2 A Single-Cell Li-ion Battery Charger IC

Features

- Input voltage range: 4.55 V to 6.5 V
- Complete charger IC for single-cell Li-ion and Li-polymer batteries
- PFM operation mode
- Regulation voltage: 4.2 V ±1%
- Fixed charge current: 2 A
- Automatic charge-current adjustment according to the loading capability of the input supply
- Automatic conditioning of deeply discharged batteries
- Automatic recharge
- JEITA-compliant battery-temperature monitoring
- Short-battery protection
- Battery overvoltage protection
- 2 charging-status indications
- Junction overtemperature protection
- Operating ambient temperature: -40 °C to +85 °C
- Available in SOP-8(EP) package
- Pb-free, RoHS-compliant, halogen-free

Applications

- Power banks
- Hand-held equipment
- E-cigarettes
- Portable industrial and medical equipment
- Standalone battery chargers

General Description

The HCR9720A is a highly integrated switch-mode single-cell lithium-ion and lithium-polymer battery charger IC that can be powered by a photovoltaic cell with few external components.

The HCR9720A charges the battery in constant-current and constant-voltage modes.
Deeply discharged batteries are automatically trickle charged until the cell voltage exceeds 2.45 V. Above 2.45 V, the HCR9720A enters constant-current mode, in which the charge current is internally fixed at 2 A. In constant-voltage mode, the regulation voltage is fixed at 4.2 V with ±1% accuracy.
The charge cycle terminates once the charge current drops to 200 mA. A new charge cycle automatically restarts if the battery voltage falls below 4.06 V.

The HCR9720A automatically enters sleep mode when the input voltage is lower than the battery voltage.

Other features include JEITA-compliant battery-temperature monitoring, short-battery protection, battery overvoltage protection, junction overtemperature protection and 2 status indications.

The HCR9720A is available in a thermally enhanced SOP-8(EP) package.

SOP-8(EP)

Figure 1. Package Type of HCR9720A

Pin Configuration

SOP-8(EP) (Top View)

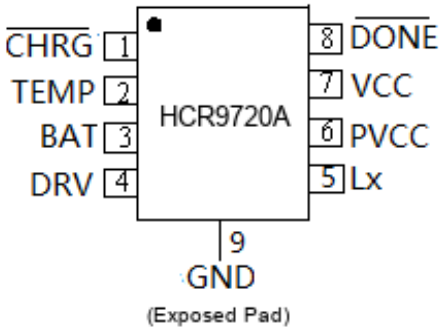


Figure 2. HCR9720A Pin Configuration

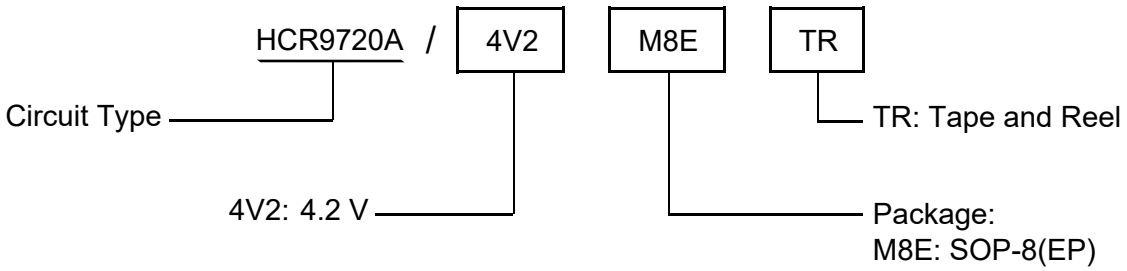
Pin Descriptions

Pin No.	Name	Description
1	$\overline{\text{CHRG}}$	Open-drain charge-status output. When the battery is being charged, an internal switch pulls this pin low. Otherwise, the pin is in a high-impedance state.
2	TEMP	Battery-temperature monitoring input. Connect a 10 kΩ NTC thermistor between TEMP and GND. • Below 0.1 V or above 0.85 V: the battery is too hot or too cold; charging is suspended. • Between 0.1 V and 0.135 V: the battery is warm; charge current is reduced to 50% of full-scale current and regulation voltage is reduced to 4.06 V. • Between 0.135 V and 0.55 V: the HCR9720A functions normally. • Between 0.55 V and 0.85 V: the battery is cool; charge current is reduced to 33% of constant current. If temperature monitoring is not needed, connect a fixed 10 kΩ resistor from TEMP to GND.
3	BAT	Positive terminal of the battery. Battery voltage is sensed through BAT. Connect BAT to the positive terminal of the battery.
4	DRV	Gate-drive pin for an external N-channel MOSFET. Connect DRV to the gate of the external N-channel MOSFET.
5	Lx	Inductor-connection pin. Connect Lx to the input terminal of the inductor. Charge current flows out of the HCR9720A through this pin. An internal high-side power MOSFET is connected between PVCC and Lx.

