2A, Single-Cell Li-ion Battery Charger IC With Photovoltaic Cell MPPT Function

CN3796

General Descriptions:

The CN3796 is a highly-integrated switch-mode single-cell lithium ion and lithium polymer battery charger IC that can be powered by photovoltaic cell with maximum power point tracking function with few external components.

The CN3796 is specially designed for charging single-cell lithium ion battery with constant current and constant voltage mode. In constant voltage mode, the regulation voltage is fixed at 4.2V with ±1% accuracy. The constant charge current is set with an external current sense resistor.

Deeply discharged batteries are automatically trickle charged until the cell voltage exceeds 58.3% of the regulation voltage. The charge cycle is terminated once the charge current drops to 21% of full-scale current, and a new charge cycle automatically restarts if the battery voltage falls below 95.8% of regulation voltage. CN3796 will automatically enter sleep mode when input voltage is lower than battery voltage.

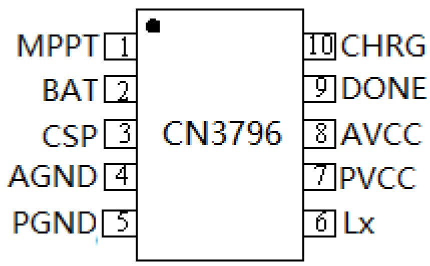
Other features include short battery protection, battery over voltage protection, over temperature protection and 2 status indications, etc..

CN3796 is available in thermally-enhanced 10-pin SSOP package.

Features:

- Photovoltaic Cell Maximum Power Point Tracking
- Input Voltage Range: 4.5V to 6.5V
- Complete Charger IC for single-cell Li-ion and Li-Polymer Battery
- Charge Current Up to 2A
- PFM Operation Mode
- Regulation Voltage: 4.2V±1%
- Charge Current is set with an External Current Sense Resistor
- Automatic Charge Current Adjustment according to Loading Capability of Input Supply
- Automatic Conditioning of Deeply Discharged Batteries
- Automatic Recharge
- Short Battery Protection
- 2 Charging Status Indications
- Battery Overvoltage Protection
- Over Temperature Protection
- Operating Ambient Temperature −40℃ to +85℃
- Available in 10 Pin SSOP Package
- Pb-free, Rohs-Compliant, Halogen Free

Pin Assignment:



Applications:

- Power Bank
- Hand-held Equipment
- E-Cigarette
- Portable Industrial and Medical Equipment
- Standalone Battery Chargers

Typical Application Circuit:

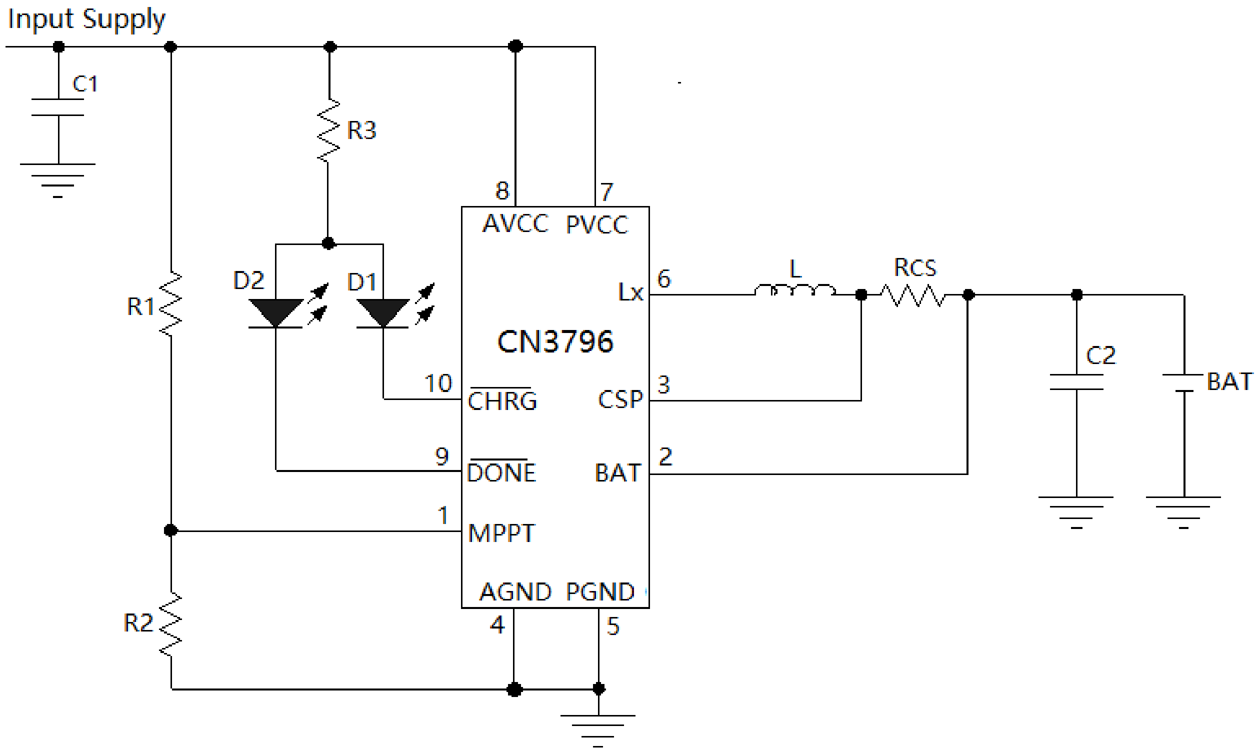


Figure 1 Typical Application Circuit

Ordering Information:

Part No.	Shipment	Operating Ambient Temperature
CN3796	Tape and Reel, 4000/Reel	－40℃ to ＋85℃

Pin Description:

Pin No.	Name	Descriptions
1	MPPT	**Photovoltaic Cell Maximum Power Point Tracking Pin.** Connect this pin to the external resistor divider for maximum power point tracking. In maximum power point tracking status, the MPPT pin's voltage is regulated to 1.205V.
2	BAT	**Positive Terminal of Battery.** Battery voltage is sensed through BAT pin, This pin is also the negative input for charge current Sensing. This pin and the CSP pin measure the voltage drop across the current sense resistor R_{CS} to provide the current signals required.
3	CSP	**Positive Input for Charge Current Sensing.** This pin and the BAT pin measure the voltage drop across the current sense resistor R_{CS} to provide the current signals required.
4	AGND	**Analog Ground.** This pin is the ground for the internal circuits except low-side power switch. Always connect AGND and PGND together in PC board.
5	PGND	**Power Ground.** PGND is connected to the low-side switch internally. The charge current flows into CN3796 from this pin during the on-time of low-side switch. Always connect PGND and AGND together in PC board.
6	Lx	**Inductor Connection Terminal.** This pin should be connected to inductor. The charge current flows out of CN3796 from this pin. Internally a high-side switch is placed between PVCC pin and Lx pin; A low-side switch is placed between Lx pin and PGND pin.
7	PVCC	**Power DC Power Supply Input.** PVCC is connected to the high-side power switch internally. The charge current flows into CN3796 during the period of on-time of high-side switch. Connect at least a 10uF ceramic capacitor from PVCC to PGND and place the capacitor as close as possible to CN3796.
8	AVCC	**Analog DC Power Supply Input.** AVCC is the power supply for internal circuit. Bypass this pin with capacitor.
9	$\overline{DONE}$	**Open-Drain Charge Termination Output.** When the charging is terminated, this pin is pulled low by an internal switch. Otherwise this pin is in high impedance state.
10	$\overline{CHRG}$	**Open-Drain Charge Status Output.** When the battery is being charged, this pin is pulled low by an internal switch. Otherwise this pin is in high impedance state.
11	Exposed PAD	**Thermal PAD beneath the IC.** Always solder the thermal PAD on the backside of the IC to ground in PC board.

Absolute Maximum Ratings

AVCC and PVCC Voltage…..………－0.3V to 6.5V
MPPT, BAT and CSP…..…. －0.3V to AVCC+0.3V
Lx…………………………. －0.3V to PVCC+0.3V
$\overline{CHRG}$ and $\overline{DONE}$…………………. －0.3V to 6.5V

Storage Temperature…............－65℃ to 150℃
Operating Temperature………....－40℃ to 85℃
Lead Temperature(Soldering, 10s)…….....260℃
Thermal Resistance (eSSOP10)…………….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.

