1A Single-Cell Lithium Battery Charger IC

Features

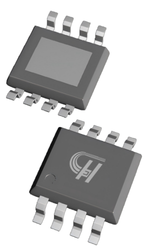
- Complete Charge Management for Single Cell Lithium Battery
- Input Voltage Range From 3.8V to 6V
- On-chip Power MOSFET
- No external Blocking Diode or Current Sense Resistors Required
- Constant Charge Voltage 4.2V, and also can be adjustable by an external resistor
- Precharge Conditioning for Reviving Deeply Discharged Cells and Minimizing Heat Dissipation During Initial Stage of Charge
- Programmable Continuous Charge Current Up to 1A
- Constant-Current/Constant-Voltage/Constant- Temp Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Automatic Low-Power Sleep Mode When Input Supply Voltage is Removed
- Status Indication for LEDs or μP Interface
- C/10 Charge Termination
- Automatic Recharge
- Battery Temperature Sensing
- Available in SOP-8(EP) Package
- Pb-free, rohs-compliant, halogen free

Applications

- Mobile Phones
- Digital Still Cameras
- Power Bank
- Portable Devices
- Variety Of Chargers

General Description

The HCR9317 is a complete constant-current /constant voltage linear charger for single cell lithium rechargeable battery. The device contains an on-chip power MOSFET and eliminates the need for the external current sense resistor and blocking diode. Its low external component count makes HCR9317 ideally suited for portable applications. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The regulation voltage is internally fixed at 4.2V, it can also be adjusted with an external resistor. The charge current can be programmed externally with a single resistor. When the input supply is removed, the HCR9317 automatically enters a low power sleep mode, dropping the battery drain current to less than 3μA. Other features include under-voltage lockout, automatic recharge, battery temperature sensing and charging/termination indicator. The HCR9317 is available in a thermally enhanced SOP-8(EP) package.



SOP-8(EP)

Figure 1. Appearance Diagram of HCR9317

Pin Configuration

SOP-8(EP) (Top View)

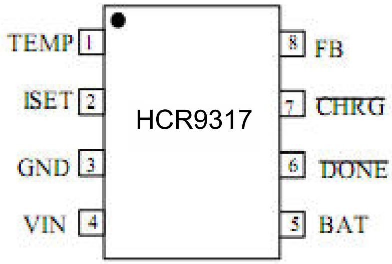


Figure 2. Pin Configuration of HCR9317

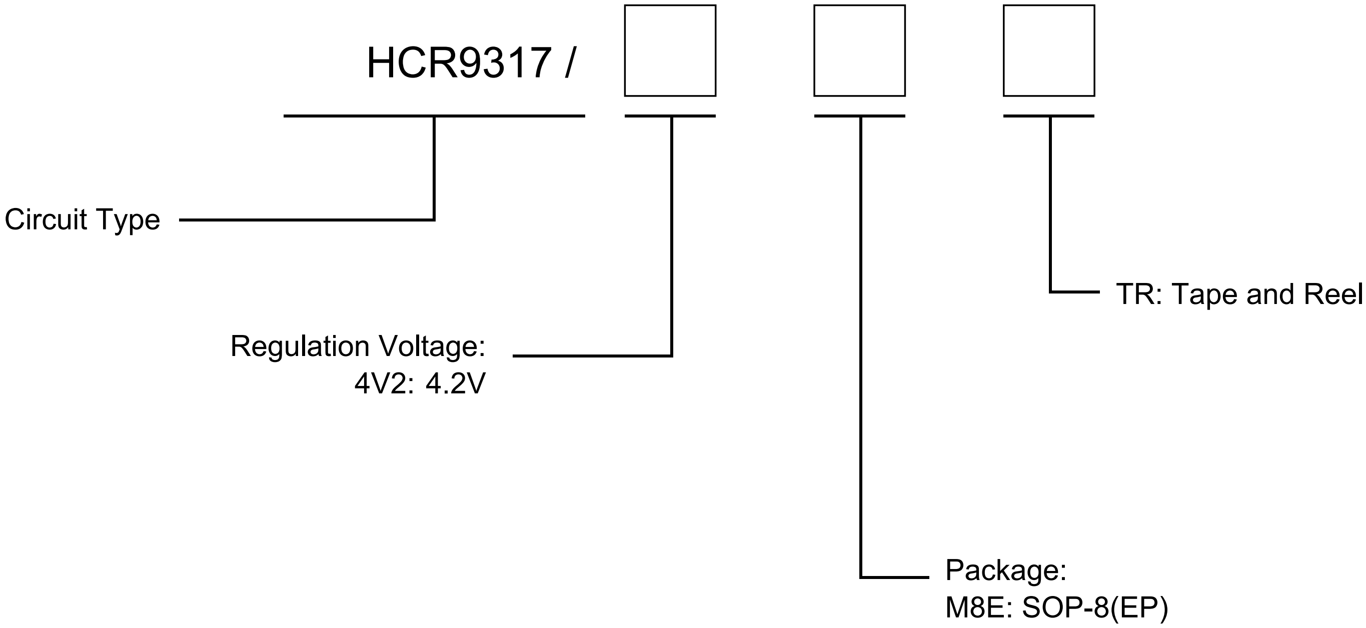
Pin Descriptions

Pin No.	Name	Description
1	TEMP	Temperature Sense Input. Connecting TEMP pin to NTC thermistor's output in Lithium ion battery pack. If TEMP pin's voltage is below 45% or above 80% of supply voltage V_{IN}, this means that battery's temperature is too high or too low, charging is suspended. If TEMP's voltage level is between 45% and 80%of supply voltage, battery fault state is released, and charging will resume. The temperature sense function can be disabled by grounding the TEMP pin.
2	ISET	Constant Charge Current Setting and Charge Current Monitor Pin. The charge current is set by connecting a resistor R_{ISET} from this pin to GND. When in precharge mode, the ISET pin's voltage is regulated to 0.12V. When in constant charge current mode, the ISET pin's voltage is regulated to 1.202V.In all modes during charging, the voltage on ISET pin can be used to measure the charge current as follows: I_{CH} = (V_{ISET} / R_{ISET})×1011
3	GND	Ground Terminal.
4	VIN	Positive Input Supply Voltage. V_{IN} is the power supply to the internal circuit. When V_{IN} drops to within 10mv of the BAT pin voltage, HCR9317 enters low power sleep mode, dropping BAT pin's current to less than 3μA.
5	BAT	Battery Connection Pin. Connect the positive terminal of the battery to BAT pin. BAT pin draws less than 3μA current in chip disable mode or in sleep mode. BAT pin provides charge current to the battery and provides regulation voltage of 4.2V.
6	$\overline{\text{DONE}}$	Open-Drain Charge termination Status Output. In charge termination status, $\overline{\text{DONE}}$ is pulled low by an internal switch; Otherwise $\overline{\text{DONE}}$ pin is in high impedance state.

