

## PFM Switch-mode Step-up Battery Charger IC CN3301

### General Descriptions:

CN3301 is a PFM mode step-up battery charging controller IC with operating voltage range between 4.5V to 32V. CN3301 adopts trickle, constant current(CC) and quasi-constant voltage(Quasi-CV™) mode to charge battery, very suitable for Lithium, LiFePO4 and Lead-acid battery charging with fewer external components.

On power up, CN3301 enters charging mode, the external N-channel MOSFET is turned on, inductor current rises. When inductor current reaches upper limit, the N-channel MOSFET is turned off, inductor is discharged, the energy stored in inductor is transferred to battery. When the inductor current is discharged to its lower limit, the N-channel MOSFET is turned on again, and so forth. When FB pin voltage reaches 1.205V(Typ.) for the first time, CN3301 enters quasi-CV mode, in which the charge current is reduced. The charge process will not be terminated until FB voltage reaches 1.205V for the second time. In termination mode, the N-channel MOSFET is turned off. If FB voltage falls below recharge threshold, CN3301 enters charge mode again. CN3301's switching frequency can be up to 1MHz, which makes a small-profile inductor usable. The other features include solar panel's maximum power point tracking, JEITA-compliant battery temperature monitoring, chip over temperature protection and status indication, etc. CN3301 is available in 10-pin SSOP package.

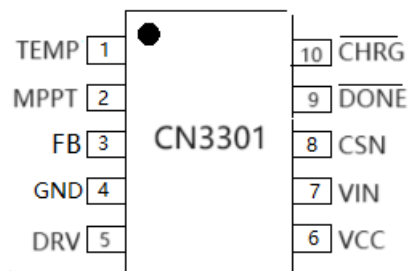
### Applications:

- Standalone Multi-cell Battery Charger
- Charging Management for Lithium, LiFePO4, Lead-acid Batteries
- Electrical Appliance
- Audio Systems
- E-bike, etc.

### Features:

- Input Voltage Range: 4.5V to 32V
- Maximum Power Point Tracking for Solar Panel
- Operating Current: 380uA@VIN=12V
- Inductor Current Sensing
- Switching Frequency: up to 1MHz
- Quasi-CV Mode to Compensate for Voltage Loss on Parasitic Resistance
- Trickle, Constant Current and Quasi-CV Charge Mode
- Automatic Recharge
- JEITA-Compliant Battery Temperature Monitoring
- Battery Over-voltage Protection
- Over Junction-temperature Protection
- 2 Open-drain Indication Outputs
- Operating Temperature Range: -40°C to 85°C
- Available in SSOP10 Package
- Lead-free, rohs-Compliant and Halogen Free

### Pin Assignment:



**Note:** Quasi-CV is the trade mark of Consonance Electronics

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## Typical Application Circuit

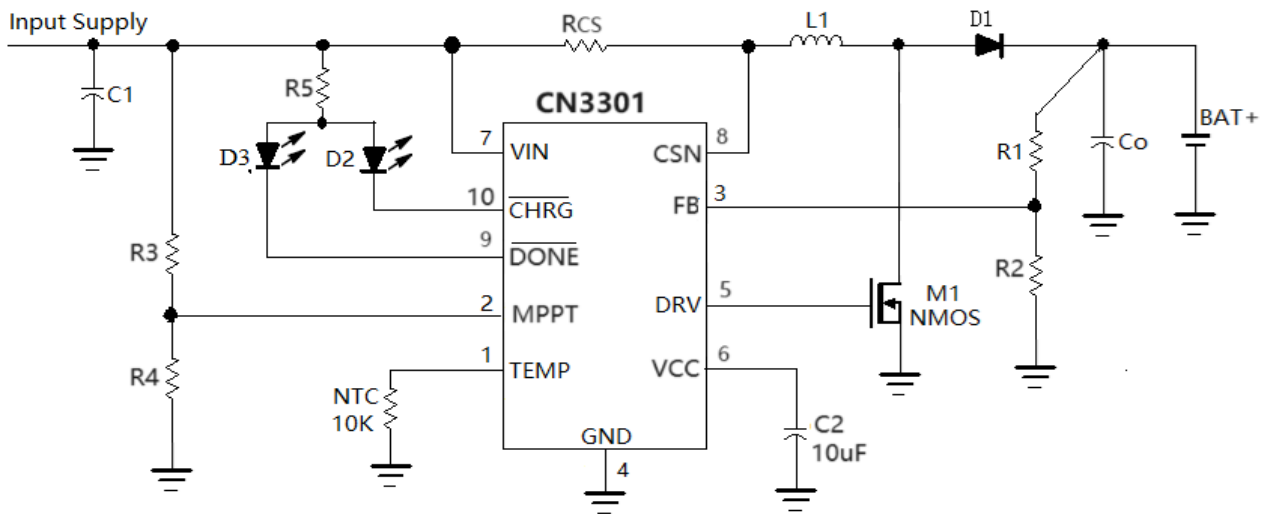


Figure 1 Typical Application Circuit

### Ordering Information:

Part No.	Package	Top Marking	Shipping	Operating Temp
CN3301	SSOP-10	CN3301	Tape & Reel, 4000/Reel	-40°C to 85°C

