# SWITCH-MODE SINGLE CELL LI-ION BATTERY CHARGER

## DESCRIPTION

The ASC8513 is a monolithic switching charger for single cell battery, It achieves up to 2.5A charge current with voltage mode PWM step- down (buck) switching architecture.ASC8513 regulates the battery voltage and charge current with CV(constant voltage) and CC(constant current) loops. Fault condition includes thermal shutdown、time out and output short. Other safety features include battery temperature monitoring and charge status indication.

The ASC8513 is available in 14-pin TSSOP package.

## APPLICATIONS

- Handheld Products
- Portable Equipment
- Distributed Power Systems
- Portable DVD Players
- Notebook
- Chargers for one cell Lion Batteries

## FEATURES

- 100% Maximum Duty Cycle
- 0.5% Charge Voltage Accuracy
- Low 10uA Reverse Battery Drain Current
- Programmable Charge Current Up To 2.5A
- Fixed 400kHz Frequency
- Build-in Battery Detection
- Suitable For One Cell Li-Ion Batteries
- Automatic Battery Recharge
- Soft Start
- Battery Temperature Monitoring
- Thermal Shutdown And Protection
- Status Indication
- 12V Maximum Input Voltage Rating
- Ambient Temperature Range: -20℃～70℃
- 14-Lead TSSOP Package Available

## TYPICAL APPLICATION

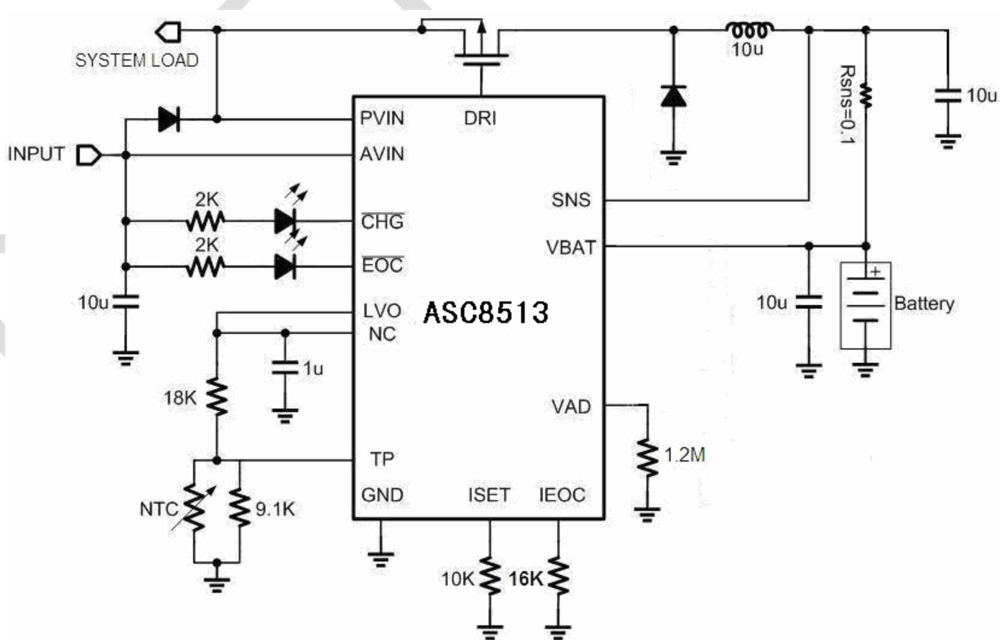



**Figure1.1 Typical Application For 1A Charge Current**

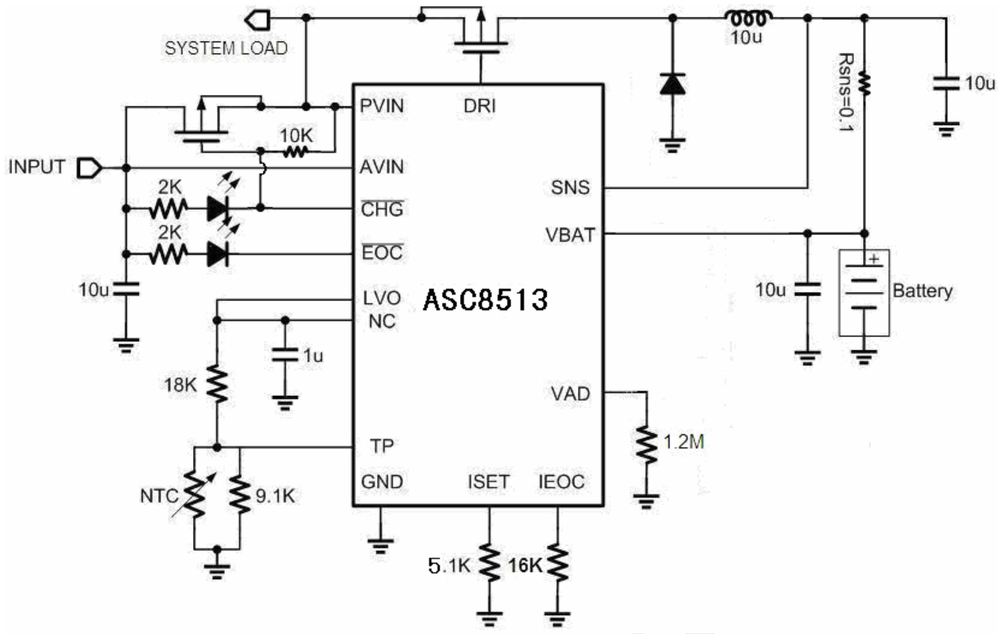
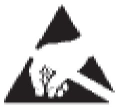



