

## USB Type-C Protector for CC Pins

### Features

- Overvoltage Protection:
  - ▶ 24VDC Tolerance on CC1/2
    - Robust 25V overshoot clamping
  - ▶ CC1/2 OVP = 5.8V
  - ▶ Ultra-fast 15ns Response Time
- Surge Protection
  - ▶ ±40V Surge Tolerance on CC1/2
- IEC61000-4-2 ESD Protection
  - ▶ ±15kV air gap on CC1/2
  - ▶ ±8kV contact on CC1/2
  - ▶ ±2kV HBM on all pins
- Moisture Detection Compatible
  - ▶ Over 10MΩ to ground on CC1/2
- CC Switches:
  - ▶ 1.25A, 240mΩ, 370pF, 13.2MHz
  - ▶ Automatic 5.1kΩ dead battery pull-down
- 2.5V to 5.5V Operating Voltage Range
- -40°C to 85°C Operating Temperature Range
- Pb-free 12 bump WLCSP (0.4mm pitch)

### Brief Description

The KTU1109 provides ESD, surge, and over-voltage protection (OVP) for USB type-C ports' CC1 and CC2 (CC and V<sub>CONN</sub>) lines. ESD protection meets IEC61000-4-2 standards, eliminating the need for external TVS diodes. Surge protection meets IEC61000-4-5 standards, increasing immunity from power surges such as lightning strikes on the power lines while the USB cable is connected. Overvoltage protection (OVP) eliminates system damage due to physical or moisture-related shorts between the signal pins and VBUS at elevated PD voltage levels.

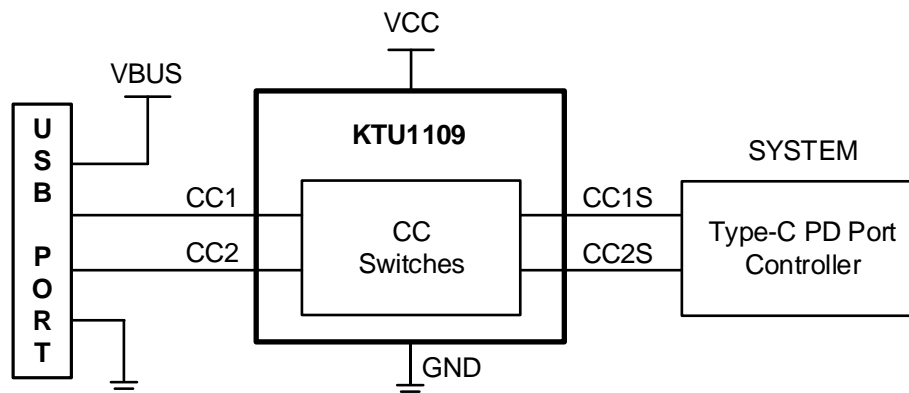
The CC1/2 switches are low on-resistance to minimize power dissipation for passing V<sub>CONN</sub> power up to 1.25A. During dead battery conditions, internal 5.1kΩ resistors automatically pull down on CC1/2 to ensure that the up-stream source provides 5V to VBUS.

The KTU1109 is packaged in RoHS and Green compliant 1.29mm x 1.69mm wafer-level chip-scale package (WLCSP).

