DESCRIPTION

This protection IC was developed for use with lithium-ion/lithium polymer 1-cell serial batteries.

It detects overcharge, overdischarge, discharge overcurrent and other abnormalities, and functions to protect the battery by turning off the external MOSFET.

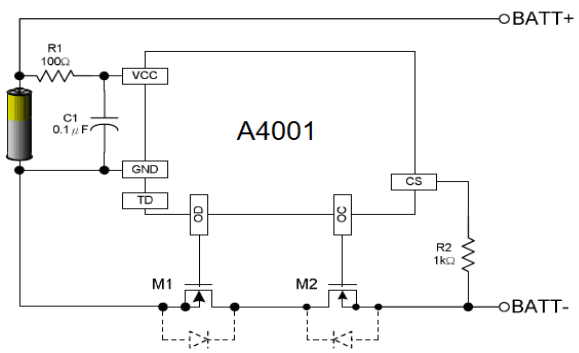
The IC also has a built-in timer circuit (for detection delay times), so fewer external parts can be used in protection circuit configuration.

The A4001 is available in SOT-26 package.

ORDERING INFORMATION

Package Type	Part Number	
SOT-26	E6	A4001E6R
		A4001E6VR
Note	V: Halogen free Package R: Tape & Reel	
AiT provides all RoHS products Suffix " V " means Halogen free Package		

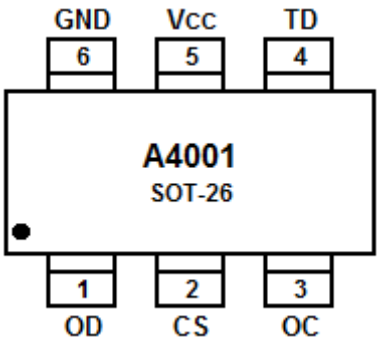
TYPICAL APPLICATION



FEATURES

- High-accuracy voltage detection circuit
  - Overcharge detection voltage
    4.200 to 4.400V; Accuracy: ±50mV
  - Overcharge release voltage
    3.900 to 4.400V; Accuracy: ±50mV
  - Overdischarge detection voltage
    2.30 to 3.00V; Accuracy: ±100mV
  - Overdischarge release voltage
    2.30 to 3.40V; Accuracy: ±100mV
  - Discharge overcurrent detection voltage
    150mV; Accuracy: ±100mV
  - Short-circuiting detection voltage
    1.35V; Accuracy: ±100mV
- Delay times are generated by an internal circuit (external capacitors are unnecessary).
  - Overcharge delay time:100ms typ.
  - Overdischarge delay time: 50ms typ.
  - Discharge overcurrent delay time:10ms typ.
  - Charge overcurrent detection voltage:10ms typ.
  - Short circuit delay time: 5μs typ.
- Power-down function "Yes" / "No" are selectable (See Model List).
- Auto overdischarge recovery function "Yes" / "No" are selectable (See Model List).
- Low current consumption
  - Operation mode: 3.0μA typ. 6.0μA max. (V_{CC}=3.9V)
  - Power-down mode: 0.1μA max. (V_{CC}=2.0V)
  - Auto overdischargemode:2.0μA max. (V_{CC}=2.0V)
- 0V battery charge function "available" / "unavailable" are selectable (See Model List).
- operation temperature range -40℃~+85℃
- Available in SOT-26 Package

PIN DESCRIPTION



Top View

Pin #	Symbol	Direction	Function
1	OD	O	MOSFET gate connection pin for discharge control
2	CS	I	Input pin for current sense, charger detect
3	OC	O	MOSFET gate connection pin for charge control
4	TD	I	Test pin for reduce delay time
5	V_{CC}	-	Power supply, through a resistor (R1)
6	GND	-	Ground pin

ABSOLUTE MAXIMUM RATINGS

GND=0V, Temperature=25℃, unless otherwise specified

V_{CC}, Input voltage between V_{CC} and GND	GND-0.3V~GND+10V
V_{OC}, OC output pin voltage	V_{CC}-14V~V_{CC}+0.3V
V_{OD}, OD output pin voltage	GND-0.3V~V_{CC}+0.3V
V_{CS}, CS input pin voltage	V_{CC}-14V~V_{CC}+0.3V
T_{OP}, Operating Temperature Range	-40℃~+85℃
T_{ST}, Storage Temperature Range	-40℃~+125℃

Stress beyond above listed “Absolute Maximum Ratings” may lead permanent damage to the device. These are stress ratings only and operations of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

MODEL LIST

Param. / Model	Overcharge Detection Voltage	Overcharge Release Voltage	Over discharge Detection	Over discharge Release	0V Battery Charge Function	Other Function
A4001	VOCP	VOCR	VODP	VODR	V0V	-
	4.30V	4.10V	2.40V	3.00V	available	Auto overdischarge recovery function

