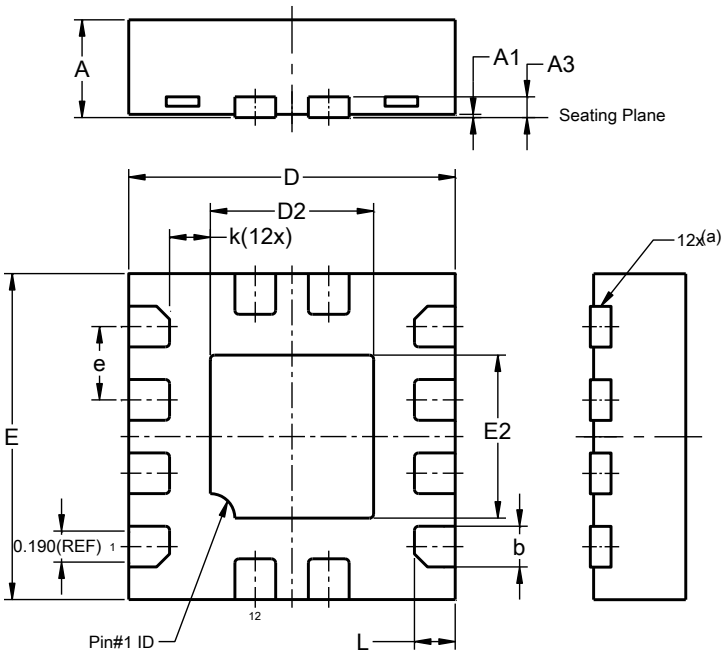


YY: Year
WW: Week 01~53

Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

U-QFN2020-12 (Type B)



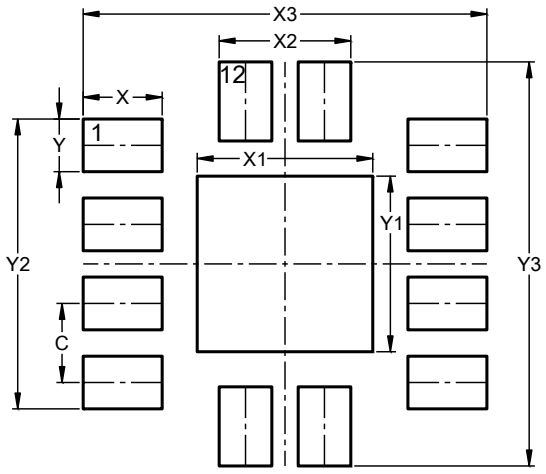
a) Actual shape depending upon manufacturing technology used.

U-QFN2020-12 (Type B)			
Dim	**Min**	**Max**	**Typ**
A	0.55	0.65	0.60
A1	0.00	0.05	0.02
A3	--	--	0.13
b	0.20	0.30	0.25
D	1.95	2.05	2.00
D2	0.90	1.10	1.00
E	1.95	2.05	2.00
E2	0.90	1.10	1.00
e	0.45 BSC		
k	--	--	0.25
L	0.20	0.30	0.25
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

U-QFN2020-12 (Type B)



Dimensions	Value (in mm)
C	0.450
X	0.450
X1	1.000
X2	0.750
X3	2.300
Y	0.300
Y1	1.000
Y2	1.650
Y3	2.300

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: NiPdAu Finish, Solderable per MIL-STD-202, Method 208 e4
- Weight: 0.007 grams (Approximate)