Datasheet

# FS8601Hx

One Cell Lithium-ion/Polymer Battery Protection IC With Built-in MOSFET



Fortune SEMICONDUCTOR CORPORATION

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## 1. General Description

FS8601Hx is a series of lithium-ion and lithium-polymer rechargeable battery protection ICs with high accurate voltage detection and delay circuits.

These Ics are suitable for protection of single cell lithium-ion or lithium polymer battery packs from over charge, over discharge and over current.

## 2. Features

- **With built-in N-MOSFET of low turn-on resistance.**
- **Reduction in Board Size due to Miniature Package DFN-5.**
- **Protection IC：**
  - **Low supply current**
    **Normal Operation : 2.5μA (typ.)**
    **@VDD=3.9V**
    **Power-down mode : 0.05μA (typ.)**
    **@VDD=2.0V**
  - **Overcharge detection voltage**
    **〔VOCU〕 4.255V~4.335V,**
    **Accuracy of ±25mV**
  - **Overdischarge detection voltage**
    **〔VODL〕 2.223V~2.400V,**
    **Accuracy of ±100mV**
  - **Over current detection voltage**
    **〔VOI1〕 0.120V~0.140 V,**
    **Accuracy of ±10mV**
  - **Charger over current detection voltage -0.09 V(FS8601HA), -0.10(FS8601HD)**
  - **0V-Battery charging function**
- **MOSFET：**
  - **Rss(ON) ＜ 48mΩ**
    **($V_{GS}$ = 3.5V , ID = 1A)**

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## 3. Ordering Information

FS8601Hx-D (DFN-5 Green-Package)

└ Serial code form A, D

*: Refer to the product name list on next page.

## 4. Applications

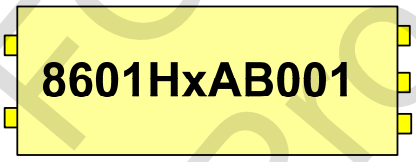
- Protection IC for One-Cell Lithium-Ion / Lithium-Polymer Battery Pack

## 5. Product Name List

| Model | Package | Overcharge detection voltage [VOCP] (V) | Overcharge release voltage [VOCR] (V) | Overdischarge detection voltage [VODP] (V) | Overdischarge release voltage [VODR] (V) | Overcurrent detection voltage [VOI1] (V) | 0V change function | Standby function release |
|---|---|---|---|---|---|---|---|---|
| | DFN-5 | | | | | | | |
| FS8601Hx | FS8601HA | 4.310±25mV | 4.110±50mV | 2.300±77mV | 2.300±77mV | 0.130±10mV | YES | Connection of charger |
| FS8601Hx | FS8601HD | 4.280±25mV | 4.080±50mV | 2.300±100mV | 2.300±100mV | 0.130±10mV | 0.65 | Connection of charger |

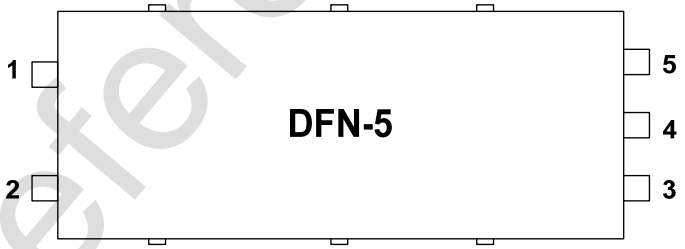
## 6. Pin Configuration and Package Marking Information

| Pin No. | Symbol | Description |
|---|---|---|
| 1 | NC | NC |
| 2 | GND | Ground pin |
| 3 | BATT- | Connect to negative of charger or load |
| 4 | VCC | Power supply, through a resistor (R1) |
| 5 | CS | Input pin for current sense, charger detect |
| 6 | D12 | Tow MOSFET common drain connection pin |

