

# Control of Lithium Ion Battery Charging and Discharging Monolithic IC MM1248

## Outline

This IC was developed for use in controlling charging and discharging of lithium ion batteries (battery modules with three cells connected in series). In charging control, the voltage of the battery module as a whole is controlled in constant-voltage control. Discharge control and monitoring of overvoltage rely on monitoring of the voltages of individual cells.

## Features

1. Charging control voltage  $V_{BATH}=12.465V\pm1.5\%$  ( $T_a=-20^{\circ}C\sim70^{\circ}C$ )
2. Overcharge detection voltage  $V_{CELL}=4.335V\pm1.5\%$  ( $T_a=-20^{\circ}C\sim70^{\circ}C$ )
3. Internal circuit for setting dead time (for overvoltage detection, discharge control)
4. Low consumption current on overdischarge  $I_{BATH3}=1\mu A$  typ.
5. High-precision internal overvoltage detection startup circuit (cell voltage 4.2V or higher at end of charging)

## Package

SOP-16B (MM1248XF)

## Absolute Maximum Ratings (Except where noted otherwise, $T_a=25^{\circ}C$ )

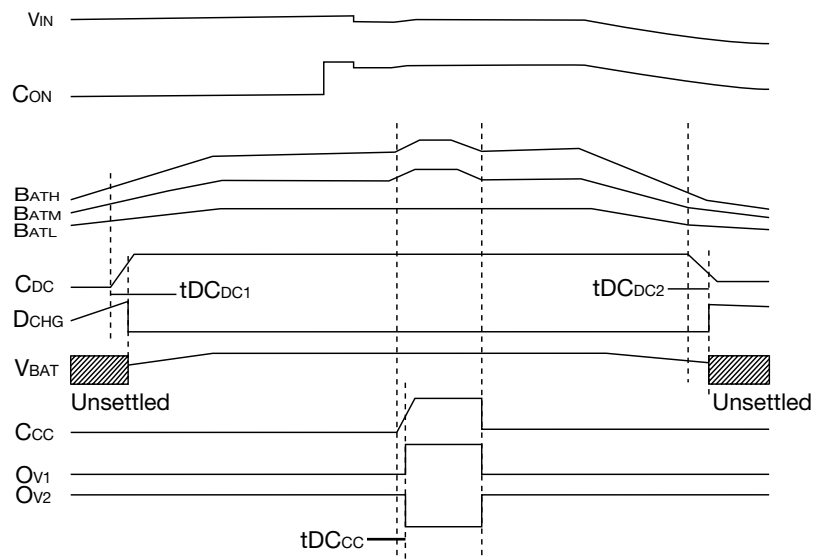
| Item                       | Symbol         | Ratings       | Units       |
|----------------------------|----------------|---------------|-------------|
| Storage temperature        | $T_{STG}$      | $-40\sim+125$ | $^{\circ}C$ |
| Operating temperature      | $T_{OPR}$      | $-20\sim+70$  | $^{\circ}C$ |
| Input voltage              | $V_{IN}$ max.  | 18            | V           |
| Charge voltage             | $V_{BAT}$ max. | 15            | V           |
| Power supply voltage       | $V_{CC}$ max.  | 15            | V           |
| Voltage applied to OV2 pin | $V_{O2}$ max.  | 10            | V           |
| Allowable loss             | $P_d$          | 350           | mW          |

