Switch Mode Li-Ion/Polymer Battery Charger

DESCRIPTION

The EUP8209 is a constant current, constant voltage Li-Ion battery charger controller that uses a current mode PWM step-down (buck) switching architecture. With a 500kHz switching frequency, the EUP8209 provides a small, simple and efficient solution to fast charge one (4.2V) or two (8.4V) cell lithium-ion batteries.

The EUP8209 charges the battery in three phases: conditioning, constant current, and constant voltage. An external sense resistor sets the charge current with ±10% accuracy. An internal resistor divider and precision reference set the final float voltage to 4.2V per cell with ± 1% accuracy. An internal comparator detects the near end-of-charge condition while an internal timer sets the total charge time and terminates the charge cycle. The EUP8209 automatically re-starts the charge if the battery voltage falls below an internal threshold, 4.05V per cell. The EUP8209 also automatically enters sleep mode when DC supplies are removed.

The EUP8209 is available in the 8-lead SOP package.

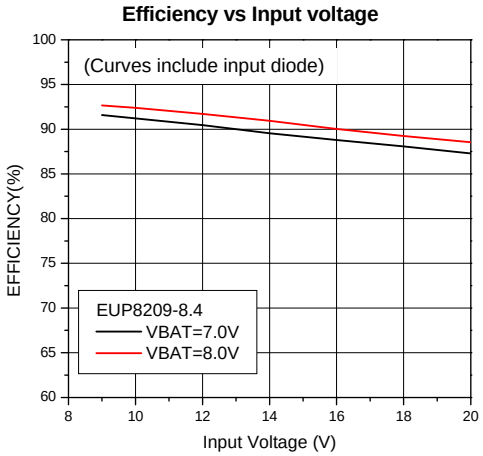
FEATURES

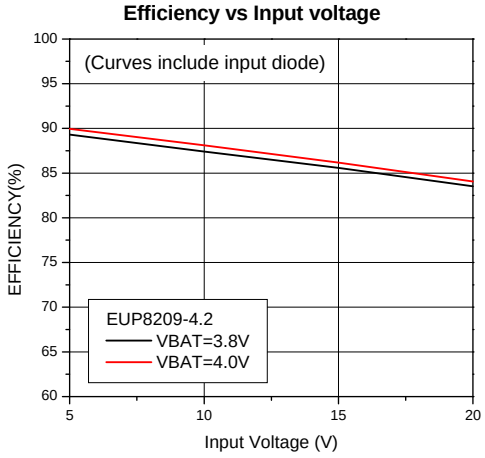
- Wide Input Supply Voltage Range:
  - 4.8V to 20V – 4.2 Version
  - 8.9V to 20V – 8.4 Version
  - 8.9V to 20V – 8.4A Version
- 500kHz Switching Frequency
- End-of-Charge Current Detection Output
- 12 Hour Charge Termination Timer
- ±1% Charge Voltage Accuracy
- ±10% Charge Current Accuracy
- Low 10μA Reverse Battery Drain Current
- Automatic Battery Recharge
- Automatic Trickle Charging of Low Voltage Batteries
- Automatic Sleep Mode for Low Power Consumption
- Battery Temperature Sensing
- Stable with Ceramic Output Capacitor
- Support up to 3A Charge Current
- 8-Lead SOP Package
- RoHS Compliant and 100% Lead (Pb)-Free Halogen-Free

