

# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## General Description

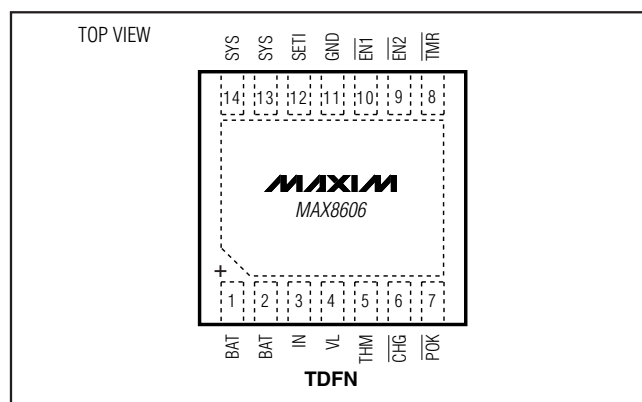
The MAX8606 complete 1-cell Li+ battery charge-management IC operates from either a USB port or AC adapter. It integrates a battery disconnect switch, current-sense circuit, PMOS pass element, and thermal-regulation circuitry, while eliminating the external reverse-blocking Schottky diode, to create a simple and small charging solution. The charging sequence initiates from power-OK indication, through prequalification, fast-charge, top-off charge, and finally charging-complete indication for single-cell Li+ batteries. Charging is controlled using constant current, constant voltage, or constant die-temperature (CCCCTJ) regulation for safe operation in handhelds.

Two logic inputs ( $\overline{\text{EN1}}$  and  $\overline{\text{EN2}}$ ) select suspend mode, 100mA, 500mA, or  $\leq 1\text{A}$  input current limits to suit USB requirements. Proprietary thermal-regulation circuitry limits the die temperature to  $+100^\circ\text{C}$  to prevent excessive heat on the system PC board. Additional safety features include an NTC thermistor input (THM) and internal timers to protect the battery. A 3.5V to 4.2V SYS output, in conjunction with the low- $R_{\text{DS(on)}}$  battery switch, powers the system even when the battery is deeply discharged or not installed. The IC also offers a  $+3.3\text{V}/500\mu\text{A}$  output (VL), a charging status flag (CHG), and an input-supply detection flag (POK). The MAX8606 operates from a  $+4.25\text{V}$  to  $+5.5\text{V}$  supply and includes undervoltage lockout below  $+3.4\text{V}$  and over-voltage protection up to  $+14\text{V}$ .

## Applications

Cellular Phones, Smartphones, PDAs  
Digital Cameras, MP3 Players  
USB Appliances, Charging Cradles and Docks

## Pin Configuration



## Features

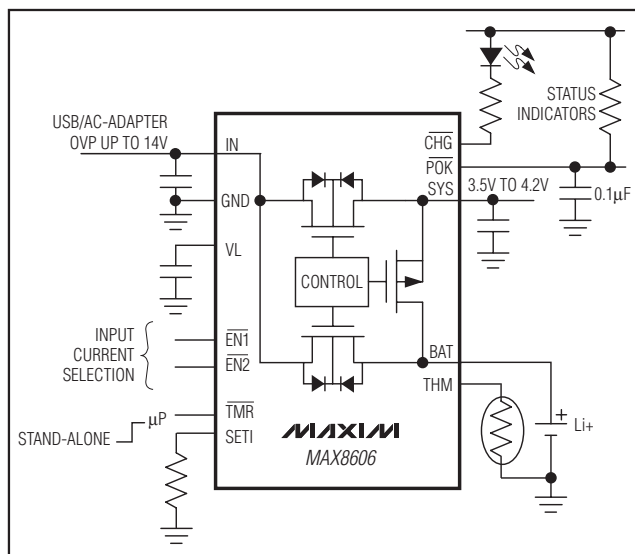
- ◆ Small 3mm x 3mm Thermally Enhanced TDFN Package (0.8mm max height)
- ◆ USB-Compliant Suspend Mode (20μA)
- ◆ Selectable 100mA, 500mA, and Up to 1A Input Current Limits
- ◆ USB or AC Adapter Input
- ◆ +6V to +14V Input Overvoltage Protection
- ◆ Input UVLO Below +4V Rising (3.5V Falling)
- ◆ Automatic Current Sharing Between Battery Charging and System
- ◆ Die Temperature Regulation ( $+100^\circ\text{C}$ )
- ◆ Prequal, Fast-Charge, and Top-Off Timers
- ◆ Low Dropout Voltage, 250mV at 0.5A
- ◆ NTC Thermistor Input
- ◆ Charge Status and Input-Supply Detection Flags

## Ordering Information

| PART        | TEMP RANGE                                 | PIN-PACKAGE                 | TOP MARK |
|-------------|--------------------------------------------|-----------------------------|----------|
| MAX8606ETD+ | $-40^\circ\text{C}$ to $+85^\circ\text{C}$ | 14 TDFN 3mm x 3mm (T1433-1) | AAF      |

+Denotes lead-free/RoHS-compliant package.

## Typical Operating Circuit



# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## ABSOLUTE MAXIMUM RATINGS

|                                                                                          |               |
|------------------------------------------------------------------------------------------|---------------|
| IN to GND .....                                                                          | -0.3V to +16V |
| BAT, SYS, $\overline{\text{EN1}}$ , $\overline{\text{EN2}}$ , POK, CHG, TMR to GND ..... | -0.3V to +6V  |
| VL, SETI, THM to GND .....                                                               | -0.3V to +4V  |
| SYS to BAT .....                                                                         | -0.3V to +6V  |
| VL to IN .....                                                                           | -16V to +0.3V |
| IN to BAT Current .....                                                                  | 1.0ARMS       |
| IN to SYS Current .....                                                                  | 1.0ARMS       |
| BAT to SYS Current .....                                                                 | 1.0ARMS       |
| BAT Short-Circuit Duration .....                                                         | Continuous    |

