USB-Compatible Lithium Ion Battery Charger

CN3051/CN3052

General Description:

The CN3051/CN3052 is a complete constant-current /constant voltage linear charger for single cell Li-ion and Li Polymer rechargeable batteries. The device contains an on-chip power MOSFET and eliminates the need for the external sense resistor and blocking diode. Furthermore, the CN3051/CN3052 is specifically designed to work within USB power specifications. Its low external component count makes CN3051/CN3052 ideally suited for portable applications.

Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The regulation voltage is fixed at 4.1V(CN3051) or 4.2V(CN3052) with 1% accuracy. The charge current can be programmed externally with a single resistor. When the input supply (wall adapter or USB supply) is removed, the CN3051/CN3052 automatically enters a low power sleep mode , dropping the battery drain current to less than 3uA. Other features include undervoltage lockout, automatic recharge, chip enable function, battery temperature sensing and a $\overline{CHRG}$ pin to indicate charge status.

The CN3051/CN3052 is available in a thermally enhanced 8-pin SOP package.

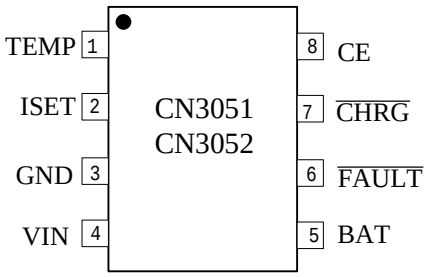
Applications:

- Cellular Telephones
- Digital Still Cameras
- MP3 Players
- Bluetooth Applications
- USB Bus-Powered Chargers

Features:

- Charges Single Cell Li-Ion Batteries Directly from USB Port or AC Adaptor
- On-chip Power MOSFET
- No external Blocking Diode or Current Sense Resistors Required
- Preset 4.1V or 4.2V Regulation Voltage with 1% Accuracy
- Precharge Conditioning for Reviving Deeply Discharged Cells and Minimizing Heat Dissipation During Initial Stage of Charge
- Programmable Charge Current Up to 500mA
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Automatic Low-Power Sleep Mode When Input Supply Voltage is Removed
- Status Indication for LEDs or uP Interface
- C/10 Charge Termination
- Automatic Recharge
- Battery Temperature Sensing
- Chip Enable Input
- Available in SOP8 Package