**Figure2.1 Typical Application For 2A Charge Current**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## ORDER INFORMATION

| PART NUMBER | PACKAGE | TOP MARKING | TEMPERATURE |
|---|---|---|---|
| ASC8513 | TSSOP-14 | ASC8513 | -20℃～70℃ |

## ABSOLUTE MAXIMUM RATING

- Supply Voltage…………………………12V
- Gate Voltage…………………… 0 to VIN
- BAT,SNS…………………………-0.3V to 12V
- $\overline{CHG}$,$\overline{EOC}$,TP……………………-0.3V to 3.3V
- ISET,IEOC,LVO………………… -0.3V to 3.3V
- Operation Temperature Range……-20℃～70℃
- Storage Temperature………………-60℃～125℃
- Lead Temperature………………..… 260℃
- HBM ESD Level.............................. 2000V

## RECOMMENDED OPERATION CONDITIONS

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage, PVIN and AVIN | 4.5(1) | | 12(2) | V |
| Operation Temperature | -20 | | 70 | ℃ |

(1) ASC8513 continues to operate until the supply voltage drop to about 3.0V, but it works abnormally, the status of $\overline{CHG}$ and $\overline{EOC}$ are not right.

(2) The switch noise voltage spikes should not exceed the absolute maximum rating on PVIN and AVIN.

## PIN CONFIGURATION

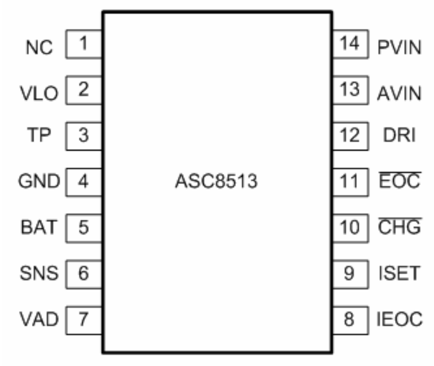



**Figure2. ASC8513 Pin Configuration**

## TABLE 1: PIN FUNCTIONS

<table>
<tr><th>PIN#</th><th>NAME</th><th>I/O</th><th colspan="3">DESCRIPTION</th></tr>
<tr><td>1</td><td>NC</td><td></td><td colspan="3">NC, connected to LVO</td></tr>
<tr><td>2</td><td>LVO</td><td>O</td><td colspan="3">Internal linear regulator 3.3V reference output. Bypass to GND with a 1uF ceramic capacitor.</td></tr>
<tr><td>3</td><td>TP</td><td>I</td><td colspan="3">Thermistor input. Connect a resistor from this pin to the pin LVO and the Thermistor from this pin to ground.</td></tr>
<tr><td>4</td><td>GND</td><td>I</td><td colspan="3">Ground.</td></tr>
<tr><td>5</td><td>BAT</td><td>I</td><td colspan="3">Positive battery terminal.</td></tr>
<tr><td>6</td><td>SNS</td><td>I</td><td colspan="3">Battery current sense positive input. Connect a resistor Rsns between SNS and VBAT.</td></tr>
<tr><td>7</td><td>VAD</td><td>I</td><td colspan="3">PIN for fine tuning of full charge voltage.</td></tr>
<tr><td>8</td><td>IEOC</td><td>O</td><td colspan="3">Connect a resistor to ground to set the end-of-charge current.</td></tr>
<tr><td>9</td><td>ISET</td><td>O</td><td colspan="3">Connect a resistor to ground to set the CC charge current.</td></tr>
<tr><td rowspan="3">10</td><td rowspan="3">$\overline{CHG}$</td><td rowspan="3">O</td><td>$\overline{EOC}$</td><td>$\overline{CHG}$</td><td>DISCRIPTION</td></tr>
<tr><td>0</td><td>0</td><td>Charge suspend, no battery exist</td></tr>
<tr><td>0</td><td>1(1)</td><td>In charging</td></tr>
<tr><td rowspan="3">11</td><td rowspan="3">$\overline{EOC}$</td><td rowspan="3">O</td><td>1</td><td>0</td><td>End of charge</td></tr>
<tr><td>0</td><td>50% DUTY</td><td>FAULT condition(time out)</td></tr>
<tr><td>0</td><td>50% DUTY</td><td>Battery temperature abnormal</td></tr>
<tr><td>12</td><td>DRI</td><td>O</td><td colspan="3">Gate drive output. Drive output for the external P-channel MOSFET.</td></tr>
<tr><td>13</td><td>AVIN</td><td>I</td><td colspan="3">Analog input voltage</td></tr>
<tr><td>14</td><td>PVIN</td><td>I</td><td colspan="3">Power input voltage</td></tr>
</table>

(1) "1" means that LED will turn on if connected. Accordingly, "0" means off.

