# Adjustable Current Limit Power Distribution Switches TD9530

## General Description

The TD9530 series of power switches integrate a 62mΩ N-channel MOSFET power switch, an enable input pin, a fault flag and some protection functions into a single package. The protection features include adjustable current limit, reverse current protection, and over temperature protection. TD9530 offer an adjustable current-limit threshold between 150mA and 2.8A (typ.) via an external resistor. The reverse current protection disable the power switch when the output voltage is driven higher than the input to protect devices on the input side of the switch. The OCB output asserts low during over current and reverse current conditions. The over-temperature protection limits the junction temperature below 140°C in case of short circuit or over load conditions.

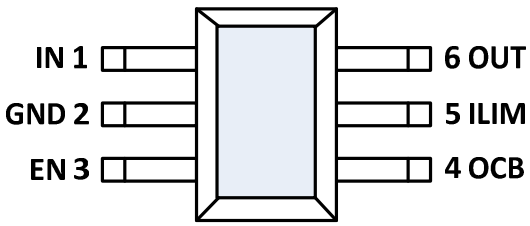
## Features

- 62mΩ Power Switch On Resistance
- Wide Supply Voltage Range: 2.7V to 5.5V
- Adjustable Current Limit Protection
- Fast Over current Response: 2us (typ.)
- Over-Temperature Protection
- Fault Indication Output
- Reverse Input-Output Voltage Protection: 25mV (typ.)
- Enable Input
- Built-in Soft-Start
- Lead Free and Green Devices Available

## Applications

- Notebook and Desktop Computers
- USB Ports
- High-Side Power Protection Switches
- MHL Ports

## Pin Configurations

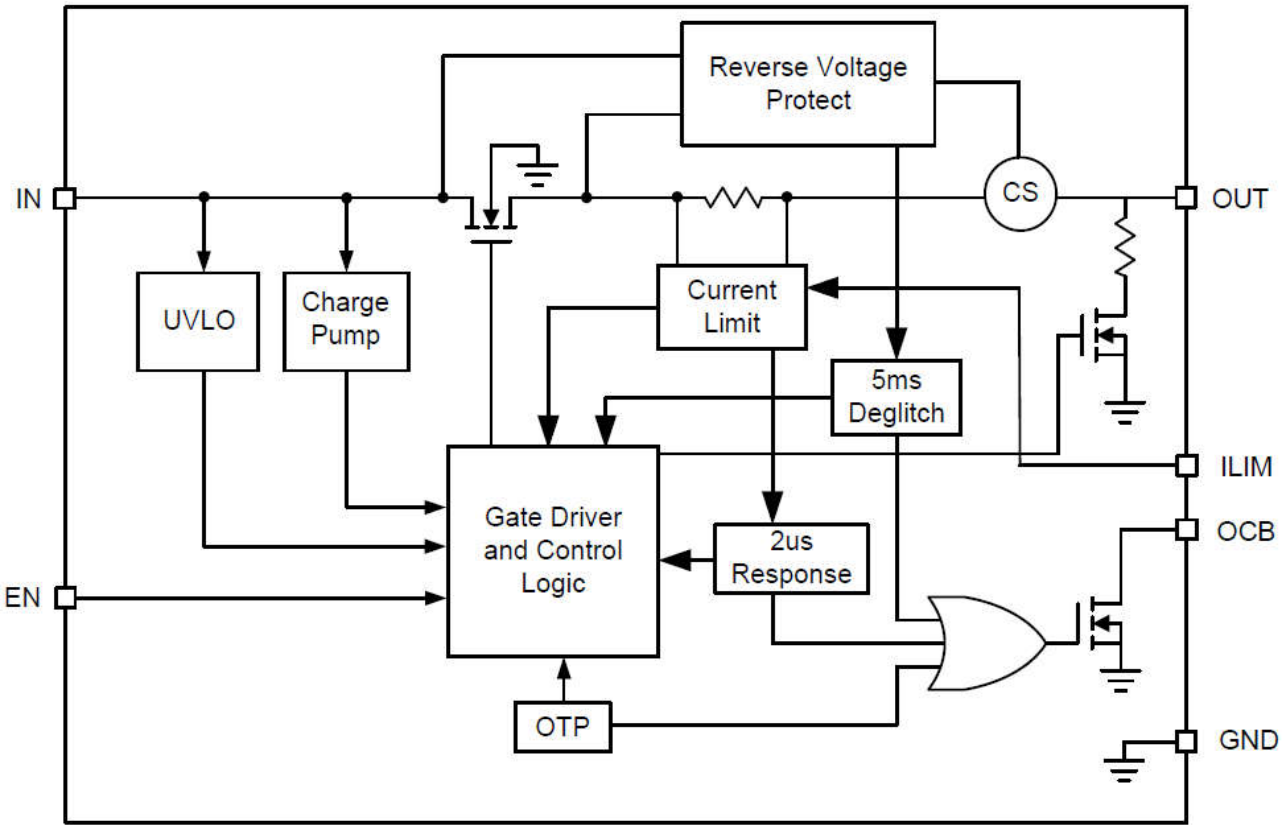



SOT-23-6(Top View)

## Pin Function Description

| Pin Number | Pin Name | Description |
|---|---|---|
| 1 | IN | Power Supply Input. Connect this pin to external DC supply. |
| 2 | GND | Ground. |
| 3 | EN | Enable Input. Pulling this pin to high will enable the device and pulling this pin to low will disable device. The EN pin cannot be left floating. |
| 4 | OCB | Fault Indication Pin. This pin goes low when a current limit or a reverse voltage condition is detected after a 12ms deglitch time. |
| 5 | ILIM | External resistor used to set current-limit threshold. |
| 6 | OUT | Output Voltage Pin. The output voltage follows the input voltage. When the device is enable. |

## Functional Block Diagram




## Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| | Voltage range on IN, OUT, EN, ILIM, OCB to GND | -0.3 to 7 | V |
| $T_J$ | Maximum Junction Temperature | 150 | °C |
| $T_{STG}$ | Storage Temperature Range | -65 to +150 | °C |
| $T_{SDR}$ | Maximum Soldering Temperature Range, 10 seconds | 260 | °C |

Note 1: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Thermal Characteristics

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $\theta_{JA}$ | Junction-to-Ambient Resistance in Free Air | 250 | °C |

Note 2: $\theta_{JA}$ is measured with the component mounted on a high effective thermal conductivity test board in free air.

## Recommended Operating Conditions

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{IN}$ | IN Input Voltage | 2.7 to 5.5 | V |
| $I_{OUT}$ | OUT Output current | 0 to 2 | A |
| $R_{ILIM}$ | Current-Limit Threshold Resistor Range | 10 to 150 | KΩ |
| $T_A$ | Ambient Temperature | -40 to 85 | ℃ |
| $T_J$ | Junction Temperature | -40 to +125 | ℃ |

Note3: Refer to the typical application circuit.

## Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN}$=5V, $V_{EN}$ =5V and $T_A$= -40 ~ 85 ℃. Typical values are at $T_A$=25℃

| Symbol | Parameter | Test Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| SUPPLY CURRENT | | | | | | | |
| $I_{IN}$ | IN Supply Current | No load, $V_{EN}$=0V | | - | - | 1 | μA |
| | | No load, $V_{EN}$=5V,$R_{ILIM}$=20kΩ | | - | 100 | 150 | μA |
| | | No load, $V_{EN}$=5V,$R_{ILIM}$ Open | | - | 90 | - | μA |
| | Leakage Current | OUT=GND, $V_{EN}$=0V | | - | - | 1 | μA |
| $I_{REV}$ | Reverse Leakage Current | $V_{IN}$=GND, $V_{OUT}$=5V, $V_{EN}$=0V | | - | - | 1 | μA |
| POWER SWITCH | | | | | | | |
| $R_{DS(ON)}$ | Power Switch On Resistance | $I_{OUT}$=1A, $T_A$= 25℃ | | - | 62 | 78 | mΩ |
| UNDER-VOLTAGE LOCKOUT (UVLO) | | | | | | | |
| | VIN UVLO Threshold Voltage | $V_{IN}$ rising, $T_A$= -40 ~ 85 ℃ | | 1.7 | - | 2.65 | V |
| | VIN UVLO Hysteresis | | | - | 0.2 | - | V |
| CURRENT-LIMIT | | | | | | | |
| | Maximum Current-limit set point | $R_{ILIM}$=10kΩ | | 2.1 | 2.8 | 3.2 | A |
| $I_{LIM}$ | Current Limit Threshold | $V_{IN}$=2.7V to 5.5V, $T_A$= -40 ~ 85°C | $R_{ILIM}$=15kΩ | 1.4 | 1.7 | 3.2 | A |
| | | | $R_{ILIM}$=20kΩ | 1.01 | 1.295 | 1.49 | A |
| | | | $R_{ILIM}$=49.9kΩ | 0.44 | 0.52 | 0.60 | A |
| | | | $R_{ILIM}$=150kΩ | 0.11 | 0.15 | 0.2 | A |
| $T_{IOS}$ | Response time of over current | $V_{IN}$ = 5V | | - | 2 | - | μs |
| | $I_{LIM}$ voltage source | $V_{IN}$=2.7V to 5.5V | | 0.38 | 0.4 | 0.42 | V |
| OCB OUTPUT PIN | | | | | | | |
| $V_{OCB}$ | OCB Output Low Voltage | $I_{OCB}$=5mA | | - | 0.2 | 0.4 | V |
| $I_{OCB}$ | OCB Leakage Current | $V_{OCB}$=5V | | - | - | 1 | μA |
| $T_{D(OCB)}$ | OCB Deglitch Time | OCB assertion, $T_A$=-40~85°C | | 5 | 12 | 20 | ms |
| REVERSE VOLTAGE PROTECT | | | | | | | |
| $I_{REV}$ | Reverse current trip point | Enable reverse current protection | | - | 100 | - | mA |

| | | | | | | |
|---|---|---|---|---|---|---|
| $V_{REV}$ | Reverse voltage comparator trip point | $V_{IN}$-$V_{OUT}$ , disable reverse current protection | - | 25 | - | mV |
| $T_{REV}$ | Time from reverse current condition to MOSFET turn off | $V_{IN}$ = 5V | 3 | 5 | 7 | ms |
| EN INPUT PIN | | | | | | |
| $V_{IH}$ | Input Logic High | $V_{IN}$=2.7V to 5V | 1.4 | - | - | V |
| $V_L$ | Input Logic Low | $V_{IN}$=2.7V to 5V | - | - | 0.6 | V |
| $I_{EN}$ | EN Input Current | | - | - | 1 | μA |
| | $V_{OUT}$ Discharge Resistance | $V_{EN}$=0V | - | 150 | - | Ω |
| $t_{D(ON)}$ | Turn On Delay Time | | - | 80 | - | μS |
| $t_{D(OFF)}$ | Turn Off Delay Time | | - | 5 | - | μS |
| $t_{SS}$ | Soft-Start Time | No load, $C_{OUT}$=1μF, $V_{IN}$=5V | - | 400 | 1000 | μS |
| OVER-TEMPERATURE PROTECTION (OTP) | | | | | | |
| $T_{OTP}$ | Over-Temperature Threshold | $T_J$ rising | - | 140 | - | ℃ |
| | Over-Temperature Hysteresis | | - | 20 | - | ℃ |