|                                                                                          |                                             |
|------------------------------------------------------------------------------------------|---------------------------------------------|
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )                               |                                             |
| 14-Pin 3mm x 3mm TDFN (derate 24.4mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ..... | 1951.2mW                                    |
| Operating Temperature Range .....                                                        | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| Junction Temperature Range .....                                                         | $-40^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Storage Temperature Range .....                                                          | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature (soldering, 10s) .....                                                  | $+300^\circ\text{C}$                        |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{\text{IN}} = 5.0\text{V}$ ,  $V_{\text{BAT}} = 3.3\text{V}$ ,  $\overline{\text{EN1}} = \overline{\text{EN2}} = \text{GND}$ ,  $R_{\text{SET1}} = 23.58\text{k}\Omega$ ,  $C_{\text{VL}} = 0.1\mu\text{F}$ ,  $C_{\text{SYS}} = 4.7\mu\text{F}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                        | CONDITIONS                                       |                       | MIN  | TYP  | MAX  | UNITS |
|----------------------------------|--------------------------------------------------|-----------------------|------|------|------|-------|
| IN                               |                                                  |                       |      |      |      |       |
| IN Voltage Range                 |                                                  |                       | 0    |      | 14   | V     |
| IN Operating Voltage Range       | (Note 2)                                         |                       | 4.25 |      | 5.50 | V     |
| IN Undervoltage Threshold        | VIN rising, 500mV hysteresis (typ)               |                       | 3.9  | 4.0  | 4.1  | V     |
| IN Overvoltage Threshold         | VIN rising, 100mV hysteresis (typ)               |                       | 5.6  | 5.8  | 6.0  | V     |
| IN Supply Current                | Charging, IBAT = ISYS = 0mA                      |                       |      | 1.2  | 3.0  | mA    |
|                                  | Suspend, EN1 = EN2 = high, IVL = 0mA             |                       |      | 20   | 40   | μA    |
| IN to BAT Switch Leakage         | VIN = 14V, BAT = GND                             | TA = +25°C            |      | 0.1  | 10   | μA    |
|                                  |                                                  | TA = +85°C            |      | 0.5  |      |       |
| SYS                              |                                                  |                       |      |      |      |       |
| SYS Regulated Voltage            | ISYS = 0mA, VBAT = 3.3V                          |                       | 3.4  | 3.5  | 3.6  | V     |
| SYS Current Limit                | VSYS = 3.3V                                      | EN1 = low, EN2 = low  | 90   | 95   | 100  | mA    |
|                                  |                                                  | EN1 = low, EN2 = high | 450  | 475  | 500  |       |
|                                  |                                                  | EN1 = high, EN2 = low | 675  | 712  | 750  |       |
| SYS Dropout Voltage (VIN - VBAT) | ISYS = 400mA, VSYS = 3.3V, EN1 = low, EN2 = high |                       |      | 350  | 700  | mV    |
| SYS Load Regulation              | ISYS = 1mA to 675mA, EN1 = high, EN2 = low       |                       |      | 10   |      | mV    |
| BAT                              |                                                  |                       |      |      |      |       |
| BAT Regulation Voltage           | IBAT = 0mA                                       | TA = +25°C            | 4.18 | 4.20 | 4.22 | V     |
|                                  |                                                  | TA = -40°C to +85°C   | 4.16 | 4.20 | 4.24 |       |
| Maximum Charging Current         |                                                  |                       | 1    |      |      | A     |
| BAT Charging Current             | EN1 = low, EN2 = low                             | ISYS = 0mA            | 87   | 95   | 100  | mA    |
|                                  |                                                  | ISYS = 50mA           |      | 45   |      |       |
|                                  | EN1 = low, EN2 = high                            | ISYS = 0mA            | 450  | 475  | 500  |       |
|                                  |                                                  | ISYS = 250mA          |      | 225  |      |       |
|                                  | EN1 = high, EN2 = low                            | ISYS = 0mA            | 675  | 712  | 750  |       |
|                                  |                                                  | ISYS = 375mA          |      | 337  |      |       |

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MAX8606

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN} = 5.0V$ ,  $V_{BAT} = 3.3V$ ,  $\overline{EN1} = \overline{EN2} = GND$ ,  $R_{SET1} = 23.58k\Omega$ ,  $C_{VL} = 0.1\mu F$ ,  $C_{SYS} = 4.7\mu F$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                                             | CONDITIONS                                                             |                                                                                | MIN   | TYP   | MAX   | UNITS |
|-----------------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------|-------|-------|-------|
| BAT Prequal Current                                                   | V <sub>BAT</sub> = 2.0V                                                | $\overline{EN1}$ = low, $\overline{EN2}$ = low, I <sub>SYS</sub> = 0mA         | 87    | 95    | 100   | mA    |
|                                                                       |                                                                        | $\overline{EN1}$ = low, $\overline{EN2}$ = high, I <sub>SYS</sub> = 0 to 350mA | 95    |       |       |       |
|                                                                       |                                                                        | $\overline{EN1}$ = high, $\overline{EN2}$ = low, I <sub>SYS</sub> = 0 to 575mA | 95    |       |       |       |
| Soft-Start Time                                                       |                                                                        |                                                                                | 1.5   |       |       | ms    |
| BAT Prequal Threshold                                                 | V <sub>BAT</sub> rising, 150mV hysteresis (typ)                        |                                                                                | 2.9   | 3.0   | 3.1   | V     |
| BAT Dropout Voltage (V <sub>IN</sub> - V <sub>BAT</sub> )             | V <sub>BAT</sub> = 4.1V, I <sub>BAT</sub> = 400mA                      |                                                                                |       | 200   | 400   | mV    |
| BAT Short-Circuit Current Limit                                       | BAT = GND                                                              |                                                                                | 70    | 95    | 120   | mA    |
| BAT to SYS Switch R <sub>ON</sub>                                     | V <sub>BAT</sub> = 3.5V, V <sub>SYS</sub> = 3.4V, V <sub>IN</sub> = 0V |                                                                                |       | 50    | 100   | mΩ    |
| BAT to SYS Switch Threshold                                           | BAT rising, 160mV hysteresis (typ)                                     |                                                                                | 3.4   | 3.5   | 3.6   | V     |
| Battery-Removal Threshold                                             | BAT rising, 210mV hysteresis (typ)                                     |                                                                                | 4.5   | 4.75  | 5.0   | V     |
| BAT Leakage Current                                                   | V <sub>IN</sub> = 0V                                                   | T <sub>A</sub> = +25°C                                                         |       | 0.1   | 10    | μA    |
|                                                                       |                                                                        | T <sub>A</sub> = +85°C                                                         |       | 0.1   |       |       |
|                                                                       | V <sub>IN</sub> = 2.4V                                                 | T <sub>A</sub> = +25°C                                                         |       | 0.1   | 10    |       |
|                                                                       |                                                                        | T <sub>A</sub> = +85°C                                                         |       | 0.1   |       |       |
|                                                                       | $\overline{EN1}$ = high, $\overline{EN2}$ = high                       | T <sub>A</sub> = +25°C                                                         | -10   | 0.1   | +10   |       |
|                                                                       |                                                                        | T <sub>A</sub> = +85°C                                                         |       | 0.1   |       |       |
| VL                                                                    |                                                                        |                                                                                |       |       |       |       |
| VL Output Voltage                                                     | I <sub>VL</sub> = 0 to 500μA                                           |                                                                                | 3.1   | 3.3   | 3.5   | V     |
| VL Shutdown Voltage                                                   | V $\overline{EN1}$ = V $\overline{EN2}$ = 5V                           |                                                                                |       | 0     |       | V     |
| THM                                                                   |                                                                        |                                                                                |       |       |       |       |
| THM Internal Pullup Resistance                                        |                                                                        |                                                                                |       | 10    |       | kΩ    |
| THM Resistance Threshold, Hot                                         | 10% hysteresis                                                         |                                                                                | 3.72  | 3.93  | 4.13  | kΩ    |
| THM Resistance Threshold, Cold                                        | 10% hysteresis                                                         |                                                                                | 26.6  | 28.3  | 30.0  | kΩ    |
| THM Resistance Threshold, Disabled                                    | 70% hysteresis                                                         |                                                                                | 274   | 305   | 336   | Ω     |
| SETI                                                                  |                                                                        |                                                                                |       |       |       |       |
| SETI Servo Voltage                                                    | $\overline{EN1}$ = low, $\overline{EN2}$ = low                         |                                                                                |       | 0.28  |       | V     |
|                                                                       | $\overline{EN1}$ = low, $\overline{EN2}$ = high                        |                                                                                |       | 1.4   |       |       |
|                                                                       | $\overline{EN1}$ = high, $\overline{EN2}$ = low                        |                                                                                |       | 2.1   |       |       |
| SETI Resistance Range                                                 |                                                                        |                                                                                | 17.68 | 23.58 | 35.36 | kΩ    |
| POK                                                                   |                                                                        |                                                                                |       |       |       |       |
| $\overline{POK}$ Trip Threshold (V <sub>IN</sub> - V <sub>BAT</sub> ) | 4.1V < V <sub>IN</sub> < 5.6V, V <sub>BAT</sub> = 4.1V                 | V <sub>IN</sub> rising                                                         | 150   | 250   | 350   | mV    |
|                                                                       |                                                                        | V <sub>IN</sub> falling                                                        | 5     | 55    | 125   |       |
| $\overline{POK}$ Voltage, Low                                         | I $\overline{POK}$ = 5mA                                               |                                                                                |       | 0.05  | 0.2   | V     |
| $\overline{POK}$ Leakage Current, High                                | V $\overline{POK}$ = 6V                                                | T <sub>A</sub> = +25°C                                                         |       | 0.01  | 1     | μA    |
|                                                                       |                                                                        | T <sub>A</sub> = +85°C                                                         |       | 0.01  |       |       |

# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN} = 5.0V$ ,  $V_{BAT} = 3.3V$ ,  $\overline{EN1} = \overline{EN2} = GND$ ,  $R_{SET1} = 23.58k\Omega$ ,  $C_{VL} = 0.1\mu F$ ,  $C_{SYS} = 4.7\mu F$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                | CONDITIONS                                                         |                        | MIN  | TYP  | MAX  | UNITS |
|------------------------------------------|--------------------------------------------------------------------|------------------------|------|------|------|-------|
| CHG                                      |                                                                    |                        |      |      |      |       |
| Full-Battery Detection Current Threshold | I <sub>BAT</sub> falling                                           |                        | 30   | 50   | 70   | mA    |
| CHG Voltage, Low                         | I <sub>CHG</sub> = 5mA                                             |                        |      | 0.05 | 0.02 | V     |
| CHG Leakage Current, High                | V <sub>CHG</sub> = 6V                                              | T <sub>A</sub> = +25°C |      | 0.01 | 1    | μA    |
|                                          |                                                                    | T <sub>A</sub> = +85°C |      | 0.01 |      |       |
| EN1, EN2, TMR                            |                                                                    |                        |      |      |      |       |
| Logic Input Leakage Current              | V <sub>TMR</sub> = V <sub>EN1</sub> = V <sub>EN2</sub> = 0 to 5.5V | T <sub>A</sub> = +25°C |      | 0.01 | 1    | μA    |
|                                          |                                                                    | T <sub>A</sub> = +85°C |      | 0.01 |      |       |
| Logic Input Low Voltage                  |                                                                    |                        |      | 0.4  |      | V     |
| Logic Input High Voltage                 |                                                                    |                        | 1.6  |      |      | V     |
| THERMAL LIMIT                            |                                                                    |                        |      |      |      |       |
| Thermal-Regulation Threshold             |                                                                    |                        |      | +100 |      | °C    |
| Thermal-Regulation Gain                  | T <sub>J</sub> to I <sub>BAT</sub> , T <sub>J</sub> > +100°C       |                        |      | -50  |      | mA/°C |
| TIMER                                    |                                                                    |                        |      |      |      |       |
| Oscillator Accuracy                      |                                                                    |                        | 112  | 140  | 168  | kHz   |
| Overvoltage Turn-On Delay                |                                                                    |                        |      | 800  |      | ms    |
| Prequal Fault Timer                      |                                                                    |                        | 24   | 30   | 36   | min   |
| Fast-Charge Fault Timer                  |                                                                    |                        |      | 480  |      | min   |
| Top-Off Timer                            |                                                                    |                        |      | 30   |      | min   |
| CHG Blinking Rate                        | In fault state, 50% duty                                           |                        | 1.68 | 2.10 | 2.52 | Hz    |

