1.5A Single-chip Li-ion and Li-POL Charge with OVP
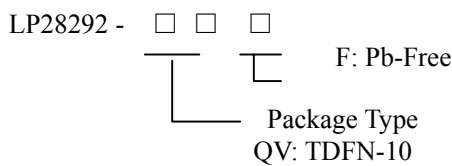
General Description

The LP28292 is a complete constant-current/ constant-voltage linear charger for single cell lithium-ion batteries. Its TDFN-10 package and low external component count make the LP28292 ideally suited for portable applications. Furthermore, the LP28292 is specifically designed to work within USB power specifications. Its have a over voltage protection in input with 6.5V and support over zero voltages of battery can charge enable.

No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be ISET rammed externally with a single resistor. The LP28292 automatically terminates the charge cycle when the charge current drops to 1/10th the ISET rammed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the LP28292 automatically enters a low current state, dropping the battery drain current to less than 2μA. The LP28292 can be put into shutdown mode, reducing the supply current to 25μA.

Other features include charge current monitor, undervoltage lockout, automatic recharge and a status pin to indicate charge termination and the presence of an input voltage.

Features

- Very Low Power Dissipation
- Vin Over Voltage Protection:6V
- Short-circuit protection
- Programmable Charge Current Up to 1500mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Constant-Current/Constant-Voltage Operation with Thermal Regulation* to Maximize Charge Rate Without Risk of Overheating
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- 25μA Supply Current in Shutdown
- Time Pre-charge Conditioning With Safety Timer Reverse Leakage Protection Prevents Battery
- Drainage Charge Current Thermal Regulation Status Outputs for LED or System Interface
- Indicates Charge and Fault Conditions
- Optional Battery Temperature Monitoring Before and During Charge Automatic Sleep Mode for Low-Power
- Consumption Available in 3mm × 3mm TDFN-10 Package
- RoHS Compliant and 100% Lead (Pb)-Free

Order Information

LP28292 - □ □ □

F: Pb-Free

Package Type
QV: TDFN-10

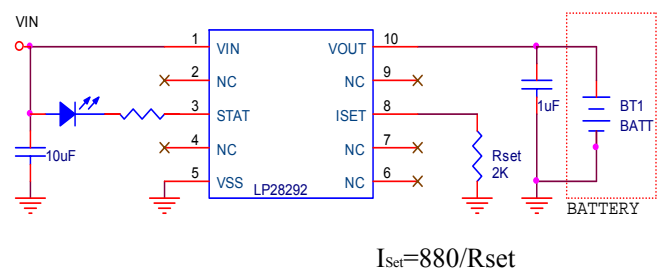## Applications

- ✧ Portable Media Players/MP3 players
- ✧ Cellular and Smart mobile phone
- ✧ PDA/DSC
- ✧ Bluetooth Applications
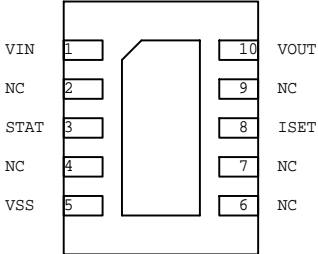
Typical Application Circuit

$I_{Set}=880/Rset$

Marking Information

Please see website.

Functional Pin Description

Package Type	Pin Configurations
TDFN- 10	VIN 1 ... 10 VOUT NC 2 ... 9 NC STAT 3 ... 8 ISET NC 4 ... 7 NC VSS 5 ... 6 NC

