30V, 1A Li-ion/Li-Polymer Linear Battery Charger

Description

The FP6908 is a single-cell Li-ion/Li-polymer battery charger IC which can be operated with an input voltage as low as 3.9V. The FP6908 can work with various types of AC adapters.

The FP6908 can also be operated as a linear charger when the AC adapter is a voltage source. The battery is charged in a CC/CV (constant current/constant voltage) profile. The charge current is programmable with an external resistor up to 1.0A with SOP-8 (Exposed Pad), TDFN-8 (2mmx2mm) packages and 500mA with SOT-23-5 packages. The FP6908 can also work with a current-limited adapter to minimize the thermal dissipation.

The FP6908 is designed with charge current thermal fold-back function to guarantee safe operation when the printed circuit board is space limited for thermal dissipation. A negative temperature coefficient (NTC) thermistor is connected between the NTC and GND to monitor the battery or ambient temperature.

Features

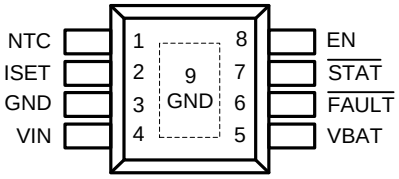
- Input Surge Up to 30V
- No External Blocking Diode Required
- Complete Charger for Single-Cell Li-ion Batteries
- Support 4.2V or 4.35V Charge Voltage
- 1% Charge Voltage Accuracy
- Input Over-Voltage Protection
- Programmable Charge Current
  1A for SOP-8 (Exposed Pad) and TDFN-8 (2mmx2mm) Packages
  500mA for SOT-23-5 Package
- Charge Current Thermal Fold-back
- Can Operate at 3.9V After Start Up
- NTC Interface
- Less than 1μA Leakage Current off the Battery when No Input Power Attached or Charger Disabled
- SOP-8 (Exposed Pad), TDFN-8 (2mmx2mm) and SOT-23-5 Packages

Applications

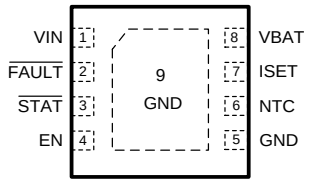
- Smart Handheld Devices
- Portable Instruments
- True Wireless Stereo (TWS)
- E-cigarette
- Toys

Pin Assignment

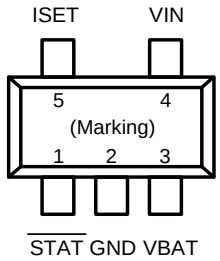
SP Package: SOP-8 (Exposed Pad)



D6 Package: TDFN-8 (2mmx2mm)



S5 Package: SOT-23-5



D6A Package: TDFN-8 (2mmx2mm)

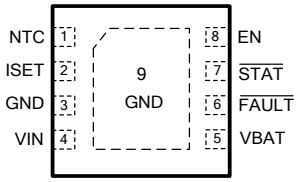


Figure1. Pin Assignment of FP6908

Ordering Information

FP6908□□

Package Type
SP: SOP-8 (Exposed Pad)
D6: TDFN-8 (2mmx2mm)
S5: SOT-23-5
D6A: TDFN-8 (2mmx2mm)

Charge Voltage
A: 4.2V
B: 4.35V

TDFN-8 (2mmx2mm) Marking

Part Number	Product Code
FP6908AD6	**Gi2**
FP6908BD6	**Gi4**
FP6908AD6A	**GS5**
FP6908BD6A	**GS6**

