

Single-/Dual-Input 1-Cell Li+ Chargers with OVP Protection and Programmable Charge Timer

ABSOLUTE MAXIMUM RATINGS

DC, USB to GND -0.3V to +16V
 BAT, CT, CHG, EN, FLT, SETI,
 POK, THM, USEL to GND -0.3V to +6.0V
 Continuous Power Dissipation ($T_A = +70^\circ\text{C}$)
 14-Pin TDFN 3mm x 3mm Multilayer PCB
 (derate 24.4mW/°C above $+70^\circ\text{C}$) 1951.2mW

Operating Temperature Range -40°C to $+85^\circ\text{C}$
 Junction Temperature $+150^\circ\text{C}$
 Storage Temperature Range -65°C to $+150^\circ\text{C}$
 Lead Temperature (soldering, 10s) $+300^\circ\text{C}$

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

($V_{DC} = V_{USB} = 5\text{V}$, $V_{BAT} = 4\text{V}$, $V_{EN} = 0\text{V}$, $R_{SETI} = 2\text{k}\Omega$, $C_{CT} = 0.068\mu\text{F}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$. Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
DC OR USB (Note 2)						
Input Voltage Range			0		14	V
Input Operating Range	(Note 3)		4.15		7.00	V
Input Undervoltage Threshold	Input rising, 500mV hysteresis (typ)		3.85	4.0	4.15	V
Input Overvoltage Threshold	Input rising, 200mV hysteresis (typ)		7.2	7.5	7.8	V
Input Overvoltage Delay	From overvoltage event to charger disabled			0.25		s
Input Supply Current	I _{BAT} = 0mA, R _{THM} = 10kΩ			750	1200	μA
Shutdown Input Current	V _{EN} = 5V, T _A = +25°C			275	435	μA
Input to BAT On-Resistance	Input = 3.7V, V _{BAT} = 3.6V			0.5	0.8	Ω
Input to BAT Dropout Voltage	Input falling, 200mV hysteresis (typ)		5	55	120	mV
BAT						
BAT Regulation Voltage	I _{BAT} = 0mA	T _A = +25°C	4.179	4.2	4.221	V
		T _A = -40°C to +85°C	4.166	4.2	4.234	
BAT Restart Fast-Charge Threshold	From BAT regulation voltage		-180	-150	-120	mV
DC Charging Current	V _{USB} = 0V	R _{SETI} = 1.5kΩ	950	1000	1050	mA
		R _{SETI} = 2kΩ	727	750	773	
		R _{SETI} = 5kΩ	280	300	320	
		Prequal, R _{SETI} = 2kΩ, V _{BAT} = 2.5V	60	75	90	
USB Charging Current	V _{DC} = 0V	V _{USEL} = 5V	450	475	500	mA
		V _{USEL} = 0V	80	95	100	
		Prequal, R _{SETI} = 2kΩ, V _{BAT} = 2.5V	60	75	90	
Soft-Start Time	Ramp time to fast-charge current			1.2		ms
BAT Prequal Threshold	V _{BAT} rising, 180mV hysteresis (typ)		2.9	3.0	3.1	V
BAT Leakage Current	V _{DC} = V _{USB} = 0V, V _{BAT} = 4.2V			0.001	5	μA
SETI						
R _{SETI} Resistance Range	Guaranteed by charging current		1.5		5.0	kΩ

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MAX8600/MAX8601

ELECTRICAL CHARACTERISTICS (continued)

