Preliminary Datasheet

TinyShield™ BATTERY PROTECTOR AND MOSFET COMBO CR6002

General Description

The CR6002 is a member of CARETTA's TinyShield™ Battery Protector product family. It uses the company's properitary **patent pending** (US & China) smart switch technology to implement on-chip MOSFETs thus reduces manufacturing cost and increases reliability. The device is designed to protect single cell Li-Ion and Li-Pol battery packs from either overcharge, overdischarge, or overcurrent.

The device contains all required protection control circuits together with very low resistance MOSFETs to minimize the number of external components. It incorporates overcharge voltage and current protections, overdischarge voltage and current protections, overtemperature protection, short circuit protection and operates with very low 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 time.

Features

1. No External MOSFETs Required
2. Equivalent of 29mΩ $R_{DS(ON)}$ on-chip MOSFET
3. Only one external capacitor required in application
4. Overcharge Current Protection
5. Three Step Overcurrent Detection: Overdischarge Current 1, Overdischarge Current 2 and Load Short-Circuiting
6. Charger Detection Function
7. Overcharge Current Detection Function
8. 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}) are generated internally. No external capacitor is necessary. Accuracy: ± 20%
9. High Accuracy Voltage Detection
   - Overcharge Detection Voltage: 3.9V to 4.4V (Applicable in 12.5mV Step) . Accuracy: ± 25mV
   - Overcharge Hysteresis Voltage: 0.0V to 0.4V. Accuracy: ± 25mV
   - Overdischarge Detection Voltage: 2.0V to 3.0V (12.5mV step). Accuracy: ± 25mV
   - Overdischarge Hysteresis Voltage: 0.0V to 0.7V. Accuracy: ± 25mV
10. Low current consumption
    - Operation mode: 2.0μA typ., 4.0μA max.
    - Power-down mode: 0.1μA max.
11. Small outline MSOP-8 Package
12. RoHS Compliant and Lead (Pb)-Free

Applications

- Single cell Lithium-Ion Rechargeable Battery Packs
- Single cell Lithium Polymer Rechargeable Battery Packs

Pin Configuration

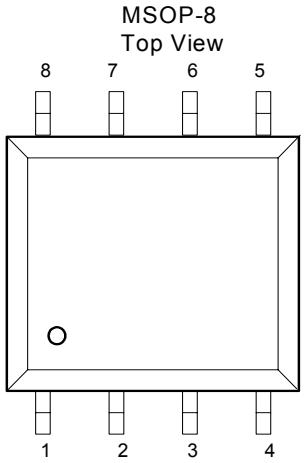


Figure 1. Pin Configuration of CR6002

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			Connect to GND
6			Connect to GND
7	VM	I/O	Positive charge input, overcurrent detection
8	VM	I/O	Positive charge input, overcurrent detection