Pin Descriptions (Continued)

Pin No.	Name	Description
7	$\overline{\text{CHRG}}$	Open Drain Charge Status Output. When the battery is being charged, the $\overline{\text{CHRG}}$ pin is pulled low by an internal switch, otherwise $\overline{\text{CHRG}}$ pin is in high impedance state.
8	FB	Battery Voltage Kevin Sense Input. This Pin can Kelvin sense the battery voltage; Also the regulation voltage in constant voltage mode can be adjusted by connecting an external resistor between FB pin and BAT pin.
9	EP	Exposed PAD. Should be connected to GND.

Ordering Information



Ordering Code

Part Number	Marking ID (Note 2)	Operating Ambient Temperature	Package	Quantity per Reel
HCR9317/4V2M8ETR	HCR9317xx	−40 to +85°C	SOP-8(EP)	4000pcs/Reel

Note 2: HCR9317 is the product type and xx is the date code.

Typical Application Circuit

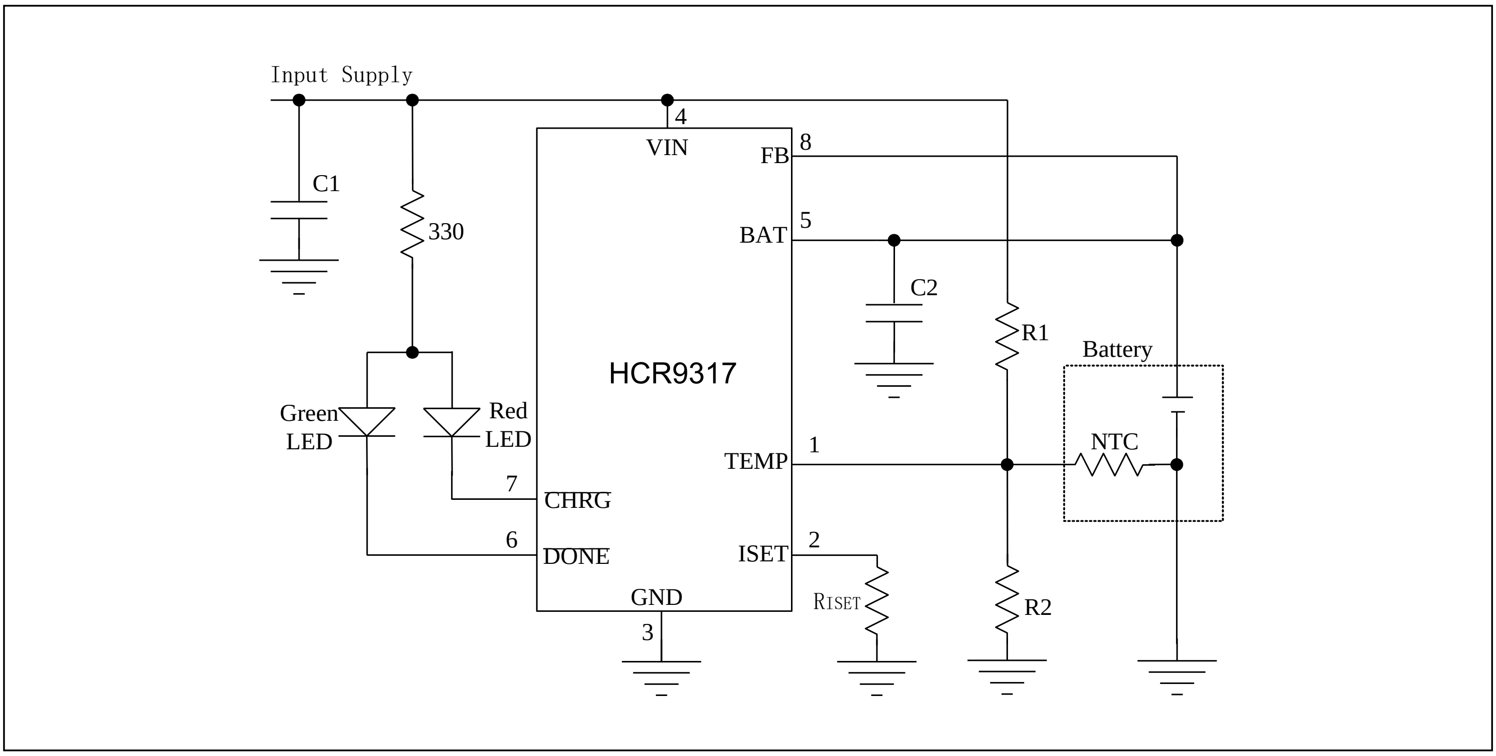


Figure 3. Typical Application Circuit(Constant Voltage Fixed at 4.2V)

