19-4279; Rev 0; 3/09

EVALUATION KIT AVAILABLE

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

General Description

The MAX8844Z/MAX8844Y intelligent, stand-alone constant-current, constant-voltage (CCCV), thermally regulated dual input linear chargers are designed for charging a single-cell lithium-ion (Li+) battery. The MAX8844Z/MAX8844Y integrate a current-sense circuit, MOSFET pass element, thermal-regulation circuitry, and eliminate the external reverse-blocking Schottky diode to create the simplest and smallest charging solutions for handheld equipment.

The IC controls the charging sequence from the prequalification state through constant current fast-charge, top-off charge, and full-charge indication. Proprietary thermal-regulation circuitry limits the die temperature during fast-charging or when the IC is exposed to high ambient temperatures, allowing maximum charging current without damaging the IC.

The MAX8844Z/MAX8844Y achieve high flexibility by providing adjustable fast-charge currents (SETI) and an adjustable top-off current threshold (MIN) through external resistors. The IC features a booting assistant circuit that distinguishes input sources and battery connection and provides an enable signal (ABO, $\overline{ABO}$) for system booting.

The ICs also integrate two input overvoltage-protected LDO outputs (SAFEOUT, SAFEUSB) for low-voltage-rated USB or charger inputs in system, and a battery pack detection circuit (DETBAT) that disables the charger when the battery pack is absent. Other features include an active-low control input ($\overline{EN}$), an active-low input power source detection output ($\overline{POK}$), and a fully charged top-off threshold detection output ($\overline{CHG}$).

The MAX8844Z/MAX8844Y automatically select between either the USB or IN source. If both sources are present at the same time, highest priority is given to the IN source. The IN source is selected to ensure the shortest charging time for the system since it is able to deliver the highest current.

The MAX8844Z/MAX8844Y accept an input supply range from 4.25V to 28V (IN and USB), but disable charging if the input voltage exceeds +7.5V to protect against unqualified or faulty AC adapters. The ICs operate over the extended temperature range (-40°C to +85°C) and are available in a compact 14-pin, thermally enhanced, lead-free TDFN 3mm x 3mm package (0.8mm max height).

Applications

- Cellular and Cordless Phones
- Smart Phones and PDAs
- Digital Still Cameras
- MP3 Players
- USB Appliances
- Charging Cradles and Docks
- Bluetooth® Equipment

Bluetooth is a registered trademark of Bluetooth SIG.

Features

- **CCCV, Thermally Regulated Linear One-Cell Li+ Battery Charger**
- **No External MOSFET, Reverse Blocking Diode, or Current-Sense Resistor**
- **Programmable Fast-Charge Currents ($1A_{RMS}$ max)**
- **Programmable Top-Off Current Threshold**
- **Input Overvoltage Protected 4.7V Output (SAFEOUT) from IN**
- **Input Overvoltage Protected 4.7V Output (SAFEUSB) from USB**
- **Proprietary Die Temperature Regulation Control (+115°C)**
- **4.25V to 28V Input Voltage Range with Input Overvoltage Protection Above +7.5V**
- **Low-Dropout Voltage (300mV at 500mA)**
- **Input Power-Source Detection Output ($\overline{POK}$), Charge Status Output ($\overline{CHG}$), Charge-Enable Input ($\overline{EN}$)**
- **Output for Autobooting (ABO, MAX8844Z)**
- **Output for Autobooting ($\overline{ABO}$, MAX8844Y)**
- **Tiny 3mm x 3mm, 14-Pin TDFN Package, 0.8mm Height (max)**

Ordering Information

PART	PIN-PACKAGE	TOP MARK	ABO ACTIVE STATE
MAX8844ZETD+	14 TDFN-EP*	AEK	Active high
MAX8844YETD+	14 TDFN-EP*	AEN	Active low

+Denotes a lead(Pb)-free/RoHS-compliant package.

**EP = Exposed pad.*

***Note:** All devices are specified over the -40°C to +85°C operating temperature range.*

Typical Operating Circuit and Pin Configuration appear at end of data sheet.

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

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ABSOLUTE MAXIMUM RATINGS

IN, USB to GND .....-0.3V to +30V
ABI, BATT, $\overline{EN}$, $\overline{POK}$, ABO, $\overline{ABO}$, $\overline{CHG}$, DETBAT, SETI, MIN, SAFEOUT, SAFEUSB to GND .....-0.3V to +6V
IN to BATT Continuous Current .....$1A_{RMS}$
Continuous Power Dissipation (T_A = +70°C)
14 TDFN (derate 24.4mW/°C above 70°C) (multilayer PCB) 1951.2mW
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 or V_{USB} = 5V, V_{BATT} = 4V, $R_{\overline{POK}}$ = 1MΩ to BATT, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, V_{DETBAT} = 0V, C_{BATT} = 2.2µF, 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
IN, USB						
Input Supply Voltage Range			0		28	V
Input Supply Operating Voltage Range			4.25		7.00	V
Overvoltage Lockout Trip Threshold	V_{IN} rising, 100mV hysteresis (typ)		7.0	7.5	8.0	V
Input Current	Constant current charging I_{IN} - I_{BATT}, I_{BATT} = 0A			0.25	0.50	mA
	Constant current charging I_{IN} - I_{BATT}, I_{BATT} = 500mA			1		
	IC disabled, $V_{\overline{EN}}$ = 5V			0.23	0.50	
	V_{IN} = 4V, V_{BATT} = 4.2V	T_A = +25°C		0.02		
		T_A = +85°C		0.03		
BATT, $\overline{CHG}$, $\overline{POK}$						
Minimum BATT Bypass Capacitance				2.2		µF
V_{BATT} Prequalification Threshold Voltage	V_{BATT} rising, 100mV hysteresis (typ)		2.3	2.5	2.7	V
Battery Regulation Voltage	I_{BATT} = 0A	T_A = 0°C to +85°C	4.175	4.200	4.225	V
		T_A = -40°C to +85°C	4.158	4.200	4.242	
Regulator Dropout Voltage (V_{IN} - V_{BATT})	V_{BATT} = 4.1V, I_{BATT} = 425mA			260		mV
BATT Input Current (Note 2)	V_{IN} = 0 to 4V, V_{BATT} = 4.2V			5	10	µA
	IC disabled			3		
Current-Sense Amplifier Gain (I_{BATT} to I_{SETI})	I_{BATT} = 500mA	T_A = 0°C to +85°C		1120		µA/A
		T_A = -40°C to +85°C		1120		

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 5V or V_{USB} = 5V, V_{BATT} = 4V, $R_{\overline{POK}}$ = 1MΩ to BATT, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, V_{DETBAT} = 0V, C_{BATT} = 2.2µF, 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
Fast-Charge Current	V_{BATT} = 3.5V, R_{SETI} = 2.8kΩ	T_A = 0°C to +85°C	400	440	480	mA
		T_A = -40°C to +85°C	375	440	505	
	V_{BATT} = 3.5V, R_{SETI} = 14kΩ		74	88	102	
USB Fast-Charge Current	MAX8844Z		332	380	418	mA
	MAX8844Y		405	450	495	
$\overline{CHG}$ Top-Off Threshold	I_{BATT} falling, battery is charged, R_{MIN} = 1.75kΩ (Note 3)			99		mA
$\overline{CHG}$ Hysteresis	I_{BATT} rising after top-off is detected, R_{MIN} = 1.75kΩ			27		mA
$\overline{CHG}$ Detection Delay	I_{BATT} falls below top-off threshold		4.0	6.2	10.7	ms
Prequalification Charge Current	Percentage of the fast-charge current, V_{BATT} = 2.2V, T_A = 0°C to +85°C		5	11	17	%
$\overline{CHG}$, $\overline{POK}$ Output Low Threshold	$I_{\overline{POK}}$ = 5mA , $I_{\overline{CHG}}$ = 5mA				0.4	V
$\overline{CHG}$, $\overline{POK}$ Output High Leakage Current	$V_{\overline{POK}}$ = 5.5V, $V_{\overline{CHG}}$ = 5.5V	T_A = +25°C			1	µA
		T_A = +85°C		0.002		
POK Threshold (Note 2)	V_{IN} - V_{BATT}	V_{IN} rising		40		mV
		V_{IN} falling		30		
DETBAT, SAFEOUT, SAFEUSB						
DETBAT Logic Input Low Threshold					0.4	V
DETBAT Logic Input High Threshold			1.3			
DETBAT Pullup Resistor	DETBAT to VL = 3V			470		kΩ
Minimum SAFEOUT Bypass Capacitance				1		µF
SAFEOUT Regulated Output	$I_{SAFEOUT}$ = 30mA, V_{IN} = 5V, T_A = 0°C to +85°C		4.5	4.7	4.9	V
SAFEOUT Current Limit				100		mA
Minimum SAFEUSB Bypass Capacitance				1		µF
SAFEUSB Regulated Output	$I_{SAFEUSB}$ = 30mA, V_{USB} = 5V, T_A = 0°C to +85°C		4.5	4.7	4.9	V
SAFEUSB Current Limit				100		mA
$\overline{EN}$, ABI, ABO, $\overline{ABO}$						
$\overline{EN}$, ABI Internal Pulldown Resistor			100	200	400	kΩ
$\overline{EN}$, Logic Input Low Threshold (Note 2)	4.25V ≤ V_{IN} ≤ 7V				0.4	V
$\overline{EN}$, Logic Input High Theshold (Note 2)	4.25V ≤ V_{IN} ≤ 7V		1.3			V

