WS4518D/DH

300mA, Single Li-ion Battery Charger

www.sh-willsemi.com

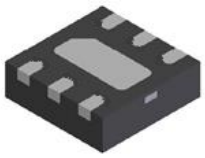
Descriptions

The WS4518D/DH 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/4.35V, and the charge current can be programmed externally with a single resistor.

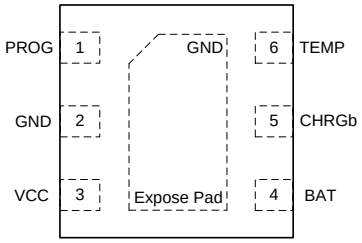
The WS4518D/DH automatically terminates the charge cycle when the charge current drops to 3/10 the programmed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the WS4518D/DH automatically enters a low current state, dropping the battery drain current to less than 0.5uA. The WS4518D/DH can be put into shutdown mode, reducing supply current to 40uA (Typ.).

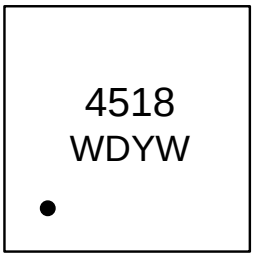
The WS4518D/DH is available in a small package with DFN2X2-6L. Standard product is Pb-Free.

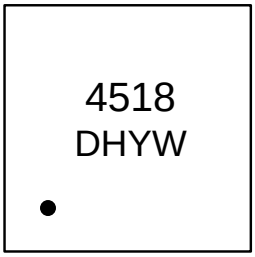


DFN2X2-6L



Pin configuration (Top view)





4518 = Device Code
WD = WS4518D
DH = WS4518DH
Y = Year
W = Week
Marking

Features

- Programmable Charge Current Up to 300mA
- Over-Temperature Protection
- Under Voltage Lockout Protection
- Automatic Recharge Threshold 4.05V/4.188V
- Charge Status Output Pin
- 2.9V/2.96V Trickle Charge Threshold
- Soft-Start Limits Inrush Current