# Electrical Characteristics

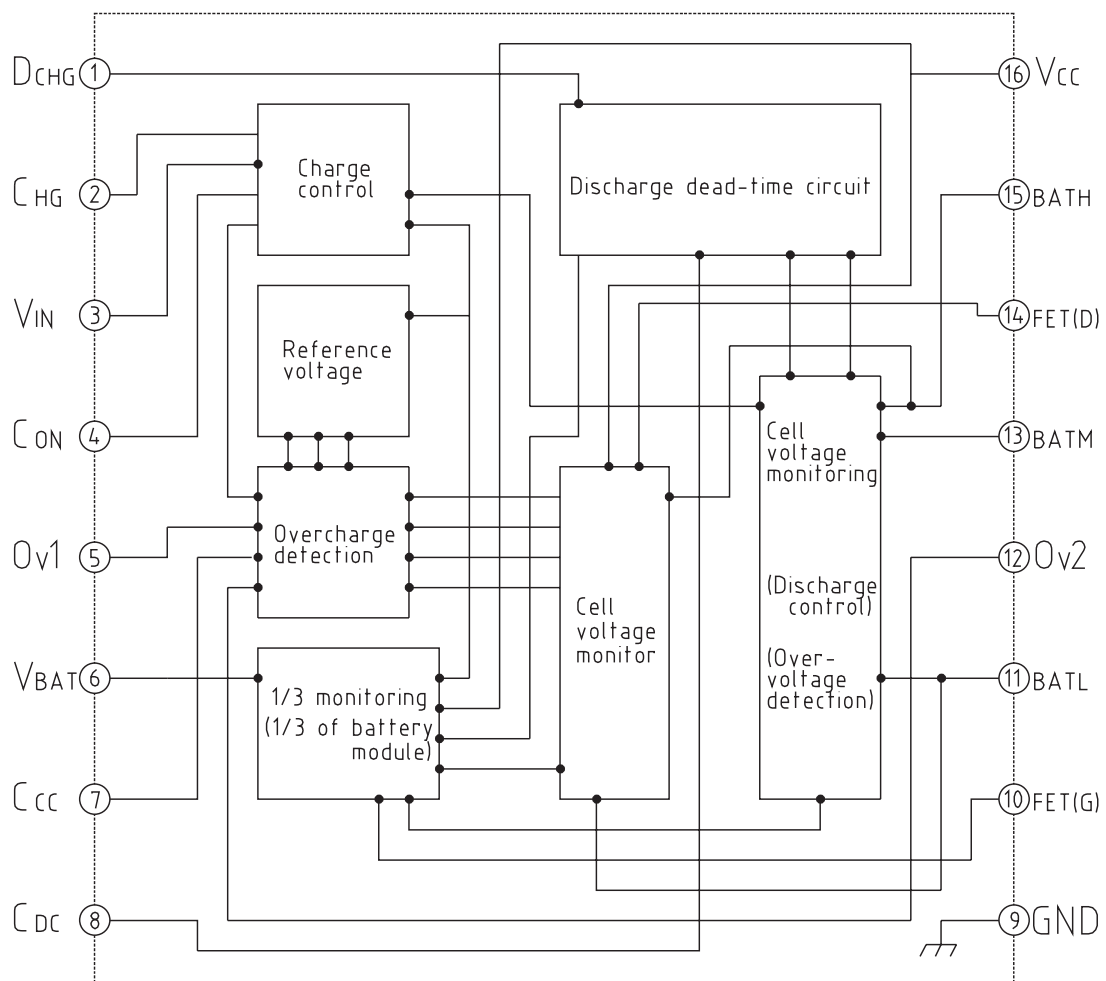
(Except where noted otherwise, Ta=25°C, VIN=15 V, CON=VIN)

