Standalone Linear Li-Ion Battery Charger with Thermal Regulation

FEATURES

- **Programmable Charge Current up to 1A**
- **No MOSFET, Sense Resistor or Blocking Diode Required**
- **Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate without Risk of Overheating**
- **Charge Single Cell Li-Ion Batteries Directly from USB Port**
- **Charge Current Monitor Output for Gas Gauging**
- **Preset 4.2V Charge Voltage with 1% Accuracy**
- **2.9V Trickle Charge Threshold**
- **C/10 Charge Termination**
- **55µA Supply Current in Shutdown Mode**
- **Automatic Recharge**
- **Soft-Start Limits Inrush Current**
- **Battery Reversed Protection**
- **Available in the Green ESOP8 Package**

APPLICATIONS

- **Mobile Phones, PDAs, MP3 Players**
- **Charging Docks and Cradles**
- **Bluetooth Applications**
- **Other Handheld Devices**

DESCRIPTION

TheYX4056B is a complete constant-current/constant voltage linear charger for single cell lithium-ion batteries. Its compact size and low external component count make the YX4056B ideally suited for portable applications. Furthermore, the YX4056B is specifically designed to work charging the battery from the power supplies of the 5V adapter and the USB port.

No external sense resistor is needed, and no blockingdiode is required due to the internal MOSFET architecture.Thermal feedback regulates the charge current to limit thedie temperature during high power operation or highambient temperature. The charge voltage is fixed at 4.2V,and the charge current can be programmed externally with a single resistor. The YX4056B automatically terminatesthe charge cycle when the charge current drops to 1/10ththe programmed value after the final float voltage isreached.

Other features include charge current monitor, battery reversed protection, undervoltagelockout, automatic recharge and a status pin to indicatecharge termination and the presence of an input voltage.

The YX4056B is available in ESOP8 package requiring minimum board space and smallest components.It is rated over the -40°C to +85°C temperature range.

TYPICAL APPLICATIONS

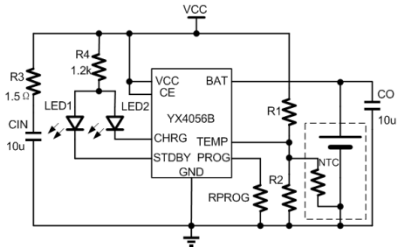


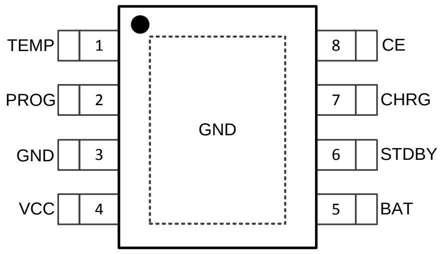
Figure 1. Typical Application Circuit

ORDERING INFORMATION

DEVICE	ORDER NUMBER	PACKAGE DESCRIPTION	AMBIENT TEMPERATURE	PACKAGE MARKING	PACKAGE OPTION	Package Qty.
YX4056B	YX4056BSE8NR	ESOP8	-40℃ to +85℃	YX4056B	Tape and Reel	3000
	YX4056BD030R	TDFN-3×3-8L	-40℃ to +85℃	YX4056B	Tape and Reel	5000

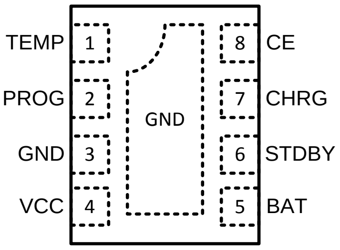
PIN CONFIGURATION

YX4056B



ESOP8

YX4056B



TDFN-3×3-8L

Table 1. PIN Descriptions

PIN	NAME	PIN FUNCTION
1	TEMP	Temperature sense input.
2	PROG	Constant Charge Current Setting and Charge Current Monitor Pin.
3	GND	Ground voltage.
4	VCC	Power input supply voltage.
5	BAT	Charge current output.
6	STDBY	Charge terminatedstatus output.
7	CHRG	Open-drain charge status output.
8	CE	Chip enable input, high voltage activity.
9	Thermal PAD	Connect this PAD to GND

ABSOLUTE MAXIMUM RATINGS

Description		Ratings / Value / Range	Units
Supply Input Voltage (VIN)		-0.3 ~ 9.0	V
Battery Pin (BAT)		-4.5 ~ 5.5	V
Other Pins		-0.3 ~ 9.0	V
Storage Temperature Range		-65 ~ +150	°C
Junction Temperature		150	°C
Lead Temperature		260	°C
ESD Rating	HBM (Human Body Mode)	2000	V
	CDM (Charge Device Mode)	250	V

THERMAL INFORMATION

Description		Ratings / Value / Range	Units
Package Thermal Resistance (θ_{JA})	ESOP8	50	°C/W
	TDFN-3×3-8L	80	°C/W
Power Dissipation,P_D@T_A=25°C	ESOP8	2.1	W
	TDFN-3×3-8L	1.3	W

RECOMMENDED OPERATION CONDITIONS

Description	Ratings / Value / Range	Units
Operating Junction Temperature	-40 ~ 125	°C
Operating Ambient Temperature	-40 ~ 85	°C
Supply Input Voltage	+2.5 ~ +5.5	V
Continuous Output Current	1	A

Note 1. Stresses beyond those listed as the above *ABSOLUTED MAXIMUM RATINGS* may cause permanent damage to the device.These are for stress ratings only.Functional operation of the device at these or any other conditions beyond those indicated in the *RECOMMENDED OPERATION CONDITIONS* section of the specifications are not implied.Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. Devices are ESD sensitive.Handling precaution recommended.