SOT-23-5 Marking

Part Number	Product Code
FP6908AS5	**Gi1**
FP6908BS5	**Gi3**

Typical Application Circuit

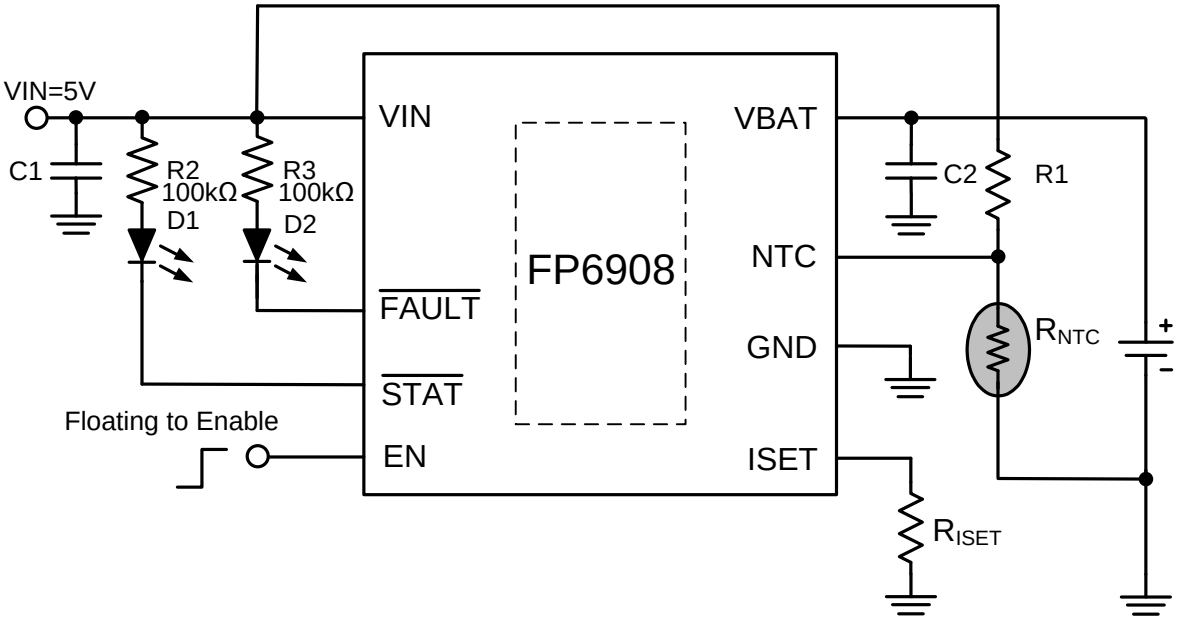


Figure 2. Typical Application Circuit of FP6908 with SOP-8 (Exposed Pad) / TDFN-8 (2mmx2mm) Packages

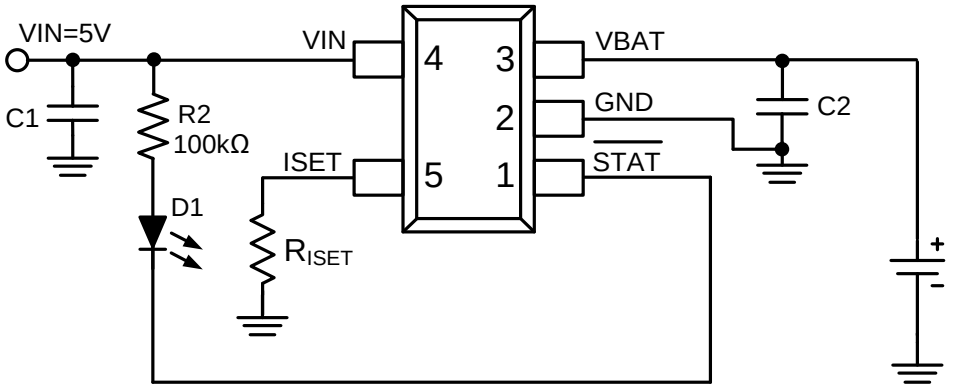


Figure 3. Typical Application Circuit of FP6908 with SOT-23-5 Package

System Application Circuit

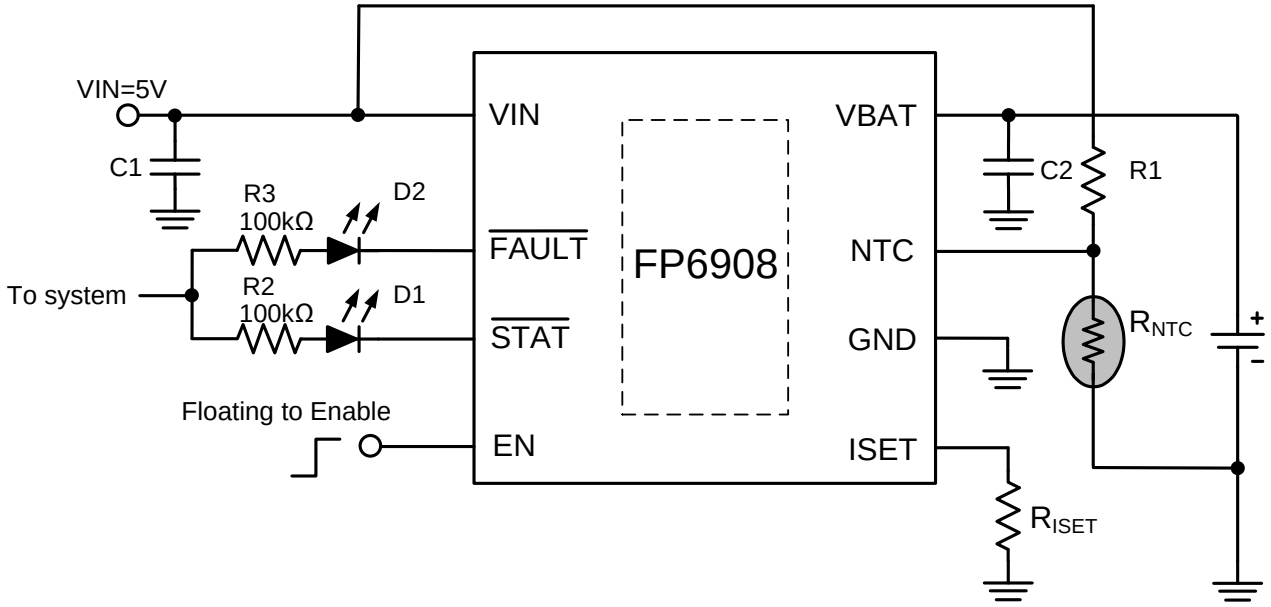


Figure 4. System Application Circuit of FP6908 with SOP-8 (Exposed Pad) / TDFN-8 (2mmx2mm) Packages

