# Advanced Lithium Ion Linear Battery Charger

## General Description

The SL1056A is a Lithium-Ion or Lithium-Polymer dual cell linear battery charger which is designed for compact and cost-sensitive handheld devices. It combines charge status indication, charge termination, battery temperature monitoring, and high accuracy current and voltage regulation in a MSOP8 or SOP8 package.

The SL1056A charges the battery in three modes, precharge, constant current, constant voltage. If the battery voltage is below the precharge threshold $V_{O(MIN)}$, the SL1056A precharges the battery with a lower conditioning current. After precharge, the SL1056A applies a constant current to the battery. An external sense-resister sets the charge current. The constant voltage mode continues until the battery reaches the regulation voltage.

The battery temperature is continuously measured by an external thermistor through the TS pin. The SL1056A inhibits charge until the temperature is within the range defined by users.

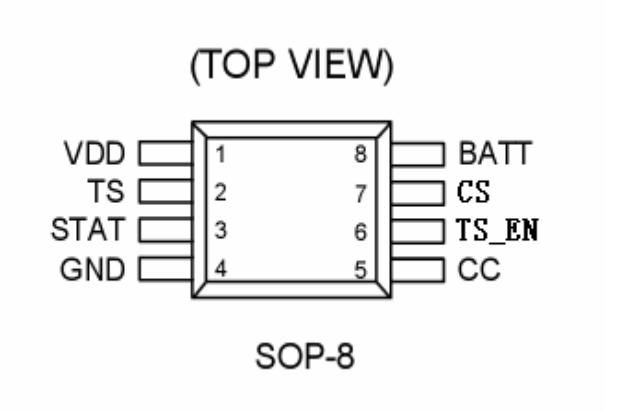
## Features

**For Lithium-Ion or Lithium-Polymer dual Cell Battery Pack ( 8.4V)**
**A Few External Components are Required**
**Precharge, Constant Current, Constant Voltage Modes**
**Battery Temperature Monitor**
**Charge Status Indication**
**Automatic Battery Recharge**
**Charge Termination Detect**
**Auto Low Power in Sleep Mode**
**SOP8 Package**
**RoHS Compliant and 100% Lead (Pb)-Free**

## Applications

Digital Cameras
PDAs
Cellular Phones
Information Appliance

## Pin Configurations



## Functional Pin Description

| Pin Name | Pin Function |
|---|---|
| VDD | Supply Voltage Input. |
| TS | Temperature Sense Input. Input from battery temperature monitoring circuit. |
| STAT | Charge Status Output. 3-state status indication of charge, charge complete and temperature fault or disable or sleep mode. |
| GND | Ground. |
| CC | Charge Control Output. Current output to drive on external PNP transistor or P-hannel MOSFET for current and voltage regulation. |
| TS_EN | Temperature Protection Enable |
| CS | Current Sense Input. Charge current is sensed according to the voltage drop from supply voltage to this pin. |
| BATT | Battery Voltage input. Input directly from battery voltage. |

## Absolute Maximum Ratings

- Supply Voltage ---------- –0.3V to 12V
- Storage Temperature Range ---------- –65° C to 150°C
- Power Dissipation, $P_D$ @ $T_A$ = 25°C ---------- 300mW
- Junction Temperature ---------- 150°C
- Package Thermal Resistance
- Operation Junction Temperature Range ---------- –40°C to 125°C
- ESD HBM ---------- 2Kv

