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Step-up Multi-Chemistry Battery Charger IC

With PhotoVoltaic Cell MPPT Function

CN3306

General Description:

The CN3306 is PWM mode step-up multi-chemistry battery charger IC. Its input voltage range is from 4.5V to 32V, also can be powered by photovoltaic cell with MPPT function. The CN3306 is ideal for lithium ion battery, LiFePO4 battery and Titanate Battery's charge management with few external components.

CN3306 adopts constant current(CC) and constant voltage(CV) mode. In constant current mode, charge current is set by an external resistor; In constant voltage mode, the regulation voltage is set by external resistors. In constant charge mode, when charge current falls below 16.6% of constant current, the charge is terminated. In charge termination mode, when battery voltage falls below 95.8% of the regulation voltage in CV mode, a new charge cycle is started again.

Other functions include chip shutdown, battery overvoltage protection, built-in 5V voltage regulator and charge status indication, etc.

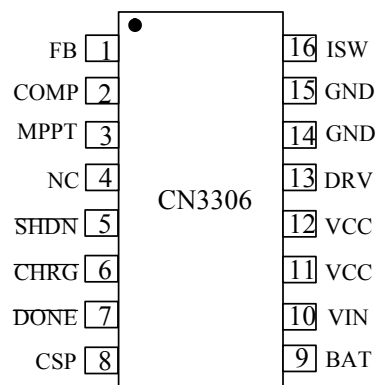CN3306 is available in 16 pin TSSOP package.

Features:

- PWM Step-up Battery Charge Management
- Input Voltage Range：4.5V to 32V
- Adaptive Charge Current
- Maximum Power Point Tracking for Photovoltaic Cell
- Switching Frequency：330kHz
- High Side Current Sense
- Charge Current Regulation：120mV
- Cycle-by-Cycle Current Limit
- Internal Slope Compensation
- Battery Over Voltage Protection
- Constant Current and Constant Voltage Mode
- Automatic Recharge
- Charge and Termination Indication
- Internal Soft Start
- Built-in 5V Voltage Regulator
- Low Shutdown Current
- Operating Temperature Range：
  $-40℃$ to $85℃$
- Available in 16 Pin TSSOP Package
- Lead-free, Rohs Compliant and Halogen-free

Applications:

- Blue Tooth Application
- POS
- Notebook
- Portable Power Bank
- Lithium Ion, LiFePO4 and Titanite Batteries' Charge Management

Pin Assignment

Pin		Pin	
FB	1	16	ISW
COMP	2	15	GND
MPPT	3	14	GND
NC	4	13	DRV
SHDN	5	12	VCC
CHRG	6	11	VCC
DONE	7	10	VIN
CSP	8	9	BAT

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Typical Application Circuit:
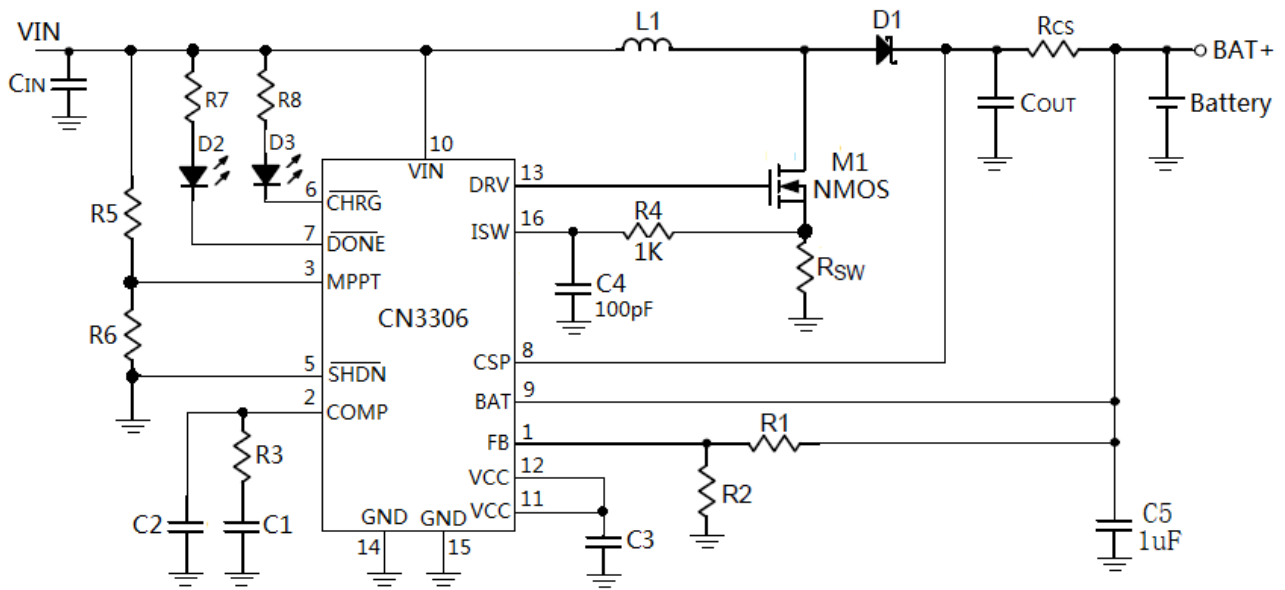

