19-4929; Rev 0; 9/09

30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

General Description

The MAX8922L linear battery charger safely charges a single-cell lithium-ion (Li+) battery. Charging rate is optimized to accommodate the thermal characteristics of a given application. There is no need to reduce the maximum charge current at the worst-case charger power dissipation. Charging is optimized for a single Li+ cell using a control algorithm that includes low-battery precharging, voltage and current-limited fast charging, and top-off charging, while continuously monitoring for input overvoltage and device die-temperature conditions. The fast-charge current and top-off current thresholds are programmable by a simple 1-Wire® serial interface. The charger status and valid input power are indicated by two open-drain outputs ($\overline{\text{CHG}}$ and $\overline{\text{POK}}$).

The fast-charge current is defaulted to 400mA and programmable through the 1-Wire interface ($\overline{\text{EN}}$/SET). The MAX8922L also can be programmable to GSM test mode through the 1-Wire interface.

The MAX8922L is available in a tiny (3mm x 2mm x 0.8mm) 10-pin TDFN package.

Applications

GSM/EDGE/UMTS/CDMA Cell Phones

Digital Cameras

PDAs

Portable Media Players and MP3 Players

Wireless Appliances

Features

- ♦ Overvoltage-Protected 30V$_{DC}$ Rated Input (IN)
- ♦ Input Overvoltage-Protected Safe 4.94V LDO Output
- ♦ 2.3A GSM RF Test Mode
- ♦ No External FET, Blocking Diode, or Sense Resistor Required
- ♦ 1-Wire Easy Programmable Fast-Charge and GSM Test Mode ($\overline{\text{EN}}$/SET)
- ♦ Resistor-Programmable Fast-Charge Current (SETI)
- ♦ Resistor-Programmable Top-Off Current Threshold (MIN)
- ♦ Prequalification Charge
- ♦ Power-OK Monitor Output ($\overline{\text{POK}}$)
- ♦ Charging-Status Output ($\overline{\text{CHG}}$)
- ♦ Die Temperature Regulation for Optimized Charge Rate
- ♦ Tiny (3mm x 2mm x 0.8mm) 10-Pin TDFN Package

Ordering Information

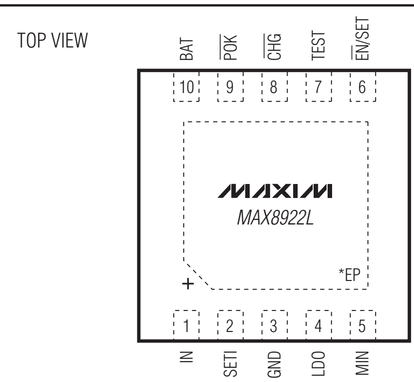
PART	PIN-PACKAGE	TOP MARK
MAX8922LETB+T	10 TDFN-EP*	AWN

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

**EP = Exposed pad.*

Note: *This device operates in the -40°C to +85°C extended operating temperature range.*

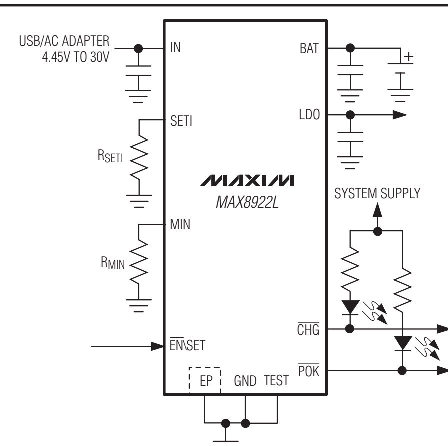
Pin Configuration



TDFN
(3mm x 2mm x 0.8mm)

*EP = EXPOSED PAD.

Typical Operating Circuit



1-Wire is a registered trademark of Maxim Integrated Products, Inc.

30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

ABSOLUTE MAXIMUM RATINGS

IN to GND ....-0.3V to +30V
BAT, $\overline{CHG}$, $\overline{EN}$/SET, $\overline{POK}$, SETI,
MIN, LDO, TEST to GND ....-0.3V to +6V
Continuous Power Dissipation (T_A = +70°C)
10-Pin (3mm x 2mm) TDFN
(derate 14.9mW/°C above +70°C)..........................1188.7mW

Operating Temperature Range ....-40°C to +85°C
Junction Temperature Range ....-40°C to +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_{BAT} = 4V, $V_{\overline{EN}/SET}$ = 0V, T_A = -40°C to +85°C, typical values are at T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
IN						
Input Voltage Range			0		28	V
Input Voltage Operating Range	(Note 2)		4.45		7	V
Input Undervoltage Threshold (UVLO)	V_{IN} rising, 500mV hysteresis (typ)		3.80	3.90	4.00	V
Input Overvoltage Threshold (OVP)	V_{IN} rising, 200mV hysteresis (typ)		7.2	7.5	7.8	V
Input Supply Current	I_{BAT} = 0mA, charge mode			700	1300	µA
	$V_{\overline{EN}/SET}$ = 5V, standby mode			250	440	
	V_{IN} = V_{BAT}, shutdown mode			200		
IN-to-BAT On-Resistance	V_{IN} = 4.15V, V_{BAT} = 4V			0.35		Ω
IN-to-BAT Comparator Threshold	V_{IN} rising		120	250	500	mV
	V_{IN} falling			100		
BAT						
BAT Regulation Voltage	I_{BAT} = 100mA	T_A = +25°C	4.179	4.2	4.221	V
		T_A = -40°C to +85°C	4.158	4.2	4.242	
Battery Removal Detection Threshold	V_{BAT} rising			4.67		V
	Hysteresis			0.2		
Charging Current	Default fast-charge current, V_{BAT} = 3.5V		365	400	435	mA
	$\overline{EN}$/SET = one pulse with low > 4ms, R_{SETI} = 3kΩ, one-pulse mode, V_{BAT} = 3.5V		460	500	540	
	$\overline{EN}$/SET = two pulses with low > 4ms, V_{BAT} = 3.5V		80	90	100	
	$\overline{EN}$/SET = three pulses with low > 4ms, V_{BAT} = 3.5V (Note 3)			2350		
Soft-Start Time	Ramp time to fast-charge current			250		µs
BAT Precharge Threshold	V_{BAT} rising, 300mV hysteresis (typ)			2.5		V
Precharge Current				80		mA
BAT Leakage Current	V_{IN} = 0V, V_{BAT} = 4.2V			1	5	µA

