12 mΩ Power Switch with Curernt Limit and Charging Port Controller

1 DESCRIPTION

The SC7005 is a power switch which integrates an ultra-low Rdson (12mΩ) N-channel MOSFET. It is designed for USB port applications or other applications which require high current switch. It provides current limit function, and the current limit can be programmable through an external resistor. The SC7005 also integrates USB Type-C Downstream Facing Port (DFP) controller function. It can support the type-C USB port with Channel Configuration (CC) signals. It can detect the attachment/detachment of the sink device, and control the on/off of the switch automatically.

The SC7005 also supports various protections, including over voltage protection, under voltage protection, short circuit protection, and thermal shutdown protection.

The SC7005 requires a minimum number of external components to complete USB switch and charging port solution. It is available in TSOT23-8 package.

2 FEATURES

- 12mΩ Ultra-low Rdson NMOS Switch
- Programmable Current Limit
- ± 5% Current Limit Accuracy at typical application
- Built-in Soft-Start
- Ultra-low Operation Current
- Status Indication
  - ✓ Device Removal Indication
  - ✓ Short Circuit Fault Indication
- USB Type-C Downstream Facing Port (DFP/Source) Controller Function
- 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
- TSOT23-8 package

3 APPLICATIONS

- USB chargers
- Type-C charger
- USB HUB
- USB power supplies
- USB peripherals

4 ORDERING INFORMATION

Part Number	Package	Dimension
SC7005SAER	TSOT23-8	2.92*2.8*0.95 mm

5 Typical Application Circuit

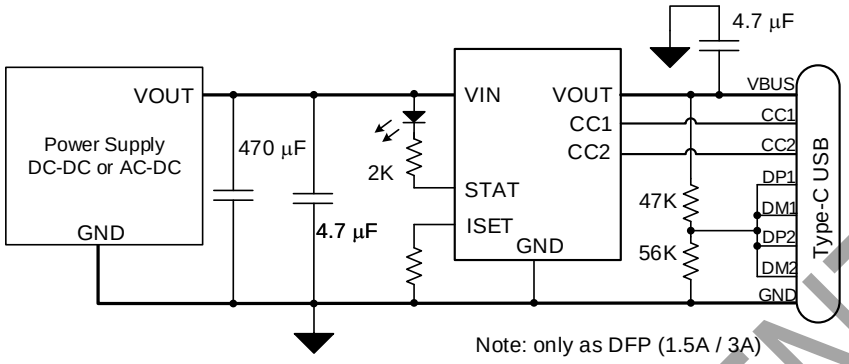


Figure 1 SC7005 typical application circuit

6 Pin Configurations and Functions

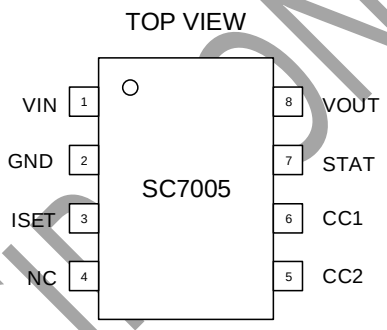


Table 1 Pin description

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	NC	-	Not connected
5	CC2	IO	Channel Configuration 2 line for Type C USB port interface
6	CC1	IO	Channel Configuration 1 line for Type C USB port interface
7	STAT	O	Open drain output. Connect an LED from VIN pin to STAT pin for status indication. It is internally pulled low to indicate the port is active.
8	VOUT	O	Output of the switch

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, STAT	-0.3	7	V
	CC1, CC2	-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 CC1 / CC2	-4	4	kV
		CC1 / CC2	-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

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	80	145	180	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 = 3A		1.5		ms
CURRENT LIMIT						
V_{REF}	Reference voltage		1.176	1.2	1.224	V
I_{LIM}	Current limit accuarcy	R_{ISET} = 120 KΩ	3.42	3.5	3.69	A
I_{LIM_CC}	1.5A/3A level detection threshold	Rising	2.2	2.5	2.8	A
		Hysteresis	0.16	0.22	0.28	A
STATUS INDICATION						
I_{STAT}	STAT pin sink current	VSTAT = 0.4 V	3	4	5	mA
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
CC LOGIC						
$VCC_{TH=0.4}$	CC1/2 0.4V comparison threshold		0.35	0.4	0.45	V
$VCC_{TH=0.8}$	CC1/2 0.4V comparison threshold		0.75	0.8	0.85	V
$VCC_{TH=1.6}$	CC1/2 1.6V comparison threshold		1.5	1.6	1.65	V
$VCC_{TH=2.6}$	CC1/2 2.6V comparison threshold		2.45	2.6	2.75	V

