

### 4 Amp Over-Voltage Protection IC with Sense Output

#### Features

- Wide Input voltage range: 2.3V to 28V
- Up to 4A Continuous current capability
- Integrated 38mΩ (typ) N-Channel MOSFET
- Wide Over-Voltage threshold range
  - ▶ Fixed internal: 5.95V
  - ▶ Adjustable: 4V to 22V
- Fast OVP response time: 0.1μs (typ.)
- Microphone Mode for audio signal on IN
- Internal 15ms Startup Debounce
- Integrated Surge Protection up to 100V
- Low Quiescent Current: 70μA (typ.)
- Thermal Shutdown and Short Circuit Protection
- Compliance to IEC61000-4-2 (Level 4)
  - ▶ Contact: ±8kV
  - ▶ Air Gap: ±15kV
- ESD Protection
  - ▶ Human Body Model: ±2kV
- Pb-free Package: 12-Bump WLCSP
- -40°C to +85°C Temperature Range

#### Brief Description

The KTS1681 over-voltage protection (OVP) device features an ultra-low 38mΩ (typical) on-resistance high current integrated MOSFET which actively protects low-voltage systems from voltage supply faults up to +28V<sub>DC</sub>. An internal clamp protects the device from surges up to 100V.

An input voltage exceeding the over-voltage threshold will cause the internal MOSFET to turn off, preventing excessive voltage from damaging downstream devices. When the OVLO input set below the external OVLO select voltage, the KTS1681 automatically chooses the internal fixed OVLO threshold, preset to 5.95V (typical). The over-voltage protection threshold can be adjusted with optional resistor divider to a voltage between 4V and 22V.

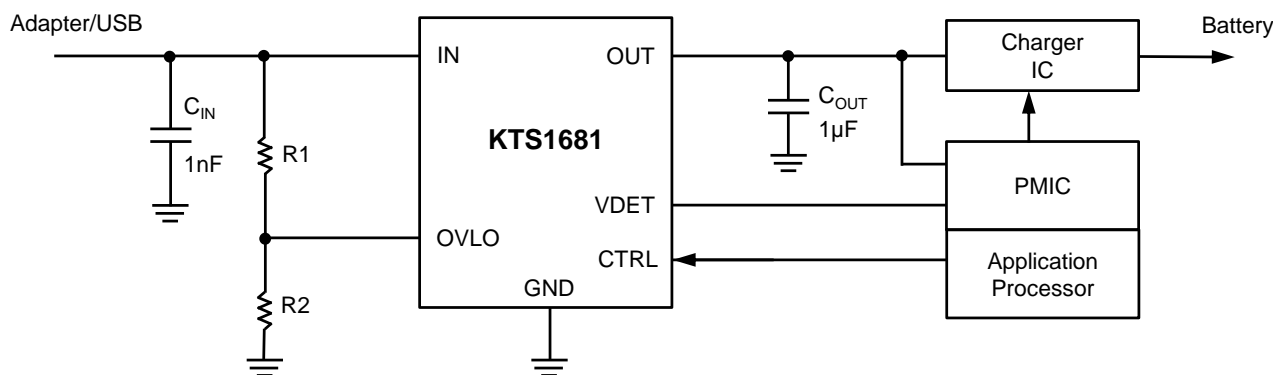
The device features a microphone mode which disables the OVP switch and allows the microphone signal present on the input to be output at VDET pin without an additional multiplexer circuit. The KTS1681 is protected against over-current faults by an internal over-temperature protection shutdown feature.

The KTS1681 is available in a RoHS and Green compliant 12-Bump 1.288mm x 1.988mm x 0.64mm WLCSP.