Pin Assignment



Typical Application Circuit

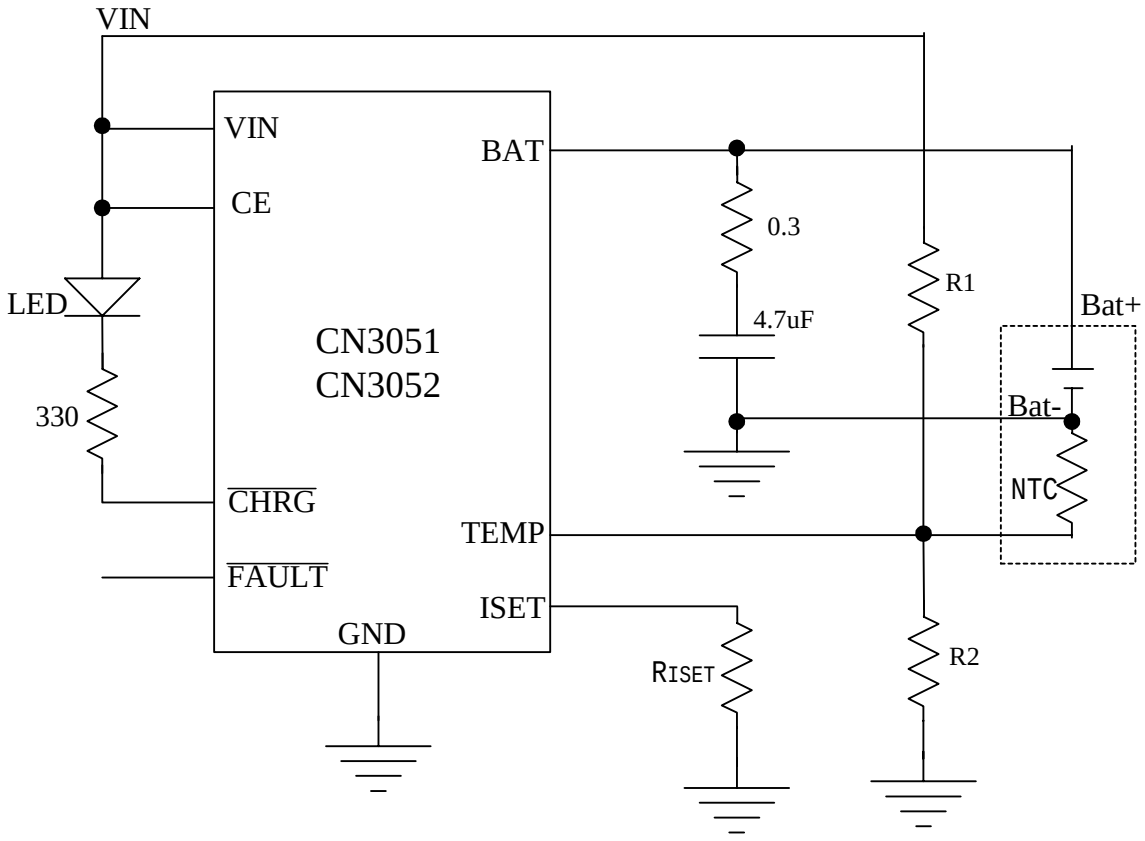


Figure 1 Typical Application Circuit

Ordering Information

Part Number	Regulation Voltage	Package	Operating Ambient Temperature
CN3051	4.1V	SOP8	－40℃ to 85℃
CN3052	4.2V	SOP8	－40℃ to 85℃