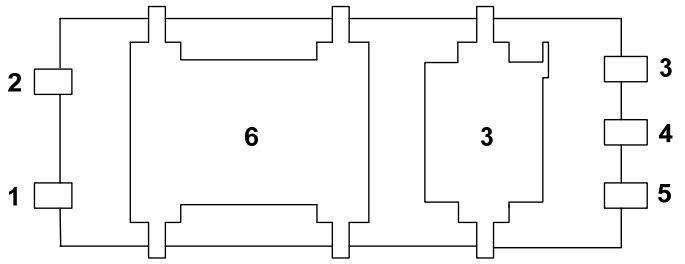



X：Serial code form A, D
A：Year.
B：Week Code, A~Z & A ~ Z
001 :Serial number

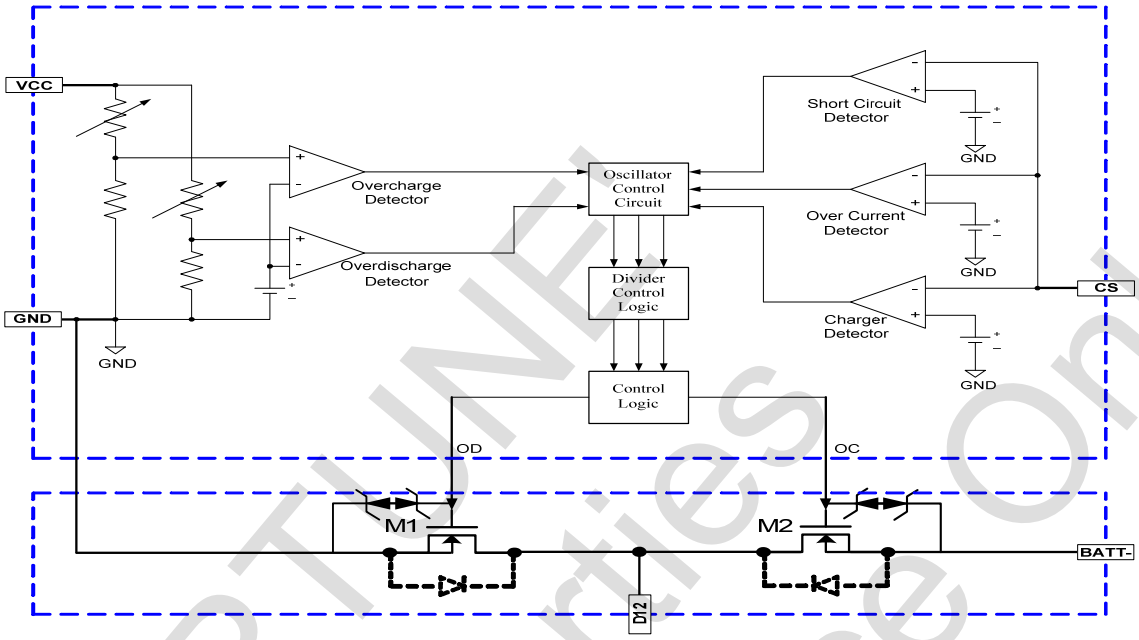
Top View



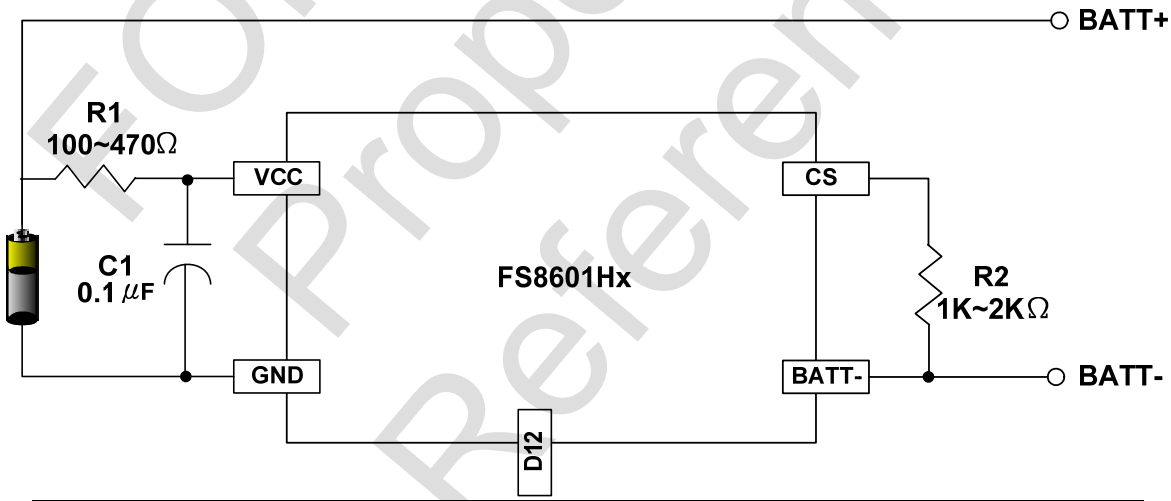

Bottom View



## 7. Functional Block Diagram




## 8. Typical Application Circuit




| Symbol | Purpose | Recommended | Remakes |
|---|---|---|---|
| R1 | ESD protection.<br>For power fluctuation. | 100~470Ω | Resistance should be as small as possible to avoid lowering of the overcharge detection accuracy caused by VDD pin current. Use 470Ω for better ESD protection. |
| C1 | For power fluctuation. | 0.1μF | |
| R2 | Protection for reverse connection of a charger. | 1k~2kΩ | Select a resistance as large as possible to prevent large current when a charge is connected in reverse. |

## 9. Absolute Maximum Ratings

(VSS=0V, Ta=25°C unless otherwise specified)

| Item | Symbol | Rating | Unit |
|---|---|---|---|
| Input voltage between VCC and GND * | VCC | GND-0.3 to GND+15 | V |
| CS input pin voltage | VCS | VCC -30 to VCC +0.3 | V |
| Operating Temperature Range | TOP | -40 to +85 | °C |
| Storage Temperature Range | TST | -40 to +125 | °C |
| Drain-Source Voltage | VDS | 30 | V |
| Gate-Source Voltage | VGS | ±12 | V |
| Continuous Drain Current3 | ID @TA=25℃ | 10 | A |
| Pulsed Drain Current1 | IDM | 60 | A |
| Total Power Dissipation | PD @TA=25℃ | 1.4 | W |
| Storage Temperature Range | TSTG | -55 to 150 | ℃ |
| Operating Junction Temperature Rang | TJ | -55 to 150 | ℃ |

Note: FS8601Hx contains a circuit that will protect it from static discharge; but please take special care that no excessive static electricity or voltage which exceeds the limit of the protection circuit will be applied to it.

- **Pulse (μ sec) noise exceeding the above input voltage (VSS+12V) may cause damage to the IC.**

## 10. Electrical Characteristics

FS8601HA(VSS=0V, Ta=25°C unless otherwise specified)

| PARAMETER | CONDITIONS | SYMBOL | Min | Typ | Max | UNIT |
|---|---|---|---|---|---|---|
