

# Control of Lithium Ion Batteries (switching regulator secondary) (two cells) Monolithic IC MM1357

## Outline

This IC is used to control two-cell chargers and the secondary side of switching regulators; it features enhanced functions for current switching and for overcharge detection and other kinds of protection. The control output is capable of driving a photocoupler LED. The charging current can be switched between high and low currents, and each can also be varied externally.

## Features

- |                                                                        |                                       |
|------------------------------------------------------------------------|---------------------------------------|
| 1. Charging voltage                                                    | : Can be set externally               |
| 2. Charging current (switchable between high and low levels, variable) | High : 320mV typ.<br>Low : 145mV typ. |
| 3. Reference voltage                                                   | : 1.207V typ.                         |

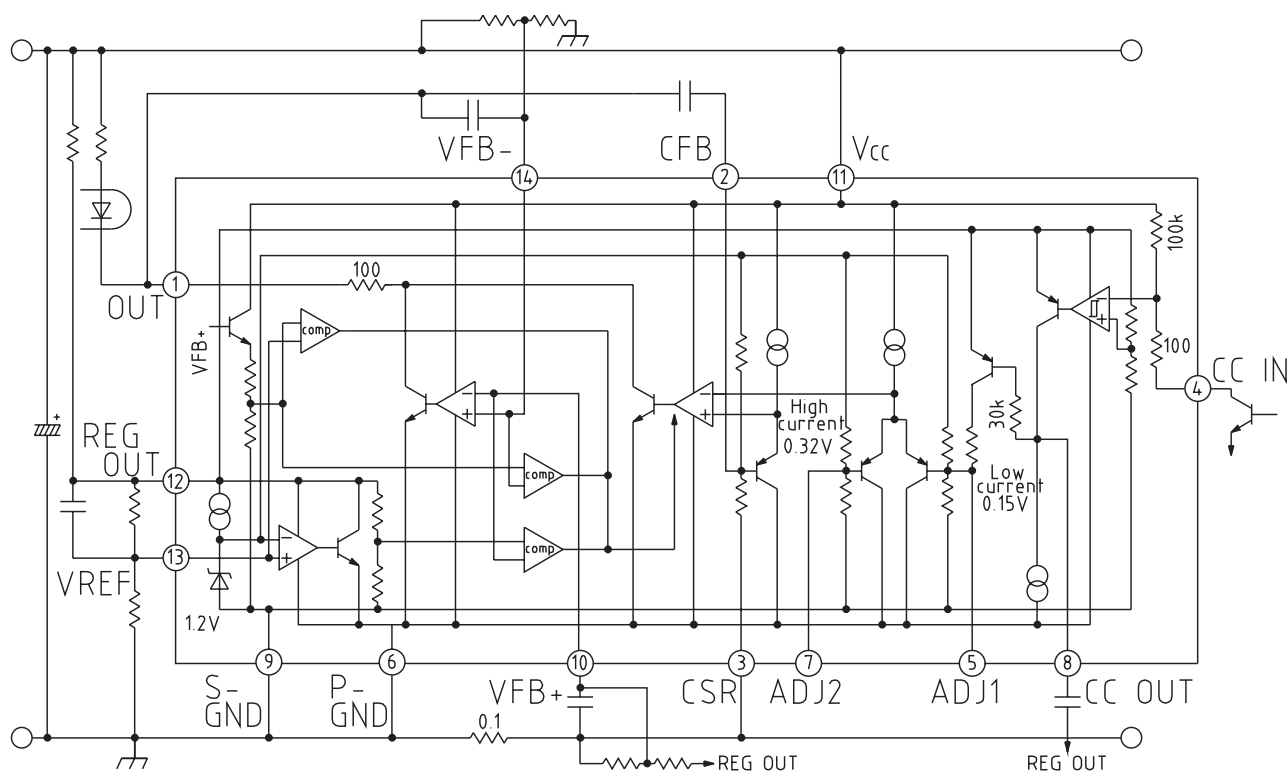
## Package

SOP-14B

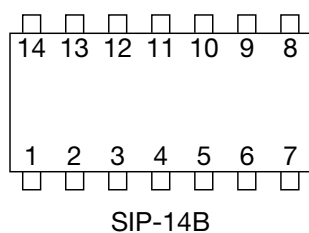
## Applications

1. Switching regulator
2. AC adapter
3. Lithium ion battery charger

## Block Diagram



## Pin Assignment



|   |       |    |         |
|---|-------|----|---------|
| 1 | OUT   | 8  | CC OUT  |
| 2 | CFB   | 9  | S-GND   |
| 3 | CSR   | 10 | VFB+    |
| 4 | CC IN | 11 | Vcc     |
| 5 | ADJ1  | 12 | REG OUT |
| 6 | P-GND | 13 | VREF    |
| 7 | ADJ2  | 14 | VFB-    |

## Pin Description

| Pin no. | Pin name | Input/output | Function                                                                                                                                                                                                                                                                                                                                                                                           |
|---------|----------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | OUT      | Output       | Output pin for charging control<br>An external photocoupler is controlled for constant-current, constant-voltage charging control.                                                                                                                                                                                                                                                                 |
| 2       | CFB      | Input        | Amp inverting input pin for current control<br>An external capacitor (approx. 0.1 $\mu$ F) is connected between CFB and OUT, and phase compensation used to improve oscillation.                                                                                                                                                                                                                   |
| 3       | CSR      | Input        | Current detection pin<br>Current is detected via the voltage drop across an external resistance between CSR and GND (R1), to control the charging current.                                                                                                                                                                                                                                         |
| 4       | CC IN    | Input        | Charging current switching signal input pin<br>H (Vcc) is the charging current 0.15V/R1, and L (GND) is the charging current 0.32V/R1. If for instance R1 is 0.1 $\Omega$ , then switching is between 1.5A and 3.2A (typ.).<br>The switching voltage VTH is as follows.<br>When REG OUT is 2.5V, VTH is 2.05V typ.<br>When REG OUT is 4V, VTH is 3.0V typ.<br>When REG OUT is 5V, VTH is 3.7V typ. |
| 5       | ADJ1     | Input        | Amp non-inverting input pin 1 for current control<br>The pin voltage is set at 0.15V typ. With CC-IN at H or open, the non-inverting input pin of the current control amp is at 0.15 V.<br>By adjusting the pin voltage using an external resistance or by other means, the charging current can be varied.                                                                                        |