#### Applications

- Smartphones
- Tablet
- Mobile Internet Devices, Peripherals

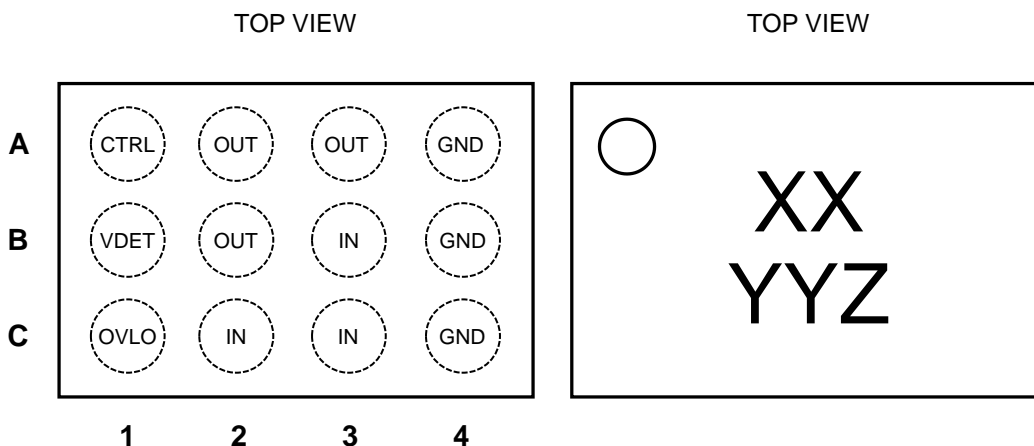
#### Typical Application



### Pin Descriptions

| Pin #      | Name | Function   |
|------------|------|--|
| A1         | CTRL | OUT power path is Enabled when CTRL is logic Low. Microphone Mode is Enabled when logic High is applied. When $IN < CTRL$ , the CTRL pin is the supply for $V_{DET}$ MOSFET gate bias.   |
| A2, A3, B2 | OUT  | Output of internal main high-current power switch. Connect OUT pins together in the PCB for proper operation.  |
| A4, B4, C4 | GND  | Ground. Connect GND pins together in the PCB for proper operation.   |
| B1         | VDET | Output from IN pin, with internal protection clamp. $V_{DET}$ can source 1mA.  |
| B3, C2, C3 | IN   | Voltage Input. Connect IN pins together in the PCB for proper operation.   |
| C1         | 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. |

### WLCSP-12



12-Bump 1.288mm x 1.988mm x 0.64mm  
 WLCSP Package  
 XX = Device Code (Top Mark)  
 YYZ (Date Code and Assembly Code)

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

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

| Symbol                | Description                                      | Value      | Units |
|-----------------------|--|------------|-------|
| IN <sup>2</sup> , OUT | Input, output Voltages                           | -0.3 to 29 | V     |
| OVLO, VDET            | OVLO, VDET Pins                                  | -0.3 to 7  | V     |
| CTRL                  | Control Pin                                      | -0.3 to 6  | V     |
| IN, OUT Current       | Continuous Current                               | 4.5        | A     |
|                       | Peak Current (10msec)                            | 8.0        | A     |
| T <sub>J</sub>        | Operating 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    |

### Thermal Capabilities

| Symbol              | Description   | Value | Units |
|---------------------|---|-------|-------|
| θ <sub>JA</sub>     | Thermal Resistance – Junction to Ambient <sup>3</sup> | 73    | °C/W  |
| P <sub>D</sub>      | Maximum Power Dissipation at T <sub>A</sub> ≤ 25°C    | 1.09  | W     |
| ΔP <sub>D</sub> /ΔT | Derating Factor Above T <sub>A</sub> = 25°C           | -13.7 | mW/°C |

### Recommended Operating Range

| Description         | Value       |
|---------------------|-------------|
| Input Voltage Range | 2.3V to 28V |

### Ordering Information

| Part Number   | Marking <sup>4</sup> | OVLO Threshold | Operating Temperature | Package  |
|---------------|----------------------|----------------|-----------------------|----------|
| KTS1681EAY-TR | GQYYZ                | 5.95V          | -40°C to +85°C        | WLCSP-12 |

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. Survives burst pulse up to 100V with 2Ω series resistance.

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. Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board.

4. "YYZ" is the date code and assembly code.

### Electrical Characteristics<sup>5</sup>

$V_{IN} = +2.3V$  to  $+28V$  and  $C_{IN} = 1.0nF$ . Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of  $-40^{\circ}C$  to  $+85^{\circ}C$ , while *Typ* values are specified at room temperature ( $25^{\circ}C$ ).  $V_{IN} = 5V$ ,  $I_{IN} \leq 3A$ .