| Supply Current | VDD=3.9V | IDD | | 2.5 | 5.2 | μA |
| Power-Down Current | VDD=2.0V | IPD | | 0.05 | 1.0 | μA |
| Overcharge detection voltage | | VOCU | 4.285 | 4.310 | 4.335 | V |
| Overcharge release voltage | | VOCR | 4.060 | 4.110 | 4.160 | V |
| Overdischarge detection voltage | | VODL | 2.223 | 2.300 | 2.377 | V |
| Overdischarge release voltage | | VODR | 2.223 | 2.300 | 2.377 | V |
| Over current detection voltage | | VOI1 | 0.120 | 0.130 | 0.140 | V |
| Short circuit detection voltage | VDD=3.6V | VOI2 | 0.80 | 0.90 | 1.00 | V |
| Charger over current detection voltage | VDD=3.6V | VCH | -0.11 | -0.09 | -0.07 | V |
| Faulty charger detect voltage | | Vdet | 5.5 | 8.0 | 10.5 | V |
| Faulty charger recovery voltage | | Vrec | 5.3 | 7.3 | 9.3 | V |
| 0V charging prohibit | | VST | 0 | 0 | 0 | V |
| Overcharge detection delay time | VDD=4.0V to 4.4V | TOC | 4 | 6.25 | 8.5 | s |
| Overdischarge detection delay time | VDD=3.0V to 2.0V | TOD | 65 | 100 | 135 | ms |
| Over current detection delay time | VDD=3.6V | TOI1 | 7.365 | 11.0 | 14.25 | ms |
| Short circuit detection delay time | VDD=3.6V | TOI2 | 0.45 | 0.750 | 1.4 | ms |
| Charger over current delay time | VDD=3.6V | Tdet | 16.25 | 32.5 | 48.75 | ms |
| Overcharge timer reset delay time | | Td1 | 5.0 | 16 | 50.0 | ms |
| Charge release delay time | | Td2 | 5.0 | 16 | 50.0 | ms |
| Charge connection detection delay | | Tdr1 | 0.3 | 1 | 3.0 | ms |
| **N-MOSFET have low turn-on resistance** | | | | | | |
| Drain-Source Breakdown Voltage (BATT- to D12 / D12 to GND) | $V_{GS}$=0V,$I_D$=1mA | BVDSS | 30 | | | V |
| Breakdown Voltage Temperature Coefficient | Reference to 25℃, $I_D$=1mA | $\Delta BV_{DSS}/\Delta T_j$ | | 0.1 | | V/℃ |
| Static Source-Source On-Resistance (BATT- to GND) | $V_{GS}$=4.5V,$I_D$=1A | RSS(ON) | 27 | 36 | 45 | mΩ |
| | $V_{GS}$=3.5V,$I_D$=1A | | 30 | 39 | 48 | mΩ |
| | $V_{GS}$=2.5V,$I_D$=1A | | 33 | 48 | 65 | mΩ |
| Drain-Source Leakage Current) (BATT- to D12 / D12 to GND) | $V_{DS}$=20V,$V_{GS}$=0V | IDSS (Tj=25℃) | | | 1 | uA |