APPLICATIONS

- Small Notebook Computer
- Portable DVD
- Handheld Instruments

Typical Operating Performance





Typical Application Circuit

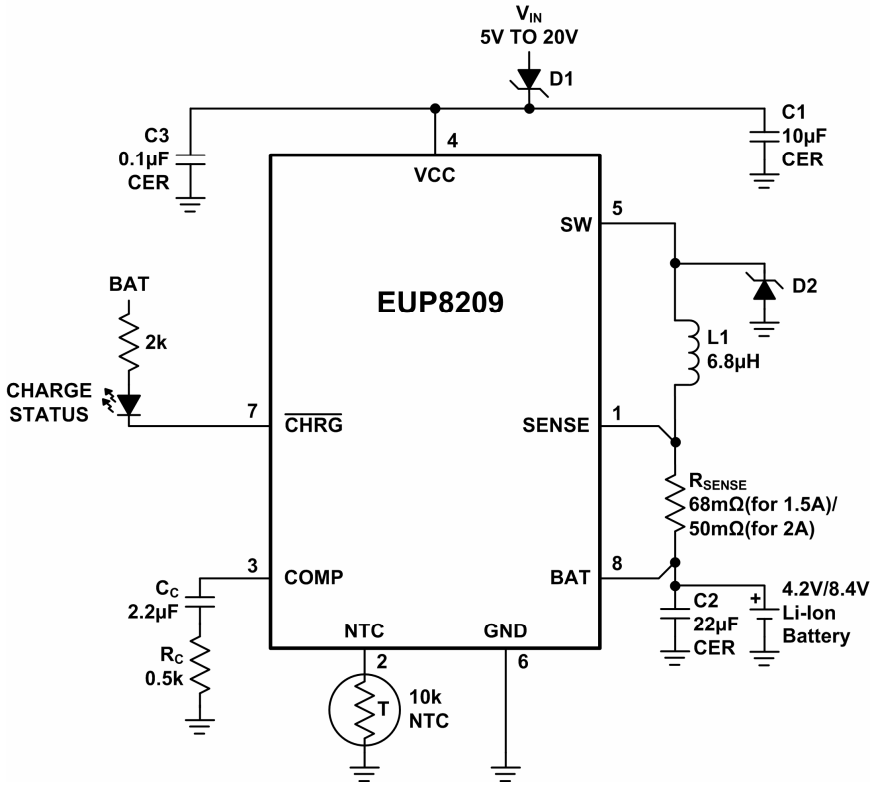


Figure 1. 1.5A Single Cell/2.0A Dual Cells Li-Ion Battery Charger

Block Diagram

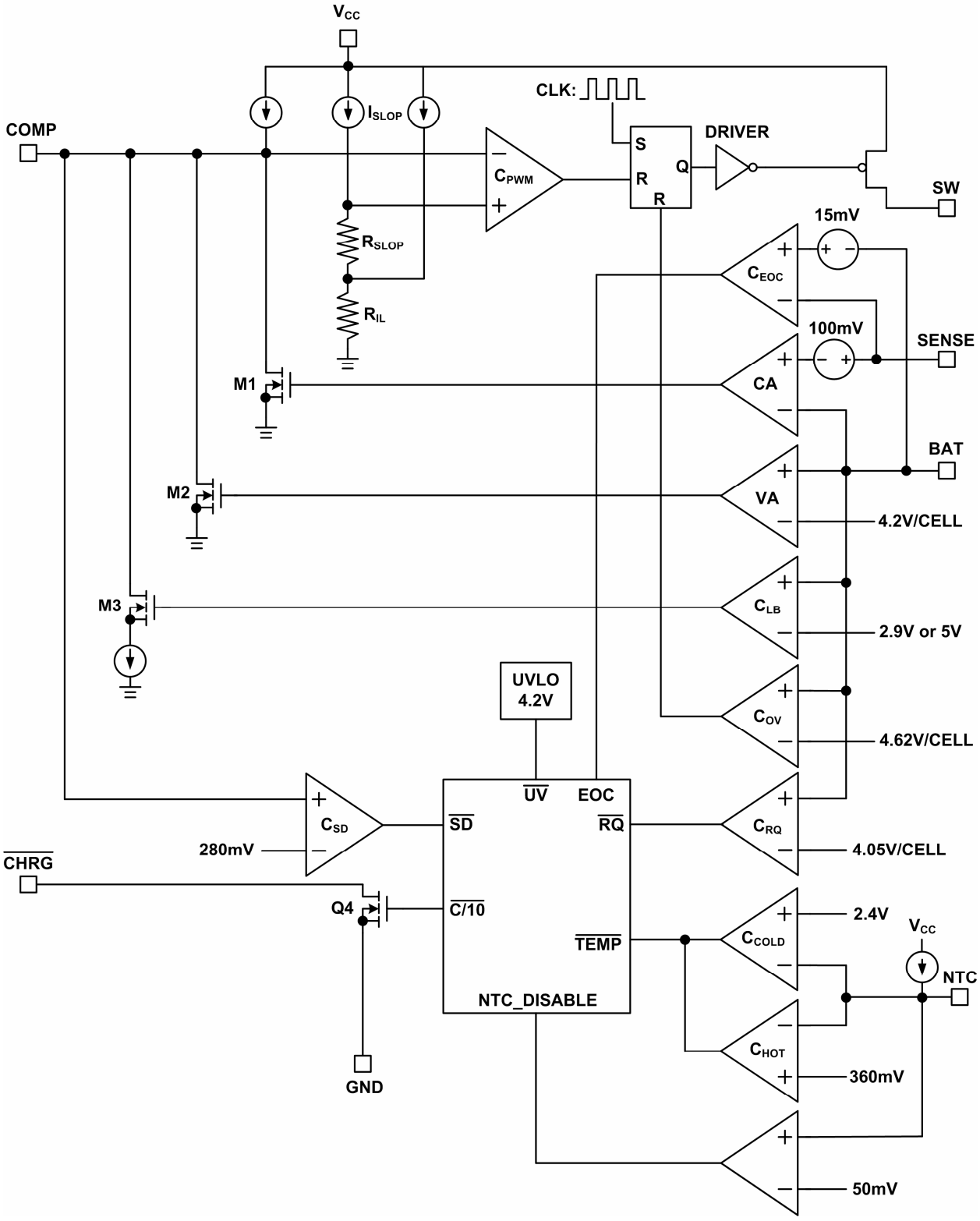
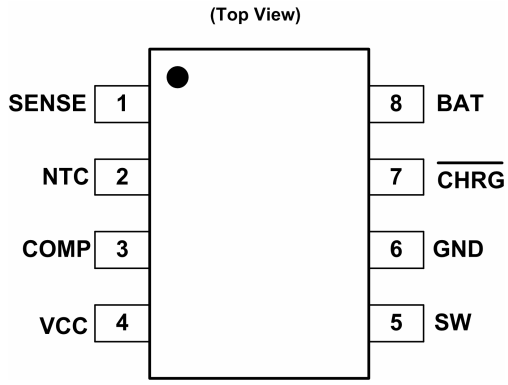


Figure 2.

Pin Configurations

Package Type	Pin Configurations
SOP-8	

Pin Description

PIN	SOP-8	DESCRIPTION
SENSE	1	Current Amplifier Sense Input. A sense resistor, RSENSE, must be connected between the SENSE and BAT pins. The maximum charge current is equal to 100mV/RSENSE.
NTC	2	NTC (Negative Temperature Coefficient) Thermistor Input. With an external 10kΩ NTC thermistor to ground, this pin senses the temperature of the battery pack and stops the charger when the temperature is out of range. To disable the temperature qualification function, ground the NTC pin.
COMP	3	Compensation, Soft-Start and Shutdown Control Pin. Charging begins when the COMP pin reaches 850mV. The recommended compensation components are a 2.2µF (or larger) capacitor and a 0.5k series resistor (or small). A 100µA current into the compensation capacitor also sets the soft-start slew rate. Pulling the COMP pin below 280mV will shut down the charger.
VCC	4	Positive Supply Voltage Input.
SW	5	Power Switching Output.
GND	6	IC Ground.
$\overline{\text{CHRG}}$	7	Charge Status Output.
BAT	8	Battery Sense Input. A bypass capacitor of 22µF is required to minimize ripple voltage. When V_{BAT} is within 250mV of V_{CC}, the EUP8209 is forced into sleep mode, dropping I_{CC} to 10µA.

Ordering Information

Order Number	Package Type	Marking	Operating Temperature Range
EUP8209-42DIR1	SOP-8	xxxxx P8209 1N	-40 °C to +85°C
EUP8209-84DIR1	SOP-8	xxxxx P8209 1P	-40 °C to +85°C
EUP8209-84ADIR1	SOP-8	xxxxx P8209 1PA	-40 °C to +85°C

EUP8209-□□□ □ □ □ □

- Lead Free Code
  1: Lead Free, Halogen Free
- Packing
  R: Tape & Reel
- Operating temperature range
  I: Industry Standard
- Package Type
  D:SOP
- Output Voltage Option

Absolute Maximum Ratings

- Supply Voltage (V_{CC}) ---------- 22V
- SW ---------- (-1V) to V_{CC}
- BAT, SENSE ---------- -0.3V to 14V
- $\overline{CHRG}$,NTC ---------- -0.3V to 8V
- Operating Temperature Range ---------- -40°C to +85°C
- Storage Temperature Range ---------- -65°C to +125°C
- Lead Temperature (Soldering, 10sec) ---------- 260°C
- ESD protection ---------- 2kV

Electrical Characteristics (T_A = 25°C, V_{CC} = 10V, unless otherwise noted.)

Symbol	Parameter	Conditions		EUP8209-4.2			Unit
				Min.	Typ.	Max.	
DC Characteristics							
V_{CC}	V_{CC} Supply Voltage			4.8		20	V
I_{CC}	V_{CC} Supply Current	Current Mode			1.5	5	mA
		Shutdown Mode			1.5	5	mA
		Sleep Mode			10	20	µA
$V_{BAT(FLT)}$	Battery Regulated Float Voltage	5V≦ V_{CC} ≦ 20V		4.158	4.2	4.242	V
$V_{SNS(CHG)}$	Constant Current Sense Voltage	3V≦ V_{BAT} ≦ 4V	T_A =25°C	90	100	110	mV
			-40°C≦ T_A ≦85°C	85		115	
$V_{SNS(TRKL)}$	Trickle Current Sense Voltage	V_{BAT} = 1V		8	15	22	mV
V_{TRKL}	Trickle Charge Threshold Voltage	V_{BAT} = Rising		2.75	2.9	3.05	V
V_{UV}	V_{CC} Undervoltage Lockout Threshold Voltage	V_{CC} = Rising		3.9	4.2	4.5	V
ΔV_{UV}	V_{CC} Undervoltage Lockout Hysteresis Voltage				200		mV
V_{MSD}	Manual shutdown Threshold Voltage	COMP Pin Falling		150	280	450	mV
V_{ASD}	Automatic shutdown Threshold Voltage	V_{CC} - V_{BAT}			250		mV
I_{COMP}	COMP Pin Output Current	V_{COMP} = 1.2V			100		µA
V_{CHRG}	$\overline{CHRG}$ Pin Output Low Voltage	I_{CHRG} = 1mA			20	50	mV
R_{EOC}	End-of-Charge Ratio	$V_{SNS(EOC)}$ /$V_{SNS(CHG)}$		6	15	32	%
t_{TIMER}	Charge time Accuracy					10	%
I_{NTC}	NTC Pin Output Current	V_{NTC} = 0.85V		75	85	95	µA
$V_{NTC-HOT}$	NTC Pin Threshold Voltage (Hot)	V_{NTC} = Falling		340	360	380	mV
		Hysteresis			5		mV
$V_{NTC-COLD}$	NTC Pin Threshold Voltage (Cold)	V_{NTC} = Rising		2.35	2.4	2.45	V
		Hysteresis			100		mV
ΔV_{RECHRG}	Recharge Battery Voltage Offset from Full Charged Battery Voltage	$V_{BAT(FULLCHARGD)}$ −V_{RECHRG}, V_{BAT} Falling		100	150	200	mV
I_{LEAK}	$\overline{CHRG}$ Pin Leakage Current	V_{CHRG}= 8V, Charging Stops				1	µA

Electrical Characteristics (T_A = 25°C, V_{CC} = 10V, unless otherwise noted.)