| Symbol                              | Description                        | Conditions   | Min  | Typ  | Max  | Units      |
|-------------------------------------|------------------------------------|--|------|------|------|------------|
| <b>Charging Mode (VCTRL = 0V)</b>   |                                    |  |      |      |      |            |
| $V_{IN}$                            | Input Voltage Range                |  | 2.3  |      | 28   | V          |
| $V_{IN\_CLAMP}$                     | Input Clamp Voltage                | $I_{IN} = 10mA$ , $T_A = +25^{\circ}C$                         |      | 32   |      | V          |
| $I_{IN}$                            | Input Supply Current               | $V_{IN} = 5V$ , $V_{IN} < V_{OVLO}$                            |      | 70   | 200  | $\mu A$    |
| <b>OVP</b>                          |                                    |  |      |      |      |            |
| $V_{IN\_OVLO}$                      | Internal Overvoltage Trip Level    | $V_{IN}$ rising, $T_A = +25^{\circ}C$                          | 5.90 | 5.95 | 5.99 | V          |
| $V_{IN\_OVLO\_HYS}$                 | OVLO Hysteresis                    | $V_{IN}$ falling, $T_A = 25^{\circ}C$                          |      | 0.2  |      | V          |
| $V_{OVLO\_TH}$                      | OVLO Set Threshold                 |  | 1.19 | 1.21 | 1.23 | V          |
| $V_{OVLO\_EXT}$                     | Adjustable OVLO Select Threshold   |  | 4    |      | 22   | V          |
| $V_{OVLO\_SEL}$                     | External OVLO Set Threshold range  |  | 0.2  |      | 0.3  | V          |
| $R_{ON}$                            | OVLO Switch On-Resistance          | $V_{IN} = 5V$ , $I_{OUT} = 1A$ , $T_A = +25^{\circ}C$          |      | 38   | 53   | m $\Omega$ |
| $I_{OUT\_LEAK}$                     | OUT Leakage Current                | $V_{IN} = V_{IN\_OVLO}$ , $V_{OUT} = 5V$                       |      | 8    | 12   | $\mu A$    |
| $I_{OVLO}$                          | OVLO Input Leakage Current         | $V_{OVLO} = V_{OVLO\_TH}$                                      | -100 |      | 100  | nA         |
| <b>CTRL</b>                         |                                    |  |      |      |      |            |
| $V_{CTRL\_H}$                       | CTRL logic high threshold          |  | 1.4  |      |      | V          |
| $V_{CTRL\_L}$                       | CTRL logic low threshold           |  |      |      | 0.4  | V          |
| <b>VDET</b>                         |                                    |  |      |      |      |            |
| $R_{VDET}$                          | VDET Switch On-Resistance          | $V_{IN} = 4.5V$ to $5.5V$ , $V_{CTRL} = 0V$ , $I_{VDET} = 1mA$ |      | 40   | 75   | $\Omega$   |
| $V_{VDET\_OUT}$                     | VDET Clamp Voltage                 | $V_{IN} = 20V$ , $V_{CTRL} = 0V$                               | 6.0  | 6.5  | 7.0  | V          |
| $I_{VDET\_LIM}$                     | VDET Current Limit                 |  |      | 30   |      | mA         |
| <b>Microphone Mode (VCTRL = 3V)</b> |                                    |  |      |      |      |            |
| $I_{VDET}$                          | VDET Input Current                 | IN unconnected, $V_{CTRL} = 3V$ , $V_{DET} = 2.5V$             |      | 6    | 28   | $\mu A$    |
| $V_{VBUS\_MIC}$                     | Microphone Mode VDET Clamp Voltage | $V_{IN} = 20V$ , $V_{CTRL} = 3V$ , VDET loaded by $1M\Omega$   |      | 6.5  |      | V          |
| $R_{MIC}$                           | Microphone Mode VDET On-Resistance | $I_{IN} = 1mA$ , $V_{CTRL} = 3V$ , $V_{IN} = 0V$ or $2.5V$     |      |      | 120  | $\Omega$   |
| $I_{CTRL\_H}$                       | CTRL Input High Current            | IN unconnected, $V_{CTRL} = 3V$ , $V_{DET} = 2.5V$             |      | 2    | 4    | $\mu A$    |
| $I_{CTRL\_L}$                       | CTRL Input Low Current             | $V_{CTRL} = 0V$  | -1   | 0    | 1    | $\mu A$    |

5. All specifications are 100% production tested at  $T_A = +25^{\circ}C$ , unless otherwise noted. Specifications are over  $-40^{\circ}C$  to  $+85^{\circ}C$  and are guaranteed by design.