Electrical Characteristics:

(V_{AVCC}＝5V, V_{PVCC}＝5V, T_A＝－40℃ to 85℃, unless otherwise noted)

Parameters	Symbol	Conditions	Min	Typ	Max	Unit
Input Voltage Range	VCC		4.5		6.5	V
Under voltage lockout Threshold	V_{UVLO}		2.9	3.2	3.5	V
Operating Current	I_{VCC}	No switching	280	350	420	uA
Regulation Voltage	V_{REG}	Constant voltage mode	4.165	4.2	4.247	V
Constant Current Sense	V_{CS}	V_{BAT}＞V_{PRE}, V_{CSP}－V_{BAT}	85	95	105	mV
Short Battery Current	I_{SRT}	V_{BAT}＝0.5V, Short battery	35	65	95	mA
Precharge Current	I_{PRE}	0.9V<V_{BAT}<V_{PRE}, Precharge	100	150	200	
Current Consumption from BAT pin		Termination, V_{BAT}＝4.2V	5	9	13	uA
	I_{SLP}	Sleep mode, V_{BAT}＝4.2V	0.8	1.2	1.6	
Precharge Threshold	V_{PRE}	V_{BAT} rises	55.6	58.3	61	%V_{REG}
Precharge Threshold Hysteresis	H_{PRE}	V_{BAT} falls		5.7		%V_{REG}
Charge Termination Threshold	I_{term}	Charge current decreases	14	21	28	%I_{CC}
Recharge Threshold	V_{RE}	V_{BAT} falls		95.8		%V_{REG}
Short Battery Threshold	V_{SRT}		0.5	0.9	1.3	V
Overvoltage Trip Level	Vov	V_{BAT} rises	1.03	1.06	1.1	V_{REG}
Overvoltage Clear Level	Vclr	V_{BAT} falls	1.0	1.02	1.04	
Over Temperature Threshold		Chip temperature rises		150		℃
Over Temperature Release Threshold		Chip temperature falls		130		
MPPT Pin						
MPPT Regulation Voltage	V_{MPPT}	Maximum power point track	1.18	1.205	1.23	V
MPPT Pin Bias Current	I_{MPPT}		－50	0	＋50	nA
$\overline{CHRG}$ Pin						
$\overline{CHRG}$ Pin Sink Current	I_{CHRG}	V_{CHRG}＝1V, charge mode	7	12	18	mA
$\overline{CHRG}$ Leakage Current	I_{LK1}	V_{CHRG}＝6.5V,termination mode			1	uA
$\overline{DONE}$ Pin						
$\overline{DONE}$ Sink Current	I_{DONE}	V_{DONE}＝1V, termination mode	7	12	18	mA
$\overline{DONE}$ Leakage Current	I_{LK2}	V_{DONE}＝6.5V, charge mode			1	uA
Sleep Mode						
Sleep Mode Threshold	V_{SLP}	AVCC falls, V_{BAT}＝3.7V, measure V_{AVCC}－V_{BAT}	0.01	0.03	0.05	V
Sleep mode Release Threshold	V_{SLPR}	AVCC rises, V_{BAT}＝3.7V, measure V_{AVCC}－V_{BAT}	0.04	0.075	0.11	V

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

Detailed Description:

The CN3796 is a highly-integrated constant current, constant voltage single-cell Li-ion and Li-polymer battery charger IC that can be powered by the photovoltaic cell with maximum power point tracking function, the device adopts PFM step-down (buck) switching architecture. The charge current is set by an external current sense resistor (R_{CS}) between CSP and BAT pins. The final battery regulation voltage in constant voltage mode is set at 4.2V typical with 1% accuracy.