### Applications

- Smartphones and Tablets
- Mobile Internet Devices, Accessories, Wearables

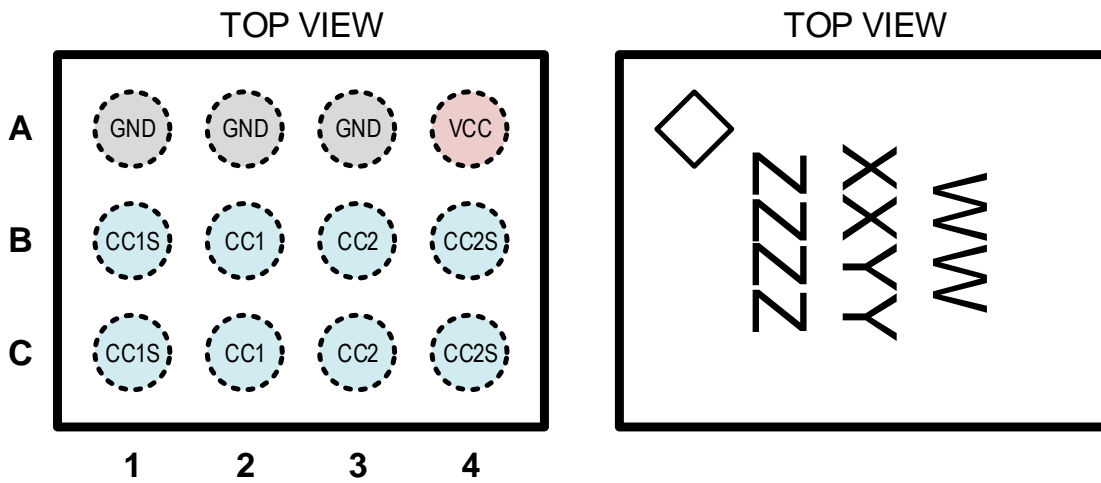
### Typical Application



**Pin Descriptions**

Pin #	Name	Function
A4	VCC	Device Supply Input – connect to a 2.5V to 5.5V source. Connect a 1µF ceramic capacitor from VCC to GND.
A1, A2, A3	GND	Ground
B2, C2	CC1	Connector side of CC1 switch
B3, C3	CC2	Connector side of CC2 switch
B1, C1	CC1S	System side of CC1 switch
B4, C4	CC2S	System side of CC2 switch

**WLCSP34-12**



12-Bump 1.29mm x 1.69mm x 0.620mm  
WLCSP Package, 0.4mm pitch

Top Mark  
 WW = Device ID Code  
 XX = Date Code, YY = Assembly Code  
 ZZZZ = Serial Number

## Absolute Maximum Ratings<sup>1</sup>

(T<sub>A</sub> = 25°C unless otherwise noted)

Symbol	Description	Value	Units
V <sub>CC</sub>	VCC to GND	-0.3 to 6	V
V <sub>IO</sub>	CC1, CC2 to GND (2.5V < VCC < 5.5V)	-0.3 to 24	V
	CC1S, CC2S to GND (2.5V < VCC < 5.5V)	-0.3 to 8	
I <sub>IO</sub>	CCn to CCnS Continuous Current	±1250	mA
	CCn to CCnS Peak Current (2.5ms)	±2000	
T <sub>J</sub>	Operating Junction Temperature Range	-40 to 150	°C
T <sub>S</sub>	Storage Temperature Range	-65 to 150	°C
T <sub>LEAD</sub>	Maximum Soldering Temperature (at leads, 10 sec)	260	°C

## ESD and Surge Protections<sup>2</sup>

Symbol	Description	Value	Units
V <sub>ESD_HBM</sub>	JEDEC JS-001 ESD Human Body Model (all pins)	±2	kV
V <sub>ESD_CD</sub>	IEC61000-4-2 ESD Contact Discharge (CC1, CC2)	±8	kV
V <sub>ESD_AGD</sub>	IEC61000-4-2 ESD Air-Gap Discharge (CC1, CC2)	±15	kV
V <sub>SURGE</sub>	IEC61000-4-5 Surge (CC1, CC2 to GND)	±40	V

## Thermal Capabilities<sup>3</sup>

Symbol	Description	Value	Units
Θ <sub>JA</sub>	Thermal Resistance – Junction to Ambient	54	°C/W
P <sub>D</sub>	Maximum Power Dissipation at 25°C	2.4	W
ΔP <sub>D</sub> /ΔT	Derating Factor Above T <sub>A</sub> = 25°C	-18.6	mW/°C

## Ordering Information

Part Number	Marking <sup>4</sup>	Operating Temperature	Package
KTU1109EFAA-TR	NFXYYZZZZ	-40°C to +85°C	WLCSP34-12

- 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.
- ESD and Surge Protection ratings conform to JEDEC and IEC industry standards. Some pins may actually have higher performance.
- 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.
- "NF" is the device ID, "XX" is the date code, "YY" is the assembly code and "ZZZZ" is the serial number.

**Electrical Characteristics<sup>5</sup>**

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 +25°C with  $V_{CC} = 3.0V$ .