| Item   | Symbol | Measurement conditions             | Min.            | Typ.            | Max.            | Units |
|--|--------|------------------------------------|-----------------|-----------------|-----------------|-------|
| Consumption current 1 (pin VIN)              | VIN    | VIN=15V, CON=0V                    |                 | 250             | 350             | μA    |
| Consumption current (pin VCC) 1              | ICC1   | VCELL=4.4V                         |                 | 2.1             | 2.6             | mA    |
| Consumption current (pin VCC) 2              | ICC2   | VCELL=4.2V, CON=0V                 |                 | 1.5             | 2.0             | mA    |
| Consumption current (pin VCC) 3              | ICC3   | VCELL=4.2V, CON=VIN                |                 | 1.0             | 1.3             | mA    |
| Consumption current (pin VCC) 4              | ICC4   | VCELL=4.0V                         |                 | 50              | 100             | μA    |
| Consumption current (pin VCC) 5              | ICC5   | VCELL=2.4V                         |                 |                 | 0.1             | μA    |
| Consumption current (pin BATH) 1             | IBATH1 | VCELL=4.4V                         |                 | 5.0             | 10.0            | μA    |
| Consumption current (pin BATH) 2             | IBATH2 | VCELL=4.0V                         |                 | 2.5             | 5.0             | μA    |
| Consumption current (pin BATH) 3             | IBATH3 | VCELL=2.4V                         |                 | 1.0             | 2.0             | μA    |
| Charging control voltage                     | VBATH  | Ta=-20~70°C                        | 12.270          | 12.465          | 12.670          | V     |
| Overcharge detection voltage                 | VCELLU | Ta=-20~70°C                        | 4.270           | 4.335           | 4.400           | V     |
| Overcharge reset voltage                     | VCELL0 |                                    | VCELLU<br>-60mV | VCELLU<br>-45mV | VCELLU<br>-30mV | V     |
| Sensing voltage margin 1                     | ΔVUO1  | VBATH/3-VCELLU                     | 100             |                 |                 | mV    |
| Sensing voltage margin 2                     | ΔVUO2  | VBATH-VCELLU×3                     | 300             |                 |                 | mV    |
| Overvoltage sensing operation voltage        | VALM   |                                    | 4.05            | 4.20            | 4.35            | V     |
| Overvoltage sensing hysteresis voltage       | ΔVALM  |                                    | 50              | 90              | 130             | mV    |
| Overdischarge detection voltage              | VCELLS |                                    | 2.31            | 2.40            | 2.49            | V     |
| Discharge resume voltage                     | VCELLD |                                    | 2.49            | 2.65            | 2.81            | V     |
| Overdischarge sensing hysteresis voltage     | ΔVCS   | VCELLD-VCELLS                      | 175             | 250             | 325             | mV    |
| Pin 11 input current 1                       | I11    | VCELL=4.0V                         | 100             | 200             | 300             | nA    |
| Pin 11 input current 2                       | I11A   | VCELL=4.4V                         | 0.7             | 1.0             | 1.3             | μA    |
| Pin 13 input current 1                       | I13    | VCELL=4.0V                         | 100             | 200             | 300             | nA    |
| Pin 13 input current 2                       | I13A   | VCELL=4.4V                         | 0.7             | 1.0             | 1.3             | μA    |
| Pin 14 input current                         | I14    | VCELL=4.0V                         | 7.7             | 10.0            | 14.3            | μA    |
| CON pin threshold voltage                    | VTHCON |                                    | VIN-1.8         |                 | VIN-0.4         | V     |
| CON pin input current                        | INCON  | VIN-CON=1.8V                       |                 |                 | 100             | μA    |
| CON pin leakage current                      | ILCON  | VIN-CON=0.4V                       |                 |                 | 1.0             | μA    |
| CHG pin pull-up resistance                   | RCHG   | Resistance across pins VIN and CHG | 14              | 20              | 26              | kΩ    |
| CHG pin sync current                         | ISCGH  | VBATT<12V                          | 100             |                 |                 | μA    |
| CHG pin output voltage L                     | VTHCHL | VIN-CHG, ICGH=20μA                 | 6.2             |                 |                 | V     |
| CHG pin output voltage H                     | VTHCHH | VIN-CHG, ICGH=20μA                 |                 |                 | 0.4             | V     |
| DCHG pin source current                      | IsoDCH |                                    | 20              |                 |                 | μA    |
| DCHG pin sync current                        | ISIDCH |                                    | 20              |                 |                 | μA    |
| DCHG pin output voltage L                    | VTHDcL | BATH-DCHG, IS=20μA                 |                 |                 | 1.0             | V     |
| DCHG pin output voltage H                    | VTHDcH | DCHG-GND, IS=-20μA                 |                 |                 | 0.8             | V     |
| OV2 pin sync current                         | IsoOv2 |                                    | 100             |                 |                 | μA    |
| OV1 pin source current                       | IsoOv1 |                                    | 100             |                 |                 | μA    |
| OV1 pin pulldown resistance                  | ROv1   |                                    | 35              | 50              | 65              | kΩ    |
| CCC pin charge current                       | ICCC   | VCELL=4.4V, CCC=3.0V               | 150             | 220             | 290             | nA    |
| CCC pin threshold voltage                    | VTHCCC | CCC=0V→5V                          | 4.10            | 4.30            | 4.50            | V     |
| CCC initialization delay time                | TINT   | CCC=0.068μF                        |                 | 10              |                 | mS    |
| CDC pin charge current                       | ICDC   | VCELL=2.8V, CCC=3.0V               | 260             | 380             | 500             | nA    |
| CDC pin threshold voltage                    | VTHCDC | CCC=0V→5V                          | 4.20            | 4.40            | 4.60            | VC    |
| Overvoltage sensing dead time                | TDCCC  | CCC=0.068μF                        | 0.5             | 1.0             | 1.5             | S     |
| Overdischarge sensing dead time              | TDCDC1 | CDC=0.1μF                          | 0.5             | 1.0             | 1.5             | S     |
| Overdischarge reset dead time                | TDCDC2 | CDC=0.1μF                          | 0.5             | 1.0             | 1.5             | S     |
| Battery voltage monitor output voltage ratio | VBMON  | $\frac{(BATH-GND) \div 3}{VBATT}$  | -1.0            | 0               | 1.0             | %     |
| Battery voltage monitor output current       | ILMON  |                                    | 50              |                 |                 | μA    |