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ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 5V or V_{USB} = 5V, V_{BATT} = 4V, $R_{\overline{POK}}$ = 1MΩ to BATT, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, V_{DETBAT} = 0V, C_{BATT} = 2.2µF, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

ABI Logic Input Low Threshold	V_{BATT} = 4V, V_{IN} = 0V	0.4	V
ABI Logic Input High Threshold	V_{BATT} = 4V, V_{IN} = 0V	1.3	V
ABO Output Low Threshold	$I_{ABO(SINK)}$ = 1mA	0.4	V
ABO Output High Threshold	$I_{ABO(SOURCE)}$ = 1mA	V_{BATT} - 0.4V	V
$\overline{ABO}$ Output Low Threshold	Open drain, $I_{\overline{ABO}(SINK)}$ = 1mA	0.4	
$\overline{ABO}$ Output High Threshold	Open drain, 100kΩ pullup on BATT	V_{BATT} - 0.4V	
THERMAL			
Die Temperature Regulation Threshold		115	°C

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

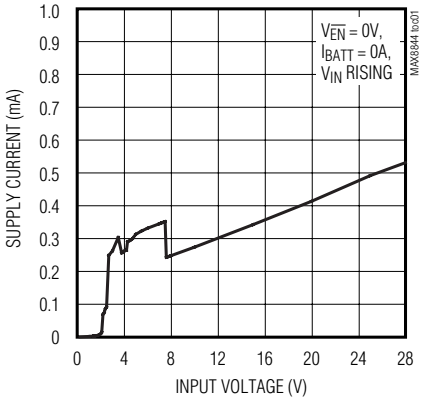
Note 2: The IN input supply and USB input supply are interchangeable (V_{IN} = V_{USB}). See the *DC and USB Power Supplies* section for further details.

Note 3: See the *Top-Off Current Threshold Setting* section for further details.

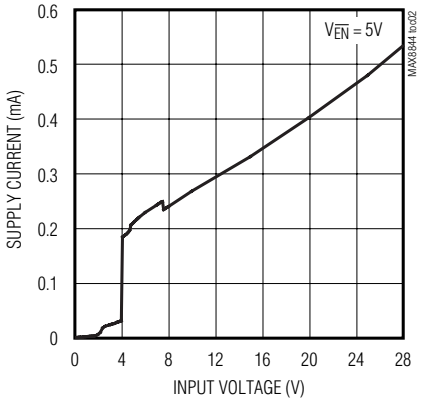
Typical Operating Characteristics

(V_{IN} = 5V or V_{USB} = 5V, V_{BATT} = 4V, $R_{\overline{POK}}$ = $R_{\overline{CHG}}$ = 200kΩ to 5V, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, R_{MIN} = 1.74kΩ to GND, R_{DETBAT} = 4.7kΩ to GND, C_{BATT} = 2.2µF, T_A = +25°C, unless otherwise noted.

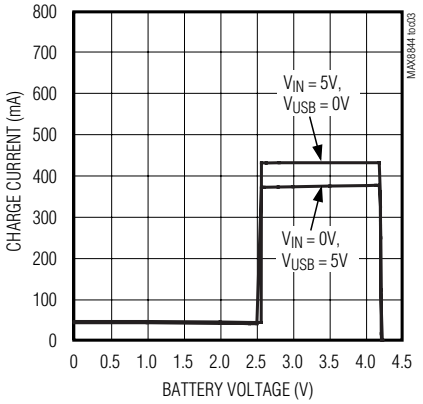
SUPPLY CURRENT vs. INPUT VOLTAGE



DISABLED MODE SUPPLY CURRENT vs. INPUT VOLTAGE



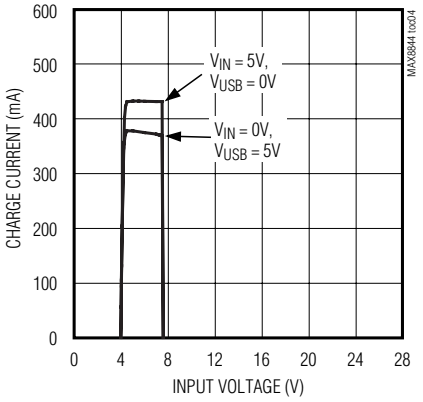
CHARGE CURRENT vs. BATTERY VOLTAGE



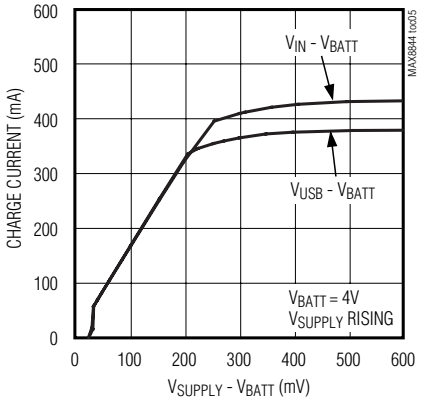
Typical Operating Characteristics (continued)

(V_{IN} = 5V or V_{USB} = 5V, V_{BATT} = 4V, $R_{\overline{POK}}$ = $R_{\overline{CHG}}$ = 200kΩ to 5V, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, R_{MIN} = 1.74kΩ to GND, R_{DETBAT} = 4.7kΩ to GND, C_{BATT} = 2.2µF, T_A = +25°C, unless otherwise noted.

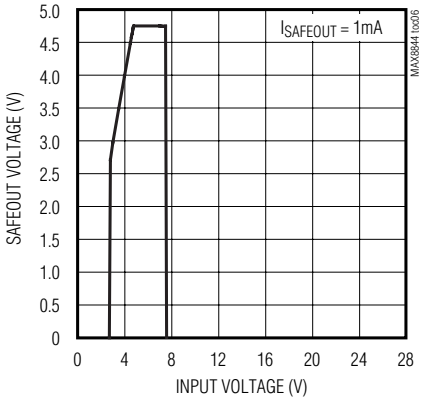
CHARGE CURRENT vs. INPUT VOLTAGE



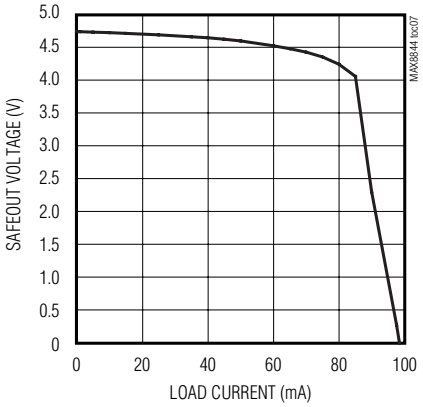
CHARGE CURRENT vs. SUPPLY VOLTAGE HEADROOM



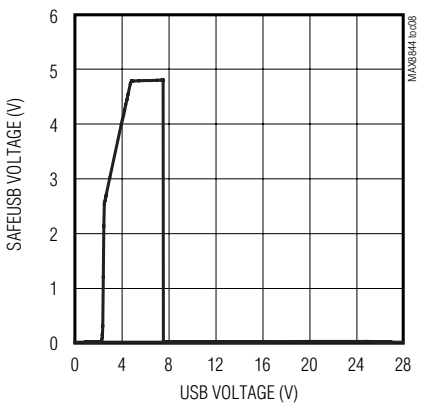
SAFEOUT OUTPUT VOLTAGE vs. INPUT VOLTAGE



