19-3670; Rev 0; 4/05

EVALUATION KIT AVAILABLE

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

General Description

The MAX8808X/MAX8808Y/MAX8808Z intelligent, stand-alone constant-current/constant-voltage (CCCV), thermally regulated linear chargers are designed for charging a single-cell lithium-ion (Li+) battery. The MAX8808X/MAX8808Y/MAX8808Z integrate the current-sense circuit, MOS pass element, and thermal-regulation circuitry, and eliminate the reverse-blocking Schottky diode to create the simplest and smallest charging solution for handheld equipment.

The MAX8808X functions as a stand-alone charger to control the charging sequence from the prequalification state through fast-charge, top-off charge, and full-charge indication. The MAX8808Y and MAX8808Z eliminate the prequalification state to allow startup into a load without a battery. Proprietary thermal-regulation circuitry limits the die temperature when fast-charging or while exposed to high ambient temperatures, allowing maximum charging current without damaging the IC.

The MAX8808X/MAX8808Y/MAX8808Z achieve high flexibility by providing an adjustable fast-charge current with an external resistor. Other features include a battery charging-status indicator ($\overline{CHG}$), an active-low control input ($\overline{EN}$) for the MAX8808X and MAX8808Z (active-high control input for the MAX8808Y), and an active-low input power-source detection output ($\overline{ACOK}$).

The MAX8808X/MAX8808Y/MAX8808Z accept a +4.25V to +15V supply, but disable charging when the input voltage exceeds +7V to protect against unqualified or faulty AC adapters. The MAX8808X/MAX8808Y/MAX8808Z operate over the extended temperature range (-40°C to +85°C) and are available in a compact 8-pin thermally enhanced 2mm x 2mm TDFN package with 0.8mm (max) height.

Applications

Cellular and Cordless Phones

Smartphones and PDAs

Digital Still Cameras and MP3 Players

USB Appliances

Charging Cradles and Docks

Bluetooth® Equipment

Pin Configuration appears at end of data sheet.

Bluetooth is a registered trademark of Bluetooth SIG.

Features

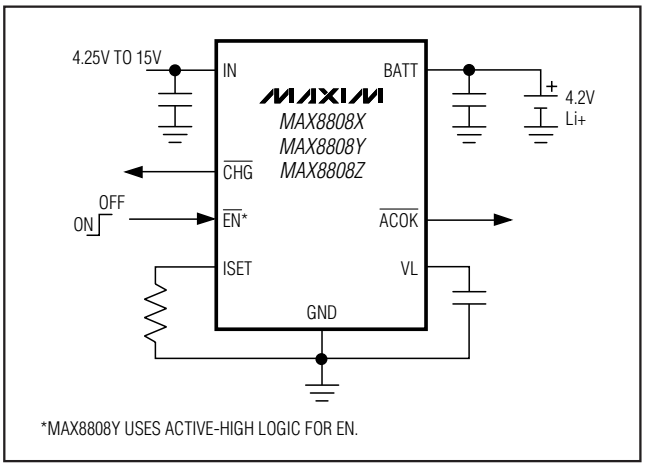
- **Stand-Alone Linear 1-Cell Li+ Battery Charger**
- **No External FET, Reverse Blocking Diode, or Current-Sense Resistor Required**
- **Programmable Fast-Charge Current (1A max)**
- **Proprietary Die Temperature Regulation Control (+115°C)**
- **+4.25V to +15V Input Voltage Range with Input OVP Above +7V**
- **Charge-Current Monitor for Fuel Gauging**
- **Low Dropout Voltage—300mV at 500mA**
- **Input Power-Source Detection Output ($\overline{ACOK}$) and Charge-Enable Input ($\overline{EN}$ or EN)**
- **Soft-Start Limits Inrush Current**
- **Charge-Status Output ($\overline{CHG}$) for LED or Microprocessor (µP) Interface**
- **Tiny 2mm x 2mm 8-Pin TDFN Package, 0.8mm (max) Height**

Ordering Information

PART	PIN-PACKAGE	TOP MARK
MAX8808XETA+	8 TDFN-EP* 2mm x 2mm (T822-1)	AAC
MAX8808YETA+	8 TDFN-EP* 2mm x 2mm (T822-1)	AAB
MAX8808ZETA+	8 TDFN-EP* 2mm x 2mm (T822-1)	AAA

All devices specified over the -40°C to +85°C operating range.
+Denotes lead-free package.
**EP = Exposed paddle.*

Typical Operating Circuit



1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

ABSOLUTE MAXIMUM RATINGS

IN to GND .....-0.3V to +16V
VL, BATT, $\overline{EN}$, $\overline{ACOK}$, $\overline{CHG}$ to GND .....-0.3V to +6V
VL, ISET to GND .....-0.3V to +4V
VL to IN .....-16.3V to +0.3V
IN to BATT Continuous Current 1.5A
Continuous Power Dissipation (T_A = +70°C)
8-Pin 2mm x 2mm TDFN (derate 15.4mW/°C above +70°C) 1234mW
BATT Short-Circuit Duration .....Continuous
Operating Temperature Range .....-40°C to +85°C
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°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_{IN} = 5V, V_{BATT} = 4.0V, $R_{\overline{ACOK}}$ = $R_{\overline{CHG}}$ = 100kΩ to 5V, $\overline{EN}$ = unconnected (for the MAX8808X and MAX8808Z), EN = VL (for the MAX8808Y), R_{ISET} = 2.8kΩ to GND, C_{VL} = 0.47µF, C_{BATT} = 1µF, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			0		15	V
Input Operating Range			4.25		6.50	V
$\overline{ACOK}$ Threshold	V_{IN} - V_{BATT}, 10mV hysteresis (typ)	V_{IN} rising	15	40	60	mV
		V_{IN} falling	10	30	45	
Overvoltage-Lockout Trip Point	V_{IN} rising, 100mV hysteresis (typ)		6.5	7	7.5	V
IN Input Current	Charging (I_{IN} - I_{BATT})			0.8	2	mA
	Disabled			0.23	0.50	
	OFF state (V_{IN} = V_{BATT} = 4.0V)				0.065	
VL Output Voltage	I_{VL} = 100µA			3.0		V
VL Load Regulation	I_{VL} = 100µA to 2mA			-5	-30	mV
VL Undervoltage-Lockout Trip Point	V_{VL} rising, 100mV hysteresis (typ)			2.74		V
BATT Input Current	V_{IN} = 0 to 4V			1	10	µA
	Disabled			1	10	
Maximum RMS Charge Current			1			A_{RMS}
Battery Regulation Voltage	I_{BATT} = 1mA		4.162	4.200	4.238	V
Minimum BATT Bypass Capacitance				2.2		µF/A
Fast-Charge Current Loop System Accuracy	V_{BATT} = 3.5V	T_A = 0°C to +85°C	418	465	512	mA

