Single Cell Li-ion/Polymer Battery Protection IC

PT6001 GENERAL DESCRIPTION

The PT6001 battery protection IC is designed for protecting single cell lithium-ion/polymer battery from being damaged or overall lifetime degrading due to over-charge, over-discharge, and/or over-current condition. The ultra-small package and minimum required external components make it easy to integrate PT6001 into the limited space available of any battery pack. The accurate ±20mV overcharging detection voltage ensures safe and full battery capacity charging. The extremely low power-down quiescent current resulted in the device only drains insignificant current from the cell in storage stage.

With auto recovery function, the device is more users friendly to applications that encounters fault conditions in common.

PT6001 APPLICATIONS

- Lithium-ion rechargeable battery packs
- Lithium-ion Polymer rechargeable battery packs

PT6001 FEATURES

- High-precision Battery Voltage Detection:
  - Overcharge Detection Voltage:
    V_{OCP} = 3.650 ~ 4.475V, Accuracy: ±20mV
  - Overcharge Release Voltage:
    ΔV_{OCR} = 0.05 ~ 0.25V
  - Over-discharge Detection Voltage:
    V_{ODP} = 2.1 ~ 3.3V, Accuracy: ±80mV
  - Over-discharge Release Voltage:
    ΔV_{ODR} = 0 ~ 0.5V
  - Discharge Overcurrent Detection Voltage:
    V_{ODIP} = 0.05 ~ 0.25V, Accuracy: ±10mV
  - Charge Overcurrent Detection Voltage:
    V_{OCIP} = -0.05 ~ -0.25V, Accuracy: ±20mV
  - Load Short-circuiting Detection Voltage:
    V_{ODIP} = 0.25~0.60V, Accuracy: ±100mV
- High-withstanding-voltage device is used for charger connection pins: 28V
- 0V battery charging function or 0V battery charge inhibiting function
- Sleep mode enable or disable
- Low current consumption
  - Operation mode: 3.5μA (typ.), 6μA (max.)
  - Power-down mode: 0.5μA (max.)
- Wide operating temperature range
- Auto recovery function
- Small package: SOT23-6

PT6001 TYPICAL APPLICATIONS

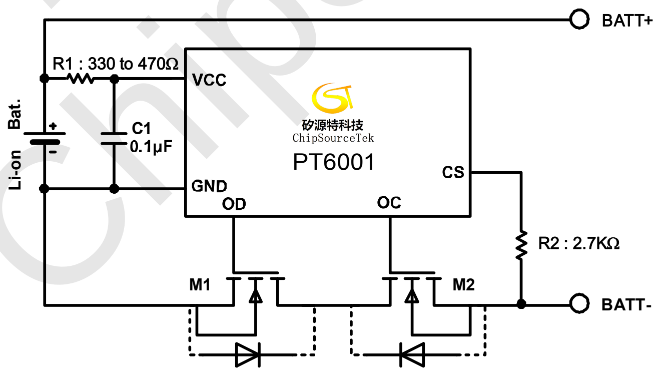

Figure1. PT6001 Typical Application Circuit

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PT6001 ORDER INFORMATION

PACKAGE	TEMPERATURE RANGE	ORDERING PART NUMBER	TRANSPORT MEDIA	MARKING
SOT23-6	-40℃~85℃	PT6001E23F-XX	Tape and Reel 3000 units	6AXX

Note1: XX is showed for optional parameter as table1.

Part Number	[V_{OCP}] (V)	[V_{OCR}] (V)	[V_{ODP}] (V)	[V_{ODR}] (V)	[V_{ODIP}] (mV)	[V_{SCP}] (mV)	[V_{OCIP}] (mV)	[T_{OCP}] (s)	[T_{ODP}] (ms)	[T_{ODIP}] (ms)	[T_{SCP}] (μs)	[T_{OCIP}] (ms)
PT6001E23F-AD	4.280	4.080	3.000	3.000	80	500	−100	1.000	128	8	280	8
PT6001E23F-CA	4.300	4.100	2.400	2.500	250	500	−250	1.000	128	8	280	8
PT6001E23F-CB	4.175	4.000	2.800	3.000	150	500	−150	1.000	128	8	280	8

Part Number	0V Battery Charge Function	Sleep Mode	ODIP Release Condition	ODIP Release Voltage
PT6001E23F-AD	Available	Yes	Load Removed	V_{ODIP}
PT6001E23F-CA	Available	Yes	Load Removed	V_{ODIP}
PT6001E23F-CB	Available	Yes	Load Removed	V_{ODIP}

Table.1 Ordering Part Number's Optional Parameter (待定)

Note2: Please contact our sales office for the products with detection voltage value other than those specified above.

Note3: **** is refer to package information.

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PT6001 PIN ASSIGNMENT

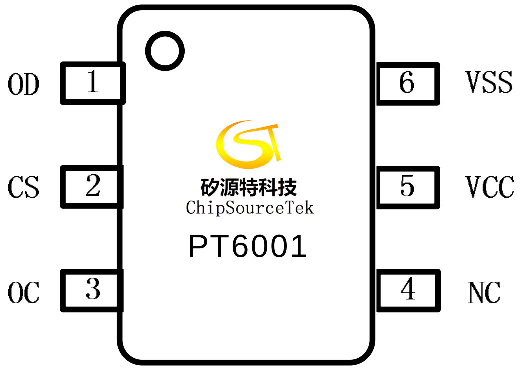

Figure2. PT6001 Pin Configuration of Package

PT6001 PIN DESCRIPTIONS

PIN NUM SOT23-6	PIN NAME	DESCRIPTIONS
1	OD	Output of over-discharge detection
2	CS	Pin for charge negative input
3	OC	Output of over-charge detection
4	NC	No Connection
5	VCC	Power supply
6	VSS	Ground

PT6001 ABSOLUTE MAXIMUM RATINGS (NOTE4)

SYMBOL	ITEM	Value			UNIT
		Min.	Typ.	Max.	
V_{CC}	Input voltage between VCC and GND	V_{GND} - 0.3		V_{GND} + 12	V
V_{CS}	CS Input voltage	V_{CC} - 28		V_{CC} + 0.3	V
V_{OC}	OC pin	V_{CS} - 0.3		V_{CC} + 0.3	V
V_{OD}	OD pin	V_{GND} - 0.3		V_{CC} + 0.3	V
P_D	Power dissipation (SOT23-5)		0.25		W
T_{OPT}	Operating temperature	-40		85	˚C
T_{STG}	Storage temperature	-55		150	˚C

Note4: Exceeding these ratings may damage the device

PT6001 RECOMMENDED OPERATING RANGE

SYMBOL	PARAMETER	VALUE			UNIT
		Min.	Typ.	Max.	
V_{CC}	Supply Voltage	2.0	3.7	5.0	V

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PT6001 ELECTRICAL CHARACTERISTICS

V_{CC} = 4.2V, T_a = 25°C unless otherwise specified

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit	TC1	TC2
V_{CC}	Operating input voltage	Voltage between VCC and GND	1.5		6.0	V		
		Voltage between VCC and CS	1.5		28			
V_{0CHA}	0 V battery starting charger voltage	0 V battery charging function	0	0.7	1.5	V	11	2
V_{0INH}	0 V battery stopping charger voltage	0 V battery charge inhibiting function	0.9	1.2	1.5	V	11	2
I_{DD}	Supply current	V_{CC}=3.9V, V_{CS}=0V		1.5	4.0	μA	5	2
I_{SLP}	Sleep current	V_{CC}=2.0V, V_{CS}=V_{CC}		0.2	0.5	μA	5	2
V_{OCP}	Over-charge threshold	Detect rising edge of supply voltage	V_{OCP} -20mV	V_{OCP}	V_{OCP} +20mV	V	1	1
V_{OCR}	Over-charge release threshold	V_{CS}=0V	V_{OCR} -50mV	V_{OCR}	V_{OCR} +50mV	V	1	1
T_{OCP}	Delay of over charge	V_{CC}=3.6V to 5.5V	0.7T_{OCP}	T_{OCP}	1.3T_{OCP}	s	9	5
T_{OCR}	Delay of over charge release	V_{CC}=5.5V to 3.6V		2.0		ms	9	5
V_{ODP}	Over-discharge threshold	Detect falling edge of supply voltage	V_{ODP} -80mV	V_{ODP}	V_{ODP} +80mV	V	2	2
V_{ODR}	Over-discharge threshold	V_{CS}=0V	V_{ODR} -100mV	V_{ODR}	V_{ODR} +100mV	V	2	2
T_{ODP}	Delay of over-discharge	V_{CC}=3.6V to 2.0V	0.7T_{ODP}	T_{ODP}	1.3T_{ODP}	ms	9	5
T_{ODR}	Delay of over-discharge release	V_{CC}=2.0V to 3.6V		2.0		ms	9	5
T_{SLP}	Delay of sleep mode enter	V_{CC}=2.0V, V_{CS}= V_{CC}		16		s	9	5
V_{ODIP}	Excess current threshold	Detect rising edge of CS pin voltage	V_{ODIP} -10mV	V_{ODIP}	V_{ODIP} +10mV	V	3	2
V_{ODIR}	Excess current release threshold		V_{CC} -1.2V	V_{CC} -0.8V	V_{CC} -0.5V	V	3	2
T_{ODIP}	Delay of excess current	V_{CC}=3.6V	0.7T_{ODIP}	T_{ODIP}	1.3T_{ODIP}	ms	10	5
T_{ODIR}	Delay of excess current release	V_{CC}=3.6V		2.0		ms	10	5
V_{OCIP}	Excess charging current threshold	Detect falling edge of CS pin voltage	V_{ODIP} -20mV	V_{ODIP}	V_{ODIP} +20mV	V	4	2
T_{OCIP}	Delay of excess charging current	V_{CC}=3.6V	0.7T_{OCIP}	T_{OCIP}	1.3T_{OCIP}	ms	10	5
T_{OCIR}	Delay of excess charging current release	V_{CC}=3.6V		2.0		ms	10	5
V_{SCP}	Short current threshold	V_{CC}=3.6V	V_{SCP} -100mV	V_{SCP}	V_{SCP} +100mV	V	3	2
T_{SCP}	Delay of short current	V_{CC}=3.6V	0.7T_{SP}	T_{SCP}	1.3T_{SCP}	μs	10	5
T_{SCR}	Delay of short current release	V_{CC}=3.6V		2.0		ms	10	5
V_{OL1}	Low voltage of OC	V_{CC}= V_{OCP} +0.1		0.35	0.50	V		
V_{OH1}	High voltage of OC	I_{OL}=50μA, V_{CC}=3.9V	3.4	3.7		V		
V_{OL2}	Low voltage of OD	I_{OL}=-50μA, V_{CC}=2V		0.2	0.5	V		
V_{OH2}	High voltage of OD	I_{OL}=50μA, V_{CC}=3.9V	3.4	3.7		V		
R_{OCH}	OC pin resistance “H”	V_{CC}=3.9V, V_{CS}=0V, V_{OC}=3.4V	5	10	20	kΩ	7	4

