1.2A Linear Li-ion Battery Charger IC

Features

- Recommended operating voltage: 4.5V to 5.5V
- Absolute maximum input voltage: 33V
- Supports 28V hot plugging with an input RC snubber
- Overvoltage protection (OVP): 6.8V typical
- Programmable charging current up to 1.2A
- Preset 4.20V or 4.35V charging voltage with ±1% accuracy
- No external MOSFET, sense resistor or isolation diode required
- Constant-current/constant-voltage operation
- Charging, charge termination, no-battery and fault status indication
- Standby quiescent current: 1.0μA typical
- Supports charging activation of 0V batteries
- Battery reverse-polarity protection at BAT
- 2.9V trickle charging; C/10 charge termination
- Automatic recharge
- Soft start limits inrush current
- Charging current regulation starts at a junction temperature of 130°C; charging shuts down at 155°C
- Operating temperature range: -40°C to +105°C
- Packages: SOP-8(EP), PDFN-2x2-8L and PDFN-3x3-8L

Applications

- Massage guns and electronic cigarettes
- Bluetooth headsets, GPS and wearable devices
- Digital cameras, mini speakers, electronic toys and other portable devices
- Hair clippers, shavers and various chargers

General Description

The HCR4056H series is a linear Li-ion battery charger IC with a 33V absolute maximum input voltage and a maximum charging current of 1.2A. It uses trickle-current, constant-current and constant-voltage charging. The charging voltage is set to 4.2V or 4.35V, and the charging current is set by an external resistor. After the battery voltage reaches 4.2V or 4.35V, charging stops when the current falls to C/10 of the programmed value, and the IC enters standby mode. When the supply is removed, the IC automatically enters low-power standby mode.

The HCR4056H is suitable for USB and adapter supplies. Its internal PMOSFET architecture and reverse-current blocking circuit eliminate the need for an external sense resistor or isolation diode.

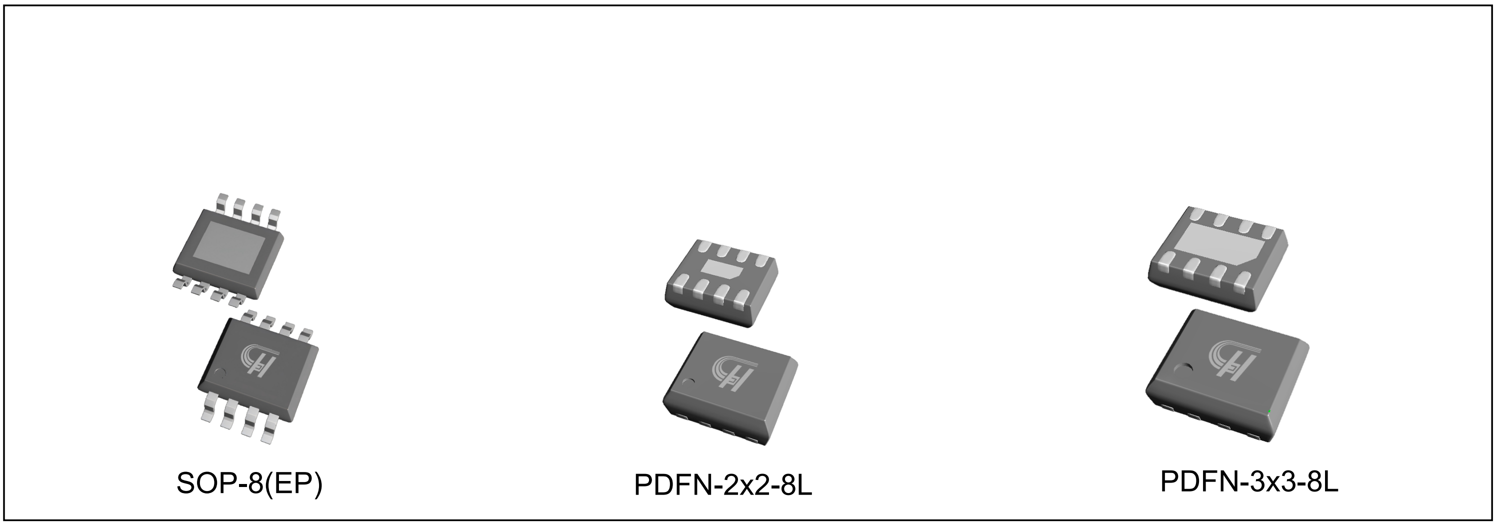


Figure 1. Appearance Diagram of HCR4056H

Pin Configuration

Top View of HCR4056H

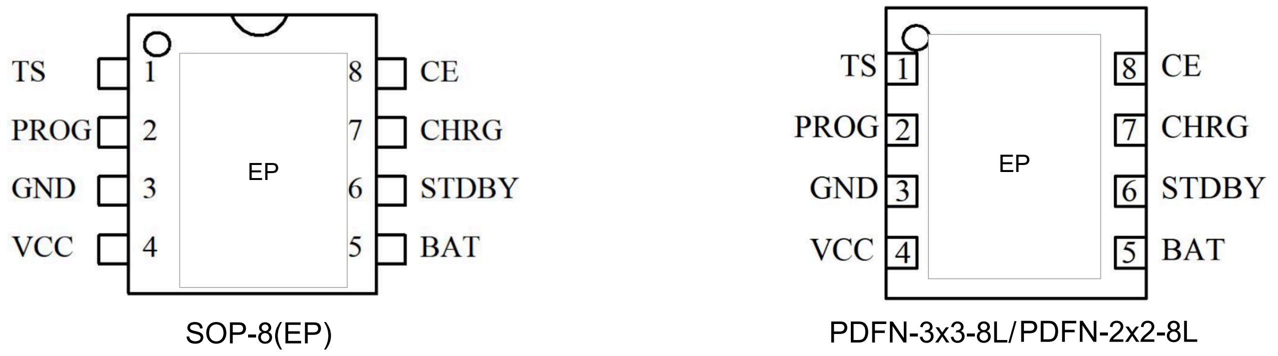


Figure 2. Pin configuration of HCR4056H

Pin Descriptions

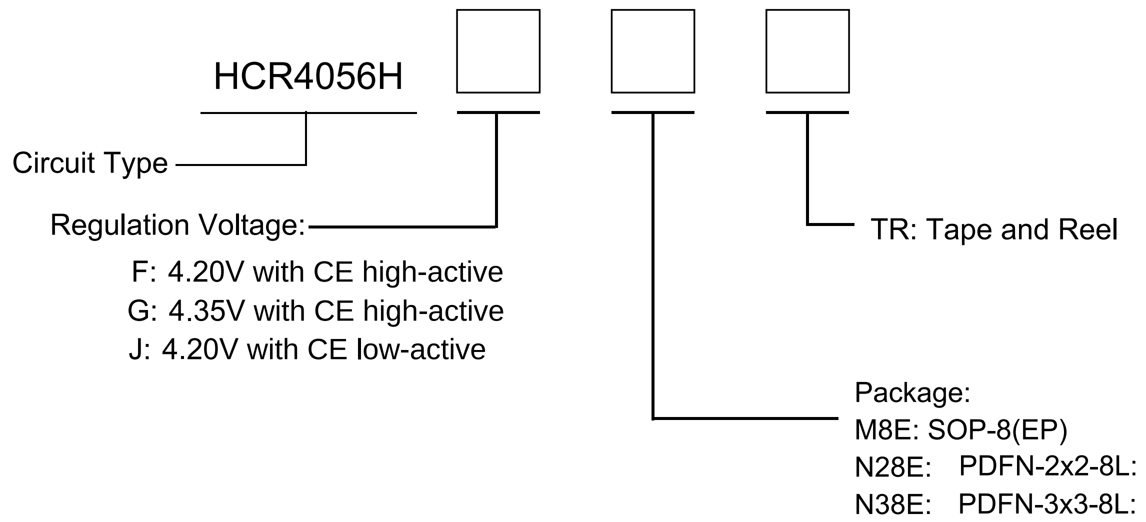
Pin No.	Name	Description
1	TS	Battery NTC temperature-sense input. Connect to ground when unused.
2	PROG	Programmable charging-current setting pin.
3	GND	Ground.
4	VCC	Power supply.
5	BAT	Connect to the positive battery terminal.
6	$\overline{\text{STDBY}}$	Battery charge-complete indication output.
7	$\overline{\text{CHRG}}$	Battery charging-status indication output.
8	CE	Chip enable.