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 5V, V_{BATT} = 4.0V, $R_{\overline{ACOK}}$ = $R_{\overline{CHG}}$ = 100kΩ to 5V, $\overline{EN}$ = unconnected (for the MAX8808X and MAX8808Z), EN = VL (for the MAX8808Y), R_{ISET} = 2.8kΩ to GND, C_{VL} = 0.47µF, C_{BATT} = 1µF, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Prequal Charge Current	Percentage of the fast-charge current, V_{BATT} = 2.2V, MAX8808X		5	10	15	%
Die Temperature Regulation Threshold				+115		°C
V_{BATT} Prequal Threshold Voltage	V_{BATT} rising, MAX8808X		2.3	2.5	2.7	V
Current-Sense Amplifier Gain, I_{BATT} to I_{ISET}	I_{BATT} = 500mA, V_{ISET} = 1.4V	T_A = 0°C to +85°C	0.97	1.08	1.19	mA/A
Regulator Dropout Voltage (V_{IN} - V_{BATT})	V_{BATT} = 4.1V, I_{BATT} = 425mA			250	430	mV
EN/$\overline{EN}$ Logic Input Low Voltage	4.25V < V_{IN} < 6.5V				0.52	V
EN/$\overline{EN}$ Logic Input High Voltage	4.25V < V_{IN} < 6.5V		1.3			V
$\overline{EN}$ Internal Pulldown Resistor	MAX8808X and MAX8808Z only		100	200	400	kΩ
EN Input Leakage Current	MAX8808Y, V_{EN} = 5.5V	T_A = +25°C			1	µA
		T_A = +85°C		0.002		
$\overline{CHG}$ Output Low Voltage	$I_{\overline{CHG}}$ = 5mA				0.4	V
$\overline{CHG}$ Output High Leakage Current	$V_{\overline{CHG}}$ = 5.5V	T_A = +25°C			1	µA
		T_A = +85°C		0.002		
$\overline{ACOK}$ Output Low Voltage	$I_{\overline{ACOK}}$ = 5mA				0.4	V
$\overline{ACOK}$ Output High Leakage Current	$V_{\overline{ACOK}}$ = 5.5V	T_A = +25°C			1	µA
		T_A = +85°C		0.002		
Full-Battery Detection Current Threshold	I_{BATT} falling, percentage of the fast-charge current		5	10	15	%

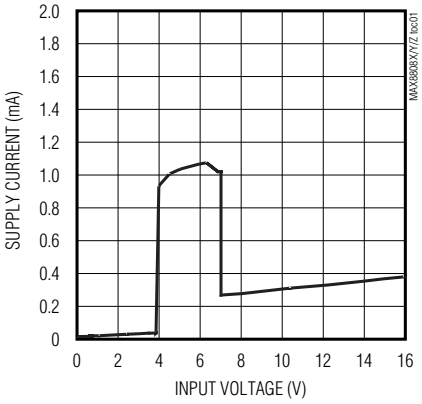
Note 1: Specifications are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design and characterization.

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

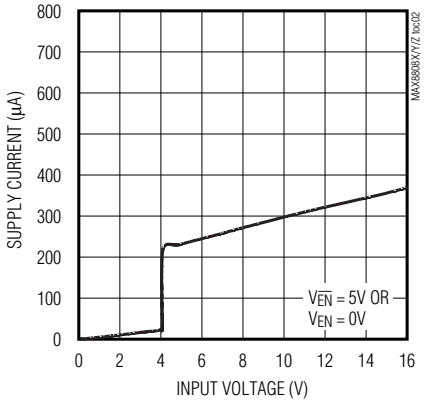
Typical Operating Characteristics

(V_{IN} = 5V, V_{BATT} = 4.0V, $\overline{ACOK}$ = $\overline{EN}$ = unconnected, R_{ISET} = 2.8kΩ to GND, C_{IN} = 1µF, C_{BATT} = 1µF, C_{VL} = 0.47µF, T_A = +25°C, unless otherwise noted.)