# FUNCTION BLOCK

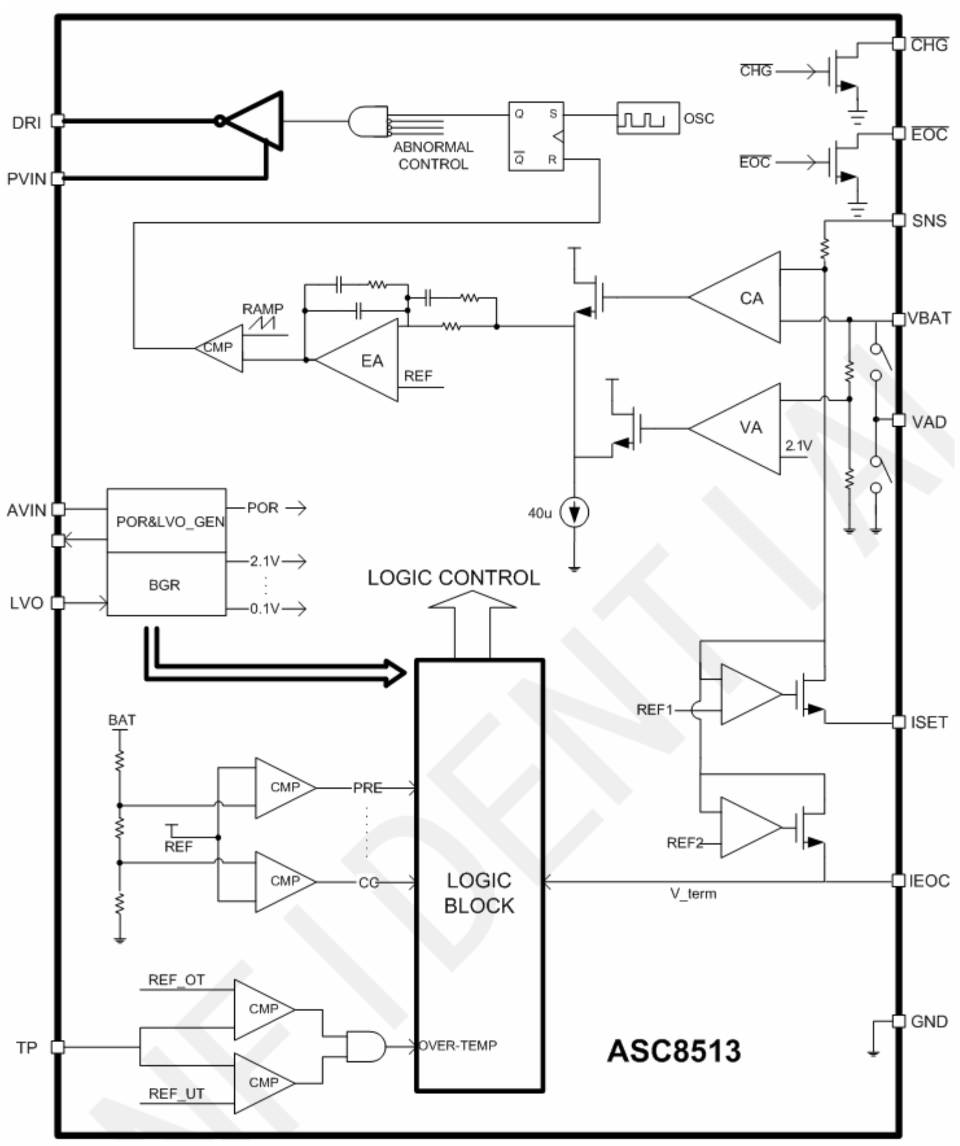



Figure3.1 ASC8513 Function Block Diagram

## OPERATION FLOW CHART

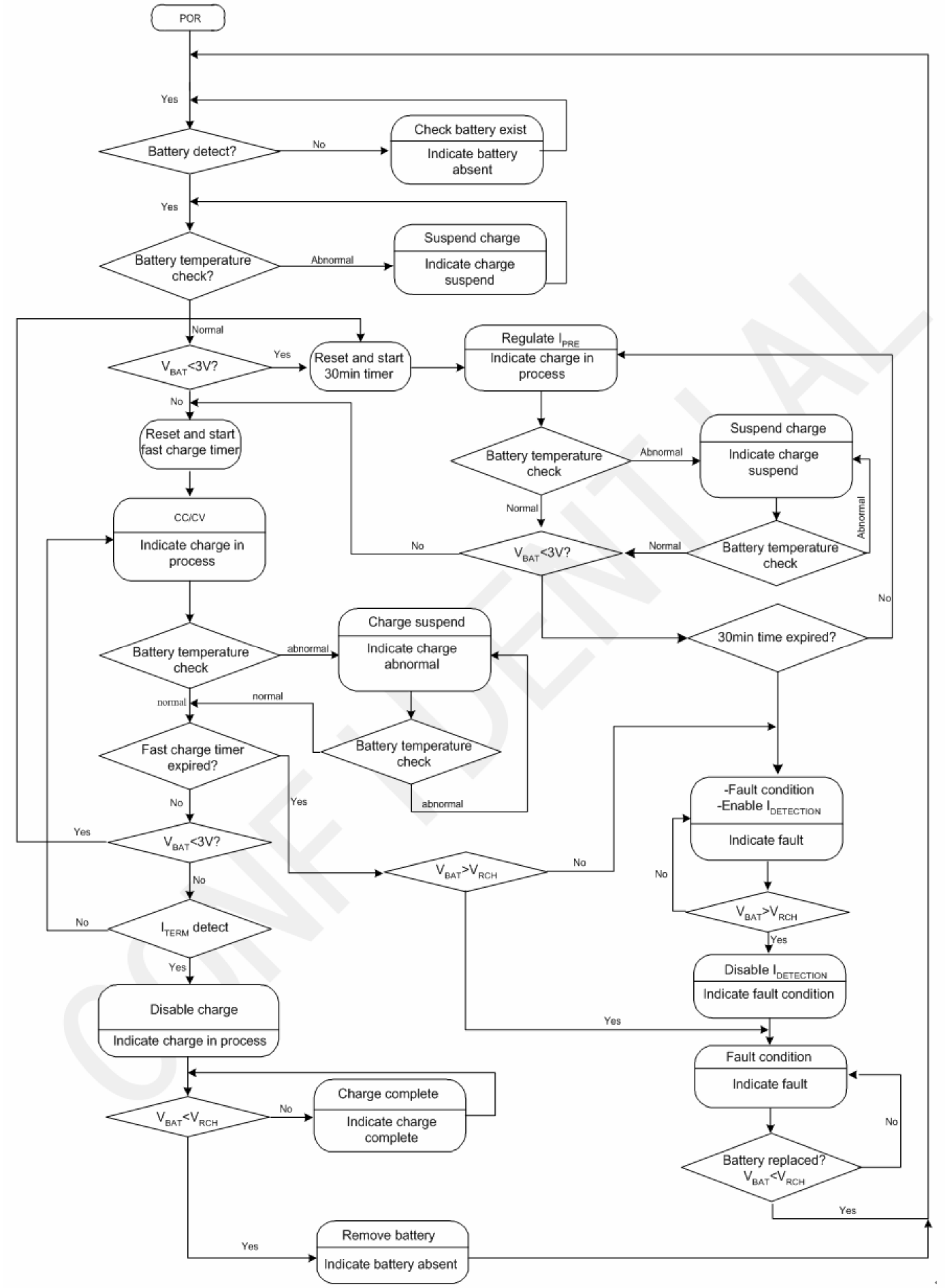





**Figure3.2 ASC8513 Operation Flow Chart**

## ELECTRICAL CHARACTERISTICS $V_{IN}$=5V, $T_A$=25℃, unless otherwise noted.

| PARAMETER | SYM | CONDITION | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input voltage range | $V_{IN}$ | | 4.5 | | 12 | V |
| Supply current | $I_Q$ | | | | 5 | mA |
| Battery reverse current(1) | | $V_{BAT}$=4.2V | | | 10 | uA |
| **VOLTAGE REGULATION** | | | | | | |
| Battery regulate voltage | $V_{REG}$ | | 4.152 | 4.18 | 4.208 | V |
| Recharge threshold voltage | $V_{RCH}$ | | | 4.10 | | V |
| **CURRENT REGULATION-FAST CHARGE** | | | | | | |
| Output current range of converter | $I_{CC}$ | 3V<$V_{BAT}$<4V | 200 | | 2500 | mA |
| Voltage regulated across $R_{SNS}$ accuracy(2) | $V_{SNS}$ | 0.1V<$V_{SNS}$<0.2V | -10% | | +10% | |
| Output current set voltage | $V_{ISET}$ | | | 1 | | V |
| Output current set factor | $K_{ISET}$ | | | 1000 | | V/A |