Functional Block Diagram

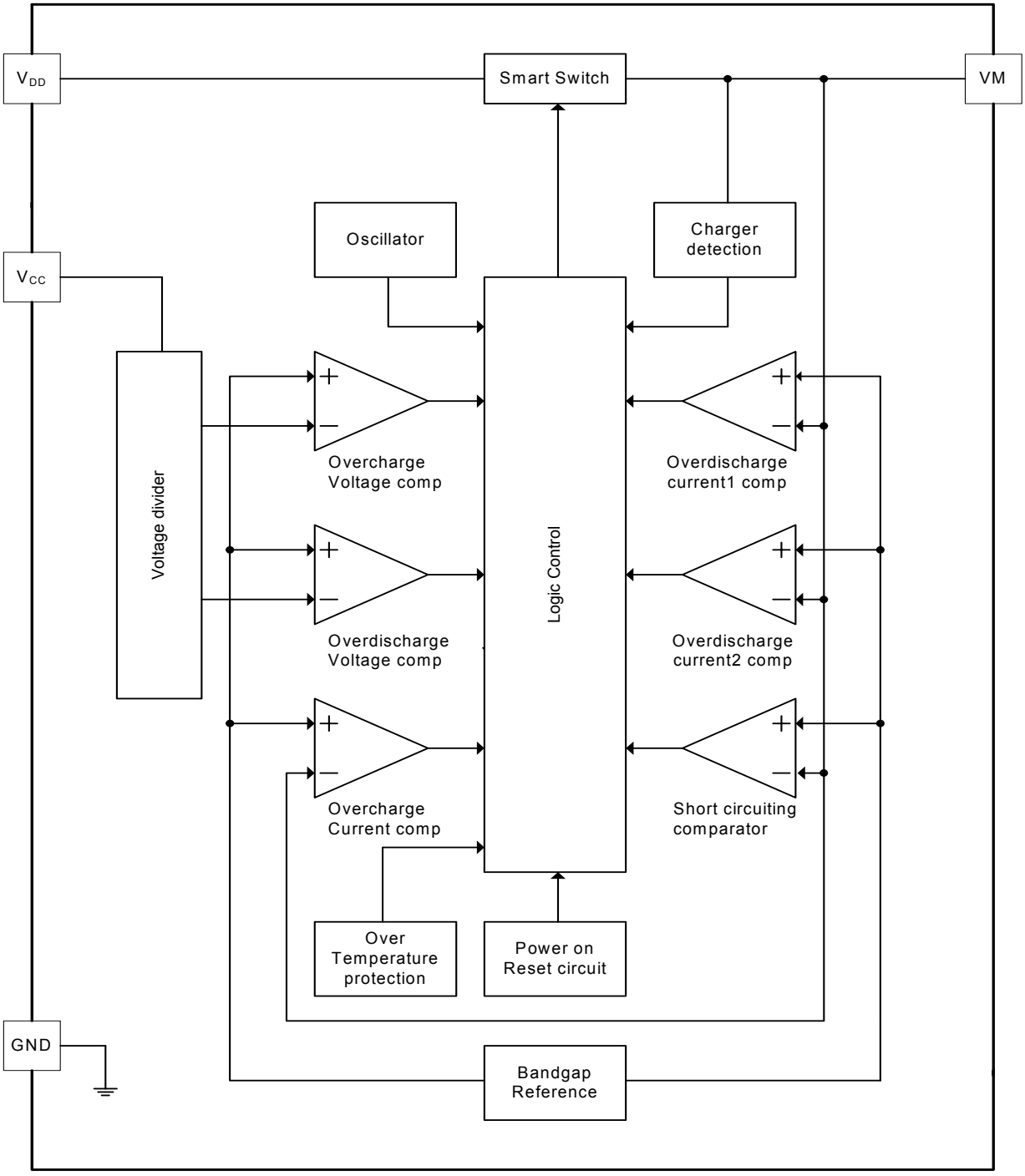
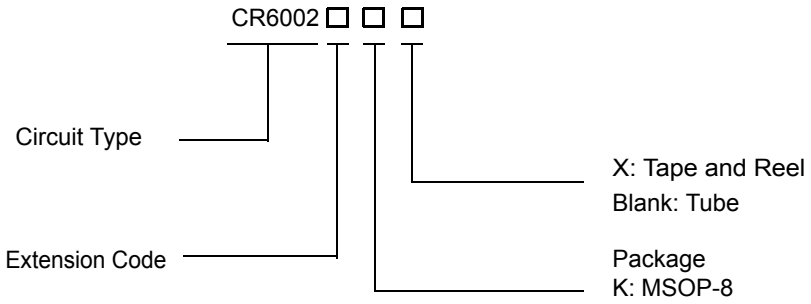


Figure 2. Functional Block Diagram

Ordering Information



Package	Temperature Range	Part Number	Marking ID	Packing Type
MSOP-8	-40 to 85°C	CR6002AKX	6002A	Tape & Reel
MSOP-8	-40 to 85°C	CR6002BKX	6002B	Tape & Reel
MSOP-8	-40 to 85°C	CR6002DKX	6002D	Tape & Reel
MSOP-8	-40 to 85°C	CR6002EKX	6002E	Tape & Reel
MSOP-8	-40 to 85°C	CR6002FKX	6002F	Tape & Reel

* Caretta Integrated Circuits's Lead Free products are RoHS compliant.

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})
CR6002A	4.275V	0.25V	2.5V	0.4V	3.0A	6.0A	1200ms
CR6002B	4.275V	0.25V	2.9V	0.4V	3.0A	6.0A	1200ms
CR6002D	4.325V	0.175V	2.5V	0.4V	3.0A	6.0A	500ms
CR6002E	4.325V	0.175V	2.5V	0.4V	3.0A	6.0A	1200ms
CR6002F	4.275V	0.20V	2.5V	0.4V	3.0A	7.5A	1200ms

Absolute Maximum Ratings (Note 1)

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
Storage Temperature Range	T_{STG}	-55	125	^{o}C
Power Dissipation	P_{MAX}		500	mW

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 implied. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

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 Characteristics

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.

