19-2890; Rev 0; 6/03

EVALUATION KIT AVAILABLE

Linear Li+ Battery Charger with Integrated Pass FET, Thermal Regulation, and $\overline{\text{ACOK}}$ in 3mm x 3mm TDFN

General Description

The MAX1508 is an intelligent, stand-alone constant-current, constant-voltage (CCCV), thermally regulated linear charger for a single-cell lithium-ion (Li+) battery. The MAX1508 integrates the current-sense circuit, MOS pass element, and thermal-regulation circuitry, and also eliminates the reverse-blocking Schottky diode, to create the simplest and smallest charging solution for hand-held equipment.

The MAX1508 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.

Proprietary thermal-regulation circuitry limits the die temperature to +100°C when fast charging or while exposed to high ambient temperatures, allowing maximum charging current without damaging the IC.

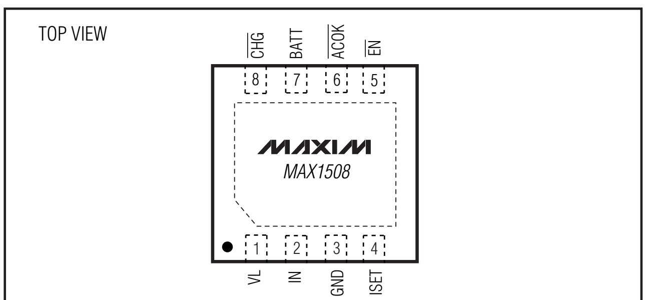
The MAX1508 achieves high flexibility by providing an adjustable fast-charge current by an external resistor. Other features include the charging status ($\overline{\text{CHG}}$) of the battery, an active-low control input ($\overline{\text{EN}}$), and an active-low-input power-source detection output ($\overline{\text{ACOK}}$).

The MAX1508 accepts a +4.25V to +13V supply, but disables charging when the input voltage exceeds +7V to protect against unqualified or faulty AC adapters. The MAX1508 operates over the extended temperature range (-40°C to +85°C) and is available in a compact 8-pin thermally enhanced 3mm x 3mm thin DFN package with 0.8mm height.

Applications

Cellular and Cordless Phones
PDAs
Digital Cameras and MP3 Players
USB Appliances
Charging Cradles and Docks
Bluetooth™ Equipment

Pin Configuration



3mm x 3mm THIN DFN

Bluetooth is a trademark of Ericsson.

Features

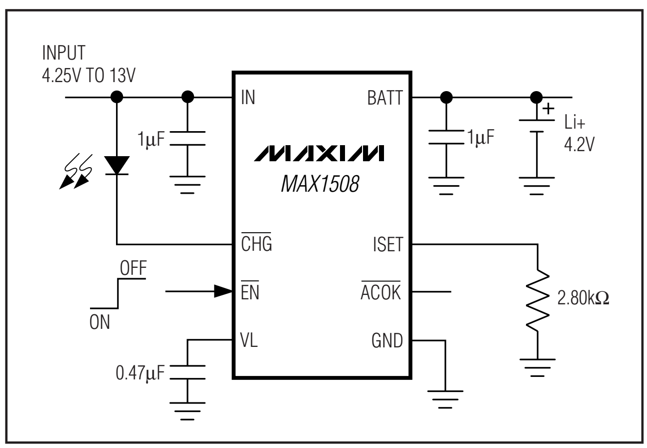
- **Stand-Alone Linear 1-Cell Li+ Battery Charger**
- **No External FET, Reverse-Blocking Diode, or Current-Sense Resistor Required**
- **Programmable Fast-Charge Current (0.8A max)**
- **Proprietary Die-Temperature Regulation Control (+100°C)**
- **+4.25V to +13V Input Voltage Range with Input Overvoltage Protection (OVP) Above +7V**
- **Charge-Current Monitor for Fuel Gauging**
- **Low Dropout Voltage—130mV at 0.425A**
- **Input Power-Source Detection Output ($\overline{\text{ACOK}}$) and Charge-Enable Input ($\overline{\text{EN}}$)**
- **Soft-Start Limits Inrush Current**
- **Charge Status Output ($\overline{\text{CHG}}$) for LED or Microprocessor Interface**
- **Small 3mm x 3mm 8-Pin Thin DFN Package, 0.8mm High**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX1508ETA	-40°C to +85°C	8 Thin DFN-EP*	AHF

