# Protection for Lithium-Ion Batteries (2-serial cells)
# Monolithic IC MM1412

October 22, 1998

## Outline

This IC protects lithium-ion batteries in the event of overcharge, overdischarge and overcurrent. It has the following two functions: an overcharge detection function that turns the external FET-SW off when a problem occurs during charging, etc. and excess voltage is impressed on each battery for longer than a certain time, and an overdischarge detection function that turns the external FET-SW off when battery voltage drops below a certain voltage during discharge, in order to prevent battery overdischarge. When these functions operate, the IC enters low current consumption mode. It also has an overcurrent detection function that turns the FET-SW off when excess current flows due to a short or the like. Since the functions above are provided, the protection circuitry for lithium-ion batteries can be comprised with fever external components.

## Series Table

**Temperature conditions A: Ta=−25 ~ 75°C, B: Ta=−20 ~ 70°C, C: Ta=0 ~ 50°C, D: Ta=0 ~ 40°C, E: Ta=−20 ~ 25°C**

| Model | Package | | Overcharge detection voltage (V) | Overcharge detection voltage temperature conditions | Overcharge detection hysteresis voltage (V) | Overdischarge detection voltage (V) | Overdischarge reset voltage (V) | Overcurrent detection voltage (mV) |
|---|---|---|---|---|---|---|---|---|
| | SOP-8C, E | VSOP-8A | | | | | | |
| MM1412 | | AW | 4.350±0.025 | C | 220±50 | 2.3±0.1 | 3.5±0.2 | 150±15 |
| | | CW | 4.295±0.025 | C | | 2.3±0.1 | 3.5±0.2 | 150±15 |
| | EF | EW | 4.250±0.025 | C | 300±50 | 2.3±0.1 | 3.5±0.2 | 150±15 |
| | | FW | 4.250±0.025 | C | 220±50 | 2.0±0.1 | 3.1±0.2 | 150±15 |
| | | GW | 4.300±0.025 | C | 220±50 | 2.0±0.1 | 3.1±0.2 | 140±15 |
| | | HW | 4.225±0.025 | C | | 2.3±0.1 | 3.5±0.2 | 150±15 |
| | | JW | 4.250±0.025 | C | 150±50 | 4.5±0.2 | | 150±15 |
| | | KW | 4.350±0.025 | C | 220±50 | 2.3±0.1 | 3.5±0.2 | 100±15 |
| | | LW | 4.125±0.025 | C | | 2.3±0.1 | 3.5±0.2 | 150±15 |
| | | MW | 4.125±0.025 | C | | 2.0±0.1 | 3.1±0.2 | 100±15 |
| | | NW | 4.190±0.025 | C | | 2.0±0.1 | 3.1±0.2 | 100±15 |
| | | PW | 4.300±0.025 | C | 220±50 | 2.0±0.1 | 3.1±0.2 | 75±15 |

## Features

| | | |
|---|---|---|
| 1. Consumption current (during overcharge) | $V_{CELL}$ = 4.5 $R_{OC}$ = 270 kΩ | 150µA typ. |
| 2. Consumption current (normal) | $V_{CELL}$ = 3.5V | 15µA typ. |
| 3. Consumption current (during overdischarge) | $V_{CELL}$ = 1.9V | 0.5µA typ. |
| 4. Consumption current (during overdischarge) | $V_{CELL}$ = 1.0V | 0.1µA max. |
| 5. Overcharge detection voltage (Ta = 0°C ~ 50°C) | | 4.35 ± 0.025V (detected for each cell) |
| 6. Hysteresis voltage | | 220mV ± 50mV (detected for each cell) |
| 7. Overdischarge detection voltage | | 2.30 ± 0.1V (detected for each cell) |
| 8. Overdischarge release voltage | | 3.50V ± 0.2V (detected for each cell) |
| 9. Overcurrent detection threshold | | 150mV ± 15mV |
| 10. Reset after overcurrent detection | | Load open (5MEGΩ or higher) |
| 11. Operating limit voltage | | 0.9V max. |

