Advanced Lithium-Ion Linear Battery Charger

■ General Description

The LN9501 is a single Lithium-Ion or Lithium-Polymer 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 MSOP-8 package.

The LN9501 charges the battery in three modes, precharge, constant current, constant voltage. If the battery voltage is below the precharge threshold VO(MIN), the LN9501 precharges the battery with a lower conditioning current. After precharge, the LN9501 applies a constant current to the battery. An external sense-resister sets the charge current. The constant voltagemode continues until the battery reaches the regulation voltage.

The battery temperature is continuously measured by anexternal thermistor through the TS pin. The LN9501 inhibits charge until the temperature is within the range defined by users.

■ Applications

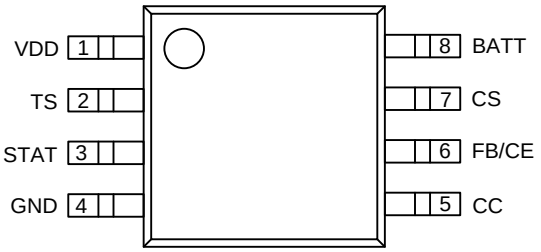
- Digital Cameras
- PDAs
- Cellular Phones
- Information Appliance

■ Features

- For Single Lithium-Ion or Lithium-Polymer Cell
- Battery Pack (4.1V or 4.2V)
- 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 Sleep Mode when VDD Power is
- Removed
- MSOP-8 Package

■ Package

- **MSOP-8**



MSOP-8
(Top View)

■ Ordering Information

LN9501 ①②③

Designator	Description	Symbol	Description
①	Package Type	F	MSOP-8
②	Voltage Version	A/B	A:4.1V
			B:4.2V
③	Device Orientation	R	Embossed tape: Standard feed
		L	Embossed tape: Reverse feed

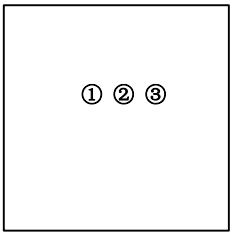
■ Pin Assignment

Pin Number MSOP-8	Pin Name	Pin Function
1	VDD	Supply Voltage Input.
2	TS	Temperature Sense Input. Input from battery temperature monitoring circuit.
3	STAT	Charge Status Output. 3-state status indication of charge, charge complete and temperature fault or disable or sleep mode.
4	GND	Ground.
5	CC	Charge Control Output. Current output to drive on external PNP transistor or P-Channel MOSFET for current and voltage regulation.
6	FB/CE	External Feedback Input or Charge Enable Function. Input from controller or finely adjust the battery regulated voltage with external voltage divider.
7	CS	Current Sense Input. Charge current is sensed according to the voltage drop from supply voltage to this pin
8	BATT	Battery Voltage input. Input directly from battery voltage.

■ Marking Rule

- **MSOP-8**

MSOP Marking



① Represents the package type

Symbol	Package
F	MSOP-8

② Represents the version of voltage

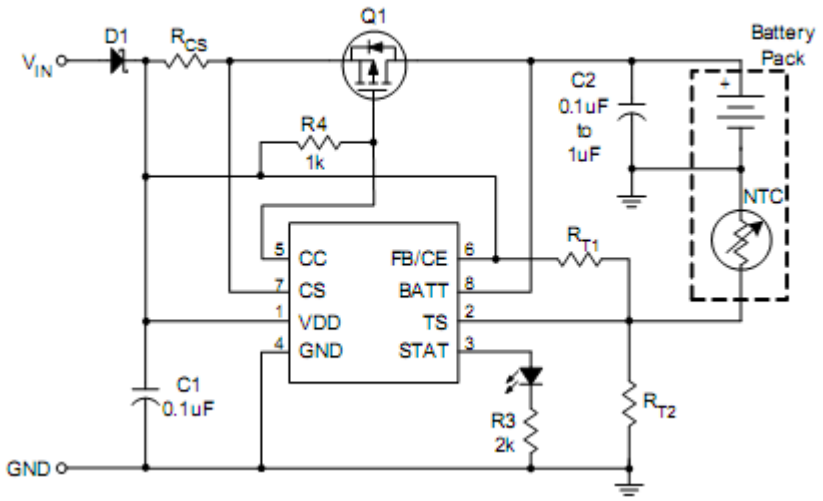
Symbol	Output voltage of FB Pin	Part of Product Series
A	4.1V	LN9501FA◆
B	4.2V	LN9501FB◆