Pin Descriptions (Continued)

Pin No.	Name	Description
6	PVCC	Power DC supply input. PVCC is internally connected to the high-side power switch. Charge current flows into the HCR9720A while the high-side switch is on. Connect at least a 10 µF ceramic bypass capacitor from PVCC to GND and place it as close as possible to the HCR9720A.
7	VCC	Analog DC supply input. VCC supplies the internal circuit. Bypass this pin with a 10 µF ceramic capacitor.
8	$\overline{\text{DONE}}$	Open-drain charge-termination output. When charging terminates, an internal switch pulls this pin low. Otherwise, the pin is in a high-impedance state.
9	GND	Exposed thermal pad. This is the ground of the HCR9720A. Always solder the exposed pad on the backside of the IC to PCB ground.

Ordering Information



Ordering Code

Part Number	Marking ID (Note 2)	Temperature Range	Package	Quantity per Reel
HCR9720A/4V2M8ETR	HCR9720Axx	-40 °C to +85 °C	SOP-8(EP)	4000 pcs/TR

Note 2: ”HCR9720A” is the product type and ”xx” is the date code.

Typical Application Circuit

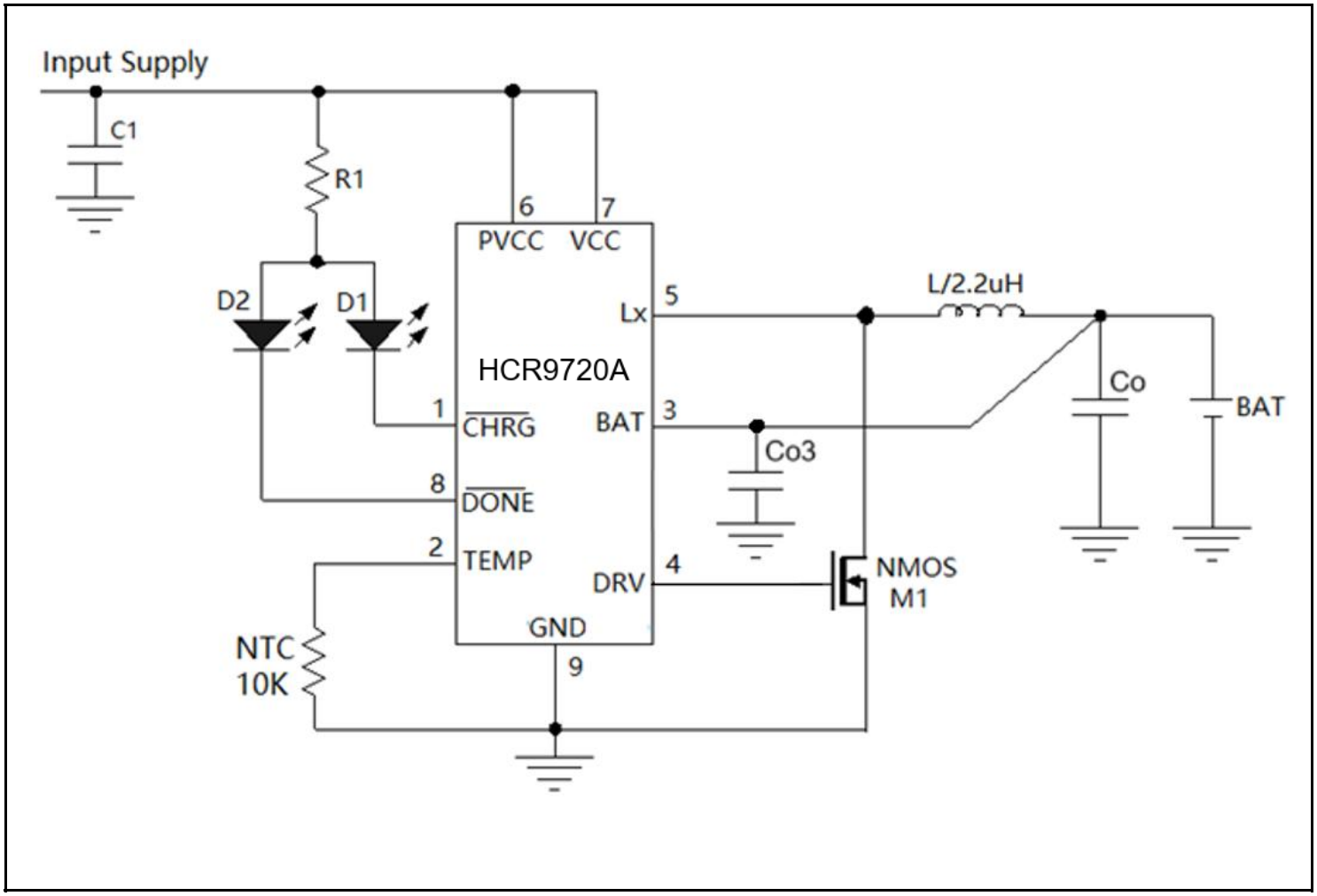


Figure 3. HCR9720A Typical Application Circuit

Absolute Maximum Ratings

Parameter	Rating	Unit
VCC, PVCC voltage	-0.3 to 7	V
TEMP, BAT voltage	-0.3 to VCC+0.3	V
Lx voltage	-0.3 to VCC+0.3	V
$\overline{CHRG}$, $\overline{DONE}$ voltage	-0.3 to 7	V
DRV voltage	-0.3 to VCC+0.3	V
Storage temperature	-65 to +150	°C
Operating temperature	-40 to +85	°C
Lead temperature (soldering, 10 s)	260	°C
Thermal resistance (ESOP8)	100	°C/W

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation at these or any other conditions above those indicated in the operational sections is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Recommend Operating Conditions (Note 2)

Parameter	Symbol	Min.	Max.	Unit
Input Voltage	VCC	4.55	6.5	V
Operating Ambient Temperature	T_A	-40	+85	°C

Note 2: The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics

VCC = 5 V; T_A = -40 °C to +85 °C. Typical values: T_A = +25 °C.

Unless otherwise noted.

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Input voltage range	VCC		4.55		6.5	V
Undervoltage lockout threshold	V_{UVLO}		2.5	3.0	3.5	V
Operating current	I_{VCC}	V_{BAT} = 4.3 V, no switching	385	510	635	μA
Regulation voltage (constant-voltage mode)	V_{REG}	Normal battery temperature	4.161	4.2	4.242	V