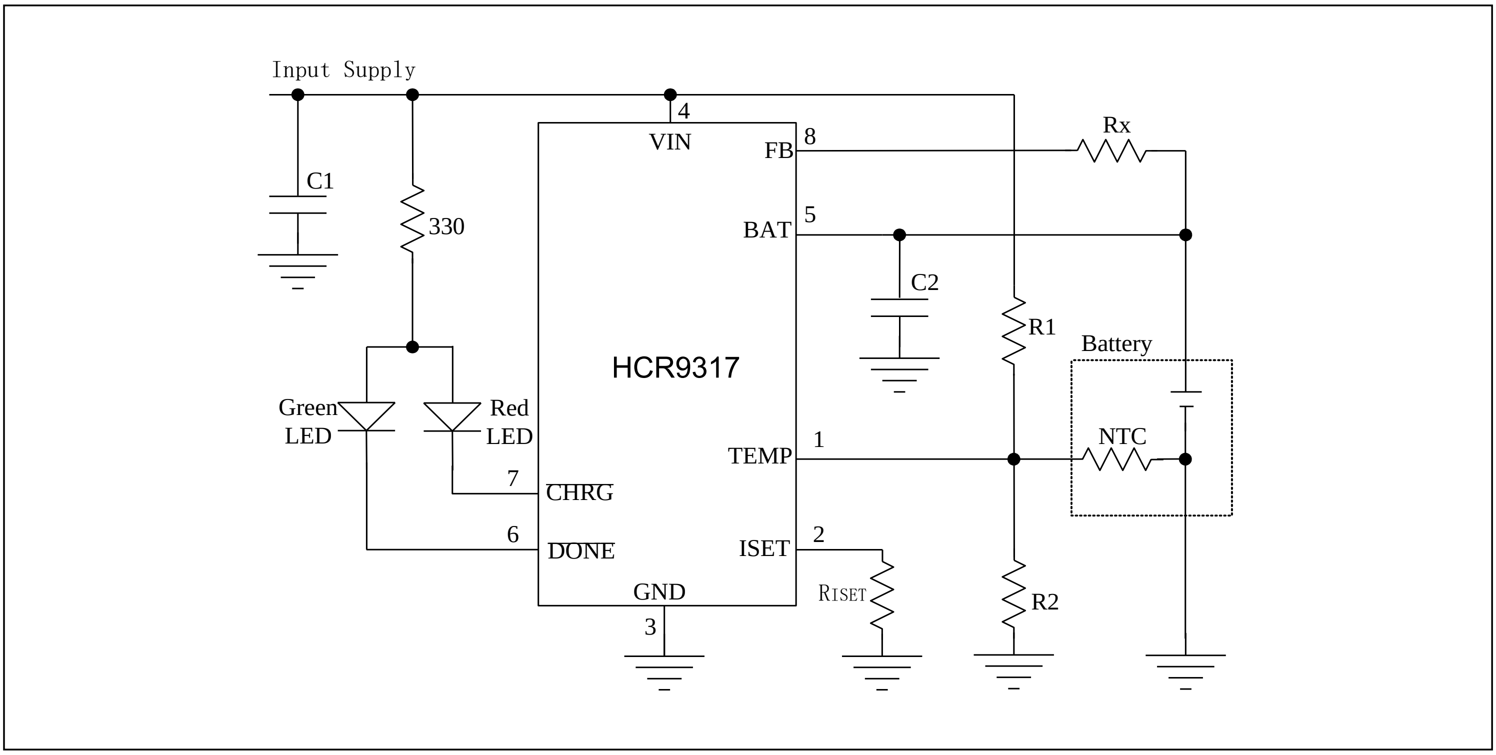


Figure 4. Application Circuit(Adjust Constant Voltage with R_x)

Typical Application Circuit (Continued)

In Figure 4, the BAT pin's voltage in constant voltage mode is given by the following equation:

$$V_{\text{bat}} = 4.2 + 3.01 \times 10^{-6} R_x$$

Where, V_{bat}'s is in volt; R_x's is in ohm

Functional Block Diagram

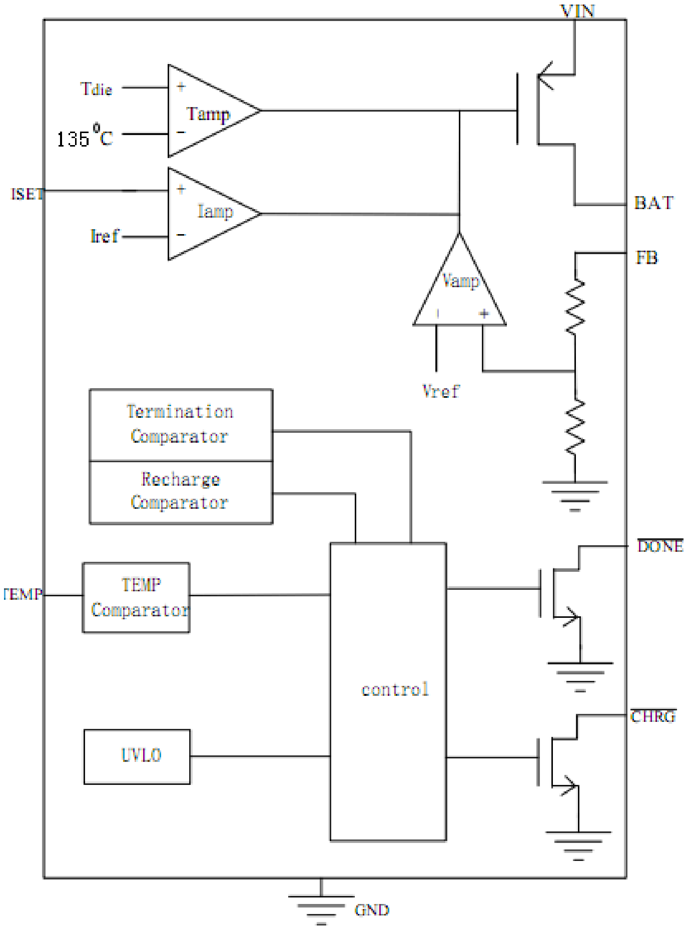


Figure 5. Block Diagram

Absolute Maximum Ratings

Parameter	Value	Unit
All Terminal Voltage	−0.3 to 6.5	V
BAT Short-Circuit Duration	Continuous	-
Storage Temperature	−65 to 150	°C
Lead Temperature (Soldering, 10 s)	260	°C
Maximum Junction Temperature	150	°C
Operating Temperature	−40 to 85	°C
Thermal Resistance (eSOP8)	TBD	-

Stresses beyond those listed under 'Absolute Maximum Ratings' may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