| 6       | P-GND    | Input        | Power ground pin                                                                                                                                                                                                                                                                                                                                                                                   |
| 7       | ADJ2     | Input        | Amp non-inverting input pin 2 for current control<br>The pin voltage is set at 0.32V typ. With CC-IN at L, the non-inverting input pin of the current control amp is at 0.32V.<br>By adjusting the pin voltage using an external resistance or by other means, the charging current can be varied.                                                                                                 |
| 8       | CC OUT   | Output       | Charging current switching signal output pin<br>Output is in phase with CC IN. By connecting an external capacitor between CC OUT and REG OUT, a delay can be added only when the current switching CC IN goes from H to L. For instance, when REG OUT is 4V, on connecting an 0.1 $\mu$ F capacitor CC OUT becomes about 50mS (an example is shown in the Timing Chart section).                  |
| 9       | S-GND    | Input        | Signal ground pin                                                                                                                                                                                                                                                                                                                                                                                  |
| 10      | VFB+     | Input        | Amp non-inverting input pin for voltage control<br>The charging voltage is set through the resistances at the VFB + pin and the VFB - pin.                                                                                                                                                                                                                                                         |
| 11      | Vcc      | Input        | Power supply input pin                                                                                                                                                                                                                                                                                                                                                                             |
| 12      | REG OUT  | Output       | Reference voltage circuit output pin<br>The reference voltage can be set between 2 and 6V. The input current to start the reference voltage should be set to 1mA or greater.                                                                                                                                                                                                                       |
| 13      | VREF     | Input        | Reference voltage circuit input pin<br>The VREF pin voltage is set at 1.2V typ. The REG OUT voltage can be set through the resistances between REG OUT and VREF, and between VREF and GND.<br>Amp inverter input pin for voltage control                                                                                                                                                           |
| 14      | VFB-     | Input        | Amp inverting input pin for voltage control<br>The charging voltage can be set through the resistances at the VFB + pin and VFB - pin.<br>By connecting an external capacitor (approx. 0.1 $\mu$ F) between VFB and OUT for phase compensation, oscillation can be improved.                                                                                                                       |

