BATTERY PROTECTOR AND MOSFET COMBO

Features

- No External MOSFETs Required
- Equivalent of 48 mΩ $R_{DS(ON)}$ on-chip MOSFET
- Only one external capacitor required in application
- Overtemperature Protection
- Overcharge Current Protection
- Three-step Overcurrent Detection: Overdischarge Current 1, Overdischarge Current 2 and Load Short Circuiting
- Charger Detection Function
- Delay Times (Overcharge Voltage: t_{CU}, Overdischarge Voltage: t_{DL}, Overdischarge Current 1: t_{ODC1}, Overdischarge Current 2: t_{ODC2}, Load Short Circuit: t_{SHORT}, Overcharge Current Detection Delay Time: t_{OCC}) are generated internally. No external capacitor is necessary. Accuracy: ±20%
- High-accuracy Voltage Detection
- Low Current Consumption
- Operation Mode: 2.0uA typ., 4.0uA max.
- Power-down Mode: 0.01uA max.
- Small Outline MSOP-8 Package
- RoHS Compliant and Lead (Pb) Free

Description

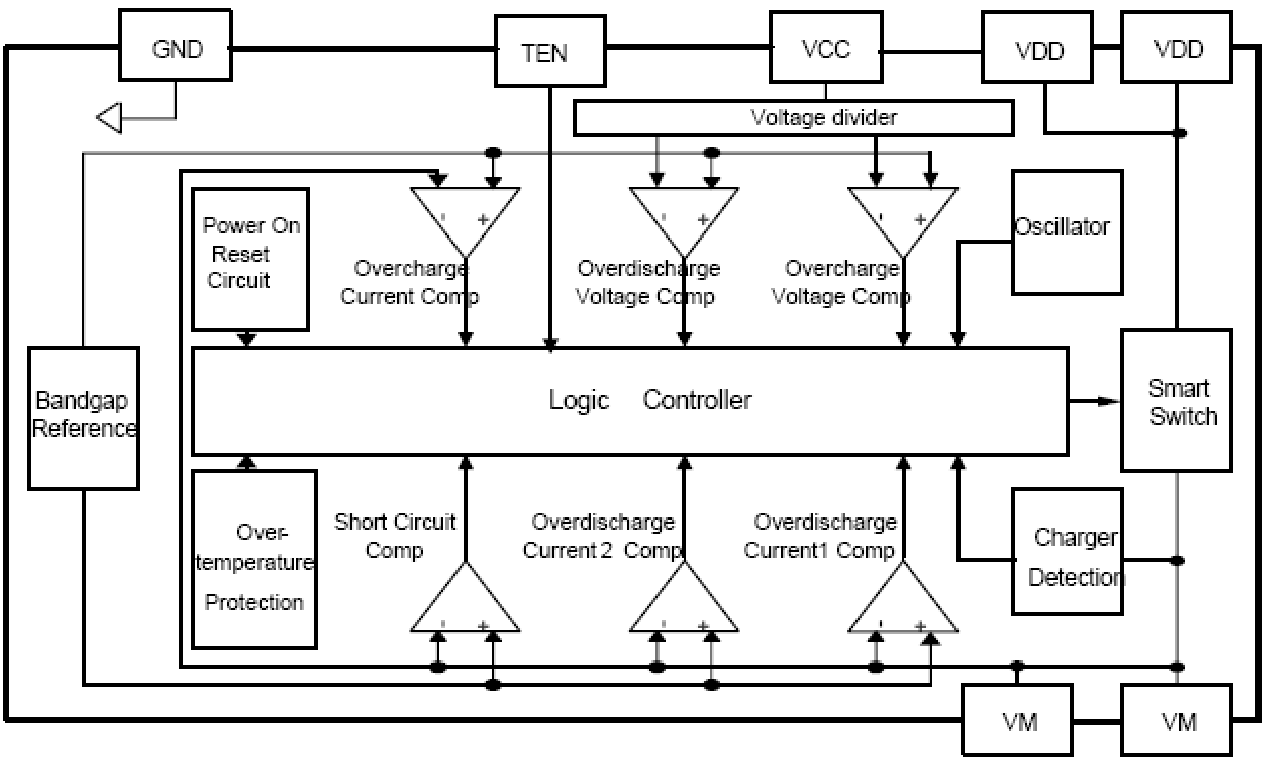
The TC6001 series is a member of Battery Protector product family. This device uses the company's properitary patent pending(US & China) Smart Switch technology to implement on-chip MOSFETs, thus reducing manufacturing cost and increaseing reliability. The device is designed to protect single-cell Li-Ion and Li-Pol battery packs from either overcharge, overdis-charge or overcurrent.

The device contains all required protection control cir cuits together with very-low-resistance MOSFETs to minimize the number of external components. It incorporates overcharge voltage and current protection, overdischarge voltage and current protection, overtemperature protection, short circuit protection and comsumes very little power.

The device is not only targeted for digital cellular phones, but also for any other Li-Ion and Li-Pol battery-powered information appliances requiring long-term battery life.

ORDER INFORMATION

See page 18.



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1. OVERVIEW

The TC6001 series is a member of the Battery Protector product family. It uses the company's properitary patent pending (US & China) Smart Switch technology to implement on-chip MOSFETs, thus reducing manufacturing costs and increasing reliability. The device is designed to protect single cell Li-Ion and Li-Pol battery packs from overcharge, overdischarge, or overcurrent.