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R_{OCL}	OC pin resistance "L"	V_{CC}=4.6V, V_{CS}=0V, V_{OC}=0.5V	5	10	20	kΩ	7	4
R_{ODH}	OD pin resistance "H"	V_{CC}=3.9V, V_{CS}=0V, V_{OD}=3.4V	5	10	20	kΩ	8	4
R_{ODL}	OD pin resistance "L"	V_{CC}=V_{CS}=2.0V, V_{OD}=0.5V	5	10	20	kΩ	8	4
R_{CSC}	Resistance between CS pin and VCC pin	V_{CC}=2.0V, V_{CS}=0V	750	1500	3000	kΩ	6	3
R_{CSG}	Resistance between CS pin and GND pin	V_{CC}=3.6V, V_{CS}=1.0V	10	20	30	kΩ	6	3
V_{CHGIN}	Charger detection voltage	V_{CC}=2.0V, fall CS voltage until chip was waken up		0.7		V		

Note1. $V_{OCR} = V_{OCP} + \Delta V_{OCR}$

Note2. $V_{ODR} = V_{ODP} + \Delta V_{ODR}$

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PT6001 ELECTRICAL CHARACTERISTICS

V_{CC} = 4.2V, T_a = -20 to 70°C unless otherwise specified (PT6001: -40 to 85°C)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit	TC1	TC2
V_{CC}	Operating input voltage	Voltage between VCC and GND	1.5		6.0	V		
		Voltage between VCC and CS	1.5		28			
V_{0CHA}	0 V battery starting charger voltage	0 V battery charging function	0	0.7	1.7	V	11	2
V_{0INH}	0 V battery stopping charger voltage	0 V battery charge inhibiting function	0.7	1.2	1.7	V	11	2
I_{DD}	Supply current	V_{CC}=3.9V, V_{CS}=0V		1.5	5.0	μA	5	2
I_{SLP}	Sleep current	V_{CC}=2.0V, V_{CS}=V_{CC}		0.2	1.0	μA	5	2
V_{OCP}	Over-charge threshold	Detect rising edge of supply voltage	V_{OCP} -50mV	V_{OCP}	V_{OCP} +50mV	V	1	1
V_{OCR}	Over-charge release threshold	V_{CS}=0V	V_{OCR} -80mV	V_{OCR}	V_{OCR} +80mV	V	1	1
T_{OCP}	Delay of over charge	V_{CC}=3.6V to 5.5V	0.5T_{OCP}	T_{OCP}	2.5T_{OCP}	s	9	5
V_{ODP}	Over-discharge threshold	Detect falling edge of supply voltage	V_{ODP} -100mV	V_{ODP}	V_{ODP} +100mV	V	2	2
V_{ODR}	Over-discharge threshold	V_{CS}=0V	V_{ODR} -120mV	V_{ODR}	V_{ODR} +120mV	V	2	2
T_{ODP}	Delay of over-discharge	V_{CC}=3.6V to 2.0V	0.5T_{ODP}	T_{ODP}	2.5T_{ODP}	ms	9	5
V_{ODIP}	Excess current threshold	Detect rising edge of CS pin voltage	V_{ODIP} -10mV	V_{ODIP}	V_{ODIP} +10mV	V	3	2
V_{ODIR}	Excess current release threshold		V_{CC} -1.4V	V_{CC} -0.8V	V_{CC} -0.3V	V	3	2
T_{ODIP}	Delay of excess current	V_{CC}=3.6V	0.5T_{ODIP}	T_{ODIP}	2.5T_{ODIP}	ms	10	5
V_{OCIP}	Excess charging current threshold	Detect falling edge of CS pin voltage	V_{ODIP} -20mV	V_{ODIP}	V_{ODIP} +20mV	V	4	2
T_{OCIP}	Delay of excess charging current	V_{CC}=3.6V	0.5T_{OCIP}	T_{OCIP}	2.5T_{OCIP}	ms	10	5
V_{SCP}	Short current threshold	V_{CC}=3.6V	V_{SCP} -100mV	V_{SCP}	V_{SCP} +100mV	V	3	2
T_{SCP}	Delay of short current	V_{CC}=3.6V	0.5T_{SP}	T_{SCP}	2.5T_{SCP}	μs	10	5
R_{OCH}	OC pin resistance "H"	V_{CC}=3.9V, V_{CS}=0V, V_{OC}=3.4V	2.5	10	30	kΩ	7	4
R_{OCL}	OC pin resistance "L"	V_{CC}=4.6V, V_{CS}=0V, V_{OC}=0.5V	2.5	10	30	kΩ	7	4
R_{ODH}	OD pin resistance "H"	V_{CC}=3.9V, V_{CS}=0V, V_{OD}=3.4V	2.5	10	30	kΩ	8	4
R_{ODL}	OD pin resistance "L"	V_{CC}=V_{CS}=2.0V, V_{OD}=0.5V	2.5	10	30	kΩ	8	4
R_{CSC}	Resistance between CS pin and VCC pin	V_{CC}=2.0V, V_{CS}=0V	500	1500	6000	kΩ	6	3
R_{CSG}	Resistance between CS pin and GND pin	V_{CC}=3.6V, V_{CS}=1.0V	7.5	20	40	kΩ	6	3

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PT6001 SIMPLIFIED BLOCK DIAGRAM

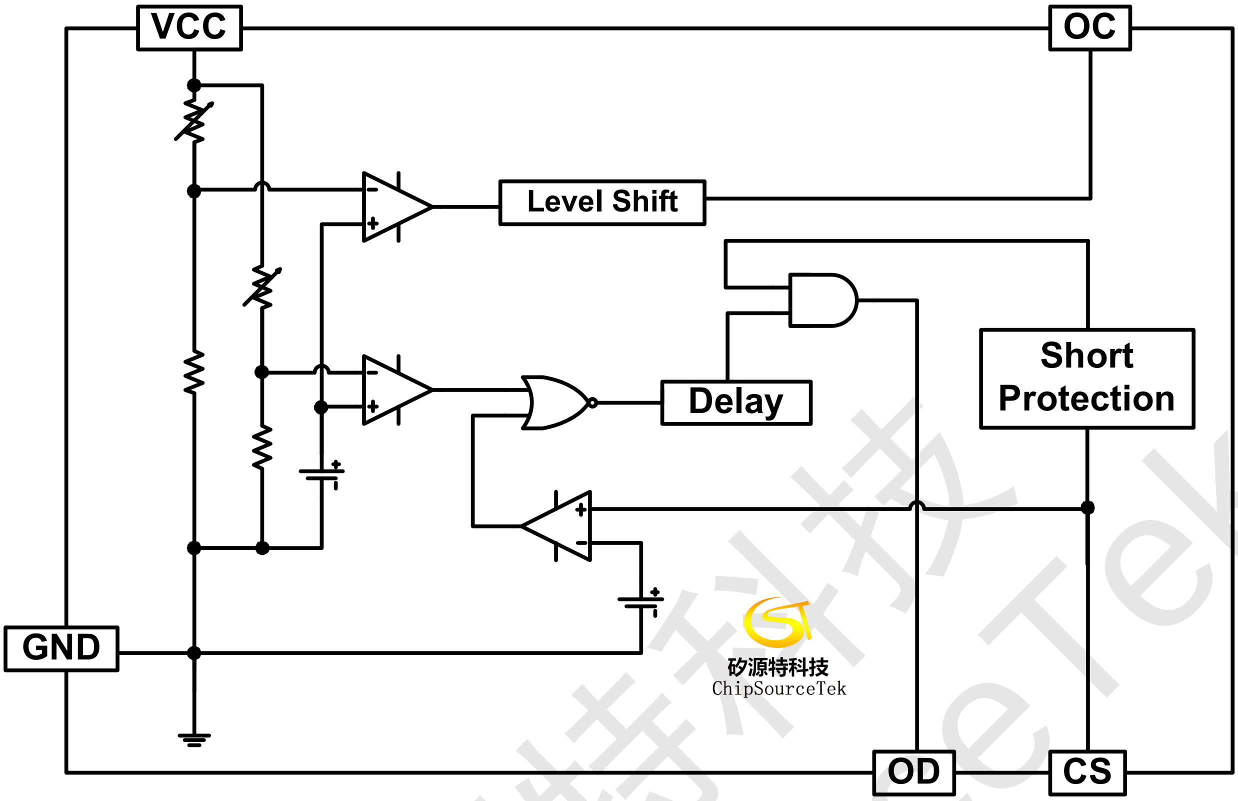

Figure3. PT6001 Simplified Block Diagram

PT6001 Test Description

Caution: Unless otherwise specified, the output voltage levels "H" and "L" at OC pin (V_{OC}) and OD pin (V_{OD}) are judged by the threshold voltage (1.0 V) of the N-channel MOSFET. Judge the OC pin level with respect to V_{CS} and the OD pin level with respect to GND.

