

1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor

Features

- Single-Chip Charger for 1-cell Li-ion or Polymer Batteries
- 4.55-V to 9.8-V Input Voltage Operating Range
- 26.5-V Maximum Input Voltage Rating
- Charging
 - Up to 1000-mA Programmable Charge Current
 - 10% Charge Current Accuracy
 - 4.2-V/4.35-V Charge Float Voltage with 0.5% Accuracy
- Charging Current Monitor and Thermal Foldback
- Battery Temperature Monitor
- Charging Status Detection and Fault Indication
- Soft Start for Inrush Current Limitation
- Trickle Current Battery Charge
- Power Presence Indication
- Automatic Battery Recharge
- No external MOSFET, Current Sensor Required
- Operational Temperature Range: -40°C to +85°C
- Package options: ESOP-8, EMSOP-8

Applications

- Portable Devices, GPS, ePOS, e-cigarette
- Wireless Devices, Bluetooth Headset
- Personal Electronics, Personal Healthcare
- Wearable Devices

Description

The TPB4056B is a cost-effective, high-integration linear charger for single cell Li-ion or Li-ion polymer batteries. The device supports CC/CV charge from either a USB port or an AC adapter. Low BOM component requirement makes the size of the whole system small. High input voltage range with over-voltage protection supports low-cost unregulated adapters.

The TPB4056B charge current is fully programmable up to 1000 mA with an external resistor. The TPB4056B automatically terminates the charge cycle when the charge current drops below 10% of the set charge current value after the battery voltage reaches the float voltage.

The TPB4056B implements two indication pins: CHRG and STDBY, allowing connection to microcontroller or LED to show device status. With open-drain structure, CHRG stays low during charging, and STDBY stays low after charging complete. Other pins are in the high-impedance state.

The TPB4056B features thermal foldback function to limit the charge current and protect the device from over junction temperature fault. The TPB4056B also integrates current monitor, UVLO, and OVP functions to prevent the device from damage.

Typical Application Circuit

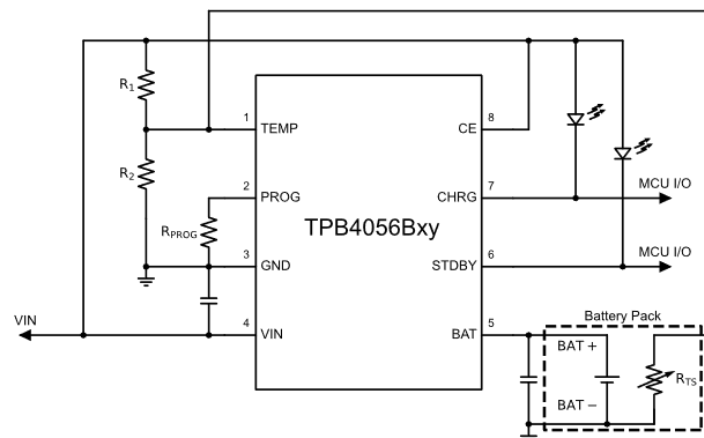


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1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor**Product Family Table**

Order Number	Float Voltage (V)	OVP (V)	Trickle Voltage (V)	Package
TPB4056B2X-ES1R	4.200	10.5	2.9	ESOP-8
TPB4056B2X-EV1R	4.200	10.5	2.9	EMSOP-8
TPB4056B3X-ES1R ⁽¹⁾	4.350	10.5	3.0	ESOP-8
TPB4056B3X-EV1R ⁽¹⁾	4.350	10.5	3.0	EMSOP-8

(1) For future products, contact the 3PEAK factory for more information and samples.

Revision History

Date	Revision	Notes
2022-04-02	Rev. A.0	First Release Version.
2023-05-02	Rev. A.1	Updated the format.
2023-08-02	Rev. A.2	Updated package thermal resistance.
2024-05-17	Rev. A.3	TEMP pin threshold was updated as percentage type, updated corresponding description in feature section.

