# 12 mΩ Power Switch with Current Limit and Charging Port Controller

## 1 DESCRIPTION

The SC7002 is a power switch that integrates an ultra-low Rdson (12mΩ) N-channel MOSFET. It is designed for USB port applications or other applications which require a high current switch. It provides a current limit function, and the current limit can be programmable through an external resistor.

The SC7002 also integrates a USB charging port controller function. It can support a traditional Type-A USB port with DP and DM signals. It monitors the DP/DM data line voltage and automatically supports the DCP schemes for Battery Charging specification (BC1.2), the divider Mode, and the 1.2V/1.2V Mode.

The SC7002 also supports various protections, including over-voltage protection, under-voltage protection, short circuit protection, and thermal shutdown protection.

The SC7002 requires a minimum number of external components to complete a USB switch and charging port solution. It is available in the TSOT23-6 package.

## 2 FEATURES

- 12mΩ Ultra-low Rdson NMOS Switch
- Programmable Current Limit
- ± 5% Current Limit Accuracy at 2.7A
- Built-in Soft-Start
- Ultra-low Operation Current
- USB Charging Port Controller Function
  - ✓ Battery Charging Specification BC1.2 for DCP
  - ✓ Chinese telecommunication industrial standard YD/T 1591-2009
  - ✓ D+/D- option for Apple device (2.4A)
  - ✓ D+/D- option for Samsung device
- Input Under Voltage Protection
- Input Over Voltage Protection
- Over Current Protection
- Short Circuit Protection
- Thermal Shutdown Protection
- ±8kV HBM ESD Rating for USB IO pins
- TSOT23-6 package

## 3 APPLICATIONS

- USB chargers
- USB HUB
- USB power supplies
- USB peripherals

## 4 ORDERING INFORMATION

| Part Number | Package | Dimension |
|---|---|---|
| SC7002SAER | TSOT23-6 | 2.9*2.8*0.95 mm |

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## 5 Typical Application Circuit

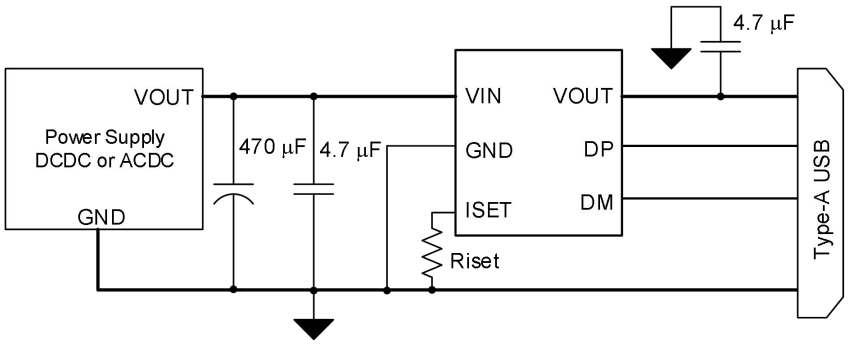


Figure 1 SC7002 typical application circuit

## 6 Pin Configurations and Functions

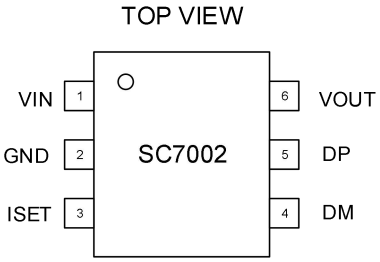


Table 1 Pin description

| Terminals | NAME | I/O | Description |
|---|---|---|---|
| 1 | VIN | I | Input to the switch |
| 2 | GND | IO | Ground |
| 3 | ISET | I | Set the current limit value |
| 4 | DM | IO | DM pin for type A USB port interface |
| 5 | DP | IO | DP pin for type A USB port interface |
| 6 | VOUT | O | The output of the switch |

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# 7 Electrical Specifications

## 7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)(1)

| | | Min. | Max. | Unit |
|---|---|---|---|---|
| Voltage(2) | VIN, VOUT | -0.3 | 7 | V |
| | DP, DM, | -0.3 | VIN+0.3V or 5.7V | V |
| | ISET | -0.3 | 5.5 | V |
| $T_J$ | Operating junction temperature | -40 | 150 | °C |
| $T_{stg}$ | Storage temperature | -65 | 150 | °C |
| $T_L$ | Lead Temperature | | 260 | °C |
| $T_D$ | Continuous power dissipation (TA=25°C) | | 1.25 | W |
| $T_{\Theta JA}$(3) | Junction to ambient thermal resistance | 100 | | °C/W |
| $T_{\Theta JC}$(3) | Junction to case thermal resistance | 12 | | °C/W |

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device.
(2) All voltages are with respect to network ground terminal.
(3) Measured on JESD51-7, 4-layer PCB.

