Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

EVALUATION KIT AVAILABLE

MAX8900A/MAX8900B/MAX8900C

1.2A Switch-Mode Li+ Chargers with ±22V Input Rating and JEITA Battery Temperature Monitoring

General Description

The MAX8900_ is a high-frequency, switch-mode charger for a 1-cell lithium ion (Li+) or lithium polymer (Li-Poly) battery. It delivers up to 1.2A of current to the battery from 3.4V to 6.3V (MAX8900A/MAX8900C) or 3.4V to 8.7V (MAX8900B). The 3.25MHz switch-mode charger is ideally suited to small portable devices such as headsets and ultra-portable media players because it minimizes component size and heat.

Several features make the MAX8900_ perfect for high-reliability systems. The MAX8900_ is protected against input voltages as high as +22V and as low as -22V. Battery protection features include low voltage prequalification, charge fault timer, die temperature monitoring, and battery temperature monitoring. The battery temperature monitoring adjusts the charge current and termination voltage as described in the JEITA* specification for safe use of secondary lithium-ion batteries.

Charge parameters are easily adjustable with external components. An external resistance adjusts the charge current from 50mA to 1200mA. Another external resistance adjusts the prequalification and done current thresholds from 10mA to 200mA. The done current threshold is very accurate achieving ±1mA at the 10mA level. The charge timer is adjustable with an external capacitor.

The MAX8900_ is available in a 0.4mm pitch, 2.44mm x 2.67mm x 0.64mm WLP package.

Applications

USB Charging
Headsets and Media Players
Smartphones
Digital Cameras
GPS, PND
eBook

Ordering Information (continued)

PART	TEMP RANGE	PIN-PACKAGE	OPTIONS
MAX8900AEWV+T	-40°C to +85°C	30 WLP	V_{OVLO} = 6.5V T1 = 0°C 2-pin status indicators V_{PQUTH} = 2.8V
MAX8900BEWV+T	-40°C to +85°C	30 WLP	V_{OVLO} = 9.0V T1 = -15°C 3-pin status indicators V_{PQUTH} = 2.8V

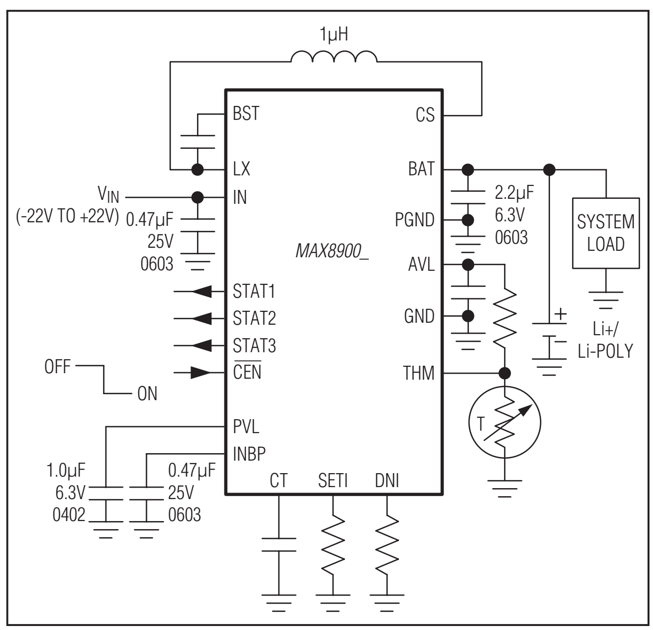
+Denotes a lead(Pb)-free/RoHS-compliant package.
T = Tape and reel.

Ordering Information continued at end of data sheet.

Features

- ♦ 3.25MHz Switching Li+/Li-Poly Battery Charger
- ♦ JEITA Battery Temperature Monitor Adjusts Charge Current and Termination Voltage
- ♦ 4.2V ±0.5% Battery Regulation Voltage (Alternate 4.1V Target Available on Request)
- ♦ Adjustable Done Current Threshold
  - Adjustable from 10mA to 200mA
  - ±1mA Accuracy at 10mA
- ♦ High-Efficiency and Low Heat
- ♦ Uses a 2.0mm x 1.6mm Inductor
- ♦ Positive and Negative Input Voltage Protection (±22V)
- ♦ Up to +20V Operating Range (Alternate OVLO Ranges Available on Request)
- ♦ Supports No-Battery Operation
- ♦ Fault Timer
- ♦ Charge Status Outputs
- ♦ 2.44mm x 2.67mm x 0.64mm Package

Simplified Applications Circuit



**JEITA (Japan Electronics and Information Technology Industries Association) standard, "A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-type Personal Computers" April 20, 2007.*

1.2A Switch-Mode Li+ Chargers with ±22V Input Rating and JEITA Battery Temperature Monitoring

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

ABSOLUTE MAXIMUM RATINGS

IN to PGND .... -22V to +22V
INBP to PGND .... (V_{BAT} - 0.3V) to +22V
IN to INBP .... -30V to +1.2V
STAT1, STAT2 to GND .... -0.3V to +30V
BST to PGND .... -0.3V to +36V
BST to LX .... -0.3V to +6.0V
BST to PVL .... -0.3V to +30V
PVL, BAT, CS to PGND .... -0.3V to +6.0V
AVL, STAT3, $\overline{CEN}$, THM to GND .... -0.3V to +6.0V
PVL to AVL .... -0.3V to +0.3V
CT to GND .... -0.3V to (AVL + 0.3V)
SETI, DNI to GND .... -0.3V to (V_{BAT} + 0.3V)
PGND to GND .... -0.3V to +0.3V
IN Continuous Current .... 2.4A_{RMS}
LX Continuous Current (Note 1) .... 1.6A_{RMS}
CS Continuous Current .... 1.3A_{RMS}
BAT Continuous Current .... 1.3A_{RMS}
Continuous Power Dissipation (T_A = +70°C)
30-Bump WLP (derate 20.4mW/°C above +70°C) 1616mW
Operating Temperature Range .... -40°C to +85°C
Junction Temperature .... -40°C to +150°C
Storage Temperature Range .... -65°C to +150°C
Soldering Temperture (reflow) .... +260°C

Note 1: LX has an internal clamp diode to PGND and INBP. Applications that forward bias these diodes should take care not to exceed the power dissipation limits of the device.

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 CHARACTERISTICS

(V_{IN} = 6V, V_{BAT} = 4V, R_{SETI} = 2.87kΩ, R_{DNI} = 3.57kΩ, V_{THM} = $V_{AVL/2}$, circuit of Figure 1, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
GENERAL							
IN Input Voltage Range (Note 3)	V_{IN}	Withstand voltage		-20		+20	V
		Operating voltage	MAX8900B	3.4		8.7	V
			MAX8900A/ MAX8900C	3.4		6.3	
IN Undervoltage Threshold	V_{UVLO}	V_{IN} falling, 400mV hysteresis (Note 4)		3.1	3.2	3.3	V
IN to BAT Shutdown Threshold	V_{IN2BAT}	When charging stops, V_{IN} falling, 200mV hysteresis		0	15	30	mV
IN Overvoltage Threshold (Note 3)	V_{OVLO}	V_{IN} rising	0.40V hysteresis (MAX8900B)	8.80	9.00	9.20	V
			0.26V hysteresis (MAX8900A/ MAX8900C)	6.35	6.50	6.65	
IN Supply Current	I_{IN}	Charger enabled, no switching			1	2	mA
		Charger enabled, f = 3.25MHz, V_{IN} = 6V			20		
		Charger disabled, $\overline{CEN}$ = high			0.04	0.2	
LX High-Side Resistance	R_{HS}				0.10		Ω
LX Low-Side Resistance	R_{LS}				0.15		Ω
LX Leakage Current		LX = GND or IN	T_A = +25°C		0.01	10	µA
			T_A = +85°C		0.1		
BST Leakage Current		V_{BST} - V_{LX} = 6V	T_A = +25°C		0.01	10	µA
			T_A = +85°C		0.1		
Current-Sense Resistor	R_{SNS}	V_{BAT} = 2.6V			0.045		Ω
IN to BAT Dropout Resistance	R_{IN2BAT}	Calculation estimates a 40mΩ inductor resistance (R_L), R_{IN2BAT} = $R_{IN2INBP}$ + R_{HS} + R_L + R_{SNS}			0.3		Ω
Switching Frequency	f_{SW}	V_{BAT} = 2.6V			3.25		MHz

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 6V, V_{BAT} = 4V, R_{SETI} = 2.87kΩ, R_{DNI} = 3.57kΩ, V_{THM} = $V_{AVL/2}$, circuit of Figure 1, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Minimum On-Time	t_{ON-MIN}				90		ns
Maximum On-Time	t_{ON-MAX}				9		µs
Minimum Off-Time	t_{OFF}				75		ns
BAT Regulation Voltage (Note 3)	V_{BATREG}	I_{BAT} = 0mA, MAX8900A/ MAX8900B/ MAX8900C (Figure 10)	T_A = +25°C, V_{THM} between T1 and T3	4.179	4.200	4.221	V
			T_A = -40°C to +85°C, V_{THM} between T1 and T3	4.158	4.200	4.242	
			T_A = +25°C, V_{THM} between T3 and T4 (Note 5)	4.055	4.075	4.095	
			T_A = -40°C to +85°C, V_{THM} between T3 and T4 (Note 5)	4.034	4.075	4.100	
Charger Restart Threshold (Note 6)	V_{RSTRT}	V_{THM} between T1 and T3		-70	-100	-125	mV
		V_{THM} between T3 and T4			-75		
BAT Prequalification Lower Threshold (Figure 6)	V_{PQLTH}	V_{BAT} rising,180mV hysteresis			2.1		V
BAT Prequalification Upper Threshold (Figure 6) (Note 3)	V_{PQUTH}	V_{BAT} rising, 180mV typical hysteresis	MAX8900A/MAX8900B	2.7	2.8	2.9	V
			MAX8900C	2.9	3.0	3.1	
Fast-Charge Current	I_{FC}	V_{THM} between T2 and T4 (Figure 10)	R_{SETI} = 2.87kΩ	1166	1190	1214	mA
			R_{SETI} = 6.81kΩ	490	500	510	
			R_{SETI} = 34.0kΩ	99	101	103	
		V_{THM} between T1 and T2 (Figure 10); the fast-charge current is reduced to 50% the value programmed by R_{SETI}			50		%
Fast-Charge Current Set Range		(Figure 5)	Minimum		50		mA
			Maximum		1200		
Fast-Charge Setting Resistor Range	R_{SETI}	(Figure 5)	Minimum		2.87		kΩ
			Maximum		68.1		
Done Current	I_{DN}	V_{THM} between T2 and T4 (Figure 10)	R_{DNI} = 3.83kΩ (Note 5)	93	99	105	mA
			R_{DNI} = 7.68kΩ (Note 5)	47	50	53	
			R_{DNI} = 38.3kΩ	9.5	10.5	11.5	
		V_{THM} between T1 and T2 (Figure 10); the done current threshold is reduced to 50% the value programmed by R_{DNI}			50		%
Prequalification Current	I_{PQ}	V_{THM} between T2 and T4 (Figure 10), V_{BAT} = 2.6V	R_{DNI} = 3.83kΩ (Note 5)	95	105	115	mA
			R_{DNI} = 7.68kΩ (Note 5)	49	54	59	
			R_{DNI} = 38.3kΩ (Note 5)	10	11.5	13	
		V_{THM} between T1 and T2 (Figure 10); the prequalification current is reduced to 50% the value programmed by R_{DNI}			50		%