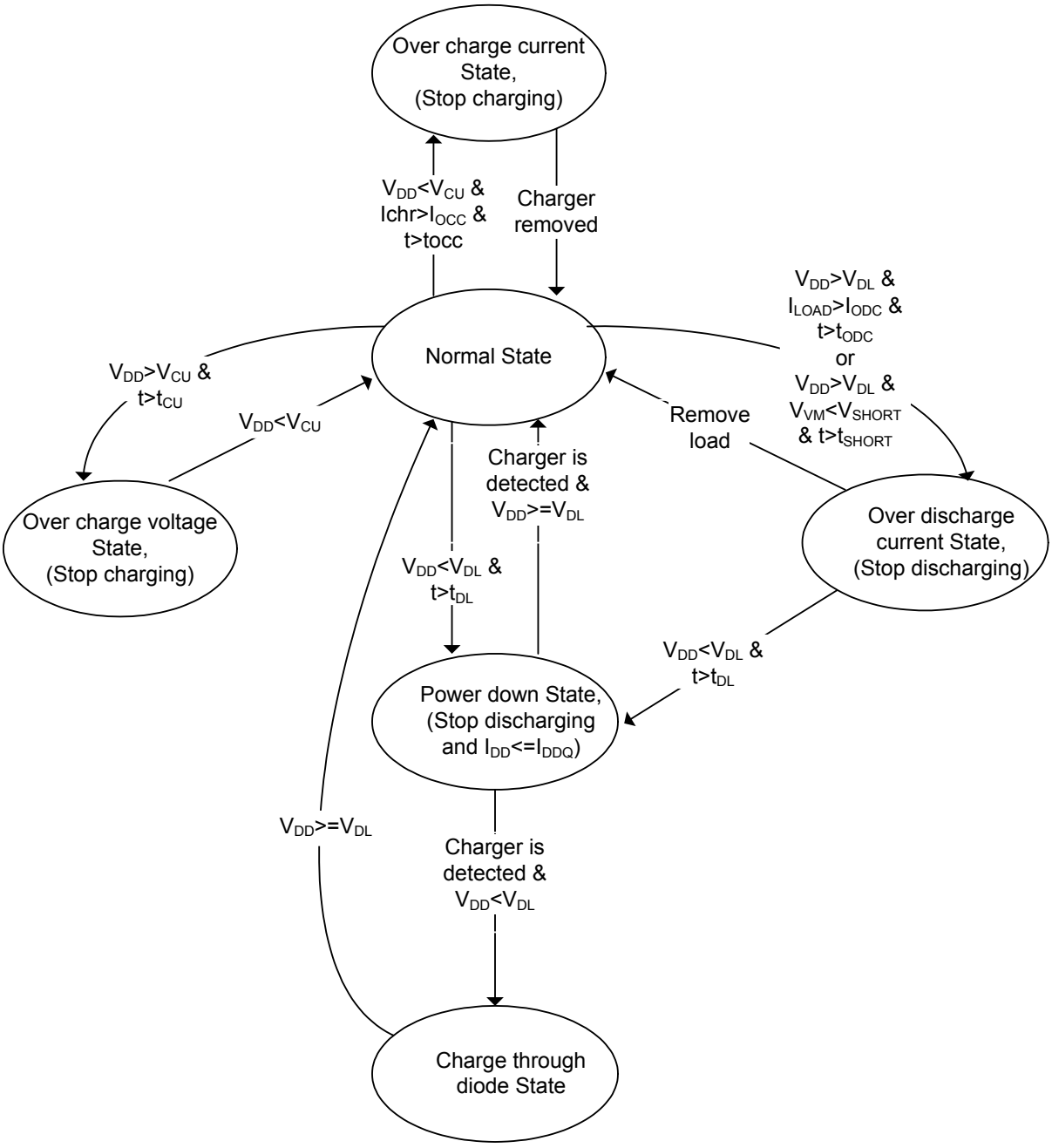
Parameter	Symbol	Test Condition		Min	Typ	Max	Unit
Detection Voltage							
Overcharge Detection Voltage V_{CU}=3.9V to 4.4V, 12.5mV Step	V_{CU}			V_{CU} -0.025	V_{CU}	V_{CU} +0.025	V
				V_{CU} -0.055	**V_{CU}**	**V_{CU} +0.040**	
Overcharge hysteresis voltage V_{HC}=0V to 0.4V, 12.5mV Step	V_{HC}			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 Step	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	P/N: CR6002A /B/D/E/F	2.1	3.0	3.9	A
				1.9	**3.0**	**4.1**	
Overdischarge Current 1 Detection Current	I_{ODC1}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	2.1	3.0	3.9	A
				1.9	**3.0**	**4.1**	
Overdischarge Current 2 Detection Current	I_{ODC2}	V_{DD}=3.5V	P/N: CR6002A /B/D/E	4.5	6.0	7.0	A
				4.0	**6.0**	**8.0**	
			P/N: CR6002F	6.0	7.5	9.0	
				5.5	**7.5**	**10.0**	
Load Short-Circuiting Detection Voltage	V_{SHORT}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	1.20	1.25	1.30	V
				1.15	**1.25**	**1.35**	