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

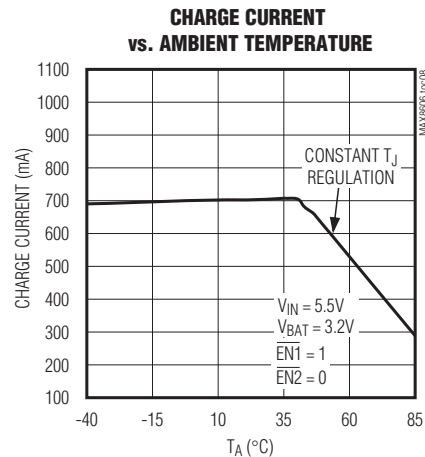
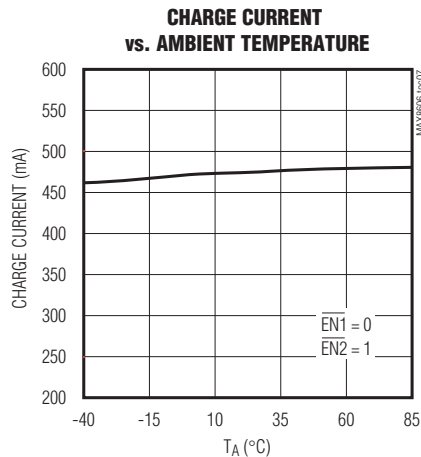
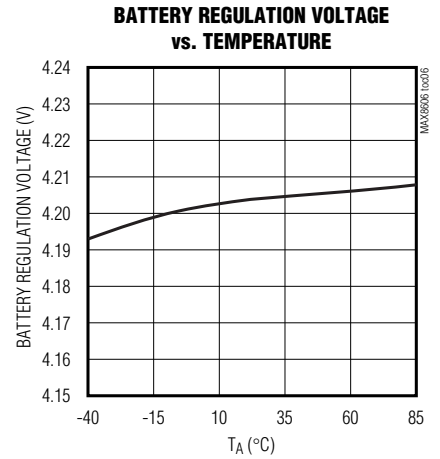
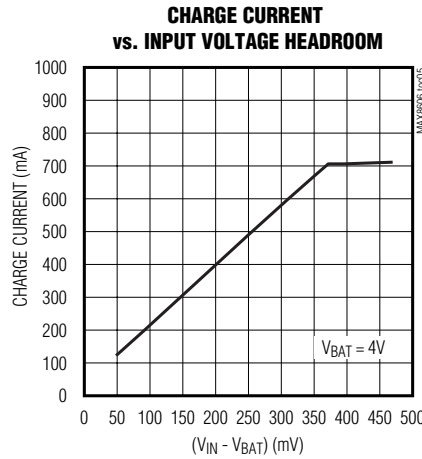
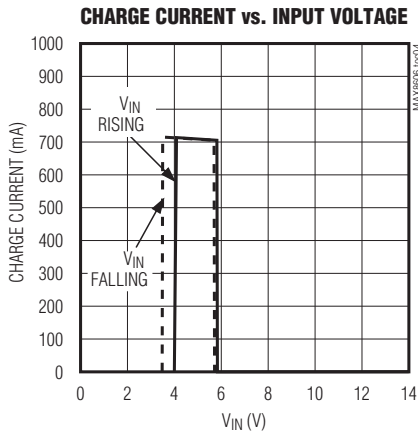
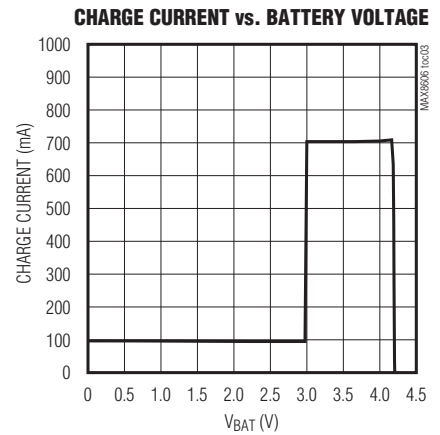
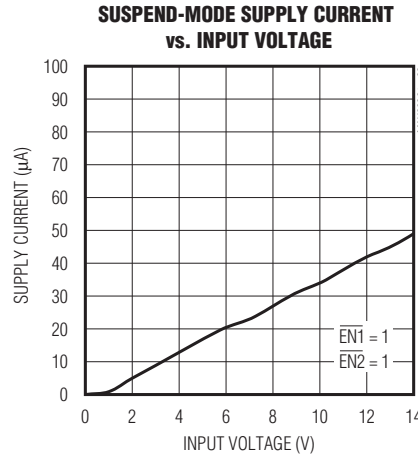
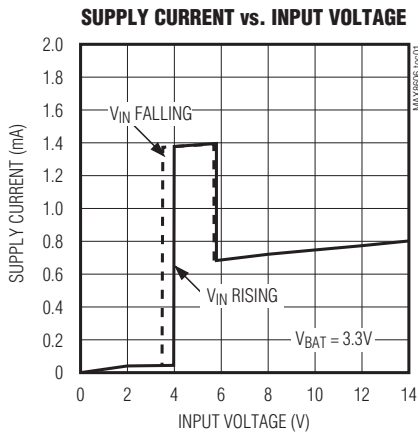
**Note 2:** Guaranteed by undervoltage and overvoltage threshold testing.

# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## Typical Operating Characteristics

( $V_{IN} = +5V$ ,  $V_{BAT} = 3.6V$ ,  $I_{SYS} = 0$ ,  $\overline{EN1} = 1$ ,  $\overline{EN2} = 0$ , circuit of Figure 3,  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX8606



# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## Pin Description

| PIN    | NAME                    | FUNCTION                                                                                                                                                                                                                                                                                                                        |
|--------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1, 2   | BAT                     | Battery Connection. The IC delivers charging current and monitors battery voltage using BAT. Connect both BAT outputs together externally. During suspend mode, BAT is internally connected to SYS.                                                                                                                             |
| 3      | IN                      | Supply Voltage Input. Connect IN to a 4.25V to 5.5V supply. Charging is suspended if $V_{IN}$ exceeds 6V. Bypass IN to GND with a 4.7μF or larger ceramic capacitor.                                                                                                                                                            |
| 4      | VL                      | +3.3V Output Voltage and Logic Supply. VL is regulated to +3.3V and is capable of sourcing 500μA to provide power for external circuits. Bypass VL to GND with a 0.1μF or larger ceramic capacitor. VL is internally pulled to GND during suspend mode.                                                                         |
| 5      | THM                     | Thermistor Input. Connect a 10kΩ NTC thermistor from THM to GND in close proximity to the battery to monitor the battery temperature. The IC suspends charging when the temperature is outside the hot and cold limits. Connect THM to GND to disable the thermistor monitoring function.                                       |
| 6      | $\overline{\text{CHG}}$ | Charging Status Output. $\overline{\text{CHG}}$ is an open-drain output that goes low when the battery is charging. $\overline{\text{CHG}}$ goes high impedance when the charge current drops below 50mA (typ) and the battery voltage is 4.2V (typ). $\overline{\text{CHG}}$ is high impedance when the IC is in suspend mode. |
| 7      | $\overline{\text{POK}}$ | Power-OK Monitor. $\overline{\text{POK}}$ is an open-drain output that pulls low when a valid charging source is detected at IN.                                                                                                                                                                                                |
| 8      | $\overline{\text{TMR}}$ | Timer-Selection Input. Drive $\overline{\text{TMR}}$ high to enable the microprocessor mode where the charge times are determined by an external device. Drive $\overline{\text{TMR}}$ low to use the internal prequal, fast-charge, and top-off timers.                                                                        |
| 9      | $\overline{\text{EN2}}$ | Charge-Current Selection Input. Drive $\overline{\text{EN2}}$ high or low to select the charge current or to put the MAX8606 into suspend mode (see Table 1).                                                                                                                                                                   |
| 10     | $\overline{\text{EN1}}$ | Charge-Current Selection Input. Drive $\overline{\text{EN1}}$ high or low to select the charge current or to put the MAX8606 into suspend mode (see Table 1).                                                                                                                                                                   |
| 11     | GND                     | Ground. Connect directly to exposed paddle under the IC.                                                                                                                                                                                                                                                                        |
| 12     | SETI                    | Charge-Current Programming Input. Connect a resistor from SETI to GND to set the maximum charging current. $R_{SETI}$ must be between 17.68kΩ and 35.36kΩ.                                                                                                                                                                      |
| 13, 14 | SYS                     | System Supply Output. SYS delivers up to 1A <sub>RMS</sub> to power an external system. Bypass SYS to GND with a 4.7μF or larger ceramic capacitor. SYS is connected to BAT through an internal 50mΩ switch when $V_{BAT}$ exceeds 3.5V or when the MAX8606 is in suspend mode.                                                 |
| —      | EP                      | Exposed Paddle. Connect to GND under the IC. Connect to a large ground plane to improve power dissipation.                                                                                                                                                                                                                      |

## Detailed Description

The MAX8606 charger uses current, voltage, and thermal control loops to charge and protect a single Li+ battery cell. It can start the system even when the battery is in deep saturation. The MAX8606 provides a SYS output that supplies the external system with a minimum 3.5V at 1A.