## 7.2 ESD Ratings

| | | | Min. | Max. | Unit |
|---|---|---|---|---|---|
| $V_{ESD}$(1) | Human-body Model (HBM) (2) | All pins except DP / DM | -4 | 4 | kV |
| | | DP / DM | -8 | 8 | kV |
| | Charged-device Model (CDM) (3) | | -1000 | 1000 | V |

(1) Electrostatic discharge (ESD) to measure device sensitivity and immunity to damage caused by assembly line electrostatic discharges into the device.
(2) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(3) Level listed above is the passing level per EIA-JEDEC JESD22-C101. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 7.3 Recommended Operation Conditions

| | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| $V_{IN}$ | VIN votlage range | 4 | 5 | 5.6 | V |
| $C_{IN}$ | VIN capacitor | 4.7 | | | μF |
| $C_{OUT}$ | VOUTcapacitor | 3.3 | | 22 | μF |
| $T_A$ | Operating ambient temperature | -40 | | 85 | °C |
| $T_J$ | Operating junction temperature | -40 | | 125 | °C |

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## 7.4 Electrical Characteristics

$T_J$= 25°C and $V_{IN}$ = 5V and $V_{OUT}$ = 5V unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **SUPPLY VOLTAGE** | | | | | | |
| $V_{IN}$ | Operating voltage | | 4 | | 5.6 | V |
| $V_{IN_UVLO}$ | Under-voltage lockout threshold | Rising | 3.7 | 3.8 | 3.9 | V |
| | | Hysteresis | 0.5 | 0.6 | 0.7 | V |
| $I_Q$ | Quiescent current | VIN=5V, No-load | 60 | 92 | 120 | μA |
| **POWER FET** | | | | | | |
| $R_{DS_ON}$ | Rdson of switch | VIN=5V | | 12 | | mΩ |
| $T_{SS}$ | Soft start time | VIN = 5V, turning on, no load | | 1 | | ms |
| | | VIN = 5V, turning on, IOUT = 2.4A | | 1.5 | | ms |
| **CURRENT LIMIT** | | | | | | |
| $V_{REF}$ | Reference voltage | | 1.176 | 1.2 | 1.224 | V |
| $I_{LIM}$ | Current limit accuracy | $R_{ISET}$ = 150 KΩ | 2.65 | 2.75 | 2.88 | A |
| **PROTECTION** | | | | | | |
| $V_{IN_OVP}$ | VIN OVP protection | Rising edge, over $V_{OUT}$, $V_{OUT}$ = 5V | 5.6 | 5.8 | 6 | V |
| | | Falling edge | 5.5 | 5.7 | 5.9 | V |
| $I_{ML}$ | Maximum current limit | $R_{ISET}$=0 | 5.5 | | | A |
| $V_{SC\text{-}th}$ | VOUT short circuit protection threshold | | 3.4 | 3.6 | 3.8 | V |
| $T_{HIC_ON}$ | OCP on time of hiccup | VOUT<1.1V | | 3 | | ms |
| $T_{HIC_OFF}$ | OCP off time of hiccup | | | 0.5 | | s |
| TSD | Thermal shutdown temperature threshold | Not in current limit | | 150 | | °C |
| | | In current limit | | 140 | | °C |
| | Thermal shutdown hysteresis | Thermal shutdown hysteresis | | 25 | | °C |
| **DP/DM LOGIC** | | | | | | |
| $V_{DP_2P75_SRC}$ | DP source 2.75V voltage | VIN=5V | 2.57 | 2.75 | 2.84 | V |
| $V_{DM_2P75_SRC}$ | DM source 2.75V voltage | VIN=5V | 2.57 | 2.75 | 2.84 | V |
| $Z_{DP/M_2P75}$ | DP/DM pin output impedance for 2.75V output | | 24 | 30 | 36 | KΩ |
| $Z_{DP/M\ 1P2}$ | DP/DM pin output impedance for1.2V output | | 70 | 100 | 130 | KΩ |
| $V_{DP/DM_1P2_SRC}$ | DP/DM source 1.2V voltage | | 1.1 | 1.2 | 1.3 | V |
| $R_{DP/DM_short}$ | DP and DM short circuit switch | | 5 | 10 | 20 | Ω |

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## 7.5 Typical Characteristics

