迅瑞创芯
centrokersing

XR4056/XR4056A

1A/18V Linear Charger for Single Cell Li-Ion Battery with Thermal Regulation

DESCRIPTION

The XR4056 and XR4056A are complete constant-current/ constant-voltage Li-Ion and Li-Polymer linear chargers targeted at spaced-limited portable applications. Furthermore, the XR4056 and XR4056A are specifically designed to work within USB power specifications.

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 (XR4056) or 4.35V (XR4056A), and the charge current can be programmable externally. The device terminates the charge cycle when the charge current drops to 1/10 of the presetting value after the final float voltage is reached.

When the input supply is removed, the XR4056/XR4056A enters a low current state, dropping the battery drain current to less than 1μA. The XR4056/XR4056A can be put into shutdown mode, reducing the supply current to 75μA during adaptor is present. The other features of XR4056/XR4056A include external battery temperature monitor, two open-drain outputs indicator, and automatic recharge function.

The XR4056/XR4056A guarantees robustness with input and battery reverse connection protection, input over voltage protection, thermal shutdown and under voltage lockout.

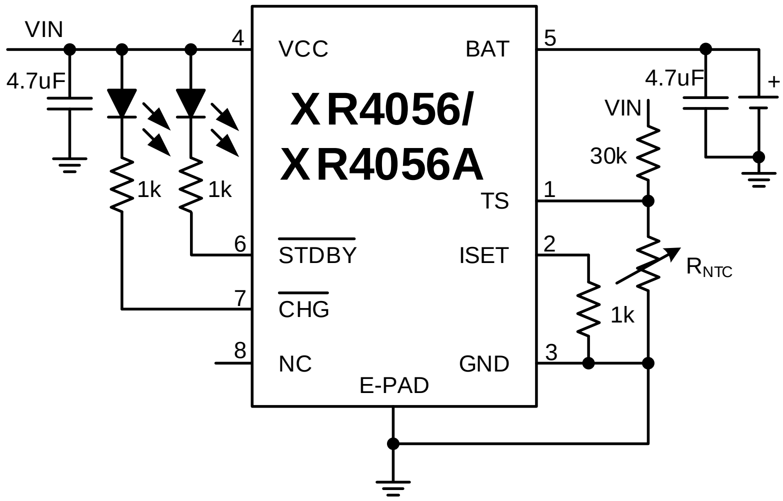
FEATURES

- 18-V Input Rating
- Programmable Charge Current Up to 1A
- Charging Management (Trickle Charge/ Constant Current Charge/ Constant Voltage Charge/ Charge Termination/Auto Recharge)
- 4.2V(XR4056) / 4.35V(XR4056A) Charge Termination Voltage with ±1% Accuracy
- 2.9V Trickle Charge Threshold
- 1/10 I_{CHG} Charge Termination
- Soft-Start Limits Inrush Current
- Operation Over JEITA Range via Battery NTC – 1/2 Fast-Charge Current at Cold, 4.1V at Hot
- Input and Battery Reverse Polarity Protection, Input Over Voltage Protection, Input Under Voltage Lockout, Thermal Shutdown
- Charge Status Indicators
- Available in ESOP8 Package

APPLICATIONS

- Portable Media Players, Digital Cameras
- Bluetooth Applications
- Toys
- Li-Ion/ Li-Polymer Battery Powered Devices

TYPICAL APPLICATION



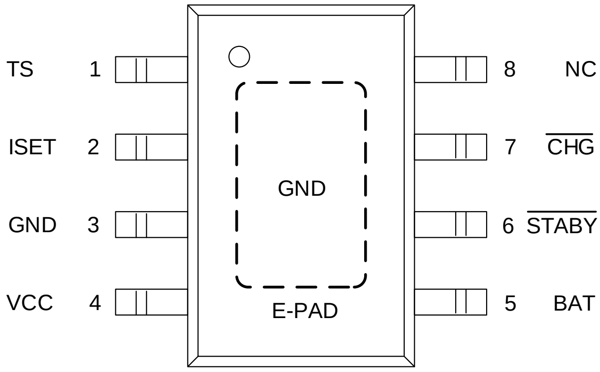
Typical application circuit

ORDER INFORMATION

DEVICE[1)]	PACKAGE	TOP MARKING[2)]
4056ESOP#TRPBF	ESOP8	4056 YW□□□□□
4056AESOP#TRPBF	ESOP8	4056A YW□□□□□

PIN CONFIGURATION

TOP VIEW



ABSOLUTE MAXIMUM RATING[1)]