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 6V, V_{BAT} = 4V, R_{SETI} = 2.87kΩ, R_{DNI} = 3.57kΩ, V_{THM} = $V_{AVL/2}$, circuit of Figure 1, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Done and Prequalification Current Set Range		(Figure 5)	Minimum		9.8		mA
			Maximum		200		
Done and Prequalification Setting Resistor Range	R_{DNI}	(Figure 5)	Minimum		1.91		kΩ
			Maximum		39.2		
Dead-Battery Charge Current	I_{DBAT}	0V ≤ V_{BAT} ≤ V_{DBAT}			45		mA
Dead-Battery Voltage Threshold (Figure 6)	V_{DBAT}				2.5		V
BAT Leakage Current		V_{IN} = 0V, V_{BAT} = 4.2V, includes LX leakage current through the inductor	T_A = +25°C		0.02	1	µA
			T_A = +85°C		0.05		
Charger Soft-Start Time (Note 3)	t_{SS}				1.5		ms
CHARGE TIMER							
Prequalification/Dead-Battery Time	t_{PQ}	C_{CT} = 0.1µF			30		min
Fast-Charge Time	t_{FC}	C_{CT} = 0.1µF			180		min
Top-Off Time	t_{TO}				16		s
Timer Accuracy				-15		+15	%
THERMISTOR MONITOR							
THM Hot Shutoff Threshold (60°C)	T4	V_{THM}/AVL falling, 1% hysteresis (thermistor temperature rising)		21.24	22.54	23.84	%AVL
THM Hot Voltage Foldback Threshold (45°C)	T3	V_{THM}/AVL falling, 1% hysteresis (thermistor temperature rising)		32.68	34.68	36.68	%AVL
THM Cold Current Foldback Threshold (15°C)	T2	V_{THM}/AVL rising, 1% hysteresis (thermistor temperature falling)		57.00	60.00	63.00	%AVL
THM Cold Shutoff Threshold (-15°C/0°C)	T1	V_{THM}/AVL rising, 1% hysteresis (thermistor temperature falling)	0°C, MAX8900A/ MAX8900C	71.06	74.56	78.06	%AVL
			-15°C, MAX8900B	81.43	86.07	90.98	
THM Input Leakage		THM = GND or AVL	T_A = +25°C	-0.2	0.001	+0.2	µA
			T_A = +85°C		0.001		
CHARGE ENABLE INPUT ($\overline{CEN}$)							
$\overline{CEN}$ Input Voltage Low	V_{IL}					0.6	V
$\overline{CEN}$ Input Voltage High	V_{IH}			1.4			V
$\overline{CEN}$ Internal Pulldown Resistance	R_{CEN}			100	200	400	kΩ

1.2A Switch-Mode Li+ Chargers with ±22V Input Rating and JEITA Battery Temperature Monitoring

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 6V, V_{BAT} = 4V, R_{SETI} = 2.87kΩ, R_{DNI} = 3.57kΩ, V_{THM} = $V_{AVL/2}$, circuit of Figure 1, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
STATUS OUTPUTS (STAT1, STAT2, STAT3)							
STAT1 and STAT2 Output Voltage Low		I_{SINK} = 1mA			0.025	0.05	V
		I_{SINK} = 15mA			0.38		
STAT1 and STAT2 Output High Leakage		$V_{STAT\_}$ = 28V	T_A = +25°C		0.001	1	µA
			T_A = +85°C		0.01		
STAT3 Output Voltage Low		I_{SINK} = 1mA			0.01		V
		I_{SINK} = 15mA			0.15	0.25	
STAT3 Output High Leakage		V_{STAT3} = 5.5V	T_A = +25°C		0.001	1	µA
			T_A = +85°C		0.01		
PVL AND AVL							
PVL and AVL Output Voltage		0 to 30mA internal load, V_{IN} = 6V, T_A = 0°C to +85°C		4.6	5.0	5.1	V
		0 to 23mA internal load, V_{IN} = 6V, T_A = -40°C to +85°C					
THERMAL							
Thermal Regulation Temperature	T_{REG}	Junction temperature when charge current is reduced			95		°C
Thermal Regulation Gain	T_{TREG}	The charge current is decreased 6.7% of the fast-charge current setting for every degree that the junction temperature exceeds the thermal regulation temperature			6.7		%/°C
Thermal-Shutdown Temperature	T_{SHDN}	Junction temperature rising, 15°C hysteresis			+155		°C

Note 2: Parameters are production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed through correlation using statistical quality control (SQC) methods.

Note 3: Contact factory for alternative values.

Note 4: V_{IN} must be greater than $V_{UVLO-RISING}$ for the part to operate when $\overline{CEN}$ is pulled low. For example, if $\overline{CEN}$ is low and the MAX8900_ is operating with $V_{UVLO-FALLING}$ < V_{IN} < $V_{UVLO-RISING}$, then toggling $\overline{CEN}$ results in a nonoperating condition.

Note 5: Guaranteed by design, not production tested.

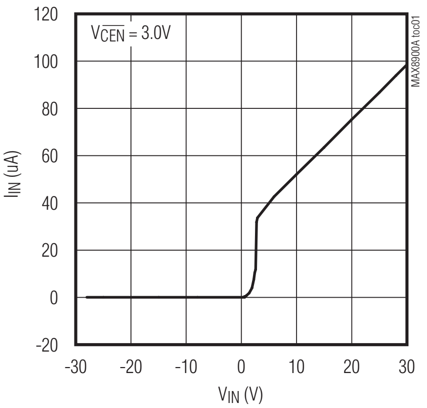
Note 6: When the charger is in its DONE state, it restarts when the battery voltage falls to the charger restart threshold. The battery voltage that causes a restart ($V_{BAT-RSTRT}$) is $V_{BAT-RSTRT}$ = 4.2V - V_{RSTRT}. For example, with the MAX8900A, $V_{BAT-RSTRT}$ = 4.2V - 100mV = 4.1V.

1.2A Switch-Mode Li+ Chargers with ±22V Input Rating and JEITA Battery Temperature Monitoring

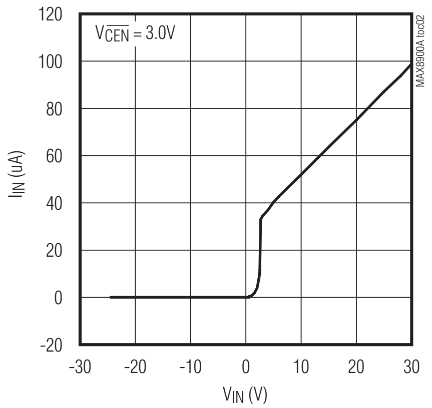
Typical Operating Characteristics

(Circuit of Figure 1, V_{IN} = 6V, V_{BAT} = 3.6V, T_A = +25°C, unless otherwise noted.)

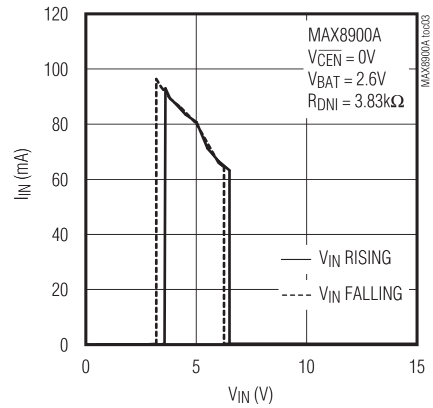
INPUT SUPPLY CURRENT vs. INPUT VOLTAGE (DISABLED, V_{BAT} = 0V)



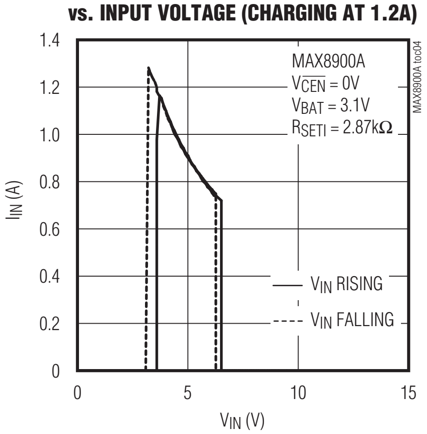
INPUT SUPPLY CURRENT vs. INPUT VOLTAGE (DISABLED, V_{BAT} = 3.6V)



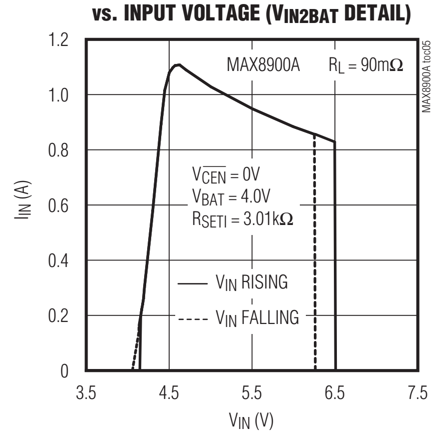
INPUT SUPPLY CURRENT vs. INPUT VOLTAGE (PREQUALIFICATION)



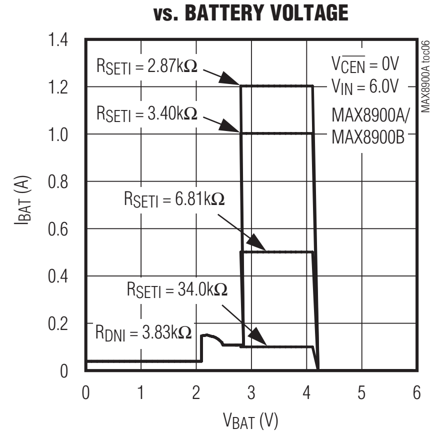
INPUT SUPPLY CURRENT vs. INPUT VOLTAGE (CHARGING AT 1.2A)



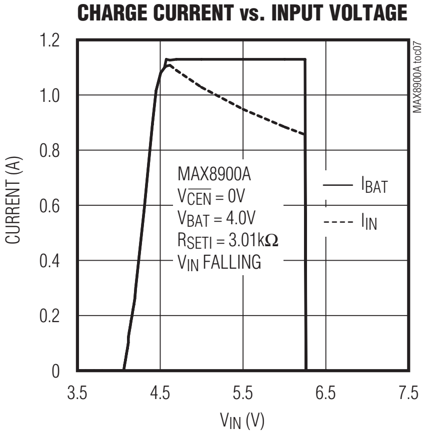
INPUT SUPPLY CURRENT vs. INPUT VOLTAGE (V_{IN2BAT} DETAIL)



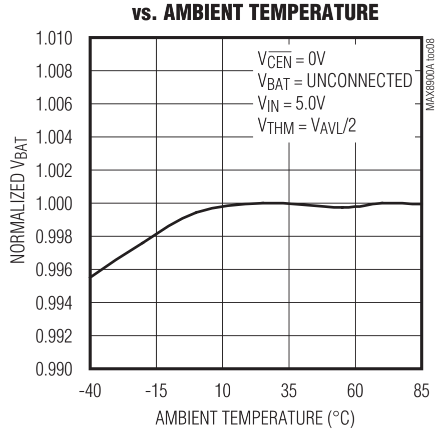
CHARGE CURRENT vs. BATTERY VOLTAGE



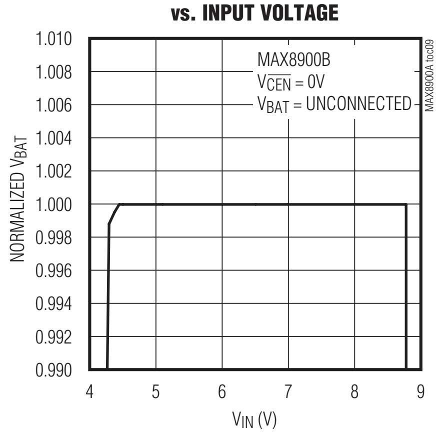
INPUT SUPPLY CURRENT AND CHARGE CURRENT vs. INPUT VOLTAGE



BATTERY REGULATION VOLTAGE vs. AMBIENT TEMPERATURE



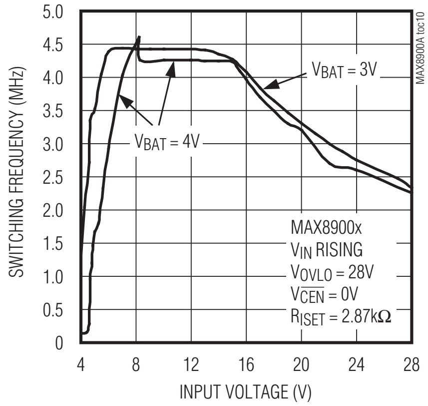
BATTERY REGULATION VOLTAGE vs. INPUT VOLTAGE



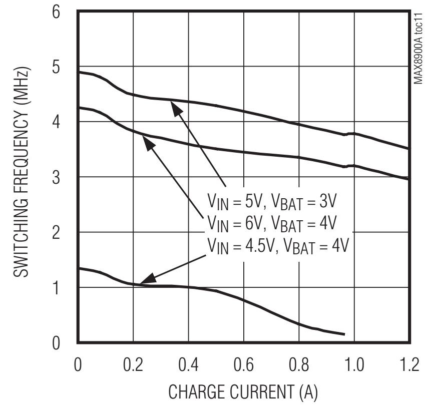
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 6V, V_{BAT} = 3.6V, T_A = +25°C, unless otherwise noted.)