Block Diagram

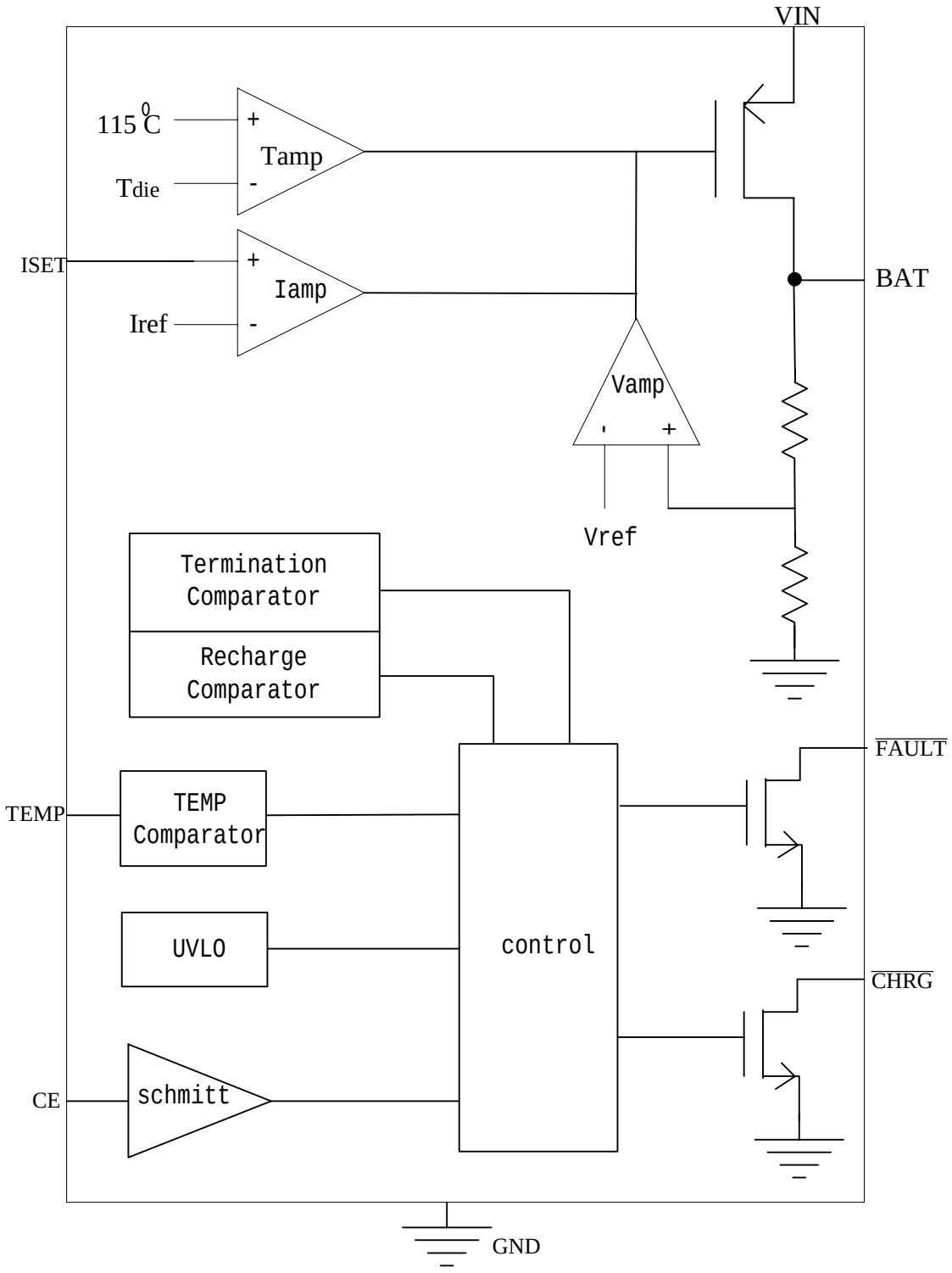


Figure 2 Block Diagram

Pin Description

Pin No.	Name	Function Description
1	TEMP	**Temperature Sense Input.** Connecting TEMP pin to NTC thermistor's output in Lithium ion battery pack. If TEMP pin's voltage is below 45% or above 80% of supply voltage V_{IN} for more than 0.15S, this means that battery's temperature is too high or too low, charging is suspended, and $\overline{FAULT}$ pin is pulled low to indicate a battery fault state. If TEMP's voltage level is between 45% and 80%of supply voltage for more than 0.15S, battery fault state is released, $\overline{FAULT}$ pin is in high impedance state, and charging will resume. The temperature sense function can be disabled by grounding the TEMP pin.
2	ISET	**Constant Charge Current Setting and Charge Current Monitor Pin.** The charge current is set by connecting a resistor R_{ISET} from this pin to GND. When in precharge mode, the ISET pin's voltage is regulated to 0.2V. When in constant charge current mode, the ISET pin's voltage is regulated to 2V.In all modes during charging, the voltage on ISET pin can be used to measure the charge current as follows: $I_{CH} = (V_{ISET} / R_{ISET}) \times 925$
3	GND	**Ground Terminal.**
4	VIN	**Positive Input Supply Voltage.** V_{IN} is the power supply to the internal circuit. When V_{IN} drops to within 40mv of the BAT pin voltage, the CN3051/CN3052 enters low power sleep mode, dropping BAT pin's current to less than 3uA.
5	BAT	**Battery Connection Pin.** Connect the positive terminal of the battery to BAT pin. BAT pin draws less than 3uA current in chip disable mode or in sleep mode. BAT pin provides charge current to the battery and provides regulation voltage of 4.1V(CN3051) or 4.2V(CN3052).
6	$\overline{FAULT}$	**Open-Drain Fault Status Output.** When the voltage at TEMP pin is below 45% of V_{IN} or above 80% of V_{IN}, this means that battery's temperature is too high or too low, $\overline{FAULT}$ is pulled low by an internal switch to indicate a battery fault state; Otherwise $\overline{FAULT}$ pin is in high impedance state.
7	$\overline{CHRG}$	**Open Drain Charge Status Output.** When the battery is being charged, the $\overline{CHRG}$ pin is pulled low by an internal switch, otherwise $\overline{CHRG}$ pin is in high impedance state.
8	CE	**Chip Enable Input.** A high input will put the device in the normal operating mode. Pulling the CE pin to low level will put the CN3051/CN3052 into disable mode. The CE pin can be driven by TTL or CMOS logic level.