VCC……...-5.5V to 18V
VCC-BAT...-8.5V to 18V
BAT..........………...-5.5V to 5.5V
TS…… ....-5.5V to 18V
$\overline{STDBY}$, $\overline{CHG}$..-0.3V to 18V
ISET, NC…..-0.3V to 6.5V
Junction Temperature[2)] 150ºC
Lead Temperature 260ºC
Storage Temperature .... -65ºC to +150ºC
Human Body Model (HBM)...±2kV
Charged-Device Model (CDM)..,,,...±1kV

RECOMMENDED OPERATING CONDITIONS[3)]

VCC...4.3V to 7.5V
Operation Junction Temperature (T_J) … ....-40ºC to +125ºC
Continuous Power Dissipation (T_A=25 ºC)[4)] 2W

THERMAL PERFORMANCE[5)]

	θ_{JA}	θ_{JC}
ESOP8	50…	10ºC/W

Note：

1) Exceeding these ratings may damage the device. These stress ratings do not imply function operation of the device at any other conditions beyond those indicated under RECOMMEND OPERATION CONDITIONS.

2) The XR4056/XR4056A includes thermal protection that is intended to protect the device in overload conditions. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.

3) The device is not guaranteed to function outside of its operating conditions.

4) The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D(MAX)} = (T_{J(MAX)} - T_A)/\theta_{JA}$.

5) Measured on JESD51-7, 4-layer PCB

ELECTRICAL CHARACTERISTICS

V_{CC}=5V, T_A=25℃, unless otherwise stated

Item	Symbol	Condition	Min.	Typ.	Max.	Units
INPUT						
Input operation voltage range	V_{CC}		4.3	5	7.5	V
Input under-voltage lock-out threshold	V_{UV}	V_{CC} rising, V_{CC}>V_{BAT}+ V_{ASD}	3.9	4.0	4.1	V
Input under-voltage lock-out hysteresis	V_{UV_HYS}	V_{CC} falling, V_{CC}>V_{BAT}+ V_{ASD}	70	120	170	mV
V_{CC}-V_{BAT} lock-out threshold	V_{ASD}	V_{CC} rising	70	100	140	mV
		V_{CC} falling	10	45	75	mV
Input over-voltage protection threshold	V_{OVP}	V_{CC} rising	7.3	7.5	7.7	V
Hysteresis on input OVP	V_{OVP_HYS}	V_{CC} falling	100	150	210	mV
Input OVP deglitch time[6)]	t_{OVP_DEG}			50		μs
Input OVP recovery time[6)]	t_{OVP_REC}			400		μs
Input pull-down resistance[6)]	R_{PD}			100		kΩ
QUIESCENT CURRENT						
Quiescent V_{CC} supply current	I_{Q_VCC}	I_{VCC}-I_{BAT}, charge mode		1.12	1.6	mA
		Charge terminated		120	220	μA
		R_{ISET} disconnected; Or V_{CC}<V_{BAT}+V_{ASD}; Or V_{CC}<V_{UV}		75	160	μA
Quiescent BAT supply current	I_{Q_BAT}	Charge terminated		2.5	6	μA
		R_{ISET} disconnected; Or V_{CC}<V_{BAT}+V_{ASD}; Or V_{CC}<V_{UV}		±1	±2	μA
BATTERY CHARGER						
Battery regulation voltage	V_{FLOAT}	XR4056, 0℃≤T_A≤85℃, TS normal temperature.	4.158	4.2	4.242	V
		XR4056A, 0℃≤T_A≤85℃, TS normal temperature.	4.306	4.35	4.394	V
		TS hot temperature, XR4056, XR4056A	4.02	4.06	4.10	V
Soft-start time[6)]	t_{SS}	I_{BAT}=0 to I_{CHG}		25		ms
Power FET "ON" resistance (between VCC and BAT)[6)]	R_{ON}			700		mΩ