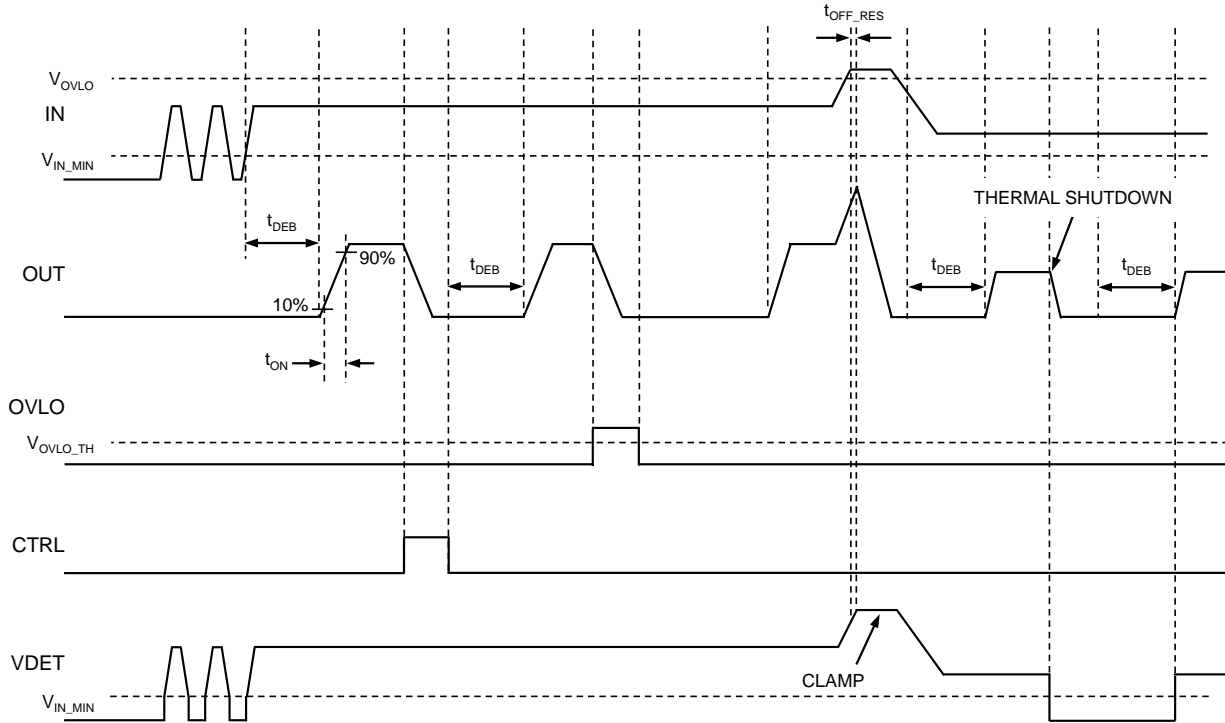


## Electrical Characteristics<sup>6</sup> (continued)

$V_{IN} = +2.3V$  to  $+28V$  and  $C_{IN} = 1.0nF$ . Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of  $-40^{\circ}C$  to  $+85^{\circ}C$ , while *Typ* values are specified at room temperature ( $25^{\circ}C$ ).  $V_{IN} = 5V$ ,  $I_{IN} \leq 3A$ .

| Symbol                                   | Description                             | Conditions   | Min | Typ      | Max | Units       |
|--|---|--|-----|----------|-----|-------------|
| <b>Timing Characteristics (Figure-1)</b> |   |  |     |          |     |             |
| $t_{DEB}$                                | Debounce Time                           | Time from $2.1V < V_{IN} < V_{IN\_OVLO}$ to $V_{OUT} = 10\%$ of $V_{IN}$ |     | 15       |     | ms          |
| $t_{ON}$                                 | Ramp Time                               | $V_{OUT} = 10\%$ of $V_{IN}$ to $90\%$ of $V_{IN}$                       |     | 2        |     | ms          |
| $t_{OFF\_RES}$                           | Switch Turn-Off Response Time           | $V_{IN} > V_{OVLO}$ to $V_{OUT}$ stop rising                             |     | 100      |     | ns          |
| <b>Thermal Protection</b>                |   |  |     |          |     |             |
| $T_{SHDN}$                               | IC junction thermal shutdown threshold  |  |     | 130      |     | $^{\circ}C$ |
| $T_{HYST}$                               | IC junction thermal shutdown hysteresis |  |     | 20       |     | $^{\circ}C$ |
| <b>ESD Protection</b>                    |   |  |     |          |     |             |
| $V_{ESD}$                                | Human Body Model (HBM) Model = 2        | IN pin   |     | $\pm 15$ |     | kV          |
|  | IEC 61000-4-2 Contact Discharge         | IN pin   |     | $\pm 8$  |     | kV          |
|  | IEC 61000-4-2 Air-Gap Discharge         | IN pin   |     | $\pm 15$ |     | kV          |
| All Pins                                 | Human Body Model (HBM) Model = 2        |  |     | $\pm 2$  |     | kV          |

6. All specifications are 100% production tested at  $T_A = +25^{\circ}C$ , unless otherwise noted. Specifications are over  $-40^{\circ}C$  to  $+85^{\circ}C$  and are guaranteed by design.