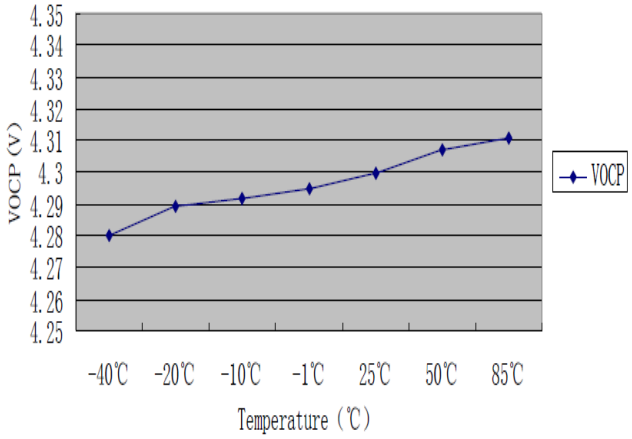
DC ELECTRICAL CHARACTERISTICS

GND=0V, Temperature=25℃, unless otherwise specified

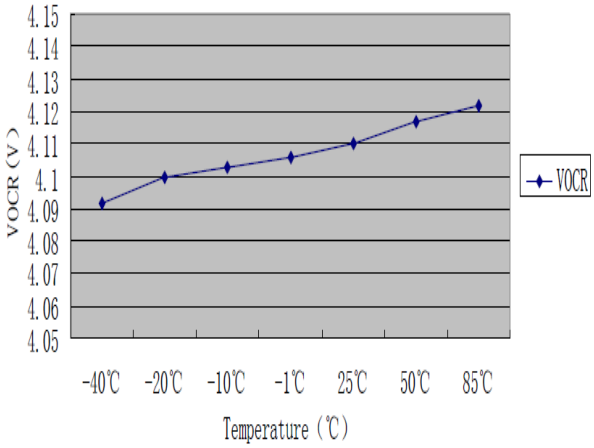
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Current	ICC	V_{CC}=3.9V		3.0	6.0	uA
Power-Down Current	IPD	V_{CC}=2.0V		0.1	0.6	uA
Auto Overdischarge Recovery Current	IOD	V_{CC}=2.0V		2.0	3.0	uA
Overcharge Protection Voltage	VOCP	4.2~4.4V，Adjustable	VOCP-0.05	VOCP	VOCP+0.05	V
Overcharge Hysteresis Voltage	VOCR	3.9~4.4V，Adjustable	VOCR-0.05	VOCR	VOCR+0.05	V
Overdischarge Protection Voltage	VODP	2.3~3.0V，Adjustable	VODP-0.1	VODP	VODP+0.1	V
Overdischarge Release Voltage	VODR	2.3~3.4V，Adjustable	VODR-0.1	VODR	VODR+0.1	V
Overcurrent Protection Voltage	VOI1		120	150	180	mV
Short Current Protection Voltage	VOI2	V_{CC}=3.6V	1.05	1.35	1.65	V
Overcharge Delay Time	TOC			100	200	ms
Overdischarge Delay Time	TOD	V_{CC}=3.6V to 2.0V		50	100	ms
Overcurrent Delay Time (1)	TOI1	V_{CC}=3.6V		10	20	ms
Overcurrent Delay Time (2)	TOI2	V_{CC}=3.6V		5	50	us
Charge Overcurrent Delay Time	TCIP	V_{CC}=3.6V，CS=-1.2V		10	20	ms
Load Detection Threshold Voltage	VLD		0.12	0.15	0.18	V
Charger Detection Threshold Voltage	VCH		-1.2	-0.7	-0.2	V
Charge Overcurrent Detection Voltage	VCIP		-1.2	-0.7	-0.2	V
OD Pin Output “H” Voltage	VODH		V_{CC}-0.1	V_{CC}-0.02		V
OD Pin Output “L” Voltage	VODL			0.1	0.5	V
OC Pin Output “H” Voltage	VOCH		V_{CC}-0.1	V_{CC}-0.02		V
OC Pin Output “L” Voltage	VOCL			0.1	0.5	V
0V Battery Charge Starting Charger Voltage	V0V	0V battery charging Function “available”	1.2			V
0V Battery Charge Inhibition Charger Voltage	V0IN	0V battery charging Function “unavailable”			0.5	V