| **PRECHARGE CURRENT REGULATION** | | | | | | |
| Pre-charge to fast charge transition voltage threshold | $V_{LOWV}$ | | | 3 | | V |
| Pre-charge current to fast charge current ratio | $K_{PRE}$ | | | 1/5 | | |
| Pre-charge set voltage | $V_{ISET}$ | | | 200 | | mV |
| Pre-charge set factor | $K_{ISET}$ | | | 1000 | | V/A |
| **CHARGE TERMINATION DETECTION** | | | | | | |
| Termination current to fast charge current ratio | $K_{TERM}$ | $R_{IEOC}$=2$R_{ISET}$ | | 1/10 | | |
| Termination current detection set voltage | $V_{IEOC}$ | | | 150 | | mV |
| **PWM** | | | | | | |
| Oscillator frequency | $f_{OSC}$ | | | 400 | | KHz |
| Duty cycle range | D | | 0 | | 100％ | |
| **BATTERY PROTECTION** | | | | | | |
| Output short voltage | $V_{SHORT}$ | | | 2 | | V |
| Output short current | $I_{SHORT}$ | | | 20 | | mA |
| **TEMPERATURE PROTECTION** | | | | | | |
| NTC low temp rising threshold | | $R_{NTC}$=MFH103 -3950(3)(0℃) | | 60 | | %$V_{LVO}$ |
| NTC high temp falling threshold | | $R_{NTC}$=MFH103 -3950(50℃) | | 14 | | %$V_{LVO}$ |

