

## Low $R_{ON}$ Load Switch with Overvoltage and Reverse Blocking Protection

### Features

- Wide Input voltage range: 3V to 23V
- 30V Absolute Ratings at  $V_{IN}$  and  $V_{OUT}$
- Maximum 5A continuous current
- Integrated FET with 30m $\Omega$  (Typ)  $R_{ON}$
- Wide Overvoltage threshold range
  - Fixed internal: 23V
  - Adjustable: 4V to 23V
- Open-Drain power good indicator
- Integrated protection
  - Thermal Shutdown
  - Under-Voltage Lockout (UVLO)
  - Overvoltage Lockout (OVLO)
  - $V_{OUT}$  to  $V_{IN}$  Reverse Current Blocking
  - Over-current limiting
- Surge and ESD Protection
  - IEC61000-4-5:  $\pm 90V$  for  $V_{IN}$
  - IEC61000-4-2:  $\pm 8KV$  Contact,  $\pm 15KV$  Air for  $V_{IN}$
  - HBM:  $\pm 2KV$  for all Pins
- Pb-free Package:
  - 15 Bump WLCSP 2.57mm x 1.57mm
- -40°C to +85°C Temperature Range

### Brief Description

The KTS1677A is a slow-rate controlled, 30m $\Omega$  (Typ), low resistance MOSFET switch intended to be inserted between a power source and a load to isolate and protect against abnormal voltage and current conditions. Featuring slow-rate turn on control, to prevent excessive large inrush current, the KTS1677A also features several additional protection functions, such as input  $\pm 90V$  surge, input overvoltage, input under-voltage protection, reverse current blocking, over-current limiting and over-temperature protection.

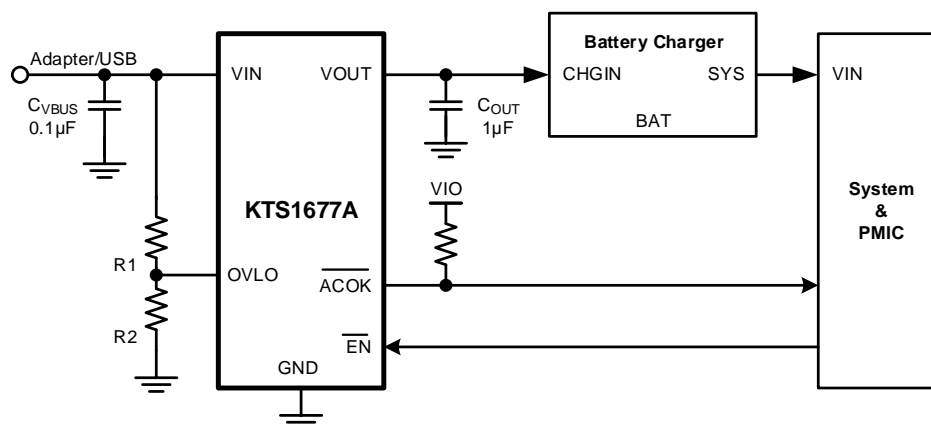
Operating from a wide input voltage range of 3V to 30V can cover USB PD applications to offer essential protection and enhance system reliability. The KTS1677A in the OFF state can block voltages on the  $V_{IN}/V_{OUT}$  pin of up to 30V and prevent reverse currents. Two KTS1677A can be used in to support dual power inputs connecting to the same downstream device.

The device is packaged in advanced, fully “green” compliant, 2.57mm x 1.57mm, Wafer-Level Chip-Scale Package (WLCSP).

### Applications

- Computers and Tablets
- Mobile Internet Devices
- Type-C Power Source Switch
- Storage, DSLR and Portable Devices

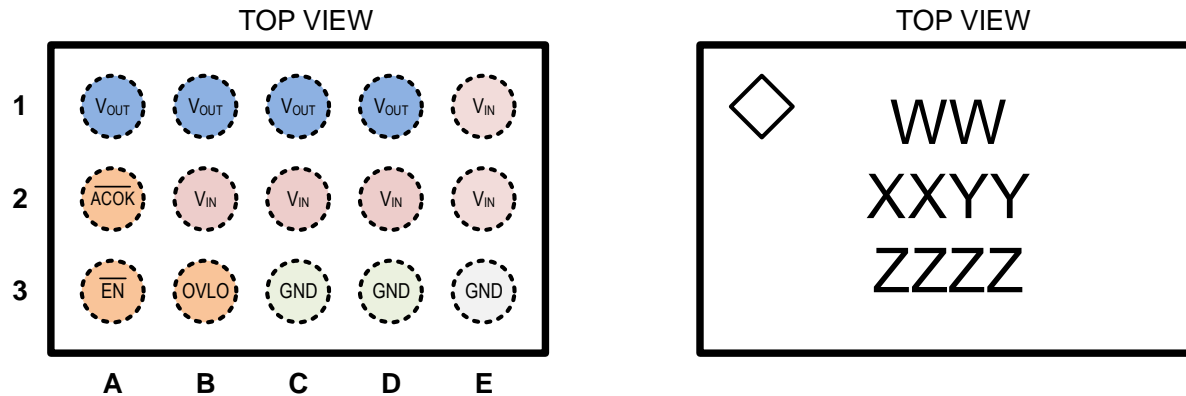
### Typical Application



## Pin Descriptions

Pin #	Name	Function
B2, C2, D2, E1, E2	VIN	Power switch input
A1, B1, C1, D1	VOUT	Power switch output
B3	OVLO	External OVLO Adjustment. Connect OVLO to GND when using the internal fixed threshold. Connect a resistor-divider to OVLO to set the adjustable OVLO threshold. The optional external resistor divider is unrelated to the internal threshold
A2	ACOK	Power Good Indicate PIN with Open Drain output
C3, D3, E3	GND	Ground
A3	EN	Enable input, active LOW.