Electrical Characteristics (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 Normal Operation	I_{OPE}	V_{DD}=3.5V VM pin floating		1.0	2.0	3.0	μA
				0.7	**2.0**	**4.0**	
Current Consumption in power Down	I_{DDQ}	V_{DD}=2.0V VM pin floating				0.1	μA
						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			29		mΩ
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}		P/N: CR6002A /B/E/F	0.96	1.2	1.4	S
				0.7	**1.2**	**2.0**	
			P/N: CR6002D	0.4	0.5	0.6	
				0.3	**0.5**	**0.8**	
Overdischarge Voltage Detection Delay Time	t_{DL}		P/N: CR6002A /B/D/E/F	115	144	173	mS
				80	**144**	**245**	
Overdischarge Current 1 Detection Delay Time	t_{ODC1}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	7.2	9.0	11	mS
				5.0	**9.0**	**15**	
Overdischarge Current 2 Detection Delay Time	t_{ODC2}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	3.6	4.48	5.4	mS
				2.4	**4.48**	**7.6**	
Load Short-Circuiting Detection Delay Time	t_{SHORT}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	220	320	380	μS
				150	**320**	**540**	
Overcharge Current Detection Delay Time	t_{OCC}	V_{DD}=3.5V	P/N: CR6002A /B/D/E/F	7.2	9.0	11	mS
				5.9	**9.0**	**15**	

Operation State Diagram



Note: Ichr: Charge current under charging condition

Figure 3. Operation State Diagram of CR6002

Function Description

The CR6002 monitors voltage and current of battery and protects the single cell Li-ion battery from being damaged due to overcharge voltage, overdischarge voltage, overdischarge current and short circuit conditions by disconnecting battery from load or charger. These functions are required in order to operate 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 29 mΩ typical.

The CR6002 supports four operating modes: normal, discharge, charge and low power.

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.

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 CR6002 will control internal MOSFET to stop charging. This condition is called the overcharge voltage condition. If error condition disappeared within overcharge voltage detection delay time (t_{CU}), no actions will be taken.

The overcharge condition is released by following two events:
(1). Charger is connected and 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 battery voltage falls below overcharge detection voltage (V_{CU}).

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

Notes:
(1). Except CR6002F, 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.

As to CR6002F, whether is charger 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.

3. Overcharge current condition
Under 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 internal MOSFET to stop charging. This situation is called overcharge current condition.

The CR6002 continuously monitors current and will release the overcharge current condition as soon as 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. 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 CR6002 disconnects battery from 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 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 power-down condition.

Function Description (Continued)

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. Moreover when battery voltage becomes overdischarge detection voltage (V_{DL}) or higher, the CR6002 returns to the normal condition.

5. Overdischarge Current Condition (Detection of Overdischarge current1, Overdischarge current 2)
If discharge current exceeds 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.

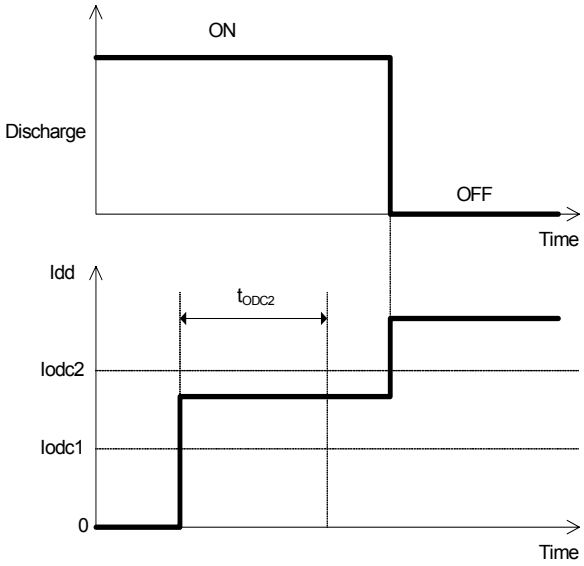
The overdischarge current status is reset when impedance between VM pin and GND increases and is equal to or higher than impedance that enables automatic restoration to normal status. Disconnecting load surely restores to normal status from overdischarge current condition.

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 short protection voltage (V_{SHORT}), such as disconnecting load.

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 CR6002 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 CR6002 releases overdischarge condition when battery voltage reaches overdischarge detection voltage (V_{DL}) +overdischarge voltage hysteresis (V_{HD}) or higher.