A charge cycle begins when the voltage at the AVCC pin meets the following 3 conditions:

- V_{AVCC} rises above V_{UVLO}
- V_{AVCC} is higher than battery voltage by V_{SLPR}
- V_{AVCC} is no less than 4.5V

At the beginning of the charge cycle, if the battery voltage is less than 58.3% of regulation voltage (V_{REG}), the charger goes into trickle charge mode. The trickle charge current is internally set to150mA, and will be further reduced to 65mA if battery voltage is below 0.9V typical, which is considered as short battery. When the battery voltage exceeds 58.3% 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 current sense resistor R_{CS} and an internal 95mV reference, hence the charge current equals to 95mV/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 21% of the full-scale current, the charge cycle is terminated, and the internal pull-down N-channel MOSFET at the $\overline{CHRG}$ pin is turned off, another internal pull-down N-channel MOSFET at the $\overline{DONE}$ pin is turned on to indicate the termination status.

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

The CN3796 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 solar panel.

When the input voltage is not present, the charger automatically enters sleep mode, CN3796 is shutdown.

To prevent the chip from being damaged by thermal run-away, over temperature protection is included. If the junction temperature is over 150℃, the internal power switches are turned off, no current flows to battery. The over temperature protection mode will not be released until the junction temperature falls below 130℃.

An overvoltage protection guards against battery voltage transient overshoot(V_{BAT}>1.06*V_{REG}). In this case, the internal high-side switch is turned off until the over-voltage condition is cleared. This feature is useful for battery load dump or sudden removal of battery.

The charging profile is shown in Figure 2.

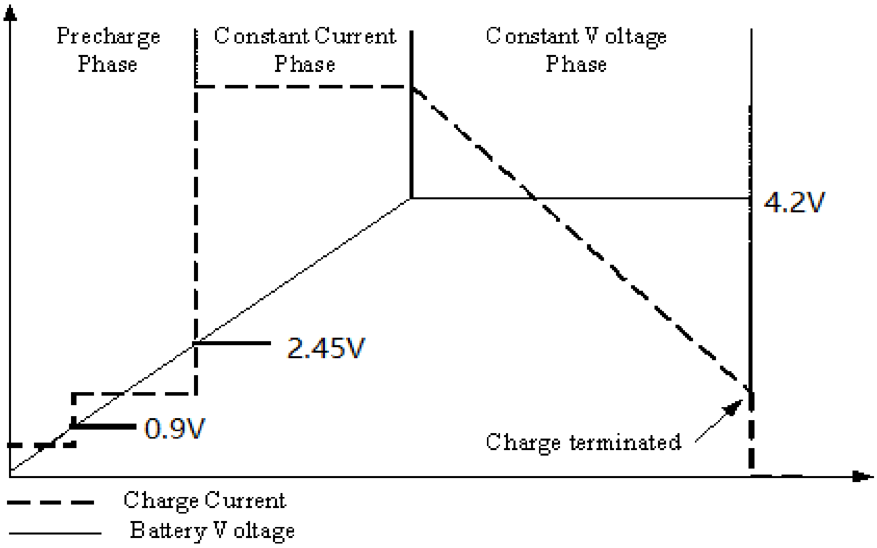


Figure 2 The Charging Profile

Application Information

Under voltage Lockout (UVLO)

An under voltage lockout circuit monitors the input voltage and keeps the CN3796 off if AVCC is below 3.5V. However a charge cycle will not be started unless the following 3 conditions are met simultaneously:

- V_{AVCC} rises above V_{UVLO}
- V_{AVCC} is higher than battery voltage by V_{SLPR}
- V_{AVCC} is no less than 4.5V

Short Battery Protection

When the battery voltage is below short battery threshold (V_{SRT}), it is considered as the short battery condition, and the charge current is reduced to about 65mA as a kind of protection mechanism for battery.

Trickle Charge Mode (Precharge Mode)

At the beginning of a charge cycle, if the battery voltage is between short battery threshold (V_{SRT}) and 58.3% of the regulation voltage, the charger goes into trickle charge mode with the charge current set at about 150mA.

Charge Current Setting

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

$$I_{CH} = \frac{95mV}{R_{CS}}$$

Where:

I_{CH} is the full scale charge current

R_{CS} is the current sense resistor between CSP pin and BAT pin

Automatic Charge Current Adjustment

If the loading capability of input power supply is less than the charge current set by current sense resistor R_{CS}, then the on-chip adaptive cell will begin to function to reduce the charge current based on the loading capability of input power supply. In this case, the charge current is maximized to the loading capability of input power supply, the voltage at AVCC pin is regulated at 4.5V maximum, which is the minimum operating voltage of CN3796. So the charge current can be set according to the maximum loading capability of input power supply, not the worst case.