## Absolute Maximun Ratings

| Item                  | Symbol               | Ratings  | Units |
|-----------------------|----------------------|----------|-------|
| Storage temperature   | T <sub>STG</sub>     | -40~+125 | °C    |
| Operating temperature | T <sub>OPR</sub>     | -20~+85  | °C    |
| Power supply voltage  | V <sub>CC</sub> max. | -0.3~+24 | V     |
| Allowable loss        | P <sub>D</sub>       | 350      | mW    |

## Recommended Operating Conditions

| Item                  | Symbol           | Ratings  | Units |
|-----------------------|------------------|----------|-------|
| Operating temperature | T <sub>OPR</sub> | -15~+80  | °C    |
| Operating voltage     | V <sub>OPR</sub> | +2~+20 * | V     |

\*The minimum operating voltage is under constant-current control

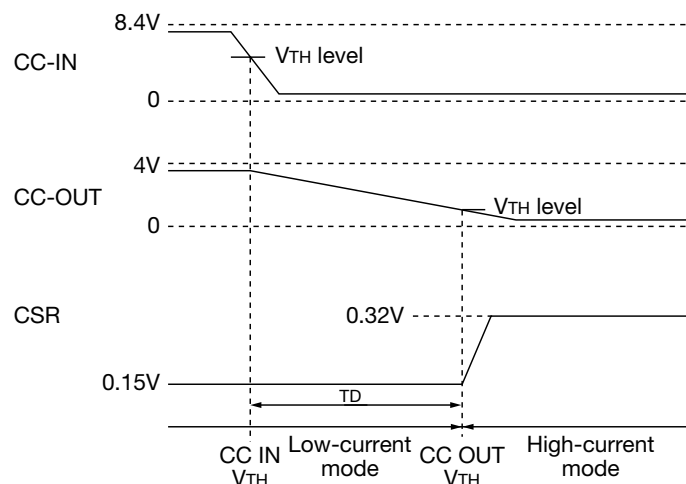
## Electrical Characteristics (Except where noted otherwise, Ta=25°C, REG OUT=4V, V<sub>CC</sub>=8.4V)

| Item                                  | Symbol            | Measurement conditions                     | Min.  | Typ.  | Max.            | Units |
|---------------------------------------|-------------------|--------------------------------------------|-------|-------|-----------------|-------|
| V <sub>CC</sub> minimum input current | I <sub>CC</sub>   | Excluding REG OUT input current            |       | 0.25  | 0.40            | mA    |
| Amp input for voltage control         |                   |                                            |       |       |                 |       |
| Input offset voltage                  | V <sub>IO</sub>   |                                            |       | 1     | 5               | mV    |
| Input bias current VFB+               | I <sub>B+</sub>   |                                            |       | 20    | 250             | nA    |
| Input bias current VFB-               | I <sub>B-</sub>   |                                            |       | 20    | 250             | nA    |
| Common-mode input voltage range       | V <sub>I</sub>    | *                                          | 0.7   |       | REG OUT<br>-0.7 | V     |
| Amp input for current control         |                   |                                            |       |       |                 |       |
| ADJ1 pin input impedance              | R <sub>ADJ1</sub> |                                            |       | 13    |                 | kΩ    |
| ADJ2 pin input impedance              | R <sub>ADJ2</sub> |                                            |       | 13    |                 | kΩ    |
| CFB pin input impedance               | R <sub>CFB</sub>  |                                            |       | 2     |                 | kΩ    |
| Current limit 1                       | V <sub>CL1</sub>  | High-current mode                          | 310   | 320   | 330             | mV    |
| Current limit 2                       | V <sub>CL2</sub>  | Low-current mode                           | 137   | 145   | 153             | mV    |
| OUT pin input current 1               | I <sub>S1</sub>   | OUT=8.4V (voltage-control amp)             | 20    |       |                 | mA    |
| OUT pin input current 2               | I <sub>S2</sub>   | OUT=4 V (voltage-control amp)              | 20    |       |                 | mA    |
| OUT pin leakage current               | I <sub>L</sub>    | OUT=24V                                    |       | 2     |                 | μA    |
| CC IN input impedance                 | R <sub>CI</sub>   |                                            |       | 100   |                 | kΩ    |
| CC switching voltage L (VTR mode)     | V <sub>CL</sub>   |                                            |       |       | 2.6             | V     |
| CC switching voltage H (CHG mode)     | V <sub>CH</sub>   |                                            | 3.4   |       |                 | V     |
| CC OUT output intake current          | I <sub>CO1</sub>  | On switching from low to high current mode |       | 6     |                 | μA    |
| CC OUT output current                 | I <sub>CO2</sub>  | On switching from high to low current mode |       | 0.5   |                 | mA    |
| CC OUT output voltage range           | V <sub>CO</sub>   |                                            | 0.4   |       | 3.6             | V     |
| Reference voltage                     | V <sub>REF</sub>  |                                            | 1.195 | 1.207 | 1.219           | V     |
| REG OUT output voltage variable range | V <sub>REG</sub>  |                                            | 2.0   |       | 6.0             | V     |
| REG OUT maximum input current         | I <sub>max.</sub> |                                            | 20    |       |                 | mA    |
| REG OUT minimum input current         | I <sub>min.</sub> |                                            |       |       | 1.0             | mA    |