### WLCSP-15



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

(T<sub>A</sub> = 25°C unless otherwise noted, Voltages are referenced to GND)

Symbol	Description	Value	Units
V <sub>OUT</sub>	Output voltage	-0.3 to 30	V
V <sub>IN</sub>	Input Voltage	-0.3 to 30	
$\overline{\text{EN}}$	Enable Control	-0.3 to 30	
OVLO	OVLO Adjust Pins	-0.3 ~ V <sub>IN</sub>	V
ACOK	Power Good Flag	0.3 ~ 6	V
I <sub>SW</sub>	Maximum Continuous Switch Current <sup>2</sup>	5	A
T <sub>J</sub>	Operating Junction Temperature	-40 to +150	°C
T <sub>STG</sub>	Storage Junction Temperature	-65 to +150	°C

## ESD Protections<sup>3</sup>

Symbol	Description	Value	Units
V <sub>ESD_HBM</sub>	JESD22-A114 Human Body Model (all pins)	±2	kV
V <sub>ESD_CD</sub>	IEC61000-4-2 Contact Discharge (IN pin)	±8	kV
V <sub>ESD_AGD</sub>	IEC61000-4-2 Air Gap Discharge (IN pin)	±15	kV

## Thermal Capabilities

Symbol	Description	Value	Units
Θ <sub>JA</sub>	Thermal Resistance – Junction to Ambient <sup>4</sup>	64.3	°C/W
P <sub>D</sub>	Maximum Power Dissipation at T <sub>A</sub> ≤ 25°C	1.94	W
ΔP <sub>D</sub> /ΔT	Derating Factor Above T <sub>A</sub> = 25°C	-15.55	mW/°C

## Recommended Operation Conditions<sup>5</sup>

Symbol	Description	Value	Units
V <sub>IN</sub>	Supply Voltage	3 to 23	V
V <sub>OUT</sub>	Output Voltage	3 to 23	V
ACOK/OVLO	Enable Control, Power Good Flag and OVLO Adjust Pins	0 to 5.5	V
$\overline{\text{EN}}$		0 to 20	V
C <sub>OUT</sub>	Output Capacitance	10 to 1000	μF

## Ordering Information

Part Number	Marking <sup>6</sup>	Operating Temperature	Package
KTS1677AEVH-TR	NBXXYYZZZ	-40°C to +85°C	WLCSP-15

1. Stress exceeding the absolute maximum rating may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.
2. Maximum Ambient Temperature = 85°C
3. Guaranteed by characterization and design
4. 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.
5. The recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Kinetic does not recommend exceeding them or designing to Absolute Maximum Rating.
6. "WWXXYYZZZ" is the mark code, date code and assembly code.

## Electrical Characteristics<sup>7</sup>

Unless otherwise noted,  $V_{IN} = 3V$  to  $23V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , typical values are at  $V_{IN} = 5V$  and  $T_A = 25^{\circ}C$ .

Symbol	Description	Conditions	Min	Typ	Max	Units
Basic Operation						
V <sub>IN</sub>	Input Voltage		3		23	V
V <sub>OUT</sub>	Output Voltage		3		23	V
V <sub>IN_CLAMP</sub>	Input clamp voltage	I <sub>IN</sub> = 10mA, T <sub>A</sub> = +25°C		32		V
I <sub>Q</sub>	V <sub>IN</sub> Quiescent Current	I <sub>OUT</sub> = 0mA, $\overline{EN}$ = 0V, V <sub>IN</sub> = 5V		130	150	μA
		I <sub>OUT</sub> = 0mA, $\overline{EN}$ = 0V, V <sub>IN</sub> = 20V		180	200	μA
I <sub>SD</sub>	V <sub>IN</sub> Shutdown Current	I <sub>OUT</sub> = 0mA, $\overline{EN}$ = 5V, V <sub>IN</sub> = 5V		2	8	μA
		I <sub>OUT</sub> = 0mA, $\overline{EN}$ = 5V, V <sub>IN</sub> = 20V		3	16	μA
Under-Voltage Protection						
V <sub>UVLO</sub>	Under-Voltage Lockout	V <sub>IN</sub> Increasing	2.3	2.7	3.0	V
V <sub>UVLO_HYS</sub>	UVLO Hysteresis			0.2		V
Leakage						
I <sub>SW_OFF</sub>	V <sub>IN</sub> OFF Leakage Current	$\overline{EN}$ = 5V, V <sub>I N</sub> = 5V, V <sub>OUT</sub> = 0V		2	8	μA
		$\overline{EN}$ = 5V, V <sub>IN</sub> = 20V, V <sub>OUT</sub> = 0V		3	16	μA
	V <sub>OUT</sub> OFF Leakage Current	$\overline{EN}$ = 5V, V <sub>IN</sub> = 0V, V <sub>OUT</sub> = 5V		1	8	μA
		$\overline{EN}$ = 5V, V <sub>IN</sub> = 0V, V <sub>OUT</sub> = 20V		3	16	μA
I <sub>SW_ON</sub>	RCP Leakage	$\overline{EN}$ = 0V, V <sub>IN</sub> = 0V, V <sub>OUT</sub> = 5V		115		μA
Switch						
R <sub>ON</sub>	ON Resistance	V <sub>IN</sub> = 5.0V, T <sub>A</sub> = 25°C		30	40	mΩ
		V <sub>IN</sub> = 20V, T <sub>A</sub> = 25°C		30	40	
Enable						
V <sub>IH</sub>	$\overline{EN}$ Input Logic HIGH Voltage		1.4			V
V <sub>IL</sub>	$\overline{EN}$ Input Logic LOW Voltage				0.4	V
R <sub>pd</sub>	$\overline{EN}$ Pull-Down Resistance		1			MΩ
ACOK						
V <sub>OL_ACOK</sub>	ACOK Output Logic LOW Voltage	I <sub>SINK</sub> = 1mA			0.2	V
I <sub>ACOK_LK</sub>	ACOK Output High Leakage Current	V <sub>IO</sub> = 5V, Switch On	-1		1	μA
Overvoltage Protection						
V <sub>OV_TRIP</sub>	Output OVP Lockout	Rising, OVLO = 0V	21.7	23	24.3	V
V <sub>OV_HYS</sub>	Output OVP Hysteresis	OVLO = 0V		0.3		V
V <sub>TH_OVLO</sub>	external OVLO set threshold voltage	$\overline{EN}$ = 0 V	1.14	1.22	1.30	V
V <sub>OV_SEL</sub>	External OVLO select threshold	OVLO from external become effective once it exceeds this value	0.2	0.25	0.3	V
T <sub>OVP</sub>	OVP Response Time	From V <sub>IN</sub> > V <sub>OVLO</sub> to V <sub>OUT</sub> stop rising; R <sub>load</sub> = 100Ω, C <sub>load</sub> = 0μF, V <sub>IN</sub> = 20V, OVLO = 0V		0.1		μs