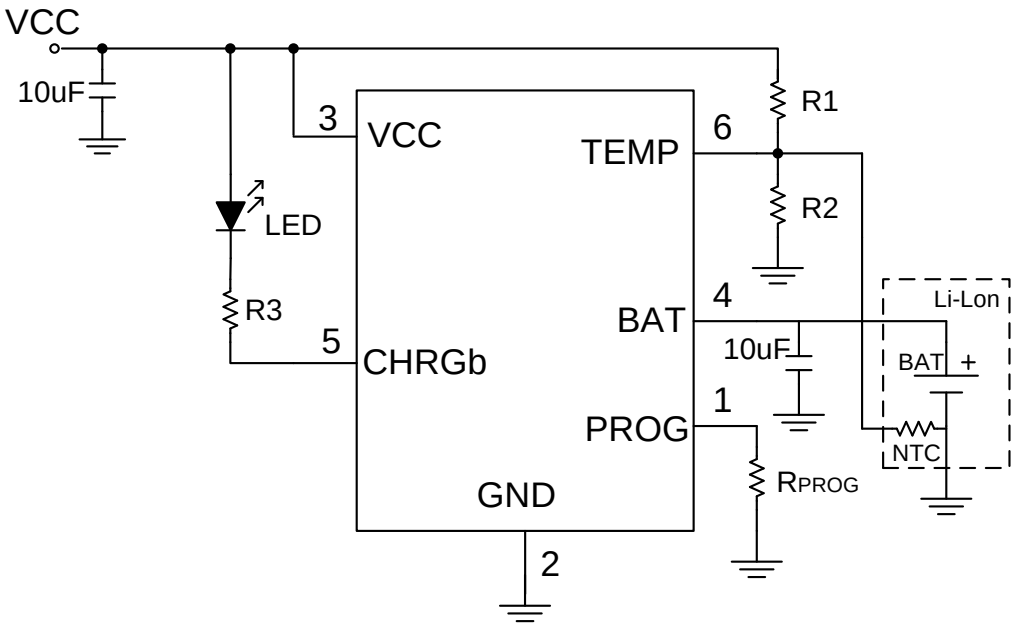
Applications

- Wireless phone
- MP3/MP4 Player
- Bluetooth device

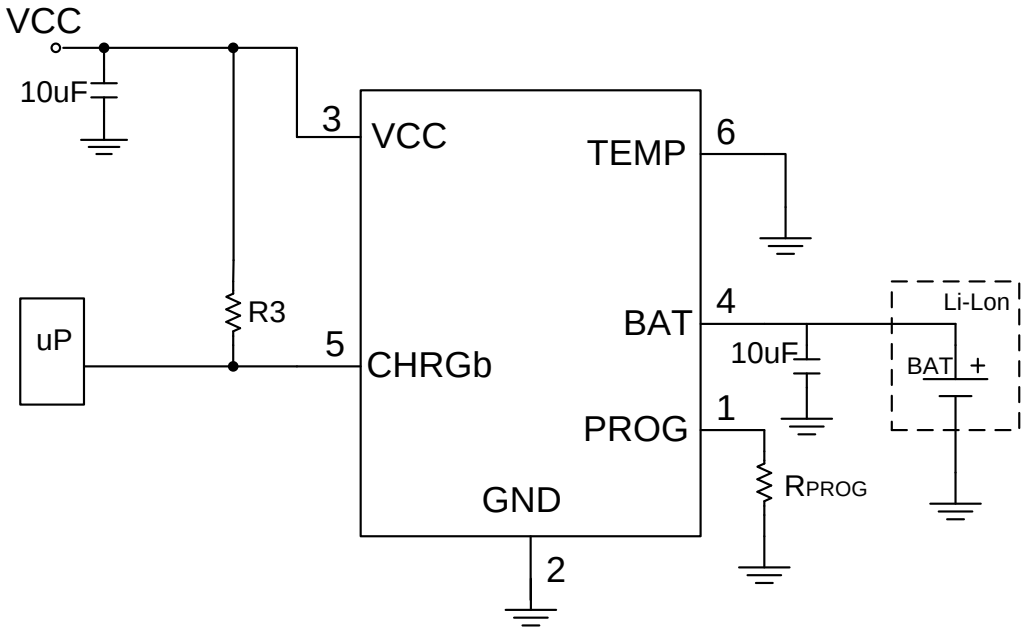
Order information

Device	Package	Shipping
WS4518D -6/TR	DFN2X2-6L	3000/Reel&Tape
WS4518DH-6/TR	DFN2X2-6L	3000/Reel&Tape