(1) AVIN is blocked by a diode and will drop to 0V without input supply voltage.

(2) To guarantee the accuracy of charge current detection, the voltage across $R_{SNS}$ should be set higher than 100mV. However, it will decrease the charge efficiency if the voltage across $R_{SNS}$ set too high. It is recommended to set between 100mV and 200mV.

(3) Typically, T=0℃, $R_{NTC}$=32.503K; T=50℃, $R_{NTC}$=3.587K.

## OPERATION

The ASC8513 is a voltage mode controller with feed forward function to regulate charge current or voltage. The feed forward function is used to help improve line transient response. The current and voltage loops are internally compensated using a type-III compensation scheme. The device can operate between 0% to 100% duty cycle. Figure 4 is the typical profile of Li-Ion battery charge.

Power P-MOS is used as pass transistor externally.

It is recommended to use low voltage P-channel MOSFET with superior $R_{DS(ON)}$ to increase efficiency.

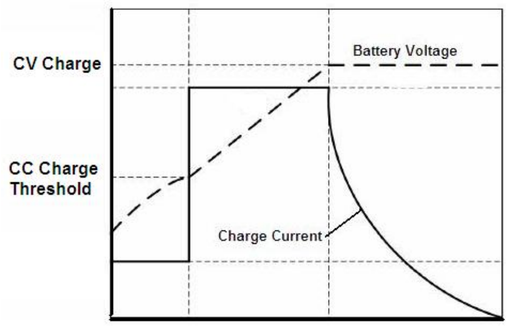



**Figure4. Battery Charge Profile**

### CHARGE CYCLE

A complete charge cycle can be divided into three stage, those are pre-charge, constant current (CC) charge and constant voltage (CV) charge. The charge will start in "trickle charging mode" (1/5 of the CC charge current), that is pre-charge stage. If the charge stays in the pre-charge stage more than 30 minutes, "time out" condition will be triggered, and the charge is terminated. As the battery voltage goes higher than $V_{LOWV}$, it will enter into CC stage. During CC stage, the charge current is constant, and the battery voltage keeps on rise. While the charge current begins to decrease, it goes into CV stage. As the charge current drops below the set value $I_{EOC}$, ASC8513 indicates "end-of-charge" (EOC) and terminate charge cycle.

### AUTOMATIC RECHARGE

After the charge cycle is completed and both the battery and the input power supply are not removed, a new charge cycle will begin if the battery voltage drops below 4.1V due to self-discharge or other reasons.

### CHARGER STATUS INDICATION

ASC8513 has two open drain status outputs: $\overline{CHG}$ and $\overline{EOC}$. Table1 describes the status of charge cycle based on the $\overline{CHG}$ and $\overline{EOC}$ outputs.

### TIMER OPERATION

ASC8513 uses internal timer to terminate the charge if the timer times out. The total time for pre-charge is 30 minutes, and about 6.5 hour for CC and CV charge.

### SWITCHING OF POWER SUPPLIES

As shown in figure5.1, the input will provide power supplies both for battery charging and system load. While the input removed, the battery will give supply to the system instead. Shown in fiure5.2, the gate of M1 is pulled low by ASC8513, and the current can flow through M1 without any additional components.