8. Delay Circuits
(1). 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 CR6002 stops discharging.



(2). When overdischarge current is detected and continues for longer than overdischarge detection delay time without releasing load, the condition changes to power-down condition when battery voltage falls below overdischarge detection voltage. When battery voltage falls below overdischarge detection voltage due to overdischarge current, the CR6002 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 CR6002 shifts to power-down condition.

Operation Timing Chart

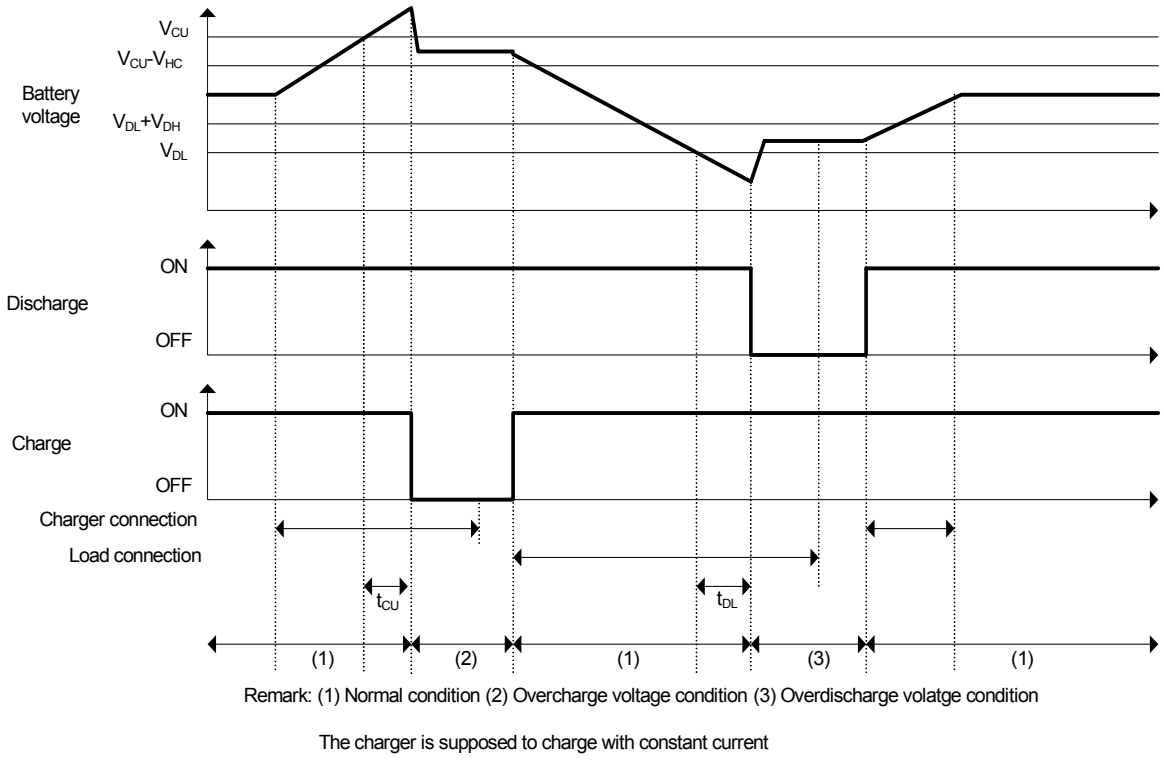
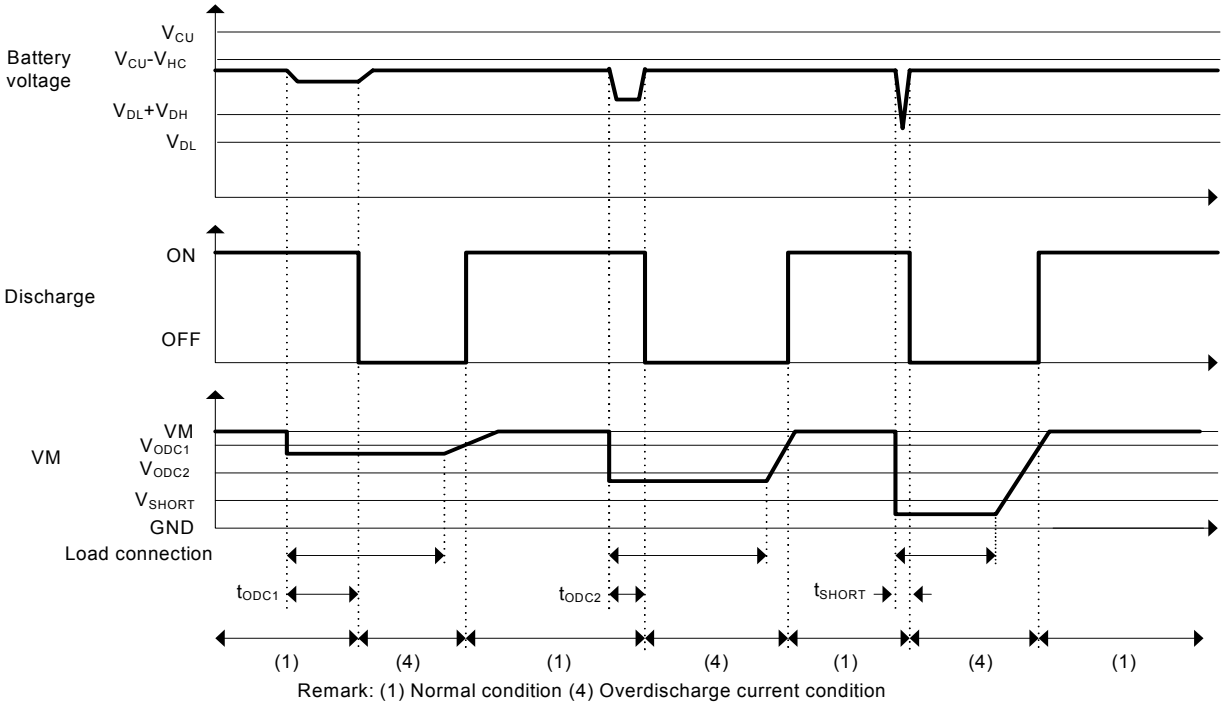