Absolute Maximum Ratings

All Terminal Voltage……－0.3V to 6.5V
BAT Short-Circuit Duration……Continuous
ESD Rating(HBM)……...2KV
Thermal Resistance (SOP8)…….TBD
Maximum Junction Temperature…...150℃
Operating Temperature…...－40℃ to 85℃
Storage Temperature…....－65℃ to 150℃
Lead Temperature(Soldering)……...300℃

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_{IN}=5V, T_A=－40℃ to 85℃, Typical Values are measured at T_A=25℃,unless otherwise noted)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Supply Voltage	V_{IN}		4.35		6	V
Operating Current	I_{VIN}	CE=V_{IN}, No load at BAT pin	400	650	950	uA
		Chip disable mode, CE=GND		4		
Undervoltage Lockout	Vuvlo	V_{IN} rising	3.9	4.0	4.1	V
Undervoltage Lockout Hysteresis	Huvlo			0.1		V
Regulation Voltage	V_{REG}	CN3051, No load at BAT pin	4.059	4.1	4.141	V
		CN3052, No load at BAT pin	4.158	4.2	4.242	
BAT pin Current	I_{BAT}	R_{ISET}=3.7K,constant current mode	450	500	550	mA
		R_{ISET}=3.7K, V_{BAT}<V_{PRE}	37.5	50	62.5	
		V_{BAT}=V_{REG}, standby mode	1.75	3.5	7	uA
		CE=GND, disable mode			3	
		V_{IN}=0V, sleep mode			3	
Precharge Threshold						
Precharge Threshold	V_{PRE}	Voltage at BAT pin rising	2.9	3.0	3.1	V
Precharge Threshold Hysteresis	H_{PRE}			0.1		V
Charge Termination Threshold						
Charge Termination Threshold	Vterm	Measure voltage at ISET pin	0.16	0.2	0.24	V
Recharge Threshold						
Recharge Threshold	V_{RECH}			V_{REG}－0.1		V
Sleep Mode						
Sleep Mode Threshold	V_{SLP}	V_{IN} from high to low, measures the voltage (V_{IN}－V_{BAT})		40		mv
Sleep mode Release Threshold	V_{SLPR}	V_{IN} from low to high, measures the voltage (V_{IN}－V_{BAT})		90		mv
ISET Pin						
ISET Pin Voltage	V_{ISET}	Precharge mode		0.2		V
		Constant current mode		2.0		
TEMP PIN						
High Input Threshold				80	82.5	%V_{IN}
Low Input Threshold			42.5	45		%V_{IN}
TEMP input Current		TEMP to V_{IN} or to GND			50	nA
CE Pin						
Logic Input Low	V_{CEL}	CE voltage falling, Chip disabled			0.75	V
Logic Input High	V_{CEH}	CE voltage rising, Chip enabled	2.0			V
CE Pin Current	I_{CEL}	CE=GND, V_{IN}=6V	－1			uA
	I_{CEH}	CE=V_{IN}=6V			1	

Electrical Characteristics(Continued from last page)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
$\overline{CHRG}$ **Pin**						
$\overline{CHRG}$ Pin Sink Current	I_{CHRG}	V_{CHRG}=0.3V, charge mode		20		mA
$\overline{CHRG}$ Leakage Current		CE=GND, V_{CHRG}=6V			1	uA
$\overline{FAULT}$ **Pin**						
$\overline{FAULT}$ Pin Sink Current	I_{FAULT}	V_{FAULT}=0.3V,Fault status		20		mA
$\overline{FAULT}$ Pin Leakage Current		CE=GND, V_{FAULT}=6V			1	uA

Typical Operating Characteristics

TBD

Detailed Description

The CN3051/CN3052 is a linear battery charger designed primarily for charging single cell lithium-ion or lithium-polymer batteries. Featuring an internal P-channel power MOSFET, the charger uses a constant-current/constant-voltage to charge the batteries. Charge current can be programmed up to 500mA with an external resistor. No blocking diode or sense resistor is required. The open-drain output $\overline{CHRG}$ and $\overline{FAULT}$ indicates the charger's status. The internal thermal regulation circuit reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 115℃. This feature protects the CN3051/CN3052 from excessive temperature, and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the CN3051/CN3052 or the external components. Another benefit of adopting thermal regulation is that charge current can be set according to typical, not worst-case, ambient temperatures for a given application with the assurance that the charger will automatically reduce the current in worst-case conditions.