### Block Diagram

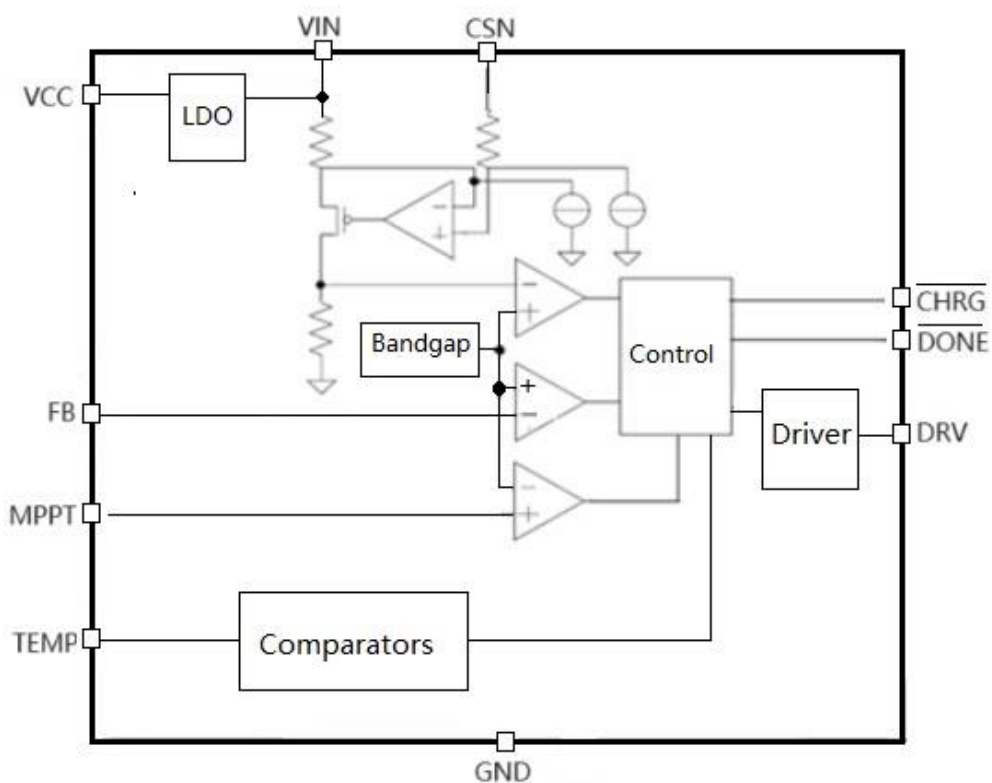


Figure 2 Block Diagram

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## Pin Description:

No.	Name	Description
1	TEMP	<p><b>Battery Temperature Monitoring Input.</b> Connecting a 10K<math>\Omega</math> NTC thermistor between TEMP pin and GND.</p> <ul style="list-style-type: none"> <li>● 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.</li> <li>● If TEMP's voltage is between 0.1V and 0.135V, which means battery is warm, charge current is reduced to 50% of full-scale current and termination voltage is reduced to 97.91%*V<sub>term</sub></li> <li>● If TEMP's voltage is between 0.135V and 0.55V, CN3301 functions normally.</li> <li>● If TEMP's voltage is between 0.55V and 0.85V, which means battery is cool, charge current is reduced to 33% of constant current.</li> </ul> <p>If battery temperature monitoring function is not needed, connect a fixed 10K ohm resistor from TEMP pin to GND.</p>
2	MPPT	<p><b>Solar Panel Maximum Power Point Tracking Pin.</b> Connect this 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.</p>
3	FB	<p><b>Battery Voltage Feedback Input.</b> Generally this pin is connected to the external feedback resistor divider to sense the battery voltage, CN3301 determines charger status based on FB pin voltage.</p>
4	GND	<p><b>Ground.</b> The negative terminal of input power supply and battery.</p>
5	DRV	<p><b>Gate Drive Output.</b> Connect this pin to the gate of external N-channel MOSFET.</p>
6	VCC	<p><b>5V Voltage Regulator (LDO) Output.</b> Connect a 10uF capacitor from VCC to GND, the maximum output current is 15mA. The 5V voltage can be used to power the external circuitry.</p>
7	VIN	<p><b>The Positive Terminal of Input Supply.</b> In addition to power the internal circuits, VIN pin also serves as the positive terminal of current sense.</p>
8	CSN	<p><b>Negative Terminal of Inductor Current Sensing.</b> A current sense resistor R<sub>CS</sub> between VIN pin and CSN pin is used to sense inductor current, also the input current.</p>
9	$\overline{\text{DONE}}$	<p><b>Open Drain Termination Output.</b> When charging is terminated, the <math>\overline{\text{DONE}}</math> pin is pulled low by an internal switch, otherwise <math>\overline{\text{DONE}}</math> pin is in high impedance state.</p>
10	$\overline{\text{CHRG}}$	<p><b>Open Drain Charge Status Output.</b> When the battery is being charged, the <math>\overline{\text{CHRG}}</math> pin is pulled low by an internal switch, otherwise <math>\overline{\text{CHRG}}</math> pin is in high impedance state.</p>

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## ABSOLUTE MAXIMUM RATINGS

VIN Voltage.....	-0.3V to 36V	Maximum Junction Temperature.....	150°C
MPPT, FB and DRV Voltage.....	-0.3V to VCC	Operating Temperature Range.....	-40°C to 85°C
VIN-V <sub>CSN</sub> Voltage.....	-0.3V to 0.3V	Storage Temperature.....	-65°C to 150°C
TEMP, VCC Voltage.....	-0.3V to 6.5V	Lead Temperature(Soldering,10s).....	260°C
CHRG, DONE Voltage.....	-0.3V to VIN		

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.

## ELECTRICAL CHARACTERICS:

(VIN = 12V, TA = -40°C to +85°C, Typical values are at TA = +25°C, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage	VIN		4.5		32	V
Operating Current	IVIN	VIN=V <sub>CSN</sub>	300	380	500	uA
Switching Frequency	f <sub>SW</sub>		200		1000	KHz
FB Pin Bias Current	I <sub>FB</sub>	V <sub>FB</sub> =5V	-100	0	100	nA
<b>Inductor Current (Input Current) Sensing</b>						
Upper Limit of Inductor Current Measure (VIN-V <sub>CSN</sub> )	V <sub>CSHI</sub>	CC mode	90	100	110	mV
		CC mode, Battery warm	43	50	57	
		Trickle, Quasi-CV, Battery cold	28	33	38	
Lower Limit of Inductor Current Measure (VIN-V <sub>CSN</sub> )	V <sub>CSLO</sub>	CC mode	67	75	83	mV
		CC mode, Battery warm	30	37	44	
		Trickle, Quasi-CV, Battery cold	20	25	30	
Propagation Delay For DRV Assertion	t <sub>DPDH</sub>	(VIN-V <sub>CSN</sub> ): 0.13V到0.065V		95		ns
Propagation Delay for DRV De-assertion	t <sub>DPDL</sub>	(VIN-V <sub>CSN</sub> ): 0.07V到0.13V		91		ns
<b>VCC Pin</b>						
Output Voltage	VCC	I <sub>VCC</sub> =0.1mA to 15mA, VIN=5.5V to 30V	4.7		5.3	V
Load Regulation		I <sub>VCC</sub> =0.1mA to 10mA,		5		Ohm
Line Regulation		VIN=6Vto 32V, I <sub>VCC</sub> =3mA		6		mV
Power Supply Rejection Ratio	PSRR	I <sub>VCC</sub> =3mA, f <sub>IN</sub> =10kHz		-35		dB
Start Time	t <sub>START</sub>	VCC=0 to 4.5V		1		ms
<b>Solar Panel Maximum Power Point Tracking (MPPT Pin)</b>						
Regulation Voltage	V <sub>MPPT</sub>	MPP tracking mode	1.18	1.205	1.23	V
MPPT Bias Current		V <sub>MPPT</sub> =5V			100	nA
		V <sub>MPPT</sub> =0V	-100			