Typical applications



Typical applications W/T LED indicate

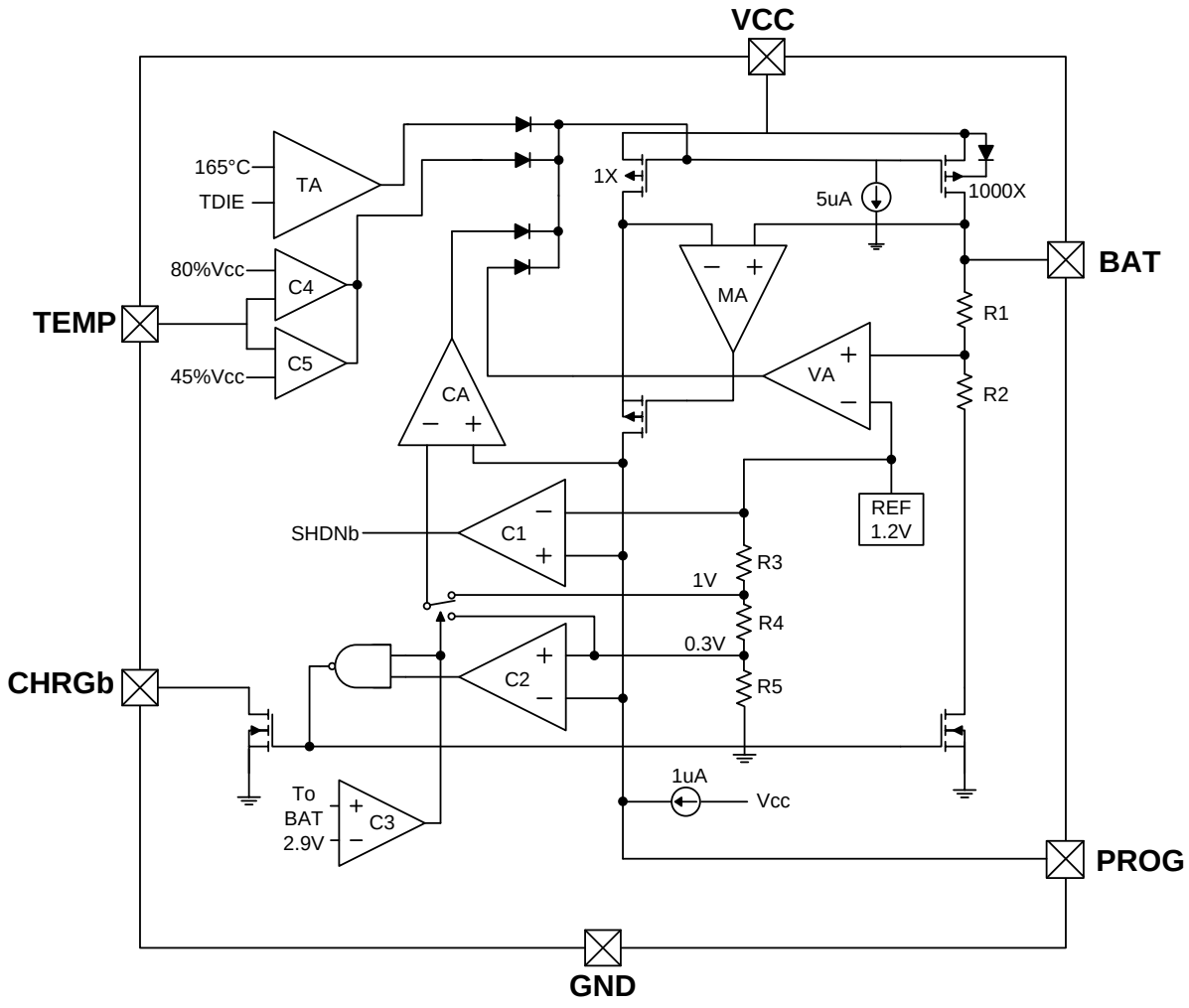


Typical applications W/T microprocessor detect

Pin descriptions

Pin Number	Pin Name	Function
1	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
2	GND	Ground
3	VCC	Power Supply
4	BAT	Charge Current Output. Provides charge current to the battery and regulates the final float voltage to 4.2V/4.35V.
5	CHRGb	Open-Drain Charge Status Output. When the battery is charging, the CHRGb pin is pulled low. When the charge cycle is completed or VCC is removed, the CHRGb is forced high impedance.
6	TEMP	Battery Temperature Sense Pin. When the battery temperature is too high or too low, the charging current will be terminated.
Expose Pad	GND	This pin must be connected to GND, and punch to the main GND to facilitate heat dissipation.

Block Diagram



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
CHRGb Voltage	V_{CHRGb}	-0.3~VCC	V
BAT Pin Current	I_{BAT}	600	mA
Power Dissipation – **Note1**	Pd	0.5	W
Power Dissipation – **Note2**	Pd	0.3	W
Junction Temperature	Tj	150	^{o}C
Operation Temperature	Top	-45~85	^{o}C
Storage Temperature	Tsg	-65~125	^{o}C
Lead Temperature (Soldering 10s)		260	^{o}C

Thermal resistance characteristics

Symbol	Parameter	Max.	Unit
$R_{\theta JA1}$	Thermal Resistance, Junction to Ambient – **Note1**	125	^{O}C/W
$R_{\theta JA2}$	Thermal Resistance, Junction to Ambient – **Note2**	165	^{O}C/W

Note1: Surface mounted on FR4 Board using 1 in sq pad size, 2oz Cu.

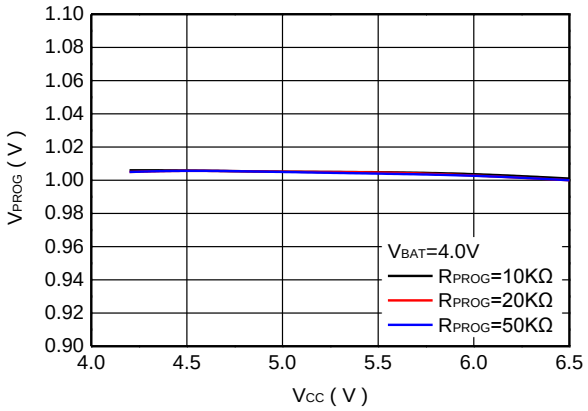
Note2: Surface mounted on FR4 board using the minimum recommended pad size, 2oz Cu.