The Maximum Power Point Tracking (MPPT)

CN3796 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.

CN3796's MPPT pin voltage is regulated to 1.205V to track the maximum power point working with the off-chip resistor divider (R1 and R2 in Figure 1).

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

$$V_{MPP}=1.205\times(1+R1/R2)$$

If photovoltaic cell is not used, connect MPPT pin to GND directly or through a pull-down resistor.

After maximum power point is set by the resistors at MPPT pin, in addition to photovoltaic cell, a DC power supply such as wall adaptor can still be used as the input power supply to CN3796, the DC power supply's voltage can either be higher than the maximum power point voltage set by the resistor at MPPT pin or be lower than 97.5% of the maximum power point voltage, namely do NOT apply a DC voltage on AVCC pin between 97.5% and 100% of the maximum power point voltage set by resistors at MPPT pin, otherwise there may be no charge current.

Charge Termination

In constant voltage mode, the charge current decreases gradually. When the charge current decreases to 21% of the full-scale current, the charging is terminated, the high-side switch is turned off, no charge current is delivered to battery any more.

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 drops below 95.8% of the regulation voltage due to self-discharge or external loading. This will keep the battery capacity at more than 80% at all times without manually restarting the charge cycle.

Battery Over-Voltage Protection

The CN3796 will turn off the high-side switch if the battery voltage rises above 106% of the regulation voltage, and the high-side switch will not be allowed to turn-on again until the battery voltage goes below 102% of the regulation voltage. This allows one-cycle response to an over-voltage condition which often occurs when the load is removed or the battery is disconnected suddenly.

Over-Temperature Protection

The CN3796 continuously monitor its junction temperature during charging process. If the junction temperature is over 150℃, the on-chip high-side switch is turned off, and no current flows to battery. The high-side switch will not be allowed to turn on again until the junction temperature falls below 130℃.

Sleep Mode

If the voltage at AVCC pin drops below $V_{BAT}+V_{SLP}$, the CN3796 will enter sleep mode. In sleep mode, the whole chip is shut down, the current consumption from battery is only 1.2uA (Typical). The CN3796 will not come out of sleep mode until the voltage at AVCC pin rises above $V_{BAT}+V_{SLPR}$.

Status Indication

The CN3796 has 2 open-drain status outputs: $\overline{CHRG}$ and $\overline{DONE}$. $\overline{CHRG}$ pin is pulled low when the charger is in charging status, otherwise $\overline{CHRG}$ becomes high impedance. $\overline{DONE}$ pin is pulled low if the charger is in termination status, otherwise $\overline{DONE}$ becomes high impedance.

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

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

The table 1 lists the two 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	State Description
Low(Red LED on)	High Impedance(Green LED off)	Charging
High Impedance(Red LED off)	Low(Green LED on)	Charge termination
Pulse (Red LED looks like being off)	Pulse (Green LED on or blinking)	Battery not present
High Impedance(Red LED off)	High Impedance(Green LED off)	There are 2 possible reasons: ● the voltage at the VCC pin below 4.5V or ● the voltage at the VCC pin below V_{BAT}

Table 1 Indication Status

Battery Detection

CN3796 does not provide battery detection function, when the battery is not present, the charger charges the output capacitor to the regulation voltage or to over voltage threshold quickly depending on the output capacitance, then the BAT pin's voltage decays slowly to recharge threshold because of low leakage current at BAT pin, which results in a ripple waveform at BAT pin.

It is generally not a good practice to connect a battery while the charger is running, otherwise the charger may be in uncertain state, or deliver a large surge current into the battery for a brief time.

Input Capacitor

Since the input capacitor (C1 in Figure 1) is 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 output charge current.

The input capacitance depends on input supply's characteristics and cable length, etc. Generally a 10uF to 22uF ceramic capacitor can meet the requirements. Cares must be taken that some ceramic capacitors exhibit large voltage coefficient, which may lead to lower capacitance when a DC voltage is applied. In this case, the capacitor value should be increased properly, and the capacitor's package should be 0805 at least.