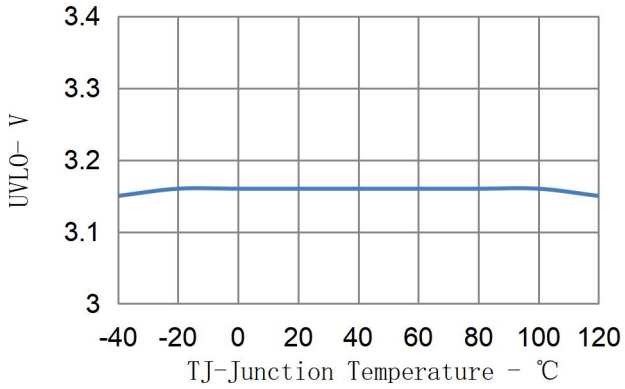


Figure 2 Under Voltage Lock Output VS. Temperature

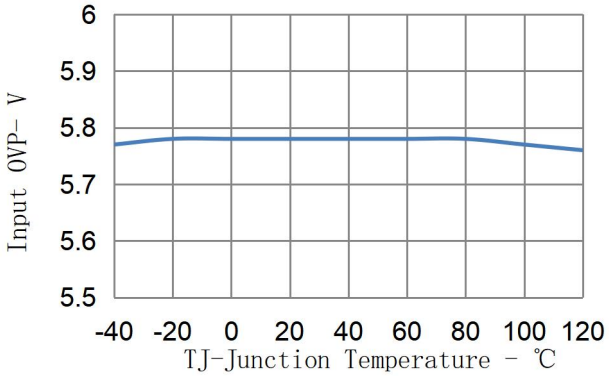


Figure 3 Input Over Voltage Protection VS. Temperature

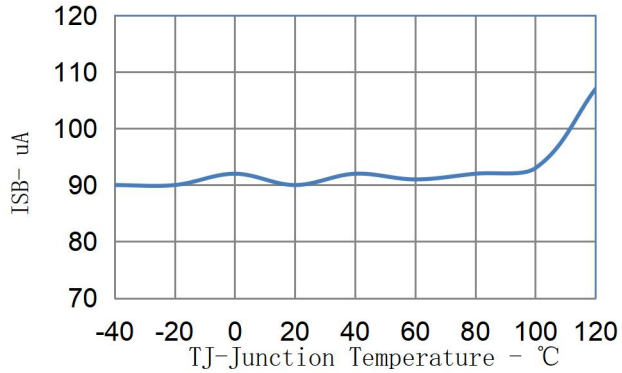


Figure 4 Standby Current (VIN=5V) VS. Temperature

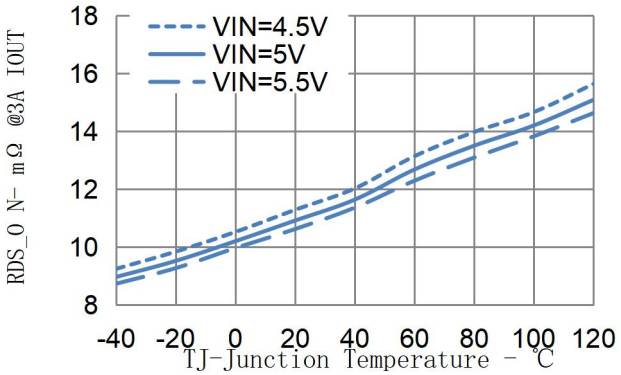


Figure 5 ON–Resistance VS. Temperature

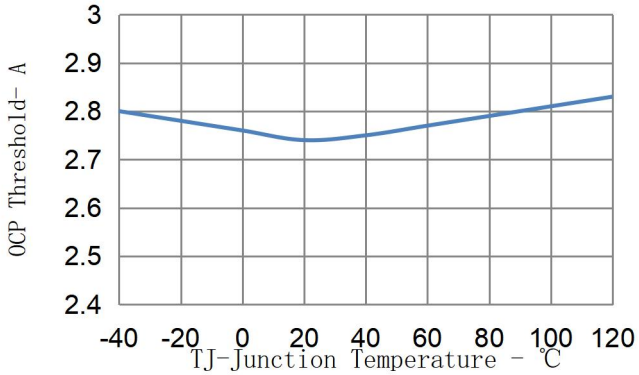


Figure 6 Over Current Protection (OCP) Threshold
($R_{IST}$=150K) VS. Temperature