($V_{DC} = V_{USB} = 5V$, $V_{BAT} = 4V$, $V_{\overline{EN}} = 0V$, $R_{SETI} = 2k\Omega$, $C_{CT} = 0.068\mu F$, $T_A = -40^\circ C$ to $+85^\circ C$, unless otherwise noted. Typical values are at $T_A = +25^\circ C$. Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS	
EN, USEL							
Logic Input Thresholds	Rising		1.6			V	
	Falling		0.4				
Logic Input Leakage Current	VEN = VUSEL = 0 to 5.5V	TA = +25°C	0.001	1	μA		
		TA = +85°C	0.01				
POK, CHG, FLT							
Logic Output Voltage, Low	IPOK, = ICHG = IFLT = 1mA		12	100	mV		
Logic Output Leakage Current, High	VPOK = VCHG = VFLT = 5.5V, VDC = VUSB = 0V	TA = +25°C	0.001	1	μA		
		TA = +85°C	0.01				
CHG							
CHG/Top-Off Threshold	IBAT falling, battery is charged	RSETI = 1.5kΩ	75	mA			
		RSETI = 2kΩ	37.5			56.25	75.0
		RSETI = 5kΩ	22.5				
THM							
THM Pullup Resistance			10	kΩ			
THM Resistance, Hot	RTHM falling, 420Ω hysteresis (typ)		3.72	3.94	4.13	kΩ	
THM Resistance, Cold	RTHM rising, 2.7kΩ hysteresis (typ)		26.7	28.3	29.7	kΩ	
THM Resistance, Disabled	RTHM falling, 230Ω hysteresis (typ)		274	309	337	Ω	
CT							
Timer Accuracy	CCT = 0.068μF		-20	+20		%	
Prequal Time Limit	From entering prequal to FLT low, VBAT < 3V		34.8	min			
Charge Time Limit	From entering fast-charge to FLT low, 3V < VBAT < 4.2V		334	min			
Top-Off Time Limit	From CHG high to charger disabled		34.8	min			
THERMAL LOOP							
Thermal-Limit Temperature	Junction temperature when the charge current is reduced, TJ rising		+100	°C			
Thermal-Limit Gain	Reduction of IBAT for increase of TJ, from VDC, RSETI = 1.5kΩ		5	% / °C			

Note 1: Limits are 100% production tested at $T_A = +25^\circ C$. Limits over the operating temperature range are guaranteed by design and characterization.

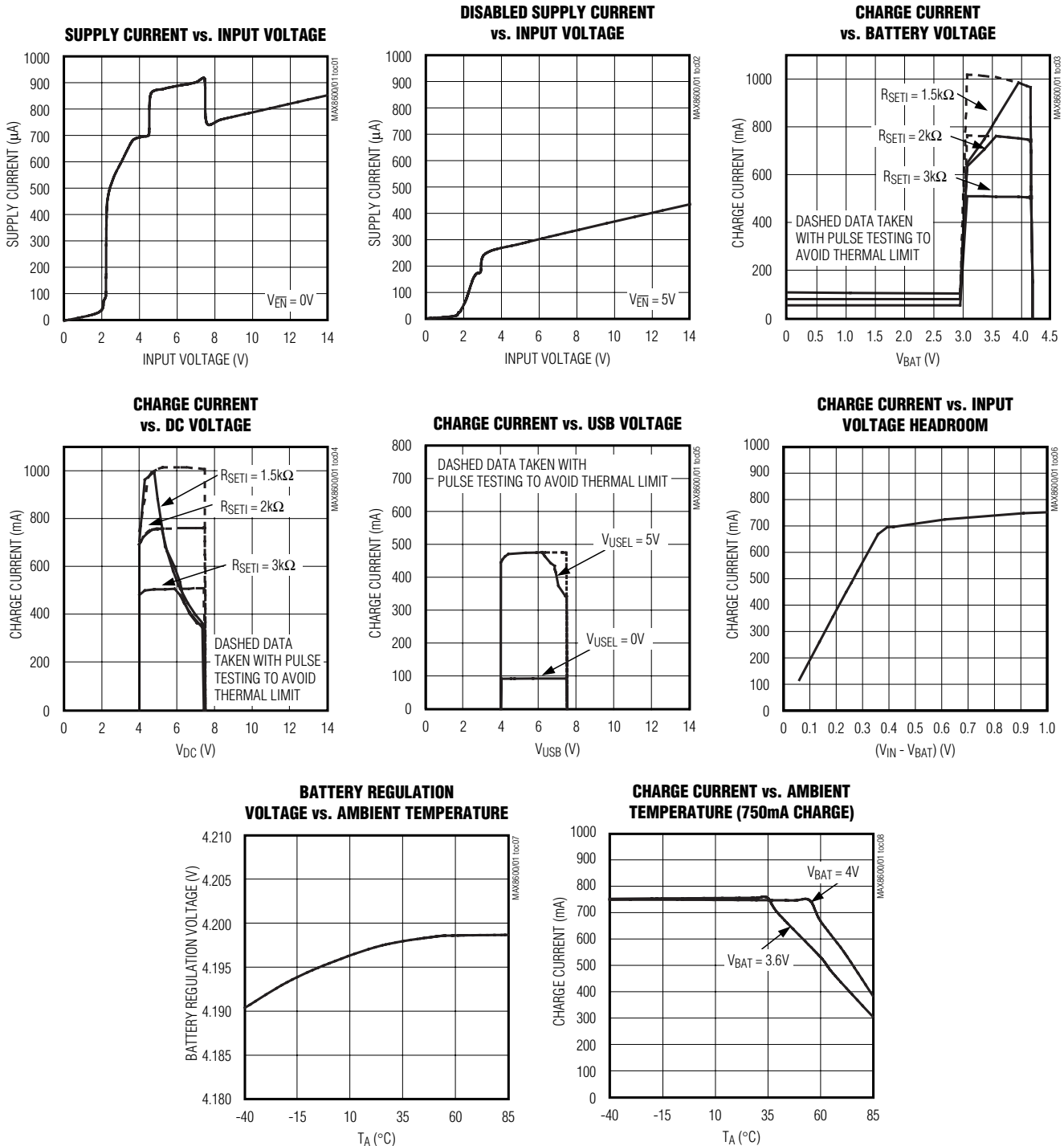
Note 2: Input refers to either DC or USB.