If electrolytic capacitor is used, then a ceramic capacitor of 1uF to 10uF should be placed in parallel with the electrolytic capacitor to filter out the high-frequency noise.

Output Capacitor

The selection of output capacitor (C2 in Figure 1) is primarily determined by the ESR required to minimize ripple voltage and load step transients. A low-ESR ceramic capacitor of 10uF to 22uF should be used as the output capacitor.

Cares must be taken that some ceramic capacitors exhibit large voltage coefficient, which may lead to lower capacitance when a DC voltage is applied. In this case, the capacitor value should be increased properly, and the capacitor's package should be 0805 at least.

If electrolytic capacitor is used, then a ceramic capacitor of 1uF to 10uF should be placed in parallel with the electrolytic capacitor to filter out the high-frequency noise.

Inductor Selection

For less electrical and magnetic radiation, the inductor's selection should make sure the inductor operates in continuous conduction mode (CCM), even in constant voltage mode, in which the charge current may be down to 20% of full-scale charge current.

The recommended inductor values under different charge current are listed in Table 2.

Charge Current	Recommended Inductor Value
2A	4.7uH to 10uH
1.5A	6.8uH to 15uH
1A	10uH to 22uH
0.75A	22uH to 33uH
0.5A	22uH to 47uH

Table 2 Inductor Value Versus Charge Current

If photovoltaic cell is used, the charge current may be much lower than full-scale charge current, the inductor value should be increased properly.

Hot Plug-in Consideration

During adapter hot plug-in, the parasitic inductance from the adapter cable and the input capacitor form a second order system. The transient voltage spike at the AVCC pin may be beyond the IC maximum voltage rating and damage the IC.

There are several methods to damping or limiting the over-voltage spike during adapter hot plug-in. An electrolytic capacitor with high ESR as an input capacitor can damp the over-voltage spike well. A high current capability TVS Zener diode can also limit the over-voltage level to an IC safe level. However, these two solutions may not be lowest cost or smallest size.

A cost-effective and small-size solution is shown in Figure 3, in which R1 and C1 forms a low-pass filter to limit the transient voltage spike. R1 can be from 20 ohm to 51 ohm, C1 is ceramic capacitor from 1uF to 10uF.

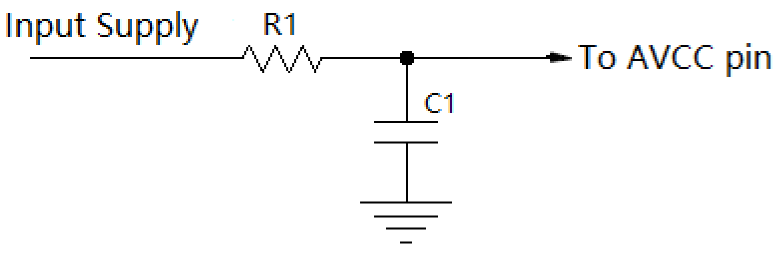


Figure 3 Low-pass Filter to Limit the Transient Voltage Spike

PCB Layout Considerations

When laying out the printed circuit board, the following considerations should be taken to ensure proper operation of the IC.

(1) Place input capacitor as close as possible to the PVCC supply and PGND connections and use the shortest copper trace connection.

(2) Connect AGND and PGND pin together and return to system ground with a generous amount of copper that is wide enough for the given charge current.

(3) The input capacitor, inductor and output capacitor should be placed on the same layer of the PCB instead of on different layers and using vias to make this connection.

(4) Place the inductor input terminal as close as possible to the Lx pin. Minimize the copper area of this trace to lower electrical and magnetic field radiation, but make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.

(5) Place output capacitor next to the current sense resistor.

(6) Output capacitor ground connections need to be tied to the same copper that connects to the input

capacitor ground and CN3796 PGND pin before connecting to system ground.

(7) It is critical that the exposed thermal pad on the backside of the IC package be soldered to the PCB ground. Ensure that there are sufficient thermal vias directly under the IC, connecting to the ground plane on the other layers.

(8) Place the current sense resistor R_{CS} right next to the inductor output but oriented such that the IC's CSP and BAT traces going to R_{CS} are not long. The 2 traces need to be routed together as a single pair on the same layer at any given time with smallest trace spacing possible.

