

WS4508S

1000mA, Single Li-ion Battery Charger

[Http://www.sh-willsemi.com](http://www.sh-willsemi.com)

Descriptions

The WS4508S is a complete constant-current / constant voltage linear charger for single cell Lithium-Ion batteries. No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor.

The WS4508S automatically terminates the charge cycle when the charge current drops to 1/10 the programmed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the WS4508S automatically enters a low current state, dropping the battery drain current to less than 0.5uA. The WS4508S can be put into shutdown mode, reducing supply current to 45uA (Typ.).

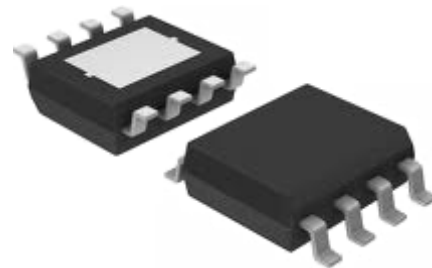
The WS4508S is available in SOP-8L-EP package. Standard product is Pb-Free.

Features

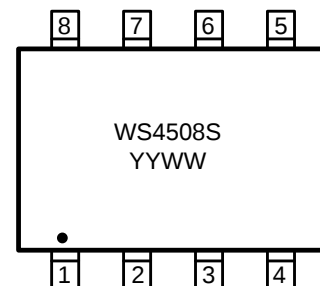
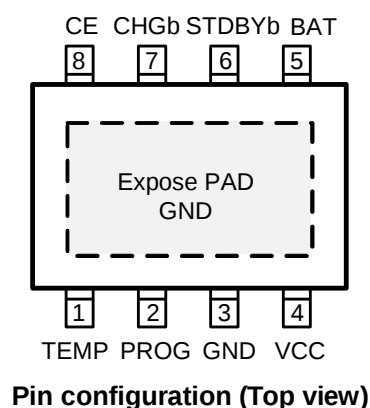
- Programmable Charge Current Up to 1000mA
- Over-Temperature Protection
- Under Voltage Lockout Protection
- Automatic Recharge Threshold 4.05V(Typ.)
- Charge Status Output Pin
- 2.9V Trickle Charge Threshold
- Soft-Start Limits Inrush Current