Selection Guide

Model	CE Active Level	Float Voltage	Trickle Current	Termination Current	Package
HCR4056HF	High	4.20V	C/5	C/10	SOP-8(EP), PDFN-2x2-8L, PDFN-3x3-8L,
HCR4056HG	High	4.35V	C/5	C/10	SOP-8(EP), PDFN-2x2-8L, PDFN-3x3-8L,
HCR4056HJ	Low	4.20V	C/5	C/10	SOP-8(EP), PDFN-2x2-8L, PDFN-3x3-8L,

1. Float-voltage options: 4.20V / 4.35V / 4.20V.
2. CE may be selected as active high or active low.

Ordering Information



Variant: F: 4.20V, CE high-active; G: 4.35V, CE high-active; J: 4.20V, CE low-active

Ordering Code

Part Number	Voltage	CE-H or L active	Marking ID (Note 2)	Temperature Range	Package	Quantity per Reel
HCR4056HFM8ETR	4.20V	H	HCR4056HFxx	-40 to +105°C	SOP-8(EP)	4000pcs/Reel
HCR4056HFN28ETR	4.20V	H	4056HFxx	-40 to +105°C	PDFN-2x2-8L	4000pcs/Reel
HCR4056HFN38ETR	4.20V	H	HCR4056HFxx	-40 to +105°C	PDFN-3x3-8L	4000pcs/Reel
HCR4056HGM8ETR	4.35V	H	HCR4056HGxx	-40 to +105°C	SOP-8(EP)	4000pcs/Reel
HCR4056HGN28ETR	4.35V	H	4056HGxx	-40 to +105°C	PDFN-2x2-8L	4000pcs/Reel
HCR4056HGN38ETR	4.35V	H	HCR4056HGxx	-40 to +105°C	PDFN-3x3-8L	4000pcs/Reel
HCR4056HJM8ETR	4.20V	L	HCR4056HJxx	-40 to +105°C	SOP-8(EP)	4000pcs/Reel
HCR4056HJN28ETR	4.20V	L	4056HJxx	-40 to +105°C	PDFN-2x2-8L	4000pcs/Reel
HCR4056HJN38ETR	4.20V	L	HCR4056HJxx	-40 to +105°C	PDFN-3x3-8L	4000pcs/Reel

Note 2: The marking consists of the variant model followed by "xx", the date code.

Typical Application Circuit

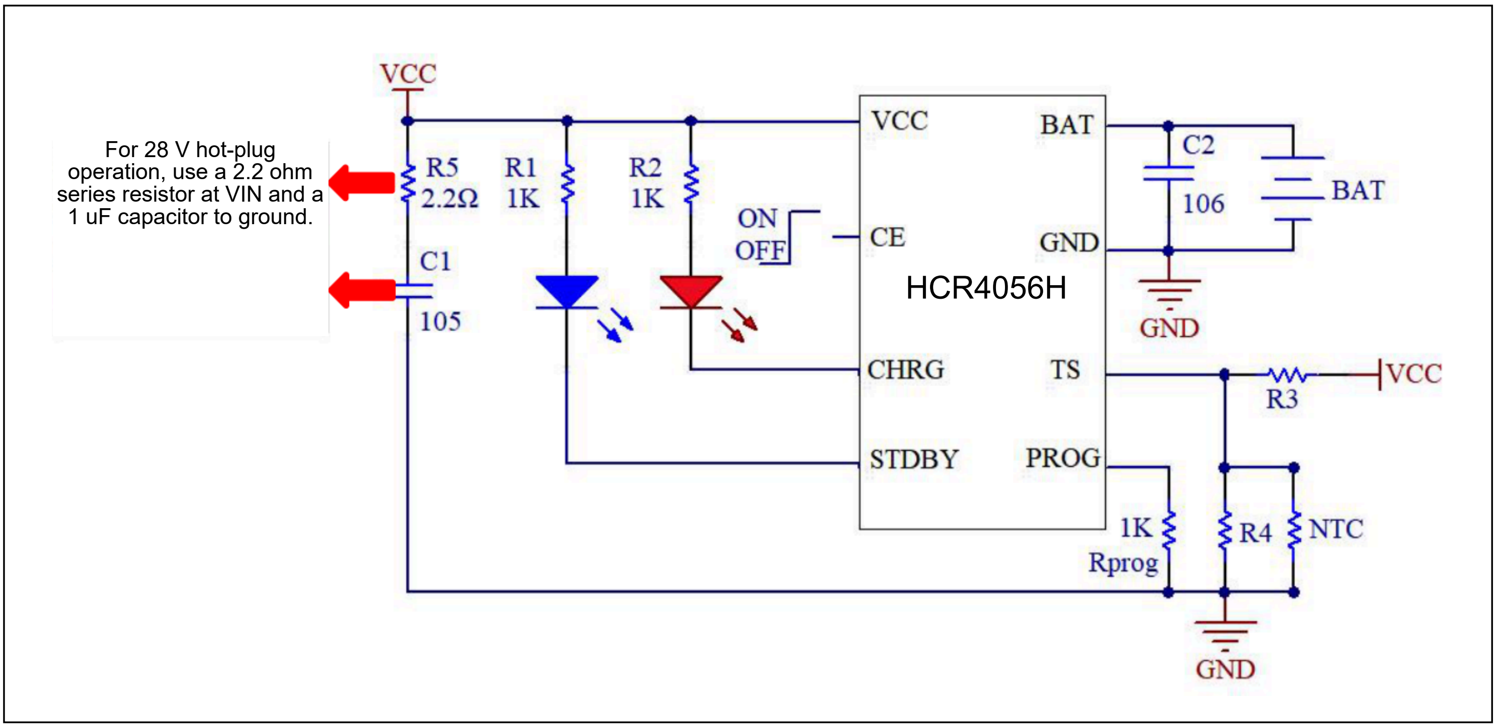


Figure 3. Typical Application Circuit

Connect TS to ground if temperature monitoring is not used.

CE is active high on HCR4056HF/HG and active low on HCR4056HJ.

