XTB1056

1A/28V Fully Integrated Linear Charger
for Single Cell Li-ion Battery

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1A/28V Single Cell Li-ion Battery Linear Charger

DESCRIPTION

The XTB1056 is a cost-effective, high-integration linear charger for single cell Li-ion or Li-ion polymer batteries. The device support CC/CV charge from either USB port or AC adapter. Low BOM component requirement makes the whole system small in size. The charger accepts an input voltage up to 28V but is disabled when the input voltage exceeds the OVP threshold. The 28V rating eliminates the over-voltage protection circuit required in a low input voltage charger.

The charge current and the end-of-charge current are programmable with external resistors. When the battery voltage is lower than typically 2.6V, the charger preconditions the battery with typically 20% of the programmed charge current.

The XTB1056 implements two indication pins, $\overline{PPR}$ and $\overline{CHG}$, allowing connection to micro-controller or LED to show device status. With open-drain structure, $\overline{PPR}$ pin stays low while input voltage is within operation range, and $\overline{CHG}$ stays low during charging state, else pins are in the high impedance state.

The XTB1056 features thermal fold-back function to limit the charge current and protect the device from over junction temperature fault. The XTB1056 also integrates current monitor, UVLO, OVP function to prevent device from damage.

FEATURES

- Single-Chip for 1-cell Li-ion or Polymer Battery
- Constant-Current/Constant-Voltage Battery Charge
- No External MOSFET, Current Sensor or Diode Required
- Low Component Count and Cost
- Programmable Charge Current
- Programmable End-of-Charge Current
- Charging Current Monitor and Thermal Fold-back
- 2.6V Trickle Charge Threshold
- With 6.8V Input Over-Voltage Protection
- 28V Maximum Voltage for the Power Input
- Input-based dynamic power management (VIN-DPM)
- Short-circuit Protection
- Protection of Reverse Connection of Battery
- Power Presence and Charge Indications
- Soft start for Inrush Current Limitation
- Automatic Battery Recharge
- Operation Temperature: -40℃~+85℃
- Package options: DFN-2×2-8L and ESOP-8

APPLICATIONS

✧ Mobile Phones
✧ Portable Devices
✧ Wireless Devices, Bluetooth Headset
✧ Personal Electronics, Personal Healthcare
✧ Wearable Device

1A/28V Single Cell Li-ion Battery Linear Charger

TYPICAL APPLICATION CIRCUIT
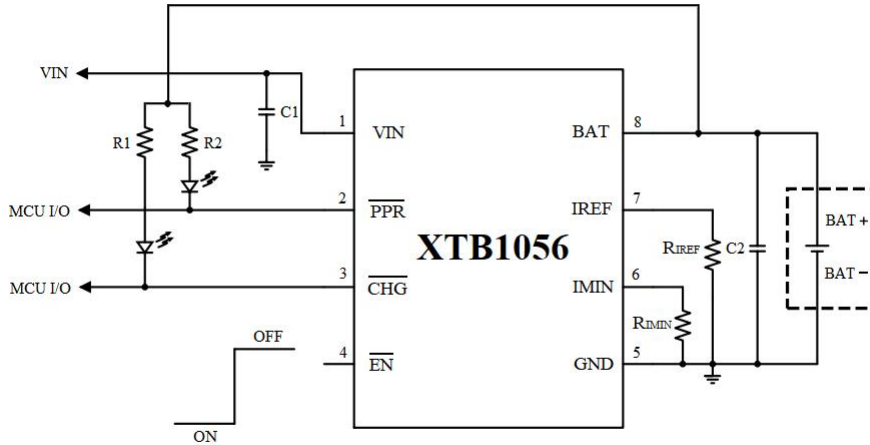
PRODUCT FAMILY TABLE
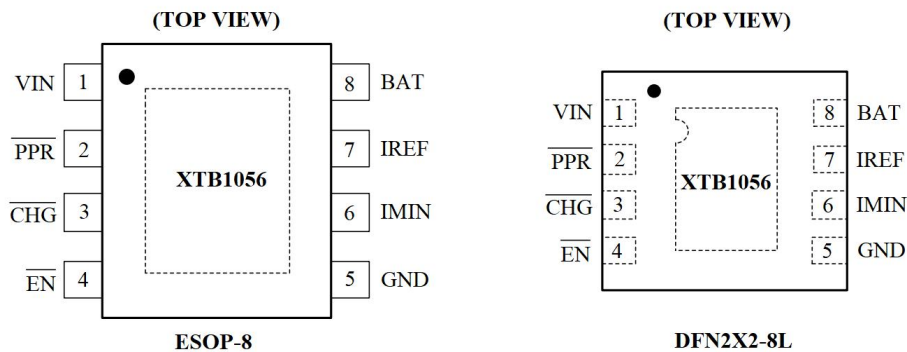
OPN	Float Voltage(V)	Package	Quantity
XTB1056L420AT3CT	4.2	ESOP-8	4000
XTB1056L420AD3CT	4.2	DFN2X2-8L	3000
XTB1056L435AT3CT	4.35	ESOP-8	4000
XTB1056L435AD3CT	4.35	DFN2X2-8L	3000