Recommend Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Input Supply Voltage	V_{IN}	3.8	6	V
Operating Temperature	T_A	−40	85	°C

Electrical Characteristics

V_{IN}=5V, T_A=−40°C to 85°C; typical values are measured at T_A=25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input Supply Voltage	V_{IN}	-	3.8	-	6	V
Operating Current	I_{VIN}	Charge Termination Mode	300	450	600	μA
Undervoltage Lockout	V_{uvlo}	V_{IN} rises	-	3.2	3.8	V
Regulation Voltage	V_{REG}	Constant Voltage Mode	4.158	4.2	4.242	V
BAT pin Current	I_{BAT}	R_{ISET}=1.22K, V_{BAT}=3.6V	850	1000	1150	mA
BAT pin Current	I_{BAT}	R_{ISET}=1.22K, V_{BAT}=2.4V	75	100	125	mA
BAT pin Current	I_{BAT}	V_{IN}=0V, sleep mode	-	-	3	μA
Precharge Threshold	V_{PRE}	Voltage at BAT pin rising	2.83	2.93	3.03	V
Precharge Threshold Hysteresis	H_{PRE}	-	-	0.24	-	V
Charge Termination Threshold	V_{term}	Measure voltage at ISET pin	0.096	0.12	0.144	V
Recharge Threshold	V_{RECH}	-	-	V_{REG}−0.15	-	V
Sleep Mode Threshold	V_{SLP}	V_{IN} falling, measures (V_{IN}−V_{BAT})	15	35	-	mV
Sleep mode Release Threshold	V_{SLPR}	V_{IN} rising, measure (V_{IN}−V_{BAT})	-	82	120	mV
ISET Pin Voltage	V_{ISET}	Precharge mode, V_{BAT}<3V	-	0.12	-	V
ISET Pin Voltage	V_{ISET}	Constant current mode	-	1.202	-	V
FB Input Current 1	I_{FB1}	V_{FB}=3.6V, normal working	1.3	2.5	6	μA
FB Input Current 1	I_{FB2}	V_{IN}<V_{uvlo} or V_{IN}<V_{BAT}	-	-	1	μA
High Input Threshold	V_{HIGH}	The voltage at TEMP increases	77.5	80	82.5	%V_{IN}
Low Input Threshold	V_{LOW}	The voltage at TEMP decreases	42.5	45	47.5	%V_{IN}
TEMP input Current	-	TEMP to V_{IN} or to GND	-	-	0.5	μA

Electrical Characteristics (Continued)

V_{IN}=5V, T_A=−40°C to 85°C; typical values are measured at T_A=25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
$\overline{CHRG}$ Sink Current	I_{CHRG}	V_{CHRG}=0.3V, charge mode	-	10	-	mA
$\overline{CHRG}$ Leakage Current	-	V_{CHRG}=6V, termination mode	-	-	1	μA
$\overline{DONE}$ Sink Current	I_{DONE}	V_{DONE}=0.3V, charge mode	-	10	-	mA
$\overline{DONE}$ Leakage Current	-	V_{DONE}=6V, termination mode	-	-	1	μA

Detailed Description

The HCR9317 is a linear battery charger designed primarily for charging single cell lithium-ion batteries. Featuring an internal P-channel power MOSFET, the HCR9317 uses a constant-current/constant-voltage to charge the batteries. Continuous charge current can be programmed up to 1A with an external resistor. No blocking diode or current sense resistor is required. The open-drain output $\overline{\text{CHRG}}$ and $\overline{\text{DONE}}$ indicates the charger's status. The internal thermal regulation circuit reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximate 135°C. This feature protects the HCR9317 from excessive temperature, and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the HCR9317 or the external components. Another benefit of adopting thermal regulation is that charge current can be set according to typical, not worst-case, ambient temperatures for a given application with the assurance that the charger will automatically reduce the current in worst-case conditions.

The charge cycle begins when the voltage at the V_{IN} pin rises above the UVLO level, a current set resistor is connected from the ISET pin to ground. The $\overline{\text{CHRG}}$ pin outputs a logic low to indicate that the charge cycle is ongoing. At the beginning of the charge cycle, if the voltage at FB pin is below 2.93V, the charger is in precharge mode to bring the cell voltage up to a safe level for charging. The charger goes into the fast charge constant current mode once the voltage on the FB pin rises above 2.93V. In constant current mode, the charge current is set by R_{ISET}. When the battery approaches the regulation voltage, the charge current begins to decrease as the HCR9317 enters the constant-voltage mode. When the current drops to charge termination threshold, the charge cycle is terminated, $\overline{\text{DONE}}$ is pulled low by an internal switch and $\overline{\text{CHRG}}$ pin assumes a high impedance state to indicate that the charge cycle is terminated. The charge termination threshold is 10% of the current in constant current mode. To restart the charge cycle, just remove the input voltage and reapply it. The charge cycle can also be automatically restarted if the FB pin voltage falls below the recharge threshold. The

on-chip reference voltage, error amplifier and the resistor divider provide regulation voltage with 1% accuracy which can meet the requirement of lithium-ion and lithium polymer batteries. When the input voltage is not present, the charger goes into a sleep mode, dropping battery drain current to less than 3μA. This greatly reduces the current drain on the battery and increases the standby time.

The charging profile is shown in the following figure:

Detailed Description (Con.)

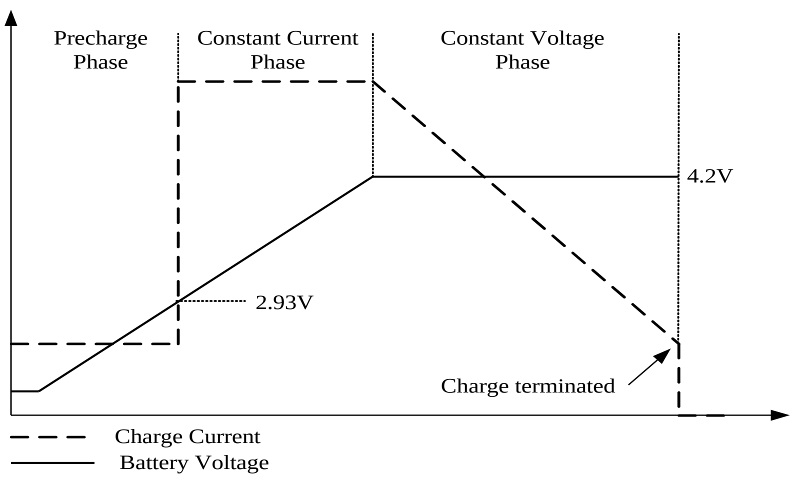


Figure 6. Charging Profile

Application Information

Undervoltage Lockout (UVLO)

HCR9317 has an internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{IN} rises above the undervoltage lockout voltage.