Symbol	Parameter	Conditions	EUP8209-4.2			Unit
			Min.	Typ.	Max.	
R_{DSON}	High-Side Switch On-Resistance			55		mΩ
Oscillator						
f_{OSC}	Switching Frequency		450	500	550	kHz
DC	Maximum Duty Cycle				100	%

Electrical Characteristics(T_A = 25°C, V_{CC} = 10V, unless otherwise noted.)

Symbol	Parameter	Conditions			EUP8209-8.4/8.4A			Unit
					Min.	Typ.	Max.	
DC Characteristics								
V_{CC}	V_{CC} Supply Voltage				8.9		20	V
I_{CC}	V_{CC} Supply Current	Current Mode				1.5	5	mA
		Shutdown Mode				1.5	5	mA
		Sleep Mode				10	20	µA
$V_{BAT(FLT)}$	Battery Regulated Float Voltage	9V≦ V_{CC} ≦ 20V	0°C≦ T_A ≦ 85°C	8.4A	8.257	8.34	8.423	V
				8.4	8.316	8.4	8.484	
$V_{SNS(CHG)}$	Constant Current Sense Voltage	6V≦ V_{BAT} ≦ 8V	T_A =25°C		90	100	110	mV
			-40°C≦ T_A ≦85°C		85		115	
$V_{SNS(TRKL)}$	Trickle Current Sense Voltage	V_{BAT} = 1V			8	15	22	mV
V_{TRKL}	Trickle Charge Threshold Voltage	V_{BAT} = Rising			4.7	5	5.3	V
V_{UV}	V_{CC} Undervoltage Lockout Threshold Voltage	V_{CC} = Rising				7.5	8.5	V
ΔV_{UV}	V_{CC} Undervoltage Lockout Hysteresis Voltage					500		mV
V_{MSD}	Manual shutdown Threshold Voltage	COMP Pin Falling			150	280	450	mV
V_{ASD}	Automatic shutdown Threshold Voltage	V_{CC} - V_{BAT}				250		mV
I_{COMP}	COMP Pin Output Current	V_{COMP} = 1.2V				100		µA
V_{CHRG}	$\overline{CHRG}$ Pin Output Low Voltage	I_{CHRG} = 1mA				20	50	mV
R_{EOC}	End-of-Charge Ratio	$V_{SNS(EOC)}$ /$V_{SNS(CHG)}$			5	15	25	%
t_{TIMER}	Charge time Accuracy						10	%
I_{NTC}	NTC Pin Output Current	V_{NTC} = 0.85V			75	85	95	µA
$V_{NTC-HOT}$	NTC Pin Threshold Voltage (Hot)	V_{NTC} = Falling			340	360	380	mV
		Hysteresis				5		mV
$V_{NTC-COLD}$	NTC Pin Threshold Voltage (Cold)	V_{NTC} = Rising			2.35	2.4	2.45	V
		Hysteresis				100		mV
ΔV_{RECHRG}	Recharge Battery Voltage Offset from Full Charged Battery Voltage	$V_{BAT(FULLCHARGD)}$ −V_{RECHRG}, V_{BAT} Falling			200	300	400	mV
I_{LEAK}	$\overline{CHRG}$ Pin Leakage Current	V_{CHRG}= 8V, Charging Stops					1	µA
R_{DSON}	High-Side Switch On-Resistance					55		mΩ

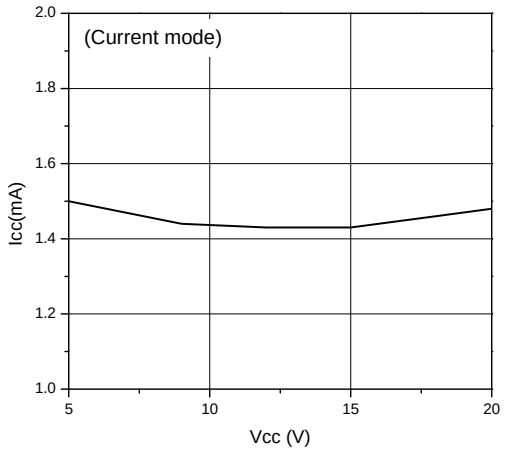
EUTECH MICROELECTRONICS

Electrical Characteristics (T_A = 25°C, V_{CC} = 10V, unless otherwise noted.)

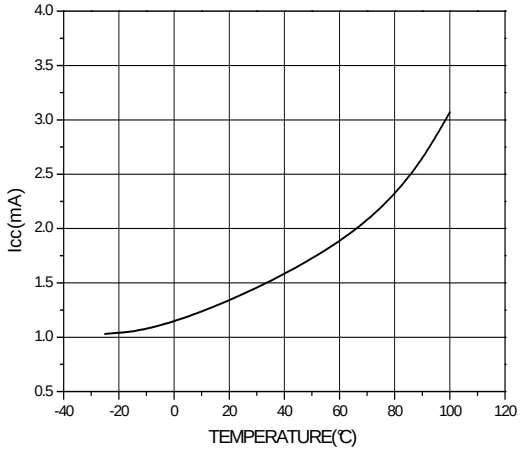
Symbol	Parameter	Conditions	EUP8209-8.4/8.4A			Unit
			Min.	Typ.	Max.	
Oscillator						
f_{OSC}	Switching Frequency		450	500	550	kHz
DC	Maximum Duty Cycle				100	%