1) **Overcharge Detection Voltage, Overcharge Release Voltage**
(Test Condition 1, Test Circuit 1)

Overcharge detection voltage (V_{OCP}) is defined as the voltage between the VCC pin and GND pin at which V_{OC} goes from "H" to "L" when the voltage V_1 is gradually increased from the starting condition of V_1 = 3.6 V. Overcharge release voltage (V_{OCR}) is defined as the voltage between the VCC pin and GND pin at which V_{OC} goes from "L" to "H" when the voltage V_1 is then gradually decreased. Overcharge hysteresis voltage (V_{HC}) is defined as the difference between overcharge detection voltage (V_{OCP}) and overcharge release voltage (V_{OCR}).

2) **Over-discharge Detection Voltage, Over-discharge Release Voltage**
(Test Condition 2, Test Circuit 2)

Over-discharge detection voltage (V_{ODP}) is defined as the voltage between the VCC pin and GND pin at which VOD goes from "H" to "L" when the voltage V_1 is gradually decreased from the starting condition of V_1 = 3.6 V, V_2 = 0 V. Over-discharge release voltage (V_{ODR}) is defined as the voltage between the VCC pin and GND pin at which V_{OD} goes from "L" to "H" when the voltage V_1 is then gradually increased. Over-discharge hysteresis voltage (V_{HD}) is defined as the difference between over-discharge release voltage (V_{ODP}) and over-discharge detection voltage (V_{ODR}).

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3) Discharge Overcurrent Detection Voltage

(Test Condition 3, Test Circuit 2)

Discharge overcurrent detection voltage (V_{ODIP}) is defined as the voltage between the CS pin and GND pin whose delay time for changing V_{OD} from "H" to "L" lies between the minimum and the maximum value of discharge overcurrent delay time when the voltage V_2 is increased rapidly (within 10 μs) from the starting condition of V_1 = 3.6 V, V_2 = 0 V.

4) Load Short-circuiting Detection Voltage

(Test Condition 3, Test Circuit 2)

Load short-circuiting detection voltage (V_{SHORT}) is defined as the voltage between the CS pin and GND pin whose delay time for changing V_{OD} from "H" to "L" lies between the minimum and the maximum value of load short-circuiting delay time when the voltage V_2 is increased rapidly (within 10 μs) from the starting condition of V_1 = 3.6 V, V_2 = 0 V.

5) Charge Overcurrent Detection Voltage

(Test Condition 4, Test Circuit 2)

Charge overcurrent detection voltage (V_{OCIP}) is defined as the voltage between the CS pin and GND pin whose delay time for changing V_{OC} from "H" to "L" lies between the minimum and the maximum value of charge overcurrent delay time when the voltage V_2 is decreased rapidly (within 10 μs) from the starting condition of V_1 = 3.6 V, V_2 = 0 V.

6) Operating Current Consumption

(Test Condition 5, Test Circuit 2)

The operating current consumption (I_{DD}) is the current that flows through the VCC pin under the set conditions of V_1 = 3.6 V and V_2 = 0 V (normal status).

7) Power-down Current Consumption

(Test Condition 5, Test Circuit 2)

The power-down current consumption ($I_{standby}$) is the current that flows through the VCC pin under the set condition of V_1 = V_2 = 2.0 V (over-discharge status).

8) Resistance between CS Pin and VCC Pin

(Test Condition 6, Test Circuit 3)

The resistance between CS pin and VCC pin (R_{CSC}) is the resistance between CS pin and VCC pin under the set conditions of V_1 = 2.0 V, V_2 = 0 V.

9) Resistance between CS Pin and GND Pin

(Test Condition 6, Test Circuit 3)

The resistance between CS pin and GND pin (R_{CSG}) is the resistance between CS pin and GND pin under the set conditions of V_1 = 3.6 V, V_2 = 1.0 V.

10) OC Pin Resistance "H"

(Test Condition 7, Test Circuit 4)

The OC pin resistance "H" (R_{OCH}) is the resistance at the OC pin under the set conditions of V_1 = 3.9 V, V_2 = 0 V, V_3 = 3.4 V.

11) OC Pin Resistance "L"

(Test Condition 7, Test Circuit 4)

The OC pin resistance "L" (R_{OCL}) is the resistance at the OC pin under the set conditions of V_1 = 4.6 V, V_2 = 0 V, V_3 =

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0.5 V.

12) OD Pin Resistance "H"

(Test Condition 8, Test Circuit 4)

The OD pin H resistance (R_{ODH}) is the resistance at the OD pin under the set conditions of V_1 = 3.9 V, V_2 = 0 V, V_4 = 3.4 V.

13) OD Pin Resistance "L"

(Test Condition 8, Test Circuit 4)

The OD pin L resistance (R_{ODL}) is the resistance at the OD pin under the set conditions of V_1 = 2.0 V, V_2 = 2.0 V, V_4 = 0.5 V.

14) Overcharge Detection Delay Time

(Test Condition 9, Test Circuit 5)

The overcharge detection delay time (T_{OC}) is the time needed for V_{OC} to change from "H" to "L" just after the voltage V_1 momentarily increases (within 10 μs) from overcharge detection voltage (V_{OCP}) −0.2 V to overcharge detection voltage (V_{OCP}) +0.2 V under the set condition of V_2 = 0 V.

15) Over-discharge Detection Delay Time

(Test Condition 9, Test Circuit 5)

The over-discharge detection delay time (T_{OD}) is the time needed for V_{OD} to change from "H" to "L" just after the voltage V_1 momentarily decreases (within 10 μs) from over-discharge detection voltage (V_{ODP}) +0.2 V to over-discharge detection voltage (V_{ODP}) −0.2 V under the set condition of V_2 = 0 V.

16) Discharge Overcurrent Detection Delay Time

(Test Condition 10, Test Circuit 5)

Discharge overcurrent detection delay time (T_{ODIP}) is the time needed for V_{OD} to go to "L" after the voltage V_2 momentarily increases (within 10 μs) from 0 V to 0.5 V under the set conditions of V_1 = 3.6 V, V2 = 0 V.

17) Load Short-circuiting Detection Delay Time

(Test Condition 10, Test Circuit 5)

Load short-circuiting detection delay time (T_{SHORT}) is the time needed for V_{OD} to go to "L" after the voltage V_2 momentarily increases (within 10 μs) from 0 V to 1.2 V under the set conditions of V_1 = 3.6 V, V_2 = 0 V.

18) Charge Overcurrent Detection Delay Time

(Test Condition 10, Test Circuit 5)

Charge overcurrent detection delay time (T_{OCIP}) is the time needed for V_{OC} to go to "L" after the voltage V_2 momentarily decreases (within 10 μs) from 0 V to −0.5 V under the set conditions of V_1 = 3.6 V, V_2 = 0 V.

19) 0 V Battery Charge Starting Charger Voltage

(Test Condition 11, Test Circuit 2)

The 0 V charge starting charger voltage (V_{0CHA}) is defined as the voltage between the VCC pin and CS pin at which V_{OC} goes to "H" (V_{CS} +0.1 V or higher) when the voltage V_2 is gradually decreased from the starting condition of V_1 = V_2 = 0 V.

