1.2A Single-chip Li-ion and Li-POL Charge

General Description

The LP28012 is a complete constant-current/ constant voltage linear charger for single cell lithium-ion batteries. Its ESOP8 package and low external component count make the LP28012 ideally suited for portable applications. 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 LP28012 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 is removed, the LP28012 automatically enters a low current state, dropping the battery drain current to less than 4μA.
Other features include charge current monitor, under voltage lockout, automatic recharge and a status pin to indicate charge termination and the presence of an input voltage.

Order Information

LP28012 □ □ □

F: Pb-Free

Package Type

QV: TDFN-10

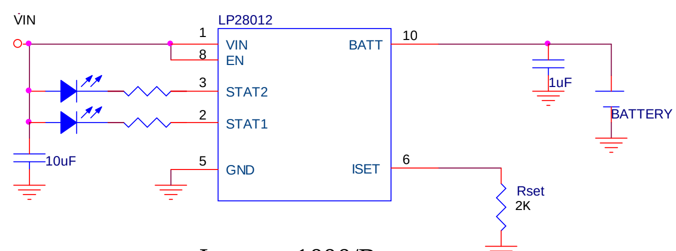
Applications

- ✧ Portable Media Players/Game
- ✧ Power Bank
- ✧ PDA/MID
- ✧ Bluetooth Applications

Features

- ◆ Very Low Power Dissipation
- ◆ Short-circuit protection
- ◆ Programmable Charge Current Up to 1200mA
- ◆ No MOSFET, Sense Resistor or Blocking Diode Required
- ◆ Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- ◆ 8μA Supply Current in Shutdown
- ◆ Drainage Charge Current Thermal Regulation Status Outputs for LED or System Interface
- ◆ Indicates Charge and Fault Conditions
- ◆ Consumption Available in TDFN-10 Package
- ◆ RoHS Compliant and 100% Lead (Pb)-Free