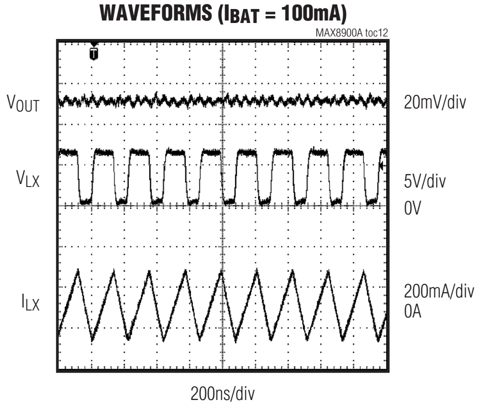
SWITCHING FREQUENCY vs. INPUT VOLTAGE



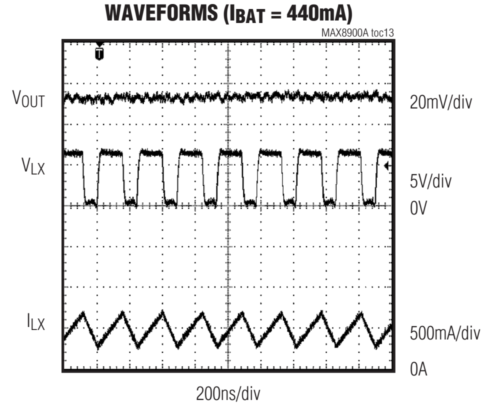
SWITCHING FREQUENCY vs. CHARGE CURRENT



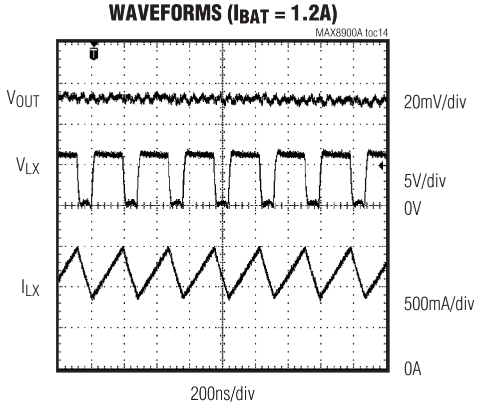
MAX8900B DC SWITCHING WAVEFORMS (I_{BAT} = 100mA)



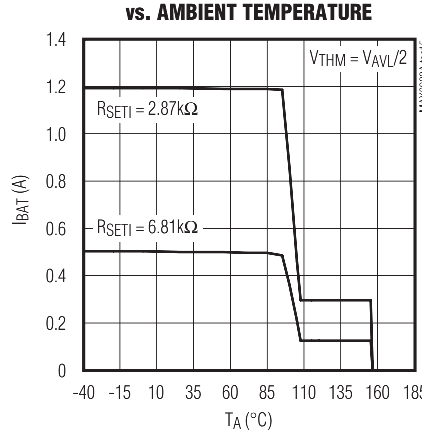
MAX8900B DC SWITCHING WAVEFORMS (I_{BAT} = 440mA)



MAX8900B DC SWITCHING WAVEFORMS (I_{BAT} = 1.2A)



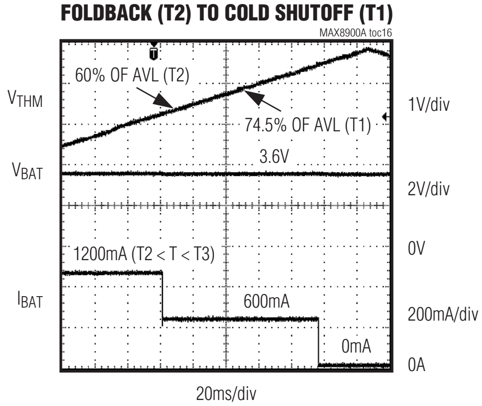
CHARGE CURRENT vs. AMBIENT TEMPERATURE



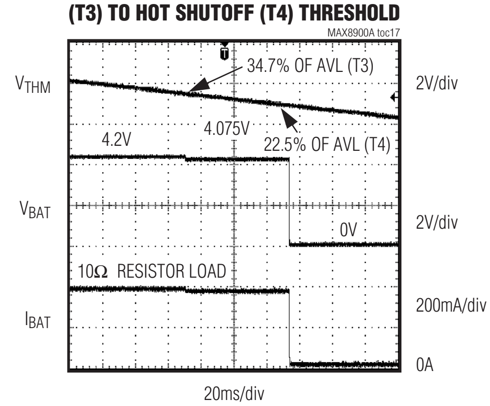
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 6V, V_{BAT} = 3.6V, T_A = +25°C, unless otherwise noted.)

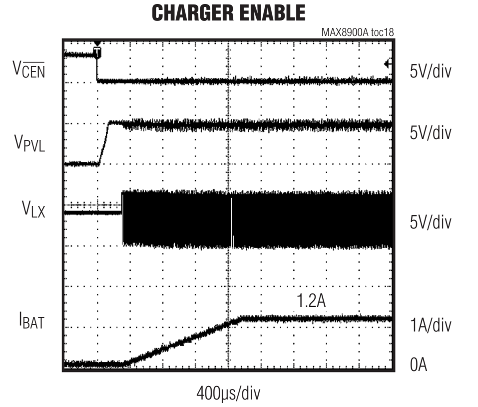
THM NORMAL TO COLD CURRENT FOLDBACK (T2) TO COLD SHUTOFF (T1)



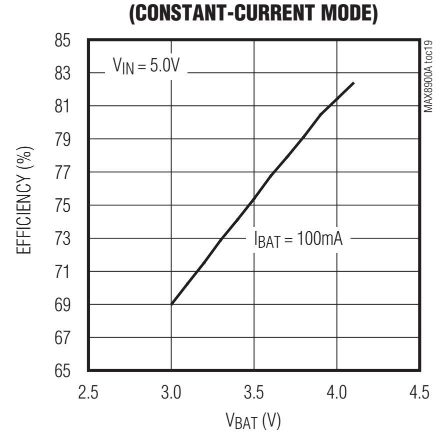
THM NORMAL TO HOT VOLTAGE FOLDBACK (T3) TO HOT SHUTOFF (T4) THRESHOLD



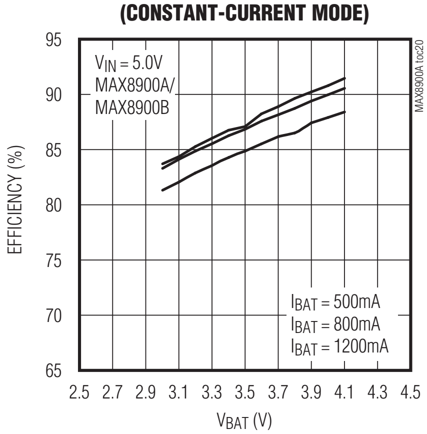
CHARGER ENABLE



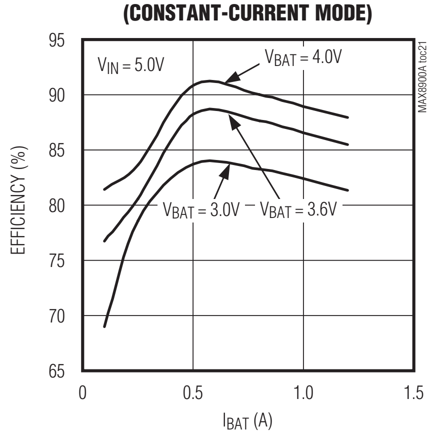
EFFICIENCY vs. BATTERY VOLTAGE (CONSTANT-CURRENT MODE)



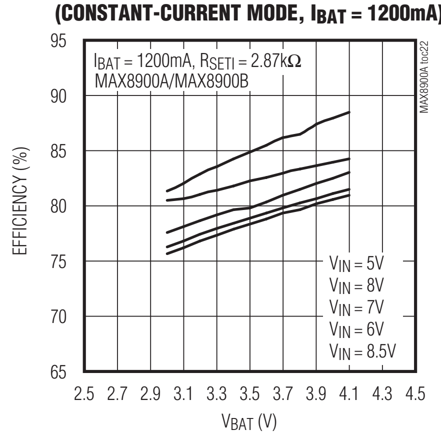
EFFICIENCY vs. BATTERY VOLTAGE (CONSTANT-CURRENT MODE)



EFFICIENCY vs. CHARGE CURRENT (CONSTANT-CURRENT MODE)



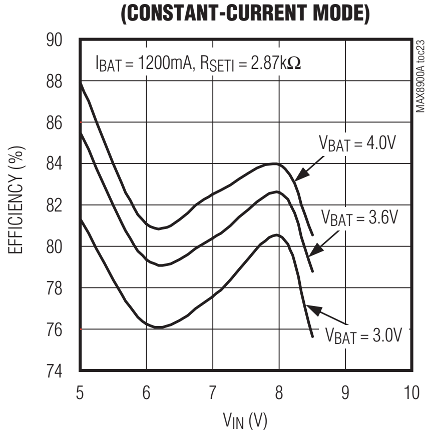
EFFICIENCY vs. BATTERY VOLTAGE (CONSTANT-CURRENT MODE, I_{BAT} = 1200mA)



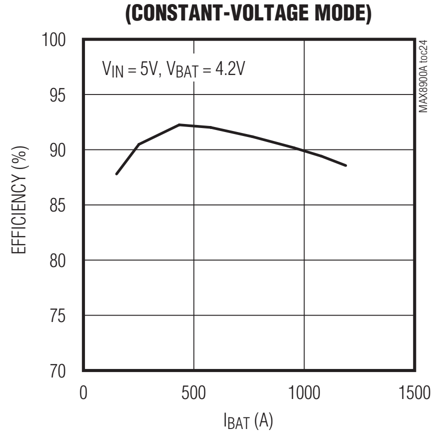
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 6V, V_{BAT} = 3.6V, T_A = +25°C, unless otherwise noted.)

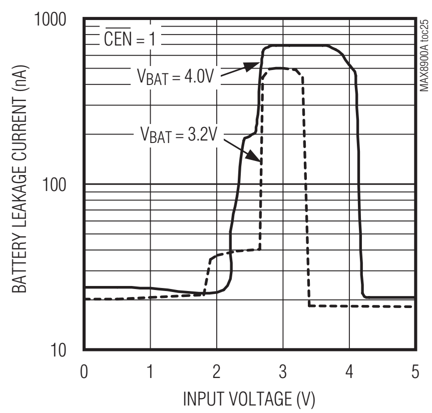
EFFICIENCY vs. INPUT VOLTAGE (CONSTANT-CURRENT MODE)



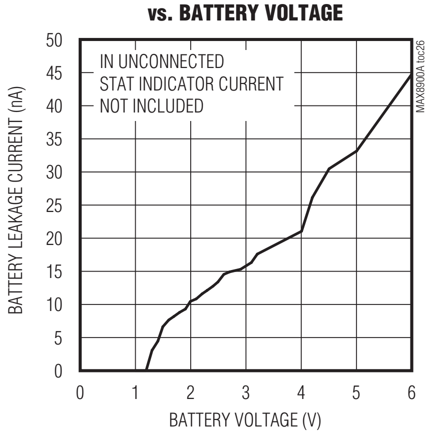
EFFICIENCY vs. CHARGE CURRENT (CONSTANT-VOLTAGE MODE)



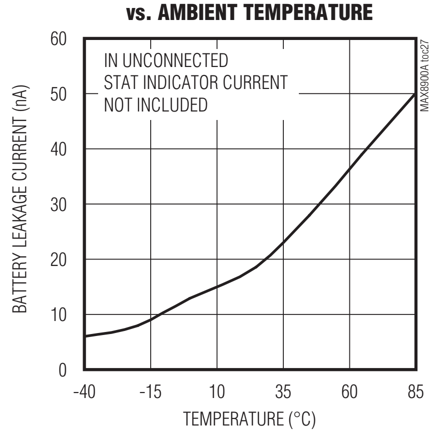
BATTERY + LX LEAKAGE CURRENT vs. INPUT VOLTAGE