7. KTS1677A is guaranteed to meet performance specifications over the  $-40^{\circ}C$  to  $+85^{\circ}C$  operating temperature range by design, characterization and correlation with statistical process controls.

## Electrical Characteristics<sup>7</sup>

Unless otherwise noted,  $V_{IN} = 3V$  to  $23V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , typical values are at  $V_{IN} = 5V$  and  $T_A = 25^{\circ}C$ .

Symbol	Description	Conditions	Min	Typ	Max	Units
<b>Over-current Limiting Protection<sup>8</sup></b>						
$I_{LIM\_TR}$	Current limiting trip point		8.3	12.2		A
$T_{REP}$	Current limit response time. See Figure 6.	$I_{AMP} = 10A$	1			ms
		$I_{AMP} = 12.5A$	300			$\mu s$
		$I_{AMP} = 15A$	100			$\mu s$
$I_{LIM}$	$I_{OUT}$ limit hold point		5.3	7.5		A
<b>Reverse Current Protection (RCP)</b>						
$V_{RC\_TRIG}$	RCP threshold voltage	$V_{RC\_TRIG} = V_{OUT} - V_{IN}$		80		mV
$V_{RC\_FTRIG}$	RCP fast threshold voltage	$V_{RC\_FTRIG} = V_{OUT} - V_{IN}$		120		mV
$V_{RC\_REC}$	RCP recovery threshold voltage	$V_{RC\_REC} = V_{IN} - V_{OUT}$		10		mV
$T_{RC\_REC}$	RCP recovery response time	From $V_{IN} > V_{OUT} + V_{RC\_REC}$ to switch on		26		ms
$T_{RC\_DEGL}$	RCP de-glitch time	From $V_{OUT} > V_{IN} + V_{RC\_TRIG}$ to switch off		4.2		ms
$T_{RC\_OFF}$	RCP turn-off time	From $V_{OUT} > V_{IN} + 120mV$ to switch off		10		$\mu s$
<b>Dynamic Characteristics</b>						
$T_{DEB}$	De-bounce Time <sup>9</sup>	From $\overline{EN}$ or $3V < V_{IN} < V_{IN\_OVLO}$ to $V_{OUT} = 10\% \cdot V_{IN}$ . $V_{IN} = 5V$ , $R_L = 100\Omega$ , $C_L = 100\mu F$		15		ms
$T_R$	$V_{OUT}$ Rise Time	$V_{OUT}$ from 10% to 90% $V_{IN}$ , $V_{IN} = 5V$ , $R_L = 100\Omega$ , $C_L = 100\mu F$		2.9		ms
		$V_{OUT}$ from 10% to 90% $V_{IN}$ , $V_{IN} = 20V$ , $R_L = 100\Omega$ , $C_L = 100\mu F$		10.6		ms
$T_{OFF}$	Turn-Off Delay	$\overline{EN}$ to $V_{OUT} = 10\% \cdot V_{IN}$ $V_{IN} = 5V$ , $R_L = 100\Omega$ , $C_L = 100\mu F$		23		ms
<b>Thermal Shutdown</b>						
$T_{SD}$	Thermal Shutdown			150		$^{\circ}C$
$T_{HYST}$	Thermal Hysteresis			20		$^{\circ}C$

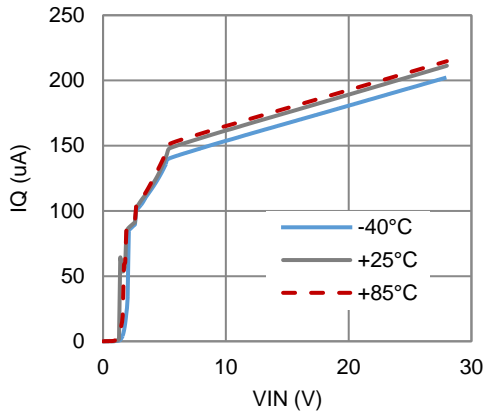
8. Guaranteed by characterization and design

9. Timing as defined in Figure 1.

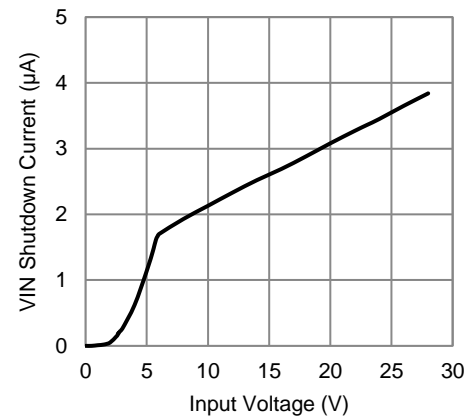
## Typical Characteristics

$V_{IN} = 20V$ ,  $C_{IN} = 0.1\mu F$ ,  $C_{OUT} = 1\mu F$ , OVLO pin = GND,  $T_A = 25^\circ C$  unless otherwise specified.