Applications

- Wireless phone
- MP3/MP4 Player
- Bluetooth device



SOP-8L-EP



WS4508S = Device Code
YY = Year
WW = Week

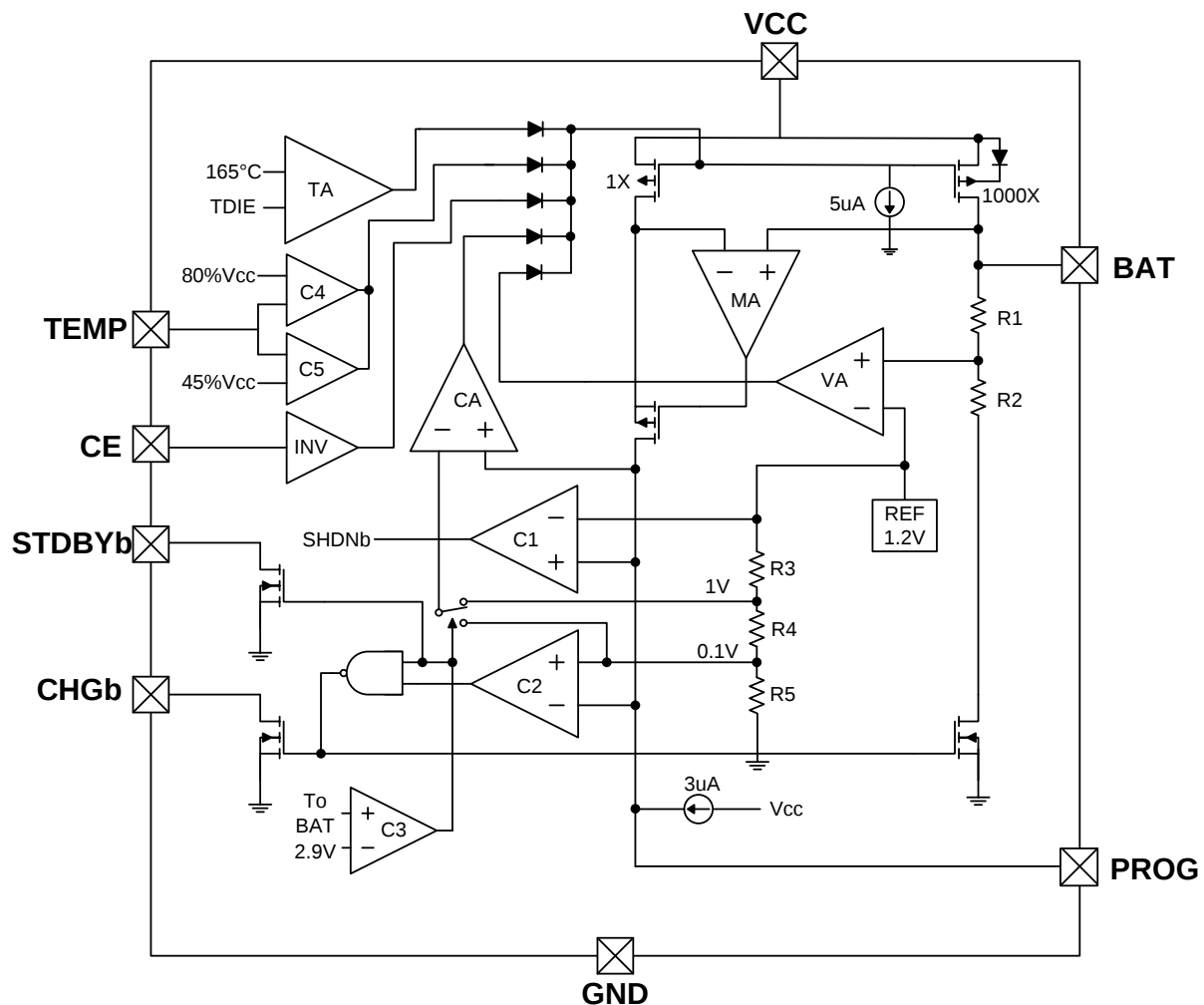
Order information

Device	Package	Shipping
WS4508S-8/TR	SOP-8L-EP	2500/Reel&Tape

Pin descriptions

Pin Number	Pin Name	Function
1	TEMP	Battery Temperature Sense Pin. When the battery temperature is too high or too low, the charging current will be terminated.
2	PROG	Charge current setting, charge current monitor and shutdown pin. The charging current is given by $I_{BAT} = (1/R_{PROG}) * 1000$. The chip will be shutdown when PROG pin floating
3	GND	Ground
4	VCC	Power Supply
5	BAT	Charge Current Output. Provides charge current to the battery and regulates the final float voltage to 4.2V.
6	STDBYb	Charge Complete Status Output. Low level status for charge finished. In addition, STDBYb pin will be in a high impedance state.
7	CHGb	Open-Drain Charge Status Output. When the battery is charging, the CHGb pin is pulled low. When the charge cycle is completed or VCC is removed, the CHGb is forced high impedance.
8	CE	Chip Enable. Active high.