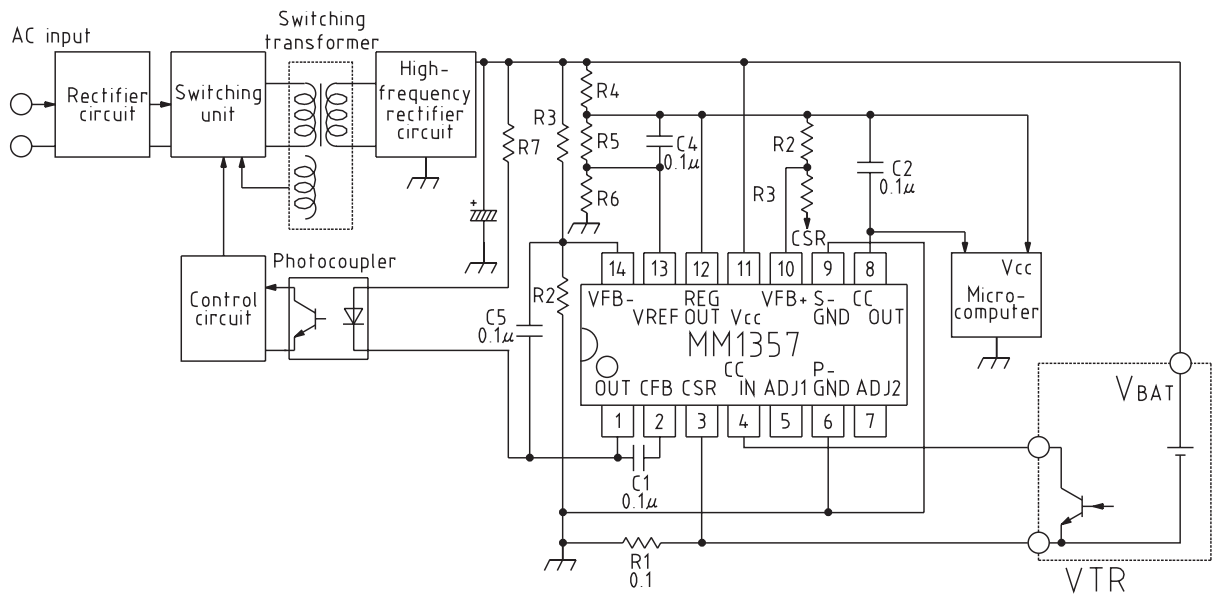
\*Because there is an internal circuit for protection against shorts of external components, the common-mode input voltage range is 0.7V to REG OUT-0.7V. Values are set such that overvoltages do not occur when there is a short between VFB+ and REG OUT or between VFB- and GND.