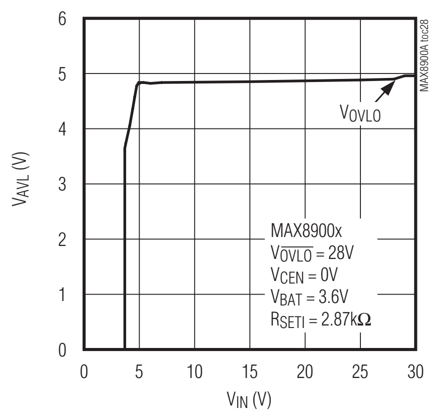
BATTERY + LX LEAKAGE CURRENT vs. BATTERY VOLTAGE



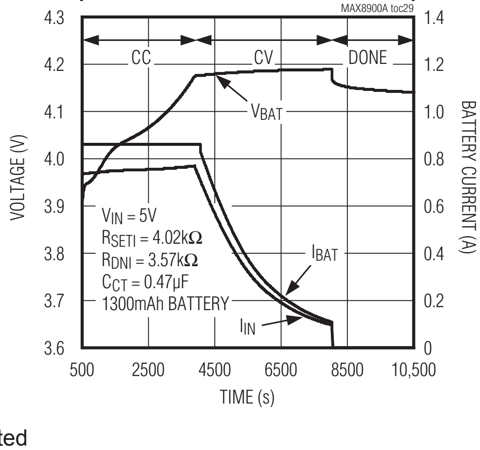
BATTERY + LX LEAKAGE CURRENT vs. AMBIENT TEMPERATURE



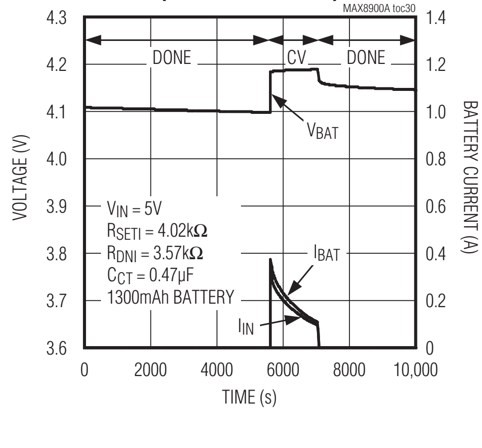
AVL VOLTAGE vs. INPUT VOLTAGE



MAX8900_ CHARGE PROFILE (CONSTANT-CURRENT TO DONE MODES)



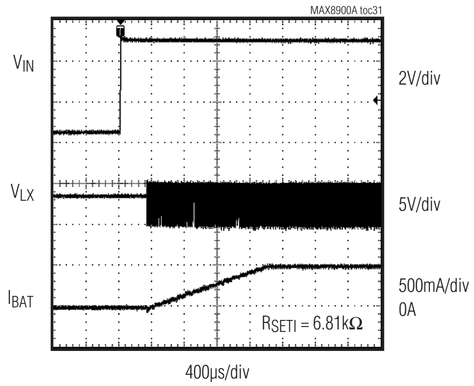
MAX8900_ CHARGE PROFILE (CHARGER RESTART)



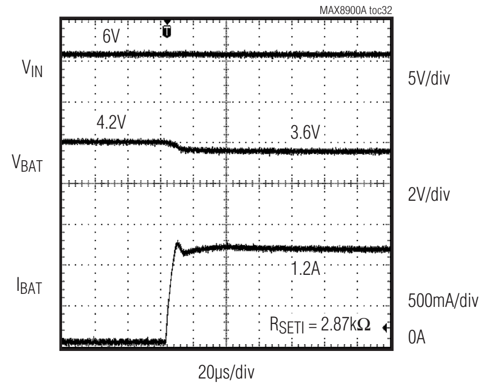
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 6V, V_{BAT} = 3.6V, T_A = +25°C, unless otherwise noted.)

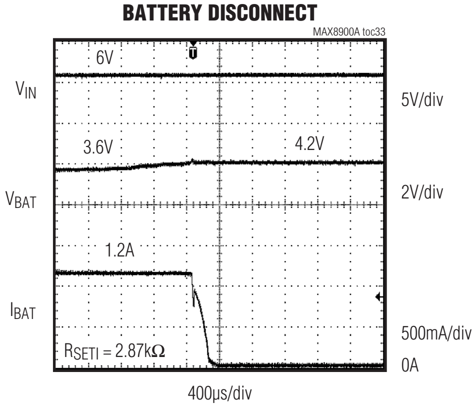
5V IN CONNECT



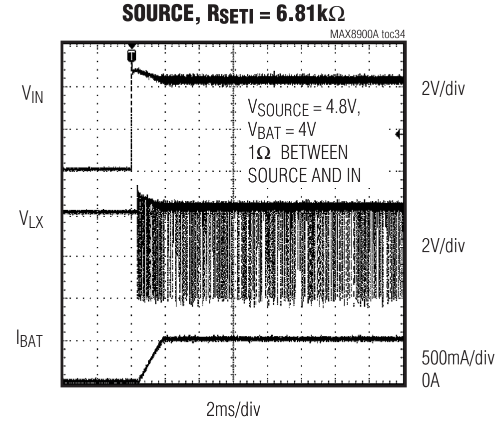
BATTERY CONNECT



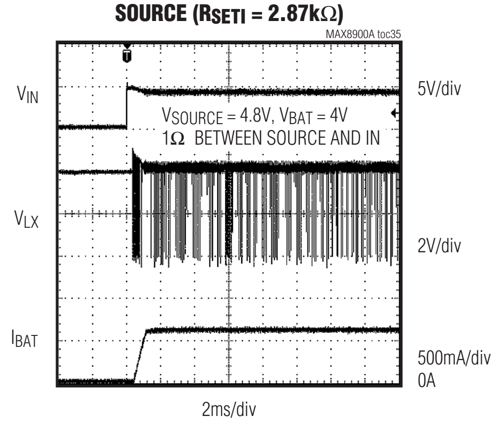
BATTERY DISCONNECT



SOFT-START INTO RESISTIVE SOURCE, R_{SETI} = 6.81kΩ

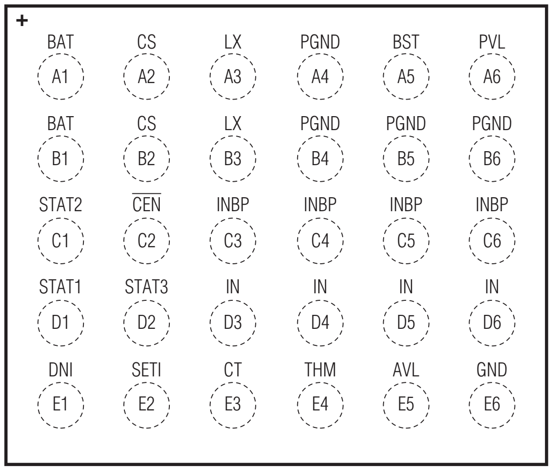


SOFT-START INTO RESISTIVE SOURCE (R_{SETI} = 2.87kΩ)



Pin Configuration

TOP VIEW (BUMPS DOWN)



30 WLP
(0.4mm PITCH)

Pin Description

PIN	NAME	FUNCTION
A1, B1	BAT	Connection to Battery. Connect to a single-cell Li+/Li-Poly battery from BAT to PGND. Connect both BAT pins together externally. Bypass BAT to PGND with a 2.2µF ceramic capacitor.
A2, B2	CS	40mΩ Current-Sense Node. Connect the inductor from LX to CS. Connect both CS pins together externally.
A3, B3	LX	Inductor Switching Node. Connect the inductor between LX and CS. Connect both LX pins together externally. When enabled ($\overline{CEN}$ = 0), LX switches between INBP and PGND to control the battery charging. When disabled ($\overline{CEN}$ = 1), the LX switches are high-impedance however they still have body diodes as shown in Figure 3.
A4, B4, B5, B6	PGND	Power Ground for Step-Down Low-Side Synchronous n-Channel MOSFET. Connect all PGND pins together externally.
A5	BST	Supply for High-Side n-Channel Gate Driver. Bypass BST to LX with a 0.1µF ceramic capacitor.
A6	PVL	5V Linear Regulator to Power Internal Circuits. PVL also charges the BST capacitor. Bypass PVL to PGND with a 1.0µF ceramic capacitor. Powering external loads from PVL is not recommended.
C1	STAT2	Status Output 2. STAT2 is an open-drain output that has a 30V absolute maximum rating and a typical pulldown resistance of 25Ω. For the MAX8900A, STAT1 and STAT2 indicate different states as shown in Table 4. For the MAX8900B/MAX8900C, STAT1, STAT2, and STAT3 indicate different operating states of the MAX8900_ as shown in Table 3.
C2	$\overline{CEN}$	Charge Enable Input. $\overline{CEN}$ has an internal 200kΩ pulldown resistor. Pull $\overline{CEN}$ low or leave it unconnected to enable the MAX8900_. Drive $\overline{CEN}$ high to disable the MAX8900_. Note: V_{IN} must be greater than $V_{UVLO-RISING}$ for the MAX8900_ to operate when $\overline{CEN}$ is pulled low. For example, if $\overline{CEN}$ is low and the MAX8900_ is operating with $V_{UVLO-FALLING} < V_{IN} < V_{UVLO-RISING}$, then toggling $\overline{CEN}$ results in a nonoperating condition.

Pin Description (continued)

PIN	NAME	FUNCTION
C3–C6	INBP	Power Input Bypass. Connect all INBP pins together externally. Bypass INBP to PGND with a 0.47µF ceramic capacitor.
D1	STAT1	Status Output 1. STAT1 is an open-drain output that has a 30V absolute maximum rating and a typical internal pulldown resistance of 25Ω. For the MAX8900A, STAT1 and STAT2 indicate different states as shown in Table 4. For the MAX8900B/MAX8900C, STAT1, STAT2, and STAT3 indicate different operating states of the MAX8900_ as shown in Table 3.
D2	STAT3	Status Output 3. STAT3 is an open-drain output that is a 6V absolute maximum rating and a typical pulldown resistance of 10Ω. For the MAX8900A, STAT1 and STAT2 indicate different states as shown in Table 4. For the MAX8900B/MAX8900C, STAT1, STAT2, and STAT3 indicate different operating states of the MAX8900_ as shown in Table 3.
D3–D6	IN	Power Input. IN is capable of delivering 1.2A to the battery and/or system. Connect all IN pins together externally. Bypass IN to PGND with a 0.47µF ceramic capacitor.
E1	DNI	Done/Prequalification Program Input. DNI is a dual function pin that sets both the done current threshold and the prequalification charge rate. Connect a resistor from DNI to GND to set the threshold between 10mA and 200mA. DNI is pulled to GND during shutdown.
E2	SETI	Fast-Charge Current Program Input. Connect a resistor from SETI to GND to set the fast-charge current from 0.05A to 1.2A. SETI is pulled to GND during shutdown.
E3	CT	Charge Timer Set Input. A capacitor (C_{CT}) from CT to GND sets the prequalification/dead-battery and fast-charge fault timers. Use 0.1µF for 180-minute fast-charge time limit and 30-minute prequalification/dead-battery time limit. Connect to GND to disable the timer.
E4	THM	Thermistor Input. Connect a negative temperature coefficient (NTC) thermistor from THM to GND. Connect a resistor equal to the thermistor's +25°C resistance from THM to AVL. Thermistor adjusts the charge current and termination voltage as described in the JEITA specification for safe use of secondary Li+ batteries. See Figure 10. To disable the THM operation, bias V_{THM} midway between AVL and GND.
E5	AVL	5V Linear Regulator to Power Low-Noise Internal Circuits. Bypass AVL to GND with a 0.1µF ceramic capacitor. Powering external loads from AVL is not recommended.
E6	GND	Ground. GND is the low-noise ground connection for the internal circuitry. See the *PCB Layout* section for more details.