Note 3. θ_{JA} is measured in the natural convection at T_A=25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

Important information and disclaimer:

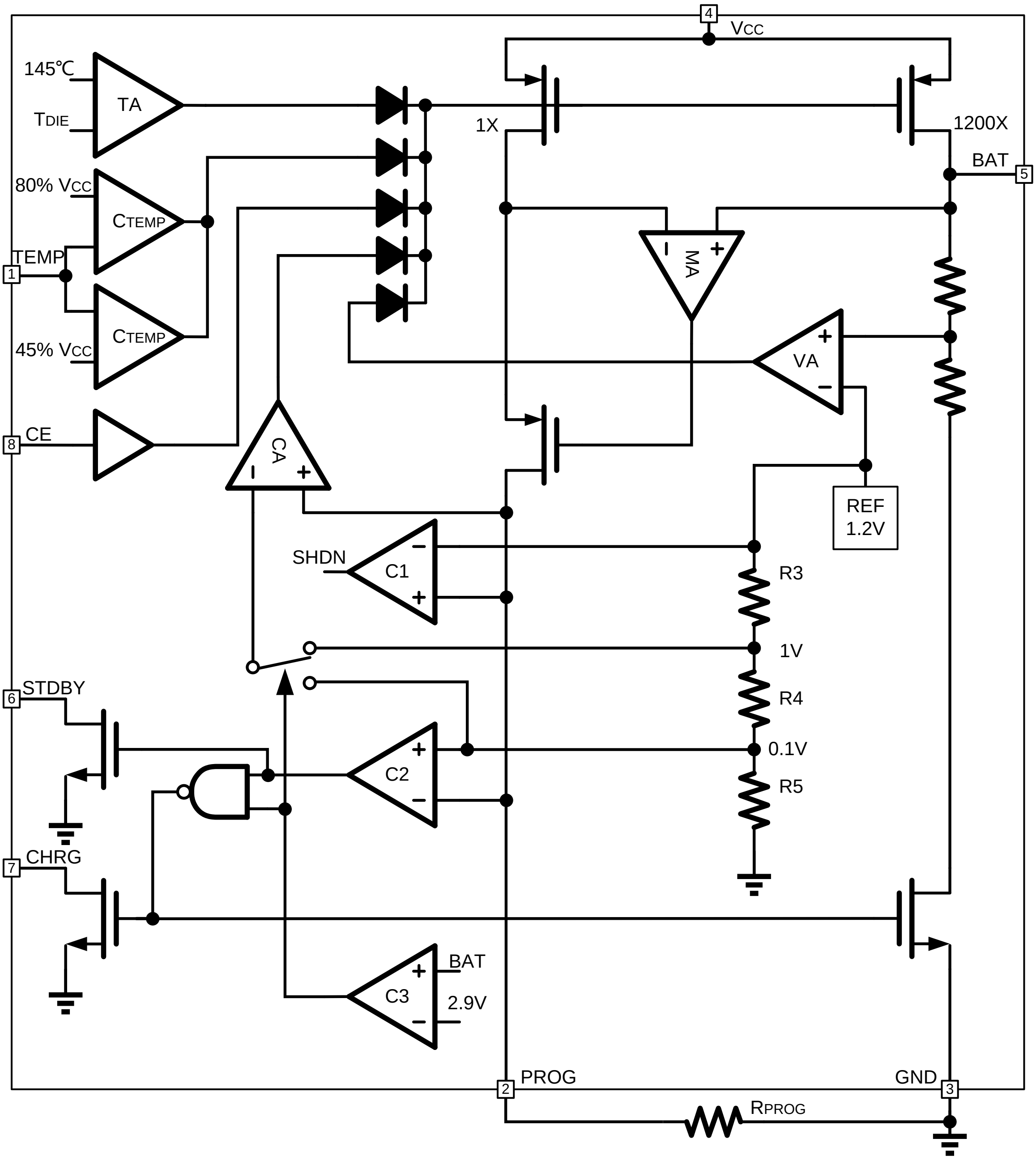
ShiningICreserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 5.0V, T_A = 25°C, unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Input Voltage Range	V_{IN}		4.3	5.0	8.0	V
Quiescent Supply Current	I_Q	Charge Mode，R_{PROG}=1.2k		150	500	μA
		Standby Mode(Charge Terminated)		55	100	μA
		Shutdown Mode(R_{PROG} Not Connected, V_{CC}< V_{BAT}, or V_{CC}< V_{UV})		55	100	μA
Regulated Output(Float)Voltage	V_{FLOAT}	0°C≤T_A≤85°C, IBAT = 40mA	4.158	4.200	4.242	V
BAT Pin Current	I_{BAT}	R_{PROG} = 2.4k, Current Mode	400	500	550	mA
		R_{PROG} = 1.2k, Current Mode	950	1000	1050	mA
		Standby Mode, V_{BAT} = 4.2V	0	-2.5	-6	μA
		Shutdown Mode (R_{PROG} Not Connected)		±1	±2	μA
		Sleep Mode, V_{CC} = 0V		-1	-2	μA
Trickle Charge Current	I_{TRIKL}	V_{BAT}< V_{TRIKL}, R_{PROG} = 1.2k	110	120	130	mA
Trickle Charge Threshold Voltage	V_{TRIKL}	R_{PROG} = 1.2k, VBAT Rising	2.8	2.9	3.0	V
Trickle Charge Hysteresis Voltage	V_{TRHYS}	R_{PROG} = 1.2k	60	80	100	mV
VCC Undervoltage Lockout Threshold	V_{UV}	From V_{CC} Low to High	3.5	3.7	3.9	V
VCC Undervoltage Lockout Hysteresis	V_{UVHYS}		150	200	300	mV
Manual Shutdown Threshold Voltage	V_{MSD}	PROG Pin Rising	3.4	3.5	3.6	V
		PROG Pin Falling	1.9	2.0	2.1	V
VCC – VBAT Lockout Threshold Voltage	V_{ASD}	V_{CC} from Low to High	60	100	140	mV
		V_{CC} from High to Low	5	30	50	mV
Battery Reversed Protection Voltage	V_{REV}	V_{BAT} Falling		-70		mV
Battery Reversed Protection Hysteresis	V_{REVHYS}	V_{BAT} Rising		-30		mV
C/10 Termination Current Threshold	I_{TERM}	R_{PROG} = 2.4k	50	60	70	mA
		R_{PROG} = 1.2k	110	120	130	mA
PROG Pin Voltage	V_{PROG}	R_{PROG} = 1.2k, Current Mode	0.9	1.0	1.1	V
CHRG Pin Output Low Voltage	V_{CHRG}	I_{CHRG} = 5mA		0.3	0.6	V
STDBY Pin Output Low Voltage	V_{CHRG}	I_{STDBY} = 5mA		0.3	0.6	V
Recharge Battery Threshold Voltage	ΔV_{RECHRG}	V_{FLOAT} - V_{RECHRG}	100	150	200	mV
Junction Temperature in Constant Temperature Mode	T_{LIM}			145		℃
Power FET “ON” Resistance (Between VCC and BAT)	R_{ON}			300		mΩ
Soft-Start Time	t_{SS}	I_{BAT} = 0 to I_{BAT} =1000V/R_{PROG}		20		μs
Recharge Comparator Filter Time	$t_{RECHARGE}$	V_{BAT} High to Low	0.8	1.8	4.0	ms
Termination Comparator Filter Time	t_{TERM}	I_{BAT} Falling Below I_{CHG}/10	0.8	1.8	4.0	ms
PROG Pin Pull-Up Current	I_{PROG}			1.0		μA
TEMP Pin High Side Protection Voltage	V_{TEMP-H}			80	82	%V_{CC}
TEMP Pin Low Side Protection Voltage	V_{TEMP-L}		43	45		%V_{CC}
EN Pin Input Rising Threshold	V_{ENH}		1.2			V
EN Pin Input Falling Threshold	V_{ENL}				0.6	V