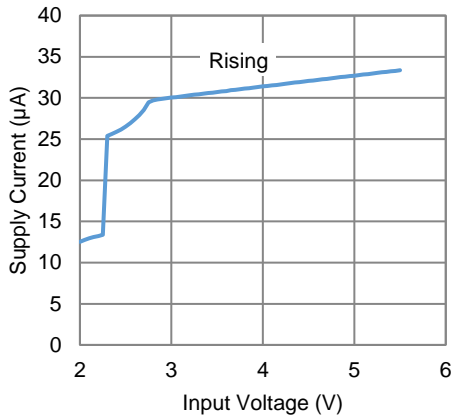
Symbol	Description	Conditions	Min	Typ	Max	Units
<b>Supply Specifications</b>						
$V_{CC}$	Supply Operating Range		2.5		5.5	V
$V_{UVLO}$	Under-Voltage Lockout Threshold	Rising threshold	2.2	2.32	2.45	V
		Hysteresis		100		mV
$I_{CC}$	Supply Current	Enabled, $V_{CC} = 3.0V$		30	50	$\mu A$
<b>Thermal Shutdown Specifications</b>						
$T_{J\_SHDN}$	IC Junction Thermal Shutdown	Rising threshold		150		°C
		Hysteresis		20		°C
<b>CC Switch Specifications</b>						
$V_{CC1/2}$	Switch Voltage Operating Range		-0.3		5.5	V
$V_{OVP\_CC}$	OVP Threshold	Rising threshold	5.55	5.8	6.1	V
		Hysteresis		100		mV
$R_{ON\_CC}$	On-Resistance	Value, $V_{CC1/2} = 0V$ to $V_{CC}$ , $I_{OUT} = 0.1A$		240	500	m $\Omega$
		Flatness, $V_{CC1/2} = 0V$ to $V_{CC}$		0.9		m $\Omega$
		Matching, $V_{CC1/2} = 0V$ to $V_{CC}$		0.5		m $\Omega$
$C_{ON\_CC}$	On-Capacitance	Frequency = 50MHz		370		pF
$BW_{ON\_CC}$	On-Bandwidth	$R_S = R_L = 50\Omega$ , $V_{CC1/2} = 0dBm$		13.2		MHz
		Intended data rate	10	300		Kbps
$R_{CC1/2\_GND}$	Resistance to GND	$V_{CC1/2} \leq V_{CC}$ , $T_A = +25^\circ C$	10	12.8		M $\Omega$
$I_{CCLK}$	Switch Off Leakage Current	$V_{CC} = 0V$ , $V_{CC1/2} = 5.5V$ , $V_{CC1/2S} = 0V$ , $T_A = +25^\circ C$ , measure current out of CC1/2S		0.1	1	$\mu A$
$R_{DB}$	Dead Battery Pull-Down Resistance	$V_{CC} < V_{UVLO}$ , $V_{CC1/2} = 2.6V$	4.1	5.1	6.1	k $\Omega$
$V_{CC1/2\_DB}$	Dead Battery Threshold Voltage	$I_{CC1/2} = 80\mu A$	0.5	0.82	1.2	V
$t_{ON\_CC}$	Switch Turn-On Time	$V_{CC}$ rising $> V_{UVLO}$		100		$\mu s$
$t_{OFF\_CC}$	Switch Turn-Off Time	$V_{CC}$ falling $< V_{UVLO}$		12		$\mu s$
$t_{OVP\_CC\_R}$	OVP Rising Response Time	$V_{CC} = 3.0V$ , $CC1/2 = +40V$ surge, $CC1/2S = 5.1k\Omega$ to GND, $T_A = +25^\circ C$		15		ns
$V_{CC1/2S\_MAX}$	OVP Rising Maximum System Voltage	$V_{CC} = 3.0V$ , $CC1/2 = +40V$ surge, $CC1/2S = 5.1k\Omega$ to GND, $T_A = +25^\circ C$ , measured at CC1/2S		5.9		V
$t_{OVP\_CC\_F}$	OVP Falling Debounce Time			30		$\mu s$

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.

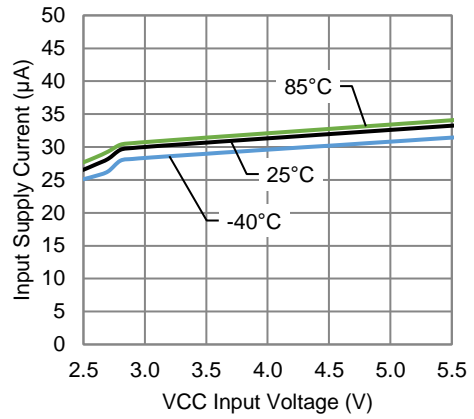
## Typical Characteristics

$V_{CC} = 3.0V$ ,  $C_{VCC} = 1\mu F$  and  $T_A = 25^\circ C$  unless otherwise specified.