I_{SET} pin voltage on CC charge phase	V_{ISET_CC}	R_{ISET}=1kΩ~10kΩ, TS normal temperature	0.9	1.0	1.1	V
		R_{ISET}=1kΩ~10kΩ, TS cold temperature	0.475	0.5	0.525	V
I_{SET} pin voltage on trickle charge phase	V_{ISET_TRIK}	R_{ISET}=1kΩ~10kΩ, trickle charge	0.08	0.1	0.12	V
Constant current factor	K_{CC}		900	1000	1100	AΩ
Trickle current factor	K_{TRIK}		40	80	120	AΩ
Charge current in CC charge phase	I_{CHG}	$V_{CC}>V_{UV}$, $V_{CC}>V_{BAT}+V_{ASD}$, $V_{BAT}>V_{TRIK}$, not DPM	K_{CC} / R_{ISET}			A
Charge current in trickle charge phase	I_{TRIK}		K_{TRIK} / R_{ISET}			A
Trickle charge threshold voltage	V_{TRIK}	V_{BAT} rising	2.8	2.9	3.0	V
Trickle charge hysteresis voltage	V_{TRIK_HYS}		150	250	350	mV
Deglitch time on charge phase switch between trickle mode and CC mode[6)]	t_{TC_DEG}	Trickle to CC charge		25		ms
		CC to trickle charge		25		ms
Termination comparator detection threshold	I_{TERM}		0.7	0.11	0.145	×I_{CHG}
Termination detected deglitch time[6)]	t_{TERM}			50		ms
Recharge detection threshold	ΔV_{RCHG}	V_{BAT} falling, $V_{FLOAT}-V_{RCHG}$	50	100	150	mV
Recharge detected deglitch time[6)]	t_{RCHG}			50		ms
VINDPM AND THERMAL REGULATION						
Input voltage threshold when charge current is reduced	V_{IN_DPM}		4.15	4.3	4.45	V
Junction temperature threshold when charge current is reduced[6)]	T_{J_DPM}			125		℃
Thermal shut down threshold[6)]	T_{J_SD}	T_J rising		155		℃
Thermal shut down hysteresis[6)]	T_{J_SDHYS}			20		℃
ISET						
ISET pin pull-up current[6)]	I_{ISET}			2		μA
Manual shutdown threshold voltage	V_{MSD}	ISET pin rising	1.45	1.5	1.55	V
		ISET pin falling	1.15	1.2	1.25	V
Maximum charge current	I_{CHG_MAX}	ISET connected to GND	1.15	1.3	1.45	A
INDICATORS						

Output LOW voltage on $\overline{\text{STDBY}}$ pin[6]	$V_{\overline{STDBY}}$	$I_{\overline{STDBY}}$ = 5mA, sink current			0.6	V
Output LOW voltage on $\overline{\text{CHG}}$ pin[6]	$V_{\overline{CHG}}$	$I_{\overline{CHG}}$ = 5mA, sink current			0.6	V
BATTERY-PACK NTC MONITOR (JEITA Thermistor Comparator)						
0℃ threshold	V_{TS_0}	TS rising	46.62	47.62	48.62	$\%V_{CC}$
10℃ threshold	V_{TS_10}	TS rising	36.45	37.45	38.45	$\%V_{CC}$
45℃ threshold	V_{TS_45}	Falling	13.07	14.07	15.07	$\%V_{CC}$
60℃ threshold	V_{TS_60}	Falling	8.14	9.14	10.14	$\%V_{CC}$
Disable NTC monitor function threshold	V_{TS_DIS}		3	4	5	$\%V_{CC}$
Deglitch time on thermistor comparator output transition	t_{TS_DEG}			25		ms
VCC, BAT REVERSE LEAKAGE						
VCC reverse leakage	I_{VCC_R}	V_{CC}= -5V, V_{BAT}= V_{FLOAT}			10	mA
BAT reverse leakage	I_{BAT_R}	VCC=5V, V_{BAT}= -V_{FLOAT}			5	mA