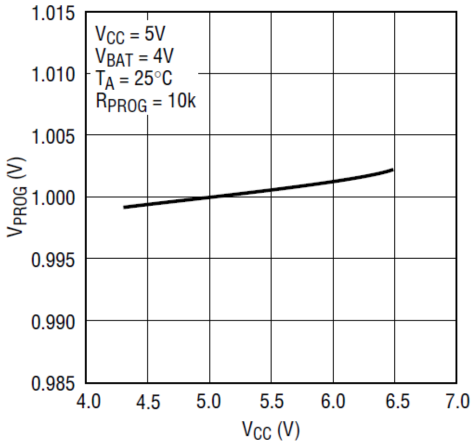
BLOCK DIAGRAM



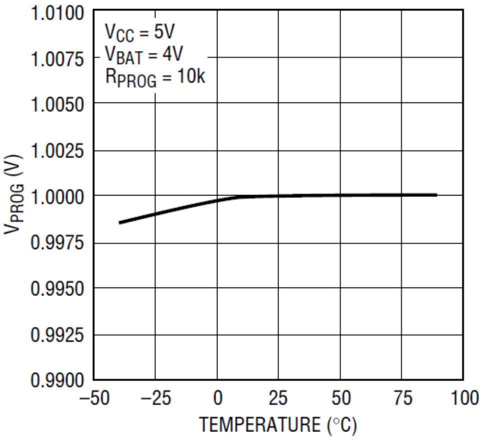
TYPICAL CHARACTERISTICS

V_{IN} = 5.0V,T_A =25°C, unless otherwise specified.

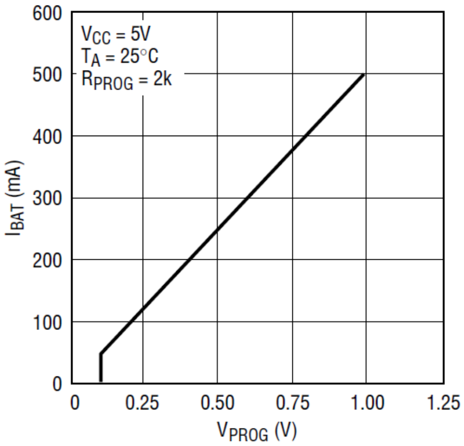
PROG Pin Voltage vs Supply Voltage (Constant Current Mode)