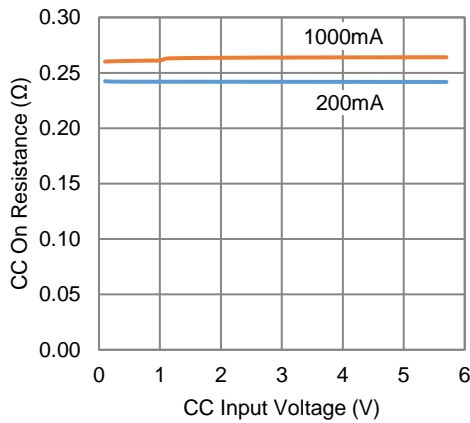
**VCC Supply Current vs. Supply Voltage**



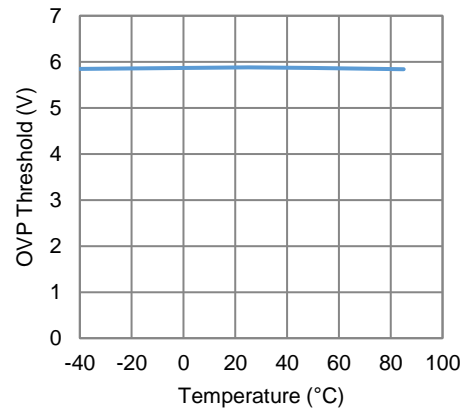
**VCC Supply Current vs. Temperature**



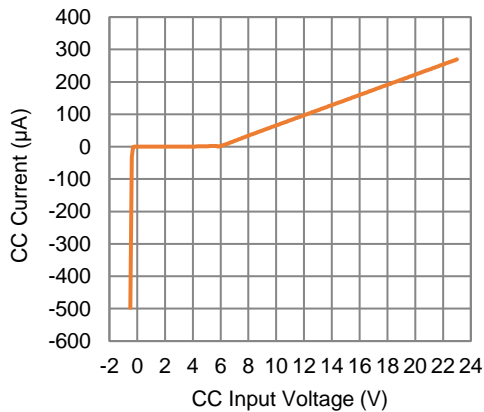
**CC Switch R<sub>ON</sub> vs. Switch Voltage**



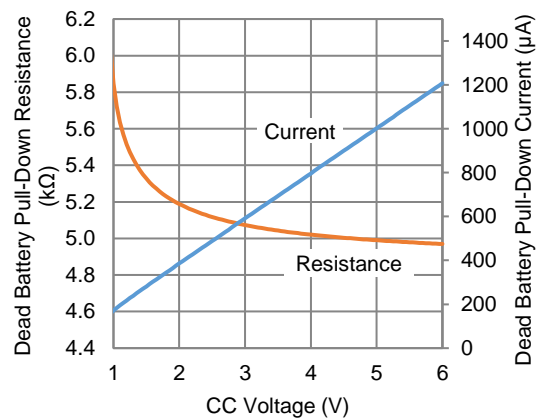
**CC Switch OVP Threshold vs. Temperature**



**CC I-V Curves**



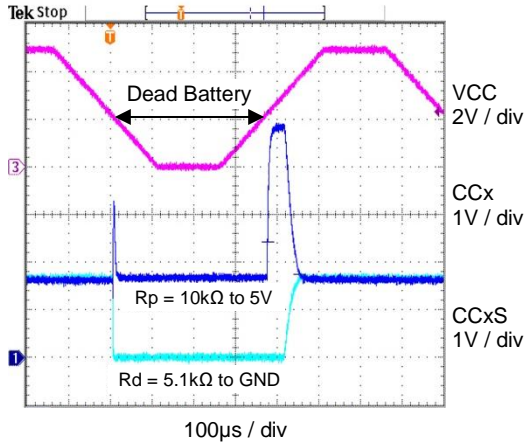
**Dead Battery 5.1kΩ Pull-Down Current & Resistance vs. CC Voltage**



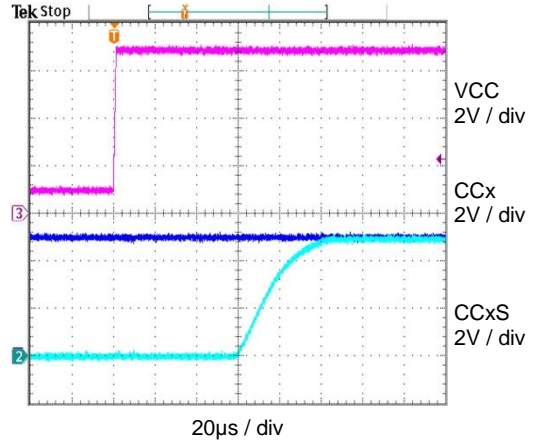
**Typical Characteristics (continued)**

$V_{CC} = 3.0V$ ,  $C_{VCC} = 1\mu F$  and  $T_A = 25^\circ C$  unless otherwise specified.