Figure 1   CN3306 Typical Application Circuit

Ordering Information:

Part Number	Shippment	Operating Environmental Temperature
CN3306	Tape and Reel, 3000/Reel	$-40℃$ to $+85℃$

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Pin Description

No.	Name	Description
1	FB	**Battery Voltage Feedback Input.** Generally this Pin is connected to the external feedback resistor divider to sense the battery voltage.
2	COMP	**Compensation Pin.** Connect the compensation network between COMP pin and GND to stabilize the PWM control loop.
3	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 mode, the MPPT pin's voltage is regulated to 1.205V.
4	NC	No Connection.
5	SHDN	**Shutdown Input Pin.** Pulling this pin high, places the CN3306 into shutdown mode. Shutdown mode is characterized by a very low quiescent current. In shutdown mode, all the functionality of all blocks is disabled and the on-chip 5V regulator is also shutdown. Pulling this pin low places the part into normal operation mode.
6	$\overline{\text{CHRG}}$	**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.
7	$\overline{\text{DONE}}$	**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.
8	CSP	**Positive Input for Charge Current Sensing.** This pin and the BAT pin measure the voltage drop across the sense resistor R_{CS} to regulate the charge current.
9	BAT	**Negative Input for Charge Current Sensing.** This pin should be connected to battery's positive terminal. This pin and the CSP pin measure the voltage drop across the sense resistor R_{CS} to regulate the charge current.
10	VIN	**Input Supply Voltage.** Positive terminal of input supply. The input voltage range is 4.5V to 32V. Connect a local bypass capacitor from this pin to GND.
11，12	VCC	**5V Regulator output.** A bypass capacitor of 4.7uF at least should be connected from this pin to GND. If the input voltage is less than 5.5V, the voltage at VCC pin may be less than 5V.
13	DRV	**Gate Drive Pin.** Gate drive for the external N-channel MOSFET. Connect this pin to the gate of external N-channel MOSFET.
14，15	GND	**Ground.** Negative terminal of input supply.
16	ISW	**Inductor Current Sense Pin.** The inductor current is sensed at ISW pin on the cycle-by-cycle basis for both the current mode control and over current protection.

Absolute Maximum Ratings

VIN，CSP，BAT Voltage…..........－0.3V to 36V
The Other Pin's Voltage.............…..－0.3V to 6.5V
Operating Ambient Temperature…..－40℃ to 85℃
Thermal Resistance(Junction to Case) …...200℃/W

Maximum Junction Temperature…….…..…150℃
Storage Temperature……….......－65℃ to 150℃
Lead Temperature(Soldering, 10 seconds)….260℃

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.

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Electrical Characteristics:

(VIN＝12V, T_A＝－40℃ to 85℃, unless otherwise noted)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	VIN		4.5		32	V
Undervoltage lockout Threshold	UVLO				4.4	V
Operating Current	I_{VIN}	V_{FB}＝1.3V, V_{SHDN}=0V	700	825	950	uA
Shutdown Current	I_{VINSD}	SHDN＝3V, VIN＝12V	3.6	5.2	6.8	uA
		SHDN＝3V, VIN＝30V	9	13	17	
FB Feedback Voltage	V_{REG}	Constant voltage mode	1.193	1.205	1.217	V
FB Bias Current	I_{FB}	V_{FB}＝1.2V		60	300	nA
BAT Bias Current	I_{BAT}	Shutdown or Charge termination			80	uA
Current Sense	V_{CS}	Constant current，V_{CSP}－V_{BAT}	108	120	132	mV
Charge Termination Threshold	I_{term}	Charge current falls		16.6		%I_{CC}
Recharge Threshold	V_{RE}	Battery voltage falls		95.8		%V_{REG}
Battery Overvoltage Protection	Vov	Battery voltage rises	1.05	1.083	1.116	V_{REG}
Battery Overvoltage Release	Vclr	Battery voltage falls	1.006	1.028	1.05	
Soft Start Time				10		mS
Inductor Over Current Threshold	$V_{ISW(OC)}$	Measure the voltage at ISW pin	180	200	220	mV
SHDN Pin						
SHDN Input High	V_{IH}		2.3		6	V
SHDN Input Low	V_{IL}		0		0.5	V
SHDN Bias Current	I_{SHDN}		－100	0	＋100	nA
MPPT Pin						
MPPT Voltage	V_{MPPT}	MPP tracking mode	1.18	1.205	1.23	V
MPPT Bias Current	I_{MPPT}		－100	0	＋100	nA
DRV Pin						
Source Current		V_{DRV}＝4V		0.8		A
Sink Current		V_{DRV}＝1V		1.5		A
Falling Time	t_f	C_{DRV}＝2nF		25		nS
Rising Time	t_r	C_{DRV}＝2nF		32		nS
VCC Pin						
Output Voltage	VCC	I_{VCC}＝0.1mA to 4mA, VIN＝5.5V to 32V	4.75		5.39	V
Load Regulation		I_{VCC}＝0.1mA to 4mA，		5		mV
Line Regulation		VIN＝6V to 32V, I_{VCC}＝3mA		6		mV