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PIN CONFIGURATIONS

(TOP VIEW)

```
VIN  [1] •        8  BAT
PPR  [2]          7  IREF
         XTB1056
CHG  [3]          6  IMIN
EN   [4]          5  GND
```

ESOP-8

(TOP VIEW)

```
VIN  [1] •        8  BAT
PPR  [2]          7  IREF
         XTB1056
CHG  [3]          6  IMIN
EN   [4]          5  GND
```

DFN2X2-8L

PIN DESCRIPTION

NO.	NAME	TYPE	DESCRIPTION
1	VIN	I	Power supply voltage input pin. Connect VIN to GND with a 1μF or greater capacitor.
2	$\overline{PPR}$	O	Input voltage good indication pin. Open-drain output low while input supply voltage within POR and OVP voltage range and high impedance otherwise.
3	$\overline{CHG}$	O	Charge State Indication pin. Open-drain output low when device is charging, while high impedance when end-of-charge (EOC) is qualified, or charger is disabled.
4	$\overline{EN}$	I	Enable input pin with active low. Pull this pin to low or left floating to enable charge, while pull high to disable charge.
5	GND	G	Ground.
6	IMIN	I	Minimal charging current programming pin. For charging current continues below minimal charging current IMIN, an end-of-charge (EOC) is qualified. Set IMIN by a resistor connecting between this pin and ground and following below equation: $$I_{MIN} = \frac{1100}{R_{IMIN}} \ (mA)$$ where R_{IMIN} unit is KΩ.
7	IREF	I	Charge current feedback pin. Connect a resistor between this pin and GND pin to set charge constant current limitation. The current is following equation: $$I_{REF} = \frac{1200}{R_{IREF}} \ (mA)$$ Where R_{IREF} unit is KΩ.
8	BAT	O	Charger output pin. Connect this pin to the positive of battery with a 1μF or greater X5R ceramic capacitor for decoupling. The BAT output is disabled, when EN pin is pulled high.
Exposed thermal pad		-	Connect this pad to GND

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ABSOLUTE MAXIMUM RATINGS

Parameter		Min	Max	Unit
Input Voltage	VIN	-0.3	30	V
	IREF,IMIN	-0.3	6	V
	$\overline{EN}$	-0.3	6	V
Output Voltage	$\overline{PPR}$, $\overline{CHG}$	-0.3	6	V
	BAT	-6	13.5	V
T_j	Maximum Junction Temperature	-40	125	°C
T_{OPR}	Operating Temperature Range	-40	85	°C
T_{stg}	Storage Temperature Range	-65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

Note: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.

Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

(1) This data was taken with the JEDEC low effective thermal conductivity test board.

(2) This data was taken with the JEDEC standard multi-layer test boards.

ESD,ELECTROSTATIC DISCHARGE PROTECTION

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001[1]	2000	V
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002[2]	1000	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

THERMAL INFORMATION

Package Type	θ_{JA}	θ_{JC}	Unit
ESOP-8	148	48	°C/W
DFN2X2-8L	103	55	°C/W

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ELECTRICAL CHARACTERISTICS

All test condition is V_{IN}=5V, T_A=25°C, unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
	Maximum supply voltage				28	V
V_{IN}	Operating supply voltage		4.55		6.1	V
I_{BAT}	BAT pin output charge current	Constant current range	50		1000	mA
		Constant current mode, R_{IREF} = 12 KΩ	90	100	110	mA
		Constant current mode, R_{IREF} = 2.4 KΩ	450	500	550	mA
		V_{IN}=0V		2.8	4	uA
V_{FLOAT}	BAT pin float voltage		4.158	4.2	4.242	V
			4.306	4.35	4.394	V
R_{ON}	Power MOSFET on resistance			0.65		Ω
V_{TCK}	Battery trickle voltage	V_{BAT}<V_{TCK}, R_{IREF} = 1.2 KΩ	2.5	2.6	2.7	V
	Hysteresis	R_{IREF} = 1.2 KΩ	50	110	170	mV
I_{TCK}	Battery trickle charge current	V_{BAT}<V_{TCK}, R_{IREF} = 1.2 KΩ	120	200	280	mA
V_{IREF}	IREF voltage	Constant current mode, R_{IREF} = 1.2 KΩ	0.92	1	1.08	V
I_{IREF}	IREF source current	V_{IREF}=5V		2		uA
V_{OS}	Battery charge lockout threshold, V_{IN}-V_{BAT}	V_{IN} rising		110	150	mV
		V_{IN} falling	20	60		mV
t_{SS}	Soft start delay time	Charge current from 0mA to I_{BAT}		1		ms
V_{POR}	Rising POR threshold	V_{BAT} = 3.0V, R_{IREF} = 1.2KΩ, use $\overline{PPR}$ to indicate the comparator output	3.11	3.80	4.55	V
	Falling POR threshold		2.86	3.60	4.35	V
V_{OVP}	Over voltage protection threshold	V_{IN} rising	6.4	6.8	7.2	V
V_{OVPHYS}	Hysteresis		140	200	260	mV
$V_{BAT,SP}$	Battery short to ground protection threshold			1.8		V
$I_{BAT,SP}$	Battery short to ground protection	BAT short to ground		17		mA