Pin Description

PIN	PIN Number	DESCRIPTION
VIN	1,2	VIN is the input power source. Connect to a wall adapter.
STAT	3	Open-Drain Charge Status Output. When the battery is charging, the STAT pin is pulled low by an internal N-channel MOSFET. When the charge cycle is completed, a weak pull-down of approximately 20µA is connected to the STAT pin, indicating an "AC present" condition. When the LP28292 detects an under voltage lockout condition, STAT is forced high impedance.
NC	4,7	No connector.
VSS	5,11	VSS is the connection to system ground.
ISET	9	Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a 1% resistor(R_{PROG}) to ground. When charging in constant-current mode, this pin servos to 1V. In all modes, the voltage on this pin can be used to measure the charge current using the following formula: $I_{BAT} = (V_{PROG}/R_{PROG}) \cdot 880$
VOUT/TS	9	VBAT is the connection to the battery. Typically a 1µF Tantalum capacitor is needed for stability when there is no battery attached. When a battery is attached, only a 0.1µF ceramic capacitor is required. A vision the pin is Vout,B vision the pin is TS.
VOUT	10	VBAT is the connection to the battery. Typically a 1µF Tantalum capacitor is needed for stability when there is no battery attached. When a battery is attached, only a 0.1µF ceramic capacitor is required.
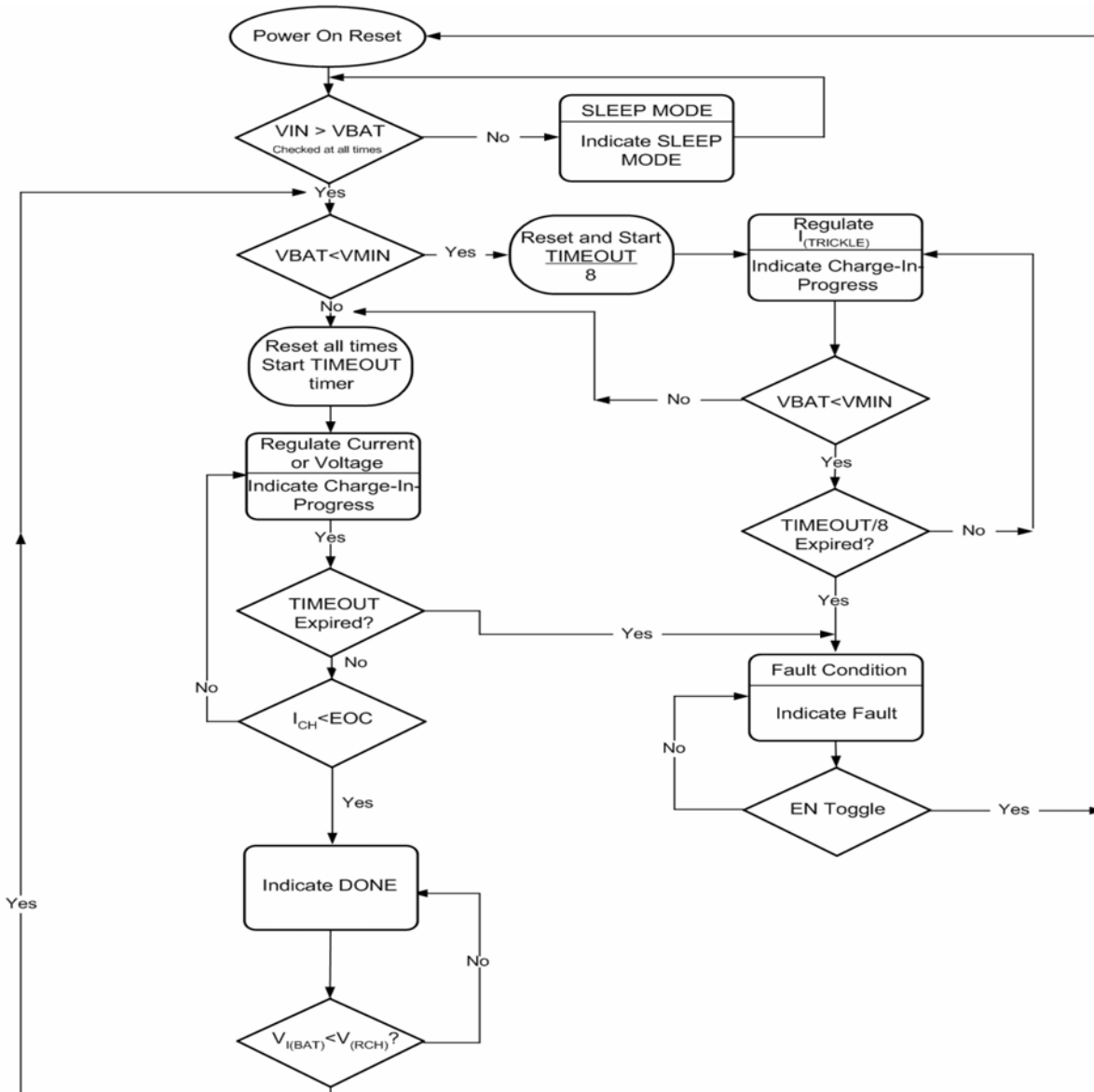
Function Block Diagram
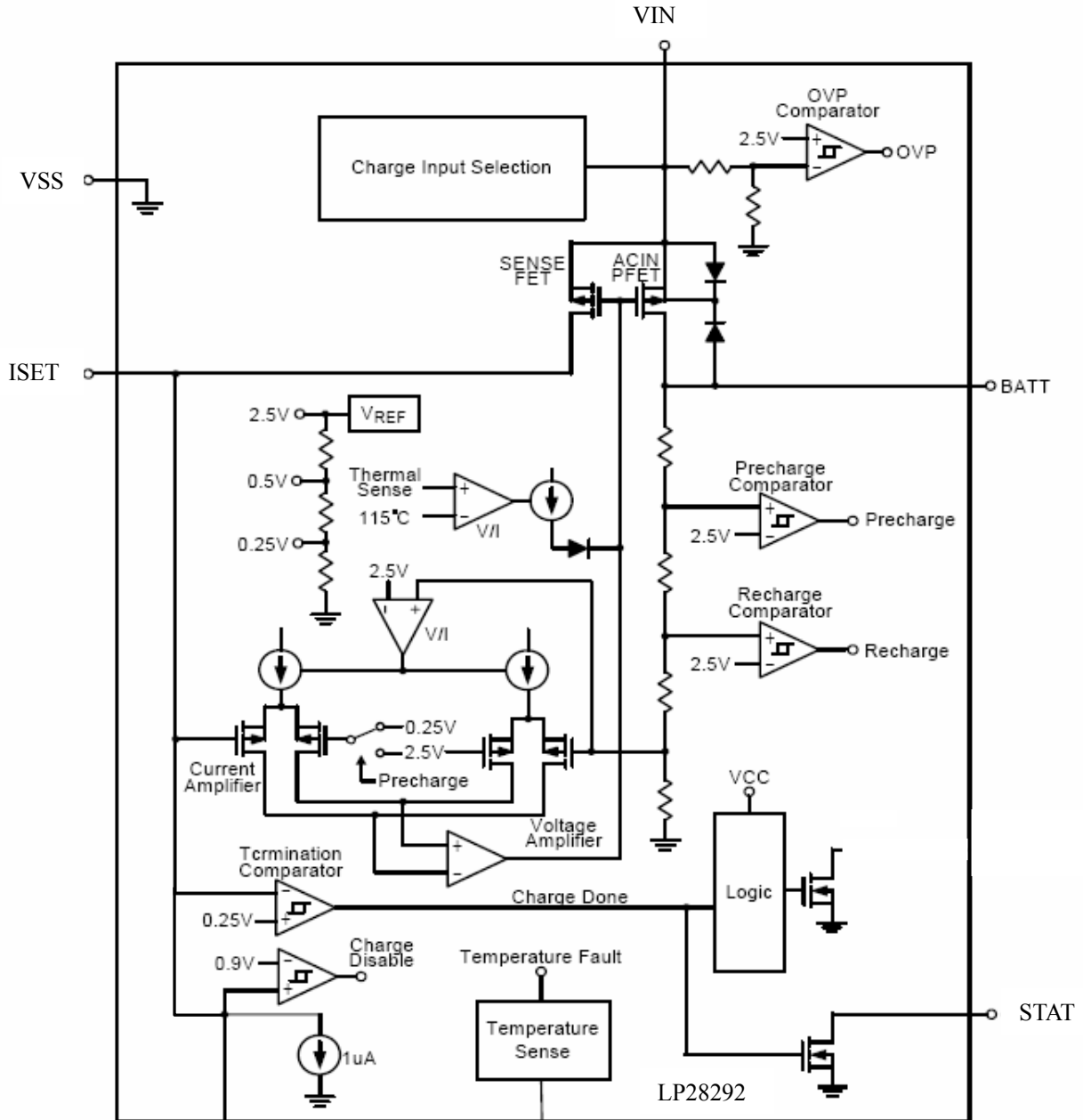
Absolute Maximum Ratings