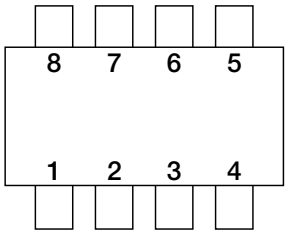
## Package

VSOP-8A

## Applications

1. Cell phone
2. Movie

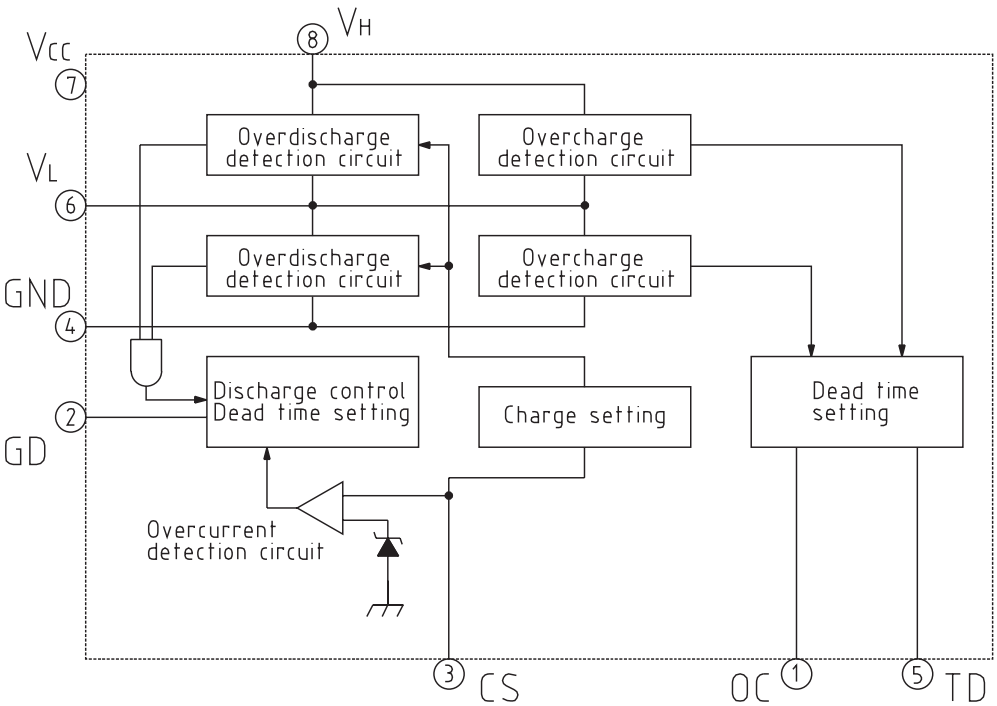
## Pin Assignment




VSOP-8A

| | |
|---|---|
| 1 | OC |
| 2 | GD |
| 3 | CS |
| 4 | GND |
| 5 | TD |
| 6 | VL |
| 7 | Vcc |
| 8 | VH |

## Block Diagram



## Pin Description

| Pin No. | Pin name | Functions |
|---|---|---|
| 1 | OC | Overcharge detection output pin<br>PNP$T_R$ open collector output<br>Overcharge mode: ON<br>Normal mode, overdischarge mode, overcurrent mode: OFF |
| 2 | GD | Discharge control FET (N-ch) control output pin<br>Normal mod, overcharge mode: H<br>Overdischarge mode, overcurrent mode: L |
| 3 | CS | Overcurrent detection input pin<br>Monitors discharge current equivalently by the voltage drop between discharge control FET source and drain. Stops discharge when voltage between CS pin and GND pin goes above overcurrent detection threshold value, and holds until load is released. |
| 4 | GND | Ground pin, or lower cell load negative pole input pin. |
| 5 | TD | Overcharge detection dead time setting pin<br>Dead time can be set by adding a capacitor between TD and GND pins. |
| 6 | VL | Battery intermediate potential input pin<br>Connection pin for lower cell positive electrode side and upper cell negative electrode side. |
| 7 | $V_{CC}$ | Power supply input pin |
| 8 | VH | Upper cell positive electrode input pin |