Electrical Characteristics (Continued)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{CC1/2\_180uA}$	CC1/2 pull up current	$I_{LIM-SET} < I_{LIM\_CC}$ $VCC_{TH=0.4} < VCC1/2 < VCC_{TH=1.6}$	165.6	180	194.4	μA
$I_{CC1/2\_330uA}$	CC1/2 pull up current	$I_{LIM-SET} > I_{LIM\_CC}$, $VCC_{TH=0.8} < VCC1/2 < VCC_{TH=2.6}$	303.6	330	356.4	μA
T_{CC_DEB}	CC debounce time		100	150	200	ms
T_{PD_DEB}	PD debounce time		10	15	20	ms

7.5 Typical Characteristics

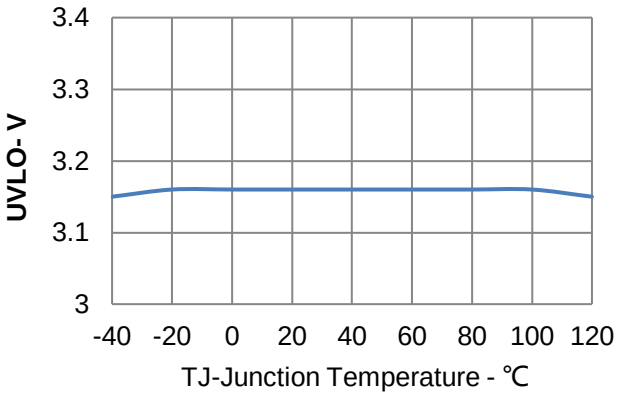


Figure 2 Under Voltage Lock Output VS. Temperature

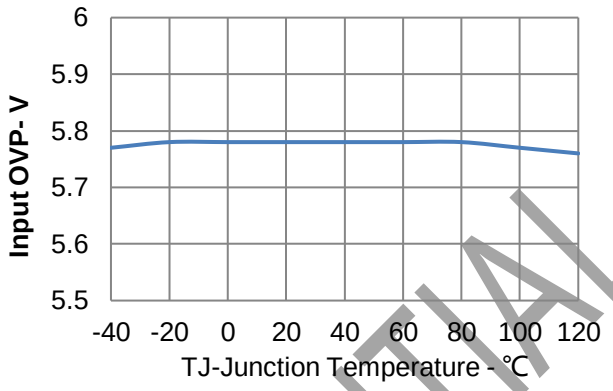


Figure 3 Input Over Voltage Protection VS. Temperature

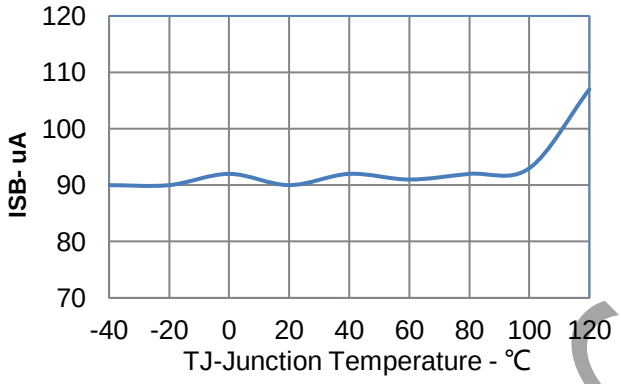


Figure 4 Standby Current (VIN=5V) VS. Temperature

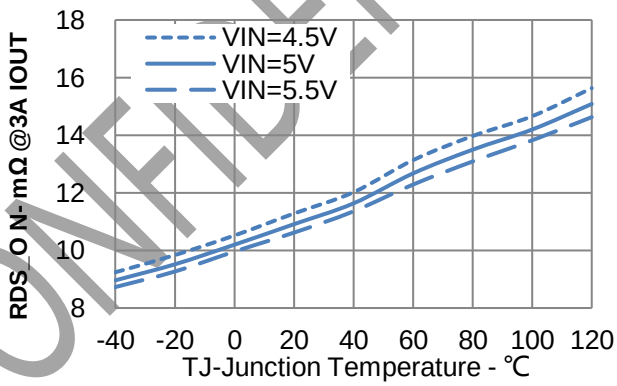


Figure 5 ON–Resistance VS. Temperature

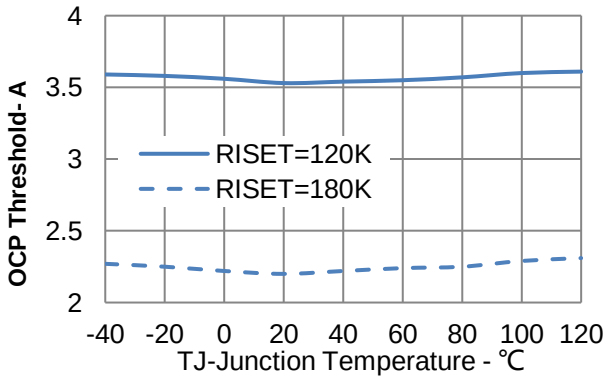
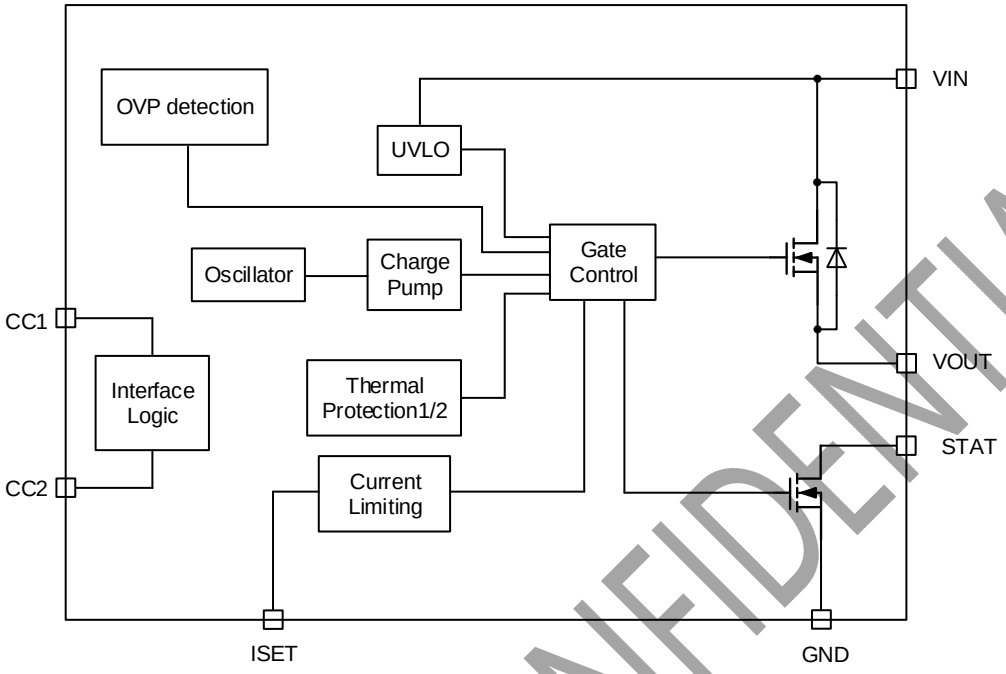


Figure 6 Over Current Protection (OCP) Threshold VS. Temperature

8 Functional Block Diagram



9 Function Description

9.1 Under Voltage Lock Out Protection

The SC7005 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 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 SC7005 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 SC7005 provides 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 SC7005 provides a constant current function which can be programmable through an external resistor at 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 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 = 350,000 typically

For example, if a 120k resistor is connected at the ISET pin, the I_{CC_LIM} is 3.5A.

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 SC7005 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 SC7005 enters into short circuit hiccup mode. The SC7005 stays in hiccup mode until the over load or short circuit fault is removed.