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2. PIN DESCRIPTION

Pin Configuration

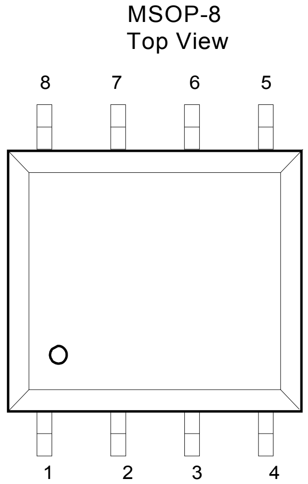


Figure 1. Pin Configuration of TC6001 Series

Pin Description

Pin Number	Pin Name	I/O	Function
1	V_{DD}	I	Positive power input
2	V_{DD}	I	Positive power input
3	V_{CC}	I	Core circuit power supply pin
4	GND	I	Ground pin
5			Open or connect to GND
6	TEN	I	Test pin, open or connect to GND
7	VM	I/O	Positive charge input, overcurrent detection
8	VM	I/O	Positive charge input, overcurrent detection

3. CHARACTERISTITC & SPECIFICATIONS

Recommended Operating Conditions

Parameter	Symbol	Min	Max	Unit
Supply voltage (between V_{DD} and GND)	V_{DD}	2.0	5.0	V
Charger input voltage (between VM and GND)	VM	-0.3	5.5	V
Operating Temperature Range	T_{OPR}	-40	85	^{o}C

Electrical CharacteristiTC for TC6001A/B/D/E/F

Typicals and limits appearing in normal type apply for T_A = 25°C. Limits appearing in **Boldface** type apply for T_A= -40°C to 85°C, unless otherwise specified.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Detection Voltage						
Overcharge Detection Voltage V_{CU}=3.9V to 4.4V, 12.5mV Step	V_{CU}		V_{CU} -0.025	V_{CU}	V_{CU} +0.025	V
			V_{CU} -0.055	**V_{CU}**	**V_{CU} +0.040**	
Overcharge hysteresis voltage V_{HC}=0V to 0.4V, 12.5mV Step	V_{HC}		V_{HC} -0.025	V_{HC}	V_{HC} +0.025	V
			V_{HC} -0.025	**V_{HC}**	**V_{HC} +0.025**	
Overdischarge Detection Voltage V_{DL}=2.0V to 3.0V, 12.5mV Step	V_{DL}		V_{DL} -0.025	V_{DL}	V_{DL} +0.025	V
			V_{DL} -0.050	**V_{DL}**	**V_{DL} +0.050**	
Overdischarge hysteresis voltage V_{HD}=0.0V to 0.7V, 12.5mV	V_{HD}		V_{HD} -0.025	V_{HD}	V_{HD} +0.025	V
			V_{HD} -0.050	**V_{HD}**	**V_{HD} +0.050**	
Charger Detection Voltage	V_{CHA}		V_{DD} +0.07	V_{DD} +0.12	V_{DD} +0.2	V
			V_{DD} +0.02	**V_{DD} +0.12**	**V_{DD} +0.25**	
Detection Current						
Overcharge Current Detection Current	I_{OCC}	V_{DD}=3.5V	2.1	3.0	3.9	A
			1.9	**3.0**	**4.1**	
Overdischarge Current 1 Detection Current	I_{ODC1}	V_{DD}=3.5V	2.1	3.0	3.9	A
			1.9	**3.0**	**4.1**	
Overdischarge Current 2 Detection Current	I_{ODC2}	V_{DD}=3.5V	7.5	9.0	10.5	A
			7.0	**9.0**	**11.5**	
Load Short-Circuiting Detection Voltage	V_{SHORT}	V_{DD}=3.5V	1.20	1.25	1.30	V
			1.15	**1.25**	**1.35**	

Electrical CharacteristiTC for TC6001F (Continued)

Typicals and limits appearing in normal type apply for T_A = 25°C. Limits appearing in **Boldface** type apply for T_A= -40°C to 85°C, unless otherwise specified.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Current Consumption						
Current Consumption in Nor- mal Operation	I_{OPE}	V_{DD}=3.5V VM pin floating	1.0	2.0	3.0	uA
			0.7	**2.0**	**4.0**	
Current Consumption in power Down	I_{DDQ}	V_{DD}=2.0V VM pin floating			0.01	uA
					0.1	
VM Internal Resistance						
Internal Resistance between VM and V_{DD}	R_{VMD}	V_{DD}=3.5V VM=1.0V	13	20	30	KΩ
			10	**20**	**40**	
Internal Resistance between VM and GND	R_{VMS}	V_{DD}=2.0V VM=1.0V	300	450	675	KΩ
			225	**450**	**900**	
FET on Resistance						
Equivalent FET on Resistance	$R_{DS(ON)}$	V_{DD}=4.0V I_{VM} =1.0A		48	53	m Ω
		V_{DD}=3.6V I_{VM} =1.0A		49		
		V_{DD}=3.0V I_{VM} =1.0A		53		
Over Temperature Protection						
Over Temperature Protection	T_{SHD+}			120		°C
Over Temperature Recovery Degree	T_{SHD-}			100		
Detection Delay Time						
Overcharge Voltage Detection Delay Time	t_{CU}		0.96	1.2	1.4	s
			0.7	**1.2**	**2.0**	
Overdischarge Voltage Detection Delay Time	t_{DL}		115	144	173	ms
			80	**144**	**245**	
Overdischarge Current 1 Detection DelayTime	t_{ODC1}	V_{DD}=3.5V	7.2	9.0	11	ms
			5.0	**9.0**	**15**	
Overdischarge Current 2 Detection DelayTime	t_{ODC2}	V_{DD}=3.5V	3.6	4.48	5.4	ms
			2.4	**4.48**	**7.6**	
Load Short-Circuiting Detec- tion Delay Time	t_{SHORT}	V_{DD}=3.5V	220	320	380	us
			150	**320**	**540**	
Overcharge Current Detection Delay Time	t_{OCC}	V_{DD}=3.5V	7.2	9.0	11	ms
			5.9	**9.0**	**15**	

Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Supply Voltage (between V_{DD} and GND)	V_{DD}	0	8.0	V
Charger Input Voltage (between VM and GND)	VM	V_{DD} -10.0	10.0	V
Junction Temperature	T_{JMAX}		150	°C
Storage Temperature Range	T_{STG}	-55	125	°C
Power Dissipation	P_{MAX}		500	mW
ESD: Human Body Mode	HBM		2000	V
ESD: Machine Mode	MM		200	V

Note: Stresses greater than 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 guaranteed. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

4. Functional Description

The TC6001 series monitors the voltage and current of a battery and protects it from being damaged due to overcharge voltage, overdischarge voltage, overdischarge current, and short circuit conditions by disconnecting the battery from the load or charger. These functions are required in order to operate the battery cell within specified limits.

The device requires only one external capacitor. The MOSFET is integrated and has a low Equivalent $R_{DS(ON)}$ of 48 mΩ typical.

The TC6001 series supports four operating modes: normal, discharge, charge, and low power.

4.1 Normal operating mode

If no exception condition is detected, charging and discharging can be carried out freely. This condition is called the normal operating mode.

4.2 Overcharge voltage condition

When the battery voltage becomes higher than the overcharge detection voltage (V_{CU}) during charging under the normal condition and the detection continues for a period equal to overcharge voltage detection delay time (t_{CU}) or longer, the TC6001 series will control the internal MOSFET to stop charging. This condition is called the overcharge voltage condition. If the error condition clears within overcharge voltage detection delay time (t_{CU}), no action will be taken.

The overcharge condition is released by the following two events:
(1). Charger is connected and the voltage of VM pin is lower than charger detection voltage (V_{CHA}), battery voltage falls below overcharge release voltage (V_{CL}).
(Note: $V_{CL} = V_{CU} - V_{HC}$)
(2). Charger is disconnected and the battery voltage falls below overcharge detection voltage (V_{CU}).

If the charger is disconnected and the battery voltage is still higher than the overcharge detection voltage, the battery will discharge via internal diode.

Notes:
(1). For all devices in this family except TC6001/TC6001F, when a charger is connected after overcharge detection voltage and voltage of VM pin is higher than charger detection voltage (V_{CHA}), overcharge voltage condition is not released even if battery voltage is below overcharge release voltage (V_{CL}). Overcharge voltage condition is released by removing charger.

For the TC6001/TC6001F, whether charger is connected, once V_{DD} is lower than overcharge release voltage (V_{CL}), overcharge voltage condition is released.

(2). During overcharge voltage condition and while battery is disconnected from charger via internal MOSFET, charger input voltage must not exceed maximum voltage rating Vmax defined for the device. Exceeding maximum voltage Vmax may damage the device and battery.

4.3 Overcharge current condition

While operating in the charge condition, if current exceeds I_{OCC} and it continues for overcharge current detection delay time (t_{OCC}) or longer, the IC will control the internal MOSFET to stop charging. This situation is called overcharge current condition.

The TC6001 series continuously monitors current and will release the overcharge current condition as soon as the voltage of VM pin is equal or lower than voltage of V_{DD} pin by connecting an external load which is already connected to battery pack or charger is removed.

4.4 Overdischarge voltage condition

When battery voltage falls below overdischarge detection voltage (V_{DL}) during discharging under normal condition and detection continues for overdischarge detection delay time (t_{DL}) or longer, the TC6001 series disconnects the battery from the load to stop further discharging. This situation is called overdischarge voltage condition. When discharge control MOSFET is turned off, VM pin voltage is pulled down by a resistor between VM and GND in the IC (R_{VMS}). When voltage difference between VM and GND is 1.5V (typical) or lower, current consumption is reduced to power-down current consumption (I_{DDQ}). This situation is called the power-down condition.

The power-down condition is released when a charger is connected and voltage difference between pin VM and GND becomes 2.0V (typical) or higher. Additionally, when the battery voltage equals the overdischarge detection voltage (V_{DL}) or is higher, the TC6001 series returns to the normal condition.

4.5 Overdischarge Current Condition (Detection of Overdischarge current1, Overdischarge current 2)
If discharge current exceeds the specified value and condition lasts for overdischarge current detection delay time, battery is disconnected from load. If current drops again below specified value during delay time, no actions will be taken.

The overdischarge current status is reset when impedance between VM pin and GND increases and is equal to or higher than impedance that enables automatic restoration to normal status. Disconnecting load surely restores to normal status from overdischarge current condition.

4.6 Load Short-circuiting condition
If voltage of VM pin is equal or below short circuiting protection voltage (V_{SHORT}), the IC will stop discharging and battery is disconnected from load. The maximum delay time to switch current off is t_{SHORT}.
This status is released when voltage of VM pin is higher than short protection voltage (V_{SHORT}), such as when disconnecting the load.

4.7 Charger Detection
When a battery in overdischarge condition is connected to a charger and provided that voltage of VM pin is equal or higher than charger detection voltage (V_{CHA}), the TC6001 series releases overdischarge condition when battery voltage becomes equal to or higher than overdischarge detection voltage (V_{DL}).