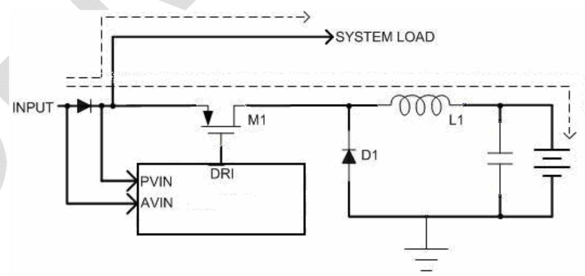



**Figure5.1. Input Supply Exist**

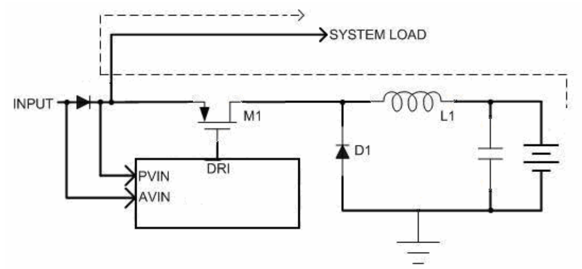



**Figure5.2. Input Supply Removed**

### NTC THERMISTOR

As shown in figure 6. The ASC8513 has a built-in NTC resistance window comparator, which allows ASC8513 to sense the battery temperature via the thermistor packed internally in the battery pack to ensure a safe operation environment of the battery.

A resistor with appropriate value should be connected from LVO to TP pin and the thermistor is connected from TP to GND. The voltage on TP is determined by the resistor divider whose divide ratio depends on the battery temperature. When the voltage of TP falls out of the window range, ASC8513 will stop the charging. For a typical 10K NTC, the resistance is 4.2K at 50℃, the value of $R_T$ is 24K.To disable battery temperature detect, just replace NTC with a resistor equal to $R_T$.

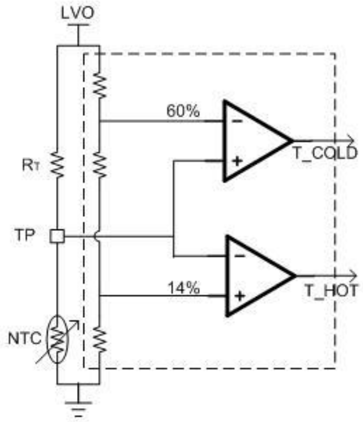



**Figure6. NTC Application-1**

User may modify these thresholds by adding two external resistors. As shown in figure 7, a typical value for $R_{T1}$ is 18K, and $R_{T2}$ is 9.1K, the batteries' temperature is prevented from higher than 50℃. User also can modify the value of $R_{T1}$ and $R_{T2}$, and then set different temperature threshold.

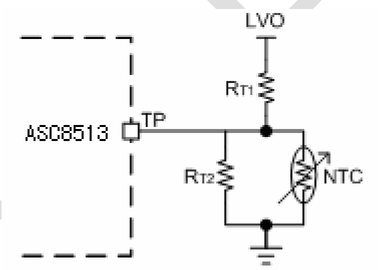



**Figure7. NTC Application-2**

**BATTERY DETECTION**

For applications with removable battery packs, ASC8513 provides a battery absent detection scheme to reliably detect insertion or removal of battery packs. A test pulse is added at BAT pin. Firstly, ASC8513 enables a discharge current, $I_{DISCHG}$, for a period $T_{DISCHG}$ and checking to see if the battery voltage is pulled down. After that, a charge current, $I_{CHG}$ is applied for a period of $T_{CHG}$, and the battery voltage is checked again to ensure it is above the recharge threshold. If battery exists, the voltage at BAT remain unchanged, otherwise, the voltage will fluctuate from 0V to $V_{BAT}$. The output capacitor is recommended not to exceed 150uF.

## APPLICATION INFORMATION

### SET BATTERY CHARGE CURRENT

The battery charge current $I_{CC}$, is established by setting the external current sense resistor, $R_{SNS}$, and $R_{ISET}$, resistor connected to the ISET pin. To set the current, first choose $R_{SNS}$. In order to achieve better current sense accuracy, $V_{SNS}$, voltage drop on $R_{SNS}$, is recommended to be set between 100mV and 200mV.

$$R_{SNS} = \frac{V_{SNS}}{I_{CC}} \quad (1)$$

If the result is not a standard sense resistor value, choose the next larger value. Using the selected standard value, solve for $V_{SNS}$. Once the sense resistor is selected, the ISET resistor, $R_{ISET}$, can be calculated using the following equation:

$$R_{ISET} = \frac{K_{ISET} \times V_{ISET}}{R_{SNS} \times I_{CC}} \quad (2)$$

$(K_{ISET}=1000)$

Where, $V_{ISET}$ is the voltage of ISET pin, which value is 1V set by internal circuit. $K_{ISET}$ is the ratio of $I_{CC}$ to sensed current. The typical value of $K_{ISET}$ is 1000.

For example, if user want to set the charge current to be 1A. First, choose $V_{SNS}$=100mV, then from equation (1), we get $R_{SNS}$=0.1Ω. According to equation (2), the value of $R_{ISET}$ is 10KΩ.

### SET PRE-CHARGE CURRENT

The pre-charge current is just 1/5 of $I_{CC}$. After $I_{CC}$ is set, the pre-charge current is set too.