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

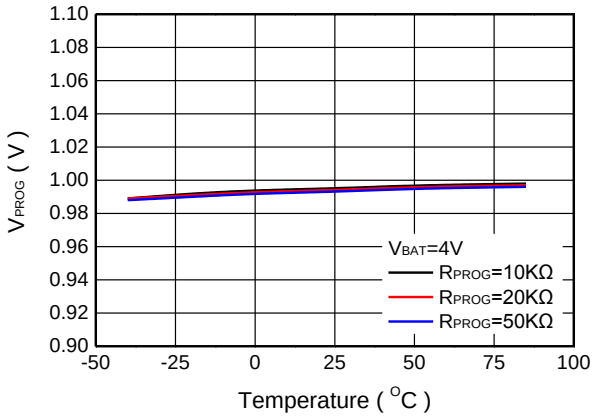
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
$I_{SPLYCHRG}$	Charge Mode Supply Current	R_{PROG}=10kΩ		250	2000	uA
		R_{PROG}=20kΩ		200	2000	uA
$I_{BATCHRG}$	Charge Mode Battery Current	R_{PROG}=10kΩ	90	100	110	mA
		R_{PROG}=20kΩ	44	49	54	mA
		R_{PROG}=33.3kΩ	25	28.5	32	mA
$V_{PROGCHRG}$	PROG Pin Voltage	R_{PROG}=10kΩ	0.93	1.00	1.07	V
		R_{PROG}=20kΩ	0.93	1.00	1.07	V
$I_{SPLYSTBY}$	Standby Mode Supply Current	Charge Terminated		136	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	42	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	42	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	42	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	WS4518D	4.158	4.2	4.242	V
		WS4518DH	4.307	4.35	4.393	V
I_{TRIKL}	Trickle Charge Current	R_{PROG}=10kΩ	19	29	39	mA
V_{TRIKL}	Trickle Charge Voltage Threshold	WS4518D	2.8	2.9	3.0	V
		WS4518DH	2.86	2.96	3.06	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}	Vcc-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	WS4518D	100	150	200	mV
		WS4518DH	110	162	215	mV
V_{CHRGb}	CHRGb Pin Output Low Voltage	I_{CHRGb}=5mA		0.3	0.6	V
T_{LIM}	Junction Temperature In CT Mode			165		°C
R_{ON}	Power FET ON Resistance			200		mΩ
T_{SS}	Soft-Start Time	R_{PROG}=2kΩ		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		0.7	1.1	1.5	uA
V_{TEMP_EN}	Battery Temperature Detect Function Threshold Voltage	TEMP Pin Rising		0.29	0.32	V
		TEMP Pin Falling	0.18	0.2		V
V_{TEMP_H}	TEMP Pin High Threshold Voltage	TEMP Pin Rising		80	82	%Vcc

		TEMP Pin Falling	72	73.5		%Vcc
V_{TEMP_L}	TEMP Pin Low Threshold Voltage	TEMP Pin Rising		48.5	50	%Vcc
		TEMP Pin Falling	43	45		%Vcc

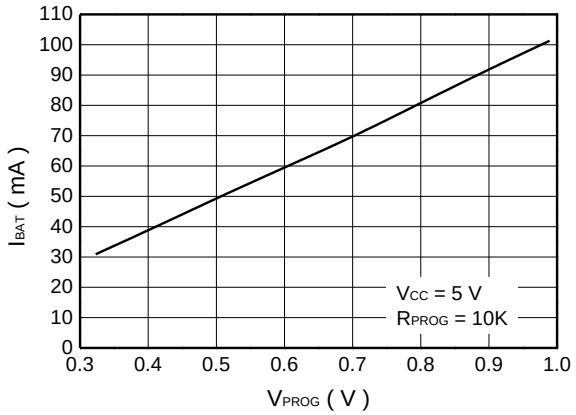
Typical Characteristics (Ta=25°C, unless otherwise noted)