FS8601HD(VSS=0V, Ta=25°C unless otherwise specified)

| PARAMETER | CONDITIONS | SYMBOL | Min | Typ | Max | UNIT |
|---|---|---|---|---|---|---|
| **CURRENT CONSUMPTION** | | | | | | |
| Supply Current | VDD=3.9V | IDD | | 2.5 | 5.5 | μA |
| Power-Down Current | VDD=2.0V | IPD | | 0.05 | 1.0 | μA |
| Overcharge detection voltage | | VOCU | 4.255 | 4.280 | 4.305 | V |
| Overcharge release voltage | | VOCR | 4.030 | 4.080 | 4.130 | V |
| Overdischarge detection voltage | | VODL | 2.200 | 2.300 | 2.400 | V |
| Overdischarge release voltage | | VODR | 2.200 | 2.300 | 2.400 | V |
| Over current detection voltage | | VOI1 | 0.120 | 0.130 | 0.140 | V |
| Short circuit detection voltage | VDD=3.6V | VOI2 | 0.60 | 0.70 | 0.80 | V |
| Charger over current detection voltage | VDD=3.6V | VCH | -0.120 | -0.100 | -0.080 | V |
| Faulty charger detect voltage | | Vdet | 6.0 | 8.0 | 10.0 | V |
| Faulty charger recovery voltage | | Vrec | 5.8 | 7.3 | 8.8 | V |
| 0V charging prohibit | | VST | 0.40 | 0.65 | 1.10 | V |
| Overcharge detection delay time | VDD=4.0V to 4.4V | TOC | 0.6 | 1 | 1.35 | s |
| Overdischarge detection delay time | VDD=3.0V to 2.0V | TOD | 65 | 100 | 140 | ms |
| Over current detection delay time | VDD=3.6V | TOI1 | 13.3 | 20.0 | 26.5 | ms |
| Short circuit detection delay time | VDD=3.6V | TOI2 | 0.60 | 1.0 | 1.80 | ms |
| Charger over current delay time | VDD=3.6V | Tdet | 5.10 | 8.50 | 12.75 | ms |
| **N-MOSFET have low turn-on resistance** | | | | | | |
| Drain-Source Breakdown Voltage (BATT- to D12 / D12 to GND) | $V_{GS}$=0V,$I_D$=1mA | $BV_{DSS}$ | 30 | | | V |
| Breakdown Voltage Temperature Coefficient | Reference to 25℃, $I_D$=1mA | $\Delta BV_{DSS}/\Delta T_j$ | | 0.1 | | V/℃ |
| Static Source-Source On-Resistance (BATT- to GND) | $V_{GS}$=4.5V,$I_D$=1A | $R_{SS(ON)}$ | 27 | 36 | 45 | mΩ |
| | $V_{GS}$=3.5V,$I_D$=1A | | 30 | 39 | 48 | mΩ |
| | $V_{GS}$=2.5V,$I_D$=1A | | 33 | 48 | 65 | mΩ |
| Drain-Source Leakage Current) (BATT- to D12 / D12 to GND) | $V_{DS}$=20V,$V_{GS}$=0V | $I_{DSS}$ (Tj=25℃) | | | 1 | uA |

## 11. Description of Operation

### Normal Condition

If VODL<VCC<VOCU and VST<VCS<VOI1, M1 and M2 are both turned on. The charging and discharging processes can be operated normally.