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

(Continued from last page)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
PSRR	PSRR	I_{VCC}＝3mA，f＝10kHz		-35		dB

Startup Time	t_{START}	VCC＝0 to 4.5V，C_{OUT}＝4.7uF		5			mS
Oscillator							
Frequency	f_{osc}		285	330	375		KHz
Maximum Duty Cycle	Dmax			93			%
$\overline{CHRG}$ **Pin**							
Pull Down Current	I_{CHRG}	V_{CHRG}=1V，Charge mode	7	12	18		mA
Leakage Current	I_{LK1}	V_{CHRG}=25V，Charge termination			1		uA
$\overline{DONE}$ **Pin**							
Pull Down Current	I_{DONE}	V_{DONE}=1V，Charge termination	7	12	18		mA
Leakage Current	I_{LK2}	V_{DONE}=25V，Charge mode			1		uA

Detailed Description:

The CN3306 is PWM mode step-up multi-chemistry battery charger IC. CN3306's input voltage range is from 4.5V to 32V, can be powered by photovoltaic cell with MPPT function. The CN3306 is ideal for lithium ion battery, LiFePO4 battery and Titanate Battery's charge management with few external components.

The CN3306 is comprised of bandgap, 330KHz oscillator, error amplifier, charge management block, current-mode PWM controller, soft start block and gate drive block, etc.

A charge cycle begins when the following 2 conditions are met:

(1) The voltage at VIN pin rises above the 4.5V

(2) The voltage at VIN pin is no less than the maximum power point voltage set by MPPT pin.

At the beginning of the charge cycle, 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 120mV reference, so the charge current equals to 120mV/R_{CS}. When the battery voltage approaches the regulation voltage set for constant voltage mode, the charger goes into constant voltage mode, and the charge current will start to decrease. In constant voltage mode, the charge cycle will be terminated once the charge current decreases to 16.6% of the full-scale current. During the charge termination status, the DRV pin is pulled down to GND, 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 automatically begin if the battery voltage drops below the recharge threshold voltage of 95.8%×V_{REG}.

CN3306 adopts the constant voltage method to track the photovoltaic cell's maximum power point. CN3306 MPPT pin's voltage is regulated to 1.205V to track the maximum power point working with the off-chip resistor divider (R5 and R6 in Figure 1).

An over voltage comparator guards against voltage transient overshoots (Greater than 8.3% of regulation voltage). In this case, the external N-channel MOSFET are turned off until the overvoltage condition is cleared. This feature is useful for battery load dump or sudden removal of battery.

The CN3306 incorporates on-chip soft start to limit inrush current on power up. Other functions include chip shutdown function, built-in +5V regulator, etc.
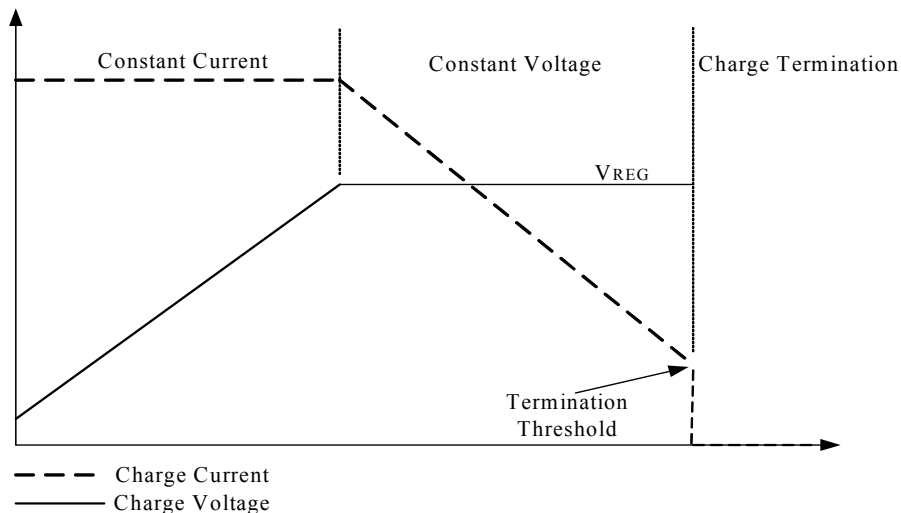
The charge profile is shown in Figure 2.