Sleep mode

There is an on-chip sleep comparator in HCR9317. The comparator keeps the charger in sleep mode if V_{IN} falls below sleep mode threshold(V_{BAT}+10mv). Once in sleep mode, the charger will not come out of sleep mode until V_{IN} rises 60mv above the battery voltage.

Precharge mode

At the beginning of a charge cycle, if the battery voltage is below 2.93V, the charger goes into precharge mode , and the charge current is 10% of fast charge current in constant current mode.

Battery Voltage Kelvin Detection

There is a battery voltage Kelvin detection of input pin (FB). This pin connects with error amplifier of constant charge though precise resistor divider network on chip. FB pin can be connected to battery's positive electrode directly, and this way can avoid the influence of parasitic resistor for charge between positive electrode and BAT pin. The existence of these parasitic resistors would prolong the charging time or come to constant charging state earlier, or even under-charge of battery. But these problems can be solved by FB pin. If vacant FB pin, HCR9317 would always in precharge state, and charging current is 10% of constant current.

Adjusting the regulation voltage in constant voltage mode

The regulation voltage in constant voltage mode can be adjusted by an external resistor connecting between FB pin and BAT pin as shown in Figure 7:

Application Information

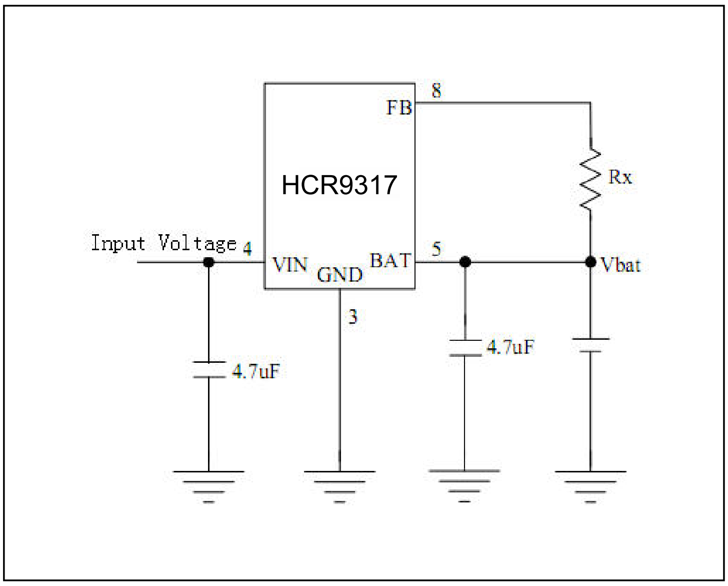


Figure 7. Adjusting Regulation Voltage in Constant Voltage Mode

In Figure 7, the regulation voltage in constant voltage mode will be given by the following equation:

$$V_{\text{bat}} = 4.2 + 3.01 \times 10^{-6} R_x$$

Where, V_{bat} is in volt R_x is in ohm

Programming Charge Current

The formula for the battery charge current in constant current mode is:

$$I_{\text{CH}} = 1215\,\text{V} / R_{\text{ISET}}$$

Where: I_{CH} is the charge current in ampere R_{ISET} is the total resistance from the ISET pin to ground in ohm

For example, if 1A charge current is required, calculate:

$$R_{\text{ISET}} = 1215\,\text{V} / 1\,\text{A} = 1.215\,\text{k}\Omega$$

For best stability over temperature and time, 1% metal film resistors are recommended. If the charger is in constant-temperature or constant voltage mode, the charge current can be monitored by measuring the ISET pin voltage, and the charge current is calculated as the following equation:

$$I_{\text{CH}} = (V_{\text{ISET}} / R_{\text{ISET}}) \times 1011$$

Battery Temperature Sense

To prevent the damage caused by the very high or very low temperature done to the battery pack, the HCR9317 continuously senses battery pack temperature by measuring the voltage at TEMP pin determined by the voltage divider circuit and the battery's internal NTC thermistor as shown in Figure 3.

The HCR9317 compares the voltage at TEMP pin (V_{TEMP}) against its internal V_{LOW} and V_{HIGH} thresholds to determine if charging is allowed. In HCR9317, V_{LOW} is fixed at ($45\% \times V_{IN}$), while V_{HIGH} is fixed at ($80\% \times V_{IN}$). If $V_{TEMP} < V_{LOW}$ or $V_{TEMP} > V_{HIGH}$, it indicates that the battery temperature is too high or too low and the charge cycle is suspended. When V_{TEMP} is between V_{LOW} and V_{HIGH}, the charge cycle resumes.

The battery temperature sense function can be disabled by connecting TEMP pin to GND.