Note 3: Guaranteed by undervoltage- and overvoltage-threshold testing. For complete charging, the input voltage must be greater than 4.32V.

Single-/Dual-Input 1-Cell Li+ Chargers with OVP Protection and Programmable Charge Timer

Typical Operating Characteristics

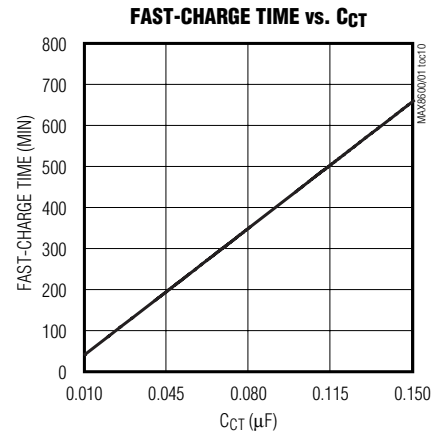
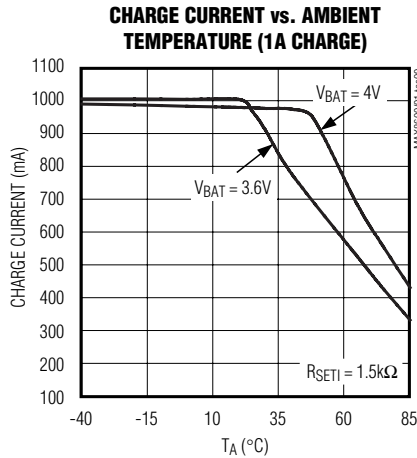
($V_{DC} = 5V$, $R_{SET1} = 2k\Omega$, $V_{BAT} = 3.6V$, MAX8601 evaluation kit with thermal resistance of $50^{\circ}C/W$. $T_A = +25^{\circ}C$, unless otherwise noted.)



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Typical Operating Characteristics (continued)

($V_{DC} = 5V$, $R_{SET1} = 2k\Omega$, $V_{BAT} = 3.6V$, MAX8601 evaluation kit with thermal resistance of $50^{\circ}C/W$. $T_A = +25^{\circ}C$, unless otherwise noted.)



Pin Description

PIN		NAME	FUNCTION
MAX8600	MAX8601		
1	1, 7	BAT	Battery Connection. The IC delivers charging current and monitors battery voltage using BAT. Bypass BAT to GND with a 2.2 μF or larger ceramic capacitor. Connect both BAT inputs together externally (MAX8601). BAT is high impedance when the IC is disabled.
2	2	SET1	DC Charge-Current Programming Input. Connect a resistor from SET1 to GND to set the maximum charging current when using the DC input, the prequal current from either input, and the CHG turn-off threshold.
3	3	THM	Thermistor Input. Connect a 10k Ω NTC thermistor, in close proximity to the battery, from THM to ground to monitor the battery temperature. Connect THM to GND to disable the thermistor functionality. The IC suspends charging when R_{THM} is outside the hot and cold limits.
4	4	GND	Ground
5	5	CT	Timing Capacitor Input. Connect a capacitor from CT to GND to set the precharge timeout, top-off time, and fast-charge timeout. Connect CT to GND to disable the timers.
6, 7, 9	—	N.C.	No Connection. Make no external circuit connection.
8	8	\overline{EN}	Active-Low Enable Input. Drive low or connect \overline{EN} to GND to enable the charger. Drive \overline{EN} high to disable the charger.
10	10	\overline{POK}	Power-OK Monitor. \overline{POK} is an open-drain output that pulls low when a valid charging source is detected at either DC or USB (MAX8601). POK is high impedance when \overline{EN} is high.
11	11	\overline{CHG}	Charging-Status Output. \overline{CHG} goes low when the battery is above 3V and being charged with a current greater than 7.5% of the current programmed with R_{SET1} . \overline{CHG} is high impedance when the charger is in prequal, top-off, or disabled.