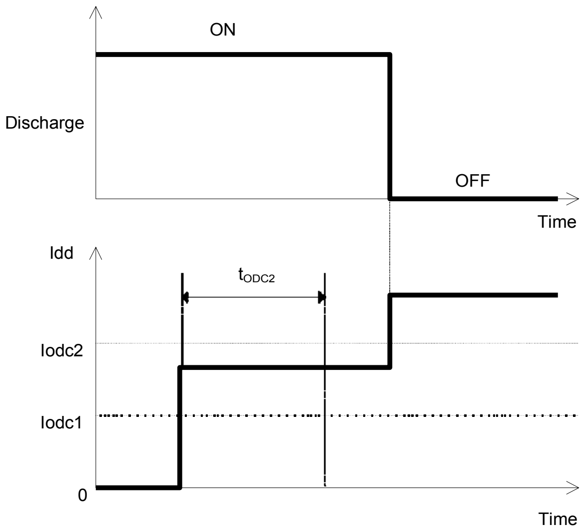
When a battery in overdischarge condition is connected to a charger and provided that voltage of VM pin is equal or higher than 2.0V (typical), and lower than charger detection voltage (V_{CHA}), the TC6001 series releases overdischarge condition when battery voltage reaches overdischarge detection voltage (V_{DL}) +overdischarge voltage hysteresis (V_{HD}) or higher.

4.8 Delay Circuits
The detection delay time for overdischarge current 2 and load short-circuiting starts when overdischarge current 1 is detected. As soon as overdischarge current 2 or load short-circuiting is detected over detection delay time for overdischarge current 2 or load short- circuiting, the TC6001 series stops discharging.

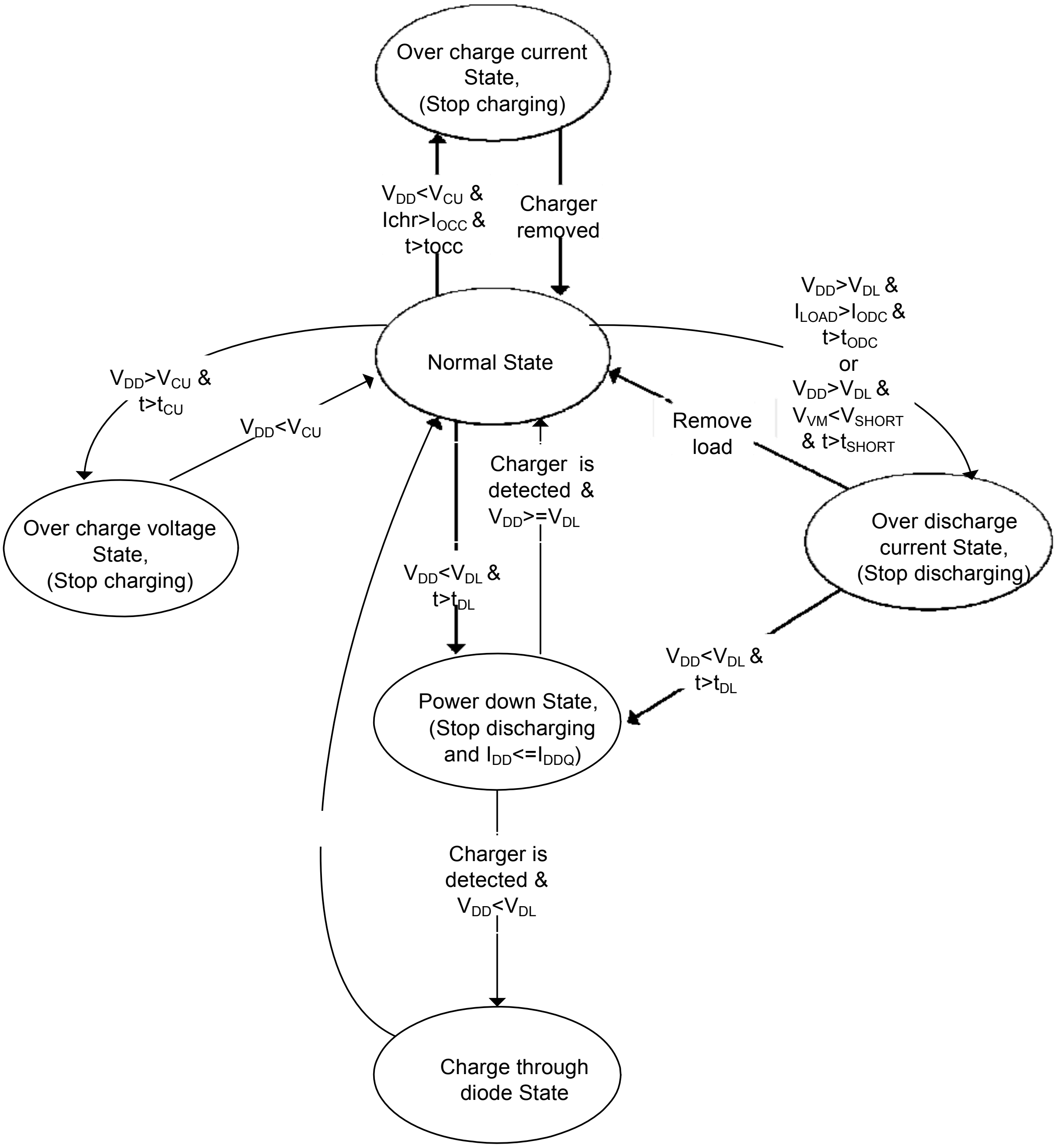
When battery voltage falls below overdischarge detection voltage due to overdischarge current, the TC6001 series stops discharging by overdischarge current detection. In this case the recovery of battery voltage is so slow that if battery voltage after overdischarge voltage detection delay time is still lower than overdischarge detection voltage, the TC6001 series shifts to power-down condition.

4.9 TEN pin
By forcing TEN to Vdd, the dely time of overcharge voltage&current, over dischanrge voltage, overdischarge current1, overdischarge current2 can be reduced. Therefore, testing time of protect circuit board can be reduced.

