10A Step-down Single-Cell Li-ion Battery Charger with MPPT

Features

- Solar Panel MPPT Function
- Standalone Charge Management for 1-cell Lithium-ion Battery
- Wide Input Voltage: 4.5V to 30V
- Charge Current up to 10A
- PWM Switching Frequency: 550kHz
- Regulation Voltage: 4.2V±1%
- Charge Current is externally set
- Automatic Conditioning of Deeply Discharged Batteries
- 100% Duty Cycle
- Automatic Recharge
- 2 Open-drain Status Indication
- JEITA-Compliant Battery Temperature Monitoring
- Built-in Soft Start
- Battery Reverse Current Blocking
- Operating Ambient Temperature −40°C to +85°C
- Available in QFN-3x3-20L Package
- Pb-free, Rohs-Compliant, Halogen Free

Applications

- Handheld Equipment
- Emergency Lighting
- Industrial and Medical Equipment
- Battery Back-up
- Audio/Video Systems
- Electric Appliance

General Description

HCR9719 is a step-down PWM switch-mode charger IC for 1-cell lithium-ion battery with few external components in small footprint package.

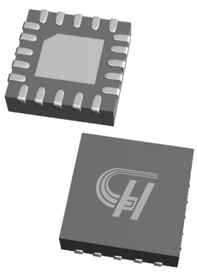
The HCR9719 is specially designed for charging 1-cell lithium ion battery with trickle charge, constant current and constant voltage mode. In constant voltage mode, the regulation voltage is fixed at 4.2V with ±1% accuracy. The constant charging current is set with an external current sense resistor.

When solar panel is used as power supply, HCR9719 can automatically adjust charge current to track solar panel's maximum power point.

Deeply discharged batteries are automatically trickle charged at 25% of the full-scale charge current until the cell voltage exceeds 66.6% of regulation voltage. The charge cycle is terminated once the charge current drops to 15% of full-scale charge current, and a new charge cycle automatically restarts if battery voltage falls below 95.8% of regulation voltage. HCR9719 will automatically enter sleep mode when input voltage is lower than battery voltage.

Other features include JEITA-compliant battery temperature monitoring, battery reverse current blocking, battery over voltage protection, 2 open-drain status indications, etc.

HCR9719 is available in QFN-3x3-20L package.



QFN-3x3-20L

Figure 1. Appearance Diagram of HCR9719

Pin Configuration

QFN-3x3-20L (Top View)

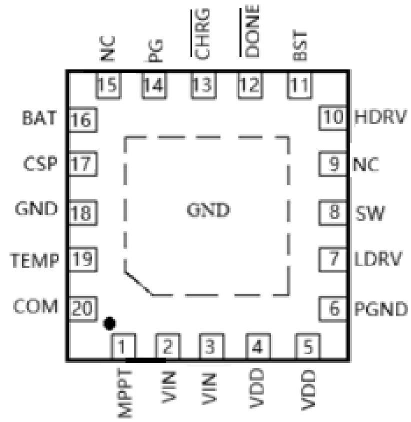


Figure 2. Pin Configuration of HCR9719

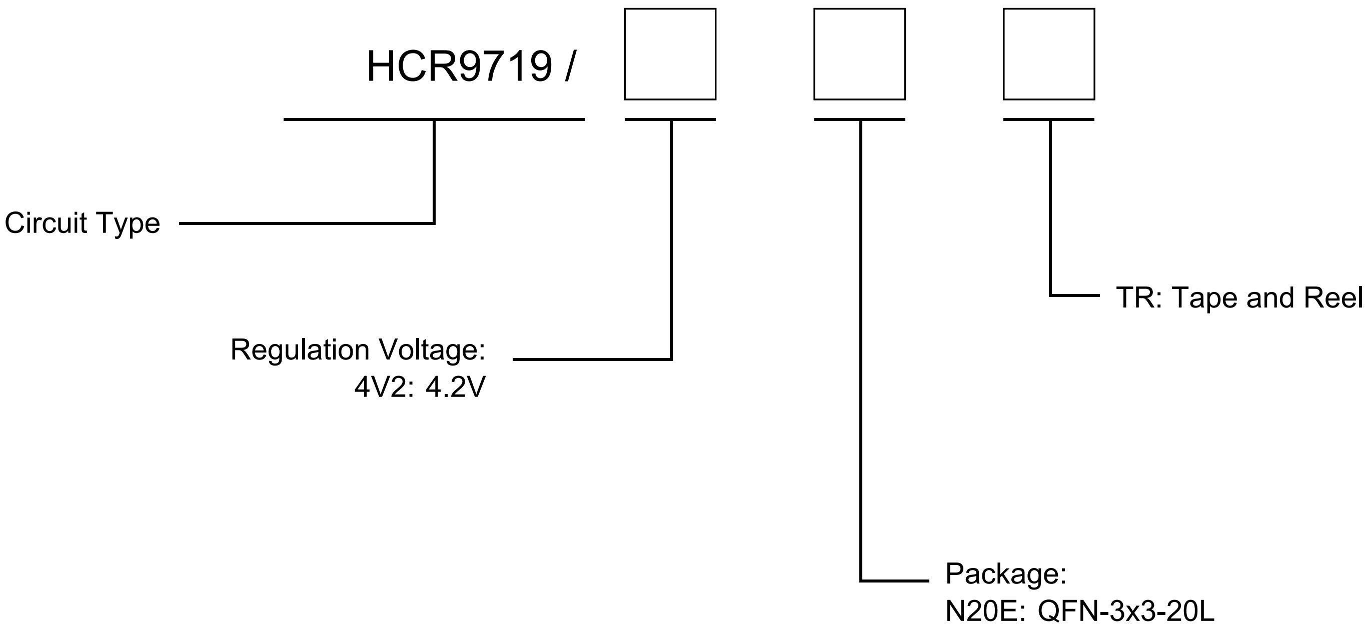
Pin Descriptions

Pin No.	Name	Description
1	MPPT	Photovoltaic Cell Maximum Power Point Tracking Pin. Connect MPPT pin to the external resistor divider for maximum power point tracking. In maximum power point tracking mode, the MPPT pin's voltage is regulated to 1.205V.
2, 3	VIN	DC Power Supply Input. V_{IN} is the power supply for internal circuit. Filtering capacitors are needed between V_{IN} and GND.
4, 5	VDD	5V Voltage Regulator (LDO) Output. Connect a 10μF capacitor from V_{DD} to GND. The maximum output current of the 5V LDO is 15mA. The 5V voltage can also be used to power the external circuitry in addition to powering the internal circuit.
6	PGND	Power Ground (PGND).
7	LDRV	The Gate Drive Pin for Low-side N-channel MOSFET. Connect to the gate of external low-side N-channel MOSFET, namely M1 in Figure 3.
8	SW	Inductor Connection Pin. Connect to inductor's input terminal, namely switching node as shown in Figure 3.
9	NC	No Connection.
10	HDRV	The Gate Drive Pin for High-side N-channel MOSFET. Connect to the gate of external high-side N-channel MOSFET, namely M2 in Figure 3.