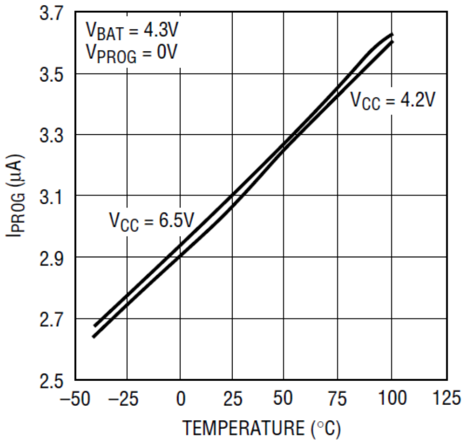
PROG Pin Voltage vs Temperature



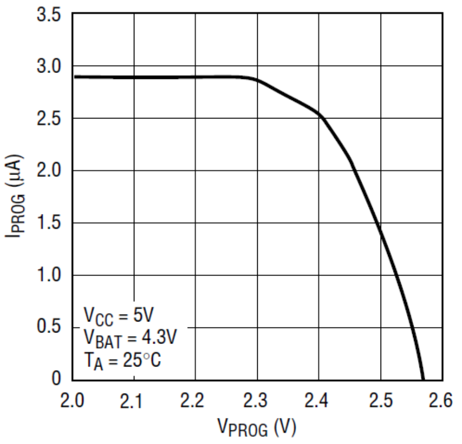
Charge Current vs PROG Pin Voltage



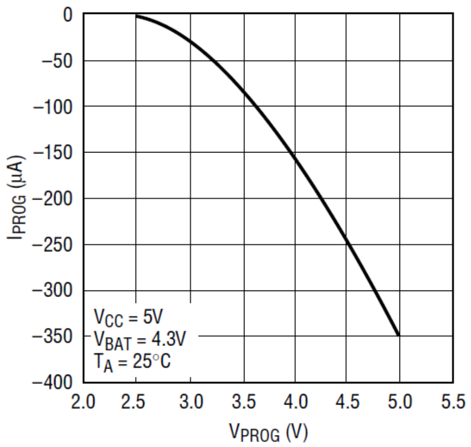
PROG Pin Pull-up Current vs Temperature and Voltage



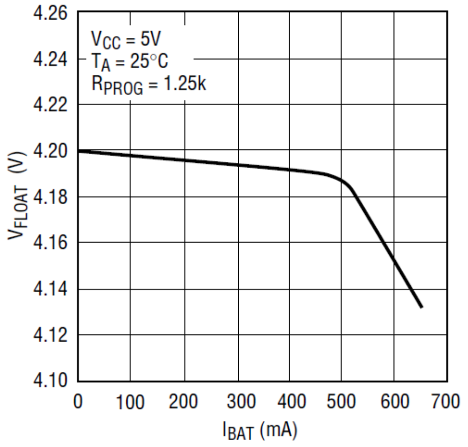
PROG Pin Current vs PROG Pin Voltage(Pull-Up Current)



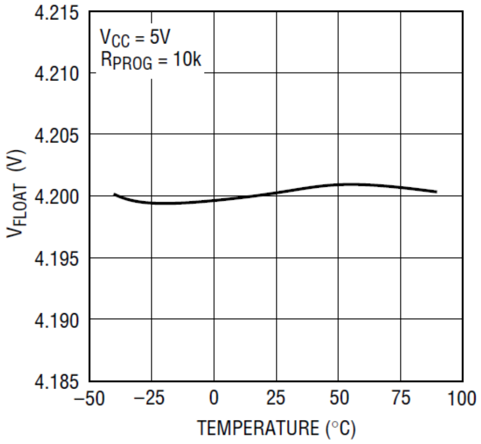
PROG Pin Current vs PROG Pin Voltage(Clamp Current)



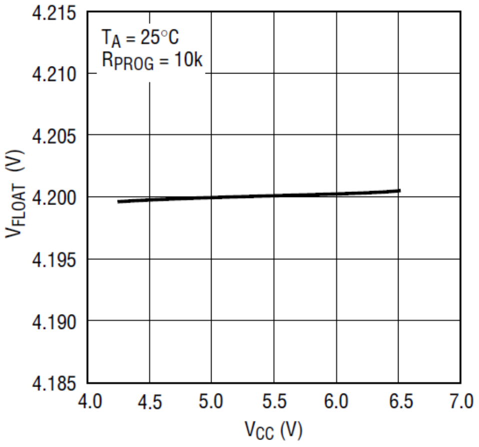
Regulated Output(Float) Voltage vs Charge Current



Regulated Output(Float) Voltage vsTemperature



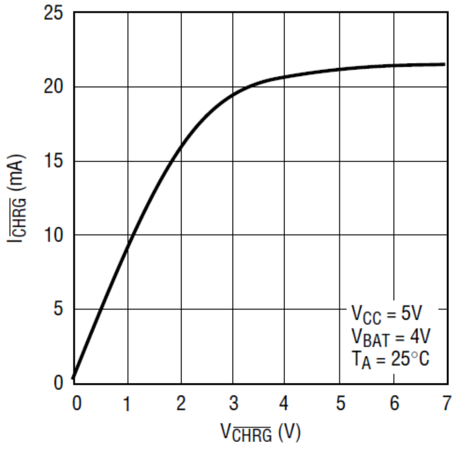
Regulated Output(Float) Voltage vs Supply Voltage



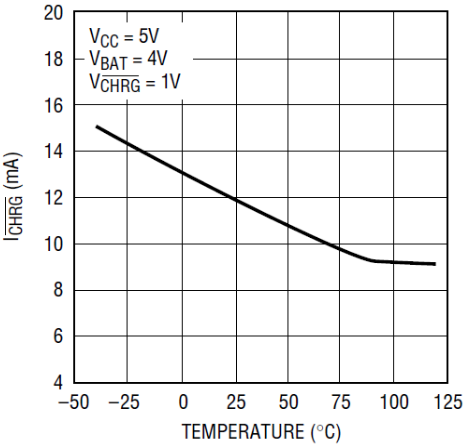
TYPICAL CHARACTERISTICS

V_{IN} = 5.0V,T_A =25°C, unless otherwise specified.