### SET CHARGE TERMINATION CURRENT

During the voltage regulation phase, the ASC8513 detects the charge current, and converts to voltage at IEOC pin. Shown as figure8, the current flow through $R_{SNS}$ is the charge current, $I_{CHG}$. The sensed current can be calculated by the following equation.

$$I_{R_S} = \frac{R_{SNS}}{R_S} \times I_{CHG} \quad (3)$$

Value of $R_S$ equals to the current sense ratio, labeled as $K_{IEOC}$. The voltage on IEOC pin can be got:

$$V_{IEOC} = \frac{R_{SNS}}{K_{IEOC}} \times I_{CHG} \times R_{IEOC} \quad (4)$$

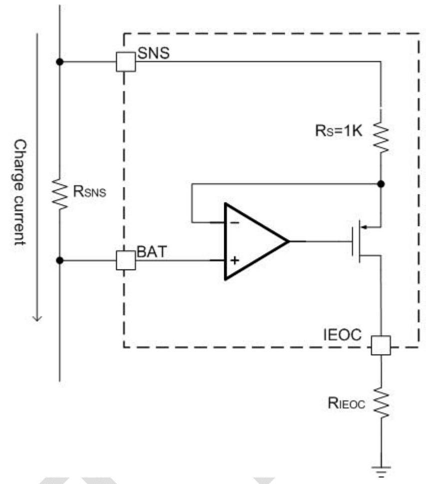



**Figure8. EOC current detection scheme**

When $V_{IEOC}$ drops below 200mV, and the battery voltage is higher than $V_{RCH}$, the ASC8513 generates an "end-of-charge" (EOC) signal, and terminates charge.

For example, the CC charge current is 1A, and $R_{SNS}$ is 0.1Ω, if user wants to set the termination current, $I_{EOC}$, to be 100mA, according to equation (4):

$$R_{IEOC} = \frac{0.2V \times 1000}{0.1 \times 100mA} = 20K\Omega$$

### INDUCTOR SELETION GUIDANCE

The current ripple of inductor can be caculated by the following equation:

$$\Delta I = \frac{1}{L \times f_S}\left(\frac{V_{IN} - V_{BAT}}{V_{IN}}\right) \times V_{BAT} \quad (5)$$

Where, $\Delta I$ is the inductor ripple current, $f_S$ is PWM oscillator frequency.

For the noise consideration, $\Delta I$ is always 30% or 50% of the maximum charge current. However, inductor of 10uH or 22uH will be suitable for most applications in experience.

### OUTPUT CAPACITOR SELECTION GUIDANCE

To insure the stability of the control loop, the selection of inductor and output capacitor must meet the following equation:

$$\frac{1}{2\pi \times \sqrt{L \times C}} \leq 12K \quad (6)$$

where, L、C are the values of inductor and output capacitor.

With a larger capacitor, the output voltage ripple will be smaller. However, to insure the proper function of battery detection, the output capacitor should not be too large. It is recommended to between 10uF and 47uF.

**FULL CHARGE VOLTAGE FINE TUNING**

User can trim the full charge voltage by connect resistors between VAD and BAT, or between VAD and GND. Shown as figure 9.

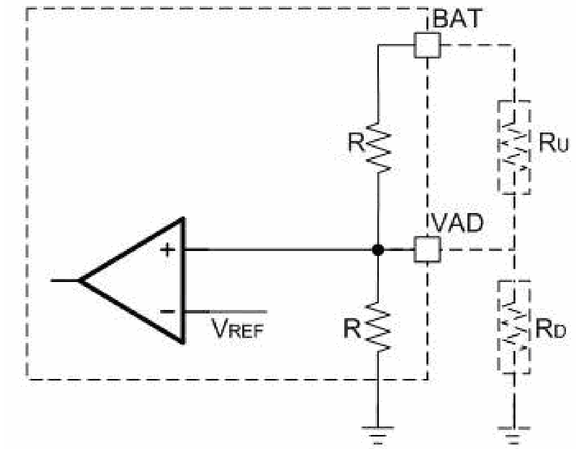



**Figure9. Diagram of voltage fine tuning**

The full charge voltage is $V_F$, if user wants to trim $V_F$ to ($V_F$+ΔV), resistor between VAD and GND should be connected, shown as $R_D$. $R_D$ can be calculated using the following equation:

$$R_D = \frac{R \times V_F}{2 \times \Delta V} \quad (7)$$

Accordingly, user also can trim $V_F$ to ($V_F$-ΔV). The equation would be as below.

$$R_U = \frac{3R \times V_F}{2 \times \Delta V} - R \quad (8)$$

Where, the value of R can be got by measure the resistor between VAD and GND. The typical value of R is 12.5K, and $V_F$ is 4.18V.