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PT6001 Test Circuits

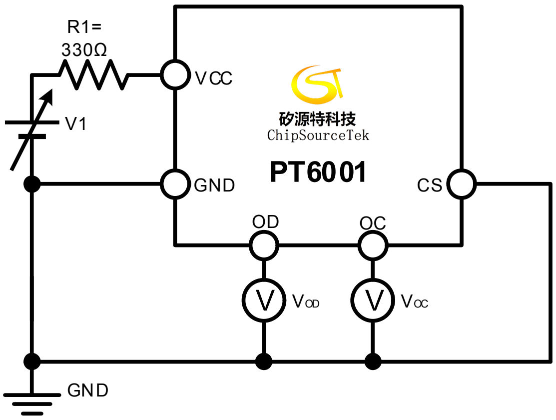

Figure4. Test Circuit 1

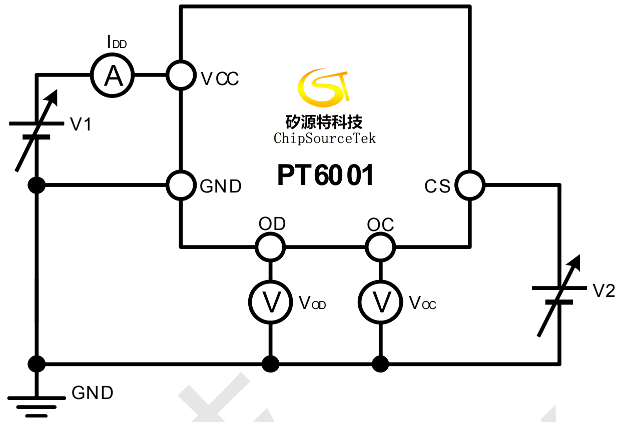

Figure5. Test Circuit 2

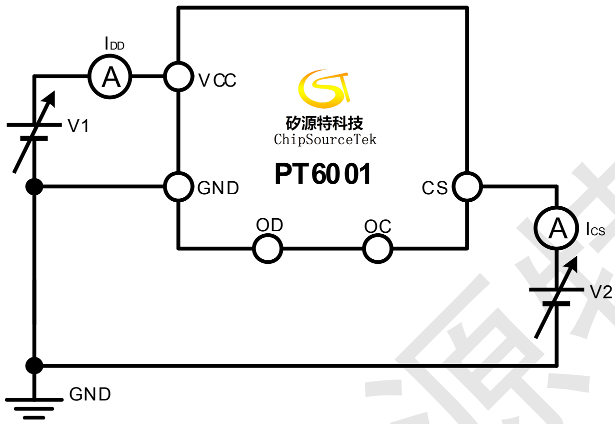

Figure6. Test Circuit 3

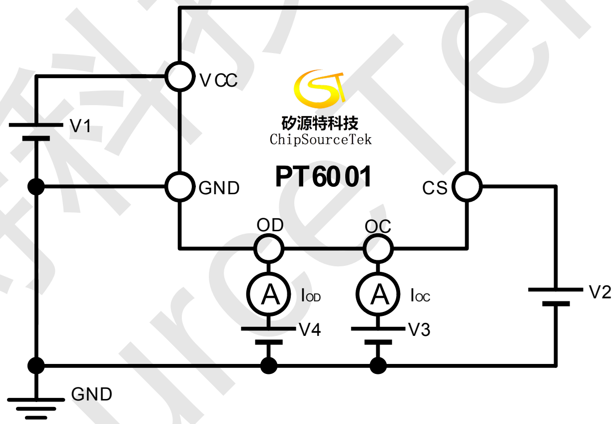

Figure7. Test Circuit 4

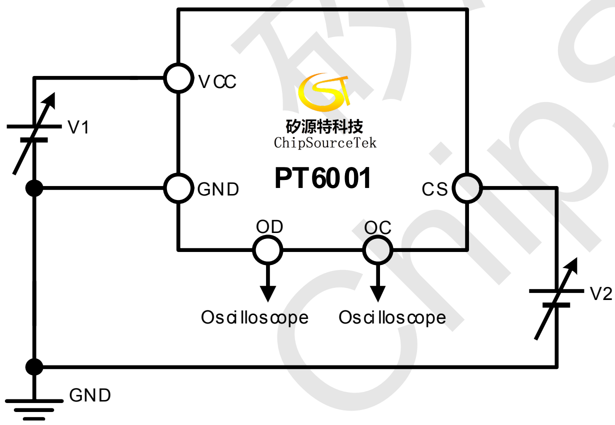

Figure8. Test Circuit 5

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Single Cell Li-ion/Polymer Battery Protection IC

PT6001 Operation Description

1. Normal Status 正常状态

PT6001 monitors the voltage of the battery connected between the VCC pin and GND pin and the voltage difference between the CS pin and GND pin to control charging and discharging. When the battery voltage is in the range from over-discharge detection voltage (V_{ODP}) to overcharge detection voltage (V_{OCP}), and the CS pin voltage is in the range from the charge overcurrent detection voltage (V_{OCIP}) to discharge overcurrent detection voltage (V_{ODIP}), PT6001 turns both the charging MOSFET and discharging MOSFET on. This condition is called the normal status, and in this condition charging and discharging can be carried out freely.

The resistance (R_{CSC}) between the CS pin and VCC pin, and the resistance (R_{CSG}) between the CS pin and GND pin are not connected in the normal status.

PT6001 监测连接在 VCC 与 GND 之间的电池电压和 CS 与 GND 之间的电压差来控制充放电。当电池电压在过放电监测电压 V_{ODP} 和过充电监测电压 V_{OCP} 之间，CS 电压在充电过电流监测电压 V_{OCIP} 和放电过电流监测电压 V_{ODIP} 之间时，PT6001 打开充放电 MOSFET。这个状态叫做正常状态，可以自由充放电。

在正常状态，CS 与 VCC 之间的电阻 R_{CSC} 和 CS 与 GND 之间的电阻 R_{CSG} 不导通。

Caution: When the battery is connected for the first time and VCC rise from 0 V to above V_{ODR}, The resistance (R_{CSC}) between the CS pin and VCC pin is connected and discharging MOSFET maybe not open if enter sleep mode. Auto Recovery mode may cause higher current consumption.

注意：当电池第一次连接时，在 VCC 从 0V 上升至 V_{ODR} 以上的过程中，允许进入休眠模式的芯片可能已经进入休眠状态，CS 与 VCC 之间的电阻 R_{CSC} 导通，放电 MOSFET 不能打开。进入休眠模式的芯片需要通过短接 CS 与 GND 来唤醒。增加进入休眠模式的延迟时间可降低电池第一次连接时进入休眠的概率。禁止进入休眠的芯片可配置成自动恢复模式，这会导致芯片有较高的功耗。

2. Overcharge Status 过充电状态

When the battery voltage becomes higher than overcharge detection voltage (V_{OCP}) during charging in the normal status and detection continues for the overcharge detection delay time (T_{OCP}) or longer, PT6001 turns the charging MOSFET off to stop charging. This condition is called the overcharge status.

The resistance (R_{CSC}) between the CS pin and VCC pin, and the resistance (R_{CSG}) between the CS pin and GND pin are not connected in the overcharge status.

The overcharge status is released in the following two cases.

当处于正常状态的芯片检测到正在充电的电池电压高于过充电监测电压 V_{OCP} 超过过充电监测延迟时间 T_{OCP}，芯片关闭充电 MOSFET。这个状态称为过充电状态。

在过充电状态，CS 与 VCC 之间的电阻 R_{CSC} 导通，CS 与 GND 之间的电阻 R_{CSG} 不导通。

以下两个条件过充电状态解除。

Case 1. In the case that the CS pin voltage is higher than or equal to the charge overcurrent detection voltage (V_{OCIP}), and is lower than the discharge overcurrent detection voltage (V_{ODIP}), PT6001 releases the overcharge status when the battery voltage falls below the overcharge release voltage (V_{OCR}) over the delay of overcharge release (T_{OCR}).

条件 1：当 CS 引脚电压高于充电过电流监测电压 V_{OCIP}，低于放电过电流监测电压 V_{ODIP}，如果芯片检测到电池电压低于过充电恢复电压 V_{OCR} 超过过充电恢复延迟时间 T_{OCR}，则退出过充电状态。

Case 2. In the case that the CS pin voltage is higher than or equal to the discharge overcurrent detection voltage (V_{ODIP}), PT6001 releases the overcharge status when the battery voltage falls below the overcharge detection voltage (V_{OCP}).

条件 2：当 CS 引脚电压高于放电过电流监测电压 V_{ODIP}，如果芯片检测到电池电压低于过充电检测电压 V_{OCP}

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超过过充电恢复延迟时间 T_{OCR}，则退出过充电状态。（此处是否需要延迟时间 T_{OCR}）

The discharge is started by connecting a load at overcharge status, the CS pin voltage rises more than the voltage at GND pin due to the forward voltage of the parasitic diode, because the discharge current flows through the parasitic diode in the charging MOSFET. If this CS pin voltage is higher than or equal to the discharge overcurrent detection voltage (V_{ODIP}), PT6001 releases the overcharge status when the battery voltage is lower than or equal to the overcharge detection voltage (V_{OCP}).

For the actual application boards, changing the battery voltage and the charger voltage simultaneously enables to measure the overcharge release voltage (V_{OCR}). In this case, the charger is always necessary to have the equivalent voltage level to the battery voltage. The charger keeps CS pin voltage higher than or equal to the charge overcurrent detection voltage (V_{OCIP}) and lower than or equal to the discharge overcurrent detection voltage (V_{ODIP}). PT6001 releases the overcharge status when the battery voltage falls below the overcharge release voltage (V_{OCR}).

过充电状态连接负载，放电开始，放电电流经过充电 MOSFET 的体二极管，CS 引脚电压上升，超过放电过电流监测电压 V_{ODIP}，芯片退出过充电状态的检测电压切换至过充电检测电压 V_{OCP}。

在实际的应用线路板上，同时改变电池电压和充电器电压可以测量过充电恢复电压 V_{OCR}。在这种情况下，充电器电压和电池电压保持一致。充电器将 CS 引脚的电压维持在充电过电流检测电压 V_{OCIP} 和放电过电流检测电压 V_{ODIP} 之间，当电池电压降低至过充电恢复电压 V_{OCR} 以下时，芯片退出过充电状态。

Caution 1. If the battery is charged to a voltage higher than overcharge detection voltage (V_{OCP}) and the battery voltage does not fall below overcharge detection voltage (V_{OCP}) even when a heavy load is connected, discharge overcurrent detection do not function and load short-circuiting detection function until the battery voltage falls below overcharge detection voltage (V_{OCP}). Since an actual battery has an internal impedance of tens of mΩ, the battery voltage drops immediately after a heavy load that causes overcurrent is connected, and discharge overcurrent detection and load short-circuiting detection function.

注意 1：对于超过 V_{OCP} 而被充电的电池，即使连接了较大值的负载，也不能使电池电压下降到 V_{OCP} 以下的情况下，在电池电压降低到 V_{OCP} 为止，放电过电流检测以及负载短路检测是不能发挥作用的。但是，实际上电池的内部阻抗有数十 mΩ，在连接了可使过电流发生的较大值负载的情况下，因为电池电压会马上降低，因此放电过电流检测以及负载短路检测是可以发挥作用的。（在过充电状态，过电流监测功能被屏蔽）

Caution 2. When a charger is connected after overcharge detection, the overcharge status is not released even if the battery voltage is below overcharge release voltage (V_{OCR}). The overcharge status is released when the CS pin voltage goes over the charge overcurrent detection voltage (V_{OCIP}) by removing the charger.