Pin Descriptions (Continued)

Pin No.	Name	Description
11	BST	The Power Supply of Driving Circuit for High-side N-channel MOSFET. A bootstrap capacitor of 100nF needs to be connected between BST pin and switching node. Also a schottky diode like SS24 is needed to be connected between BST pin and V_{DD} pin (5V LDO output).
12	$\overline{\text{DONE}}$	Open-Drain Termination Status Indication Output. When charging is terminated, this pin is pulled low to GND by an internal switch. Otherwise this pin is in high impedance state.
13	$\overline{\text{CHRG}}$	Open-Drain Charge Status Indication Output. When the battery is being charged, this pin is pulled low to GND by an internal switch. Otherwise this pin is in high impedance state.
14	PG	The Gate Drive for External P-channel MOSFET. As shown in Figure 3, PG pin should be connected to gate of external P-channel MOSFET. The P-channel MOSFE is used to prevent reverse current from battery when input supply is absent or is lower than battery voltage. If the P-channel MOSFET is not used, leave PG pin floating.
15	NC	No Connection.
16	BAT	Battery Voltage Sensing Input and the Negative Terminal for Charge Current Sensing. Externally BAT pin should be connected to positive terminal of battery to sense battery voltage. BAT pin and the CSP pin measure the voltage drop across current sense resistor R_{CS} to regulate charge current.
17	CSP	Positive Input for Charge Current Sensing. CSP pin and the BAT pin measure the voltage drop across current sense resistor R_{CS} to regulate charge current. In constant current mode, (CSP−BAT) is regulated at 80mV.
18	GND	Analog GND of HCR9719.
19	TEMP	Battery Temperature Monitoring Input. Connecting a 10KΩ NTC thermistor between TEMP pin and GND. • If TEMP pin's voltage is below 0.1V or above 0.85V, which means battery is too hot or too cold, charging is suspended. • If TEMP's voltage is between 0.1V and 0.135V, which means battery is warm, charge current is reduced to 47% of full-scale current and regulation voltage is reduced to 95.8%*V_{REG}. • If TEMP's voltage is between 0.135V and 0.55V, HCR9719 functions normally. • If TEMP's voltage is between 0.55V and 0.85V, which means battery is cool, charge current is reduced to 25% of constant current. If battery temperature monitoring function is not needed, connect a fixed 10K ohm resistor from TEMP pin to GND.
20	COM	Loop Compensation Pin. Connect a 100nF capacitor from COM pin to GND to stabilize current and voltage regulation loops.
21	Exposed PAD	Heat Sinking Metal on back of the Chip. The heat sinking metal should be connected to the analog GND of HCR9719.

Ordering Information



Ordering Code

Part Number	Marking ID (Note 2)	Operating Ambient Temperature	Package	Quantity per Reel
HCR9719/4V2N20ETR	HCR9719xx	−40 to +85°C	QFN-3x3-20L	5000pcs/Reel

Note 2: HCR9719 is the product type and xx is the date code.

Typical Application Circuit

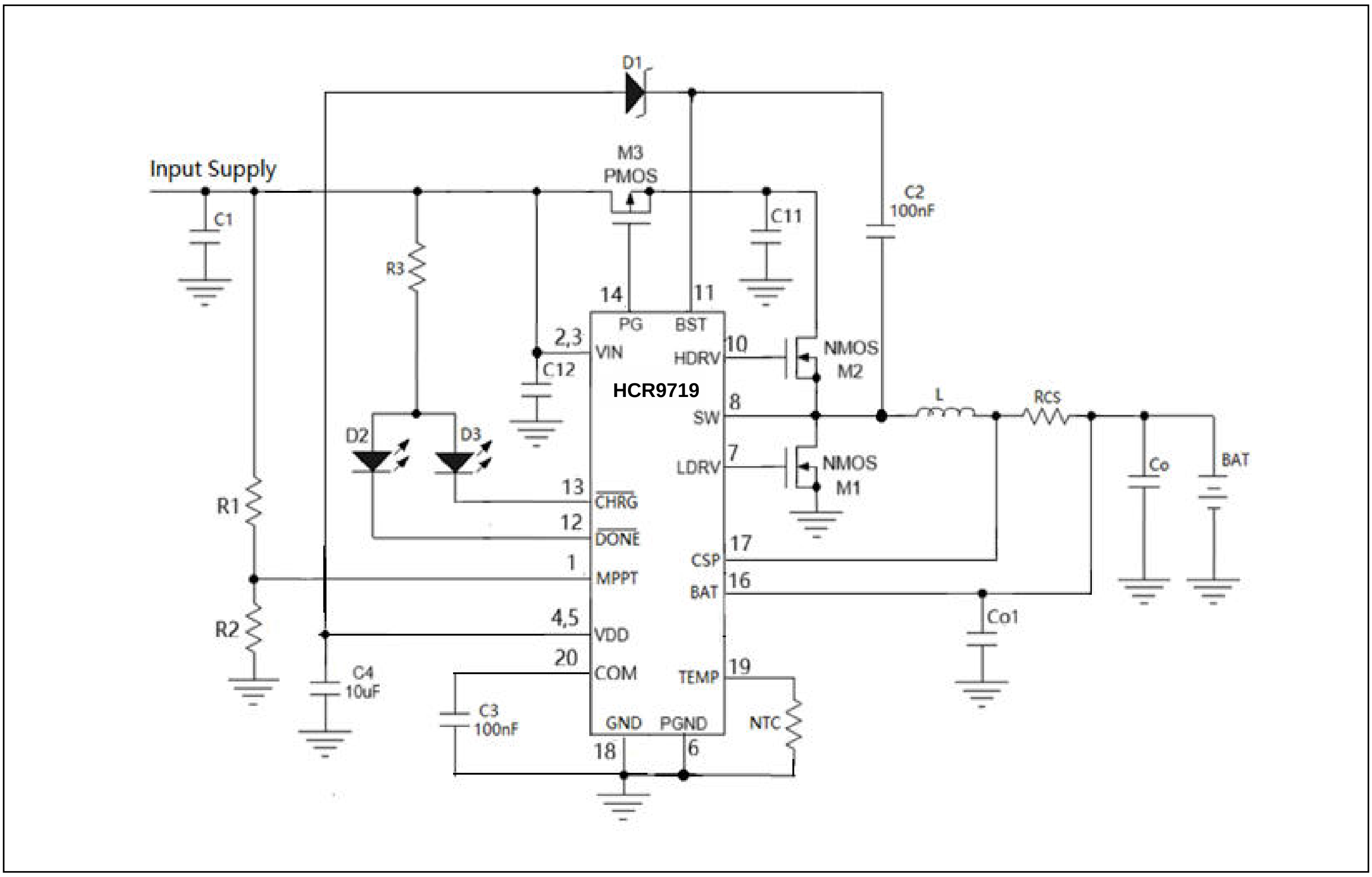


Figure 3. Typical Application Circuit

Absolute Maximum Ratings

Parameter	Value	Unit
V_{IN} Voltage to GND	−0.3 to 32	V
$\overline{CHRG}$, $\overline{DONE}$ Voltage to GND	−0.3 to 32	V
SW Voltage to GND	−0.3 to 32	V
BST, HDRV Voltage to SW	−0.3 to 6.5	V
CSP, BAT Voltage to GND	−0.3 to 6.5	V
PG Voltage to GND	−0.3 to BAT+0.3	V
V_{DD} Voltage to GND	−0.3 to 6.5	V
COM Voltage to GND	−0.3 to V_{DD}+0.3	V
LDRV Voltage to GND	−0.3 to V_{DD}+0.3	V
Maximum Junction Temperature	150	°C
Operating Temperature Range	−40 to 85	°C
Storage Temperature	−65 to 150	°C
Lead Temperature (Soldering, 10 s)	260	°C
Thermal Resistance (QFN20)	TBD	-
MPPT Voltage to GND	−0.3 to V_{DD}+0.3	V
TEMP Voltage to GND	−0.3 to V_{DD}+0.3	V

