USB Type-C Port Protector for CC, SBU and D+/- Pins

Features

- Over-Voltage Protection
  - 22VDC Tolerance on CC1/2, SBU1/2
  - CC1/2 OVP = 5.8V ±0.15V
  - SBU1/2 OVP = 4.8V ±0.15V
  - Ultra-Fast 15ns Response Time
- IEC61000-4-2 ESD Protection
  - ±10kV air gap on CC1/2, SBU1/2, D1/2
  - ±5kV contact on CC1/2, SBU1/2, D1/2
  - ±2kV HBM on all pins (JEDEC JS-001-2017)
- CC Switches:
  - DPST, 1.25A, 270mΩ, 15pF, 400MHz
  - Automatic 5.1kΩ dead battery pull-down
- SBU Switches:
  - DPST, 3Ω, 6pF, 1000MHz
- 2.5V to 5.5V Operating Supply Voltage Range
- -40°C to 85°C Operating Temperature Range
- 20 pin UQFN 3x3mm (0.4mm pitch)
- RoHS and Green Compliant

Brief Description

The KTU1131 provides four conducting paths with over-voltage protection (OVP) for Type-C's CC, SBU signals. Once an over-voltage event is detected, it will shut down all paths to protect circuits in system side, like PD controller from damage.

All the SBU and CC switches have very low on-capacitance for broad bandwidth to allow high-speed signal passing through without loss. The CC1/2 switches have low on-resistance for passing V_{CONN} power up to 1.25A.

During dead battery conditions, internal 5.1kΩ resistors automatically pull down on CC1/2 to ensure that the up-stream source provides 5V on VBUS.

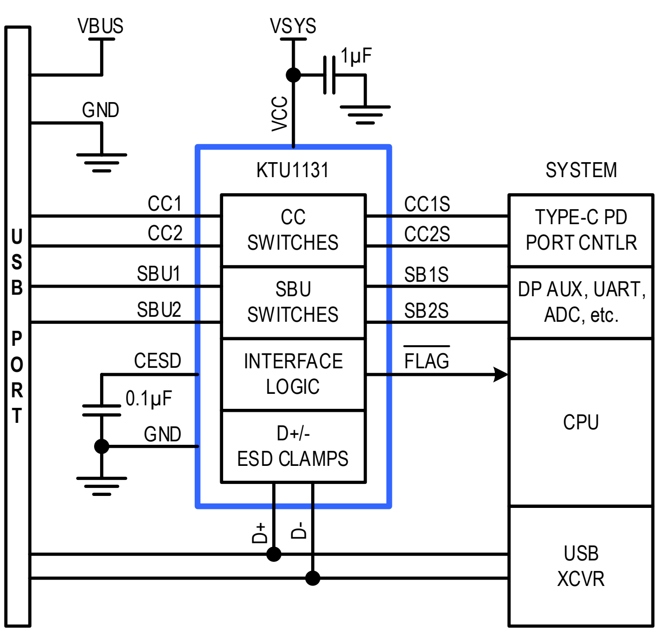
Also, it contains clamping circuits aiming at D+/D- ESD protection, eliminating the need for external TVS diodes. Trivial capacitance is presented from those pins to ground to achieve USB Hi-Speed data integrity.

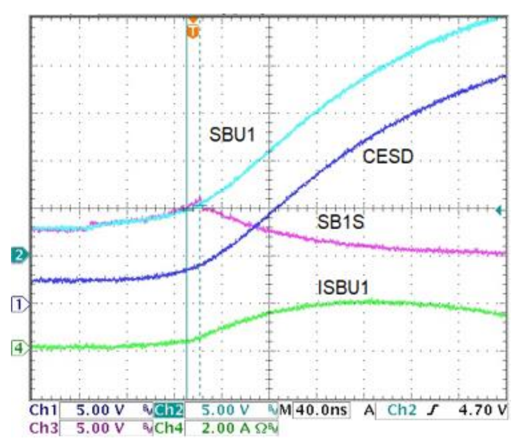
The KTU1131 is packaged in RoHS and Green compliant 3mm x 3mm UQFN package.

Applications

- Notebooks, PCs, Netbooks, Tablets, Monitors, TVs
- Gaming Devices, Set-Top Boxes, Networking

Typical Application





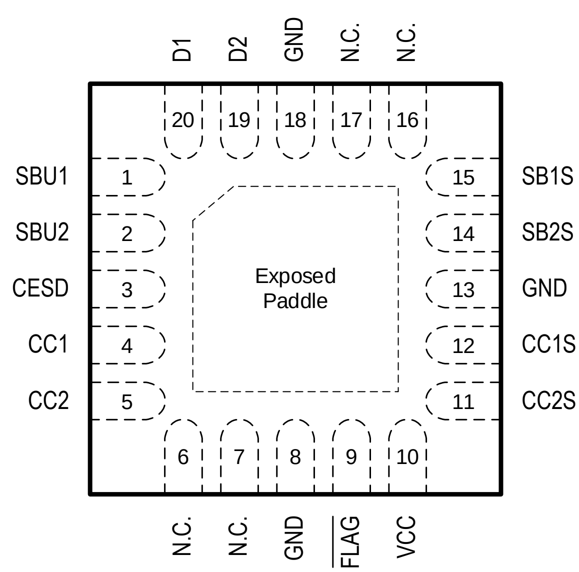
- Conditions: V_{CC} = 3.0V, initial V_{SBU1} = 3.3V, short SBU1 to V_{BUS} (20V), T_A = +25°C
- 12ns OVP Response Time with 6.2V Peak Voltage on SB1S