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Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Charge Termination (FB Pin)</b>						
Charge Termination Threshold	$V_{term}$	FB voltage rises	1.193	1.205	1.217	V
		FB voltage rises, Battery warm	1.16	1.175	1.19	
<b>Recharge (FB Pin)</b>						
Recharge Threshold	$V_{rech}$	FB voltage falls	1.127	1.15	1.173	V
		FB voltage falls, Battery warm	1.078	1.1	1.122	
<b>Trickle Charge (FB Pin)</b>						
Trickle to CC Threshold	$V_{trickleH}$	FB voltage rises	675	700	725	mV
CC to Trickle Threshold	$V_{trickleL}$	FB voltage falls	650	680	710	
<b>Battery Over-voltage Protection (FB Pin)</b>						
Over-voltage Protection Threshold	$V_{OVP}$	FB voltage rises	1.26	1.285	1.31	V
Over-voltage Protection Release Threshold	$V_{OVRLS}$	FB voltage falls	1.215	1.235	1.255	
<b>Over Junction-Temperature Protection (OTP)</b>						
OTP Threshold	$T_{OTP}$	Junction temperature rises		145		°C
OTP Release Threshold	$T_{RLS}$	Junction temperature falls		128		°C
<b>DRV Pin</b>						
DRV Source Current	$I_{SRC}$	$V_{CSN}=VIN, V_{DRV}=0.5 \times VCC$		0.65		A
DRV Sink Current	$I_{SINK}$	$V_{CSN}=VIN-0.2V, V_{DRV}=0.5 \times VCC$		0.65		
DRV Output High	$V_{OH}$	$I_{DRV}=5mA$	$VCC-0.3$			V
DRV Output Low	$V_{OL}$	$I_{DRV}=-5mA$				0.3 V
<b><math>\overline{CHRG}</math> Pin</b>						
$\overline{CHRG}$ Sink Current	$I_{CHRG}$	$V_{CHRG}=1V$ , Charge mode	7	12	18	mA
$\overline{CHRG}$ Leakage Current	$I_{LK1}$	$V_{CHRG}=30V$ , Termination mode				1 uA
<b><math>\overline{DONE}</math> Pin</b>						
$\overline{DONE}$ Sink Current	$I_{DONE}$	$V_{DONE}=1V$ , Termination mode	7	12	18	mA
$\overline{DONE}$ Leakage Current	$I_{LK2}$	$V_{DONE}=30V$ , Charge mode				1 uA
<b>TEMP Pin</b>						
TEMP Pin Current	$I_{TEMP}$		27	30	33	uA
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	
Cool Threshold	$V_{COOL}$	$V_{TEMP}$ rises, normal to cool	510	550	590	
Cool Release Threshold	$V_{COOLR}$	$V_{TEMP}$ falls, cool to normal	465	505	545	
Warm Threshold	$V_{WARM}$	$V_{TEMP}$ falls, normal to warm	120	135	150	
Warm Release Threshold	$V_{WARMR}$	$V_{TEMP}$ rises, warm to normal	138	155	172	
Hot Threshold	$V_{HOT}$	$V_{TEMP}$ falls, warm to hot	85	100	115	
Hot Release Threshold	$V_{HOTR}$	$V_{TEMP}$ rises, hot to warm	105	120	135	

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## Detailed Descriptions:

CN3301 is a PFM mode step-up battery charge controller IC with operating voltage range between 4.5V to 32V. CN3301 consists of circuit blocks such as voltage reference, inductor current sensing, over voltage protection, over junction-temperature protection, MPPT, control and gate driver, etc., and adopts trickle, constant current (CC) and quasi-constant voltage(Quasi-CV™) modes to charge battery, which make CN3301 very suitable for Lithium, LiFePO4 and Lead-acid batteries charging management with fewer external components.

Since there is an on-chip maximum power point tracking circuit, solar panel can be used to power CN3301.

On power up, CN3301 enters charging mode, the external N-channel MOSFET is turned on, inductor current rises. When inductor current reaches upper limit, the N-channel MOSFET is turned off, inductor is discharged, the energy stored in inductor is transferred to battery. When the inductor current is discharged to its lower limit, the N-channel MOSFET is turned on again, and so forth.

In charging mode, if the voltage at FB pin is below 0.7V(Typical), CN3301 is in trickle charge mode, in which the charge current is 33% of that in constant current mode; If FB voltage is between 0.7V and 1.205V, CN3301 is in constant current mode. When FB voltage reaches 1.205V(Typ.) for the first time, CN3301 enters quasi-CV mode, in which the charge current is reduced. The charge process will not be terminated until FB voltage reaches 1.205V for the second time.

In termination mode, the N-channel MOSFET is turned off, no current flows to battery. If FB voltage falls below recharge threshold (1.15V typical), the CN3301 enters charge mode again.