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Figure 2 The Charging Profile

Application Information

Input Voltage Range

CN3306 is intended to implement step-up battery charge management. The input voltage range is from 4.5V to 32V, photovoltaic cell can also be used to power CN3306 due to MPPT function.

Shutdown Mode

The SHDN pin is active high shutdown input. Pulling this pin above 2.3V causes the CN3306 to completely shut down and enter a low current consumption state. Pulling SHDN pin below 0.5V brings the CN3306 back to normal operation.

+5V Regulator

The CN3306 includes a fixed +5V output regulator that delivers up to 4mA of load current for low-power applications throughout the +5.5V to +32V input voltage range. The regulator supplies power for the internal low voltage circuitry of the controller including the gate driver.

Connect a 4.7μF at least bypass capacitor from VCC pin to GND.

If the +5V regulator is used to power the external circuitry, cares must be taken not to overload the +5V regulator, otherwise the gate drive capability may be affected.

When SHDN pin is pulling high, the 5V regulator is also turned off.

Set the Regulation Voltage

As shown in Figure 1, battery voltage is feedback to FB pin via the resistor divider composed of R1 and R2. CN3306 decided the charging status based on FB's voltage. When FB's voltage approaches 1.205V(Typical), the charger goes into constant voltage mode. In constant voltage mode, the charge current decreases gradually, and the battery voltage remains unchanged.

The regulation voltage in constant voltage mode is determined by the following equation:

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

The maximum regulation voltage that can be set is 32V.

R1 and R2 will consume some current from battery, when choosing R1 and R2's value, R1+R2 should be determined first based on the consideration of battery current consumption, then calculate R1 and R2's value according to the above equation.

Set Charge Current

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

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formula:

$$I_{CH} = \frac{120mV}{R_{CS}}$$

In any charge mode, the charge current is determined by the following equation:

$$I_{CH} = \frac{V_{CS}}{R_{CS}}$$

Where,

I_{CH} is the charge current

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

V_{CS} is the voltage across R_{CS}

Charge Termination

In constant voltage mode, the charge current decreases gradually. When the charge current decreases to 16.6% of the full-scale current, the charging is terminated.

If the voltage at FB pin is less than 1.18V, the charging will not be terminated even though the charge current is less than 16.6% of the full-scale current.

Automatic Recharge

After the charge cycle is completed and both the battery and the input power supply (wall adapter) are still Connected, a new charge cycle will begin if the battery voltage drops below $95.8\% \times V_{REG}$ due to self-discharge or external loading. This will keep the battery capacity at more than 90% at all times without manually restarting the charge cycle.

Over Voltage Protection at Battery Terminal

An overvoltage comparator guards against voltage transient overshoots (Greater than 8.3% of regulation voltage). In this case, the external N-channel MOSFET are turned off until the overvoltage condition is cleared. This feature is useful for battery load dump or sudden removal of battery.

The Maximum Power Point Tracking

CN3306 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.

CN3306 MPPT pin's voltage is regulated to 1.205V to track the maximum power point working with the off-chip resistor divider (R5 and R6 in Figure 1).

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

$$V_{MPPT} = 1.205 \times (1 + R5 / R6)$$

MPPT Pin Used for Adaptive Charge Current

In addition to photovoltaic cell's maximum power point tracking function, MPPT pin can also be used for automatic charge current adjusting based on input supply's loading capability. If USB port or an adaptor with poor loading capability is used to charge a battery, the input supply can be regulated to a lower voltage V_L (For example, 4.75V) with the help of CN3306's MPPT pin and two external resistors (R5 and R6 in Figure 1), then CN3306 will automatically reduce the charge current, even though the charge current is set at a higher level. The voltage V_L is calculated by the following equation:

$$V_L = 1.205 \times (1 + R5 / R6)$$

Status Indication

The CN3306 has 2 open-drain status outputs: $\overline{CHRG}$ and $\overline{DONE}$. $\overline{CHRG}$ is pulled low when the charger is in charging status, otherwise $\overline{CHRG}$ becomes high impedance. $\overline{DONE}$ is pulled low if the charger is in charge

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termination status, otherwise $\overline{\text{DONE}}$ becomes high impedance.