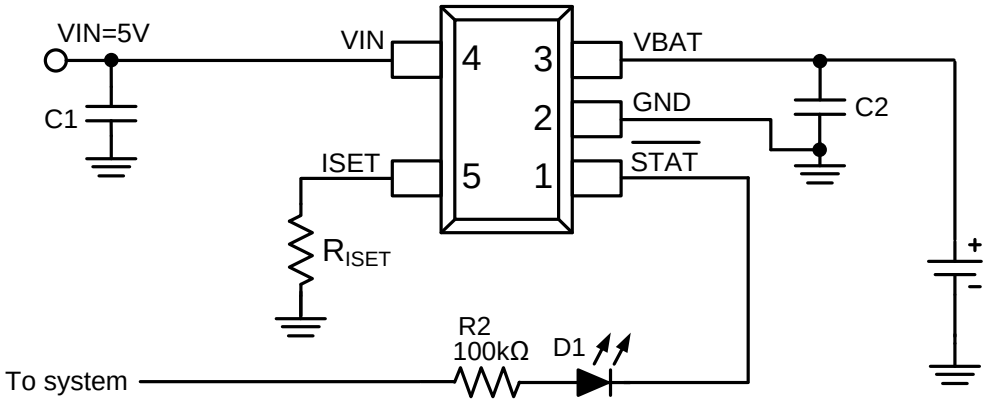


Figure 5. System Application Circuit of FP6908 with SOT-23-5 Package

Functional Pin Description

Pin Name	Pin NO.				Pin Function
	SP SOP-8 (Exposed Pad)	D6 TDFN-8 (2mmx2mm)	S5 SOT-23-5	D6A TDFN-8 (2mmx2mm)	
NTC	1	6	--	1	External NTC thermistor input. NTC Pin is the input for an external NTC thermistor in FP6908.
ISET	2	7	5	2	This is the programming input for the constant charging current. It maintains at 1V when the charger is in normal operation.
GND	3	5	2	3	GND is the connection to system ground.
VIN	4	1	4	4	VIN is the input power source.
VBAT	5	8	3	5	VBAT is the connection to the battery. Typically a 10μF tantalum capacitor when there is no battery attached. When a battery is attached, only a 1μF ceramic capacitor is required.
$\overline{\text{FAULT}}$	6	2	--	6	It is an open-drain output indicating fault status. This pin is pulled to low under any fault conditions.
$\overline{\text{STAT}}$	7	3	1	7	It is an open-drain output indicating charging and inhibits states. The $\overline{\text{STAT}}$ pin is pulled low when the charger is charging a battery.
EN	8	4	--	8	EN is the enable logic input. Connect the EN pin to low to disable the charger or leave it floating to enable the charger.
Thermal Pad	9	9	--	9	The thermal pad must be connected to the same potential as the GND pin on the printed circuit board.