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Pin Configuration and Functions

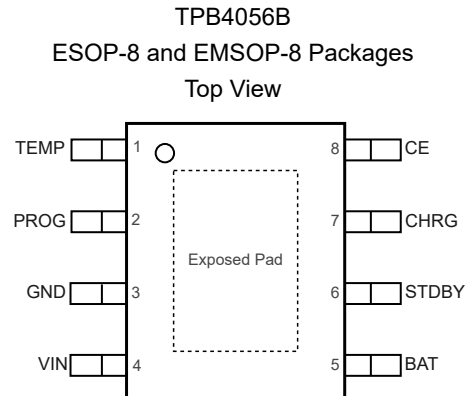


Table 1. Pin Functions: TPB4056B

Pin		I/O	Description
No	Name		
1	TEMP	I	Temperature monitor pin. Connect this pin to battery internal temperature sensor output pin to monitor the battery internal temperature. Connect this pin to GND to disable temperature monitor function.
2	PROG	I	Constant charge current set pin. Connect an external resistor from PROG pin to GND pin to adjust the charge current.
3	GND	-	Ground.
4	VIN	I	Power supply voltage input pin. Bypass VIN to GND with a 1 μ F or greater capacitor.
5	BAT	O	Battery charge output pin. Connect BAT pin to the battery. Bypass BAT to GND with a 1 μ F or greater capacitor.
6	STBY	O	Battery fully charged indication pin. This pin internally pulls low when device enter standby mode after battery charge complete.
7	CHRG	O	Battery charging indication pin. This pin internally pulls low when battery is under charging.
8	CE	I	Device enable pin. Drive this pin high to turn on the battery charge function. Drive this pin low to turn off the battery charge function.
E	PAD	-	Exposed pad must be connected to PCB ground plane to maximum the thermal performance.

1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor**Specifications****Absolute Maximum Ratings**

Parameter		Min	Max	Unit
Input Voltage	VIN	-0.3	26.5	V
	PROG	-0.3	6	V
	CE	-0.3	26.5	V
Output Voltage	CHRG, STDBY	-0.3	26.5	V
	BAT	-6	6	V
T _J	Maximum Junction Temperature	-40	125	°C
T _A	Operating Temperature Range	-40	85	°C
T _{STG}	Storage Temperature Range	-65	150	°C
T _L	Lead Temperature (Soldering 10 sec)		260	°C

(1) 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.

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

(3) This data was taken with the JEDEC standard multilayer test boards.

ESD, Electrostatic Discharge Protection

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⁾	1500	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	53	40	°C/W
EMSOP-8	75	42	°C/W

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Electrical Characteristics

All test conditions: $V_{IN} = 5\text{ V}$, $T_A = +25^\circ\text{C}$, unless otherwise noted.

Parameter			Conditions	Min	Typ	Max	Unit
Supply Voltage and Current							
V _{IN}	Operating Supply Voltage			4.55		9.8	V
I _{CC}	VIN Pin Supply Current		V _{BAT} = 4.4 V, CE = High		180	250	μA
I _{SD}	Shutdown Current		CE = Low, V _{IN} > UVLO ⁽¹⁾		55	110	μA
UVLO	Under Voltage Lockout		V _{IN} rising	3.5	3.7	3.9	V
	Hysteresis		V _{IN} drop	120	200	280	mV
Charge Voltage and Current							
V _{PROG}	PROG Voltage		Constant current mode,	0.92	1	1.08	V
			R _{PROG} = 1.2 kΩ				
I _{PROG}	PROG Source Current		V _{PROG} = 5 V		2		μA
V _{FLOAT}	BAT Pin Float Voltage or Battery End of Charge Voltage	TPB4056B2x		4.158	4.2	4.242	V
		TPB4056B3X		4.306	4.35	4.394	V
R _{ON}	Power FET Turn on Resistance				650		mΩ
I _{BAT}	BAT Pin Output Charge Current		Constant current range	50		1000	mA
			Constant current mode,	450	500	550	mA
			R _{PROG} = 2.4 kΩ				
			Constant current mode,	930	1000	1070	mA
			R _{PROG} = 1.2 kΩ				
	Battery Quiescent Current		Standby mode, V _{BAT} = 4.2V		-2.5	-6	μA
			Shutdown mode		-1	-2	μA
			Sleep mode, V _{IN} = 0 V		-1	-2	μA
t _{SS}	Soft-Start Delay Time		Charge current from 0 mA to I _{CC}		1		ms
V _{TCK}	Battery Trickle Charge Voltage		V _{BAT} < V _{TCK} , R _{PROG} = 1.2 kΩ	2.8	2.9	3	V
	Hysteresis		R _{PROG} = 1.2 kΩ	70	130	200	mV
I _{TCK}	Battery Trickle Charge Current		V _{BAT} < V _{TCK} , R _{PROG} = 1.2 kΩ	70	100	140	mA
V _{BAT,LO}	Battery Charge Lockout Threshold, V _{IN} – V _{BAT}		V _{IN} rising	70	100	130	mV
			V _{IN} failing	15	30	60	mV

(1) Only tested at $V_{IN} > UVLO$

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All test conditions: $V_{IN} = 5\text{ V}$, $T_A = +25^\circ\text{C}$, unless otherwise noted.