When the battery is not present, the charger charges the output capacitor to the regulation voltage quickly, then the BAT pin's voltage decays slowly to recharge threshold because of BAT pin's operating current and loading current, which results in a ripple waveform at BAT pin, in the meantime, $\overline{\text{CHRG}}$ pin outputs a pulse to indicate that the battery's absence.

The open drain 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(the red LED on)	High Impedance(the green LED off)	Charging
High Impedance(the red LED off)	Low(the green LED on)	Charge termination
Pulse signal	Pulse signal	Battery absent
High Impedance(the red LED off)	High Impedance(the green LED off)	The voltage at the VIN pin is below the UVLO level

Table 1 Indication Status

N-Channel MOSFET Gate Driver (DRV Pin)

The CN3306 offers a built-in gate driver for driving an external N-channel MOSFET. The DRV pin can source/sink currents in excess of 800mA/1500mA. The gate driver is powered by on-chip 5V regulator, so the voltage at DRV pin is 5V while output high.

Duty Cycle Estimation

As shown in Figure 1, for a step-up battery charger operating in continuous conduction mode (CCM), the duty cycle is:

$$D = 1 - \frac{VIN}{V_{BAT} + V_D}$$

Where, VIN is input voltage, V_{BAT} is battery voltage, V_D is the forward voltage of freewheeling diode.

So the maximum duty cycle occurs when VIN is minimum, namely:

$$Dmax = 1 - \frac{VINmin}{V_{BAT} + V_D}$$

The minimum duty cycle occurs When VIN is maximum, namely:

$$Dmin = 1 - \frac{VINmax}{V_{BAT} + V_D}$$

Maximum Inductor Current (Input Current)

CN3306 measures the inductor current (Input current) by sensing the voltage across the inductor current sense resistor (R_{SW} in Figure 1) between the source of external N-channel MOSFET and GND. So the charge current needs to be reflected back to the input in order to guarantee the correct charge current regulation. Based on the fact that, ideally, the output power is equal to the input power, the maximum average inductor current is:

$$I_{IN} = I_L = \frac{I_{CH}}{1 - Dmax}$$

Where, I_{CH} is the charge current in constant current mode.

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The internal current mode control loop will not allow the inductor peak to exceed $0.2/R_{SW}$. In practice, one should allow some margin for variations in the CN3306 and external component values, and a good guide for selecting the peak inductor current (Input current) is:

$$I_{INpeak} = I_{Lpeak} = 1.8 \times \frac{I_{CH}}{1 - Dmax}$$

Inductor Selection

An inductor should be chosen that can carry the maximum input DC current which occurs at the minimum input voltage.

The peak-to-peak ripple current is set by the inductance and a good starting point is to choose a ripple current of 30% of its maximum value:

$$\triangle I_L = \frac{VIN_{max} \times Dmin}{fsw \times L} \leqslant 30\% \times \frac{I_{CH}}{1 - Dmin}$$

The inductor value should meet the requirement of the following equation:

$$L \geqslant \frac{VIN_{max} \times Dmin \times (1 - Dmin)}{0.3 \times fsw \times I_{CH}}$$

Where, f_{SW} is switching frequency, whose typical value is 330KHz.

Selection of Inductor Current Sense Resistor

The CN3306 is a current mode controller and use a resistor in series with the source terminal of external N-channel MOSFET to perform cycle-by-cycle inductor current sense for both the current mode control and over current protection. The inductor current sense resistor is shown in Figure 1 as R_{SW}. The DRV pin will become low and turn off the external N-channel MOSFET if the voltage at the ISW pin exceeds the current limit threshold voltage $V_{ISW}(oc)$ from the electrical specifications table.

So the value of R_{SW} should meet the requirement of the following equation:

$$R_{SW} \leqslant \frac{V_{ISW(oc)}}{I_{Lpeak}} = \frac{1 - Dmax}{9 \times I_{CH}}$$

The CN3306 adopts peak current mode control to regulate charge current, which needs a compensation slope to prevent the device from sub-harmonic oscillation. In CN3306, the compensation slope is applied in a fixed amount. At ISW pin, the compensation slope is:

$$S_e = 4.49 \times 10^4 \text{ V/S}$$

To ensure that the converter does not enter into sub-harmonic oscillation, the compensation slope S_e must be at least half of the down slope of the current sense signal at ISW pin. Since the compensation slope is fixed in the CN3306, this places a constraint on the selection of the current sense resistor.