Typical Operating Characteristics

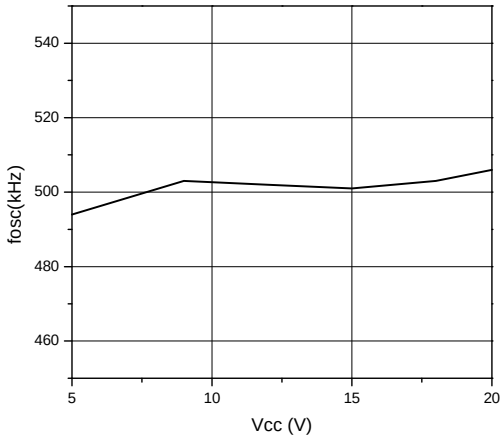
Supply Current vs Vcc



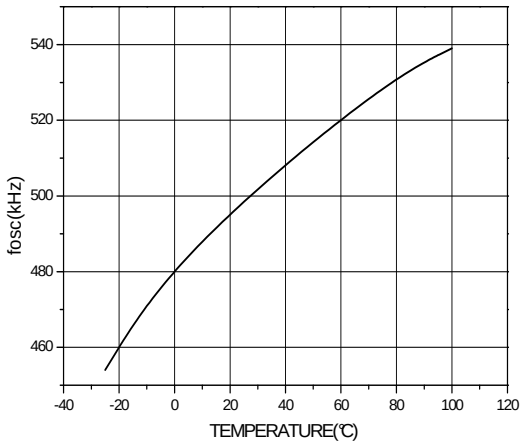
Supply Current vs Temperature



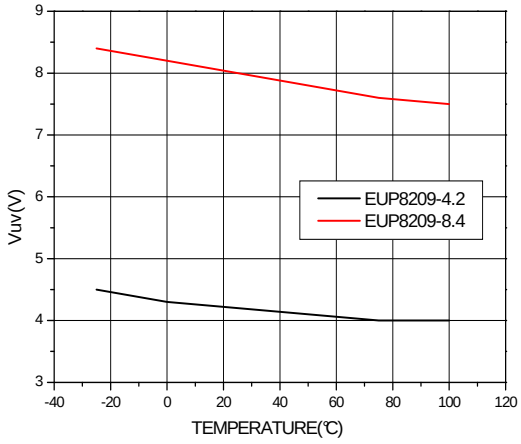
Oscillator Frequency vs Vcc



Oscillator Frequency vs Temperature

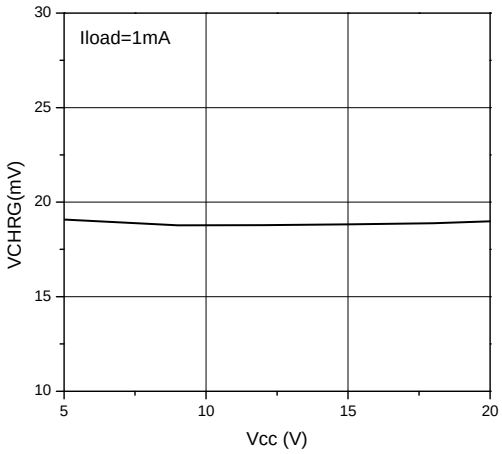


Undervoltage Lockout Threshold vs Temperature

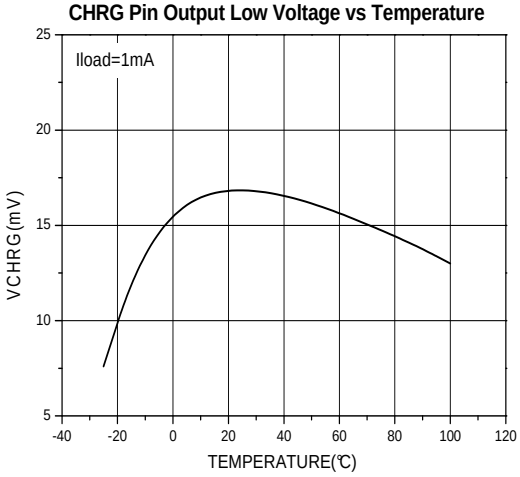


Typical Operating Characteristics (continued)

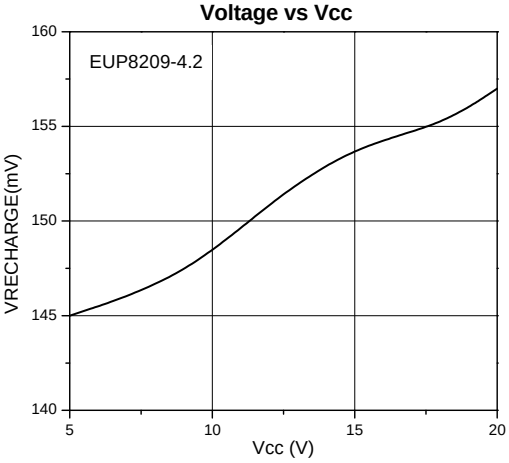
$\overline{\text{CHRG}}$ Pin Output Low Voltage vs Vcc



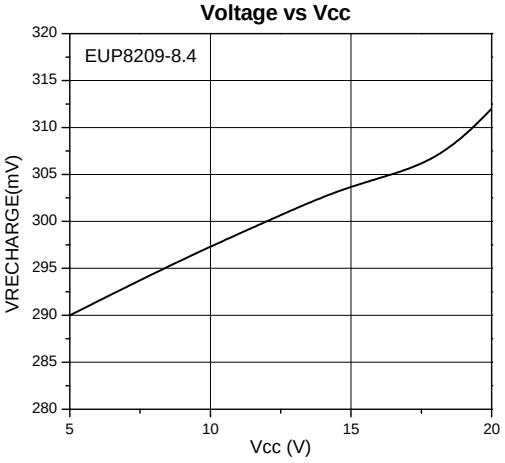
$\overline{\text{CHRG}}$ Pin Output Low Voltage vs Temperature



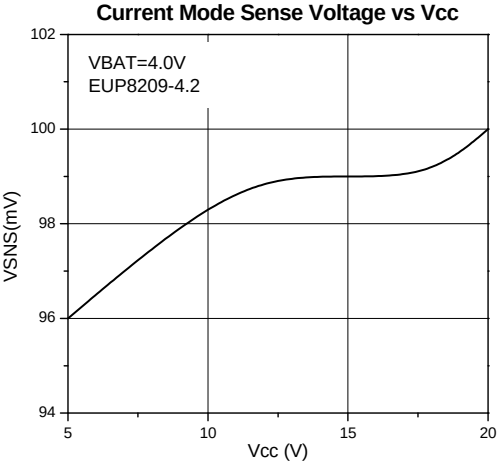
Recharge Voltage Offset from Full Charged Voltage vs Vcc



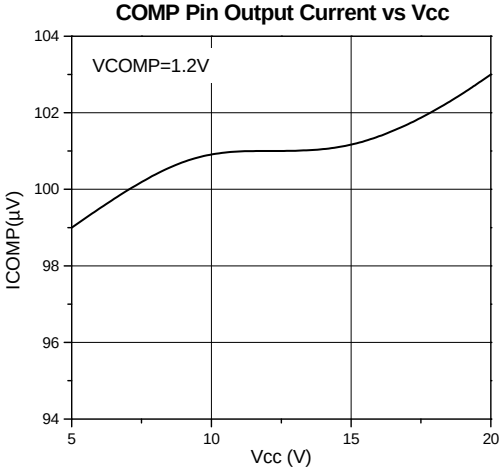
Recharge Voltage Offset from Full Charged Voltage vs Vcc