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 beyond 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 Voltage Range	V_{IN}	4.5	30	V
Operating Ambient Temperature	T_A	−40	85	°C

Electrical Characteristics

V_{IN}=15V, T_A=−40°C to +85°C; typical values are at T_A=+25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input Voltage Range	V_{IN}	-	4.5	-	30	V
Under Voltage Lockout Threshold	UVLO	-	2.7	3.6	4.4	V
Operating Current	I_{VIN}	V_{BAT}=4.4V, No Switching	520	650	795	μA
BAT Pin Current	I_{BAT1}	Termination, V_{BAT}=4.4V	5	10	15	μA
BAT Pin Current	I_{BAT2}	Sleep mode, V_{BAT}=4V	2	3.6	5.5	μA
Regulation Voltage (Constant Voltage Mode)	V_{REG}	Normal battery temperature	4.16	4.2	4.242	V
Regulation Voltage (Constant Voltage Mode)	V_{REG}	Battery warm	3.975	4.025	4.075	V
Charge Current Sense; Measure (V_{CSP}−V_{BAT})	V_{CS}	V_{BAT}>V_{PRE}	70	80	90	mV
Charge Current Sense; Measure (V_{CSP}−V_{BAT})	V_{CS}	V_{BAT}>V_{PRE}, Battery warm	31	38	45	mV
Charge Current Sense; Measure (V_{CSP}−V_{BAT})	V_{CS}	V_{BAT}<V_{PRE}, or Battery cool	12	20	28	mV
Precharge Threshold	V_{PRE}	BAT Voltage rises	64	66.6	69	%V_{REG}
Hysteresis	H_{PRE}	BAT Voltage falls	-	2.5	-	%V_{REG}
Termination Threshold	V_{term}	Charge Current Falls; Measure (V_{CSP}−V_{BAT})	8	13	18	mV
Recharge Threshold	V_{RE}	BAT falls	93	95.8	98.6	%V_{REG}

Electrical Characteristics (Continued)

V_{IN}=15V, T_A=−40°C to +85°C; typical values are at T_A=+25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Recharge Threshold	V_{RE}	BAT falls, Battery warm	88.5	91.6	94.7	$\%V_{REG}$
Over Voltage Threshold	V_{ov}	BAT Voltage rises	1.036	1.068	1.1	V_{REG}
Over Voltage Release Threshold	V_{clr}	BAT Voltage falls	1.0	1.024	1.049	V_{REG}
MPPT Regulation Voltage	V_{MPPT}	MPP Tracking Mode	1.18	1.205	1.23	V
MPPT Bias Current	I_{MPPT}	-	−100	0	100	nA
Frequency	f_{osc}	-	430	550	670	kHZ
Maximum Duty Cycle	D_{max}	-	-	-	100	%
Sleep Mode Threshold; Measure (V_{IN}−V_{BAT})	V_{SLP}	V_{IN} falls, V_{BAT}=8V	0.0	0.05	0.1	V
Sleep Mode Release Threshold; Measure (V_{IN}−V_{BAT})	V_{SLPR}	V_{IN} rises, V_{BAT}=8V	0.05	0.1	0.15	V
Over Temperature Protection Threshold	T_{OTP}	Junction temperature rises	-	145	-	°C
Over Temperature Release Threshold	T_{RLS}	Junction temperature falls	-	128	-	°C
LDRV Output High	V_{Hpin8}	I_{DRV}=−10mA	V_{DD}−0.05	-	-	V
LDRV Output Low	V_{Lpin8}	I_{DRV}=+10mA	-	-	0.04	V
LDRV Rise Time	t_{rpin8}	C_{load}=2nF, 10% to 90%	30	40	60	nS
LDRV Fall Time	t_{fpin8}	C_{load}=2nF, 90% to 10%	18	25	35	nS
HDRV Output High	V_{Hpin10}	I_{DRV}=−10mA	BST−0.05	-	-	V
HDRV Output Low	V_{Lpin10}	I_{DRV}=+10mA	-	-	SW+0.04	V
HDRV Rise Time	t_{rpin10}	C_{load}=2nF, 10% to 90%	30	40	60	nS
HDRV Fall Time	t_{fpin10}	C_{load}=2nF, 90% to 10%	20	30	45	nS

Electrical Characteristics (Continued)

V_{IN}=15V, T_A=−40°C to +85°C; typical values are at T_A=+25°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
TEMP Current	I_{TEMP}	-	27	30	33	μA
Cold Threshold	V_{COLD}	V_{TEMP} rises, cool to cold	800	850	900	mV
Cold Release Threshold	V_{COLDR}	V_{TENP} falls, cold to cool	755	805	855	mV
Cool Threshold	V_{COOL}	V_{TEMP} rises, normal to cool	510	550	590	mV
Cool Release Threshold	V_{COOLR}	V_{TENP} falls, cool to normal	465	505	545	mV
Warm Threshold	V_{WARM}	V_{TENP} falls, normal to warm	120	135	150	mV
Warm Release Threshold	V_{WARMR}	V_{TEMP} rises, warm to normal	138	155	172	mV
Hot Threshold	V_{HOT}	V_{TENP} falls, warm to hot	85	100	115	mV
Hot Release Threshold	V_{HOTR}	V_{TEMP} rises, hot to warm	105	120	135	mV
PG Output High	V_{PGH}	Sleep mode	-	BAT	-	V
PG Output Low	V_{PGL}	Normal operation	-	0	-	V
PG Pull-up Current	I_{PGSRC}	Sleep mode, V_{BAT}=4V; $V_{BAT}-V_{PG}$=0.2V	-	8	-	mA
PG Pull-down Current	I_{PGSINK}	Normal operation, V_{PG}=0.2V	-	15	-	mA
$\overline{\text{CHRG}}$ Sink Current	I_{CHRG}	V_{CHRG}=1V, charge mode	7	12	18	mA
$\overline{\text{CHRG}}$ Leakage Current	I_{LK1}	V_{CHRG}=30V, termination	-	-	1	μA
$\overline{\text{DONE}}$ Sink Current	I_{DONE}	V_{DONE}=1V, termination	7	12	18	mA
$\overline{\text{DONE}}$ Leakage Current	I_{LK2}	V_{DONE}=30V, charge mode	-	-	1	μA

V_{REG} is the regulated voltage in constant voltage mode; I_{CC} is the charge current in constant current mode.

Detailed Information

HCR9719 is a constant current, constant voltage battery charger controller IC that can be powered by the photovoltaic cell with maximum power point tracking function. The HCR9719 adopts PWM step-down switching architecture, and is specially designed to charge 1-cell Lithium ion batteries. The charge current is set by an external current sense resistor (R_{CS}) across the CSP and BAT pins. The final battery regulation voltage in constant voltage mode is internally fixed at 4.2V with ±1% accuracy.