- ✧ Input Voltage to GND (VIN) -- 2.6V to 8V
- ✧ BAT, ISET, STAT (VX) -- 0.3V to VIN+0.3V
- ✧ BAT Short-Circuit Duration --- Continuous
- ✧ BAT Pin Current -- 1500mA
- ✧ Maximum Junction Temperature -- 125°C
- ✧ Operating Junction Temperature Range (TJ) -- -40℃ to 85°C
- ✧ Maximum Soldering Temperature (at leads, 10 sec) -- 260°C

Thermal Information

- ✧ Maximum Power Dissipation (PD,TA<40°C) --- 1.5W
- ✧ Thermal Resistance (JA) --- 46℃/W

Electrical Characteristics (The specifications which apply over the full operating temperature range, otherwise specifications are at TA = 25°C. VCC = 5V, unless otherwise noted.)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP.	MAX	UNITS
V_{IN}	Adapter/USB Voltage Range		2.65	5	6	V
I_{CC}	Input Supply Current	Charge Mode (Note 4), R_{ISET} = 10k Standby Mode (Charge Terminated)		300	2000	uA
		Shutdown Mode (R_{ISET} Not Connected,		200	500	
		$V_{CC} < V_{BAT}$, or $V_{CC} < V_{UV}$)		25	50	
V_{FLOAT}	Regulated Output (Float) Voltage	0°C ≤ T_A ≤ 85°C, I_{BAT} = 40mA	4.158	4.2	4.242	V
I_{BAT}	BAT Pin Current	R_{ISET} = 1k, Current Mode	840	880	920	mA
		R_{ISET} = 2k, Current Mode	386	44	455	
		Standby Mode, V_{BAT} = 4.2V Shutdown Mode (R_{ISET} Not Connected) Sleep Mode, V_{CC} = 0V	0	-2.5 ±1 ±1	-6 ±2 ±2	uA
I_{TRIKL}	Trickle Charge Current	$V_{BAT} < V_{TRIKL}$, R_{ISET} = 2k (Note 5)	20	45	70	mA
V_{TRIKL}	Trickle Charge Threshold Voltage	R_{ISET} = 10k, V_{BAT} Rising (Note 5)	2.8	2.9	3.0	V
V_{TRHYS}	Trickle Charge Hysteresis Voltage	R_{ISET} = 10k (Note 5)	60	80	110	mV
V_{UV}	V_{CC} Undervoltage Lockout Threshold	From V_{CC} Low to High	3.7	3.8	3.95	V
V_{UVHYS}	V_{CC} Undervoltage Lockout Hysteresis		150	200	300	mV
V_{MSD}	Manual Shutdown Threshold Voltage	ISET Pin Rising	1.15	1.21	1.30	V
		ISET Pin Falling	0.9	1.0	1.1	V
V_{ASD}	V_{CC} – V_{BAT} Lockout Threshold Voltage	V_{CC} from Low to High	70	100	140	mV
		V_{CC} from High to Low	5	30	50	mV
I_{TERM}	C/10 Termination Current Threshold	R_{ISET} = 10k (Note 6)	0.085	0.10	0.115	mA/mA
		R_{ISET} = 2k	0.085	0.10	0.115	mA/mA
V_{ISET}	ISET Pin Voltage	R_{ISET} = 10k, Current Mode	0.9	1.0	1.1	V
I_{STAT}	STAT Pin Weak Pull-Down Current	V_{STAT} = 5V	8	20	35	uA
V_{STAT}	STAT Pin Output Low Voltage	I_{STAT} = 5mA		0.35	0.6	V
ΔV_{RESTAT}	Recharge Battery Threshold Voltage	V_{FLOAT} - V_{RESTAT}	100	150	200	mV
T_{LIM}	Junction Temperature in Constant Temperature Mode				120	°C
R_{ON}	Power FET "ON" Resistance (Between V_{CC} and BAT)				600	mΩ
t_{SS}	Soft-Start Time	I_{BAT} = 0 to I_{BAT} =850V/R_{ISET}		100		uS
I_{ISET}	ISET Pin Pull-Up Current			3		uA
VIN OVP	Over voltage protection		5.9	6.2	6.5	V