TEN pin should be left open or connect to GND in the actual application.



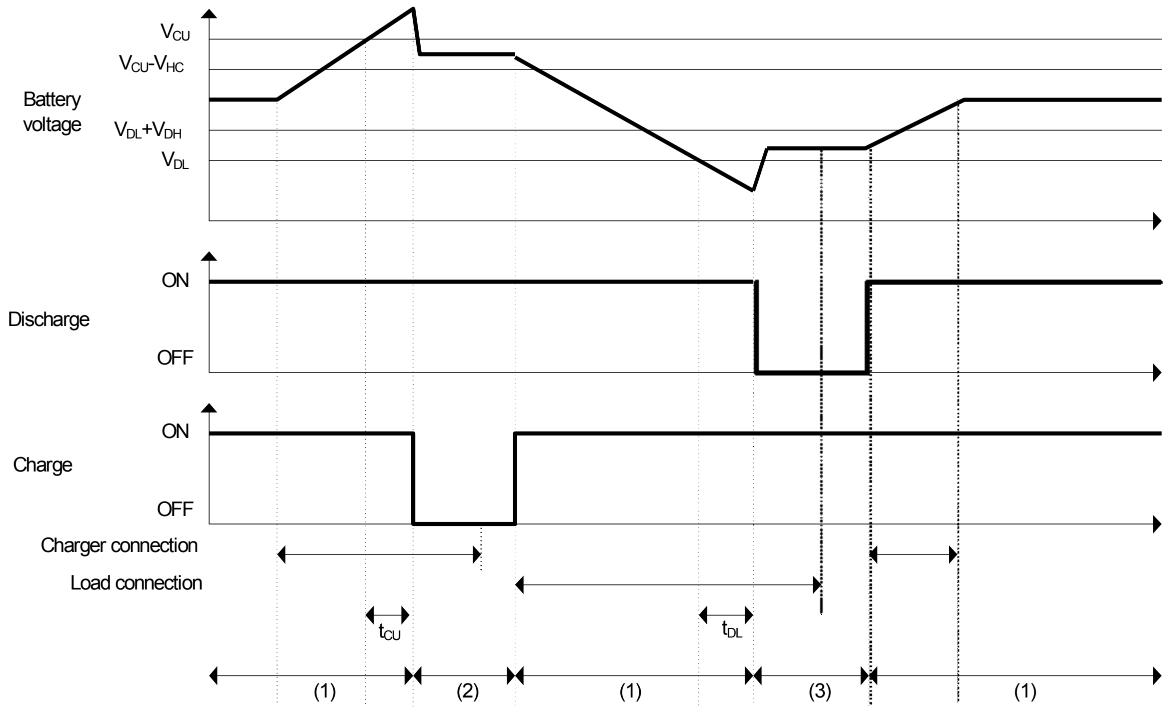
5. State Machine



Note: Ichr: Charge current under charging condition

Figure 2. Operation State Diagram of TC6001 Series

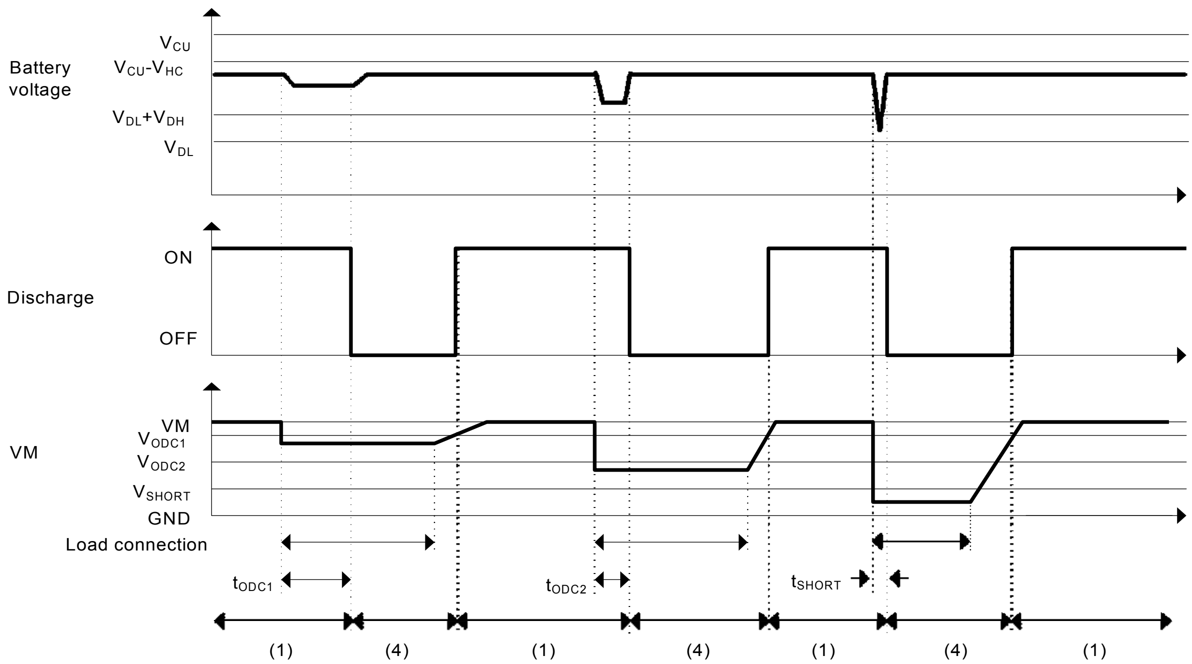
6. Timing



Remark: (1) Normal condition (2) Overcharge voltage condition (3) Overdischarge volatge condition