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 5V, V_{BAT} = 4V, $V_{\overline{EN}/SET}$ = 0V, T_A = -40°C to +85°C, typical values are at T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
LDO							
Minimum LDO Bypass Capacitance					1		µF
LDO Regulated Output Voltage	I_{LDO} = 10mA, V_{IN} = 5V			4.8	4.94		V
LDO Output-Current Limit					100		mA
$\overline{EN}$/SET							
Logic Input Thresholds	Rising					1.4	V
	Falling			0.4			
Program Lock Time				4			ms
Shutdown Delay	V_{IN} = 5V, $\overline{EN}$/SET from low to high			4			ms
t_{LOW}	(Note 4)			100		1400	µs
t_{HIGH}	(Note 4)			100		1400	
Pulldown Resistor					2		MΩ
$\overline{POK}$, $\overline{CHG}$							
Logic Output Voltage, Low	$I_{\overline{POK}}$ = $I_{\overline{CHG}}$ = 5mA				0.05	0.2	V
Logic Output Current, High	$V_{\overline{POK}}$ = $V_{\overline{CHG}}$ = 5.5V, V_{IN} = 0V		T_A = +25°C		0.001	1	µA
			T_A = +85°C		0.01		
$\overline{CHG}$							
Top-Off Threshold	I_{BAT} falling, battery is charged	Default top-off threshold, hysteresis (typ) = 80mA		60	80	100	mA
		$\overline{EN}$/SET = one pulse, R_{MIN} = 1.875kΩ, hysteresis (typ) = 130mA		60	80	100	
		$\overline{EN}$/SET = two pulses, hysteresis (typ) = 22mA		50	60	70	
Detection Delay	I_{BAT} falls below top-off threshold			2	4	6	ms
THERMAL LOOP							
Thermal-Limit Temperature	Junction temperature when the charge current is reduced, T_J rising				+105		°C
Thermal-Limit Gain	Reduction of I_{BAT} for increase of T_J, default mode				-28		mA/°C

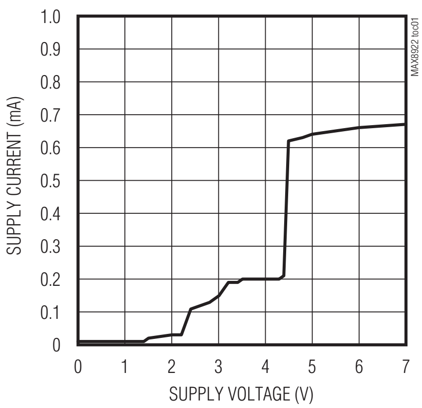
Note 1: Limits are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design and characterization.
Note 2: Guaranteed by undervoltage- and overvoltage-threshold testing. If V_{BAT} = 4.2V, V_{IN} needs to be > 4.2V + 250mV (typ) to start normal operation. After the MAX8922L turns on, it can operate until V_{BAT} + 100mV (typ). For complete charging, the input voltage must be > 4.45V. See the *Input Sources* section.
Note 3: Used for factory GSM RF calibration. 217Hz, 12.5% current pulse, T_A = +25°C. Not for continuous charge current.
Note 4: Not tested. Design guidance only.

30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

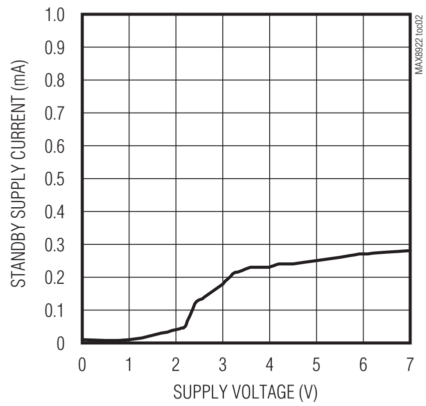
Typical Operating Characteristics

(V_{IN} = 5V, $V_{\overline{EN}/SET}$ = 0V. V_{BAT} = 4V, MAX8922L Evaluation Kit. T_A = +25°C, unless otherwise noted.)

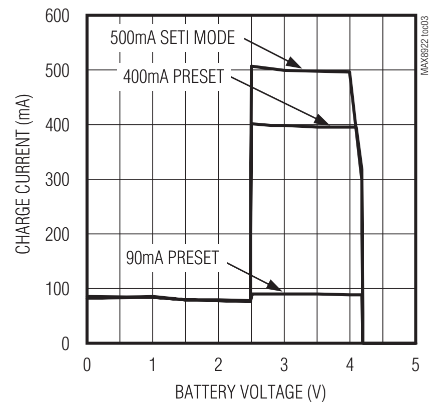
SUPPLY CURRENT vs. SUPPLY VOLTAGE



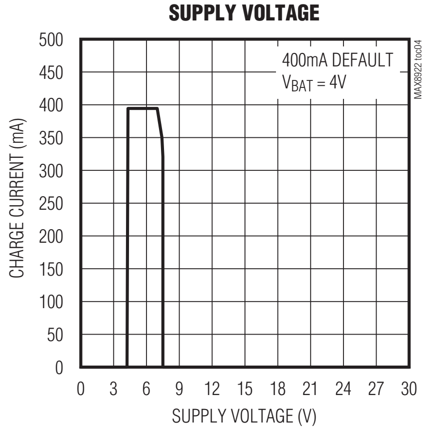
DISABLED SUPPLY CURRENT vs. SUPPLY VOLTAGE