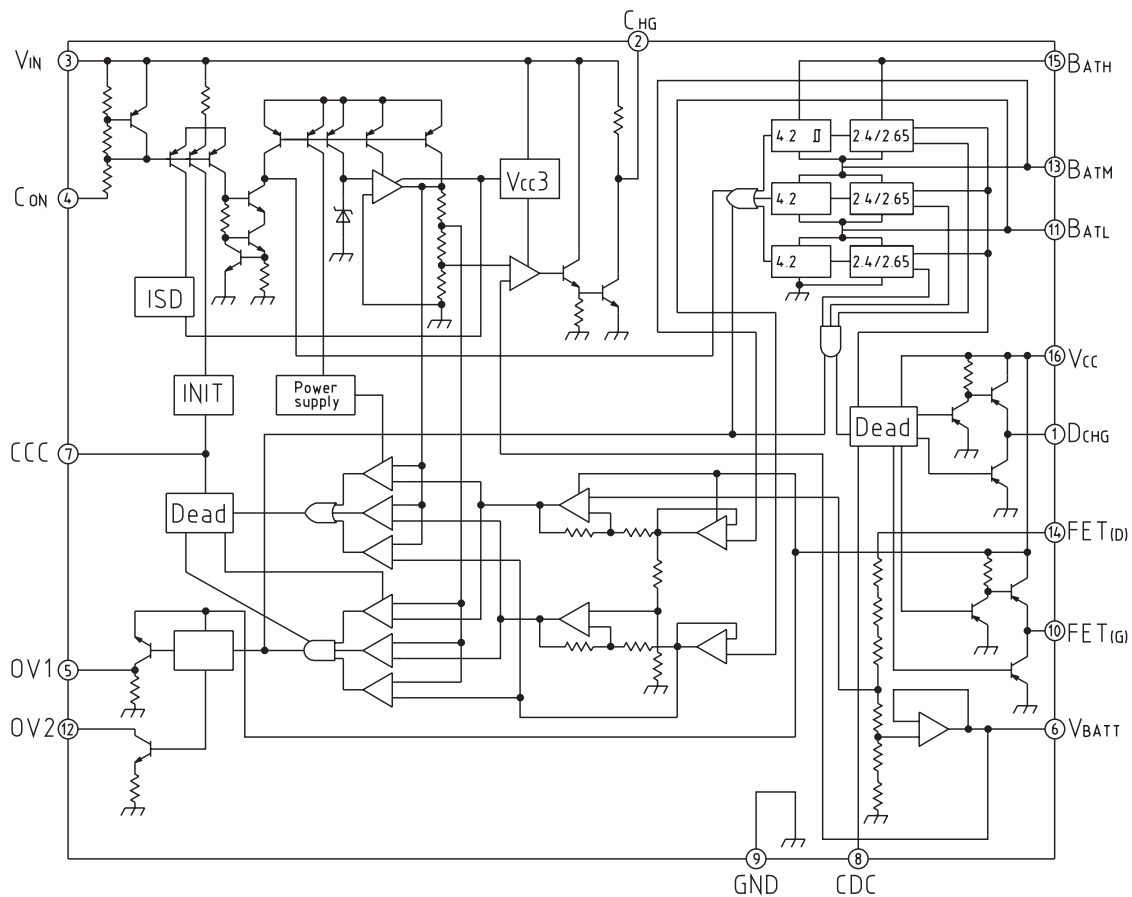