Block Diagram



Typical applications

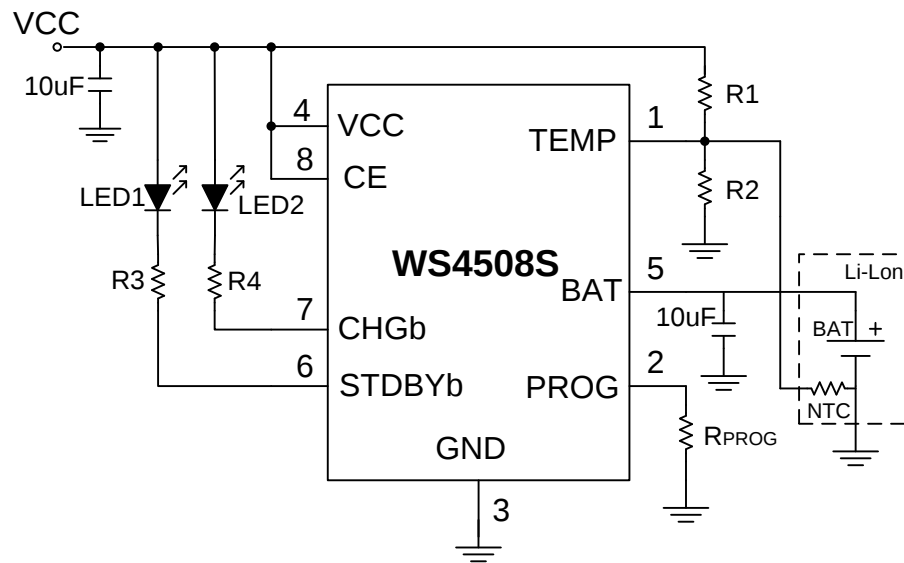


Figure1. Typical Applications W/T LED Indicate Circuit

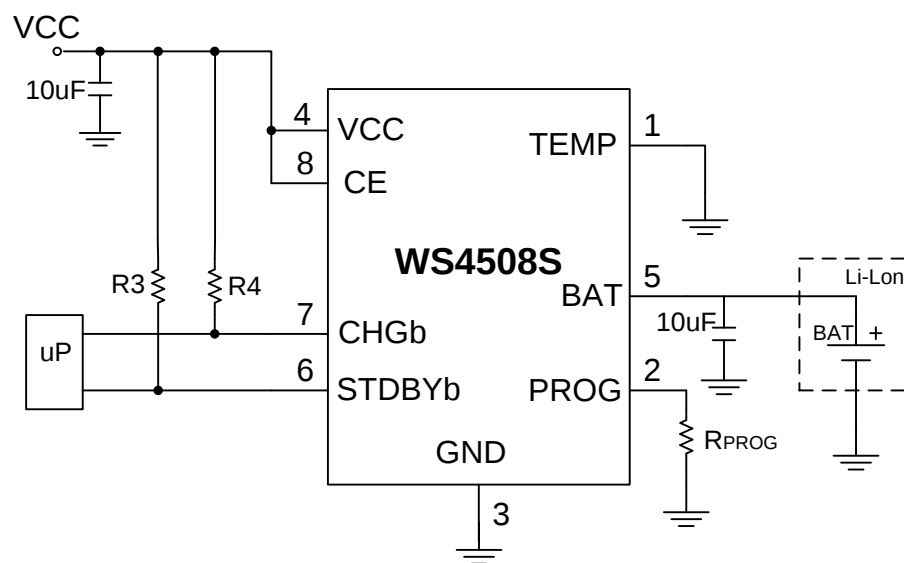


Figure2. Typical Applications W/T Microprocessor Detect Circuit

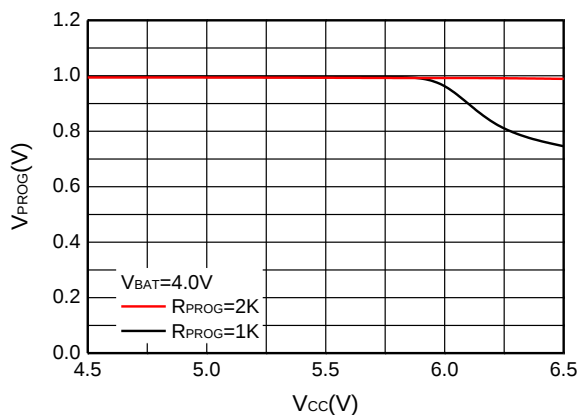
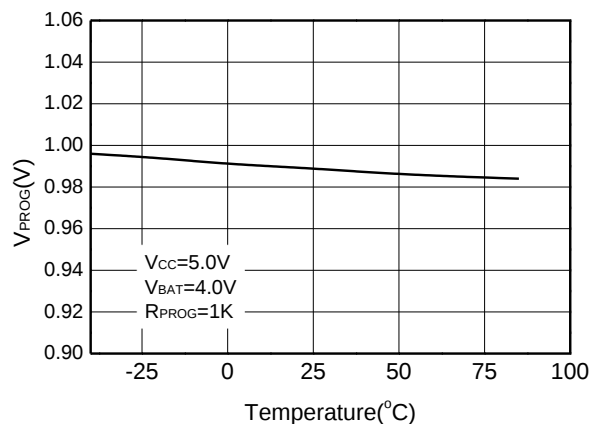
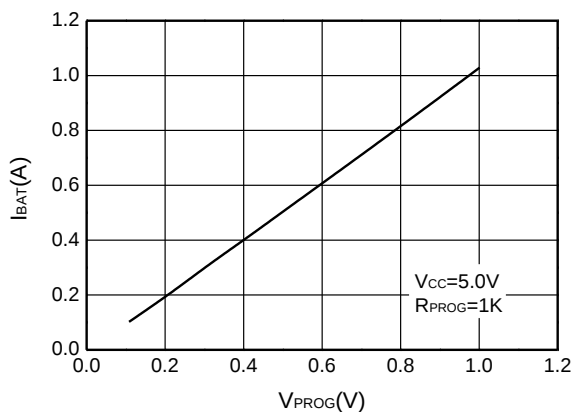
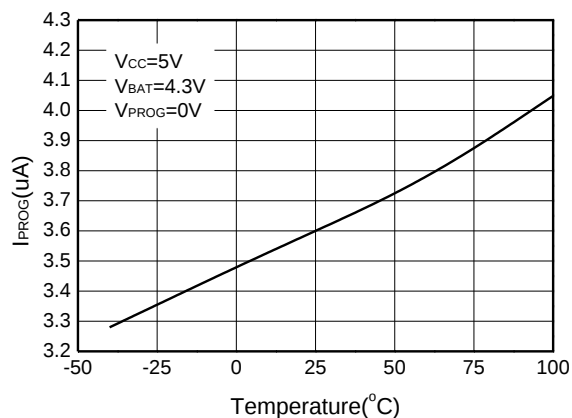
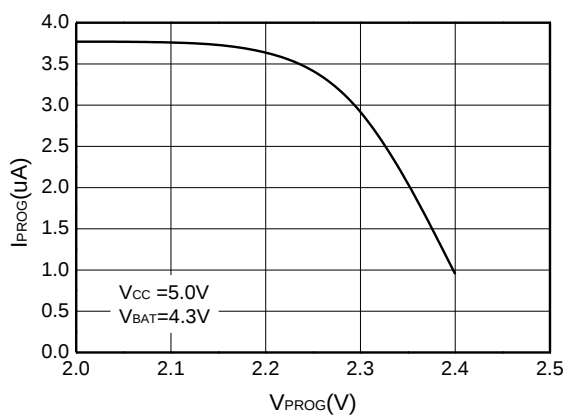
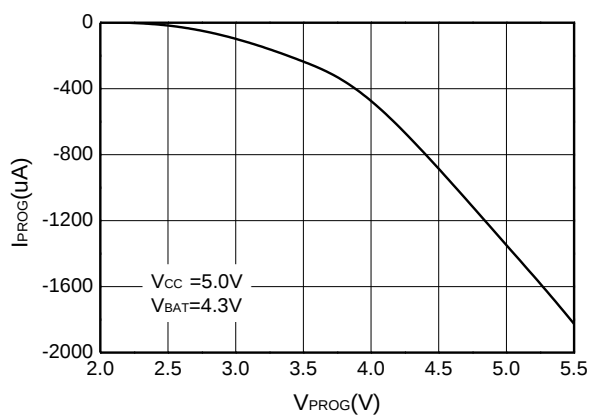
Electronics Characteristics (VCC=5V, Ta=25°C, unless otherwise noted)