Pin Descriptions

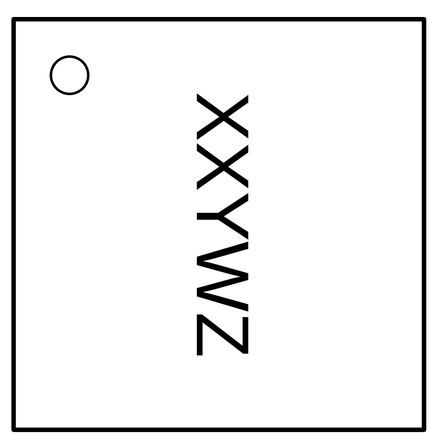
Pin #	Name	Function
1	SBU1	Connector side of SBU1 switch
2	SBU2	Connector side of SBU2 switch
3	CESD	Capacitor connection for ESD protection for CC1, CC2, SBU1 and SBU2 inputs
4	CC1	Connector side of CC1 switch
5	CC2	Connector side of CC2 switch
6, 7	N.C.	Not connected – they can be treated in different ways: 1) Both are float; 2) Both are connected to PCB ground plane; 3) Connected to CC1 and CC2 separately.
8, 13, 18	GND	Ground
9	$\overline{\text{FLAG}}$	Active low fault flag output to alert system to an OVP or OTP fault condition
10	VCC	Device supply input – connect to a 2.5V to 5.5V source.
11	CC2S	System side of CC2 switch
12	CC1S	System side of CC1 switch
14	SB2S	System side of SBU2 switch
15	SB1S	System side of SBU1 switch
16, 17	NC	Not connected
19	D2	ESD clamp for either D+ or D-
20	D1	ESD clamp for either D+ or D-
--	E.P.	Exposed paddle – connect to PCB ground plane.

UQFN33-20

TOP VIEW



TOP VIEW



20-Pin 3mm x 3mm x 0.52mm
UQFN Package, 0.4mm pitch
Top Mark
XX = Device ID Code, YW = Date Code, Z = Serial Number

Absolute Maximum Ratings[1]

(T_A = 25°C unless otherwise noted)

Symbol	Description	Value	Units
V_{CC}	VCC to GND	-0.3 to 6	V
V_{IO}	CC1, CC2, SBU1, SBU2 to GND	-0.3 to 22	V
	CC1S, CC2S, SB1S, SB2S to GND	-0.3 to 8	
	$\overline{\text{FLAG}}$ to GND	-0.3 to 6	
I_{IO}	CCx to CCxS Continuous Current	±1250	mA
	CCx to CCxS Peak Current (2.5ms)	±2000	
	SBUx to SBxS Continuous Current	±100	
V_{CESD}	CESD to GND	-0.3 to 22	V
$V_{D1/2}$	D1, D2 to GND	-0.3 to 6	V
T_J	Operating Temperature Range	-40 to 150	°C
T_S	Storage Temperature Range	-55 to 150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	260	°C

ESD and Ratings[2]

Symbol	Description	Value	Units
V_{ESD_HBM}	JEDEC JS-001-2017 ESD Human Body Model (all pins)	±2	kV
V_{ESD_CDM}	JEDEC JS-002-2014 Charged Device Model (all pins)	±1	kV
V_{ESD_CD}	IEC61000-4-2 ESD Contact Discharge (CC1, CC2, SBU1, SBU2, D1, D2)	±5	kV
V_{ESD_AGD}	IEC61000-4-2 ESD Air-Gap Discharge (CC1, CC2, SBU1, SBU2, D1, D2)	±10	kV

Thermal Capabilities[3]

Symbol	Description	Value	Units
Θ_{JA}	Thermal Resistance – Junction to Ambient	35.9	°C/W
P_D	Maximum Power Dissipation at 25°C	3.48	W
$\Delta P_D/\Delta_T$	Derating Factor Above T_A = 25°C	-27.86	mW/°C

Ordering Information

Part Number	Marking[4]	Operating Temperature	Package
KTU1131EUAC-TR	NKYWZ	-40°C to +85°C	UQFN33-20

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum rating should be applied at any one time.
2. ESD and Surge Ratings conform to JEDEC and IEC industry standards. Some pins may actually have higher performance.
3. Junction to Ambient thermal resistance is highly dependent on PCB layout. Values are based on thermal properties of the device when soldered to an EV board.
4. NK = Device ID code, YW = Date code, Z = Serial number.

Electrical Characteristics[5]

Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of -40°C to +85°C and V_{CC} = 2.5V to 5.5V. Typical values are specified at T_A = +25°C with V_{CC} = 3.0V.

Symbol	Description	Conditions	Min	Typ	Max	Units
Supply Specifications						
V_{CC}	Supply Operating Range		2.5		5.5	V
V_{UVLO}	Under-Voltage Lockout Threshold	Rising threshold	2.12	2.3	2.48	V
		Hysteresis		100		mV
I_{CC}	Supply Current	V_{CC} = 3.0V		55	80	µA
Logic Specifications						
V_{OL}	Output Logic Low ($\overline{FLAG}$)	I_{OSINK} = 3mA		0.1	0.5	V
I_{O_LK}	Output Logic Leakage ($\overline{FLAG}$)	T_A = +25°C, V_O = high-Z or V_{CC}		0.01	1	µA
t_{FLAGB}	$\overline{FLAG}$ Response Time (with 100k pull-up)	Activation		15		ns
$t_{FLAG\_RECOVER}$	From OVP removed to $\overline{FLAG}$ recovered			5		ms
Thermal Shutdown Specifications						
T_{J_SHDN}	IC Junction Thermal Shutdown	T_J rising		150		°C
		Hysteresis		20		°C
D+/- ESD Clamp Specifications						
V_{DX}	Clamp Stand-Off Voltage Range	I_{DX}<1uA	0		5.5	V
V_{BD_DX}	Clamp Break-Down Voltage	Positive: I_{DX} = 1mA	6.1	8		V
		Negative: I_{DX} = -8mA		-0.8	-0.6	V
C_{DX}	Clamp Capacitance	V_{DX} = 2.5V, f =1MHz		1.7		pF

(continued next page)

5. Device is guaranteed to meet performance specifications over the –40°C to +85°C operating temperature range by design, characterization and correlation with statistical process controls.