Block Diagram

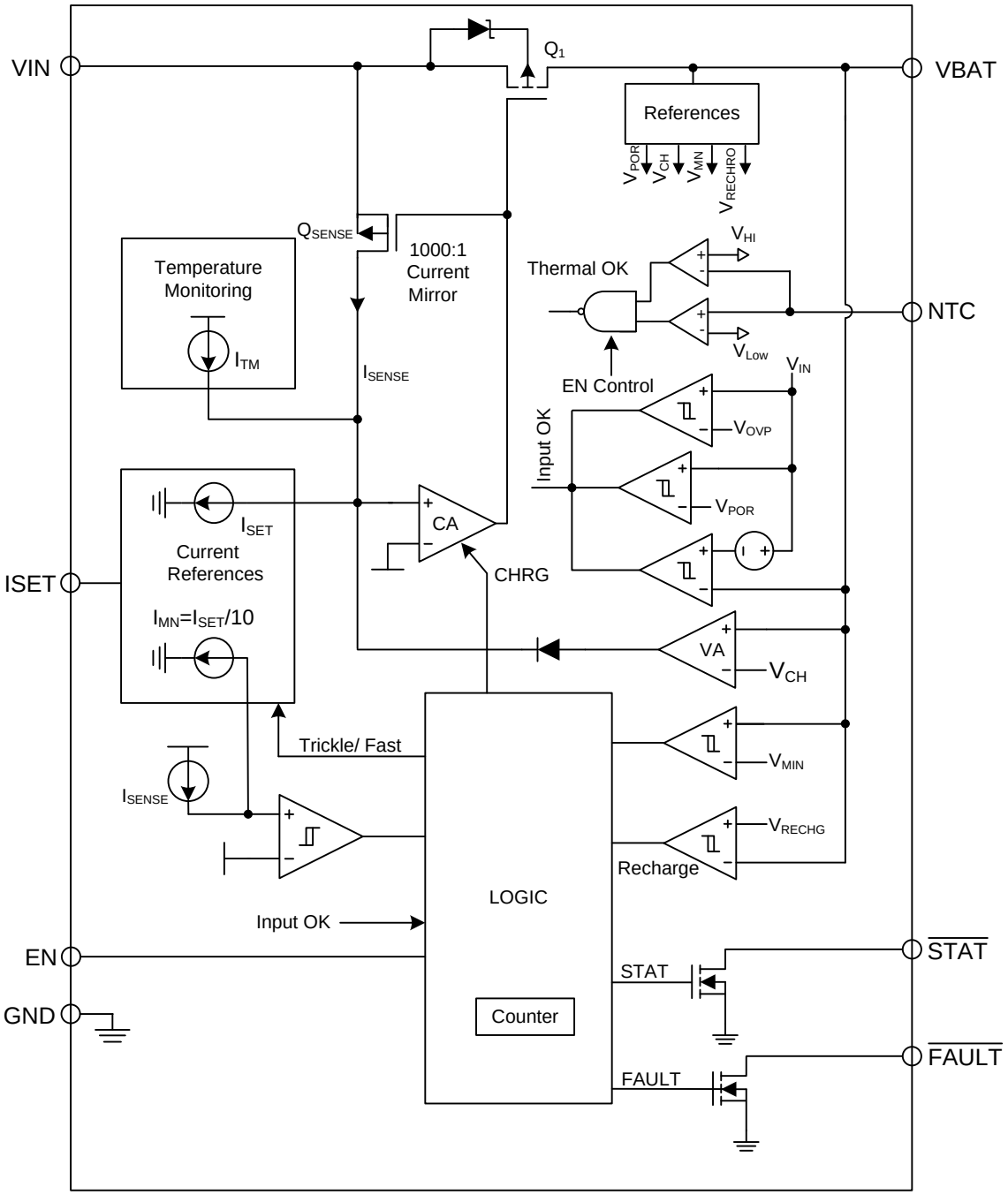


Figure 6. Block Diagram of FP6908

Absolute Maximum Ratings (Note 1)

- Supply Voltage (VIN) ---------- -0.3V to +30V
- Output Pin Voltage (VBAT, EN) ---------- -0.3V to +12V
- Output Pin Voltage ($\overline{STAT}$, $\overline{FAULT}$) ---------- -0.3V to +12V
- Signal Input Voltage (ISET, NTC) ---------- -0.3V to +6V
- Charge Current ---------- 1A
- Power Dissipation @ T_A=25°C, (P_D)
  - SOP-8 (Exposed Pad) ---------- 2.08W
  - TDFN-8 (2mmx2mm) ---------- 1.25W
  - SOT-23-5 ---------- 0.5W
- Package Thermal Resistance, SOP-8 (Exposed Pad) (θ_{JA}) (Note 2)
  - SOP-8 (Exposed Pad) ---------- 60°C/W
  - TDFN-8 (2mmx2mm) ---------- 80°C/W
  - SOT-23-5 ---------- 250°C/W
- Lead Temperature (Soldering, 10sec.) ---------- +260°C
- Maximum Junction Temperature(T_J) ---------- +150°C
- Storage Temperature (T_{STG}) ---------- -65°C to +150°C

Note 1: Stresses beyond this listed under “Absolute Maximum Ratings" may cause permanent damage to the device.
Note 2: θ_{JA} is measured at 25°C ambient with the component mounted on a high effective thermal conductivity 4-layer board of JEDEC-51-7. The thermal resistance greatly varies with layout, copper thickness, number of layers and PCB size.

Recommended Operating Conditions

- Input operating Voltage ---------- +4.6V to +6V
- Operating Temperature Range ---------- -20°C to +85°C

Electrical Characteristics

(V_{IN}=5V, VBAT=3V, T_A=25°C, maximum and minimum values are with a supply voltage in the range of 4.6V to 6V, unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Power-On Reset						
Input Voltage Range for charging	V_{IN}		4.6		6	V
UVLO Threshold Voltage	V_{IN_UVLO}		3.5	3.9	4.3	V
UVLO Hysteresis Voltage	V_{UVLO_HYS}			300		mV
EN Pin Input High	$V_{EN(H)}$	By SOP-8 (Exposed Pad) ,TDFN-8 (2mmx2mm) Packages	1.5			V
EN Pin Input Low	$V_{EN(L)}$	By SOP-8 (Exposed Pad) ,TDFN-8 (2mmx2mm) Packages			0.5	V
Regulated Output Voltage	V_{CH}		4.158	4.20	4.242	V
			4.306	4.35	4.394	
Soft-Start Time	T_{SS}			100		us
Input Overvoltage Protection Threshold	V_{IN_OVP}	VIN Rising	6.5	7	7.5	V
Input Overvoltage Protection Hysteresis	V_{IN_OVPHYS}	VIN Rising		0.1		V
Standby Current						
VIN Pin Supply Current	I_{IN}	Charge Mode ISET=0.1A		300	500	μA
	$I_{IN(EOC)}$	Stand by Mode		75	100	μA
	I_{SD}	Shutdown Mode		45	65	μA
BAT Pin Sink Current	I_{BAT}	Stand by Mode, VBAT=4.2V		2.5	4	μA
		Shutdown Mode		0.15	0.35	μA
		Sleep Mode, VIN=0V			1	uA
Power FET Resistance on	R_{ON}			0.5		Ω
Charge Current						
Constant Charge Current (Note 3)	I_{CHARGE}	R_{ISET} =10K,Current mode	85	100	115	mA
		R_{ISET} =2K,Current mode	450	500	550	mA
		R_{ISET} =1K,Current mode	900	1000	1100	mA
Trickle Charge Threshold	V_{TRIKL}		2.75	2.9	3.05	V
Trickle Charge Threshold Hysteresis	$V_{TRIKL(HYS)}$			200		mV
Trickle Charge Current	$I_{TRICKLE}$	R_{ISET} = 1kΩ	85	100	115	mA
End-of-Charge Current Threshold	I_{MIN}	R_{ISET} = 1kΩ		100		mA
End-of-Charge Current Delay Time	$T_{(EOC)}$			2		ms
Recharge Voltage Threshold	V_{RECHRG}	V_{BAT}- V_{RECHRG}		170		mV
Recharge Delay Time	$T(_{REC})$			2		ms
Ambient Temperature Monitoring						
High Voltage Threshold				2.4		V
High Voltage Threshold Hysteresis				0.3		V
Low Voltage Threshold				0.8		V
Low Voltage Threshold Hysteresis				0.2		V
NTC Thermistor Disable Threshold				0.4		V