TYPICAL PERFORMANCE CHARACTERISTICS

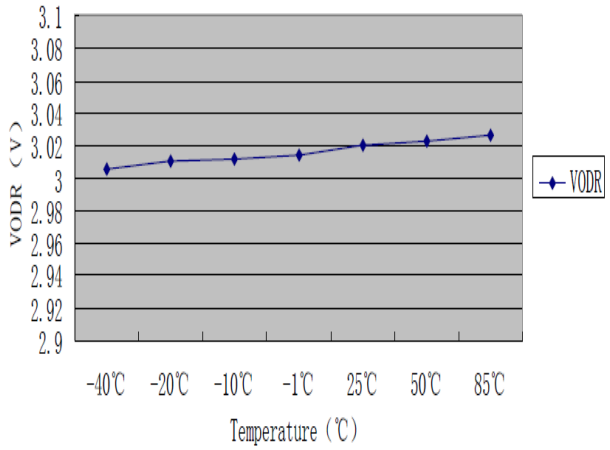
1. VOCP vs. Temperature



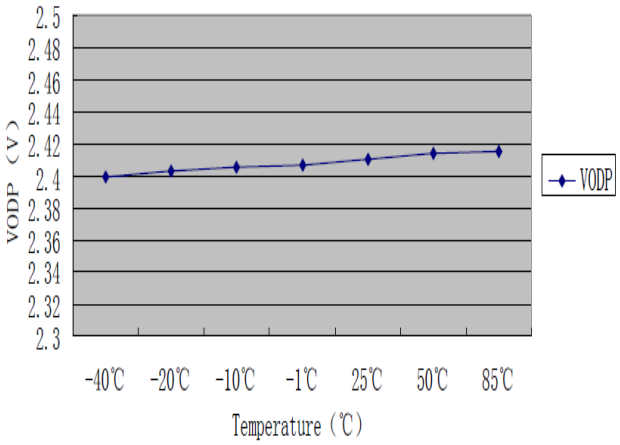
2. VOCR vs. Temperature



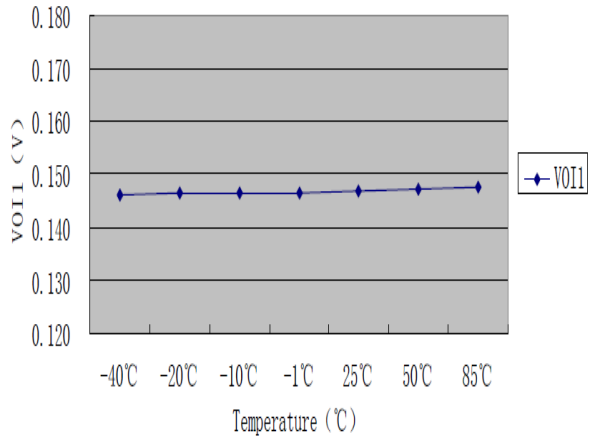
3. VODR vs.Temperature



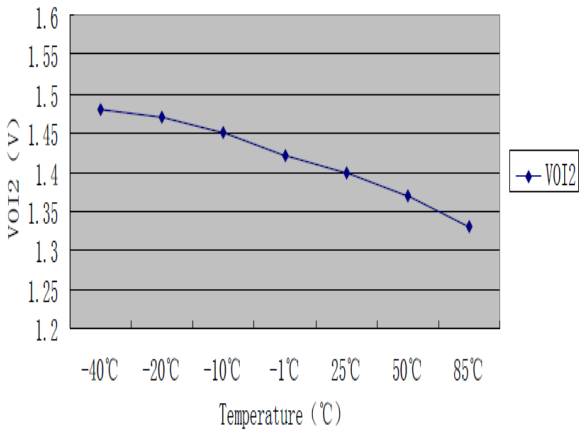
4. VODP vs. Temperature



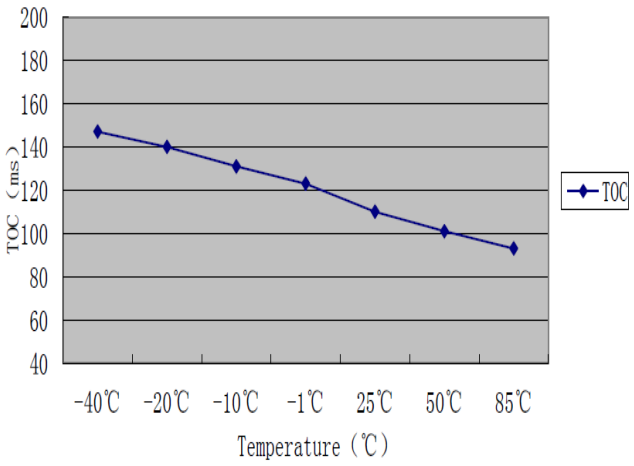
5. VOI1 vs. Temperature



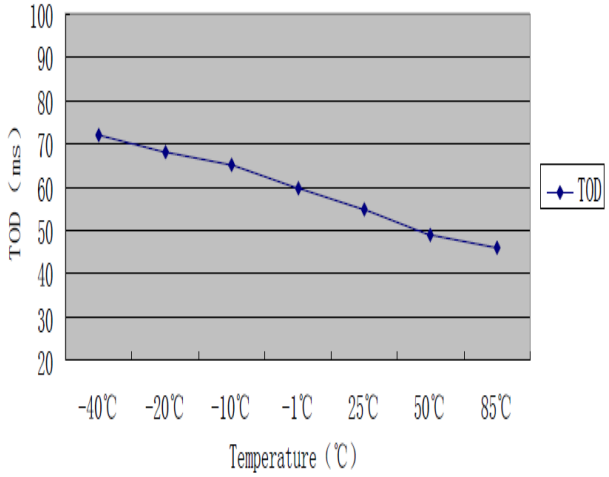
6. VOI2 vs. Temperature



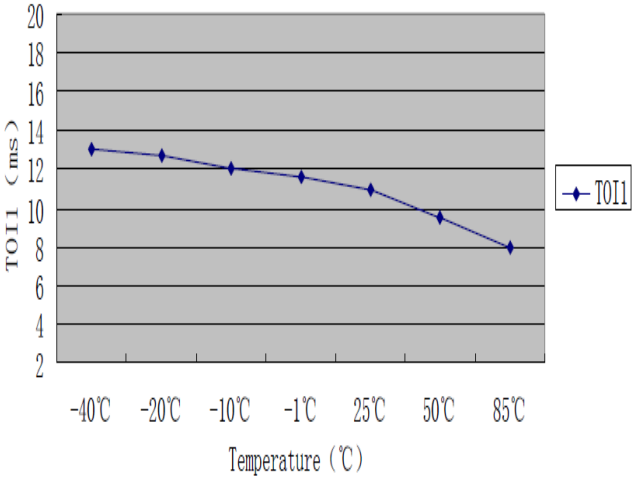
7. TOC vs. Temperature



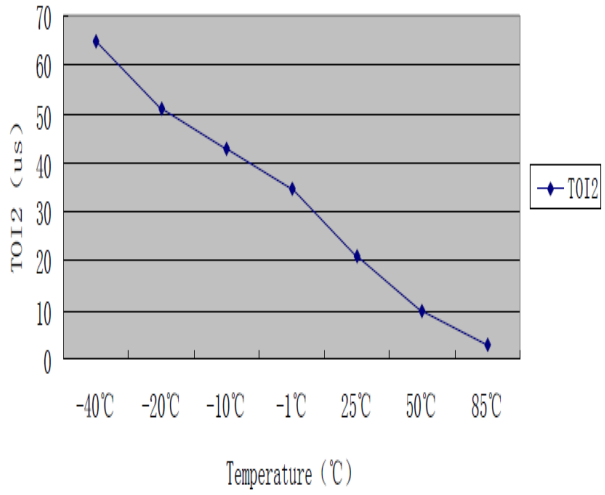
8. TOD vs. Temperature