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ELECTRICAL CHARACTERISTICS(continued)

All test condition is V_{IN}=5V, T_A=25°C, unless otherwise noted

| Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
I_{VIN}	VIN pin supply current	V_{BAT} = 4.3V, R_{IREF} = 2.4KΩ, charger disabled		60	80	uA
		V_{BAT} = 4.3V, R_{IREF} = 2.4KΩ, charger enabled		130	220	uA
$I_{STANDBY}$	BAT pin sink current	Charger disabled or the input is floating		0.02	1	uA
I_{MIN}	Minimal charging current threshold	R_{IMIN} = 24 KΩ	15	45	70	mA
t_{MIN}	End of charge deglitch time			2		ms
	EOC rising threshold	R_{IREF} = 2.4KΩ	325	380	445	mA
t_{RECHG}	Recharge deglitch time			2		ms
$V_{EN,IH}$	$\overline{EN}$ logic-input high level (enable)		1.5			V
$V_{EN,IL}$	$\overline{EN}$ logic-input low level (disable)				0.8	V
R_{EN}	$\overline{EN}$ pin internal pull-down resistance	V_{IN}=5V		200		KΩ
	$\overline{CHG}$ sink current when low	Pin Voltage = 1V	15	24		mA
	$\overline{CHG}$ leakage current when high impedance	$V_{\overline{CHG}}$ = 5.5V			20	uA
	$\overline{PPR}$ sink current when low	Pin Voltage = 1V	15	24		mA
	$\overline{PPR}$ leakage current when high impedance	$V_{\overline{PPR}}$ = 5.5V			20	uA
T_{OTP}	Over temperature protection threshold			150		°C

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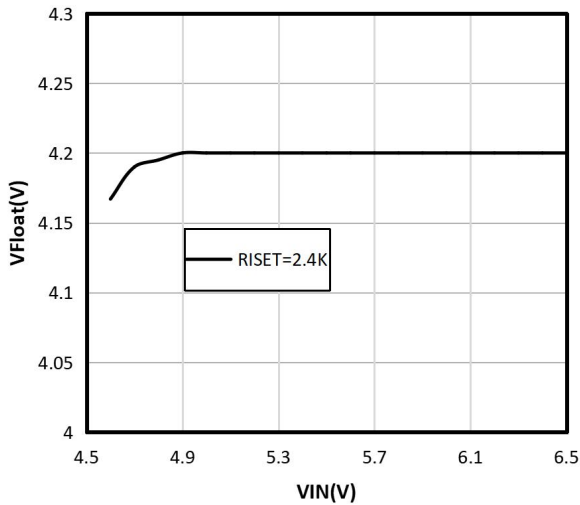
TYPICAL PERFORMANCE CHARACTERISTICS