## Electrical Characteristics

($T_A$ = 25°C, unless otherwise specification)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Operating Current | $I_{DD(OPE)}$ | 9V < $V_{DD}$ < 10V, Excluding external loads | -- | 1 | 2 | mA |
| $V_{DD}$ Sleep Current | $I_{DD(SLP)}$ | $V_{BATT}$ –$V_{DD}$ ≥ 0.2V | -- | -- | 3 | μA |
| Input Bias Current @ BATT pin | $I_{BATT}$ | $V_{BATT}$ = $V_{O(REG)}$, $V_{BATT}$ – $V_{DD}$ ≥ 0.2V | -- | 1.5 | 2.5 | μA |
| Input Bias Current @ CS pin | $I_{CS}$ | $V_{CS}$ =10V, $V_{BATT}$ – $V_{DD}$ ≥ 0.2V | -- | -- | 1 | μA |
| Input Bias Current @ TS pin | $I_{TS}$ | $V_{TS}$ =10V, $V_{BATT}$ – $V_{DD}$ ≥ 0.2V | -- | -- | 1 | μA |
| Input Bias Current @ FB/CE pin | $I_{CE}$ | $V_{CE}$ =10V, $V_{BATT}$ – $V_{DD}$ ≥ 0.2V | -- | -- | 1 | μA |
| Input Low Voltage @ CE pin | $V_{CE}$ | | -- | -- | 1.5 | V |
| Input High Voltage @ CE pin | $V_{CE}$ | | $V_{DD}$–1.2V | -- | -- | V |
| Output Voltage | $V_{O(REG)}$ | | 8.32 | 8.40 | 8.48 | V |
| Current Regulation Threshold | $V_{I(SNS)}$ | $V_{I(SNS)}$ = $V_{DD}$ – $V_{CS}$ | 95 | 110 | 125 | mV |
| Precharge Current Regulation | $V_{(PRE)}$ | V (PRE) =VDD–VCS | 12 | 16 | 20 | mV |
| Precharge Threshold | $V_{O(MIN)}$ | | 5.4 | 5.8 | 6.2 | V |
| Recharge Threshold | $V_{O(RCH)}$ | | $V_{O(REG)}$ – 170mV | $V_{O(REG)}$ – 110mV | $V_{O(REG)}$ – 50mV | V |
| ChargeTerminated Current DetectThreshold | $V_{(TERM)}$ | | 10 | 16 | 22 | mV |
| Output (Low) Voltage @ STAT pin | $V_{STAT(LOW)}$ | $I_{OL}$ = 10mA | -- | 0.4 | 0.6 | V |
| Output (High) Voltage @ STAT pin | $V_{STAT(HIGH)}$ | $I_{OH}$ = 5mA | $V_{DD}$–0.5 | -- | -- | V |
| Lower Temperature Threshold | $V_{TS1}$ | | 29 | 31 | 33 | %$V_{DD}$ |
| Upper Temperature Threshold | $V_{TS2}$ | | 57.5 | 59.5 | 61.5 | %$V_{DD}$ |