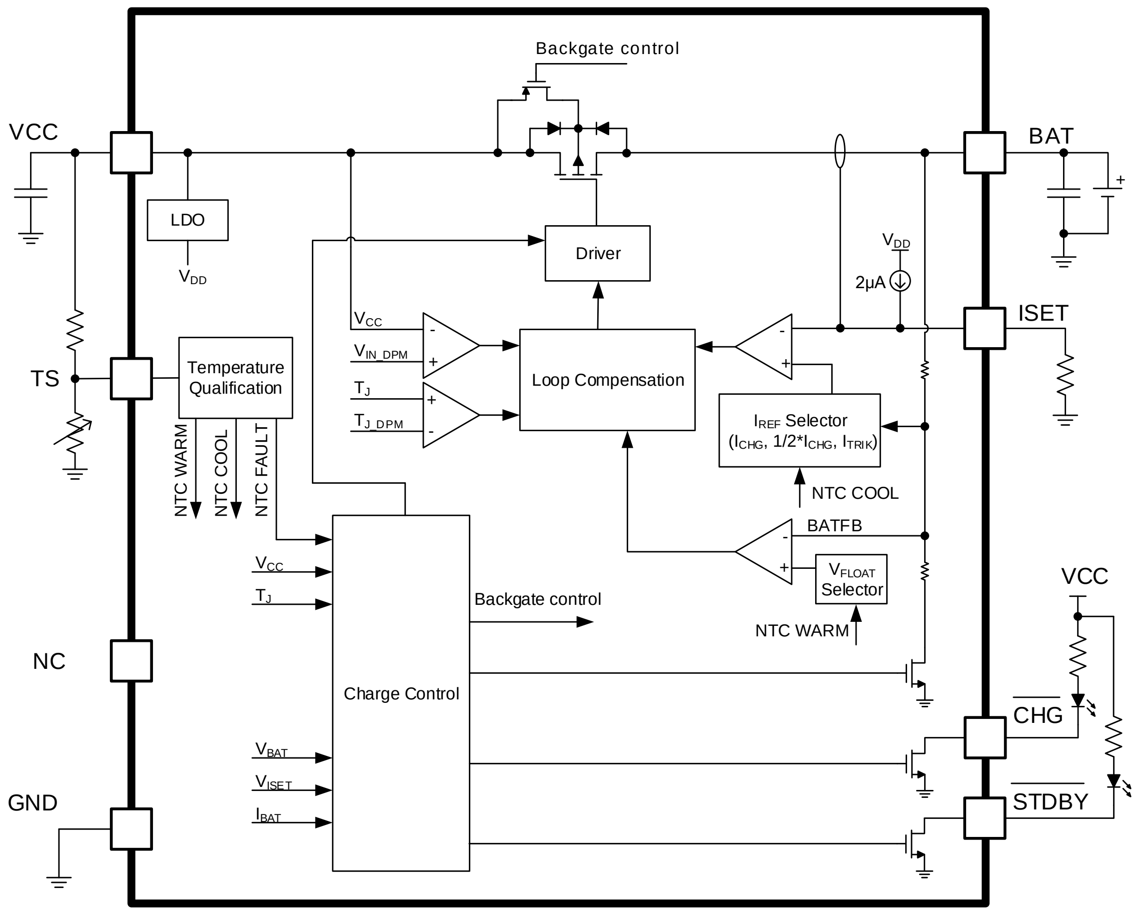
Notes:

6) Guaranteed by design.