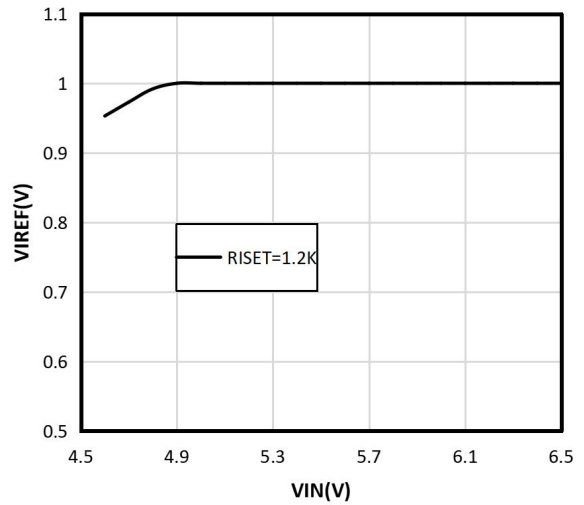### Charge Current vs. Supply Voltage @VBAT=3.8V
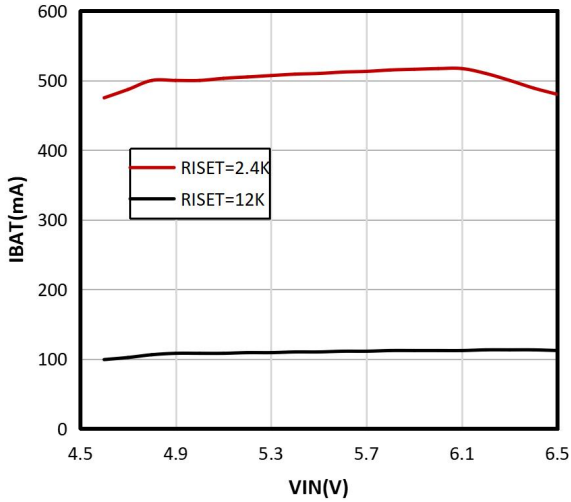
Trickle Charge Current vs. Supply Voltage @VBAT=2.4V
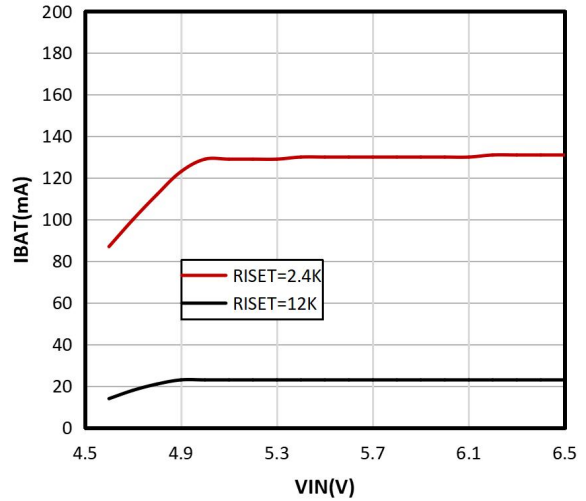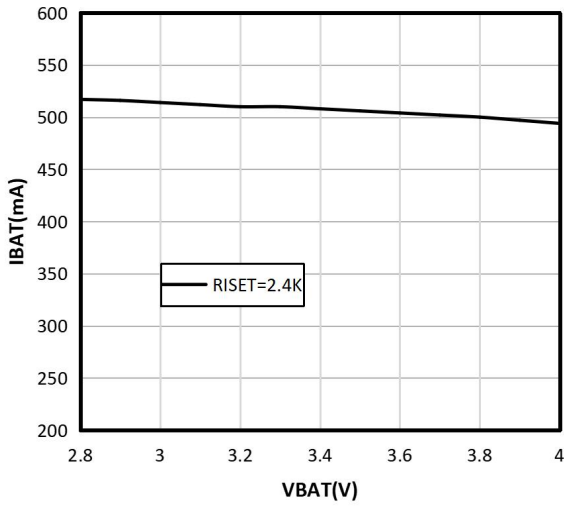

VFloat Voltage vs. Supply Voltage

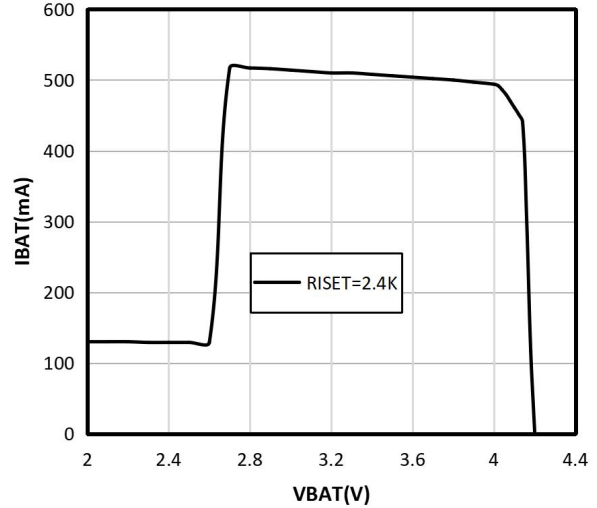### IREF Pin Voltage vs. Supply Voltage @VBAT=3.8V

1A/28V Single Cell Li-ion Battery Linear Charger
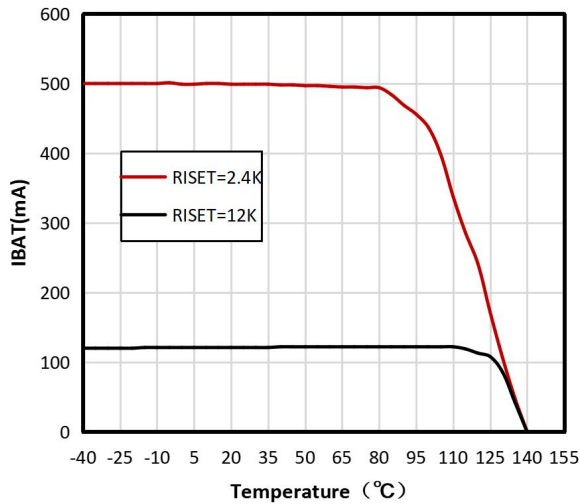
TYPICAL PERFORMANCE CHARACTERISTICS