The down slope of the current sense signal at ISW pin is:

$$m2 = \frac{R_{SW} \times (V_{BAT} + V_D - V_{IN})}{L}$$

Where,

- S_e is the compensation slope applied to ISW pin in V/S
- m2 is the down slope of the inductor current sense waveform seen at ISW pin in V/s
- R_{SW} is the inductor current sense resistor at ISW pin in ohm(Ω)
- V_{BAT} is the battery voltage in volt(V)

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- V_D is the forward voltage of freewheeling diode in volt (V)
- VIN is the input voltage in volt(V)
- L is the inductor value in Henry(H)

Since the compensation slope must be at least half, and preferably equal to the down slope of the current sense waveform seen at ISW pin, namely,

$$Se \geqslant \frac{1}{2} m2$$

Hence, a maximum value is placed on the inductor current sense resistor R_{SW} when operating in continuous conduction mode at 50% duty cycle or greater, that is:

$$R_{SW} \leqslant \frac{2 \times 4.49 \times 10^4 \times L}{V_{BAT} + V_D - VIN_{min}}$$

As a conclusion, R_{SW} should simultaneously meet the requirements of the following 2 equations for inductor over current protection and current mode control purposes:

$$R_{SW} \leqslant \frac{V_{ISW(oc)}}{I_{Lpeak}} = \frac{1 - D_{max}}{9 \times I_{CH}} \qquad \text{and}$$

$$R_{SW} \leqslant \frac{2 \times 4.49 \times 10^4 \times L}{V_{BAT} + V_D - VIN_{min}}$$

For design purposes, some margin should be applied to the actual value of the inductor current sense resistor R_{SW}. As a starting point, the actual resistor chosen should be 80% or less that the value calculated in the above equations.

Inductor Current Sense Filtering

In most cases, a small filter placed on the ISW pin improves performance of the converter. These are the components R4 and C4 in Figure 1. The time constant of this filter should be approximately 100ns. R4 should be less than 2KΩ.

Freewheeling Diode Selection

For better efficiency and less power dissipation, a low forward voltage schottky diode should be used as the freewheeling diode (D1 in Figure 1), the diode must have a breakdown voltage that is a few volts higher than the output voltage. The diode's average current should be higher than the maximum output current, the diode's peak current should be higher than the inductor's peak current estimated by the following equation:

$$I_{INpeak} = I_{Lpeak} = 1.8 \times \frac{I_{CH}}{1 - D_{max}}$$

MOSFET Selection

The CN3306 drives an external N-channel MOSFET. The voltage stress on the MOSFET ideally equals the sum of battery voltage and the forward drop of the freewheeling diode. In practice, voltage overshoot and ringing occur due to action of circuit parasitic elements during the turn-off transition. The MOSFET voltage rating should be selected with the necessary margin to accommodate this extra voltage stress.

The MOSFET's power rating and on-resistance should be chosen based on the inductor current.

Output Capacitor Selection

In a boost charger, the output capacitor requirements are demanding due to the fact that the current waveform is pulsed. The choice of component is driven by the acceptable ripple voltage which is affected by the ESR, ESL and bulk capacitance. The total ripple voltage at the output capacitor is:

$$\Delta V_{CAP} = I_{CH} \times \left(\frac{1}{f_{sw} \cdot C_{OUT}} + \frac{r_{esr}}{1 - D_{MAX}} \right)$$

where the first term is due to the bulk capacitance and second term due to the ESR of output capacitor.

Since the ripple voltage at the output capacitor decides the ripple charge current, the ripple voltage at the output capacitor should be kept below 40mV.

For many designs it is possible to choose a single capacitor type that satisfies both the ESR and bulk C requirements. In certain demanding applications, however, the ripple voltage can be improved significantly by connecting two or more types of capacitors in parallel. For example, using a low ESR ceramic capacitor can minimize the ESR step, while an electrolytic capacitor can be used to supply the required bulk C.

It should be carefully chosen to account for derating due to temperature and operating voltage. When ceramic capacitor is used, special attention should be given to the capacitance derating due to operating voltage.

The output capacitor must also have the necessary RMS current rating.

Input Capacitor Selection (C_{IN} in Figure 1)

The input capacitor supplies the transient input current for the inductor of the converter and must be placed and sized according to the transient current requirements. The inductor current, tolerable input voltage ripple, input voltage source impedance and cable length determine the size of the input capacitor, which is typically in the range of 10μF to 100μF. A low ESR capacitor or two types of capacitor in parallel is recommended.

Please note that the input capacitor can see a very high surge current when a input supply is suddenly connected to the input of the converter and solid tantalum capacitors can fail catastrophically under these conditions.