Electrical Characteristics (Continued)

(V_{IN}=5V, T_A=25°C, maximum and minimum values are with a supply voltage in the range of 4.6V to 6V, unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Internal Temperature Monitoring						
Thermal Shunt Down Temperature	T_{SD}			150		°C
Thermal Shunt Down Temperature Hysteresis	T_{SD-HYS}			30		°C
Charge Current Fold-back Threshold (Note 4)	T_{FOLD}			125		°C
Current Fold-back Gain (Note 4)	G_{FOLD}			20		mA/°C

Note 3: The actual charge current may be affected by the thermal fold-back function if the thermal dissipation capability is not enough or by the on resistance of the power MOSFET if the charger input voltage is too close to the output voltage.
Note 4: The specification is guaranteed by design, not production tested.

Functional Description

Operation

The FP6908 is an integrated charger IC for single-cell Li-ion/Li-polymer batteries. The FP6908 functions as a traditional linear charger when powered with a voltage source adapter. When powered with a current-limited adapter, the charger minimizes the thermal dissipation commonly seen in traditional linear chargers.

When powered as a linear charger, the FP6908 charges a battery in the popular constant current (CC) and constant voltage (CV) profile. The constant charge current ISET is programmable up to 1.0A with an external resistor. The charge voltage VCH has 1% accuracy over the entire recommended operating condition range.

If the battery voltage is below the minimum fast charge voltage VMIN threshold, the charger always preconditions the battery with 1/10 of the programmed current at the beginning of a charge cycle, until the battery voltage is verified to be above the VMIN. This low current charge mode is named trickle mode. A thermal-fold-back feature is designed to throttle back the charge current to remove the thermal concern typically seen in linear chargers.

When the battery voltage drops below a recharge threshold, the charger automatically re-charges the battery.

The $\overline{\text{STAT}}$ pin is an open-drain logic output that turns LOW when FP6908 starts a charge cycle until the condition is: the battery voltage rises above the recharge threshold and the charge current falls below 1/10 of ISET.

Once the EOC condition is qualified, the $\overline{\text{STAT}}$ output rises to high and is latched. The latch is released at the beginning of a charge or re-charges cycle.

The current loop consists of current amplifier and the sense MOSFET $Q_{SENSE,}$ The current reference is set by the ISET pin. The current amplifier regulates the gate of the sense MOSFET Q_{SENSE} and Mirror MOSFET Q_1 in order to the sense current I_{SENSE} match the reference current I_{SET}. The Mirror MOSFET Q_1 and sense MOSFET Q_{SENSE} from current mirror 1000:1, so that the output charge current is 1000 times I_{SET}.

Power on Reset (POR)

The FP6908 resets itself as the input voltage rises above the POR rising threshold. The internal oscillator starts to oscillate, the internal timer is reset, and the charger begins to charge the battery. The two indication pins, $\overline{\text{STAT}}$ and $\overline{\text{FAULT}}$, indicate a LOW and a HIGH logic signal respectively. Figure 5 illustrates the start up of the charger. The FP6908 has a typical rising POR threshold of 4.2V and a falling POR threshold of 4.1V.

Charge Cycle

There are 3 charge modes in a charge cycle: trickle mode, constant current (CC) mode, and constant voltage (CV) mode. The charge cycle always starts with the trickle mode until the battery voltage stays above V_{MIN} (3V typical). The charger proceeds to the CC mode after verifying the battery voltage. As the battery-pack terminal voltage rises to the final charge voltage VCH, the CV mode begins. The terminal voltage is regulated at the constant VCH in the CV mode and the charge current is expected to decline. When the charge current drops below I_{EOC} (1/10 of ISET, see End-of-Charge Current for more detail), the FP6908 indicates the end-of-charge (EOC) with the $\overline{\text{STAT}}$ pin.

The following events initiate a new charge cycle:

1. POR.

2. The battery voltage drops below a recharge threshold after completing a charge cycle.

3. The EN pin is toggled from GND to floating.

Further descriptions of these events are given later in this data sheet.