### Overcharge Protection

When the voltage of the battery cell exceeds the overcharge detection voltage (VOCU) 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:

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

The voltage of the battery cell falls below the overcharge detection voltage (VOCU) and a load is connected.
When the battery voltage is above VOCU, the overcharge condition will not release even a load is connected to the pack.

### Overdischarge Protection

When the voltage of the battery cell goes below the overdischarge detection voltage (VODL) beyond the overdischarge delay time (TOD) period, discharging is inhibited by turning off the discharge control MOSFET.

The default of overdischarge delay time is 100ms. Inhibition of discharging is immediately released when the voltage of the battery cell becomes higher than overdischarge release voltage (VODR) through charging.

### Overcurrent Protection

In normal mode, the FS8601HX continuously monitors the discharge current by sensing the voltage of CS pin. If the voltage of CS pin exceeds the overcurrent detection voltage (VOI1) beyond the overcurrent delay time (TOI1) period, the overcurrent protection circuit operates and discharging is inhibited by turning off the discharge control MOSFET. The overcurrent condition returns to the normal mode when the load is released or the impedance between BATT+ and BATT- is larger than 150kΩ. The FS8601HX provides two overcurrent detection levels (0.13V and 0.7V or 0.9V) with two overcurrent delay time (TOI1 and TOI2) corresponding to each overcurrent detection level.

### Charge Detection after Overdischarge

When overdischarge occurs, the discharge control MOSFET turns off and discharging is inhibited. However, charging is still permitted through the parasitic diode of MOSFET. Once the charger is connected to the battery pack, the FS8601HX immediately turns on all the timing generation and detection circuitry. Charging progress is sensed if the voltage between CS and GND is below charge detection threshold voltage.

### Power Down after Overdischarge

When overdischarge occurs, the FS8601HX will enter into power-down mode, turning off all the timing generation and detection circuitry to reduce the quiescent current to 1.0$\mu$A (VCC=2.0V). At the same time, the CS pin is pull-up to VCC through an internal resistor.

### Supervising charger voltage

By supervising the charge voltage, charging can be prohibited instantly when a charger with overvoltage is connevted. The charger voltage detection circuit supervises the voltage between the VDD and CSI pins. When this voltage exceeds Vdet(Vdet < (VDD – VCSI)),regardless of the battery voltage,the charge FET control pin output alow level(CSI level)signal and the charge FET is turned off. When the charger voltage drops to Vrec or lower, the charger FET control output level is dependent on battery voltage.

**Note: When a battery is connected to FS8601HX for the first time, it may not enter the normal condition (dischargeable may not be enabled). In this case, short the CS and VSS pins or connect to a charger to restore to the normal condition.**

## 12. Design Guide

### 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=VOIP/ (2 x 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 with temperature variation due to heat 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 from Charger