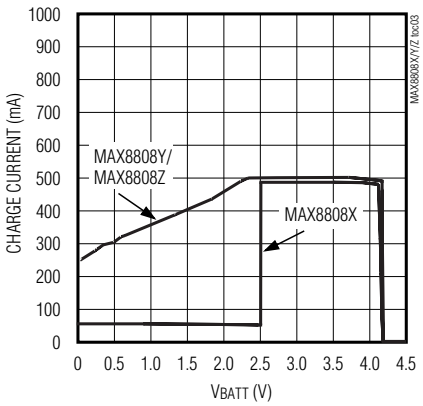
SUPPLY CURRENT vs. INPUT VOLTAGE



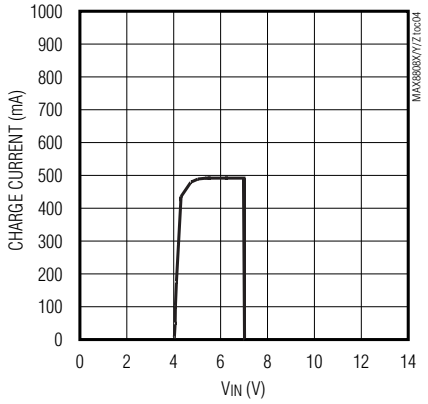
DISABLED-MODE SUPPLY CURRENT vs. INPUT VOLTAGE



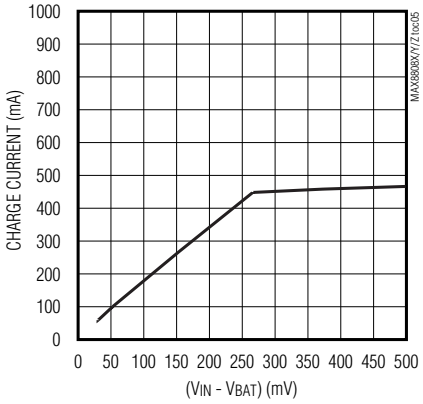
CHARGE CURRENT vs. BATTERY VOLTAGE



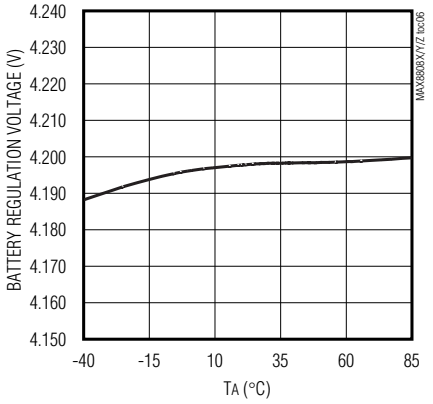
CHARGE CURRENT vs. INPUT VOLTAGE



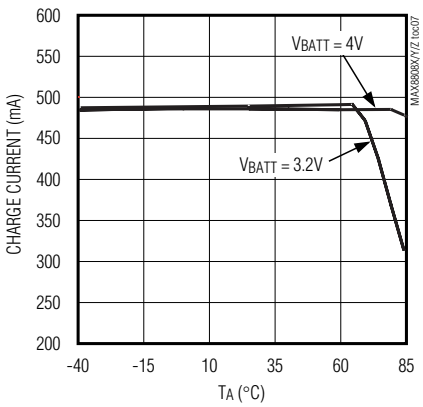
CHARGE CURRENT vs. INPUT VOLTAGE HEADROOM



BATTERY REGULATION VOLTAGE vs. AMBIENT TEMPERATURE



CHARGE CURRENT vs. AMBIENT TEMPERATURE



Pin Description

PIN	NAME	FUNCTION
1	IN	Input Supply Voltage. Bypass IN to GND with a 1µF or larger ceramic capacitor to improve line noise and input transient rejection.
2	VL	Internally Generated Logic Supply for IC. Bypass VL to GND with a 0.47µF ceramic capacitor.
3	GND	Ground. Connect GND and exposed pad to a large copper ground plane for maximum power dissipation. Connect GND to the exposed paddle directly under the IC.
4	ISET	Charge-Current Program and Fast-Charge Current Monitor. Output current from ISET is 1.08mA per amp of battery charging current. Set the charging current by connecting a resistor from ISET to GND. Fast-charge current = 1302V / $R_{ISET}\Omega$.
5	$\overline{CHG}$	Charging Indicator. $\overline{CHG}$ is an open-drain output that goes low (LED capable) when charging begins. $\overline{CHG}$ is high impedance when the battery current drops below 10% of the fast-charging current, or when the IC is disabled. Connect a pullup resistor to the µP's I/O voltage when interfacing with a µP logic input.
6	$\overline{EN}$ (MAX8808X/ MAX8808Z)	Logic-Level Enable Input. Drive $\overline{EN}$ high to disable charger. Pull $\overline{EN}$ low or leave unconnected for normal operation. $\overline{EN}$ has an internal 200kΩ pulldown resistor.
	EN (MAX8808Y)	Logic-Level Enable Input. Drive EN low to disable charger. Pull EN high for normal operation. EN has no internal pullup or pulldown resistor.
7	$\overline{ACOK}$	Input Status Indicator. $\overline{ACOK}$ is an open-drain output that asserts low when V_{IN} < +7V and (V_{IN} – V_{BATT}) ≥ 40mV. $\overline{ACOK}$ requires an external 100kΩ pullup resistor. $\overline{ACOK}$ is high impedance during shutdown.
8	BATT	Li+ Battery Connection. Bypass BATT to GND with a ceramic capacitor of at least 2.2µF per ampere of charge current.
—	EP	Exposed Paddle. Connect the exposed paddle to a large ground plane for maximum power dissipation. Connect GND to the exposed paddle directly under the IC.

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

Detailed Description

The MAX8808X/MAX8808Y/MAX8808Z chargers use voltage, current, and thermal-control loops to charge a single Li+ cell and protect the battery (Figure 1). When a Li+ battery with a cell voltage below 2.5V is inserted, the MAX8808X charger enters the prequalification stage where it precharges that cell with 10% of the user-programmed fast-charge current (Figure 2). The $\overline{CHG}$ indicator output is driven low to indicate entry into the prequalification state. When battery voltage exceeds 2.5V, the charger soft-starts as it enters the fast-charge stage. In the MAX8808X/MAX8808Y/MAX8808Z, the fast-charge current level is programmed through a resistor from ISET to GND. As the battery voltage approaches 4.2V, the charging current is reduced. If the battery current drops to less than 10% of the fast-charging current, the $\overline{CHG}$ indicator goes high impedance, signaling that the battery is fully charged. The ICs then enter a constant voltage-regulation mode to maintain the battery at full charge.

