## General Description

The TD7501/TD7502 series of power switches are designed for USB applications. The 62mΩ N-channel MOSFET power switch satisfies the voltage drop requirements of USB specification.

The protection features include current-limit protection, short-circuit protection, and over-temperature protection.The device limits the output current at current limit threshold level. When $V_{OUT}$ drops below 1.5V, the devices limit the current to a lower and safe level. The over-temperature protection limits the junction temperature below 140℃in case of short circuit or over load conditions.Other features include a deglitched OCB output to indicate the fault condition and an enable input to enable or disable the device.

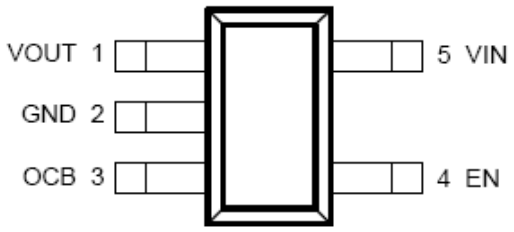
## Features

- 62mΩ High Side MOSFET
- Wide Supply Voltage Range: 2.7V to 5.5V
- Current-Limit and Short-Circuit Protections
- Over-Temperature Protection
- Fault Indication Output
- Enable Input
- Lead Free and Green Devices Available

## Applications

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

## Pin Configurations



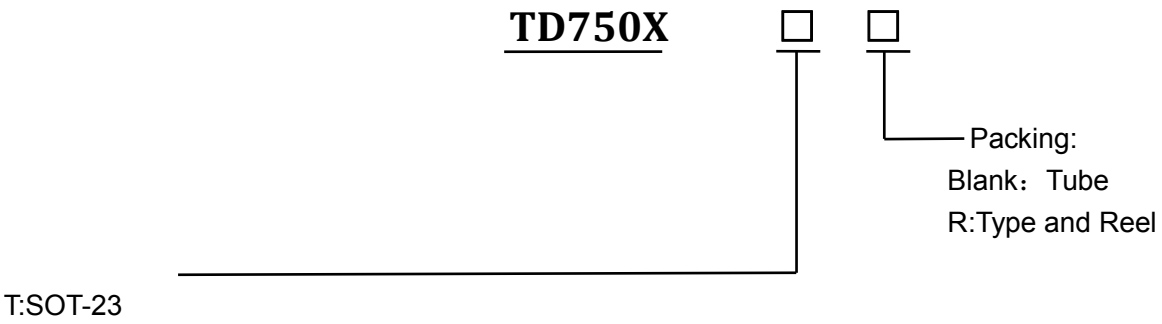

**SOT-23-5(Top View)**

**Figure Pin Configuration of TD7501/TD7502 (Top View)**

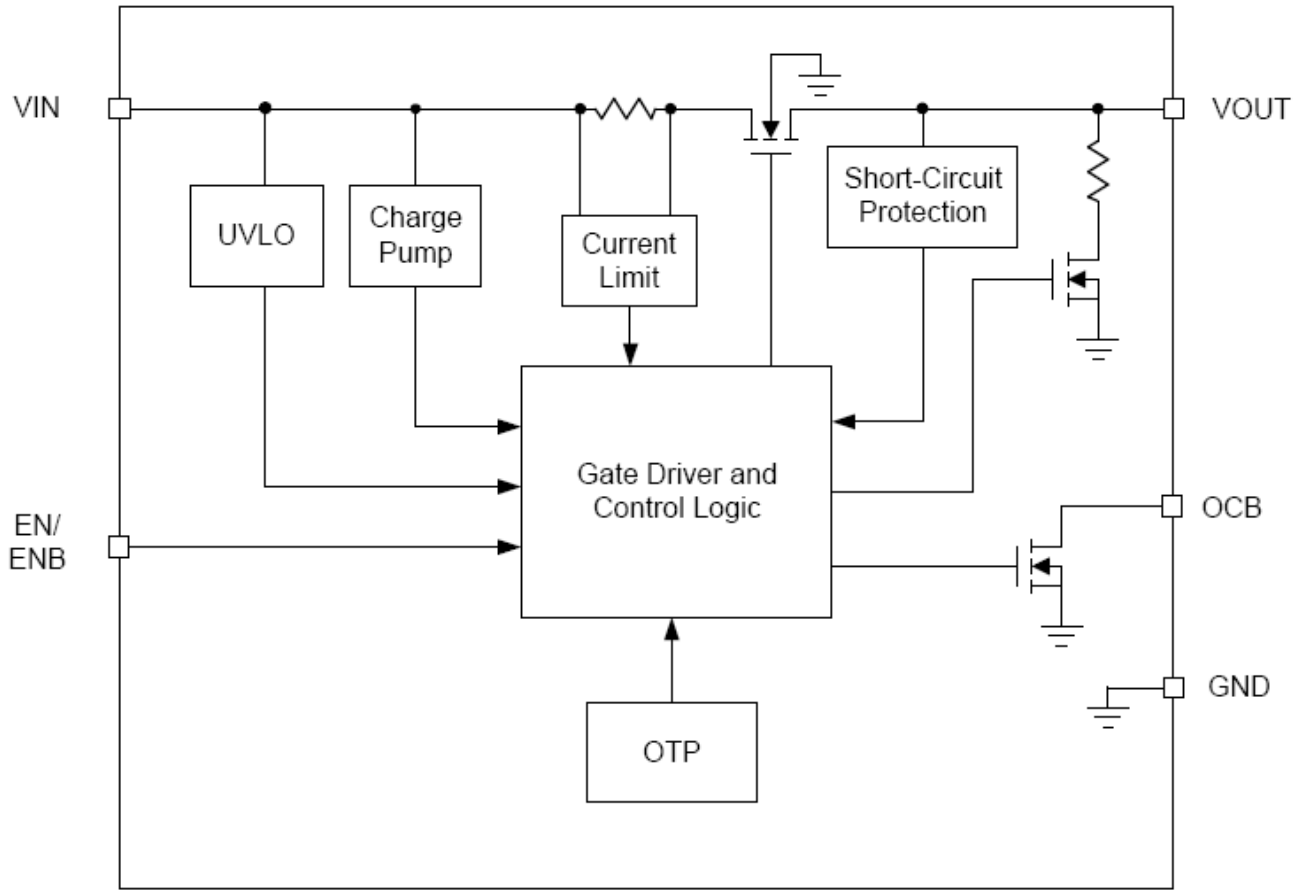
## Pin Description

| Pin Name | | Description |
|---|---|---|
| **TD7501/TD7502** | | |
| 1 | VOUT | Output Voltage Pin. The output voltage follows the input voltage. When ENB is high or EN is low, the output voltage is discharged by an internal resistor. |
| 2 | GND | Ground. |
| 3 | OCB | Fault Indication Pin. This pin goes low when a current limit or an over-temperature condition is detected after a 12ms deglitch time. |
| 4 | 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. |
| 5 | VIN | Power Supply Input. Connect this pin to external DC supply. |

## Ordering Information



## Functional Block Diagram




## Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{IN}$ | VIN Input Voltage (VIN to GND) | -0.3 ~ 7 | V |
| $V_{OUT}$ | VOUT to GND Voltage | -0.3 ~ 7 | V |
| $V_{ENB}$, $V_{EN}$ | EN, ENB to GND Voltage | -0.3 ~ 7 | V |
| $V_{OCB}$ | OCB to GND Voltage | -0.3 ~ 7 | V |
| $T_J$ | Maximum Junction Temperature | 150 | °C |
| $T_{STG}$ | Storage Temperature | -65 ~ 150 | °C |
| $T_{SDR}$ | Maximum Soldering Temperature, 10 Seconds | 260 | °C |

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Recommended Operating Conditions

| Symbol | Parameter | Range | Unit |
|---|---|---|---|
| $V_{IN}$ | VIN Input Voltage | 2.7~5.5 | V |
| VCC | VCC Supply Voltage | 4.5 ~ 5.5 | V |
| $I_{OUT}$ | OUT Output Current (TD7501) | 0~1 | A |
| | OUT Output Current (TD7502) | 0~ 2.4 | A |
| $T_A$ | Ambient Temperature | -40 ~ 85 | °C |
| $T_J$ | Junction Temperature | -40 ~ 125 | °C |

Note: Refer to the typical application circuit.