Electrical Characteristics (continued)[5]

Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of -40°C to +85°C and V_{CC} = 2.5V to 5.5V. Typical values are specified at T_A = +25°C with V_{CC} = 3.0V.

Symbol	Description	Conditions	Min	Typ	Max	Units
CC Switch Specifications						
$V_{CC1/2}$	Switch Voltage Operating Range		-0.3		5.5	V
V_{OVP_CC}	OVP Threshold	Rising threshold	5.5	5.8	6.1	V
		Hysteresis		160		mV
R_{ON_CC}	On-Resistance (–40°C ≤ TJ ≤ +85°C)	Value, $V_{CC1/2}$ = 0V to V_{CC}		245	390	mΩ
		Flatness, $V_{CC1/2}$ = 0V to V_{CC}		20		mΩ
		Matching, $V_{CC1/2}$ = 0V to V_{CC}		20		mΩ
C_{ON_CC}	On-Capacitance (at 1MHz)			15		pF
BW_{ON_CC}	On-Bandwidth	R_S = R_L = 50Ω, $V_{CC1/2}$ = -3dBm		400		MHz
$R_{CC1/2\_GND}$	Resistance to GND	$V_{CC1/2}$ ≤ V_{CC}, T_A = +25°C		6		MΩ
I_{CCLK}	Switch Off Leakage Current	V_{CC} = 0V, $V_{CC1/2}$ = 5.5V, $V_{CC1/2S}$ = 0V, T_A = +25°C, measure current out of CC1/2S		0.1	1	µA
$V_{CC1/2\_DB}$	Dead Battery Threshold Voltage	V_{CC} < V_{UVLO}, $I_{CC1/2}$ = 80µA		0.82		V
t_{ON_CC}	Switch Turn-On Time	V_{CC} rising > V_{UVLO}		300		µs
t_{OFF_CC}	Switch Turn-Off Time	V_{CC} falling < V_{UVLO}		5		µs
$t_{OVP\_CC\_R}$	OVP Rising Response Time	V_{CC} = 3.0V, short CC1/2 to VBUS (20V), T_A = +25°C		15		ns
$V_{CC1/2S\_MAX}$	OVP Rising Maximum System Voltage			7		V
$t_{OVP\_CC\_F}$	OVP Falling Debounce Time			0.2		ms
SBU Switch Specifications						
$V_{SBU1/2}$	Switch Voltage Operating Range		-0.3		4.5	V
V_{OVP_SBU}	OVP Threshold	Rising threshold	4.46	4.8	5.14	V
		Hysteresis		80		mV
R_{ON_SBU}	On-Resistance (–40°C ≤ TJ ≤ +85°C)	Value, $V_{SBU1/2}$ = 0V to V_{CC}		3	6.5	Ω
		Flatness, $V_{SBU1/2}$ = 0V to V_{CC}		0.02		Ω
		Matching, $V_{SBU1/2}$ = 0V to V_{CC}		0.02		Ω
C_{ON_SBU}	On-Capacitance			6		pF
BW_{ON_SBU}	On-Bandwidth	R_S = R_L = 50Ω, $V_{SBU1/2}$ = -3dBm		1000		MHz
$R_{SBU1/2\_GND}$	Resistance to GND	$V_{SBU1/2}$ ≤ V_{CC}, T_A = +25°C		12		MΩ
I_{SBULK}	Switch Off Leakage Current	V_{CC} = 0V, $V_{SBU1/2}$ = 4.5V, $V_{SB1/2S}$ = 0V, T_A = +25°C, measure current out of SB1/2S		0.1	1	µA
t_{ON_SBU}	Switch Turn-On Time	V_{CC} rising > V_{UVLO}		160		µs
t_{OFF_SBU}	Switch Turn-Off Time	V_{CC} falling < V_{UVLO}		5		µs
$t_{OVP\_SBU\_R}$	OVP Response Time	V_{CC} = 3.0V, short SBU1/2 to VBUS (20V), T_A = +25°C		15		ns
$V_{SB1/2S\_MAX}$	OVP Rising Maximum System Voltage			6		V
$t_{OVP\_SBU\_F}$	OVP Falling Debounce Time			0.1		ms

(continued next page)

Electrical Characteristics (continued)[5]

Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of -40°C to +85°C and V_{CC} = 2.5V to 5.5V. Typical values are specified at T_A = +25°C with V_{CC} = 3.0V.

Symbol	Description	Conditions	Min	Typ	Max	Units
Dead Battery Resistors Specifications						
$t_{ON\_DB\_DELAY}$	From VCC exceeding UVLO to dead battery resistors are off. (CCx and SBUx channels should be on prior to DB off)			4.5		ms
$t_{ON\_DB\_OVP}$	From OVP recover to DB resistors back to turn off. Same period as $t_{FLAG\_RECOVER}$. See Figure 2 for more details			4.5		ms
R_{DB}	Dead Battery Pull-Down Resistance	$V_{CC} < V_{UVLO}$, $V_{CC1/2}$ = 2.6V	4.1	5.1	6.1	kΩ