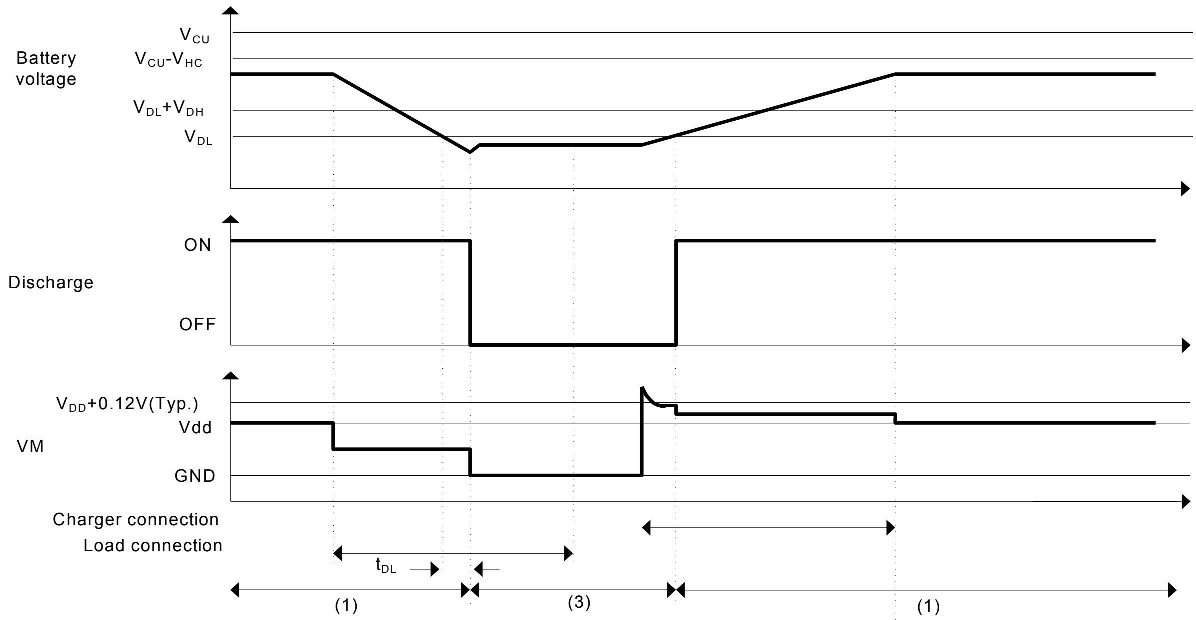
The charger is supposed to charge with constant current

Figure 3. Overcharge and Overdischarge Voltage Detection



Remark: (1) Normal condition (4) Overdischarge current condition

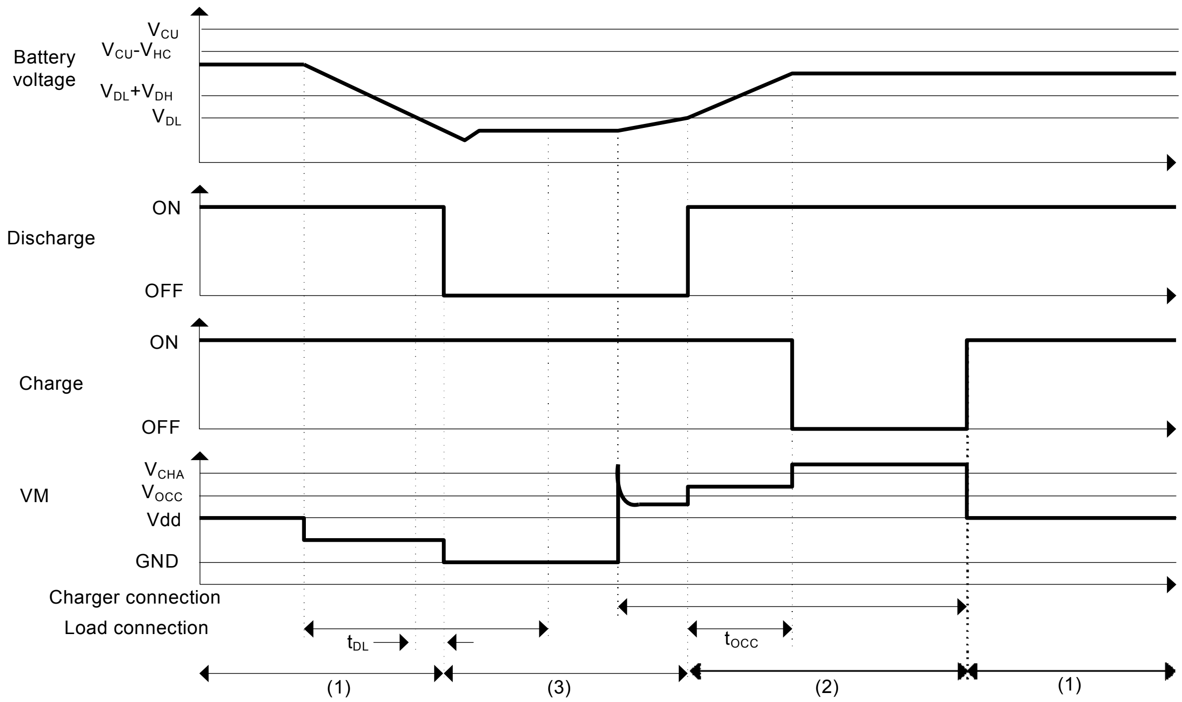
Figure 4. Overdischarge Current Detection



Remark: (1) Normal condition (3) Overdischarge voltage condition

The charger is supposed to charge with constant current

Figure 5. Charger Detection



Remark: (1) Normal condition (2) Overcharge current condition (3) Overdischarge voltage condition