## Timing Chart

Timing chart for connection of a timing capacitor C<sub>T</sub> to CC OUT  
With REG OUT at 4V and C<sub>T</sub>=0.1μF, T<sub>D</sub> is approx. 50mS.



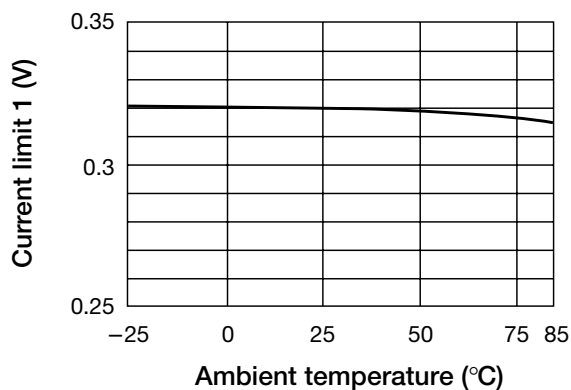
## Application Circuits



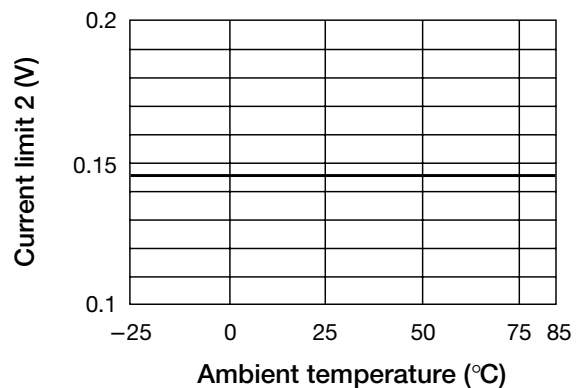
- Note 1 : 1. The REG OUT voltage can be set to  $1.2V \text{ typ.} \times (R5+R6)/R6$ . (REG OUT = 2 to 6V)  
 2. The value of R4 should be set according to the load. (Consider it to be a shunt regulator.)  
 3. The voltage under constant-voltage charging is equal to  $(R3/R2) \times \text{REG OUT}$ . When a high-precision voltage is required, use the knob for adjustment.  
 4. The current in constant-current charging can be set to either of two values,  $0.15V/R1$  (when CC-IN is H), and  $0.32V/R1$  (when CC-IN is L).  
 5. R7 is a resistance for current limiting.  
 6. The capacitors C1 and C5 are to prevent oscillation; C4 is for soft starting of the REG OUT voltage; and C2 is used to delay current switching (CC-OUT switched from H to L).
- Note 2 : This IC incorporates a voltage-controlling amp and protection against shorting to VREF ; when R2, R3, R5 and R6 are shorted, the voltage is limited to its minimum value. By means of a comparator within the VFB+, VFB- and VREF pin area, upon resistance shorting the OUT pin is forced to L.
- Note 3 : The above diagram is an example for reference purposes; in actual use the circuit should be studied thoroughly prior to use.