Charge Current vs. Battery Voltage @VIN=5V
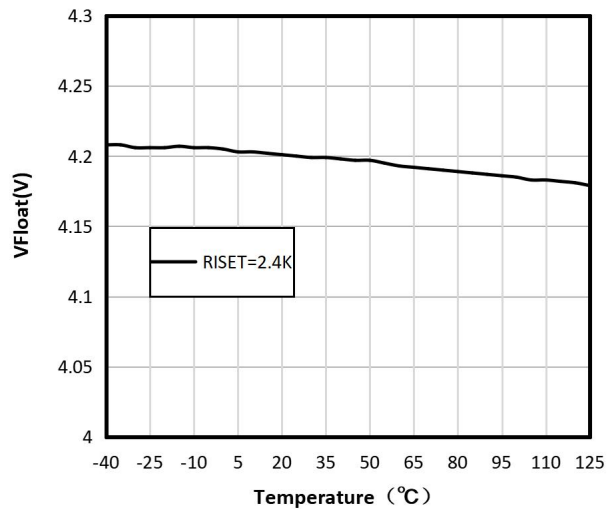

Charge Current vs. Battery Voltage @VIN=5V
TA=25°C

Charge Current vs. Temperature @VIN=5V
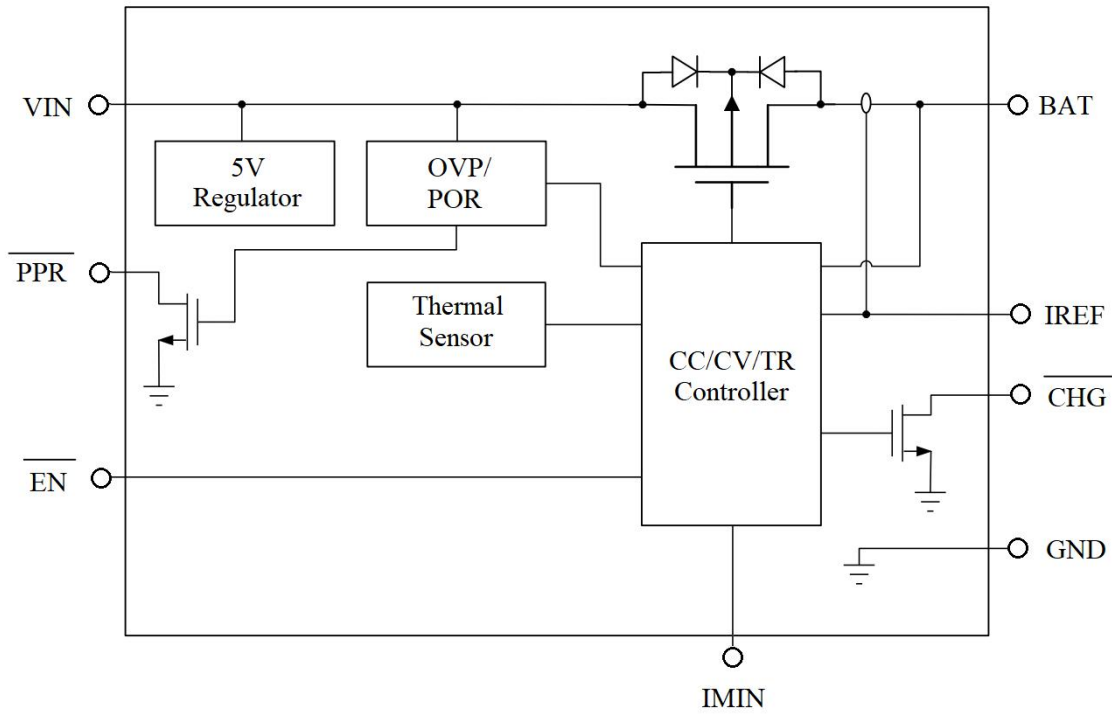**VBAT=3.8V**

VFloat Voltage vs. Temperature @VIN=5V

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FUNCTION BLOCK DIAGRAM

1A/28V Single Cell Li-ion Battery Linear Charger

DETAILED DESCRIPTION

OVERVIEW

The XTB1056 is a cost-effective, high-integrated linear charger for single cell Li-ion or Li-ion polymer batteries. The device support CC/CV charge from either USB port or AC adapter. Low BOM component requirement makes the whole system small in size. High input voltage range with over-voltage protection supports low-cost unregulated adapters. The XTB1056 charge current is fully programmable from 50 mA to 1000 mA with an external resistor, and the charge current can automatically terminate the charge cycle when the charge current drops below a minimal current which is set by external resistor on IMIN pin with a range from 5% (or 10 mA, which one is higher) to 50% of constant current set by IREF pin after reaches float voltage.

ENABLE($\overline{\text{EN}}$)

The XTB1056 is in shutdown mode when chip enable pin ($\overline{\text{EN}}$) is high. Connect this pin to the GPIO of an external processor or digital logic control circuit to enable and disable the device. Or connect this pin to the VIN pin for self-bias applications.

OVER VOLTAGE PROTECTION(OVP)

The XTB1056 uses an over-voltage protection circuit to prevent the device from damage when the supply voltage is higher than OVP threshold. The internal power FET, if previously on, turns off after a certain deglitch period. After the supply voltage falls below the normal voltage range, the device recovers to the normal operating mode after another deglitch period.