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

9.6 Thermal Shutdown Cycling

The SC7005 provides two independent thermal sensing blocks that monitor the junction temperature in constant current mode and load switch mode.

When the SC7005 works in constant current mode, the IC keeps the switch on if the output voltage stays above 3.8V. In the case, there is a large voltage drop across the power switch, leading to high thermal dissipation. Once the SC7005 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 SC7005 works in load switch mode, the IC turn on the switch fully, the output voltage is almost equal to the input put voltage with dozens of millivolt drop which caused by the R_{DSON}. Once the SC7005 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 Status Indicator

The SC7005 features status indication at STAT pin. STAT pin is an open drain output, so can be connected with a pull up resistor and LED diode to VIN. The STAT pin is pulled low by the IC when the output is active.

9.8 Type C Controller

The SC7005 integrates a USB Type-C Downstream Facing Port (DFP) controller. It acts as a DFP/Source device, and monitors the Type-C Configuration Channel (CC) lines to determine when an USB device is attached. If an Upstream Facing Port (UFP) or Sink device is attached, the SC7005 turns on the power switch automatically with soft-start so to apply power to VOUT. Then it advertises its current source capability through CC line.

The SC7005 can support 1.5A and 3A Type-C current advertisements. The current capability is determined by

ISET pin. If the IC detects the ISET current is set ≥ 3A, it advertises 3A level to UFP; if it detects the ISET current is lower than 2.2A, it advertises 1.5A. The real current limit value is still set by the ISET resistor.

For example, if a 120kΩ resistor is connected at ISET pin, the SC7005 detects the ISET current is 3.5A, so it will advertise 3A level to UFP, and it limits the current at 3.5A; if a 220kΩ resistor is applied, the SC7005 detects the ISET current is 1.8A, so it advertises 1.5A level, and limits the current at 1.8A.

In order to avoid that the output current can't satisfy the UFP device, it is required to set the current limit value higher than the advertisement value. Below setting is highly recommended.

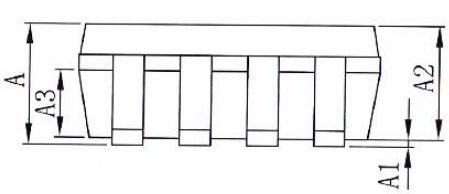
Table 2 ISET Setting for Type-C Advertisement

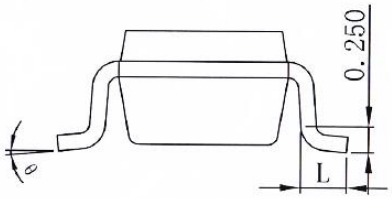
Advertisement	ISET Current	RISET Value
1.5A level	1.8A	220kΩ
3A level	3.5A	120kΩ

If the ISET is set within 2.2A ~ 3A, it may cause wrong advertisement, so user should avoid 2.2A~3A setting.

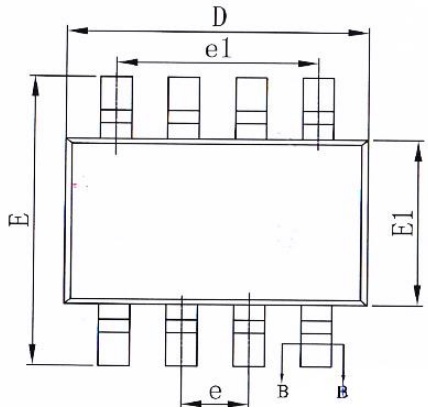
PACKAGE

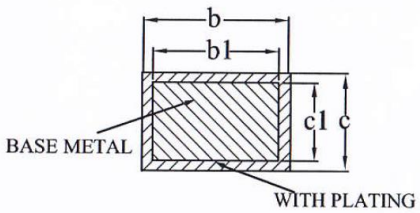
TSOT23-8





SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	0.95
A1	0.00	—	0.10
A2	0.75	0.80	0.85
A3	0.35	0.40	0.45
b	0.28	—	0.38
b1	0.27	0.30	0.33
c	0.11	—	0.21
c1	0.11	0.13	0.15
D	2.82	2.92	3.02
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
e	0.65BSC		
e1	1.95BSC		
L	0.30	—	0.60
θ	0	—	8°





SECTION B-B