Functional Block Diagram

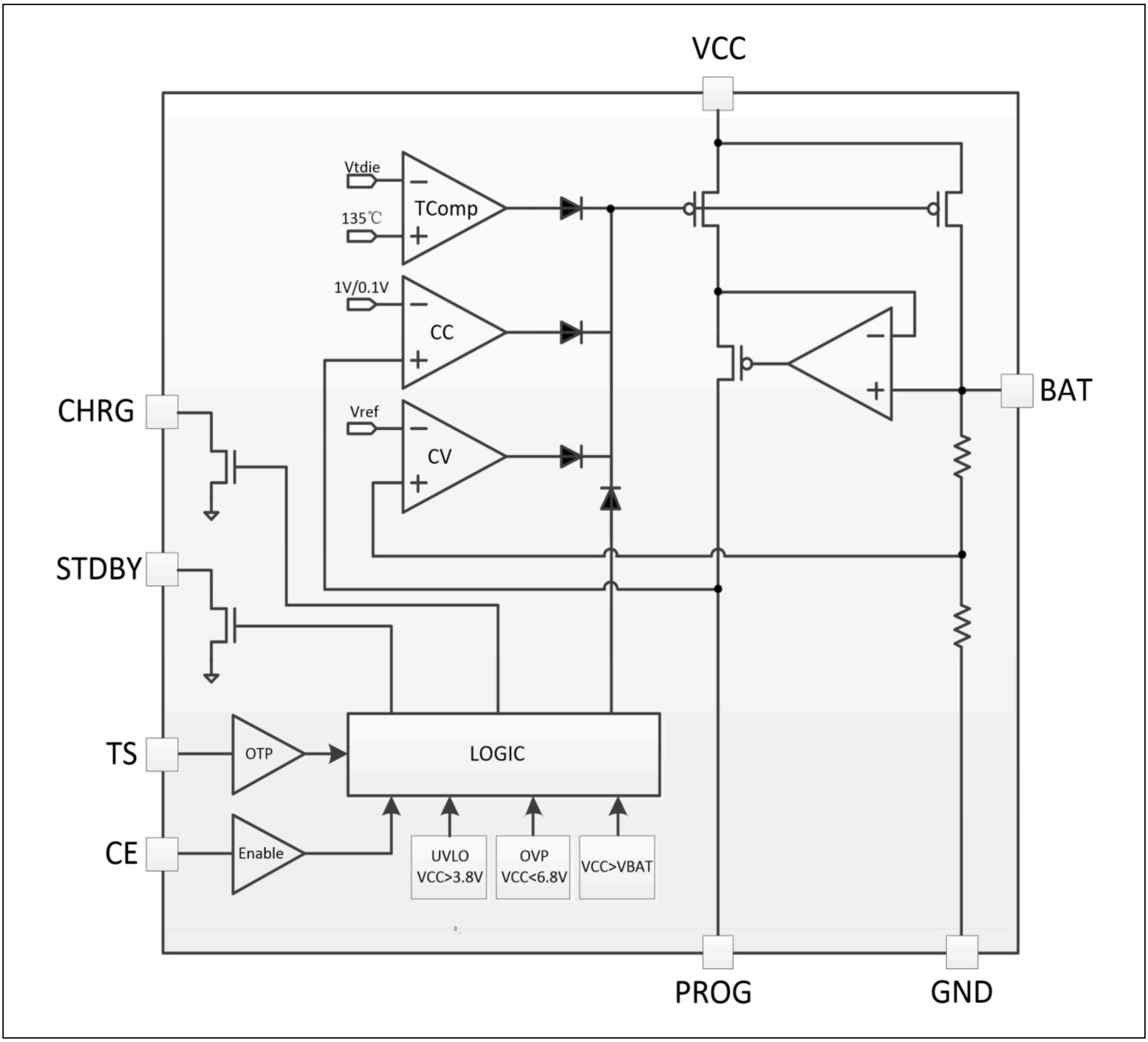


Figure 4. Functional Block Diagram

Absolute Maximum Ratings

Parameter	Symbol	Range	Unit
V_{IN} and CE input voltage	V_{IN}, V_{CE}	-0.3 to 33	V
$\overline{CHRG}$, $\overline{STDBY}$ and TS voltage	V_{CHRG}, V_{STDBY}, V_{TS}	-0.3 to 33	V
BAT voltage	V_{BAT}	-0.3 to 12	V
PROG voltage	V_{PROG}	-0.3 to 10	V
Maximum BAT pin current	I_{BAT}	1200	mA
Maximum PROG pin current	I_{PROG}	1.2	mA
Power dissipation at T_A = +25°C	P_D (SOP-8(EP))	1.8	W
Power dissipation at T_A = +25°C	P_D (PDFN-3x3-8L)	1.3	W
Power dissipation at T_A = +25°C	P_D (PDFN-2x2-8L)	1.0	W
Storage temperature range	T_{STG}	-65 to +150	°C
Maximum operating junction temperature	TJ(MAX)	155	°C
Lead soldering temperature (10s)	T_{LEAD}	260	°C
ESD (HBM)	HBM	VDD to GND ≥ 5k	V

Exceeding the absolute maximum ratings may damage the device.

Recommend Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Input voltage	V_{IN}	4.5	5.5	V
Ambient operating temperature	T_{OP}	-40	+105	°C
Charging current	I_{BAT}	30	1200	mA

Electrical Characteristics

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Input supply voltage	V_{IN}		4.5	5.0	5.5	V
Input overvoltage lockout threshold (OVP)	V_{OVLO}	V_{CC} rising	6.6	6.8	7.0	V
OVP hysteresis voltage	V_{OVLO}-HYS	V_{CC} falling		500		mV
Input supply current	I_{CC}	Charging mode, R_{PROG} = 2kΩ		200	350	μA
Input supply current	I_{CC}	Standby mode (charge terminated)		100	150	μA
Input supply current	I_{CC}	Shutdown mode (R_{PROG} disconnected); $V_{CC} < V_{BAT}$, or $V_{CC} < V_{OVLO}$		55	100	μA
Regulated output (float) voltage	V_{FLOAT}	0°C ≤ T_A ≤ 85°C, I_{BAT} = 40mA	4.158	4.20	4.242	V
Regulated output (float) voltage	V_{FLOAT}	0°C ≤ T_A ≤ 85°C, I_{BAT} = 40mA	4.306	4.35	4.393	V
BAT charging current	I_{BAT}	Constant-current mode, R_{PROG} = 1kΩ	900	1000	1100	mA
BAT charging current	I_{BAT}	Standby mode, V_{BAT} = 4.20V		1.0		μA
BAT charging current	I_{BAT}	Shutdown mode (R_{PROG} disconnected)		1.0		μA
BAT charging current	I_{BAT}	Sleep mode, V_{CC} = 0V		0.1		μA
Trickle-charge current	I_{TRIKL}	$V_{BAT} < V_{TRIKL}$, R_{PROG} = 1kΩ, C/5	160	200	240	mA
Trickle-charge threshold voltage	V_{TRIKL}	R_{PROG} = 1kΩ, V_{BAT} rising	2.8	2.9	3.0	V
Trickle-charge hysteresis voltage	V_{TRHYS}	R_{PROG} = 1kΩ, V_{BAT} falling	40	80	120	mV
V_{CC} undervoltage protection threshold	V_{OVLO}	V_{CC} rising	3.6	3.8	4.0	V
V_{CC} undervoltage lockout hysteresis	V_{UVHYS}	V_{CC} falling	150	200	250	mV
Manual shutdown threshold voltage	V_{MSD}	PROG voltage	1.3			V

Electrical Characteristics (Continued)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
V_{CC} - V_{BAT} lockout voltage	V_{ASD}	V_{CC} rising		275		mV
V_{CC} - V_{BAT} lockout voltage	V_{ASD}	V_{CC} falling		240		mV
Termination current threshold	I_{TERM}	R_{PROG} = 1kΩ, C/10		100		mA
PROG pin voltage	V_{PROG}	Constant-current mode, R_{PROG} = 1kΩ	0.9	1.0	1.1	V
$\overline{CHRG}$ output low voltage	V_{CHRG}	I_{CHRG} = 5mA		0.35	0.5	V
$\overline{STDBY}$ output low voltage	V_{STDBY}	I_{STDBY} = 5mA		0.35	0.5	V
Battery recharge threshold voltage	V_{RECHG}	IFLOAT - V_{RECHG}	100	150	200	mV
Recharge delay time	t_{RECHG}	V_{BAT} falling		1.2		ms
CE enable threshold voltage (HCR4056HF/HG)	V_{CEH}	CE rising	2			V
CE shutdown threshold voltage (HCR4056HF/HG)	V_{CEL}	CE falling			0.5	V
CE enable threshold voltage (HCR4056HJ)	V_{CEL}	CE falling			0.5	V
CE shutdown threshold voltage (HCR4056HJ)	V_{CEH}	CE rising	2			V
TS upper trip voltage	V_{TS_H}	TS connected to NTC resistor		80		%V_{CC}
TS lower trip voltage	V_{TS_L}	TS connected to NTC resistor		45		%V_{CC}
Charge termination delay	t_{TERM}	I_{BAT} falls below I_{CHRG}/10		1.6		ms
PROG pull-up current	I_{PROG}			2.0		μA
Power FET on-resistance	R_{ON}			500		mΩ
Soft-start time	t_{SS}	I_{BAT} = 0 to I_{BAT} = 1000/R_{PROG}		450		μs
Junction temperature in temperature-limited mode	T_{LIM}			155		°C

Some parameters may vary slightly between production lots.