Functional Description (Continued)

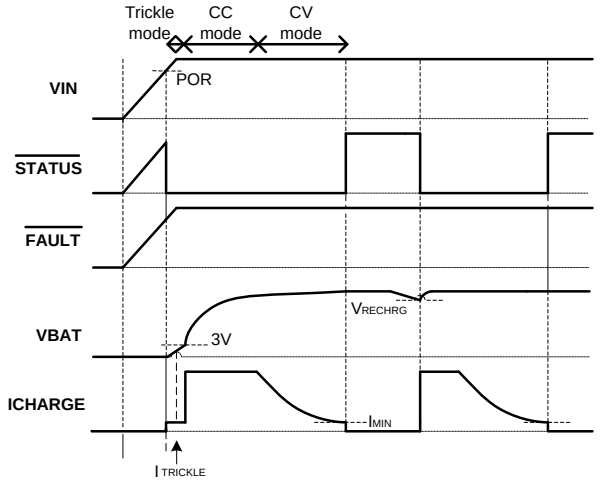


Figure 7. Charge Cycle Operation Waveform

Recharge

After a charge cycle completes, charging is prohibited until the battery voltage drops to a recharge threshold, V_{RECHRG}. Then a new charge cycle starts charge battery.

Charge Current Programming

The charging current during the constant current mode is 1000 times that of the current in the R_{ISET} resistor. The charge current in the CC mode is programmed by the ISET pin. The voltage of ISET is regulated to a 1.0V reference voltage. Hence, the charge current is:

I_{CHARGE} (mA) = 1.0V x 10^3 / R_{ISET} (kΩ)

R_{ISET} (kΩ)	Charge Current (mA)		
	Min.	Typ	Max.
10	85	100	115
5	180	200	220
2	450	500	550
1	900	1000	1100

Table1. Charge Current vs. R_{ISET} Values

The charger will resume charging after the fault condition is removed.

End-of-Charge (EOC) Current

The EOC current I_{MIN} sets the level at which the charger starts to indicate the end of the charge with the $\overline{STAT}$ pin, as shown in Figure 7. In the FP6908, the EOC current is internally set to 1/10 of the charge current that is:

$$I_{EOC} = 0.1 \times I_{CHARGE}$$

At the EOC, the $\overline{STAT}$ signal rises to high and is latched. The latch is not reset until a recharge cycle or a new charge cycle starts.

Indication

The FP6908 has three indications: the input presence, the charge status, and the fault indication. The input presence is indicated while the other two indications are presented by the $\overline{STAT}$ pin and $\overline{FAULT}$ pin respectively. Table 2 summarizes the two pins.

$\overline{FAULT}$	$\overline{STAT}$	Indication
High	High	Charge completed with no fault or standby
High	Low	Charging in one of the three modes
Low	High	Fault : OVP / UVLO UVP / OTP

Table2. State Indications

Functional Description (Continued)

Temperature Monitoring and Thermal Fold-back

The FP6908 has an external temperature monitoring function. A negative temperature coefficient (NTC) thermistor can be connected between the NTC pin and GND pin. The FP6908 is therefore monitoring the battery temperature if the thermistor is packed by the battery. The voltage of NTC pin is inversely proportional to the temperature. When the voltage of NTC pin is lower than the low voltage threshold 0.8V, it indicates the temperature is over-heating. Similarly, when the voltage of NTC pin is higher than the high voltage threshold 2.4V, it represents the temperature is too low. To sum up, the charger will be suspended and issue the fault indication when the voltage of NTC pin is not between 0.8V and 2.4V. In addition, the timer is still counting while the temperature is abnormal.

The maximum power dissipation usually occurs at the beginning of a charge cycle when the battery voltage is at its minimum but the charge current is at its maximum. The charge current thermal fold-back function in the FP6908 frees users from the over-heating concern. The I_{TM} has no impact before internal temperature reaches ~120°C. I_{SENSE} is equal to (I_{SET}-I_{TM}). Charge current is 1000 times of the sensed current and reduces at a rate of 20mA/°C. For a charger with the constant charge current set at 1A.

Input and Output Capacitor Selection

Typically any type of capacitors can be used for the input and the output. Use of a 1µF or higher value ceramic capacitor for the input is recommended. When the battery is attached to the charger, the output capacitor can any ceramic type with the value higher than 1µF. However, if there is a chance the charger without battery, a 10µF ceramic capacitor is recommended.