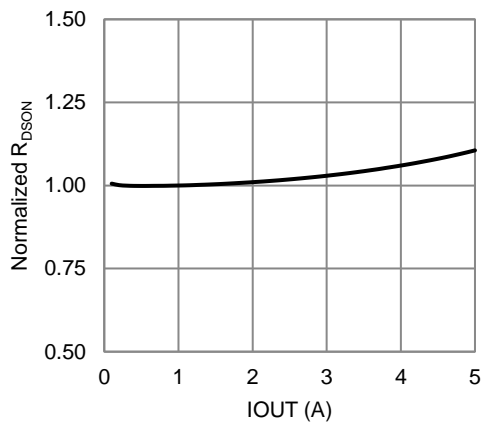
**Supply Current vs VIN vs Temperature**



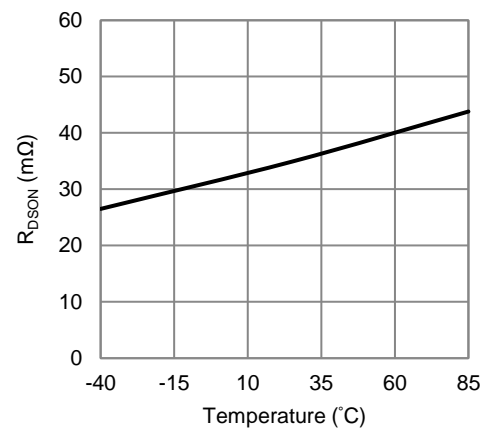
**Shutdown Current vs VIN**



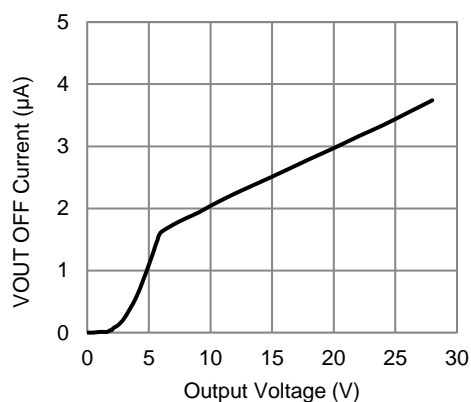
**Normalized  $R_{DS(on)}$  vs. Output Current**



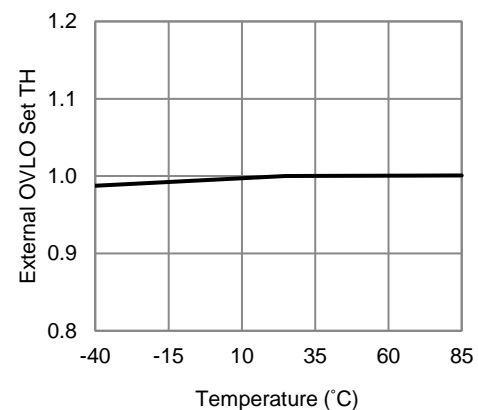
**$R_{DS(on)}$  vs. Temperature ( $I_{OUT} = 1A$ )**



**OFF-state Leakage Current on OUT pin**



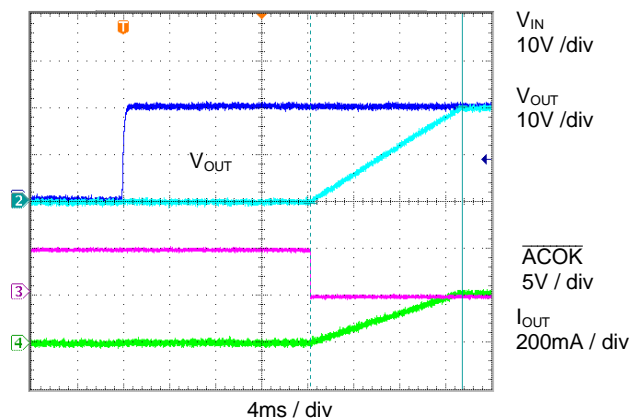
**Normalized OVLO Set Threshold vs Temperature**



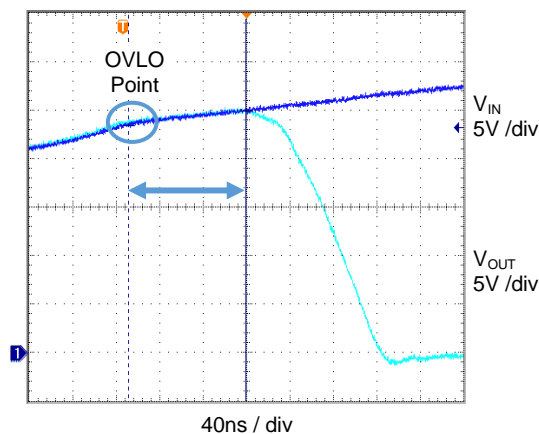
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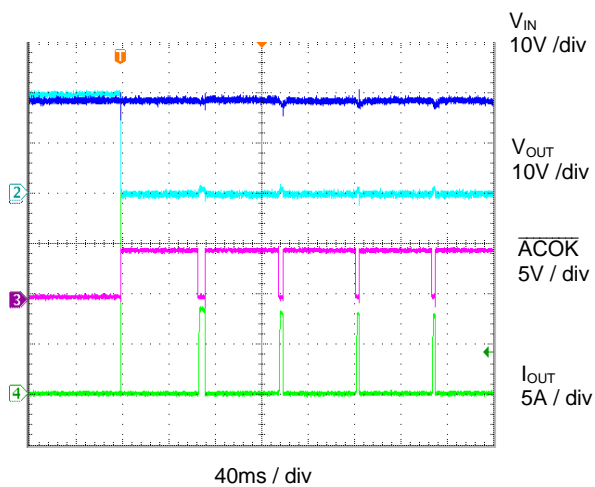
**Power-up ( $C_{OUT} = 1\mu F$ ,  $100\Omega$  Load)**



