DIO5509/B/C
250mA Single Cell Li-ion Battery Charger

Features

- Programmable Charge Current Up to 250mA
- Over-Temperature Protection
- Under Voltage Lockout Protection
- Over Voltage Lockout Protection
- Reverse current protection between BAT and GND pins
- Automatic Recharge Threshold
  DIO5509: 4.05V
  DIO5509B: 4.2V
  DIO5509C: 4.25V
- Final Float Voltage:
  DIO5509: 4.2V
  DIO5509B: 4.35V
  DIO5509C: 4.4V
- Charge Status Output Pin
- 2.5V Trickle Charge Threshold

Applications

- Wireless phone
- MP3/MP4 Player
- Bluetooth device

Descriptions

The DIO5509/B/C 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. The charge voltage is fixed at 4.2V for DIO5509, 4.35V for DIO5509B and 4.4V for DIO5509C, and the charge current can be programmed externally with a single resistor.

The DIO5509/B/C 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 DIO5509/B/C automatically enters a low current state, dropping the battery drain current to less than 0.5μA. The DIO5509/B/C can be put into shutdown mode, reducing supply current to 18μA (Typ.).

The DIO5509/B/C is available in a small package with DFN1*1-6. Standard product is Pb-Free.

Ordering Information

Order Part Number	Top Marking		T_A	Package	
DIO5509TN6	WC	Green	-40 to 85°C	DFN1*1-6	Tape & Reel, 5000
DIO5509BTN6	WD	Green	-40 to 85°C	DFN1*1-6	Tape & Reel, 5000
DIO5509CTN6	WE	Green	-40 to 85°C	DFN1*1-6	Tape & Reel, 5000

Pin Assignment

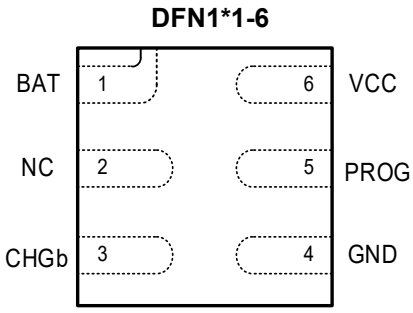


Figure 1. Top View

Pin Descriptions

Name	Description
BAT	Charge Current Output. Provides charge current to the battery an regulates the final float voltage to 4.2, 4.35V and 4.4V.
NC	No connected.
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.
GND	Ground.
PROG	Charge current setting, charge current monitor and shutdown pin. The charging current is given by I_{BAT}= (1/R_{PROG})*250. The chip will be shut down when PROG pin floating.
VCC	Power Supply.

Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Rating” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameter	Rating	Unit
Supply Voltage	-0.3 to 10	V
PROG Voltage	-0.3 to V_{CC}	V
BAT Voltage	-0.3 to 10	V
CHGb Voltage	-0.3 to V_{CC}	V
BAT Pin Current	250	mA
Junction Temperature	150	°C
Operation Temperature	-45 to 85	°C
Storage Temperature	-65 to 125	°C
Lead Temperature (Soldering 10s)	260	°C

Recommend Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended Operating conditions are specified to ensure optimal performance to the datasheet specifications. DIOO does not Recommend exceeding them or designing to Absolute Maximum Ratings.

Parameter		Rating	Unit
Input Supply Voltage	DIO5509	4.5 to 5.5	V
	DIO5509B	4.65 to 5.5	
	DIO5509C	4.7 to 5.5	
Operating Temperature Range		-40 to 85	°C