The charge cycle begins when the voltage at the V_{IN} pin rises above the UVLO level, a current set resistor is connected from the ISET pin to ground, and the CE pin is pulled above the chip enable threshold. The $\overline{CHRG}$ pin outputs a logic low to indicate that the charge cycle is ongoing. At the beginning of the charge cycle, if the battery voltage is below 3V, the charger is in precharge mode to bring the cell voltage up to a safe level for charging. The charger goes into the fast charge constant-current mode once the voltage on the BAT pin rises above 3V. In constant current mode, the charge current is set by R_{ISET}. When the battery approaches the regulation voltage, the charge current begins to decrease as the CN3051/CN3052 enters the constant-voltage mode. When the current drops to charge termination threshold, the charge cycle is terminated, and $\overline{CHRG}$ pin assumes a high impedance state to indicate that the charge cycle is terminated. The charge termination threshold is 10% of the current in constant current mode. The charge cycle will be restarted if the BAT pin voltage falls below the recharge threshold. The on-chip reference voltage, error amplifier and the resistor divider provide regulation voltage with 1% accuracy which can meet the requirement of lithium-ion and lithium polymer batteries. When the input voltage is not present, the charger goes into a sleep mode, dropping battery drain current to less than 3uA. This greatly reduces the current drain on the battery and increases the standby time. The charger can be shutdown by forcing the CE pin to GND.

Application Information

Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{IN} rises above the undervoltage lockout voltage(4.0V typical). The UVLO circuit has a built-in hysteresis of 0.1V.

Sleep mode

There is an on-chip sleep comparator. The comparator keeps the charger in sleep mode if V_{IN} falls below sleep mode threshold(VBAT+40mv). Once in sleep mode, the charger will not come out of sleep mode until V_{IN} rises 90mv above the battery voltage.

Precharge mode

At the beginning of a charge cycle, if the battery voltage is below 3V, the charger goes into precharge mode , and the charge current is 10% of fast charge current in constant current mode.

Chip Enable/Disable

The CN3051/CN3052 can be disabled by pulling the CE pin to less than 0.75V. For normal operation, pull the CE pin above 2.0V. Applying a voltage between 0.75V to 2.0V to this pin may cause larger operating current, and the CN3051/CN3052 may be in uncertain state. When the chip is disabled, the internal linear regulator and the power MOSFET are turned off.

Programming Charge Current

The formula for the battery charge current in constant current mode is:

$$I_{CH} = 1850V / R_{ISET}$$

Where:

I_{CH} is the charge current in ampere

R_{ISET} is the total resistance from the ISET pin to ground in ohm.

For example, if 500mA charge current is required, calculate:

$$R_{ISET} = 1850V/0.5A = 3.7k\Omega$$

For best stability over temperature and time, 1% metal film resistors are recommended. If the charger is in constant-temperature or constant voltage mode, the charge current can be monitored by measuring the ISET pin voltage, and the charge current is calculated as the following equation:

$$I_{CH} = (V_{ISET} / R_{ISET}) \times 925$$

USB and Wall Adapter Power

Although the CN3051/CN3052 allows charging from a USB port, a wall adapter can also be used to charge Li-Ion/Li-polymer batteries. Figure 3 shows an example of how to combine wall adapter and USB power inputs. A P-channel MOSFET, M1, is used to prevent back conducting into the USB port when a wall adapter is present and Schottky diode, D1, is used to prevent USB power loss through the $1k\Omega$ pull-down resistor.

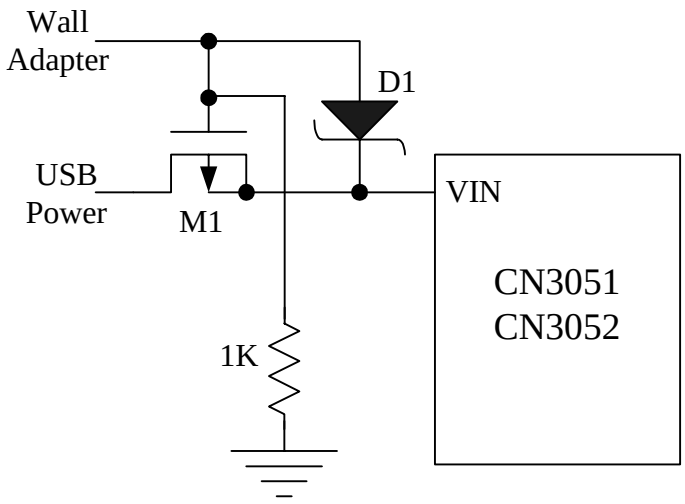


Figure 3 Combining Wall Adapter and USB Power

Battery Temperature Sense

To prevent the damage caused by the very high or very low temperature done to the battery pack, the CN3051/CN3052 continuously senses battery pack temperature by measuring the voltage at TEMP pin determined by the voltage divider circuit and the battery's internal NTC thermistor as shown in Figure 1.