Two active-low enable inputs ( $\overline{\text{EN1}}$  and  $\overline{\text{EN2}}$ ) are supplied to set the SYS and charging current limits. During prequal and fast-charge modes, the  $\overline{\text{CHG}}$  output status flag is pulled low. As the battery voltage approaches

4.2V, the charging current is reduced. When the charging current drops below 50mA and the battery voltage equals 4.2V, the  $\overline{\text{CHG}}$  output goes high impedance, signaling a full battery. At any time during charging, if both  $\overline{\text{EN1}}$  and  $\overline{\text{EN2}}$  are driven high, the charger enters suspend mode, charging stops, and  $\overline{\text{CHG}}$  goes high impedance.

The MAX8606 contains an internal timer to measure the prequal, fast-charge, and top-off charge time. If the battery voltage has not risen above 3V after 30 minutes or has not completed fast-charge in 8 hours, the charger goes into a fault state where the charging is

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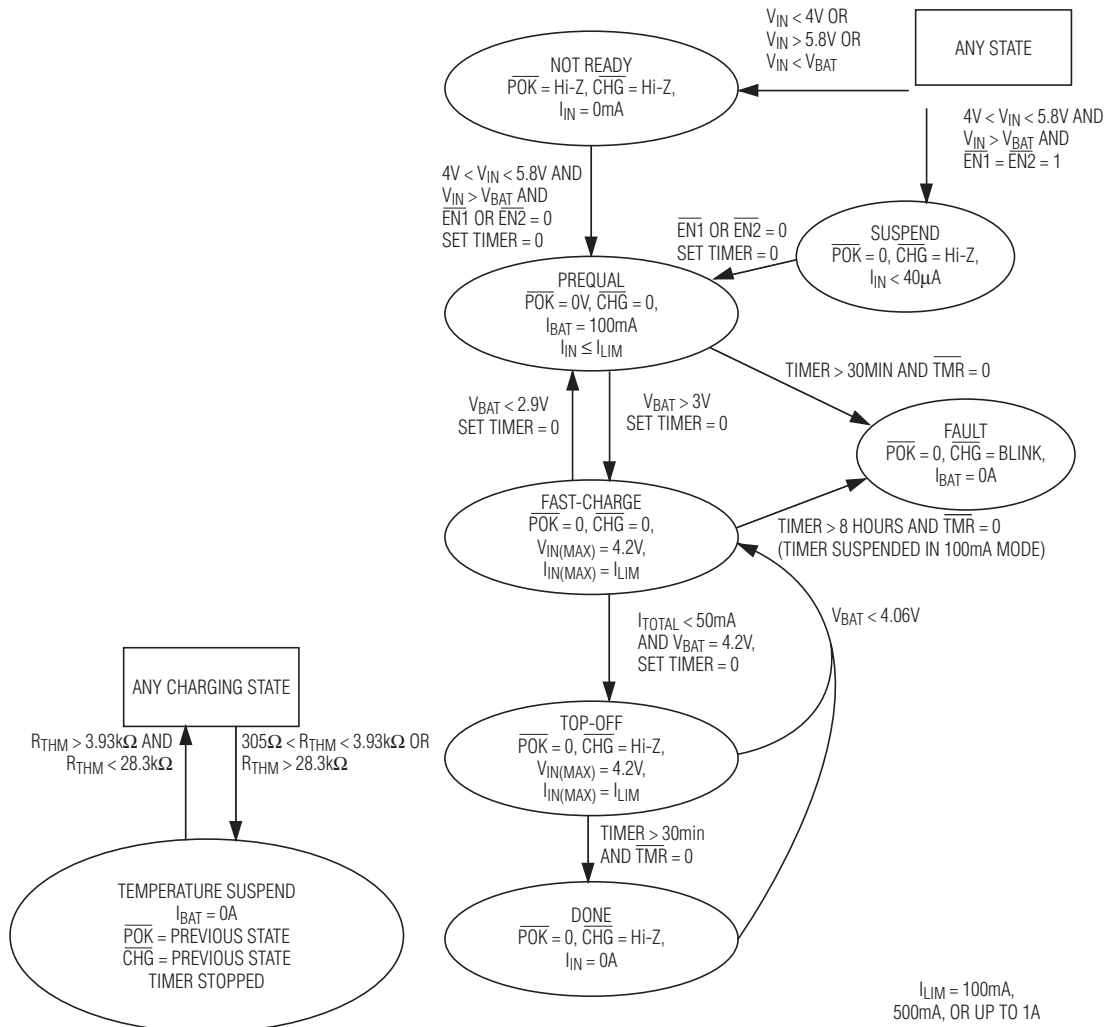


Figure 1. MAX8606 State Diagram

suspended and the  $\overline{\text{CHG}}$  flag turns on and off at 2Hz. Either the input power must be cycled or the suspend mode enabled to clear the fault.

## $\overline{\text{EN1}}$ and $\overline{\text{EN2}}$ Inputs

$\overline{\text{EN1}}$  and  $\overline{\text{EN2}}$  are logic inputs that enable the charger and select the charging current (see Table 1). Drive  $\overline{\text{EN1}}$  and  $\overline{\text{EN2}}$  high to place the IC in suspend mode.

# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

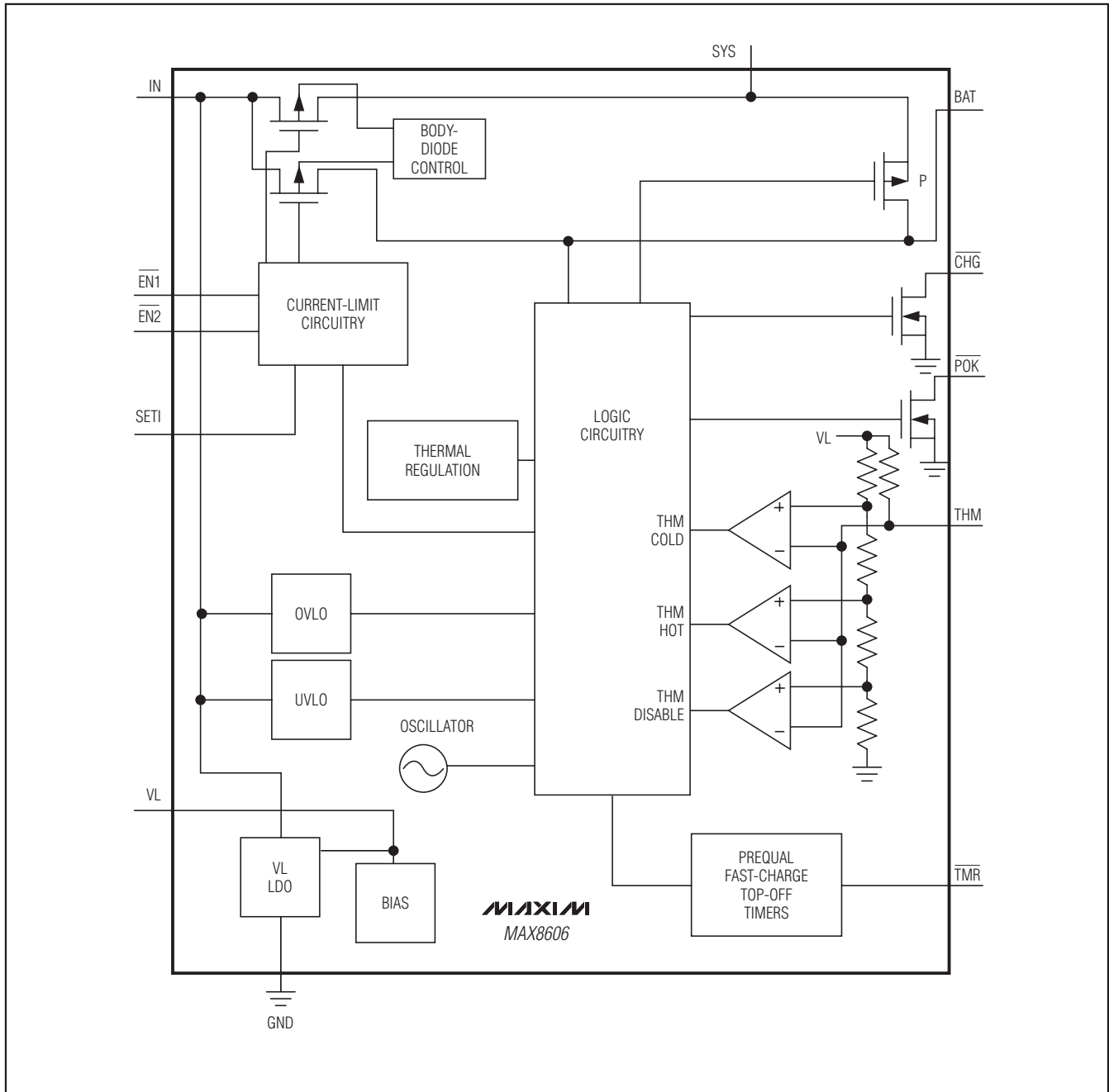


Figure 2. MAX8606 Block Diagram

# USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN

## VL Internal Voltage Regulator

The MAX8606 linear charger contains an internal linear regulator to supply the power for the IC. Bypass VL to GND with a 0.1μF ceramic capacitor. VL is regulated to 3.3V whenever the input voltage is above the battery voltage and can source up to 500μA for external loads.

## CHG Charge-Indicator Output

CHG is an open-drain output that indicates charger status and can be used with an LED. CHG goes low during charging. CHG goes high impedance when VBAT equals 4.2V and the charging current drops below 50mA. When the MAX8606 is used in conjunction with a microprocessor (μP), connect a pullup resistor between CHG and the logic I/O voltage to indicate charge status to the μP. CHG also indicates a timer fault. If the internal prequal or fast-charge timer expires without completing the charge cycle, charging is suspended and the CHG output “blinks” at 2.1Hz.

## 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 1ms for the charger to go from 0mA to the maximum fast-charge current.

## TMR Input

The MAX8606 includes a 30-minute prequalification fault timer, an 8-hour fast-charge fault timer, and a 30-minute top-off timer to terminate the charging cycle. Drive TMR low to enable the internal timers. Drive TMR high to disable the internal timers and allow an external device to determine charge times.

## THM Input

The MAX8606 monitors the battery temperature with an external NTC thermistor that is in close thermal contact with the battery. Select a thermistor resistance that is 10kΩ at +25°C and has a beta of 3500 Kelvins. The IC compares the resistance from THM to GND and suspends charging when it is greater than 28.3kΩ or less than 3.93kΩ, which translates to a battery temperature of 0°C or +50°C, respectively. Connect THM to GND to disable the temperature control function.

## SYS Output

The MAX8606 contains a SYS output that delivers up to 1ARMS at 3.5V to 4.2V to power an external system. Bypass SYS to GND with a 4.7μF or larger ceramic capacitor. When VBAT exceeds 3.5V or when the MAX8606 is in suspend mode, the MAX8606 internally connects SYS to BAT through a 50mΩ switch. When charging a battery, the load on SYS is serviced first and

Table 1. EN1 and EN2 Control

| EN1 | EN2 | MODE                |
|-----|-----|---------------------|
| 0   | 0   | 100mA               |
| 0   | 1   | 500mA               |
| 1   | 0   | 8000 × 2.1V / RSETI |
| 1   | 1   | Suspend             |

the remaining available current goes to charge the battery. SYS is connected to BAT when VIN is not valid.

## POK

The MAX8606 contains an open-drain POK output that goes low when a valid input source is detected at IN. A valid input source is one whose voltage is between 4V and 5.8V and exceeds the battery voltage by 250mV. After a valid input has been established, charging is sustained with inputs as low as 3.5V as long as the input voltage remains above the battery voltage by at least 55mV. POK is high impedance otherwise.

## Applications Information

### Charge-Current Selection

For USB applications, the charging current is internally limited to 100mA or 500mA. For wall-cube applications requiring a different current requirement, set the charging current with an external resistor from SETI to GND (RSETI). Calculate RSETI as follows:

$$RSETI = 8000 \times 2.1V / (I_{BAT} + I_{SYS})$$

where EN1 = high and EN2 = low.

The SETI input also enables the user to monitor the charging current. Under fast-charge operation, the SETI voltage regulates to 1.4V (EN1 low and EN2 high) or 2.1V (EN1 high and EN2 low). As the charging current decreases, VSETI decreases. This is due to either the thermal regulation control or voltage regulation control (4.2V) of the MAX8606. VSETI is calculated using the following equation:

$$VSETI = (I_{BAT} + I_{SYS}) \times RSETI / 8000$$

### Thermal Regulation

The MAX8606 features a thermal limit that reduces the charge current when the die temperature exceeds +100°C. As the temperature increases, the IC lowers the charge current by 50mA/°C above +100°C.

### Capacitor Selection

Connect a ceramic capacitor from SYS to GND as close to the IC as possible for proper stability. Use a 4.7μF X5R ceramic capacitor for most applications.

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Connect a 4.7μF ceramic capacitor from IN to GND as close to the IC as possible. Use a larger input bypass capacitor to reduce supply noise.