Single-/Dual-Input 1-Cell Li+ Chargers with OVP Protection and Programmable Charge Timer

Pin Description (continued)

PIN		NAME	FUNCTION
MAX8600	MAX8601		
12, 13	12, 13	DC	DC Input Supply. Connect DC to a 4.5V to 7V charging source. Bypass DC to GND with a 1 μ F or larger capacitor. DC takes priority over USB when both are present (MAX8601). Both DC inputs should be connected together externally.
14	14	$\overline{\text{FLT}}$	Fault Status Output. $\overline{\text{FLT}}$ goes low when either the prequal timer or the fast-charge timers expire and the battery voltage is not above the required threshold. Clear the fault by raising $\overline{\text{EN}}$ or removing input power.
—	9	USB	USB Input Source. Connect to a USB port. Bypass USB to GND with a 1 μ F or larger capacitor.
—	6	USEL	USB Charge-Select Input. Logic input that determines the maximum charge current drawn from the USB input. $I_{\text{BAT}} = 95\text{mA}$ when USEL = low, and $I_{\text{BAT}} = 475\text{mA}$ when USEL = high.
—	—	EP	Exposed Pad. Connect to the GND plane for optimum thermal dissipation.

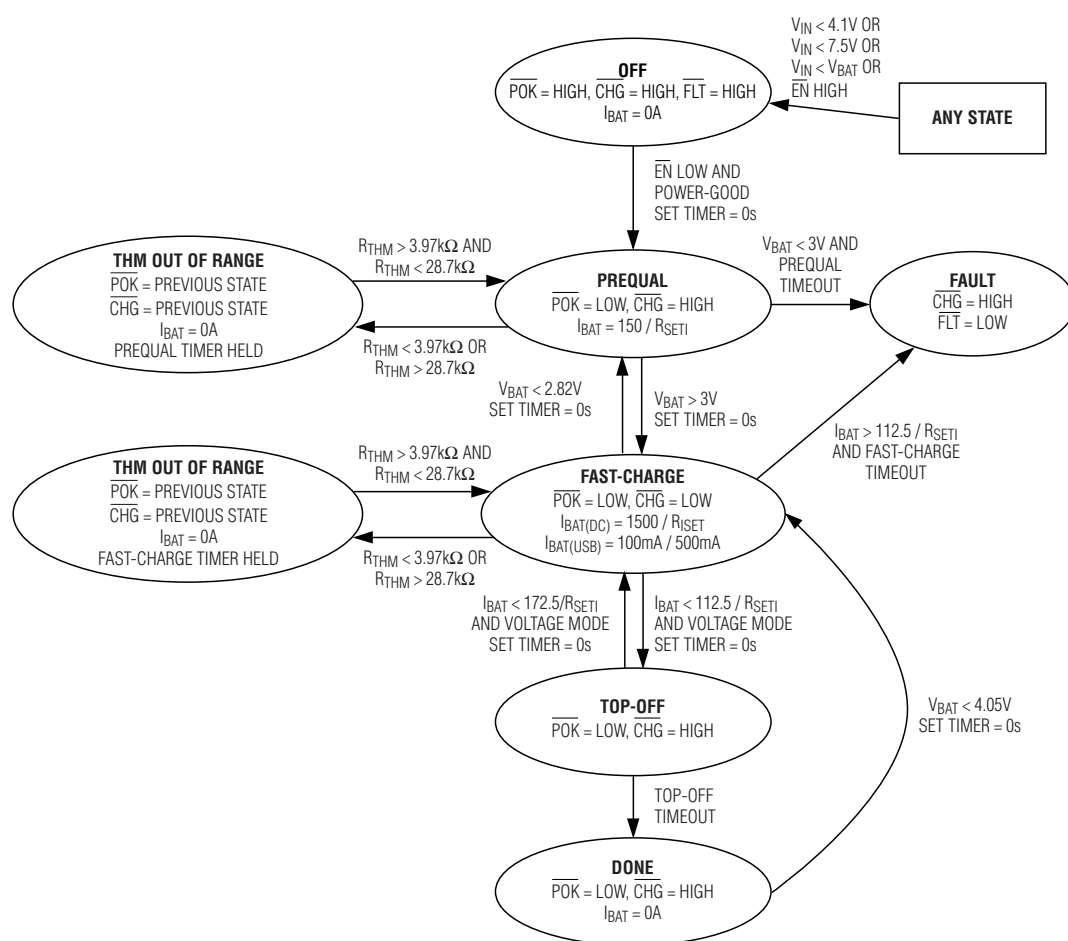


Figure 1. Charger State Diagram

MAX8600/MAX8601

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Table 1. Fault Temperatures for Different Thermistors