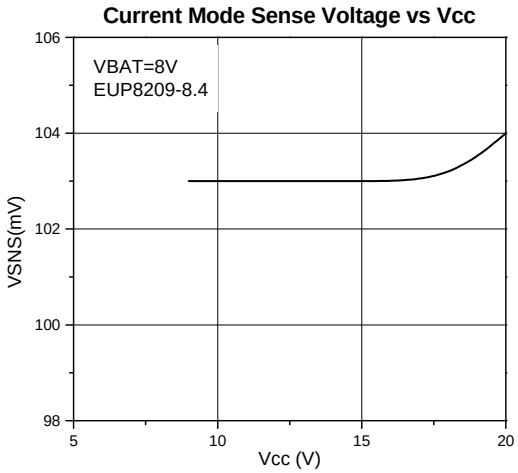
Current Mode Sense Voltage vs Vcc

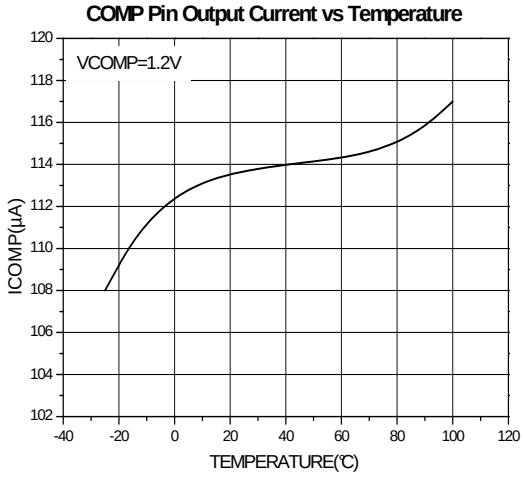


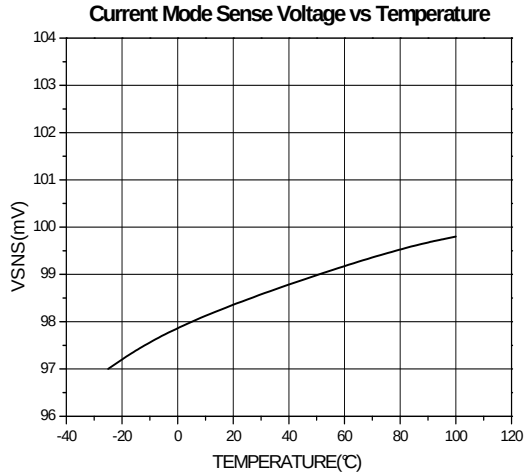
COMP Pin Output Current vs Vcc

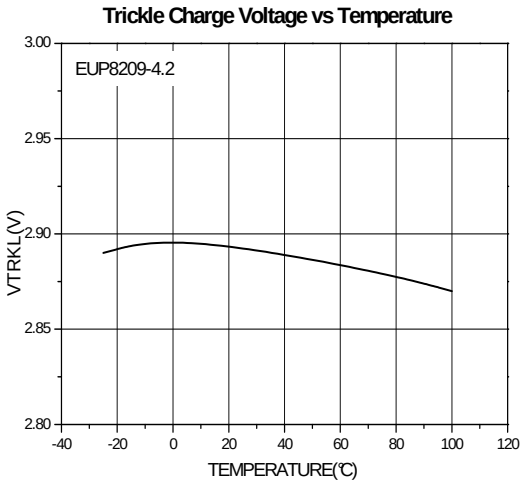


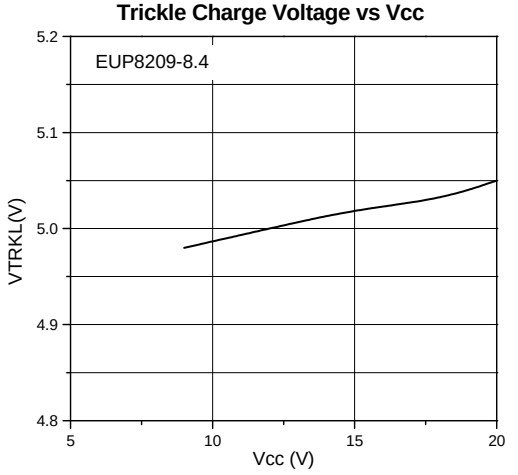
Typical Operating Characteristics (continued)

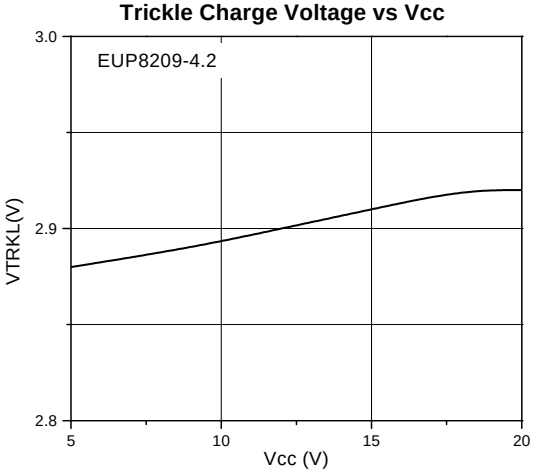






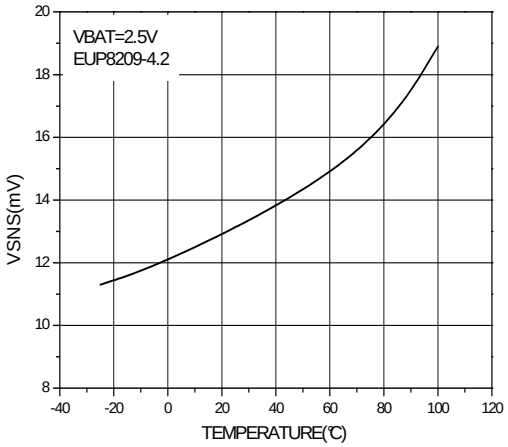




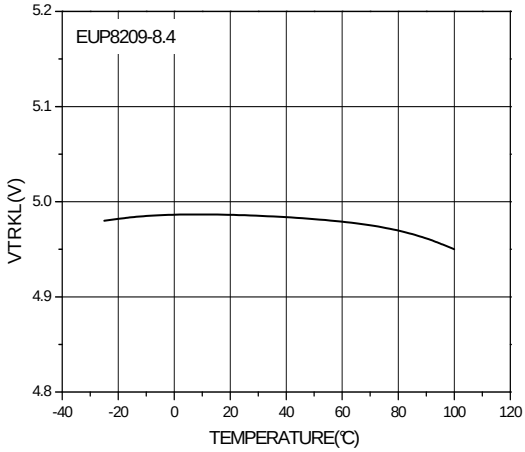


Typical Operating Characteristics (continued)

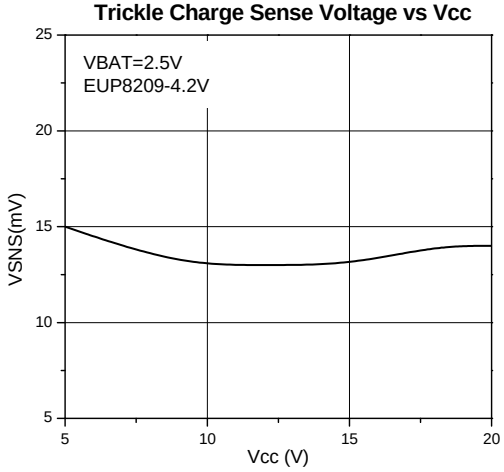
Trickle Charge Sense Voltage vs Temperature



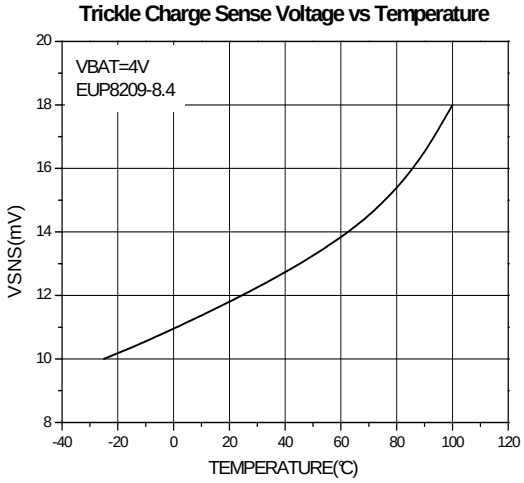
Trickle Charge Voltage vs Temperature



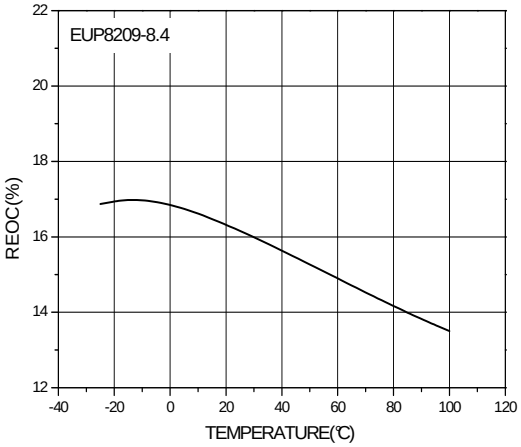
Trickle Charge Sense Voltage vs Vcc



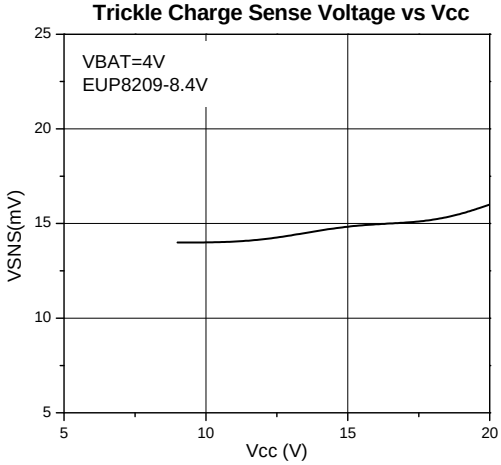
Trickle Charge Sense Voltage vs Temperature