PIN DESCRIPTION

Pin No.	Name	Description
1	TS	External NTC thermistor input. Program temperature window with a resistor divider from VCC to TS to GND. It is recommended to use a 103AT thermistor.
2	ISET	ISET pin sets the charge current of constant-current phase by regulating the ISET voltage at 1V or 0.5V (at cool temperature). A resistor is connected from ISET pin to ground to set the constant-current as I_{CHG}=1000AΩ/R_{ISET}. In trickle charge phase, the ISET voltage is regulating at 0.1V and set the trickle-current as I_{TRIK}=100AΩ/R_{ISET}.
3	GND	Ground. Connect to the thermal pad and to the ground rail of the circuit.
4	VCC	Input power connection. This pin provides power to the charger. Connect bypass ceramic capacitor 1μF to 10μF to ground.
5	BAT	Charge current output. Provides charge current to the battery and regulates the final float voltage to 4.2V or 4.35V. Bypass BAT to GND with a 4.7μF to 47μF ceramic capacitor.
6	$\overline{\text{STABY}}$	Open-drain charge finished status indication output. $\overline{\text{STABY}}$ pulls to LOW only when the charging is complete. Otherwise, $\overline{\text{STABY}}$ is high impedance.
7	$\overline{\text{CHG}}$	Open-drain charges status indication output. When the battery is charging, the $\overline{\text{CHG}}$ pulled low by an internal N-channel MOSFET. In other status, $\overline{\text{CHG}}$ is high impedance.
8	NC	Do not make a connection to this terminal (for internal use) – Do not route through this terminal.
-	Thermal Pad	Exposed pad. The exposed package pad is ground and must be soldered to the PCB for maximum heat transfer.

BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

The XR4056 and XR4056A are complete constant-current/ constant-voltage linear chargers for single cell Li-Ion/ Li-Polymer batteries. The device can deliver up to 1A charge current (using a good thermal PCB layout) with a final voltage accuracy of ±1%. No blocking diode or external current sense resistor is required. The input power source for charging the battery can be an AC adapter or a USB port. When charging from a USB port, the input dynamic power management (V_{IN}-DPM) circuit reduced the input current if the input voltage falls below a threshold, thus preventing the USB port from crashing. An internal thermal limit reduces the charge current if the die temperature attempts to rise above a preset value of approximately 125℃. This feature protects the XR4056/XR4056A from excessive temperature, and allows the user to take full advantage of the power handling capability at a given circuit board without risk of damaging the XR4056/XR4056A or external components.

Normal Charge Cycle

The XR4056/XR4056A powers internal bias circuits from VCC. When VCC rises above UVLO threshold, the device wakes up from sleep mode, the VCC comparator, TS comparator, ISET comparator and junction temperature comparator are active.

XR4056/XR4056A enables the power MOSFET and starts a charge cycle when all the below conditions are valid:

- V_{CC} above V_{UV}
- V_{CC} above V_{BAT}+V_{ASD}
- V_{CC} below V_{OVP}
- T_J below T_{J_SD}
- V_{TS_0}<V_{TS}<V_{TS_60} or V_{TS}<V_{TS_DIS}
- V_{ISET}<V_{MSD}

If any one of the above conditions is not valid, the device keeps the power MOSFET off, and draws less than typical 75μA from VCC, draws less than typical 1μA from battery.

The device charges the battery in three phases: trickle charging, constant current charging and constant voltage charging. At the beginning of a charging cycle, the device checks the battery voltage and regulates current and voltage accordingly. If the voltage at the BAT pin is less than V_{TRIK}, the charger enters trickle charging phase, the charge current is reduced to nearly 1/10 of the presetting value. The charger switches to constant current charging phase as the BAT pin voltage rises above V_{TRIK}, the charge current is thus resumed to full presetting value. When the final float voltage is reached, the device enters constant voltage charging phase and charge current begins to decrease until it drops to 1/10 of the presetting value and ends the charge cycle.