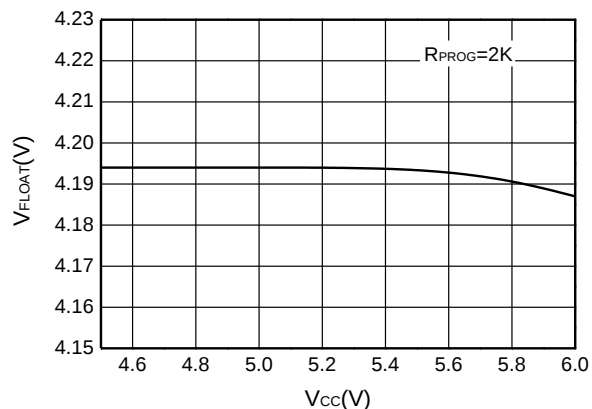
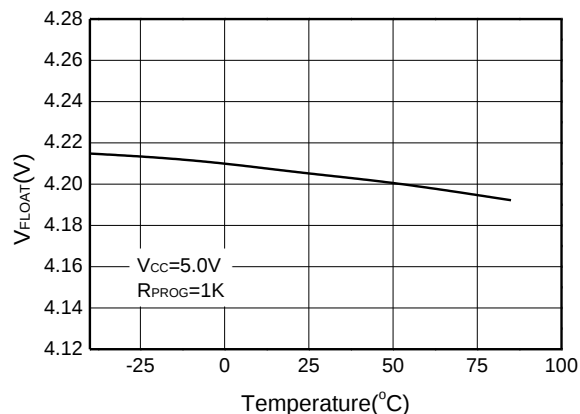
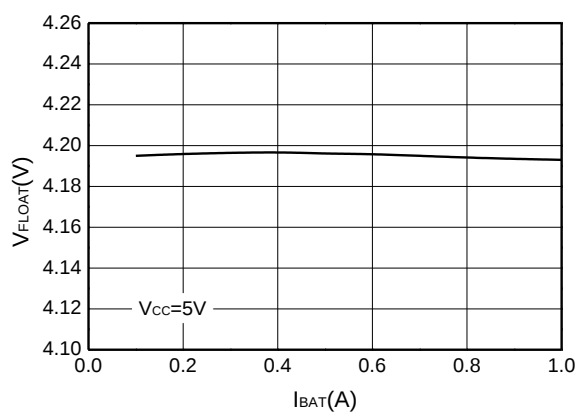
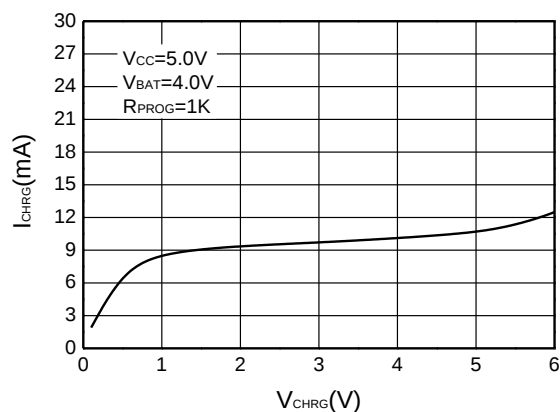
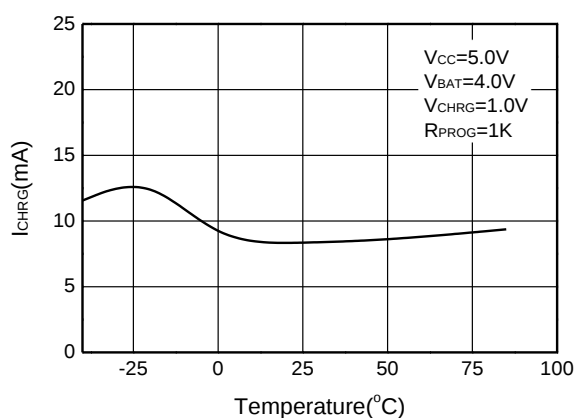
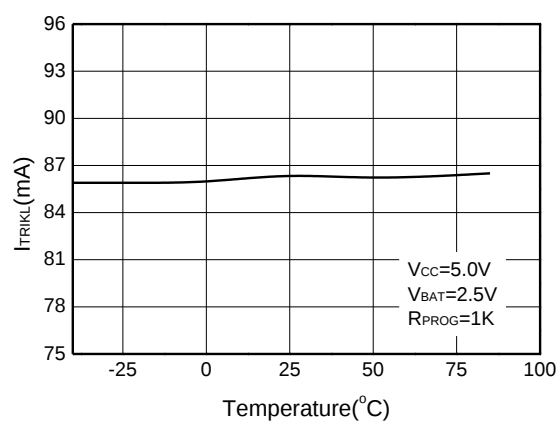
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
I _{SPLYCHRG}	Charge Mode Supply Current	R _{PROG} =10kΩ	170	240	2000	uA
I _{BATCHRG}	Charge Mode Battery Current	R _{PROG} =1kΩ	900	1000	1100	mA
		R _{PROG} =10kΩ	80	93	110	mA
V _{PROGCHRG}	PROG Pin Voltage	R _{PROG} =10kΩ	0.93	1.00	1.07	V
I _{SPLYSTBY}	Standby Mode Supply Current	Charge Terminated		140	500	uA
I _{BATSTBY}	Standby Mode Battery Current	Charge Terminated	0	-2.5	-6	uA
I _{SPLYASD}	Shutdown Mode Supply Current	V _{CC} <V _{BAT}	20	45	90	uA
I _{BATASD}	Shutdown Mode BAT Pin Current	V _{CC} <V _{BAT}		±0.05	±1	uA
I _{SPLYUVLO}	UVLO Mode Supply Current	V _{CC} <V _{UV}	20	45	90	uA
I _{BATUVLO}	UVLO Mode BAT Pin Current	V _{CC} <V _{UV}		±0.05	±1	uA
I _{SPLYSHUT}	Shutdown Mode Supply Current	R _{prog} not Connected	20	48	70	uA
I _{BATSHUT}	Shutdown Mode BAT Pin Current	R _{prog} not Connected		±0.05	±1	uA
I _{BATMSD}	Manual Shutdown BAT Pin Current	V _{prog} =1.3V		±0.05	±1	uA
I _{BATSLEEP}	Sleep Mode BAT Pin Current	V _{CC} =0V		±0.05	±1	uA
V _{FLOAT}	Float Voltage		4.158	4.2	4.242	V
I _{TRIKL}	Trickle Charge Current	R _{PROG} =1kΩ	40	100	140	mA
V _{TRIKL}	Trickle Charge Voltage Threshold	R _{PROG} =10kΩ	2.8	2.9	3.0	V
V _{TRIKL, HYS}	Trickle Charge Voltage Hysteresis	R _{PROG} =10kΩ		100		mV
V _{UVLO}	UVLO Threshold	From V _{CC} Low to High	3.6	3.8	4.0	V
V _{UVLO, HYS}	UVLO Hysteresis			250		mV
V _{MSD}	Manual Shutdown Threshold Voltage	PROG Pin Rising		1.2	1.3	V
		PROG Pin Falling		1.0		V
V _{ASD}	V _{CC} -V _{BAT} Lockout Threshold Voltage	V _{CC} from Low to High		120		mV
		V _{CC} from High to Low	5	50		mV
ΔV _{RECHRG}	Auto Recharge Battery Voltage		100	150	200	mV
V _{CHGb}	CHGb Pin Output Low Voltage	I _{CHGb} =5mA		0.3	0.6	V
V _{STDBYb}	STDBYb Pin Output Low Voltage	I _{STDBYb} =5mA		0.3	0.6	V
T _{LIM}	Junction Temperature In Constant Temperature Mode			165		°C
R _{ON}	Power FET ON Resistance			200		mΩ
T _{SS}	Soft-Start Time	R _{PROG} =1kΩ		100		us
T _{RECHRG}	Recharge Comparator Filter Time			2		ms
T _{TERM}	Termination Comparator Filter Time			1		ms
I _{PROG}	PROG Pin Pull-up Current			3		uA
V _{CE}	CE Pin Input Low Voltage				0.4	V
	CE Pin Input High Voltage		1.2			V