## Thermal Characteristics

| Symbol | Parameter | Typical Value | Unit |
|---|---|---|---|
| θJA | Junction-to-Ambient Resistance in Free Air | 235 | °C/W |

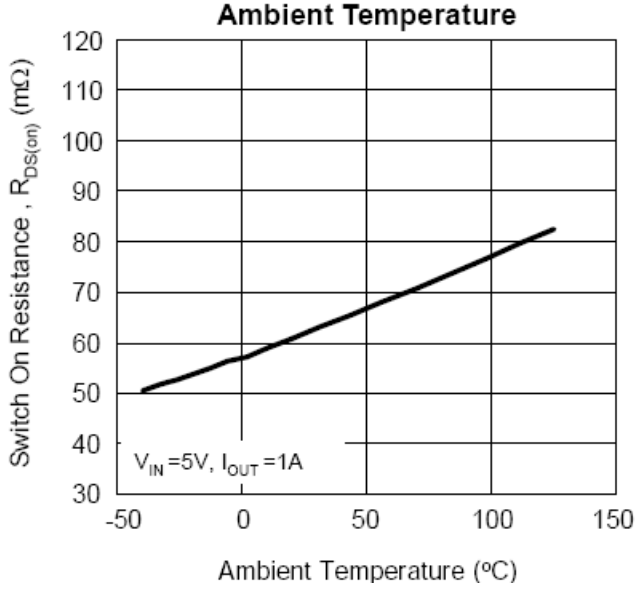
## Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN}$=5V, $V_{EN}$ =5V or $V_{ENB}$=0V and $T_A$= -40 ~ 85 ℃. Typical values are at $T_A$=25℃.

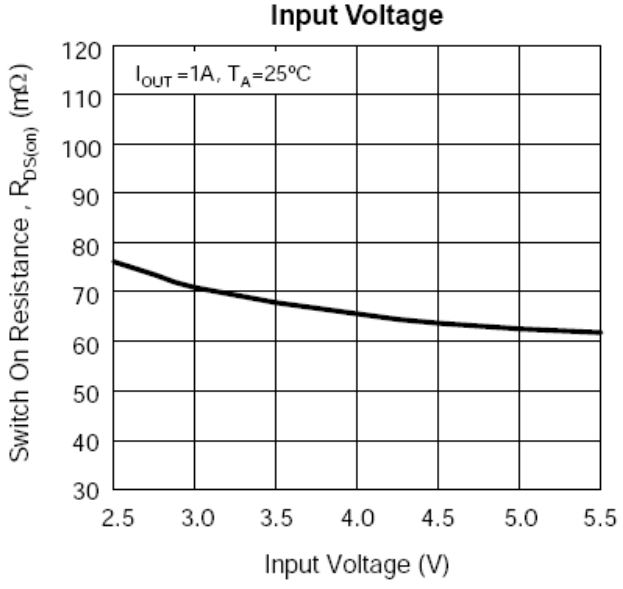
| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **SUPPLY CURRENT** | | | | | | |
| | VIN Supply Current | No load, $V_{EN}$=0V or $V_{ENB}$=5V | – | – | 1 | μA |
| | | No load, $V_{EN}$=5V or $V_{ENB}$=0V | | 60 | 100 | μA |
| | Leakage Current | VOUT=GND, $V_{EN}$=0V or $V_{ENB}$=5V | – | – | 1 | μA |
| | Reverse Leakage Current | VIN=GND, $V_{OUT}$=5V, $V_{EN}$=0V or $V_{ENB}$=5V | – | – | 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 AND SHORT-CIRCUIT PROTECTIONS** | | | | | | |
| $I_{LIM}$ | Current Limit Threshold | TD7502 $V_{IN}$=2.7V to 5.5V, $T_A$= -40 ~ 85℃ | 2.5 | 2.8 | 3.1 | A |
| | | TD7501 $V_{IN}$=2.7V to 5.5V, $T_A$= -40 ~ 85 ℃ | 1.1 | 1.3 | 1.5 | A |
| $I_{SHORT}$ | Short-Circuit Output Current | TD7502, $V_{IN}$=2.7V to 5.5V | | 1.5 | | A |
| | | TD7501, $V_{IN}$=2.7V to 5.5V | | 0.8 | | A |
| **OCB OUTPUT PIN** | | | | | | |
| | OCB Output Low Voltage | $I_{OCB}$=5mA | | 0.2 | 0.4 | V |
| | OCB Leakage Current | $V_{OCB}$=5V | | | 1 | uA |
| $t_{D(OCB)}$ | OCB Deglitch Time | OCB assertion, $T_A$= -40 ~ 85℃ | 5 | 12 | 20 | mS |
| **EN OR ENB INPUT PIN** | | | | | | |
| $V_{IH}$ | Input Logic HIGH | $V_{IN}$=2.7V to 5V | 2 | | | V |
| $V_{IL}$ | Input Logic LOW | $V_{IN}$=2.7V to 5V | | | 0.8 | V |
| | Input Current | | | | 1 | uA |
| | VOUT Discharge Resistance | $V_{EN}$=0V or $V_{ENB}$=5V, $V_{OUT}$=1V | | 40 | | Ω |
| $t_{D(ON)}$ | Turn On Delay Time | | | 30 | | uS |
| $t_{D(OFF)}$ | Turn Off Delay Time | | | 30 | | uS |
| $t_{SS}$ | Soft-Start Time | No load, $C_{OUT}$=1μF, $V_{IN}$=5V | | 400 | | uS |
| **OVER-TEMPERATURE PROTECTION (OTP)** | | | | | | |
| $T_{OTP}$ | Over-Temperature Threshold | $T_J$ rising | | 140 | | °C |
| | Over-Temperature Hysteresis | | | 20 | | °C |

## Typical Operating Characteristics

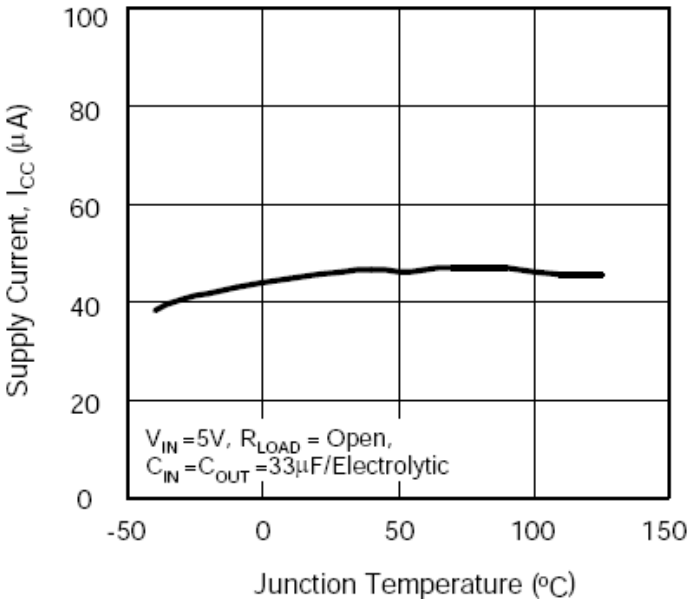
**Switch On Resistance vs. Ambient Temperature**