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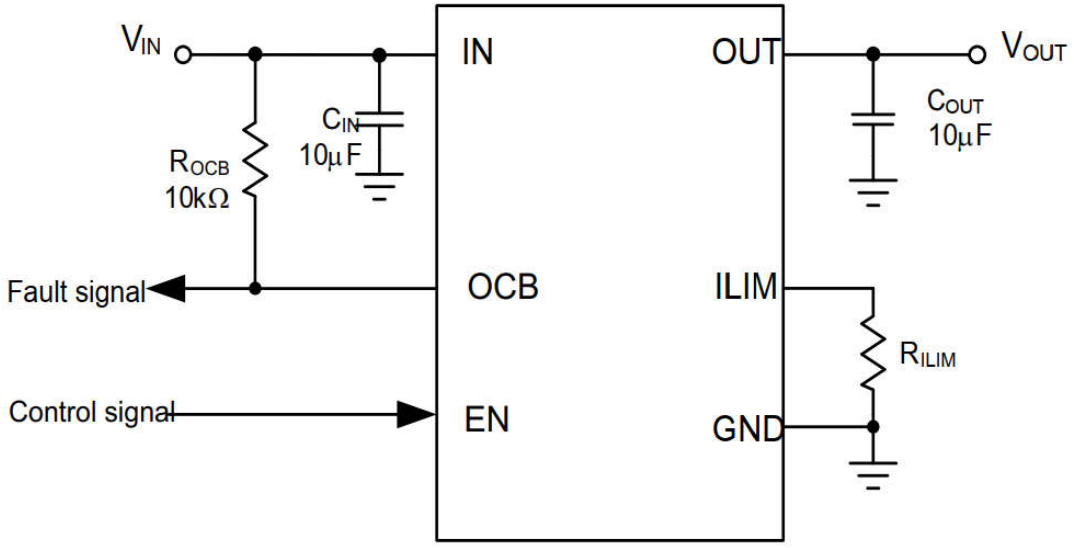
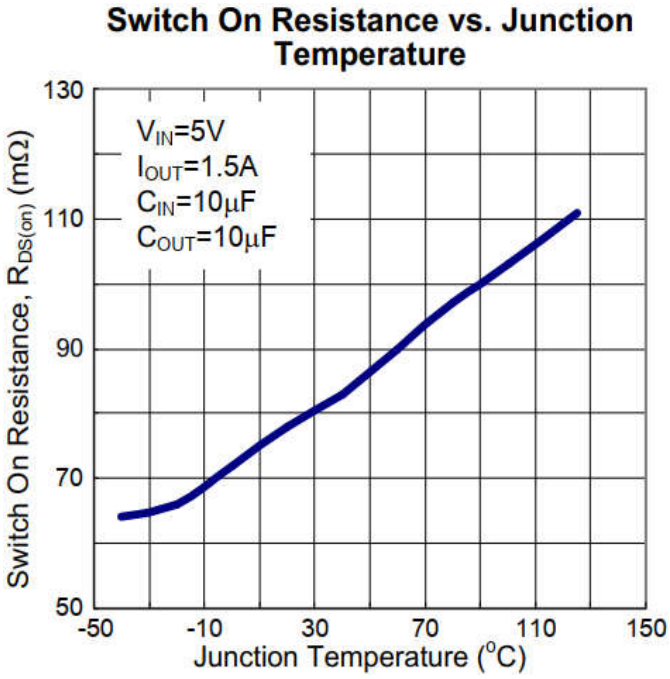
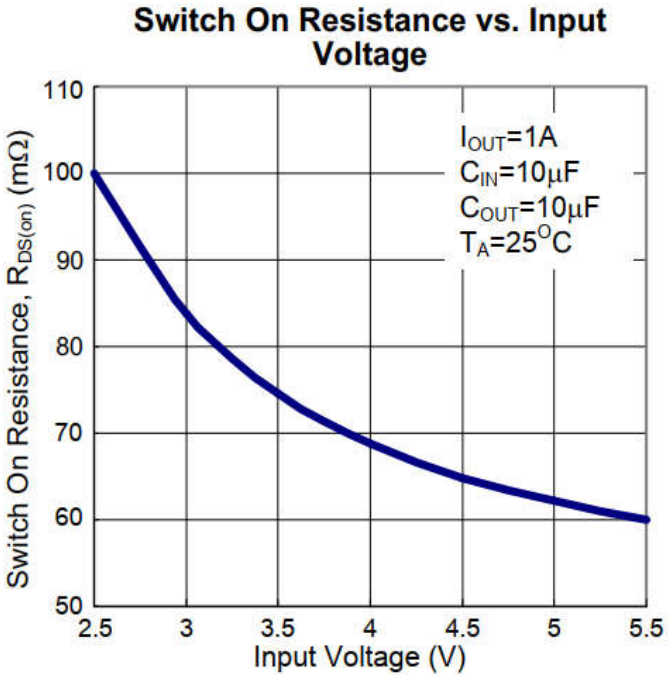
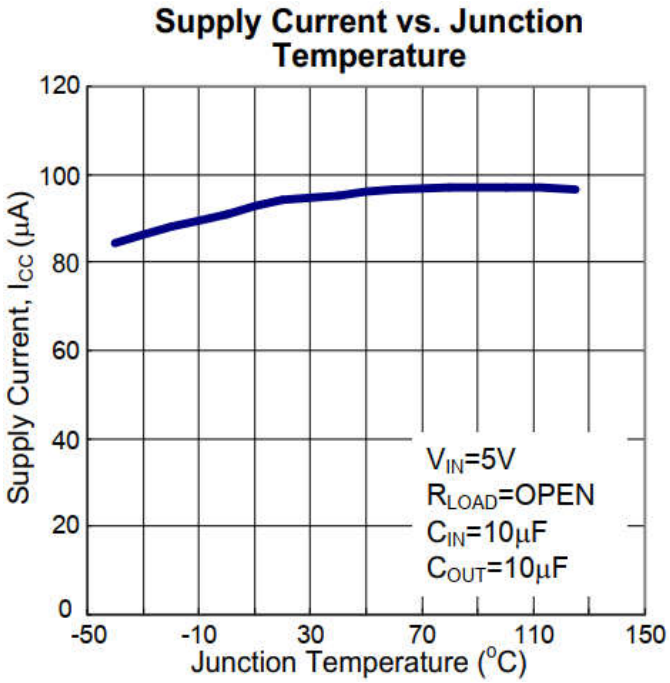
## Typical Application Circuit