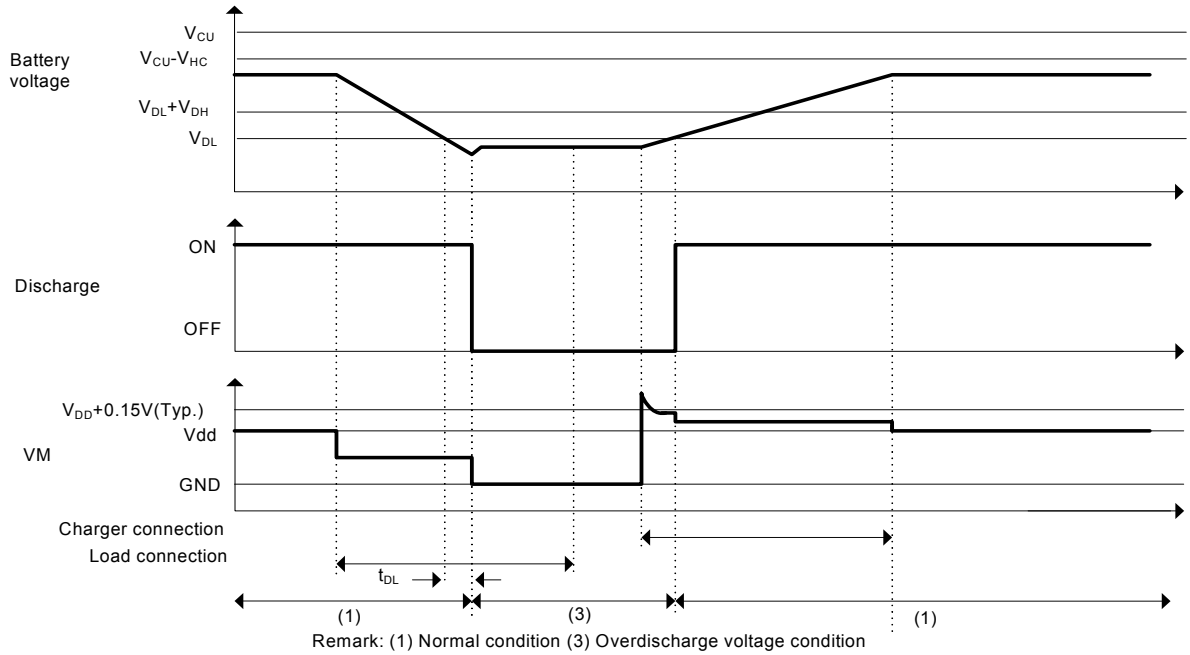
Figure 4. Overcharge and Overdischarge Voltage Detection

Operation Timing Chart (Continued)