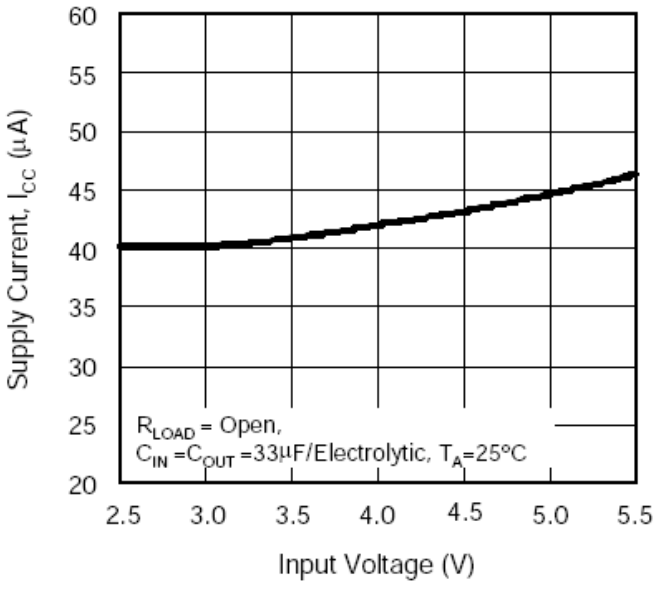

**Switch On Resistance vs. Input Voltage**



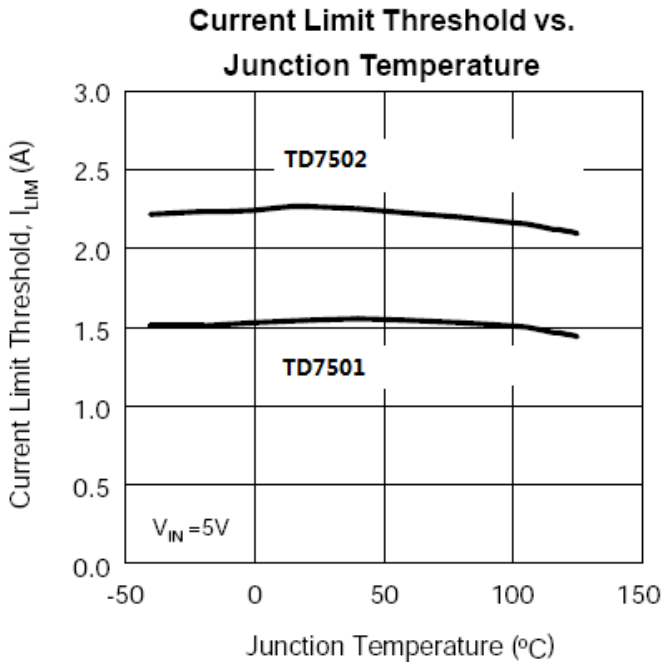

**Supply Current vs. Junction Temperature**

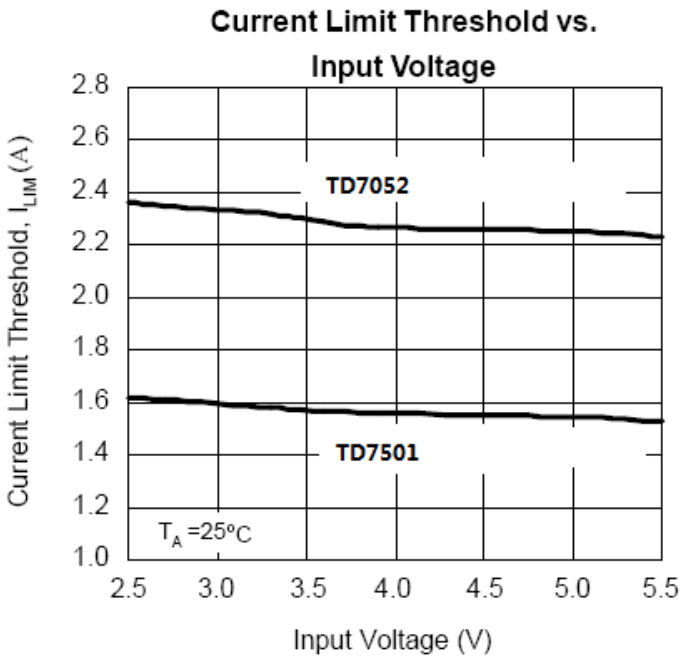


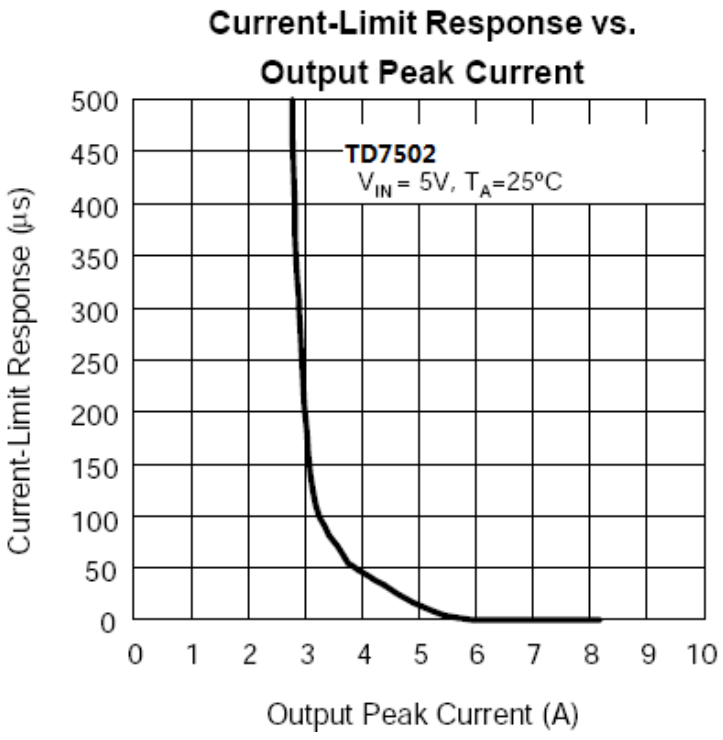

**Supply Current vs. Input Voltage**

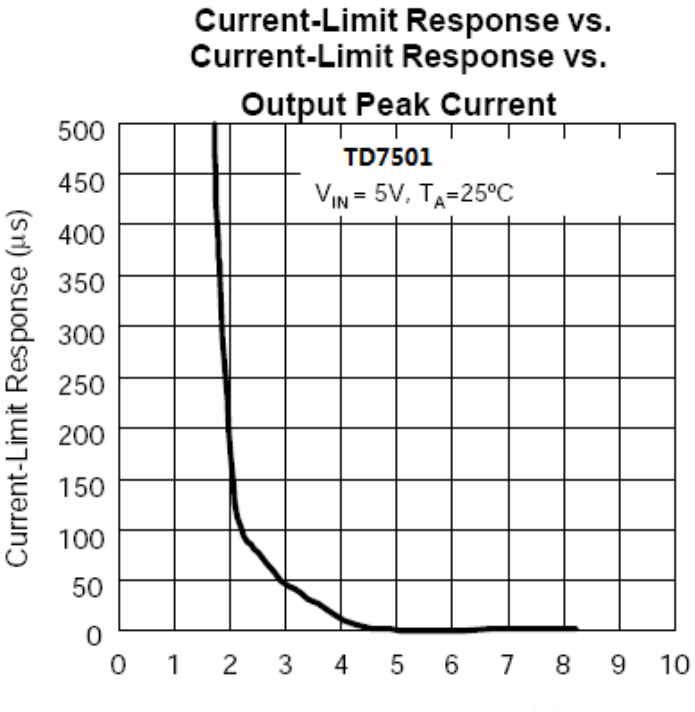


## Typical Operating Characteristics(Cont.)



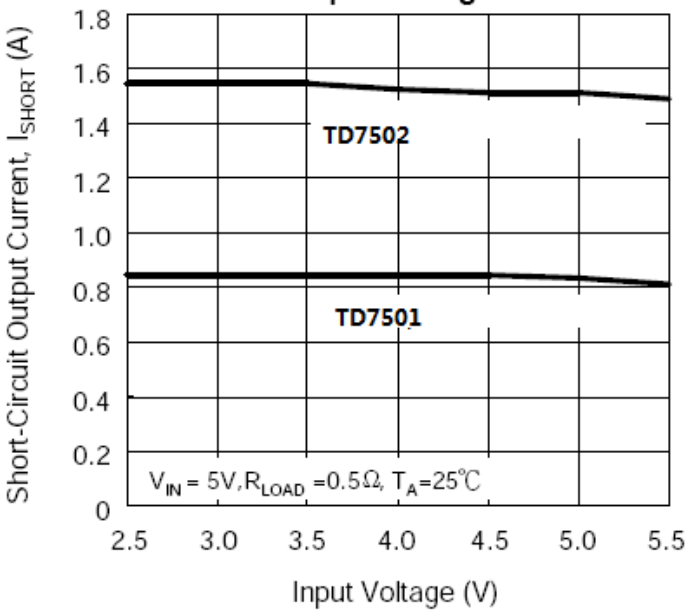



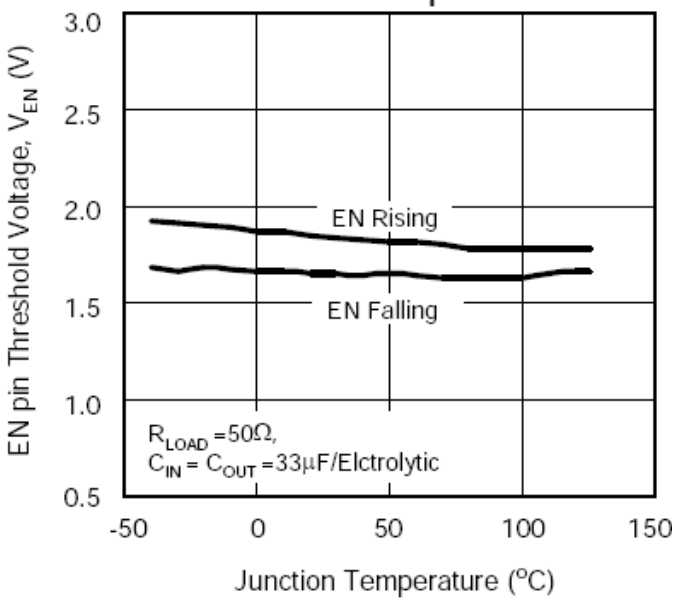



## Typical Operating Characteristics(Cont.)

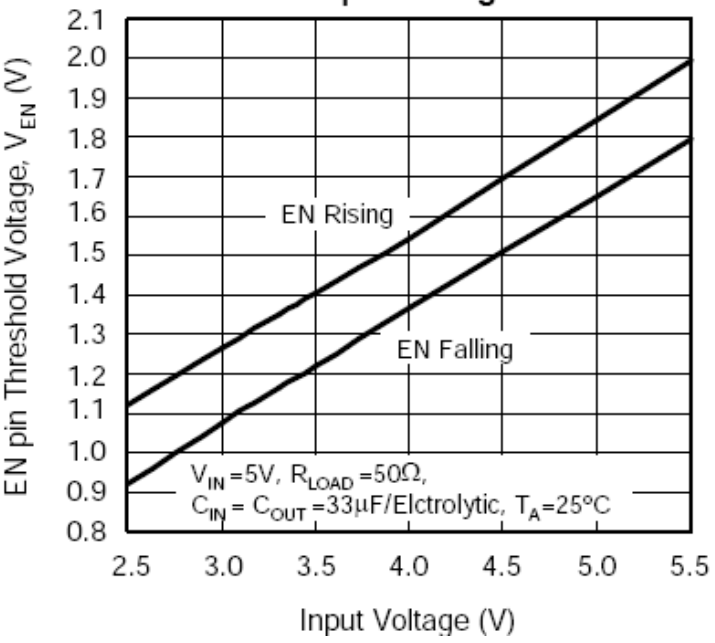
**Short-Circuit Output Current vs. Input Voltage**