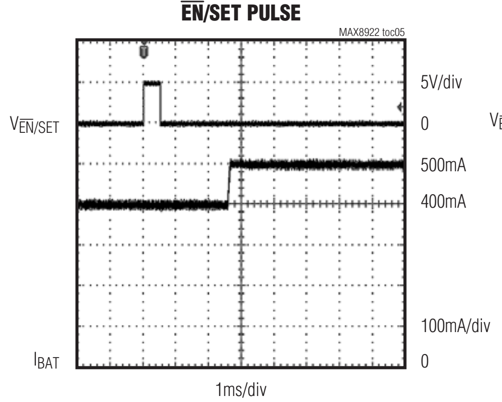
CHARGE CURRENT vs. BATTERY VOLTAGE



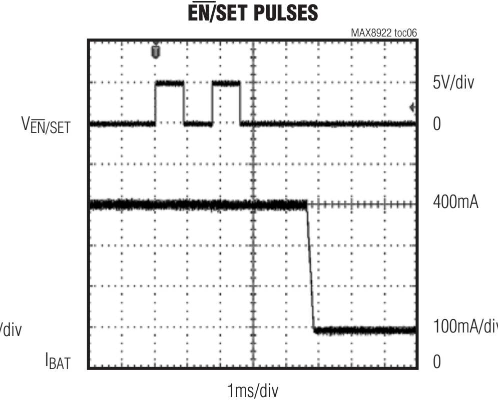
CHARGE CURRENT vs. SUPPLY VOLTAGE



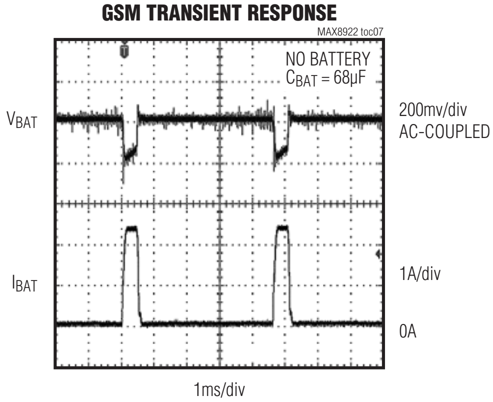
CHARGE CURRENT WITH ONE $\overline{EN}$/SET PULSE



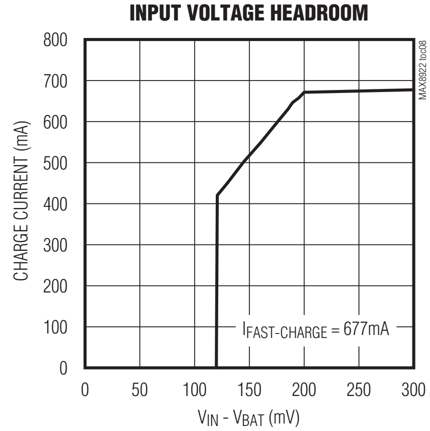
CHARGE CURRENT WITH TWO $\overline{EN}$/SET PULSES



GSM TRANSIENT RESPONSE



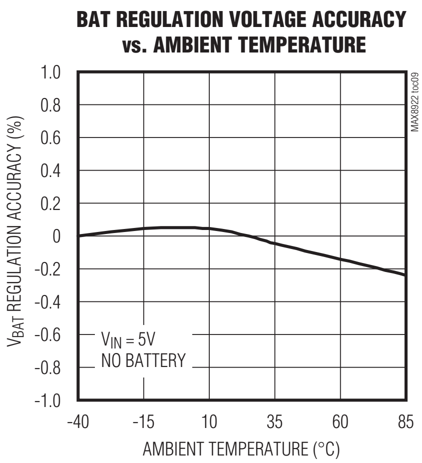
CHARGE CURRENT vs. INPUT VOLTAGE HEADROOM

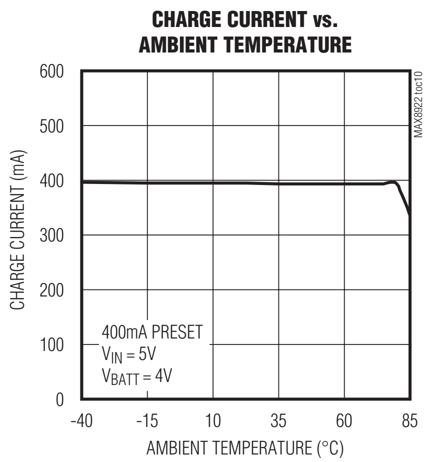


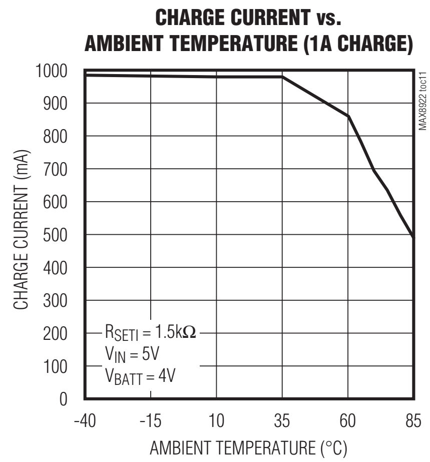
30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

Typical Operating Characteristics (continued)

(V_{IN} = 5V, $V_{\overline{EN}/SET}$ = 0V. V_{BAT} = 4V, MAX8922L Evaluation Kit. T_A = +25°C, unless otherwise noted.)







Pin Description

PIN	NAME	FUNCTION
1	IN	DC Input Supply. Connect IN to V_{IN} > 4V and (V_{IN} - V_{BAT}) ≥ 250mV up to a 7V charging source. Bypass IN to GND with a 1µF or larger ceramic capacitor.
2	SETI	Charge-Current Program and Fast-Charge Current Monitor. Output current from SETI is 1000µA per ampere of battery-charging current. Set the charging current by connecting a resistor (R_{SETI} in Figure 1) from SETI to GND. $I_{FAST-CHARGE}$ = 1500V/R_{SETI}. **Connect to GND if pulse 1 mode (external SETI) is not used.**
3	GND	Ground
4	LDO	4.94V Regulated LDO Output with Input Overvoltage Protection. Bypass LDO to GND with a 1µF or larger ceramic capacitor. LDO can be used to supply low-voltage-rated USB systems.
5	MIN	Top-Off Current Threshold Programmable Input. I_{MIN} = 150V/R_{MIN}. **Connect to GND if pulse 1 mode (external SETI) is not used.**
6	$\overline{EN}$/SET	Active-Low Enable Input. $\overline{EN}$/SET is used for programming fast-charge current and GSM test mode. For detailed descriptions, see the *Charger-Enable and Program Input ($\overline{EN}$/SET)* section.
7	TEST	Factory Test Input. Connect to GND.
8	$\overline{CHG}$	Charging-Status Output. $\overline{CHG}$ is internally pulled low when the charger is in prequalification or fast-charge mode. $\overline{CHG}$ is high impedance when the charger is in top-off or disabled.
9	$\overline{POK}$	Input Power-OK Monitor. $\overline{POK}$ is an open-drain output that is internally pulled low when V_{IN} is greater than V_{UVLO} and lower than V_{OVP} and V_{IN} > V_{BAT} + 250mV. $\overline{POK}$ is high impedance when V_{IN} is less than V_{UVLO} or greater than V_{OVP} or V_{IN} < V_{BAT} + 100mV.
10	BAT	Battery Connection. The IC delivers charging current and monitors battery voltage using BAT. Bypass BAT to GND with a 2.2µF or larger ceramic capacitor. BAT is high impedance when the IC is disabled.
—	EP	Exposed Pad. Connect to the GND plane for increased thermal dissipation.