THERMISTOR BETA	3000	3250	3500	3750
Resistance at +25°C	10,000Ω	10,000Ω	10,000Ω	10,000Ω
Resistance at +50°C	4587.78Ω	4299.35Ω	4029.06Ω	3775.75Ω
Resistance at 0°C	25,140.55Ω	27,148.09Ω	29,315.94Ω	31,656.90Ω
Nominal Hot Trip Temperature	+55.14°C	+52.60°C	+50.46°C	+48.63°C
Nominal Cold Trip Temperature	-3.24°C	-1.26°C	+0.46°C	+1.97°C

Charge Current Selection

The maximum charging current from a supply connected to DC is programmed by an external resistor (R_{SETI}) connected from SETI to GND. Calculate the R_{SETI} value as follows:

$$R_{SETI} = 1500 / I_{CHARGE(MAX)}$$

where $I_{CHARGE(MAX)}$ is in amps and R_{SETI} is in ohms. SETI can also be used to monitor the actual charge-current level. The output voltage at SETI is proportional to the charging current as follows:

$$V_{SETI} = (I_{CHARGE} \times R_{SETI}) / 1000$$

Note that the prequal current for both USB and DC input operation is 1/10 of the fast-charge current set by R_{SETI} . Also, the top-off charge-current threshold for both USB and DC input operation is set to 7.5% of the fast-charge current set by R_{SETI} .

$$I_{PREQUAL} = 150 / R_{SETI}$$

$$I_{TOP-OFF} = 112.5 / R_{SETI}$$

Timer Capacitor Selection

The MAX8600/MAX8601 contain timers for prequal, fast-charge, and top-off operation. These time periods are determined by the capacitance from CT to GND. To set the charge times, calculate C_{CT} as follows:

$$T_{FASTCHARGE} = 334\text{min} \times (C_{CT} / 0.068\mu\text{F})$$

$$T_{PREQUAL} = T_{TOPOFF} = 34.8\text{min} \times (C_{CT} / 0.068\mu\text{F})$$

Note that when charging at 100mA from the USB input (MAX8601), the fast-charge timer is inhibited. When THM halts charging, the timers stop and hold their value.

Battery Temperature Control

The MAX8600/MAX8601 monitor battery temperature through a negative TC thermistor which is in close thermal contact with the battery. Select a thermistor resistance that is 10kΩ at +25°C and has a beta of 3500. The IC compares the resistance from THM to GND and suspends charging when it is greater than 28.3kΩ or

less than 3.94kΩ, which translates to a temperature of 0°C to +50°C. Table 1 shows the nominal temperature limits that result from a wide range of available thermistor temperature curves. The curves are defined by the following equation:

$$R_T = R_{25^\circ\text{C}} \times e^{\left\{ \beta \left[\left(\frac{1}{T+273} \right) - \left(\frac{1}{298} \right) \right] \right\}}$$

where β is the BETA term in Table 1.

Connect THM to GND to disable the temperature-control function. When R_{THM} disables charging, all timers pause and hold their value.

Capacitor Selection

Connect a 2.2μF ceramic capacitor from BAT to GND for proper stability. Connect a 1μF ceramic capacitor from DC to GND. If using the USB input for the MAX8601, bypass USB to GND with a 1μF ceramic capacitor. Use a larger input bypass capacitor for high charging currents to reduce supply noise. All capacitors should be X5R dielectric or better. Be aware that some capacitors have large voltage coefficients and should be avoided.

Thermal Considerations

The MAX8600/MAX8601 are in a thermally enhanced TDFN package with an exposed paddle. Connect the exposed paddle of the package to a large copper ground plane to provide a thermal contact between the device and the circuit board. The exposed paddle transfers heat away from the device, allowing the IC to charge the battery with maximum current, while minimizing the increase in die temperature. Note that the MAX8600/MAX8601s' thermal-limit control allows the charger to be tolerant of thermally restricted PC board layouts that are sometimes unavoidable in compact portable designs. With such non-optimal layouts, the charger still operates, but may reduce charge current to manage temperature rise.