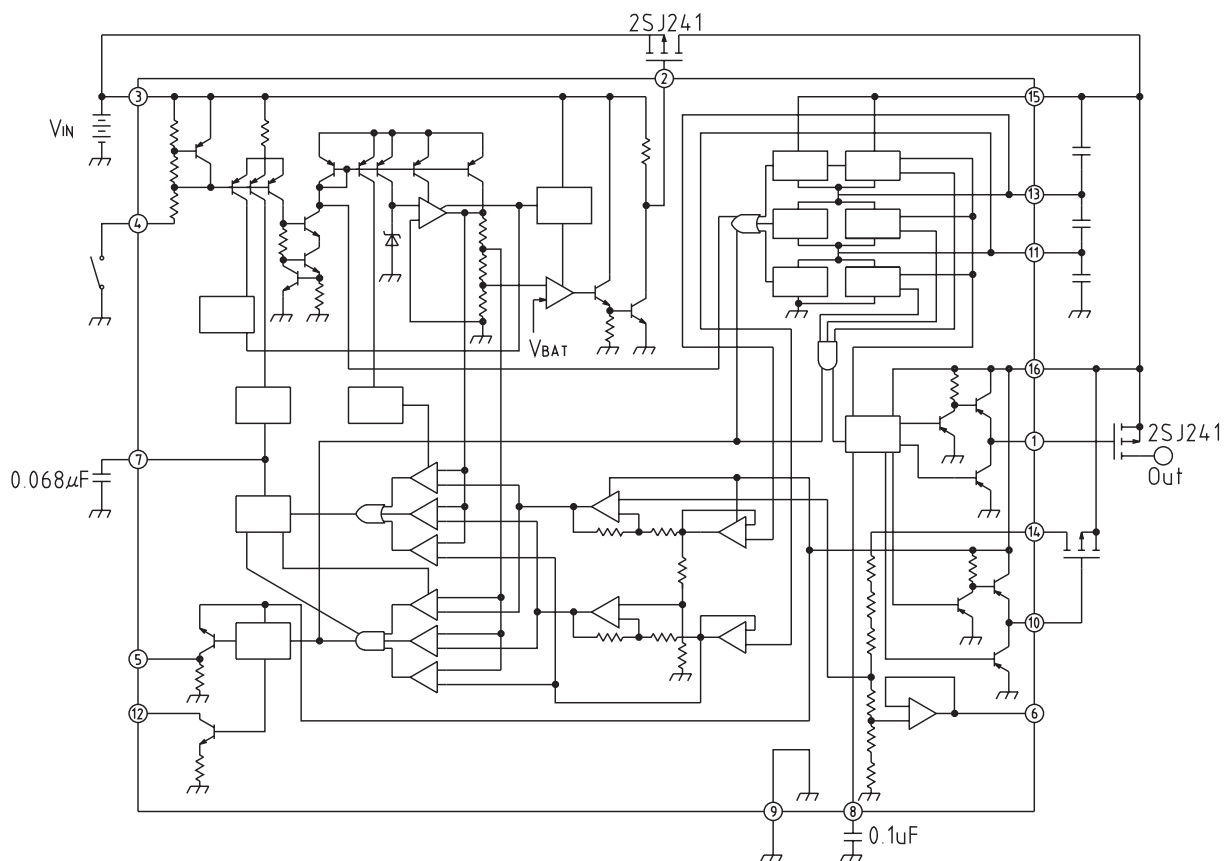
## Timing Chart