30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

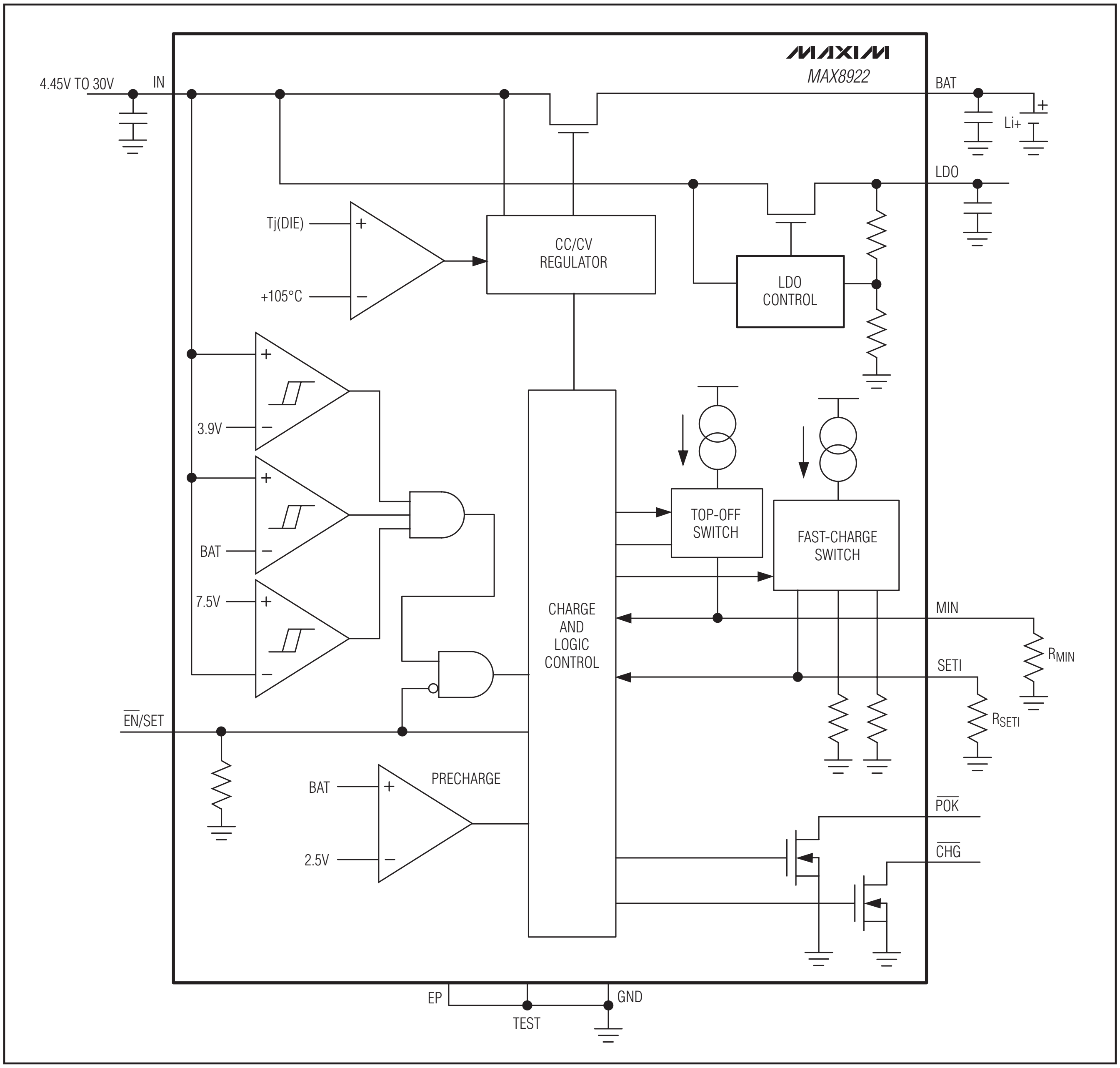


Figure 1. MAX8922L Functional Diagram

Detailed Description

The MAX8922L is designed to charge a single-cell Li+ battery from a DC source voltage between 4.45V and 7V, while V_{IN} can withstand up to 30V. The fast-charge current and top-off current thresholds are programmable with $\overline{EN}$/SET, SETI, and MIN.

Charger-Enable and Program Input ($\overline{EN}$/SET)

$\overline{EN}$/SET is an active-low logic input that enables the charger. Drive $\overline{EN}$/SET high longer than 4ms to disable the charger-control circuitry. If $\overline{EN}$/SET is left unconnected, an internal 2MΩ pulldown resistor enables 400mA fast-charge current by default. The pulse programming scheme shown in Table 1 and Figure 3 is used to program the charge current and GSM test mode. There are four different fast-charge current states. Default fast-charge current state is 400mA mode. More than three pulses are interpreted to 90mA mode. After programming is locked, the MAX8922L ignores pulses until the IC is disabled/enabled or input power is cycled. Each fast-charge state is locked after a 4ms logic-low is asserted on $\overline{EN}$/SET, followed by programming pulses. However, during default mode, if $\overline{EN}$/SET does not receive any pulses, the charger stays in default mode unlocked indefinitely.

Debounce Timer

To prevent the MAX8922L from charging the battery momentarily upon IN power-up with $\overline{EN}$/SET held low, a 2ms (typ) debounce timer delays the charging loop upon power-up. If $\overline{EN}$/SET is logic-low or unconnected (pulled down by an internal pulldown resistor) during IN power-up, the charger starts charging the battery 2ms after $V_{UVLO} < V_{IN} < V_{OVP}$ and $V_{BAT} + 250mV < V_{IN}$. If $\overline{EN}$/SET is logic-high during IN power-up, the charger does not charge the battery.

Soft-Start

To prevent input transients, the rate of change of the charge current is limited when the charger is turned on or changes its current compliance. It takes approximately 250µs (typ) ($t_{SOFTSTART}$) for the charger to go from 0mA to the maximum fast-charge current.

Thermal-Limit Control

The MAX8922L features a thermal limit that reduces the charge current when the die temperature exceeds +105°C. As the temperature increases above +105°C, the IC decreases the charge current by 28mA/°C.