A charge cycle begins when the voltage at the V_{IN} pin rises above the UVLO level and is greater than the battery voltage by V_{SLPR}. At the beginning of the charge cycle, if the battery voltage is less than 66.6% of regulation voltage (V_{REG}), the charger goes into trickle charge mode. The trickle charge current is internally set to 25% (Typical) of the full-scale charge current. When the battery voltage exceeds 66.6% of regulation voltage, the charger goes into the full-scale constant current charge mode. In constant current mode, the charge current is set by the external sense resistor R_{CS} and an internal 80mV reference, the charge current equals to $80mV/R_{CS}$. When the battery voltage approaches the regulation voltage, the charger goes into constant voltage mode, and the charge current will start to decrease. When the charge current drops to 15% of the full-scale charge current, the charge cycle is terminated, $\overline{CHRG}$ pin outputs high impedance and $\overline{DONE}$ pin is pulled down to GND to indicate the termination status.

To restart the charge cycle, just remove and reapply the input supply. Also, a new charge cycle will begin if the battery voltage falls below the recharge threshold of 95.8% of the regulation voltage in constant voltage mode.

The HCR9719 adopts the constant voltage method to track the photovoltaic cell's maximum power point. The MPPT pin's voltage is regulated to 1.205V to track the maximum power point of the photovoltaic cell.

When the input supply is not present, the charger automatically goes into sleep mode, all the internal circuits are shutdown.

An over-voltage comparator guards against voltage transient overshoots (>6.8% of regulation voltage). In this case, both 2 external N-channel MOSFET is turned off until the overvoltage condition is cleared. This feature is useful for battery load dump or sudden removal of battery.

The charging profile is shown in Figure 4.

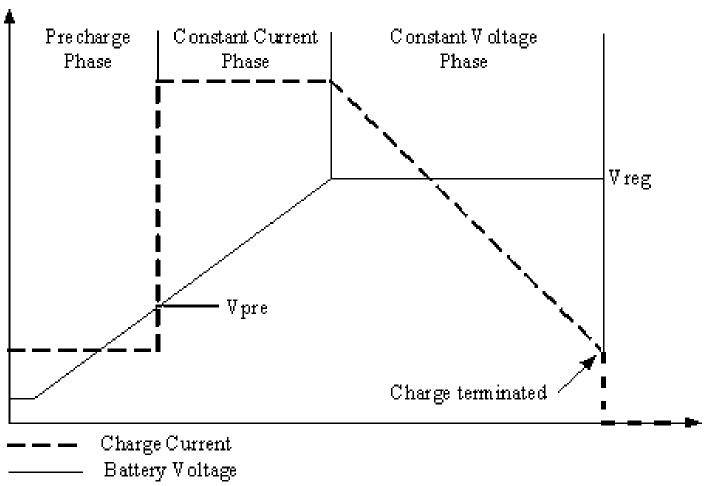


Figure 4. Charging Profile

Application Information

Under voltage Lockout (UVLO)

An under-voltage lockout circuit monitors the input voltage and keeps the charger off if V_{IN} falls below 4.4V (Maximum).

Trickle Charge Mode

At the beginning of a charge cycle, if the battery voltage is below 66.6% of the regulation voltage, the charger goes into trickle charge mode with the charge current reduced to 25% of the full-scale charge current.

Charge Current Setting

The full-scale charge current, namely the charge current in constant current mode, is decided by the following formula:

$$I_{\mathrm{CH}} = \frac{80\,\mathrm{mV}}{R_{\mathrm{CS}}}$$

Where:

I_{CH} is the full scale charge current R_{CS} is the current sense resistor between the CSP pin and BAT pin

The Maximum Power Point Tracking

HCR9719 adopts the constant voltage method to track the photovoltaic cell's maximum power point. From I-V curve of photovoltaic cell, under a given temperature, the photovoltaic cell's voltages at the maximum power point are nearly constant regardless of the different irradiances. So the maximum power point can be tracked if the photovoltaic cell's output voltage is regulated to a constant voltage.

HCR9719's MPPT pin's voltage is regulated to 1.205V to track the maximum power point working with the off-chip resistor divider (R_1 and R_2 in Figure 3).

The maximum power point voltage is decided by the following equation:

$$V_{\mathrm{MPPT}} = 1.205\left(1 + \frac{R_1}{R_2}\right)$$

If MPPT function is not used, R_1 and R_2's resistance should be selected so that MPPT pin voltage is between 1.5V and 6V.

Charge Termination

In constant voltage mode, the charge current decreases gradually. When the charge current decreases to 15% of the full-scale charge current, the charging is terminated. In charge termination mode, $\overline{\mathrm{CHRG}}$ pin outputs high impedance and $\overline{\mathrm{DONE}}$ pin is pulled down to GND to indicate the charge termination mode. In termination mode, both the external N-channel MOSFETs are turned off, no current flows to battery.

In photovoltaic cell's maximum power point tracking mode, the charging will not be terminated until the battery voltage is higher than 95.8% of the regulation voltage, even though the charge current is lower than 15% of the full-scale charge current. Namely to terminate charging, the battery voltage has to be higher than 95.8% of the regulation voltage, and charge current is lower than 15% of the full-scale charge current.

Automatic Recharge

After the charge cycle is completed and both the battery and the input power supply (wall adapter) are still present, a new charge cycle will begin if the battery voltage falls below 95.8% of the regulation voltage in constant voltage mode.

Battery Temperature Monitoring

To prevent the damage caused by the very high or very low temperature done to the battery, the HCR9719 continuously monitor battery temperature by measuring the voltage at TEMP pin which is determined by TEMP pin's source current (30μA

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typical) and a 10KΩ negative temperature coefficient (NTC) thermistor connected between TEMP pin and GND as shown in Figure 3.

If battery temperature monitoring function is not needed, connect a fixed 10KΩ resistor from TEMP to GND.

The battery temperature monitoring function for HCR9719 is designed to follow the JEITA standard; charge current or charge termination voltage is reduced based on battery temperature ranges.

There are totally five battery temperature ranges for HCR9719:

• Hot: Above 55°C, • Warm: 45°C to 55°C, • Normal: 10°C to 45°C • Cool: 0°C to 10°C, • Cold: Below 0°C.

Normal operation occurs when battery temperature is between 10°C and 45°C, charge current and voltage will be the normal values.

When battery is in the Cool temperature range, which is between 0°C and 10°C, the charge current is 25% of full-scale charge current and regulation voltage is not changed.

When the battery is in the Warm temperature range, which is between 45°C and 55°C, the charge current is reduced to 47% of full-scale charge current and regulation voltage is reduced to 95.8% of nominal value.

Charging is suspended if battery temperature is below Cold temp of 0°C or above Hot temp of 55°C. When charging is suspended, both $\overline{\text{CHRG}}$ and $\overline{\text{DONE}}$ pin becomes high impedance state.

Once battery temperature is not in hot range and cold range, charging resumes automatically.

TEMP pin voltage is the product of its source current and NTC's resistance, so the selection of NTC should make sure TEMP pin voltage meet the requirements of hot, warm, cool and cold threshold. An NTC of nominal resistance 10KΩ at room temperature may be suitable for HCR9719.

A resistor of small resistance in series with NTC thermistor and a resistor of large resistance in parallel with NTC thermistor can fine tune HCR9719's temperature range.

The following table lists TEMP pin voltage, charge current and termination voltage in the above-mentioned 5 battery temperature range.