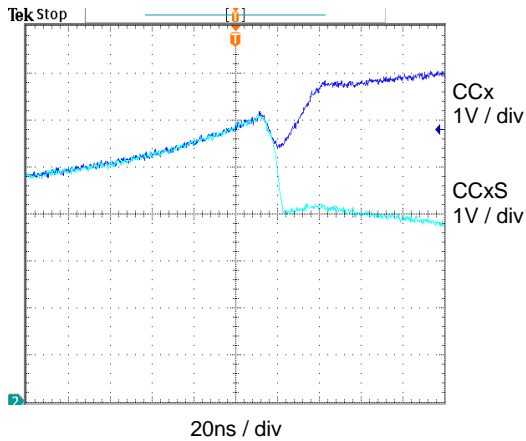
**Dead Battery 5.1kΩ Activation & Recovery**



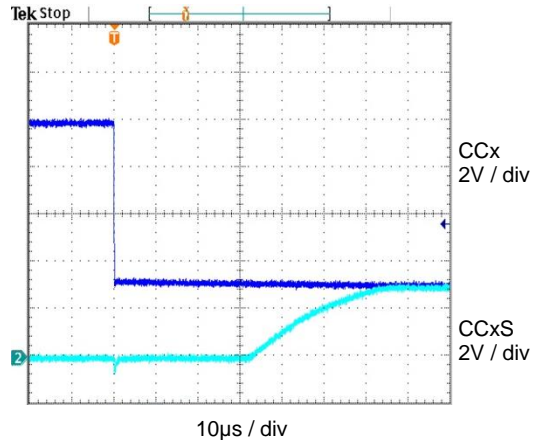
**CC Switch Turn-On**



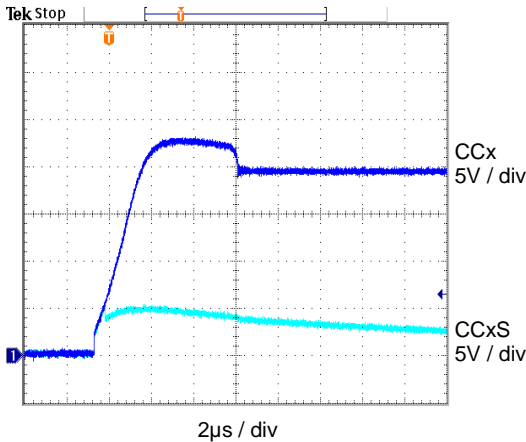
**CC OVP Event**



**CC OVP Recovery**

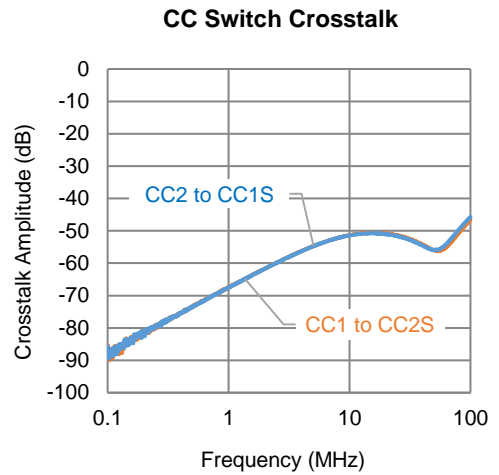
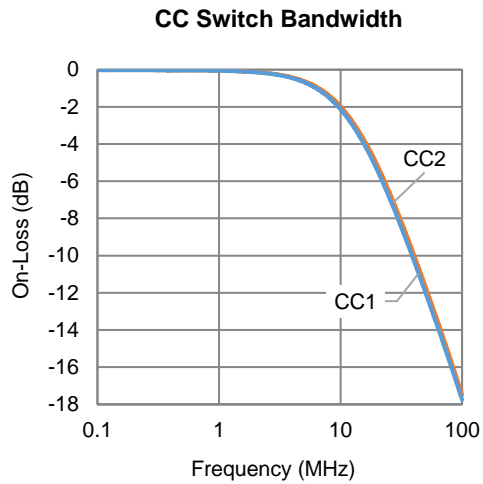