Charge-Indicator Output ($\overline{CHG}$)

$\overline{CHG}$ is an open-drain output that indicates charger status. $\overline{CHG}$ goes low during charging in prequalification or fast-charge mode. The $\overline{CHG}$ internal open-drain MOSFET turns off when the charge current reaches the top-off threshold. The $\overline{CHG}$ status is latched after the top-off threshold is reached. The latch can be reset as follows:

- Disable and re-enable the MAX8922L.
- Input power is cycled.
- Battery-charge current increases greater than the top-off threshold + hysteresis.

When the MAX8922L is used in conjunction with a microprocessor, connect a pullup resistor between $\overline{CHG}$ and the logic I/O voltage to indicate charge status to the µP. Alternatively, $\overline{CHG}$ can sink 5mA or more for an LED charge indicator.

Table 1. Charge-Current Pulse Settings

CHARGE CURRENT	DEFAULT	NUMBER OF PULSES + > 4ms LOGIG-LOW	FAST-CHARGE CURRENT SETTING
I_{BAT} (mA)	400mA	One	SETI, resistor programmable
		Two	90mA
		Three	2.3A (GSM test)
		Four and more	90mA

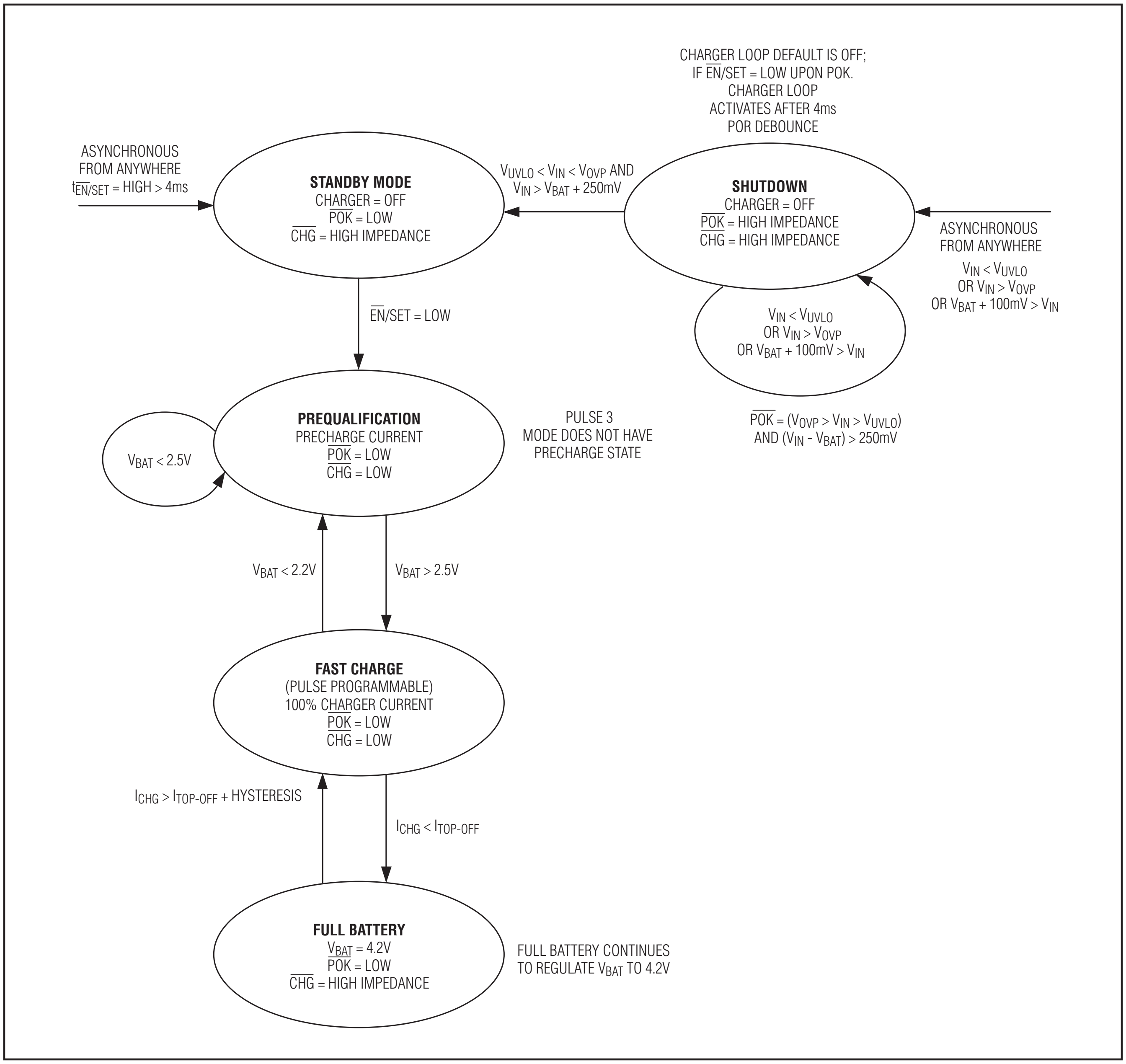


Figure 2. Charger State Diagram

Power-OK Indicator ($\overline{POK}$)

The MAX8922L contains an open-drain $\overline{POK}$ output that goes low when V_{IN} is greater than V_{UVLO} and lower than V_{OVP} and V_{IN} exceeds the battery voltage by 250mV. Once charging has started, charging is sustained with inputs as low as 3.5V, as long as the input voltage remains above the battery voltage by at least 100mV. $\overline{POK}$ status should be maintained even though the charger is disabled by $\overline{EN}$/SET. When $V_{IN} > V_{OVP}$, $\overline{POK}$ is high impedance.