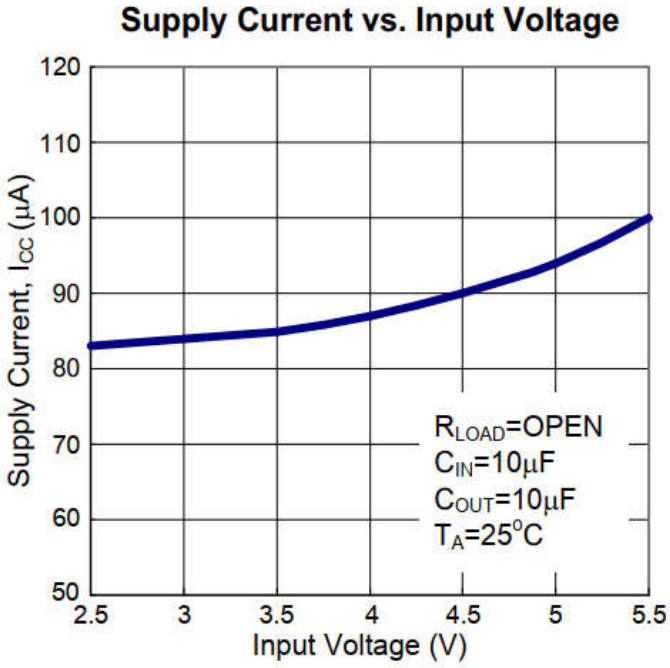


## Typical Operating Characteristics

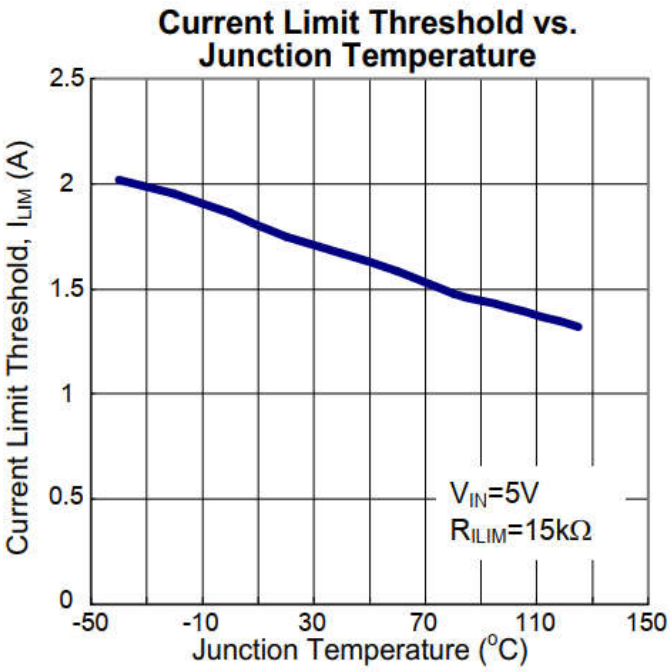


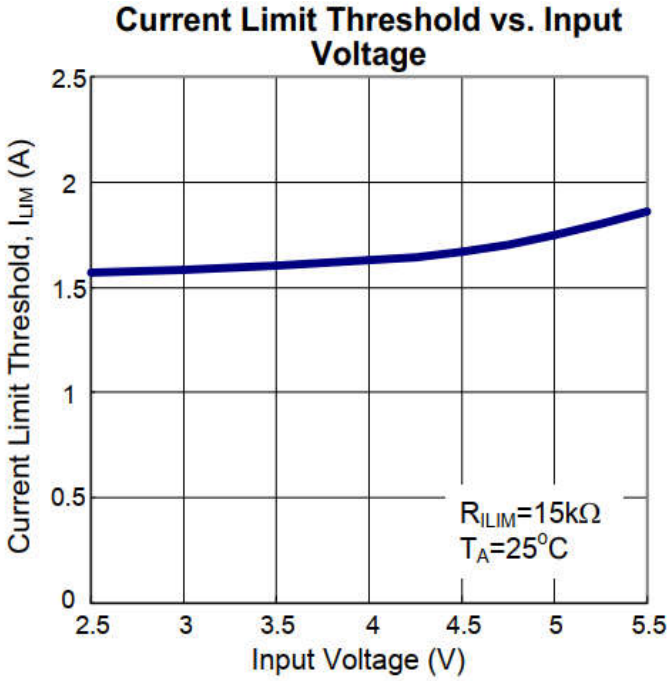



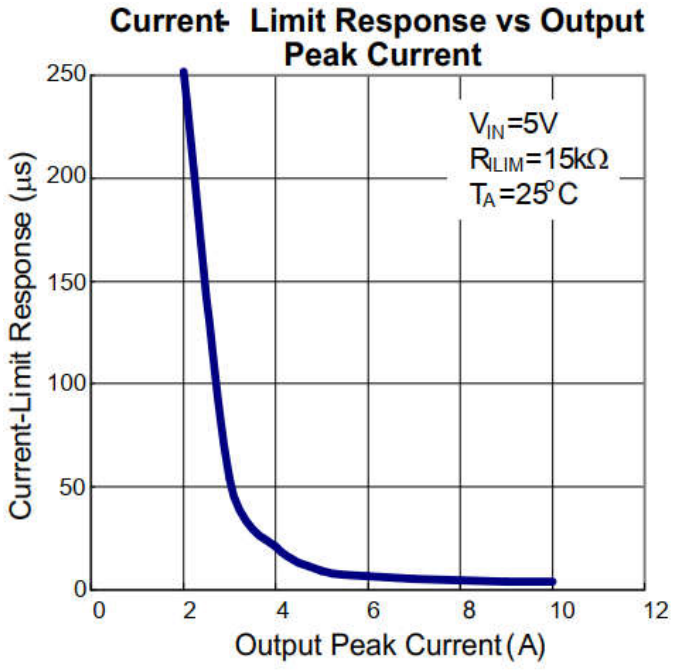



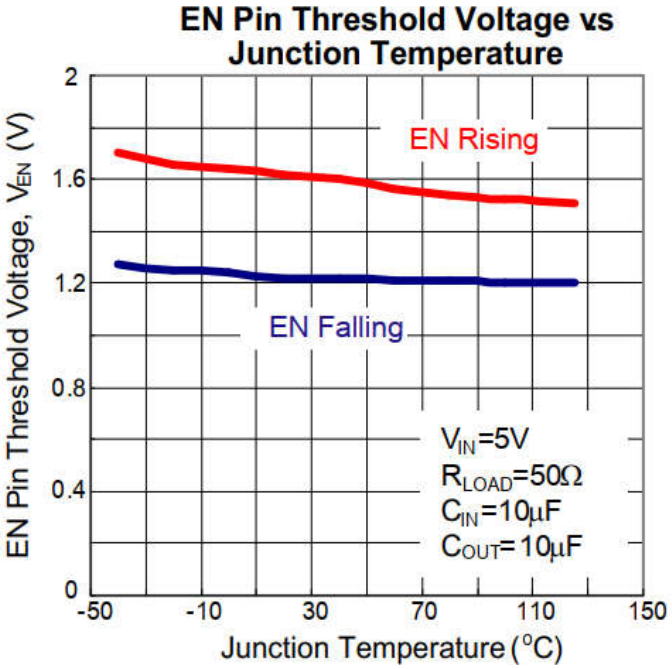



## Typical Operating Characteristics(Cont.)

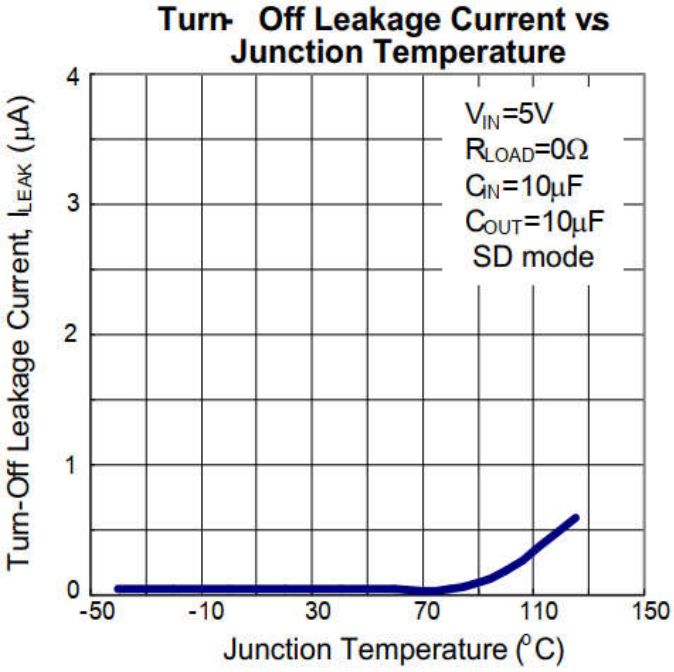


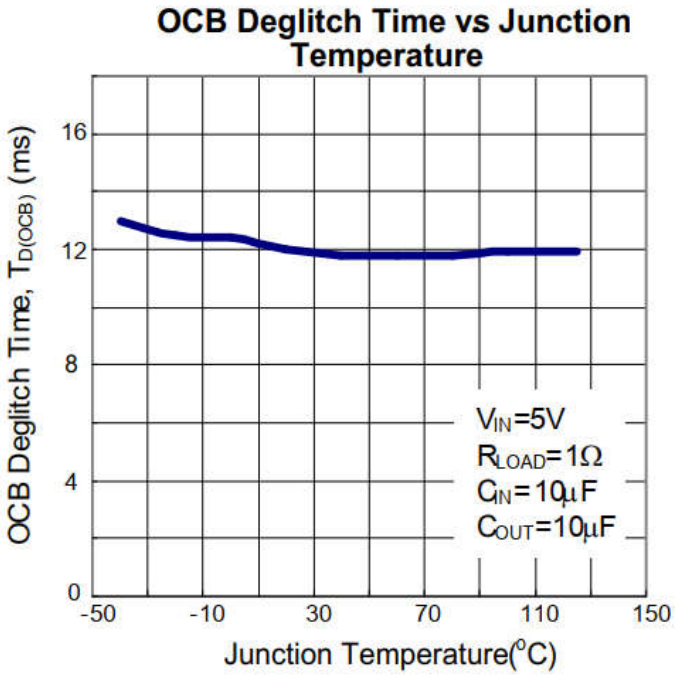



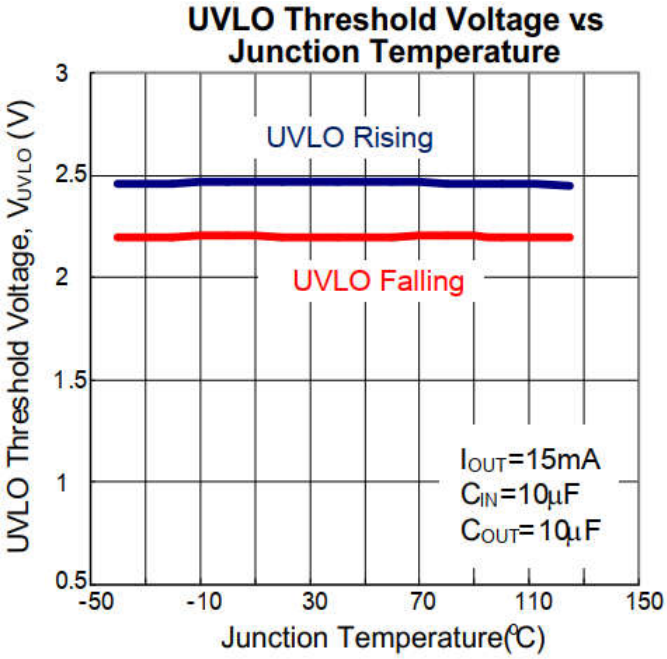



## Typical Operating Characteristics(Cont.)

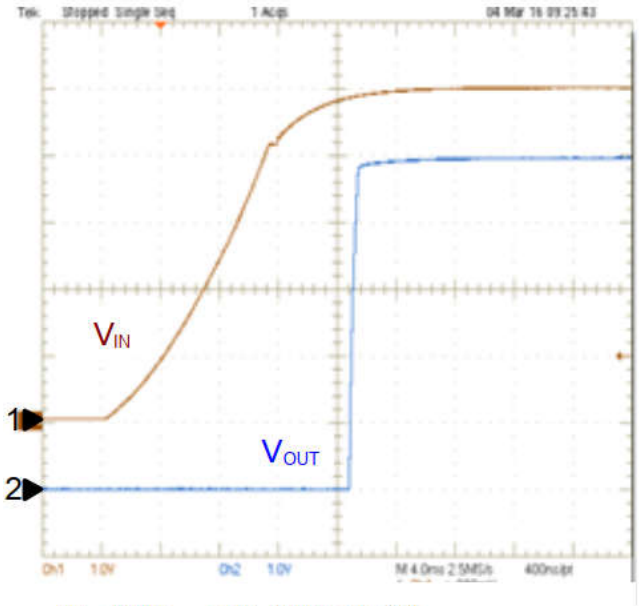