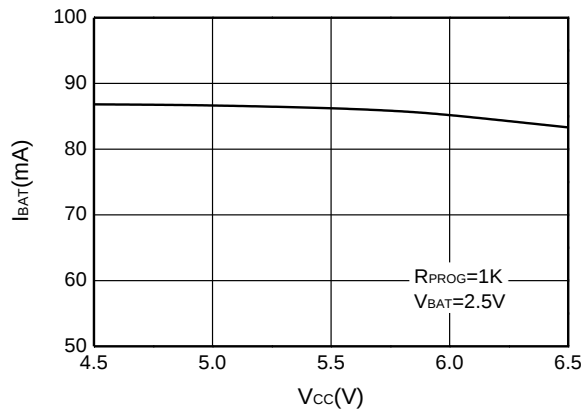
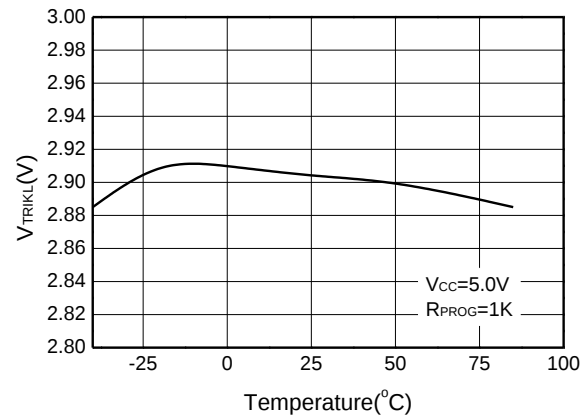
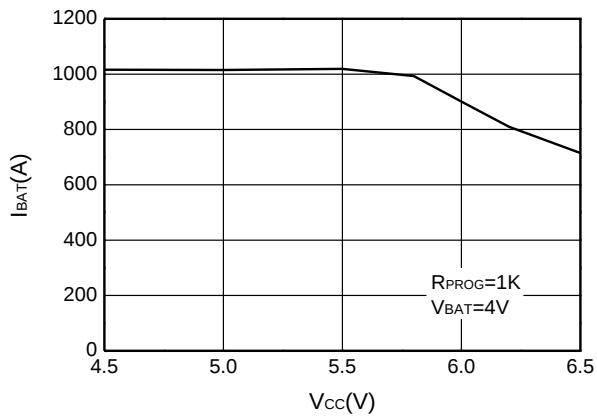
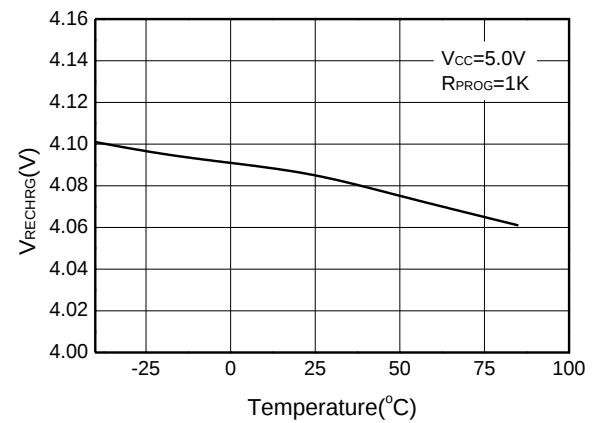
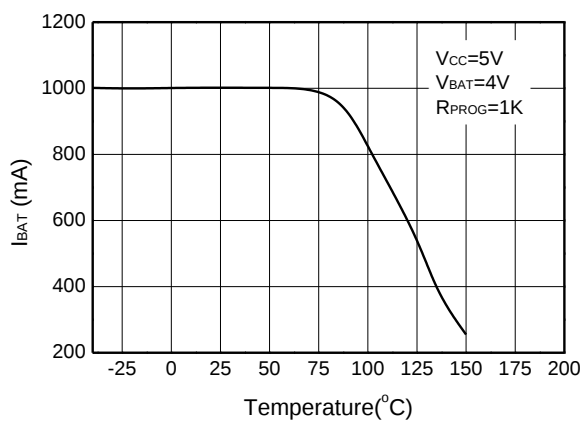
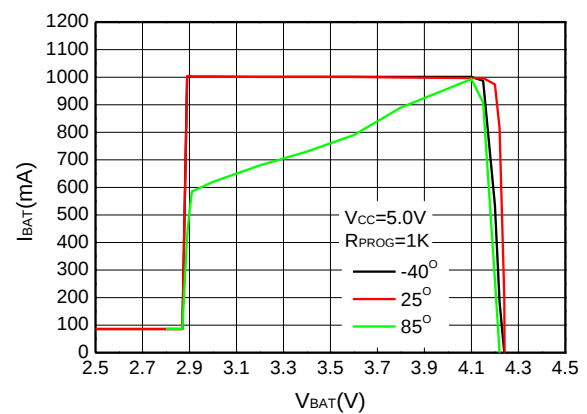
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{TEMP_EN}	Battery Temperature Detect Function Threshold Voltage	TEMP Pin Rising(Vcc=5V)		0.29	0.32	V
		TEMP Pin Falling(Vcc=5V)	0.18	0.2		V
V_{TEMP_H}	TEMP Pin High Threshold Voltage	TEMP Pin Rising(Vcc=5V)		80	82	%Vcc
		TEMP Pin Falling(Vcc=5V)	72	73.5		%Vcc
V_{TEMP_L}	TEMP Pin Low Threshold Voltage	TEMP Pin Rising(Vcc=5V)		48.5	50	%Vcc
		TEMP Pin Falling(Vcc=5V)	43	45		%Vcc