Typical Performance Characteristics

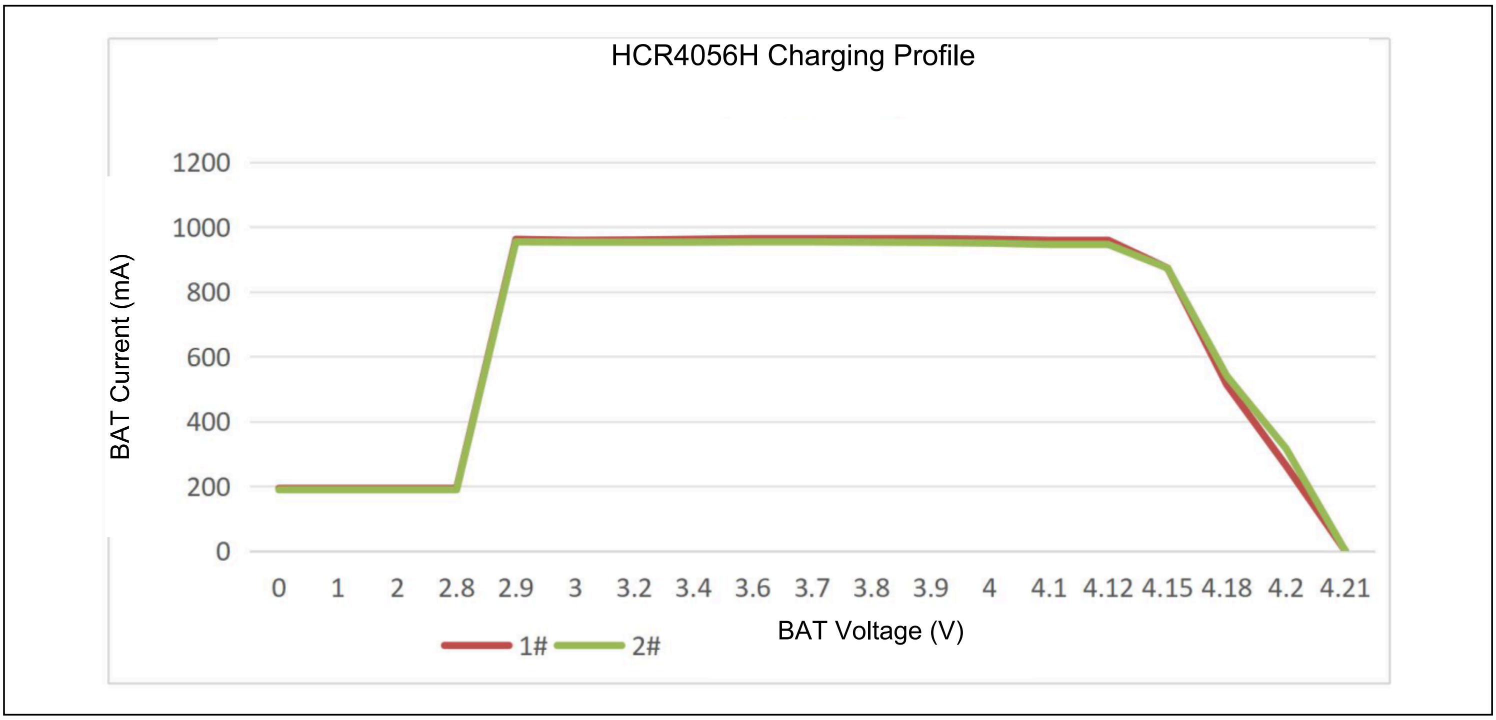


Figure 5. Charging Curve (V_{IN} = 5V, PROG = 1kΩ, SOP-8(EP))

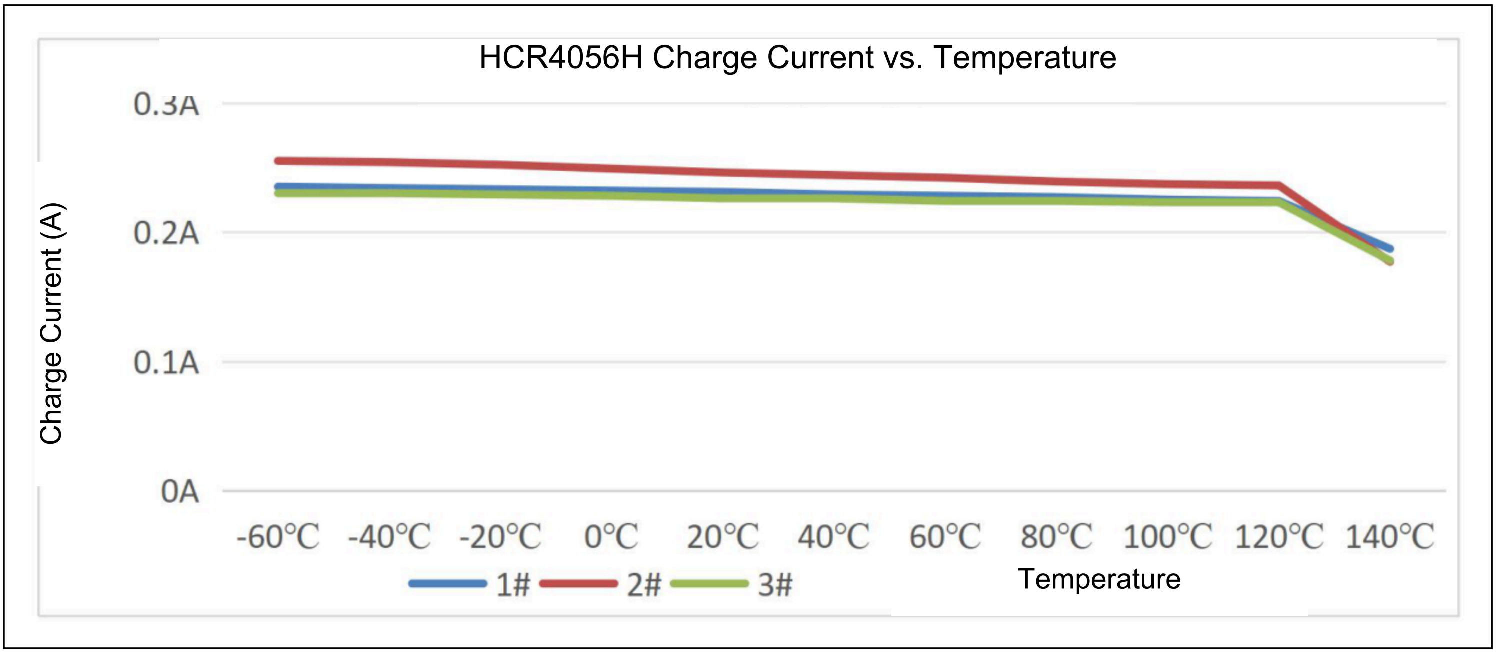


Figure 6. Charging Current vs. Temperature (V_{IN} = 5V, PROG = 5.1kΩ, SOP-8(EP))