Timing Diagrams

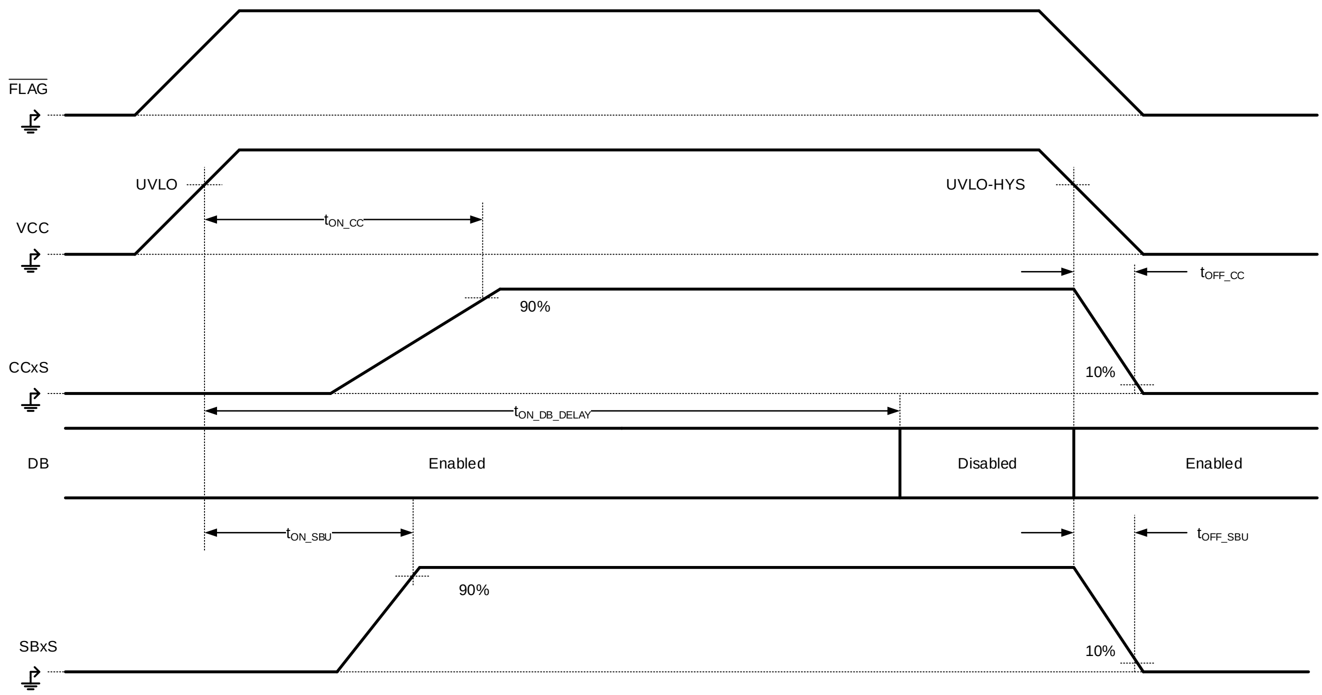


Figure 1. Power Up and Down

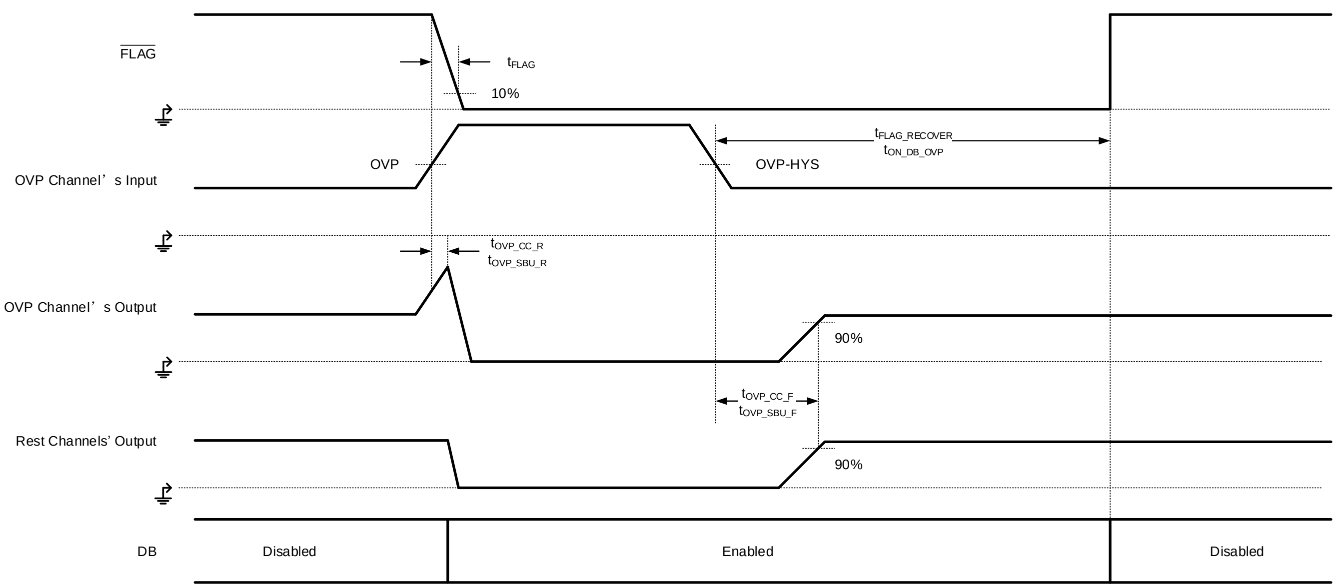


Figure 2. OVP

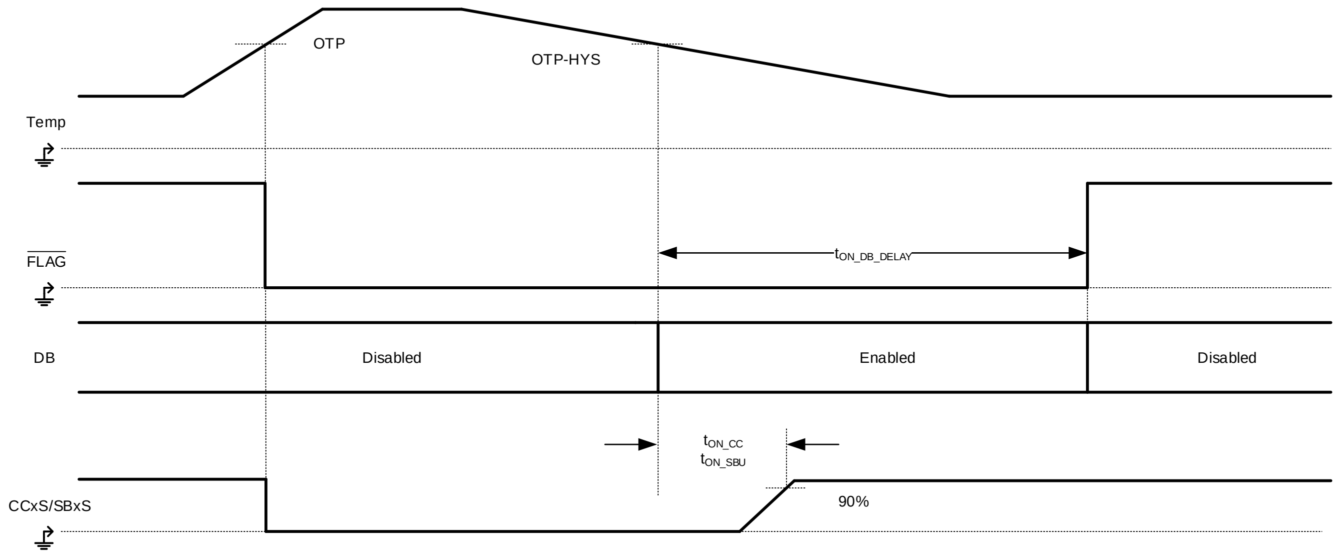
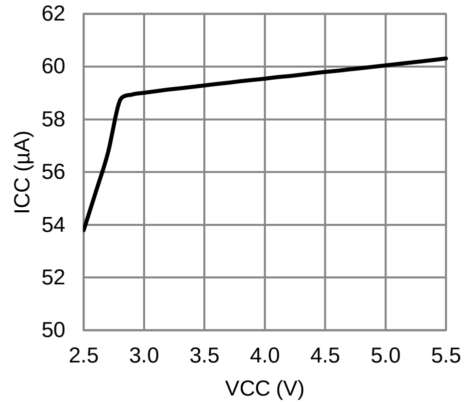

OTP
OTP-HYS
Temp
FLAG
tON_DB_DELAY
DB
Disabled
Enabled
Disabled
tON_CC
tON_SBU
CCxS/SBxS
90%

Figure 3. OTP

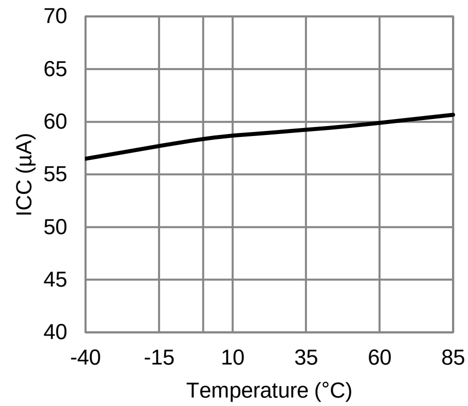