Typical Application Circuit

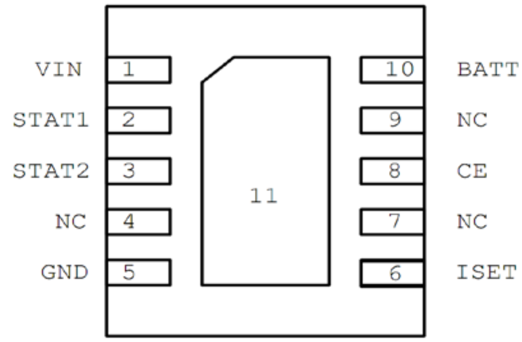


I_{CHARG}=1000/Rset

Marking Information

Device	Marking	Package	Shipping
LP28012	LPS LP28012 XXXX	QV:TDFN-10	3K/REEL

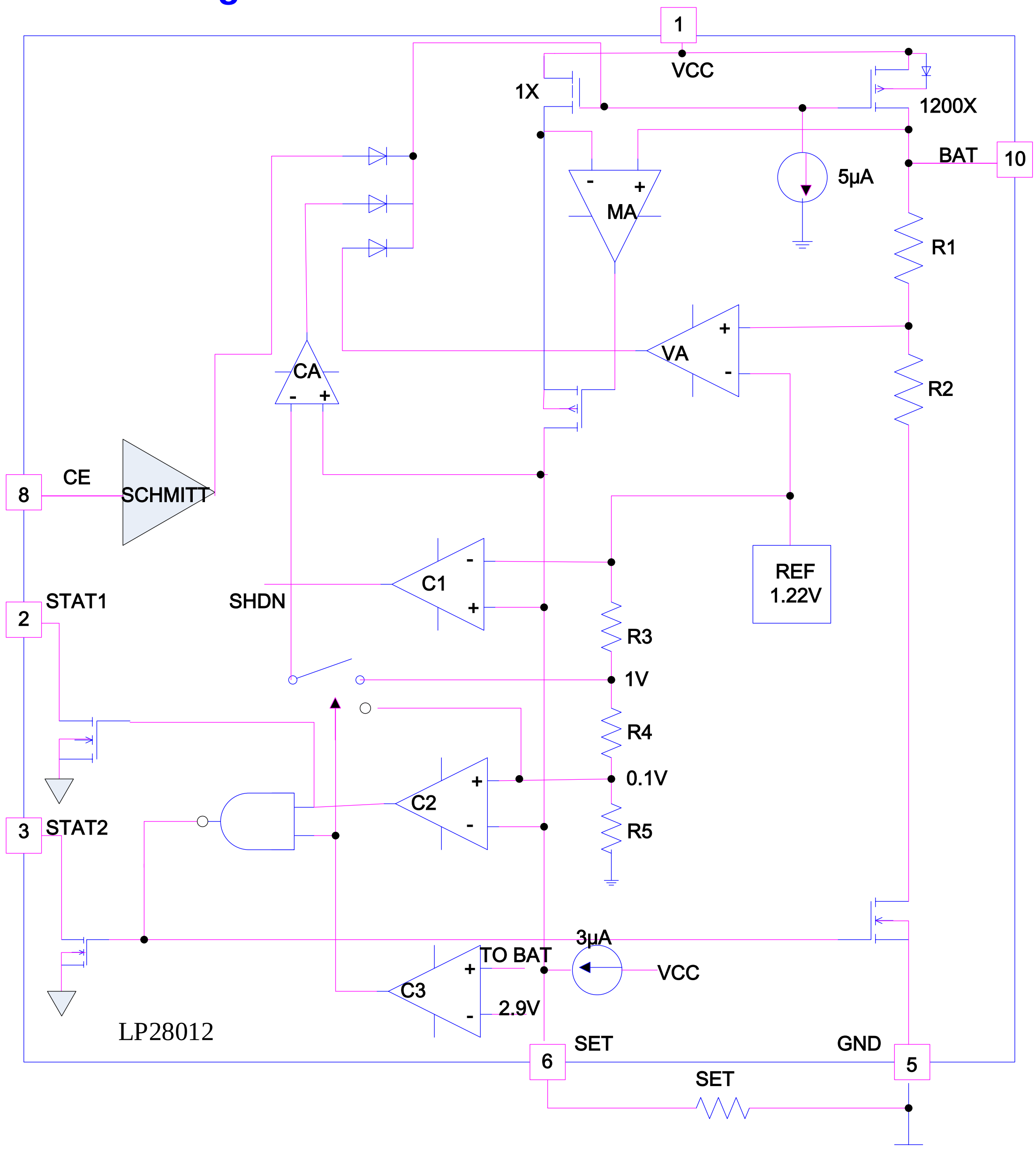
Functional Pin Description

Package Type	Pin Configurations
TDFN-10	

Pin Description

PIN	PIN No.	DESCRIPTION
4,7,9	NC	No Connector.
6	Iset	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. Iset=1000/Riset.
5,11	GND	VSS is the connection to system ground.
1	Vin	VIN is the input power source. Connect to a wall adapter.
10	BATT	BAT is the connection to the battery. Typically a 10μF 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.
3	STAT2	Open-Drain Charge Status Output. When the battery is charging, the STAT pin is pulled High by an internal N-channel MOSFET. When the charge cycle is completed, the pin is pulled Low.
2	STAT1	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, the pin is pulled High.
8	EN	Chip enable pin. Charging when the pin Voltage is floating and high, discharge when the pin in Low voltage.

Function Block Diagram



Absolute Maximum Ratings

- ✧ Input Voltage to GND (VIN) -- 3.9V to 7V
- ✧ BAT, ISET, STAT (VX) --0.3V to VIN+0.3V
- ✧ BAT Short-Circuit Duration --- Continuous
- ✧ BAT Pin Current -- 1200mA
- ✧ Maximum Junction Temperature -- 125°C
- ✧ Operating Junction Temperature Range (TJ) -- -40°C 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°C/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
VIN	Adapter/USB Voltage Range		2.65	5	7	V
ICC	Input Supply Current	Charge Mode, RISET = 10k		300	2000	uA
		Standby Mode (Charge Terminated)		200	500	
		Shutdown Mode (RISET Not Connected, VCC < VBAT, or VCC < VUV)		25	50	
VFLOAT	Regulated Output (Float) Voltage	0°C ≤ TA ≤ 85°C, IBAT = 40mA	4.158	4.2	4.242	V
IBAT	BAT Pin Current	RISET = 1k, Current Mode		1000		mA
		RISET = 2k, Current Mode		500		
		Standby Mode, VBAT = 4.2V Shutdown Mode (RISET Not Connected) Sleep Mode, VCC = 0V	0	-2.5 ±1 ±1	-6 ±2 ±2	uA
ITRIKL	Trickle Charge Current	VBAT < VTRIKL, RISET = 2k		60		mA
VTRIKL	Trickle Charge Threshold Voltage	RISET = 10k, VBAT Rising	2.8	2.9	3.0	V
VTRHYS	Trickle Charge Hysteresis Voltage	RISET = 10k		120		mV
VUV	VCC Under voltage Lockout Threshold	From VCC Low to High		3.9		V
VUVHYS	VCC Under voltage Lockout Hysteresis		150	200	300	mV
VMSD	Manual Shutdown Threshold Voltage	ISET Pin Rising		2		V
		ISET Pin Falling		2.2		V
VASD	VCC – VBAT Lockout Threshold Voltage	VCC from Low to High	70	100	140	mV
		VCC from High to Low	5	30	50	mV
ITERM	C/10 Termination Current Threshold	RISET = 10k	0.085	0.10	0.115	mA/mA
		RISET = 2k	0.085	0.10	0.115	mA/mA
VISET	ISET Pin Voltage	RISET = 10k, Current Mode		2		V
ISTAT	STAT Pin Weak Pull-Down Current	VSTAT = 5V		5		uA
VSTAT	STAT Pin Output Low Voltage	ISTAT = 5mA		0.35	0.6	V
ΔVRESTAT	Recharge Battery Threshold Voltage	VFLOAT - VRESTAT	100	150	200	mV
TLIM	Junction Temperature in Constant Temperature Mode			120		°C
RON	Power FET “ON” Resistance (Between VCC and BAT)			600		mΩ
Tss	Soft-Start Time	IBAT = 0 to IBAT =850V/RISET		100		uS
IISET	ISET Pin Pull-Up Current			150		uA