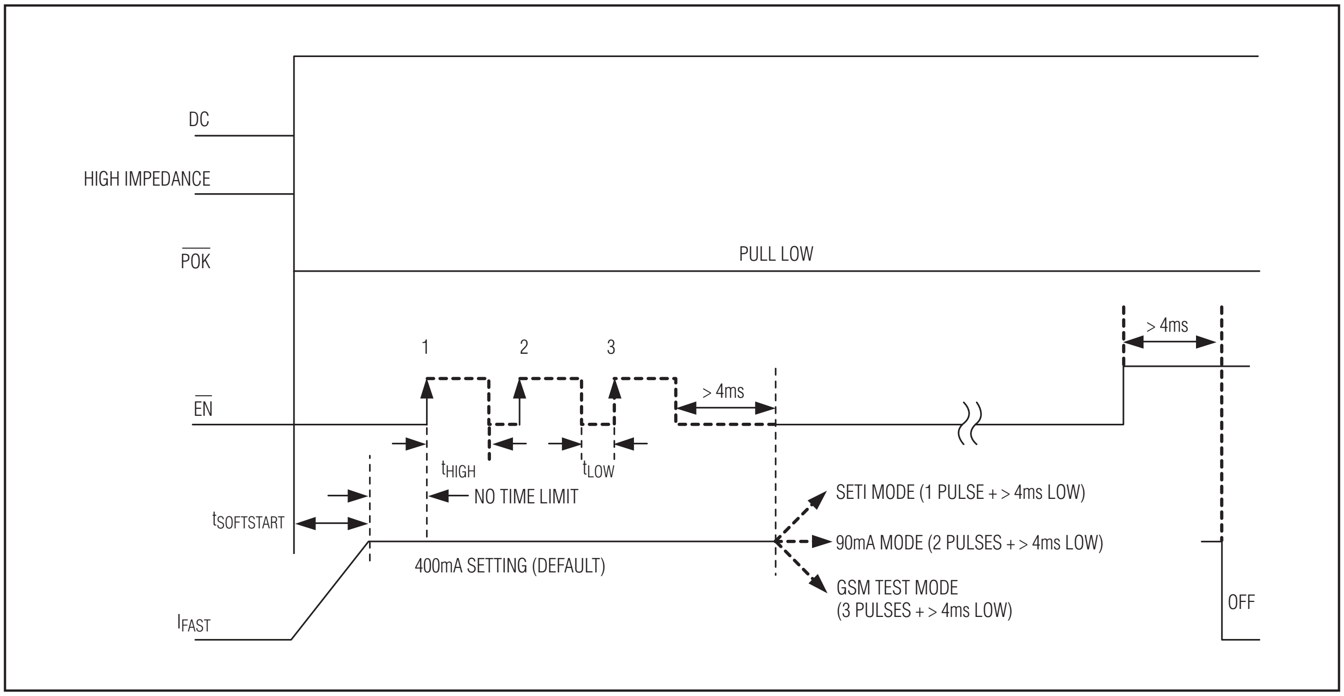


Figure 3. Charge-Current Programming

LDO Output

The LDO is preset to an output voltage of 4.94V and a 100mA current limit (typ). The LDO is powered from IN and has input overvoltage protection. The LDO is on if a valid input is present ($V_{UVLO} < V_{IN} < V_{OVP}$).

Bypass LDO to GND with a 1µF or larger ceramic capacitor. The LDO can be used to supply low-voltage-rated USB systems.

Applications Information

Fast-Charge Current Settings

In pulse 1 mode, the maximum charging current is programmed by an external resistor connected from SETI to GND (R_{SETI}). Calculate R_{SETI} as follows:

$$R_{SETI} = 1500V/I_{FAST\text{-}CHARGE}$$

where $I_{FAST\text{-}CHARGE}$ is in amperes and R_{SETI} is in ohms. SETI can be used to monitor the fast-charge current level in the one-pulse mode (R_{SETI} mode). The output current from SETI is 1000µA per ampere of charging current.

The output voltage at SETI is proportional to the charging current (I_{CHARGE}) when SETI mode is used for the fast-charge current:

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

The voltage at ISET is nominally 1.5V at the selected fast-charge current and decreases with charging current as the cell becomes fully charged or as the thermal-regulation circuitry activates.

Top-Off Current Settings

The top-off charging current is programmed by an external resistor connected from MIN to GND (R_{MIN}) in the one-pulse mode (R_{SETI} mode). Calculate R_{MIN} as follows:

$$R_{MIN} = 150V/I_{MIN}$$

where I_{MIN} is in amperes and R_{MIN} is in ohms.

Capacitor Selection

Connect a 2.2µF ceramic capacitor from BAT to GND for proper stability. Connect a 1µF ceramic capacitor from IN to GND. 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.

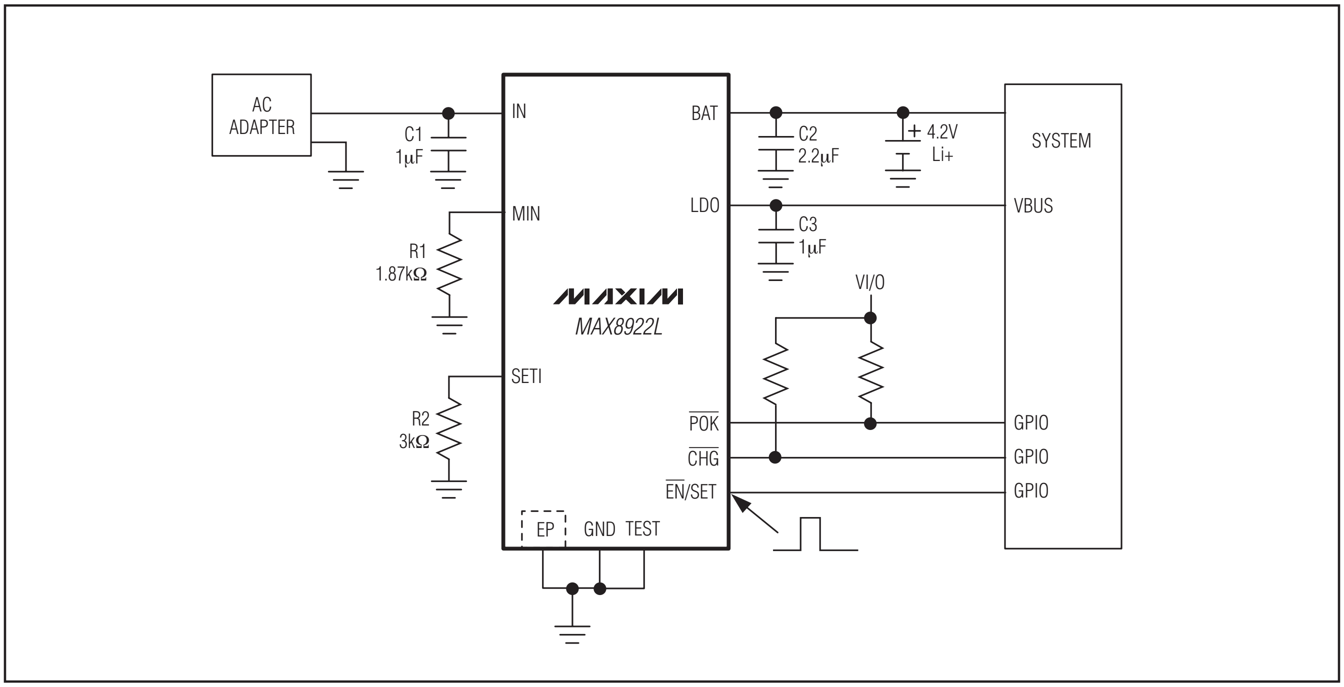


Figure 4. AC Adapter Charger Application

Thermal Considerations

The MAX8922L is in a thermally enhanced TDFN package with an exposed pad. Connect the exposed pad of the package to a large copper ground plane to provide a thermal contact between the device and the circuit board. 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.