Typical Characteristics

V_{CC} = 3.3V, C_{VCC} = 1µF, C_{ESD} = 0.1µF, T_{AMB} = 25°C unless otherwise specified.

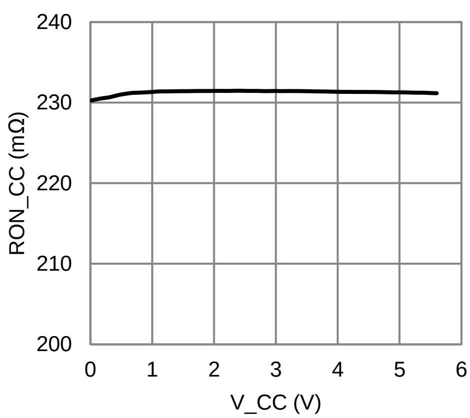
VCC Supply Current vs VCC Voltage



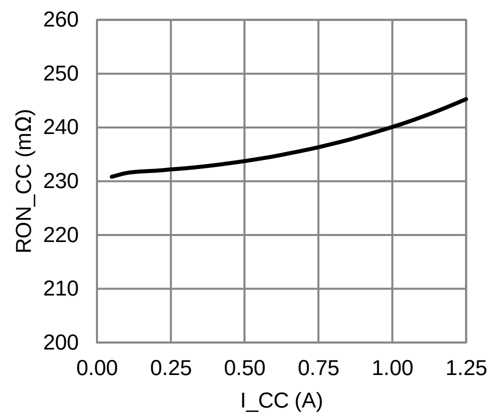
VCC Supply Current vs. Temperature



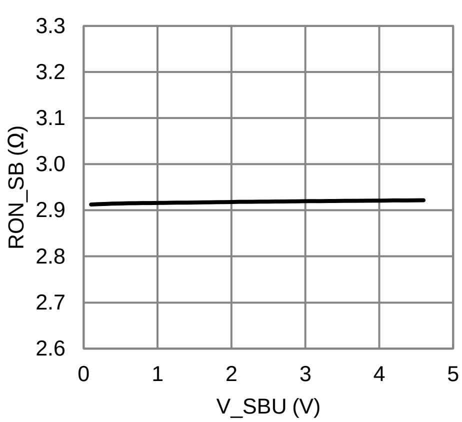
CC Switch R_{ON} vs. Switch Voltage
(I_CC = 200mA)