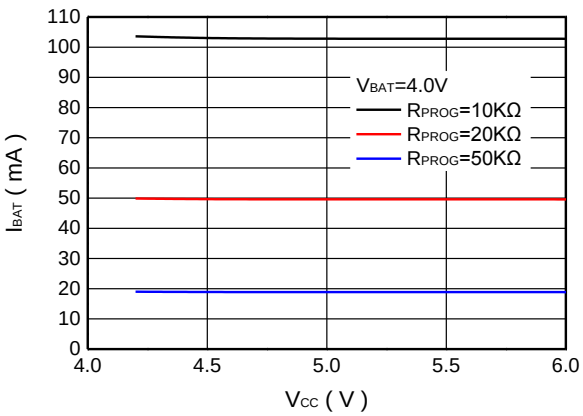
PROG Pin Voltage vs Supply Voltage



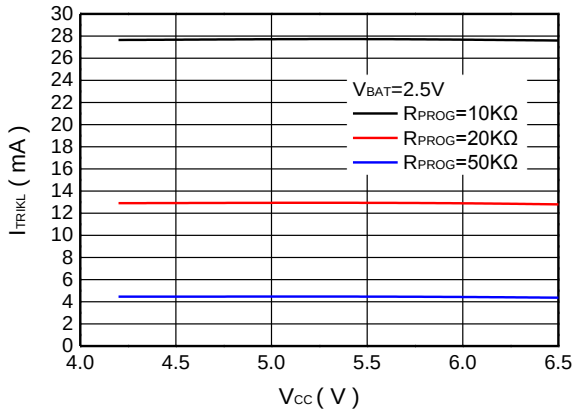
PROG Pin Voltage vs Ambient Temperature



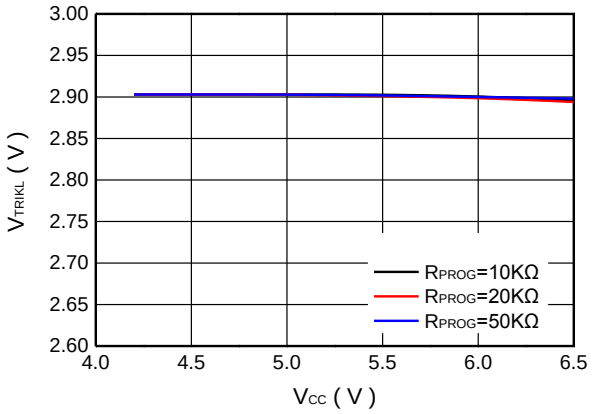
Charge Current vs PROG Pin Voltage



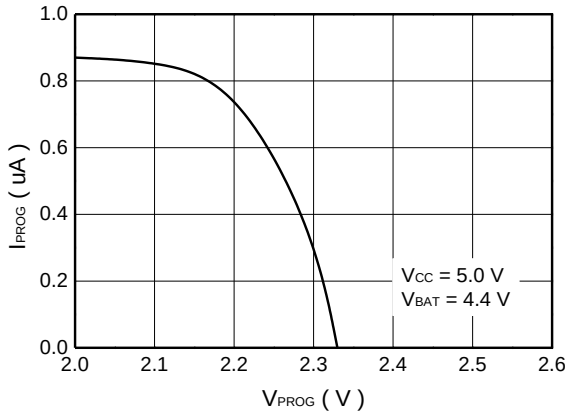
Charge Current vs Supply Voltage



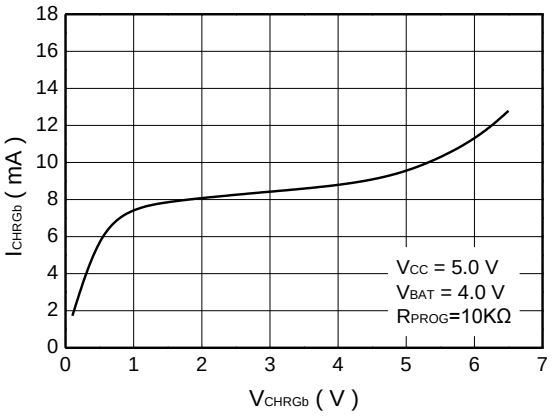
Trickle Charge Current vs Supply Voltage



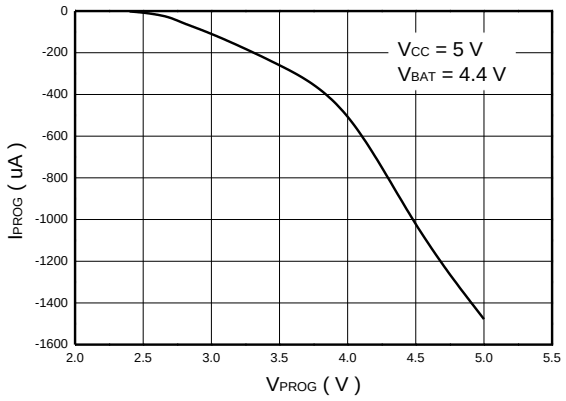
Trickle Voltage vs Supply Voltage



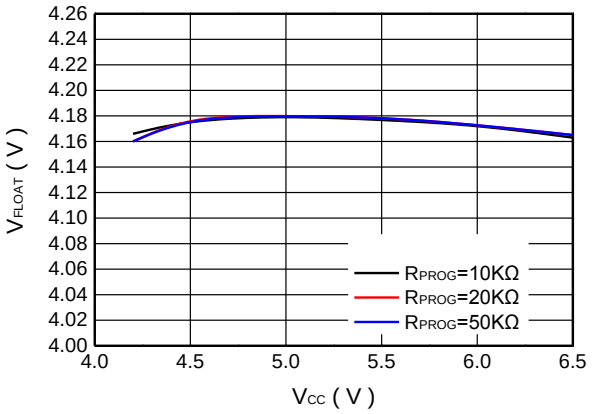
PROG Pin Pull-Up Current vs PROG Pin Voltage