Electrical Characteristics

V_{CC}=5V, T_A = 25°C (unless otherwise noted)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$I_{SOLYCHRG}$	Charge Mode Supply Current	R_{PROG}=10kΩ		160	200	μA
$I_{BATCHRG}$	Charge Mode Battery Current	R_{PROG}=1kΩ	225	250	275	mA
		R_{PROG}=2.5kΩ	90	100	110	mA
		R_{PROG}=10kΩ	22.5	25	27.5	mA
$V_{PROGCHRG}$	PROG Pin Voltage	R_{PROG}=1kΩ	0.93	1.00	1.07	V
		R_{PROG}=10kΩ	0.93	1.00	1.07	V
$I_{SPLYSTBY}$	Standby Mode Supply Current	Charge Terminated			80	μA
$I_{BATSTBY}$	Standby Mode Battery Current	Charge Terminated		±0.05	1	μA
$I_{SPLYASD}$	Shutdown Mode Supply Current	V_{CC}<V_{BAT}		18	30	μA
I_{BATASD}	Shutdown Mode BAT Pin Current	V_{CC}<V_{BAT}		0.4	0.7	μA
$I_{SPLYUVLO}$	UVLO Mode Supply Current	V_{CC}<V_{UV}		17	30	μA
$I_{BATUVLO}$	UVLO Mode BAT Pin Current	V_{CC}<V_{UV}		±0.05	1	μA
$I_{SPLYOVLO}$	OVLO Mode Supply Current	V_{CC}>V_{OV}		19	30	μA
$I_{BATOVLO}$	OVLO Mode BAT Pin Current	V_{CC}>V_{OV}		±0.05	1	μA
$I_{SPLYSHUT}$	Shutdown Mode Supply Current	R_{PROG} not Connected		18	30	μA
$I_{BATSHUT}$	Shutdown Mode BAT Pin Current	R_{PROG} not Connected		±0.05	1	μA
I_{BATMSD}	Manual Shutdown BAT Pin Current	V_{PROG}=1.3V		±0.05	1	μA
$I_{BATSLEEP}$	Sleep Mode BAT Pin Current	V_{CC}=0V		±0.05	1	μA
$I_{PROG\_CHRGTEM}$	PROG pin current	R_{PROG}=1kΩ		100		μA
$V_{PROG\_CHRGTEM}$	PROG pin voltage	R_{PROG}=1kΩ		0.1		V
V_{FLOAT}	Float Voltage	DIO5509	4.158	4.2	4.242	V
		DIO5509B	4.306	4.35	4.394	
		DIO5509C	4.356	4.4	4.444	
I_{TRIKL}	Trickle Charge Current	R_{PROG}=1kΩ		25		mA
V_{TRIKL}	Trickle Charge Voltage Threshold	R_{PROG}=1kΩ	2.4	2.5	2.6	V
$V_{TRIKL, HYS}$	Trickle Charge Voltage Hysteresis	R_{PROG}=1kΩ		100		mV
V_{UVLO}	UVLO Threshold	From V_{CC} Low to High	3.4	3.5	4.0	V

Electrical Characteristics (continued)

V_{CC}=5V, T_A= 25°C (unless otherwise noted)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{UVLO, HYS}$	UVLO Hysteresis			200		mV
V_{OVLO}	OVLO Threshold	From V_{CC} Low to High		6.0		V
V_{OVP_Hys}	OVLO Hysteresis			200		mV
V_{MSD}	Manual Shutdown Threshold Voltage	PROG Pin Rising PROG Pin Falling		1.2 1.1	1.3	V V
V_{ASD}	Vcc-V_{BAT} Lockout Threshold Voltage	V_{CC} from low to High V_{CC} from High to Low		130 80		mV mV
$\Delta_{VRECHRG}$	Auto Recharge Battery Voltage		100	150	200	mV
V_{CHGb}	CHGb Pin Output Low Voltage	I_{CHGb}=5mA		0.25	0.3	V
T_{LIM}	Junction Temperature In CT Mode			155		°C
T_{RECHRG}	Recharge Comparator Filter Time			2.5		ms
T_{TERM}	Termination Comparator Filter Time			40		ms
I_{PROG}	PROG Pin Pull-up Current			0.2	0.4	μA

Specifications subject to change without notice.