## Typical Application Circuit

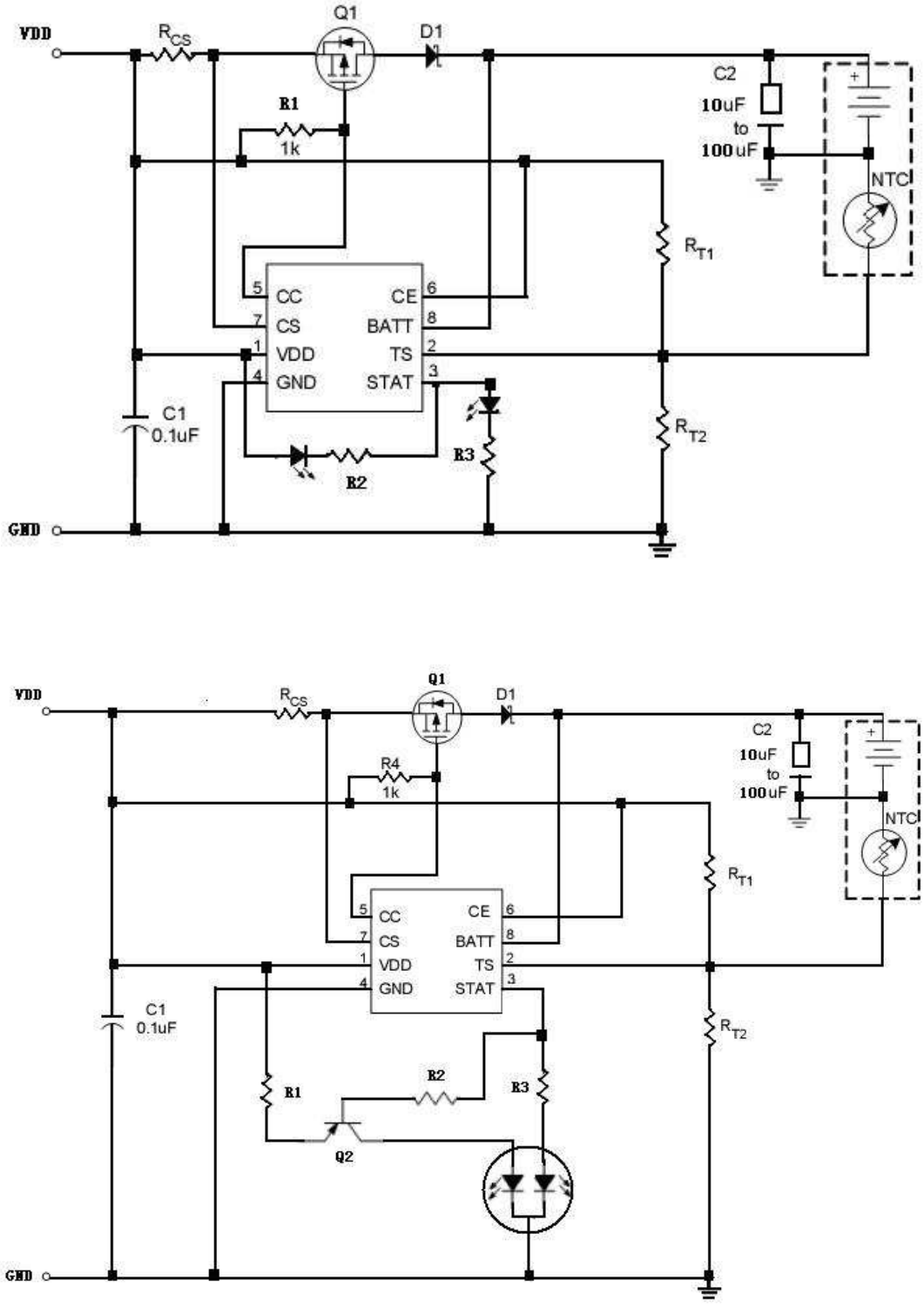



Figure 1. Application circuit using P-Channel MOSFET

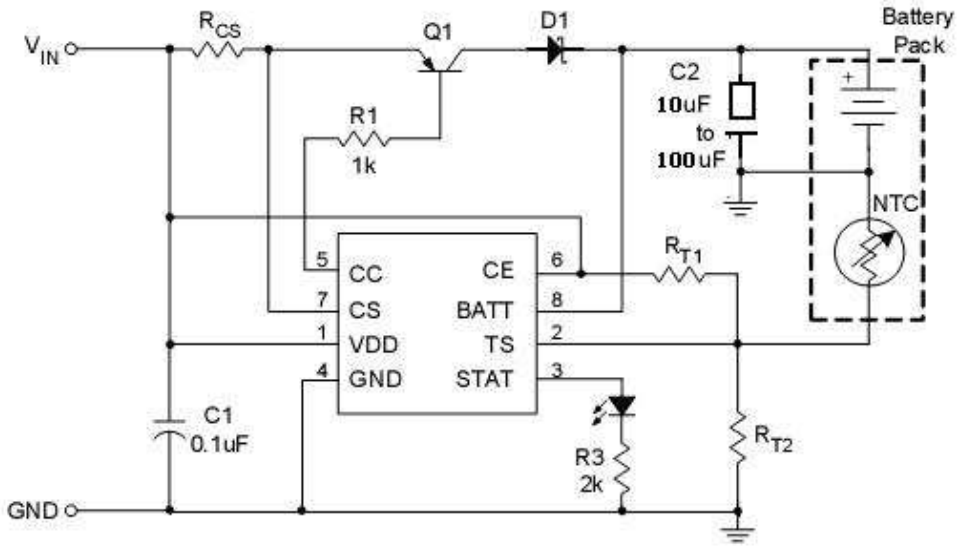



Figure 2. Application circuit using PNP transistor

## Application Information

### Charge Profile

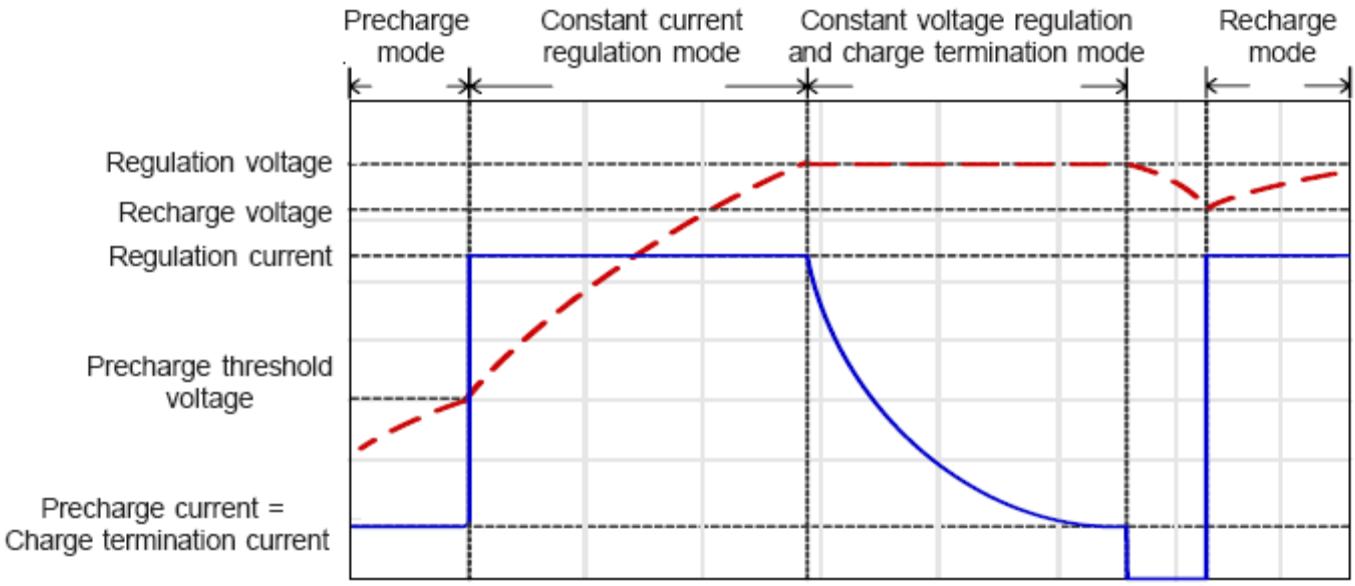



Figure 3. Typical charge profile

**Detection**

First, the FB/CE pin must connect to VDD or a voltage divider to enable the charge function. And then if a battery is already inserted and the input power source is absent, the SL1056A will enter sleep mode to prevent draining power from battery. When input power source and battery are both existed, another detection is the battery temperature. The TS pin voltage must be in the allowed range as shown in Figure 6 and the electrical characteristics, and then the SL1056A will start the charge cycle according to the battery voltage conditions.