**CC Short-to-VBUS (20V) Event**

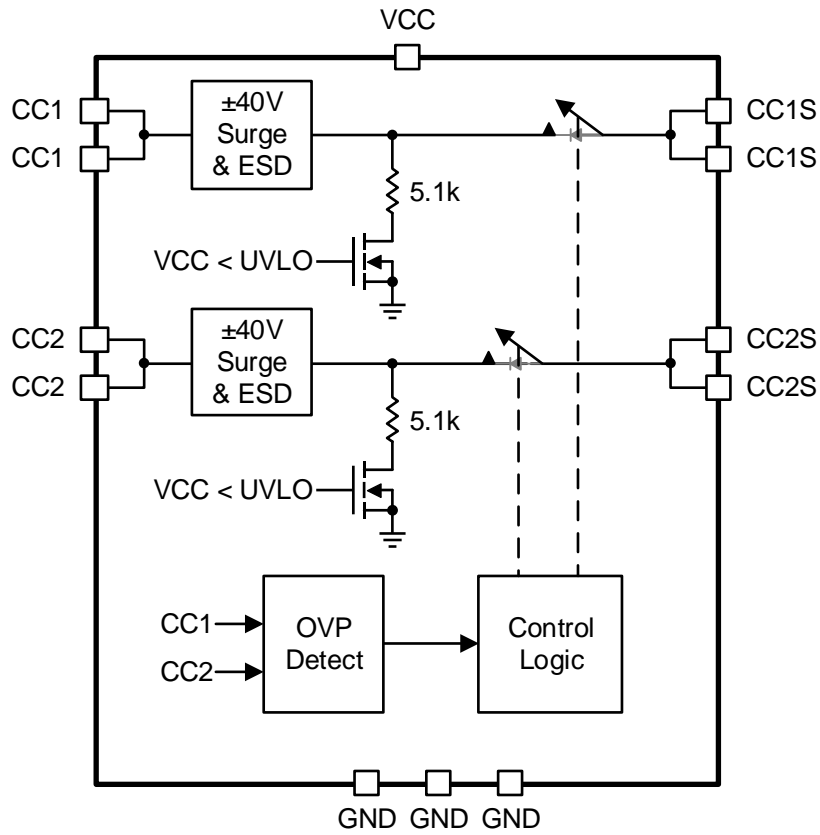


**Typical Characteristics (continued)**

$V_{CC} = 3.0V$ ,  $C_{VCC} = 1\mu F$  and  $T_A = 25^\circ C$  unless otherwise specified.



**Functional Block Diagram**



**Figure 1. KTU1109 Functional Block Diagram**



## Functional Description

The KTU1109 is designed to provide overvoltage protection (OVP) switches for USB Type-C port CC1/2 signal pins, with protection from voltage surges, and electro-static discharge (ESD). Fault conditions can occur at the input port receptacle due to mechanical shorts between the CC pins to VBUS PD levels up to 24V. The KTU1109 provides these functions in a space saving WLCSP34-12 package.

The CC1/2 protection switches have a low on-resistance value that is typically 240m $\Omega$ . This low on-resistance allows the CC1/2 switches to pass  $V_{CONN}$  power up to 1.25A without excess voltage drop or power dissipation issues. The typical 370pF switch capacitance provides a typical signal bandwidth of 13.2Mhz which is more than required to normal USB PD data rates that usually do not exceed 300kbps.

The KTU1109 has a dead battery function for CC1/2 USB Type-C operation which presents internal 5.1K $\Omega$  pull-downs in the event of a dead battery. To aid in moisture detection within the USB Type-C receptacle, the CC1/2 switches have over 10M $\Omega$  resistance to ground in normal operation. Refer to the IC application information section for dead battery and moisture detection features.

### Overvoltage Protection (OVP)

Overvoltage events can occur on the CC signal lines caused by a short to VBUS with voltages that can range up to the full USB PD 20V level. Overvoltage events can also be induced by faulty external adaptors or USB devices connected to the USB Type-C input. To guard against such events, the CC1/2 protection switches are overvoltage tolerant up to 24VDC and include 27V surge clamps.