Parameter		Conditions	Min	Typ	Max	Unit
Charge Voltage and Current						
I_{TERM}	Termination Current Threshold, 10% of I_{CC}	$R_{PROG} = 2.4\text{ k}\Omega$		50		mA
		$R_{PROG} = 1.2\text{ k}\Omega$		100		mA
t_{TERM}	Termination Deglitch Time		0.8	1.8	4	ms
ΔV_{RECHG}	Recharge Threshold	$V_{FLOAT} - V_{RECHG}$	50	110	200	mV
t_{RECHG}	Recharge Deglitch Time		0.8	1.8	4	ms
Logic Input and Output						
$V_{CE.IH}$	CE Logic-Input High Level (enable)		1.6			V
$V_{CE.IL}$	CE Logic-Input Low Level (disable)				0.4	V
I_{CE}	CE Pin Leakage Current	$V_{CE} = 5\text{ V}$			1	μA
$V_{CHRG.OL}$	CHRG Low Level Output Voltage	$I_{CHRG} = 5\text{ mA}$		0.25	0.6	V
$V_{STDBY.OL}$	STDBY Low Level Output Voltage	$I_{STDBY} = 5\text{ mA}$		0.25	0.6	V
$V_{TEMP.IH}$	TEMP High-Level Threshold	Percentage of V_{IN}	78	80	82	%
$V_{TEMP.IL}$	TEMP Low-Level Threshold	Percentage of V_{IN}	43	45	47	%
Protection						
V_{OVP}	Input Over-Voltage Protection	V_{IN} rising	9.8	10.5	11.2	V
	Hysteresis			200		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		20		mA
Junction Temperature Protection						
T_{OTP}	Over Temperature Protection Threshold			150		$^\circ\text{C}$

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Typical Performance Characteristics

All test conditions: $V_{IN} = 5\text{ V}$, $T_A = +25^\circ\text{C}$, unless otherwise noted.