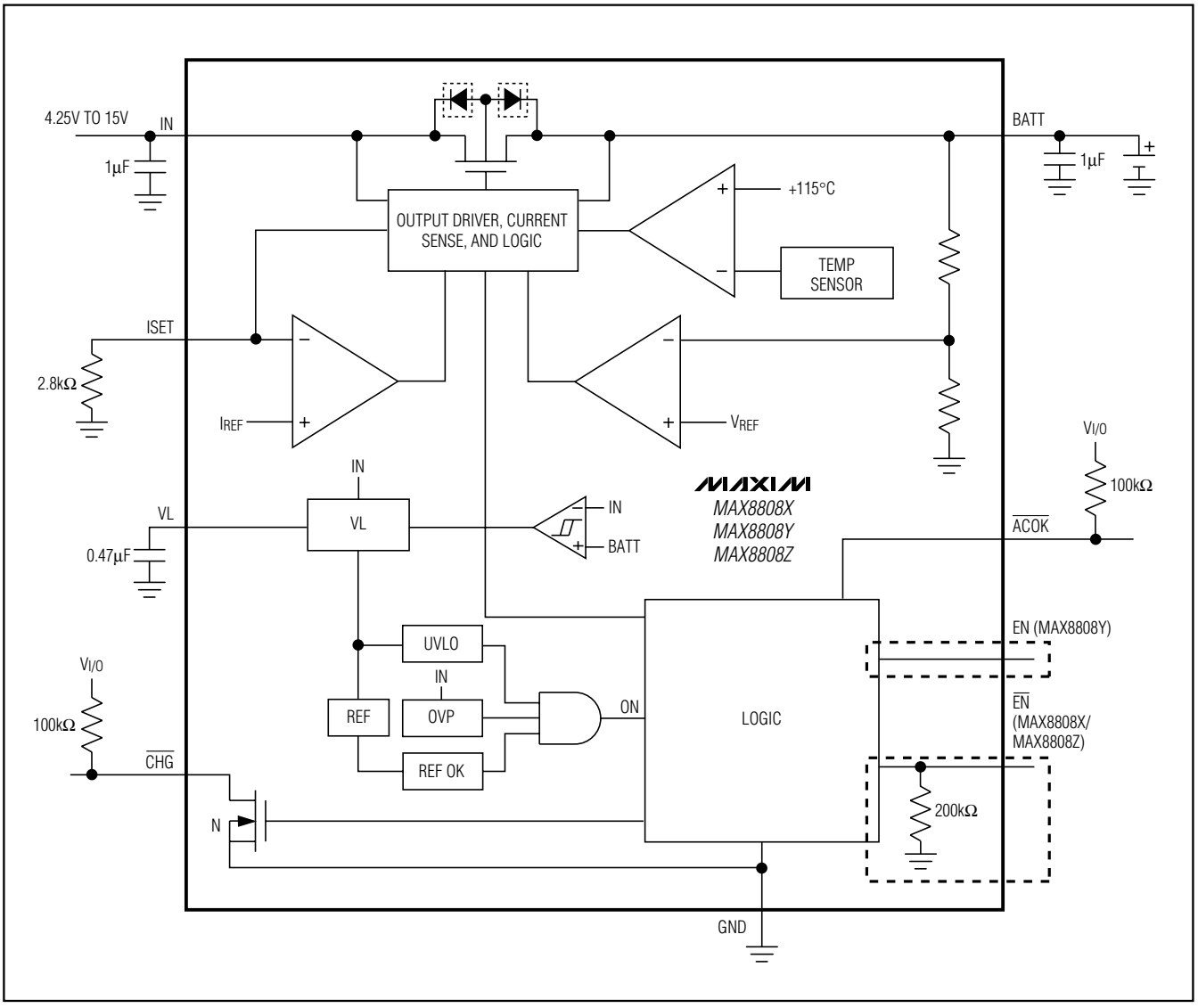


Figure 1. Functional Diagram

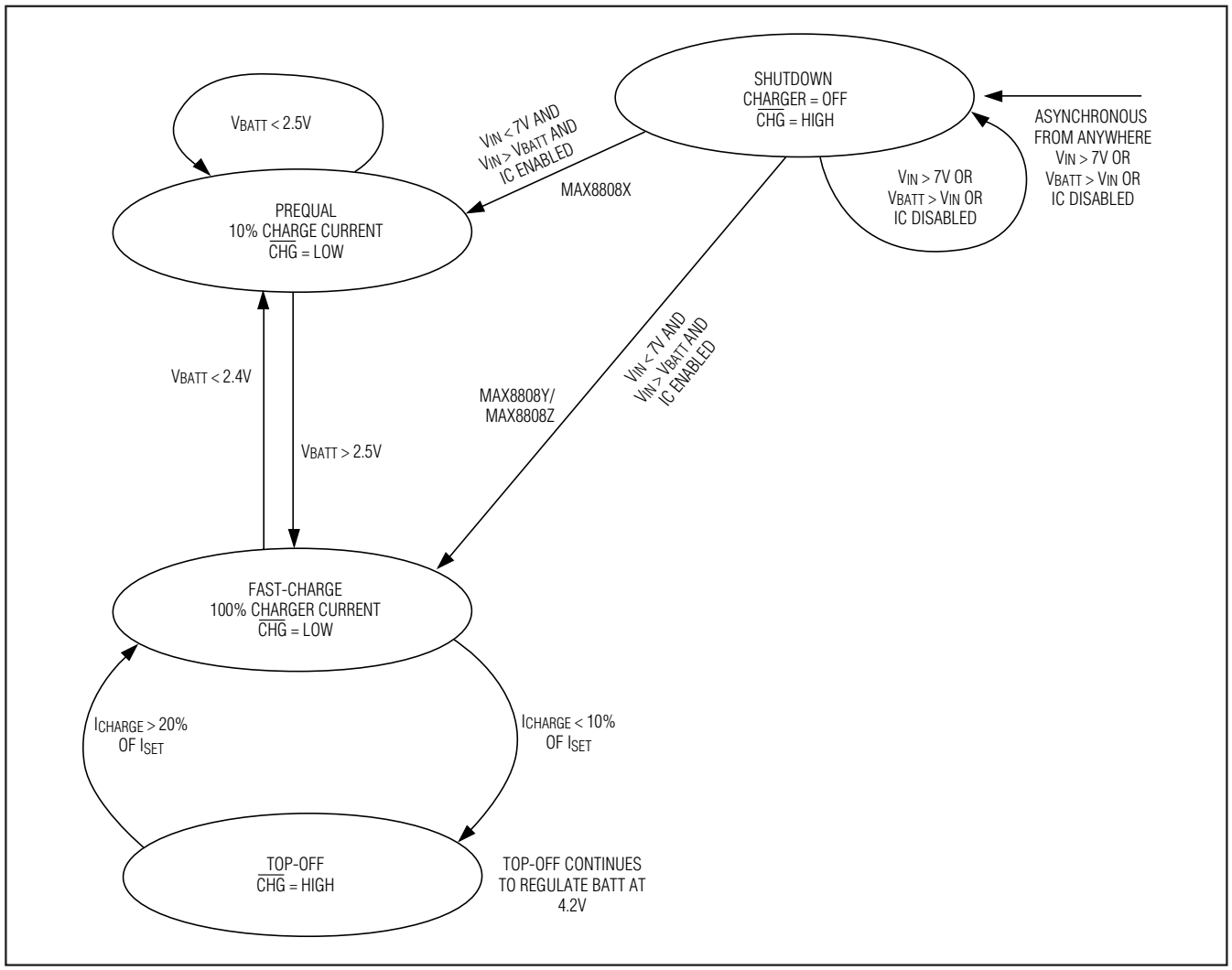


Figure 2. Charge-State Diagram

Thermal Regulation

The thermal-regulation loop limits the MAX8808X/MAX8808Y/MAX8808Z die temperature to +115°C by reducing the charge current as necessary. This feature not only protects the ICs from overheating, but also allows a higher charge current without risking damage to the system.

$\overline{EN}$ (MAX8808X/MAX8808Z) and EN (MAX8808Y) Charger Enable Input

The MAX8808X/MAX8808Z contain an active-low logic input ($\overline{EN}$) used to enable the charger. Drive $\overline{EN}$ low, leave floating, or connect to GND to enable the charge-control circuitry. Drive $\overline{EN}$ high to disable the charger-control circuitry. $\overline{EN}$ has a 200kΩ internal pull-down resistor.

The MAX8808Y contains an active-high enable input (EN) to enable the charger. Drive EN high to enable the charge-control circuitry. Drive EN low to disable the charger-control circuitry. Do not leave EN floating. It has no internal pullup or pulldown resistor.

$\overline{ACOK}$ Output

The open-drain $\overline{ACOK}$ output asserts low when +4.25V ≤ V_{IN} ≤ +7V and V_{IN} - V_{BATT} ≥ 40mV. $\overline{ACOK}$ requires an external pullup resistor (100kΩ typ). $\overline{ACOK}$ is high impedance during shutdown.

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

VL Internal Voltage Regulator

The MAX8808X/MAX8808Y/MAX8808Z linear chargers contain an internal linear regulator to supply the power for the IC. Bypass VL to GND with a 0.47µF ceramic capacitor. VL is regulated to 3.0V whenever the input voltage is above the battery voltage.

$\overline{CHG}$ Charge-Indicator Output