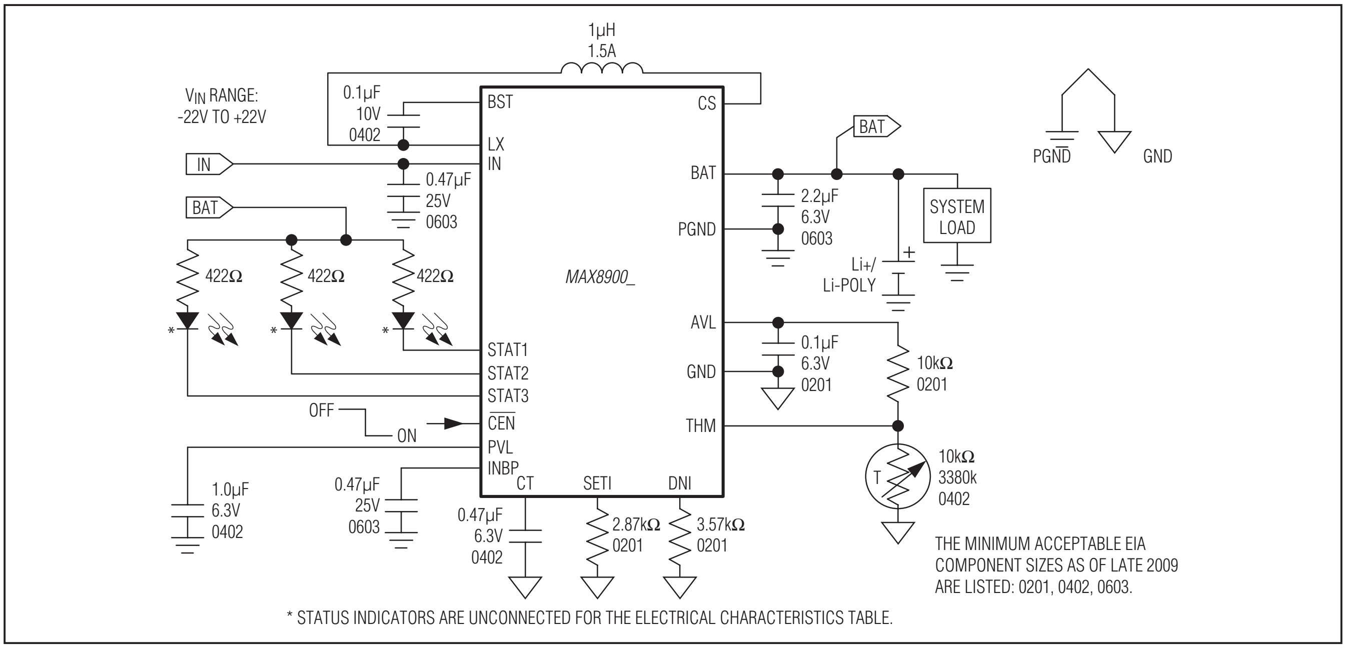
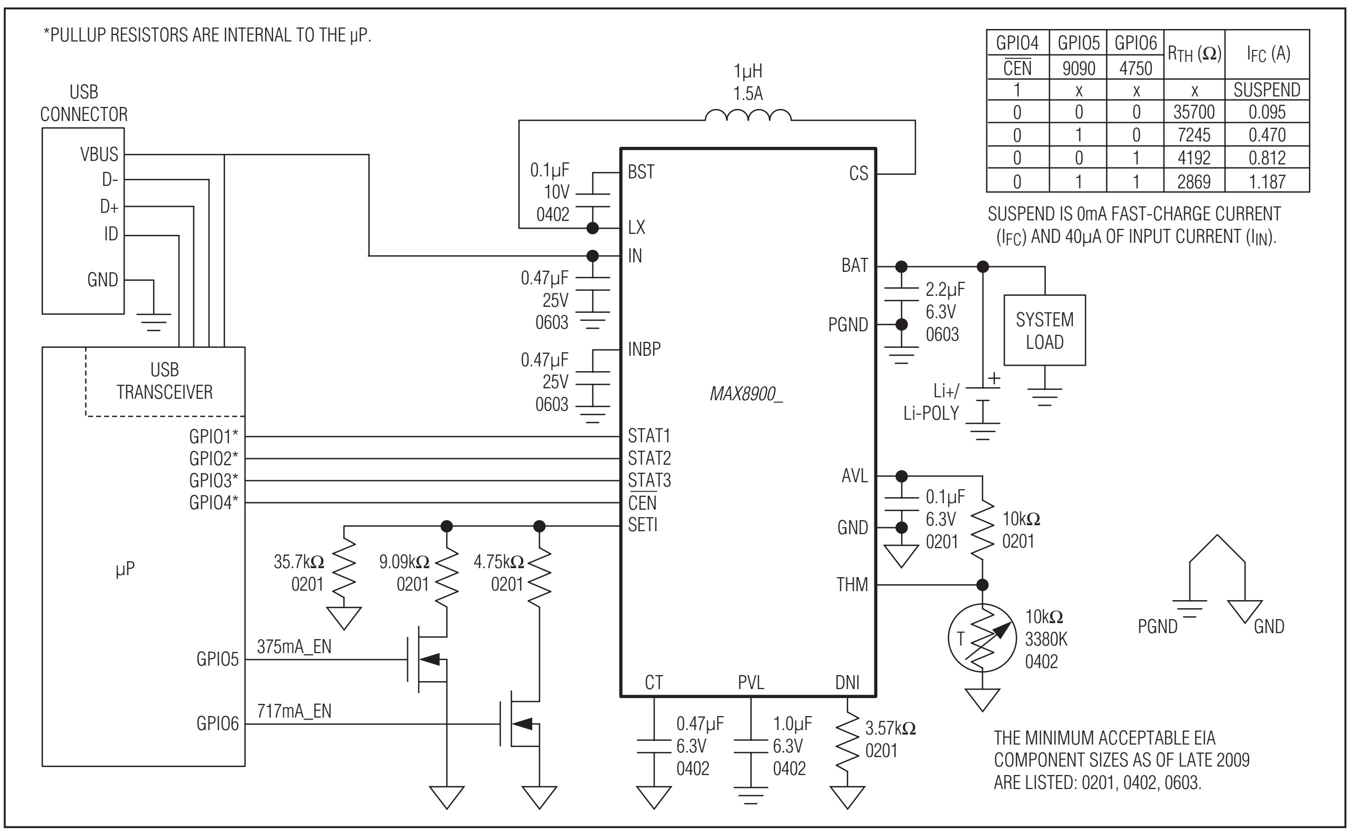


Figure 1. Applications Circuit: Single SETI Resistor, Status Indicators Connected to LEDs



GPIO4	GPIO5	GPIO6	R_{TH} (Ω)	I_{FC} (A)
CEN	9090	4750		
1	x	x	x	SUSPEND
0	0	0	35700	0.095
0	1	0	7245	0.470
0	0	1	4192	0.812
0	1	1	2869	1.187

Figure 2. Applications Circuit: Multiple Charge Rates Managed by µP to Be USB Compliant, Status Indicators Connected to a µP

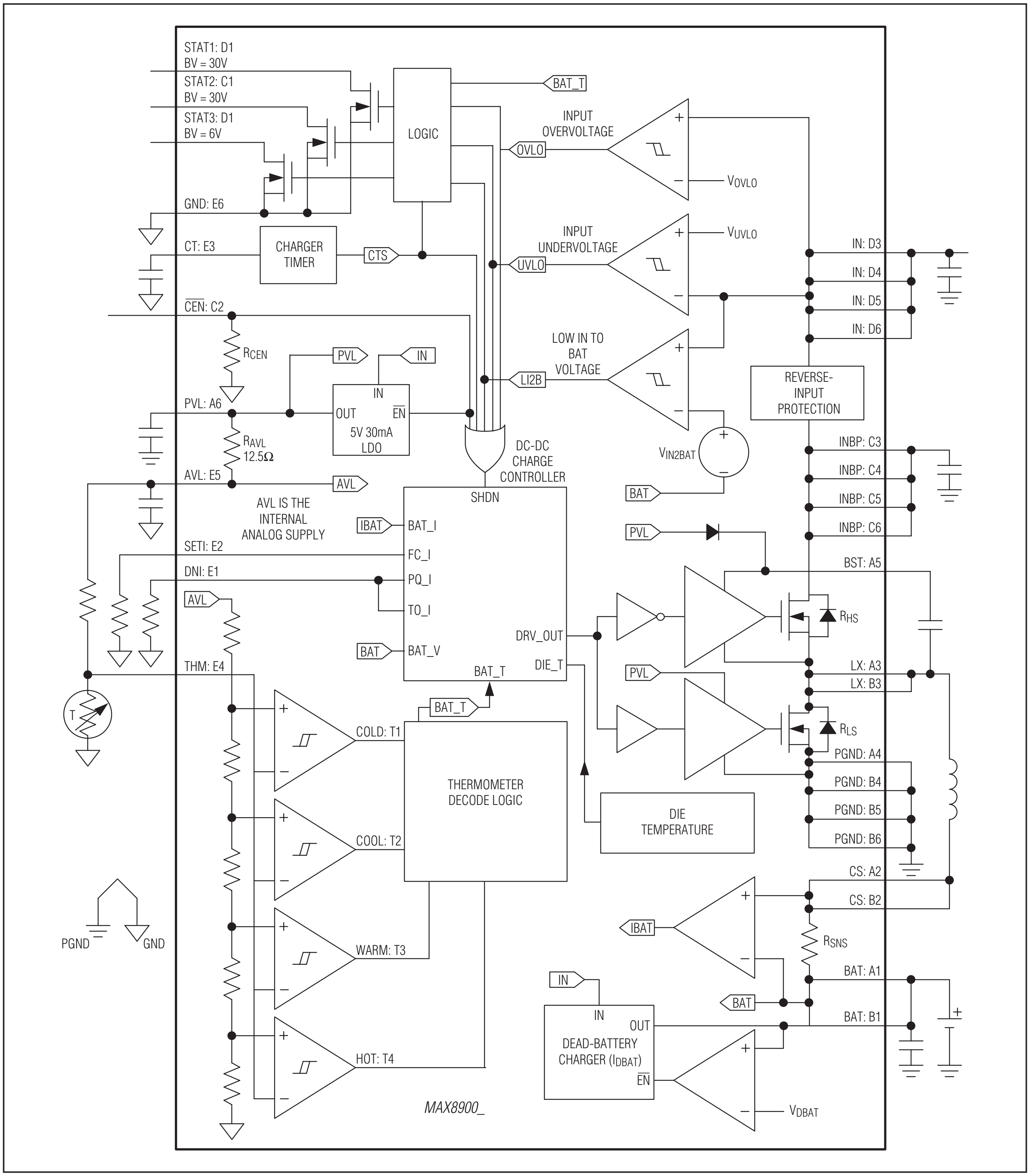


Figure 3. Functional Diagram

Detailed Description

The MAX8900_ is a full-featured, high-frequency switch-mode charger for a 1-cell Li+ or Li-Poly battery. It delivers up to 1.2A to the battery from 3.4V to 6.3V (MAX8900A/MAX8900C) or 3.4V to 8.7V (MAX8900B). Contact the factory for input operating voltage ranges up to +20V. The 3.25MHz switch-mode charger is ideally suited to small portable devices such as headsets and ultra-portable media players because it minimizes component size and heat.

Several features make the MAX8900_ ideal for high reliability systems. The MAX8900_ is protected against input voltages as high as +22V and as low as -22V. Battery protection features include low voltage prequalification, charge fault timer, die temperature monitoring, and battery temperature monitoring. The battery temperature monitoring adjusts the charge current and termination voltage as described in the JEITA (Japan Electronics and Information Technology Industries Association) specification for safe use of secondary Li+ batteries. The full title of the standard is *A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-Type Personal Computers, April 20, 2007*.

Charge parameters are easily adjustable with external components. An external resistance adjusts the charge current from 50mA to 1200mA. Another external resistance adjusts the prequalification and done current thresholds from 10mA to 200mA. The done current threshold is very accurate achieving ±1mA at the 10mA level. The charge timer is adjustable with an external capacitor.

Control Scheme

A proprietary hysteretic current PWM control scheme ensures high efficiency, fast switching, and physically tiny external components. Inductor ripple current is internally set to provide 3.25MHz. At very high duty factors, when the input voltage is lowered close to the output voltage, the steady-state duty ratio does not allow 3.25MHz operation because of the minimum off-time. The controller then provides minimum off-time, peak current regulation. Similarly, when the input voltage is too high to allow 3.25MHz operation due to the minimum on-time, the controller becomes a minimum on-time, valley current regulator. In this way, the ripple current in the inductor is always as small as possible to reduce the output ripple voltage. The inductor ripple current is made to vary with input and output voltage in a way that reduces frequency variation.

Soft-Start

To prevent input current transients, the rate of change of the input current (di/dt) and charge current is limited. When the input is valid, the charge current ramps from 0mA to the fast-charge current value in 1.5ms. Charge current also soft-starts when transitioning from the prequalification state to the fast-charge state. There is no di/dt limiting when transitioning from the done state to the fast-charge state (Figures 7 and 8). Similarly, if R_{SETI} is changed suddenly when using a switch or variable resistor at SETI as shown in Figure 2 there is no di/dt current limiting.