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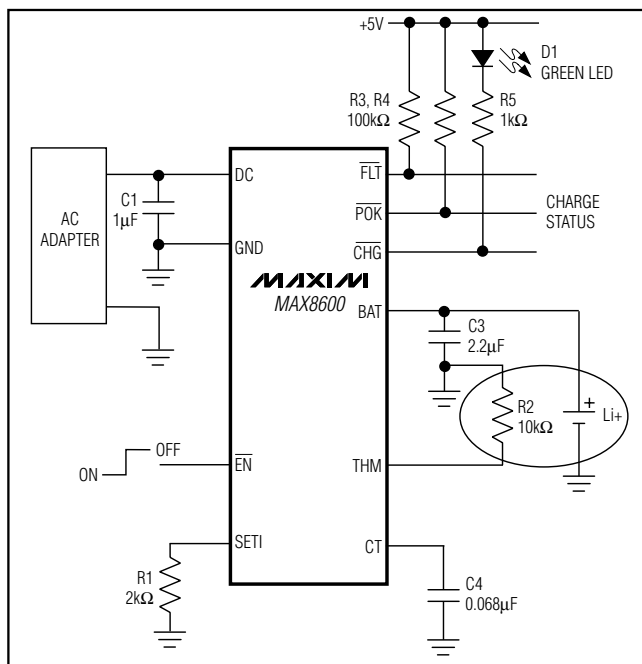


Figure 3. Stand-Alone Li+ Battery-Charger with the MAX8600

DC Input Sources

The MAX8600/MAX8601 operating input voltage range is 4.15V to 7V. The device survives input voltages up to 16V without damage to the IC. If the input voltage is greater than 7.5V (typ), the IC stops charging. An appropriate power supply must provide at least 4.2V plus the voltage drop across the internal pass transistor when sourcing the desired maximum charging current.

$$V_{IN(MIN)} > 4.2V + I_{CHARGE(MAX)} \times R_{ON}$$

where R_{ON} is the input-to-BAT resistance (typically 0.5Ω). Failure to meet this requirement results in an incomplete charge or increased charge time.

Stand-Alone Li+ Charger

The MAX8600 provides a complete Li+ charging solution. Figure 3 shows the MAX8600 as a stand-alone Li+ battery charger. The $2k\Omega$ resistor connected to SETI sets a charging current of 750mA. The LED indicates when fast-charge has begun. When fast-charge is complete, the LED turns off.

USB-Powered Li+ Charger (MAX8601)

The universal serial bus (USB) provides a high-speed serial communication port as well as power for the