Block Diagram

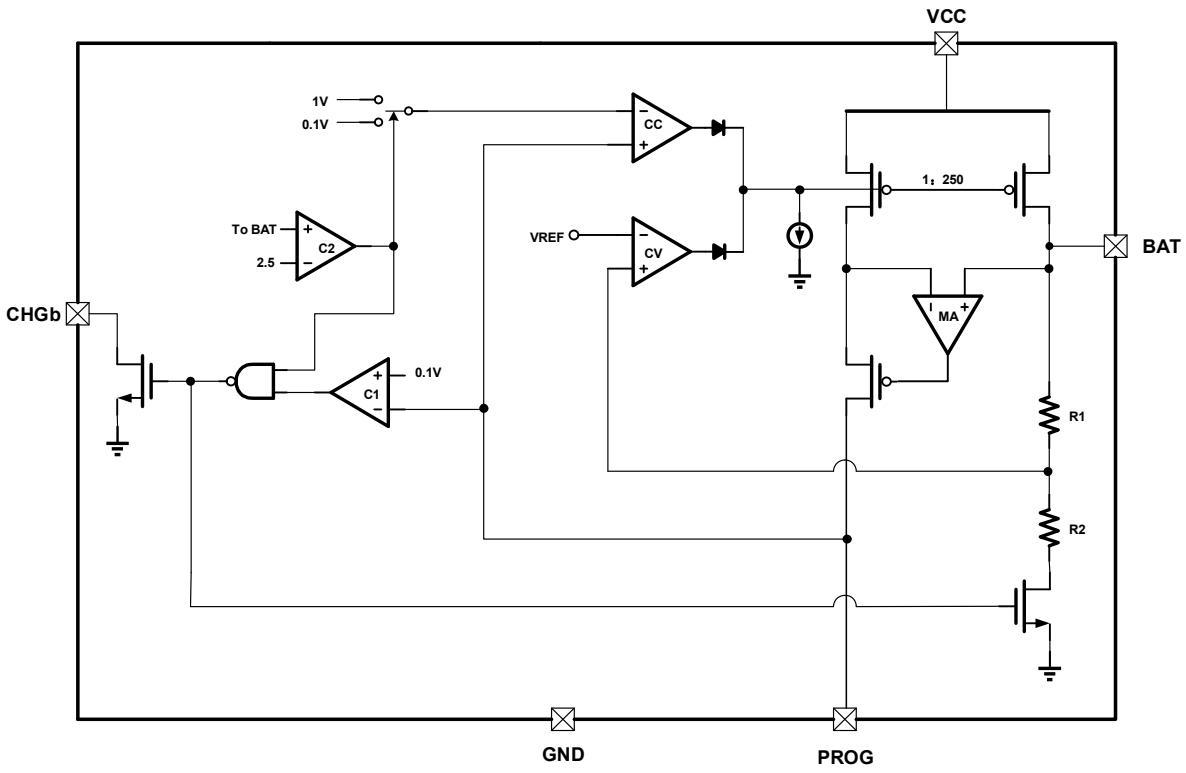


Figure 2. Function Block Diagram

Operation information

The DIO5509/B/C is a single cell Lithium-Ion battery charger using a constant-current / constant-voltage algorithm. It can deliver up to 250mA of charge current with a final float voltage accuracy of ±1%. The DIO5509/B/C 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 DIO5509/B/C is capable of operating from a USB power source.

Normal charge cycle

A charge cycle begins when the voltage at the V_{CC} 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 2.5V, the charger enters trickle charge mode. In this mode, the DIO5509/B/C 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 2.5V, 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 DIO5509/B/C 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 250 times the current out of the PROG pin. The program resistor and the charge current of constant current are calculated using the following equations:

$$I_{CHRG} = \left(\frac{1V}{R_{PROG}}\right) \times 250$$

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 40ms), charging is terminated. The charge current is latched off and the DIO5509/B/C enters standby mode, where the input supply current drops to 43μA. (Note: CC/10 termination is disabled in trickle charging mode).