Setting the Fast-Charge Current (SETI)

As shown in Figure 4, a resistor from SETI to ground (R_{SETI}) sets the fast-charge current (I_{FC}). The MAX8900_ supports values of I_{FC} from 50mA to 1200mA. Select R_{SETI} as follows:

$$I_{FC} = 3405V/R_{SETI}$$

Determine the optimal I_{FC} for a given system by considering the characteristics of the battery and the capabilities of the charge source.

> **Example 1:** If you are using a 5V ±5% 1A charge source along with an 800mAh battery that has a 1C fast-charge rating, then choose R_{SETI} to be 4.42kΩ ±1%. This value provides a typical charge current of 770mA. Given the ±2% six sigma limit on the MAX8900_ fast-charge current accuracy along with the ±1% accuracy of the resistor, we can reasonably expect that the 770mA typical value has an accuracy of ±2.2% ($2.2 \approx \text{sqrt}(2^2 + 1^2)$) or ±17mA. Furthermore, since the MAX8900_ charger uses a step-down converter topology, we can guarantee that the input current is less than or equal to the output current so we do not violate the 1A rating of the charge source.

Depending on its mode of operation, the MAX8900_ controls the voltage at SETI to be between 0V and 1.5V. Avoid adding capacitance directly to the SETI pin that exceeds 10pF.

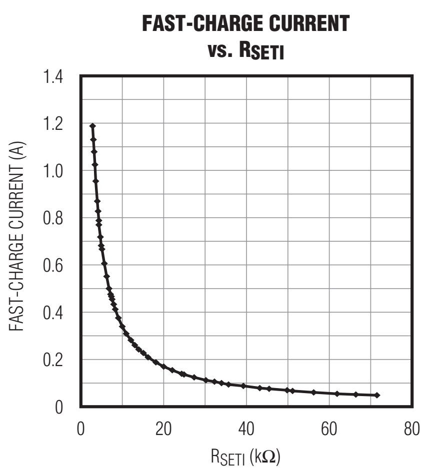
As a protection feature, if the battery temperature is between the T2 and T4 thresholds and SETI is shorted to ground, then the MAX8900_ latches off the battery charger and enters the timer fault state. This protection feature is disabled outside of fast-charge, top-off, done mode and inside thermal foldback. Furthermore, if SETI is unconnected, then the battery fast-charge current is 0A.

Setting the Prequalification Current and Done Threshold (DNI)

As shown in Figure 5, a resistor from DNI to ground (R_{DNI}) sets the prequalification current (I_{PQ}) and done current (I_{DN}). The MAX8900_ supports values of R_{DNI} from 1.19kΩ to 38.2kΩ. Select R_{DNI} as follows:

$I_{DN} = 384V/R_{DNI}$ $I_{PQ} = 415V/R_{DNI}$

Determine the optimal I_{PQ} and I_{DN} for a given system by considering the characteristics of the battery.



R_{SETI} (kΩ)	I_{FC} (A)	R_{SETI} (kΩ)	I_{FC} (A)	R_{SETI} (kΩ)	I_{FC} (A)
2.87	1.186	7.15	0.476	24.9	0.137
3.01	1.131	7.32	0.465	27.4	0.124
3.16	1.078	7.87	0.433	30.1	0.113
3.32	1.026	8.25	0.413	32.2	0.106
3.57	0.954	9.09	0.375	34.0	0.100
3.92	0.869	10.0	0.341	35.7	0.095
4.12	0.826	11.0	0.310	39.2	0.087
4.32	0.788	12.1	0.281	43.2	0.079
4.42	0.770	13.0	0.262	45.5	0.075
4.75	0.717	14.0	0.243	49.9	0.068
4.99	0.682	15.0	0.227	51.1	0.067
5.11	0.666	16.2	0.210	56.2	0.061
5.62	0.606	18.2	0.187	61.9	0.055
6.19	0.550	20.0	0.170	66.5	0.051
6.81	0.500	22.1	0.154	68.1	0.050
7.5	0.454	24.3	0.140		

*Figure 4. Fast-Charge Current vs. R_{SETI} (**www.maxim-ic.com/tools/other/software/MAX8900-RSETI.XLS**)*

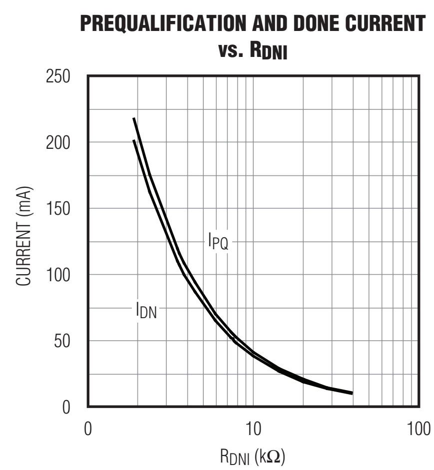
Depending on its mode of operation, the MAX8900_ controls the voltage at DNI from 0 to 1.5V. Avoid adding capacitance directly to the SETI pin that exceeds 10pF.

As shown in Figure 10, the prequalification current and done threshold is set to 50% of programmed value when T1 < THM < T2, and 100% of programmed value when T2 < THM < T4.

As a protection feature, if the battery temperature is between the T2 and T4 thresholds and DNI is shorted to ground, then the MAX8900_ latches off the battery charger and enters the timer fault state. This protection feature is disabled inside of dead-battery mode and thermal foldback. Furthermore, if DNI is unconnected, then the prequalification and done current is 0A and the charge timer prevents the MAX8900_ from indefinitely operating in its done state.

Charge Enable Input ($\overline{CEN}$)

$\overline{CEN}$ is a digital input. Driving $\overline{CEN}$ high disables the battery charger. Pull $\overline{CEN}$ low or leave it unconnected



R_{DNI} (kΩ)	I_{PQ} (mA)	I_{DN} (mA)	R_{DNI} (kΩ)	I_{PQ} (mA)	I_{DN} (mA)
1.91	217.3	201.0	7.5	55.3	51.2
2.37	175.1	162.0	7.68	54.0	50.0
3.48	119.3	110.3	7.87	52.7	48.8
3.57	116.2	107.6	10.0	41.5	38.4
3.83	108.4	100.3	14.3	29.0	26.9
4.42	93.9	86.9	20.0	20.8	19.2
5.9	70.3	65.1	28.0	14.8	13.7
7.32	56.7	52.5	39.2	10.6	9.8

*Figure 5. Prequalification Current and Done Threshold vs. R_{DNI} (**www.maxim-ic.com/tools/other/software/MAX8900-DNI.XLS**)*

to enable the MAX8900_. $\overline{\text{CEN}}$ has an internal 200kΩ pulldown resistor. When disabled, the MAX8900_ supply current is reduced, the step-down converter high-side and low-side switches are off, and the AVL is disabled.

In many systems, there is no need for the system controller (typically a microprocessor (µP)) to disable the charger because the MAX8900_ independently manages the charger. In these situations, $\overline{\text{CEN}}$ can be connected to ground or left unconnected. **Note:** if $\overline{\text{CEN}}$ is permanently connected to ground or left unconnected, the input power must be cycled to escape from a timer fault state (see Figures 7 and 8 for more information).

V_{IN} must be greater than $V_{UVLO-RISING}$ for the MAX8900_ to operate when $\overline{\text{CEN}}$ is pulled low. For example, if $\overline{\text{CEN}}$ is low and the MAX8900_ is operating with $V_{UVLO-FALLING} < V_{IN} < V_{UVLO-RISING}$, then toggling $\overline{\text{CEN}}$ results in a nonoperating condition.

Charger States

The MAX8900_ utilizes several charging states to safely and quickly charge batteries as shown in Figure 7. Figure 6 shows an exaggerated view of a Li+/Li-Poly battery progressing through the following charge states when the die and battery are close to room temperature: dead battery ➔ prequalification ➔ fast-charge ➔ top-off ➔ done.