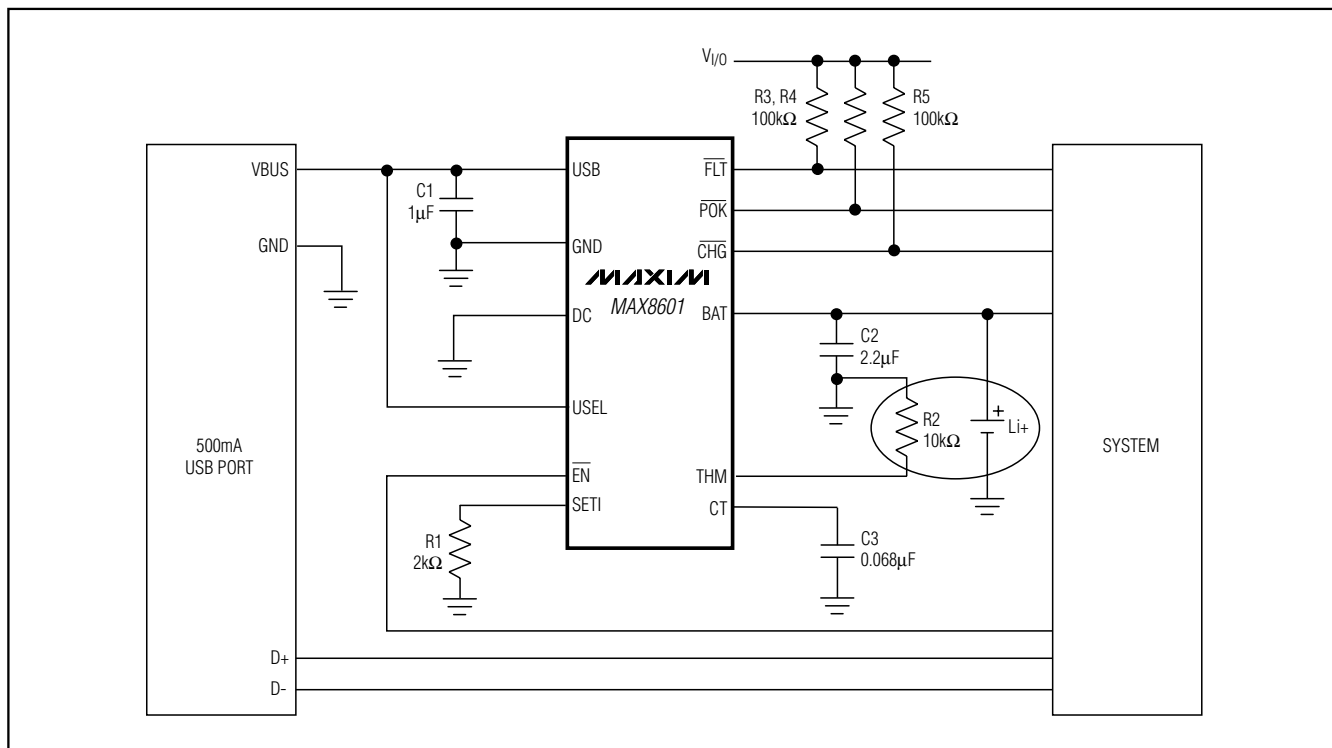


Figure 4. USB Battery Li Charger with the MAX8601

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remote device. The MAX8601 can be configured to charge its battery at the highest current possible from the host port. Figure 4 shows the MAX8601 configured as a USB battery charger. A USEL input sets the maximum charging current from the USB input at 100mA or 500mA.

Layout and Bypassing

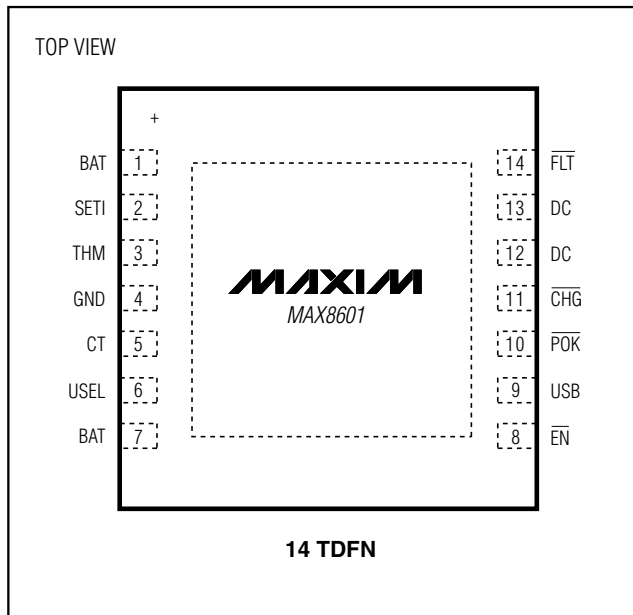
Connect the input capacitors as close to the device as possible. Provide a large copper GND plane to allow the exposed paddle to sink heat away from the device. Connect the battery to BAT as close to the IC as possible to provide accurate battery voltage sensing. Make all high-current traces short and wide to minimize voltage drops. For an example layout, refer to the MAX8601 evaluation kit.

Chip Information

TRANSISTOR COUNT: 6838

PROCESS: BiCMOS

Pin Configurations (continued)