注意 2：如果在过充电状态下连接充电器，即使电池电压低于 V_{OCR}，过充电状态也不会解除。只有通过移除充电器，使 CS 引脚的电压高于 V_{OCIP}，过充电状态才会解除。

3. Over-discharge Status

When the battery voltage falls below over-discharge detection voltage (V_{ODP}) during discharging in the normal status and the detection continues for the over-discharge detection delay time (T_{ODIP}) or longer, PT6001 turns the discharging MOSFET off to stop discharging. This condition is called the over-discharge status.

Under the over-discharge status, the CS pin voltage is pulled up by the resistor between the CS pin and VCC pin in PT6001 (R_{CSC}). The resistance (R_{CSG}) between the CS pin and GND pin is not connected.

1) Without charger: If the CS pin voltage is higher than V_{CHGIN}, over-discharge status will not release even if the battery voltage reaches V_{ODR} or higher.
2) With charger: If the CS pin voltage is lower than V_{OCIP}, PT6001 releases the over-discharge status and turns the discharging MOSFET on when the battery voltage reaches over-discharge detection voltage (V_{ODP}) or higher over

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T_{ODR}.

3) With charger: If the CS pin voltage is lower than V_{CHGIN} and higher than V_{OCIP}, PT6001 releases the over-discharge status when the battery voltage reaches over-discharge release voltage (V_{ODR}) or higher over T_{ODR}.

当处于正常状态的芯片检测到电池电压低于过放电检测电压 V_{ODP} 超过过放电延迟时间 T_{ODIP}，芯片关闭放电 MOSFET。这个状态称为过放电状态。

在过放电状态，CS 与 VCC 之间的电阻 R_{CSC} 导通，CS 引脚的电压被上拉至 VCC。CS 与 GND 之间的电阻 R_{CSG} 不导通。

1) 充电器不连接： 当 CS 引脚电压高于 V_{CHGIN}，即使电池电压高于 V_{ODR}，过放电状态也不会解除。
2) 充电器连接：当 CS 引脚电压低于 V_{OCIP}，如果电池电压高于 V_{ODP} 超过 T_{ODR}，过放电状态解除。（是否需要该延迟）
3) 充电器连接：当 CS 引脚电压低于 V_{CHGIN} 高于 V_{OCIP}，如果电池电压高于 V_{ODR} 超过 T_{ODR}，过放电状态解除。

注意：充电器检测比较器误差大功耗低，放电过电流检测比较器精度高功耗也高，如果休眠时的功耗要求不高，充电器检测可以复用放电过电流检测比较器。

Sleep mode 休眠模式

When the voltage of CS pin is higher than V_{ODIR}, the current consumption is reduced to the sleep current consumption (I_{SLP}). This condition is called the sleep status.

The sleep status is released when a charger is connected and the voltage of CS pin is lower than V_{CHGIN}.

当时 CS 引脚电压差高于 V_{ODIR}，电流消耗降低至 I_{SLP} 以下。这个状态称为休眠状态。

当充电器连接，CS 引脚电压低于 V_{CHGIN}，休眠状态退出。

Auto recovery mode 自动恢复模式

Under the over-discharge status, PT6001 maintains active. This condition is called auto recovery mode.

1) Without charger: If the CS pin voltage is higher than V_{CHGIN}, over-discharge status will release when the battery voltage reaches V_{ODR} or higher over T_{ODR}.
2) With charger: If the CS pin voltage is lower than V_{OCIP}, PT6001 releases the over-discharge status and turns the discharging MOSFET on when the battery voltage reaches over-discharge detection voltage (V_{ODP}) or higher over T_{ODR}.
3) With charger: If the CS pin voltage is lower than V_{CHGIN} and higher than V_{OCIP}, PT6001 releases the over-discharge status when the battery voltage reaches over-discharge release voltage (V_{ODR}) or higher over T_{ODR}.

如果在过放电状态禁止进入休眠模式的芯片一直处于活动状态，这个状态称为自动恢复模式。

1) 充电器不连接： 当 CS 引脚电压高于 V_{CHGIN}，如果电池电压高于 V_{ODR} 超过 T_{ODR}，过放电状态解除。
2) 充电器连接：当 CS 引脚电压低于 V_{OCIP}，如果电池电压高于 V_{ODP} 超过 T_{ODR}，过放电状态解除。（是否需要该延迟）
3) 充电器连接：当 CS 引脚电压低于 V_{CHGIN} 高于 V_{OCIP}，如果电池电压高于 V_{ODR} 超过 T_{ODR}，过放电状态解除。

4. Discharge Overcurrent Status (Discharge Overcurrent, Load Short-circuiting) 放电过电流状态（放电过流，短路）

When a battery in the normal status is in the status where the voltage of the CS pin is equal to or higher than the discharge overcurrent detection voltage (V_{ODIP}) because the discharge current is higher than the specified value and the status lasts for the discharge overcurrent detection delay time (T_{ODIP}), the discharge MOSFET is turned off and discharging is stopped. This status is called the discharge overcurrent status.

The release condition of charge overcurrent status is optional as below:

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1) Load remove and $V_{CS}<V_{ODIP}$

In the discharge overcurrent status, the CS pin and GND pin are shorted by the resistor between CS pin and GND pin (R_{CSG}) in PT6001. However, the voltage of the CS pin is at the VCC potential due to the load as long as the load is connected. When the load is disconnected, the CS pin returns to the GND potential.

PT6001 detects the status when the impedance between the BATT+ pin and BATT− pin (Refer to the Figure1.) increases and is equal to the impedance that enables automatic restoration and the voltage at the CS pin returns to discharge overcurrent detection voltage (V_{ODIP}) or lower over T_{ODIR}, the discharge overcurrent status is restored to the normal status.

The resistance (R_{CSC}) between the CS pin and VCC pin is not connected in the discharge overcurrent detection status.

2) Load remove and $V_{CS}<V_{ODIR}$

In the discharge overcurrent status, the CS pin and GND pin are shorted by the resistor between CS pin and GND pin (R_{CSG}) in PT6001. However, the voltage of the CS pin is at the VCC potential due to the load as long as the load is connected. When the load is disconnected, the CS pin returns to the GND potential.

PT6001 detects the status when the impedance between the BATT+ pin and BATT− pin (Refer to the Figure1.) increases and is equal to the impedance that enables automatic restoration and the voltage at the CS pin returns to discharge overcurrent detection voltage (V_{ODIR}) or lower over T_{ODIR}, the discharge overcurrent status is restored to the normal status.

The resistance (R_{CSC}) between the CS pin and VCC pin is not connected in the discharge overcurrent detection status.

3) Charger is plugged in and $V_{CS}<V_{ODIP}$

In the discharge overcurrent status, the CS pin and VCC pin are shorted by the resistor between CS pin and VCC pin (R_{CSC}) in PT6001. However, the voltage of the CS pin is at the VCC potential even if the load is removed. When the charger is connected, the voltage at the CS pin returns to discharge overcurrent detection voltage (V_{ODIP}) or lower over T_{ODIR}, the discharge overcurrent status is restored to the normal status.

The resistance (R_{CSG}) between the CS pin and GND pin is not connected in the discharge overcurrent detection status.

当处于正常状态的芯片检测到 CS 引脚的电压 V_{ODIP} 高于超过 T_{ODIP}，放电 MOSFET 关闭，这个状态称为放电过电流状态。

放电过电流状态的解除条件是可选的，如下：

1) 负载移除且 $V_{CS}<V_{ODIP}$

在放电过电流状态，CS 与 GND 之间的电阻 R_{CSG} 导通。CS 引脚的电压一直被负载连接至 VCC。当负载移除，CS 引脚电压降低至 GND。

芯片检测图 1 中 BATT+和 BATT-之间的阻抗，当 CS 引脚的电压低于 V_{ODIP} 超过 T_{ODIP}，放电过电流状态解除。

在过放电状态，CS 与 VCC 之间的电阻 R_{CSC} 不导通。

2) 负载移除且 $V_{CS}<V_{ODIR}$

在放电过电流状态，CS 与 GND 之间的电阻 R_{CSG} 导通。CS 引脚的电压一直被负载连接至 VCC。当负载移除，CS 引脚电压降低至 GND。

芯片检测图 1 中 BATT+和 BATT-之间的阻抗，当 CS 引脚的电压低于 V_{ODIR} 超过 T_{ODIP}，放电过电流状态解除。

在过放电状态，CS 与 VCC 之间的电阻 R_{CSC} 不导通。

3) 充电器连接且 $V_{CS}<V_{ODIP}$

在放电过电流状态，CS 与 VCC 之间的电阻 R_{CSC} 导通。即使负载移除，CS 引脚的电压也一直被连接至 VCC。通过连接充电器使 CS 引脚电压低于 V_{ODIP} 超过 T_{ODIP}，放电过电流状态解除。

在过放电状态，CS 与 GND 之间的电阻 R_{CSG} 不导通。

5. Charge Overcurrent Status 充电过电流状态

When a battery in the normal status is in the status where the voltage of the CS pin is lower than the charge overcurrent detection voltage (V_{OCIP}) because the charge current is higher than the specified value and the status lasts for the charge overcurrent detection delay time (T_{OCIP}), the charging MOSFET is turned off and charging is stopped. This status is called the

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charge overcurrent status.

The charge overcurrent detection function does not work in the over-discharge status.

PT6001 will be restored to the normal status from the charge overcurrent status when, the voltage at the CS pin returns to charge overcurrent detection voltage (V_{OCIP}) or higher by removing the charger.

The resistance (R_{CSC}) between the CS pin and VCC pin, and the resistance (R_{CSG}) between the CS pin and GND pin are not connected in the charge overcurrent status.