Selecting R_1 and R_2

The values of R_1 and R_2 in the application circuit can be determined according to the assumed temperature monitor range and thermistor's values. The Follows is an example:

Application Information

Assume temperature monitor range is $T_L \sim T_H$ ($T_L < T_H$=; the thermistor in battery has negative temperature coefficient (NTC), R_{TL} is thermistor's resistance at T_L, R_{TH} is the resistance at T_H, so $R_{TL} > R_{TH}$, then at temperature T_L, the voltage at TEMP pin is:

$$V_{\mathrm{TEMPL}} = \frac{R_2 \parallel R_{\mathrm{TL}}}{R_1 + R_2 \parallel R_{\mathrm{TL}}} \times V_{\mathrm{IN}}$$

At temperature T_H, the voltage at TEMP pin is:

$$V_{\mathrm{TEMPH}} = \frac{R_2 \parallel R_{\mathrm{TH}}}{R_1 + R_2 \parallel R_{\mathrm{TH}}} \times V_{\mathrm{IN}}$$

We know,

$$V_{\mathrm{TEMPL}} = V_{\mathrm{HIGH}} = k_2 \times V_{\mathrm{IN}} \quad (k_2 = 0.8)$$

$$V_{\mathrm{TEMPH}} = V_{\mathrm{LOW}} = k_1 \times V_{\mathrm{IN}} \quad (k_1 = 0.45)$$

Then we can have:

$$R_1 = \frac{R_{\mathrm{TL}} R_{\mathrm{TH}} (k_2 - k_1)}{(R_{\mathrm{TL}} - R_{\mathrm{TH}}) k_1 k_2}$$

$$R_2 = \frac{R_{\mathrm{TL}} R_{\mathrm{TH}} (k_2 - k_1)}{R_{\mathrm{TL}} (k_1 - k_1 k_2) - R_{\mathrm{TH}} (k_2 - k_1 k_2)}$$

Likewise, for positive temperature coefficient thermistor in battery, we have $R_{TH} > R_{TL}$ and we can calculate:

$$R_1 = \frac{R_{\mathrm{TL}} R_{\mathrm{TH}} (k_2 - k_1)}{(R_{\mathrm{TH}} - R_{\mathrm{TL}}) k_1 k_2}$$

$$R_2 = \frac{R_{\mathrm{TL}} R_{\mathrm{TH}} (k_2 - k_1)}{R_{\mathrm{TH}} (k_1 - k_1 k_2) - R_{\mathrm{TL}} (k_2 - k_1 k_2)}$$

We can conclude that temperature monitor range is independent of power supply voltage V_{IN} and it only depends on R_1, R_2, R_{TL} and R_{TH}: The values of R_{TH} and RTLcan be found in related battery handbook or deduced from testing data.

In actual application, if only one terminal temperature is concerned(normally protecting overheating), there is no need to use R_2 but R_1. In this case it becomes very simple to calculate R_1.

Recharge

After a charge cycle has terminated, if the battery voltage drops below the recharge threshold voltage, a new charge cycle will begin automatically.

Constant-Current/Constant-Voltage/Constant-Temperature

The HCR9317 use a unique architecture to charge a battery in a constant-current, constant-voltage, constant temperature fashion as shown in Figure 5. Amplifiers Iamp, Vamp, and Tamp are used in three separate feedback loops to force the charger into constant-current, constant-voltage, or constant-temperature mode, respectively. In constant current mode the charge current delivered to the battery equal to 1218V/R_{ISET}. If the power dissipation of the HCR9317 results in the junction temperature approaching 135°C, the amplifier Tamp will begin decreasing the charge current to limit the die temperature to approximately 135°C. As the battery voltage rises, the HCR9317 either returns to constant-current mode or it enters constant voltage mode straight from constant-temperature mode.

Open-Drain Status Outputs

The HCR9317 have 2 open-drain status outputs: $\overline{\text{CHRG}}$ and $\overline{\text{DONE}}$. $\overline{\text{CHRG}}$ is pulled low when the charger is in charging status, otherwise $\overline{\text{CHRG}}$ becomes high impedance. $\overline{\text{DONE}}$ is pulled low if the charger is in charge termination status, otherwise $\overline{\text{DONE}}$ becomes high impedance.

When the battery is not present, the charger charges the output capacitor to the regulation voltage quickly, then the BAT pin's voltage decays slowly to recharge threshold because of low leakage current at BAT pin, which results in a 150mv ripple waveform at BAT pin,

Application Information

meanwhile, $\overline{CHRG}$ pin outputs high-impedance, $\overline{DONE}$ pin outputs pulse.

The open drain status output that is not used should be tied to ground.

The following table lists the two indicator status and its corresponding charging state. It is supposed that red LED is connected to $\overline{CHRG}$ pin and green LED is connected to $\overline{DONE}$ pin.

$\overline{CHRG}$ pin	$\overline{DONE}$ pin	State Description
Low (red LED on)	High Impedance (green LED off)	Charging
High Impedance (red LED off)	Low (green LED on)	Charge termination
High Impedance (red LED off)	Pulse (green LED on)	Battery absent
High Impedance (red LED off)	High Impedance (green LED off)	There are three possibilities: • the voltage at the V_{IN} pin below the UVLO level or • the voltage at the V_{IN} pin below V_{BAT} or • abnormal battery temperature

V_{IN} Bypass Capacitor

Many types of capacitors can be used for input bypassing(C_1 in Figure 3 and 4), Generally, a 1μF ceramic capacitor, placed in close proximity to V_{IN} and GND pins, works well. In some applications depending on the power supply characteristics and cable length, it may be necessary to increase the capacitor's value.

If the ceramic capacitor is used as the input supply bypassing purpose, a voltage spike may be created when the input voltage is applied to the HCR9317 via a cable. If the cable is a bit long, the circuit shown in Figure 8 or a TVS diode from V_{IN} pin to GND should be considered to use to prevent the HCR9317 from being damaged by the voltage spike.

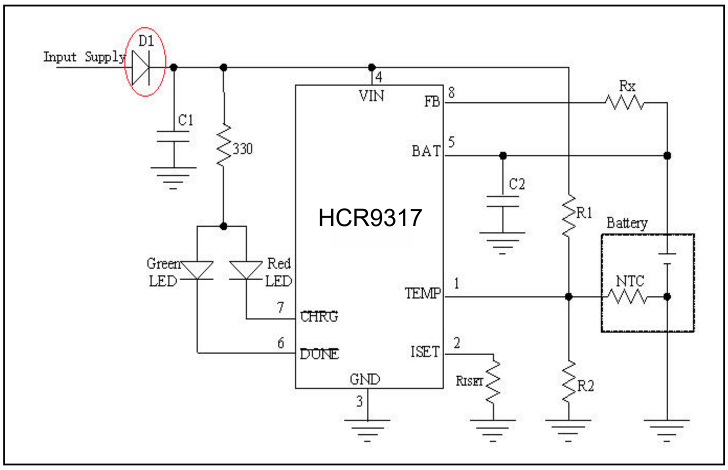


Figure 8. Adding Diode D1 to Suppress Voltage Spike

Stability

Typically a 4.7μF to 10μF capacitor(C_2 in Figure 3 and 4) from BAT pin to GND is required to stabilize the feedback loop.