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 40ms 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 DIO5509/B/C 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.

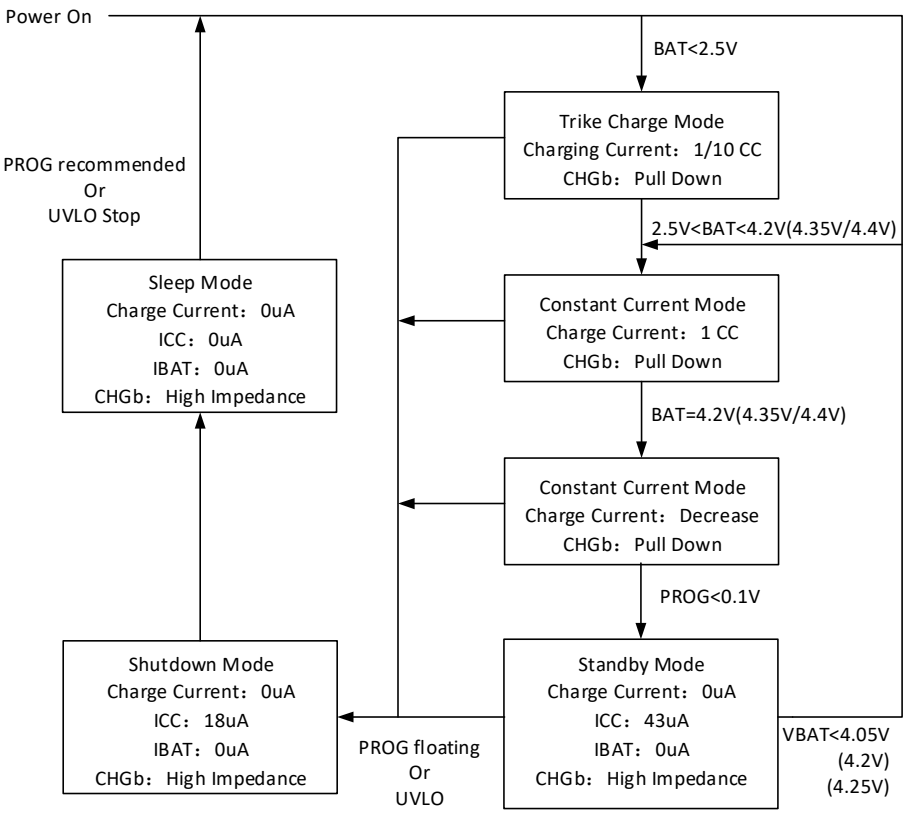


Figure 3. State Diagram of a Typical Charge Cycle

The DIO5509/B/C constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V/4.2V/4.25V 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 Figure 3.

Charge status indicator

DIO5509/B/C has an open-drain status indicator output CHGb. CHGb is pull-down when the DIO5509/B/C in a charge cycle. In other status CHGb is in high impedance. CHGb is in high impedance when the battery out of the normal temperature.

Under-voltage Lockout (UVLO)

An internal under-voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the under-voltage lockout threshold. The UVLO circuit has a built-in hysteresis of 200mV. 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 80mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 130mV above the battery voltage.

Overvoltage Lockout (OVLO)

An internal overvoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the overvoltage lockout threshold. The OVLO circuit has a built-in hysteresis of 200mV. Furthermore, to protect against reverse current in the power MOSFET, the OVLO circuit keeps the charger in shutdown mode if V_{CC} falls to within 80mV of the battery voltage. If the OVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 130mV above the battery voltage.

Manual Shutdown

At any point in the charge cycle, the DIO5509/B/C can be put into shutdown mode by removing R_{PROG} thus floating the PROG pin. This reduces the battery drain current to less than 1μA and the supply current to less than 30μA. A new charge cycle can be initiated by reconnecting the program resistor.