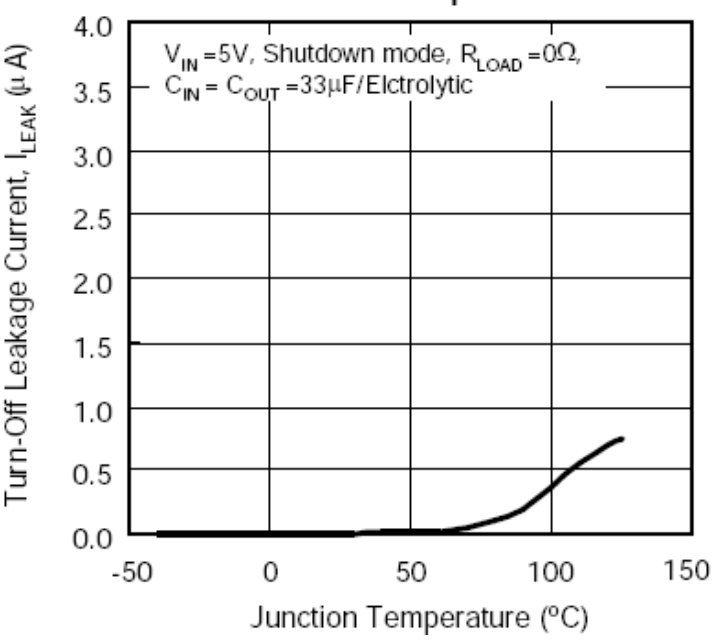

**EN pin Threshold Voltage vs. Junction Temperature**




**EN pin Threshold Voltage vs. Input Voltage**

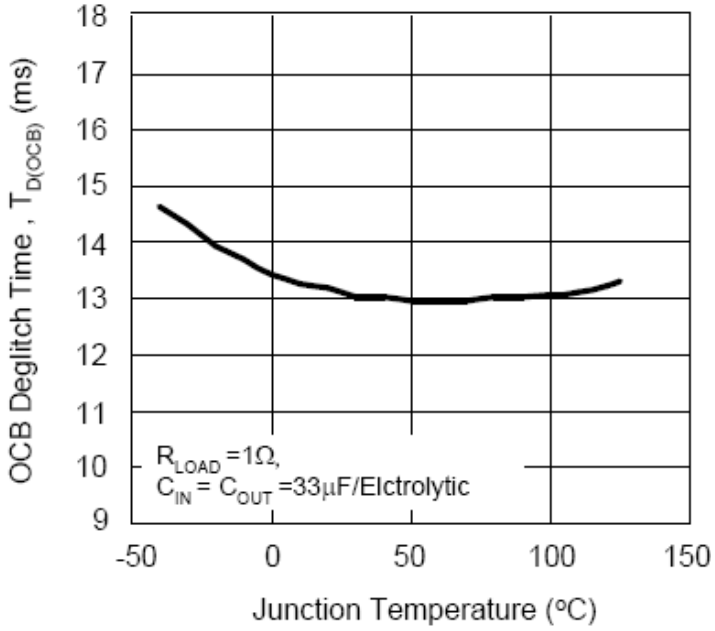



**Turn-Off Leakage Current vs. Junction Temperature**

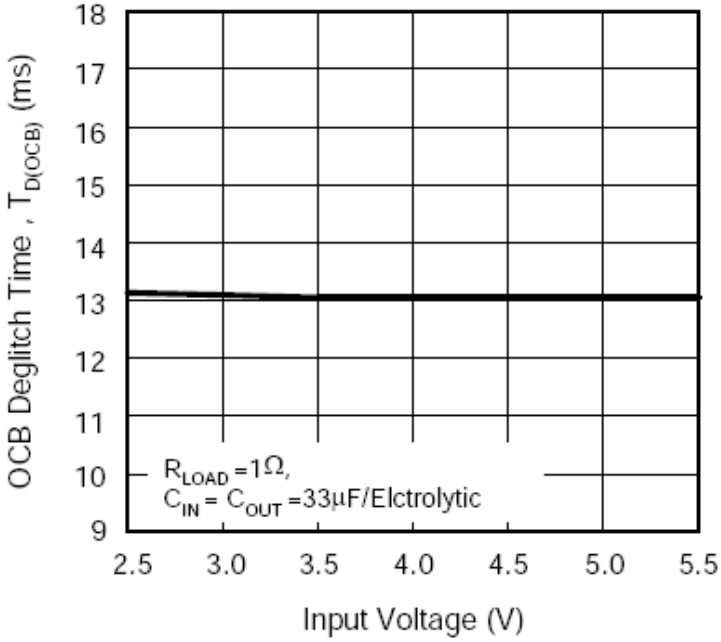


## Typical Operating Characteristics(Cont.)

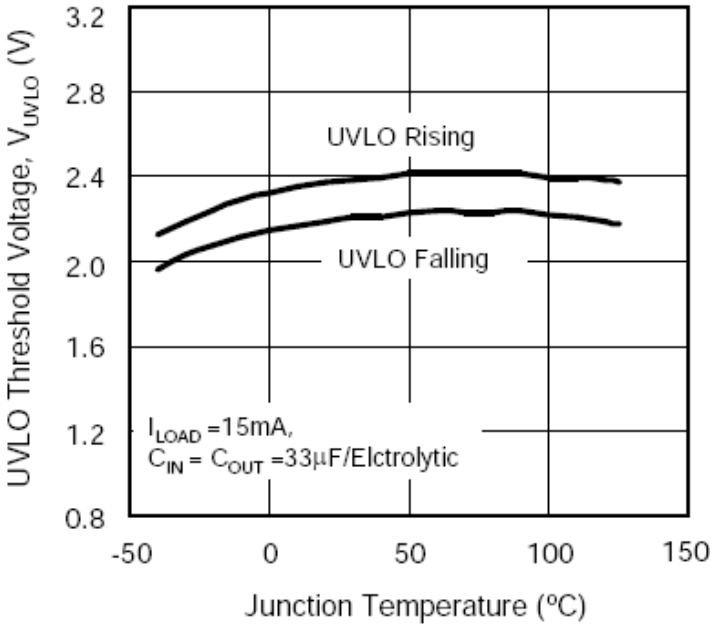
**OCB Deglitch Time vs. Junction Temperature**