TYPICAL CHARACTERISTICS

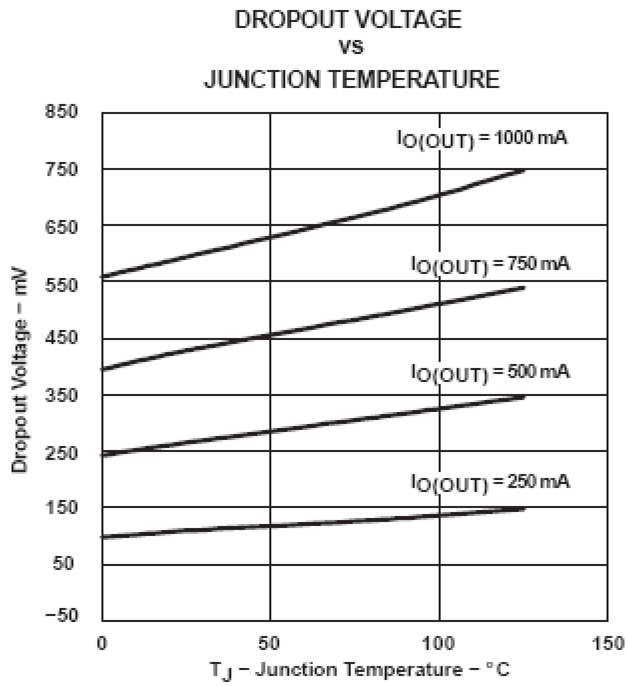


Figure 1

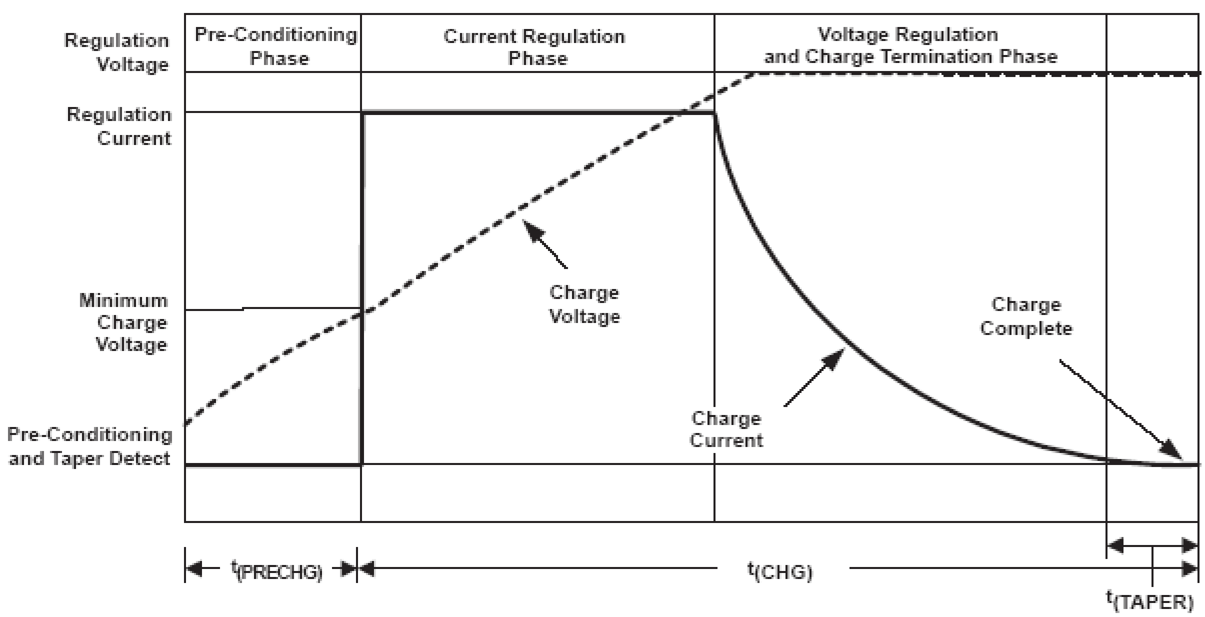


Figure 2. Typical Charging Profile

Application Information

The LP28012 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 1200mA of charge current (using a good thermal PCB layout) with a final float voltage accuracy of ±1%. The LP28012 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 LP28012 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 LP28012 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 LP28012 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 LP28012 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 600 times the current out of the ISET pin. The ISET ram resistor and the charge current are calculated using the following equations:

RSET=1000V/ICHG , ICHG= 1000V/RSET

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

IBAT= VSET x 500/RSET

Note: Vset is 2Volts.