## Thermal Considerations

The MAX8606 is available in a thermally enhanced TDFN package with exposed paddle. Connect the exposed paddle to a large copper ground plane to provide a good thermal contact between the device and the circuit board. The exposed paddle transfers heat away from the device, allowing the MAX8606 to charge the battery with maximum current while minimizing the increase in die temperature.

## DC Input Sources

The MAX8606 operates from well-regulated DC sources. The full-charging input voltage range is 4.25V to 5.8V. The device survives input voltages up to 14V without damage to the IC. If  $V_{IN}$  is greater than 5.8V (typ), the IC stops charging. An appropriate power supply must provide at least 4.25V when sourcing the desired peak charging current. It also must stay below 5.8V when unloaded.

## Application Circuits

### Stand-Alone Li+ Charger

The MAX8606 provides a complete Li+ charging solution. Figure 3 shows the MAX8606 as a stand-alone Li+ battery charger. The 23.58kΩ resistor connected to SET1 sets a charging current of 712mA (typ). The LED indicates when either prequal or fast-charging has begun. When the battery is charged the LED turns off.

### USB Application with AC Adapter

The MAX8606 can be configured for USB applications with an optional AC-adapter input (Figure 4). The p-channel MOSFET disconnects the USB port when the AC adapter is installed. Alternately, the USB port and AC adapter may be excluded from each other by mechanical means, such as using a single connector.

### 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 MAX8606 can be configured to charge a battery at the highest current possible from the host port. Figure 5 shows the MAX8606 as a USB battery charger. To make the circuit compatible with either 100mA or 500mA USB ports, the system software begins at 100mA charging current. The microprocessor then enumerates with the host to determine its current capability. If the host port is capable, the charging current is increased to 475mA to avoid exceeding the 500mA USB specification.

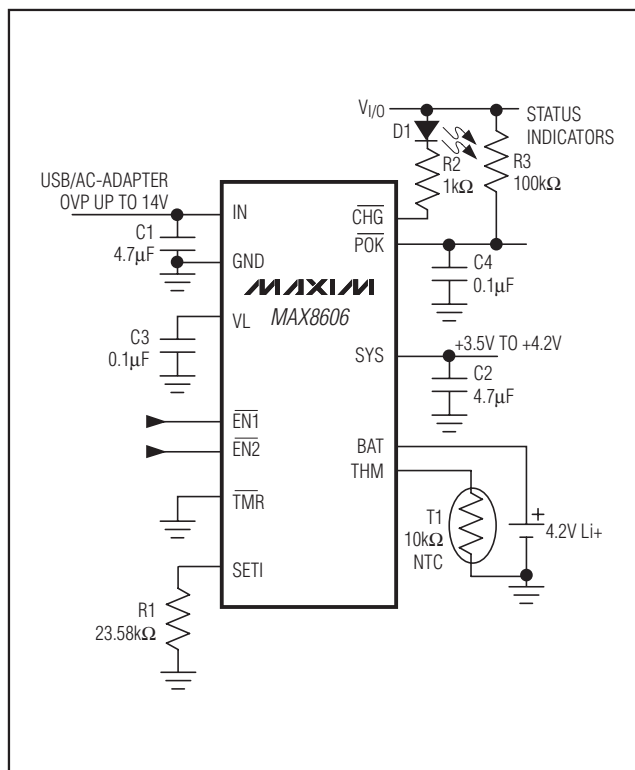


Figure 3. Stand-Alone Application

## 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 BAT 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 MAX8606 evaluation kit to help speed designs.