BATTERY CHARGE CURRENT VALUE SETTING

The XTB1056 provides fully programmable charge current from 50 mA to 1000 mA under normal charge conditions. A single current-programming resistor connected from IREF pin to GND determines the constant battery charge current value at the BAT pin, and no additional block diode or sensing resistor is required. Use to calculate the resistor value.

$$I_{BAT} = \frac{1200}{R_{IREF}}$$

Where,

I_{BAT} is the desired constant charge current,

R_{IREF} is the external current setting resistor.

The XTB1056 implements IREF pin short protection function. When the R_{IREF} resister set too small or short to GND unintentionally, short protection occurs, and the battery charge current is limited to 1.5 A, IREF short protection charge current. Meanwhile the thermal foldback and over temperature protection still limit the constant current I_{BAT}.

When XTB1056 is powered up, the whole battery charging process can be divided into five sections below:

TRICKLE CURRENT BATTERY CHARGE

The XTB1056 operates in the trickle charge mode when detects the battery voltage below the trickle charge threshold, V_{TCK}. In trickle charge mode, battery charge current is limited to small current range, I_{TCK}, to protect the battery.

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CONSTANT CURRENT BATTERY CHARGE

The XTB1056 enters constant current (CC) battery charge mode when the battery voltage ramps higher than trickle charge threshold V_{TCK}. In this mode, constant current, determined by the resistor from IREF to GND, flows out from BAT pin to the positive side of load battery.

CONSTANT VOLTAGE BATTERY CHARGE

The XTB1056 enters constant voltage (CV) battery charge mode when the battery voltage reaches the floating voltage V_{FLOAT}. In this mode, battery charge current decreases from the constant current value, and the BAT pin voltage keeps constant at V_{FLOAT}.

BATTERY CHARGE TERMINATION

When the charge current falls below IMIN, the XTB1056 terminates the battery charge cycle after a deglitch period with $\overline{CHG}$ pin goes to high. Meanwhile, XTB1056 keeps a very small charging current to force battery stays at full charged.

BATTERY RECHARGE

In battery charge standby mode, the XTB1056 monitors the battery voltage continuously. The figure as below shows the typical behavior during one battery charging cycle.
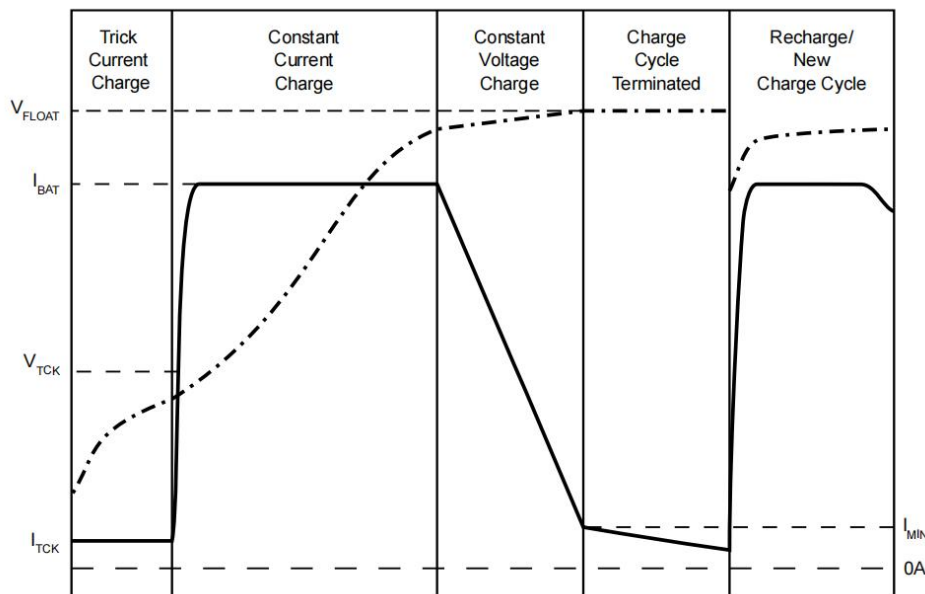
$\overline{PPR}$ **INDICATION**

The $\overline{PPR}$ pin is an open-drain output to indicate the presence of the AC adapter. Whenever the input voltage is higher than the POR threshold, the $\overline{PPR}$ pin turns on the internal open-drain MOSFET to indicate a logic low signal, independent on the $\overline{EN}$ pin input. When the internal open-drain FET is turned off, the $\overline{PPR}$ pin leaks less than 20μA current. When turned on, the $\overline{PPR}$ pin is able to sink at least 15mA current under all operating conditions. The $\overline{PPR}$ pin can be used to drive an LED or to interface with a microprocessor.

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POWER GOOD RANGE

The power good range is defined by the following three conditions:

1. $V_{IN} > V_{POR}$

2. $V_{IN} - V_{BAT} > V_{OS}$

3. $V_{IN} < V_{OVP}$

where the V_{OS} is the offset voltage for the input and output voltage comparator, discussed shortly, and the V_{OVP} is the over-voltage protection threshold given in the Electrical Characteristics table. All V_{POR}, V_{OS}, and V_{OVP} have hysteresis, as given in the Electrical Characteristics table. The charger will not charge the battery if the input voltage is not in the power good range.