TYPICAL CHARACTERISTICS
DROPOUT VOLTAGE
vs
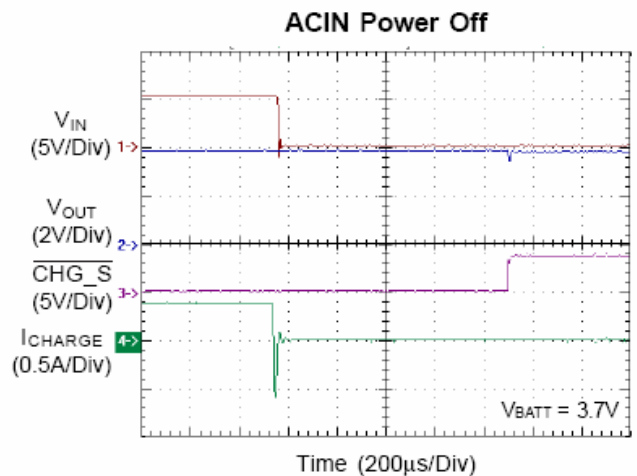### JUNCTION TEMPERATURE
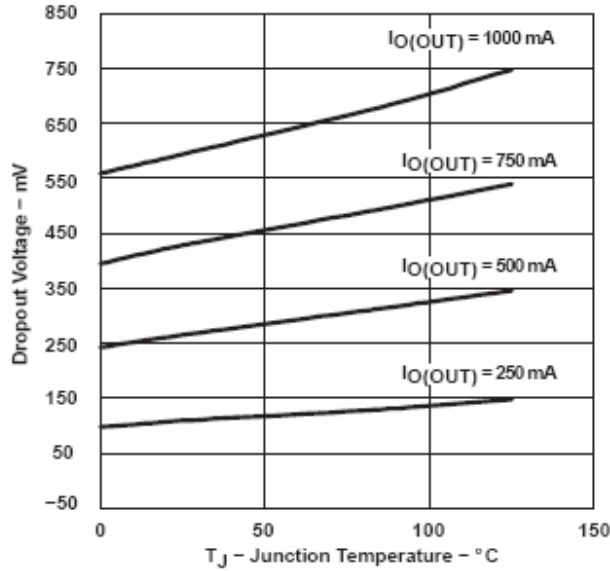
Figure 1
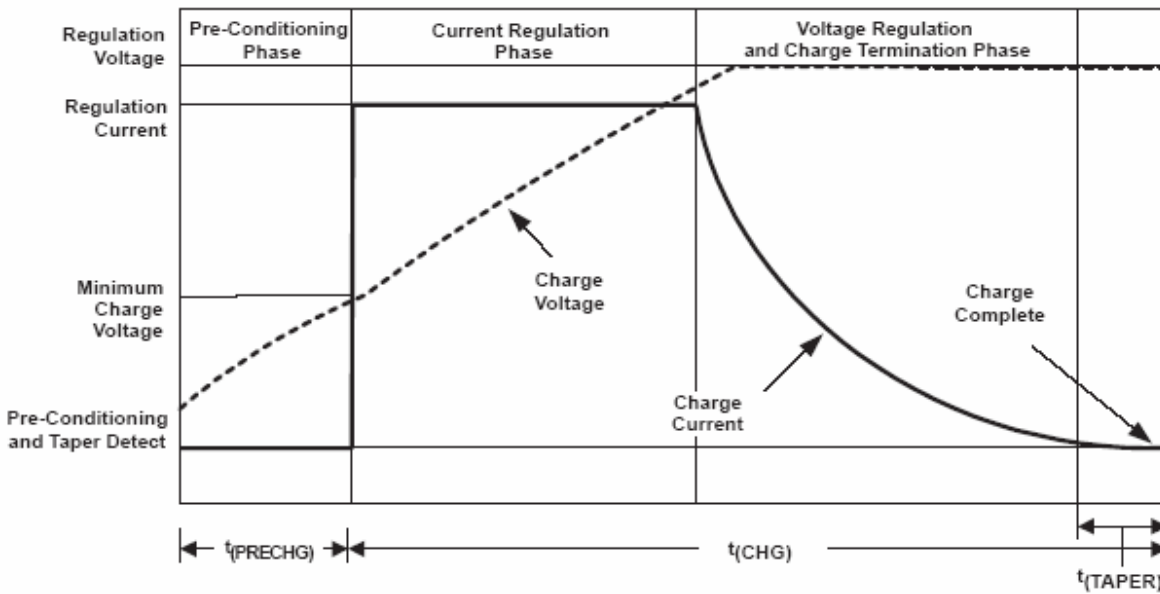
Figure 2. Typical Charging Profile

Typical Operating Characteristics

ACIN Power On

Time (250μs/Div)

V$_{BATT}$ = 3.7V

OVP

Time (1ms/Div)

ACIN = 5V to 8V to 5V, V$_{BATT}$ = 3.7V

ACIN Power Off

Time (500μs/Div)

V$_{BATT}$ = 3.7V

ACIN Power Off

Time (200μs/Div)

V$_{BATT}$ = 3.7V

Input Voltage Transition

ACIN Power Off

Time (500μs/Div)

V$_{BATT}$ = 3.7V

Input Voltage Transition

ACIN Power On

Time (500μs/Div)