Battery Temperature Range	TEMP Pin Voltage	Charge Current	Regulation Voltage
Hot: above 55°C	$V_{TEMP}<V_{HOT}$	Charge Suspended	Charge Suspended
Warm: 45°C to 55°C	$V_{HOTR}<V_{TEMP}<V_{WARM}$	$47\%*I_{CC}$	$95.8\%*V_{REG}$
Normal: 10°C to 45°C	$V_{WARMR}<V_{TEMP}<V_{COOLR}$	Normal Value	Normal Value
Cool: 0°C to 10°C	$V_{COOL}<V_{TEMP}<V_{COLDR}$	$25\%*I_{CC}$	Normal Value
Cold: below 0°C	$V_{TEMP}>V_{COLD}$	Charge Suspended	Charge Suspended

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Status Indication

The HCR9719 has 2 open-drain status output: $\overline{\text{CHRG}}$ and $\overline{\text{DONE}}$. $\overline{\text{CHRG}}$ pin is pulled down to GND when charger is in charging status, otherwise $\overline{\text{CHRG}}$ becomes high impedance. In termination status, $\overline{\text{DONE}}$ is pulled down to GND.

When the battery is not present, the charger charges the output capacitor to regulation voltage or the over-voltage protection threshold quickly, HCR9719 enters termination mode or over-voltage protection mode, then battery voltage decays slowly to recharge threshold or over-voltage release threshold because of discharge by the feedback resistors, HCR9719 enters charge mode, and the output capacitor is charged to regulation voltage or over-voltage protection threshold again, and so forth. Then a ripple waveform is formed at charger's output, namely battery positive terminal,

in the meantime, $\overline{\text{CHRG}}$ pin outputs high impedance, $\overline{\text{DONE}}$ pin outputs pulse to indicate the battery's absence.

The $\overline{\text{CHRG}}$ and $\overline{\text{DONE}}$ pin should be tied to ground if not used.

The table 1 lists the indicator status and its corresponding charging status. It is supposed that red LED is connected to $\overline{\text{CHRG}}$ pin and green LED is connected to $\overline{\text{DONE}}$ pin.

$\overline{\text{CHRG}}$ Pin	$\overline{\text{DONE}}$ Pin	Description
Low (Red LED ON)	High Impedance (Green LED OFF)	Charging Status
High Impedance (Red LED OFF)	Low (Green LED ON)	Termination Status
High Impedance (Red LED OFF)	High Impedance (Green LED OFF)	There are 3 Possible Reasons: • $V_{IN}<V_{UVLO}$, or • $V_{IN}<V_{BAT}$, or • Battery Hot or Cold

Table 1 Status Indication

Preventing Reverse Current from Battery

In the application circuit shown in Figure 3, if there is no P-channel MOSFET M3, when input supply is absent or input supply voltage is less than battery voltage, the current flows back from battery to input supply via inductor and body diode of N-channel MOSFET M2, the reverse current may drain the battery, or damage input supply. So the P-channel MOSFET M3 is adopted to prevent the reverse current from battery.

When input supply is absent or input supply voltage is less than battery voltage, HCR9719 enters sleep mode, PG pin is pulled up to voltage level as same as battery, P-channel MOSFET M3 is turned off, hence the reverse current from battery is blocked.

In normal operation mode, the P-channel MOSFET M3 remains in on state, since the on-resistance of the P-channel MOSFET can be chosen low enough, the converter's efficiency will not be degraded significantly.

If the P-channel MOSFET is not used, PG pin can be left floating.

The logic-low-level voltage at PG pin is 0V in normal operation, so the P-channel MOSFET's source-gate voltage is equal to input supply voltage. If input supply voltage is higher than maximum rating of source-gate voltage of the P-channel MOSFET, the circuit shown

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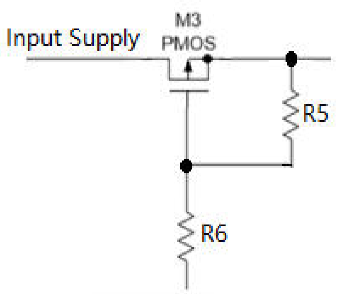
in Figure 5 can be used, in which 2 resistors R5 and R6 are used to limit source-gate voltage within the maximum rating. The selection of R5 and R6 should be in such a way that the actual source-gate voltage is less than the P-channel MOSFET's maximum rating, even at input supply's maximum voltage.



HCR9719 PG Pin

Figure 5. Add R5 and R6 to limit P-channel MOSFET Source-Gate Voltage

A schottky diode can be used to replace the P-channel MOSFET, but special consideration should be given to the diode's forward voltage drop and power dissipation.

Loop Compensation

In order to make sure that the current and the voltage regulation loops are stable, a 100nF ceramic capacitor from the COM pin to GND is necessary.

Input Supply Bypassing Capacitors

To ensure HCR9719's proper operation, at least 3 bypassing capacitors are needed at input supply.

The first capacitor is for the bypassing of HCR9719's V_{IN} pin (Pin 2 and Pin 3), C12 in Figure 3 is the capacitor. A ceramic capacitor of at least 1μF for C12 can meet the requirement. In PCB design, C12 should be placed as close as possible to V_{IN} pin (Pin 2 and Pin 3).

The second and third capacitor (C_1 and C11 in Figure 3) are assumed to absorb all input switching ripple current in the converter, it must have an adequate ripple current rating. Worst-case RMS ripple current is approximately one-half of charge current. Generally a 10μF capacitor for C_1 is sufficient.

In order to depress the high-frequency oscillation during N-channel MOSFET's turning on and off, it is best that the input bypassing capacitor C11 consists of the following 3 capacitors in parallel:

- Electrolytic capacitor for low-frequency filtering
- A ceramic capacitor from 1μF to 10μF
- A high-frequency capacitor from 47nF to 1μF

In PCB design, capacitor C_1 should be placed as close as possible to drain of P-channel MOSFET M3 in Figure 3.

C11 should be placed very close to N-channel MOSFET M2's drain and M1's source.

Inductor Selection

During high-side N-channel MOSFET's on time, the inductor current increases, and decreases during low-side N-channel MOSFET's off time, the inductor's ripple current increases with lower inductance and higher input voltage. Higher inductor ripple current results in higher charge current ripple and greater core losses. So the inductor's ripple current should be limited within a reasonable range.

The inductor's ripple current is given by the following formula:

$$\Delta I_L = \frac{1}{fL} V_{\mathrm{BAT}} \left(1 - \frac{V_{\mathrm{BAT}}}{V_{\mathrm{IN}}}\right)$$

Where, f is the switching frequency 550kHz L is the inductor value V_{BAT} is the battery voltage V_{IN} is the input voltage A reasonable starting point for setting inductor ripple current is $\Delta I_L \leq 0.3 \times I_{CH}$, I_{CH} is the charge current.

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Remember that the maximum ΔI_L occurs at the maximum input voltage and the lowest inductor value. So lower charge current generally calls for larger inductor value.

So the inductor value should meet the requirement of the following formula:

$$L \geq \frac{V_{\mathrm{BAT}}(V_{\mathrm{IN}} - V_{\mathrm{BAT}})}{0.3 I_{\mathrm{CH}} f V_{\mathrm{IN}}}$$

If solar panel is used as the input supply, the inductor value should be increased accordingly.

Output Capacitors

To ensure HCR9719's proper operation, at least 2 bypassing capacitors are needed at output.