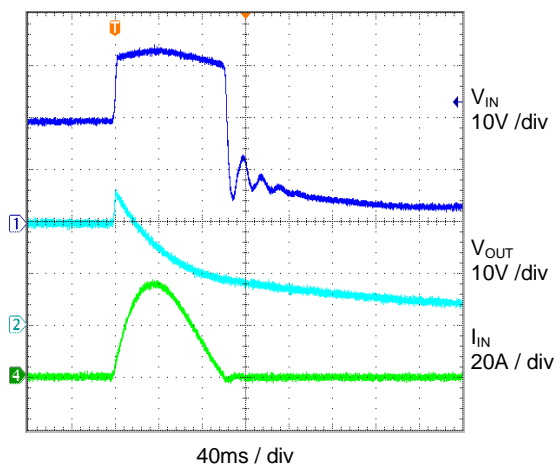
**OVP Response Time ( $V_{IN} = 20V$  to 90V Surge)**



**Short-Circuit Fault Protection (OUT short to GND)**



**Surge Transient (90V)**



## Timing Diagram

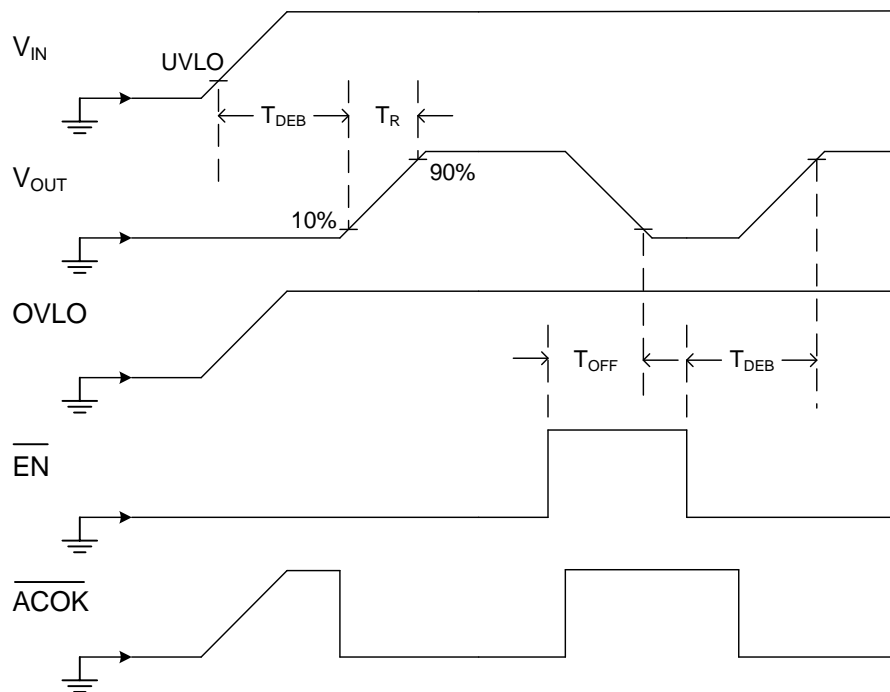


Figure 1. Ramp-up and  $\overline{\text{EN}}$  Toggling

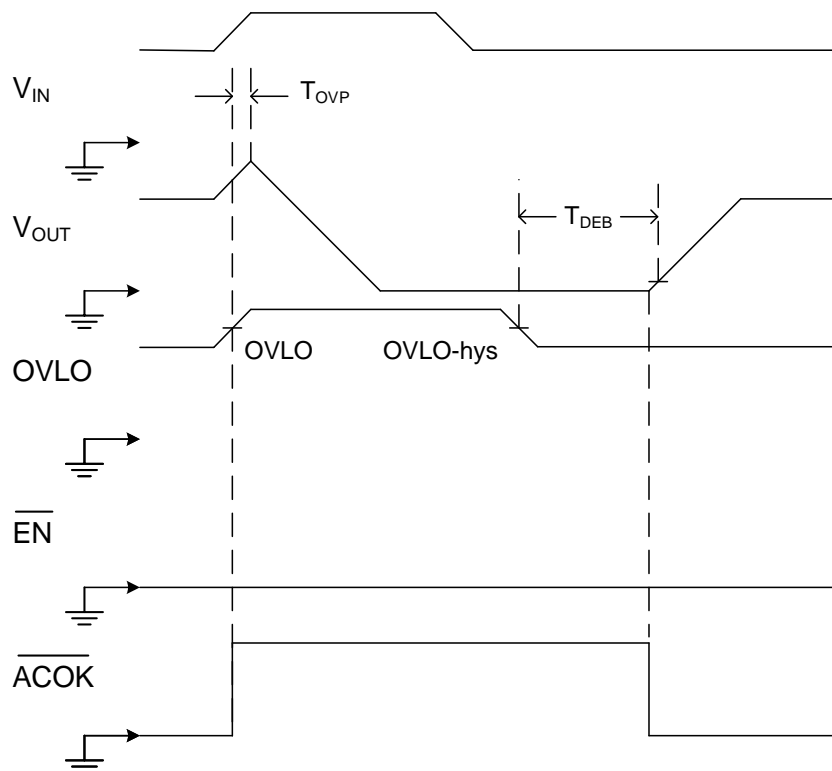
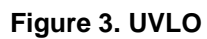
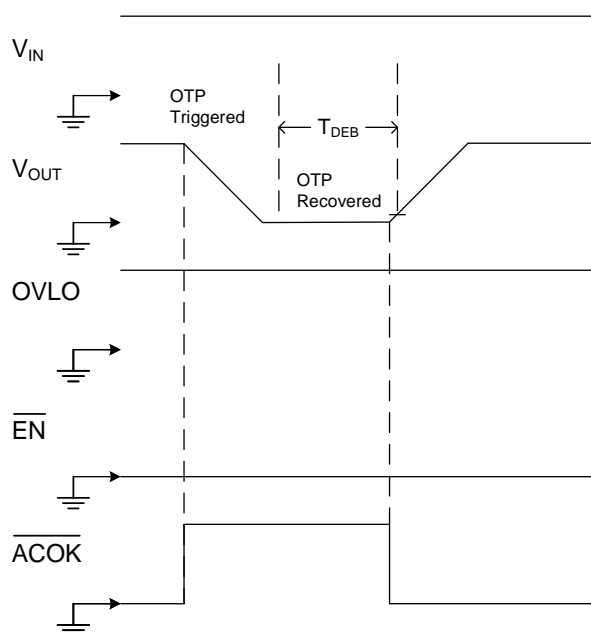