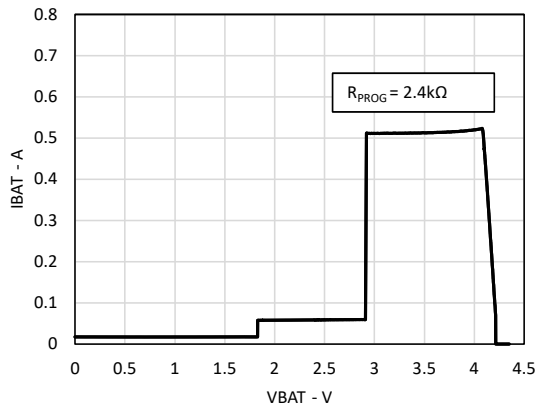


Figure 1. Charging Current IBAT vs VBAT Voltage

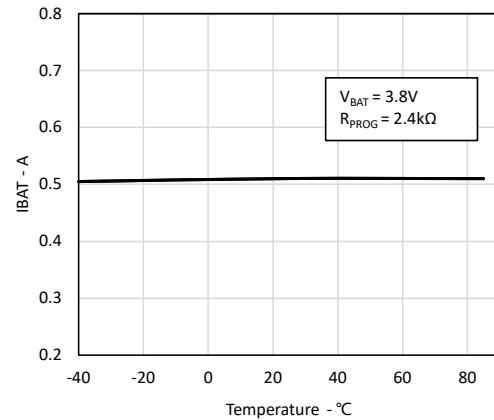


Figure 2. Charging Current IBAT vs Temperature

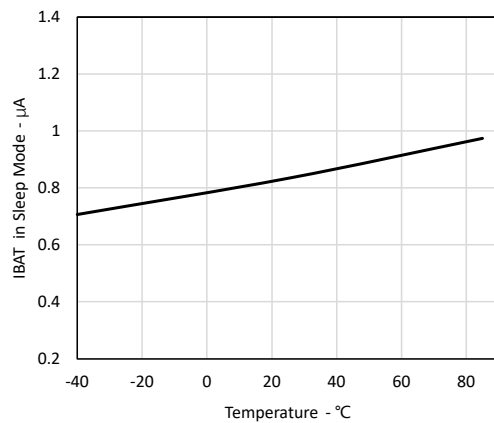


Figure 3. IBAT in Sleep Mode vs Temperature

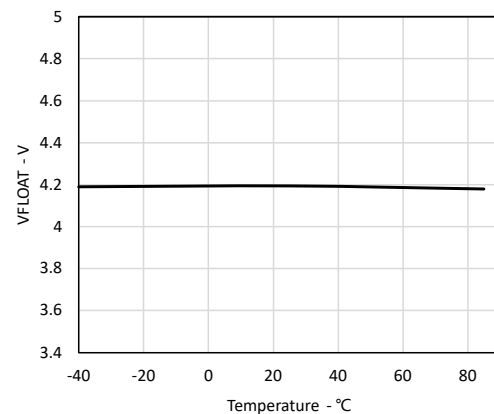


Figure 4. VFLOAT Voltage vs Temperature

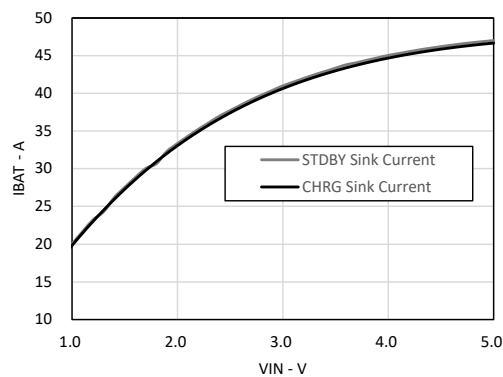


Figure 5. Sink Current of STDBY or CHRG vs VIN

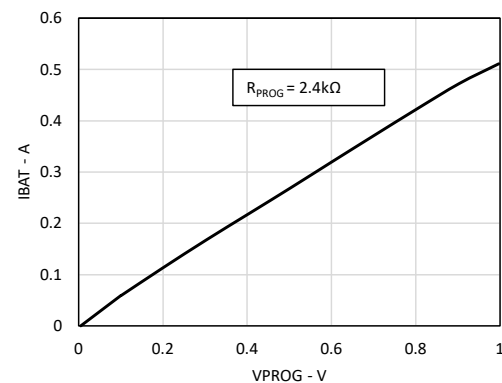


Figure 6. Charging Current IBAT vs PROG Voltage

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Detailed Description

Overview

The TPB4056B device is a cost-effective, high-integration linear charger for single cell Li-ion or polymer batteries. The device supports CC/CV charge from either a USB or an AC adapter. Low BOM components requirement makes the size of the whole system small. High input voltage range with over-voltage protection supports low-cost unregulated adapters. The TPB4056B device charge current is fully programmable from 50 mA to 1000 mA with an external resistor. The device can automatically terminate the charge cycle when the charge current drops below 10% of the set charge current value after the battery voltage reaches float voltage.

Feature Description

Enable (CE)

The TPB4056B device is in shutdown mode when the chip enable pin (CE) is low. Connect this pin to GPIO of an external processor or digital logic control circuit to enable or disable the device. Or connect this pin to the V_{CC} pin for self-bias applications.

Under-Voltage Lockout (UVLO)

The TPB4056B device uses an under-voltage lockout circuit to keep the device in shutdown mode until the supply voltage is higher than the UVLO threshold.

Over Voltage Protection (OVP)

The TPB4056B device uses an over-voltage protection circuit to prevent the device from damage when the supply voltage is higher than the OVP threshold. The internal power FET, if previously on, turns off after a 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 TPB4056B device provides fully programmable charge current from 50 mA to 1000 mA under normal charge conditions. A single current-programming resistor connected from the PROG 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 [Equation 1](#) to calculate the resistor value.

$$I_{CC} = \frac{1200}{R_{PROG}} \text{ (mA)} \quad (1)$$

Where,

I_{CC} is the desired constant charge current, R_{PROG} is the external current setting resistor of which the unit is kΩ.

The TPB4056B device implements the PROG pin short protection function, when PROG is short to ground, the battery charge current is limited to 1.5 A.

When the TPB4056B is powered up, the whole battery charging process can be divided into five sections below:

1. Trickle Current Battery Charge

The TPB4056B device operates in the trickle charge mode when the battery voltage is detected below the trickle charge threshold, V_{TRK}. In trickle charge mode, battery charge current is limited to a small current range, I_{TRK}, to protect the battery.