**Precharge Mode**

When the battery voltage is lower than the precharge threshold $V_{O(MIN)}$, the SL1056A begins to charge the battery in precharge mode. In this condition, the precharge current is set at approximately 10% of the constant regulation current. The purposes of small precharge current are to minimize the power dissipation on the external switch during the precharge period and to revive deeply discharged battery cells.

**Constant Current Regulation Charge Mode**

When the battery voltage is between the precharge threshold $V_{O(MIN)}$ and the regulation voltage $V_{O(REG)}$, the SL1056A starts the constant current regulation charge mode. SL1056A monitors charge current with voltage drop between two terminals of a sense-resistor, $R_{CS}$, which connects to pin VDD and CS. The following equation can calculate the desired charging current.

$$I_{O(REG)} = \frac{V_{I(SNS)}}{R_{CS}}$$

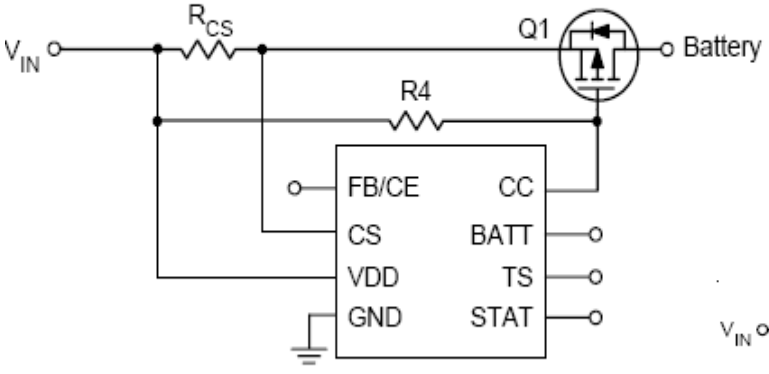



Figure 4

**Constant Voltage Regulation and Charge Termination Mode**

When the battery voltage reaches the regulation voltage $V_{O(REG)}$, the constant voltage feedback control starts, and then the charge current begins to decrease as the typical charge profile shown. As the charge current decreases to lower than charge terminated current threshold, the SL1056A will terminate the charge cycle.

**Recharge Mode**

After the charge termination mode, if the battery voltage falls to lower than the recharge threshold voltage $V_{O(RCH)}$, the SL1056A will begin a new charge cycle according to the battery voltage.

**Battery Temperature Detection**

The SL1056A continuously detects the battery temperature by measuring the TS pin voltage. A NTC or PTC thermistor can parallel with $R_{T2}$ to deviate the TS pin voltage. (As shown in Figure 5) The TS pin voltage must be within normal temperature voltage range that is shown in Figure 6 and electrical characteristics, and then SL1056A can start working normally.

The $R_{T1}$ and $R_{T2}$ can be derived from following equations.

For NTC Thermistors:

$$R_{T1} = \frac{5 \times R_{TH} \times R_{TL}}{3 \times (R_{TL} - R_{TH})}$$

$$R_{T2} = \frac{5 \times R_{TH} \times R_{TL}}{[(2 \times R_{TL}) - (7 \times R_{TH})]}$$

For PTC Thermistors:

$$R_{T1} = \frac{5 \times R_{TH} \times R_{TL}}{3(R_{TH} - R_{TL})}$$

$$R_{T2} = \frac{5 \times R_{TH} \times R_{TL}}{[(2 \times R_{TH}) - (7 \times R_{TL})]}$$

Where $R_{TL}$ is the resistance value in lowest desired operation temperature and $R_{TH}$ is the resistance value in highest desired operation temperature. The resistances of thermistors are specified by the thermistor manufacturer. If the temperature monitoring function is not desired, there's an easy method to set $R_{T1}$ and $R_{T2}$ at the same value and disconnect the thermistor to disable this function.