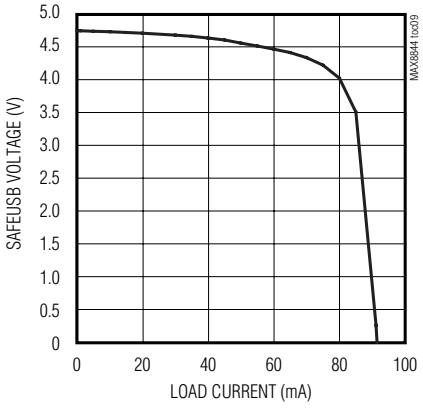
SAFEOUT OUTPUT VOLTAGE vs. LOAD CURRENT



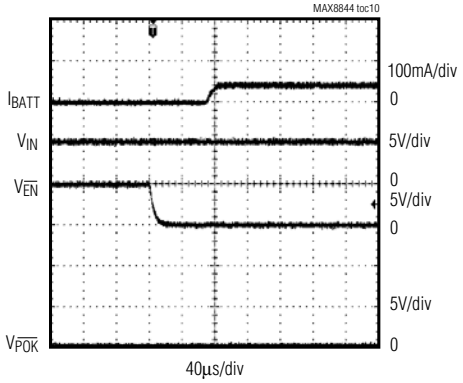
SAFEUSB OUTPUT VOLTAGE vs. USB VOLTAGE



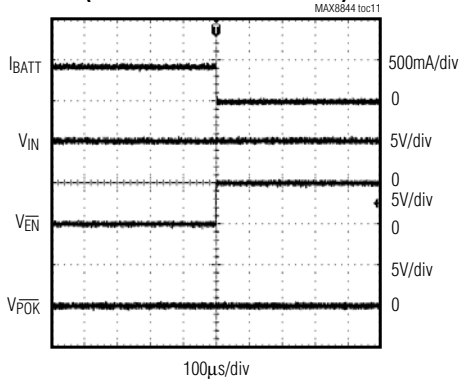
SAFEUSB OUTPUT VOLTAGE vs. LOAD CURRENT



STARTUP INTO PRECHARGE



SHUTDOWN (FAST-CHARGE TO SHUTDOWN)

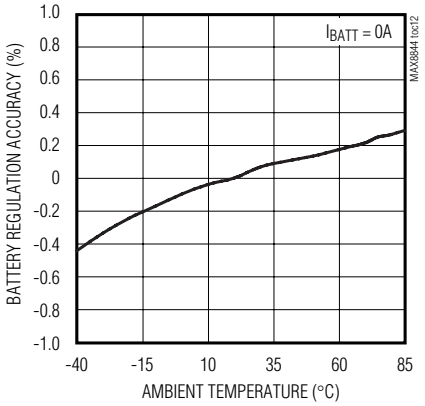


28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

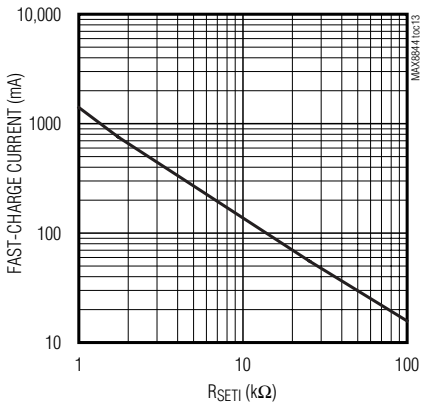
Typical Operating Characteristics (continued)

(V_{IN} = 5V or V_{USB} = 5V, V_{BATT} = 4V, $R\overline{POK}$ = $R\overline{CHG}$ = 200kΩ to 5V, $\overline{EN}$ = unconnected, R_{SETI} = 2.8kΩ to GND, R_{MIN} = 1.74kΩ to GND, R_{DETBAT} = 4.7kΩ to GND, C_{BATT} = 2.2µF, T_A = +25°C, unless otherwise noted.

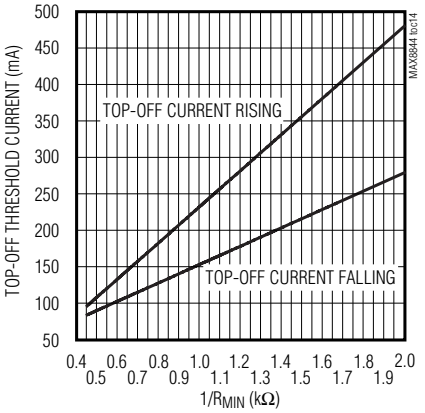
BATTERY REGULATION ACCURACY vs. AMBIENT TEMPERATURE



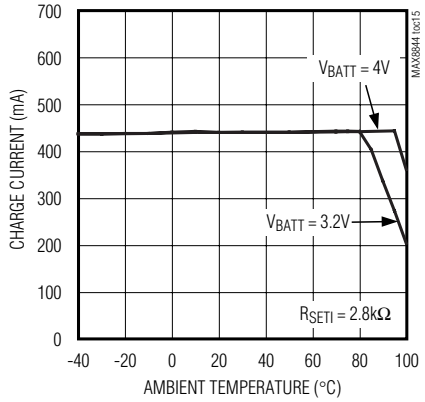
FAST-CHARGE CURRENT vs. R_{SETI}



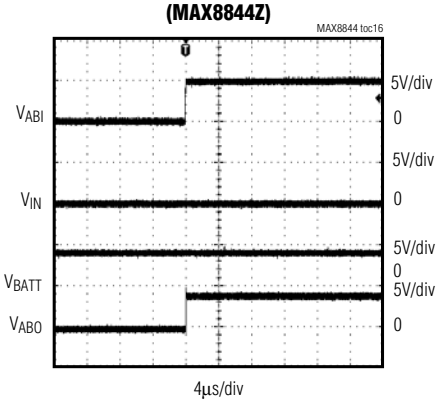
TOP-OFF THRESHOLD CURRENT vs. $1/R_{MIN}$ (kΩ)



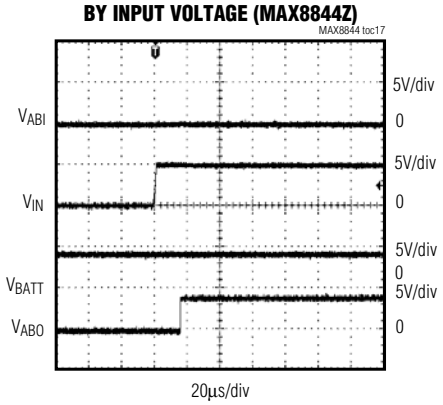
CHARGE CURRENT vs. AMBIENT TEMPERATURE



AUTOBOOT ENABLED BY ABI SIGNAL (MAX8844Z)



AUTOBOOT ENABLED BY INPUT VOLTAGE (MAX8844Z)



Pin Description

PIN		NAME	FUNCTION
MAX8844Z	MAX8844Y		
1	1	IN	Input Supply Voltage. IN is the power supply for the SAFEOUT linear regulator and the battery charger. See the *DC and USB Power Supplies* section. Bypass IN to GND with a 1µF or larger ceramic capacitor to improve line noise and input transient rejection.
2	2	$\overline{POK}$	Active-Low, Input Voltage Status Indicator. $\overline{POK}$ is an open-drain output that asserts low when 2.35V < (V_{IN} or V_{USB}) < 7V and [(V_{IN} or V_{USB}) - V_{BATT}] ≥ 40mV. If (V_{IN} or V_{USB}) > +7.5V or V_{BATT} > (V_{IN} or V_{USB}), the IC is shut down and $\overline{POK}$ becomes high impedance. Connect a pullup resistor to the microprocessor's I/O voltage when interfacing with a microprocessor logic input.
3	3	USB	USB Input Supply Voltage. USB is the power supply for the SAFEUSB linear regulator and the battery charger. See the *DC and USB Power Supplies* section. Bypass USB to GND with a 1µF or larger ceramic capacitor to improve line noise and input transient rejection.
4	4	ABI	Autobooting External Input. See the *Autobooting Assistant* section and Table 1 for autobooting conditions. ABI is pulled to GND through an internal 200kΩ resistor.
5	—	ABO	Active-High, Autobooting Logic Output. See the *Autobooting Assistant* section and Table 1 for autobooting conditions.
—	5	$\overline{ABO}$	Active-Low, Autobooting Logic Output. See the *Autobooting Assistant* section and Table 1 for autobooting conditions.
6	6	MIN	Top-Off Current Threshold Programmable Input. I_{MIN} (mA) falling = 126V/R_{MIN} (kΩ) + 27 (mA).
7	7	SETI	Charge-Current Program and Fast-Charge Current Monitor. Output current from SETI is 1120µA per ampere of battery charging current. Set the charging current by connecting a resistor (R_{SETI} in Figure 3) from SETI to GND. $I_{FAST-CHARGE}$ = 1250V/R_{SETI}. To configure the MAX8844Z/MAX8844Y as a USB charger, see Figure 5.
8	8	DETBAT	Battery Pack ID Resistor Detection Input. If DETBAT is pulled low through a pulldown resistor less than 51kΩ, the charger is enabled. If DETBAT is left unconnected, the charger is disabled.
9	9	$\overline{CHG}$	Active-Low, Charging Indicator. $\overline{CHG}$ is an open-drain output that is pulled low once charging begins. $\overline{CHG}$ is high impedance when the battery current drops below MIN, or when the IC is disabled. Connect a pullup resistor to the microprocessor's I/O voltage when interfacing with a microprocessor logic input.
10	10	$\overline{EN}$	Active-Low, Logic-Level Enable Input. Drive $\overline{EN}$ high to disable charger. Drive $\overline{EN}$ low or leave unconnected for normal operation. $\overline{EN}$ has an internal 200kΩ pulldown resistor.
11	11	GND	Ground. Connect GND and the exposed pad to a large copper ground plane for maximum power dissipation. Connect GND to the exposed pad directly under the IC.
12	12	BATT	Li+ Battery Connection. Bypass BATT to GND with a 2.2µF ceramic capacitor.
13	13	SAFEUSB	4.7V Regulated LDO Output with Input Overvoltage Protection. Bypass SAFEUSB to GND with a 1µF or larger ceramic capacitor. SAFEUSB can be used to supply low-voltage-rated USB systems.