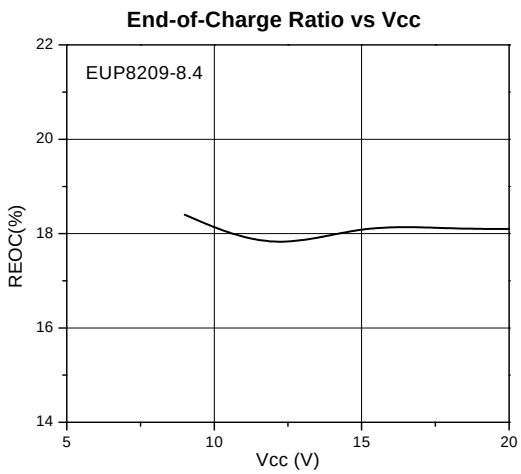
End-of-Charge Ratio vs Temperature

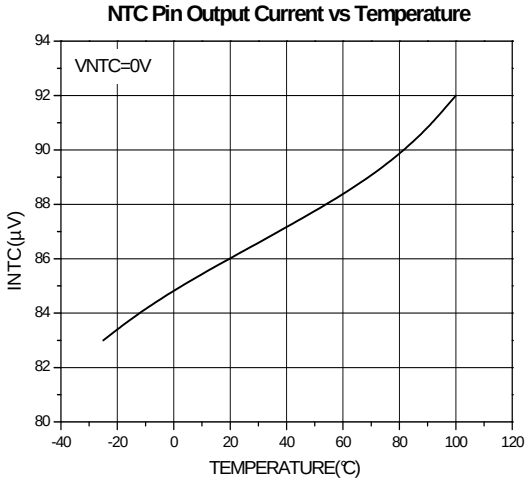


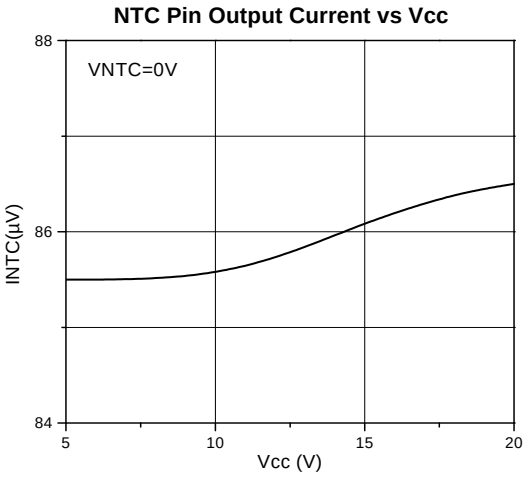
Trickle Charge Sense Voltage vs Vcc



Typical Operating Characteristics (continued)







Application Information

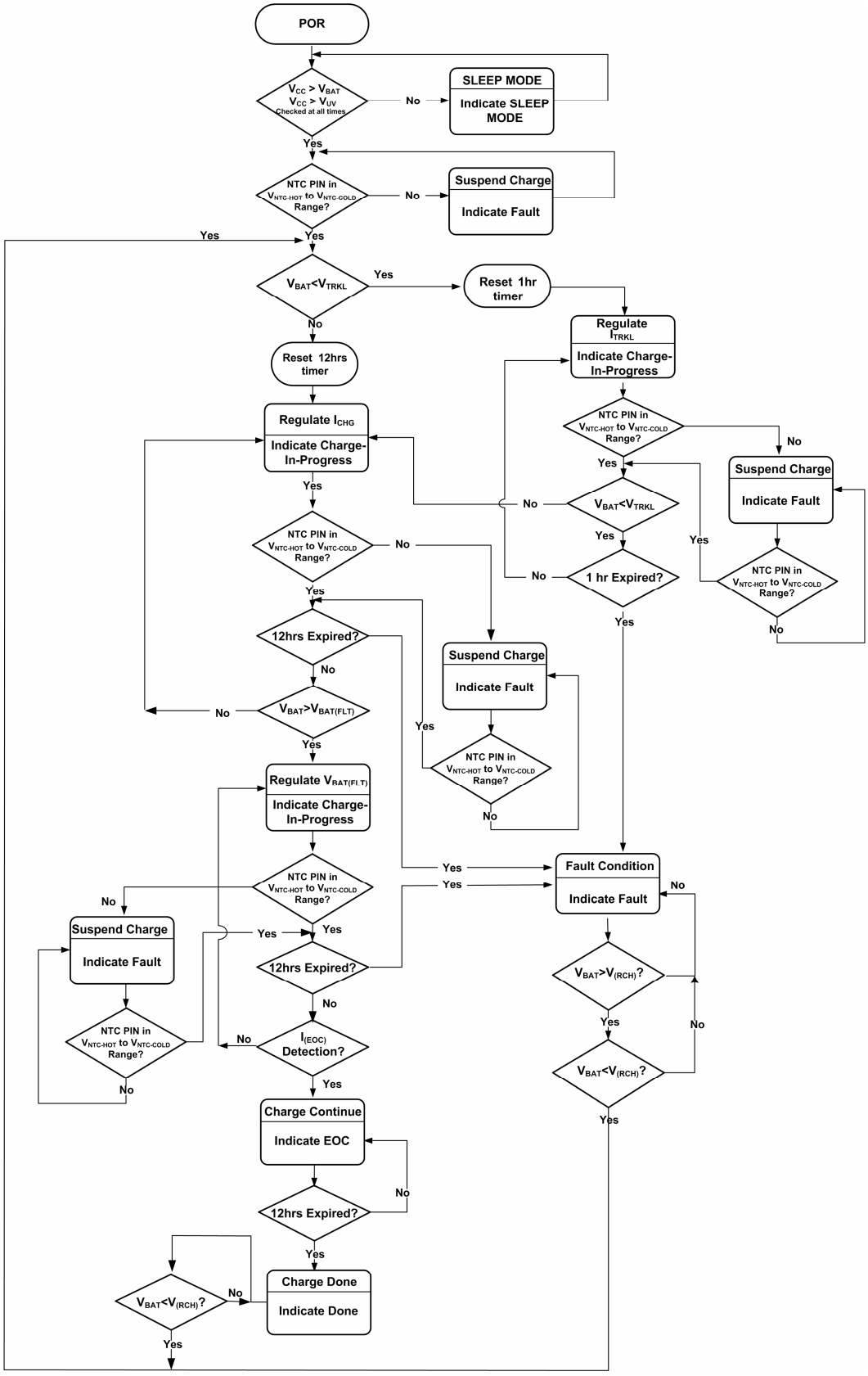


Figure 3. Operational Flow Chart

OPERATION

The EUP8209 is a constant current, constant voltage Li-Ion battery charger controller that uses a current mode PWM step-down (buck) switching architecture. The charge current is set by an external sense resistor (R_{SENSE}) across the SENSE and BAT pins. The final battery float voltage is internally set to 4.2V per cell. For batteries like lithium-ion that require accurate final float voltage, the internal 2.4V reference, voltage amplifier and the resistor divider provide regulation with ±1% accuracy.