Regulation voltage (constant-voltage mode)	V_{REG}	Battery warm	4.02	4.06	4.1	V
Constant charge current	I_{CC}	V_{PRE} < V_{BAT} < 4.2 V	1.6	2	2.4	A
BAT pin current		Termination, V_{BAT} = 4.3 V	5	9	13	μA
BAT pin current	I_{SLP}	Sleep mode, V_{BAT} = 4.2 V			3	μA
Trickle-Charge Mode						
Precharge threshold	V_{PRE}	BAT voltage rises	2.35	2.45	2.55	V
Precharge hysteresis	H_{PRE}	BAT voltage falls		0.14		V
Trickle-charge current	I_{PRE}	V_{SRT} < V_{BAT} < V_{PRE}	80	150	220	mA
Charge Termination						
Termination threshold	I_{term}	Charge current falls	125	200	280	mA
Recharge						
Recharge threshold (BAT voltage falls)	V_{RECH}	Normal battery temperature	3.98	4.06	4.14	V
Recharge threshold (BAT voltage falls)	V_{RECH}	Battery warm	3.77	3.85	3.93	V
Battery-Short Protection						
Battery-short threshold	V_{SRT}		0.5	0.9	1.3	V
Battery-short current	I_{SRT}	V_{BAT} = 0.5 V	35	65	95	mA
Battery Overvoltage Protection						
Overvoltage threshold	Vov	BAT voltage rises	4.29	4.46	4.63	V
Overvoltage release threshold	Vclr	BAT voltage falls	4.13	4.29	4.45	V

Electrical Characteristics (Continued)

VCC = 5 V; T_A = -40 °C to +85 °C. Typical values: T_A = +25 °C.

Unless otherwise noted.

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Junction Overtemperature Protection						
Overtemperature threshold		Junction temperature rises		145		°C
Overtemperature release		Junction temperature falls		125		°C
TEMP Pin						
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_{TEMP} 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_{TEMP} falls, cool to normal	465	505	545	mV
Warm threshold	V_{WARM}	V_{TEMP} 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_{TEMP} falls, warm to hot	85	100	115	mV
Hot release threshold	V_{HOTR}	V_{TEMP} rises, hot to warm	105	120	135	mV
$\overline{CHRG}$ Pin						
$\overline{CHRG}$ sink current	I_{CHRG}	V_{CHRG} = 1 V, charging status	7	12	18	mA
$\overline{CHRG}$ leakage current	I_{LK1}	V_{CHRG} = 6.5 V, termination			1	µA
$\overline{DONE}$ Pin						
$\overline{DONE}$ sink current	I_{DONE}	V_{DONE} = 1 V, termination	7	12	18	mA
$\overline{DONE}$ leakage current	I_{LK2}	V_{DONE} = 6.5 V, charge mode			1	µA
Sleep Mode						
Sleep-mode threshold	V_{SLP}	VCC falls; test VCC - V_{BAT}	0.01	0.03	0.05	V
Sleep-mode release threshold	V_{SLPR}	VCC rises; test VCC - V_{BAT}	0.04	0.075	0.11	V