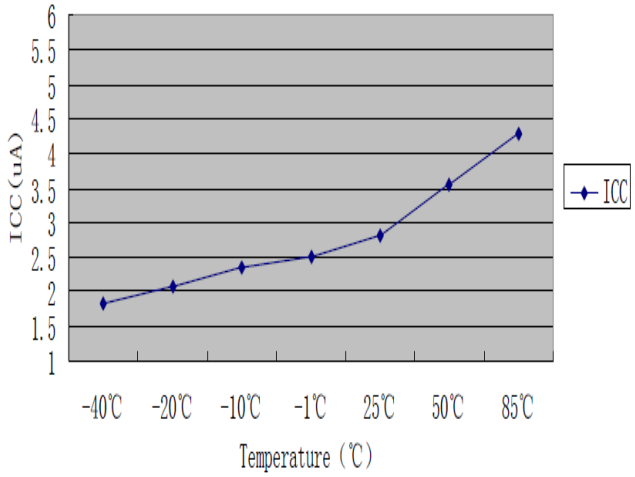
9. TOI1 vs. Temperature



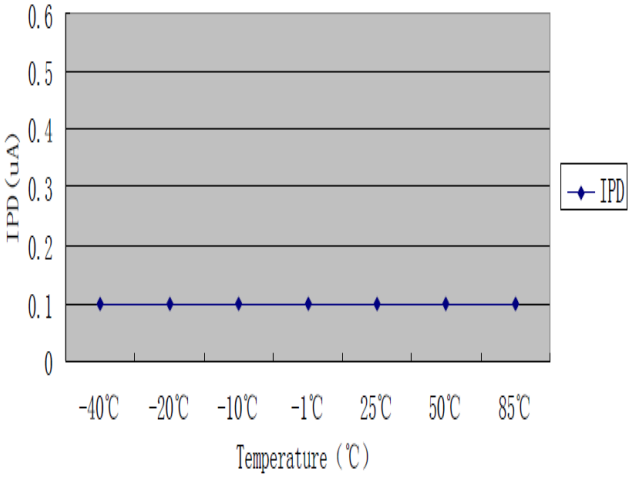
10. TOI2 vs. Temperature



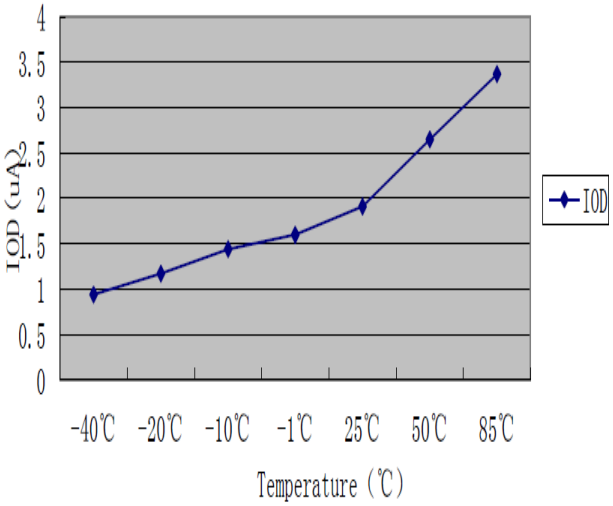
11. ICC vs. Temperature



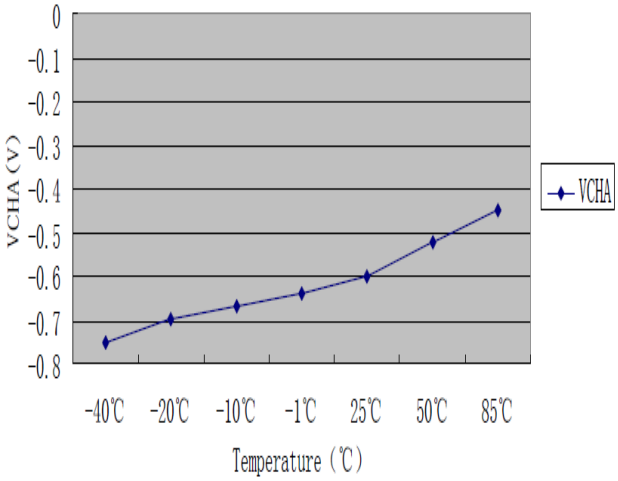
12. IPD vs. Temperature



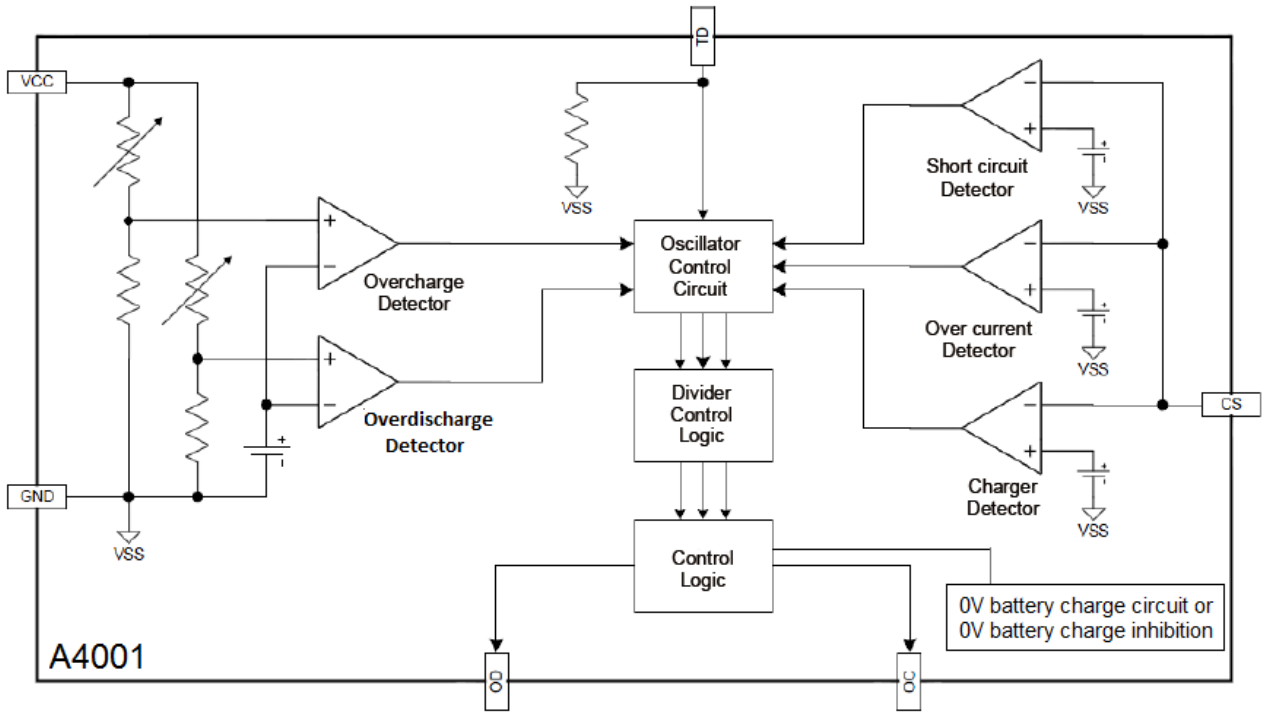
13. IOD vs. Temperature



14. VCHA vs. Temperature



BLOCK DIAGRAM



DETAILED INFORMATION

Normal Condition

This IC monitors the voltage of the battery connected between the V_{CC} 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 overdischarge detection voltage (VODP) to overcharge detection voltage (VOCP), and the CS pin voltage is in the range from the charger detection voltage (VCH) to discharge overcurrent detection voltage (VOI1), the IC turns both the charging and discharging control MOSFET on. This condition is called the normal status. Under this condition, charging and discharging can both be carried out freely.

Caution: Discharging may not be enacted when the battery is first time connected. To regain normal status, CS and GND pin must be shorted or the charger must be connected.