③ Represents the device orientation

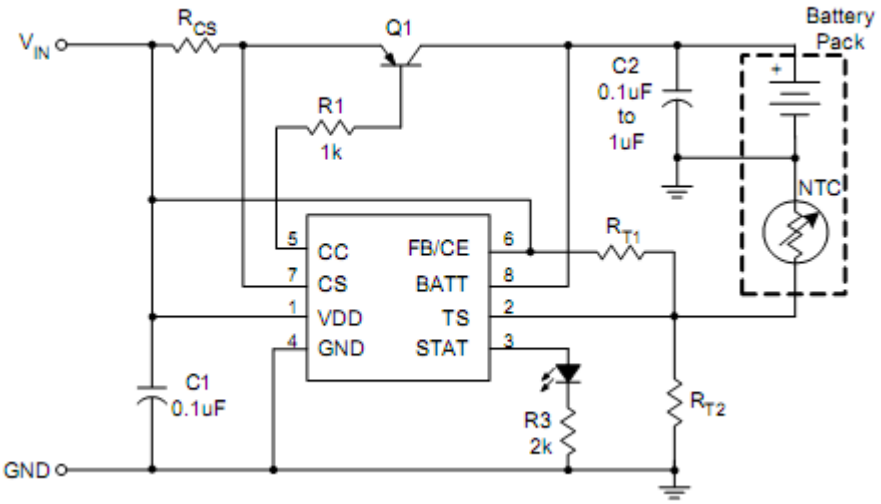
Symbol	Embossed tape
R	Standard feed
L	Reverse feed

■ Typical Application Circuit

- **Application circuit using P-Channel MOSFET**



- **Application circuit using PNP transistor**

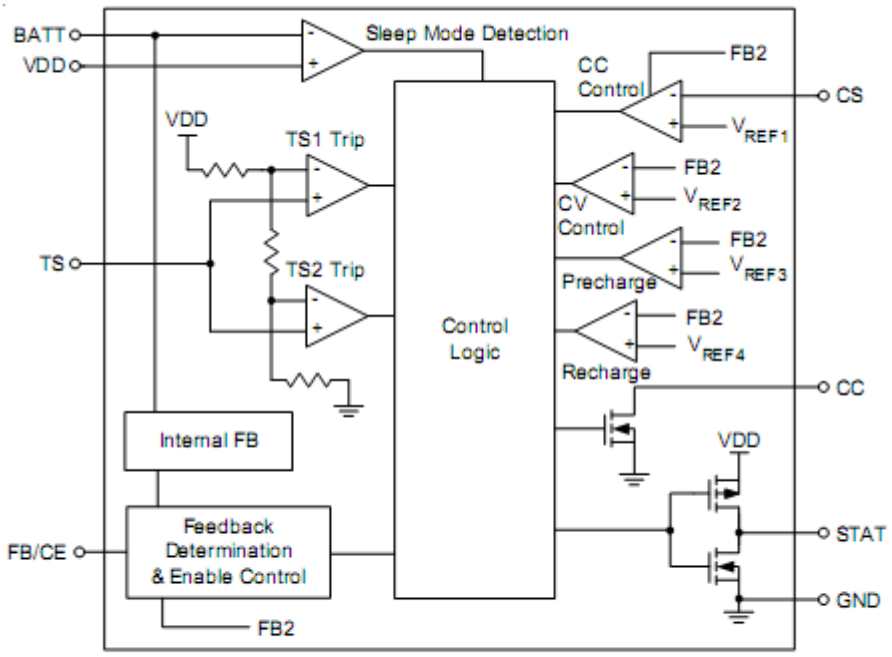


■ Absolute Maximum Ratings

Parameter	Symbol		Maximum Rating	Unit
Input Supply Voltage	V_{IN}		V_{SS}-0.3～V_{SS}+7	V
Power Dissipation	P_D	MSOP-8	300	mW
Operating Ambient Temperature	Topa		-40～+85	°C
Storage Temperature	Tstr		-65～+150	