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

Figure 5. Overdischarge Current Detection

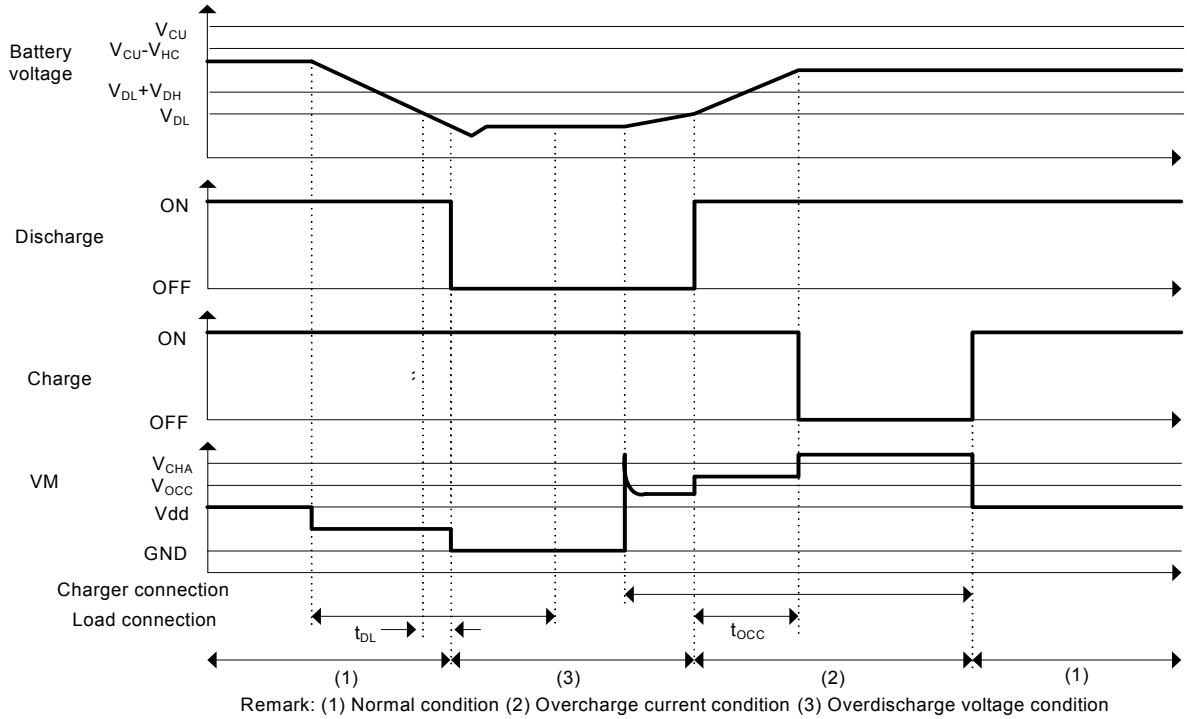


Remark: (1) Normal condition (3) Overdischarge voltage condition

The charger is supposed to charge with constant current

Figure 6. Charger Detection

Operation Timing Chart (Continued)



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

The charger is supposed to charge with constant current

Figure 7. Overcharge Current Detection

Measurement Test Set-up

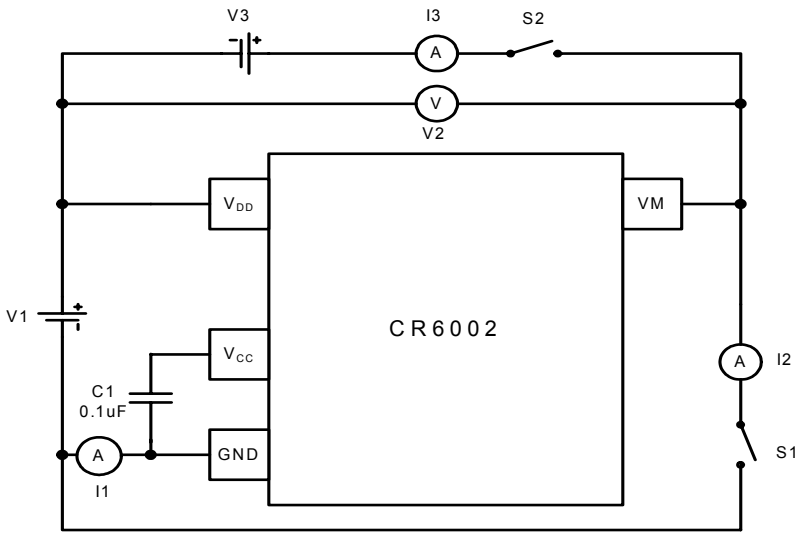


Figure 8. Test Circuit

Measurement Test Set-up (Continued)

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.