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 LP28012 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 200mV 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 LP28012 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 LP28012 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 LP28012 is in a charge cycle. Once the charge cycle has terminated, the pin state is determined by under voltage lockout conditions. A weak pull-down indicates that V_{CC} meets the UVLO conditions and the LP28012 is ready to charge. High impedance indicates that the LP28012 is in under voltage 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.

Function	STAT1(pin2)	STAT2(pin3)
Charging	Low	High
Charge END	High	Low

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 LP28012 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 LP28012. 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.

Under voltage Lockout (UVLO)

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the under voltage 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 LP28012 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 LP28012 is in under voltage 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 LP28012 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 LP28012 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 LP28012 power dissipation is approximately:

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

Where PD is the total power dissipated within the IC, ADP is the input supply voltage, VBAT is the battery voltage, IBAT is the charge current and PD_BUCK is the power dissipation due to the regulator. PD_BUCK can be calculated as:

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

Where VOUTB is the regulated output of the switching regulator, IOUTB 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 LP28012 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 protect the IC is:

$$T_A = 115^\circ C - P_D \theta_{JA}$$
$$T_A = 115^\circ C - (V_{ADP} - V_{BAT}) \times I_{CHG} \times \theta_{JA}$$

if the regulator is off.

Example: Consider the extreme case when an LP28012 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 LP28012 will begin to reduce the 250mA charge current is approximately: (Correctly soldered to a 2500mm^2 double-sided 1 oz. copper board, the LP28012 has a thermal resistance of approximately 43°C/W.)

$$T_A = 115^\circ C - (6V - 3V) \times (250mA) \times 43^\circ C/W$$

$$T_A = 115^\circ C - 0.75W \times 43^\circ C/W = 115^\circ C - 32.25\ ^\circ C$$

$$T_A = 82.75^\circ C$$

T =

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 LP28012 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

$$I_{CHG} = \frac{115^\circ C - T_A}{(V_{ADP} - V_{BAT}) \times \theta_{JA}}$$

calculated:

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

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

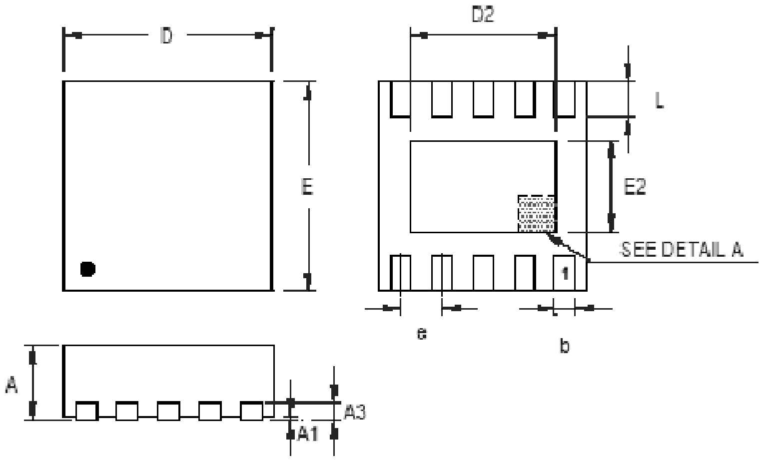
Furthermore, the voltage at the ISET pin will change proportionally with the charge current as discussed in the ISET ramming Charge Current section.

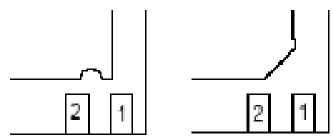
PCB Layout Considerations

It is important to pay special attention to the PCB layout. The following provides some guidelines:

- To obtain optimal performance, the decoupling capacitor from VCC to V(IN) and the output filter capacitors from OUT to VSS should be placed as close as possible to the bq24080, with short trace runs to both signal and VSS pins. The VSS pin should have short trace runs to the GND pin.
- All low-current VSS connections should be kept separate from the high-current charge or discharge paths from the battery. Use a single-point ground technique incorporating both the small-signal ground path and the power ground path.
- The high-current charge paths into IN and from the OUT pins must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.
- The LP28012 is packaged in a thermally enhanced MLP package. The package includes a thermal pad to provide an effective thermal contact between the device and the printed circuit board (PCB). Full PCB design guidelines for this package are provided in the application note entitled, QFN/SON PCB Attachment

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