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Function Block Diagram



■ Electrical Characteristics

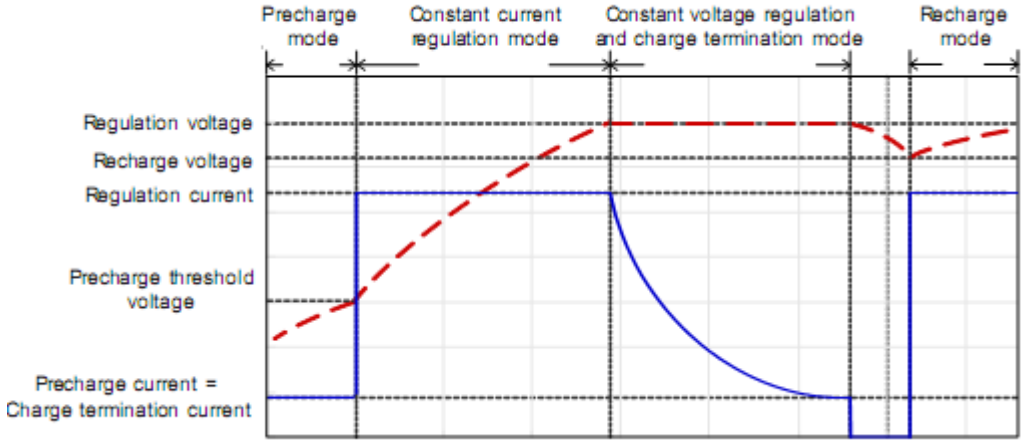
(TA=25℃ unless otherwise noted)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating current	$I_{DD\ (OPE)}$	4.5V<VDD<7V Excluding external loads	-	1	2	mA
V_{DD} sleep current	$I_{DD\ (SLP)}$	V_{BATT}-V_{DD}≥0.2V	-		1	uA
Input bias current @BATT pin	I_{BATT}	V_{BATT}=$V_{O(REG)}$ V_{BATT}-V_{DD}≥0.2V	-	1.5	2.5	uA
Input bias current @CS pin	I_{CS}	V_{CS}=5 V_{BATT}-V_{DD}≥0.2V	-	-	1	uA
Input bias current @TS pin	I_{TS}	V_{TS}=5 V_{BATT}-V_{DD}≥0.2V	-	-	1	uA
Input bias current @FB/CE pin	I_{CE}	V_{CE}=5 V_{BATT}-V_{DD}≥0.2V	-	-	1	uA
Input low voltage @ CE pin	V_{CE}	-	-	-	1.5	V
Input high voltage @ CE pin	V_{CE}	-	V_{DD}-1.5	-	-	v
Feedback voltage @FB pin	V_{FB}	-	2.048	2.1	2.152	v
Output voltage	$V_{O(REG)}$	-	4.16	4.2	4.25	v
Current Regulation Threshold	$V_{I(SNS)}$	$V_{I(SNS)}$=V_{DD}-V_{CS}	100	110	121	mV
Charge Terminated Current Detect Threshold	$V_{(TERM)}$	-	2	12	22	mV
Lower Temperature Threshold	V_{TS1}	-	29.1	30	30.9	%V_{DD}
Upper Temperature Threshold	V_{TS2}	-	53.8	60	61.8	%V_{DD}
Precharge Threshold	$V_{O(MIN)}$	-	2.8	2.9	3.0	V
Recharge Threshold	$V_{O(RCH)}$	-	-140	-100	-60	△VO

(*1)△VO is the difference between V_{OREG}

■ Application Information

- **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 LN9501 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 3 and the electrical characteristics, and then the LN9501 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 LN9501 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 LN9501 starts the constant current regulation charge mode. LN9501 monitors charge current with voltage drop between two terminals of a sense-resistor, R_{CS}, which connects to pin V_{DD} and CS. The following equation can calculate the desired charging current.