The charger is supposed to charge with constant current

Figure 6. Overcharge Current Detection

7. Measurement Test Setup

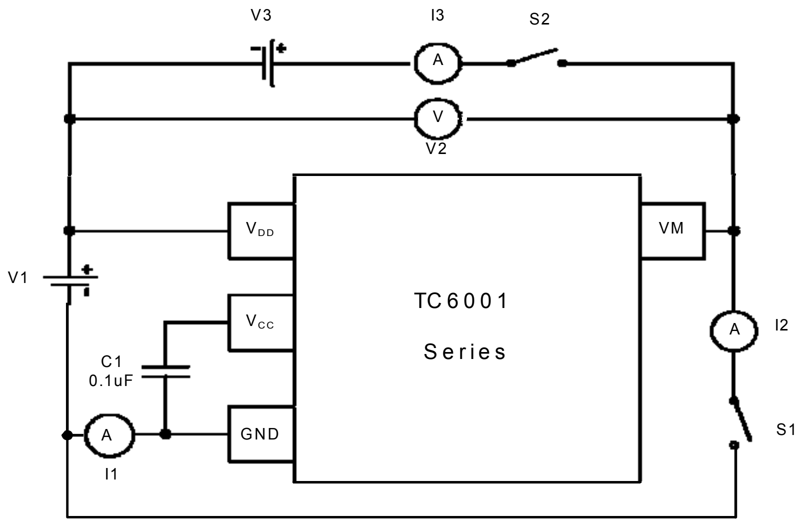


Figure 7. Test Circuit

The test setup in Figure 8 can be used to measure the performance of the battery protection IC. All measurements assume the part is in normal mode.

7.1 Overdischarge Voltage

(Overdischarge detection voltage, low power mode current, Overdischarge release voltage)
Settings:

Battery	V1	3.5V, 10mA Current Limit
Charger	V3	-0.05V, 5mA Current Limit
Switch 1	S1	Open
Switch 2	S2	Closed

Instruction:

- Decrease V1 from 3.5V gradually
- When current I3=0 then overdischarge voltage V1 is detected
- Opening switch 1 and switch 2 to measure I1 current in low power mode
- Close switch 2
- Increase V1 gradually until voltage I3=5mA
- V1 represents the overdischarge release voltage

7.2 Overcharge Voltage

(Overcharge detection voltage, Overcharge release voltage)

Settings:

Battery	V1	3.5V, 10mA Current Limit
Charger	V3	0.05V, 5mA Current Limit
Switch 1	S1	Open
Switch 2	S2	Closed

Instruction:

- Increase V1 from 3.5V gradually
- When current I3=0 then overcharge voltage V_{CU} is detected
- Decrease overcharge voltage V1 gradually
- When current I3=5mA then overcharge release voltage V_{CL} is detected
- Hysteresis voltage is calculated by $V_{CH}=V_{CU}-V_{CL}$

7.3 Overdischarge Current

Settings:

Battery	V1	3.5V, 10mA Current Limit
Charger	V3	-2.0V, 10mA Current Limit
Switch 1	S1	Open
Switch 2	S2	Closed

Instruction:

- Increase current limit settings of charger V3 rapidly (within 10∝s) from its starting point, When current I3=0 whose delay time lies between the minimum and maximum value of overdischarge current 1 delay time (t_{ODC1}), then overdischarge current 1 is detected
- Open switch2
- Increase current limit settings of charger V3 rapidly (within 10∝s) from its starting point, When current I3=0 whose delay time lies between minimum and maximum value of overdischarge current 2 delay time (t_{ODC2}), then overdischarge current 2 is detected
- Open switch2
- Increase current limit settings of charger V3 rapidly (within 10∝s) from its starting point, When current I3=0 whose delay time lies between minimum and maximum value of short circuiting detection delay time (t_{SHORT}), then voltage of VM is the short circuiting detection voltage

7.4 Overcharge Current

Settings:

Battery	V1	3.5V, 10mA Current Limit
Charger	V3	2.0V, 10mA Current Limit
Switch 1	S1	Open
Switch 2	S2	Closed

Instruction:

- Increase current limit settings of charger V3 rapidly (within 10∝s) from its starting point, When current I3=0 whose delay time lies between minimum and maximum value of overcharge current delay time (t_{OCC}), then overcharge current I_{OCC} is detected
- Open switch 2
- Close switch 1 to connect load with I2=10mA
- Part is released into normal mode

8. Typical Application

As shown in Figure 8, the bold line is the high density current path which must be kept as short as possible. For thermal management, ensure that these trace widths are adequate. C1 is a decoupling capacitor which should be placed as close as possible to the IC. These principles are implemented in Figure 9, the typical PCB layout.

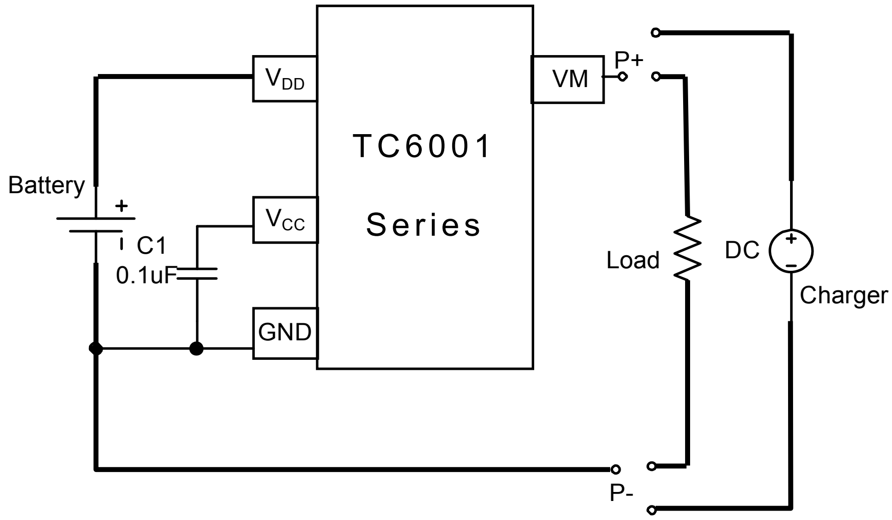


Figure 8. TC6001 Series in a Typical Battery Protection Circuit

Note: C1 is used for protecting power fluctuation. Recommended typical value is 0.1uF (min 0.022uF, max 1.0uF).