The CN3051/CN3052 compares the voltage at TEMP pin (V_{TEMP}) against its internal V_{LOW} and V_{HIGH} thresholds to determine if charging is allowed. In CN3051/CN3052, V_{LOW} is fixed at (45%×VCC), while V_{HIGH} is fixed at (80%×VCC). If $V_{TEMP}<V_{LOW}$ or $V_{TEMP}>V_{HIGH}$ for 0.15 seconds, it indicates that the battery temperature is too high or too low and the charge cycle is suspended. When V_{TEMP} is between V_{LOW} and V_{HIGH} for more than 0.15 seconds, the charge cycle resumes.

The battery temperature sense function can be disabled by connecting TEMP pin to GND.

Recharge

After a charge cycle has terminated, if the battery voltage drops below the recharge threshold(4.0V for CN3051, 4.1V for CN3052), a new charge cycle will begin automatically.

Constant-Current/Constant-Voltage/Constant-Temperature

The CN3051/CN3052 use a unique architecture to charge a battery in a constant-current, constant-voltage, constant temperature fashion as shown in Figure 2. Amplifiers Iamp, Vamp, and Tamp are used in three separate feedback loops to force the charger into constant-current, constant-voltage, or constant-temperature mode, respectively. In constant current mode the charge current delivered to the battery equal to $1850V/R_{ISET}$. If the power dissipation of the CN3051/CN3052 results in the junction temperature approaching 115℃, the amplifier Tamp will begin decreasing the charge current to limit the die temperature to approximately 115℃. As the battery voltage rises, the CN3051/CN3052 either returns to constant-current mode or it enters constant voltage mode straight from constant-temperature mode.

Open-Drain Status Outputs

The CN3051/CN3052 have 2 open-drain status outputs: $\overline{CHRG}$ and $\overline{FAULT}$. $\overline{CHRG}$ is pulled low when the charger is in charging status, otherwise $\overline{CHRG}$ becomes high impedance. $\overline{FAULT}$ is pulled low if battery pack's temperature is in out of temperature condition for more than 0.15S, otherwise $\overline{FAULT}$ 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 low leakage current at BAT pin, which results in a 100mv ripple waveform at BAT pin, in the meantime, $\overline{CHRG}$ pin outputs a pulse to indicate that the battery's absence. The pulse's frequency is around 10Hz when a 4.7uF output capacitor is used.

V_{IN} Bypass Capacitor C_{IN}

Many types of capacitors can be used for input bypassing, C_{IN} is typically a 4.7uF capacitor.

Stability

In constant voltage mode, typically a 4.7uF capacitor in series with a 0.3ohm resistor from BAT pin to GND is required to stabilize the feedback loop.

In constant current mode, it is the ISET pin that is in the feedback loop and not the BAT pin. The constant current mode stability is affected by the impedance at the ISET pin . With no additional capacitance on the ISET pin, the loop is stable with current set resistors values as high as 50KΩ . However, additional capacitance on ISET pin reduces the maximum allowed current set resistor. The pole frequency at ISET pin should be kept above 200KHz. Therefore, if ISET pin is loaded with a capacitance C, the following equation should be used to calculate the maximum resistance value for R_{ISET}:

$$R_{ISET} < 1/(6.28\times2\times10^5\times C)$$

In order to measure average charge current or isolate capacitive load from ISET pin, a simple RC filter can be used on ISET pin as shown in Figure 4.