Note: Mode Descriptions

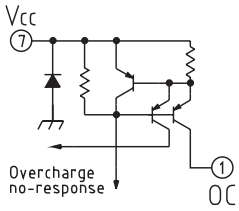
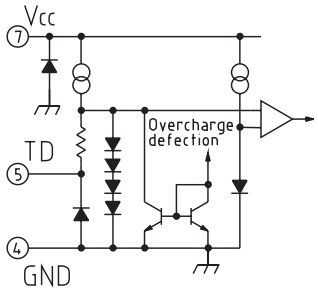
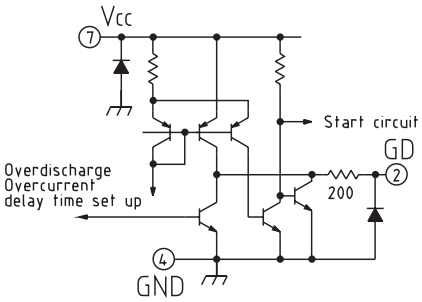
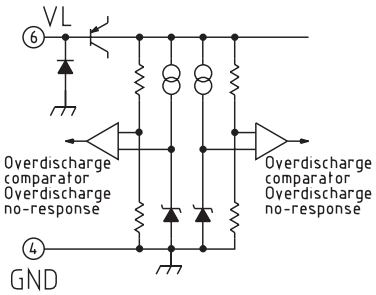
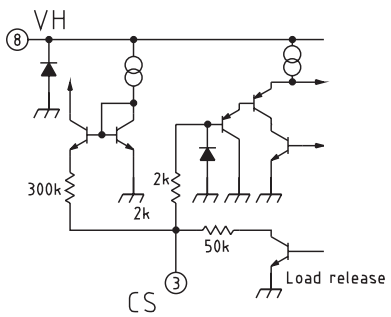
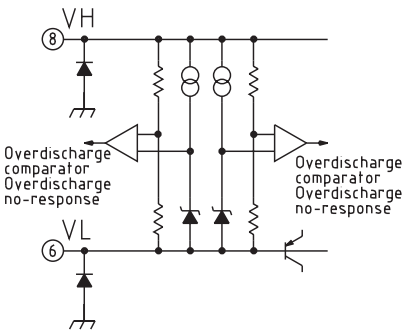
(1) Overcharge mode
Either upper cell or lower cell battery voltage exceeds overcharge detection voltage. Overcharge detection operation delay can be set by the dead time setting pin.

(2) Normal mode
Both upper cell and lower cell battery voltages exceed overdischarge detection voltage and are less than overcharge detection voltage.

(3) Overdischarge mode
Either upper cell or lower cell battery voltage is less than overdischarge detection voltage.
Overdischarge detection dead time is set internally. Overdischarge mode is released when charging causes voltage to rise above overdischarge detection voltage. Also, when battery voltage goes above overdischarge release voltage, it resets without charging, but the value is set high. (This function is included in case charging can not be detected. Also, this release voltage has a temperature coefficient of −6mV/°C.)

(4) Overcurrent mode
Voltage between CS and GND exceeds overcurrent detection voltage during discharge.

## Pin Description

| Pin No. | Pin name | Equivalent circuit diagram | Pin No. | Pin name | Equivalent circuit diagram |
|---|---|---|---|---|---|
| 1 | OC |  | 5 | TD |  |
| 2 | GD |  | 6 | VL |  |
| 3 | CS |  | 8 | VH |  |

## Absolute Maximum Ratings

| Item | Symbol | Ratings | Unit |
|---|---|---|---|
| Storage temperature | $T_{STG}$ | −40~+125 | °C |
| Operating temperature | $T_{OPR}$ | −20~+70 | °C |
| Power supply voltage | $V_{CC}$ max. | −0.3~+18 | V |
| OC pin impressed voltage | $V_{OC}$ max. | −0.6~$V_{CC}$ | V |
| CS pin impressed voltage | $V_{CS}$ max. | −0.6~$V_{CC}$ | V |
| Allowable loss | Pd | 300 | mW |