The first capacitor is for the bypassing of HCR9719's BAT pin (Pin 16), this capacitor is to ensure the correct sampling of battery voltage and charge current, CO1 in Figure 3 is the capacitor. A ceramic capacitor of at least 1µF for CO1 can meet the requirement. In PCB design, CO1 should be placed as close as possible to BAT pin (Pin 16).

The second capacitor (C_o in Figure 3) is used to minimize ripple voltage and load step transients, so the ceramic capacitor with low ESR should be selected.

If only ceramic capacitor is used, cares must be taken that some ceramic capacitors exhibit large voltage coefficient, which may lead to high voltage at BAT pin when battery is not present. In this case, the capacitor value should be increased properly so that no damage will be done.

In order to make closed loop stable, the actual output capacitance should also meet the requirement of the following formula:

$$\frac{175}{L} \leq C_o \leq \frac{400}{L}$$

Where, C_o is in µF L is the inductance calculated in the above section of "Inductor Selection", its unit is uH.

The Selection of N-channel MOSFET

HCR9719 needs 2 external N-channel MOSFETs as power switch, M1 and M2 in Figure 3 are the 2 N-channel MOSFETs. The following 5 parameters should be considered carefully while selecting the 2 N-channel MOSFETs:

• Turn-on voltage V_{th} The supply voltage of driving the 2 N-channel MOSFETs is internally fixed at 5V(Typical), the turn-on voltage of the 2 N-channel MOSFETs should be low enough so that the 2 N-channel MOSFETs can be fully turned on when driving voltage is 5V.

• Turn-on-resistance R_{ds}(on) The on-resistance R_{ds}(on) should meet the requirement of the following formula:

$$30\,\mathrm{mV} < R_{\mathrm{ds(on)}} I_{\mathrm{CH}} < 55\,\mathrm{mV}$$

• Total gate charge Q_g and Reverse transfer capacitance C_{RSS} On the condition that on resistance R_{ds}(on) meet the above formula's requirement, the total gate charge Q_g and reverse transfer capacitance C_{RSS} should be chosen as small as possible to reduce switching losses.

• Drain-source breakdown voltage B_{Vdss} The 2 N-channel MOSFETs' drain-source breakdown voltage B_{Vdss} should be greater than input supply voltage plus a safe margin. For example, if input supply voltage is 20V, it is better that the 2 N-channel MOSFETs have a B_{Vdss} of 30V. For 30V input supply voltage, the B_{Vdss} of 40V is a good choice.

• Continuous drain current I_D The continuous drain current of the 2 N-channel MOSFETs should be chosen according to the following formula:

$$I_D \geq 1.5 I_{\mathrm{CH}} \frac{V_{\mathrm{BAT}}}{V_{\mathrm{IN}}}$$

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In the above formulas, I_{CH} is the full-scale charge current, V_{BAT} is battery voltage, V_{IN} is input voltage.

The Selection of P-channel MOSFET

The HCR9719 needs an external P-channel MOSFET (M3 in Figure 3) to prevent reverse current from battery. The P-channel MOSFET is in on state in normal operation, only in sleep mode the P-channel MOSFET is turned off.

The following 4 parameters should be considered carefully while selecting the P-channel MOSFET:

• Turn-on resistance R_{ds}(on) The on-resistance R_{ds}(on) of the P-channel MOSFET should be chosen as small as possible to reduce conduction loss. It is best that the on-resistance R_{ds}(on) can meet the requirement of the following equation:

$$R_{\mathrm{ds(on)}} I_{\mathrm{CH}} < 55\,\mathrm{mV}$$

• Maximum gate-source voltage The maximum rating of source-gate voltage of the P-channel MOSFET should be no less than input supply voltage. If input supply voltage is higher than the maximum rating of source-gate voltage, the circuit in Figure 5 should be adopted.

• Source-drain breakdown voltage B_{Vdss} The P-channel MOSFET's source-drain breakdown voltage B_{Vdss} should be greater than input supply voltage plus a safe margin. For example, if input supply voltage is 20V, it is better that the P-channel MOSFET has a B_{Vdss} of 30V. For 30V input supply voltage, the B_{Vdss} of 40V is a good choice.

• Continuous drain current Id The continuous drain current of the P-channel MOSFET should meet the requirement of the following formula:

$$I_D \geq 1.5 I_{\mathrm{CH}} \frac{V_{\mathrm{BAT}}}{V_{\mathrm{IN}}}$$

Where, I_{CH} is the full-scale charge current, V_{BAT} is the battery voltage, V_{IN} is the input voltage.

In most cases, P-channel MOSFET CN30P14 can meet the above requirement.

The Case of Input Supply Voltage Being Greater Than 20V

When the input supply voltage is greater than 20V, to depress the transient voltage overshoot, the application circuit shown in Figure 6 should be adopted, in which a 4.7 ohm resistor between input supply and HCR9719 V_{IN} pin (Pin 2 and Pin 3) is added, also C12 in Figure6 should be 10μF at least.

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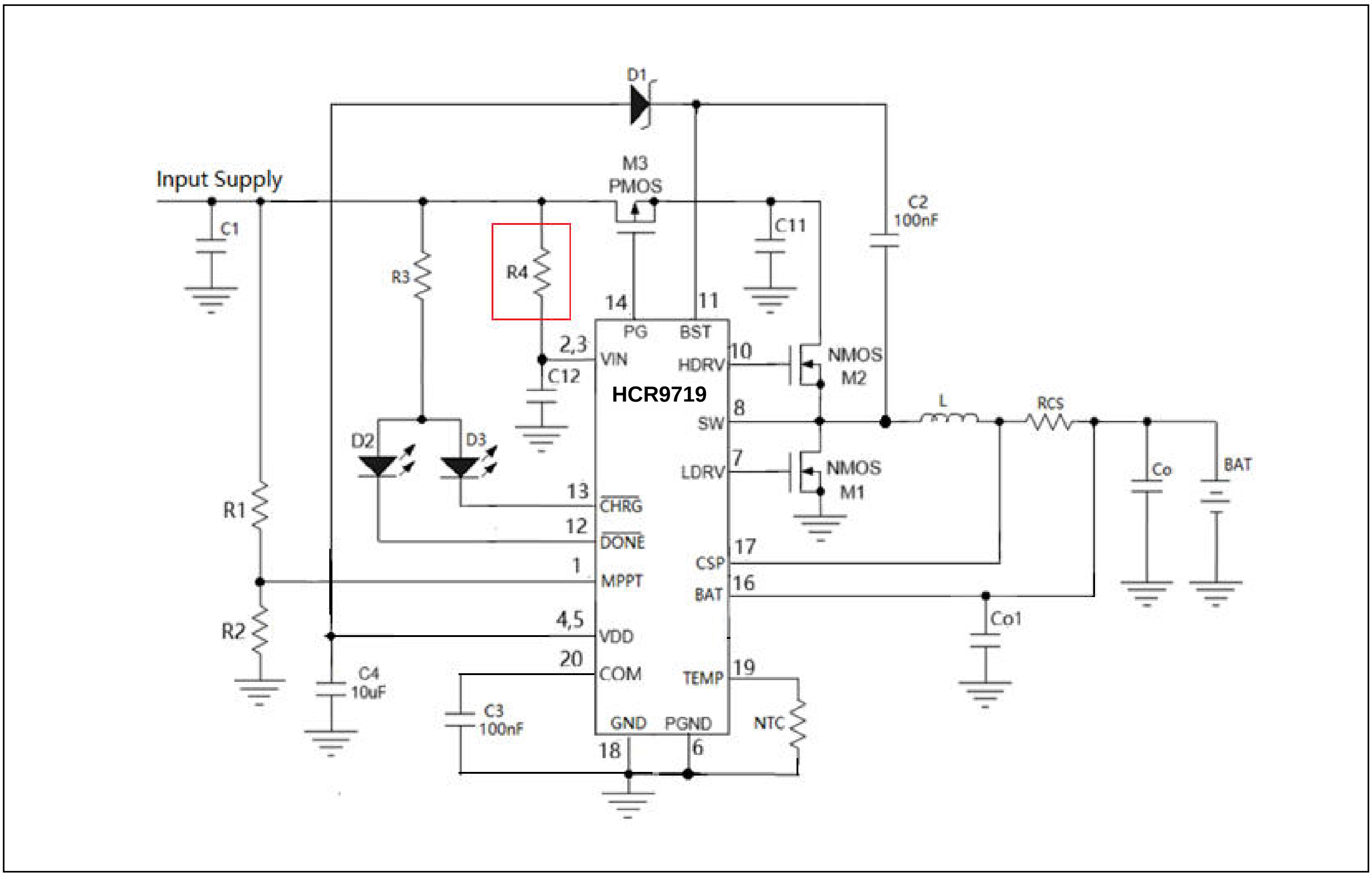