The Design of Frequency Compensation Network

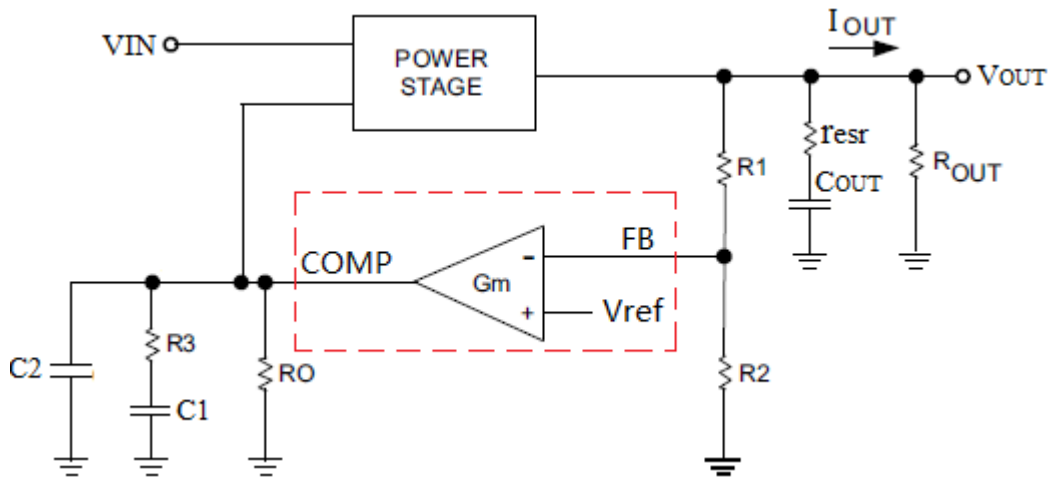Figure 3 shows the AC response-related circuit for CN3306's application circuit.

Figure 3   AC Response-Related Circuit

Inductor L, output capacitor C_{OUT} and load impedance R_{OUT} form a pole and 2 zero, they are:

● Output capacitor C_{OUT} and load impedance form a pole:

$$\omega_{p1} = \frac{2}{R_{OUT} C_{OUT}}$$

● Output capacitor C_{OUT} and its ESR form a zero:

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$$\omega_{z1} = \frac{1}{r_{esr} \, C_{OUT}}$$

If output capacitor's ESR is low enough, then the zero can be ignored.

● There is another right half plane zero:

$$\omega_{Z2} = \frac{R_{OUT}(1-D)^2}{L}$$

In the above 3 equations,

- ● R_{OUT} is load impedance, and is calculated by V_{REG} / I_{CH};
- ● C_{OUT} is output capacitor;
- ● r_{esr} is output capacitor's ESR;
- ● L is inductor value;
- ● D is duty cycle of the step-up charger. For worst case, D's maximum value should be used, it is:

$$Dmax = 1 - \frac{VINmin}{V_{BAT} + V_D}$$

In Figure 3, C1, C2 and R3 form the compensation network. The design procedure of the compensation network is:

Step 1: Calculate ω_{P1}, ω_{z1} and ω_{z2} based on the above 3 equations

Step 2: Determine the crossover frequency ω_c of the overall loop

For stable operation, the overall loop gain should cross 0dB with -20dB/decade slope. Due to the presence of the RHP zero, the 0dB crossover frequency ω_c should be from $0.3 \times \omega_{z2}$ to $0.4 \times \omega_{z2}$.

Step 3: Determine R3's value in ohm (Ω)

$$R3 = \frac{33000}{\sqrt{\dfrac{\omega_c^2}{\omega_{p1}^2} + 2}}$$

Step 4: Determine C1's value in Farad (F)

$$C1 = \frac{1}{R3 \cdot \omega_{p1}}$$

Step 5: Calculate C2's value in Farad(F)

R3 and C2 form a pole to cancel the zero ω_{z1} formed by output capacitor C_{OUT} and its ESR.

C2 can be calculated by the following equation:

$$C2 = \frac{1}{R3 \cdot \omega_{z1}}$$

If low ESR capacitor is used, which leads to ignorance of ω_{z1}, hence C2 can be omitted.

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Board Layout Considerations

Careful PCB design is very important for correct function and good performance of the step-up charger. For the application circuit shown in Figure 1, the following suggestions should be followed.

- All connections carrying large pulsed currents must be very short and as wide as possible. The inductance of these connections must be kept to an absolute minimum due to the high di/dt of the currents. This implies that the C_{IN}, inductor, MOSFET, R_{SW}, diode, R_{CS} and C_{OUT} should be placed in a compact area. Additionally, small current loop areas reduce radiated EMI.

- The copper plane of the MOSFET should be minimized as much as possible for less EMI.

- The ground plane for the power section of the converter should be kept separate from the analog ground plane. The power ground includes negative terminal of C_{IN}, R_{SW}, C_{OUT} and battery, which should share the same copper plane.

- The CN3306's GND pin and the negative terminal of R2, R6, C1, C2, C3 and C4 should be connected together and return to the system ground separately.

- For higher charge current, multi-layer PCB is recommended.