$\overline{CHG}$ INDICATION

The $\overline{CHG}$ is an open-drain output capable of sinking at least 15mA current when the charger starts to charge, and turns off when the EOC current is reached. The $\overline{CHG}$ signal is interfaced either with a microprocessor GPIO or an LED for indication.

$\overline{EN}$ INPUT

$\overline{EN}$ is an active-low logic input to enable the charger. Drive the $\overline{EN}$ pin to low or leave it floating to enable the charger. This pin has a 200KΩ internal pull-down resistor so when left floating, the input is equivalent to logic low. Drive this pin to high to disable the charger. The threshold for high is given in the Electrical Characteristics table.

IREF PIN

The IREF pin has the two functions as described in the Pin Description section. When setting the fast charge current, the charge current is guaranteed to have 10% accuracy with the charge current set at 500mA. When monitoring the charge current, the accuracy of the IREF pin voltage vs. the actual charge current has the same accuracy as the gain from the IREF pin current to the actual charge current.

SOFT-START

The XTB1056 integrates a soft-start circuit to reduce the inrush current after new charge cycle starts. When one new charge cycle starts, the battery charge current is limited to ramp up from 0 to set value in 20 μs.

OPERATION WITHOUT THE BATTERY

The XTB1056 relies on a battery for stability and works under LDO mode if the battery is not connected. With a battery, the charger will be stable with an output ceramic decoupling capacitor in the range of 1μF to 200μF. In LDO mode, its stability depends on load current, C_{OUT}, etc. The maximum load current is limited by the dropout voltage, the programmed IREF and the thermal foldback.

BATTERY SHORT CIRCUIT AND REVERSE POLARITY PROTECTION

The XTB1056 features the BAT output short to ground protection and the battery reverse polarity protection. When the XTB1056 detects the BAT output voltage below the short to ground protection threshold, the BAT output short to ground protection works after a deglitch period, and the BAT output current is limited to 20 mA. When the XTB1056 detects the BAT output voltage below the reverse protection threshold, the battery reverse protection works after a deglitch period, and the leakage current of BAT pin is limited to 100 μA.

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OVER TEMPERATURE PROTECTION (OTP)

The XTB1056 integrates Foldback circuit and over-temperature protection to prevent device from over-heated and damage. When the junction temperature is higher than T_{OTP}, 150°C, a current thermal Foldback circuit starts to work and decrease the device output charge current gradually with T_J rise. If T_J still rises and reaches 180°C, the device will shut down charging loop until T_J drops below 100°C.

APPLICATION INFORMATION

VIN INPUT CAPACITOR AND BAT OUTPUT CAPACITOR

XTB1056 recommends to add a 1 µF to 10 µF capacitor with a 0.1 µF bypass capacitor in parallel at VIN to keep the input voltage stable. The voltage rating must be greater than the maximum power supply voltage. XTB1056 recommends to select a X5R- or X7R-type 1 µF to 10 µF high-frequency decoupling ceramic capacitor at the BAT output. Both input capacitors and output capacitors must be placed as close to the device pins as possible.

POWER DISSIPATION AND THERMAL CONSIDERATION

During normal operation, junction temperature limitation is 150°C. When junction temperature exceeds 150°C, the charge current decreases with the temperature value. Using Equation 1 and Equation 2 to calculate the power dissipation and estimate the junction temperature. The maximum power dissipation can be calculated using Equation 1.

$$P_D = (V_{IN} - V_{BAT}) \times I_{BAT} = \frac{T_{J,max} - T_A}{\theta_{JA}} \qquad (1)$$

Where,

$T_{J,max}$ is the junction temperature limitation, 150°C,

T_A is the ambient temperature,

θ_{JA} is the junction-to-ambient thermal resistance

Solve Equation 1, the constant charge current value is calculated in Equation 2.

$$I_{BAT} = \frac{150°C - T_A}{(V_{IN} - V_{BAT}) \times \theta_{JA}} \qquad (2)$$

LAYOUT GUIDELINE

Both input capacitors and output capacitors must be placed to the device pins as close as possible. It is recommended to bypass the input pin to ground with a 0.1 µF bypass capacitor. The loop area formed by the bypass capacitor connection, IN pin and the GND pin of the system must be as small as possible. It is recommended to use wide trace lengths or thick copper weight to minimize I×R drop and heat dissipation. Exposed pad must be connected to the PCB ground plane directly, the copper area must be as large as possible. To get the best thermal performance, thermal via should be placed under and around the exposed pad with enough number and size.