当处于正常状态的芯片检测到 CS 引脚的电压低于 V_{OCIP} 超过 T_{OCIP}，充电 MOSFET 关闭，这个状态称为充电过电流状态。

当移除充电器，CS 引脚的电压高于 V_{OCIP} 超过 T_{OCIR}，充电过电流状态解除。

充电过电流监测功能在过放电状态不工作。

在充电过电流状态，CS 与 VCC 之间的电阻 R_{CSC} 和 CS 与 GND 之间的电阻 R_{CSG} 不导通。

6. 0 V Battery Charging Function “Available” 0V 电池允许充电功能

This function is used to recharge a connected battery whose voltage is 0 V due to self-discharge. When the 0 V battery charge starting charger voltage (V_{0CHA}) or a higher voltage is applied between the BATT+ and BATT− pins by connecting a charger, the charging MOSFET gate is fixed to the VCC pin voltage.

When the voltage between the gate and source of the charging MOSFET becomes equal to or higher than the turn on voltage due to the charger voltage, the charging MOSFET is turned on to start charging. At this time, the discharging MOSFET is off and the charging current flows through the internal parasitic diode in the discharging MOSFET. When the battery voltage becomes equal to or higher than over-discharge release voltage (V_{ODP}), PT6001 enters the normal status.

这个功能用于给因自放电而电压降低至 0V 的电池充电。当充电器连接，高于 V_{0CHA} 的电压加在 BATT+和 BATT-之间，充电 MOSFET 的栅极与 VCC 引脚导通。

当充电 MOSFET 的栅极与源极之间电压高于开启阈值，充电 MOSFET 打开，充电器开始充电。此时放电 MOSFET 关闭，充电电流经过放电 MOSFET 的体二极管。

Caution 1. Some battery providers do not recommend charging for a completely self-discharged battery. Please ask the battery provider to determine whether to enable or inhibit the 0 V battery charging function.

Caution 2. The 0 V battery charge function has higher priority than the charge overcurrent detection function. Consequently, a product in which use of the 0 V battery charging function is enabled charges a battery forcibly and the charge overcurrent cannot be detected when the battery voltage is lower than over-discharge detection voltage (V_{ODP}). (Charger abnormal function can be used to protect the battery from charger overcurrent)

注意 1：一些电池供应商不推荐对完全自放电的电池充电，请向电池供应商咨询来决定是否允许和禁止 0V 电池充电功能。

注意 2：0V 电池充电允许功能的优先级比充电过电流监测功能高。因此，使用 0V 电池充电允许功能的芯片允许对电压低于的电池强制充电，而不进行充电过电流的检测。（增加充电器异常检测功能）

7. 0 V Battery Charging Function “Unavailable”

This function inhibits recharging when a battery that is internally short-circuited (0 V battery) is connected. When the battery voltage is the 0 V battery charge inhibition battery voltage (V_{0INH}) or lower, the charging MOSFET gate is fixed to the BATT− pin voltage to inhibit charging. When the battery voltage is the 0 V battery charge inhibition battery voltage (V_{0INH}) or higher, charging can be performed.

这个功能禁止向内部短路的电池（0V 电池）充电。当电池电压低于 V_{0INH} 时，充电 MOSFET 的栅极被笃定在 BATT-端子电压。当电池电压高于 V_{0INH} 时，可以进行充电。

Caution: Some battery providers do not recommend charging for a completely self-discharged battery. Please ask the battery

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provider to determine whether to enable or inhibit the 0 V battery charging function.

注意：有些电池供应商不推荐对完全自放电的电池进行充电，请向电池供应商咨询。

8. Delay Circuit

The detection delay times are determined by dividing an internal clock by the counter.

各种检测的延迟时间是对内部时钟进行计数后得出。

Remark 1. The discharge overcurrent detection delay time (T_{ODIP}) and the load short-circuiting detection delay time (T_{SHORT}) start when the discharge overcurrent detection voltage (V_{ODIP}) is detected. When the load short-circuiting detection voltage (V_{SHORT}) is detected over the load short-circuiting detection delay time (T_{SHORT}) after the detection of discharge overcurrent detection voltage (V_{ODIP}), PT6001 turns the discharging control FET off within T_{SHORT} from the time of detecting V_{SHORT}.

备注 1：PT6001 的 T_{ODIP} 和 T_{SHORT} 复用了计数器，故 T_{ODIP} 和 T_{SHORT} 的计时是从检测出 V_{ODIP} 开始的。因此，从检测出 V_{ODIP} 时起到超过 T_{SHORT} 之后，当检测出 V_{SHORT} 时，从检测出 V_{SHORT} 时起在 T_{SHORT} 之内立即关闭放电控制用 MOSFET。若 T_{ODIP} 和 T_{SHORT} 的计时器分开使用不存在此问题。

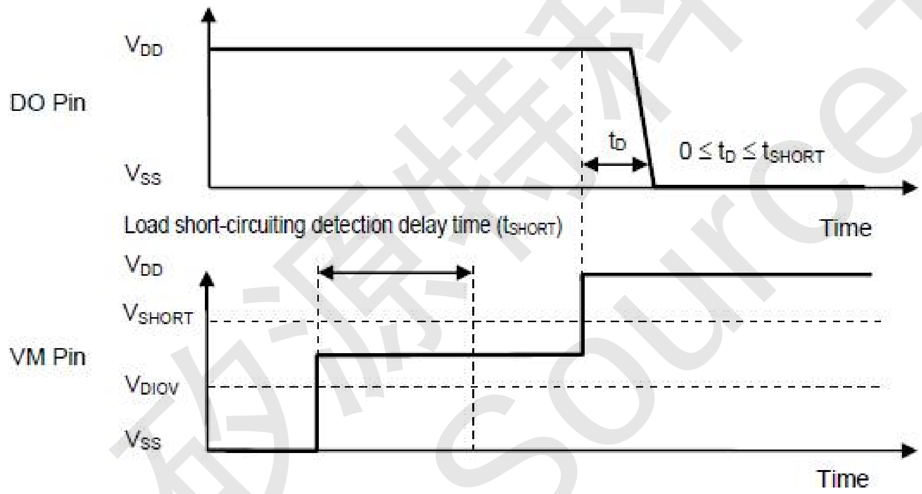

Figure9

Remark 2. When any overcurrent is detected and the overcurrent continues for longer than the over-discharge detection delay time (T_{ODP}) without the load being released, the status changes to sleep status at the point where the battery voltage falls below over-discharge detection voltage (V_{ODP}). When the battery voltage falls below over-discharge detection voltage (V_{ODP}) due to overcurrent, PT6001 turns the discharging MOSFET off via overcurrent detection. In this case, if the recovery of the battery voltage is so slow that the battery voltage after the over-discharge detection delay time (T_{ODP}) is still lower than the over-discharge detection voltage (V_{ODP}), PT6001 shifts to sleep status.

备注 2：当芯片检测到放电过电流时先触发过放电状态而没有断开负载，芯片进入休眠状态。当芯片检测到过放电电压时先触发放电过电流状态，如果电池电压恢复慢而超过过放电延迟时间，芯片转移至休眠状态。

(PT6001 休眠状态的进入是由过放电状态下 VM 引脚的电压来决定，没有延迟时间。原来的版本有延迟时间。)

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PT6001 Timing Chart

(1) Overcharge Detection

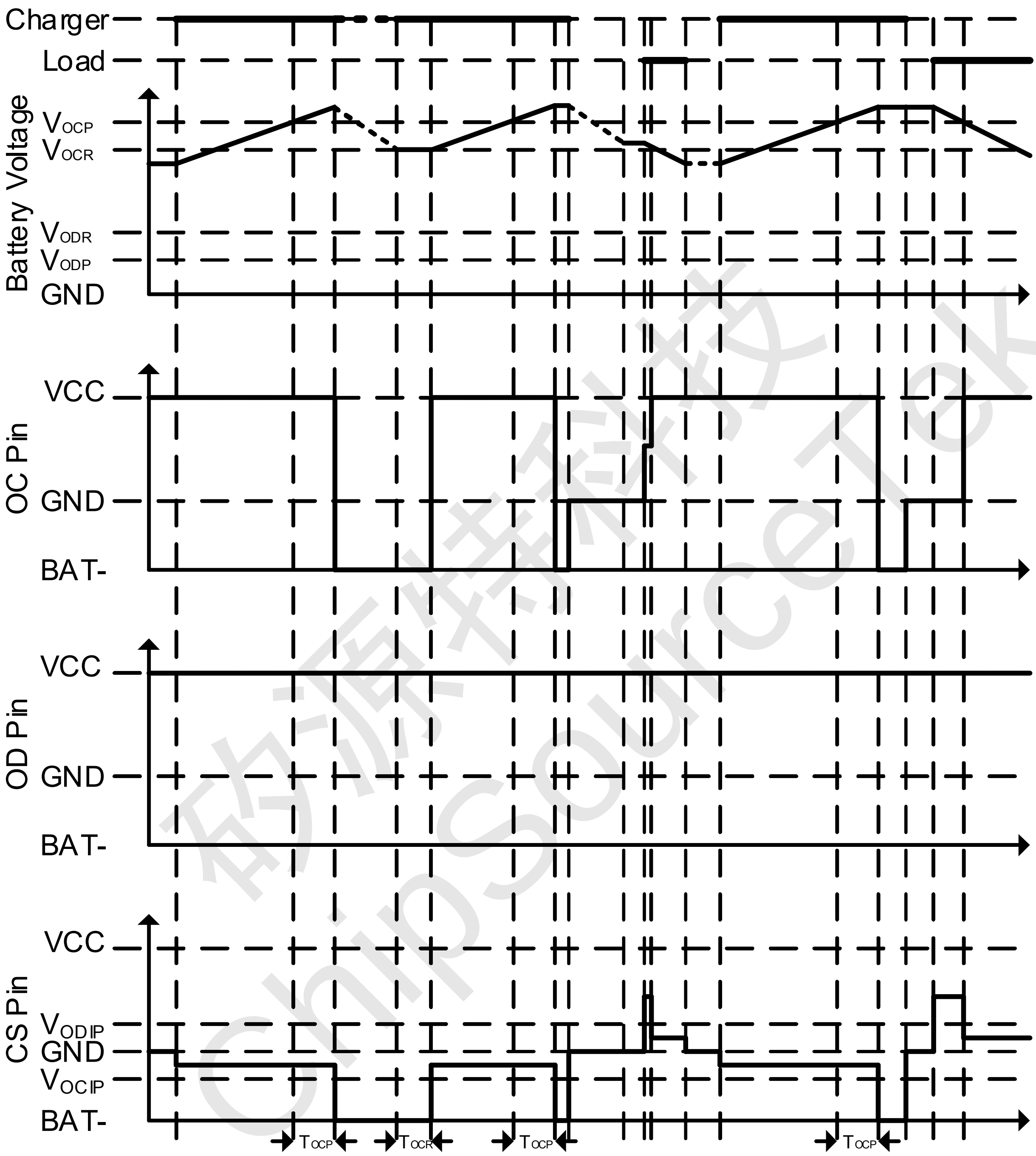

Figure10. Overcharge Detection Time Chart

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(2) Over-discharge Detection