V$_{BATT}$ = 3.7V
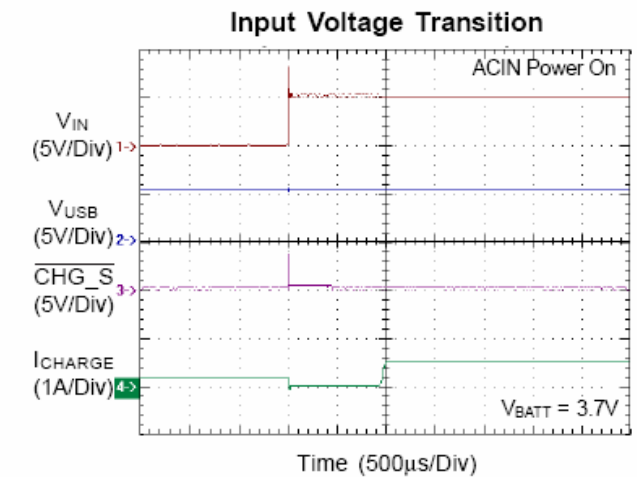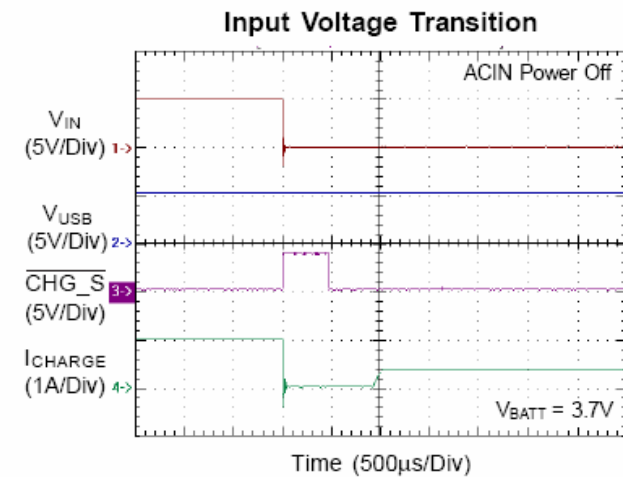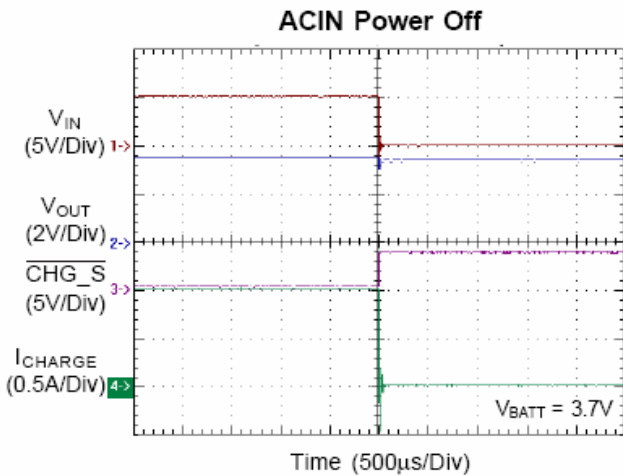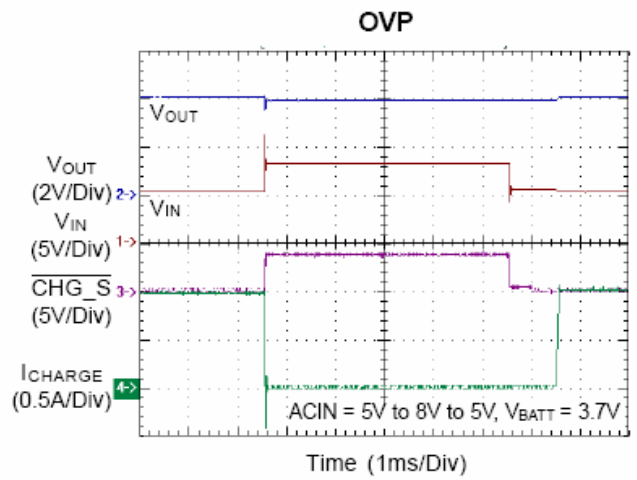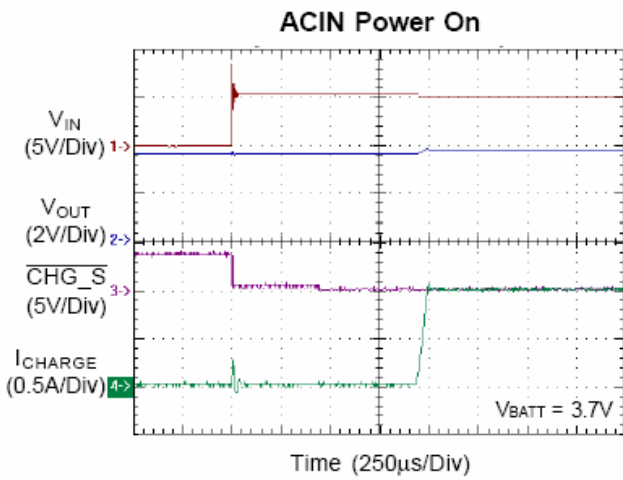
Operation

The LP28292 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 800mA of charge current (using a good thermal PCB layout) with a final float voltage accuracy of ±1%. The LP28292 includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external current sense resistor is required; thus, the basic charger circuit requires only two external components. Furthermore, the LP28292 is capable of operating from a USB power source.