2. Constant Current Battery Charge

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The TPB4056B device enters constant current (CC) battery charge mode when the battery voltage ramps higher than the trickle charge threshold V_{TCK} . In this mode, constant current, determined by the resistor from PROG to GND, flows out from the BAT pin to the battery.

3. Constant Voltage Battery Charge

The TPB4056B device 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} .

4. Battery Charge Termination

When the charge current falls below 1/10 of the constant current value, the TPB4056B device terminates the battery charge cycle after a deglitch period, and the TPB4056B device enters the battery charge standby mode.

5. Battery Recharge

In battery charge standby mode, the TPB4056B monitors the battery voltage continuously. When the battery voltage falls below the battery recharge voltage threshold V_{RECHG} , the TPB4056B starts a new charge cycle after a deglitch period.

Figure 7 shows the typical behavior during one battery charging cycle.

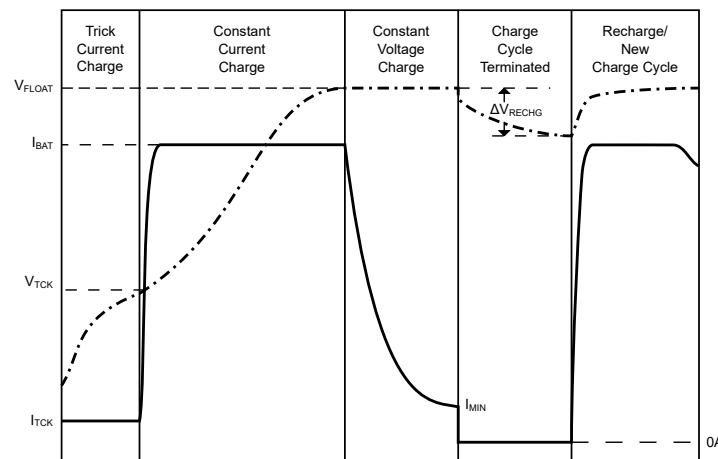


Figure 7. Current and Voltage During One Charging Cycle

Soft-Start

The TPB4056B device integrates a soft-start circuit to reduce the inrush current after new charge cycle starts. When one new charge cycle starts, the ramp-up period of the battery charge current is within 20 μ s from 0 to the set value.

Battery Short Circuit and Reverse Polarity Protection

The TPB4056B features the BAT output short to ground protection. When the TPB4056B device 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.

The TPB4056B implements battery reverse polarity protection, when the TPB4056B device detects the BAT output voltage below -0.1 V, battery reverse protection works after a deglitch period, and the leakage current of the BAT pin is limited to 100 μ A.

Battery Temperature Monitor

The TPB4056B device implements temperature monitor circuit to protect battery from damage due to over or under temperature range. By measuring the TEMP pin voltage whether it maintains in the normal operating voltage range or not, the TPB4056B device calculates the internal temperature of the battery and turns on or off the output charge FET. The normal operating temperature range is determined by a resistor divider and the internal temperature sense resistor of the battery.

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Use [Equation 2](#) and [Equation 3](#) to calculate the resistors divider.

$$V_{TEMP, IH} = \frac{R_2 // R_{TS, L}}{R_1 + R_2 // R_{TS, L}} \quad (2)$$

$$V_{TEMP, IL} = \frac{R_2 // R_{TS, H}}{R_1 + R_2 // R_{TS, H}} \quad (3)$$

Where,

- $V_{TEMP, IH}$ is the TEMP pin high level threshold.
- $V_{TEMP, IL}$ is the TEMP pin low level threshold.
- $R_{TS, H}$ is the temperature sense resistance at high temperature.
- $R_{TS, L}$ is the temperature sense resistance at low temperature.

If only single temperature protection is under consideration, e.g. over temperature protection, R_2 can be removed and then calculation is simplified, vice versa. If the battery temperature monitor function is not used, connect the TEMP pin to ground directly.

Battery Charge Status Indication

The TPB4056B device has two pins to indicate the battery charge status: CHRG and STDBY. Connect these two pins to the GPIO of a microcontroller to read the TPB4056B device working status or connect with LEDs pull-up circuit as the status indicators. Pull down these two pins to ground directly when the status indication function is not used.