When enabled, the KTU1109 continuously monitor the voltage level present on the CC1/2 signal lines. If the voltage on either CC1 or CC2 exceeds 5.8V (nominal), the IC control shuts down (turns off) all switches to protect the downstream system from the overvoltage event. The CC1/2 switches will typically respond to an OVP event in 15ns. Switch operation automatically resumes when the applied CC1/2 voltage drops below 5.7V as there is a 100mV OVP threshold hysteresis for both of signal switches.

### ESD and Surge Protection

The KTU1109 ESD protection is compliant to IEC61000-4-2 levels, providing CC1/2 pins air gap protection up to  $\pm 15$ kV and contact protection up to  $\pm 8$ kV. The KTU1109 is also  $\pm 2$ kV HBM compliant to JEDEC JS-001-2017 standards. The CC1/2 inputs are able to stand off ESD events up to the stated specifications. To protect the IC and system from CC line voltage surges, the KTU1109 CC1/2 input pins can stand off input surge events up to  $\pm 40$ V.

### IC Protection

In addition to ESD, surge and OVP protection, the KTU1109 also includes internal thermal monitoring/shutdown and input supply undervoltage lockout features. The IC will automatically shut down if the internal die temperature exceeds 150 $^{\circ}$ C (nominal). There is 20 $^{\circ}$ C of hysteresis allowing the IC to automatically restart and resume operation when the internal die temperature cools to a level below 130 $^{\circ}$ C (nominal).

## Application Information

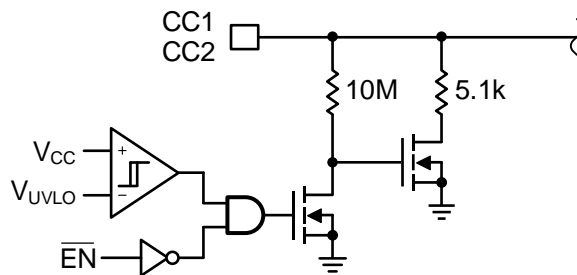
For typical USB Type-C CC input port protection applications, only one external component is required for the KTU1109 to provide protection functions.

### Input Supply and Bypass Capacitor Selection

Place a 1.0 $\mu$ F/10V or greater value 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.

### 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. Automatic 5.1k $\Omega$  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 5.1k $\Omega$  pull-down on CC1/2, 5V should be applied to the VBUS line to enable charging. For this reason, the KTU1109 contains an automatic dead battery sub-circuit – see Figure 2. The CC1/2 pin impedance to ground is 5.1k $\Omega$  when no supply is present at VCC or when the device is in UVLO shutdown. Under regular operation conditions with 2.5V to 5.5V applied to VCC, the CC1/2 impedance to ground is switched to 10M $\Omega$  to support normal CC line functions.



**Figure 2. Simplified Schematic for Dead Battery Automatic 5.1k $\Omega$  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 KTU1109 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 1M $\Omega$  of external leakage resistance to ground. To simplify moisture detection, the KTU1109 features over 10M $\Omega$  internal impedance from the connector-side pins to ground. However, it is important to keep in mind that KTU1109's internal impedance reduces when the voltage on the connector-side pins (CC1/2) 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, 30k $\Omega$  pull-up to 2.7V.

### PCB Layout Guidelines

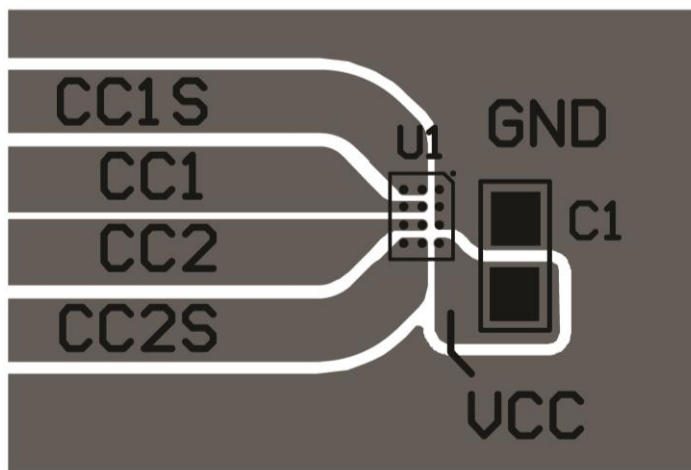
Good PCB layout is important to maintain USB CC signal integrity and optimize KTU1109 protection features. The following guidelines are recommended for best system performance:

1. Multi-layer printed circuits boards are recommended for hi-speed data communication applications. Best USB CC signal quality is realized with 4 layer or greater PCB assemblies. A multilayer board minimizes the board material thickness between the signal trace layer and adjacent ground plane layer, which aids in maintaining consistent trace impedance for high-frequency signals.
2. The KTU1109 IC package should be placed as close as possible to the USB Type-C connector to maximize ESD, surge and OVP protection for the system.
3. The use of data trace vias should be minimized or ideally avoided altogether as they introduce impedance discontinuities at high frequencies and compromise signal quality.