**EP = Exposed paddle.*

Typical Operating Circuit



ABSOLUTE MAXIMUM RATINGS

IN, $\overline{CHG}$ to GND ....-0.3V to +14V
VL, BATT, ISET, $\overline{EN}$, $\overline{ACOK}$ to GND ....-0.3V to +6V
VL to IN..-14V to +0.3V
IN to BATT Continuous Current..0.9A
Continuous Power Dissipation (T_A = +70°C)
8-Pin TDFN (derate 24.4mW/°C above +70°C) 1951mW
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, $\overline{ACOK}$ = $\overline{EN}$ = $\overline{CHG}$ = unconnected, R_{ISET} = 2.8kΩ to GND, C_{VL} = 0.47µF, BATT bypassed to GND with 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		13	V
Input Operating Range			4.25		6.50	V
$\overline{ACOK}$ Trip Point, IN	V_{IN} - V_{BATT}, V_{IN} rising		20	40	60	mV
	V_{IN} - V_{BATT}, V_{IN} falling		15	30	45	
Overvoltage Lockout Trip Point	V_{IN} rising		6.5	7	7.5	V
	V_{IN} hysteresis			0.11		
IN Input Current	Charging (I_{IN} - I_{BATT})			1	2	mA
	Disabled, $\overline{EN}$ = VL			0.8	1.5	
	OFF state (V_{IN} = V_{BATT} = 4.0V)				0.065	
VL Output Voltage	I_{VL} = 100µA			3.3		V
VL Load Regulation	I_{VL} = 100µA to 2mA			-71	-200	mV
VL Temperature Coefficient	I_{VL} = 100µA			-2		mV/°C
VL Undervoltage Lockout Trip Point	V_{IN} rising			2.95		V
	Hysteresis			0.17		
BATT Input Current	V_{IN} = 0 to 4V			3	10	µA
	$\overline{EN}$ = VL			4	10	
Maximum RMS Charge Current				0.8		A
Battery Regulation Voltage	I_{BATT} = 0	T_A = 0°C to +85°C	4.162	4.2	4.238	V
		T_A = -40°C to +85°C	4.150	4.2	4.250	
BATT Removal Detection Threshold	V_{BATT} rising		4.4	4.67	4.9	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 5V, V_{BATT} = 4.0V, $\overline{ACOK}$ = $\overline{EN}$ = $\overline{CHG}$ = unconnected, R_{ISET} = 2.8kΩ to GND, C_{VL} = 0.47µF, BATT bypassed to GND with 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
BATT Removal Detection-Threshold Hysteresis				200		mV
Minimum BATT Bypass Capacitance				1		µF/A
Fast-Charge Current-Loop System Accuracy	V_{BATT} = 3.5V		478	520	562	mA
Precharge Current System Accuracy	Percentage of the fast-charge current, V_{BATT} = 2.2V		5	10	15	%
Die-Temperature-Regulation Set Point				100		°C
V_{BATT} Precharge Threshold Voltage	V_{BATT} rising		2.3	2.5	2.7	V
Current-Sense Amplifier Gain, I_{SET} to I_{BATT} in Fast-Charge Mode	I_{BATT} = 500mA, V_{ISET} = 1.4V		0.880	0.958	1.035	mA/A
Regulator Dropout Voltage (V_{IN} - V_{BATT})	V_{BATT} = 4.1V, I_{BATT} = 425mA			130	200	mV
$\overline{EN}$ Logic Input Low Voltage	4.25V < V_{IN} < 6.5V				0.52	V
$\overline{EN}$ Logic Input High Voltage	4.25V < V_{IN} < 6.5V		1.3			V
$\overline{EN}$ Internal Pulldown Resistor			100	200	400	kΩ
$\overline{CHG}$ Output Low Current	$V_{\overline{CHG}}$ = 1V		5	12	20	mA
$\overline{CHG}$ Output High Leakage Current	$V_{\overline{CHG}}$ = 13V	T_A = +25°C			1	µA
		T_A = +85°C		0.002		
$\overline{ACOK}$ Output Low Voltage	$I_{\overline{ACOK}}$ = 0.5mA				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 (as a Percentage of the Fast-Charge Current)	I_{BATT} falling		5	10	15	%

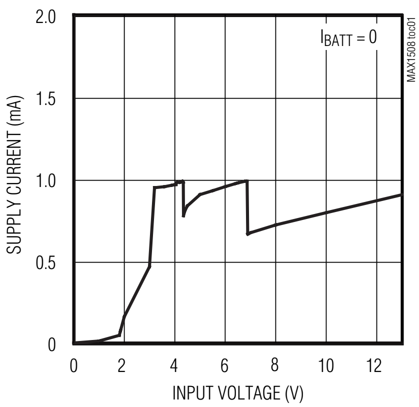
Note 1: Limits are 100% production tested at T_A = +25°C. Limits over operating temperature range are guaranteed through correlation using statistical quality control (SQC) methods.

Linear Li+ Battery Charger with Integrated Pass FET, Thermal Regulation, and $\overline{ACOK}$ in 3mm x 3mm TDFN