## Recommended Operating Conditions

| Item | Symbol | Ratings | Unit |
|---|---|---|---|
| Operating temperature | $T_{OPR}$ | −20~+70 | °C |
| Operating power supply voltage | $V_{OP}$ | +0.9~+18 | V |

## Electrical Characteristics (Except where noted otherwise, Ta=25°C) Models listed MM1412A

| Item | Symbol | Measurement conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Overcharge detection voltage | $V_{OC}$ | Ta=0°C~50°C | 4.325 | 4.350 | 4.375 | V |
| Overcharge detection hysteresis voltage | $\Delta V_{OC}$ | | 170 | 220 | 270 | mV |
| Overdischarge detection voltage | $V_{OD}$ | | 2.20 | 2.30 | 2.40 | V |
| Consumption current 1 | $I_{VH1}$ | $V_H$=$V_L$=1.0V $V_{CS}$=1.4V | | | 0.1 | µA |
| Consumption current 2 | $I_{VH2}$ | $V_H$=$V_L$=1.9V $V_{CS}$=3.2V | | 0.5 | 0.8 | µA |
| Consumption current 3 | $I_{VH3}$ | $V_H$=$V_L$=3.5V | | 15.0 | 20.0 | µA |
| Consumption current 4 | $I_{VH4}$ | $V_H$=$V_L$=4.5V, $R_{OC}$=270kΩ | | 150 | | µA |
| VL pin input current | $I_{VL}$ | $V_H$=$V_L$=3.5V | −0.3 | 0 | 0.3 | µA |
| Overdischarge release voltage | $V_{DF}$ | Discharge resume by voltage rise | 3.30 | 3.50 | 3.70 | V |
| GD pin H output voltage | $V_{GDH}$ | $V_H$=$V_L$=3.5V, IL=−10µA | $V_H$−0.3 | $V_H$−0.2 | | V |
| GD pin L output voltage | $V_{GDL}$ | $V_H$=$V_L$=3.5V, IL=10µA | | 0.2 | 0.3 | V |
| OC pin output current | $I_{OCH}$ | $V_H$=$V_L$=4.5V | 30 | 150 | | µA |
| Overcurrent detection threshold value | $V_{CS1}$ | | 135 | 150 | 165 | mV |
| Overcurrent short threshold value | $V_{CS2}$ | When both battery pack pins are shorted | 0.35 | 0.45 | 0.55 | V |
| Overcurrent release | | Load release: Load of 5MEGΩ or more between both battery pack pins | | | | |
| Overcurrent detection delay time 1 | $t_{OC1}$ | | 7 | 12 | 18 | ms |
| Overcurrent detection delay time 2 | $t_{OC2}$ | *1 | | 30 | 100 | µs |
| Overdischarge detection delay time | $t_{OD}$ | | 8 | 13 | 20 | ms |
| Overcharge detection dead time | $t_{OCH}$ | $C_{TD}$=0.18µF | 0.5 | 1.0 | 1.5 | s |
| Start-up voltage | $V_{ST}$ | $V_H$=$V_L$=2.5V | −0.24 | −0.12 | −0.04 | V |

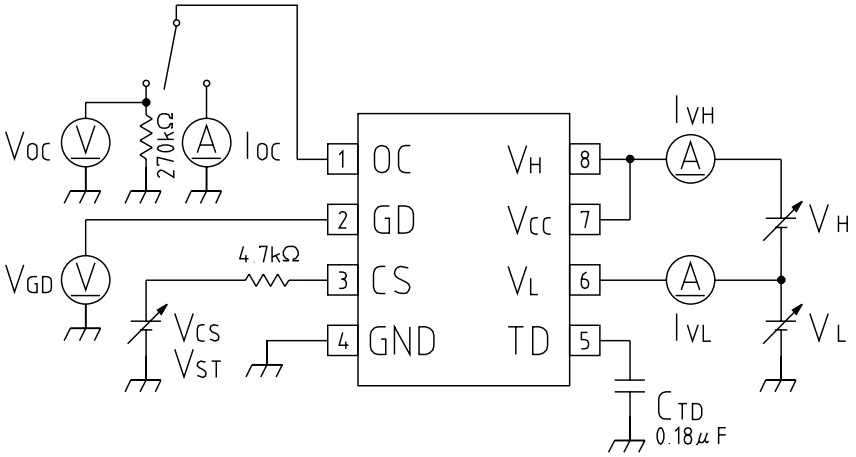
Note 1: Overcurrent short mode delay time (overcurrent delay time 2) is IC response speed.
In actual use, the time for discharging the discharge control FET gate capacity is added.
Also, when voltage change is large due to excess current, the IC internal bias current may turn off temporarily, causing response time to lengthen. Select the time constant for the capacitor connected to the power supply pin so that power supply fluctuation is more than 100µs/1V.