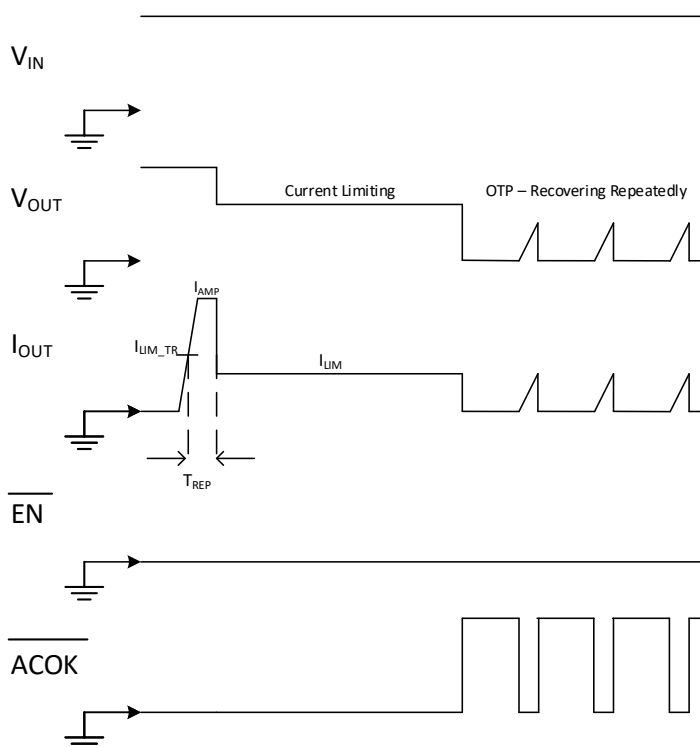
Figure 2. OVP





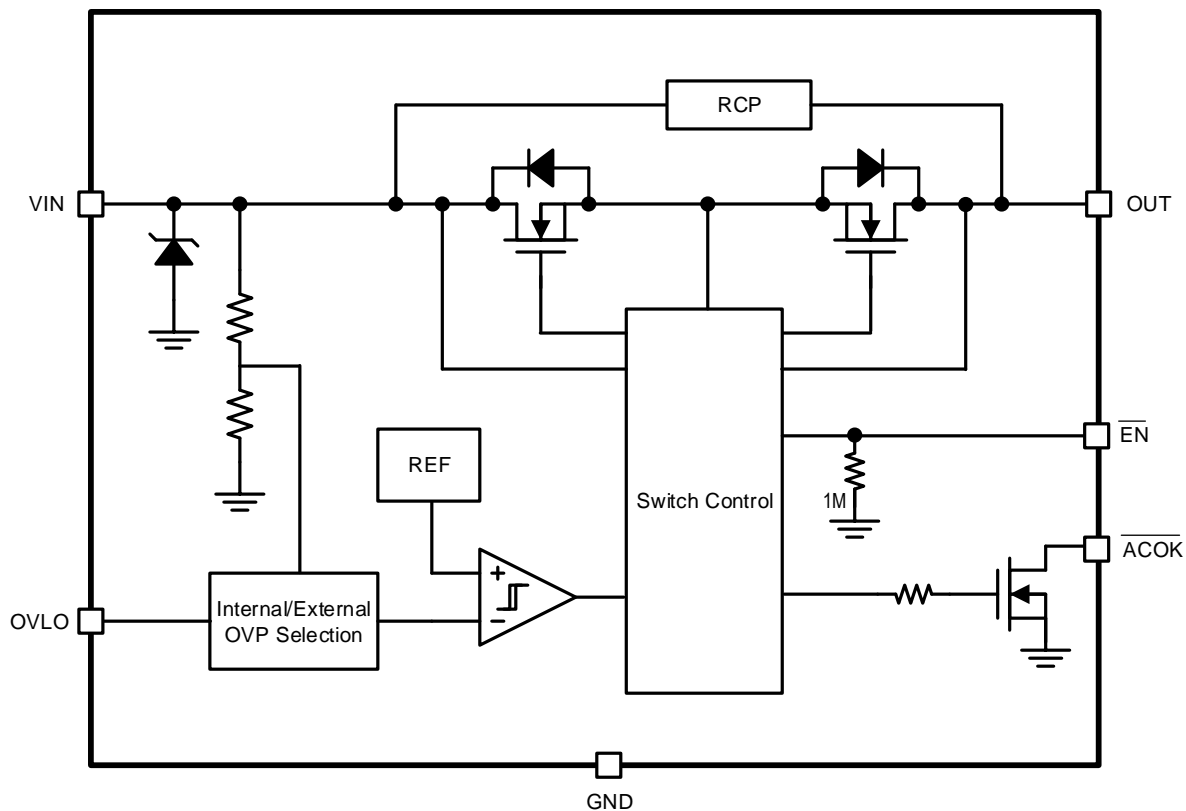


### Figure 5. OTP



### Figure 6. Current Limiting

## Functional Block Diagram



## Functional Description

The KTS1677A is a slew-rate controlled, 30mΩ (Typ), low resistance MOSFET switch intended to be inserted between a power source and a load to isolate and protect against abnormal voltage and current conditions. Featuring slew-rate turn-on control, to prevent excessive large inrush currents, the KTS1677A also features several additional protection functions, such as input  $\pm 90\text{V}$  surge, input overvoltage, input under-voltage protection, reverse current blocking, short-circuit and over-temperature protection.