Stability with Large Ceramic Output Capacitors

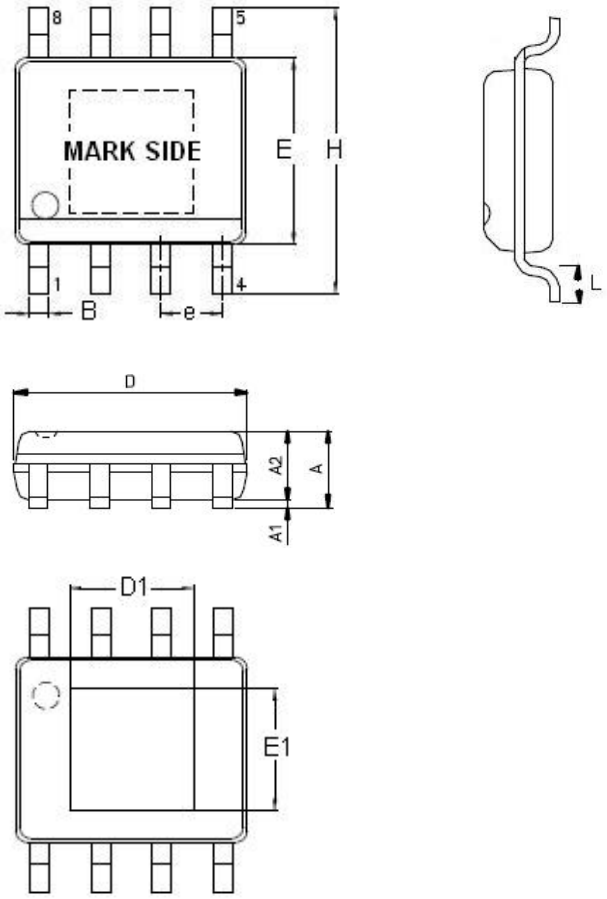
The FP6908 partially relies on the ESR (equivalent series resistance) of the output capacitor for the loop stability. When the system has a large ceramic capacitor or a number of ceramic capacitors in parallel, the ESR value can be too low for a stable operation.

Board Layout Recommendations

In order to maximize the current capability, it is very important that the exposed pad under the package is properly soldered to the board and is connected to other layers through thermal vias. More thermal vias and more copper attached to the exposed pad usually result in better thermal performance. On the other hand, the number of vias is limited by the size of the pad. The SOP-8 (Exposed Pad) package allows 8 vias be placed in two rows. Since the pins on the SOP-8 (Exposed pad) package are on only two sides, as much top layer copper as possible should be connected to the exposed pad to minimize the thermal impedance.

Outline Information

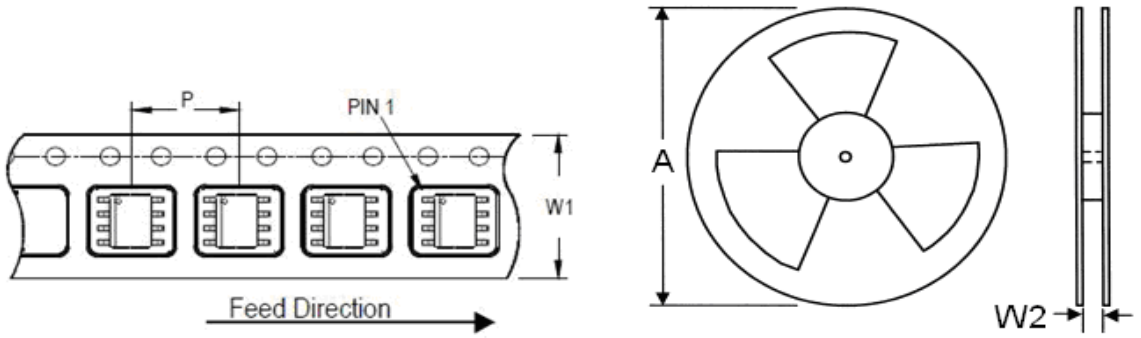
SOP-8 (Exposed Pad) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	1.25	1.70
A1	0.00	0.15
A2	1.25	1.55
B	0.31	0.51
D	4.80	5.00
D1	3.04	3.50
E	3.80	4.00
E1	2.15	2.41
e	1.20	1.34
H	5.80	6.20
L	0.40	1.27

Note 5: Followed From JEDEC MO-012-E.

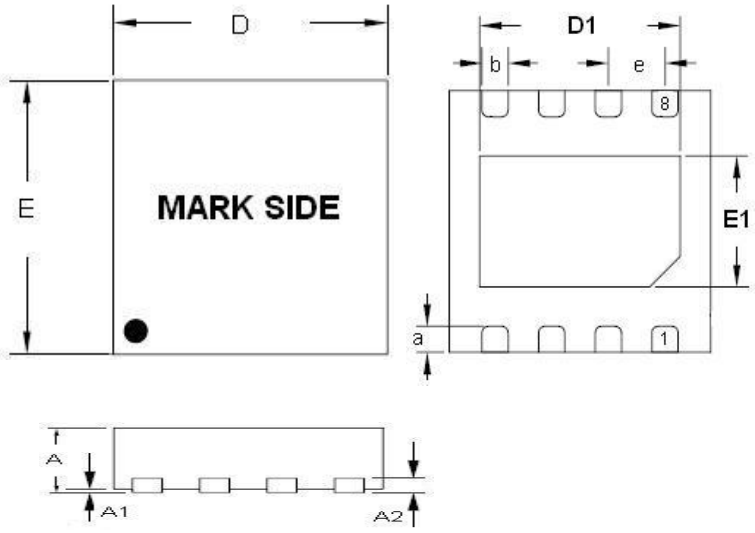
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	8	13	330	12.4	400~1000	2,500