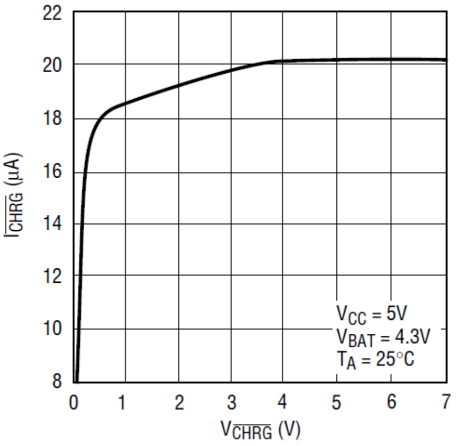
CHRG Pin I-V Curve (Strong Pull-Down State)



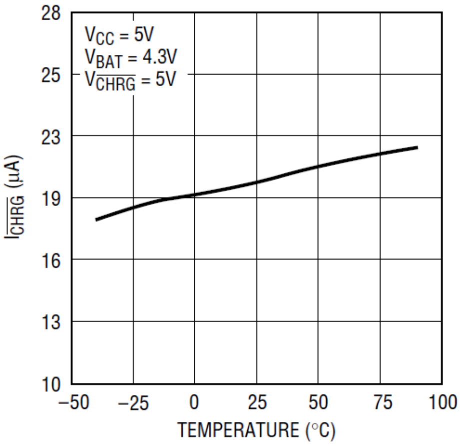
CHRG Pin Current vs Temperature (Strong Pull-Down State)



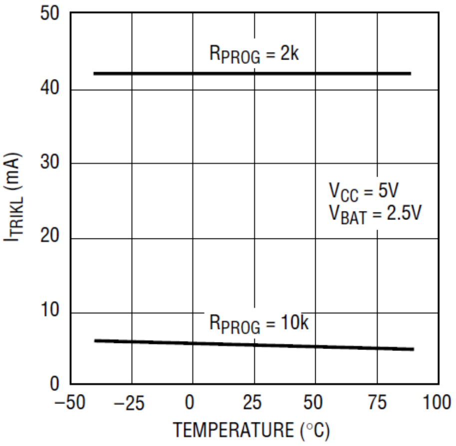
CHRG Pin I-V Curve (Weak Pull-Down State)



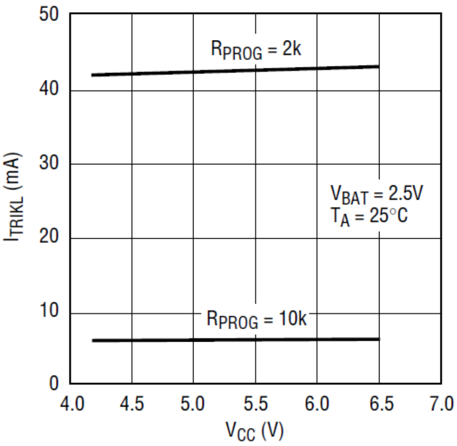
CHRG Pin Current vs Temperature (Weak Pull-Down State)



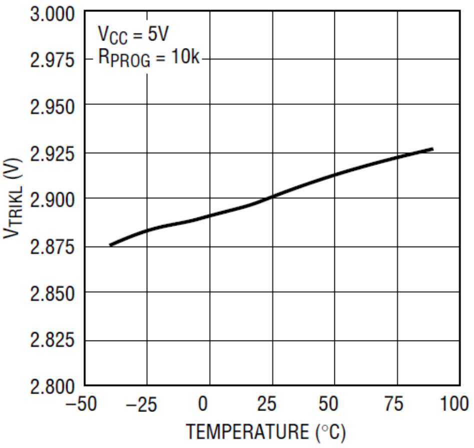
Trickle Charge Current vs Temperature



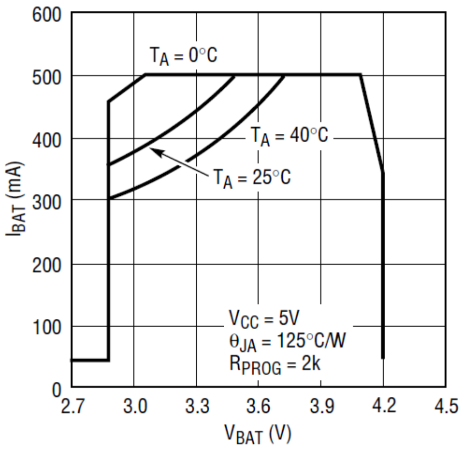
Trickle Charge Current vs Supply Voltage