$\overline{CHG}$ is an open-drain output that indicates charge status. Table 1 describes the state of $\overline{CHG}$ during different stages of operation. $\overline{CHG}$ is suitable for driving a charge-indication LED. If the MAX8808X/MAX8808Y/MAX8808Z is used in conjunction with a µP, a pullup resistor to the logic I/O voltage allows $\overline{CHG}$ to indicate charge status to the µP instead of driving an LED.

Soft-Start

The soft-start algorithm activates when entering fast-charge mode. In the MAX8808X, when the prequalification state is complete (V_{BATT} exceeds +2.5V), the charging current ramps up in 1ms to the full charging current. This reduces the inrush current on the input supply. Note that the MAX8808Y and MAX8808Z do not have a prequalification state and enter soft-start directly after being enabled.

Applications Information

Charge-Current Selection

The maximum charging current is programmed by an external resistor connected from ISET to GND (R_{ISET}).

Calculate R_{ISET} as follows:

$$R_{ISET} = 1302V / I_{FASTCHG}$$

where $I_{FASTCHG}$ is in Amps and R_{ISET} is in Ohms. ISET can be used to monitor the fast-charge current level. The output current from ISET is 1.08mA per amp of charging current. The output voltage at ISET is proportional to the charging current:

$$V_{ISET} = (I_{CHARGE} \times R_{ISET}) / 930$$

The voltage at ISET is nominally 1.4V at the selected fast-charge current, and falls with charging current as the cell becomes fully charged or as the thermal-regulation circuitry activates.

Capacitor Selection

Connect a ceramic capacitor from BATT to GND for proper stability. Use a 1µF X5R ceramic capacitor for most applications. Connect a 1µF ceramic capacitor from IN to GND. Use a larger input bypass capacitor for high charging currents to reduce supply noise. Connect a 0.47µF ceramic capacitor from VL to GND.