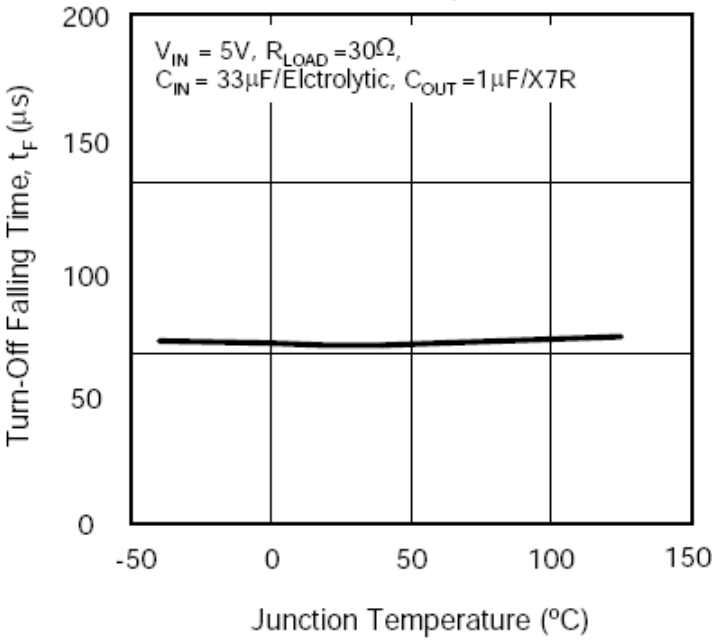

**OCB Deglitch Time vs. Input Voltage**




**UVLO Threshold Voltage vs. Junction Temperature**

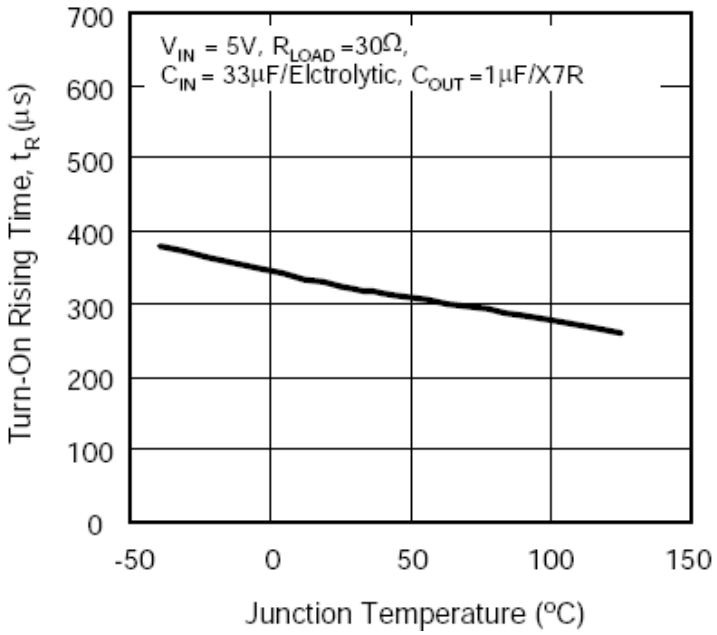



**Turn-Off Falling Time vs. Junction Temperature**

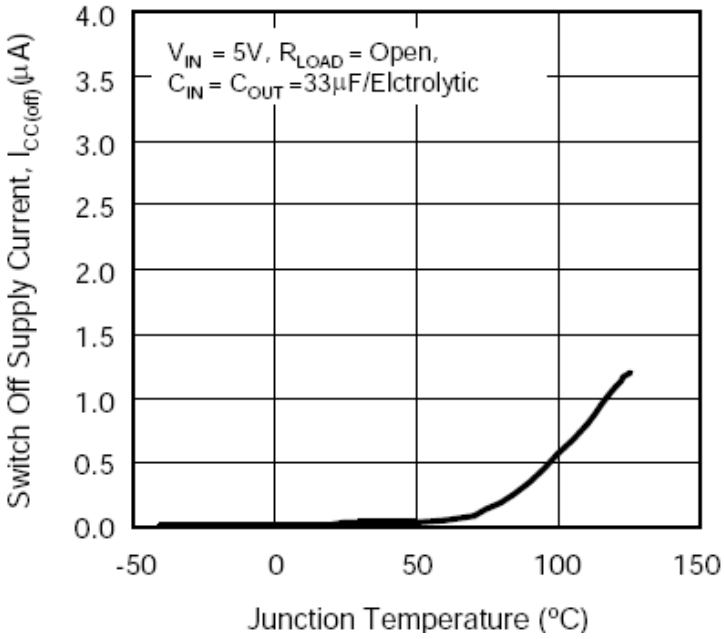


## Typical Operating Characteristics(Cont.)

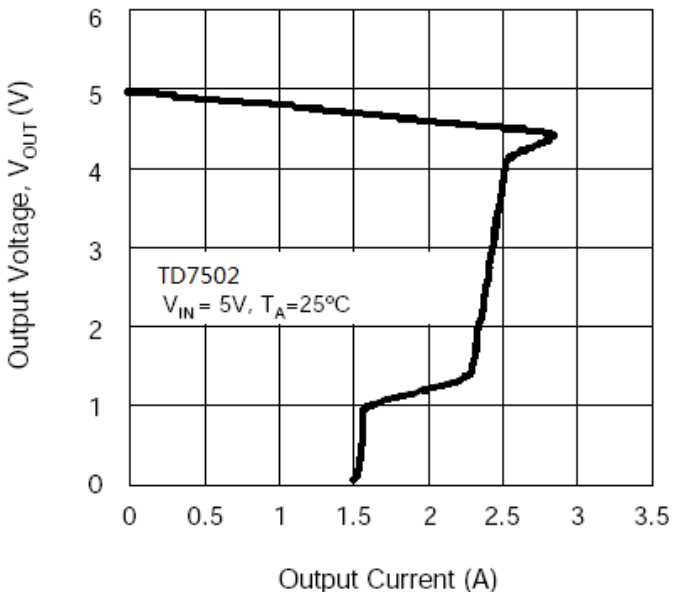
**Turn-On Rising Time vs. Junction Temperature**