CN3301's switching frequency can be up to 1MHz, which makes a small-profile inductor usable.

The CN3301 has 2 open-drain status outputs:  $\overline{\text{CHRG}}$  and  $\overline{\text{DONE}}$ .  $\overline{\text{CHRG}}$  pin is pulled low when the charger is in charging mode, otherwise  $\overline{\text{CHRG}}$  becomes high impedance.  $\overline{\text{DONE}}$  pin is pulled low if the charger is in termination mode, otherwise  $\overline{\text{DONE}}$  becomes high impedance.

The other features include JEITA-compliant battery temperature monitoring, chip over temperature protection and battery over voltage protection, etc.

Charging profile is shown in Figure 3.

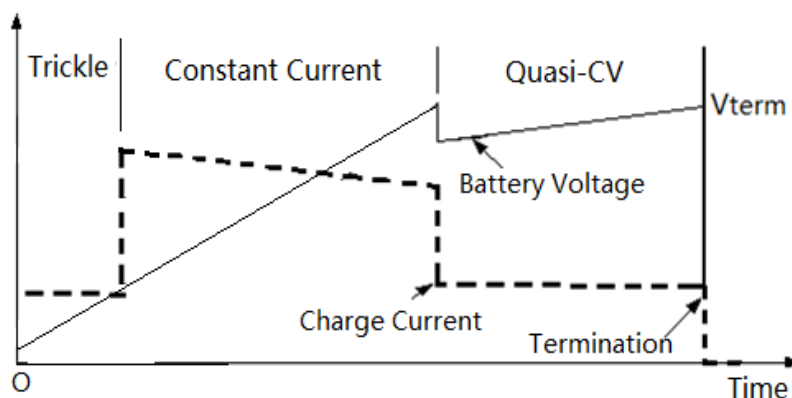


Figure 3 Charging Profile

# CONSONANCE

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## Application Information:

### Input Voltage Range

The CN3301 functions well when the input voltage is between 4.5V to 32V. On-chip UVLO circuit will shut down the CN3301 if input voltage falls below UVLO threshold (4.3V Max.).

### +5V Voltage Regulator (VCC Pin)

VCC is the output of an on-chip 5V voltage regulator (LDO) capable of sourcing 15mA, which can be used to power external circuitry. Always bypass VCC to GND with a 10µF ceramic capacitor.

The 5V voltage regulator will be shut down in junction over temperature protection mode.

### About Quasi-CV Mode

If the voltage at FB pin is lower than 1.205V (Typical), CN3301 charges the battery in constant current mode. When FB voltage reaches 1.205V for the first time, CN3301 enters quasi-CV mode, the charge current is reduced to 33% of that in constant current mode. When FB voltage reaches 1.205V in quasi-CV mode, CN3301 terminates the charging after deglitching. The quasi-CV mode can compensate for the voltage drop across the battery internal resistance to some extent, which is similar to constant voltage mode, this is why the quasi-CV is named.

### Charge Termination Voltage

In the application circuit shown in Figure 1, when the voltage at FB reaches 1.205V in quasi-CV mode, CN3301 enters charge termination mode, the corresponding voltage at battery positive terminal is decided by the following formular:

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

### Trickle Charge and Constant Current Charge Mode

In charge mode, if the voltage at FB pin rises above 0.7V, CN3301 enters constant current mode; If the voltage at FB pin falls below 0.68V, CN3301 enters trickle charge mode, in which the charge current is 33% of the current in constant current mode.

If the voltage is between 0.7V and 1.205V, CN3301 is in constant current mode.

### Charge Termination

In quasi-CV charge mode, if the voltage at FB pin reaches charge termination threshold  $V_{term}$  (1.205V typical), charging is terminated, CN3301 is in termination mode, the external N-channel MOSFET is turned off, no current flows to battery.

If battery temperature is in warm range, the charge termination threshold  $V_{term}$  is 1.175V(Typical).

### Recharge

In charge termination mode, if the voltage at FB pin falls below recharge threshold  $V_{rech}$  (1.15V typical), CN3301 enters charge mode again.

If battery temperature is in warm range, the recharge threshold  $V_{rech}$  is 1.1V (Typical)

### The Maximum Power Point Tracking

CN3301 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.

CN3301 MPPT pin's voltage is regulated to 1.205V to track the maximum power point working with the off-chip resistor divider (R3 and R4 in Figure 1).

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

$$V_{MPPT} = 1.205 \times (1 + R3 / R4)$$

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## Inductor Current (Input Current)

In the application circuit shown in Figure 1, CN3301 sets the inductor current through a current sense resistor  $R_{CS}$  connected between VIN and CSN pin.