## Block Diagram



## Application Circuits



## Circuit conventions

- Charge control unit
- Overcharge detection unit
  - Subtraction amp, buffer amp, voltage comparator, dead time setting circuit
- Discharge control unit
  - Cell voltage monitoring circuit, dead time setting circuit
- Overvoltage sensing (rough detection) unit
- High-precision reference voltage unit

## Operating outline

### 1. Charge control

Charge control is turned on and off using the CON pin; when CON is low the charge control unit is in operation. The error amp of the charge control unit takes inputs of 4.155V from the high-precision reference voltage unit and the battery module voltage monitor output. The battery module voltage monitor outputs a voltage equal to 1/3 the battery module voltage, so that in charging control the charging control FET (pin 2) is controlled such that the battery module voltage is  $4.155 \times 3$  V.

This block performs constant-voltage control only; current limiting (constant-current control) should be implemented on the charging input side.

### 2. Overcharge detection

There are two blocks for overcharge detection; three output modes are provided according to input conditions and cell voltage.

1. Charging signal on (during discharge)
2. Charging signal off (during discharge)
3. Discharge off

#### 2-1. Charging signal on

The high-precision overcharge sensing unit is always in the operating state, and the voltage of each cell is monitored.

In order to monitor each cell's voltage precisely, subtraction amps are provided for monitoring M and H cell voltages, and a buffer amp is used to monitor the L cell voltage. By means of these amps the voltage of each cell is converted to a GND-reference voltage, and compared with the high-precision reference voltage of 4.335V.

If the voltage of any one of the cells exceeds 4.335V, the overvoltage is sensed, and the dead time setting pin (CCC pin 7) is charged by a constant current; when the CCC pin is charged to the threshold voltage of the dead time setting circuit (4.35V), an overvoltage signal is output.

(OV1 pin "H", OV2 pin "L")

When an overcharge signal is output, the overvoltage monitoring unit switches from the overvoltage state to the reset monitoring state, and an overcharge signal is output until the voltages of all cells fall to 4.16 V. To summarize the sequence of operations, when the voltage of any of the cells remains in the overcharge state continuously for the specified time (the dead time), that cell is judged to be in an overcharged state and is switched to overvoltage output; when all the cell voltages drop to the overcharge reset voltage or below, the overcharge state is canceled.

On entering the overcharge state, if the charge control unit circuit is turned off, the latter unit will not operate.

| Pin | Output logic   |             | Output type                               |
|-----|----------------|-------------|---|
|     | Normal         | Overvoltage |   |
| OV1 | L              | H           | PNP output, internal pull-down resistance |
| OV2 | High impedance | L           | NPN open-collector output                 |

## 2.2. Charging signal off

When the charging signal is off (CON pin "H"), the high-precision overvoltage sensing unit is in standby state. A rough overcharging sensing unit is provided internally to sense the overvoltage in this state. The rough overcharging sensing unit monitors the voltages of each cell, and if the voltage of any cell rises to or exceeds 4.2V, triggering overvoltage sensing (rough), the high-precision overcharging sensing unit enters the operating state.

Thereafter operation is the same as in "(2-1) Charging signal on" above.

## 2-3. Discharge off

In an overdischarge state, if the rough overvoltage detection voltage for any cell reaches or exceeds 4.2V, an overvoltage signal is output.

Hence in this case a dead time is not set. Further, reset depends on the hysteresis voltage at the time of rough overvoltage detection.