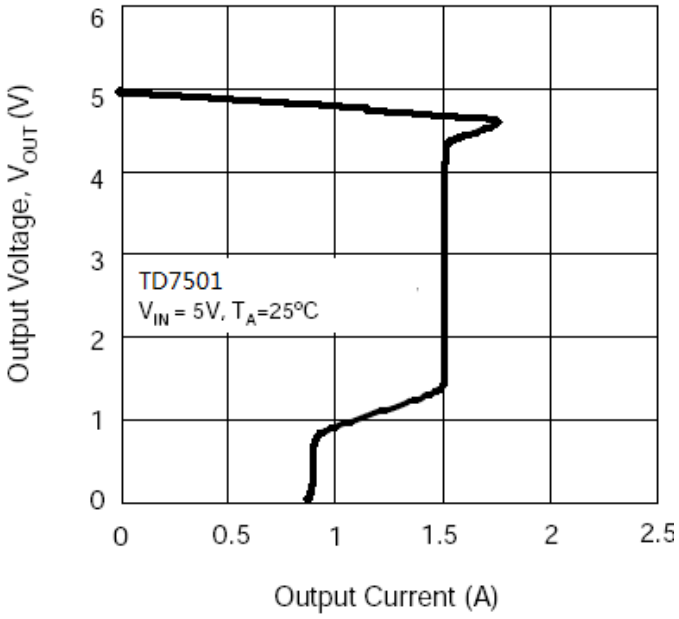

**Switch Off Supply Current vs. Junction Temperature**




**Output Voltage vs. Output Current**

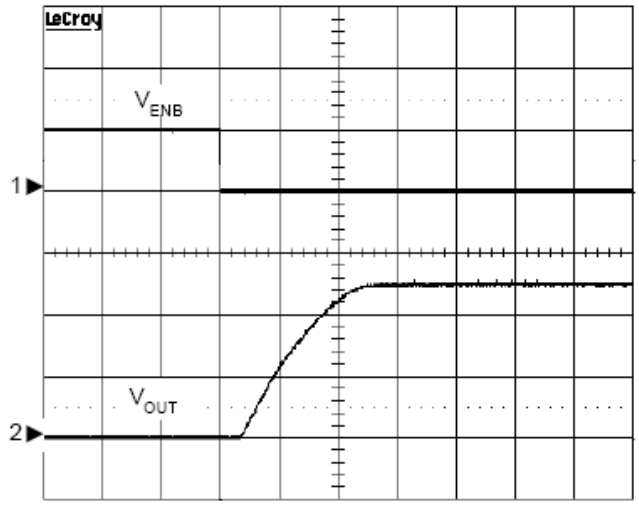



**Output Voltage vs. Output Current**



## Operating Waveforms

### Turn On Response




$V_{IN}$ =5V, $R_{LOAD}$ =30Ω, $C_{IN}$ =33μF/Electrolytic,

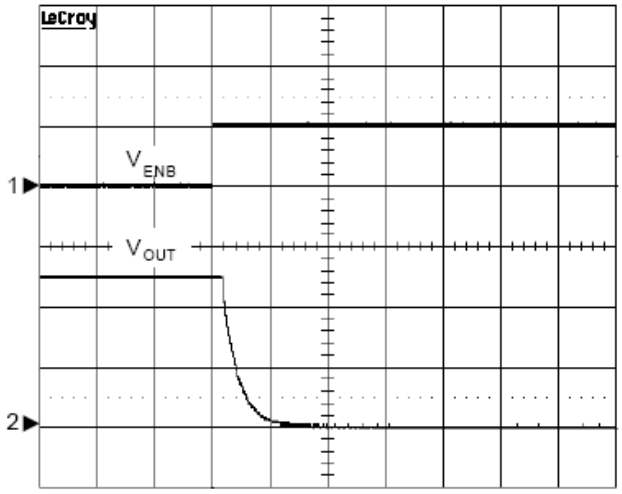
$C_{OUT}$ =1μF/Electrolytic

CH1: $V_{ENB}$, 5V/Div, DC

CH2: $V_{OUT}$, 2V/Div, DC

TIME: 200μs/Div

### Turn Off Response




$V_{IN}$ =5V, $R_{LOAD}$ =30Ω, $C_{IN}$ =33μF/Electrolytic,

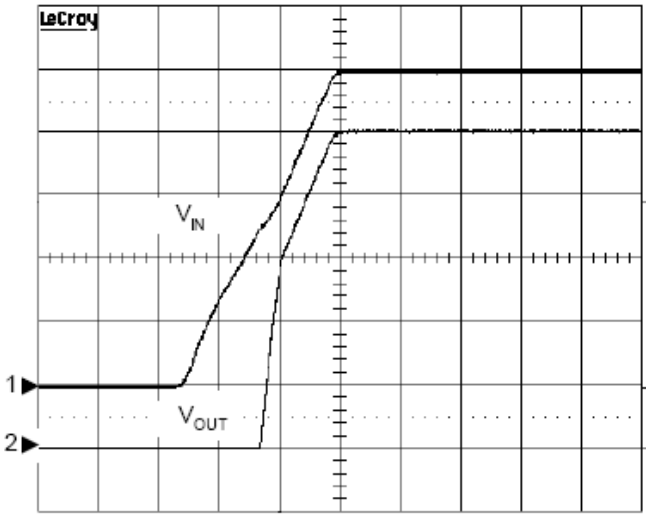
$C_{OUT}$ =1μF/Electrolytic

CH1: $V_{ENB}$, 5V/Div, DC

CH2: $V_{OUT}$, 2V/Div, DC

TIME: 100μs/Div

### UVLO at Rising




$V_{IN}$ =5V, $R_{LOAD}$ =30Ω, $C_{IN}$ =33μF/Electrolytic,

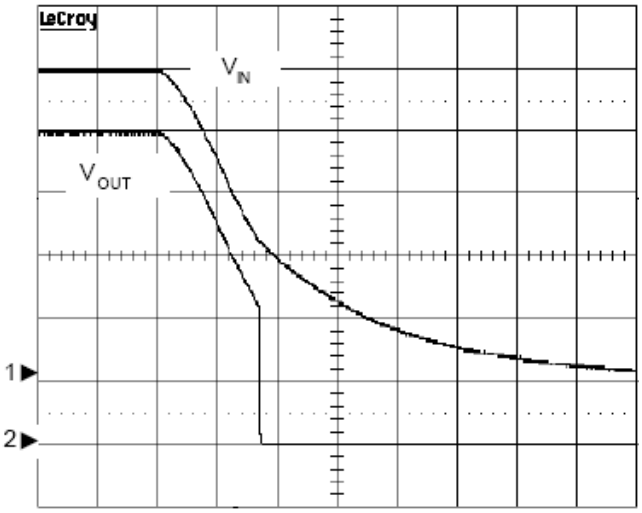
$C_{OUT}$ =1μF/Electrolytic

CH1: $V_{IN}$, 1V/Div, DC

CH2: $V_{OUT}$, 1V/Div, DC

TIME: 2ms/Div

### UVLO at Falling




$V_{IN}$ =5V, $R_{LOAD}$ =30Ω, $C_{IN}$ =33μF/Electrolytic,

$C_{OUT}$ =1μF/Electrolytic

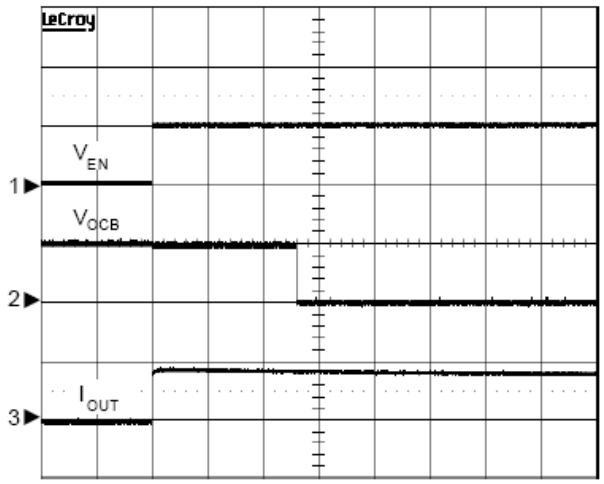
CH1: $V_{IN}$, 1V/Div, DC

CH2: $V_{OUT}$, 1V/Div, DC

TIME: 2ms/Div

## Operating Waveforms(Cont.)

### OCB Response during Short Circuit




TD7501, $V_{IN}$ =5V, OUT short to GND,

$C_{IN}$ =$C_{OUT}$=33μF/Electrolytic

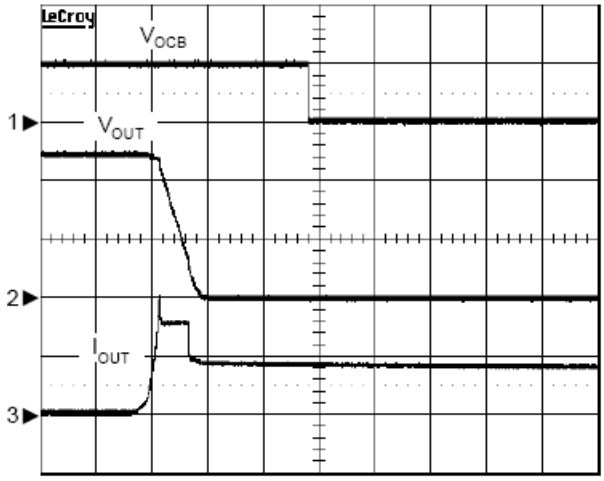
CH1: $V_{EN}$, 5V/Div, DC

CH2: $V_{OCB}$, 5V/Div, DC

CH3: $I_{OUT}$, 1A/Div, DC

TIME: 5ms/Div

### OCB Response with Ramped Load




TD7501, $V_{IN}$ =5V, $C_{IN}$ =$C_{OUT}$=33μF/Electrolytic

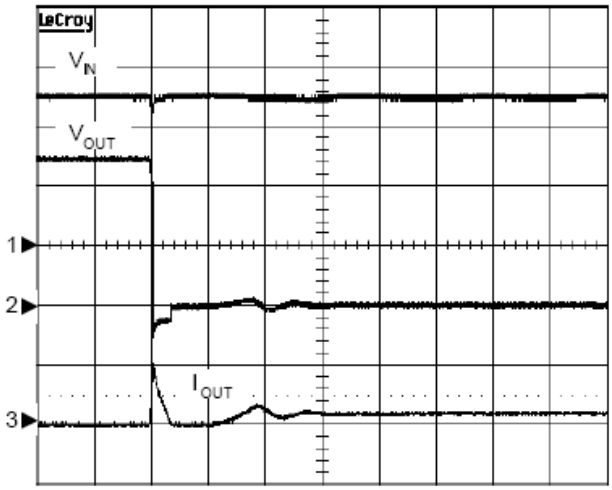
CH1: $V_{OCB}$, 5V/Div, DC

CH2: $V_{OUT}$, 2V/Div, DC