Detailed Description

The HCR9720A is a highly integrated constant-current, constant-voltage single-cell Li-ion and Li-polymer battery charger IC that can be powered by a photovoltaic cell. The device uses a PFM step-down (buck) switching architecture. Charge current is internally fixed at 2 A. The final battery regulation voltage in constant-voltage mode is 4.2 V typical with 1% accuracy.

A charge cycle begins when the voltage at VCC meets all three conditions:

- VCC rises above V_{UVLO}.
- VCC is higher than battery voltage by V_{SLPR}.
- VCC is no less than 4.55 V.

At the beginning of a charge cycle, if battery voltage is below the precharge threshold (2.45 V typical), the charger enters trickle-charge mode. Trickle-charge current is internally set to 150 mA. It is further reduced to 65 mA if battery voltage is below 0.9 V typical, which is considered a short-battery condition.

When battery voltage exceeds the precharge threshold, the charger enters full-scale constant-current mode. As battery voltage approaches the regulation voltage, the charger enters constant-voltage mode and charge current starts to decrease. When current drops to the termination threshold (200 mA typical), the charge cycle terminates; $\overline{CHRG}$ becomes high impedance and $\overline{DONE}$ goes low to indicate termination.

To restart the charge cycle, remove and reapply the input supply. A new cycle also starts if battery voltage drops below the recharge threshold (4.06 V typical). When the input supply is absent, the charger automatically enters sleep mode.

Junction overtemperature protection prevents thermal-runaway damage. Above 145 °C, the internal power switches turn off and no current flows to the battery. Protection is released only after junction temperature falls below 125 °C.

Overvoltage protection guards against transient battery-voltage overshoot. The internal high-side switch turns off until the overvoltage condition clears. This is useful for battery load dump or sudden battery removal. The charging profile is shown in Figure 4.

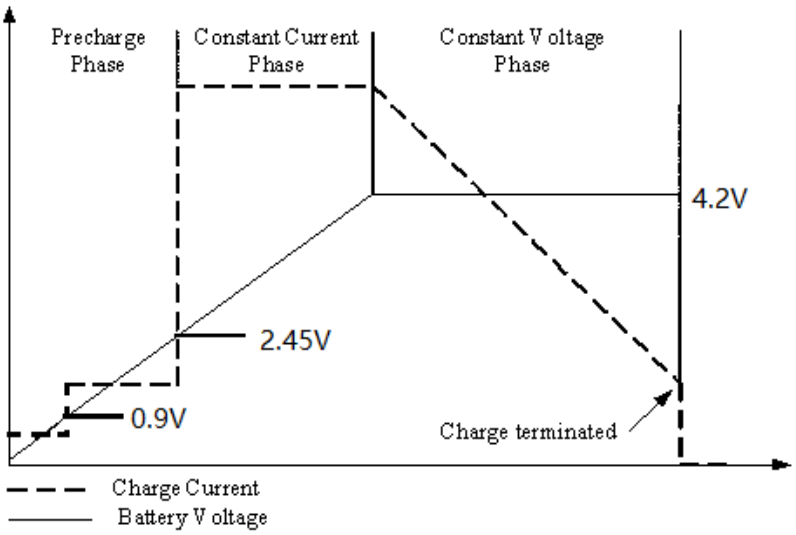


Figure 4. Charging Profile

Application Information

Undervoltage Lockout (UVLO)

An undervoltage-lockout circuit monitors the input supply and keeps the HCR9720A off if VCC is below 3.5 V.

A charge cycle starts only when all three conditions are met simultaneously:

- VCC rises above V_{UVLO}.
- VCC is higher than battery voltage by V_{SLPR}.
- VCC is no less than 4.55 V.

Short-Battery Protection

When battery voltage is below the short-battery threshold V_{SRT}, a short-battery condition is assumed and charge current is reduced to about 65 mA as a battery-protection mechanism.

Trickle-Charge Mode (Precharge)

At the beginning of a charge cycle, if battery voltage is between the short-battery threshold V_{SRT} and the precharge threshold (2.45 V typical), the charger enters trickle-charge mode with current set to about 150 mA.