When the external N-channel MOSFET is turned on, inductor current rises, when inductor current rises above the upper limit decided by the following 3 equations (The propagation delay is already considered):

$$\begin{aligned} I_{Lhigh} &= 0.108V / R_{CS} && \text{(Constant current mode)} \\ I_{Lhigh} &= 0.058V / R_{CS} && \text{(Constant current mode, Battery warm)} \\ I_{Lhigh} &= 0.039V / R_{CS} && \text{(Trickle mode, Quasi-CV mode and Battery cool)} \end{aligned}$$

The external N-channel MOSFET is turned off, inductor current falls, the energy stored in inductor is transferred to battery and output capacitor. When inductor current falls below the lower limit decided by the following 3 equations (The propagation delay is already considered):

$$\begin{aligned} I_{Llow} &= 0.07V / R_{CS} && \text{(Constant current mode)} \\ I_{Llow} &= 0.033V / R_{CS} && \text{(Constant current mode, Battery warm)} \\ I_{Llow} &= 0.02V / R_{CS} && \text{(Trickle mode, Quasi-CV mode and Battery cool)} \end{aligned}$$

The external N-channel MOSFET is turned on again, a new switching cycle is started.

So the average inductor current is:

$$\begin{aligned} I_L &= 0.089V / R_{CS} && \text{(Constant current mode)} \\ I_L &= 0.046V / R_{CS} && \text{(Constant current mode, Battery warm)} \\ I_L &= 0.03V / R_{CS} && \text{(Trickle mode, Quasi-CV mode and Battery cool)} \end{aligned}$$

In the above equations,  $I_{Lhigh}$  is the upper limit of inductor current in Ampere

$I_{Llow}$  is the lower limit of inductor current in Ampere

$R_{CS}$  is the inductor current sense resistor in ohm

## Calculate Switching Frequency and Inductor

In the application circuit shown in Figure 1, the on-time of external N-channel MOSFET is:

$$t_{on} = \frac{0.04 \times L}{V_{IN} \times R_{CS}} \text{ --- (1)}$$

The off-time of the N-channel MOSFET is:

$$t_{off} = \frac{0.04 \times L}{(V_{BAT} + V_D - V_{IN}) \times R_{CS}} \text{ --- (2)}$$

So the switching frequency is:

$$f_{sw} = \frac{1}{t_{on} + t_{off}} = \frac{1}{\frac{0.04 \times L}{V_{IN} \times R_{CS}} + \frac{0.04 \times L}{(V_{BAT} + V_D - V_{IN}) \times R_{CS}}}$$

CN3301 requires that the minimum switching frequency is no less than 200KHz. A frequency between 300KHz and 600KHz can achieve a good balance between efficiency and inductor size.

The switching frequency varies with input voltage and battery voltage, so when determining the switching frequency, the nominal battery voltage should be used.

The duty cycle of pulse at CN3301 DRV pin:

$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{V_{BAT} + V_D - V_{IN}}{V_{BAT} + V_D}$$



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In the above equations:

L is the inductor value in Henry(H)

V<sub>IN</sub> is the input voltage in Volt

V<sub>BAT</sub> is battery voltage in Volt

V<sub>D</sub> is the forward voltage drop of diode in Volt

R<sub>CS</sub> is the total current sense resistance in ohm(Ω), R<sub>CS</sub>=R<sub>EXT</sub>+R<sub>INT</sub>

## Estimate Charge Current in Constant Current Mode

CN3301 controls charge current by monitoring inductor current, so the charge current in constant current mode may vary with the input voltage and battery voltage.

Normally the following equation can be used to estimate the charge current:

$$I_{CH} = \frac{V_{IN} \times I_L \times \eta}{V_{BAT}}$$

Where,

I<sub>CH</sub> is charge current in Ampere

V<sub>IN</sub> is input voltage in Volts

I<sub>L</sub> is the average inductor current in Ampere, and decided by 0.089 / R<sub>CS</sub>

η is the conversion efficiency varying between 85% and 92%, generally 88% can be used.

V<sub>BAT</sub> is battery voltage in Volt

## Battery Temperature Monitoring

To prevent the damage caused by the very high or very low temperature done to the battery, the CN3301 continuously monitor battery temperature by measuring the voltage at TEMP pin which is determined by TEMP pin's source current (30uA typical) and a 10KΩ negative temperature coefficient (NTC) thermistor connected between TEMP pin and GND as shown in Figure 1.