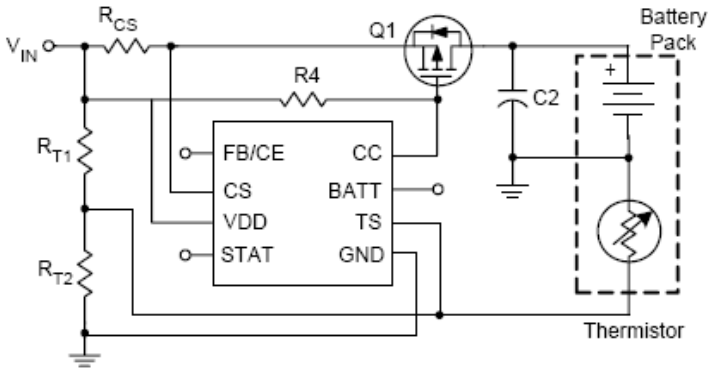



Figure 5

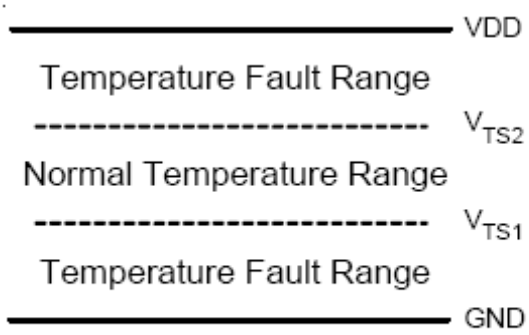



Figure 6

**FB/CE Pin Functions**

This pin has two functions, one is to enable/disable the charge function, and the other is to finely adjust battery regulation voltage. Connect this pin to VDD to enable SL1056A, and connect to ground to disable it (Figure 7). If this pin is connected to a voltage divider as shown in Figure 8, it can be a 2.1V reference voltage to adjust the output regulation voltage as desired.

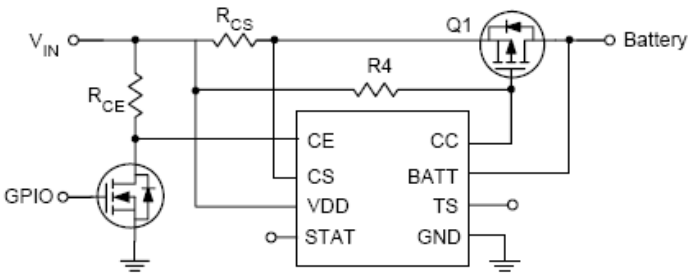



Figure 7. For CE pin Function

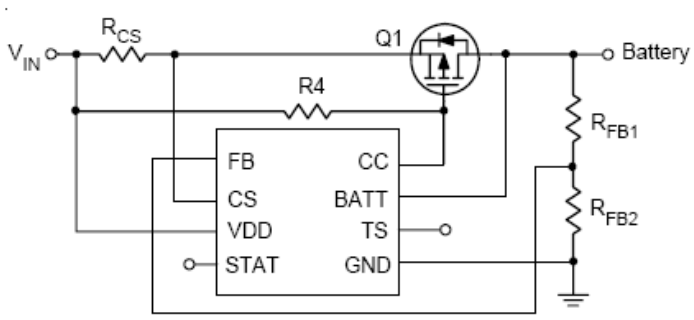



Figure 8. For FB pin Function

$$V_{O(REG)} = 2.1 \times (1 + \frac{R_{FB1}}{R_{FB2}})\ V$$

| Condition | STAT Pin |
|---|---|
| In battery charging cycle | High |
| Charge cycle completed | Low |
| Temperature fault or charge function disable or sleep mode | High Impedance |

**Selecting an External PNP Pass-Transistor or P-Channel MOSFET:**

The SL1056A drives an external PNP transistor or PChannel MOSFET to control the charging current. The specifications must be concerned are the voltage and current rating and package power dissipation. The external switch is performed as a linear regulator. The maximum power loss occurs when the constant current regulation starts at the beginning, and it can be calculated approximately from following equation:

$I_{(SNS)}$ is the constant regulation current.