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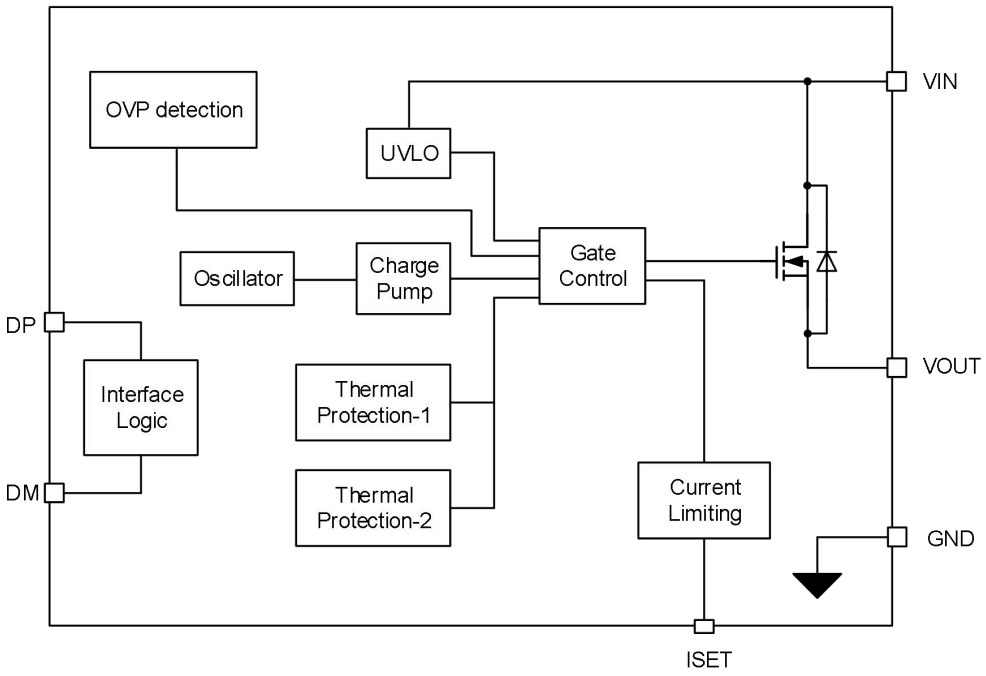
## 8 Functional Block Diagram

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# 9 Function Description

## 9.1 Under Voltage Lock-Out Protection

The SC7002 provides Under Voltage Lock Out (UVLO) protection. When the input voltage is below the UVLO threshold, the switch is turned off. Once VIN is above the UVLO threshold, the IC is enabled and it turns on the power switch after a 6ms delay time. Built-in hysteresis for UVLO threshold is implemented to prevent unwanted shutdown due to the input voltage variation caused by load transient.

## 9.2 Enable and Disable

The SC7002 is enabled automatically once the input voltage is above the UVLO threshold. With VIN power on, these parts can't be disabled.

## 9.3 Internal soft-start

The SC7002 provides a built-in soft-start function. After enabled, it turns on the switch slowly (in 1 ~ 2ms) to limit the inrush current and voltage surges.

## 9.4 Constant Current Mode

The SC7002 provides a constant current function that can be programmable through an external resistor at the ISET pin. Once the device detects the current reaches the current limit value, it works in constant current mode: it controls the gate driver voltage of the power switch so to regulate the current of the switch at the set value. The current limit value can be calculated by the below equation:

$$ICC_LIM = \frac{VREF}{RISET} \times k$$

where ICC_LIM is the target current limit

VREF = internal reference voltage, 1.2V typically

RISET = ISET resistor value

k = 338,000 typically

For example, if a 150k resistor is connected to the ISET pin, the $I_{CC_LIM}$ is 2.7A.

When the IC works in constant current mode, the output voltage will be pulled down by the load current. If the output voltage still keeps higher than 3.8V at this mode, the SC7002 keeps limiting the current at the set value until the overload condition is removed or the IC begins thermal shutdown cycling. If the IC detects the output voltage drops below 3.8V, it starts short circuit protection (SCP).

## 9.5 Short Circuit Protection

When the IC detects the output voltage drops below 3.8V, the SC7002 enters into short circuit hiccup mode. The SC7002 stays in hiccup mode until the overload or short circuit fault is removed.

Through the power cycling in hiccup mode, the average output current under short circuit conditions can be significantly reduced to relieve the thermal stress on the chip.

The parasitic inductance at power leads and PCB traces may cause high voltage spikes between VIN and VOUT pin when the Power FET turn-off rapidly. This may happen during VOUT short to ground, over current, and fast load release from a heavy load. These voltage spikes with current may exceed the SOA area and damage the device. To decrease the parasitic inductance and improve the robustness, multi-layer ceramic capacitors (MLCC) are highly recommended and applied to the VIN and VOUT pin. Place at least a 4.7μF 0805 size MLCC close to the VIN and GND pin and a 10μF 0805 size MLCC close to the VOUT and GND pin. If a 0603 size MLCC is applied, a higher capacitance with enough effective value is recommended due to the derating effect of MLCC.