## Characteristics

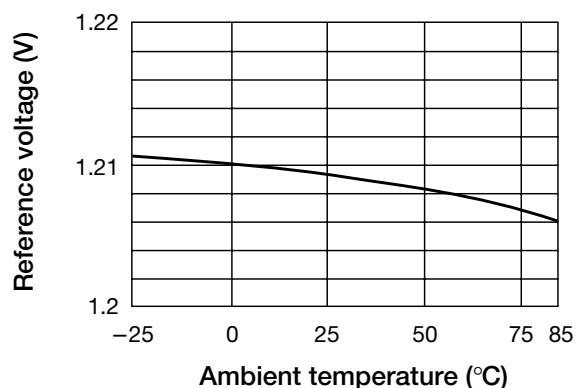
### Current limit 1 vs temperature



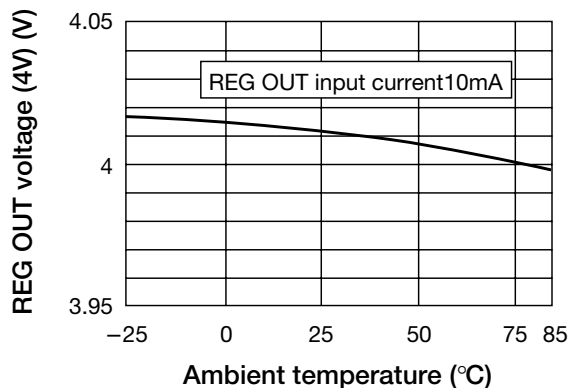
### Current limit 2 vs temperature



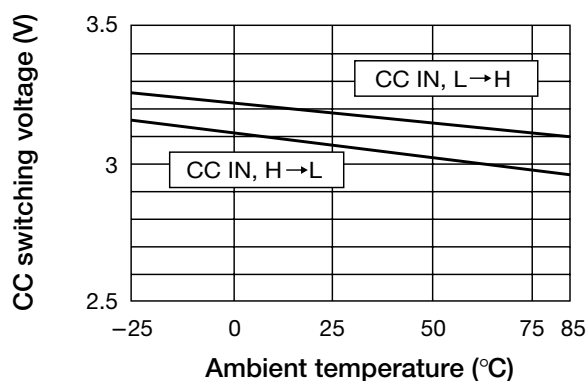
■ Reference voltage vs temperature



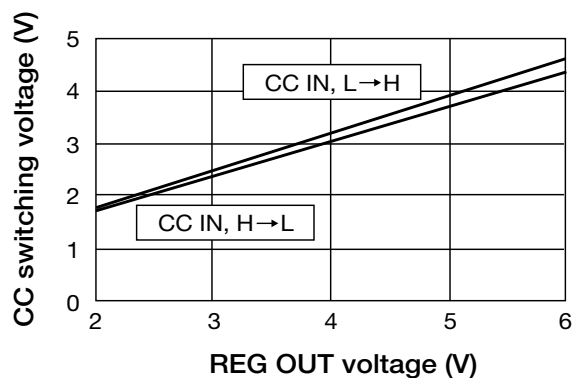
■ REG OUT voltage (4V)– temperature



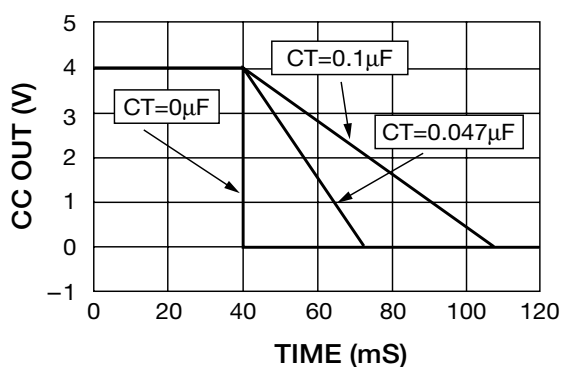
■ CC switching voltage vs temperature  
REG OUT=4V



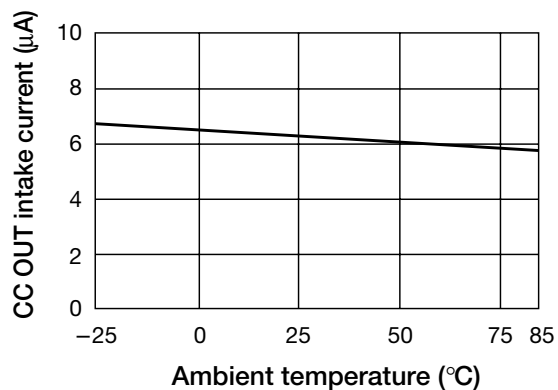
■ CC switching voltage vs REG OUT voltage



■ CC OUT-DELAY TIME  $T_a=25^\circ\text{C}$  REG OUT=4V  
( $C_T$  is the capacitance between CC OUT and REG OUT)



■ CC OUT intake current vs temperature



■ REG OUT voltage vs REG OUT input current  $T_a=25^\circ\text{C}$