Constant Charge Current

When battery voltage is between the precharge threshold V_{PRE} (2.45 V typical) and V_{REG} (4.2 V typical), the HCR9720A operates in constant-current mode with current internally fixed at 2 A.

Automatic Charge-Current Adjustment

If the loading capability of the input supply is less than that required for 2 A charge current, the on-chip adaptive circuit reduces charge current according to the input supply capability.

Charge current is maximized to the loading capability of the input supply. VCC is regulated at 4.55 V maximum, which is the minimum operating voltage of the HCR9720A.

Charge Termination

In constant-voltage mode, charge current gradually decreases. Below the termination threshold (200 mA typical), charging terminates, the high-side switch turns off and no charge current is delivered to the battery.

Automatic Recharge

After charging completes, if both the battery and input supply (wall adapter) remain present, a new cycle starts when battery voltage falls below the recharge threshold (4.06 V typical) due to self-discharge or external loading. This keeps battery capacity above 80% at all times without manually restarting the charge cycle.

Protection and Status Indication

Battery Overvoltage Protection

The HCR9720A turns off the high-side switch if battery voltage rises above the overvoltage threshold (4.46 V typical). The switch cannot turn on again until battery voltage falls below 4.29 V typical. This provides a one-cycle response to overvoltage, which often occurs when the load is removed or the battery is suddenly disconnected.

Overtemperature Protection

The HCR9720A continuously monitors junction temperature during charging. Above 145 °C, the on-chip high-side switch turns off and no current flows to the battery. The switch cannot turn on again until junction temperature falls below 125 °C.

Sleep Mode

If VCC drops below V_{BAT} + V_{SLP}, the HCR9720A enters sleep mode. The whole chip shuts down and current consumption from the battery is 3 μA maximum. Sleep mode ends only when VCC rises above V_{BAT} + V_{SLPR}.

Status Indication

The HCR9720A has two open-drain status outputs: $\overline{CHRG}$ and $\overline{DONE}$. $\overline{CHRG}$ is pulled low during charging and otherwise becomes high impedance. $\overline{DONE}$ is pulled low in termination status and otherwise becomes high impedance.

When no battery is present, the charger quickly charges the output capacitor to the regulation voltage or overvoltage threshold, depending on output capacitance. BAT voltage then slowly decays to the recharge threshold because of the low leakage current at BAT, producing a ripple waveform.

Any unused $\overline{CHRG}$ or $\overline{DONE}$ open-drain status output should be tied to ground.

Table 1 shows indicator behavior, assuming a red LED is connected to $\overline{CHRG}$ and a green LED to $\overline{DONE}$.

Table 1. Status Indications

$\overline{CHRG}$ Pin / Red LED	$\overline{DONE}$ Pin / Green LED	State Description
Low (red on)	High impedance (green off)	Charging
High impedance (red off)	Low (green on)	Charge termination
Pulse (red appears off)	Pulse (green on or blinking)	Battery not present
High impedance (red off)	High impedance (green off)	Three possible reasons: • VCC below 4.55 V • VCC below V_{BAT} • Battery too hot or too cold

Battery-Temperature Monitoring

To prevent damage caused by very high or very low battery temperature, the HCR9720A continuously measures TEMP voltage, which is determined by the TEMP source current (30 µA typical) and a 10 kΩ NTC thermistor connected between TEMP and GND, as shown in Figure 3.

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

The temperature-monitoring function is designed to follow the JEITA standard. Charge current or charge-termination voltage is reduced according to battery temperature. There are five ranges:
• 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 between 10 °C and 45 °C, with normal charge current and voltage. In the cool range (0 °C to 10 °C), charge current is 33% of full-scale current and regulation voltage is unchanged.

In the warm range (45 °C to 55 °C), current is reduced to 50% of full-scale current and regulation voltage is reduced to 4.06 V typical.

Charging is suspended below 0 °C or above 55 °C. Both $\overline{CHRG}$ and $\overline{DONE}$ become high impedance. Charging resumes automatically once battery temperature is outside the hot and cold ranges.

TEMP voltage is the product of its source current and NTC resistance. Select the NTC to meet the hot, warm, cool and cold voltage thresholds. An NTC with nominal resistance of 10 kΩ at room temperature may be suitable for the HCR9720A.

A small resistor in series with the NTC and a large resistor in parallel with the NTC can fine-tune the temperature ranges. Table 2 lists TEMP voltage, charge current and regulation voltage for the five ranges.