## 9.6 Thermal Shutdown Cycling

The SC7002 provides two independent thermal sensing blocks that monitor the junction temperature in constant current mode and load switch mode.

When the SC7002 works in constant current mode, the IC keeps the switch on if the output voltage stays above 3.8V. In this case, there is a large voltage drop across the power switch, leading to high thermal dissipation. Once the SC7002 detects the junction temperature rises above 140°C, it turns off the switch; after it detects the temperature falls below 115°C, it turns on the switch again with the soft-start process.

When the SC7002 works in load switch mode, the IC turn on the switch fully, and the output voltage is almost equal to the input put voltage with dozens of millivolt drop caused by the $R_{DSON}$. Once the SC7002 detects the junction temperature rises above 150°C, it turns off the switch; after it detects the temperature falls below 125°C, it turns on the switch again with the soft-start process.

## 9.7 Charging Port Controller

The SC7002 integrates a USB type-A port dedicated charging port controller. It can detect the type of the

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attached phone, and automatically support the below common charging protocols:

1. USB battery charging specification, revision 1.2 (BC1.2)

2. Chinese Telecommunication Industry Standard YD/T 1591-2009

3. The divider mode for Apple device (DP = 2.7V, DM = 2.7V)

4. The 1.2V/1.2V Mode for Samsung device

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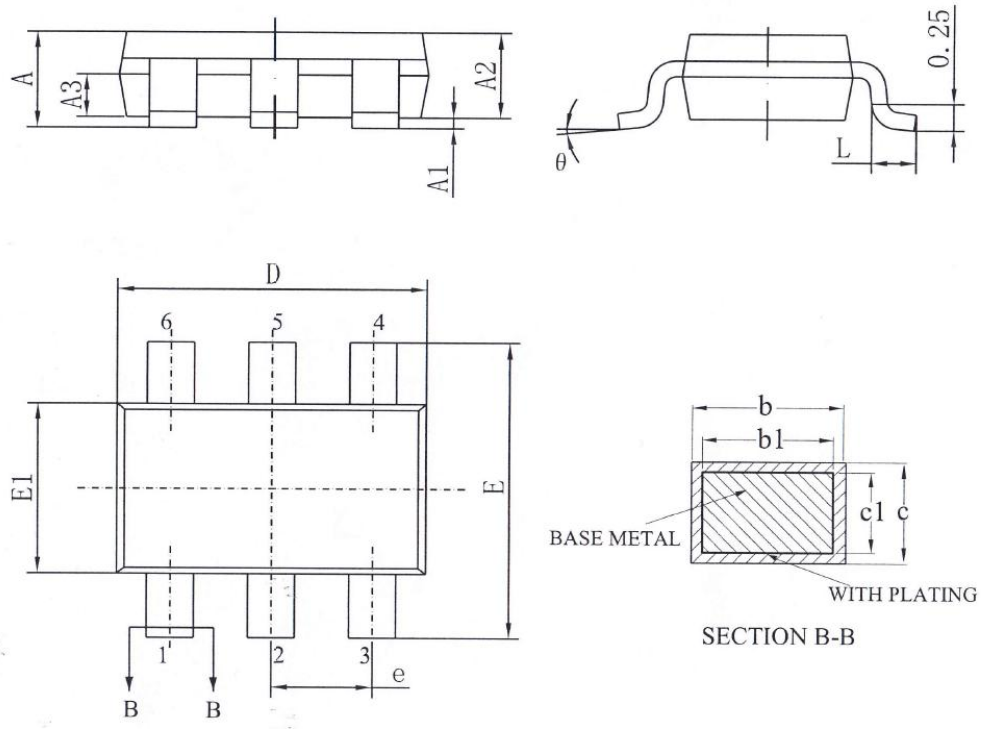
## PACKAGE

TSOT23-6




| SYMBOL | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | — | — | 0.95 |
| A1 | 0 | — | 0.10 |
| A2 | 0.75 | 0.80 | 0.85 |
| A3 | 0.35 | 0.40 | 0.45 |
| b | 0.30 | 0.44 | 0.50 |
| b1 | 0.30 | 0.40 | 0.45 |
| c | 0.11 | 0.16 | 0.20 |
| c1 | 0.11 | 0.13 | 0.15 |
| D | 2.70 | 2.90 | 3.10 |
| E | 2.60 | 2.80 | 3.00 |
| E1 | 1.50 | 1.60 | 1.70 |
| e | 0.95BSC | | |
| L | 0.30 | 0.40 | 0.50 |
| θ | 0 | — | 8° |

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