(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 4 as an example.

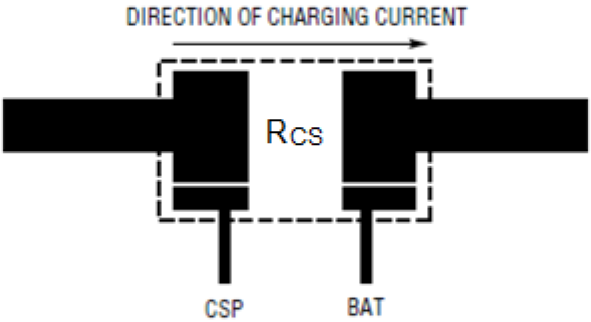
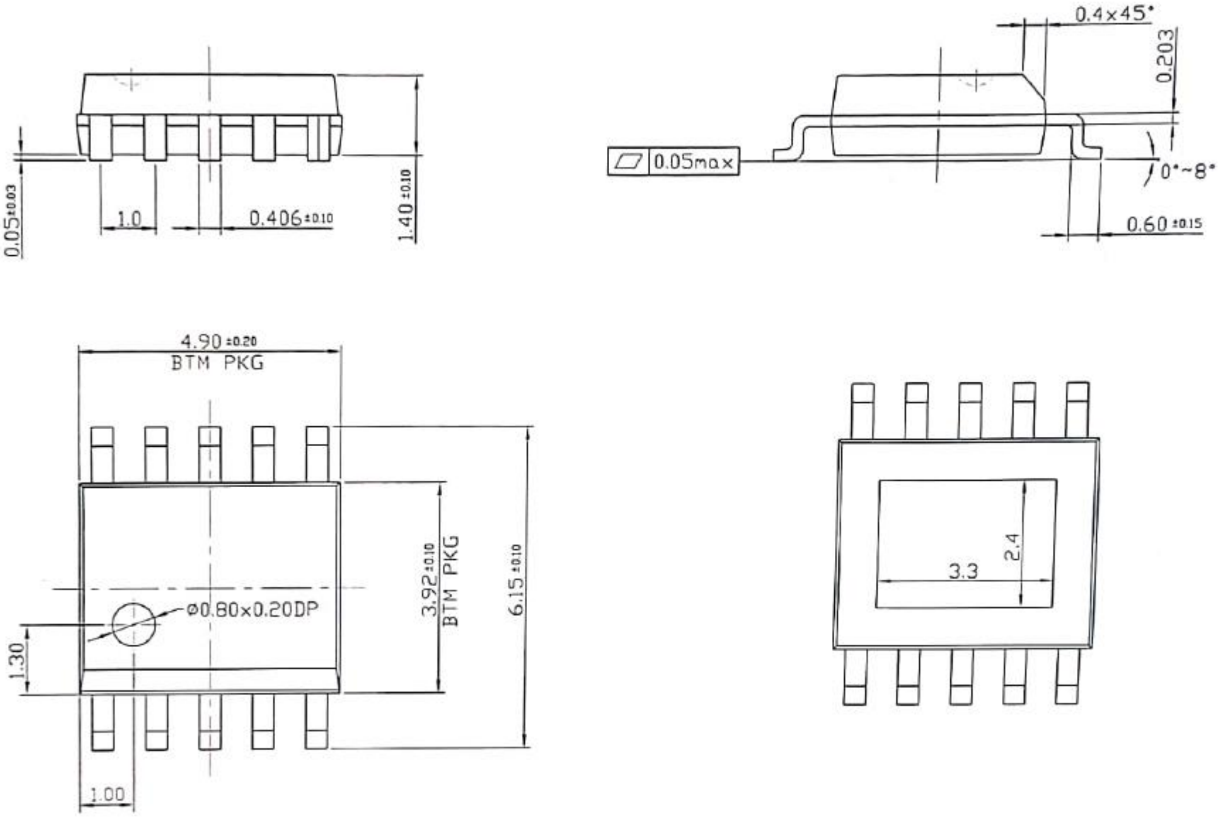


Figure 4　Kelvin Sensing of Charge Current

Package Information



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