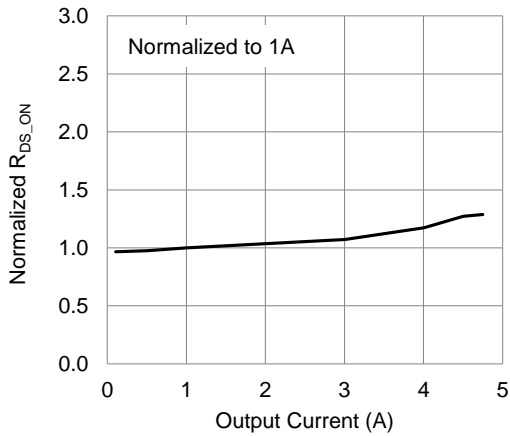
\* NOTE: WAVEFORMS ARE NOT TO SCALE

**Figure 1. Timing Diagram**

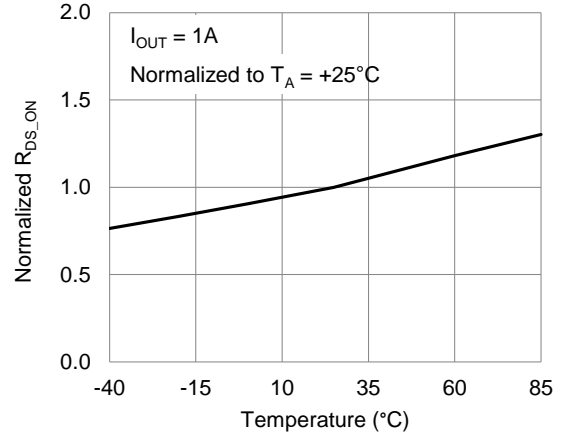
### Typical Characteristics

$V_{IN} = 5V$ ,  $C_{IN} = 0.1\mu F$ ,  $C_{OUT} = 1\mu F$ , OVLO pin = GND, CTRL = GND, Temp = 25°C unless otherwise specified.

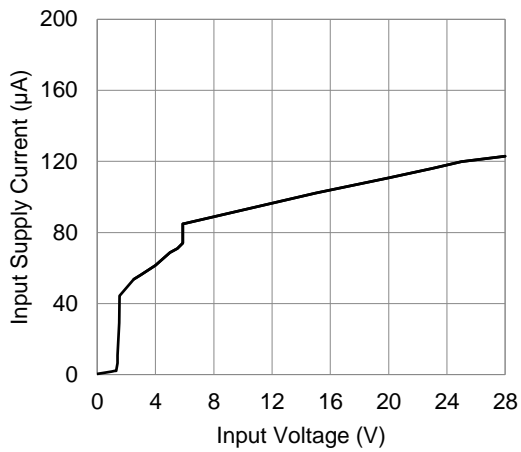
Normalized  $R_{DS(on)}$  vs. Output Current



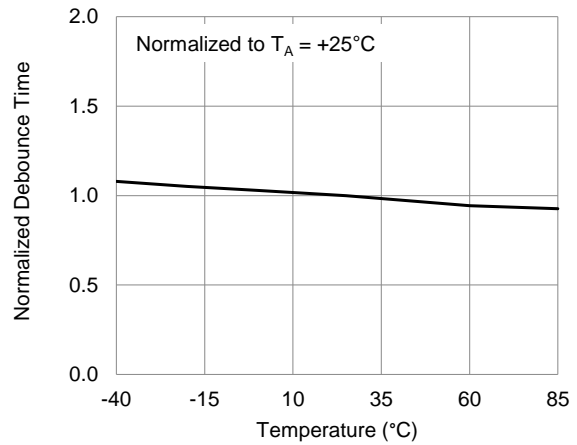
Normalized  $R_{DS(on)}$  vs. Temperature



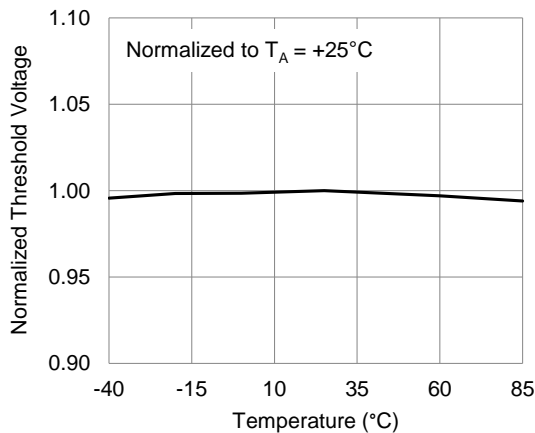
Input Supply Current vs. Input Voltage (no load)



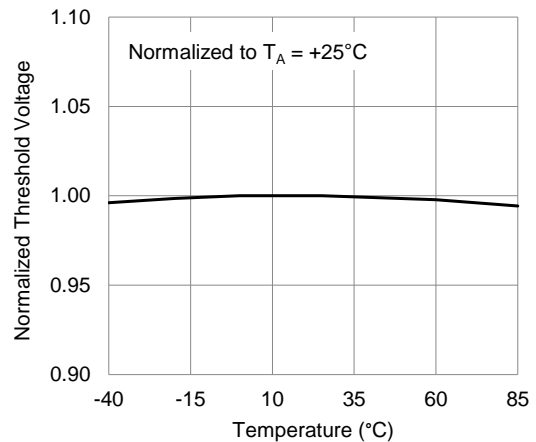
Normalized Debounce Time vs. Temperature



Normalized Fixed OVLO vs. Temperature (OVLO pin GND)