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

The battery temperature monitoring function for CN3301 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 CN3301:

- 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 33% of full-scale charge current and charge termination 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 50% of full-scale charge current and charge termination voltage is reduced to 97.91% 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 CN3301.

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A resistor of small resistance in series with NTC thermistor and a resistor of large resistance in parallel with NTC thermistor can fine tune CN3301'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	Termination Voltage
Hot: above 55°C	$V_{TEMP} < V_{HOT}$	Charge Suspended	Charge Suspended
Warm: 45°C to 55°C	$V_{HOTR} < V_{TEMP} < V_{WARM}$	50% * I <sub>CC</sub>	97.91% * V <sub>TERM</sub>
Normal: 10°C to 45°C	$V_{WARMR} < V_{TEMP} < V_{COOLR}$	Normal Value	Normal Value
Cool: 0°C to 10°C	$V_{COOL} < V_{TEMP} < V_{COLDR}$	33% * I <sub>CC</sub>	Normal Value
Cold: below 0°C	$V_{TEMP} > V_{COLDR}$	Charge Suspended	Charge Suspended

## Selection of N-Channel MOSFET

The CN3301's gate driver is capable of sourcing 0.65A and sinking 0.65A of current. MOSFET selection is based on the maximum battery voltage, inductor current and operating switching frequency. Choose an N-channel MOSFET that has a higher breakdown voltage than the maximum battery voltage, low R<sub>ds</sub> (ON), and low total gate charge (Q<sub>g</sub>) for better efficiency. MOSFET threshold voltage must be adequate if operated at the low end (4.5V) of the input-voltage operating range.

## Selection of Free-Wheeling Diode

The forward voltage of the freewheeling diode (D1 in Fig.1) should be as low as possible for better efficiency. A Schottky diode is a good choice as long as the breakdown voltage is high enough to withstand the maximum battery voltage. The current rating of the diode must be greater than the maximum charge current.

## Input Capacitor

In most applications, a bypass capacitor at VIN is needed. An at least 10uF ceramic capacitor, placed in close proximity to VIN and GND pins, works well. In some applications depending on input current, the power supply characteristics and cable length, it may be necessary to increase the capacitor's value. The capacitor's breakdown voltage should be higher than the maximum input voltage.

Generally a capacitor between 10uF and 47uF works well, ceramic capacitor of X5R or X7R is highly recommended.

## Output Capacitor

A filter capacitor (C<sub>o</sub> in Figure 1) is needed between battery positive terminal and ground, the capacitor also supply energy to battery when the N-channel MOSFET is turned on.

The output capacitance is determined by the requirement of output ripple voltage. The ripple voltage is decided by the following equation:

$$\Delta V_{BAT} = \frac{I_{CH} \cdot t_{off}}{C_o} + \frac{0.04 \cdot r_{esr}}{R_{cs}}$$

Where, I<sub>CH</sub> is the charge current flowing into battery

t<sub>off</sub> is the off time of N-channel MOSFET

C<sub>o</sub> is the output capacitance

r<sub>esr</sub> is the equivalent series resistance of output capacitor

R<sub>cs</sub> is the inductor current sense resistor shown in Figure 1

So ESR of output capacitor should be as small as possible, X5R or X7R ceramic capacitors are recommended.

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## Status Indication

The CN3301 has 2 open-drain status outputs:  $\overline{\text{CHRG}}$  and  $\overline{\text{DONE}}$ .  $\overline{\text{CHRG}}$  pin is pulled low when the charger is in charging mode, otherwise  $\overline{\text{CHRG}}$  becomes high impedance.  $\overline{\text{DONE}}$  pin is pulled low if the charger is in termination mode, otherwise  $\overline{\text{DONE}}$  becomes high impedance.

When the battery is not present, the charger charges the output capacitor to the over-voltage protection threshold quickly, CN3301 enters over-voltage protection mode, both  $\overline{\text{CHRG}}$  and  $\overline{\text{DONE}}$  becomes high impedance, then battery voltage decays slowly to over-voltage release threshold because of discharge by the feedback resistors, CN3301 enters charge mode, and the output capacitor is charged to 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 pulse to indicate the battery's absence,  $\overline{\text{DONE}}$  pin is in high impedance.