Application Information

In constant current mode, the stability is also affected by the impedance at the ISET pin . With no additional capacitance on the ISET pin, the loop is stable with current set resistors values as high as 50KΩ. However, additional capacitance on ISET pin reduces the maximum allowed current set resistor. The pole frequency at ISET pin should be kept above 200kHz. Therefore, if ISET pin is loaded with a capacitance C, the following equation should be used to calculate the maximum resistance value for R_{ISET}:

$$R_{\mathrm{ISET}} < \frac{1}{6.28 \times 2 \times 10^5 \times C}$$

Board Layout Considerations

1. R_{ISET} at ISET pin should be as close to HCR9317 as possible, also the parasitic capacitance at ISET pin should be kept as small as possible.

2. The capacitance at V_{IN} pin and BAT pin should be as close to HCR9317 as possible.

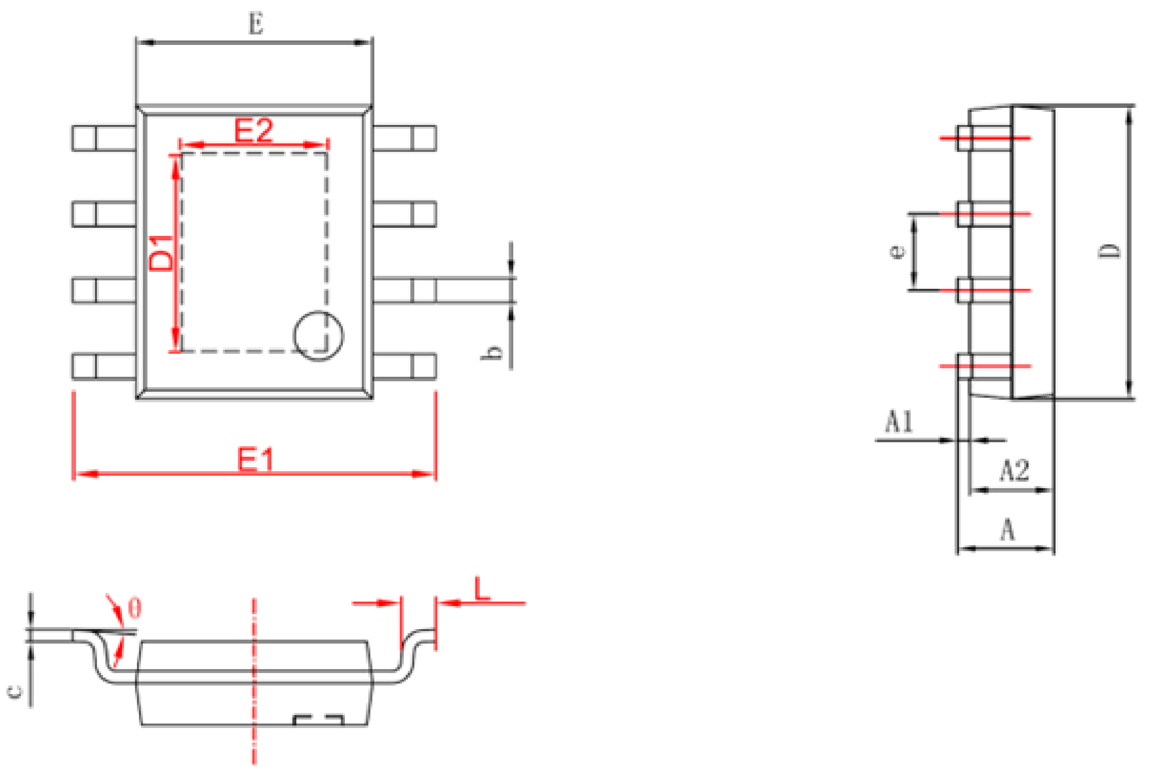
3. During charging, HCR9317's temperature may be high, the NTC thermistor should be placed far enough to HCR9317 so that the thermistor can reflect the battery's temperature correctly.

4. It is very important to use a good thermal PC board layout to maximize charging current. The thermal path for the heat generated by the IC is from the die to the copper lead frame through the package lead(especially the ground lead) to the PC board copper, the PC board copper is the heat sink. The footprint copper pads should be as wide as possible and expand out to larger copper areas to spread and dissipate the heat to the surrounding ambient. Feedthrough vias to inner or backside copper layers are also useful in improving the overall thermal performance of the charger. Other heat sources on the board, not related to the charger, must also be considered when designing a PC board layout because they will affect overall temperature rise and the maximum charge current.

The ability to deliver maximum charge current under all conditions require that the exposed metal pad on the back side of the HCR9317 package be soldered to the PC board ground. Failure to make the thermal contact between the exposed pad on the backside of the package and the copper board will result in larger thermal resistance.