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

Pin Description (continued)

PIN		NAME	FUNCTION
MAX8844Z	MAX8844Y		
14	14	SAFEOUT	4.7V Regulated LDO Output with Input Overvoltage Protection. Bypass SAFEOUT to GND with a 1µF or larger ceramic capacitor. SAFEOUT can be used to supply low-voltage-rated charging systems.
—	—	EP	Exposed Pad. Connect the exposed pad to a large ground plane for maximum power dissipation. Connect GND to the exposed pad directly under the IC.

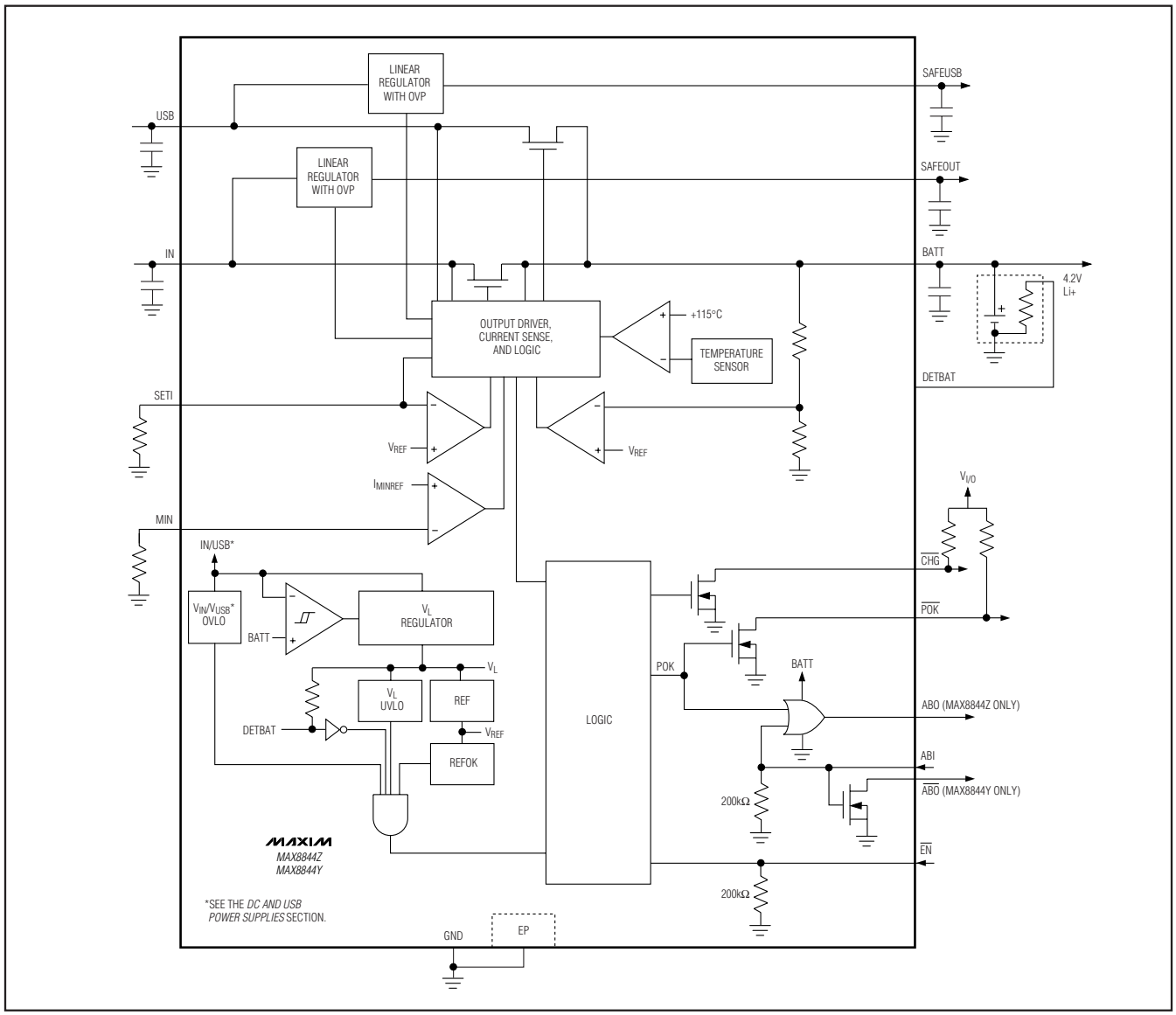


Figure 1. Functional Diagram

Detailed Description

The MAX8844Z/MAX8844Y 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 MAX8844Z/MAX8844Y chargers enter a prequalification stage where they precharge that cell with 10% of the user-programmed fast-charge current (Figure 2). The $\overline{CHG}$ indicator is driven low to indicate entry into the prequalification state. When the battery voltage exceeds 2.5V, the charger soft-starts as it enters the fast-charge stage. The fast-charge current level is programmed through a resistor from SETI to GND. As the battery voltage approaches 4.2V, the battery current is reduced. If the battery current drops to less than the top-off current threshold set by R_{MIN}, the charger enters top-off mode and the $\overline{CHG}$ indicator goes high impedance, signaling that the battery is fully charged.

Overvoltage-Protected Output (SAFEOUT)

SAFEOUT is a linear regulator that provides an output voltage of 4.7V and can be used to supply low-voltage-rated charging systems. The SAFEOUT linear regulator turns on when $V_{IN} \geq 4.25V$ regardless of $\overline{EN}$ and is disabled when V_{IN} is greater than the overvoltage threshold (7.5V typ).

Overvoltage Protected Output (SAFEUSB)

SAFEUSB is a linear regulator that provides an output voltage of 4.7V and can be used to supply low voltage rated USB systems. The SAFEUSB linear regulator turns on when $V_{USB} \geq 4.25V$ regardless of $\overline{EN}$ and is disabled when V_{USB} is greater than the overvoltage threshold (7.5V typ).

Battery Pack Detection Input (DETBAT)

DETBAT is a battery pack ID resistor detector that enables the battery charger if pulled low through a resistor that is less than 51kΩ. If DETBAT is left unconnected or the pulldown resistor is 51kΩ or greater, the battery charger is disabled.

$\overline{POK}$ Output

The open-drain $\overline{POK}$ output asserts low when $2.35V \leq (V_{IN}$ or $V_{USB}) \leq 7V$, $[(V_{IN}$ or $V_{USB}) - V_{BATT}] \geq 40mV$ (typ V_{IN} or V_{USB} rising), and DETBET is pulled low through a resistor that is less than 51kΩ. $\overline{POK}$ is high