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

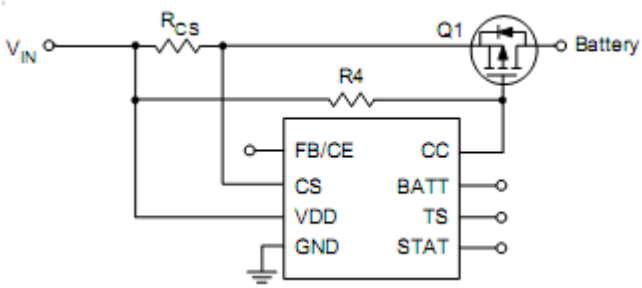


Figure .1

- **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 LN9501 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 LN9501 will begin a new charge cycle according to the battery voltage.

- **Battery Temperature Detection**

The LN9501 continuously detects the battery temperature by measuring the TS pin voltage. A NTC or PTC thermistor can parallel with RT2 to deviate the TS pin voltage. (As shown in Figure 2) The TS pin voltage must be within normal temperature voltage range that is shown in Figure 3 and electrical characteristics, and then LN9501 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:

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

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

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.

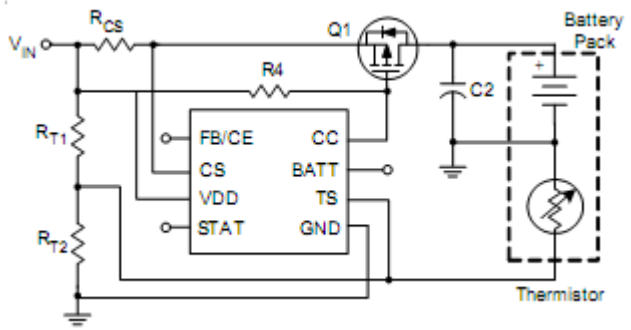


Figure 2.

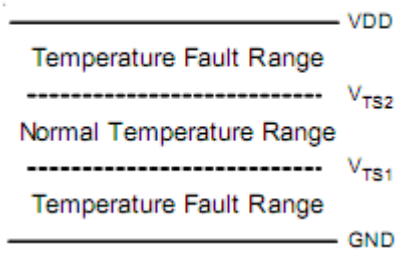


Figure3

- 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 V_{DD} to enable LN9501, and connect to ground to disable it (Figure 4). If this pin is connected to a voltage divider as shown in Figure 5, it can be a 2.1V reference voltage to adjust the output regulation voltage as desired.

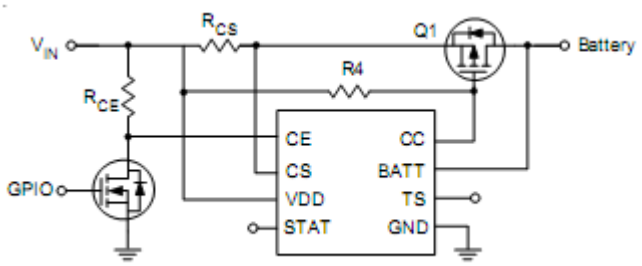


Figure 4. For CE pin Function

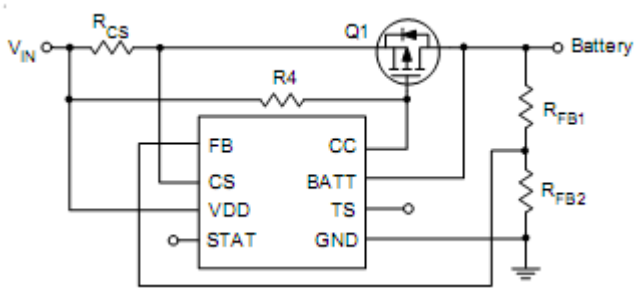


Figure 5. For FB pin Function

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

- **Charge status indication**

The LN9501 indicates the status of the charger on the 3-state STAT pin. The following table shows the statuses of this pin.