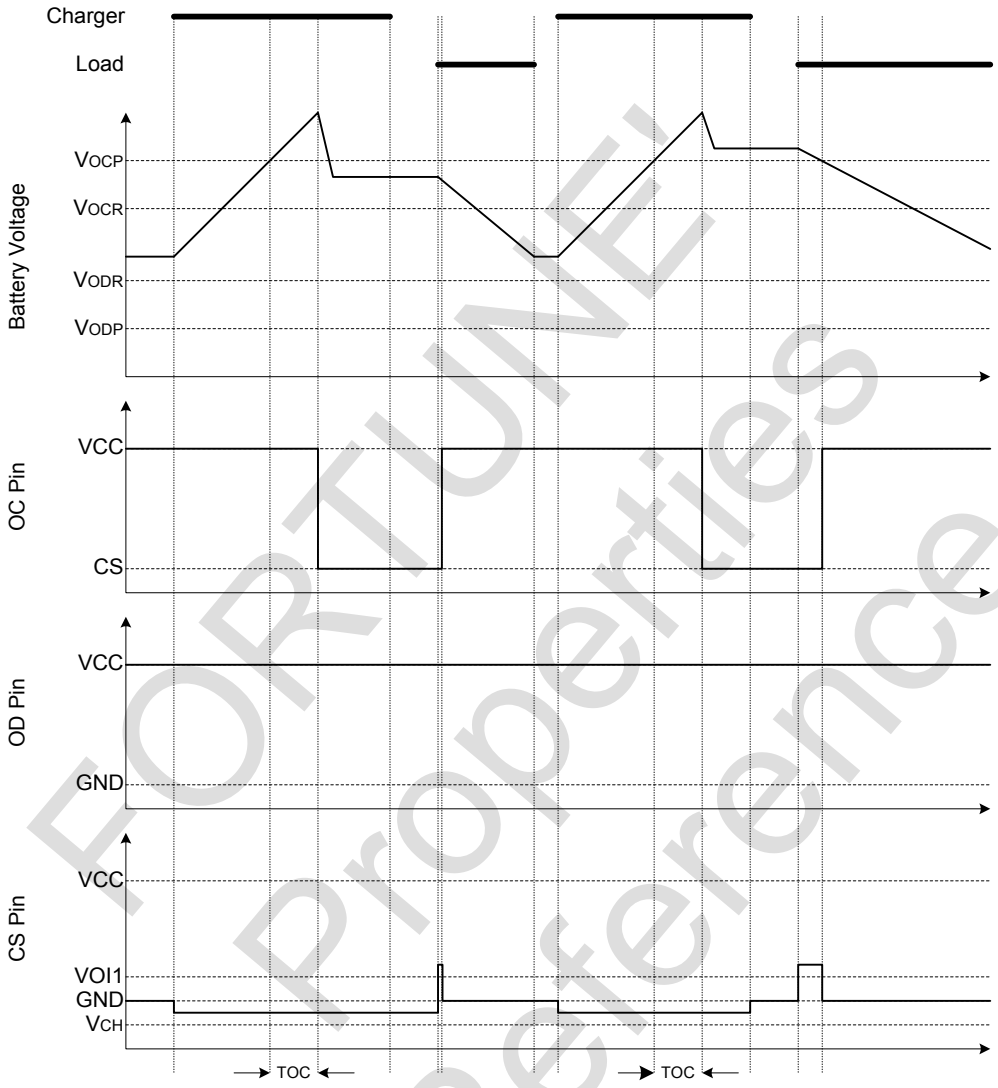
To suppress the ripple and disturbance from charger, connecting R1 and C1 to VCC is recommended.

### Protection the CS pin

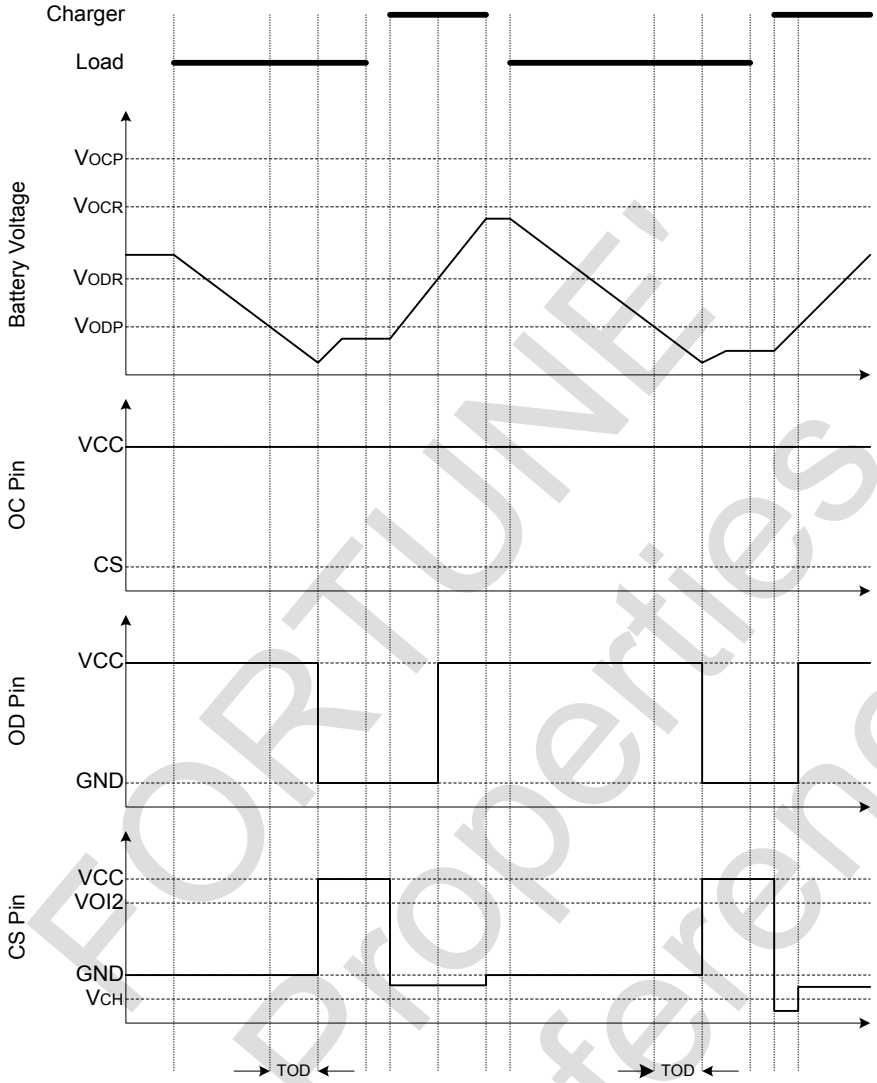
R2 is used for latch-up protection when charger is connected under overdischarge condition and overstress protection at reverse connecting of a charger.