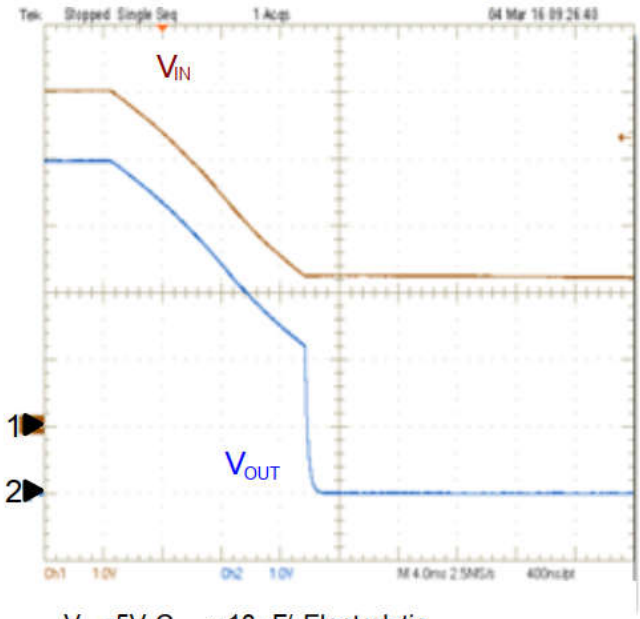
## Operating Waveforms

### UVLO at Rising



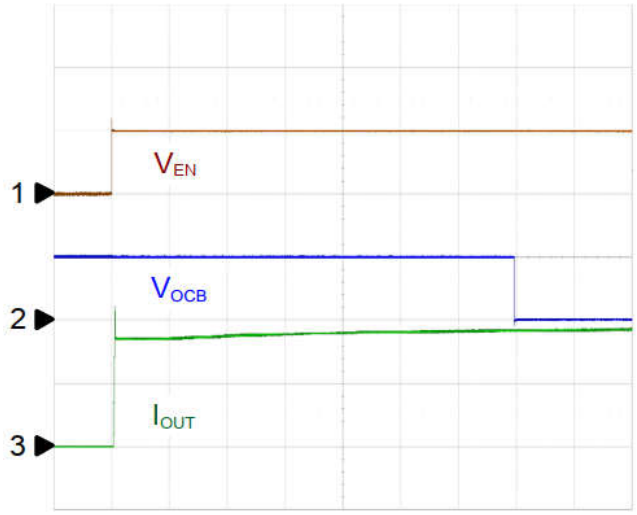

$V_{IN}$=5V, $C_{OUT}$= 10μF/ Electrolytic
$C_{IN}$=10μF/ Electrolytic $R_{LOAD}$= 30Ω
CH1:$V_{IN}$, 1V/Div , DC
CH2:$V_{OUT}$, 1V/ Div , DC
TIME: 4ms/Div

### UVLO at Falling



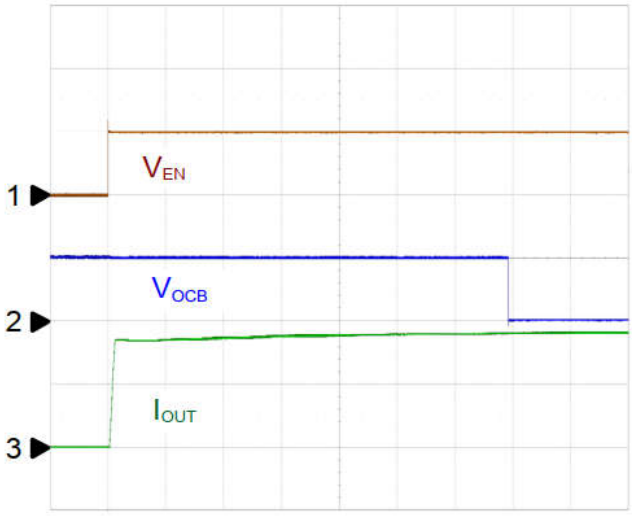

$V_{IN}$=5V, $C_{OUT}$= 10μF/ Electrolytic
$C_{IN}$=10μF/ Electrolytic $R_{LOAD}$= 30Ω
CH1:$V_{IN}$, 1V/Div , DC
CH2:$V_{OUT}$, 1V/ Div , DC
TIME: 4ms/Div