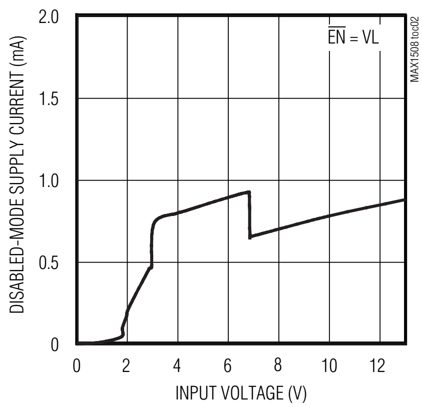
Typical Operating Characteristics

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

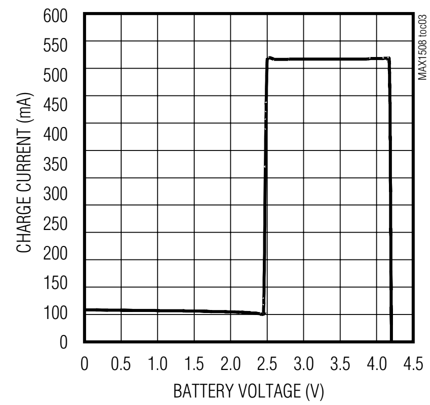
SUPPLY CURRENT vs. INPUT VOLTAGE



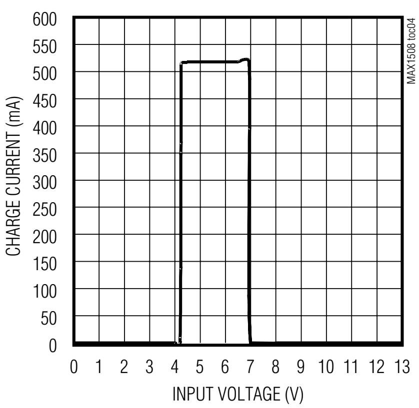
DISABLED-MODE SUPPLY CURRENT vs. INPUT VOLTAGE



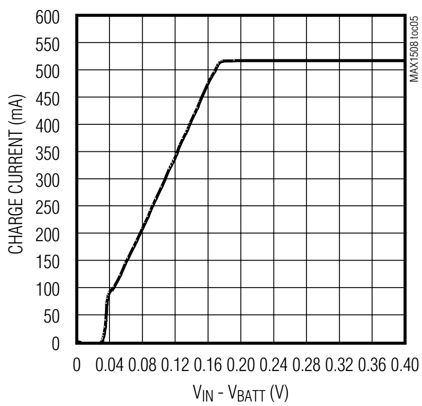
CHARGE CURRENT vs. BATTERY VOLTAGE



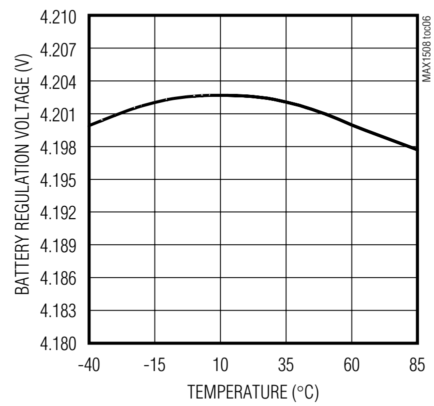
CHARGE CURRENT vs. INPUT VOLTAGE



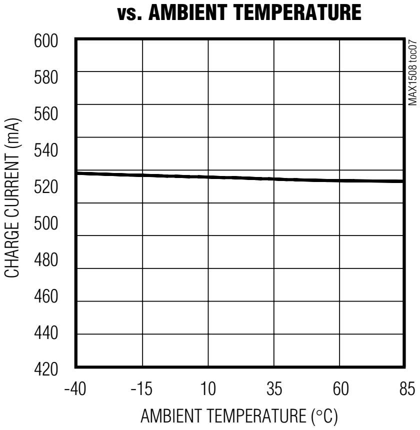
CHARGE CURRENT vs. INPUT-VOLTAGE HEADROOM



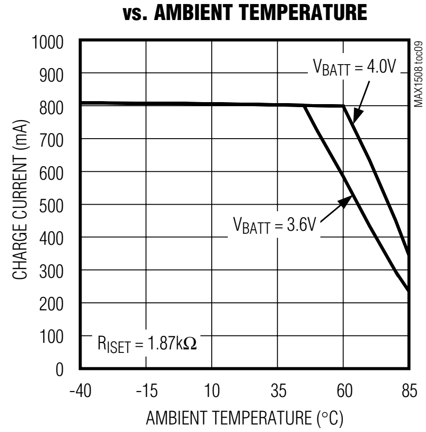
BATTERY REGULATION VOLTAGE vs. TEMPERATURE



CHARGE CURRENT vs. AMBIENT TEMPERATURE



CHARGE CURRENT vs. AMBIENT TEMPERATURE



Pin Description

PIN	NAME	FUNCTION
1	VL	Internally Generated Logic Supply for Chip. Bypass VL to GND with a 0.47µF capacitor.
2	IN	Input Supply Voltage. Bypass IN to GND with a 1µF capacitor to improve line noise and transient rejection.
3	GND	Ground. Connect GND and exposed pad to a large copper trace for maximum power dissipation.
4	ISET	Charge-Current Program and Fast-Charge Current Monitor. Output current from ISET is 0.958mA per amp of battery charging current. The charging current is set by connecting a resistor from ISET to GND. Fast-charge current = 1461V / $R_{ISET}\Omega$.
5	$\overline{\text{EN}}$	Logic-Level Enable Input. Drive $\overline{\text{EN}}$ high to disable charger. Pull $\overline{\text{EN}}$ low or float for normal operation. $\overline{\text{EN}}$ has an internal 200kΩ pulldown resistor.
6	$\overline{\text{ACOK}}$	Input Power-Detection Output. The open-drain $\overline{\text{ACOK}}$ output asserts low when $+4.25V \le V_{IN} \le +7V$ and $V_{IN} - V_{BATT} \ge 40mV$. $\overline{\text{ACOK}}$ requires an external 100kΩ pullup resistor. $\overline{\text{ACOK}}$ is high impedance in shutdown.
7	BATT	Li+ Battery Connection. Bypass BATT to GND with a capacitor of at least 1µF per ampere of charge current.
8	$\overline{\text{CHG}}$	Charging Indicator, Open-Drain Output. $\overline{\text{CHG}}$ goes low (and can turn on an LED) when charging begins. $\overline{\text{CHG}}$ is high impedance when the battery current drops below 10% of the fast-charging current, or when $\overline{\text{EN}}$ is high. Connect a pullup resistor to the µP's I/O voltage when interfacing with a µP logic input.
—	PAD	Exposed Pad. Connect exposed pad to a large copper trace for maximum power dissipation. The pad is internally connected to GND.