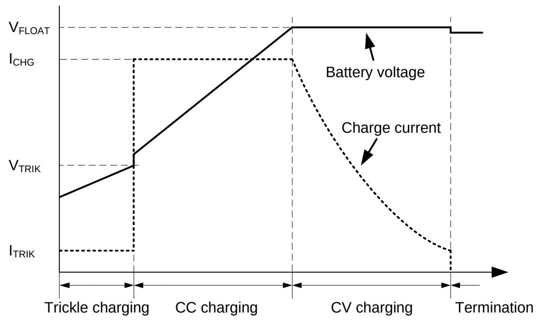


Figure 1. Battery Charging Profile

Programming Charge Current

The charge current is programmable 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 program resistor and the charge current are calculated using the following equations:

R_{ISET}=1000V / I_{CHG}, I_{CHG}= 1000V / R_{ISET}

The ISET pin voltage is regulated at 1V in constant current charging and 0.1V in trickle charging. The charge current can be determined at any time by monitoring the ISET pin voltage using the following equation:

I_{BAT}=1000 × V_{ISET} / R_{ISET}

Charge Termination and Recharge

XR4056/XR4056A terminates a charge cycle when the battery voltage is above the recharge threshold V_{RCHG}, and the current is below termination current I_{TERM} for longer than t_{TERM}. The termination current is 1/10 I_{CHG}.

After charge termination, XR4056/XR4056A constantly monitors the BAT pin voltage. If the voltage drops below the recharge threshold V_{RCHG} longer than t_{RCHG}, another charge cycle automatic begins and current is once again supplied to the battery. To manually restart a charge cycle after charge termination, the input voltage must be removed and reapplied, or the charge current program resistor R_{ISET} must be disconnected and reconnected.

Input Dynamic Power Management

To meet maximum current in USB spec and avoid over loading the adapter, XR4056/XR4056A features input dynamic power management which continuously monitors the input voltage when charging. When input source is over-loaded, the input voltage falls below the input voltage limit (V_{IN_DPM}). The device then reduces the charge current until the input voltage rises above the input voltage limit.

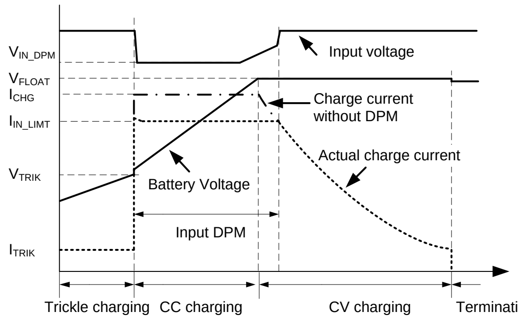


Figure 2. Battery Charging Profile with Input DPM

Thermal Limiting

An internal thermal feedback loop reduces the charge current if the die temperature attempts to rise above a preset value of approximately 125℃, hence prevents the temperature from further increase and ensure device safe operation.

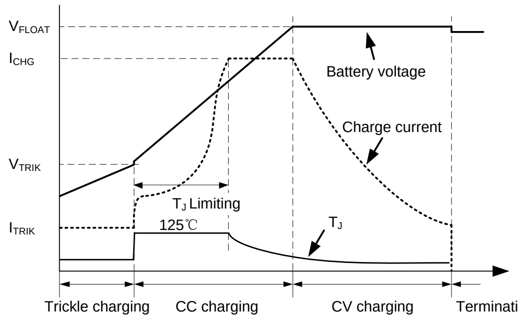


Figure 3. Battery Charging Profile with T_J Limiting

Under-Voltage Lockout

Build-in under-voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VCC rises above the under-voltage lockout threshold. The UVLO circuit has a built-in hysteresis of 150mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if VCC falls below the V_{BAT}+30mV. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until VCC rises 100mV above the battery voltage.

Input Over-voltage

If VCC voltage exceeds V_{OVP} longer than t_{OVP_DEG}, the power MOSFET turns off. During input over-voltage event, $\overline{CHG}$ and $\overline{STDBY}$ are forced high impedance. The device will automatically resume normal operation when VCC falls 150mV below over-voltage threshold longer than t_{OVP_REC}.

Manual Shutdown

At any point in the charge cycle, the XR4056/XR4056A can enter shutdown mode by removing R_{ISET} and floating the ISET pin. In shutdown mode, the battery current is less than 1μA and the VCC current is less than 75μA. A new charge cycle can be initiated by reconnecting the R_{ISET} resistor.

In manual shutdown mode, the ISET pin is in high impedance state. A true open-drain or open-collector structure should be used to disconnect the R_{ISET}, and no external capacitor is allowed to connect to this pin.