### OCB Response During Short Circuit




$V_{IN}$=5V, $C_{OUT}$=10μF/Electrolytic,
$C_{IN}$=10μF/Electrolytic, $R_{ILIM}$=15kΩ, $R_{LOAD}$=0Ω
CH1:$V_{EN}$, 5V/Div, DC
CH2:$V_{OCB}$, 5V/Div, DC
CH3:$I_{OUT}$, 1A/Div, DC
TIME:2ms/Div

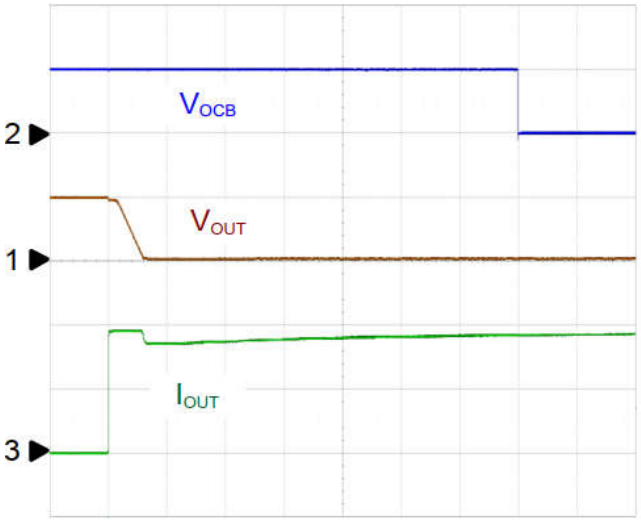
### OCB Response During Over Load




$V_{IN}$=5V, $C_{OUT}$=10μF/Electrolytic,
$C_{IN}$=10μF/Electrolytic, $R_{ILIM}$=15kΩ, $R_{LOAD}$=1Ω
CH1:$V_{EN}$, 5V/Div, DC
CH2:$V_{OCB}$, 5V/Div, DC
CH3:$I_{OUT}$, 1A/Div, DC
TIME:2ms/Div

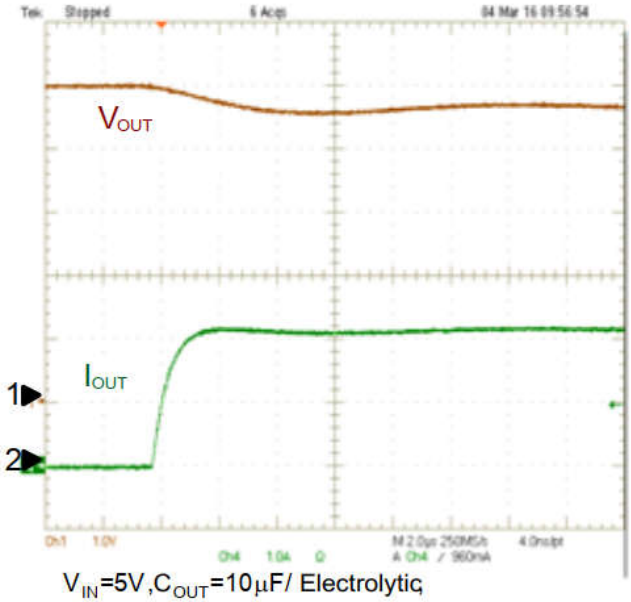
## Operating Waveforms

**OCB Response with Ramped Load**




$V_{IN}$=5V,$C_{OUT}$=10μF/Electrolytic,
$C_{IN}$=10μF/Electrolytic,$R_{ILIM}$=15kΩ
CH1:$V_{OUT}$,5V/Div, DC
CH2:$V_{OCB}$,5V/Div, DC
CH3:$I_{OUT}$,1A/Div, DC
TIME:2ms/Div

**Load- Transient Response**




$V_{IN}$=5V,$C_{OUT}$=10μF/ Electrolytic
$C_{IN}$= 10μF/ Electrolytic,$I_{OUT}$= 0 to 2A
CH1:$V_{OUT}$,1 V/Div , DC
CH2:$I_{OUT}$, 1A/ Div, DC
TIME:2μs/Div