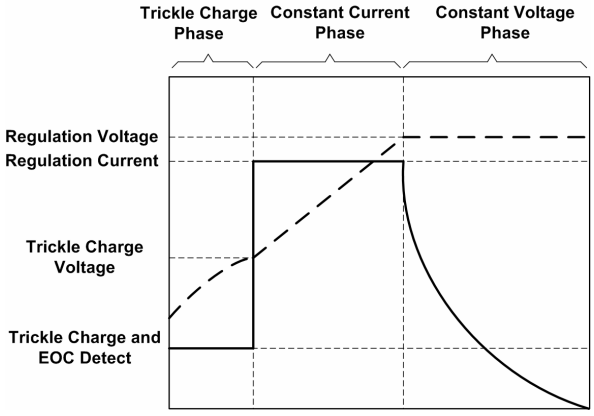


Figure 4.Typical Charge Profile

A charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO level and is 250mV or more greater than the battery voltage. At the beginning of the charge cycle, if the battery voltage is less than the trickle charge threshold, 2.9V for the 4.2 version and 5V for the 8.4 version, the charger goes into trickle charge mode. The trickle charge current is internally set to 15% of the full-scale current. If the battery voltage stays low for 1 hour, the battery is considered faulty and the charge cycle is terminated.

When the battery voltage exceeds the trickle charge threshold, the charger goes into the full-scale constant current charge mode. In constant current mode, the charge current is set by the external sense resistor R_{SENSE} and an internal 100mV reference;

$$I_{CHG} = \frac{V_{SNS(CHG)}}{R_{SENSE}} = \frac{100mV}{R_{SENSE}}$$

When the battery voltage approaches the programmed float voltage, the charge current will start to decrease. When the current drops to 15% (4.2 version) or 15% (8.4 version) of the full-scale charge current, an internal comparator turns off the internal pull-down N-channel MOSFET at the $\overline{CHRG}$ pin, and to indicate a near end-of-charge condition.

An internal 12 hour timer determines the total charge time. After a time out occurs, the charge cycle is terminated and the CHRG pin is forced high impedance. To restart the charge cycle, remove and reapply the input voltage or momentarily shut the charger down. Also, a new charge cycle will begin if the battery voltage drops below the recharge threshold voltage of 4.05V per cell.

When the input voltage is present, the charger can be shut down (I_{CC} =1.5mA) by pulling the COMP pin low. When the input voltage is not present, the charger goes into sleep mode, dropping I_{CC} to 10µA. This will greatly reduce the current drain on the battery and increase the standby time.

A 10kΩ NTC (negative temperature coefficient) thermistor can be connected from the NTC pin to ground for battery temperature qualification. The charge cycle is suspended when the temperature is outside of the 0˚C to 50˚C window.

APPLICATIONS INFORMATION

Undervoltage Lockout (UVLO)

An undervoltage lockout circuit monitors the input voltage and keeps the charger off until VCC rises above the UVLO threshold (4.2V for the 4.2 version, 7.5V for the 8.4 version) and at least 250mV above the battery voltage. To prevent oscillation around the threshold voltage, the UVLO circuit has 200mV per cell of built-in hysteresis. When specifying minimum input voltage requirements, the voltage drop across the input blocking diode must be added to the minimum V_{CC} supply voltage specification.

Trickle Charge and Defective Battery Detection

At the beginning of a charge cycle, if the battery voltage is below the trickle charge threshold, the charger goes into trickle charge mode with the charge current reduced to 15% of the full-scale current. If the low-battery voltage persists for 1 hour, the battery is considered defective, the charge cycle is terminated and the $\overline{CHRG}$ pin is forced high impedance.

$$I_{TRKL} = \frac{V_{SNS(TRKL)}}{R_{SENSE}} = \frac{15mV}{R_{SENSE}}$$

Shutdown

The EUP8209 can be shut down by pulling the COMP pin to ground which turning off the P-channel MOSFET. When the COMP pin is released, the internal timer is reset and a new charge cycle starts. In shutdown, the output of the $\overline{CHRG}$ pin is high impedance and the quiescent current remains at 1.5mA. Removing the input power supply will put the charger into sleep mode. If the voltage at the V_{CC} pin drops below (V_{BAT} + 250mV) or below the UVLO level, the EUP8209 goes into a low current (I_{CC} = 10µA) sleep mode, reducing the battery drain current.

$\overline{\text{CHRG}}$ Status Output Pin

When a charge cycle starts, the $\overline{\text{CHRG}}$ pin is pulled to ground by an internal N-channel MOSFET which is capable of driving an LED. When the charge current drops below the End-of-Charge threshold, the N-channel MOSFET turns off is connected to the $\overline{\text{CHRG}}$ pin and until the timer ends the charge cycle, or the charger is in manual shutdown or sleep mode.

Table1: $\overline{\text{CHRG}}$ Status Pin Summary

CHARGE STATE	$\overline{\text{CHRG}}$ Pin
Trickle Charge in Process	Strong On
Constant Current Charge in Process	Strong On
Constant Voltage Charge in Process	Strong On
Charge Suspend (Temperature)	Strong On (remains the same)
Timer Fault	Hi-Z
Sleep / Shutdown	Hi-Z
End of Charge	Hi-Z
Battery Disconnected	Hi-Z

After a time out occurs (charge cycle ends), the pin will become high impedance.

Stability

Both the current loop and the voltage loop share a common, high impedance, compensation node (COMP pin). A series capacitor and resistor on this pin compensates both loops. The resistor is included to provide a zero in the loop response and boost the phase margin. The compensation capacitor also provides a soft-start function for the charger. Upon start-up, then ramp at a rate set by the internal 100µA pullup current source and the external capacitor. Battery charge current starts ramping up when the COMP pin voltage reaches 0.85V and full current is achieved with the COMP pin at 1.3V. With a 2.2µF capacitor, time to reach full charge current is about 10ms. Capacitance can be increased if a longer start-up time is needed.

Automatic Battery Recharge

After the 12 hour 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 4.05V per cell 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 Temperature Detection

A negative temperature coefficient (NTC) thermistor located close to the battery pack can be used to monitor battery temperature and will not allow charging unless the battery temperature is within an acceptable range. Connect a 10kΩ thermistor from the NTC pin to ground. If the temperature rises to 50°C, the resistance of the NTC will be approximately 4.2kΩ. With the 85µA pull-up current source, the Hot temperature voltage threshold is 360mV. For Cold temperature, the voltage threshold is set at 2.4V which is equal to 0°C ($R_{NTC} \cong$ 28kΩ) with 85µA of pull-up current. If the temperature is outside the window, turning off P-channel MOSFET and the timer frozen while the output status at the $\overline{\text{CHRG}}$ pin remains the same. The charge cycle begins or resumes once the temperature is within the acceptable range. Short the NTC pin to ground to disable the temperature qualification feature. However the user may modify these thresholds by adding two external resistor. See figure 6.

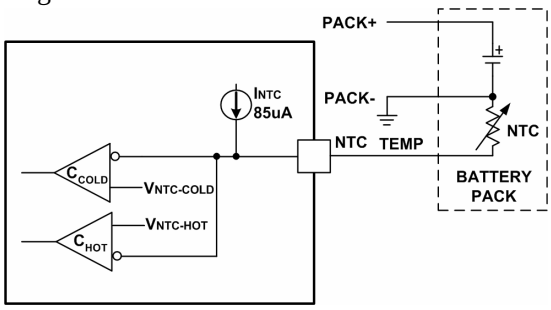


Figure 5. Temperature Sensing Configuration

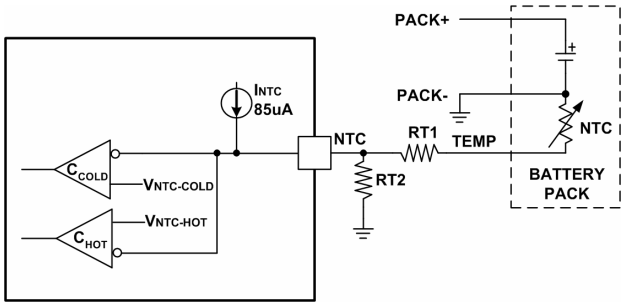


Figure 6. Temperature Sensing Thresholds

Input and Output Capacitors

Since the input capacitor 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. Actual capacitance value is not critical. Solid tantalum capacitors have a high ripple current rating in a relatively small surface mount package, but caution must be used when tantalum capacitors are used for input bypass. High input surge currents can be created when the adapter is hot-plugged to the charger and solid tantalum capacitors have a known failure mechanism when subjected to very high turn-on surge currents. Selecting the highest possible voltage rating on the capacitor will minimize problems. Consult with the manufacturer before use.