Table 2. Battery-Temperature Operating Ranges

Battery Temperature	TEMP Pin Voltage	Charge Current	Regulation Voltage
Hot: above 55 °C	$V_{TEMP} < V_{HOT}$	Suspended	Suspended
Warm: 45 to 55 °C	$V_{HOTR} < V_{TEMP} < V_{WARM}$	50% × I_{CC}	4.06 V
Normal: 10 to 45 °C	$V_{WARMR} < V_{TEMP} < V_{COOLR}$	Normal value	4.2 V
Cool: 0 to 10 °C	$V_{COOL} < V_{TEMP} < V_{COLDR}$	33% × I_{CC}	4.2 V
Cold: below 0 °C	$V_{TEMP} > V_{COLD}$	Suspended	Suspended

External Component Selection

Input Capacitor

The input capacitor C1 in Figure 3 is assumed to absorb all converter input switching ripple current and must have an adequate ripple-current rating. Worst-case RMS ripple current is approximately one-half of the charge current (2 A typical).

Input capacitance depends on supply characteristics, cable length and other factors. A 10 µF to 22 µF ceramic capacitor generally meets the requirements. Some ceramic capacitors have a large voltage coefficient and lower capacitance under DC bias; increase the capacitance appropriately and use at least an 0805 package.

If an electrolytic capacitor is used, place a 1 µF to 10 µF ceramic capacitor in parallel to filter high-frequency noise.

Output Capacitor

At least two output bypass capacitors are required for proper HCR9720A operation.

The first capacitor, C_{O3} in Figure 3, bypasses BAT (pin 3) to ensure correct sampling of battery voltage. A ceramic capacitor of at least 1 µF meets this requirement. Place C_{O3} as close as possible to BAT (pin 3).

The second output capacitor, C_O in Figure 3, is selected primarily for the ESR needed to minimize ripple voltage and load-step transients. Use a low-ESR 10 µF to 22 µF ceramic capacitor.

Some ceramic capacitors have a large voltage coefficient and lower capacitance under DC bias. Increase the capacitance appropriately and use at least an 0805 package.

If an electrolytic capacitor is used for C_O, place a 1 µF to 10 µF ceramic capacitor in parallel to filter high-frequency noise.

Inductor Selection

A 2.2 µH inductor with saturation current I_{SAT} above 3.5 A and DCR below 40 mΩ is generally suitable for most applications.

N-Channel MOSFET Selection

The HCR9720A requires an external N-channel MOSFET (M1 in Figure 3) as the rectifier power switch. Pay particular attention to these four parameters:

Turn-on threshold Vth: the minimum operating voltage is 4.55 V. Select a sufficiently low threshold to ensure that the MOSFET is fully turned on at VCC = 4.55 V.

On-resistance Rds(on): the MOSFET on-resistance should be between 18 mΩ and 50 mΩ.

Total gate charge Qg and reverse-transfer capacitance C_{RSS}: while meeting the on-resistance requirement, choose Qg and C_{RSS} as small as possible.

Continuous drain current I_D: the continuous drain current must be at least 1.5 A.

The N-channel MOSFET CN30N06 is a suitable candidate for most applications.

Application and PCB Layout Considerations

Hot Plug-In Consideration

During adapter hot plug-in, parasitic adapter-cable inductance and the input capacitor form a second-order system. A transient spike at VCC may exceed the IC maximum voltage rating and damage the IC.

The following three methods may damp or limit this spike:
1. Use an electrolytic input bypass capacitor with high ESR.
2. Connect a TVS diode between VCC (PVCC) and GND.
3. Add overvoltage-protection circuitry at VCC and PVCC.

Battery Inductive Load

If an inductive load, such as a motor or step-up DC-DC converter, is connected to the battery, use both measures below to prevent damage from counter electromotive force when the load turns off:

1. Add a 1 kΩ resistor between BAT and the battery positive terminal.
2. Add a Schottky diode between the battery positive terminal and GND, with its anode connected to GND.

PCB Layout Considerations

Observe the following layout requirements to ensure proper IC operation:

1. Place input bypass capacitors as close as possible to VCC and PVCC. Keep the traces as short as possible.

2. Solder the exposed thermal pad on the backside of the IC to PCB ground. The exposed pad is analog ground and must return to system ground separately.

3. Place C_{O3} in Figure 3 as close as possible to BAT (pin 3). Connect its ground terminal to analog GND.

4. Place the input capacitor, inductor and output capacitor on the same PCB layer instead of using different layers and vias for their connections.