Table 2. Battery Charge Status indication

Conditions	Battery temperature monitor	CHRG Pin/LED	STDBY Pin/LED
Battery charging	Yes	Low/On	High-Z/Off
Battery fully charged	Yes	High-Z/Off	Low/On
Shutdown mode (CE = Low, or PROG float, $V_{IN} < UVLO$, or $V_{IN} < V_{BAT}$)	Yes	High-Z/Off	High-Z/Off
V_{IN} over voltage (OVP)			
No battery connected			
Battery out of operating temperature range	No (TEMP = GND)	Pulse/Flicker every 0.5~4s when $C_{BAT} = 10 \mu F$	Low/On
No battery connected			

Over Temperature Protection (OTP)

The TPB4056B device integrates foldback circuit and over-temperature protection to prevent device over-heated. When the junction temperature is higher than T_{OTP} , 145°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 150°C, the device will shut down.

Application and Implementation

Note

Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

The TPB4056B device is a cost-effective, high-integration linear charger for single cell Li-ion or polymer batteries. The device supports CC/CV charge from either USB or AC adapter. Low BOM components requirement makes the size of the whole system small. The following sections show a typical application of the TPB4056B.

Typical Application

Figure 8 shows the typical application schematic of the TPB4056B.

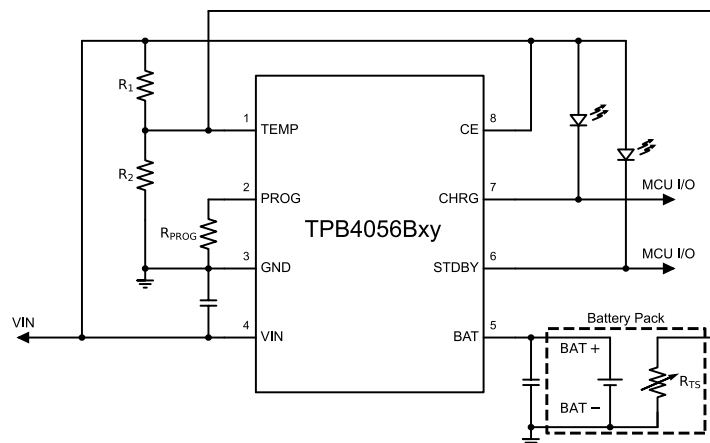


Figure 8. Typical Application Circuit

VIN Input Capacitor and BAT Output Capacitor

3PEAK recommends adding a 1- μ F to 10- μ F capacitor with a 0.1- μ F bypass capacitor in parallel at V_{IN} to keep the input voltage stable. The voltage rating must be greater than the maximum power supply voltage.

3PEAK recommends selecting an X5R- or X7R-type 1- μ F to 10- μ F 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 145°C. When junction temperature exceeds 145°C, the charge current decreases with the temperature value. Using Equation 4 and Equation 5 to calculate the power dissipation and estimate the junction temperature.

The maximum power dissipation can be calculated using [Equation 4](#).

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$$P_D = (V_{IN} - V_{BAT}) \times I_{BAT} = \frac{T_{J,max} - T_A}{\theta_{JA}} \quad (4)$$

Where,

$T_{J,max}$ is the junction temperature limitation, 145°C,

T_A is the ambient temperature,

θ_{JA} is the junction-to-ambient thermal resistance (See Section [Thermal Information](#)).

Solve [Equation 4](#), the constant charge current value is calculated in [Equation 5](#).

$$I_{BAT} = \frac{T_{J,max} - T_A}{(V_{IN} - V_{BAT}) \times \theta_{JA}} \quad (5)$$