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

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 $V_{CH}=V_{CU}-V_{CL}$

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 10μs) 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 10μs) 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 10μs) 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

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

Measurement Test Set-up (Continued)

Instruction:

- Increase current limit settings of charger V3 rapidly (within 10μs) 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

Typical Application

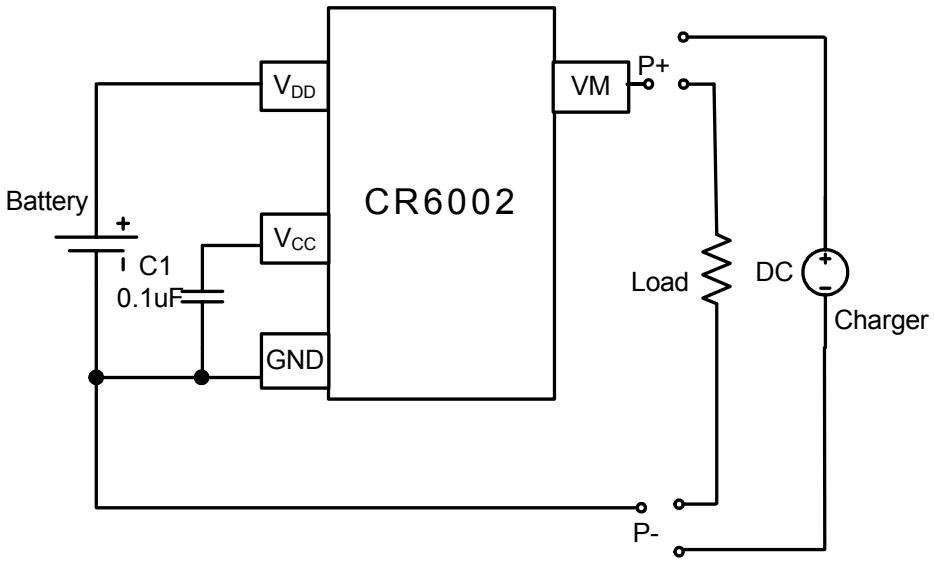


Figure 9. CR6002 in a Typical Battery Protection Circuit

Note: C1 is used for protecting power fluctuation. Recommended value is 0.1μF, minimum value 0.022μF, maximum value 1.0μF.

Mechanical Dimensions

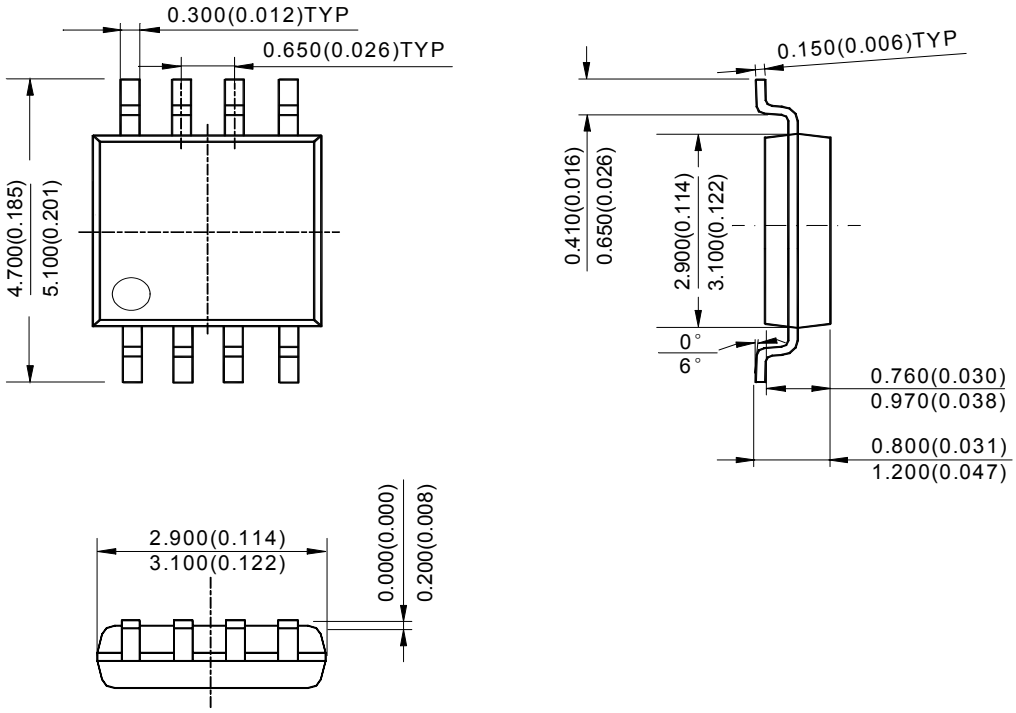


Figure 10. Package Outline Drawing