CH3: $I_{OUT}$, 1A/Div, DC

TIME: 5ms/Div

### Short Circuit Response




TD7501, $V_{IN}$ =5V, OUT Short to GND,

$C_{IN}$ =33μF/Electrolytic, No $C_{OUT}$

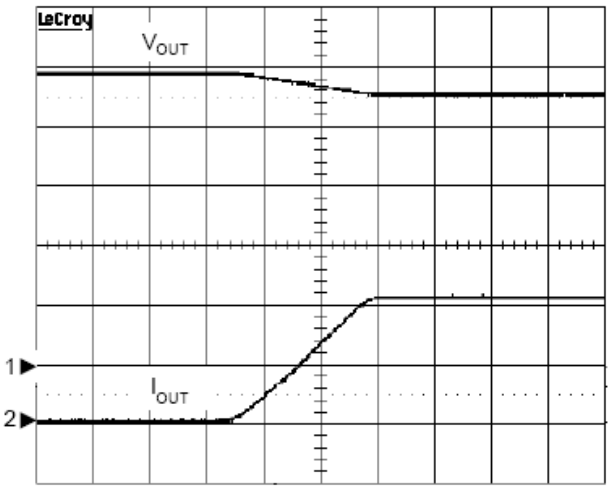
CH1: $V_{IN}$, 2V/Div, DC

CH2: $V_{OUT}$, 2V/Div, DC

CH3: $I_{OUT}$, 5A/Div, DC

TIME: 50μs/Div

### Load Transient Response




TD7502, $V_{IN}$ =5V, $R_{LOAD}$ =1kΩ to 2.2Ω,

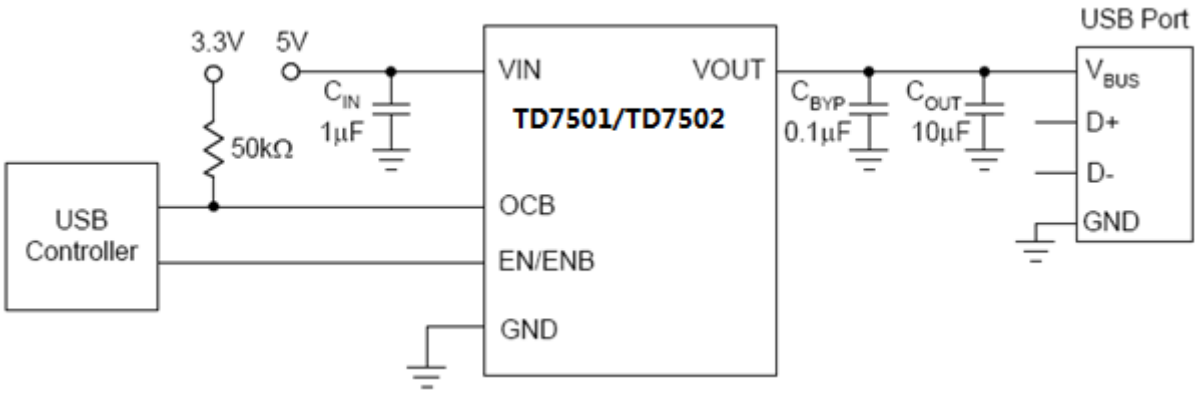
$C_{IN}$ =$C_{OUT}$=33μF/Electrolytic

CH1: $V_{OUT}$, 1V/Div, DC

CH2: $I_{OUT}$, 1A/Div, DC

TIME: 1ms/Div

## Type Application Circuit




## Function Description

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

The TD750X 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.

**Current-Limit Protection**

The TD750X series of power switches provide the current- limit protection function. 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.

**Short-Circuit Protection**

When the output voltage drops below 1.5V, which is caused by an over-load or a short-circuit, the devices limit the output current down to a safe level. The short-circuit current limit is used to reduce the power dissipation during short-circuit conditions. If the junction temperature reaches over-temperature threshold, the

**OCB Output**

TheTD750X series of power switches provide an open-drain 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. Since the OCB pin is an open-drain output, connecting a resistor to a pull high voltage is necessary.