Operating from a wide input voltage range of 3V to 23V the KTS1677A can cover USB PD applications to offer essential protection and enhance system reliability. The KTS1677A in the OFF state can block voltages on the VIN/VOUT pin of up to 28V and prevent reverse currents. Two KTS1677A can be used to support dual power inputs connecting to the same downstream device.

### EN Input

$\overline{\text{EN}} = \text{H}$  disables the power switch and puts the device into low power mode.  $\overline{\text{EN}} = \text{L}$  enables the protection circuits and the power switch. An internal 1MΩ pull-down resistor is mounted on  $\overline{\text{EN}}$  pin to ensure the power switch turns on under dead-battery situations. To ensure that the input voltage is stable, a 15 ms de-bounce time has been deployed prior to initiating device turn-on.

### Under Voltage Lockout

When  $\overline{\text{EN}} = \text{L}$  and  $V_{\text{IN}} < V_{\text{UVLO}}$ , power switch is disabled. Once  $V_{\text{IN}}$  exceeds  $V_{\text{UVLO}}$  and no other protection fault is detected, the power switch is controlled by the  $\overline{\text{EN}}$  pin.

### Over Voltage Lockout

When  $\overline{EN} = L$  and  $V_{IN} > V_{OVLO}$ , the power switch is disabled. Once  $V_{IN}$  drops below  $V_{OVLO}$  and no other protection is detected, the power switch resumes operation. OVLO pin is used to set the overvoltage threshold externally. The default overvoltage threshold is 23V when OVLO pin is tied to GND. Biasing OVLO pin with a resistor adjusts the over voltage threshold from 4V to 23V as below formula:

$$V_{BUS\_OVLO\_THRESHOLD} = V_{OVLO\_TH} \times \left(1 + \frac{R1}{R2}\right)$$

### Over-Temperature Protection

When device junction temperature exceeds 150°C the OTP circuit disables the power switch and sets the  $\overline{ACOK}$  output Hi-Z. Once the device junction temperature falls below 130°C and no other fault condition is detected, the power switch turn-on sequence is initiated and the  $\overline{EN}$  pin regains control.

### Over-Current Limiting Protection

If the output is shorted to ground or heavily loaded exceeding  $I_{LIM\_TR}$ , after a short time,  $T_{REP}$ , the KTS1677A limits its output current to  $I_{LIM}$  by adjusting  $V_{OUT}$  to a lower level. The resulting power dissipation increases, and accelerates the part towards thermal shutdown. If the short-circuit or heavy load is not removed, the device will remain OFF until the junction temperature falls to the OTP hysteresis level and the device will turn back on and thermally cycle OFF and ON, until either the fault condition is removed or  $\overline{EN} = L$ . See Figure 6 for more details.

### $\overline{ACOK}$ Output

The  $\overline{ACOK}$  output is an open-drain output that requires an external pull-up resistor. The  $\overline{ACOK}$  pin indicates input voltage status. When UVLO, OVLO, OTP are not triggered, and power switch is on,  $\overline{ACOK}$  is low, otherwise it stays at high impedance. The pull up resistor value is recommended to be 10kΩ to 200kΩ.

### Reverse Current Protection

KTS1677A offers reverse current protection regardless of  $\overline{EN}$  status. Once the voltage on  $V_{OUT}$  is greater than  $V_{IN}$  for 80 mV, the RCP circuit is triggered after a 4.2ms de-glitch time. If the voltage difference is greater than 120 mV, RCP triggers immediately to switch off the power switch. During the startup de-bounce time, if the device detects the  $V_{OUT}$  voltage is higher than  $V_{IN}$  by 80 mV, the power switch will not be turned on. When  $V_{OUT}$  voltage falls 10mV below  $V_{IN}$ , the power switch will be turned on back again within 26ms if  $\overline{EN} = L$  and other faults are not detected. The RCP circuit enables the parallel connection of two USB charging ports to a single charger input, without reverse leakage.

## Applications

### Input Capacitor

For most applications, connect a 1nF ceramic capacitor as close as possible to the device from IN to GND to minimize the effect of parasitic trace inductance.

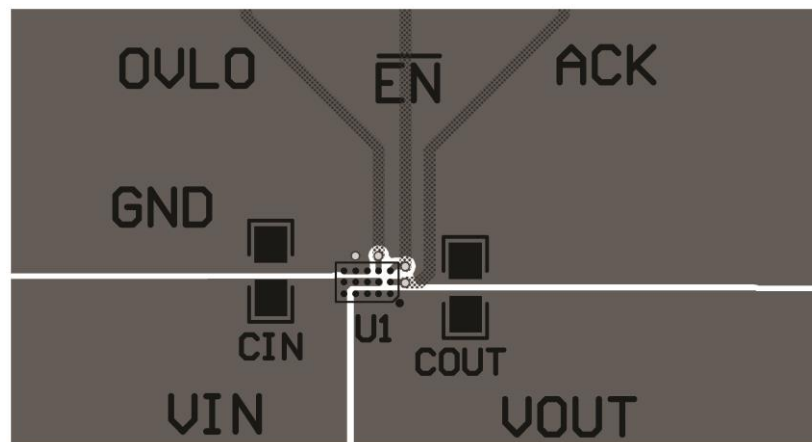
### OUT Output Capacitor

The internal soft-start function allows the KTS1677A to charge an output capacitor up to 1000 $\mu$ F without turning off due to overcurrent. As a minimum it is recommended to bypass OUT with a 1 $\mu$ F ceramic capacitor.