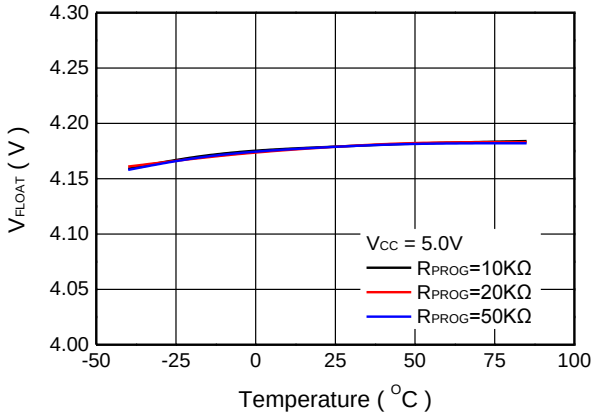
CHRGb Pin Current vs CHRGb Pin Voltage



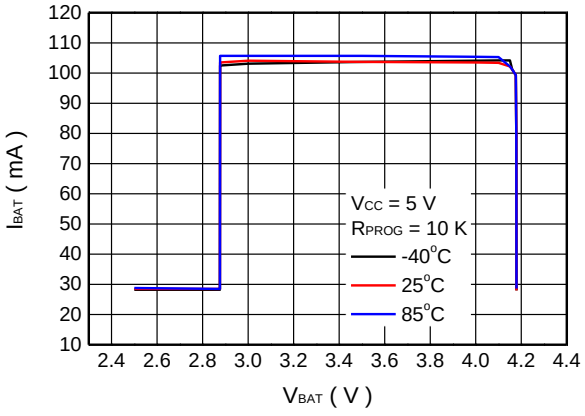
PROG Pin Clamp Current vs PROG Pin Voltage



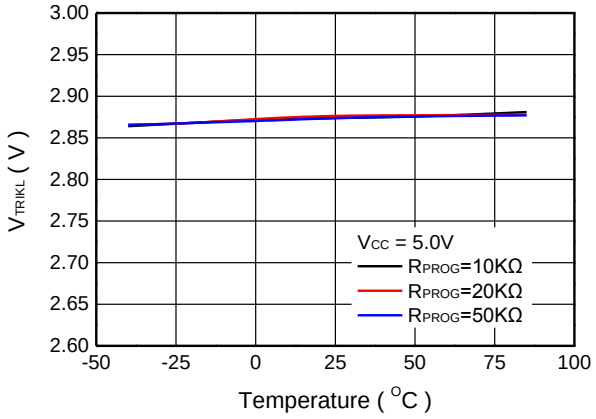
Float Voltage vs Supply Voltage



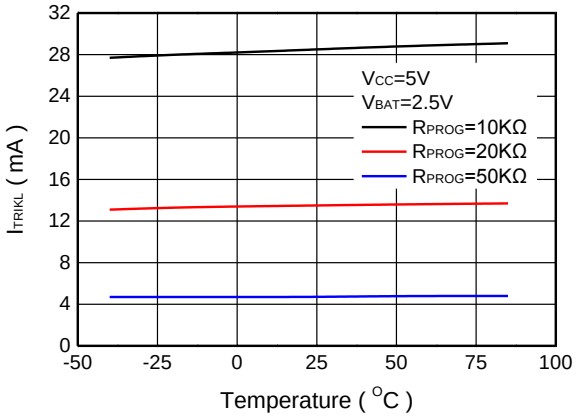
Float Voltage vs Ambient Temperature



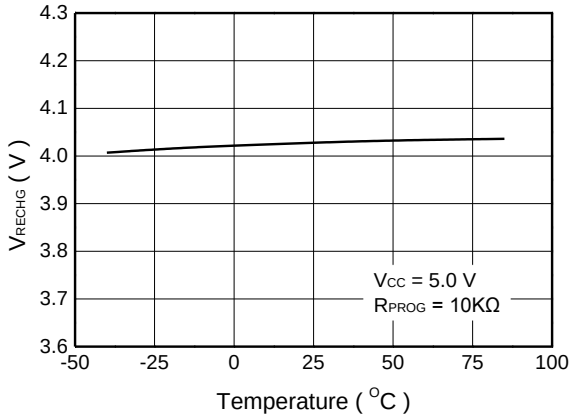
Charge Current vs Battery Voltage



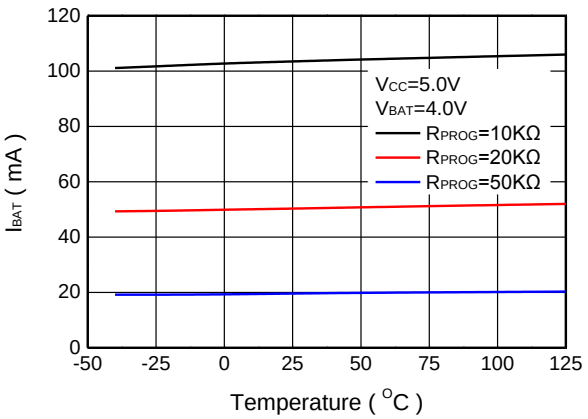
Trickle Charge Threshold vs Ambient Temperature



Trickle Charge Current vs Ambient Temperature



Recharge Voltage Threshold vs Ambient Temperature



Charge Current vs Ambient Temperature

Operation information

The WS4518D/DH is a single cell Lithium-Ion battery charger using a constant-current / constant-voltage algorithm. It can deliver up to 300mA of charge current with a final float voltage accuracy of ±1%. The WS4518D/DH 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 WS4518D/DH 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/2.96V, the charger enters trickle charge mode. In this mode, the WS4518D/DH supplies approximately 3/10 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/2.96V, 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 WS4518D/DH enters constant-voltage mode and the charge current begins to decrease. The charge cycle ends when the PROG voltage is less than 300mV.