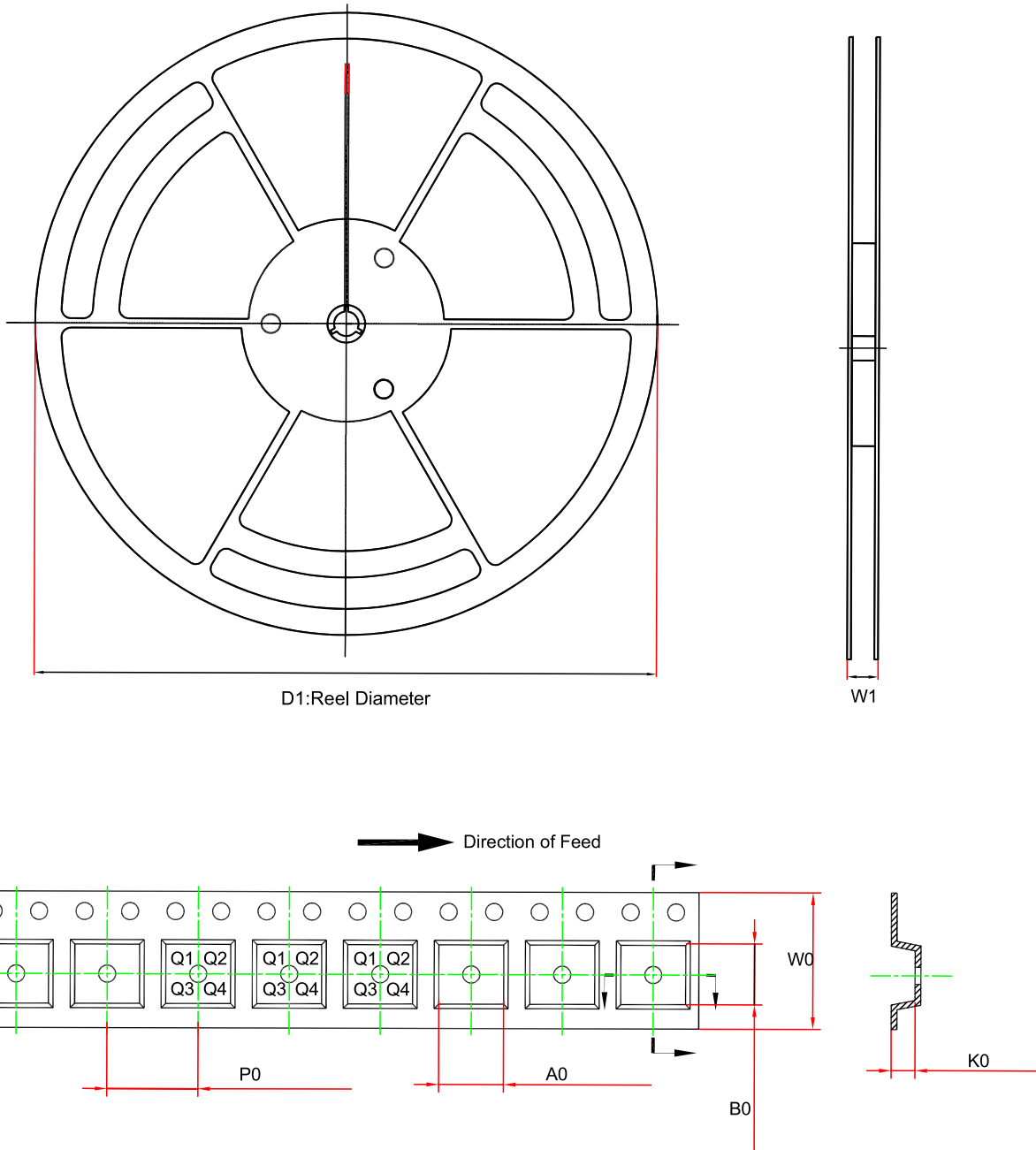
Layout

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- μ F bypass capacitor. The loop area formed by the bypass capacitor connection, the IN pin, and the GND pin of the system must be as small as possible.
- It is recommended to use wide and thick trace to minimize $I \times R$ drop and heat dissipation.
- The 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 vis should be placed under and around the exposed pad with enough number and size.

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Tape and Reel Information



Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPB4056B2X-ES1R	ESOP-8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TPB4056B2X-EV1R	EMSOP-8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TPB4056B3X-ES1R	ESOP-8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1

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Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPB4056B3X- EV1R	EMSOP-8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1