Absolute Maximum ratings

Parameter	Symbol	Rating	Unit
Supply Voltage	VCC	-0.3~8	V
PROG Voltage	V_{PROG}	-0.3~VCC	V
BAT Voltage	V_{BAT}	-0.3~8	V
CHGb Voltage	V_{CHGb}	-0.3~VCC	V
PROG Pin Current	I_{PROG}	1000	mA
Junction Temperature	T_j	150	°C
Operation Temperature	T_{op}	-45~85	°C
Storage Temperature	T_{sg}	-65~125	°C
Lead Temperature (Soldering 10s)		260	°C

Typical Characteristics (Ta=25°C, unless otherwise noted)

PROG Pin Voltage vs. Supply Voltage

PROG Pin Voltage vs. Temperature

Charge current vs. PROG pin voltage

PROG Pin Pull-Up current vs. Temperature

PROG Pin Pull-Up Current vs. PROG Pin Voltage

PROG Pin Clamp Current vs. PROG Pin Voltage


BAT Pin Output Float Voltage vs. Supply Voltage

BAT Pin Output Float Voltage vs. Temperature

BAT pin output float voltage vs. Charge current

CHGb pin current vs. CHGb pin voltage

CHGb pin current vs. Temperature

Trickle charge current vs. Temperature


Trickle charge current vs. Supply voltage

Trickle charge threshold vs. Temperature

Charge current vs. Supply voltage

Recharge Voltage Threshold vs. Temperature

Charge current vs. Temperature

Fully charge period waveform

Operation Information

The WS4508S 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 $\pm 1\%$. The WS4508S 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 WS4508S 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 WS4508S 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, the WS4508S enters constant-voltage mode and the charge current begins to decrease. The charge cycle ends when the PROG voltage is less than 100mV.

Programming charge current

The charge current is programmed using a single resistor from the PROG pin to ground. The battery charge current of constant current mode is 1000 times the current out of the PROG pin. The program resistor and the charge current of constant current are calculated using the following equations:

$$I_{\text{CHRG}} = \left(\frac{1\text{V}}{R_{\text{PROG}}} \right) \times 1000$$

Charge termination

A charge cycle is terminated when the charge current falls to 1/10 of 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} (typically 1ms), charging is terminated. The charge current is latched off and the WS4508S enters standby mode, where the input supply current drops to 130uA. (Note: CC/10 termination is disabled in trickle charging mode and thermal limiting modes).

When charging, transient loads on the BAT pin can cause the PROG pin to fall below 100mV for short periods of time before the DC charge current has dropped to 1/10 of the programmed value. The 1ms filter time (T_{TERM}) on the termination comparator ensures that transient loads of this nature do not result in premature charge cycle termination. Once the average charge current drops below 1/10 of the programmed value, the WS4508S terminates the charge cycle and ceases to provide any current through the BAT pin, the chip will be put into standby mode. In this state, all loads on the BAT pin must be supplied by the battery.

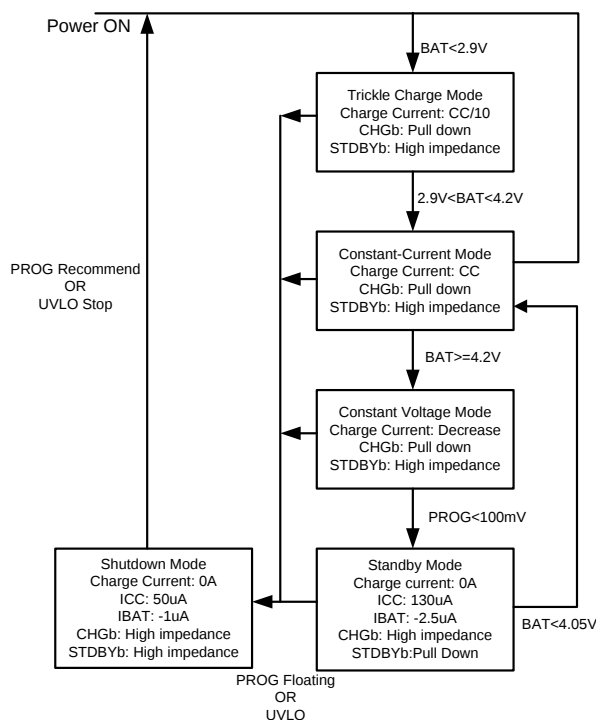


Figure3. State Diagram of a Typical Charge Cycle

The WS4508S constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V recharge threshold (V_{RECHRG}), another charge cycle begins and current is once again supplied to the battery. The state diagram of a typical charge cycle is as Figure3.

Charge status indicator

WS4508S has two open-drain status indicator output CHGb and STDBYb. CHGb is pull-down when the WS4508S in a charge cycle. In other status CHGb is in high impedance. CHGb and STDBYb are all in high impedance when the battery out of the normal temperature.

Represent in failure state, when TEMP pin in typical connecting, and the charger with no battery: red LED and green LED all don't light. The battery temperature sense function is disabled by connecting TEMP pin to GND. If battery is not connected to charger and the BAT pin connects a 10 μ F capacitor, the frequency of CHGb flicker about 1-4s.

Charger state	Red CHGb	Green STDBYb
Charging	light	dark
Battery in full state	dark	light
UVLO, Battery temperature is outside TEMP range, battery is not connected(Use TEMP)	dark	dark
BAT pin is connected to 10uF and no battery mode (TEMP=GND)	Green LED bright Red LED flicker and the frequency is 1~4s	

Thermal Limiting

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 165 °C. This feature protects the WS4508S from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the WS4508S. The charge current can be set according to typical (not worst-case) ambient temperature with the assurance that the charger will

automatically reduce the current in worst-case conditions.