Input Sources

The MAX8922L operates from well-regulated DC sources. The charger input voltage range is 4.45V to 7V. The device survives input voltages up to 30V 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 peak charging current.

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

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

Recommended PCB Layout and Routing

Place all bypass capacitors for IN and BAT as close as possible to the IC. Connect the battery to BAT as close as possible to the IC 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 MAX8922L Evaluation Kit to speed designs.

Typical Application Circuits

AC Adapter Charge

Figure 4 shows the MAX8922L as a Li+ battery charger with an AC adapter. The MAX8922L detects the presence of an input supply resulting in $\overline{\text{POK}}$ pulled low. Once $\overline{\text{POK}}$ is pulled low, the MAX8922L begins charging the battery when $\overline{\text{EN}}$/SET is low or unconnected. The system can program the charge current by $\overline{\text{EN}}$/SET pulses. By monitoring $\overline{\text{CHG}}$, the system can detect the top-off threshold and terminate the charge through $\overline{\text{EN}}$/SET. The MAX8922L also provides an overvoltage-protected 4.94V LDO output to a low-voltage-rated USB system input.

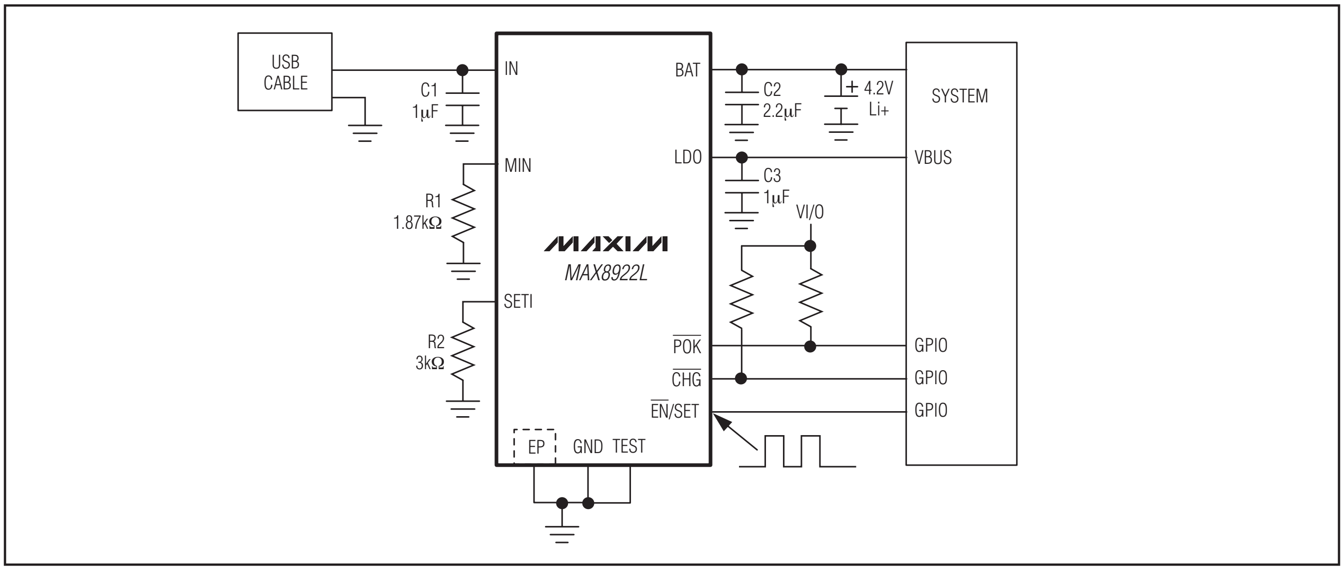


Figure 5. USB-Powered Li+ Battery-Charger Application

USB Charge

The universal serial bus (USB) provides a high-speed serial communications port as well as power for the remote device. The MAX8922L can be configured to charge a single Li+ battery at the highest current possible from the host port. Figure 5 shows the MAX8922L as a USB battery charger. The microprocessor enumerates the host to determine its current capability. The system can program the charge current to 90mA, I_{SETI}, or 400mA by $\overline{EN}$/SET pulses if the host port is capable. The MAX8922L also provides an overvoltage-protected 4.94V LDO output to a low-voltage-rated USB system input.

GSM Test Mode

Figure 6 shows the MAX8922L in a GSM test mode. By sending three pulses to $\overline{EN}$/SET, the MAX8922L goes into GSM test mode. GSM PA can pull up to 2.3A for 576μs once every 217Hz from the MAX8922L's output. The configuration in Figure 6 is used for system development, testing, and calibrations in the production or design stage.