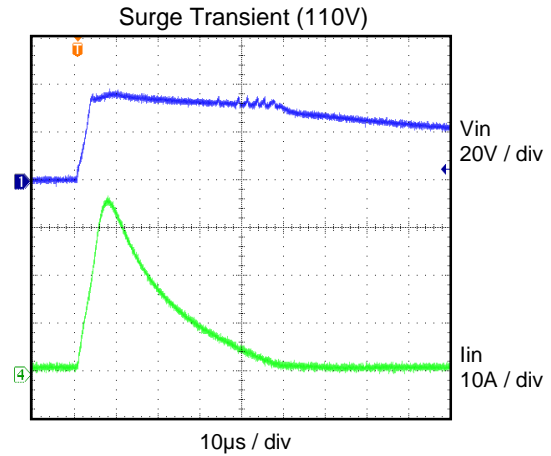
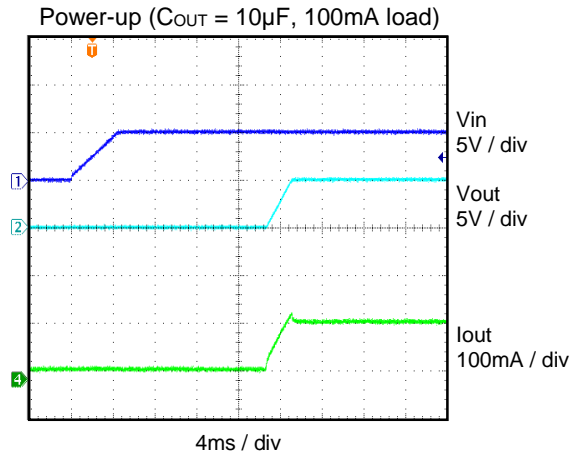


Normalized Adjustable OVLO Threshold vs. Temperature



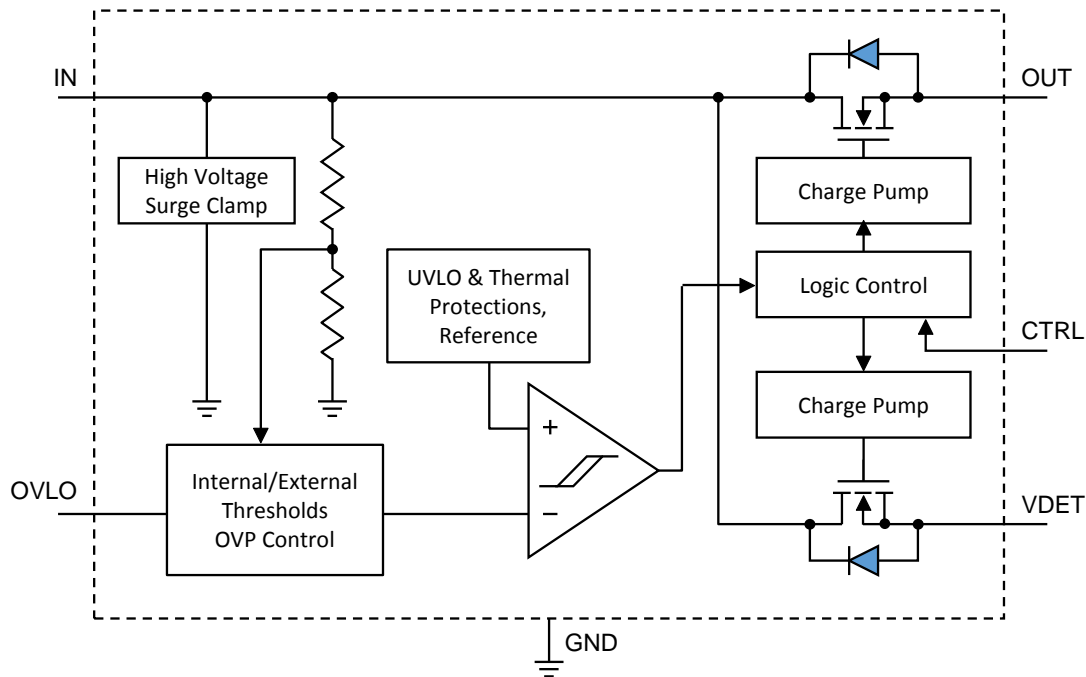
### Typical Characteristics (continued)

$V_{IN} = 5V$ ,  $C_{IN} = 0.1\mu F$ ,  $C_{OUT} = 1\mu F$ , OVLO pin = GND, CTRL = GND, Temp = 25°C unless otherwise specified.