- Place R1, R2, R5, R6, R3, C1, C2, C3 and C4 as close to the CN3306 as possible.

- The anode of D1 must be connected very close to the drain of the external N-channel MOSFET. The cathode of D1 must be connected very close to C_{OUT}.

- The capacitor C5 should be as close as possible to feedback resistor R1.

CONSONANCE

Package Information
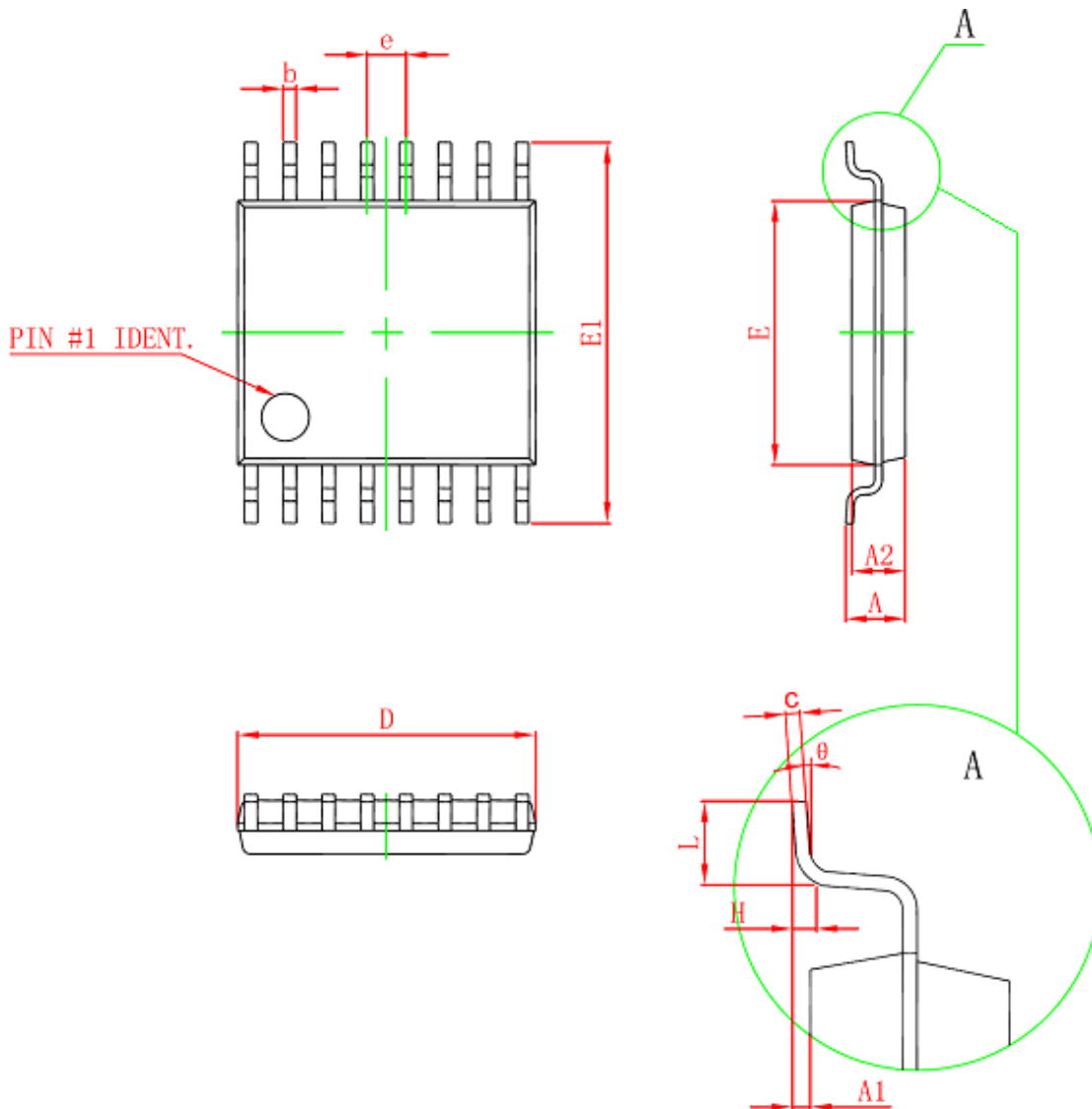
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
D	4.900	5.100	0.193	0.201
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.100		0.043
A2	0.800	1.000	0.031	0.039
A1	0.020	0.150	0.001	0.006
e	0.65 (BSC)		0.026 (BSC)	
L	0.500	0.700	0.020	0.028
H	0.25 (TYP)		0.01 (TYP)	
θ	1°	7°	1°	7°

Consonance does not assume any responsibility for use of any circuitry described. Consonance reserves the right to change the circuitry and specifications without notice at any time.