30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

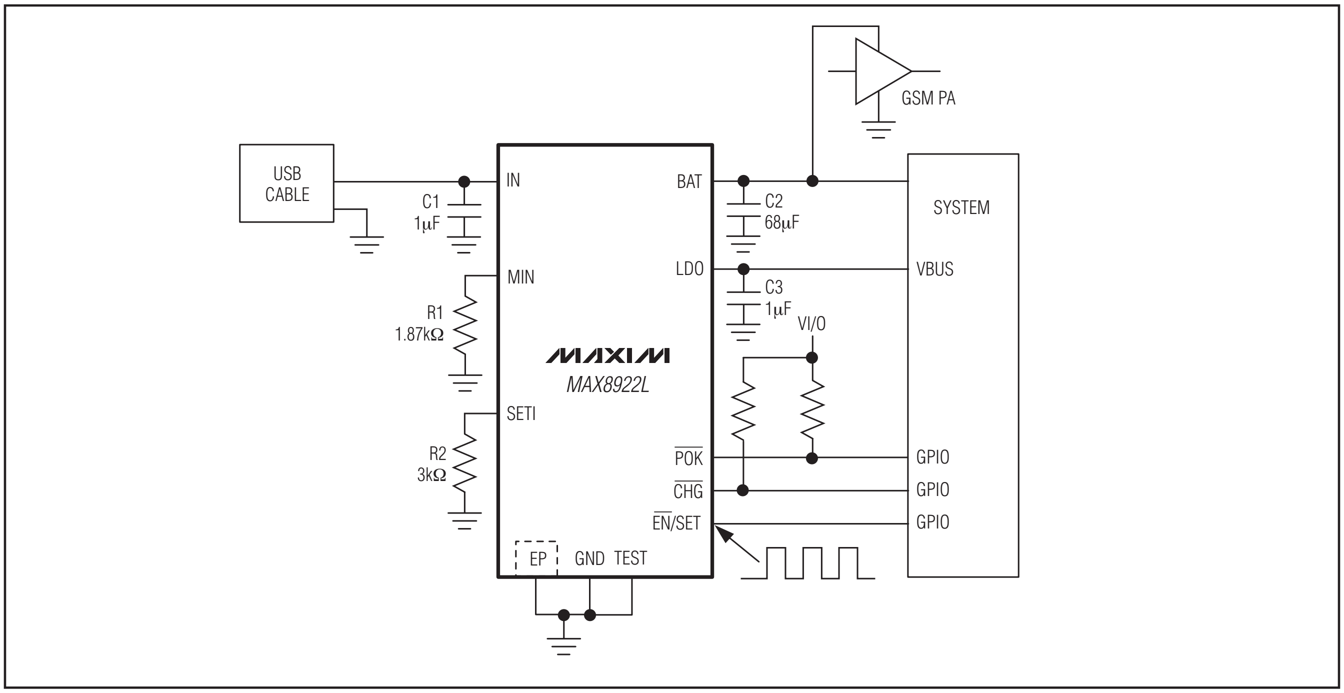


Figure 6. GSM Test Mode

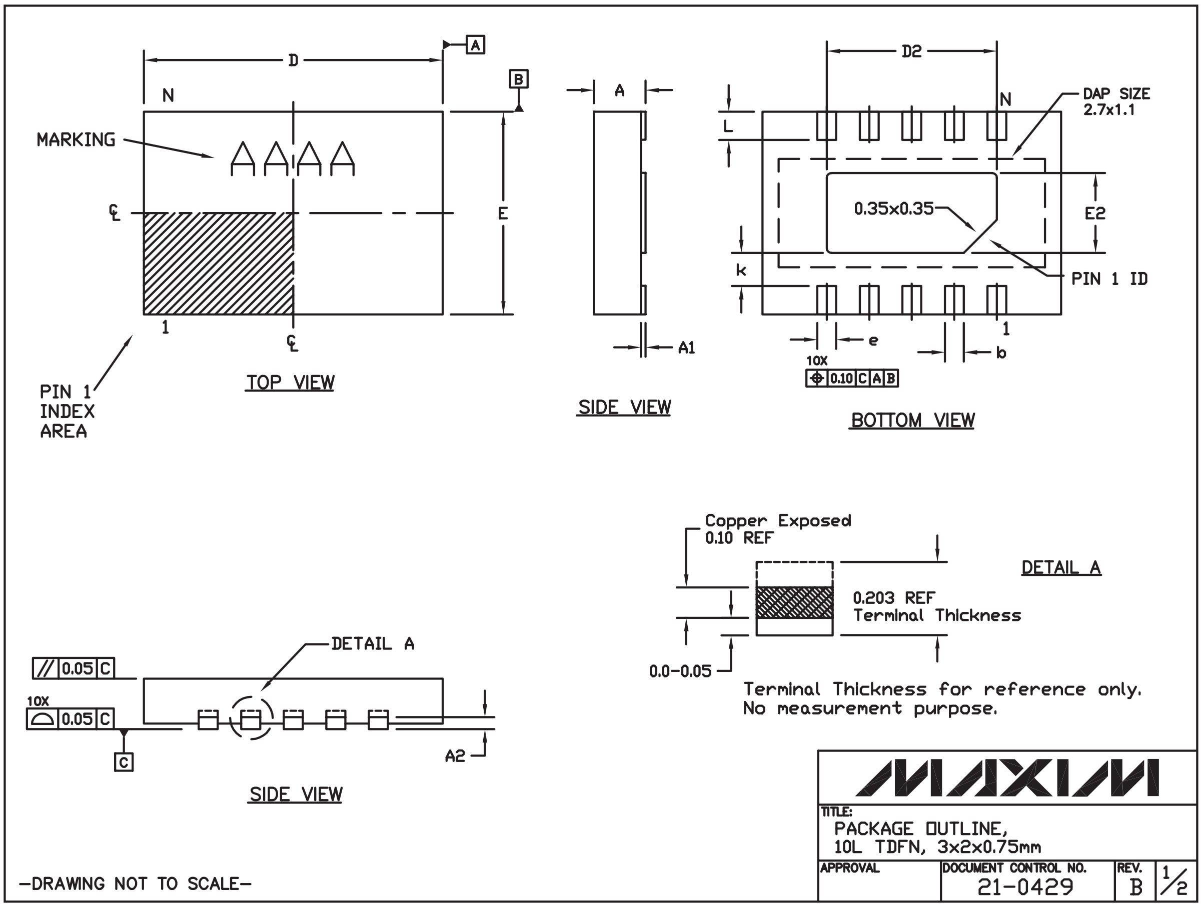
Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
10 TDFN-EP	T1032N-1	21-0429



30V Li+ Linear Battery Charger with GSM Test Mode in 3mm x 2mm TDFN

Package Information (continued)

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

NOTES:
1. N IS THE TOTAL NUMBER OF LEADS.
2. ND AND NE REFER TO THE NUMBER OF TERMINALS OF EACH D AND E SIDE RESPECTIVELY.
3. REFER TO JEDEC MO-229(WECD-2) WITH VARIATION OF D2, E2 & L.
4. WARPAGE SHALL NOT EXCEED 0.10 mm.
5. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS. COPLANARITY SHALL NOT EXCEED 0.08 mm.
6. PKG. LENGTH/PKG. WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
8. MARKING SHOWN IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
9. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND PbFREE (+) PKG. CODES.

COMMON DIMENSIONS

SYMBOL	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
A1	0.0		0.05
A2	0.10 REF.		
D	2.90	3.00	3.10
E	1.90	2.00	2.10
D2	1.90	2.00	2.10
E2	0.80	0.90	1.00
N	10		
b	0.25±0.05		
e	0.50 REF		
L	0.20	0.30	0.40
PKG. CODE: T1032N-1			

-DRAWING NOT TO SCALE-

MAXIM

TITLE: PACKAGE OUTLINE, 10L TDFN, 3x2x0.75mm

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0429	B	2/2