4. If CC inputs are to be used in  $V_{CONN}$  applications, size trace widths wide enough for the high current capacity requirements for this function. The KTU1109 is designed to support up to 1.25A through the CC1/2 switches.
5. CC1/2 signal traces should be routed directly over ground planes placed on the next PCB layer. To maintain best PCB trace impedance characteristic and minimize electro-magnetic interference (EMI), the ground plane layer should have no breaks under the signal trace layer. The ground plane layer should be referenced back to the system power source ground at one single point to avoid stray current paths through the ground plane.

### Recommended Layout

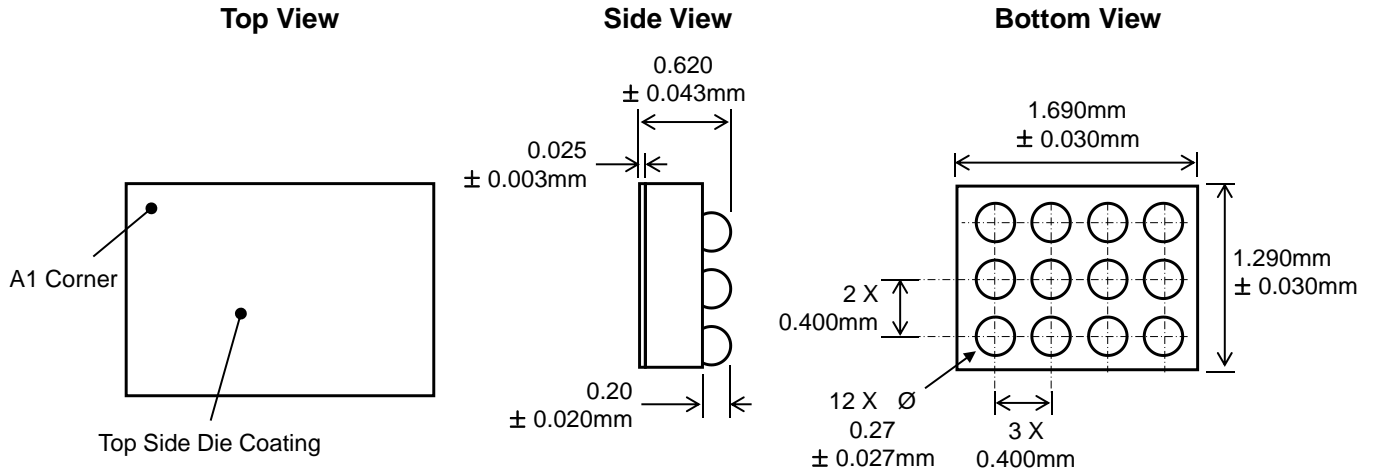
It is recommended to place the decoupling capacitor close to the IC and the trace length to VCC and GND should be minimized. The VCC pin requires a capacitor for decoupling. Use a  $1\mu\text{F}$ , 10V rated, low ESR, X5R ceramic capacitor for best performance.



**Figure 3. Recommended Layout**

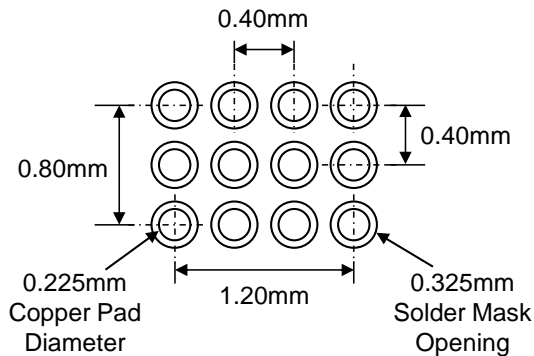
**Packaging Information**

WLCSP34-12 (1.690mm x 1.290mm x 0.620mm)



**Recommended Footprint**

(NSMD Pad Type)



\* Dimensions are in millimeters.

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