Battery Temperature Sensing

To prevent the damage caused by the very high or very low temperature done to the battery pack, the WS4508S continuously senses the battery pack temperature by measuring the voltage at TEMP pin determined by the voltage divider circuit and the battery's internal NTC thermistor as shown in Figure 1.

The WS4508S compares the voltage at TEMP pin (V_{TEMP}) against its internal V_{LOW} and V_{HIGH} thresholds to determine if charging is allowed. In WS4508S, V_{LOW} is fixed at $45\% \times V_{CC}$, while V_{HIGH} is fixed at $80\% \times V_{CC}$. If $V_{TEMP} < V_{LOW}$ or $V_{TEMP} > V_{HIGH}$, it indicates that the battery temperature is too high or too low and the charge cycle is suspended. When the V_{TEMP} is between V_{LOW} and V_{HIGH} , charging cycle resumes. The battery temperature sensing function can be disabled by connecting the TEMP pin to GND.

Selecting R1 and R2

The values of R1 and R2 in the application circuit (Figure1) can be determined according to the assumed temperature monitor range and thermistor's values. The Follows is an example: Assume temperature monitor range is $T_L \sim T_H$, ($T_L < T_H$); the thermistor in battery has negative temperature coefficient (NTC), R_{TL} is thermistor's resistance at T_L , R_{TH} is the resistance at T_H , so $R_{TL} > R_{TH}$, then

At temperature T_L , the voltage at TEMP pin is:

$$V_{TEMP_L} = \frac{R_2 \parallel R_{TL}}{R_1 + R_2 \parallel R_{TL}} \times V_{CC}$$

At temperature T_H , the voltage at TEMP pin is:

$$V_{TEMP_H} = \frac{R_2 \parallel R_{TH}}{R_1 + R_2 \parallel R_{TH}} \times V_{CC}$$

Because $V_{TEMP_L} = V_{HIGH} = K_2 \times V_{CC}$ ($K_2 = 0.8$)

$$V_{TEMP_H} = V_{LOW} = K_1 \times V_{CC} \text{ (} K_1 = 0.45 \text{)}$$

Then we can have:

$$R_1 = \frac{R_{TL} \times R_{TH}(K_2 - K_1)}{(R_{TL} - R_{TH})K_1 \times K_2}$$

$$R_2 = \frac{R_{TL} \times R_{TH}(K_2 - K_1)}{R_{TL}(K_1 - K_1 \times K_2) - R_{TH}(K_2 - K_1 \times K_2)}$$

Likewise, for positive temperature coefficient thermistor in battery, we have $R_{TH} > R_{TL}$ and we can calculate:

$$R_1 = \frac{R_{TH} \times R_{TL}(K_2 - K_1)}{(R_{TH} - R_{TL})K_1 \times K_2}$$

$$R_2 = \frac{R_{TH} \times R_{TL}(K_2 - K_1)}{R_{TH}(K_1 - K_1 \times K_2) - R_{TL}(K_2 - K_1 \times K_2)}$$

We can conclude that temperature monitor range is independent of power supply voltage V_{CC} and it only depends on R_1 , R_2 , R_{TL} and R_{TH} . The values of R_{TH} and R_{TL} can be found in related battery handbook or deduced from testing data. In actual application, if only one terminal temperature is concerned (normally protecting overheating), there is no need to use R_2 but R_1 . It becomes very simple to calculate R_1 in this case.

Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the undervoltage lockout threshold. The UVLO circuit has a built-in hysteresis of 250mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if V_{CC} falls to within 50mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 120mV above the battery voltage.

Manual Shutdown

At any point in the charge cycle, the WS4508S can be put into shutdown mode by removing R_{PROG} thus floating the PROG pin. This reduces the battery drain current to less than 1uA and the supply current to less than 50uA. A new charge cycle can be

initiated by reconnecting the program resistor.

The CE pin can also shutdown the charger when the CE pin voltage is less than 0.4V. To restart the charge cycle, the CE pin voltage must be larger than 1.2V. In manual shutdown, The CHGb pin and the STDBYb pin are in a high impedance state if the WS4508S is in manual shutdown mode or in the undervoltage lockout mode: either V_{CC} is within 120mV of the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin.

Automatic recharge

Once the charge cycle is terminated, the WS4508S continuously monitors the voltage on the BAT pin using a comparator with a 2ms filter time (T_{RECHRG}). A charge cycle restarts when the battery voltage falls below 4.05V (Typ.) (which corresponds to approximately 80% to 90% battery capacity). This ensures that the battery is kept at or near a fully charged condition and eliminates the need for periodic charge cycle initiations. CHGb output enters a pull-down state during recharge cycles.

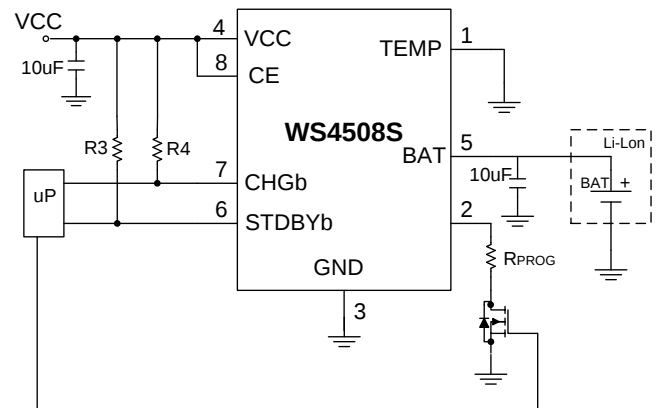


Figure4. Manual Shutdown Mode Application Circuit

Application Information

Stability considerations

The constant-voltage mode feedback loop is stable without an output capacitor provided a battery is connected to the charger output. With no battery present, an output capacitor is recommended to reduce ripple voltage. When using high value, low ESR ceramic capacitors, it is recommended to add a 1Ω resistor in series with the capacitor. No series resistor is needed if tantalum capacitors are used.