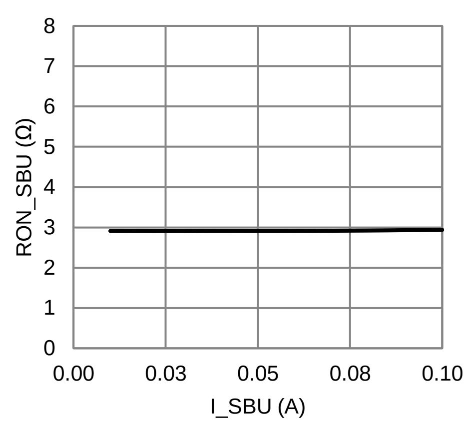
CC Switch R_{ON} vs. Switch Current



SBU Switch R_{ON} vs. Switch Voltage
(I_SBU = 100mA)



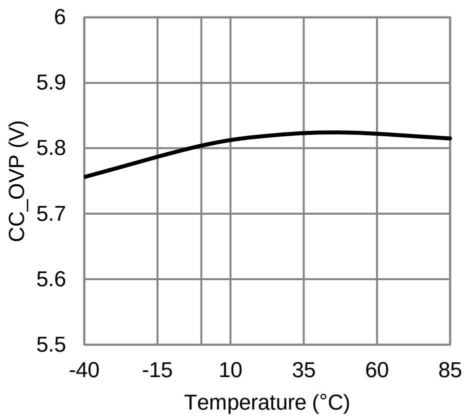
SBU Switch R_{ON} vs. Switch Current



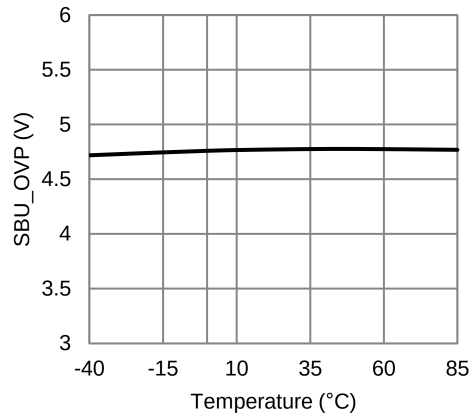
Typical Characteristics (continue)

V_{CC} = 3.3V, C_{VCC} = 1µF, C_{ESD} = 0.1µF, T_{AMB} = 25°C unless otherwise specified.