Note 2: Calculate overcharge dead time according to the following formula:
Overcharge detection dead time: $t_{ALM} - 5.55 \times C_{TD}$[s]
[$C_{TD}$: external capacitor, Unit:µF]

# Measuring Circuit

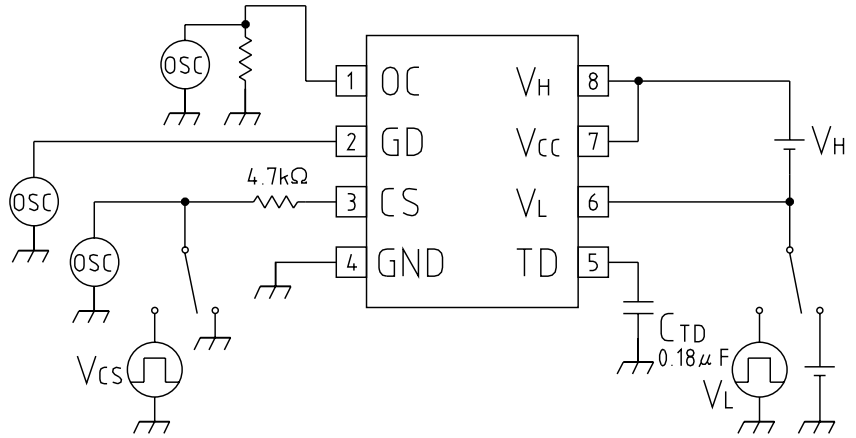
## Measuring Circuit 1

(VOC, ⊿VOC, VOD, VDF, VST, VCS, IDCH, VGDH, VGDL)