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:

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

Charge termination

A charge cycle is terminated when the charge current falls to 3/10 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 300mV for longer than T_{TERM} (typically 1ms), charging is terminated. The charge current is latched off and the WS4518D/DH enters standby mode, where the input supply current drops to 136uA. (Note: 3CC/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 300mV for short periods of time before the DC charge current has dropped to 3/10 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 3/10 of the programmed value, the WS4518D/DH 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.

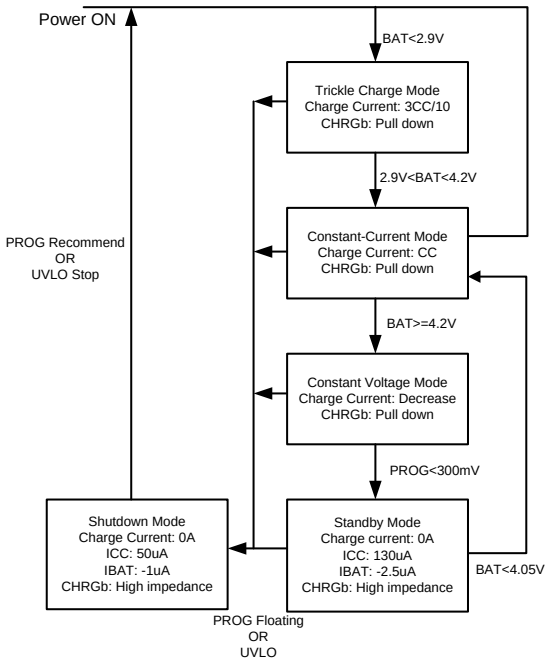


Figure3. State Diagram of a Typical Charge Cycle for WS4518D

The WS4518D/DH constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V/4.188V 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

WS4518D/DH has an open-drain status indicator output CHRGb. CHRGb is pull-down when the WS4518D/DH in a charge cycle. In other status CHRGb is in high impedance. CHRGb is 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 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 10μF capacitor, the frequency of CHRGb flickers is about 1-4s.

Charger state	Red CHRGb
Charging	light
Battery in full state	dark
UVLO, Battery temperature is outside TEMP range, battery is not connected(Use TEMP)	dark
BAT pin is connected to 10uF and no battery mode (TEMP=GND)	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℃. This feature protects the WS4518D/DH 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 WS4518D/DH. 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 WS4518D/DH 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 WS4518D/DH compares the voltage at TEMP pin (V_{TEMP}) against its internal V_{LOW} and V_{HIGH} thresholds to determine if charging is allowed. In WS4518D/DH, 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～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:

$$V_{TEMPL}=\frac{R_2 \,||\, R_{TL}}{R_1+R_2 \,||\, R_{TL}}\times V_{CC}$$

At temperature T_H, the voltage at TEMP pin is:

$$V_{TEMPH}=\frac{R_2 \,||\, R_{TH}}{R_1+R_2 \,||\, R_{TH}}\times V_{CC}$$

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

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

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 R1, R2, 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 R2 but R1. It becomes very simple to calculate R1 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 WS4518D/DH 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.

In manual shutdown, The CHRGb pin is in a high impedance state if the WS4518D/DH is in manual shutdown mode or in the undervoltage lockout mode: either VCC is within 120mV of the BAT pin voltage or insufficient voltage is applied to the VCC pin.

Automatic recharge

Once the charge cycle is terminated, the WS4518D/DH 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/4.188V (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. CHRGb output enters a pull-down state during recharge cycles.

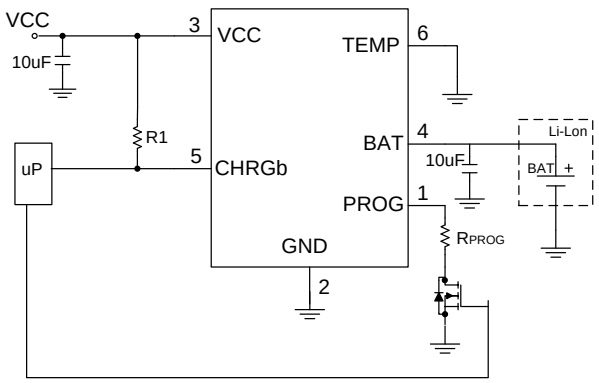


Figure4. Manual Shutdown Mode Application Circuit

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 50KΩ. 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 WS4518D/DH 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 WS4518D/DH. 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 WS4518D/DH 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 WS4518D/DH 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