## Chip Information

PROCESS: BiCMOS

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MAX8606

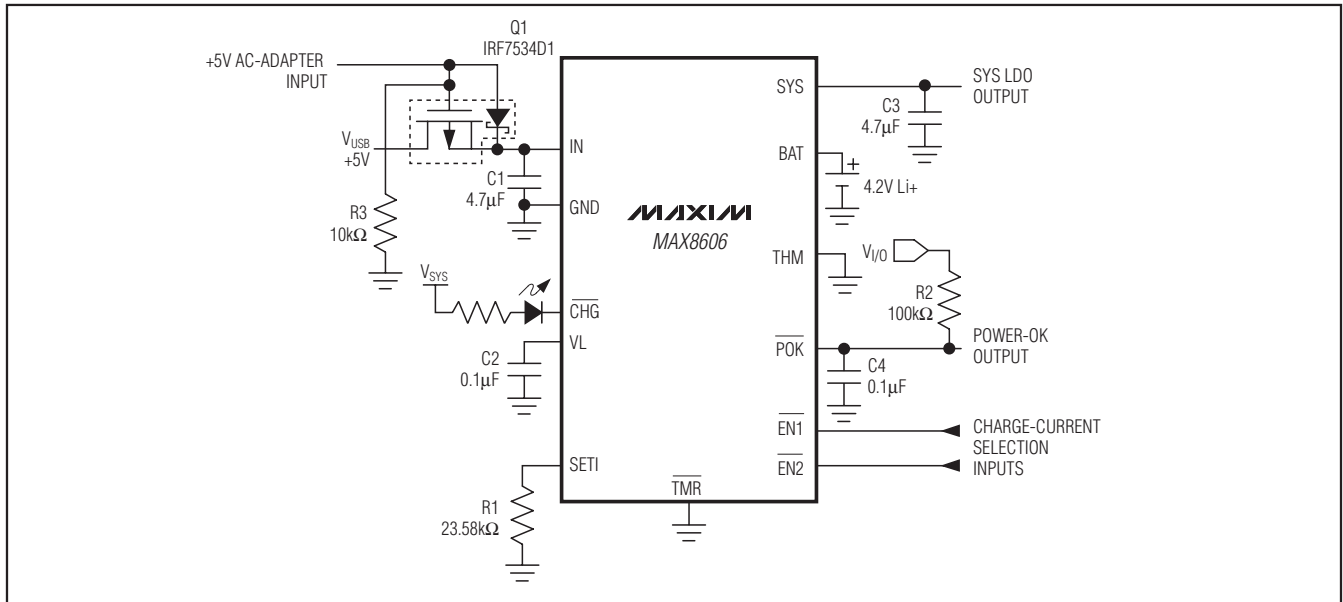


Figure 4. USB Application with AC Adapter

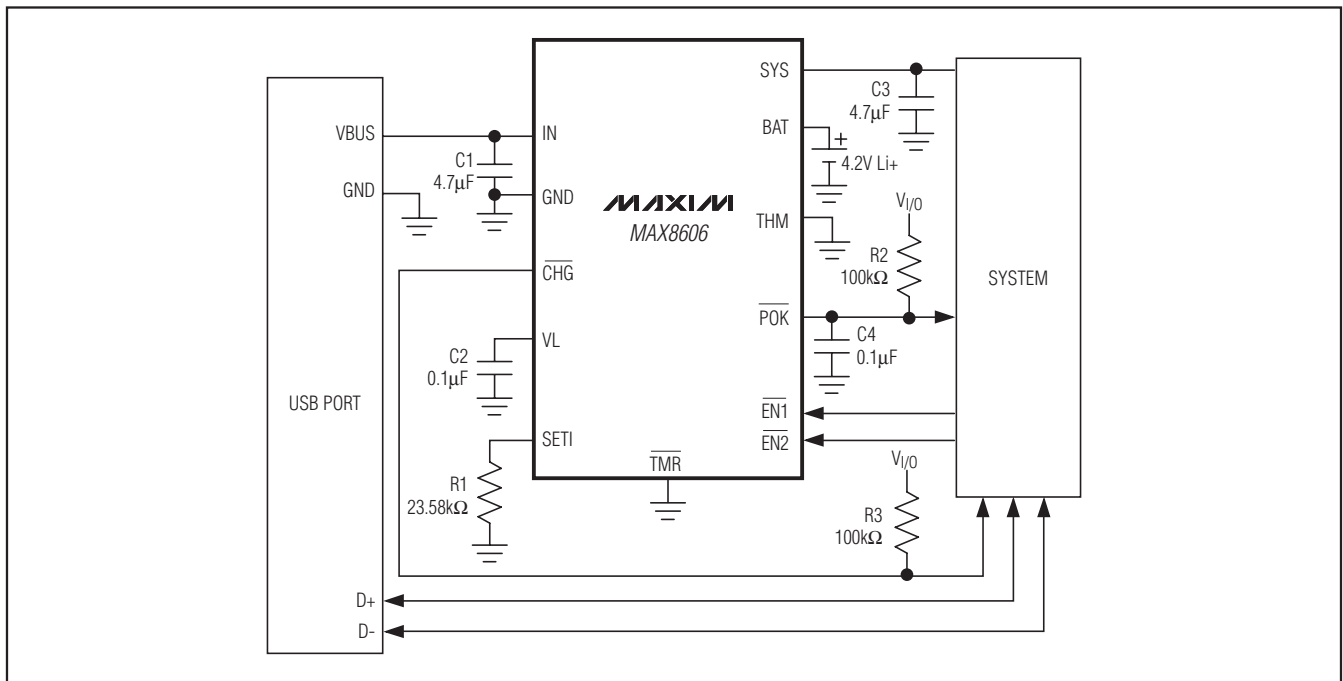


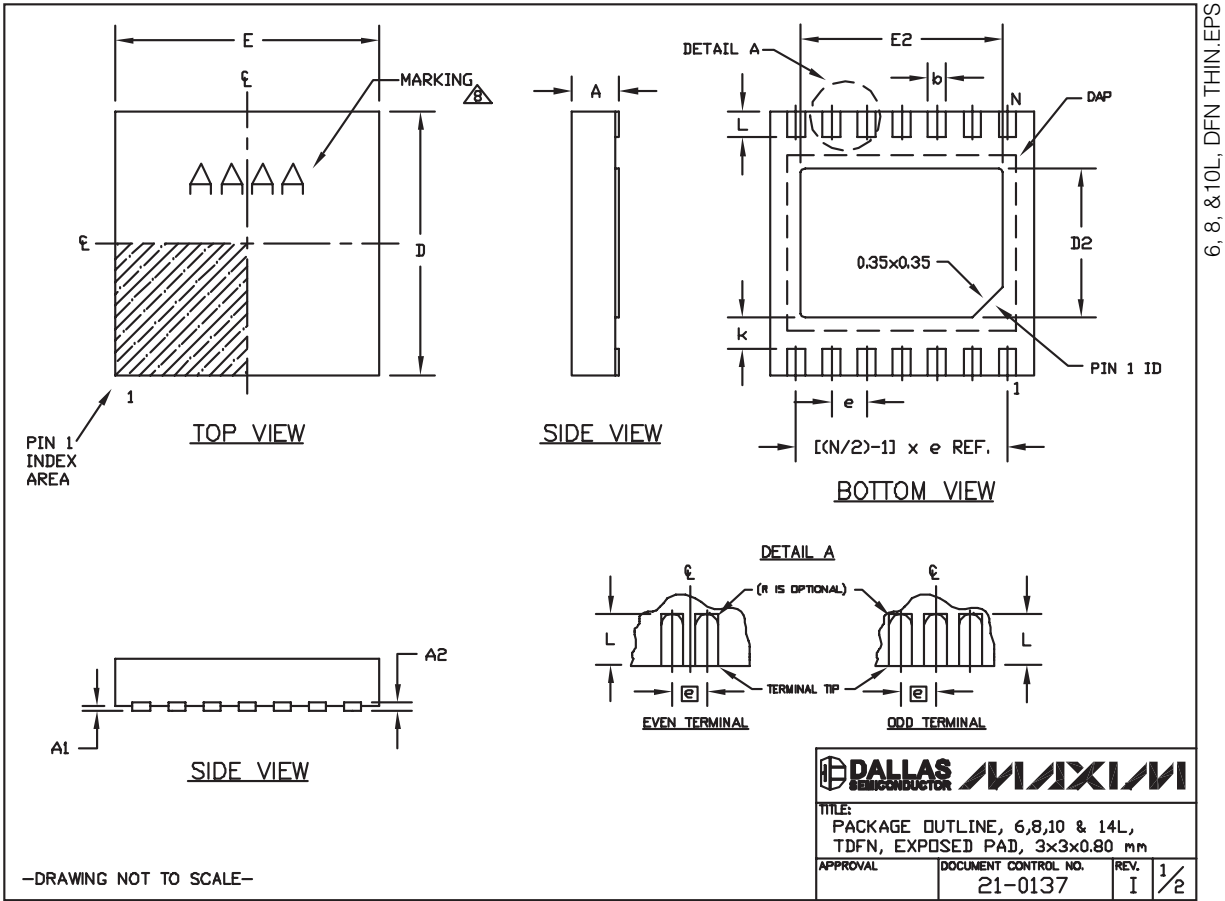
Figure 5. USB Charger Application

# **USB/AC Adapter, Li+ Linear Battery Charger with Integrated 50mΩ Battery Switch in TDFN**

## **Package Information**

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO.            |
|--------------|--------------|-------------------------|
| 14 TDFN      | T2444-4      | <a href="#">21-0137</a> |



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## Package Information (continued)

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

MAX8606

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

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

### NOTES:

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

—DRAWING NOT TO SCALE—

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

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## Revision History

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION                                                                                 | PAGES<br>CHANGED |
|--------------------|------------------|---------------------------------------------------------------------------------------------|------------------|
| 0                  | 8/05             | Initial release                                                                             | —                |
| 1                  | 12/08            | Updated Continuous Power Dissipation and derating factor in <i>Absolute Maximum Ratings</i> | 2                |

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