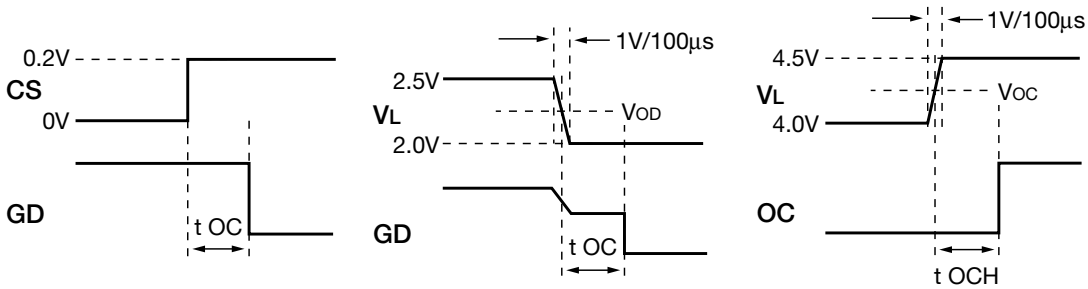



## Measuring Circuit 2

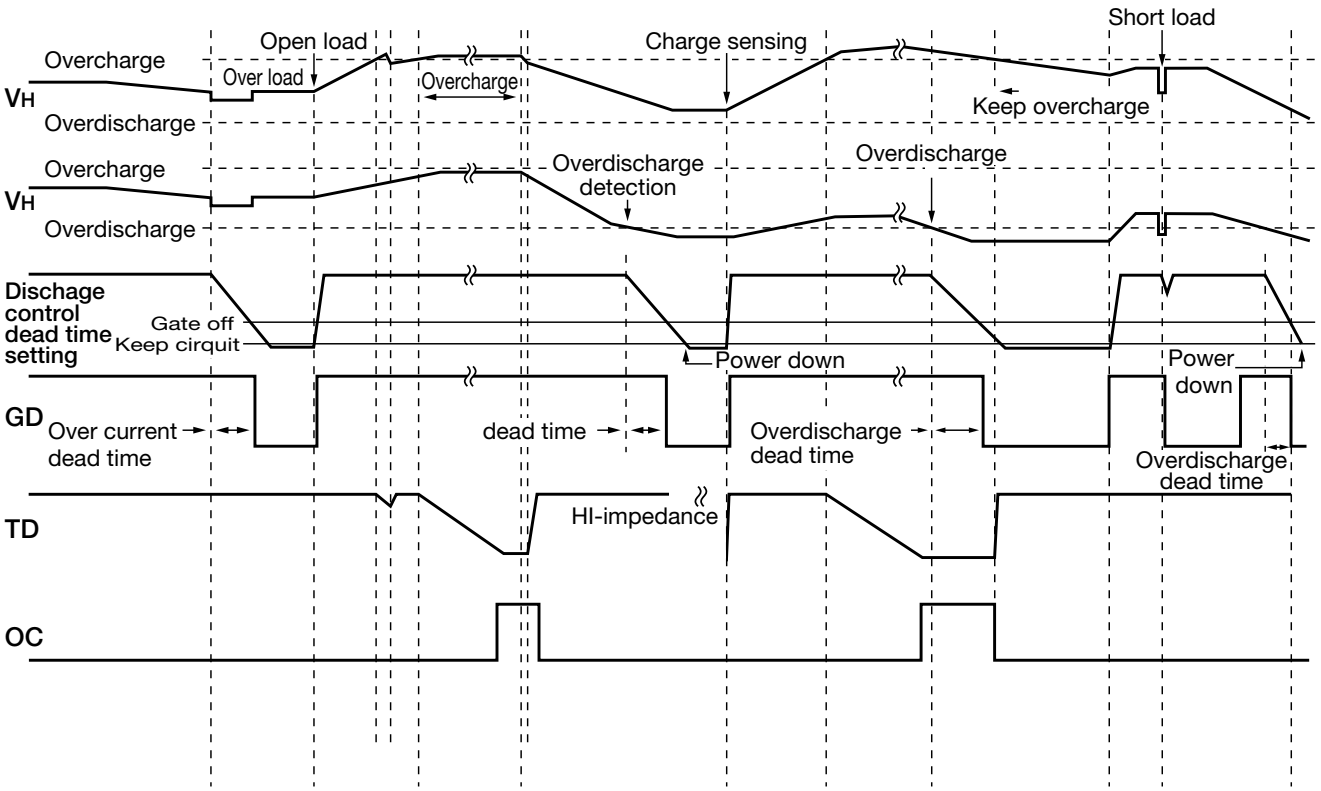
(tOC, tOD, tOCH)




Note :