Overcharge Protection

When the voltage of the battery cell exceeds the overcharge protection voltage (VOCP) beyond the overcharge delay time (TOC) period, charging is inhibited by turning off of the charge control MOSFET. The overcharge condition is released in two cases:

(1) The voltage of the battery cell becomes lower than the overcharge release voltage (VOCR) through self-discharge.

(2) The voltage of the battery cell falls below the overcharge protection voltage (VOCP) and a load is connected.

When the battery voltage is above VOCP, the overcharge condition will not release even a load is connected to the pack.

Overdischarge Status

Products with Power-down Function

When the battery voltage falls below than the overdischarge detection voltage (VODR) during discharging in the normal status and the detection continues longer than the overdischarge detection delay time (TOD), the A4001 series will turn the discharging control MOSFET off(OD pin) so as to stop discharging. This condition is called the overdischarge status.

When the MOSFET is off, CS pin voltage is pulled up by the resistor to V_{CC} in the IC, at this time; the power consumption is reduced to the lowest. This condition is called the “SLEEP MODE”.

The overdischarge status will be released by two cases:

(1) When CS pin voltage is equal to or lower than the charge overcurrent detection voltage (VCIP) by charging and the V_{CC} pin voltage is higher than the overdischarge detection voltage (VODR).

(2) When CS pin voltage is equal to or higher than the charge overcurrent detection voltage (VCIP) by charging and the V_{CC} pin voltage is higher than the overdischarge release voltage (VODR).

Products with Auto Overdischarge Recovery Function

When the battery voltage falls below than the overdischarge detection voltage (VODP) during discharging in the normal status and the detection continues longer than the overdischarge detection delay time (TOD), the A4001 series will turn the discharging control MOSFET off(OD pin) so as to stop discharging. This condition is called the overdischarge status.

The overdischarge status will be released by three cases:

(1) When CS pin voltage is equal to or lower than the charge overcurrent detection voltage (VCIP) by charging and the V_{CC} pin voltage is higher than the overdischarge detection voltage (VODP).

(2) When CS pin voltage is equal to or higher than the charge overcurrent detection voltage (VCIP) by charging and the V_{CC} pin voltage is higher than the overdischarge release voltage (VODR).

(3) Without connecting a charger, if the V_{CC} pin voltage is higher than overdischarge release voltage (VODR), the overdischarge status will be released, namely Auto Overdischarge Recovery Function.

Charge Overcurrent Status

When a battery is in the normalstatus, the voltage of the CS pin is lower than the charge overcurrent detection voltage (VCIP). When the charge current is higher than the specified value and the status lasts beyond the charge overcurrent detection delay time(TCIP), the charge control MOSFET will be turned off and charging is stopped. This status is called the charge overcurrent status.

This IC 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 (VCIP) or higher by removing the charger.

0V Battery Charging Function "Available"

This function is used to recharge a connected battery which voltage is 0V due to self-discharge. When the 0V battery charge starting charger voltage (V0V) or a higher voltage is applied between the battery+ (BATT+) and battery- (BATT-) pins by connecting a charger, the charging control MOSFET gate is fixed to the V_{CC} pin voltage.

When the voltage between the gate and the source of the charging control MOSFET becomes equal to or higher than the turn on voltage due to the charger voltage, the charging control MOSFET is turned on to initiate charging. At this time, the discharging control MOSFET is off and the charging current flows through the internal parasitic diode

In the discharging control MOSFET. When the battery voltage becomes equal to or higher than overdischarge detection voltage (VODP), the A4001 series will enter into the normal status.

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 prohibit the 0V battery charging function.

(2) The 0V battery charge function has higher priority than the charge overcurrent detection function. Consequently, a product in which use of the 0V battery charging function is enabled to forcibly charge a battery and the charge current cannot be detected when the battery voltage is lower than overdischarge detection voltage (VODP).

0V Battery Charging Function "Unavailable"

When a battery that is internally short-circuited (0V battery) is connected, the unavailable 0V charging function will prohibit recharging. When the battery voltage equals to the 0V battery charge inhibition battery voltage (V0IN) or lower, the charging control MOSFET gate is fixed to the BATT- pin voltage to prohibit charging. When the battery voltage equals to the 0V battery charge inhibition battery voltage (V0IN) or higher, charging can be implemented.

Caution

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

Selection of External Control MOSFET

Because the overcurrent protection voltage is preset, the threshold current for overcurrent detection is determined by the turn-on resistance of the charge and discharge control MOSFETs. The turn-on resistance of the external control MOSFETs can be determined by the equation: RON=VOI1/(2*IT) (IT is the overcurrent threshold current). For example, if the overcurrent threshold current IT is designed to be 3A, the turn-on resistance of the external control MOSFET must be 25mΩ. Be aware that turn-on resistance of the MOSFET changes perawith temture variation due to heal dissipation. It changes with the voltage between gate and source as well. (Turn-on resistance of MOSFET increases as the voltage between gate and source decreases). As the turn-on resistance of the external MOSFET changes, the design of the overcurrent threshold current changes accordingly.