Thermal Considerations

The MAX8808X/MAX8808Y/MAX8808Z are available in a thermally enhanced TDFN package with exposed paddle. Connect the exposed paddle to a large copper ground plane to provide a thermal contact between the device and the circuit board for increased power dissipation. The exposed paddle transfers heat away from the device, allowing the ICs to charge the battery with maximum current, while minimizing the increase in die temperature.

Table 1. $\overline{CHG}$ States

$\overline{EN}$ MAX8808X	EN MAX8808Y	$\overline{EN}$ MAX8808Z	V_{IN}	V_{BATT}	I_{BATT}	$\overline{CHG}$	STATE
X	X	X	≤V_{BATT}	≥V_{IN}	0	High-Impedance	Shutdown
Low	—	—	4.25V ≤ V_{IN} ≤ 7V	<2.4V	10% of I_{FAST}	Low	Prequal
Low	High	Low	4.25V ≤ V_{IN} ≤ 7V	≥2.5V	I_{FAST}*	Low	Fast-Charge
Low	High	Low	4.25V ≤ V_{IN} ≤ 7V	4.2V	<10% of I_{FAST}	High-Impedance	Top-off
Low	High	Low	>7V	X	0	High-Impedance	Shutdown
High	Low	High	X	X	0	High-Impedance	Disabled

X = Don't care.

— = Prequal not applicable to MAX8808Y and MAX8808Z.

**I_{FAST} is reduced as necessary to prevent the die temperature from exceeding +115°C.*

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

DC Input Sources

The MAX8808X/MAX8808Y/MAX8808Z operate from well-regulated DC sources. The full charging input voltage range is 4.25V to 7V. The device can withstand up to 15V on the input without damage to the IC. If V_{IN} is greater than 7V, the internal overvoltage-protection circuitry disables charging until the input falls below 7V. An appropriate power supply must provide at least 4.25V at the desired peak charging current. It also must stay below 6.5V when unloaded.

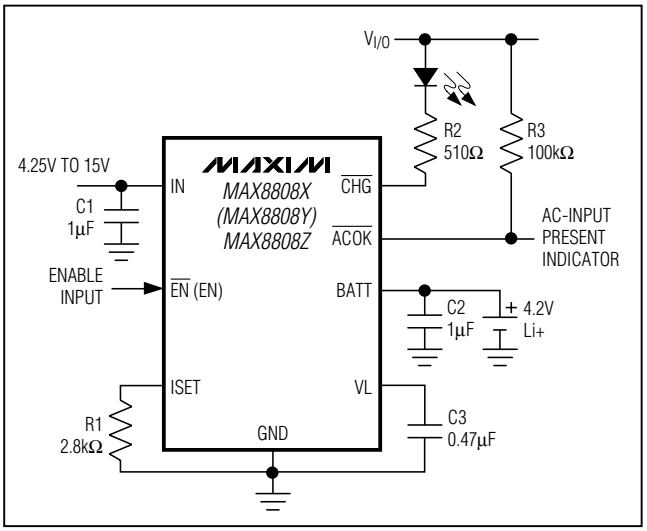


Figure 3. Stand-Alone Li+ Battery Charger

Application Circuits

Stand-Alone Li+ Charger

The MAX8808X/MAX8808Y/MAX8808Z provide a complete Li+ charging solution. Figure 3 shows a stand-alone Li+ battery charger. The 2.8kΩ resistor connected to ISET sets a charging current of 465mA. The LED connected to the $\overline{CHG}$ output indicates when either fast-charge or precharge qualification has begun. When the battery is full, $\overline{CHG}$ turns high impedance and the LED turns off.

Microprocessor-Interfaced Charger

Figure 4 shows the MAX8808X as a µP co-operated Li+ battery charger. The MAX8808X begins charging the battery when $\overline{EN}$ is low. The µP can drive $\overline{EN}$ high to disable the charger. The MAX8808X generates a $\overline{ACOK}$ signal to indicate the presence of an input supply. $\overline{CHG}$ is used to detect the charge status of the battery. By monitoring V_{ISET}, the system can measure the charging current.