## Timing Chart



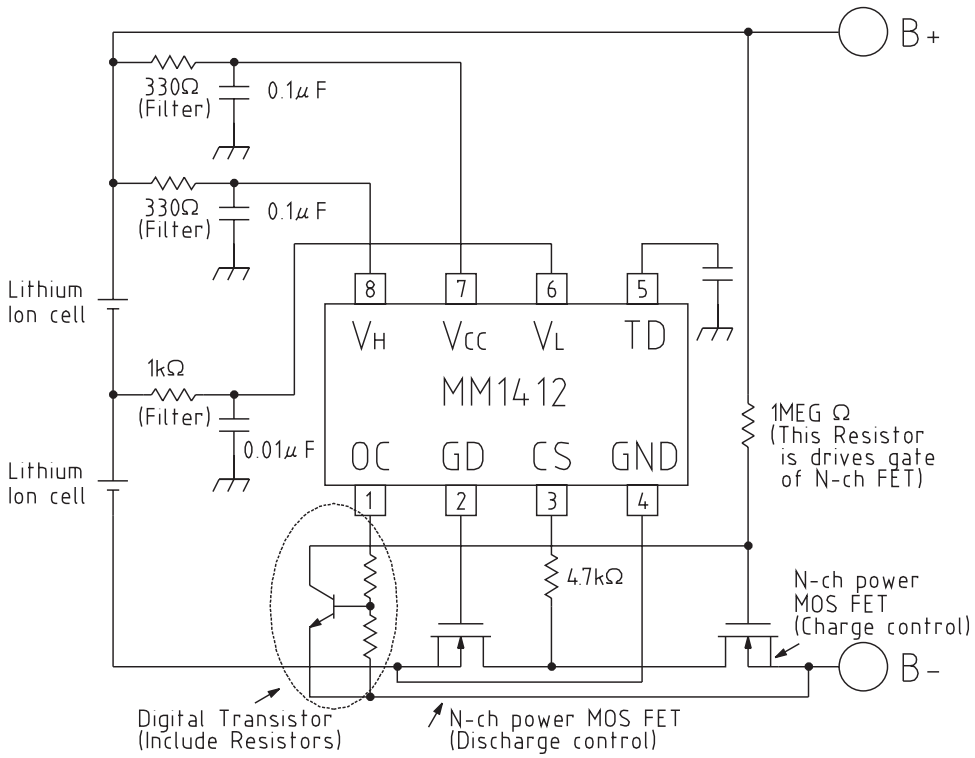

## Description

This IC is a lithium ion battery (2-cell in-series type) protection IC. It has built-in overcharge detection, overdischarge detection and overcurrent detection circuits, and controls the FET (external N-MOS FET) that controls charge and discharge.

The operation modes can be divided broadly into four, as follows.

1) Overcharge mode
   The battery voltage of either the upper cell or lower cell goes above overcharge detection voltage. Detection operation delay for overcharge detection can be set with the dead time setting pin.
2) Normal mode
   The battery voltage of both upper cells and lower cells is above overdischarge detection voltage and below overcharge detection voltage.
3) Overdischarge mode
   The battery voltage of either the upper cell or lower cell drops below overdischarge detection voltage. Dead time for overdischarge detection is set internally. Overdischarge mode is released when charging takes place and the voltage goes above overdischarge detection voltage. Also, reset will occur even without charging if battery voltage goes above overdischarge release voltage, but the set value is high. (This function is provided as a measure for cases when charging can not be detected. Further, this release voltage has a temperature coefficient of -6mV/°C.)
4) Overcurrent mode
   The voltage between CS-GND goes above overcurrent detection voltage during discharge.

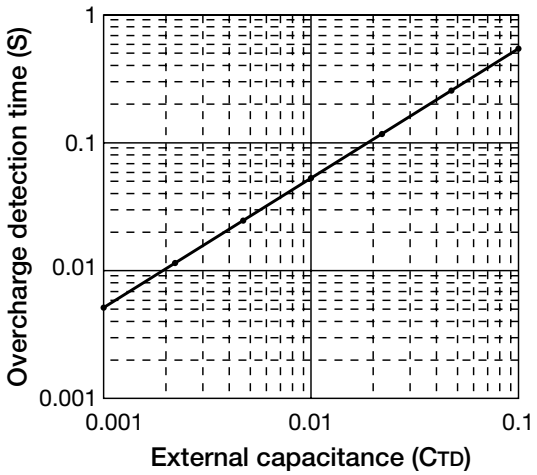
## Application Circuit




Note: Applicable circuits shown are typical examples provided for reference purposes. Mitsumi cannot assume responsibility for any problems arising out of the use of these circuits or for any infringement of third party patent and other right due to same.

## Characteristics

### Overcharge Detection Time (Dead Time)




Note: Dead time can be calculated according to the following formula:

$t_{OC}=5.55\times C_{TD}$ [s]

$t_{OC}$=Overcharge sensing dead time

$C_{TD}$=External Capacitor···Unit : μF

The above specifications are representative, and are not guaranteed values.