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

The table 1 lists the two indicators' 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 (the red LED on)	High impedance (the green LED off)	Charging
High impedance (the red LED off)	Low (the green LED on)	Termination
Pulse (the red LED blinking)	High impedance (the green LED off)	Battery not present
High impedance (the red LED off)	High impedance (the green LED off)	There are 4 possible reasons: <ul style="list-style-type: none"> <li>● the voltage at the VIN pin below the UVLO level or</li> <li>● Battery over-voltage protection, or</li> <li>● CN3301 over junction temperature, or</li> <li>● Battery hot or cold</li> </ul>

Table 1 Indication Status

## Design Procedures

The following design procedures can be followed to design the parameters of CN3301 application circuit:

- (1) To determine the charge current based on the battery capacity and the requirement of charge time.
- (2) To estimate the input current based on the input voltage range, battery voltage range and charge current. The input current is also the inductor current.
- (3) To decide the input bypassing capacitor based on the input supply's characteristics, input supply's cable length and input current.
- (4) To select diode and N-channel MOSFET based on input voltage, inductor current, charge current and the battery's highest voltage.
- (5) To calculate the current sense resistor  $R_{CS}$  based on the average inductor current.
- (6) To determine the inductor value according to the switching frequency. The switching frequency can be from 200KHz to 1MHz. Generally speaking, a switching frequency between 300KHz and 600KHz can achieve a good balance between efficiency and inductor's profile.
- (7) To select the output capacitor based on the switching frequency and charge current.

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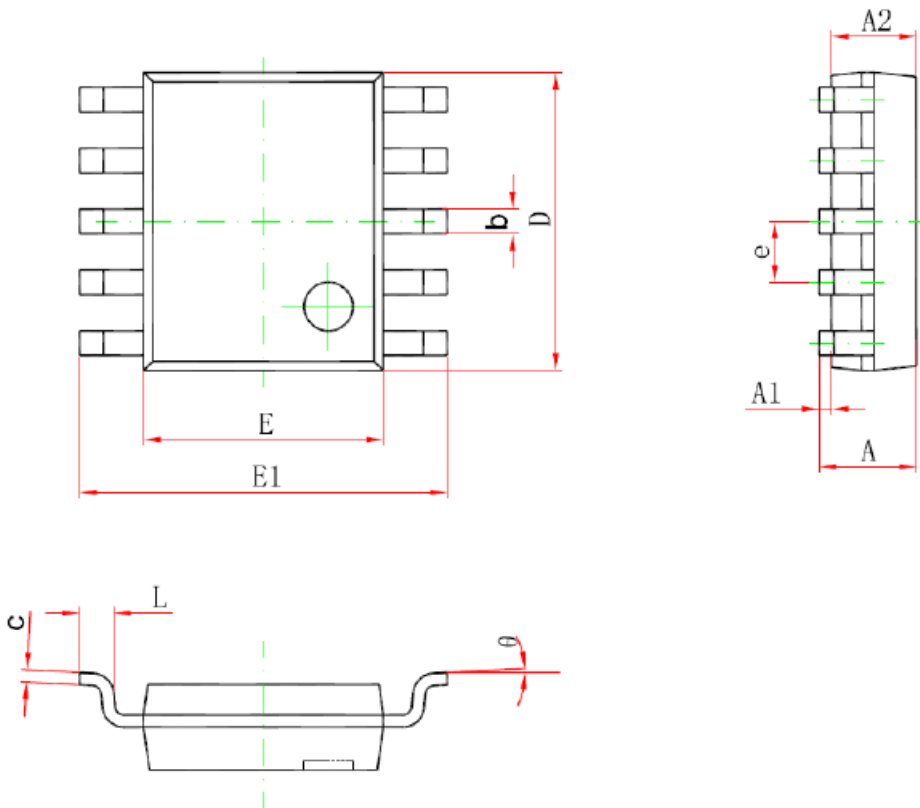
## PCB Considerations

A good PCB design is very important to efficiency and performance. When laying out the printed circuit board, the following considerations should be taken to ensure proper operation of the IC.

- If possible, use multi-layer PCB for better performance.
- The high-current ground connections of output capacitor, source of N-channel MOSFET and battery negative terminal need to feed into same copper that connects to the input capacitor ground before tying back into system ground. This copper should be wide enough, and back to system ground separately.
- The analog ground connections of CN3301's pin 4, R2, R4, C2 and NTC's grounding terminals as shown in Figure 1 should be back to system ground separately.
- To minimize radiation, the diode, MOSFET, inductor, the input bypass capacitor and the output capacitor traces should be kept as short as possible. The connection between the diode and the MOSFET should also be kept as short as possible.
- Place the inductor current sense resistor  $R_{CS}$  right next to the input capacitor and inductor but oriented such that the IC's CSN and VIN 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.

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## Package Information (SSOP10)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.300	0.450	0.012	0.018
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.000 (BSC)		0.039 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	1°	8°

### Important Notice

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