Suppressing the Ripple and Disturbance form Charger

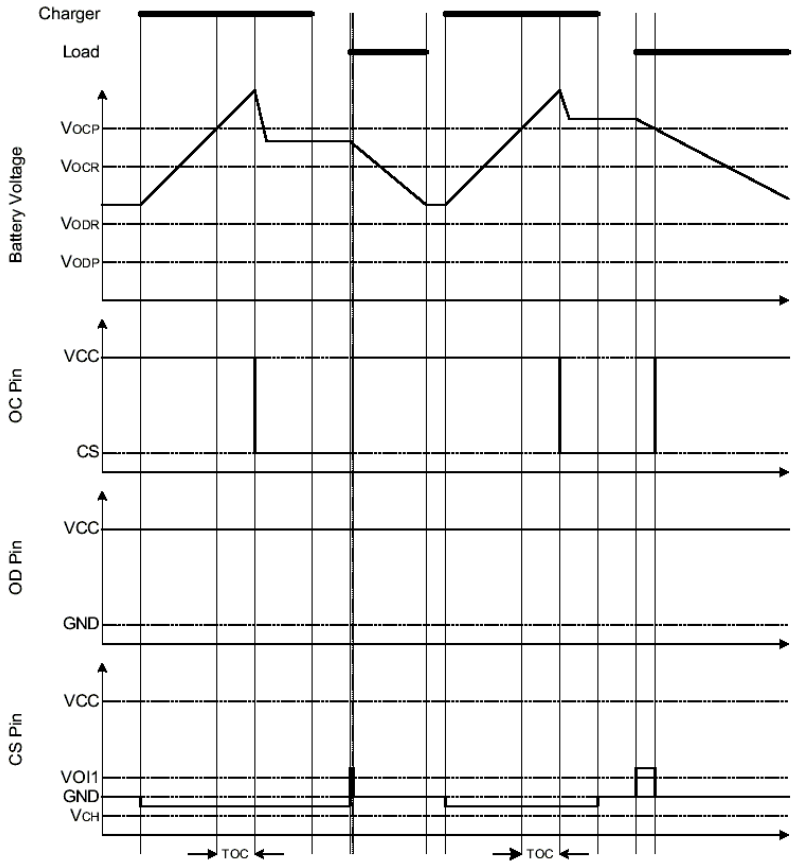
To suppress the ripple and disturbance from charger, connection R1 and C1 to V_{CC} is recommended.

Protection the CS pin

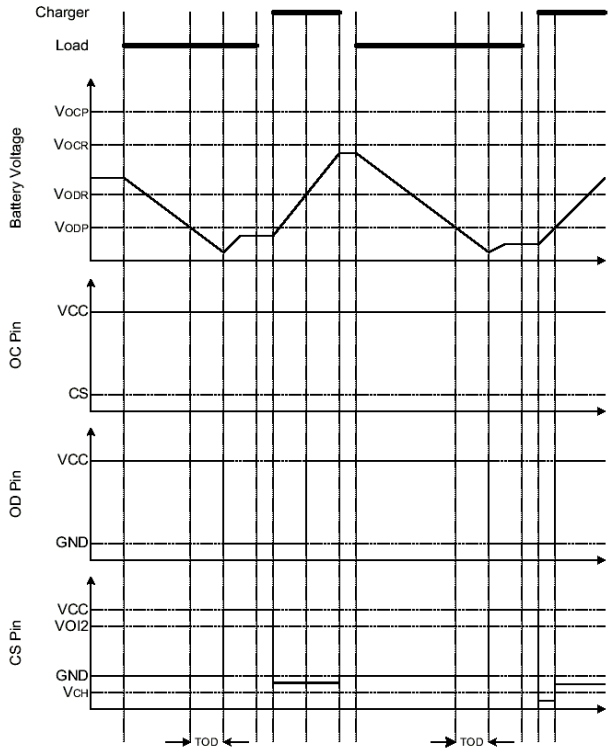
R2 is used for latch-up protection when charger is connected under overdischarge condition and overstress protection at reverse connection of a charger.

Timing Diagram

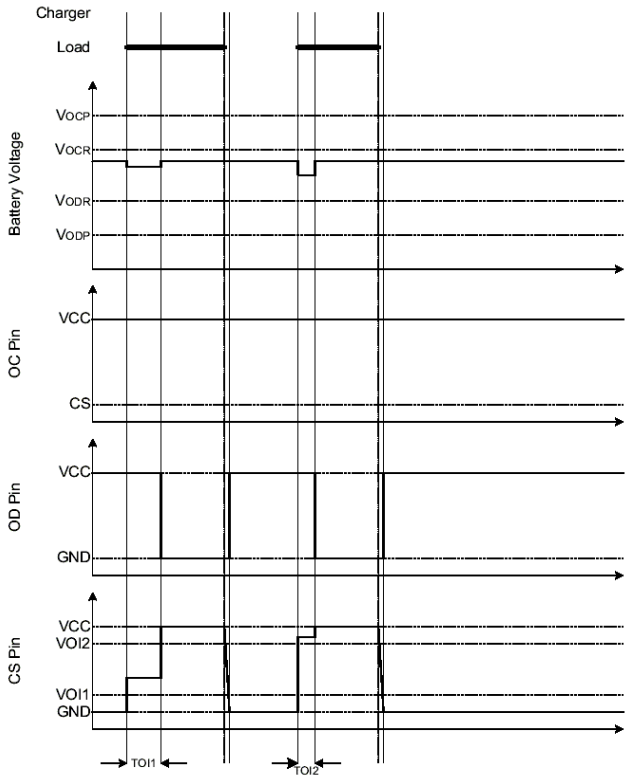
Overcharge Condition→Load Discharging→Normal Condition