Typical Performance Characteristics

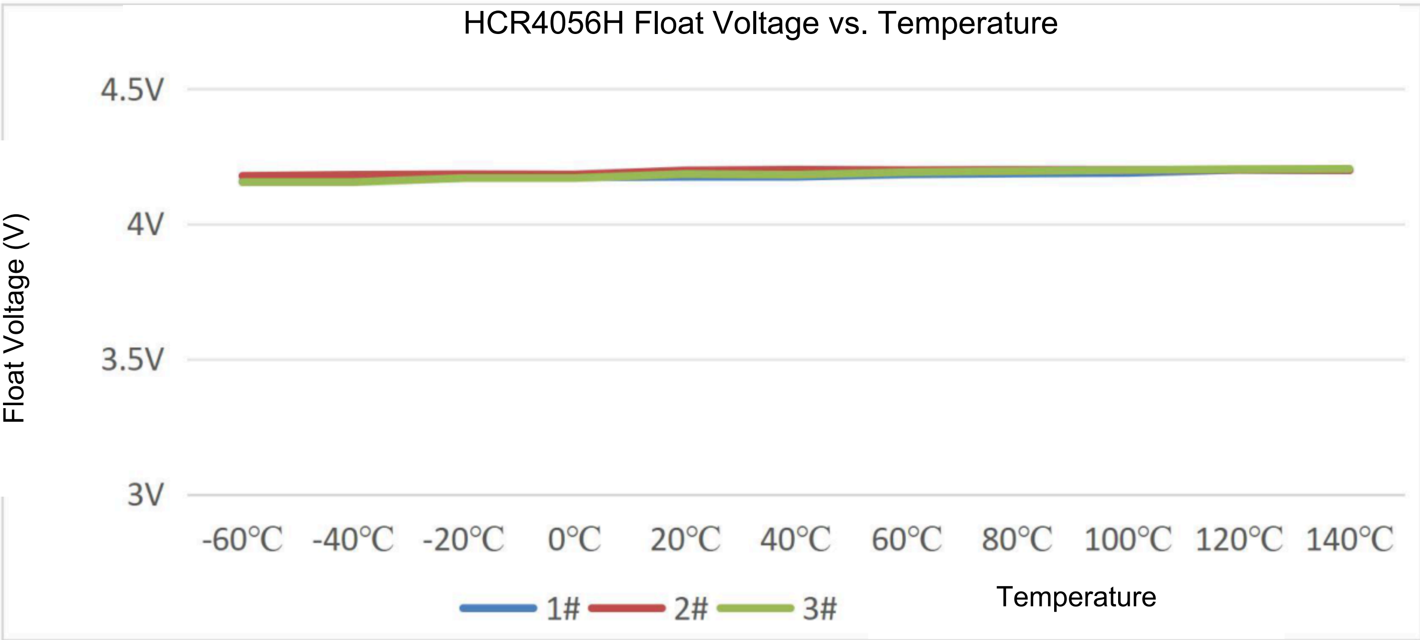


Figure 7. Float Voltage vs. Temperature (V_{IN} = 5V, PROG = 5.1kΩ, SOP-8(EP))

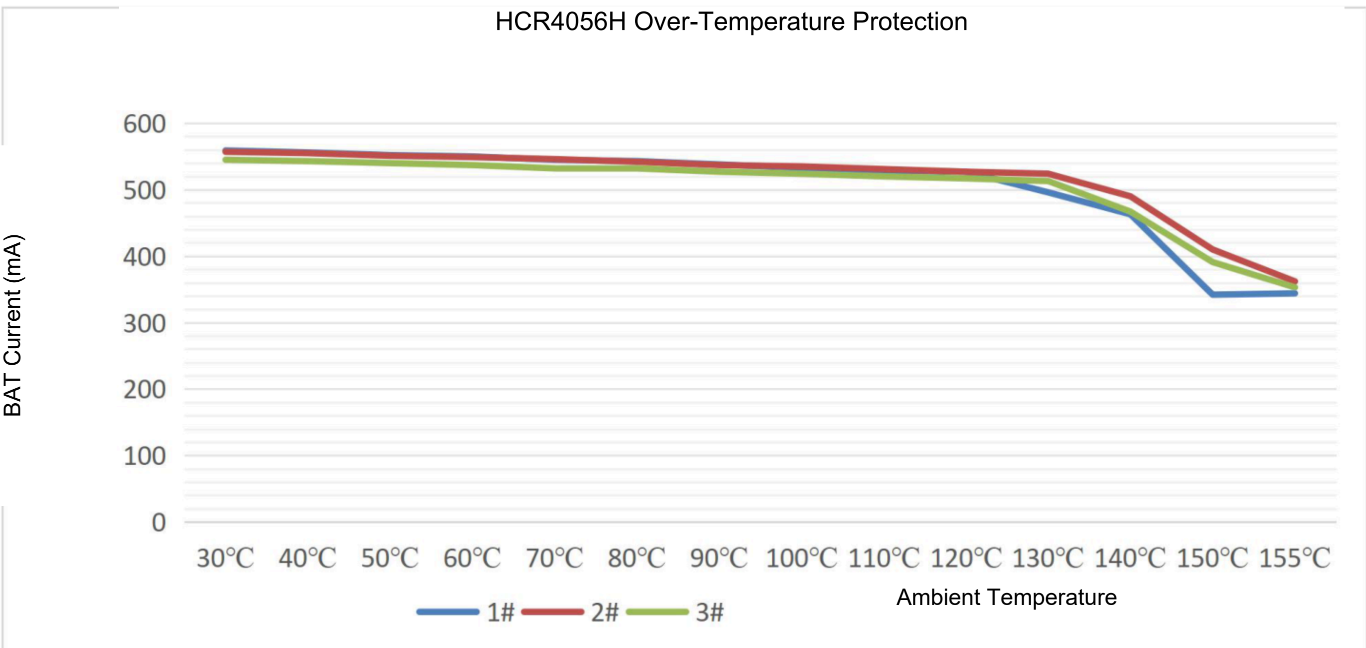


Figure 8. Overtemperature Protection (V_{IN} = 5V, PROG = 2kΩ, SOP-8(EP))

Typical Performance Characteristics

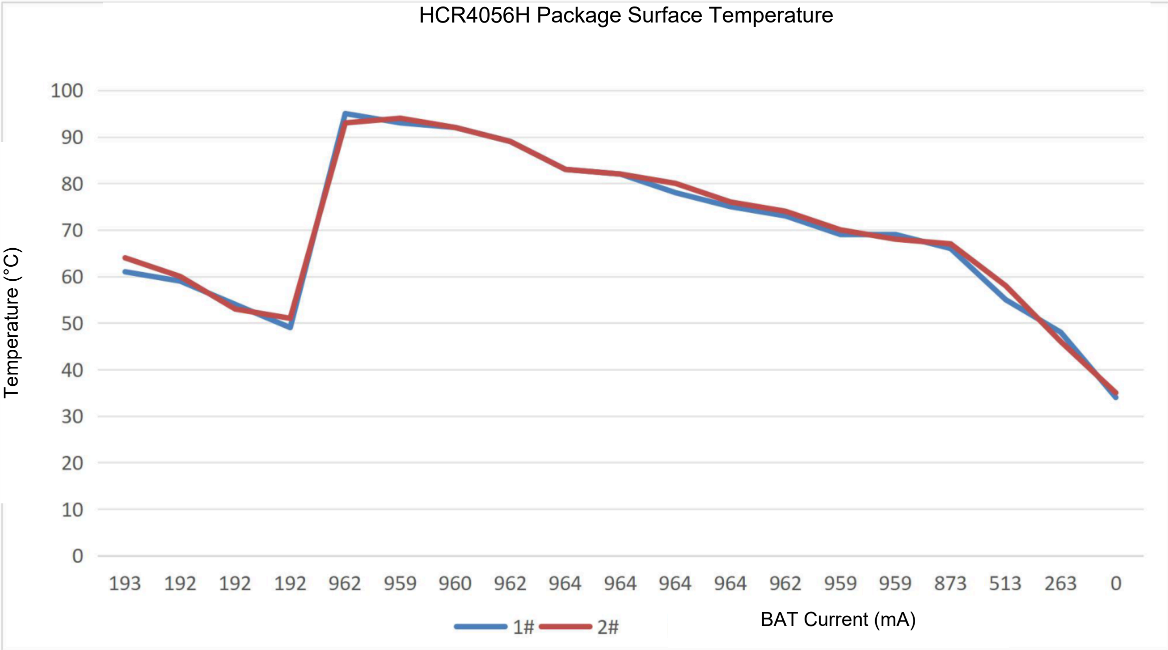


Figure 9. IC Surface Temperature at Different Charging Currents (V_{IN} = 5V, PROG = 1kΩ, SOP-8(EP))

Measured with a UTi120S infrared thermal imager. The distance from the instrument housing to the IC surface is 25.8mm.

Detailed Description and Application Information

Operating Principle

The HCR4056H is a linear charger for a single-cell Li-ion or lithium-polymer battery. The internal power MOSFET charges the battery in constant-current/constant-voltage mode. An external resistor programs the charging current, up to 1200mA. Two open-drain status outputs are provided: $\overline{\text{CHRG}}$ indicates charging and $\overline{\text{STDBY}}$ indicates charge completion. The internal power circuit automatically reduces charging current when the junction temperature exceeds 130°C. This permits maximum use of the charging capability, with charging disabled at 155°C, without overheating and damaging the IC or external components. Input overvoltage protection protects the IC in complex input environments.

Normal Charging

A charging cycle begins when the V_{CC} pin voltage rises above the UVLO threshold and a 1%-accuracy programming resistor is connected between PROG and ground. If the BAT pin voltage is below the 2.9V trickle-charge threshold, the charger enters trickle-charge mode. In this mode, the HCR4056H supplies approximately C/5 of the programmed charging current to raise the battery voltage to a safe level. When BAT rises above the trickle-charge threshold, the charger enters constant-current mode and supplies a constant charging current to the battery. When BAT reaches the final float voltage of 4.2V or 4.35V, the IC enters constant-voltage mode and the charging current begins to decrease. The charging cycle ends when the current falls to C/10 of the programmed value.