**Enable/Disable**

Pull the ENB above 2V or EN below 0.8V will disable the device, and pull ENB pin below 0.8V or EN above 2V will enable the device. When the IC is disabled, the supply current is reduced to less than 1μA. The enable input is compatible with both TTL and CMOS logic levels. The EN/ENB pin cannot be left floating.

**Over-Temperature Protection**

When the junction temperature exceeds 140℃, 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 20ₒC, 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℃.

device will enter the thermal shutdown.

## Application Information

**Input Capacitor**

A 1μF ceramic bypass capacitor from $V_{IN}$ to GND, located near the TD750X, 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.

**Output Capacitor**

A low-ESR 10μF aluminum electrolytic or tantalum between $V_{OUT}$ and GND is strongly recommended to reduce the voltage drop during hot-attachment of downstream peripheral. (Per USB 2.0, output ports must have a minimum 120μF of low-ESR bulk capacitance per hub).

Higher-value output capacitor is better when the output load is heavy. Additionally, bypassing the output with a 0.1μF ceramic capacitor improves the immunity of the device to short-circuit transients.

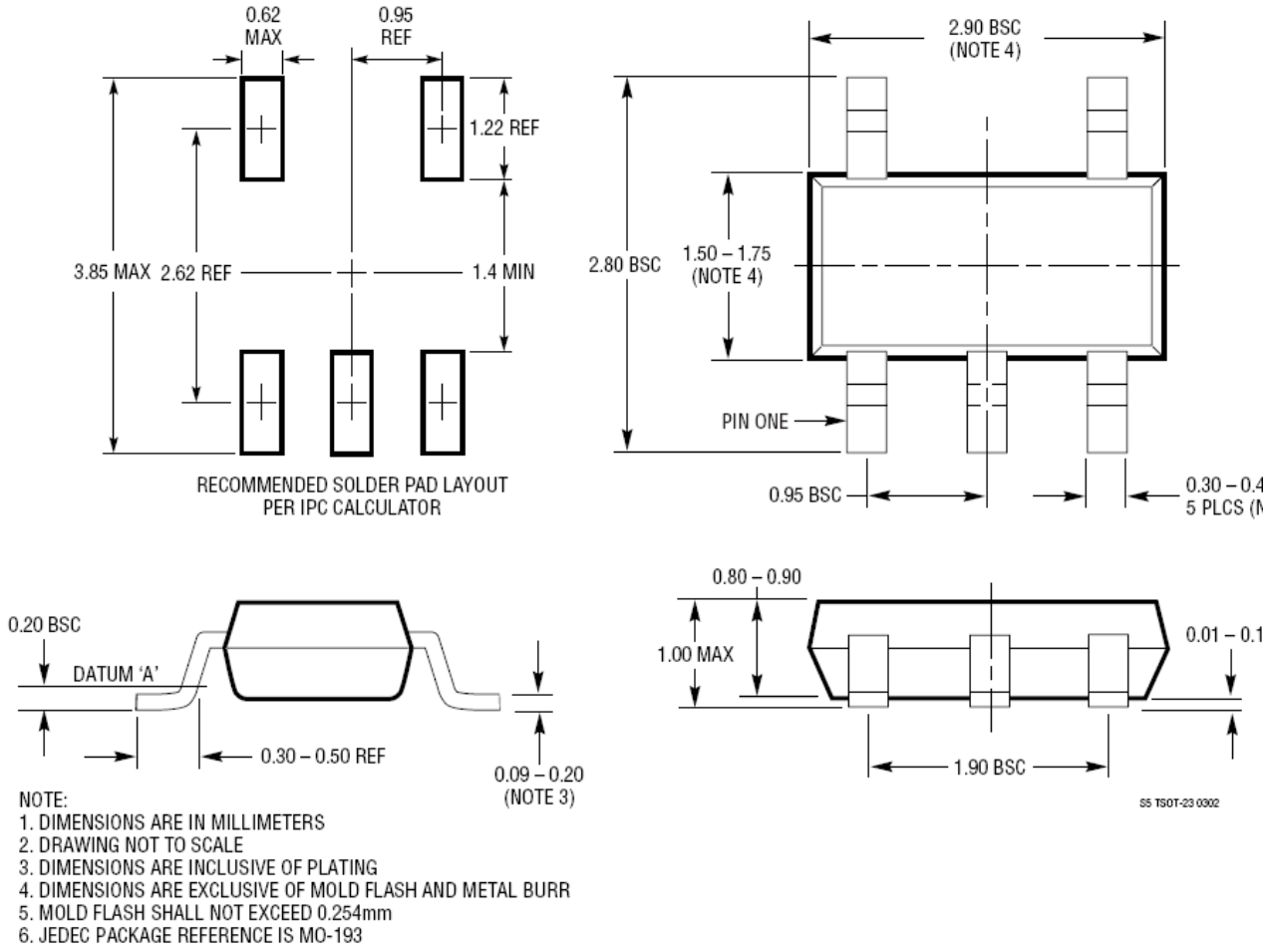
**Layout Consideration**

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 VIN pin as close as possible.
2. Output decoupling capacitors for load must be placed near the load as close as possible for decoupling highfrequency ripples.
3. Locate TD750X 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 $V_{IN}$ and $V_{OUT}$ traces as wide and short as possible.

## Package Information

TSOT23-5 Package Outline Dimensions




NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

# Design Notes