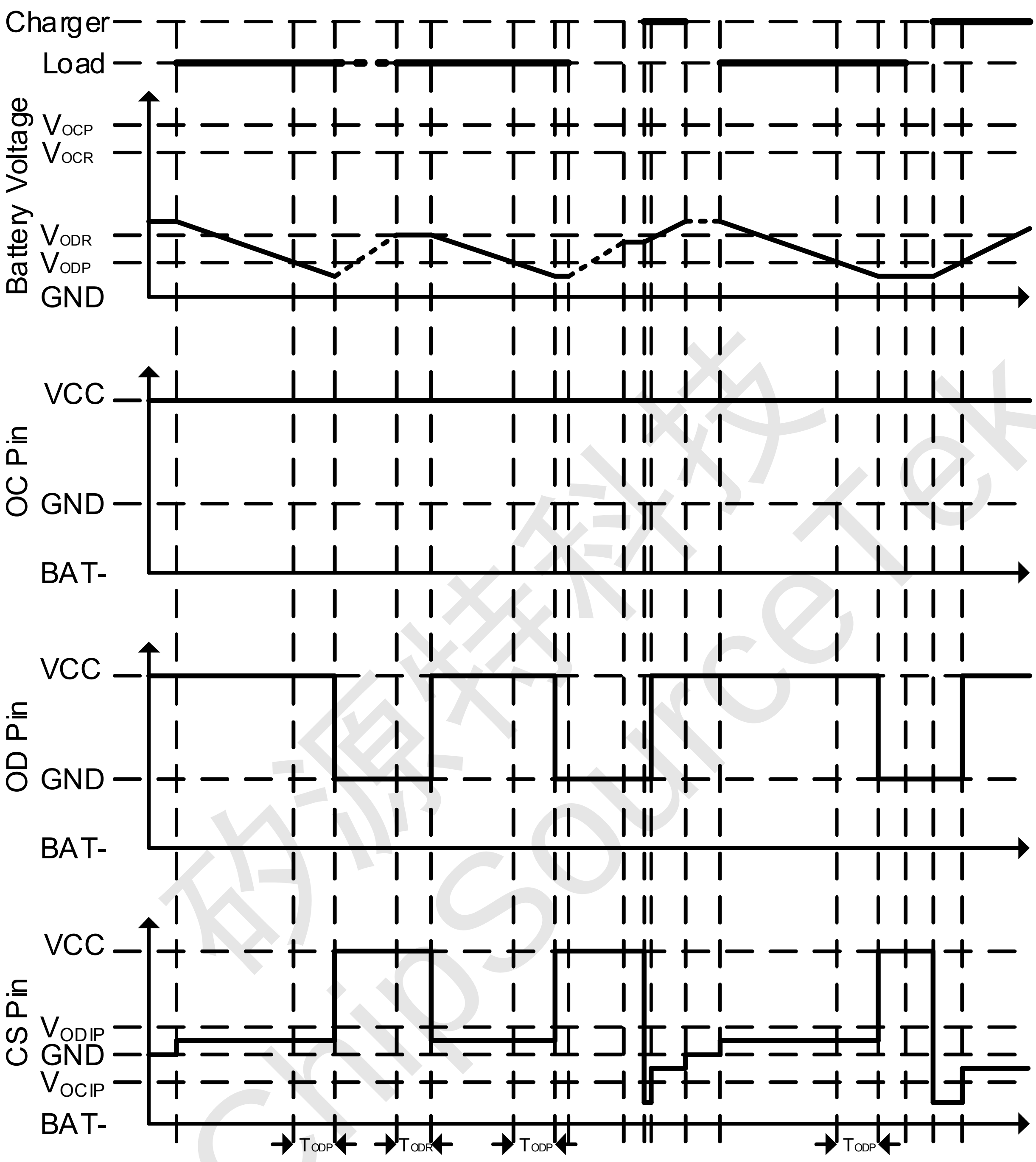

Figure11. Over-discharge Detection Time Chart

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(3) Discharge Overcurrent Detection

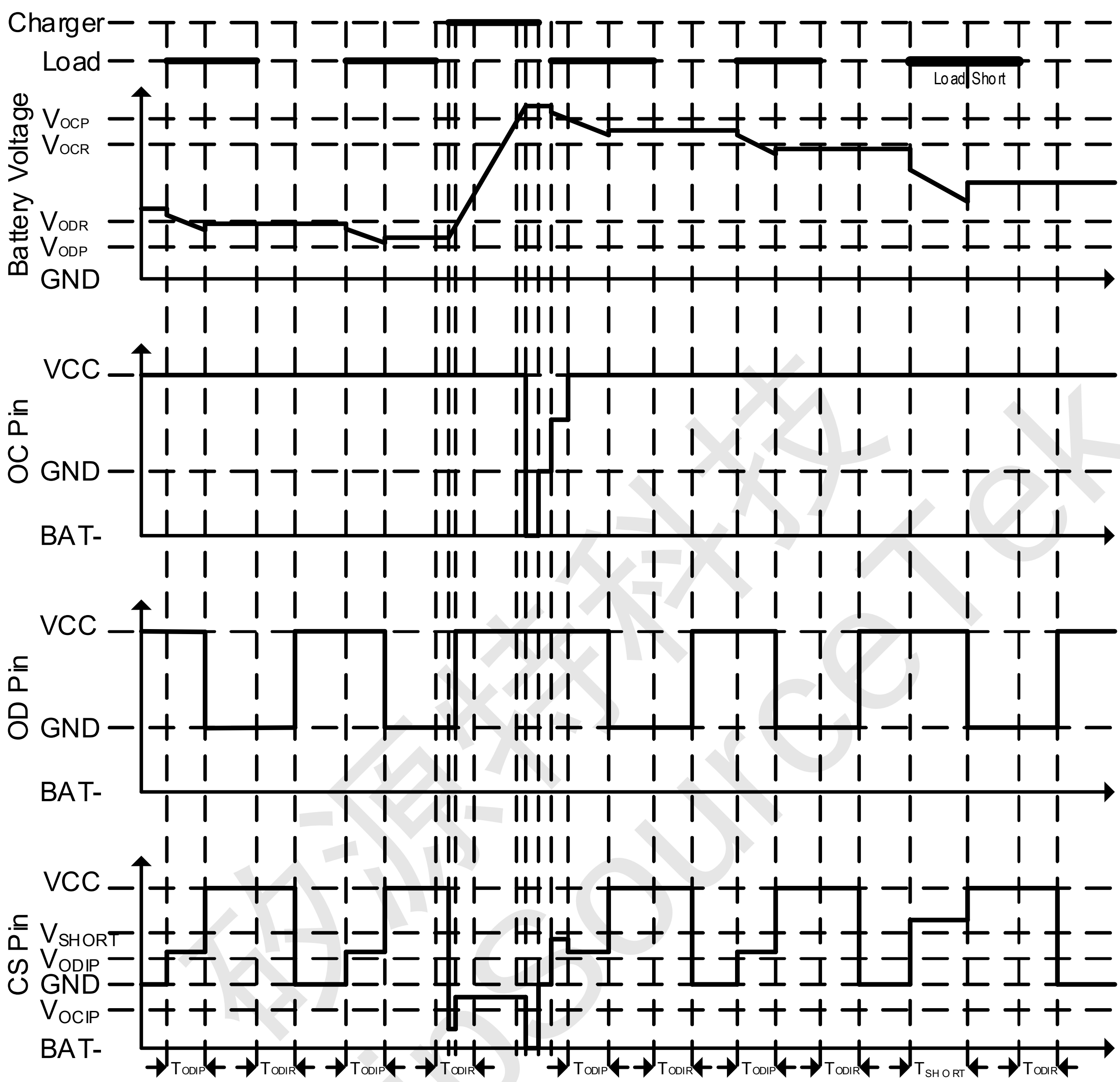

Figure12. Discharge Overcurrent Detection Time Chart

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(4) Charge Overcurrent Detection