Charging Current Programming

The charging current is programmed by a resistor connected between PROG and ground. The charging current is 1000 times the PROG output current. The programming resistor and charging current are calculated as follows:

$$R_{\text{PROG}} = \frac{1000}{I_{\text{BAT}}} \quad \text{or} \quad I_{\text{BAT}} = \frac{1000}{R_{\text{PROG}}}$$

The charging current from BAT can be determined at any time by monitoring the PROG voltage:

$$I_{\text{BAT}} = \frac{V_{\text{PROG}}}{R_{\text{PROG}}} \times 1000$$

When the programmed charging current exceeds 1A, the IC generates more heat and thermal protection reduces the charging current. Current measured under different environmental conditions may therefore differ from the theoretical value calculated by the formula. Select a suitable R_{PROG} for the application using the following recommended values:

R_{PROG} (kΩ)	I_{BAT} (mA)
0.82	1200
1	1000
1.2	800
2	550
2.2	500
5.1	200

Charge Termination

The charging cycle terminates when the current falls to C/10 of the programmed value after the final float voltage is reached. An internal filtered comparator monitors PROG to detect this condition. When the PROG voltage falls below 100mV (C/10), charging terminates and the HCR4056H enters standby mode, reducing the input supply current to approximately 100µA.

Detailed Description and Application Information

Charging Status Indication

The HCR4056H has two open-drain status outputs, $\overline{CHRG}$ and $\overline{STDBY}$. $\overline{CHRG}$ is pulled low during charging and is high impedance in other states. When no battery is connected, $\overline{CHRG}$ outputs pulses to indicate that the battery is absent. With a 1μF external capacitor at the battery terminal, the $\overline{CHRG}$ flashing period is approximately 0.1 to 0.8s. With a 10μF external capacitor at BAT, the flashing period is approximately 1 to 2s. Connect unused status outputs to ground. The complete indicator states are listed below:

Charging State	$\overline{CHRG}$ Level (LED)	$\overline{STDBY}$ Level (LED)
Charging	Low (on)	High impedance (off)
Fully charged	High impedance (off)	Low (on)
Input undervoltage, overvoltage or reversed battery	High impedance (off)	High impedance (off)
10μF at BAT, no battery	Flashing, 1 to 2s	Low (on)

If the battery is removed after V_{IN} is applied, both LEDs may be off.

Thermal Regulation

When the IC temperature rises above 130°C, an internal thermal feedback loop reduces the programmed charging current. The output shuts down directly above 155°C. This prevents the HCR4056H from overheating and allows the upper limit of power handling on a given circuit board to be increased with less risk of damaging the IC.

Undervoltage Lockout

An internal undervoltage lockout circuit monitors the input voltage and holds the HCR4056H in shutdown until V_{CC} rises above the undervoltage lockout threshold. The UVLO circuit keeps the charger in shutdown. If the UVLO comparator changes state, the charger does not leave shutdown until V_{CC} rises 100mV above the battery voltage.

Automatic Recharge

After the battery reaches the float voltage and the charging cycle terminates, the HCR4056H immediately monitors BAT. A new charging cycle begins when BAT falls below approximately 4.05V (4.20V float voltage) or 4.20V (4.35V float voltage). This keeps the battery nearly fully charged and eliminates the need to periodically initiate charging cycles.

Detailed Description and Application Information

Battery Reverse-Polarity Protection

The HCR4056H includes Li-ion battery reverse-polarity protection. If a battery is connected in reverse to BAT, the IC shuts down and indicates a fault. The reversed battery leakage current is approximately 0.1mA. Correcting the battery connection automatically starts a charging cycle. If a reversed battery is removed, the capacitor at BAT remains at a negative potential, so the charging indicator does not immediately return to normal. Correctly connecting a battery automatically activates charging. Alternatively, wait for the negative charge on the BAT capacitor to discharge. When BAT rises above 0V, the IC displays the normal no-battery indication.

Charging Current Soft Start

The HCR4056H includes a soft-start circuit that minimizes inrush current at the beginning of a charging cycle. When a cycle starts, charging current rises from zero to the full-scale value in approximately 450μs, minimizing the transient current load on the supply during startup.

Input Overvoltage Protection (OVP)

The HCR4056H provides input overvoltage protection. When V_{CC} reaches 6.8V, OVP shuts down the IC and stops battery charging. The IC resumes operation when the supply falls to 6.2V.

Battery Temperature Monitoring

The HCR4056H integrates a battery temperature monitoring circuit to prevent battery damage caused by excessively high or low temperatures. It measures the voltage at TS, which is generated by the battery NTC thermistor and a resistor divider. The IC compares TS against two internal thresholds, V_{LOW} and V_{HIGH}, to determine whether the battery temperature is outside its normal range. V_{LOW} is fixed at 45% × V_{CC} and V_{HIGH} at 80% × V_{CC}. If $V_{TS} < V_{LOW}$ or $V_{TS} > V_{HIGH}$, the battery is too hot or too cold and charging pauses. Charging continues when V_{TS} is between V_{LOW} and V_{HIGH}.

Detailed Description and Application Information

Determining R_3 and R_4 for Temperature Sensing

Determine R_3 and R_4 from the battery temperature monitoring range and thermistor resistance, as illustrated below.

Assume the required battery temperature range is T_L to T_H, where $T_L < T_H$, and the battery uses a negative-temperature-coefficient (NTC) thermistor. R_{TL} is its resistance at T_L, and R_{TH} is its resistance at T_H; therefore, $R_{TL} > R_{TH}$. At temperature T_L, the TS voltage is:

$$V_{\text{TS}} = \frac{R_4 \parallel R_{\text{TH}}}{R_3 + R_4 \parallel R_{\text{TH}}} \times V_{\text{IN}}$$

Using $V_{TS} = V_{HIGH} = K_2 \times V_{CC}$ ($K_2 = 0.8$) and $V_{TS} = V_{LOW} = K_1 \times V_{CC}$ ($K_1 = 0.45$) gives:

$$R_3 = \frac{R_{\text{TL}} R_{\text{TH}} (K_2 - K_1)}{(R_{\text{TL}} - R_{\text{TH}}) K_2 K_1}$$

$$R_4 = \frac{R_{\text{TL}} R_{\text{TH}} (K_2 - K_1)}{R_{\text{TL}} (K_1 - K_2 K_1) - R_{\text{TH}} (K_2 - K_2 K_1)}$$

Similarly, if the battery uses a positive-temperature-coefficient (PTC) thermistor:

$$R_3 = \frac{R_{\text{TL}} R_{\text{TH}} (K_2 - K_1)}{(R_{\text{TH}} - R_{\text{TL}}) K_2 K_1}$$

$$R_4 = \frac{R_{\text{TL}} R_{\text{TH}} (K_2 - K_1)}{R_{\text{TH}} (K_1 - K_2 K_1) - R_{\text{TL}} (K_2 - K_2 K_1)}$$

These equations show that the required temperature range is independent of V_{CC} and depends only on R_3, R_4, R_{TH} and R_{TL}. R_{TH} and R_{TL} can be obtained from the battery documentation or by measurement.

If only one temperature limit is required, such as overtemperature protection, R_4 may be omitted and only R_3 used.

Note: Refer to the application circuit for the positions of R_3 and R_4.

Input/Output Capacitor and Resistor Selection and PCB Layout

To ensure reliable operation under various conditions and prevent damage from voltage spikes and glitches, use an RC filter at the input (refer to the typical application circuit). Capacitor values: C_1 = 105, C_2 = 106. Place the capacitors as close as possible to the IC pins on the PCB.

Recommended resistor values: R_1 and R_2 = 1kΩ. These resistors must not be omitted, to prevent incorrect LED indications.