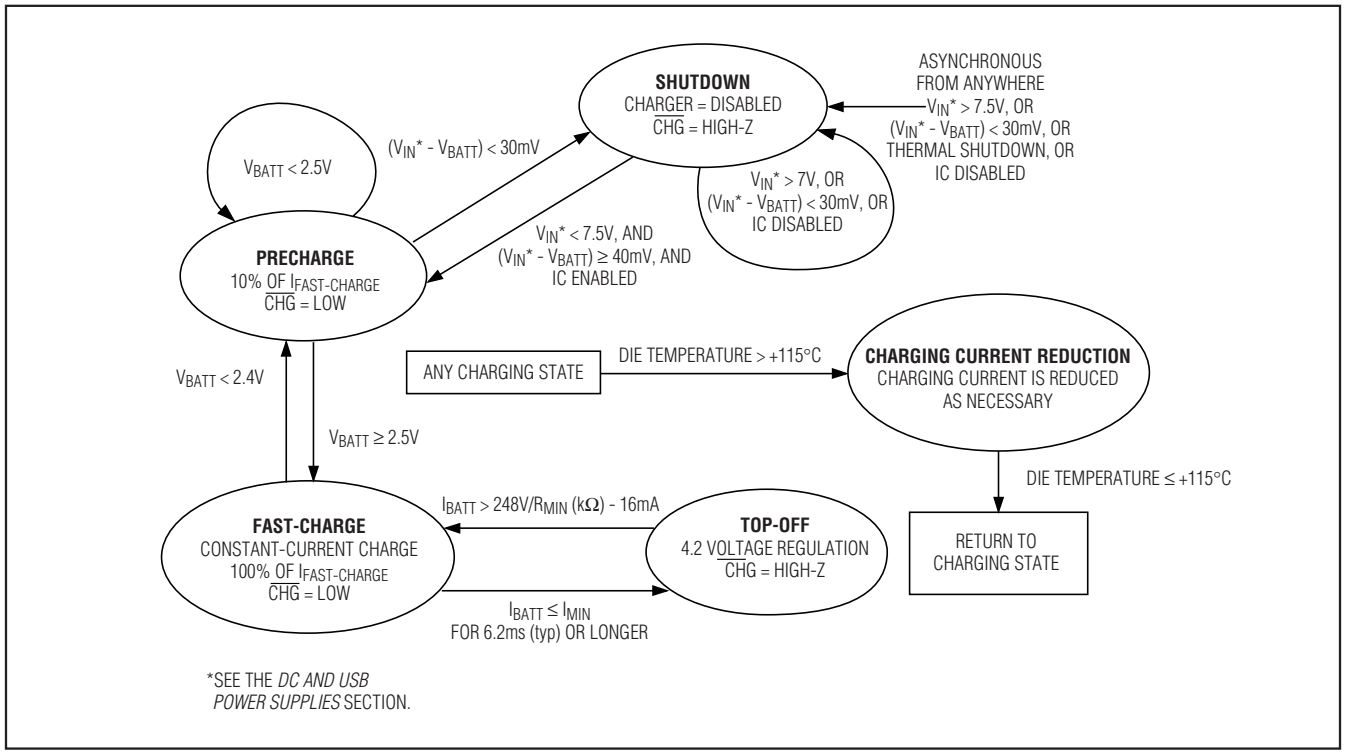


Figure 2. Charge-State Diagram

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

Table 1. Autobooting Output States

ABI	BATT	POK	CHARGER STATE	ABO (MAX8844Z)	$\overline{ABO}$ (MAX8844Y)
Low	Present	High-Z	Shutdown	Low	High-Z
High	Present	High-Z	Shutdown	High	Low
Low	Not present	Low	CC/CV mode	High	High-Z
Low	Present	Low	Fast-charge/top-off	High	High-Z
High	Present	Low	Fast-charge/top-off	High	Low

Note: *Present indicates that $V_{BATT} \geq 2.0V$ and Not Present indicates that the battery is not connected.*

impedance during shutdown. When interfacing with a microprocessor logic input, a pullup resistor to the microprocessor's I/O voltage may be required. If DETBAT is not used, connect DETBAT to GND for normal operation.

Autobooting Assistant

The MAX8844Z/MAX8844Y contain an autobooting assistant circuit that generates an enable signal for system booting (ABO, $\overline{ABO}$). For the MAX8844Z, the booting assistant functions as an internal OR gate (Figure 1). The first input is dependent on the input supply voltage (V_{IN} or V_{USB}) and DETBAT while the second input is an external signal applied to ABI. The first input (POK) is driven high once DETBAT is pulled low through a resistor less than 51kΩ, 2.35V ≤ (V_{IN} or V_{USB}) ≤ 7V, and [(V_{IN} or V_{USB}) - V_{BATT}] ≥ 40mV (typ V_{IN} rising).

The second input signal (ABI) is driven by an external source (Table 1). ABI enables an autoboot signal when a battery is connected at BATT and is independent of $\overline{POK}$. If $\overline{POK}$ is pulled low, the booting assistant always drives ABO high regardless of ABI. ABI is pulled to GND through an internal 200kΩ resistor. If ABI is supplied from an outside exposed pin, an RC filter (Figure 4) is required for ESD protection and noise filtering. If ABI is supplied by a system's internal GPIO, or logic, the RC filter is not required.

For the MAX8844Y, the output $\overline{ABO}$ is only dependent on the state of ABI (Table 1).

$\overline{CHG}$ Charge Indicator Output

$\overline{CHG}$ is an open-drain output that indicates charge status. Table 2 describes the state of $\overline{CHG}$ during different stages of operation. $\overline{CHG}$ is suitable for driving a charge indication LED. If the MAX8844Z/MAX8844Y are used in conjunction with a microprocessor, a pullup resistor to the logic I/O voltage allows $\overline{CHG}$ to indicate charge status to the microprocessor instead of driving an LED.

Thermal Regulation

The thermal-regulation loop limits the MAX8844Z/MAX8844Y die temperatures to +115°C by reducing the charge current as necessary. This feature not only protects the IC from overheating, but also allows a higher charge current without risking damage to the system.

Table 2. $\overline{CHG}$ States

$\overline{EN}$	V_{IN}*	V_{BATT}	I_{BATT}	$\overline{CHG}$	STATE
High	X	X	0	High-Z	Disabled
Low	> 7.5V	X	0	High-Z	Shutdown
	X	> V_{IN}* - 30mV			
Low	4.25V ≤ V_{IN}* ≤ 7.5V	< 2.4V	10% of $I_{FAST-CHARGE}$†	Low	Precharge
Low	4.25V ≤ V_{IN}* ≤ 7.5V	≥ 2.5V	100% of $I_{FAST-CHARGE}$†	Low	Fast-charge
Low	4.25V ≤ V_{IN}* ≤ 7.5V	4.2V	< I_{MIN}	High-Z	Top-off

X = Don't care.

** V_{IN} and V_{USB} are interchangeable. See the DC and USB Power Supplies section.*

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

Charger Enable Input

The MAX8844Z/MAX8844Y contain an active-low logic input ($\overline{EN}$) used to enable the chargers. Drive $\overline{EN}$ low, leave unconnected, or connect to GND to enable the charge-control circuitry. Drive $\overline{EN}$ high to disable the charger-control circuitry. $\overline{EN}$ has an internal 200kΩ pull-down resistor.

Soft-Start

The 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 250µs to the full charging current. This reduces the inrush current demand on the input supply.

Applications Information

Fast-Charge Current Setting

The maximum charging current is programmed by an external resistor connected from SETI to GND (R_{SETI}). Use the following equation to determine the fast-charge current ($I_{FAST-CHARGE}$):

$$I_{FAST-CHARGE} = \frac{1250V}{R_{SETI}}$$

where $I_{FAST-CHARGE}$ is in amps and R_{SETI} is in ohms. R_{SETI} must always be 1.25kΩ or higher due to the continuous charging current limit of $1A_{RMS}$.

Top-Off Current Threshold Setting

The top-off current threshold is programmed by an external resistor connected from MIN to GND (R_{MIN}). Use the following equation to determine the top-off current (I_{MIN}):

$$I_{MIN}\ (falling) = 126V/R_{MIN}\ (k\Omega) + 27mA$$

$$I_{MIN}\ (rising) = 248V/R_{MIN}\ (k\Omega) - 16mA$$

where I_{MIN} is in mA and R_{MIN} is in kΩ. Use $R_{MIN} \le 2.2k\Omega$.

Capacitor Selection

Connect a ceramic capacitor from BATT to GND for proper stability. Use a 2.2µF ceramic capacitor for most applications. Connect 1µF ceramic capacitors from IN to GND and from USB to GND. A larger input capacitor can be used for high charging current to reduce input voltage ripple.

Connect 1µF ceramic capacitors from SAFEOUT to GND and from SAFEUSB to GND. A larger bypass capacitor for SAFEOUT and SAFEUSB can be used for optimum noise immunity. Ceramic capacitors with X5R or X7R dielectric are highly recommended due to their small size, low ESR, and small temperature coefficients.

Thermal Considerations

The MAX8844Z/MAX8844Y are available in a thermally enhanced TDFN package with an exposed pad. Connect the exposed pad to a large copper ground plane to provide a thermal contact between the device and the circuit board for increased power dissipation. The exposed pad transfers heat away from the device, allowing the IC to charge the battery with maximum current, while minimizing the increase in die temperature.

Table 3. Input Power-Supply Selection

IN	USB	CHARGER STATE
$4.25V \le V_{IN} \le 7V$	$4.25V \le V_{USB} \le 7V$	Enabled, selects IN power supply
$4.25V \le V_{IN} \le 7V$	Not present	Enabled, selects IN power supply
Not present	$4.25V \le V_{USB} \le 7V$	Enabled, selects USB power supply
$V_{IN} \ge 7.5V$	$4.25V \le V_{USB} \le 7V$	Disabled
$4.25V \le V_{IN} \le 7V$	$V_{USB} \ge 7.5V$	Enabled