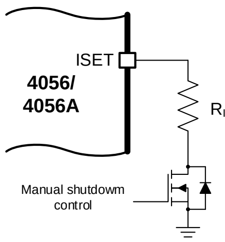


Figure 4. Manual Shutdown Mode Application

Thermistor Qualification

The JEITA guideline emphasized the importance of avoiding a high charge current and high charge voltage at certain low and high temperature ranges.

XR4056/XR4056A provides a single thermistor input TS pin for battery temperature monitor. To initiate a charge cycle, the voltage on TS pin must be within the V_{TS_0} to V_{TS_60} thresholds. If TS voltage exceeds the V_{TS_0}-V_{TS_60} range, the device suspends charge by turning off the power MOSFET. Charge is resumed when the temperature returns to the V_{TS_0}-V_{TS_60} range.

The TS function for XR4056/XR4056A is designed to follow the JEITA temperature standard for Li-Ion and Li-Polymer batteries. At cool temperature (V_{TS_0}-V_{TS_10}), the ISET pin voltage is regulated at 0.5V, the charge current is reduced to half of the presetting charge current. At warm temperature (V_{TS_45}-V_{TS_60}), the battery charge voltage is reduced to 4.1V, and charge termination is temporarily disabled.

The external resistors R_{T1} and R_{T2} enable selecting a temperature window. If R_{TC} and R_{TH} are the thermistor impedances for the Cold (0℃) and Hot (60℃) thresholds, the values for R_{T1} and R_{T2} can be calculated as follows, for a NTC thermistor.

$$R_{T1}=\frac{R_{TC}R_{TH}(K_2-K_1)}{K_1K_2(R_{TC}-R_{TH})}$$

$$R_{T2}=\frac{R_{TC}R_{TH}(K_2-K_1)}{R_{TC}(K_1-K_1K_2)-R_{TH}(K_2-K_1K_2)}$$

Where, K_1=0.45, K_2=0.8.

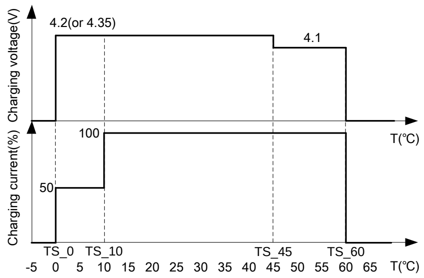


Figure 5. JEITA Profile

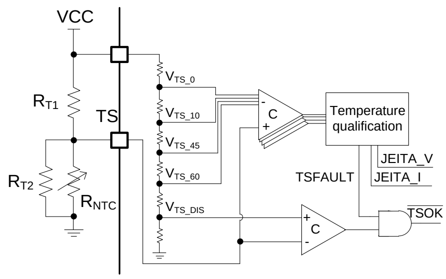


Figure 6. Battery Temperature Qualification

The temperature sensing feature can be disabled by connecting TS pin to ground to keep TS pin voltage below V_{TS_DIS}.

Charge Current Soft-Start

The XR4056/XR4056A includes a soft-start circuit to minimize the inrush current. When a charge cycle is initialed or charge phase transfers from trickle charging to constant current charging, the charge current ramps from zero to the full-scale current over a period of approximately 25ms.

Charge Status Indicators

The XR4056/XR4056A has two open-drain charge status indication output pins. $\overline{STDBY}$ is pulled LOW only when the charging is complete. Otherwise, $\overline{STDBY}$ is high impedance. $\overline{CHG}$ is battery in charging indicator, it is pulled LOW when battery in charging and output high impedance when charge finished or charge disabled.