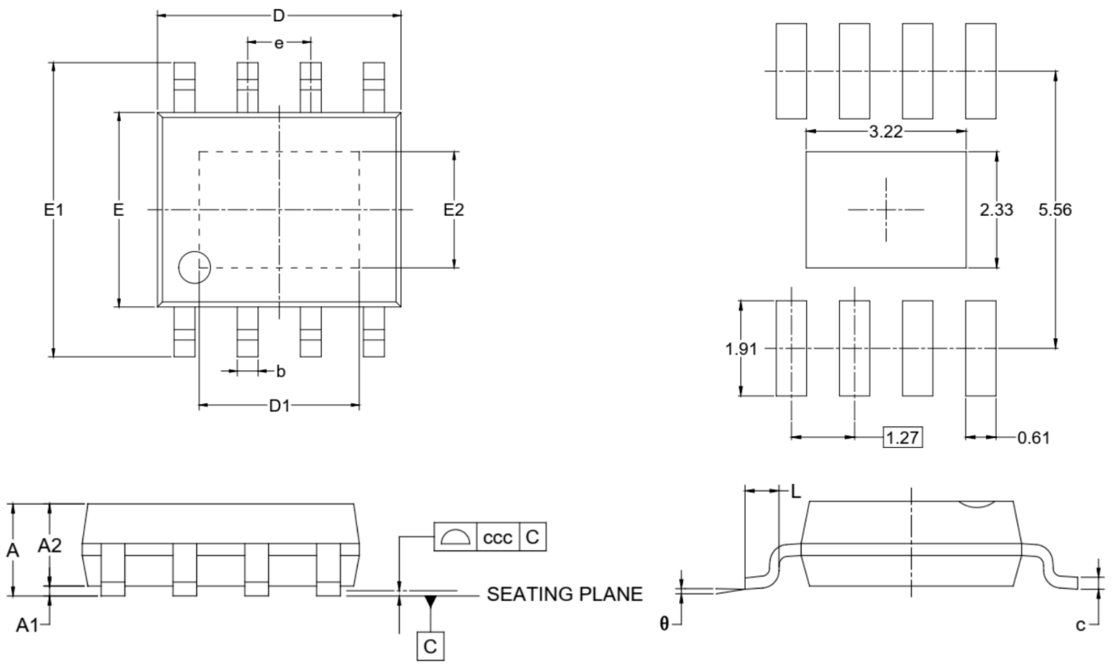
Solder the exposed pad (EP) on the bottom of the IC securely to the PCB. Add vias in the bottom thermal area and preferably use a large copper area for heat dissipation. A multilayer PCB with sufficient vias improves heat dissipation. Poor heat dissipation may reduce charging current through thermal protection. Suitable vias in the rear thermal area also facilitate hand soldering: solder can be fed through the vias from the rear to securely solder the thermal pad.

For high-current charging applications above 1000mA, add a heat-dissipation resistor at V_{IN} to shorten charging time. Select a suitable resistance from 0.2Ω to 0.4Ω according to the application.

Mechanical Dimensions

M8E PKG: SOP-8(EP)

Unit: mm



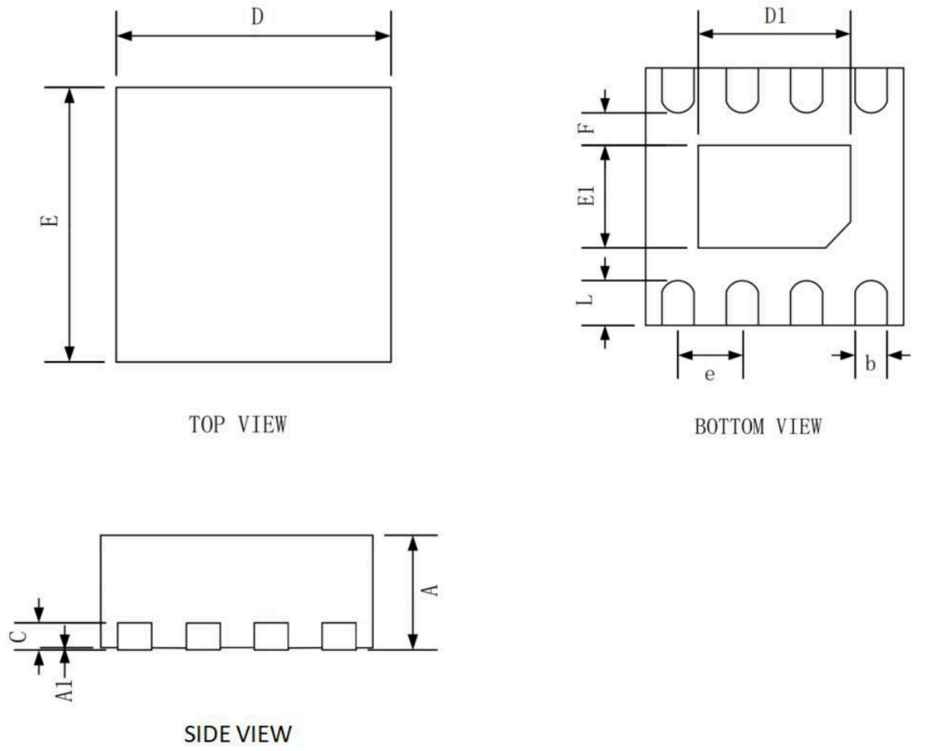
Symbol	MIN (mm)	MOD (mm)	MAX (mm)
A			1.700
A1	0.000	-	0.150
A2	1.250	-	1.650
b	0.330	-	0.510
c	0.170	-	0.250
D	4.700	-	5.100
D1	3.020	-	3.420
E	3.800	-	4.000
E1	5.800	-	6.200
E2	2.130	-	2.530
e	1.27 BSC		
L	0.400	-	1.270
θ	0°	-	8°
ccc	0.100		

1. This drawing is subject to change without notice.
2. The dimensions do not include mold flashes, protrusions or gate burrs.
3. Reference JEDEC MS-012.

Mechanical Dimensions

N28E PKG: PDFN-2x2-8L

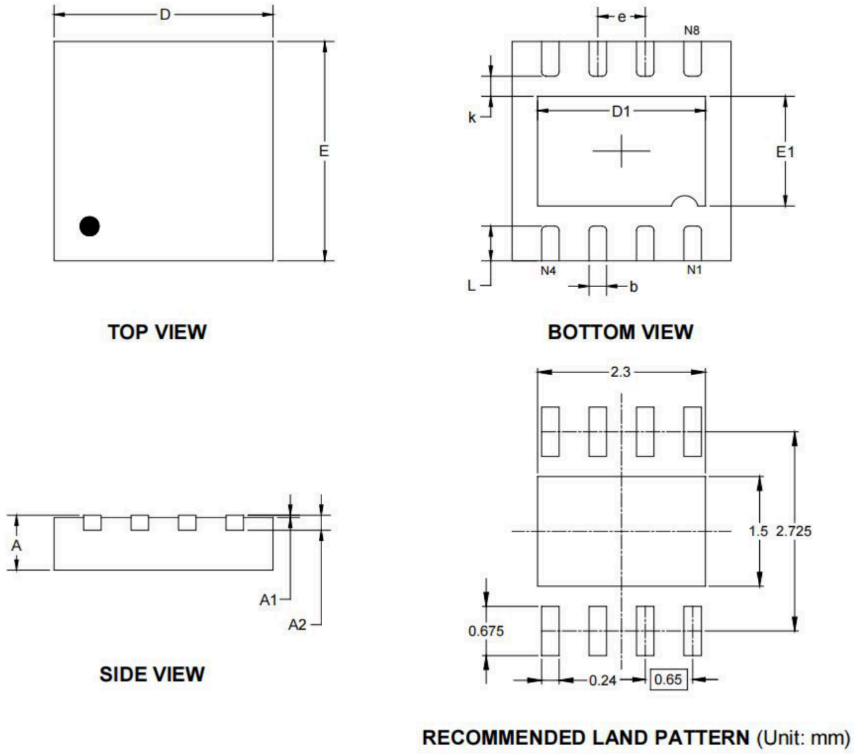
Dimensions: mm / inch



Symbol	MIN (mm)	MAX (mm)	MIN (inch)	MAX (inch)
A	0.45	0.55	0.018	0.022
A1	0.00	0.05	0.000	0.002
b	0.25BSC		0.01BSC	
c	0.15BSC		0.006BSC	
D	1.90	2.10	0.075	0.083
D1	1.4	1.60	0.055	0.063
E	1.90	2.10	0.075	0.083
E1	0.8	1.00	0.032	0.039
e	0.50BSC		0.020BSC	
L	0.20	0.40	0.008	0.016
F	0.25BSC		0.01BSC	