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

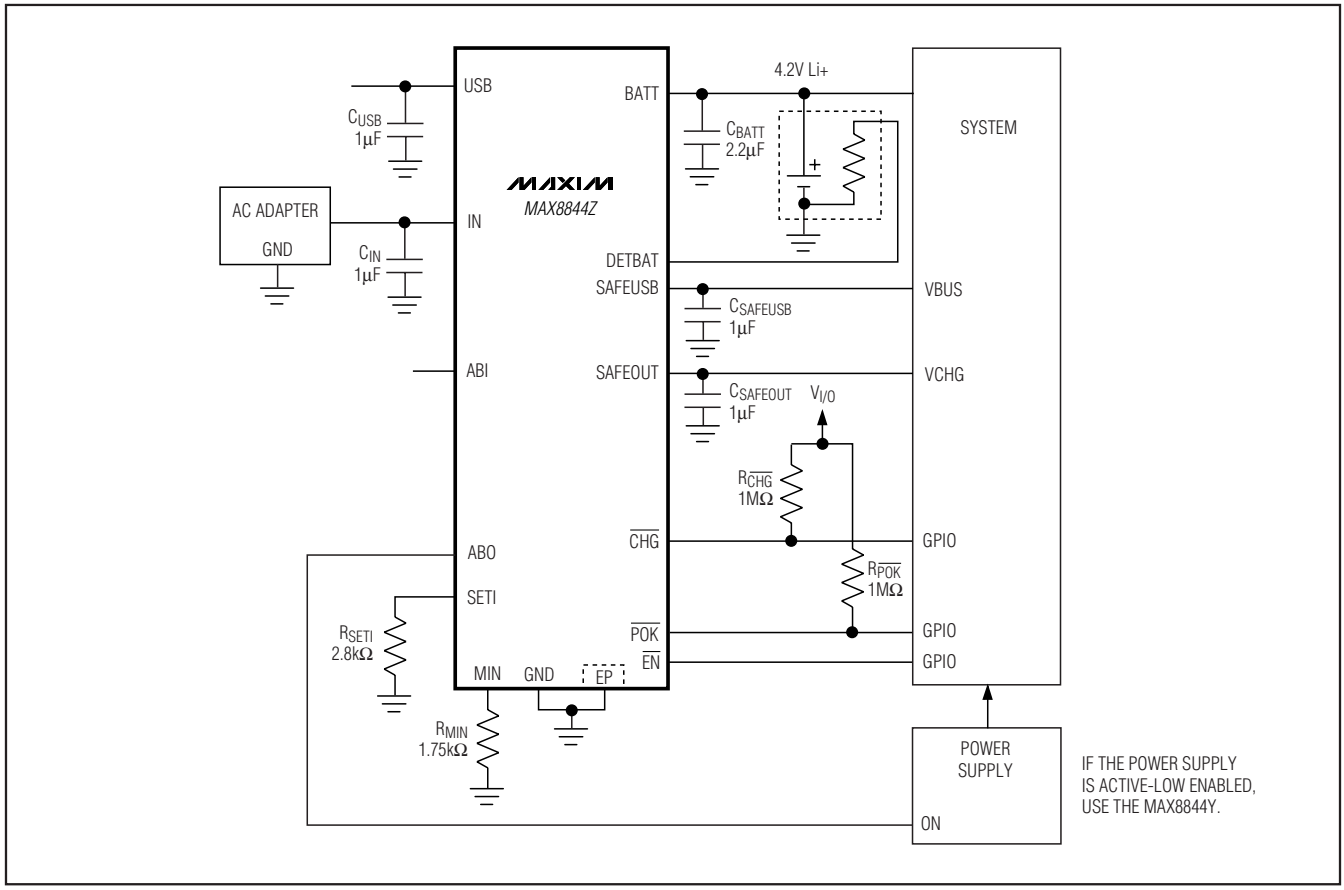


Figure 3. AC Adapter Application

DC and USB Power Supplies

The MAX8844Z/MAX8844Y operate from well-regulated DC sources and automatically select between both input power supply connections (Table 3). If both sources are present at the same time, highest priority is given to the IN source. The IN source is selected to ensure the shortest charging time for the system since it is able to deliver the highest current. The USB fast-charge current is fixed at 380mA (MAX8844Z) and 450mA (MAX8844Y).

The full charging input voltage range for IN and USB is 4.25V to 7.5V. The device can withstand up to 28V on both inputs, IN and USB, without damage to the IC. If V_{IN} or V_{USB} is greater than 7.5V, the internal overvoltage-protection circuitry disables charging until the input falls below 7.5V. The power supplies must provide at least 4.25V at the desired peak charging current and stay below 7V when unloaded.

Typical Application Circuits

AC Adapter Application

Figure 3 shows the MAX8844Z as a Li+ battery charger with an AC adapter. The MAX8844Z detects the presence of an input supply and DETBET resulting in $\overline{POK}$ pulled low. Once $\overline{POK}$ is pulled low, the autobooting assistant drives ABO high and enables the power supplies of the system to boot up. The MAX8844Z begins charging the battery when $\overline{EN}$ is low or unconnected. By monitoring $\overline{CHG}$, the system can detect the top-off threshold and terminate the charge through $\overline{EN}$. The MAX8844Z also provides an overvoltage-protected SAFEOUT and SAFEUSB to the system.

Factory System Interface Connector Application

Figure 4 shows the MAX8844Z as an autoboot assistant with the factory system interface connector. The MAX8844Z detects the ABI input even though there is no input voltage available and drives ABO high to turn

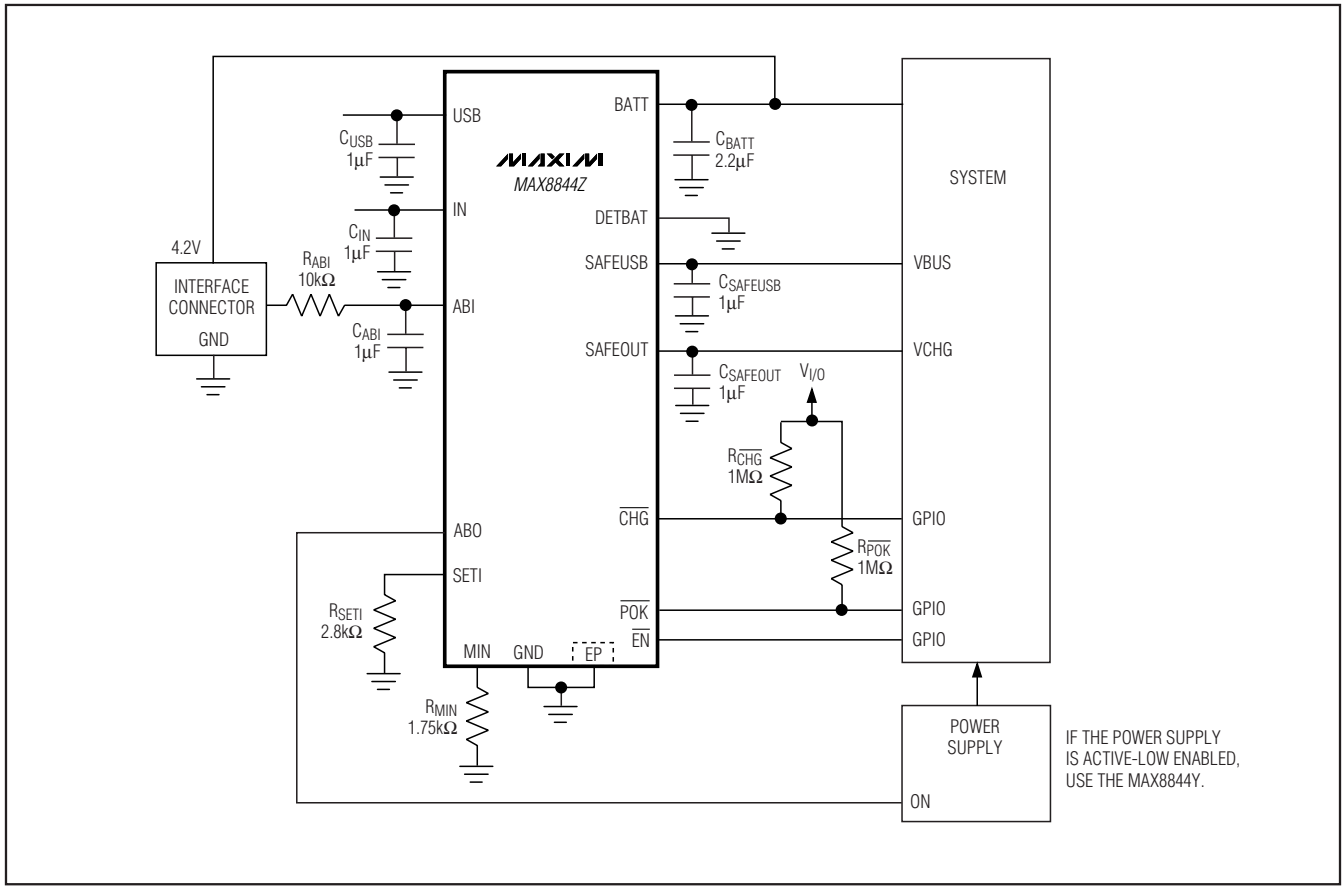


Figure 4. Factory System Interface Connector Application

on power supplies to boot up the system. The configuration in Figure 4 is used for system development, testing, and calibrations in production or design stage.

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 MAX8844Z can be configured to charge a battery at the highest current possible from the host port. Figure 5 shows the MAX8844Z as a USB battery charger with the default charging current as 380mA. The MAX8844Z also provides an overvoltage protected SAFEUSB to the system.