Detailed Description

The MAX1508 charger uses voltage, current, and thermal-control loops to charge a single Li+ cell and to protect the battery (Figure 1). When a Li+ battery with a cell voltage below 2.5V is inserted, the MAX1508 charger enters the prequalification stage where it precharges that cell with 10% of the user-programmed fast-charge current. The $\overline{\text{CHG}}$ indicator output is driven low (Figure 2) to indicate entry into the prequalification state. Once the cell has passed 2.5V, the charger soft-starts before it enters the fast-charge stage. The fast-charge current level is programmed through a resistor from ISET to ground. 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 $\overline{\text{CHG}}$ indicator goes high impedance, signaling the battery is fully charged. At this point the MAX1508 enters a constant voltage-regulation mode to maintain the battery at full charge. If, at any point while charging the battery, the die temperature approaches +100°C, the MAX1508 reduces the charging current so the die temperature does not exceed the temperature-regulation set point.

The thermal-regulation loop limits the MAX1508 die temperature to +100°C by reducing the charge current as necessary (see the *Thermal Regulation* section). This feature not only protects the MAX1508 from overheating, but also allows higher charge current without risking damage to the system.

$\overline{\text{EN}}$ Charger Enable Input

$\overline{\text{EN}}$ is a logic input (active low) to enable the charger. Drive $\overline{\text{EN}}$ low, leave floating, or connect to GND to enable the charger control circuitry. Drive $\overline{\text{EN}}$ high to disable the charger control circuitry. $\overline{\text{EN}}$ has a 200kΩ internal pulldown resistance.

$\overline{\text{ACOK}}$ Output

Active-Low Output. The open-drain $\overline{\text{ACOK}}$ output asserts low when $+4.25V < V_{IN} < +7V$ and $V_{IN} - V_{BATT} > 40mV$. $\overline{\text{ACOK}}$ requires an external 100kΩ pullup resistor to the system's logic I/O voltage. $\overline{\text{ACOK}}$ is high impedance in shutdown.

VL Internal Voltage Regulator

The MAX1508 linear charger contains an internal linear regulator available on the VL output pin. VL requires a 0.47µF ceramic bypass capacitor to GND. VL is regulated to 3.3V whenever the input voltage is above 3.5V.

$\overline{\text{CHG}}$ Charge Indicator Output

$\overline{\text{CHG}}$ is an open-drain current source for indicating charge status. Table 1 describes the state of $\overline{\text{CHG}}$ during different stages of operation.

$\overline{\text{CHG}}$ is a nominal 12mA current source suitable for driving a charge-indication LED. If the MAX1508 is used in conjunction with a microprocessor, a pullup resistor to the logic I/O voltage allows $\overline{\text{CHG}}$ to indicate charge status to the µP instead of driving an LED.

Soft-Start

An analog soft-start algorithm activates when entering fast-charge mode. When the prequalification state is complete (V_{BATT} exceeds +2.5V), the charging current ramps up in 3ms to the full charging current. This reduces the inrush current on the input supply.