## 3. Discharge control

Voltage monitoring for discharge control is performed for each cell; if the voltage of any cell falls to 2.4V or less, the dead time setting pin (CDC pin 8) is discharged, and if the voltage drops to the discharge-off threshold voltage, an overdischarge state is detected and the discharge switch gate pin (pin 1) is set "H" and the battery module monitor unit input gate (pin 10) is also set "H"; the battery module monitor output impedance goes high.

At this time the monitoring circuit switches to a low consumption current (1μA typ. when all cell voltages are 2.4V), and the state switches from overdischarge to the reset monitoring state (with reset occurring when all cell voltages reach 2.65V).

Reset from the overdischarge state occurs when the CDC pin is charged under constant current after all cell voltages have reached 2.65V; when this pin reaches the threshold voltage for overdischarge reset, discharge is again turned on.

The dead time setting block of the discharge control unit has a circuit configuration such that if either the overdischarge or the reset state continues for longer than the set time, the state is switched. Hence when the state changes within the set time, the CDC pin undergoes rapid charging or discharging.

## 4. Battery module voltage monitor output

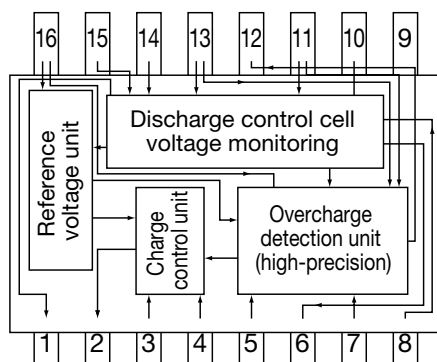
This block outputs a voltage equal to 1/3 the voltage of the battery module; within the IC, it is used as the charge control input. One-third the battery module voltage is supplied by a bleeder resistance, but in order to reduce the consumption current on overdischarge, a switch is provided such that current does not flow through this resistance when overdischarge occurs. The charging voltage and overvoltage detection are both highly precise, and so this switch is designed to use an external FET.

When battery voltage information is to be input to a microcomputer, this feature may be used, but with the following caveats regarding use.

1. The output upon overdischarge is at high impedance.
2. The output sink current is small.

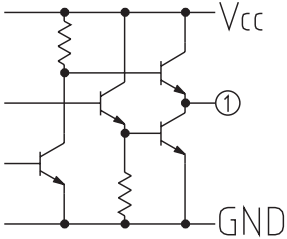
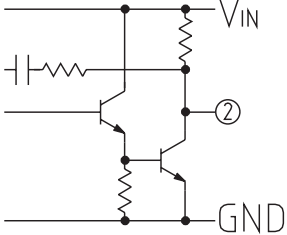
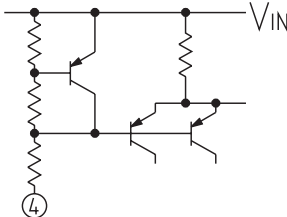
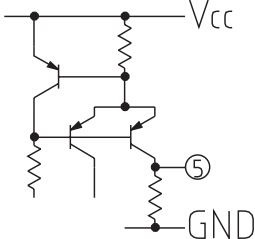
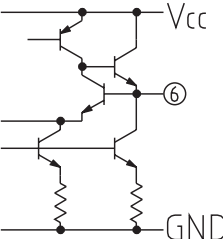
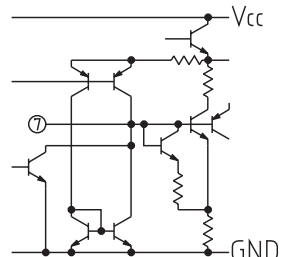
In order to reduce the consumption current, the output sink current is held low; but depending on the external components used, response may be slow, affecting charging control and resulting in oscillation under constant-voltage control. In such cases, a resistance (of about 300kΩ) should be inserted between the monitor output and GND, to boost the sink capacity.