USB Connector and AC Adapter

Figure 6 shows the MAX8844Z as a Li+ battery charger with an AC adapter and USB connector. The MAX8844Z detects the presence of input supplies and DETBET resulting in $\overline{POK}$ pulled low. Once $\overline{POK}$ is pulled low, the autobooting assistant drives ABO high and enables the power supplies of the system to boot up. The MAX8844Z begins charging the battery from IN source when $\overline{EN}$ is low or open. By monitoring $\overline{CHG}$, the system can detect the top-off threshold and terminate the charge through the $\overline{EN}$ pin. The MAX8844Z provides overvoltage protected SAFEOUT and SAFEUSB to the system.

Figure 7 shows the timing diagram.

Recommended PCB Layout and Routing

Place all bypass capacitors for IN, USB, BATT, SAFEOUT, and SAFEUSB as close to the device as possible. Connect the battery to BATT as close as possible to the device to provide accurate battery voltage sensing. Provide a large copper ground plane to allow the exposed pad to sink heat away from the device. Make all high-current traces short and wide to minimize voltage drops. A sample layout is available in the MAX8844Z evaluation kit to speed designs.

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

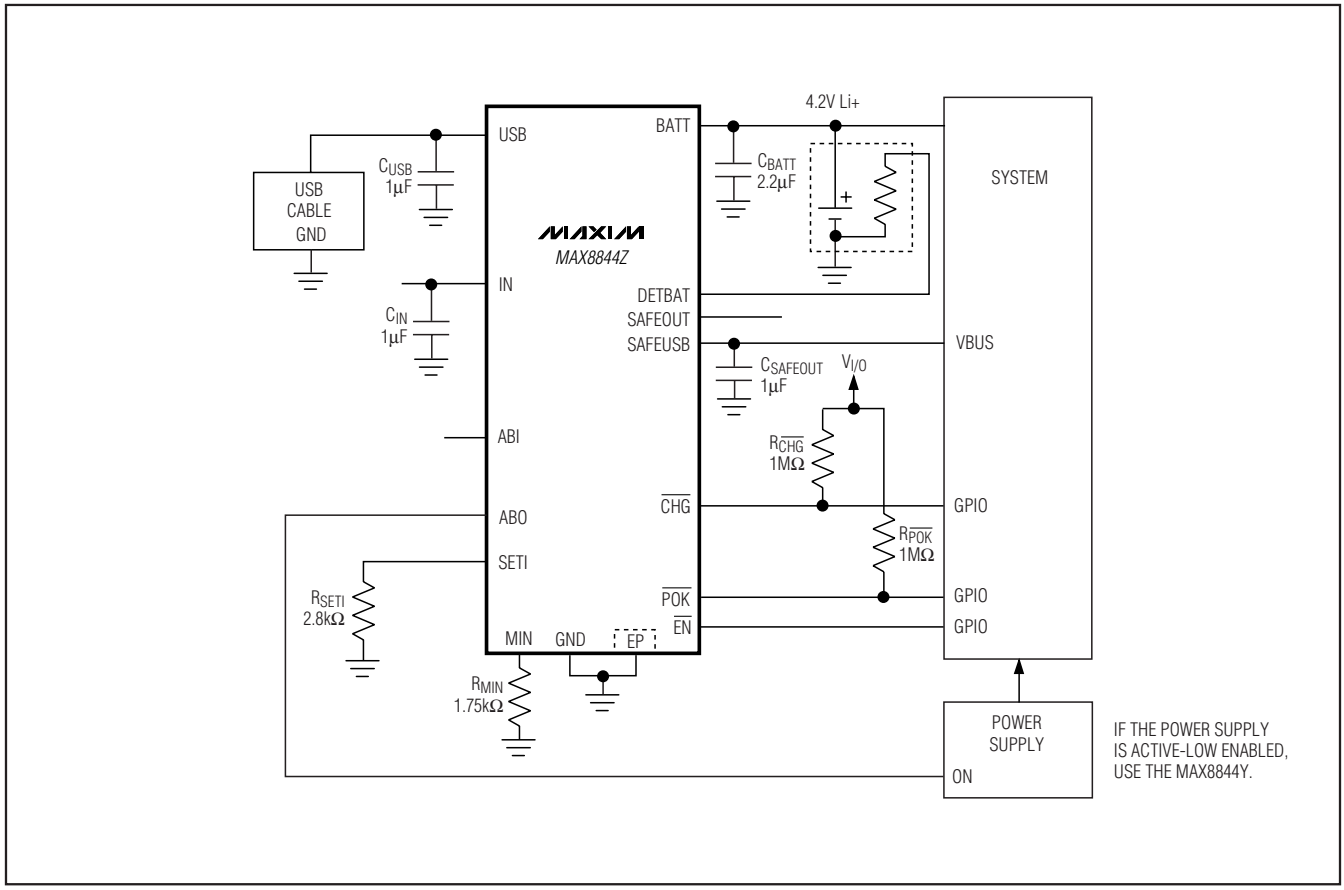


Figure 5. USB Battery Charger

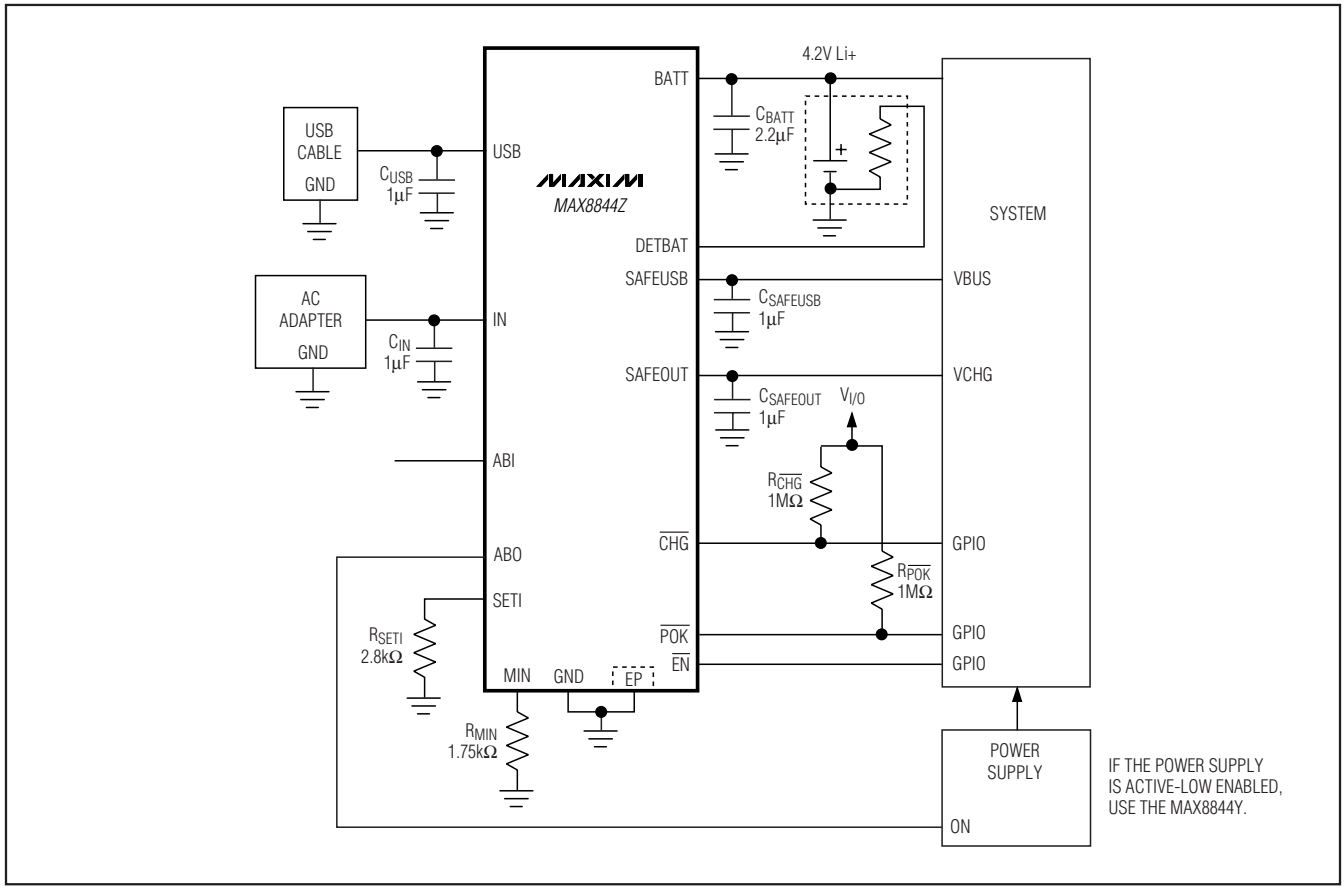


Figure 6. USB Connector and AC Adapter Application

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

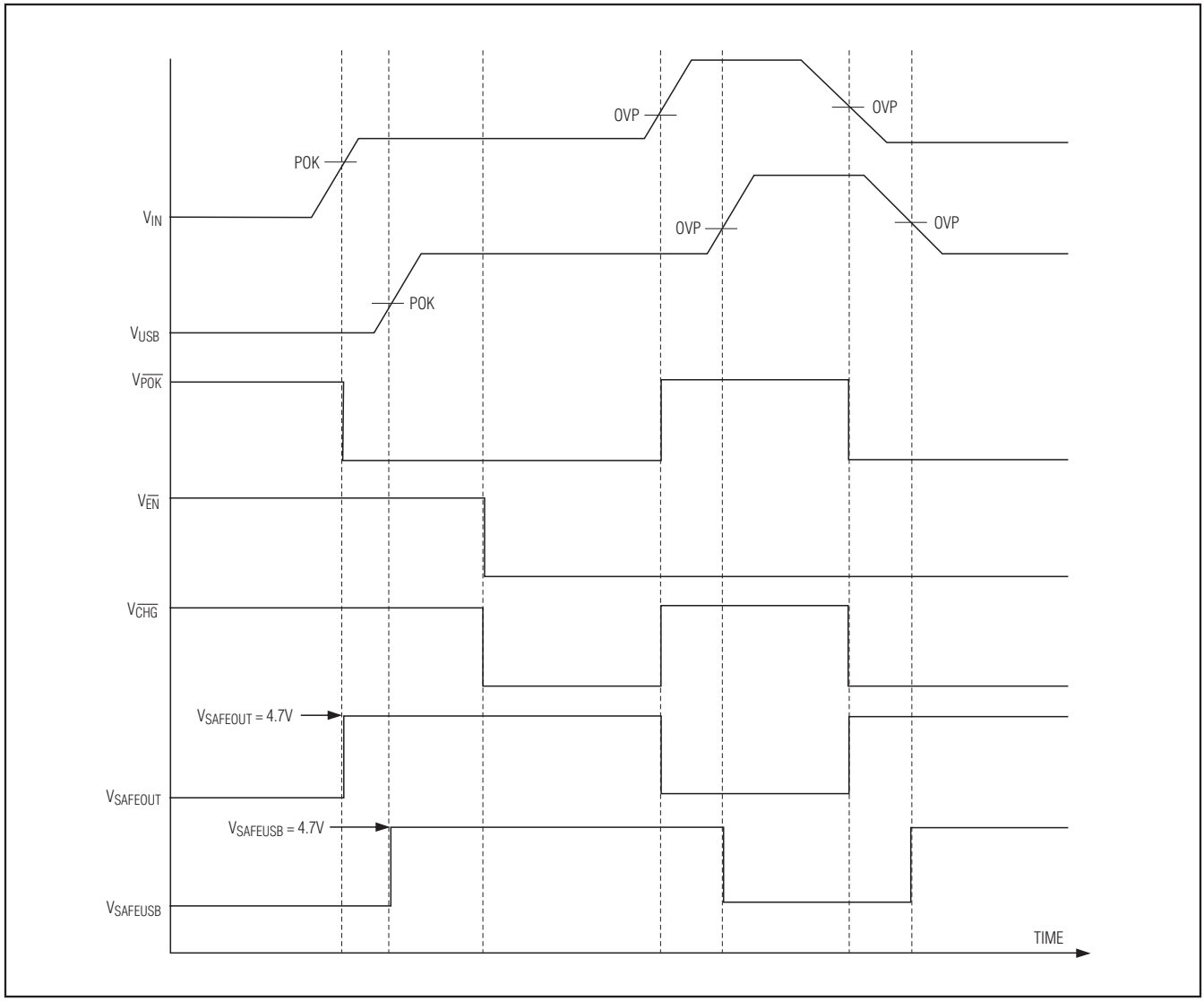
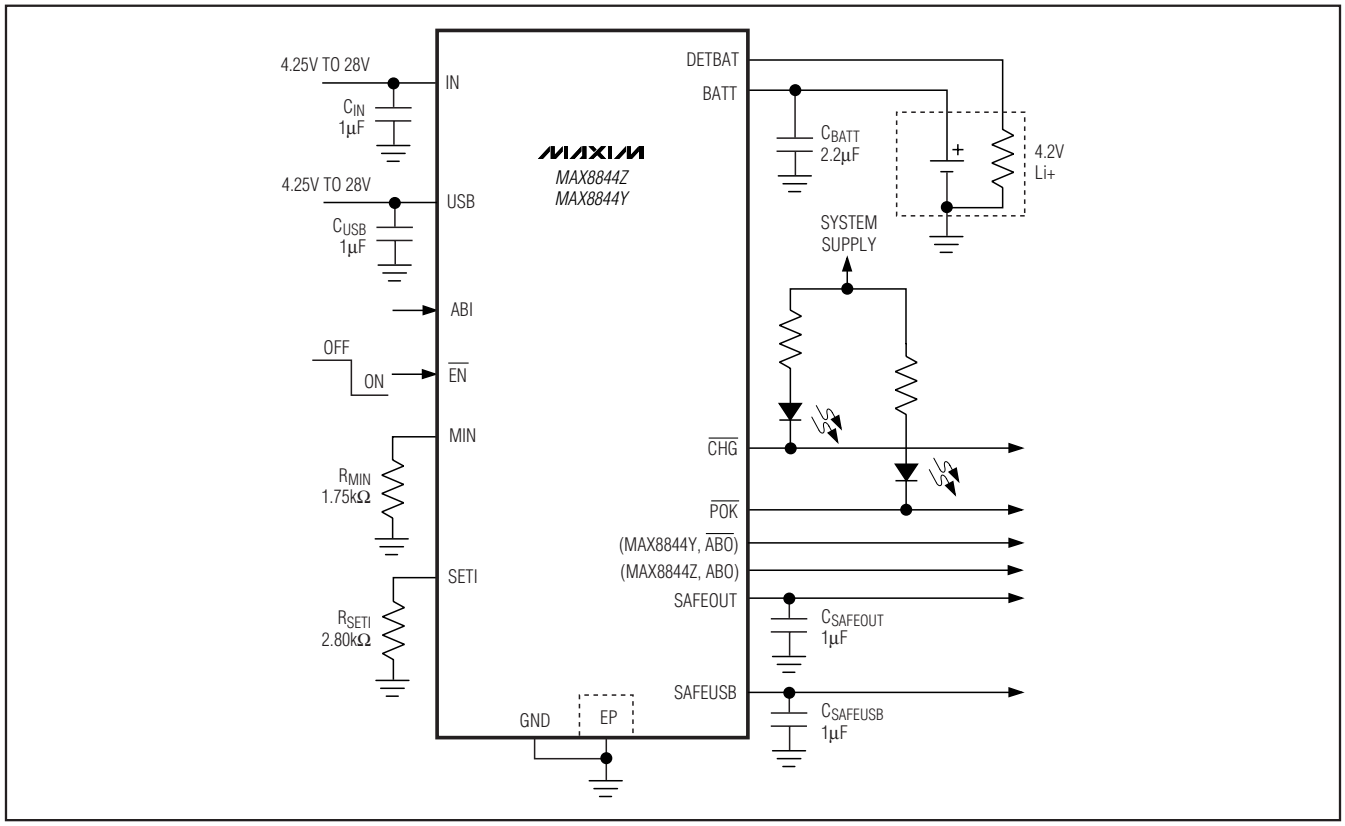


Figure 7. Timing Diagram

28V Dual Input Linear Li+ Battery Chargers with Battery Detection and Overvoltage-Protected Output

Typical Operating Circuit



Chip Information

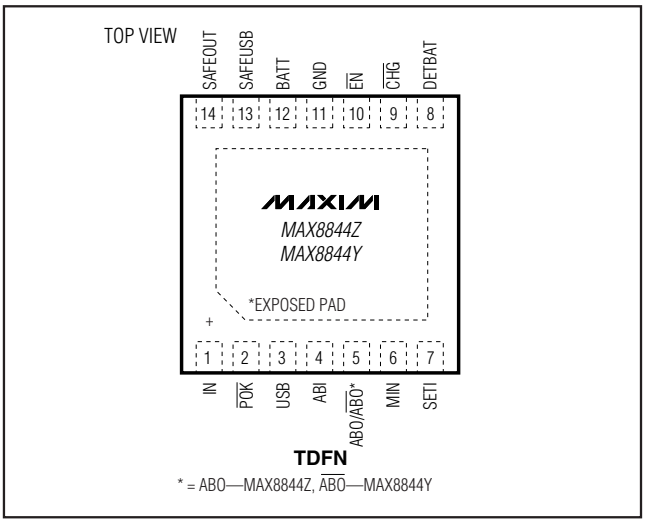
PROCESS: BiCMOS

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 (3mm x 3mm)	T1433-2	21-0137

Pin Configuration



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