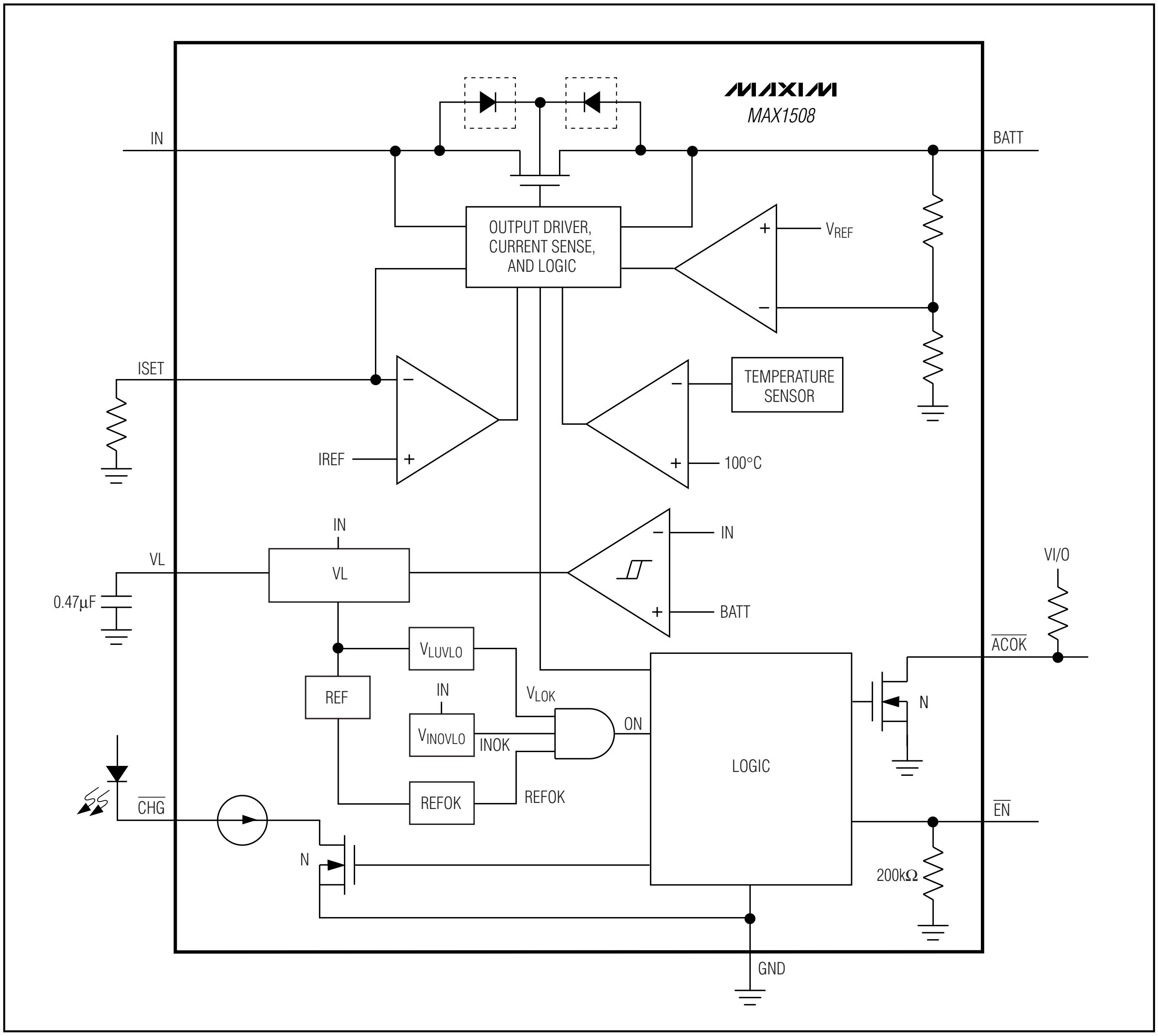


Figure 1. Functional Diagram

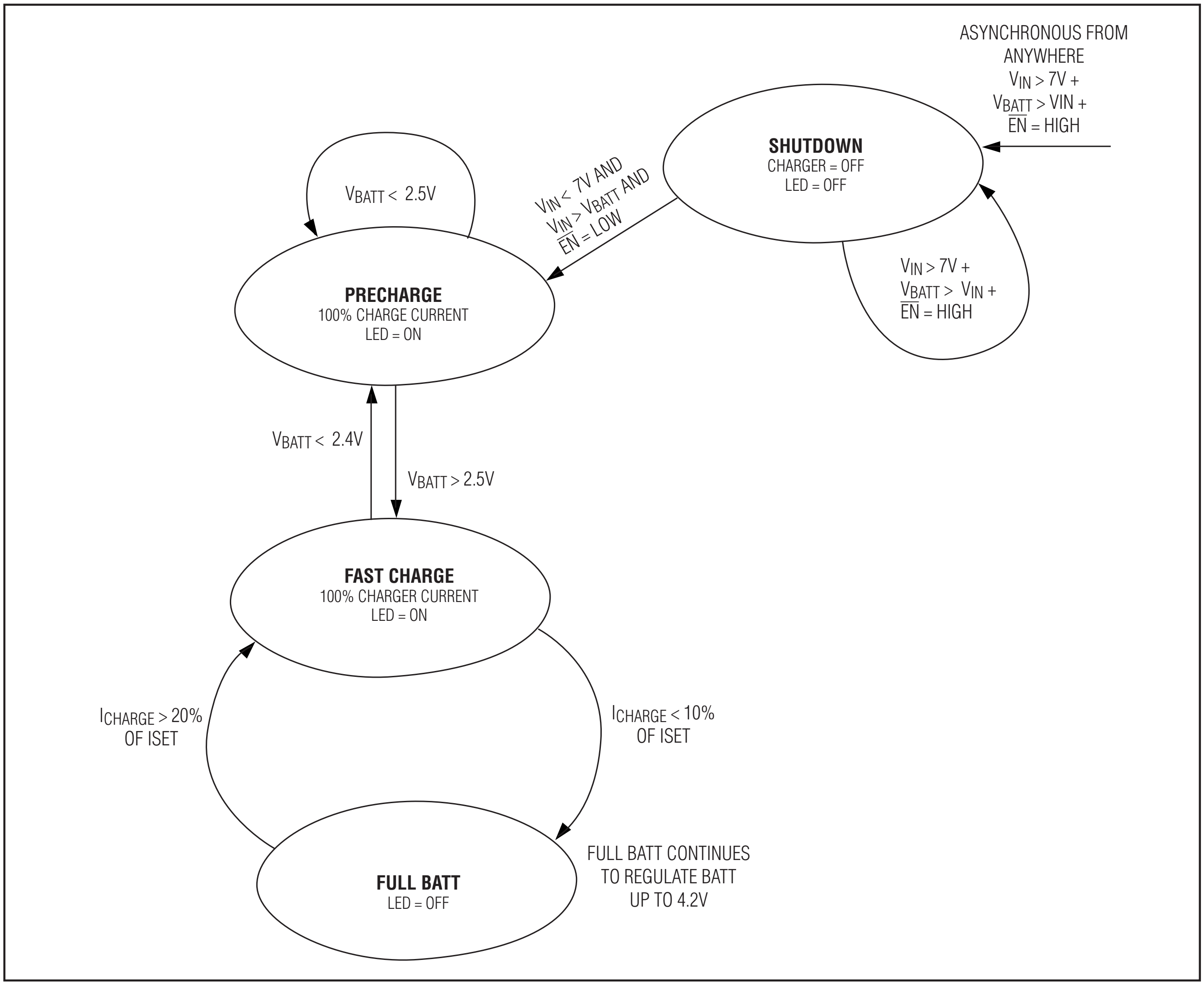


Figure 2. Charge State Diagram

Applications Information

Charge-Current Selection

The maximum charging current is programmed by an external R_{ISET} resistor connected from ISET to GND. Select the R_{ISET} value based on the following formula:

$$I_{FAST} = 1461V / R_{ISET}\Omega$$

where I_{FAST} is in amps and R_{ISET} is in ohms. ISET can also be used to monitor the fast-charge current level. The output current from the ISET pin is 0.958mA per amp of charging current. The output voltage at ISET is proportional to the charging current as follows:

$$V_{ISET} = (I_{CHG} \times R_{ISET}) / 1044$$

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.

Thermal Regulation

The MAX1508 features a proprietary thermal-regulation circuit to protect both the IC and the system from excessive heat. When the MAX1508's die temperature reaches +100°C, the charge current is reduced to prevent any additional increase in the die temperature. An active thermal loop does not indicate a fault condition. Thermal regulation allows the MAX1508 to provide continuous charge to the battery under adverse conditions without causing excessive power dissipation.

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 input voltages or high charging currents to reduce supply noise.

Connect a 0.47µF ceramic capacitor from VL to GND.

Thermal Considerations

The MAX1508 is in a thermally enhanced thin DFN package with exposed paddle. Connect the exposed paddle of the MAX1508 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 MAX1508 to charge the battery with maximum current, while minimizing the increase in die temperature.

DC Input Sources

The MAX1508 operates from well-regulated DC sources. The full-charging input voltage range is 4.25V to 7V. The device can stand up to 13V on the input without damage to the IC. If V_{IN} is greater than 7V, then the MAX1508 stops charging.

An appropriate power supply must provide at least 4.25V when sourcing the desired peak charging current. It also must stay below 6.5V when unloaded.

Application Circuits