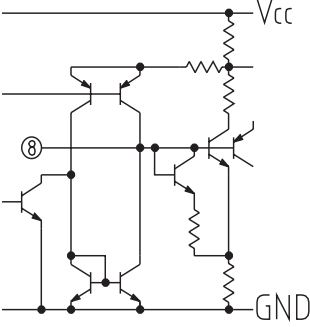
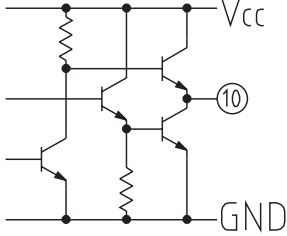
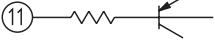
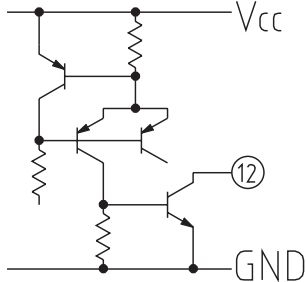
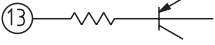
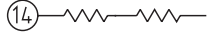
## Pin Assignment



|   |                  |    |                 |
|---|------------------|----|-----------------|
| 1 | DCHG             | 9  | GND             |
| 2 | CHG              | 10 | FET (G)         |
| 3 | V <sub>IN</sub>  | 11 | BATL            |
| 4 | CON              | 12 | OV2             |
| 5 | OV1              | 13 | BATM            |
| 6 | V <sub>BAT</sub> | 14 | FET (D)         |
| 7 | CCC              | 15 | BATH            |
| 8 | CDC              | 16 | V <sub>CC</sub> |

## Pin Description

| Pin no. | Pin name | Equivalent circuit  | Function  |
|---------|----------|---|---|
| 1       | DCHG     |    | Pch-FET gate connector pin for discharge control<br>"L" output during discharge, "H" when discharge is stopped  |
| 2       | CHG      |    | Pch-FET gate connector pin for charge control<br>Feedback loop for constant-voltage control formed during charging; "H" output when charging is stopped<br>When overvoltage or overheating is sensed (during charging), the gate is turned off ("H" level). |
| 3       | VIN      |   | Power supply input pin for the charge control unit  |
| 4       | CON      |   | Input pin for charge control signal.<br>Input "L" to turn charging on, "H" to turn charging off (when open, charging is off)  |
| 5       | OV1      |  | Overvoltage signal output pin. PNP output, with internal pull-down resistance (50 kΩ typ.)<br>"L" output in normal operation, "H" output on overvoltage   |
| 6       | VBAT     |  | On discharge, 1/3 the battery module voltage is output; when discharge stops, switches to high-impedance output   |
| 7       | CCC      |  | Pin for connection to a capacitor to set the dead time for overcharge detection<br>Normal operation : GND level; overcharge : approx. 5V<br>Dead time is approx 1S for an 0.068μF capacitance   |

| Pin no. | Pin name | Equivalent circuit  | Function  |
|---------|----------|---|---|
| 8       | CDC      |    | Pin for connection to a capacitor to set the dead time for discharge on/off switching<br>During discharge : approx. 5V; when discharge stops : GND level<br>Dead time is set when discharge is turned off and discharge stopped<br>Dead time is approx. 1S for an 0.1μF capacitance |
| 9       | GND      |   | GND pin for this IC   |
| 10      | FET (G)  |   | Pin for connection to P-ch FET gate for battery module voltage level input<br>During discharge "L" is output; when discharge is stopped switches to "H"   |
| 11      | BATL     |  | Pin for input of L cell+terminal voltage (in a battery module with three cells in series, cells are defined, starting from the high side, as the H cell, M cell and L cell)   |
| 12      | OV2      |  | Pin for overvoltage signal output; NPN open collector output<br>High-impedance output during normal operation; switches to "L" on overcharge<br>The high-potential side of the pull-up resistance should be 10 V max  |
| 13      | BATM     |  | Pin for input of M cell+terminal voltage  |
| 14      | FET (D)  |  | Pin for connection to drain of P-ch FET for battery module voltage level input  |
| 15      | BATH     |   | Pin for input of H cell+terminal voltage  |
| 16      | VCC      |   | Power supply input pin for overcharge detection, discharge control, battery module voltage monitoring units<br>Voltage at same potential as BATH should be input  |