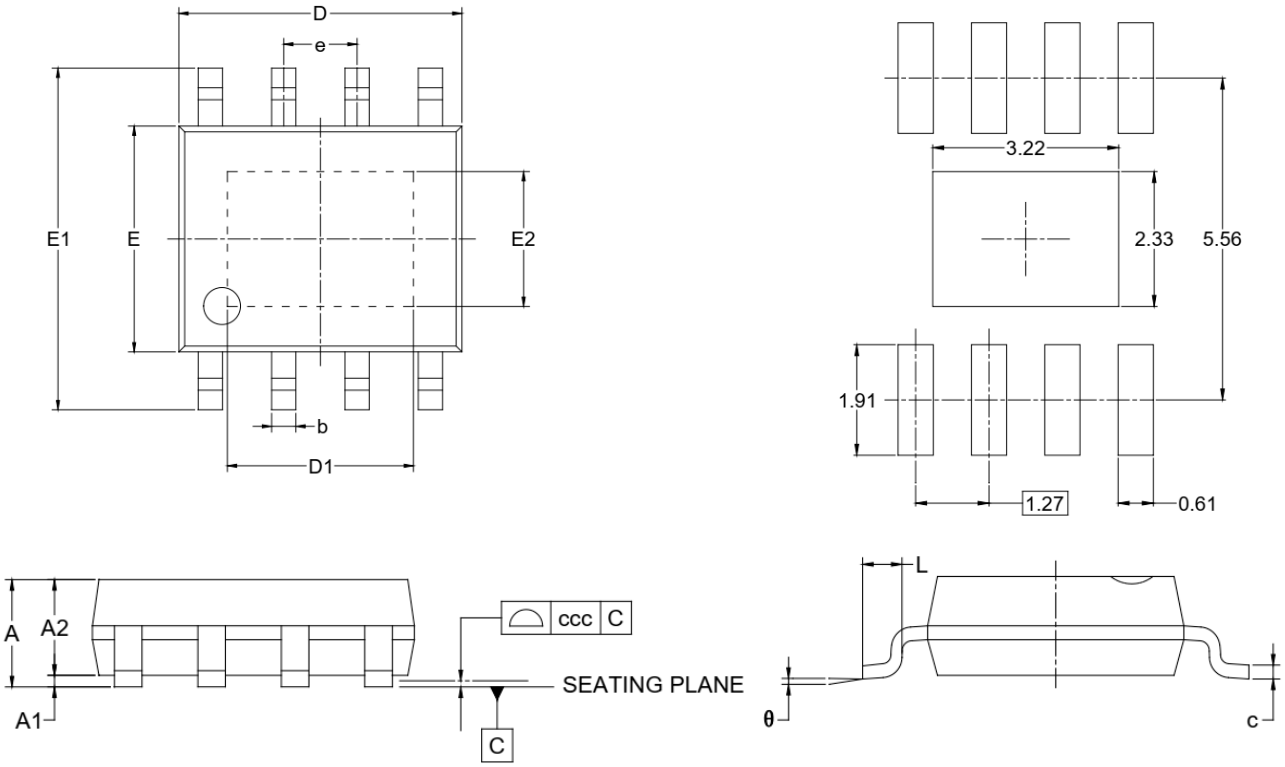
5. Place the inductor input as close as possible to Lx and its output as close as possible to the output capacitor. Minimize inductor-trace copper area to reduce electric and magnetic field radiation, while keeping traces wide enough to carry charge current. Minimize parasitic capacitance from this area to other traces or planes.

6. Connect the output-capacitor ground and N-channel MOSFET source to the same copper as the input-capacitor ground. Return this connection separately to system ground as power ground.

Mechanical Dimensions

M8E PKG: SOP-8(EP)

Unit: mm

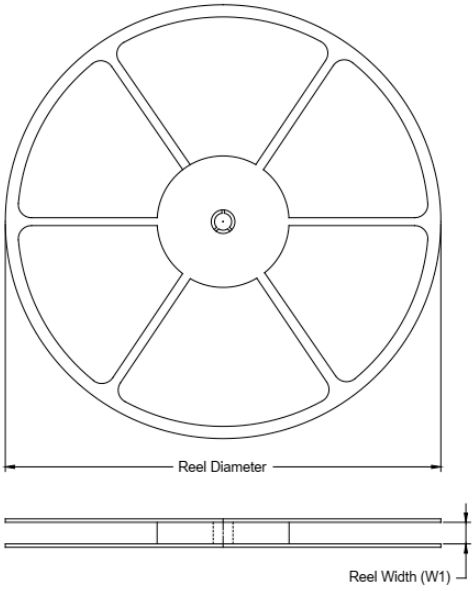


Symbol	Dimensions in Millimeters		
	MIN	MOD	MAX
A			1.700
A1	0.000	-	0.150
A2	1.250	-	1.650
b	0.330	-	0.510
c	0.170	-	0.250
D	4.700	-	5.100
D1	3.020	-	3.420
E	3.800	-	4.000
E1	5.800	-	6.200
E2	2.130	-	2.530
e	1.27 BSC		
L	0.400	-	1.270
θ	0°	-	8°
ccc	0.100		