Stand-Alone Li+ Charger

The MAX1508 provides a complete Li+ charging solution. The *Typical Operating Circuit* on the front page shows the MAX1508 as a stand-alone Li+ battery charger. The 2.8kΩ resistor connected to ISET sets a charging current of 520mA. The LED indicates when either fast-charge or precharge qualification has begun. When the battery is full, the LED turns off.

Microprocessor-Interfaced Charger

Figure 3 shows the MAX1508 as a µP-cooperated Li+ battery charger. The MAX1508 starts charging the battery when $\overline{EN}$ is low. The µP can drive $\overline{EN}$ high to disable the charger. The MAX1508's $\overline{ACOK}$ output indicates the presence of a valid AC adapter to the µP. $\overline{CHG}$ can be used to detect the charge status of a battery. By monitoring V_{ISET}, the system can measure the charge current.

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 MAX1508 can be configured to charge its battery at the highest current possible from the host port. Figure 4 shows the MAX1508 as a USB battery charger. To make the circuit compatible with either 100mA or 500mA USB ports, the circuit initializes at 95mA charging current. The microprocessor then interrogates the host to determine its current capability. If the host port is capable, the charging current is increased to 435mA. The 435mA current was chosen to avoid exceeding the 500mA USB specification.

Layout and Bypassing

Connect a 1µF ceramic input capacitor 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 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. For an example layout, refer to the MAX1507/MAX1508 evaluation kit layout.

Chip Information

TRANSISTOR COUNT: 1812

PROCESS: BiCMOS

Table 1. $\overline{CHG}$ States

$\overline{EN}$	V_{IN}	V_{BATT}	I_{BATT}	$\overline{CHG}$	STATE
X	V_{BATT}	V_{IN}	0	Hi-Z	Shutdown
Low	$4.25V \le V_{IN} \le 7V$	< 2.5V	10% of I_{FAST}	Low	Prequalification
Low	$4.25V \le V_{IN} \le 7V$	≥ 2.5V	I_{FAST}*	Low	Fast Charge
Low	$4.25V \le V_{IN} \le 7V$	4.2V	10% of I_{FAST}	Hi-Z	Full Charge
Low	>7V	X	0	Hi-Z	Overvoltage
High	X	X	0	Hi-Z	Disabled

X = Don't care.

I_{FAST} is reduced as necessary to maintain the die temperature at +100°C.