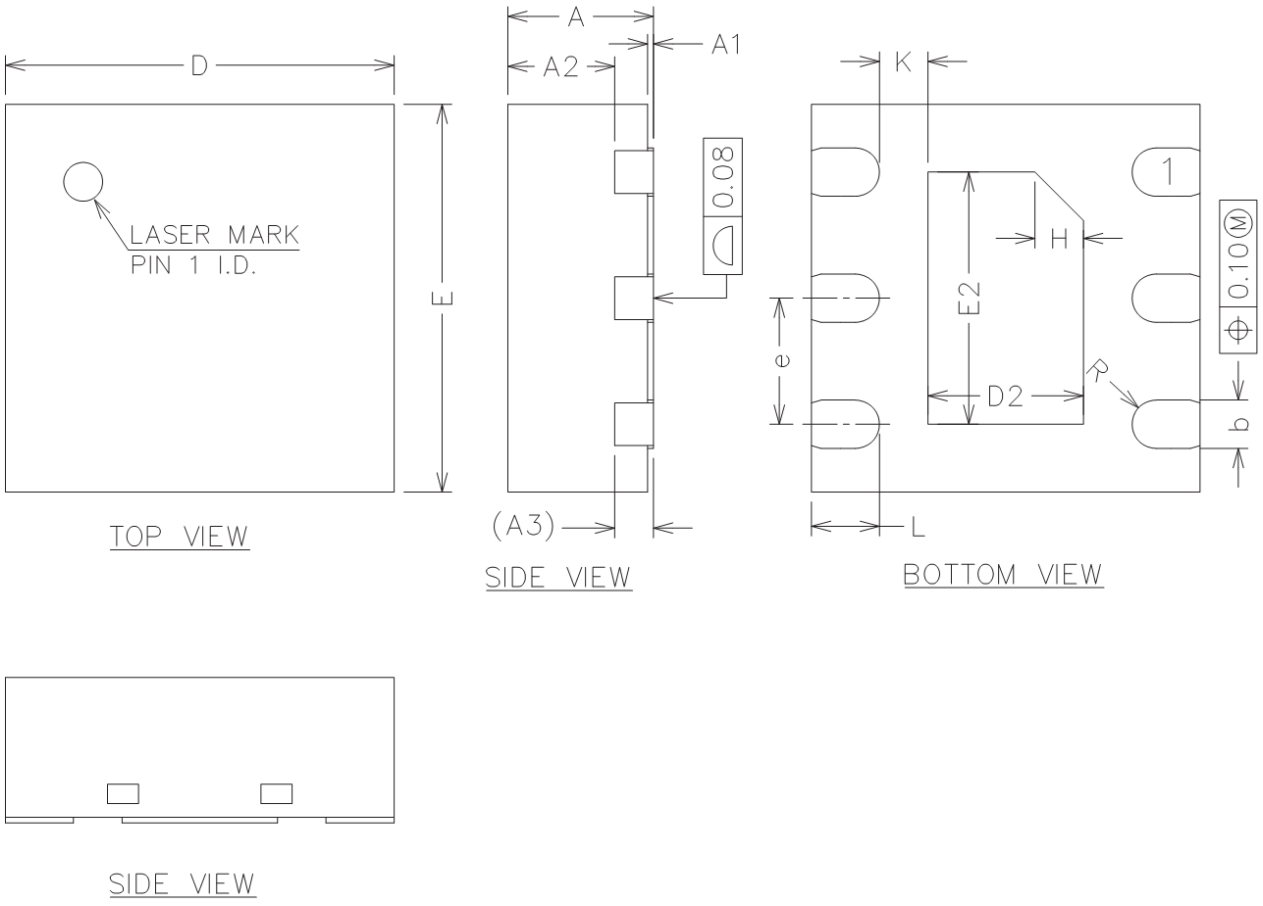
Many types of capacitors can be used for input bypass, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, a 10uF ceramic capacitor is recommended for this bypass capacitor. Due to a 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 WS4518D/DH 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

DFN2X2-6L



Symbol	Dimensions in millimeter		
	Min.	Typ.	Max.
A	0.700	0.750	0.800
A1	0.000	0.020	0.050
A2	0.500	0.550	0.600
A3		0.200 REF.	
b	0.200	0.250	0.300
D	1.900	2.000	2.100
E	1.900	2.000	2.100
D2	0.700	0.800	0.900
E2	1.200	1.300	1.400
e	0.550	0.650	0.750
H		0.250 REF.	
K	0.200	-	-
L	0.300	0.350	0.400
R	0.110	-	-