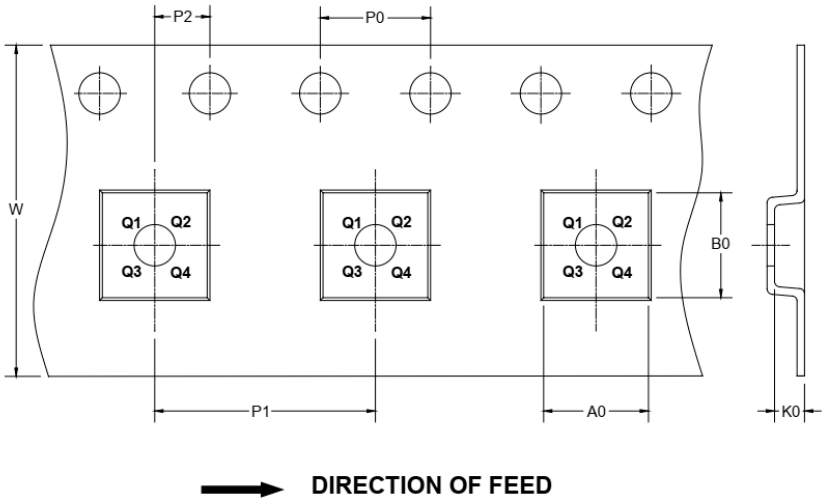
NOTES:
1. This drawing is subject to change without notice.
2. The dimensions do not include mold flashes, protrusions or gate burrs.
3. Reference JEDEC MS-012.

Tape and Reel Information

REEL DIMENSIONS



TAPE DIMENSIONS



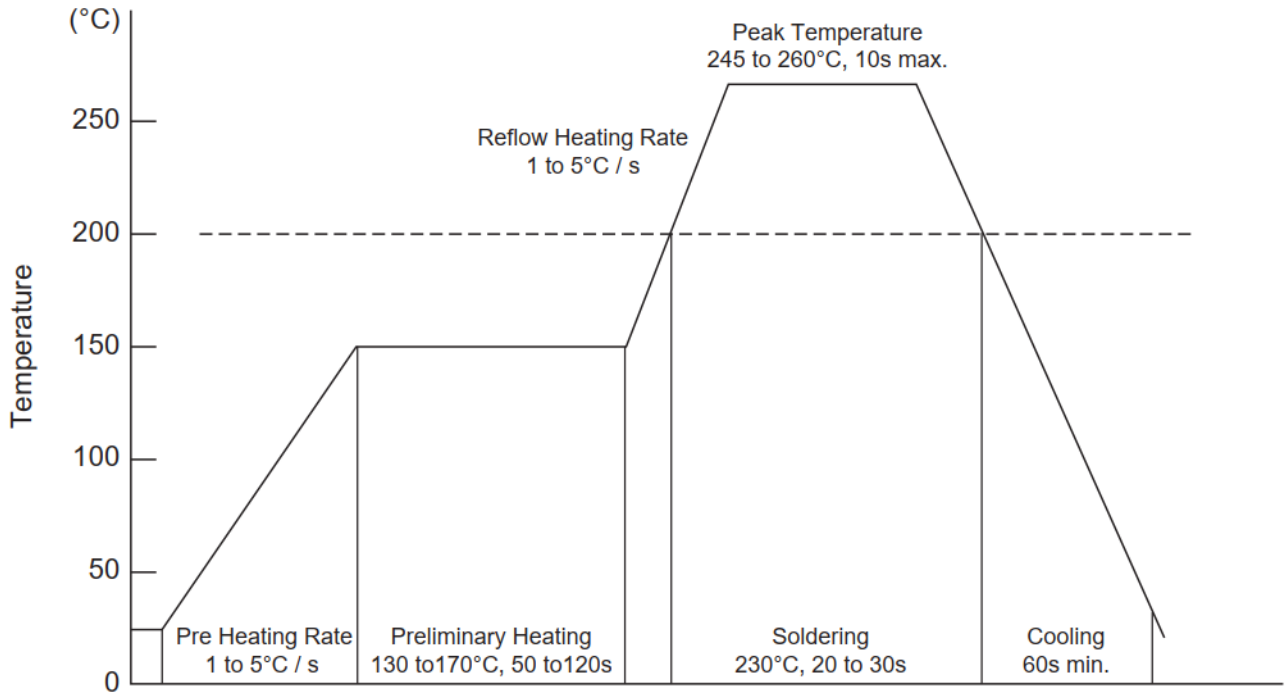
NOTE: The picture is only for reference. Please make the object as the standard.

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

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: 3 s max.
- Times: one time

Storage conditions

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