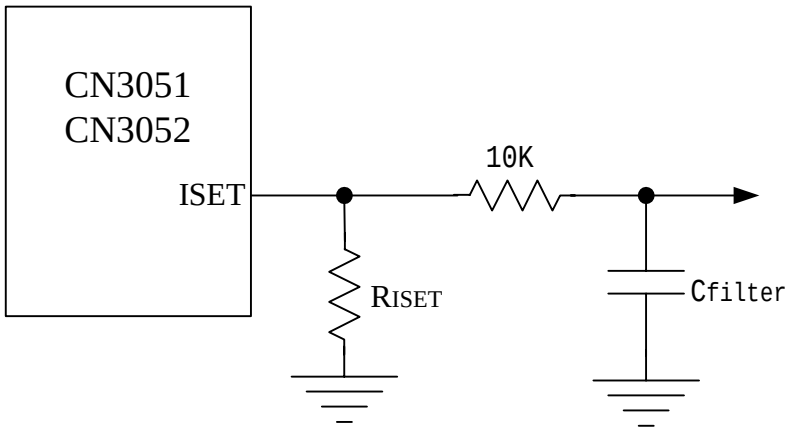
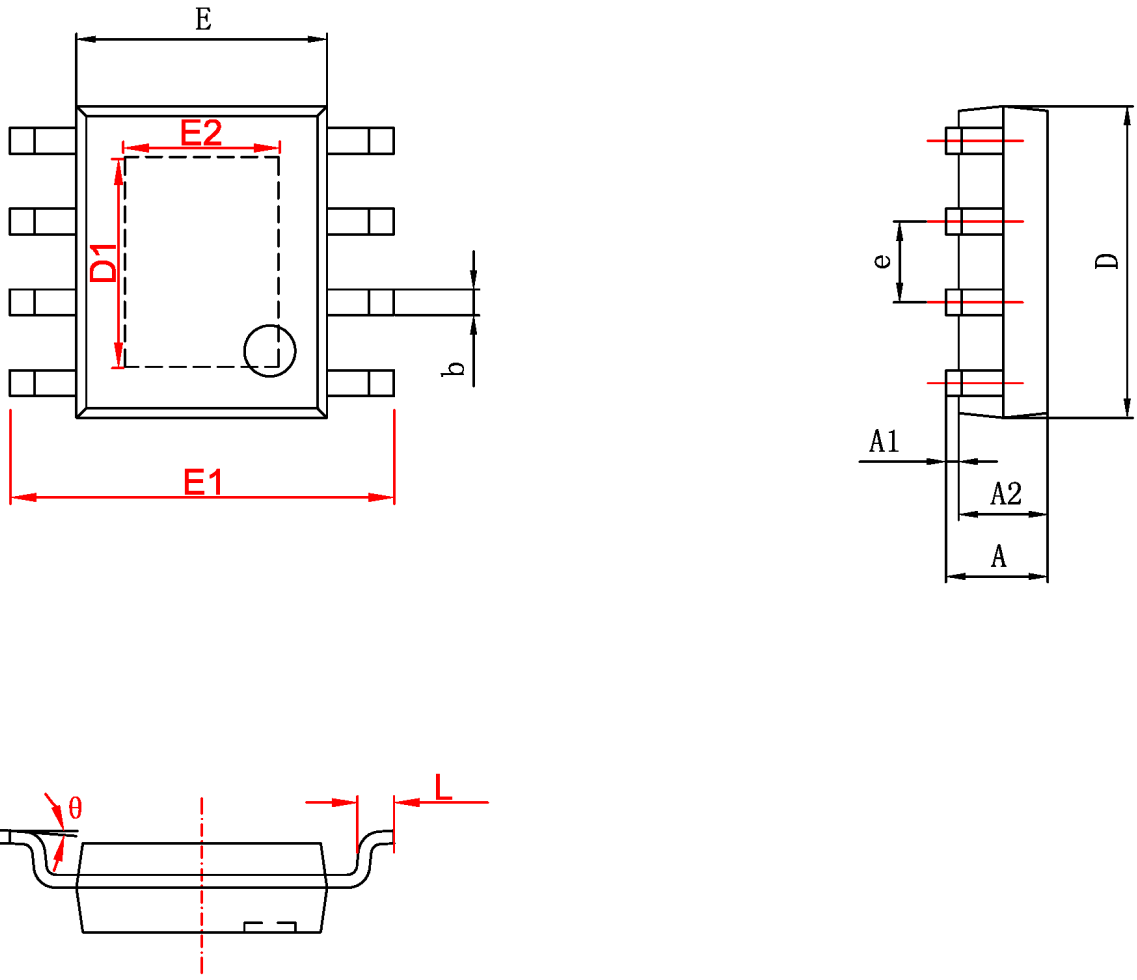


Figure 4 Isolating Capacitive Load on ISET Pin

Board Layout Considerations

The ability to deliver maximum charge current under all conditions require that the exposed metal pad on the back side of the CN3051/CN3052 package be soldered to the PC board ground. Failure to make the thermal contact between the exposed pad on the backside of the package and the copper board will result in larger thermal resistance.

Package Information



字符	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°