## 13. Timing Diagram

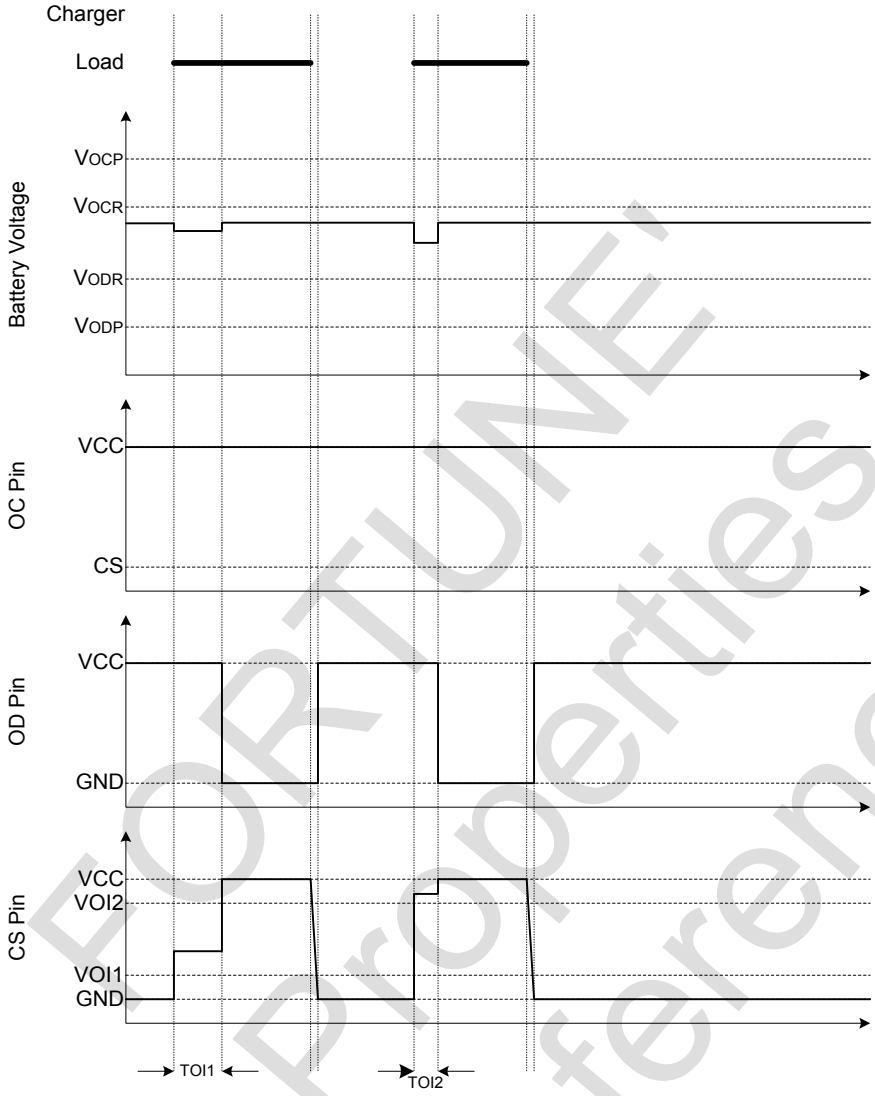
Overcharge Condition →Load Discharging → Normal Condition