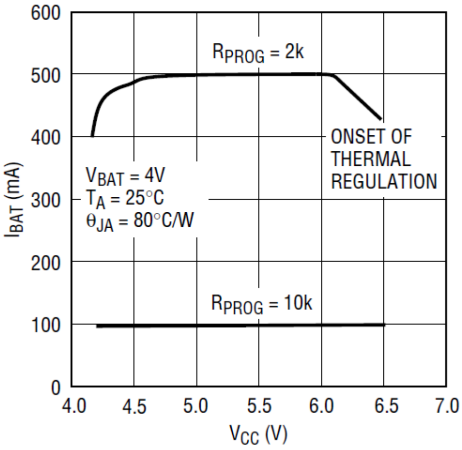
Trickle Charge Thershold vs Temperature



Charge Current vs Battery Voltage



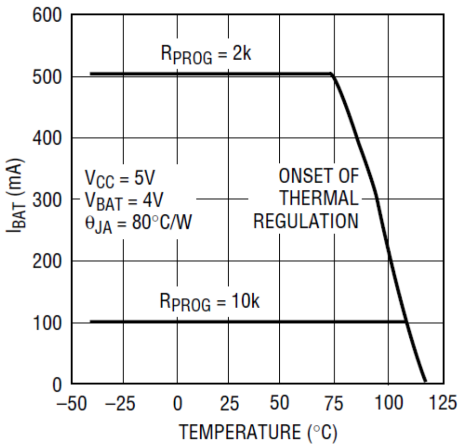
Charge Current vs Supply Voltage



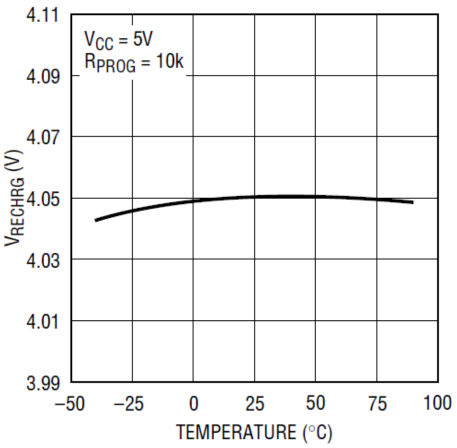
TYPICAL CHARACTERISTICS

V_{IN} = 5.0V,T_A =25°C, unless otherwise specified.

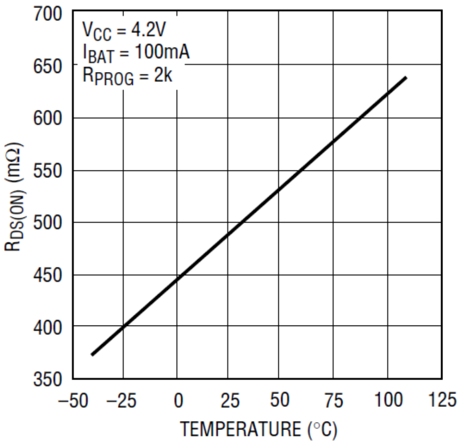
Charge Current vs Ambient Temperature



Recharge Voltage Threshold vs Temperature



Power FET ON Resistance vs Temperature



FUNCTION DESCRIPTION

The YX4056B is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 1A of charge current (using a good thermal PCB layout) with a final float voltage accuracy of ±1%. The YX4056B 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 YX4056B is capable of operating from a USB power source.

Normal Charge Cycle

A charge cycle begins when the voltage at the VCC pin rises above the UVLO threshold level and a 1% program resistor is connected from the PROG 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 YX4056B supplies approximately 1/10 the programmed charge current to bring the battery voltage up to a safe level for full current charging. When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the programmed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the YX4056B enters constant voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the programmed value, the charge cycle ends.

Programming Charge Current

The charge current is programmed using a single resistorfrom the PROG pin to ground. The battery charge currentis 1200 times the current out of the PROG pin. Theprogram resistor and the charge current are calculatedusing the following equations:

$$R_{PROG} = \frac{1200}{I_{CHG}}, \text{ or } I_{CHG} = \frac{1200}{R_{PROG}}$$

The charge current out of the BAT pin can be determinedat any time by monitoring the PROG pin voltage using thefollowing equation:

$$I_{BAT} = \frac{V_{PROG} \bullet 1200}{R_{PROG}}$$

Charge Termination

Charge cycle is terminated when the charge current falls to 1/10th the programmed value after the final float voltage is reached. This condition is detected by using an internal, filtered comparator to monitor the PROG pin. When the PROG pin voltage falls below 100mV for longer than t_{TERM}, charging is terminated. The charge current is latched off and the YX4056B enters standby mode, where the input supply current drops to 55μA. (Note: C/10 termination is disabled in trickle charging and thermal limiting modes).

When charging, transient loads on the BAT pin can causethe PROG pin to fall below 100mV for short periods of timebefore the DC charge current has dropped to 1/10th theprogrammed value. The 1ms filter time (t_{TERM}) on thetermination comparator ensures that transient loads ofthis nature do not result in premature charge cycle termination.Once the average charge current drops below1/10th the programmed value, the YX4056B terminatesthe charge cycle and ceases to provide any current throughthe BAT pin. In this state, all loads on the BAT pin must besupplied by the battery.

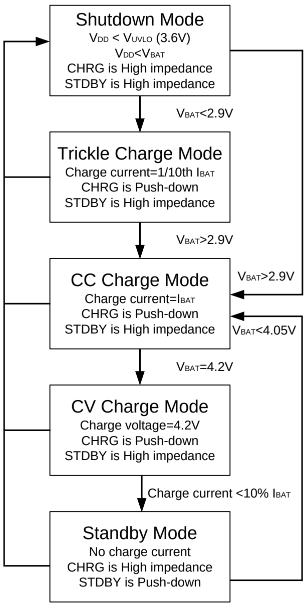


Figure 2. State Diagram of a Typical Charge Cycle

The YX4056B constantly monitors the BAT pin voltage in standbymode. If this voltage drops below the 4.05Vrecharge threshold (V_{RECHRG}), another charge cycle beginsand current is once again supplied to the battery. Tomanually restart a charge cycle when in standby mode, theinput voltage must be removed and reapplied, or thecharger must be shut down and restarted using the PROGpin. Figure 2 shows the state diagram of a typical chargecycle.