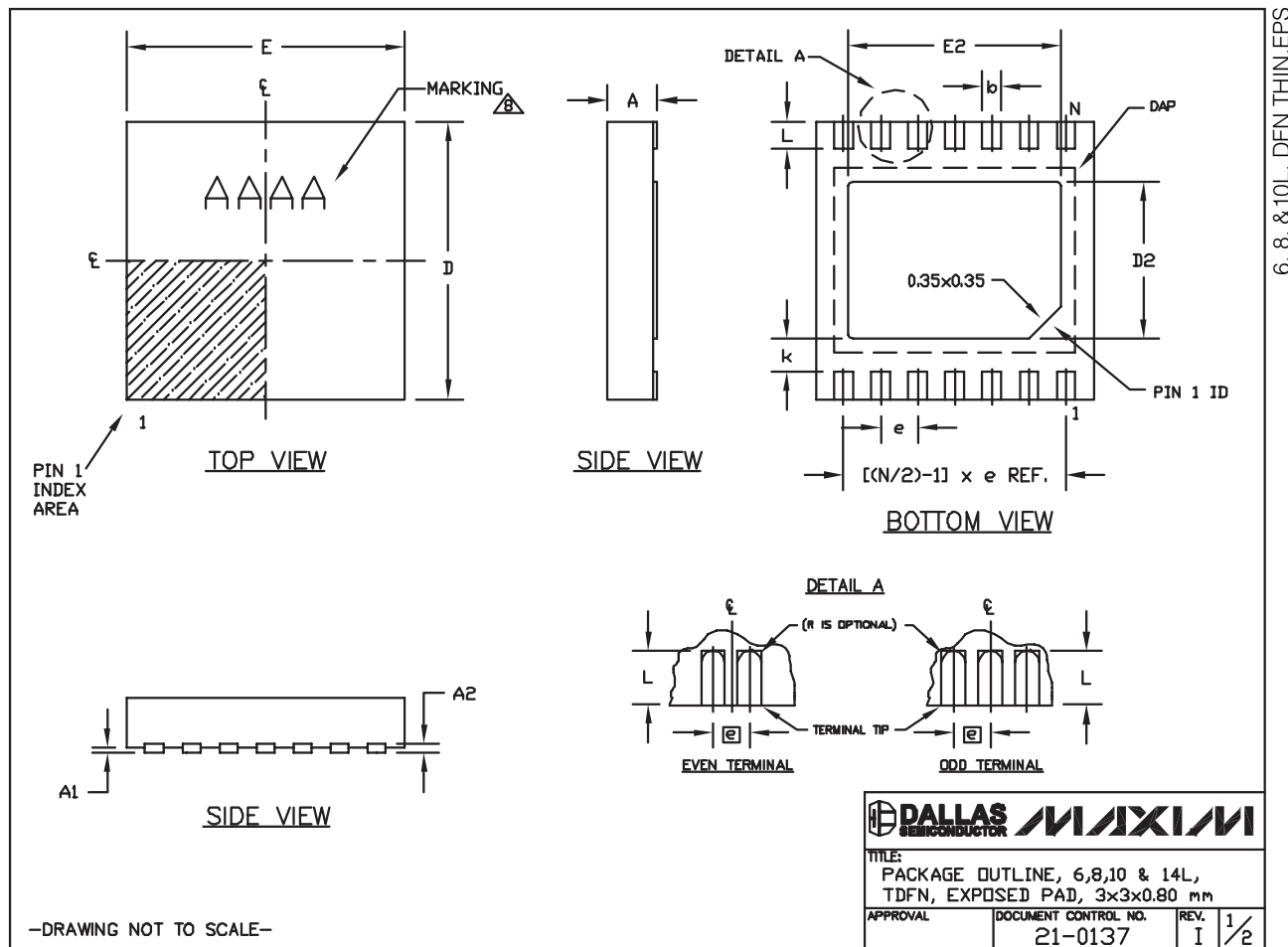


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Package Information

For the latest package outline information and land patterns, go to www.maxim-ic.com/packages.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
14 TDFN-EP	T1433-2	21-0137



MAX8600/MAX8601

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Package Information (continued)

For the latest package outline information and land patterns, go to www.maxim-ic.com/packages.


COMMON DIMENSIONS		
SYMBOL	MIN.	MAX.
A	0.70	0.80
D	2.90	3.10
E	2.90	3.10
A1	0.00	0.05
L	0.20	0.40
k	0.25 MIN.	
A2	0.20 REF.	

PACKAGE VARIATIONS								
PKG. CODE	N	D2	E2	e	JEDEC SPEC	b	[(N/2)-1] x e	
T633-2	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF	
T833-2	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF	
T833-3	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF	
T1033-1	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF	
T1033-2	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF	
T1433-1	14	1.70±0.10	2.30±0.10	0.40 BSC	----	0.20±0.05	2.40 REF	
T1433-2	14	1.70±0.10	2.30±0.10	0.40 BSC	----	0.20±0.05	2.40 REF	

NOTES:

1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.10 mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2.
6. "N" IS THE TOTAL NUMBER OF LEADS.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
8. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

—DRAWING NOT TO SCALE—

			
TITLE: PACKAGE OUTLINE, 6,8,10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm			
APPROVAL	DOCUMENT CONTROL NO.	REV.	2/2
	21-0137	I	

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Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
2	7/08	Corrected Absolute Maximum Rating	2
3	12/08	Corrected <i>Absolute Maximum Ratings</i> and made various updates	1, 2, 3, 6, 7

MAX8600/MAX8601

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