## Parameter Measurement Information

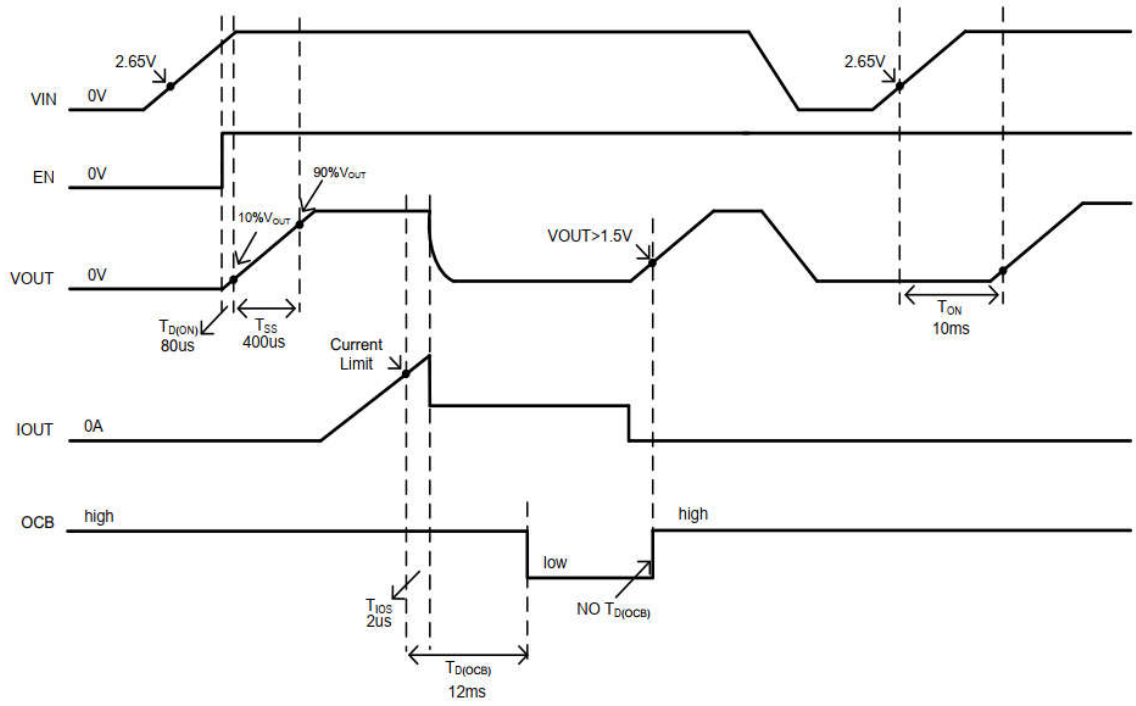



Figure 1. Sequence of Power On & Current Limit & OCB Indicate

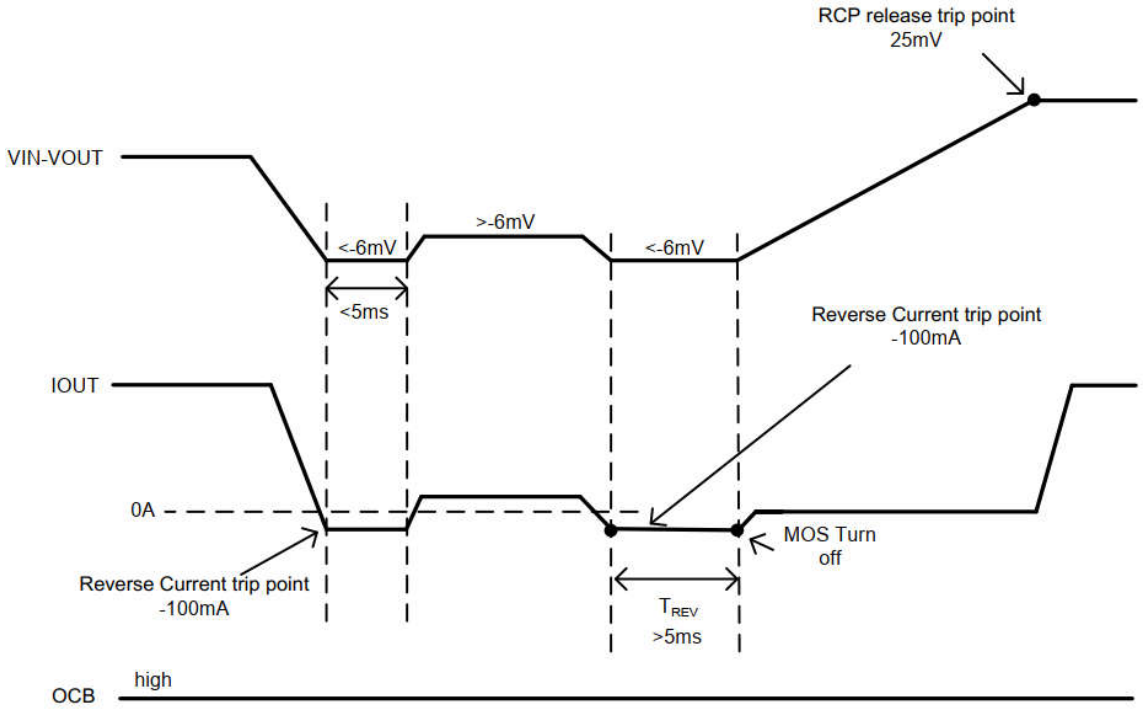



Figure 2. Reverse Current trip point & Recovery

## Function Description

**VIN Under-Voltage Lockout (UVLO)**

The TD9530 series of power switches have a built-in under-voltage lockout circuit to keep the output shutting off until internal circuitry is operating properly. The UVLO circuit has hysteresis and a de-glitch feature so that it will typically ignore undershoot transients on the input. When input voltage exceeds the UVLO threshold, the output voltage starts a soft-start to reduce the inrush current.

**Power Switch**

The power switch is an N-channel MOSFET with a low $R_{DS(ON)}$. The internal power MOSFET does not have the body diode. When IC is off, the MOSFET prevents a current flowing from the VOUT back to VIN and VIN to VOUT.

**OCB Output**

The TD9530 series of power switches provide an opendrain output to indicate that a fault has occurred. When any of current-limit or over-temperature protection occurs for a deglitch time of $t_{D(OCB)}$, the OCB goes low. If fault condition release, OCB will goes high when VOUT > 1.5V (see Figure 1). Since the OCB pin is an open-drain output, connecting a resistor to a pull high voltage is necessary.

**Enable/Disable**

Pull the EN below 0.6V will disable the device, and pull EN above 1.4V will enable the device. When the IC is disabled, the supply current is reduced to less than 1uA. The enable input is compatible with both TTL and CMOS logic levels. The EN pin cannot be left floating.

**Reverse-Voltage Protection**

The reverse voltage protection feature turns off the Nchannel MOSFET when a reverse current of (VOUT - VIN)/$R_{DS(on)}$) over 100mA(typ.) for 5ms (typ) deglitch time(see Figure 2). The TD9530 device allows the N-channel MOSFET immediately turn on once the output voltage goes lower than the input voltage by 25 mV (typ)(see Figure 2). this prevents damage to devices on the input side of the TD9530 by preventing significant current from sinking into the input capacitance.

**Over-Temperature Protection**

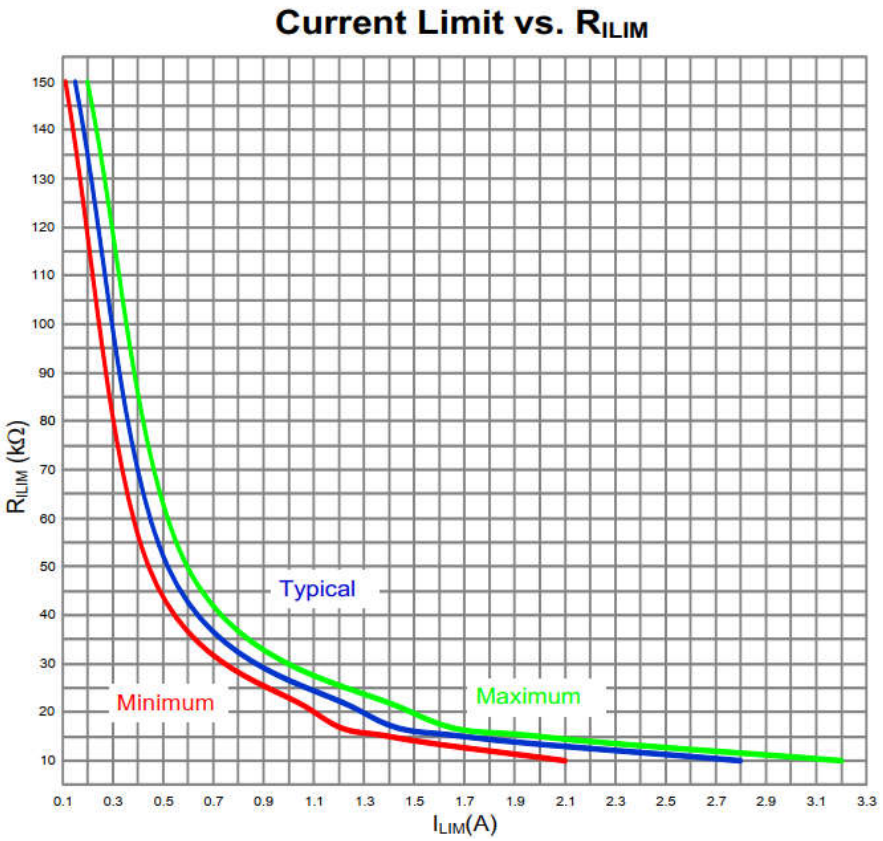
When the junction temperature exceeds 140°C, the internal thermal sense circuit turns off the power FET and allows the device to cool down. When the device's junction temperature cools by 20°C, the internal thermal sense circuit will enable the device, resulting in a pulsed output during continuous thermal protection. Thermal protection is designed to protect the IC in the event of over temperature conditions. For normal operation, the junction temperature cannot exceed $T_J$=+125°C.