The minimum voltage drop between the sense-resistor is 100mV, and the minimum precharge threshold voltage is 2.8V.

The external pass device with PCB heatsinking must be rated for the maximum power dissipation.

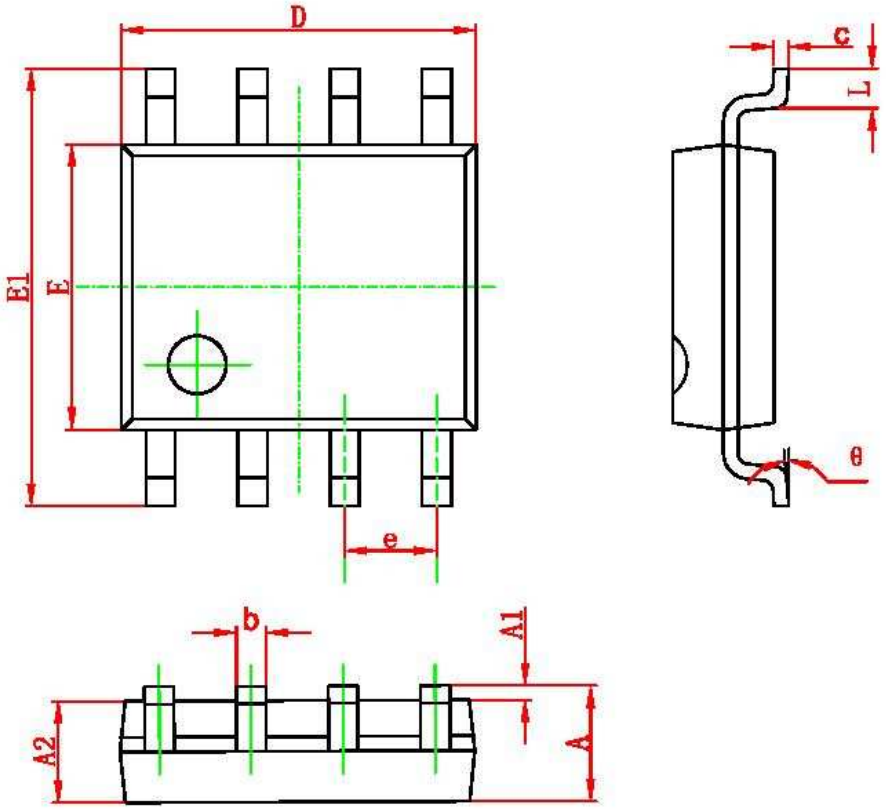
**Selecting Input/Output Capacitor**

In analog circuit applications, to place a high-frequency decoupling capacitor nearby the controller IC between input power source and ground is very important. A 0.1uF ceramic is recommended. If a high ripple and noise input power is chosen, it should have enough capacitance to reduce the disturbance.

A 10uF to 100uF output capacitor is recommended to control the output voltage and keep the output voltage ripple small when the battery is disconnected.

## Outline Dimension

**SOP8 PACKAGE OUTLINE DIMENSIONS**




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 1.350 | 1.750 | 0.053 | 0.069 |
| A1 | 0.100 | 0.250 | 0.004 | 0.010 |
| A2 | 1.350 | 1.550 | 0.053 | 0.061 |
| b | 0.330 | 0.510 | 0.013 | 0.020 |
| c | 0.170 | 0.250 | 0.006 | 0.010 |
| D | 4.700 | 5.100 | 0.185 | 0.200 |
| E | 3.800 | 4.000 | 0.150 | 0.157 |
| E1 | 5.800 | 6.200 | 0.228 | 0.244 |
| e | 1.270(BSC) | | 0.050(BSC) | |
| L | 0.400 | 1.270 | 0.016 | 0.050 |
| θ | 0° | 8° | 0° | 8° |

8-Lead MSOP Plastic Package