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 LN9501 drives an external PNP transistor or P-Channel 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:

$$P_{D(MAX)} = I_{(SNS)} \times (V_{DD} - 0.1V - 2.8V)$$

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.

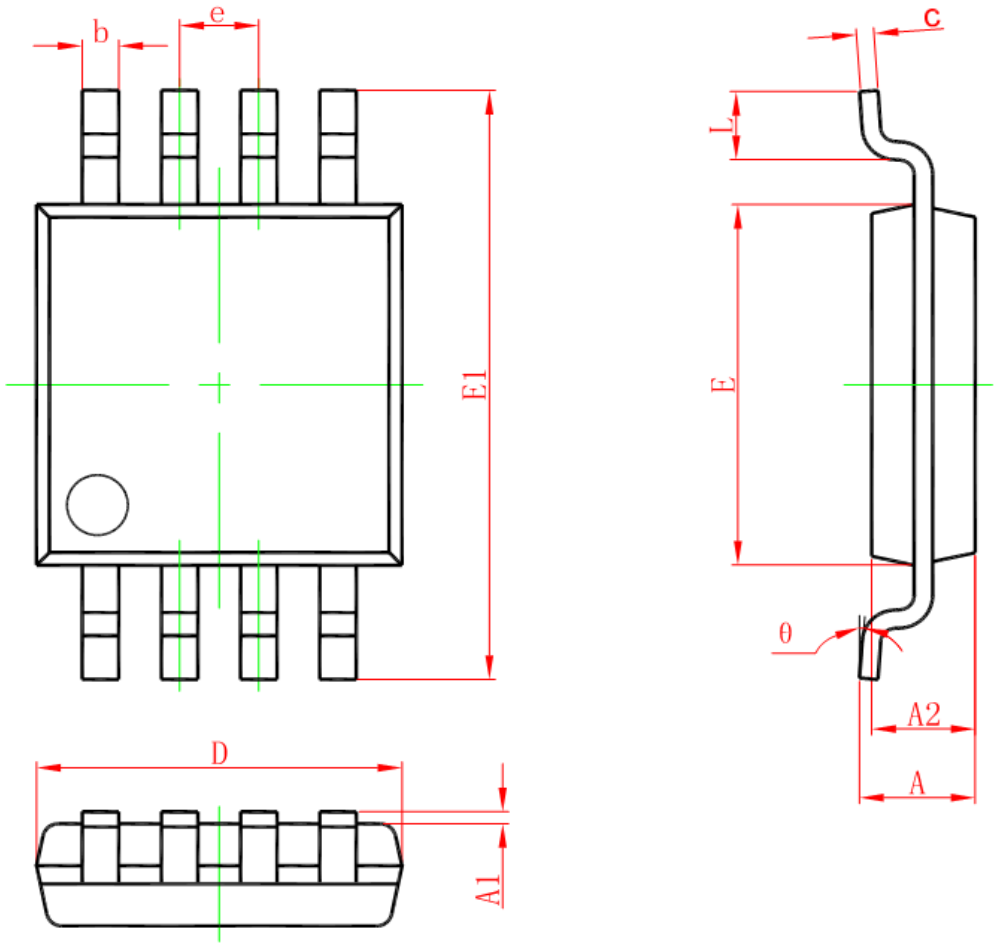
- **Selecting Input/Output Capacitor**

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 0.1uF to 1uF output capacitor is recommended to control the output voltage and keep the output voltage ripple small when the battery is disconnected.

■ Package Information

- **MSOP-8**



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°