Normal Charge Cycle

A charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO threshold level and a 1% ISET ram resistor is connected from the ISET pin to ground or when a battery is connected to the charger output. If the BAT pin is less than 2.9V, the charger enters trickle charge mode. In this mode, the LP28292 supplies approximately 1/10 the ISET rammed charge current to bring the battery voltage up to a safe level for full current charging. (Note: The LP28292X does not include this trickle charge feature).

When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the ISET rammed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the LP28292 enters constant-voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the ISET rammed value, the charge cycle ends.

ISET ramming Charge Current

The charge current is ISET rammed using a single resistor from the ISET pin to ground. The battery charge current is 1000 times the current out of the ISET pin. The ISET ram resistor and the charge current are calculated using the following equations:

$$R_{SET}=880V/I_{CHG}，\quad I_{CHG}= 880V/R_{SET}$$

The charge current out of the BAT pin can be determined at any time by monitoring the ISET pin voltage using the following equation:

$$I_{BAT}= V_{SET} \text{ x } 880/R_{SET}$$

Charge Termination

A charge cycle is terminated when the charge current falls to 1/10th the ISET rammed value after the final float voltage is reached. This condition is detected by using an internal, filtered comparator to monitor the ISET pin. When the ISET pin voltage falls below 100mV[1] for longer than

t_{TERM} (typically 1ms), charging is terminated. The charge current is latched off and the LP28292 enters standby mode, where the input supply current drops to 200μA. (Note: C/10 termination is disabled in trickle charging and thermal limiting modes).

When charging, transient loads on the BAT pin can cause the ISET pin to fall below 100mV for short periods of time before the DC charge current has dropped to 1/10th the ISET rammed value. The 1ms filter time (t_{TERM}) on the termination comparator ensures that transient loads of this nature do not result in premature charge cycle termination. Once the average charge current drops below 1/10th the ISET rammed value, the LP28292 terminates the charge cycle and ceases to provide any current through the BAT pin. In this state, all loads on the BAT pin must be supplied by the battery.

The LP28292 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V recharge threshold (V_{RESTAT}), another charge cycle begins and current is once again supplied to the battery. To manually restart a charge cycle when in standby mode, the input voltage must be removed and reapplied, or the charger must be shut down and restarted using the ISET pin. Figure 1 shows the state diagram of a typical charge cycle.

Charge Status Indicator (STAT)

The charge status output has three different states: strong pull-down (~10mA), weak pull-down (~20μA) and high impedance. The strong pull-down state indicates that the LP28292 is in a charge cycle. Once the charge cycle has terminated, the pin state is determined by undervoltage lockout conditions. A weak pull-down indicates that V_{CC} meets the UVLO conditions and the LP28292 is ready to charge. High impedance indicates that the LP28292 is in undervoltage lockout mode: either V_{CC} is less than 100mV above the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin. A microprocessor can be used to distinguish between these three states—this method is discussed in the Applications Information section.

Thermal Limiting

An internal thermal feedback loop reduces the ISET rammed charge current if the die temperature attempts to rise above a preset value of approximately 120°C. This feature protects the LP28292 from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the LP28292. The charge current can be set according to

typical (not worst-case) ambient temperature with the assurance that the charger will automatically reduce the current in worst-case conditions. TDFN power considerations are discussed further in the Applications Information section.

Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the undervoltage lockout threshold. The UVLO circuit has a built-in hysteresis of 200mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if V_{CC} falls to within 30mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 100mV above the battery voltage.

Manual Shutdown

At any point in the charge cycle, the LP28292 can be put into shutdown mode by removing R_{ISET} thus floating the ISET pin. This reduces the battery drain current to less than 2µA and the supply current to less than 50µA. A new charge cycle can be initiated by reconnecting the ISETram resistor.

In manual shutdown, the STAT pin is in a weak pull-down state as long as V_{CC} is high enough to exceed the UVLO conditions. The STAT pin is in a high impedance state if the LP28292 is in undervoltage lockout mode: either V_{CC} is within 100mV of the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin.

Automatic Recharge

Once the charge cycle is terminated, the LP28292 continuously monitors the voltage on the BAT pin using a comparator with a 2ms filter time ($t_{RECHARGE}$). A charge cycle restarts when the battery voltage falls below 4.05V (which corresponds to approximately 80% to 90% battery capacity). This ensures that the battery is kept at or near a fully charged condition and eliminates the need for periodic charge cycle initiations. STAT output enters a strong pull-down state during recharge cycles.