## Function Descriptions (Cont.)

**Current-Limit Protection**

The TD9530 series of power switches provide the current limit protection function. The adjustable current limit threshold of TD9530 is user programmable via an external resistor. The recommended 1% resistor range for $R_{ILIM}$ is 10kΩ<$R_{ILIM}$<150kΩ to ensure stability of the internal regulation loop.

While the maximum recommend value of $R_{ILIM}$ is 150kΩ, there is one additional configuration that allows for a lower current-limit threshold. During current limit, the devices limit output current at current limit threshold. For reliable operation, the device should not be operated in current limit for extended period.



## Application Information

**Input Capacitor**

A 10uF ceramic bypass capacitor from IN to GND, located near the TD9530, is strongly recommended to suppress the ringing during short circuit fault event. Without the bypass capacitor, the output short may cause sufficient ringing on the input (from supply lead inductance) to damage internal control circuitry. Additional low-ESR ceramic capacitance may be necessary from IN to GND to prevent unwanted noise from coupling into the sensitive ILIM circuitry.

**Output Capacitor**

A low-ESR 150uF aluminum electrolytic between OUT and GND is strongly recommended to reduce the voltage droop during hot-attachment of downstream peripheral. Higher value output capacitor is better when the output load is heavy. Additionally, bypassing the output with a 0.1uf ceramic capacitor improves the immunity of the device to short-circuit transients.

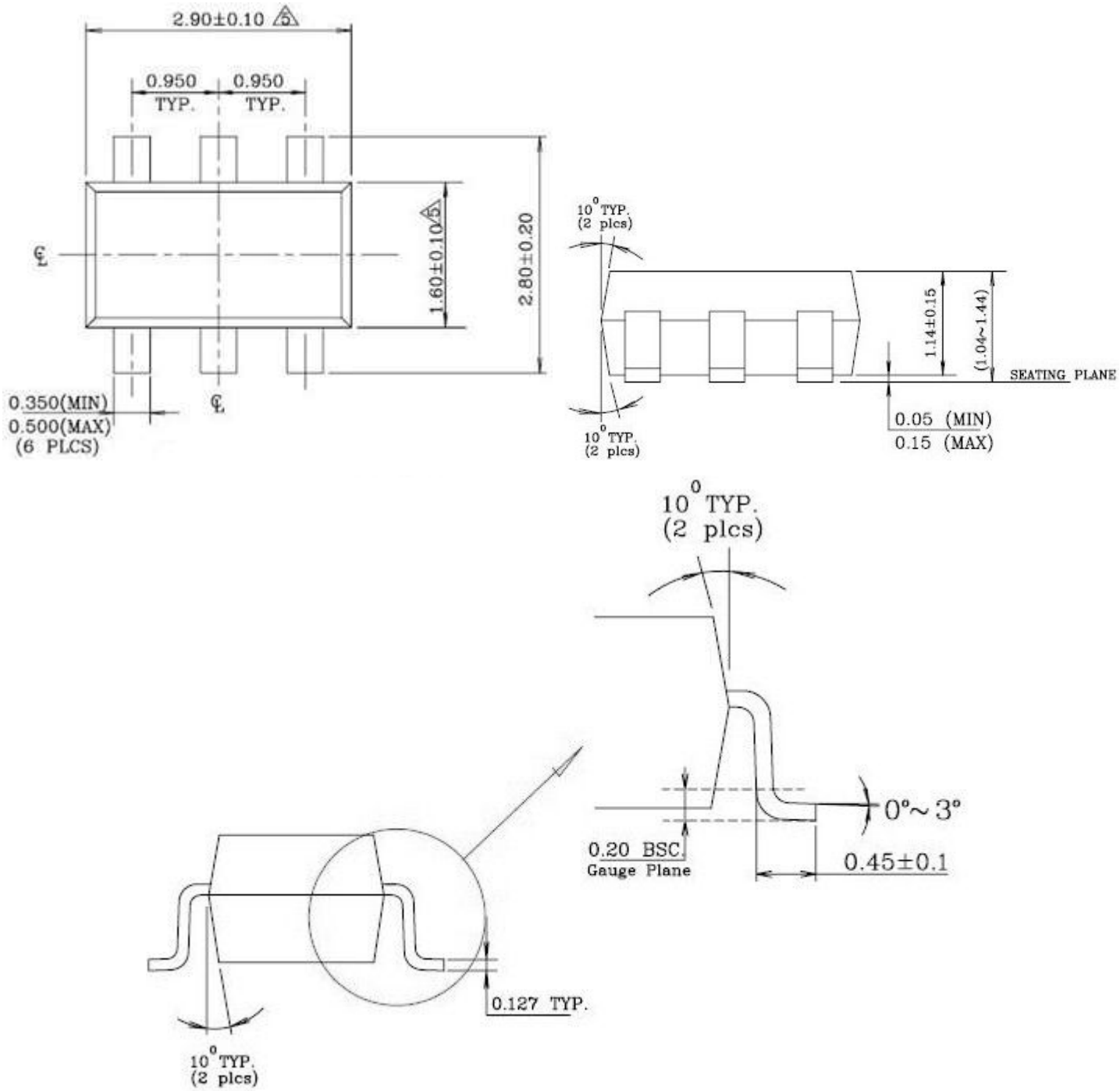
**Layout Consideration**

The PCB layout should be carefully performed to maximize thermal dissipation and to minimize voltage drop, droop and EMI. The following guidelines must be considered:

1. Please place the input capacitors near the IN pin as close as possible.
2. Output decoupling capacitors for load must be placed near the load as close as possible for decoupling high frequency ripples.
3. Locate TD9530 and output capacitors near the load to reduce parasitic resistance and inductance for excellent load transient performance.
4. The negative pins of the input and output capacitors and the GND pin must be connected to the ground plane of the load.
5. Keep IN and OUT traces as wide and short as possible.
6.The traces routing the $R_{ILIM}$ resistor to the TD9530 should be as short as possible to reduce parasitic effects on the current limit accuracy.

## Package Information

### SOT23-6 Package Outline Dimensions



## Design Notes