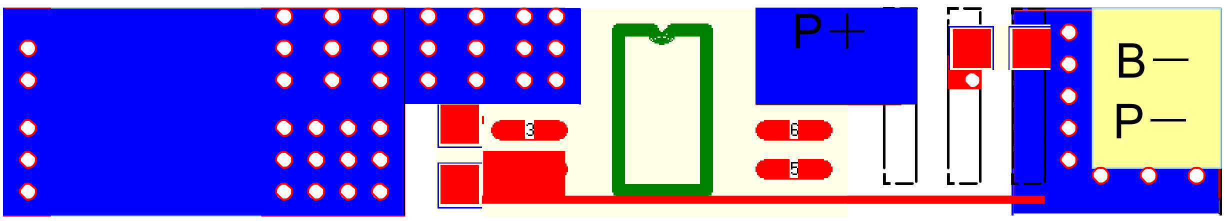
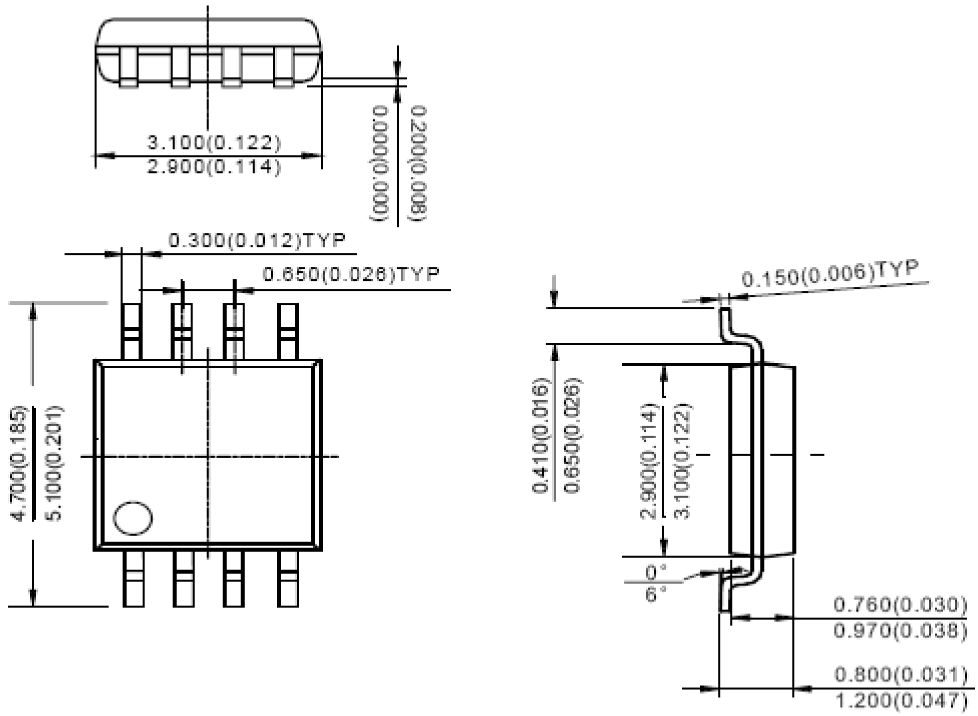


Figure 9. Typical PCB Layout

Note: Red is Top, Blue is Bottom; Via resistance: 10mΩ.

9. Package Dimensions



Note: unit: mm (inch)

Figure 10. Package Outline Drawing

10. Ordering Information

TC6001 □ □ □

Circuit Type

Extension Code

X: Tape and Reel
Blank: Tube

Package
K: MSOP-8

Package	Temperature Range	Part Number	Marking ID	Packing Type
MSOP-8	-40 to 85°C	TC6001FKX	6001F	Tape & Reel

Product Family Available

Product Model	Overcharge Detection Voltage (V_{CU})	Overcharge Hysteresis Voltage (V_{HC})	Overdis-charge Detection Voltage (V_{DL})	Overdis-charge Hysteresis Voltage (V_{HD})	Overdis-charge Current 1 (I_{ODC1})	Overdis-charge Current 2 (I_{ODC2})	Overcharge Voltage Detection Delay Time(t_{CU})
TC6001F	4.275V	0.20V	2.5V	0.4V	3.0A	9.0A	1200ms

11. ENVIRONMENTAL, MANUFCTURING, & HANDING INFORMATION

Part Number	Peak Reflow Temp	MSL Rating*	Max Floor Life
TC6001 Series	260°C	min 3	min 7 Days

* MSL (Moisture Sensitivity Level) as specified by IPC/JEDEC J-STD-020.

12. REVISION HISTORY

Revision	Date	Changes
V1.1	Nov 2008	Preliminary Release

Contacting TopChip Semiconductor Support

For all product questions and inquiries contact TopChip Semiconductor.

To find the one nearest to you go to www.topchipsemi.com