Charge Status Indicator

YX4056B has two open-drain status indicator output CHRG and STDBY. CHRG is pull-down when the YX4056B in a charge cycle. In other status CHRG is in high impedance. CHRG and STDBY are all in high impedance when the battery out of the normal temperature.

Represent in failure state, when TEMP pin is in typical connecting, and the battery is not connected, red LED and green LED are all not light. The battery temperature sense function is disabled by connecting TEMP pin to ground, if BAT pin connects a 10μF capacitor and the battery is not connected, the green LED is light and the red LED is blinked with 1-4s cycle time.

Charger's status	Red LED CHRG	Green LED STDBY
Charging	Light	Dark
Charge termination	Dark	Light
UVLO, Battery out of the normal temperature, or battery is not connected(TEMP is used)	Dark	Dark
10uF capacitor is connected to BAT pin, and battery is not connected(TEMP=GND)	Green LED is light, red LED is blinked with T=1-4s	

Battery Reversed Protection

The YX4056B includes an internal battery reversed protection circuitry, it can protect the chip damaged when the battery reversed in application or assembling. When the voltage of BAT pin blow to -70mV, the charge loop is closed and when the voltage of BAT pin over -30mV, the charge loop is restarted.

Thermal Limiting

An internal thermal feedback loop reduces the programmedcharge current if the die temperature attempts to riseabove a preset value of approximately 145°C. This featureprotects theYX4056B from excessive temperature andallows the user to push the limits of the power handlingcapability of a given circuit board without risk of damagingthe YX4056B. The charge current can be set according totypical (not worst-case) ambient temperature with theassurance that the charger will automatically reduce thecurrent in worst-case conditions.

Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the inputvoltage and keeps the charger in shutdown mode until VCCrises above the undervoltage lockout threshold. The UVLOcircuit has a built-in hysteresis of 200mV. Furthermore, toprotect against reverse current in the power MOSFET, theUVLO circuit keeps the charger in shutdown mode if VCCfalls to within 30mV of the battery voltage. If the UVLOcomparator is tripped, the charger will not come out ofshutdown mode until VCC rises 100mV above the batteryvoltage.

Automatic Recharge

Once the charge cycle is terminated, the YX4056B continuouslymonitors the voltage on the BAT pin using a comparatorwith a 2ms filter time ($t_{RECHARGE}$). A charge cyclerestarts when the battery voltage falls below 4.05V (whichcorresponds to approximately 80% to 90% battery capacity).This ensures that the battery is kept at or near a fullycharged condition and eliminates the need for periodiccharge cycle initiations. CHRG is push-down and the STDBY is in high impedanceduring recharge cycles.

Stability Considerations

The constant-voltage mode feedback loop is stable without an output capacitor provided and a battery is connected to the charger output.

In constant-current mode, the PROG pin is in the feedback loop, not the battery. The constant-current mode stability is affected by the impedance at the PROG pin. With no additional capacitance on the PROG pin, the charger is stable with program resistor values as high as 20k. However, additional capacitance on this node reduces the maximum allowed program resistor. The pole frequency at the PROG pin should be kept above 100kHz. Therefore, if the PROG pin is loaded with a capacitance, C_{PROG}, the following equation can be used to calculate the maximum resistance value for R_{PROG}:

$$R_{PROG} \le \frac{1}{2\pi \cdot 10^5 \cdot C_{PROG}}$$

Average, rather than instantaneous, charge current may be of interest to the user. For example, if a switching power supply operating in low current mode is connected in parallel with the battery, the average current being pulled out of the BAT pin is typically of more interest than the instantaneous current pulses. In such a case, a simple RC filter can be used on the PROG pin to measure the average battery current as shown in Figure 3. A 10k resistor has been added between the PROG pin and the filter capacitor to ensure stability.

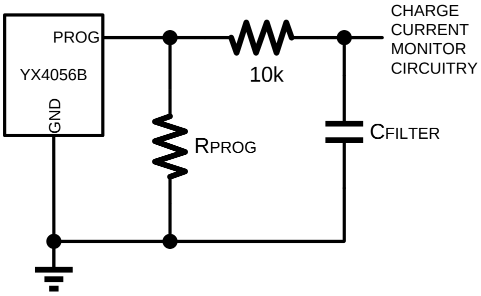


Figure 3. Isolating Capacitive Load on PROG Pin and Filtering

Power Dissipation

The device's junction temperature depends on several factors such as ambient temperature, PCB layout, the load and package type. Equations that can be used to calculate power dissipation and junction temperature are found below:

$P_D=R_{DS(ON)} \times I_{OUT}^2$

To relate this P_D to junction temperature, the following equation can be used:

$T_J=P_D \times \theta_{JA} + T_A$

Where:

T_J is junction temperature,

T_A is ambient temperature,

θ_{JA} is the thermal resistance of the package type.