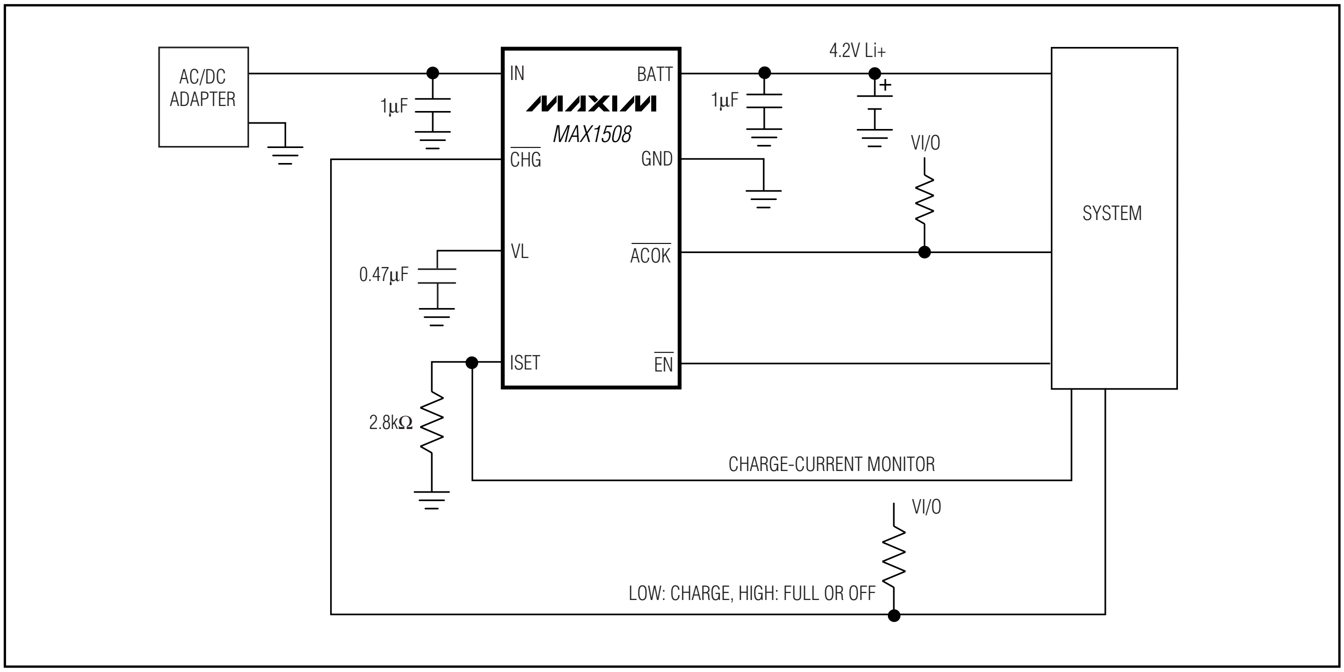


Figure 3. µP-Interfaced Li+ Battery Charger

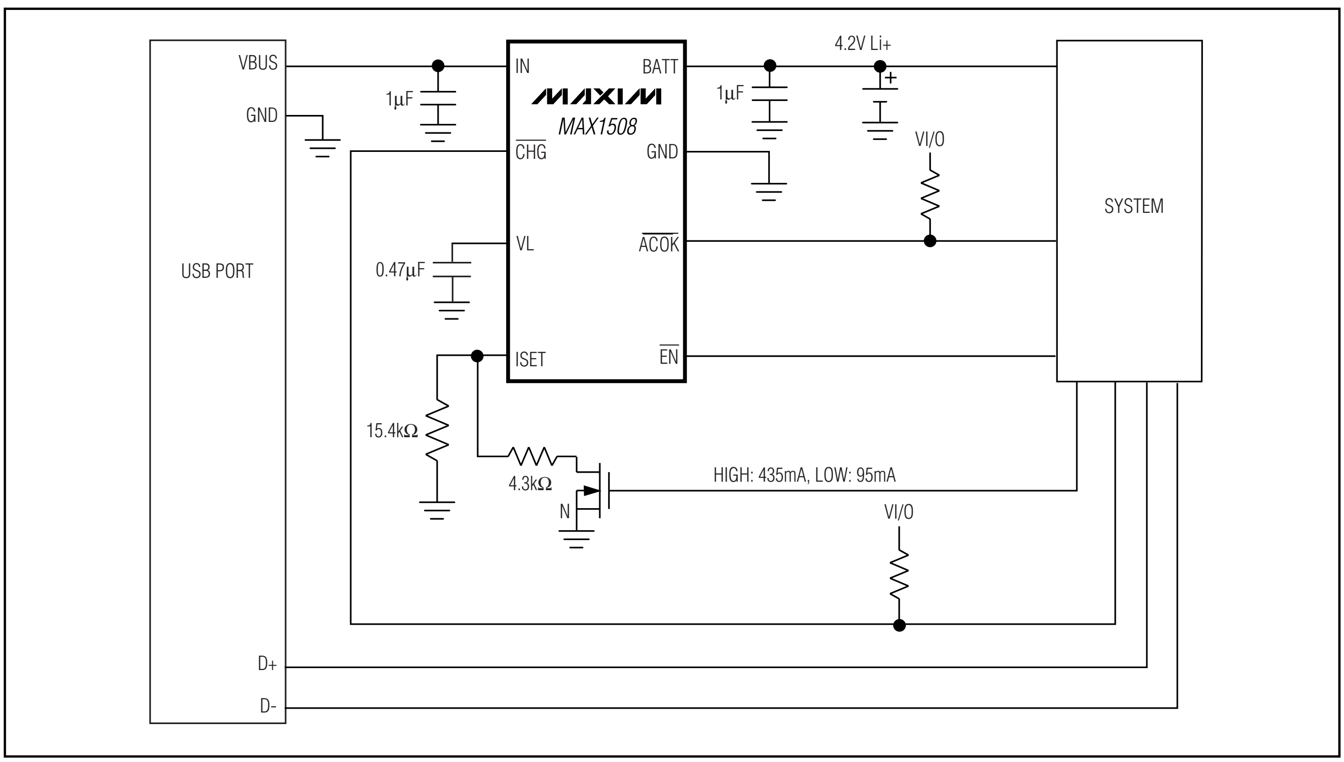
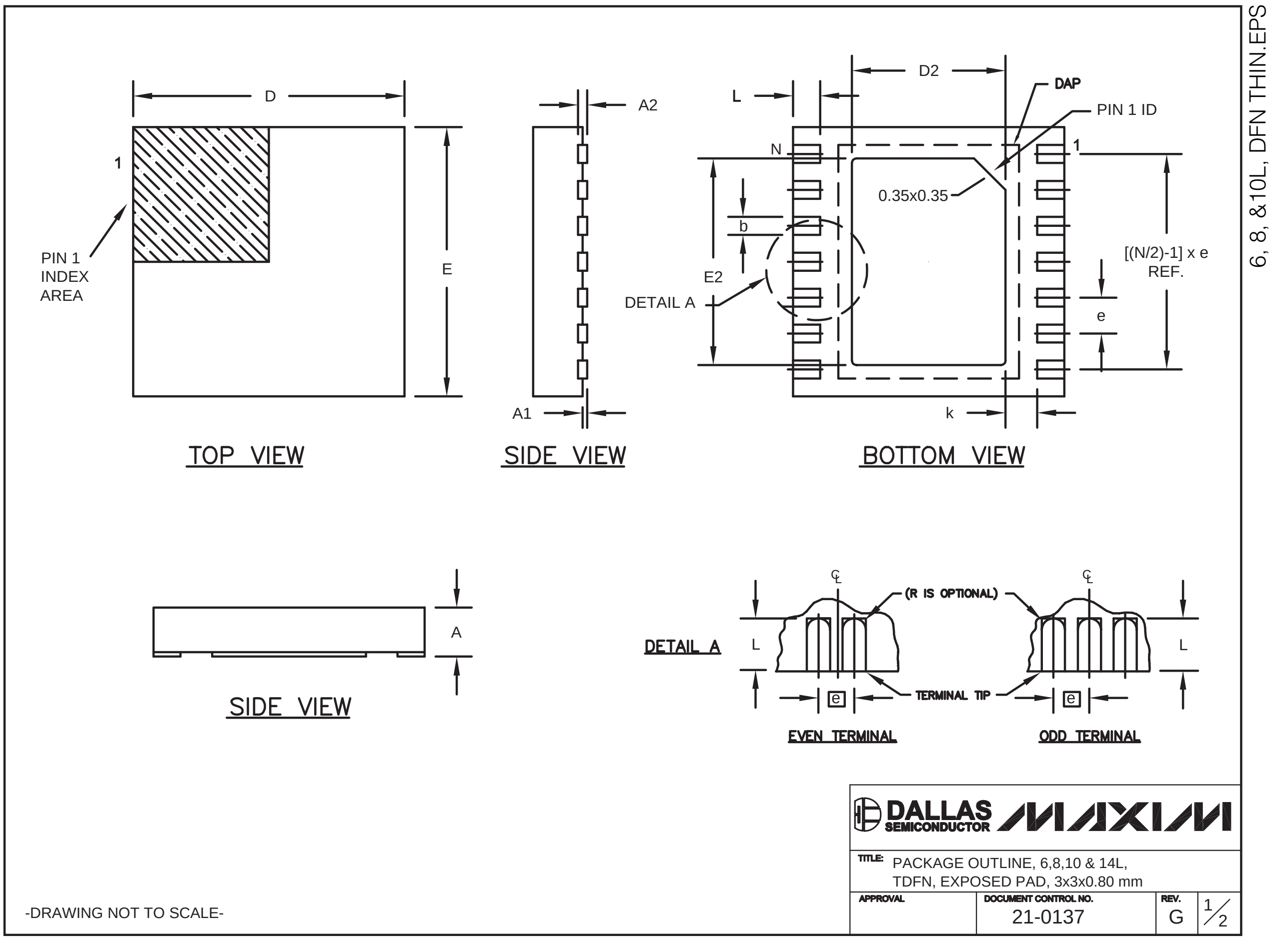


Figure 4. USB Battery Charger

Linear Li+ Battery Charger with Integrated Pass FET, Thermal Regulation, and ACOK in 3mm x 3mm 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**.)



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	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	DOWNBONDS ALLOWED
T633-1	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF	NO
T633-2	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF	NO
T833-1	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF	NO
T833-2	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF	NO
T833-3	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF	YES
T1033-1	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF	NO
T1433-1	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.05	2.40 REF	YES
T1433-2	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.05	2.40 REF	NO

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.

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 6,8,10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm

APPROVAL | DOCUMENT CONTROL NO. 21-0137 | REV. G | 2/2