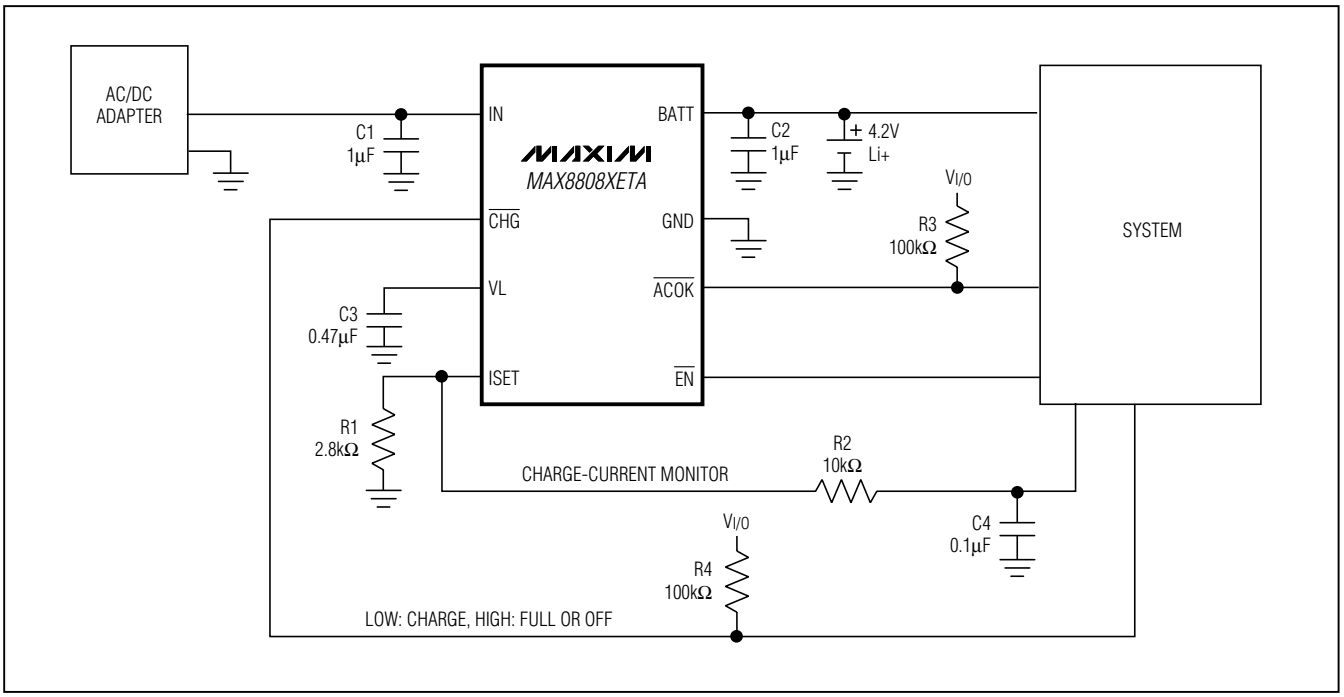


Figure 4. µP-Interfaced Li+ Battery Charger

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

USB-Powered Li+ Charger

The universal serial bus (USB) provides a high-speed serial communication port as well as power for the remote device. The MAX8808X/MAX8808Y/MAX8808Z can be configured to charge a battery at the highest current possible from the host port. Figure 5 shows the MAX8808X as a USB battery charger. To make the circuit compatible with either 100mA or 500mA USB ports, the circuit initializes at 100mA charging current. The µP then enumerates the host to determine its current capability. If the host port is capable, the charging current is increased to 425mA to avoid exceeding the 500mA USB specification.

Layout and Bypassing

Place the input capacitor as close to the device as possible. Provide a large copper ground plane to allow the exposed paddle to sink heat away from the device. Connect the battery to BATT as close to the device as possible to provide accurate battery voltage sensing. Make all high-current traces short and wide to minimize voltage drops. A sample layout is available in the MAX8808 evaluation kit to speed designs.

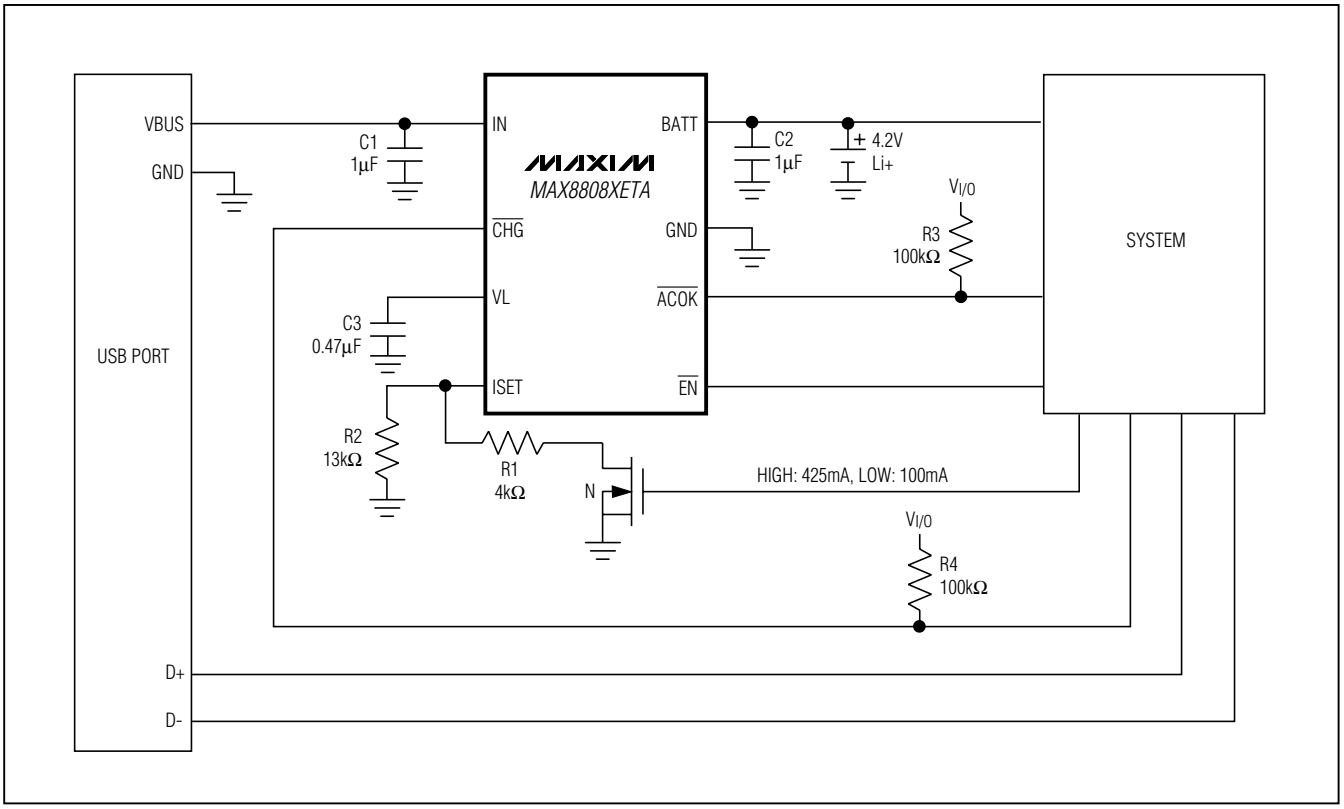
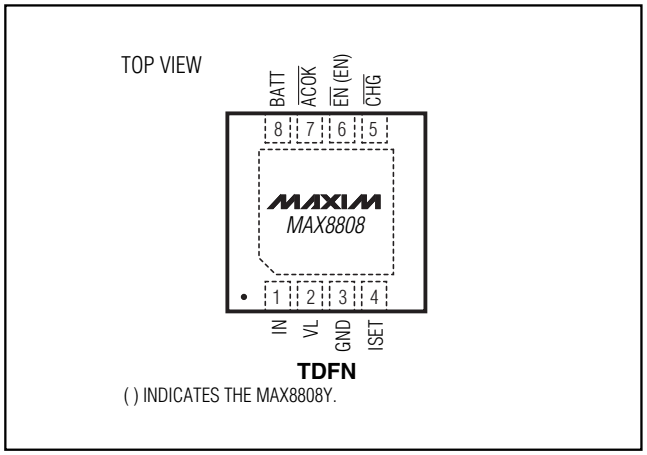