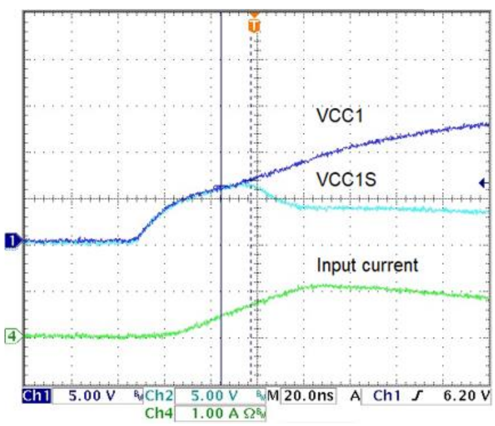
CC Switch OVP Level vs. Temperature



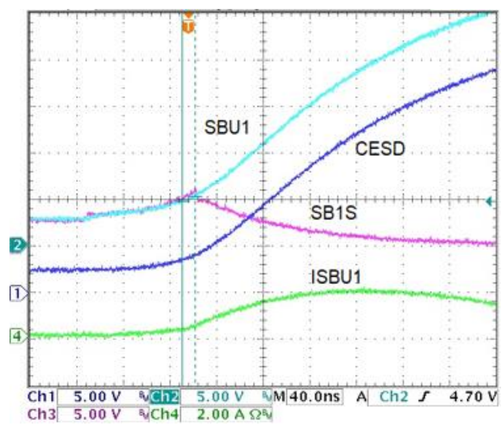
SBU Switch OVP Level vs. Temperature



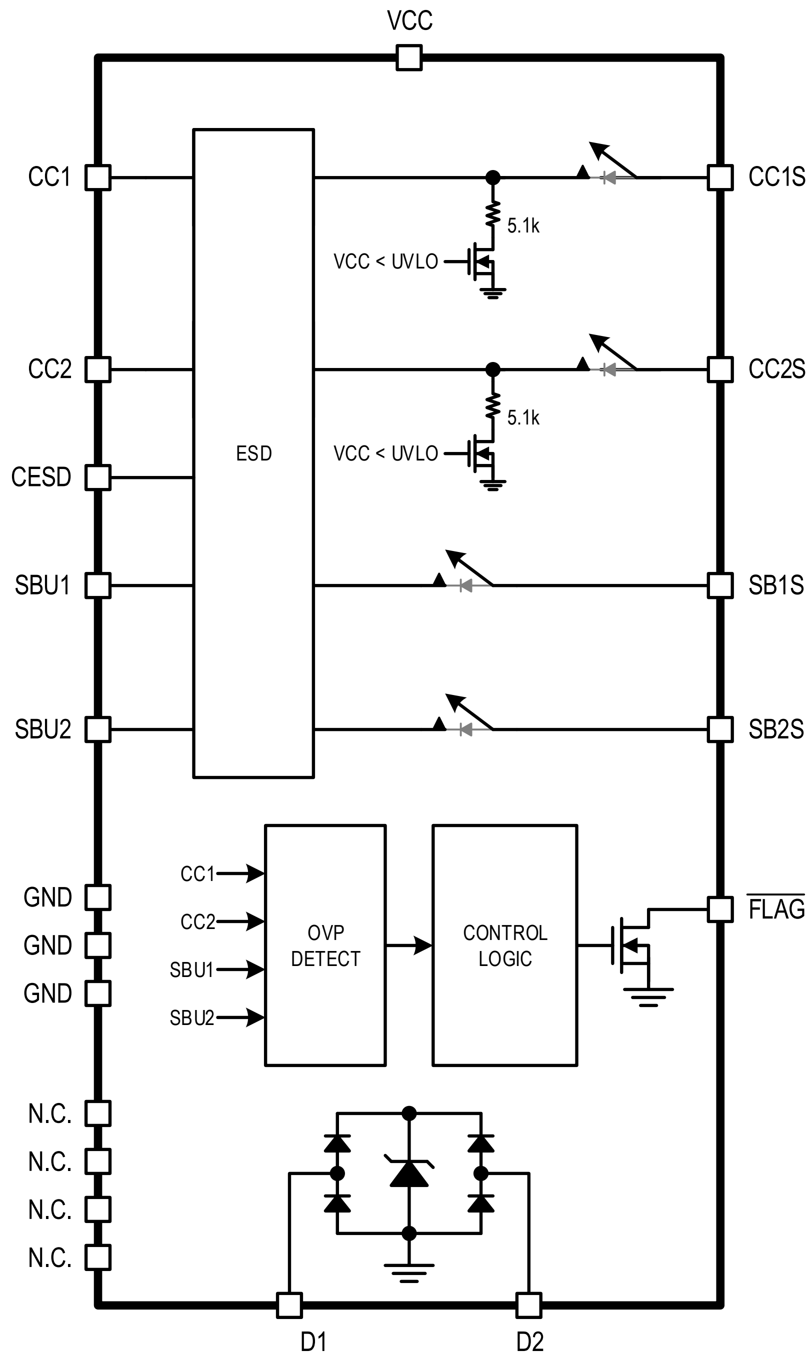
Hot-plug CC1 to 20V



Hot-plug SBU1 to 20V



Functional Block Diagram



Functional Description

The KTU1131 integrates 4 switches to provide over-voltage protections for CC and SBU channels. Once there is a high voltage applied on any of them, for example, any of CC1/2 and SBU1/2 is shorted to VBUS (CC and SBU are adjacent to VBUS for a type-C connector.), all switches would be turned off to prevent the harmful voltage from being sent to system side.

Power Up and Down

After VCC ramps up and beyond UVLO, part will turn on CC and SBU switches with respective delays of t_{ON_CC} and t_{ON_SBU}. However, longer time of $t_{ON\_DB\_DELAY}$ needs to wait for exiting DB (disconnecting 5.1k from CCx to GND), until stable connections have been established for CC channels.

When VCC ramps down and below UVLO, all switches are turned off, and DB resistors are re-connected immediately.

More details could be found from Figure 1.

Table 1. Control Logic Table

IC Power	Conditions	Switch On/Off Status			$\overline{\text{FLAG}}$
		CC1/2	SBU1/2	Dead Battery	
$V_{CC} > V_{UVLO}$	No Faults	ON	ON	OFF	High-Z
	$V_{CC1/2} > V_{OVP\_CC}$	OFF	OFF	ON	Active Low
	$V_{SBU1/2} > V_{OVP\_SBU}$	OFF	OFF	ON	Active Low
	$T_J > T_{J\_SHDN}$	OFF	OFF	OFF	Active Low
$V_{CC} < V_{UVLO}$	$V_{CC1/2}$ = 2.6V	OFF	OFF	ON	High-Z

Dead Battery Automatic 5.1kΩ Pull-Down

KTU1131 integrated pull down resistor from CCx to GND. When under dead battery condition, DFP or adpaper can recognize the device through these pull down resistors and start to feed power in. After CC channels are turned on, KTU1131 cut those pull down resistors automatically with a short period of delay. And it reconnects those resistors when CCx channels are off, for example caused by UVLO or OVP, except OTP event.

See Figure 1 to Figure 3 for more details.

Over-Voltage Protection

Once any of those channels met with OVP event, KTU1131 will shut all channels at once. $\overline{\text{FLAG}}$ will be pulled low to indicate there is a fault. After part is recovered, $\overline{\text{FLAG}}$ would be released to High-Z again automatically.

Over-Temperature Protection

KTU1131 will also turn off all channels when OTP happens. $\overline{\text{FLAG}}$ will be pulled low to indicate there is a fault. However, dead-battery resistors will not be presented when OTP is lasting. They will be presented when OTP is over and before CCx channels are closed. See Figure 3.

Applications Information

For typical USB Type-C CC and SBU input port protection applications, only two external components are required for the KTU1131 to provide protection functions.

Input Supply and Bypass Capacitor Selection

Place a 1.0µF/10V ceramic capacitor between the VCC pin and ground. X5R or X7R dielectric ceramic capacitors are preferred for input supply bypassing applications as they maintain better capacitance value and tolerances over operating voltage and temperature ranges when compared to lower cost Y5V dielectric type ceramic capacitors.

ESD Capacitor

KTU1131 utilizes an ESD support capacitor to meet ESD protection requirements. The ESD support capacitor should be placed between the CESD pin and ground. The CC1/2 and SBU1/2 inputs can have as much as 20V applied during a short-to-VBUS event. A 0.1µF/50V X5R or X7R dielectric ceramic capacitor is recommended for this application.

Dead Battery Detection / Operation

USB Type-C specification allows the host and peripheral device to charge internal batteries through the Type-C port receptacle. Dead battery detection is an important feature that allows a device to be charged when its internal battery supply is depleted. Another scenario for dead battery support is when the CC1/2 or SBU1/2 switches are shut down due to an OVP condition. Automatic 5.1kΩ dead battery pull-down resistors on the CC1/2 inputs signal to a connected upstream USB current source PD host or wall adapter to allow charging through the USB Type-C port VBUS. When an applied adapter senses a 5.1kΩ pull down on CC1/2, 5V should be applied to the VBUS line to enable charging. For this reason, the KTU1131 contains an automatic dead battery sub-circuit – see Figure 4. The CC1/2 pin impedance to ground is 5.1kΩ when the IC is shut down by the UVLO function due to a dead battery. When the IC is enabled under regular operation conditions, the CC1/2 impedance to ground is switched to over 6MΩ to support normal CC line functions. Refer to Table 1 control logic for CC1/2 line-states versus operation conditions.