### Layout Recommendation

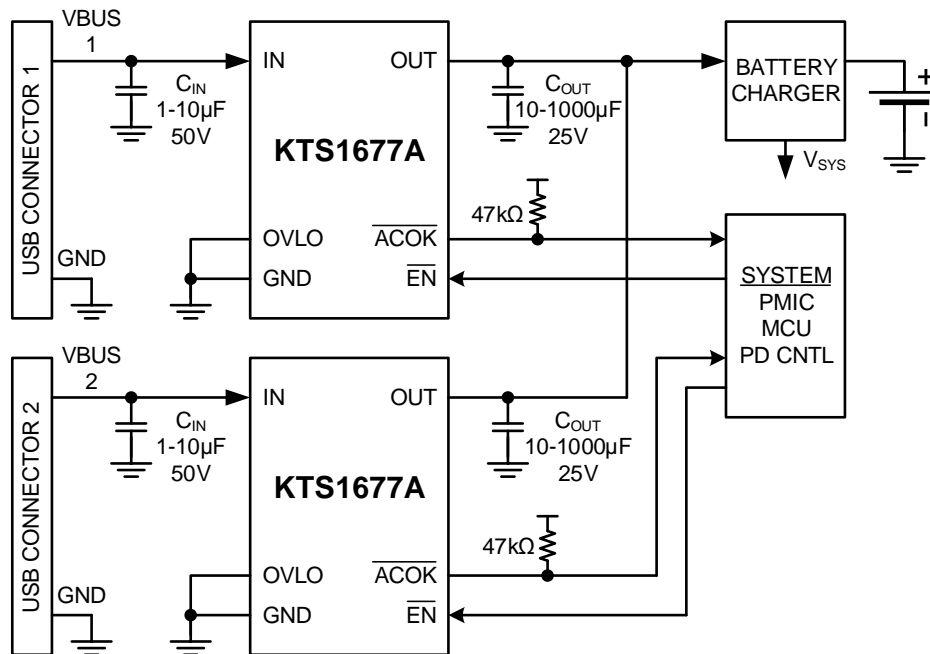
To minimize the resistance in series with the switch, all VIN and VOUT pads should be connected together on the PCB with wide traces to handle the large current and also improve the IC thermal dissipation. All GND pads should be connected together directly to the GND plane. This is important for best protection during surge transient.

The input and output capacitors should be placed as close as possible to the IC.



**Figure 7. Recommended PCB Layout for WLCSP53-15 Package**

## Application Example

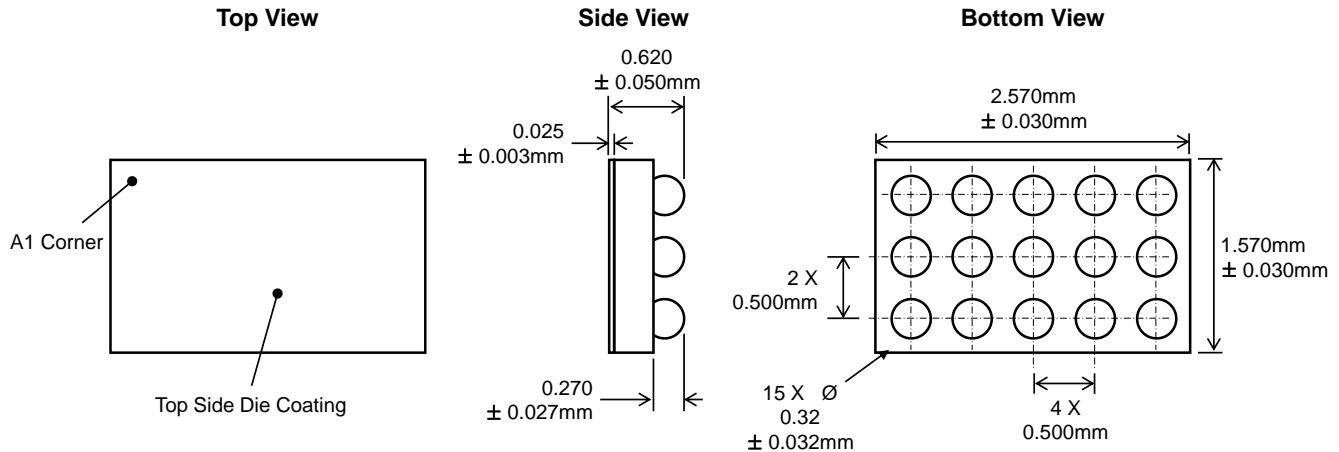


**Figure 8. Two Input USB Adapter Configuration**

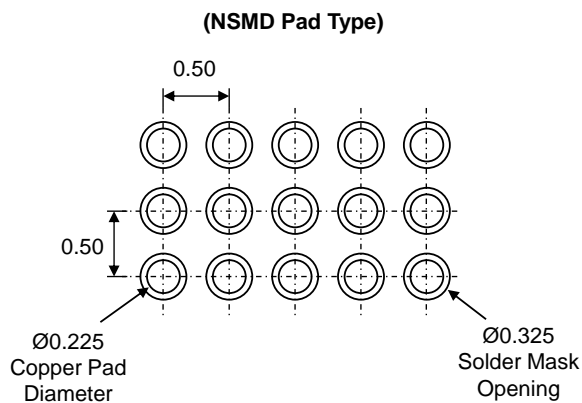
In Figure 8, two KTS1677A are used to select the power from one of two potential USB supplies, while providing protection on both ports. The reverse blocking feature of the KTS1677A prevents VBUS 1 voltage appearing at VBUS 2 and vice-versa.

## Packaging Information

WLCSP53-15 (2.570mm x 1.57mm x 0.620mm)



## Recommended Footprint



\* Dimensions are in millimeters.

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