Power Dissipation

The conditions that cause the LP28292 battery charger to reduce charge current through thermal feedback can be approximated by considering the total power dissipated in the IC. For high charge currents, the LP28292 power dissipation is approximately:

$$P_D = (V_{ADP} - V_{BAT}) \times I_{CHG} + P_{D\_BUCK} + \left(V_{INA} - V_{OUTA}\right) \times I_{OUTA}$$

Where PD is the total power dissipated within the IC, ADP is the input supply voltage, V_{BAT} is the battery voltage, I_{BAT} is the charge current and P_{D_BUCK} is the power dissipation due to the regulator. P_{D_BUCK} can be calculated as:

$$P_{D\_BUCK} = V_{OUTB} \times I_{OUTB}\left(\frac{1}{\eta} - 1\right)$$

Where V_{OUTB} is the regulated output of the switching regulator, I_{OUTB} is the regulator load and is the regulator efficiency at that particular load.

It is not necessary to perform worst-case power dissipation scenarios because the LP28292 will automatically reduce the charge current to maintain the die temperature at approximately 125°C. However, the approximate ambient temperature at which the thermal feedback begins to rotect the IC is:

$$T_A = 115°C - P_D\theta_{JA}$$
$$T_A = 115°C - (V_{ADP} - V_{BAT}) \times I_{CHG} \times \theta_{JA}$$
if the regulator is off.

Example: Consider the extreme case when an LP28292 is operating from a 6V supply providing 250mA to a 3V Li-Ion battery, the switching regulator and the LDO are off. The ambient temperature above which the LP28292 will begin to reduce the 250mA charge current is approximately: (Correctly soldered to a 2500mm^2 double-sided 1 oz. copper board, the LP28292 has a thermal resistance of approximately 43°C/W.)

$$T_A = 115°C - (6V - 3V) \times (250mA) \times 43°C/W$$
$$T_A = 115°C - 0.75W \times 43°C/W = 115°C - 32.25°C$$
$$T_A = 82.75°C$$

If there is more power dissipation due to the switching regulator or the LDO, the thermal regulation will kick in at a somewhat lower temperature than this. In the above circumstances, the LP28292 can be used above 82.75°C, but the charge current will be reduced from 250mA. The approximate current at a given ambient temperature can be calculated:
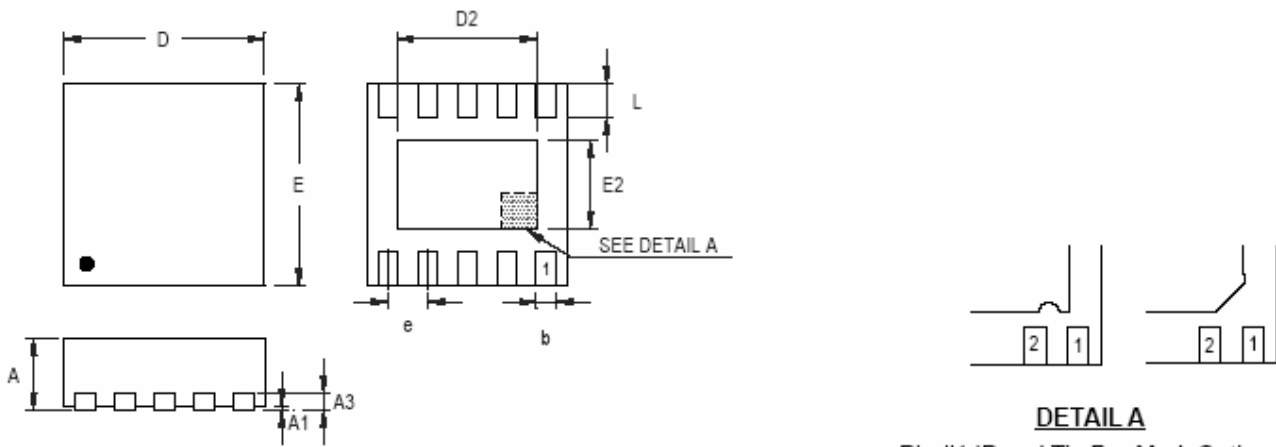
$$I_{CHG} = \frac{115°C - T_A}{(V_{ADP} - V_{BAT}) \times \theta_{JA}}$$

$$I_{CHG} = \frac{115°C - 85°C}{(6V - 3V) \times 43°C/W} = \frac{30°C}{129°C/A} = 232.6mA$$

Note: 1V = 1J/C = 1W/A

Furthermore, the voltage at the ISET pin will change proportionally with the charge current as discussed in the ISET ramming Charge Current section.

Packaging Information

DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	2.950	3.050	0.116	0.120
D2	2.300	2.650	0.091	0.104
E	2.950	3.050	0.116	0.120
E2	1.500	1.750	0.059	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 10L DFN 3x3 Package