Overdischarge Condition → Charging by a Charger →Normal Condition

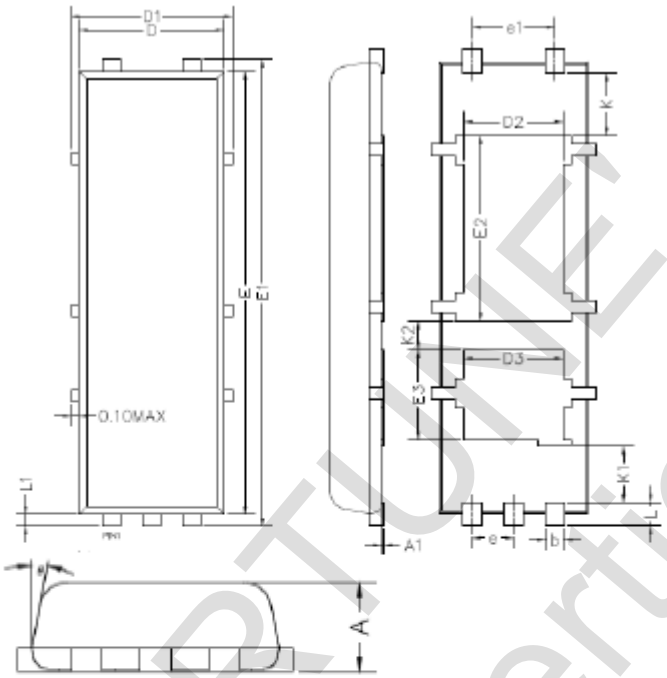


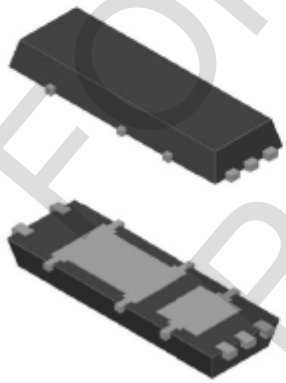
Over Current Condition → Normal Condition



## 14. Package Outline

### DFN-5



Unit: mm

| Symbol | Min. | TYP. | Max. |
|---|---|---|---|
| A | 0.58 | 0.63 | 0.68 |
| A1 | 0.00 | 0.02 | 0.05 |
| b | 0.18 | 0.23 | 0.28 |
| D | 1.70 | 1.8 | 1.90 |
| E | 5.40 | 5.50 | 5.60 |
| D1 | - | - | 2.10 |
| E1 | 5.70 | 5.80 | 5.90 |
| D2 | 1.10 | 1.20 | 1.30 |
| E2 | 2.10 | 2.25 | 2.35 |
| D3 | 1.10 | 1.20 | 1.30 |
| E3 | 1.00 | 1.10 | 1.20 |
| e | 0.50 BSC | | |
| e1 | 1.00 BSC | | |
| K | 0.67 | 0.77 | 0.87 |
| K1 | 0.59 | 0.69 | 0.79 |
| K2 | 0.25 | 0.35 | 0.45 |
| L | 0.25 | 0.35 | 0.45 |
| L1 | 0.15 BSC | | |
| θ | 10° | 12° | 14° |

Note:
All dimensions do not include mold flash, gate burrs or protrusions.

## 15. Revision History

| Version | Date | Page | Description |
|---|---|---|---|
| 1.0 | 2011/09/27 | ALL | New release |
| 1.1 | 2012/02/10 | 0<br>6 | Rename Sign Head<br>Revise Drain-Source Voltage |
| 1.2 | 2012/09/12 | 14 | Revise package outline |
| 1.3 | 2014/01/09 | 4 | Revise VOI1 Specified Unit |