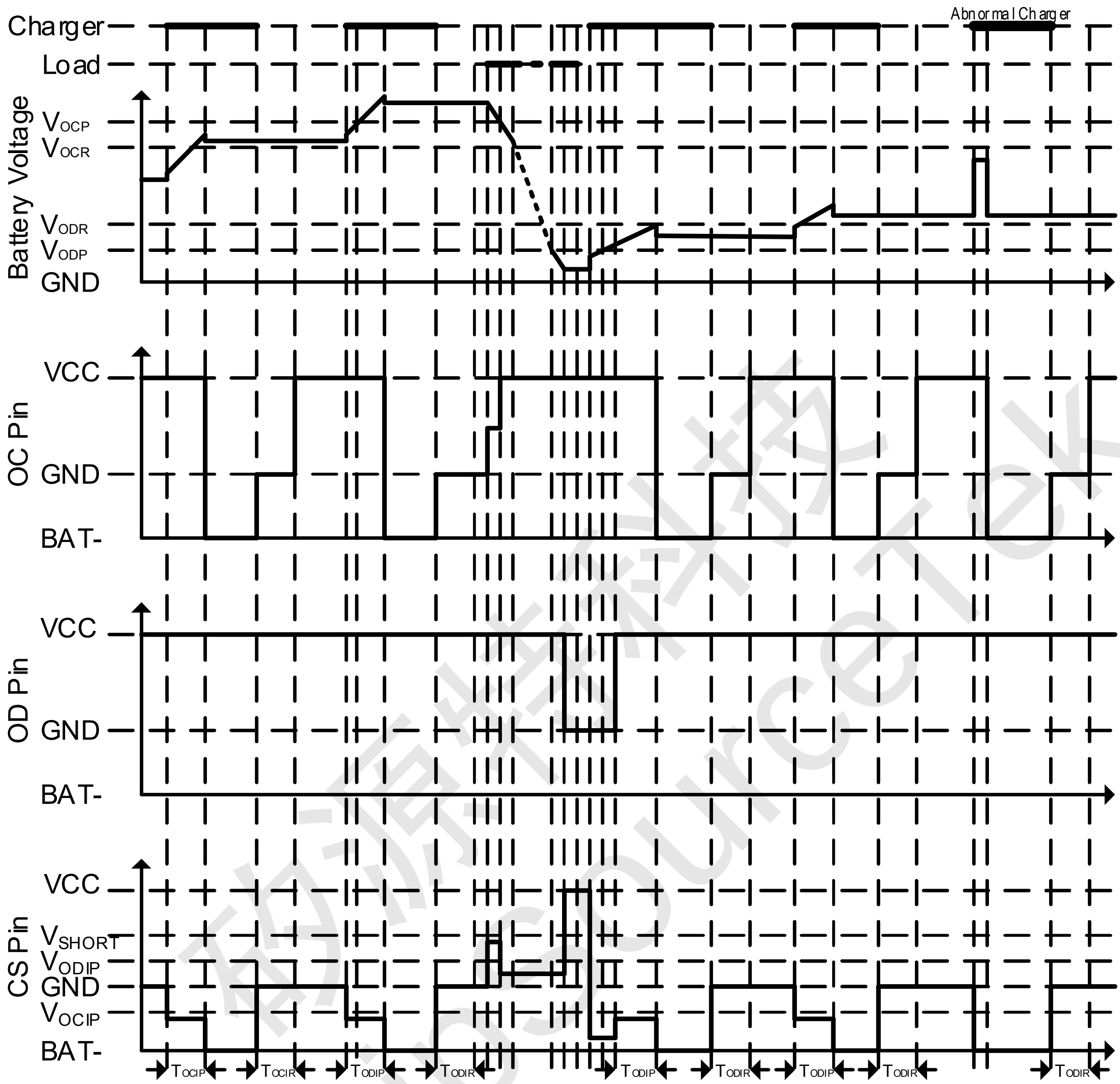

Figure13. Charge Overcurrent Detection Time Chart

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(5) 0 V Charge

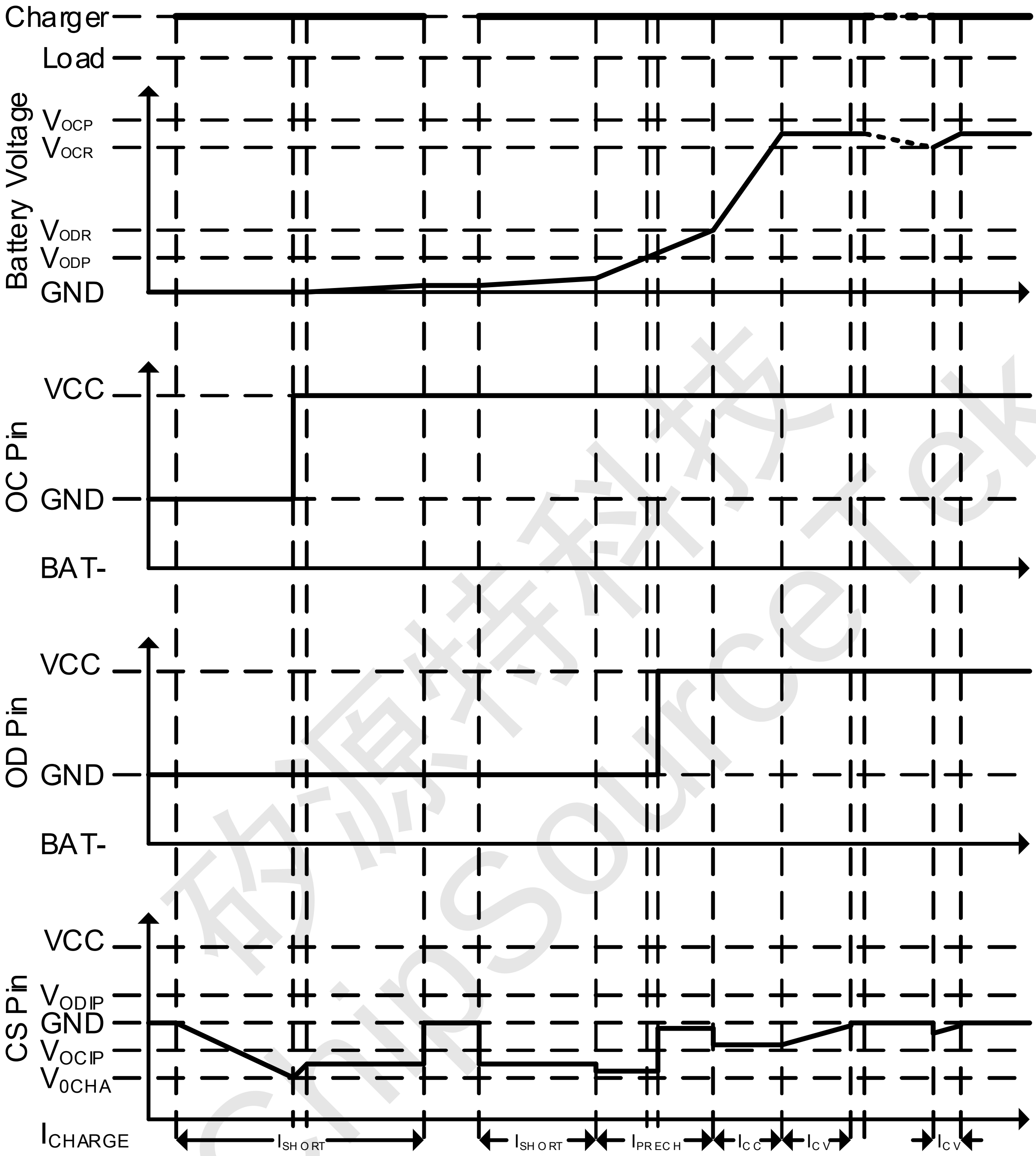

Figure14. 0 V Charge Time Chart

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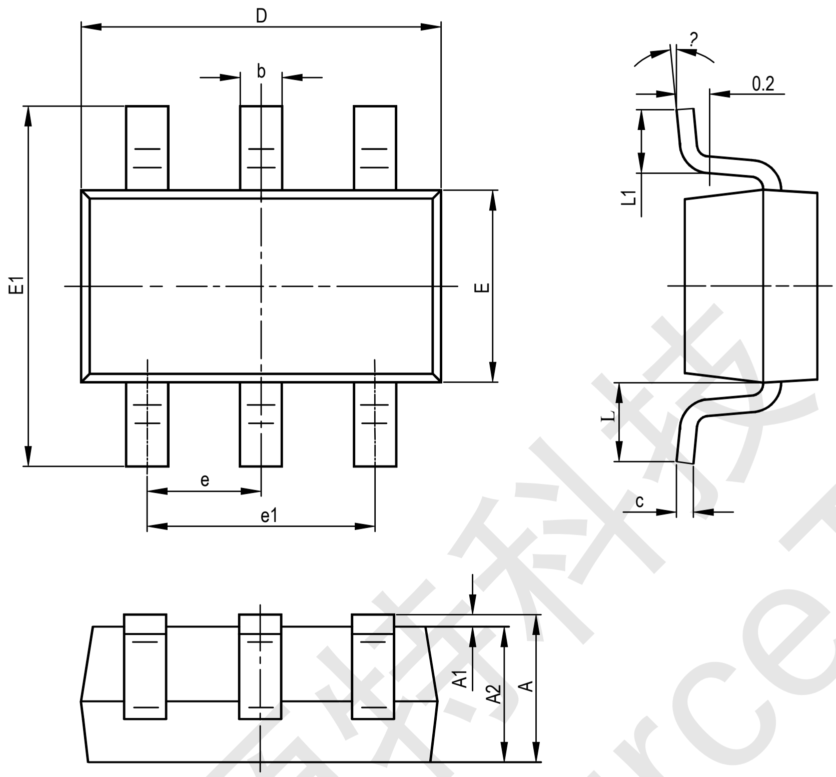
PT6001 PACKAGE INFORMATION

SOT23-6



Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	-	1.450	-	0.057
A1	0.000	0.150	0.000	0.006
A2	0.900	1.300	0.035	0.051
b	0.300	0.500	0.012	0.020
c	0.080	0.220	0.003	0.009
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.600	2.950	0.102	0.116
e	0.950TYP		0.037TYP	
e1	1.800	2.000	0.071	0.079
L	0.600REF		0.024REF	
L1	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

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