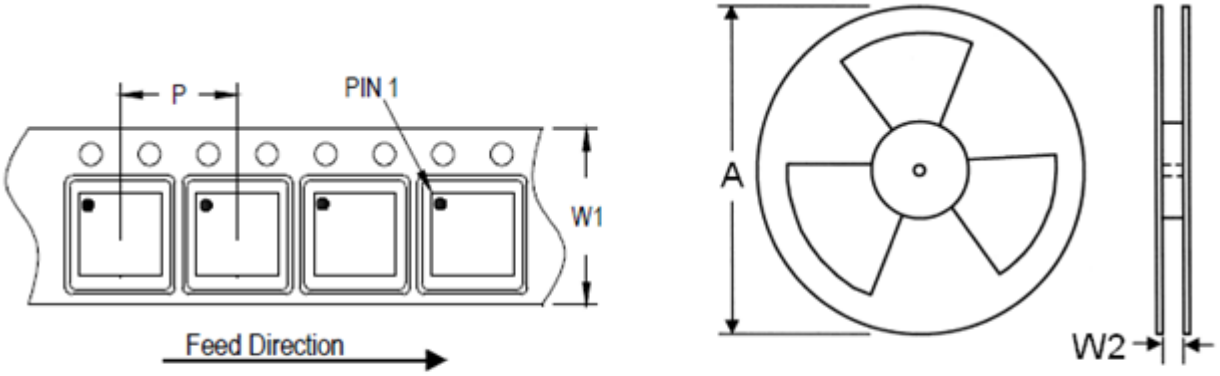
Outline Information (Continued)

TDFN-8 (2mmx2mm) (pitch 0.5mm) Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.18	0.25
D	1.90	2.10
E	1.90	2.10
a	0.20	0.40
b	0.18	0.30
e	0.45	0.55
D1	1.10	1.30
E1	0.60	0.80

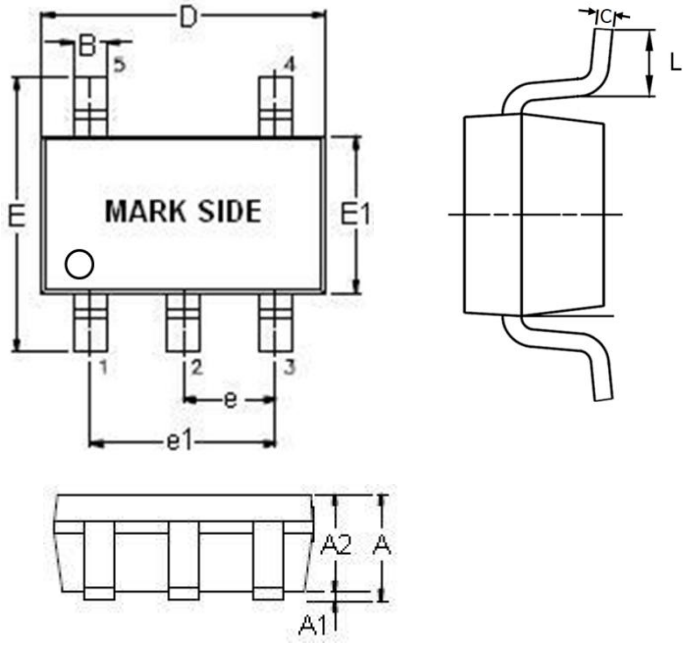
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	400~1000	3,000

Outline Information (Continued)

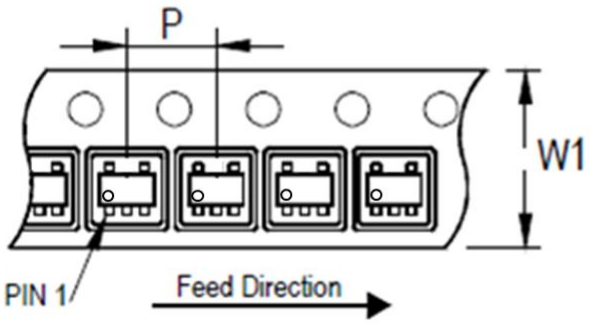
SOT-23-5 Package (Unit: mm)

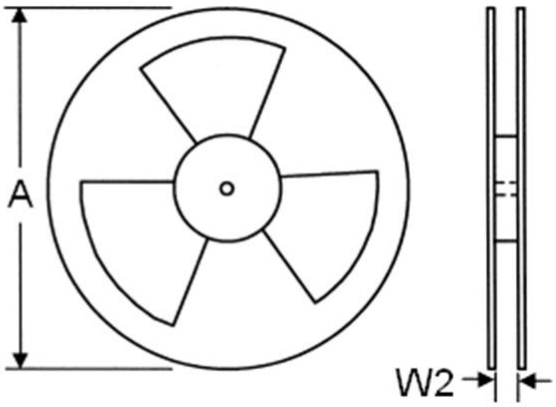


SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.90	1.30
A1	0.00	0.15
A2	0.90	1.15
B	0.28	0.50
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.95	
e1	1.90	
C	0.08	0.20
L	0.30	0.60

Note 6: Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.3mm.

Carrier Dimensions





Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	300~1000	3,000