For example, if we want trim 4.18 to 4.20, that is:

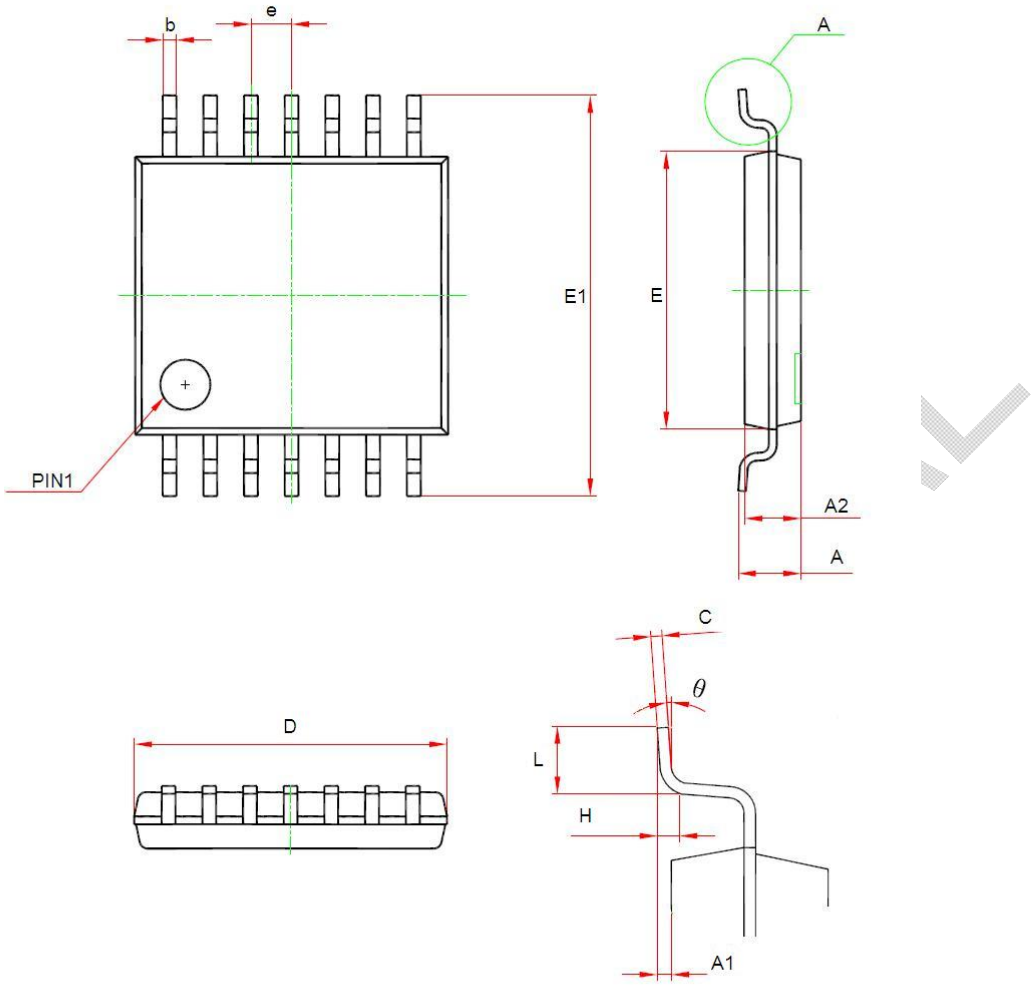
$$R_D = \frac{12.5K \times 4.18}{2 \times 20mV} = 1.31M\Omega$$

The value of trimming resistor is 1.31M.

**BOARD LAYOUT SUGGESTIONS**

1. The capacitors should be placed as close as possible to the relevant pins.
2. For better performance, put a 10uF capacitor at the pin of PVIN.
3. DRI pin will rise and fall periodically, to minimize radiation, the catch diode, pass transistor and the input bypass capacitor traces should be kept as short as possible.
4. The connection between the catch diode and the pass transistor should be kept as short as possible.
5. For better EMI immunity performance, a resistor and a capacitor connected in series parrelled with the catch diode should be placed between the two ends of the catch diode. The value of capacitor is recommended to be 1nF, and 10Ω for the resistor.
6. Avoid routing the PC board trace connecting pin TP and VAD near the power MOSFET to minimize switching noise coupling.

## PACKAGE INFORMATION




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | **MIN** | **MAX** | **MIN** | **MAX** |
| D | 4.900 | 5.100 | 0.193 | 0.201 |
| E | 4.300 | 4.500 | 0.169 | 0.177 |
| b | 0.190 | 0.300 | 0.007 | 0.012 |
| c | 0.090 | 0.200 | 0.004 | 0.008 |
| E1 | 6.250 | 6.550 | 0.246 | 0.258 |
| A | | 1.200 | | 0.047 |
| A2 | 0.800 | 1.000 | 0.031 | 0.039 |
| A1 | 0.050 | 0.150 | 0.002 | 0.006 |
| e | 0.65(BSC) | | 0.026(BSC) | |
| L | 0.500 | 0.700 | 0.020 | 0.028 |
| H | 0.25(TYP) | | 0.01(TYP) | |
| θ | $1^{o}$ | $7^{o}$ | $1^{o}$ | $7^{o}$ |

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