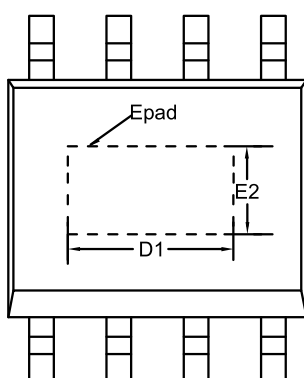
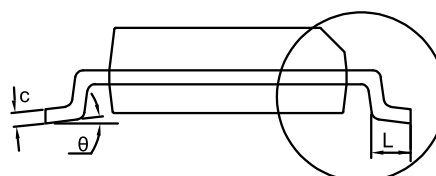
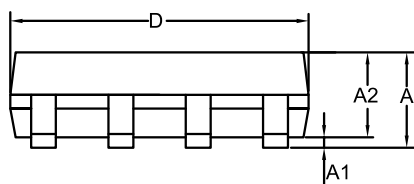
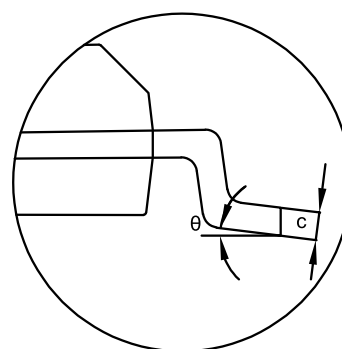
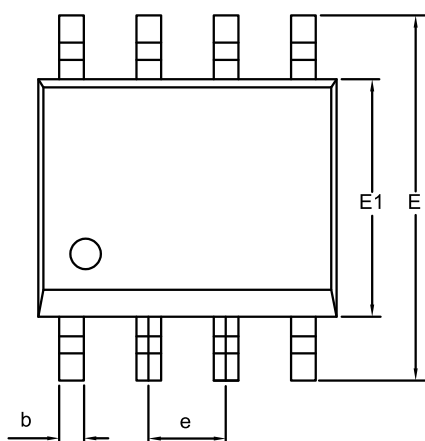
1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor

Package Outline Dimensions

ESOP8

Package Outline Dimensions

ES1(ESOP-8-F)



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
D1	3.050	3.250	0.120	0.128
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
E2	2.160	2.360	0.085	0.093
e	1.270 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0	8°	0	8°

NOTES

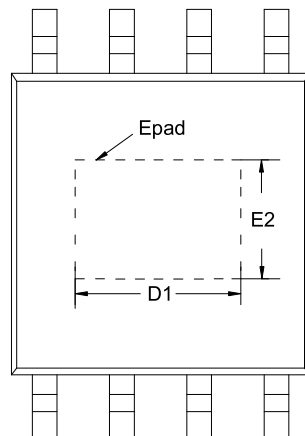
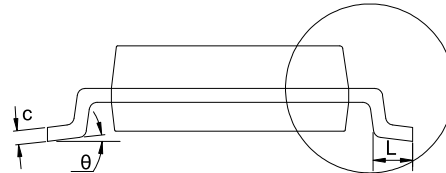
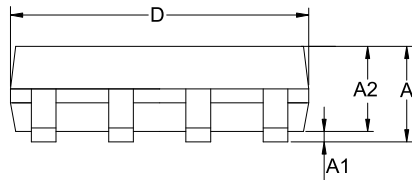
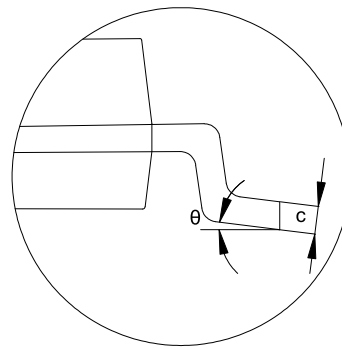
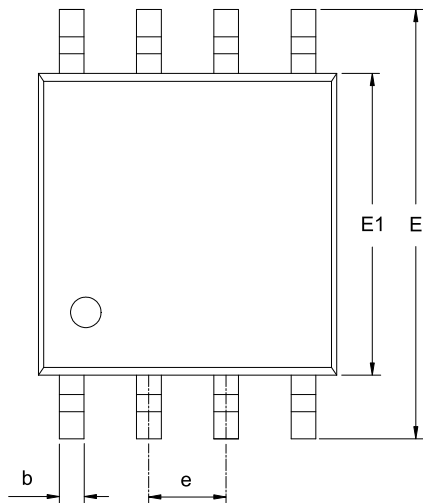
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor

EMSOP8

Package Outline Dimensions

EV1(EMSOP-8-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.050	0.150	0.002	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
D1	1.700	1.900	0.067	0.075
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
E2	1.450	1.650	0.057	0.065
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

- Do not include mold flash or protrusion.
- This drawing is subject to change without notice.

1-A Single Cell Li-Ion Battery Linear Charger with NTC Monitor**Order Information**

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPB4056B2X-ES1R	-40 to 85°C	ESOP-8	6B2X	3	Tape and Reel, 4000	Green
TPB4056B2X-EV1R	-40 to 85°C	EMSOP-8	6B2X	3	Tape and Reel, 3000	Green
TPB4056B3X-ES1R	-40 to 85°C	ESOP-8	6B2X	3	Tape and Reel, 4000	Green
TPB4056B3X-EV1R	-40 to 85°C	EMSOP-8	6B2X	3	Tape and Reel, 3000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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