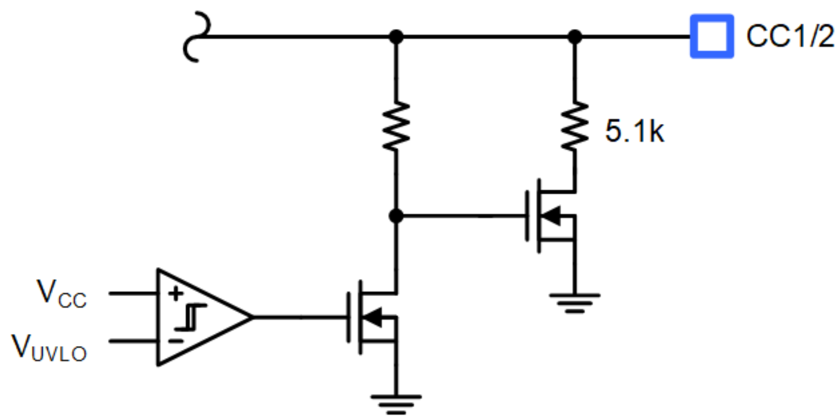


Figure 4. Simplified Schematic for Dead Battery Automatic 5.1kΩ Pull-Down Sub-Circuit

Moisture Testing

In systems that perform moisture detection on the USB port, it is typical to apply a test current through the KTU1131 and out of the connector-side pins. Moisture presents itself as a resistance path from the connector-side pins to ground. The threshold for moisture detection is usually less than 1MΩ of external leakage resistance to ground. To simplify moisture detection, the KTU1131 features over 6MΩ internal impedance from the connector-side pins to ground (SBU1/2 even has a bigger value of 12MΩ). However, it is important to keep in mind that KTU1131's internal impedance reduces when the voltage on the connector-side pins (CC1/2, SBU1/2) is greater than the device supply voltage (VCC). Therefore, it is important to use a weak test current for a suitably low moisture detection threshold. An alternate solution is to use a pullup resistor to a voltage source, for example, 30kΩ pull-up to 2.7V.

Fault Flag Operation

The KTU1131 fault flag will alert the system controller to an OVP, surge or IC over temperature fault. The fault flag circuit is an open-drain MOSFET output that connects the $\overline{\text{FLAG}}$ pin to ground when there is an active fault condition. Refer to the IC functional block diagram for internal fault flag circuit connections. Common system controllers can typically be configured to place a logic pull up on the fault flag input signal, in these cases the $\overline{\text{FLAG}}$ output can be connected directly to the controller I/O. If a logic pull-up termination is not available, the $\overline{\text{FLAG}}$ output may be manually pulled-up high to a logic level voltage supply through a 10kΩ or greater value resistor.

Recommended PCB Layout

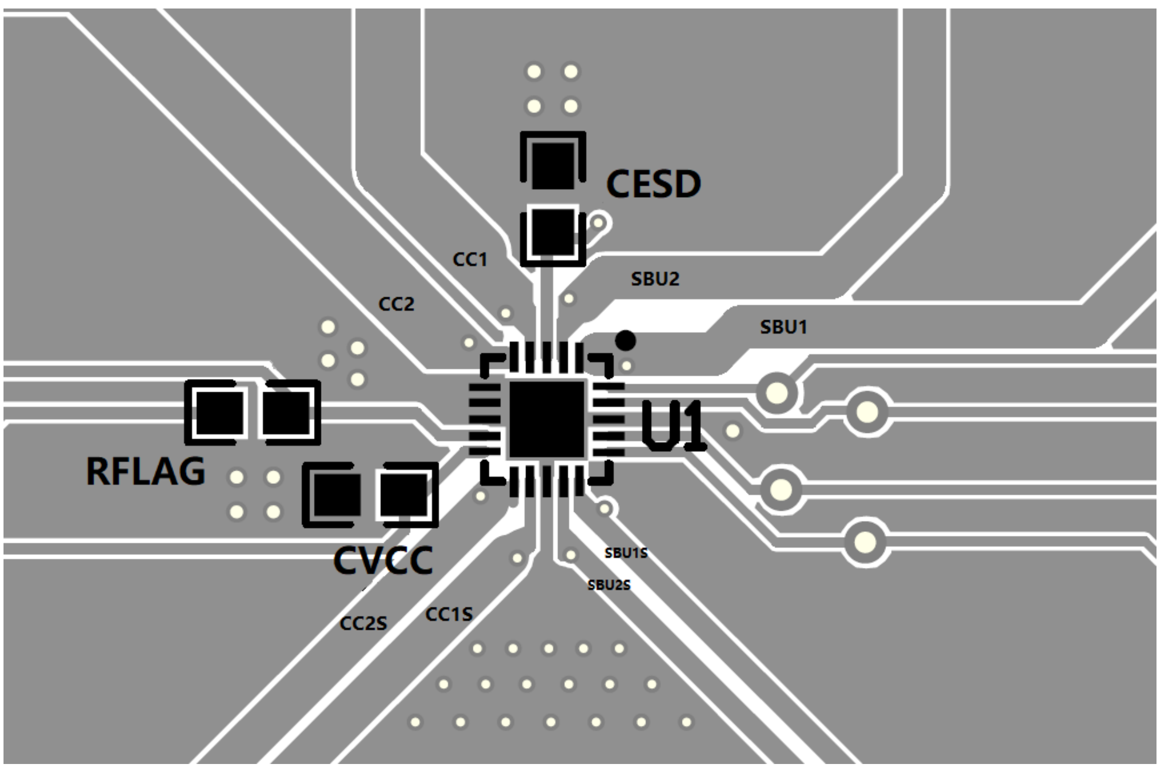


Figure 5. Recommended PCB Layout