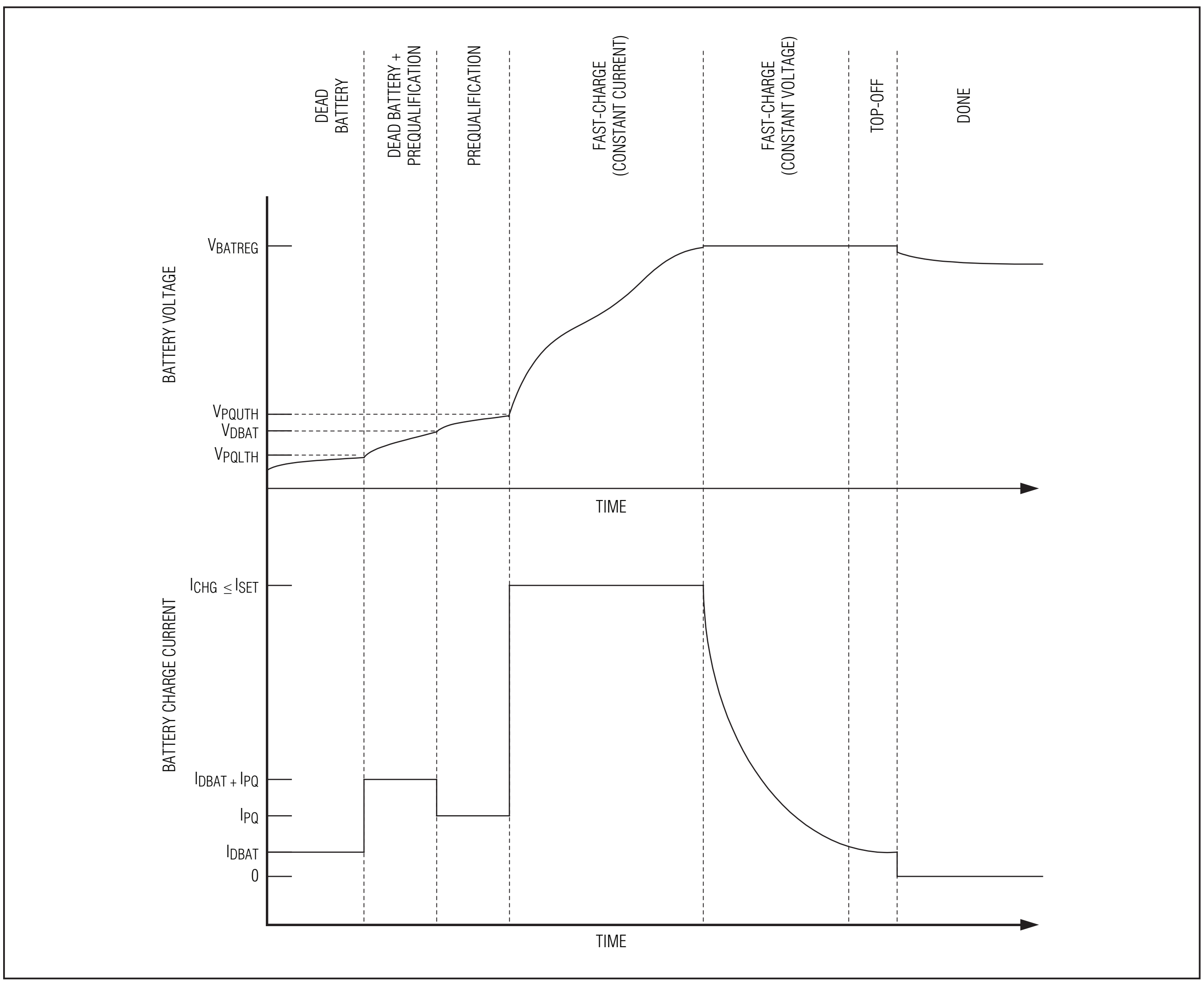


Figure 6. Li+/Li-Poly Charge Profile

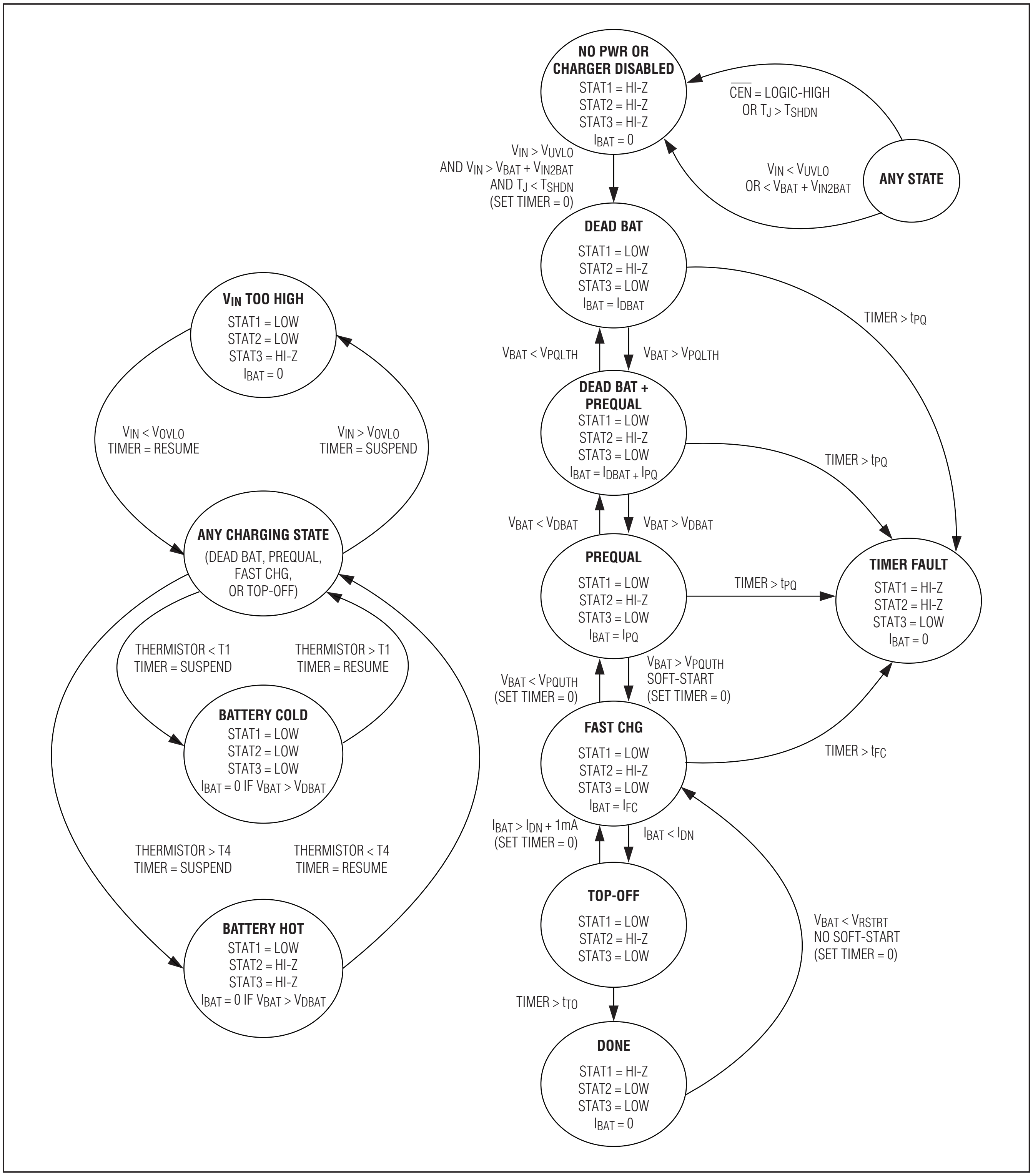


Figure 7. Charger State Diagram (3-Pin Status)

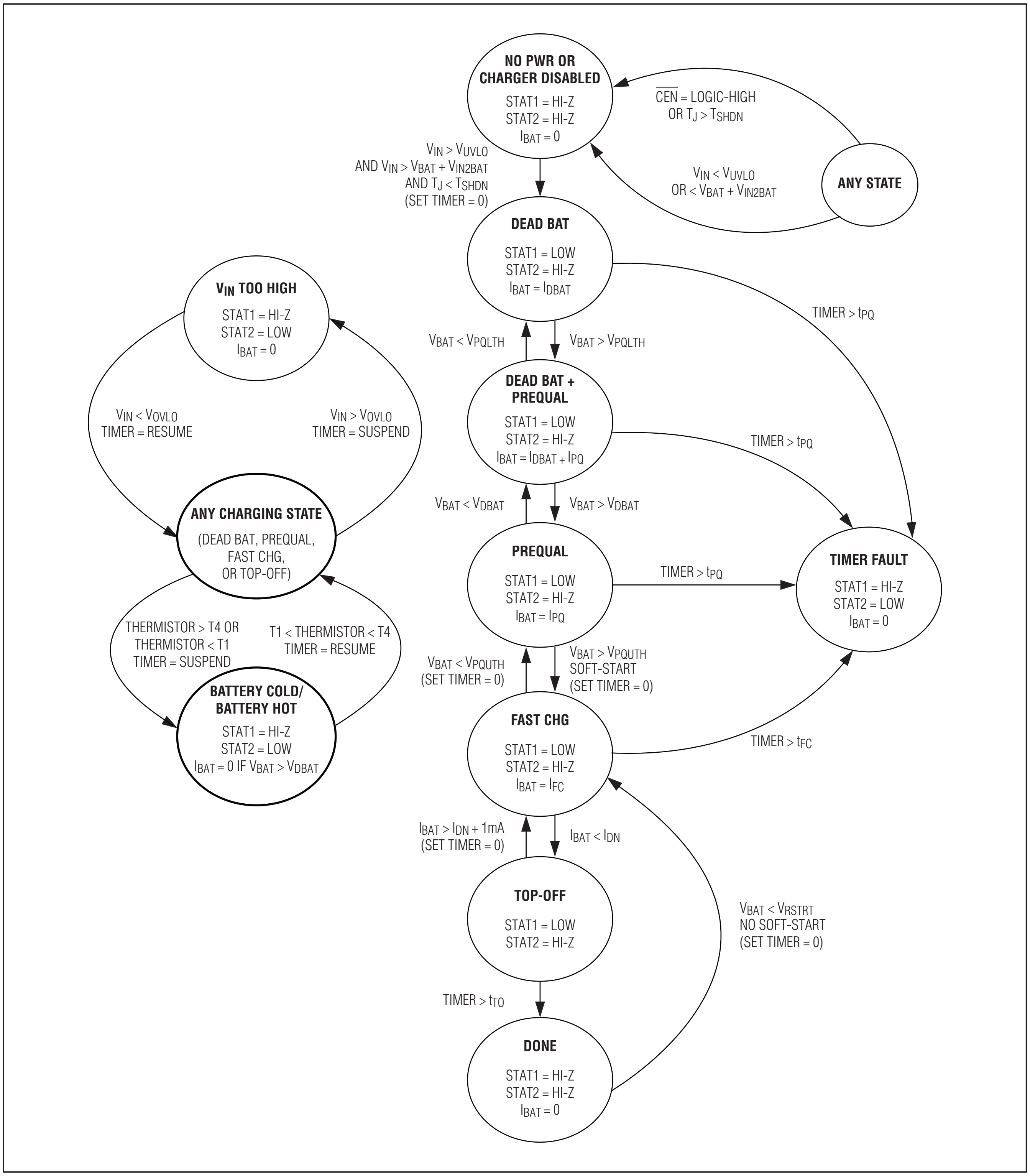


Figure 8. Charger State Diagram (2-Pin Status)

Charger Disabled State

When $\overline{CEN}$ is high or the input voltage is out of range, the MAX8900_ disables the charger. To exit this state, $\overline{CEN}$ must be low and the input voltage must be within its valid range.

Dead-Battery State

When a deeply discharged battery is inserted with a voltage of less than V_{PQLTH}, the MAX8900_ disables the switching charger and linearly charges with I_{DBAT}. If the MAX8900_ remains in this dead-battery state for longer than t_{PQ}, then it transitions to the timer fault state. This dead-battery state prevents the MAX8900_ from dissipating excessive power in the event of a shorted battery. Once V_{BAT} increases beyond V_{PQLTH}, the MAX8900_ transitions to the dead battery + prequalification state.

Dead Battery + Prequalification State

The dead battery + prequalification state occur when the battery voltage is greater than V_{PQLTH} and less than V_{DBAT}. In this state, both the linear dead-battery charger and the switching charger are on and delivering current to the battery. The total battery current is I_{DBAT} + I_{PQ}. If the MAX8900_ remains in this state for longer than t_{PQ}, then it transitions to the timer fault state. A normal battery typically stays in the dead-battery + prequalification state for several minutes or less and when the battery voltage rises above V_{DBAT}, the MAX8900_ transitions to the prequalification state.

Prequalification State

The prequalification state occurs when the battery voltage is greater than V_{DBAT} and less than V_{PQUTH}.

In this state, the linear dead-battery charger is turned off and only the switching charger is on and delivering current to the battery. The total battery current is I_{PQ}. If the MAX8900_ remains in this state for longer than t_{PQ}, then the MAX8900_ transitions to the timer fault state. A normal battery typically stays in the prequalification state for several minutes or less and when the battery voltage rises above V_{PQUTH}, the MAX8900_ transitions to the fast-charge constant current state.

As shown in Figure 10, the prequalification current and done threshold is set to 50% of programmed value when T1 < THM < T2, and 100% of programmed value when T2 < THM < T4.

Fast-Charge Constant Current State

The fast-charge constant current state occurs when the battery voltage is greater than V_{PQUTH} and less than V_{BATREG}. In this state, the switching charger is on and delivering current to the battery. The total battery current is I_{FC}. If the MAX8900_ remains in this state and the fast-charge constant voltage state for longer than t_{FC}, then the MAX8900_ transitions to the timer fault state. When the battery voltage rises to V_{BATREG}, the MAX8900_ transitions to the fast-charge constant voltage state. As shown in Figure 10, the fast-charge constant current is set to 50% of programmed value when T1 < THM < T2, and 100% of programmed value when T2 < THM < T4.

The MAX8900_ dissipates the most power in the fast-charge constant current state. This power dissipation causes the internal die temperature to rise. If the die temperature exceeds T_{REG}, I_{FC} is reduced. See the *Thermal Foldback* section for more detail.

If there is low input voltage headroom (V_{IN} - V_{BAT}), then I_{FC} decreases due to the impedance from IN to BAT. See Figure 13 for more detail.

Fast-Charge Constant Voltage State

The fast-charge constant voltage state occurs when the battery voltage is at the V_{BATREG} and the charge current is greater than I_{DN}. In this state, the switching charger is on and delivering current to the battery. The MAX8900_ maintains V_{BATREG} and monitors the charge current to detect when the battery consumes less than the I_{DN} current. When the charge current decreases below the I_{DN} threshold, the MAX8900_ transitions to the top-off state. If the MAX8900_ remains in the fast-charge constant current state and this state for longer than t_{FC}, then the MAX8900_ transitions to the timer fault state. Please note when the battery temperature is between T3 and T4 the BAT regulation voltage is reduced to 4.075V.

The MAX8900_ offers an adjustable done current threshold (I_{DN}) from 10mA to 200mA. The accuracy of the top-off current threshold is ±1mA when it is set for 10mA. This accurate threshold allows the maximum amount of charge to be stored in the battery before the MAX8900_ transitions into done state.

Top-Off State

The top-off state occurs when the battery voltage is at V_{BATREG} and the battery current decreases below I_{DN}. In this state, the switching charger is on and delivers current to the battery. The MAX8900_ maintains V_{BATREG} for a specified time (t_{TO}). When t_{TO} expires, the MAX8900_ transitions to the done state. If the charging current increases to I_{DN} + 1mA before t_{TO} expires, then the charger re-enters the fast-charge constant voltage state.

Done State

The MAX8900_ enters its done state after the charger has been in the top-off state for t_{TO}. In this state, the switching charger is off and no current is delivered to the battery. Although the charger is off, the SETI and DNI pins are biased in the done state and the MAX8900_ consumes the associated current from the battery (I_{BAT} = 1.5V/R_{SETI} + 1.5V/R_{DNI} + 3μA). If the system load presented to the battery is low (<< 100μA), then a typical system can remain in the done state for many days. If left in the done state long enough, the battery voltage decays below the restart threshold (V_{RSTRT}) and the MAX8900_ transitions back into the fast-charge state. There is no soft-start (di/dt limiting) during the done-to-fast-charge state transition.

Timer Fault State

The timer fault state occurs when either the prequalification or fast-charge timers expire, or SETI/DNI is shorted to ground (see the *Setting the Fast-Charge Current (SETI)* and *Setting the Prequalification Current and Done Threshold (DNI)* sections for more details). In this state the charger is off. The charger can exit the timer fault state by either cycling $\overline{CEN}$ or input power.