TYPICAL APPLICATION

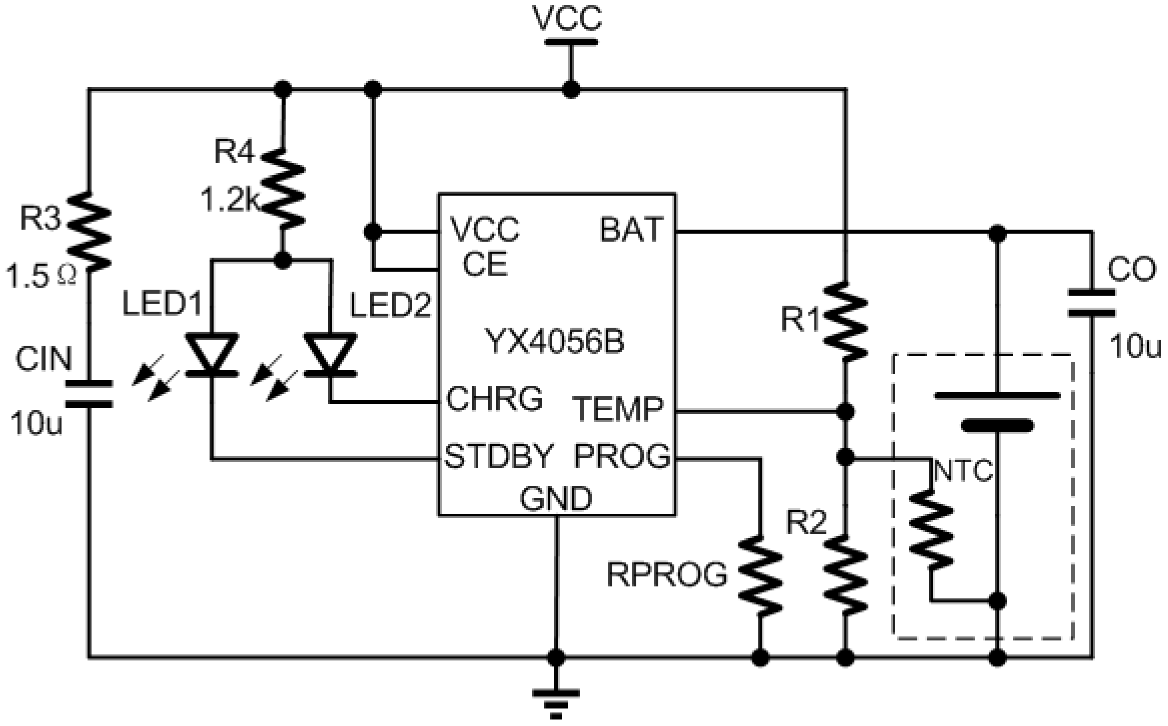
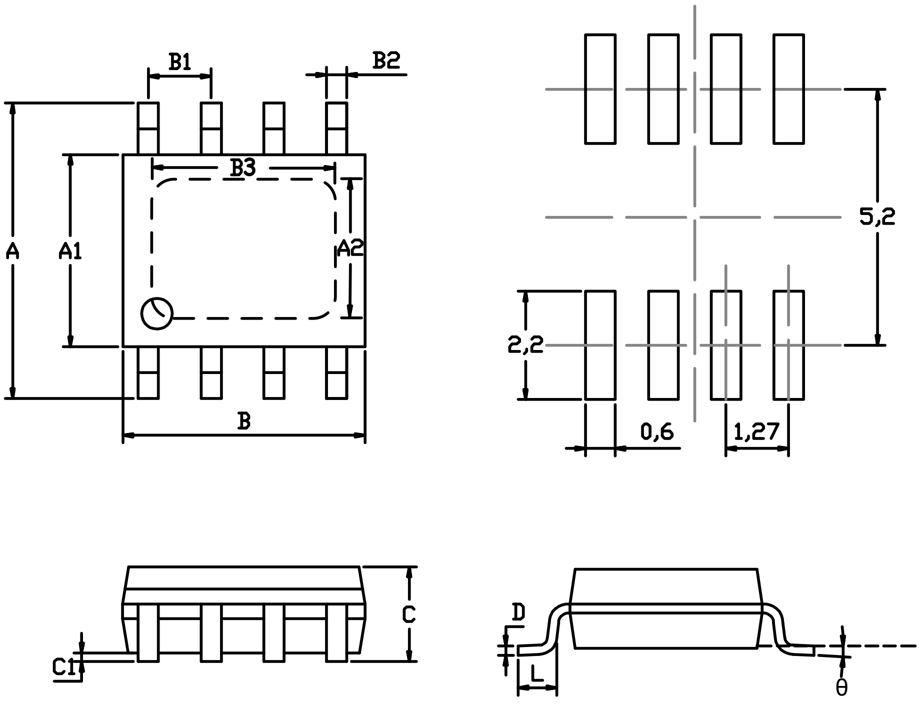


Figure 4. Typical Application Circuit

PACKAGE DESCRIPTION

ESOP8 package mechanical drawing



ESOP8 package mechanical data

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	5.8	6.2	0.2283	0.2441
A1	3.8	4	0.1496	0.1575
A2	2.292	2.534	0.090	0.100
B	4.8	5	0.1890	0.1969
B1	1.27		0.0500	
B2	0.31	0.51	0.0122	0.0201
B3	3.137	3.467	0.124	0.136
C		1.75MAX		0.0689MAX
C1	0.1	0.25	0.0039	0.0098
L	0.4	1.27	0.0157	0.0500
D	0.13	0.25	0.0051	0.0098
θ	0°	8°	0°	8°