Figure 6. Add R_4 for Input Supply Voltage Being Greater Than 20V

PCB Layout Considerations

A good printed circuit board design is very critical for the proper operation of DC-DC converter. When laying out the printed circuit board, it is essential to follow the below priority list:

(1) At least 3 bypassing capacitors are needed for input supply. The first one (C12 in Figure 3) should be placed as close as possible to V_{IN} pin (Pin 2 and Pin 3), its grounding terminal should be tied to analog GND. The second capacitor (C_1 in Figure 3) should be placed as close as possible to drain of P-channel MOSFET M3. The third capacitor C11 should be placed as close as possible to N-channel MOSFET M2's drain and M1's source.

(2) The bypassing capacitor at Pin 4 and Pin 5 (V_{DD} pin) should be placed as close to Pin 4 and Pin 5 as possible, its grounding terminal should be tied to analog GND.

(3) At least 2 bypassing capacitors are needed for output. The first one (CO1 in Figure 3) should be placed as close as possible to BAT pin (Pin 16), its grounding terminal should be tied to analog GND. The second capacitor (C_o in Figure 3) should be placed as close as possible to current sense resistor R_{CS}.

(4) To minimize radiation, the input supply bypassing capacitor, P-channel MOSFET, the 2 N-channel MOSFETs, inductor, current sense resistor and output capacitor traces should be kept as short as possible. Especially the connection between the inductor and

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the 2 N-channel MOSFETs should also be kept as short as possible.

(5) The grounding terminal of NTC, compensation capacitor connected at the COM pin and the resistor divider at MPPT pin should be connected to analog GND of the HCR9719. This will prevent ground noise from disrupting the loop stability. Place R_1, R_2 and C_3 as close to the HCR9719 as possible.

(6) Output capacitor ground and rectifier N-channel MOSFET (M1 in Figure 3) ground connections need to feed into same copper that connects to the input capacitor ground before tying back into system ground. This ground is power ground, and should be wide enough, as wide as possible.

(7) Analog ground and power ground (or switching ground) should return to system ground separately.

(8) The ground pins also work as a heat sink, therefore use a generous amount of copper around the ground pins.

This is especially important for high V_{IN} and/or high gate capacitance applications.

(9) The CSP and BAT pins should be connected directly to the 2 terminals of current sense resistor (Kelvin sensing) for best charge current accuracy. See Figure 7 as an example.

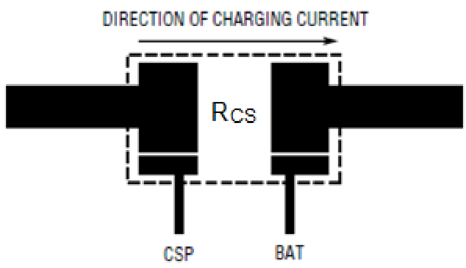
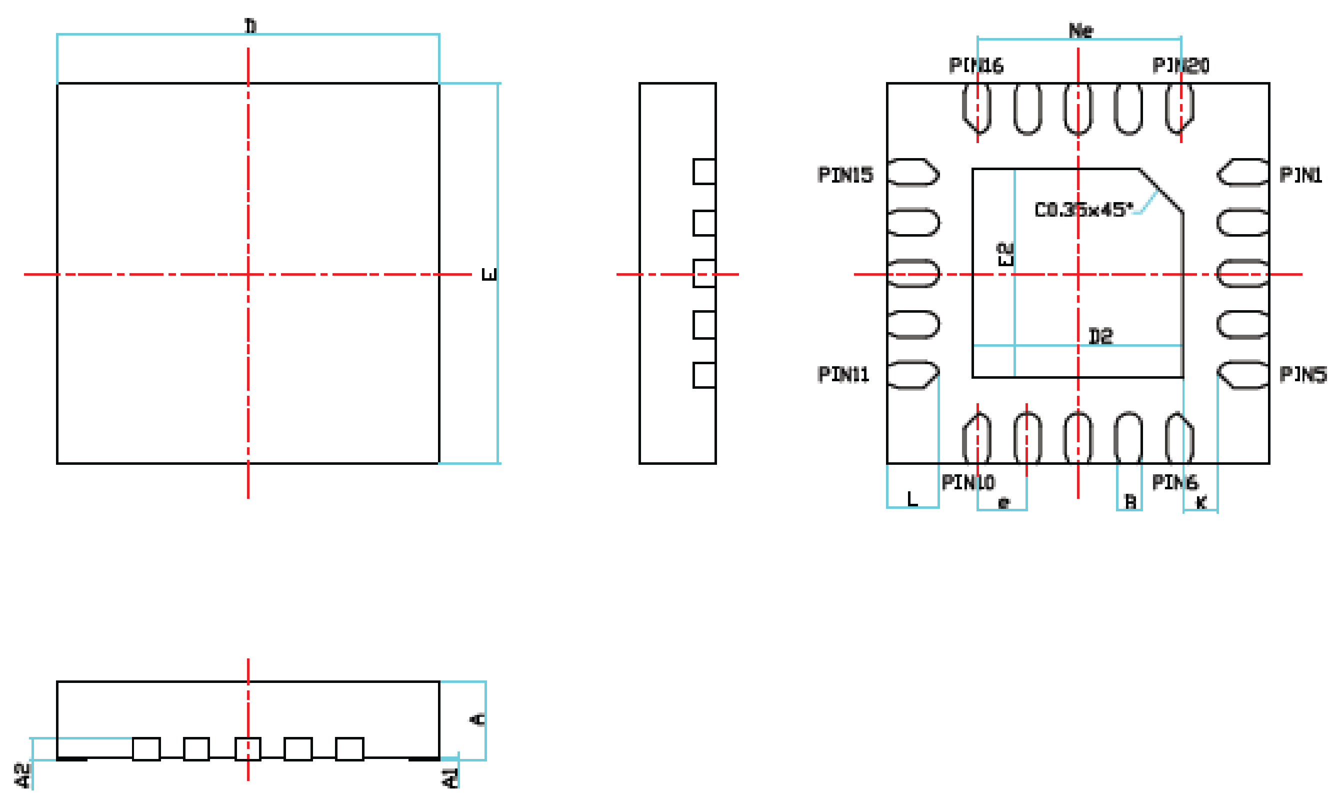