Charge Status	$\overline{CHG}$	$\overline{STDBY}$
In charging	Low	High Z
Charge finished	High Z	Low
• $V_{CC}<V_{UV}$ • $V_{CC}<V_{BAT}+V_{ASD}$ • VCC OVP • TS voltage out of range • $V_{ISET}> V_{MSD}$ • VCC reverse connection • Battery reverse connection • Junction OTP	High Z	High Z

VCC Reverse Polarity Protection

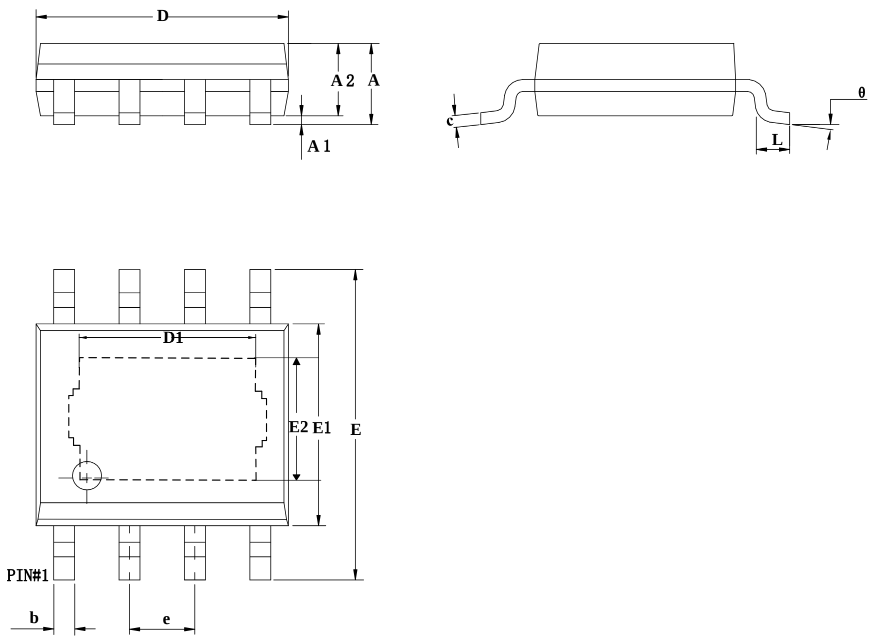
XR4056/XR4056A provides reverse polarity input voltage protection. The device keeps in shutdown mode when input voltage polarity is reversed, and two open-drain indication pins are high impedance. The reverse leakage current is below 10mA. When battery is connected, the reverse input voltage should not exceed 5.5V. Exceeding this rating may damage the device.

Battery Reverse Polarity Protection

XR4056/XR4056A provides reverse polarity battery voltage protection. The device keeps in shutdown mode when battery voltage polarity is reversed, and two open-drain indication pins are high impedance. The reverse leakage current is below 5mA. The device will automatically resume normal operation when battery is connected correctly.

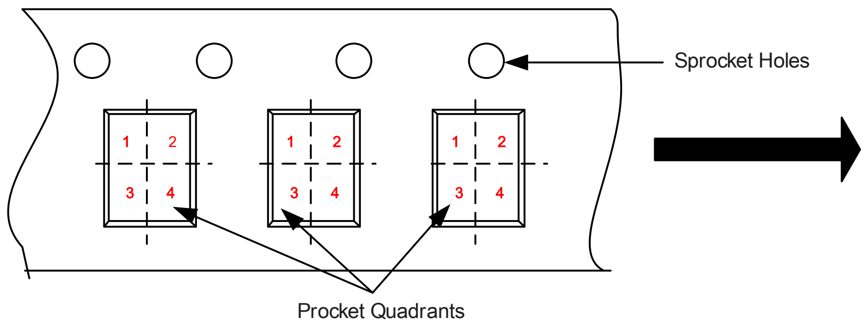
PACKAGE OUTLINE

ESOP8 UNIT: mm



Symbol	MILLIMETER		
	MIN	NOM	MAX
A	1.30	—	1.70
A1	0.00	—	0.10
A2	1.35	—	1.60
b	0.33	—	0.51
c	0.17	—	0.25
D	4.70	—	5.10
E	5.80	6.00	6.20
E1	3.75	3.90	4.15
D1	3.05	—	3.40
E2	2.16	—	2.50
e	1.27BSC		
L	0.40	—	1.27
θ	0°	—	8°

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPAE



Package Type	Pin1 Quadrant
ESOP8	1