# 1A/28V Single Cell Li-ion Battery Linear Charger

PACKAGE OUTLINE DIMENSIONS

ESOP-8
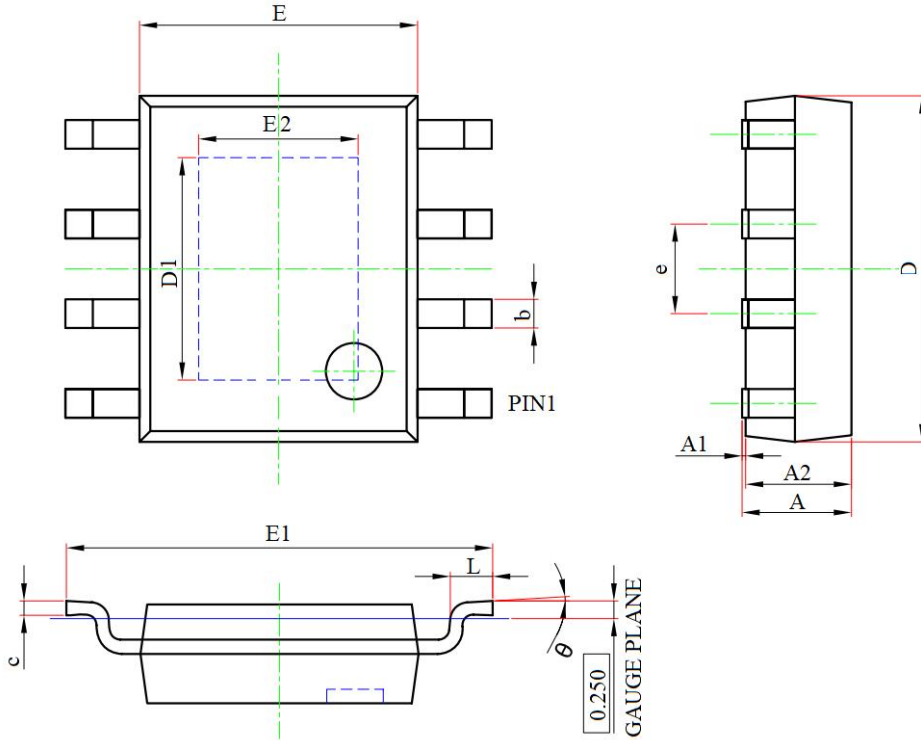
SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	1.300	1.700	0.051	0.067
A1	0.000	0.100	0.000	0.004
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
D1	3.050	3.350	0.120	0.132
E1	5.800	6.200	0.228	0.244
E2	2.160	2.360	0.085	0.093
e	1.27BSC		0.050BSC	
L	0.400	1.270	0.016	0.050
θ	0	8°	0	8°

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1A/28V Single Cell Li-ion Battery Linear Charger

DFN2X2-8L

TOP VIEW

SIDE VIEW

BOTTOM VIEW
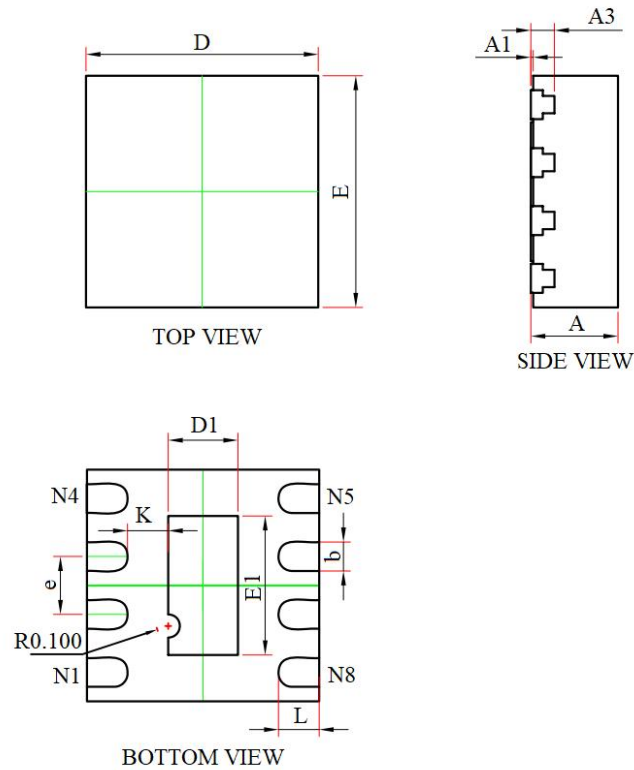
SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203REF		0.008REF	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	0.500	0.700	0.020	0.028
E1	1.100	1.300	0.043	0.051
k	0.350REF		0.014REF	
b	0.200	0.300	0.008	0.012
e	0.500BSC		0.020BSC	
L	0.274	0.426	0.011	0.017

1A/28V Single Cell Li-ion Battery Linear Charger

REVISION HISTORY

Number	Date	Description
Rev 0.0	2023/02	XTB1056 datasheet release
Rev 0.1	2023/08	Update "electrical characteristics" and "typical performance characteristics"
Rev 0.2	2023/09	Update "ABSOLUTE MAXIMUM RATINGS"
Rev 0.3	2023/10	Update "electrical characteristics"