Figure 7. Kelvin Sensing of Charge Current

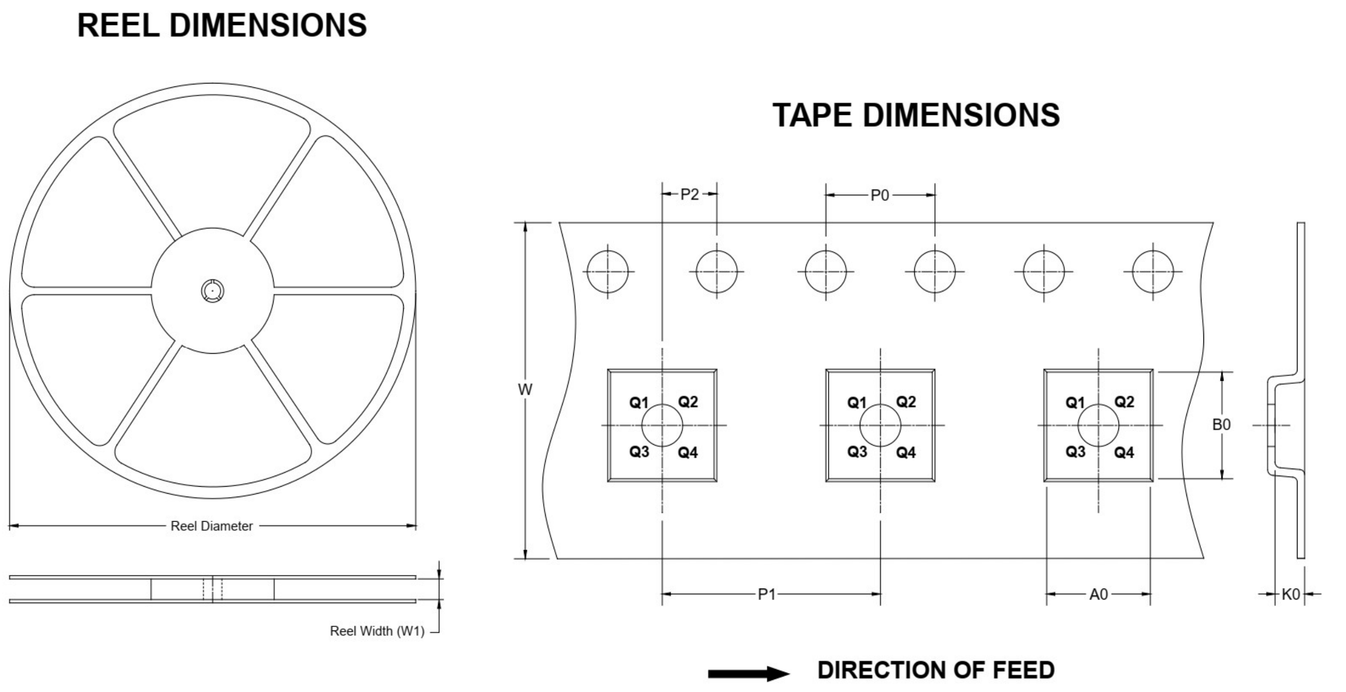
Mechanical Dimensions

QN20E PKG: QFN-3x3-20L



Symbol	Dimensions in Millimeters		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A2	0.203 REF		
B	0.15	0.20	0.25
D	2.93	2.98	3.03
D2	1.55	1.65	1.75
E	2.93	2.98	3.03
E2	1.55	1.65	1.75
e	0.40 BSC		
K	-	0.276	-
L	0.35	0.40	0.45
Ne	1.60 BSC		

Tape and Reel Information



NOTE: The picture is only for reference. Please make the objects 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
QFN-3x3-20L	13″	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

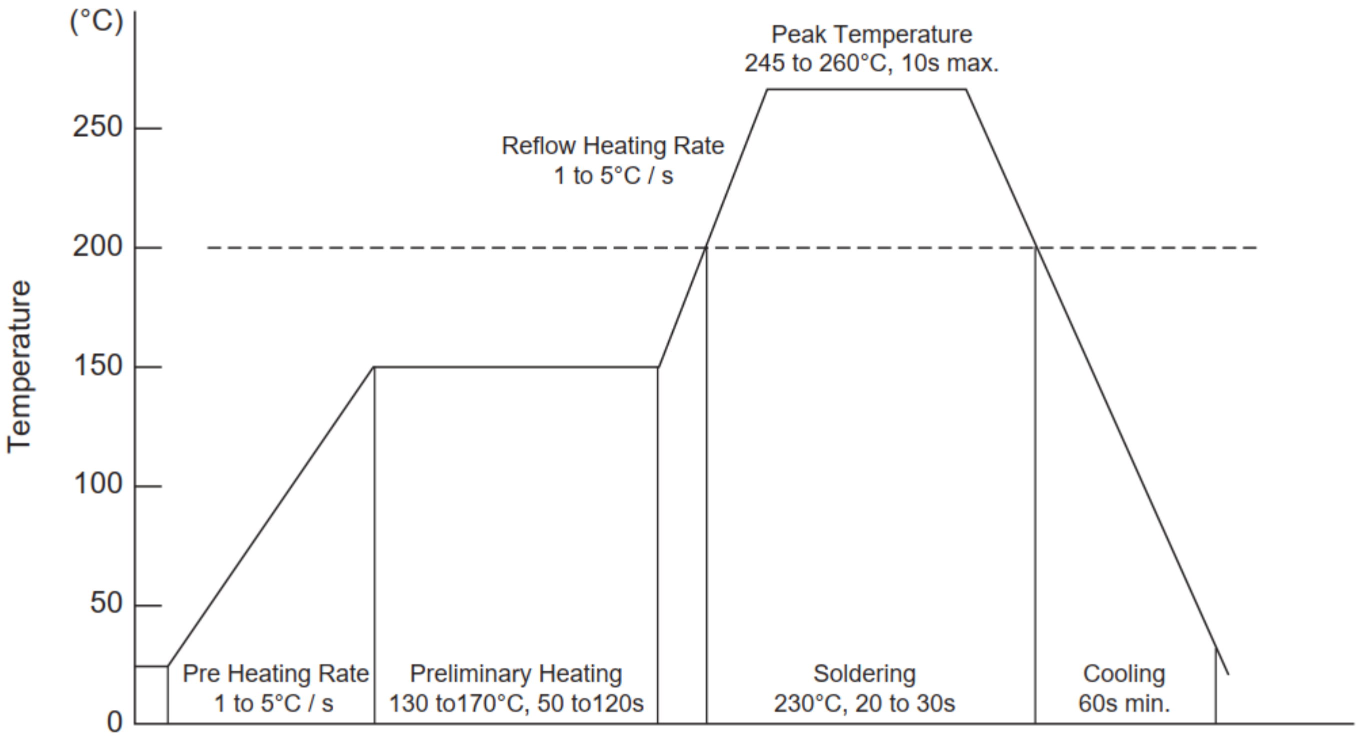
Part Number: HCR9719/4V2N20ETR

Packing Type: Tape and Reel

Quantity per Reel: 5000pcs/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