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 10KΩ. However, additional capacitance on this node reduces the maximum allowed program resistor thus it should be avoided.

Thermal limit

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 165°C. This feature protects the WS4508S from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the WS4508S. The charge current can be set according to typical (not worst-case) ambient temperature with the assurance that the charger will automatically reduce the current in worst-case conditions.

Power dissipation

The conditions that cause the WS4508S to reduce charge current through thermal feed-back can be approximated by considering the power dissipated in the IC. Nearly all of this power dissipation is generated by the internal MOSFET. This is calculated to be approximately:

$$P_D = (V_{CC} - V_{BAT}) \times I_{BAT}$$

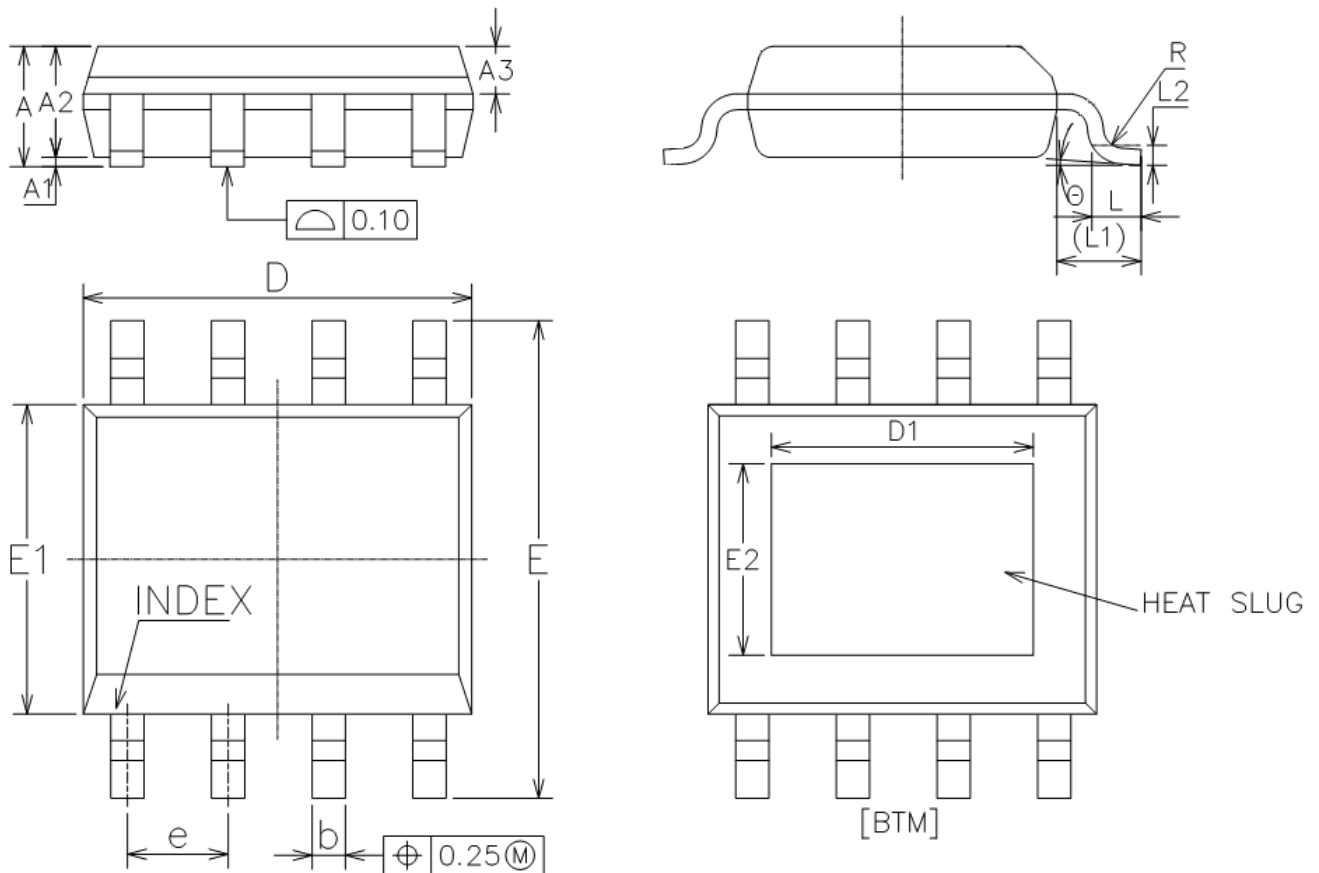
It is important to remember that WS4508S applications do not be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 165°C (Constant temperature mode).

VCC bypass capacitor

Many types of capacitors can be used for input bypass, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, a 10uF ceramic capacitor is recommended for this bypass capacitor. Due to a high voltage transient will be generated under some start-up conditions, such as connecting the charger input to a live power source.

Charge current soft-start

The WS4508S includes a soft-start circuit to minimize the inrush current at the start of a charge cycle. When a charge cycle is initiated, the charge current ramps from zero to the full-scale current over a period of approximately 100us. This has the effect of minimizing the transient current load on the power supply during start-up.

Package outline dimensions
SOP-8L-EP


Symbol	Dimensions In Millimeters		
	Min.	Typ.	Max.
A	1.35	1.55	1.70
A1	0.00	0.10	0.15
A2	1.25	1.40	1.65
A3	0.50	0.60	0.70
b	0.38		0.51
D	4.80	4.90	5.00
D1	3.10	3.30	3.50
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
E2	2.20	2.40	2.60
e	1.17	1.27	1.37
L	0.45	0.60	0.80
L1	1.04REF		
L2	0.25BSC		
R	0.07		
θ	0°		8°