Battery Hot/Cold State

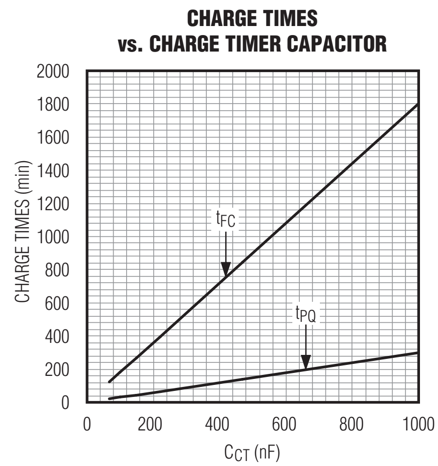
The battery hot/cold state occurs when the MAX8900_ is in any of its charge states (dead battery, prequalification, fast-charge, top-off) and thermistor temperature is either less than T1 or greater than T4. In this state, the charger is off and timers are suspended. The MAX8900_ exits the temperature suspend state and returns to the state it came from once the thermistor temperature is greater than T1 and less than T4. The timer resumes once the MAX8900_ exits this state.

V_{IN} Too High State

The V_{IN} too high state occurs when the MAX8900_ is in any of its charge states (dead battery, prequalification, fast-charge, top-off) and V_{IN} exceeds V_{OVLO}. In this state, the charger is off and timers are suspended. The MAX8900_ exits the V_{IN} too high state and returns to the state it came from when V_{IN} decreases below V_{OVLO}. The timer resumes once the MAX8900_ exits this state.

Charge Timer (CT)

As shown in Figure 7, a fault timer prevents the battery from charging indefinitely. In the dead-battery, prequalification, and fast-charge states, the timer is controlled by the capacitance at CT (C_{CT}). The MAX8900_ supports values of C_{CT} from 0.01μF to 1.0μF. Calculate the prequalification time (t_{PQ}) and fast-charge time (t_{FC}) as follows (Figure 9):



C_{CT} (nF)	t_{PQ} (min)	t_{FC} (min)	t_{FC} (hrs)	t_{TO} (s)
68	20.4	122.4	2	16
100	30.0	180.0	3	16
150	45.0	270.0	4.5	16
220	66.0	396.0	6.6	16
470	141.0	846.0	14.1	16
1000	300.0	1800.0	30.0	16

Figure 9. Charge Times vs. C_{CT}

$$t_{PQ} = 30\text{min} \times \frac{C_{CT}}{0.1\mu F}$$

$$t_{FC} = 180\text{min} \times \frac{C_{CT}}{0.1\mu F}$$

The top-off time (t_{TO}) is fixed at 16s:

$$t_{TO} = 16s$$

Connect CT to GND to disable the prequalification/dead-battery and fast-charge timers. With the internal timers of the MAX8900_ disabled, an external device, such as a μP can control the charge time through the $\overline{CEN}$ input.

Thermal Management

The MAX8900_ is packaged in a 2.44mm x 2.67mm x 0.64mm, 0.4mm pitch WLP package and withstands a junction temperature of +150°C. The MAX8900_ is rated for the extended ambient temperature range from -40°C to +85°C. Table 1 and Application Note 1891: *Wafer-Level Packaging (WLP) and Its Applications* (**www.maximintegrated.com/ucsp**) show the thermal characteristics of this package. The MAX8900_ uses

Table 1. 2.44mm x 2.67mm x 0.64mm, 0.4mm Pitch WLP Thermal Characteristics

	FOUR-LAYER PCB (JESD51-9:2s2p)
Continuous Power Dissipation	1619mW Derate 20.2mW/°C above +70°C/W
θ_{JA}	49.4°C/W
θ_{JC}	9°C/W
Board Parameters	• Still air • 4-layer board • 1.5oz copper on outer layers • 1oz copper on inner layers • 1.6mm thick board (62mil) • 4in x 4in board • Four center thermal vias • FR-4

several thermal management techniques to prevent excessive battery and die temperatures.

Thermistor Monitor (THM)

The MAX8900_ adjusts the charge current and termination voltage as described in the JEITA specification for safe use of secondary Li+ batteries (*A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-type Personal Computers, April 20, 2007*). As shown in Figure 10, there are four temperature thresholds that change the battery charger operation: T1, T2, T3, and T4. When the thermistor input exceeds the extreme temperatures (< T1 or > T4), the charger shuts off and all respective charging timers are suspended. While the thermistor remains out of range, no charging occurs, and the timer counters hold their state. When the thermistor input comes back into range, the charge timers continue to count. The middle thresholds (T2 and T3) do not shut the charger off, but adjust the current/voltage targets to maximize charging while reducing battery stress. Between T3 and T4, the voltage target is reduced (see V_{BATREG} in the *Electrical Characteristics* table); however, the charge timers continue to count. Between T1 and T2, the charging current target is reduced to 50% of its normal operating value; and similarly the charge timers continue to count.

If the thermistor functionality is not required, connect a 1MΩ resistor from THM to AVL and another 1MΩ resistor from THM to GND. This biases the THM node to be ½ of the AVL voltage telling the MAX8900_ that the battery temperature is between the T2 and T3 temperature range. Furthermore, the high 2MΩ impedance presents a minimal load to AVL.

Table 2 shows that the MAX8900_ is compatible with several standard thermistor values. When using a 10kΩ thermistor with a beta of 3380K, the configuration of Figure 11A provides for temperature trip thresholds that are very close to the nominal T1, T2, T3, and T4 (see the *Electrical Characteristics* table). When using alternate resistance and/or beta thermistors, the circuit of Figure 11A may result in temperature trip thresholds that are different from the nominal values. In this case, the circuit of Figure 11B allows for compensating the thermistor to shift the temperature trip thresholds back to the nominal value. In general, smaller values of R_{TP} shift all the temperature trip thresholds down; however, the lower temperature thresholds are affected more then the higher temperature thresholds. Furthermore, larger values of R_{TS} shift all the temperature trip thresholds up; however, the higher temperature thresholds are affected more than the lower temperature thresholds. For assistance with thermistor calculations, use the spreadsheet at the following link: **www.maximintegrated.com/tools/other/software/MAX8900-THERMISTOR.XLS**

The general relation of thermistor resistance to temperature is defined by the following equation:

$$R_{THRM} = R_{25} \times e^{\left(\beta\left(\frac{1}{T+273°C} - \frac{1}{298°C}\right)\right)}$$

where:

R_{THRM} = The resistance in Ω of the thermistor at temperature T in Celsius.

R_{25} = The resistance in Ω of the thermistor at T_A = +25°C.

β = The material constant of the thermistor, which typically ranges from 3000K to 5000K.

T = The temperature of the thermistor in °C.

Table 2. Trip Temperatures for Different Thermistors

THERMISTOR	TEMPERATURE						
R_{THRM} at T_A = +25°C	10,000	10,000	10,000	47,000	47,000	100,000	100,000
Thermistor Beta (β[Ω])	3380	3940	3940	4050	4050	4250	4250
RTB (Ω)	10,000	10,000	10,000	47,000	47,000	100,000	100,000
RTP (Ω)	OPEN	OPEN	301,000	OPEN	1,200,000	OPEN	1,800,000
RTS (Ω)	SHORT	SHORT	499	SHORT	2,400	SHORT	6,800
Resistance at T1_n15 (Ω)	61,788	61,788	77,248	290,410	380,716	617,913	934,027
Resistance at T1_0 (Ω)	29,308	29,308	31,971	137,750	153,211	293,090	343,283
Resistance at T2 (Ω)	15,000	15,000	15,288	70,500	72,500	150,002	156,836
Resistance at T3 (Ω)	5,309	5,309	4,906	24,954	23,083	53,093	47,906
Resistance at T4 (Ω)	2,910	2,910	2,439	13,676	11,434	29,099	22,777
Temperature at T1_n15 (°C) [-15°C nom]	-16.2	-11.1	-14.9	-10.2	-14.8	-8.7	-15.4
Temperature at T1_0 (°C) [0°C nom]	-0.8	2.6	0.9	3.2	1.2	4.1	1.3
Temperature at T2 (°C) [+15°C nom]	14.7	16.1	15.7	16.4	15.8	16.8	15.9
Temperature at T3 (°C) [+45°C nom]	42.6	40.0	42.0	39.6	41.5	38.8	41.2
Temperature at T4 (°C) [+60°C nom]	61.4	55.7	60.6	54.8	59.6	53.2	59.2

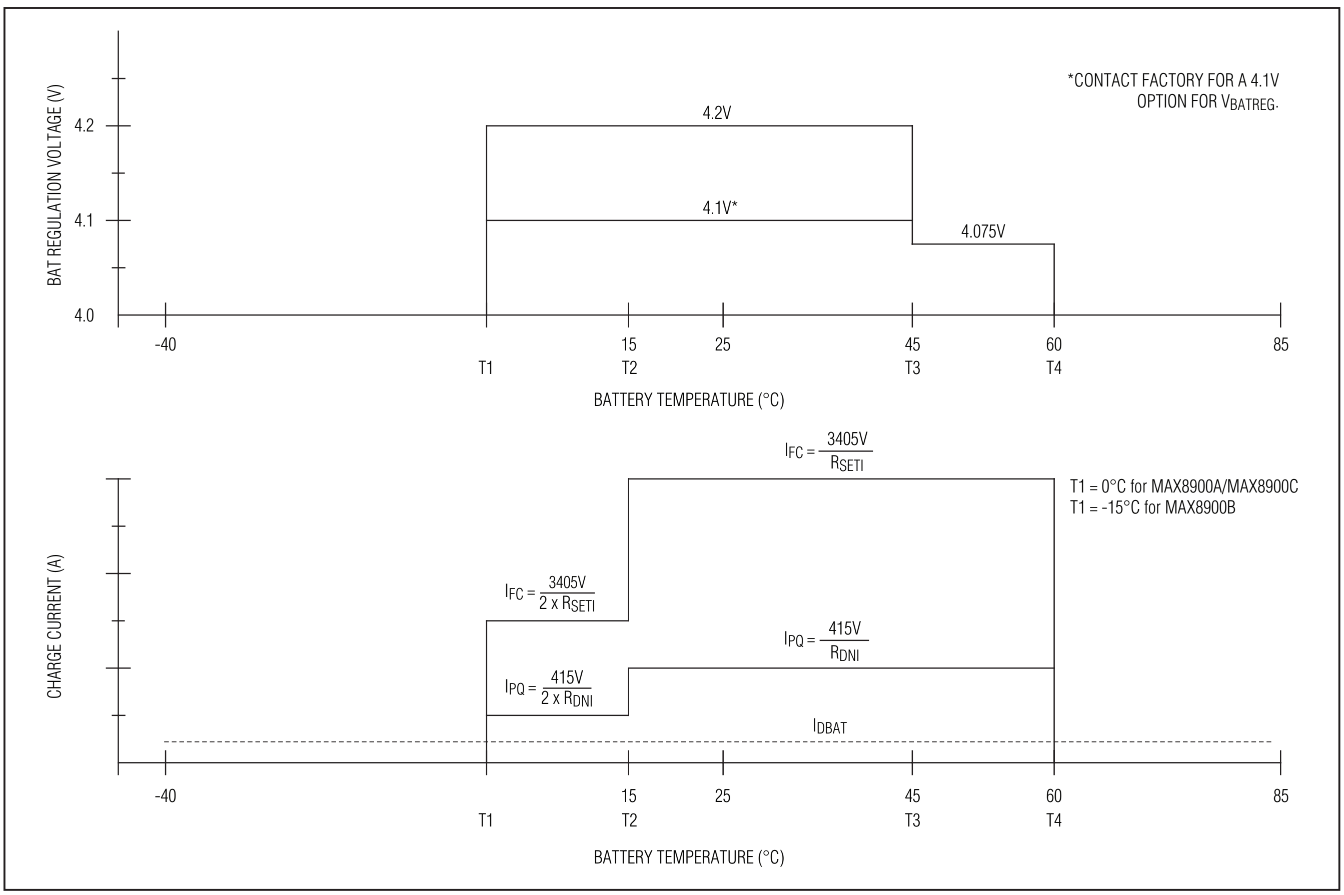


Figure 10. JEITA Battery Safety Regions