### Functional Block Diagram



### Functional Description

The KTS1681 is inserted between the power supply or charger source and the load to be protected. The overvoltage protection (OVP) switch features an ultra-low 38mΩ (typical) on-resistance MOSFET and protects low-voltage systems against voltage faults up to +28V<sub>DC</sub>. An internal clamp also protects the device from input surge transients up to 100V. If the input IN pin voltage exceeds the overvoltage threshold, the internal MOSFET is turned off to prevent damage to any downstream components connected to the output. A 15ms debounce time built into the device delays the internal MOSFET turn on time.

The overvoltage protection threshold can be externally programmed with an optional resistor divider to set a threshold between 4V and 22V. With the OVLO input pin tied to GND (or below the external OVLO select voltage), the KTS1681 automatically selects the internal OVLO threshold. The internal overvoltage threshold ( $V_{IN\_OVLO}$ ) is preset to 5.95V typical.

KTS1681 also features a microphone mode which turns off the main power switch allowing the microphone signal from IN pin to be output at VDET pin without an additional multiplexer circuit.

#### Device Operation

During normal operation, with CTRL input low, once IN voltage is present, the main power switch connecting IN and OUT turns on after a 15ms debounce delay (see Functional Diagram). After the debounce delay, a soft-start limits the inrush current for 2ms (typical), during that time OUT voltage ramps up to IN voltage.

The main power switch turns off, OUT disconnected from IN, if one of the following fault condition becomes true. The fault conditions are:

- Overvoltage protection mode (OVP) when either  $V_{IN} > V_{IN\_OVLO}$  or OVLO pin voltage  $V_{OVLO} > V_{OVLO\_TH}$  (if a resistor divider is used to program OVLO).
- Undervoltage lockout when  $V_{IN}$  below the normal operating range.
- Thermal shutdown.

### Internal Main MOSFET Switch

In normal operating mode (main power switch turned on), the CTRL input must be set to the logic low state (CTRL = GND). The KTS1681 integrates an N-Channel power MOSFET with ultra-low 38mΩ (typical) on-resistance between IN and OUT. The MOSFET is internally driven by an internal charge pump supply rail that generates the gate voltage ( $V_{GS}$ ) greater than IN.

### Overvoltage Lockout (OVLO)

The KTS1681 has a 5.95V (typical) overvoltage threshold. If the IN input voltage is above this threshold, the internal MOSFET is turned off and OUT is disconnected from IN.

### Protected Bus Voltage

The KTS1681 passes a protected VIN voltage through to VDET. The VDET pin can provide up to 1mA of DC current. VDET contains an internal 6.5V clamp to protect devices connected to VDET, while still allowing the devices to operate from the VDET voltage. The voltage at VDET is not present while the KTS1681 is in thermal shutdown or IN is lower than the input operating range.

### Microphone Mode

The KTS1681 features a microphone mode which turns off the internal main MOSFET and allows a microphone signal at IN to pass through to the VDET pin. This enables the user to select the path of IN without an additional multiplexer circuit. The CTRL input recommended voltage is 3V or higher in order to put the device in microphone mode.

### Thermal-Shutdown Protection

Both the internal main MOSFET and VDET switches are turned off when the junction temperature exceeds +130°C (typ). The device exits thermal shutdown after the junction temperature cools by +20°C (typ).

## Application Information

### Input Capacitor

For most applications, connect a 1nF ceramic capacitor as close as possible to the device from IN to GND. During surge voltage transients, the internal input clamp keeps the input IN pin voltage below 40V, so 50V rated capacitors are ideal for most OVP applications.

### OUT Output Capacitor

The internal soft-start function allows the KTS1681 to charge an output capacitor up to 100μF without turning off due to overcurrent.

### External OVLO Adjustment Functionality

If the OVLO pin is connected to ground, KTS1681 uses the factory programmed OVLO value for its internal OVLO comparator.

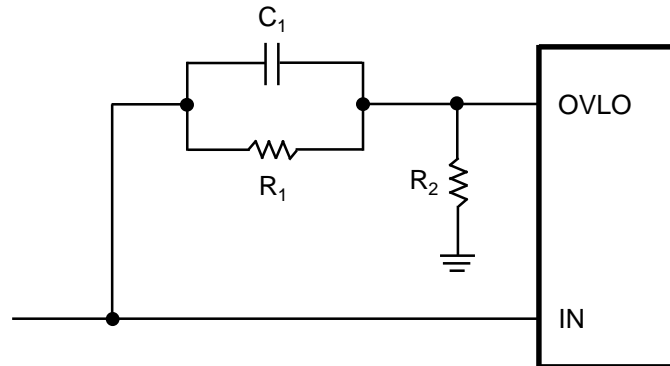
If an external resistor-divider is connected to OVLO and  $V_{OVLO}$  exceeds the OVLO select voltage,  $V_{OVLO\_SELECT}$ , the internal OVLO comparator reads the IN fraction fixed by the external resistor divider. Starting with  $R_1 = 1M\Omega$  to minimize current consumption,  $R_2$  can be calculated from the following formula:

$$V_{OVLO\_EXT} = V_{OVLO\_THRESH} \times \left(1 + \frac{R_1}{R_2}\right)$$

This external resistor-divider is separate from the internal resistor-divider circuit. An external resistor-divider could slow the OVLO response time, affecting the surge protection. An RC divider can be used to improve response speed. The capacitor can be calculated as follows:

$$C_1 > 5 \times t_R \times \left[ \frac{R_1 + R_2}{R_1 R_2} \right]$$

Where  $t_R$  is the rise time of the worst-case transient at IN pin (measured from the start of rising edge to the point where IN reaches  $V_{IN\_OVLO}$ ). See Figure 2.



**Figure 2. External OVLO Set Circuit**

### USB On-The-GO (OTG) Operation

When used in an OTG application the KTS1681 can provide power from OUT to IN regardless of the condition of the CTRL pin.

When the CTRL pin is LOW (power switch automatically enabled), initially, the OTG voltage applied at OUT will forward bias the power switch bulk diode and present a voltage drop of approximately 0.7V between OUT and IN. The maximum current in this mode is limited by the thermal performance of the device and at an ambient temperature of 25°C

$$I_{MAX} = \frac{1.09W}{0.7V} = 1.56A$$

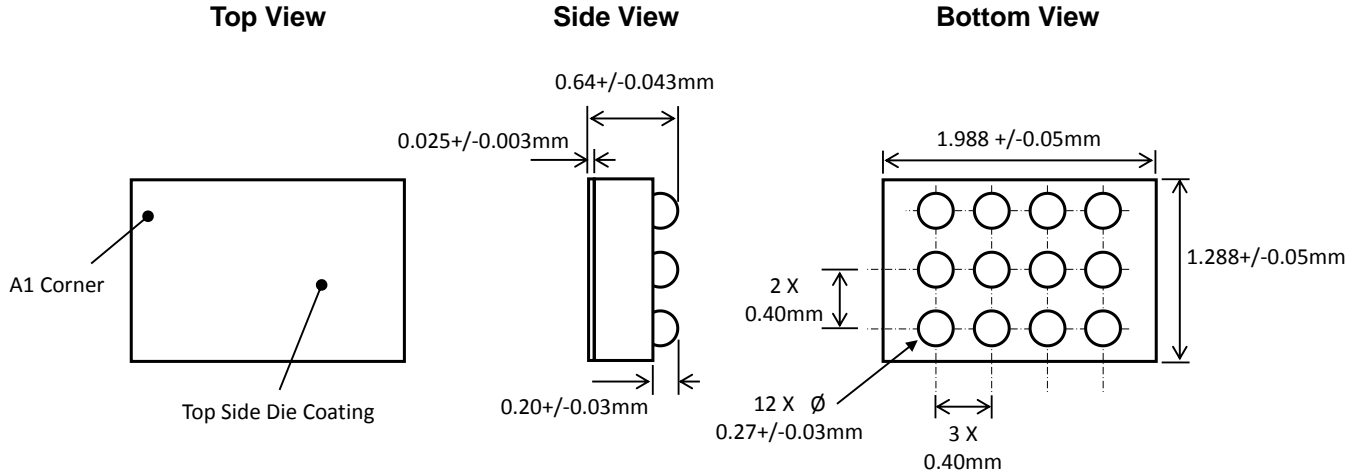
This is purely a transitional condition as once the voltage at IN exceeds 2.1V and the debounce time of 15ms has elapsed, the main power switch will turn fully ON, significantly reducing the voltage drop from OUT to IN.

When the CTRL is HIGH (power switch is OFF), the OTG voltage applied at OUT will also forward bias the power switch bulk diode, but as the switch will not turn ON unless CTRL is pulled LOW, the high forward voltage drop of 0.7V and consequent high power dissipation will remain. For this reason, it is highly recommended to pull CTRL LOW in all OTG applications.

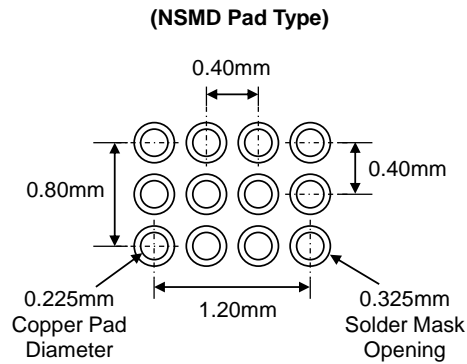
Please note in OTG mode, under no circumstance should any load, or any voltage be connected to VDET.

### Packaging Information

WLCSP-12, 1.288mm x 1.988mm x 0.64mm



### Recommended Footprint



\* Dimensions are in millimeters.

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