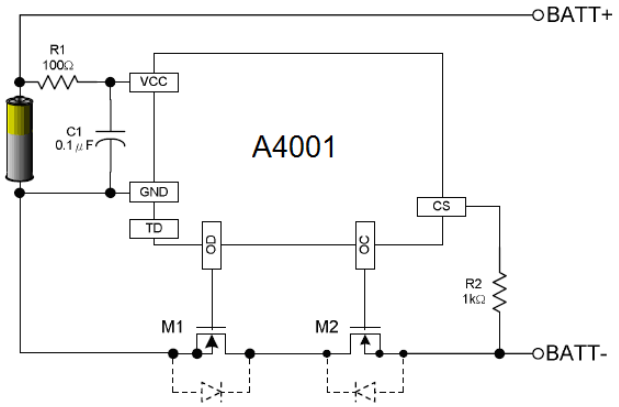
Overdischarge Condition→Charging by a Charger→Normal Condition



Over Current Condition→Normal Condition



Typical Application Circuit



Symbol	Components	Purpose	Min.	Typ.	Max.	Remarks
R1	Resistor	Limit current, stabilize VCC and Strengthen ESD protection	100Ω	100Ω	200Ω	(1)
R2	Resistor	Limit current	1KΩ	1KΩ	2KΩ	(2)
C1	Capacitor	Stabilize VCC	0.01uF	0. 1uF	1.0uF	(3)
M1	N-MOSFET	Discharge control	-	-	-	(4)
M2	N-MOSFET	Charge control	-	-	-	(5)

(1) R1 should be as small as possible to avoid lowering the overcharge detection accuracy due to current consumption. When a charger is connected in reversed, the current flows from the charger to the IC. At this time, if R1 is connected to high resistance, the voltage between V_{CC} pin and V_{SS} pin may exceed the absolute maximum rating.

(2) If R2 has a resistance higher than 2kΩ, the charging current may not be cut when a high-voltage charger is connected. Please select as large a resistance as possible to prevent current when a charger is connected in reversed.

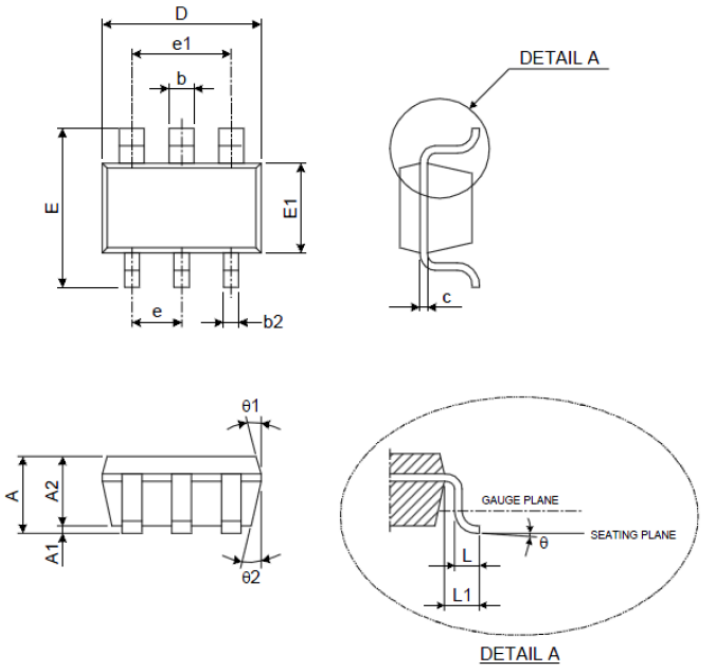
(3) C1 will stabilize the supply voltage of V_{CC} , the value of C1 should be equal to or more than 0.01μF.

(4) If a NMOSFET with a threshold voltage equal to or higher than the overdischarge detection voltage is applied, discharging may be stopped before overdischarge is detected.

(5) If the withstanding voltage between the gate and source is lower than the charger voltage, the FET may be destroyed.

PACKAGE INFORMATION

Dimension in SOT-26 Package (Unit: mm)



SYMBOL	MIN	MAX
A	1.050	1.350
A1	0.050	0.150
A2	1.000	1.200
b	0.400	0.550
b2	0.250	0.400
c	0.080	0.200
D	2.7000	3.000
E	2.600	3.000
E1	1.500	1.700
L	0.350	0.550
L1	0.600(REF)	
e	0.950(BSC)	
e1	1.900(BSC)	
θ	0°	10°
θ1	3°	7°
θ2	6°	10°

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