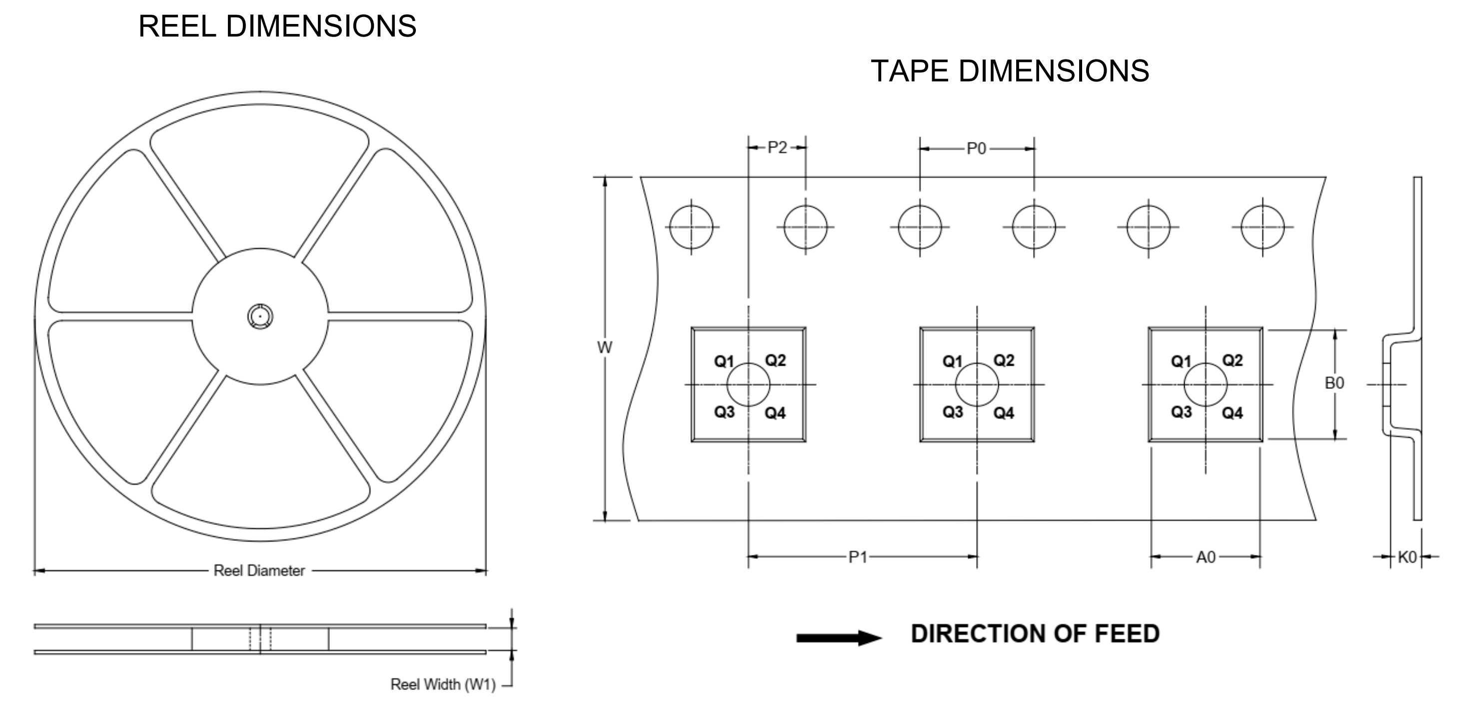
Mechanical Dimensions

M8E PKG: SOP-8(EP)



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	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
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270 (BSC)		0.050 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Tape and Reel Information



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

Key Parameter List of Tape and Reel

Package Type	Reel Diameter	Reel Width 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

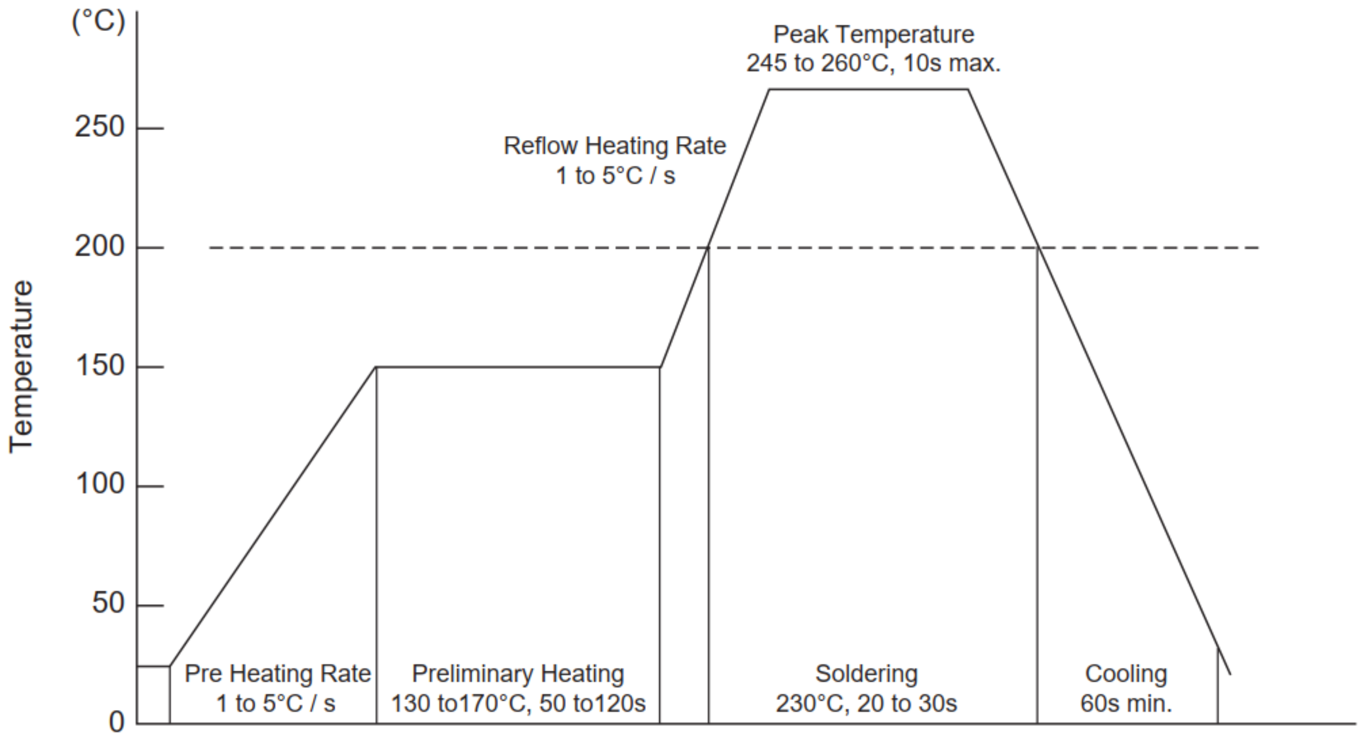
Part Number: HCR9317/4V2M8ETR

Packing Type: Tape and Reel

Quantity per Reel: 4000pcs/Reel

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