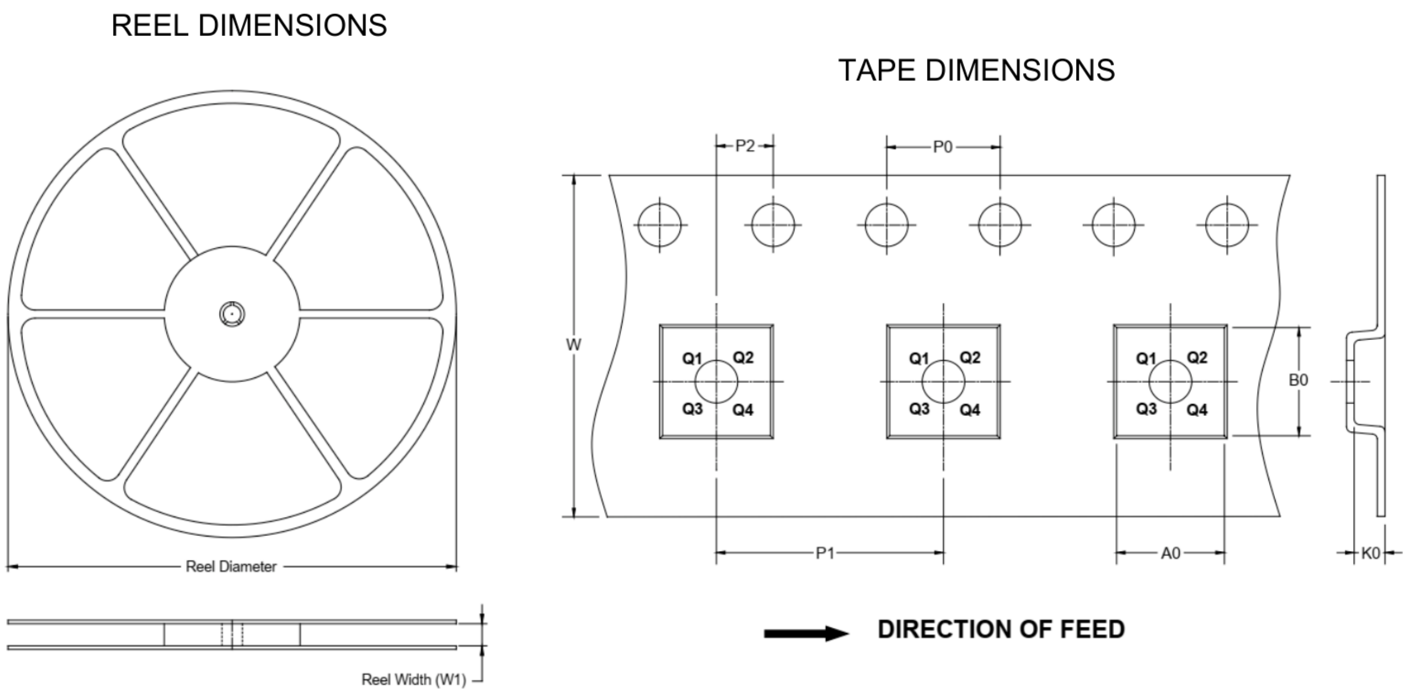
Mechanical Dimensions

N38E PKG: PDFN-3x3-8L　　　　Dimensions: mm / inch



Symbol	MIN (mm)	MAX (mm)	MIN (inch)	MAX (inch)
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203BSC		0.008BSC	
D	2.900	3.100	0.114	0.122
D1	2.200	2.400	0.087	0.094
E	2.900	3.100	0.114	0.122
E1	1.400	1.600	0.055	0.063
k	0.200BSC		0.008BSC	
b	0.180	0.300	0.007	0.012
e	0.650BSC		0.026BSC	
L	0.375	0.575	0.015	0.023

Tape and Reel Information



Reel and Tape Dimensions

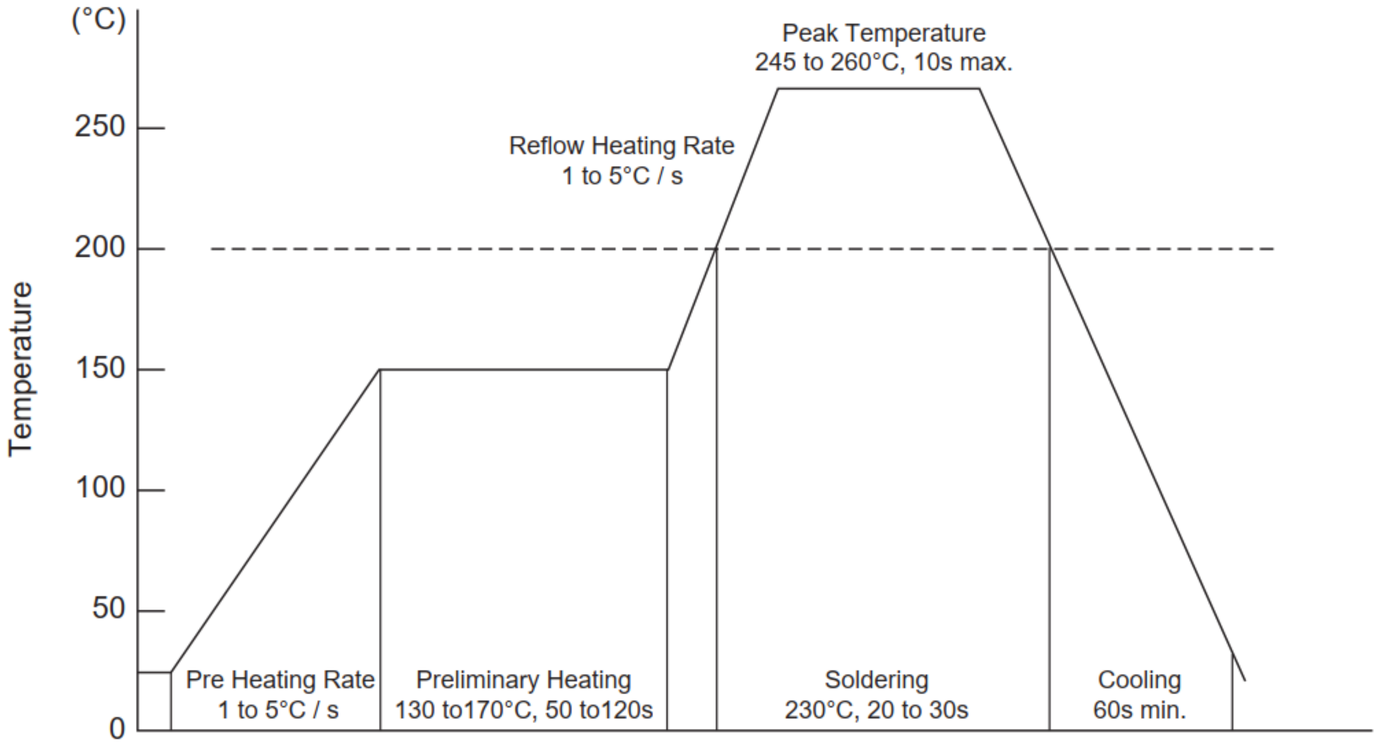
NOTE: The picture is only for reference. Please make the object as the standard.

Key Parameter List of Tape and Reel

Package	Reel Diameter	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOP-8(EP)	13”	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1
PDFN-2x2-8L	13”	12.4	2.35	2.35	1.13	4.0	8.0	2.0	12.0	Q1
PDFN-3x3-8L	13”	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

Conditions of Soldering and Storage

Recommended Condition of Reflow Soldering



Recommended peak temperature is over 245°C. If peak temperature is below 245°C, you may adjust the following parameters:

- Time length of peak temperature (longer)
- Time length of soldering (longer)
- Thickness of solder paste (thicker)

Conditions of Hand Soldering

- Temperature: 300°C
- Time: 3s max
- Times: one time

Storage Conditions

- Temperature: 5 to 40°C
- Humidity: 30 to 80% RH
- Recommended period: One year after manufacturing