Figure 5. USB Battery Charger

Pin Configuration



Chip Information

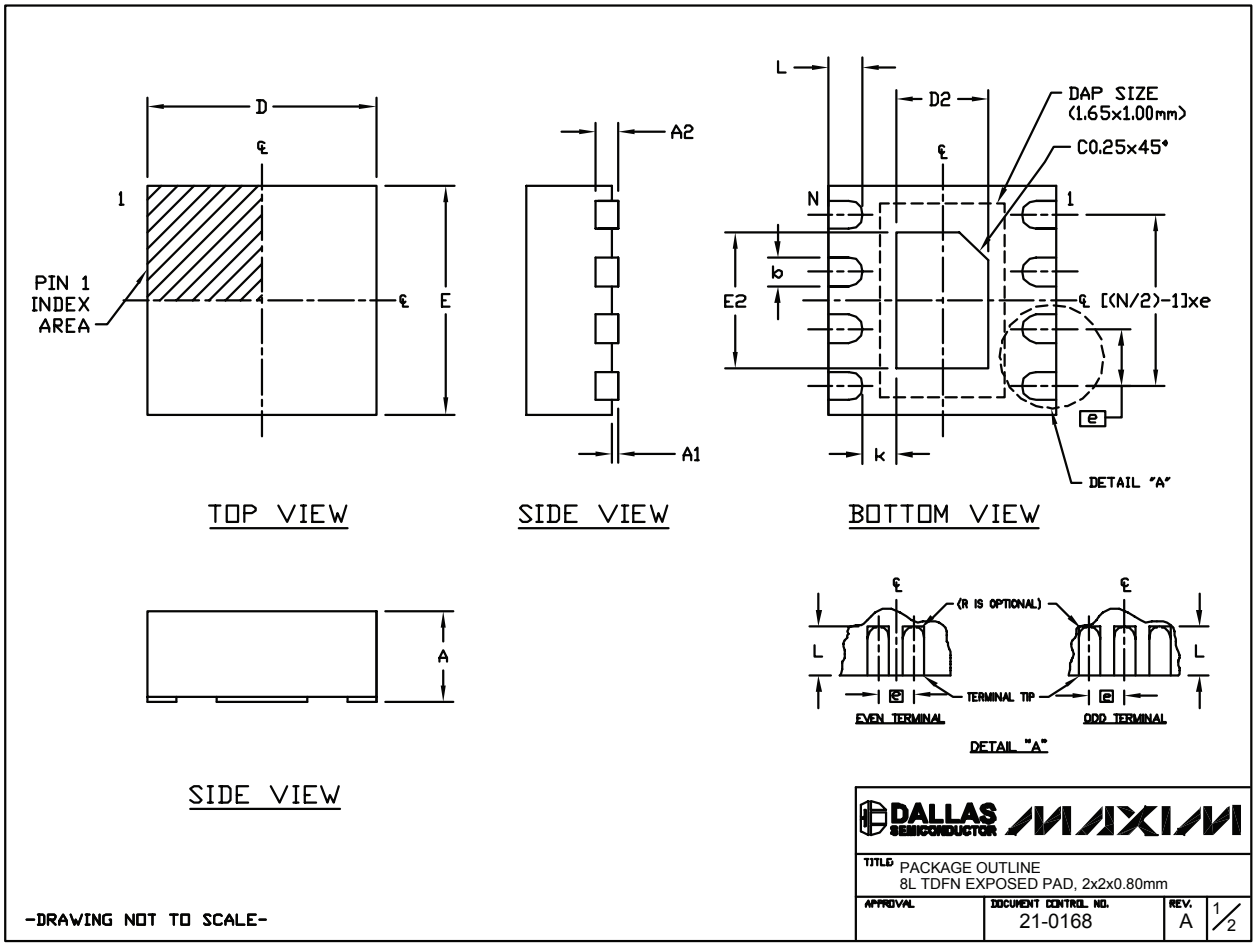
PROCESS: BiCMOS

1A Linear Li+ Battery Chargers with Integrated Pass FET and Thermal Regulation in 2mm x 2mm TDFN

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to **www.maxim-ic.com/packages**.)

8L TDFN EXPOSED PADS.EPS



Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to **www.maxim-ic.com/packages**.)

COMMON DIMENSIONS		
SYMBOL	MIN.	MAX.
A	0.70	0.80
D	1.90	2.10
E	1.90	2.10
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	DOWNBONDS ALLOWED
T822-1	8	0.70±0.10	1.30±0.10	0.50 TYP.	MO229	0.25±0.05	1.50 REF	NO

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.08 mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. COMPLY TO JEDEC MO229 EXCEPT D2 AND E2 DIMENSIONS.
6. "N" IS THE TOTAL NUMBER OF LEADS.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE	PACKAGE OUTLINE 8L TDFN EXPOSED PAD, 2x2x0.80mm		
APPROVAL	DOCUMENT CONTROL NO. 21-0168	REV. A	2/2

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