The selection of output capacitor C_{OUT} is primarily determined by the ESR required to minimize ripple voltage and load step transients. The output ripple ΔV_{OUT} is approximately bounded by:

$$\Delta V_{OUT} \le \Delta I_L \left(ESR + \frac{1}{8 f_{OSC} C_{OUT}} \right)$$

Since ΔI_L increases with input voltage, the output ripple is highest at maximum input voltage. Typically, once the ESR requirement is satisfied, the capacitance is adequate for filtering and has the necessary RMS current rating.
Switching ripple current splits between the battery and the output capacitor depending on the ESR of the output capacitor and the battery impedance. EMI considerations usually make it desirable to minimize ripple current in the battery leads. Ferrite beads or an inductor may be added to increase battery impedance at the 500kHz switching frequency. If the ESR of the output capacitor is 0.2Ω and the battery impedance is raised to 4Ω with a bead or inductor, only 5% of the current ripple will flow in the battery.

Design Example

As a design example, take a charger with the following specifications:
For single cell charge, V_{IN} = 5V to 20V, V_{BAT} = 4V nominal, I_{BAT} =1.5A, f_{OSC} = 500kHz, see Figure 1.

First, calculate the SENSE resistor :

$$R_{SENSE} = \frac{100mV}{1.5A} = 68m\Omega$$

Choose the inductor for about 65% ripple current at the maximum V_{IN}:

$$L = \frac{4V}{(500kHz)(0.65)(1.5A)}\left(1 - \frac{4V}{20V}\right) = 6.56\mu H$$

Selecting a standard value of 6.8µH results in a maximum ripple current of :

$$\Delta I_L = \frac{4V}{(500kHz)(6.8\mu H)}\left(1 - \frac{4V}{20V}\right) = 941.2mA$$

$$I_{LPK} = I_{CHG} + \frac{\Delta I_L}{2} = 1.5A + \frac{941.2mA}{2} \approx 1.975A$$

Next, the P-channel MOSFET. For example, a SOP-8 package with $R_{DS(ON)}$ = 42mΩ (nom), 55mΩ (max) offers a small solution. The maximum power dissipation with V_{IN} = 5V and V_{BAT} = 4V at 50°C ambient temperature is:

$$P_D = \frac{(1.5A)^2 (55m\Omega)(4V)}{5V} = 0.099W$$

T_J = 50°C + (0.099W)(65°C /W) = 56.5°C

C_{IN} is chosen for an RMS current rating of about 0.8A at 85°C. The output capacitor is chosen for an ESR similar to the battery impedance of about 100mΩ The ripple voltage on the BAT pin is:

$$V_{OUT(RIPPLE)} = \frac{\Delta I_{L(max)} (ESR)}{2} = \frac{(0.94A)(0.1\Omega)}{2} = 47mV$$

For dual cells charge,
V_{IN} = 5V to 20V, V_{BAT} = 8V nominal, I_{BAT} =3A,
f_{OSC} = 500kHz, I_{EOC}=0.45A,

$$R_{SENSE} = \frac{100mV}{3A} = 33m\Omega$$

Choose the inductor for about 50% ripple current at the maximum V_{IN}:

$$L = \frac{8V}{(500kHz)(0.5)(3A)}\left(1 - \frac{8V}{20V}\right) = 6.4\mu H$$

Selecting a standard value of 6.8µH results in a maximum ripple current of :

$$\Delta I_L = \frac{8V}{(500kHz)(6.8\mu H)}\left(1 - \frac{8V}{20V}\right) = 1.441A$$

$$I_{LPK} = I_{CHG} + \frac{\Delta I_L}{2} = 3A + \frac{1.441A}{2} \approx 3.720A$$

The maximum power dissipation with V_{IN} = 9V and V_{BAT} = 8V at 50°C ambient temperature is:

$$P_D = \frac{(3A)^2 (55m\Omega)(8V)}{9V} = 0.44W$$

T_J = 50°C + (0.44W)(65°C /W) = 78.6°C

$$V_{OUT(RIPPLE)} = \frac{\Delta I_{L(max)} (ESR)}{2} = \frac{(1.441A)(0.1\Omega)}{2} = 72mV$$

The Schottky diode D2 shown in Figure 1 conducts current when the pass transistor is off. In a low duty cycle case, the current rating should be the same or higher than the charge current. Also it should withstand reverse voltage as high as V_{IN}.

Board Layout Suggestions

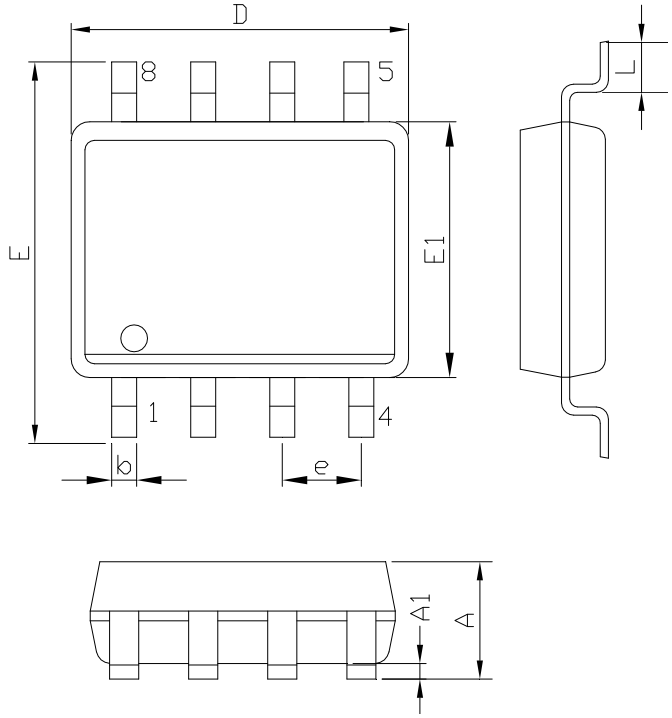
When laying out the printed circuit board, the following considerations should be taken to ensure proper operation of the EUP8209.

To minimize radiation, the catch diode and the input bypass capacitor traces should be kept as short as possible. The positive side of the input capacitor should be close to the source of the P-channel MOSFET; it provides the AC current to the pass transistor. The connection between the catch diode and the pass transistor should also be kept as short as possible. The SENSE and BAT pins should be connected directly to the sense resistor (Kelvin sensing) for best charge current accuracy. Avoid routing the NTC PC board trace near the SW switch to minimize coupling switching noise into the NTC pin.

The compensation capacitor connected at the COMP pin should return to the ground pin of the IC or as close to it as possible. This will prevent ground noise from disrupting the loop stability. The ground pin also works as a heat sink, therefore use a generous amount of copper around the ground pin. This is especially important for high V_{CC}.

Packaging Information

SOP-8



SYMBOLS	MILLIMETERS			INCHES		
	MIN.	Normal	MAX.	MIN.	Normal	MAX.
A	1.35	-	1.75	0.053	-	0.069
A1	0.05	-	0.25	0.002	-	0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E1	3.70	3.90	4.00	0.146	0.154	0.157
E	5.80	6.00	6.20	0.228	0.236	0.244
L	0.40	-	1.27	0.016	-	0.050
b	0.31	-	0.51	0.012	-	0.020
e	1.27 REF			0.050 REF		