In manual shutdown, The CHGb pin is in a high impedance state if the DIO5509/B/C is in manual shutdown mode or in the under-voltage lockout mode: either V_{CC} is within 130mV of the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin.

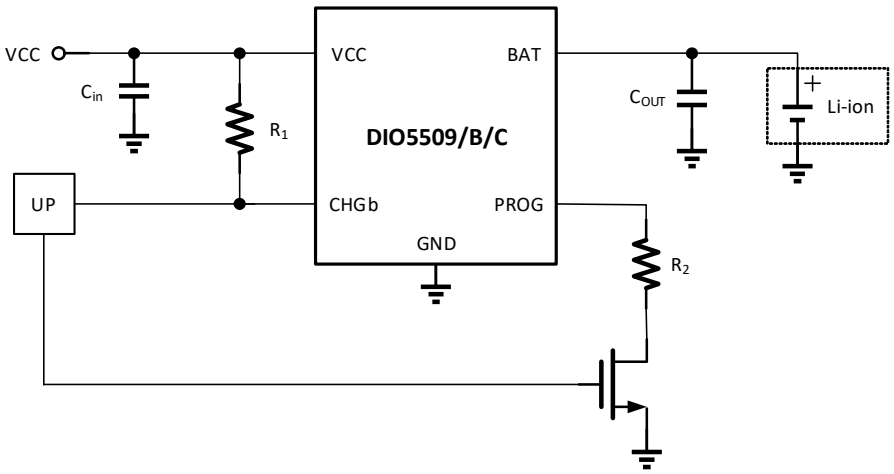


Figure 4. Manual Shutdown Mode Application Circuit

Automatic recharge

Once the charge cycle is terminated, the DIO5509/B/C continuously monitors the voltage on the BAT pin using a comparator with a 2.5ms filter time (T_{RECHRG}). A charge cycle restarts when the battery voltage falls below 4.05V/4.2V/4.25V (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.

Application Information

Typical Application

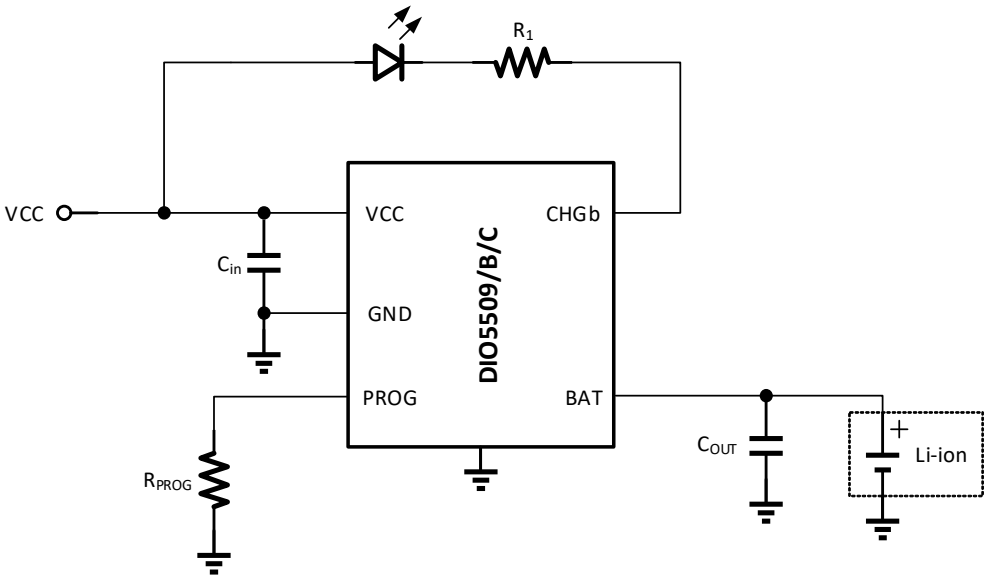


Figure 5. Typical applications W/T LED indicate

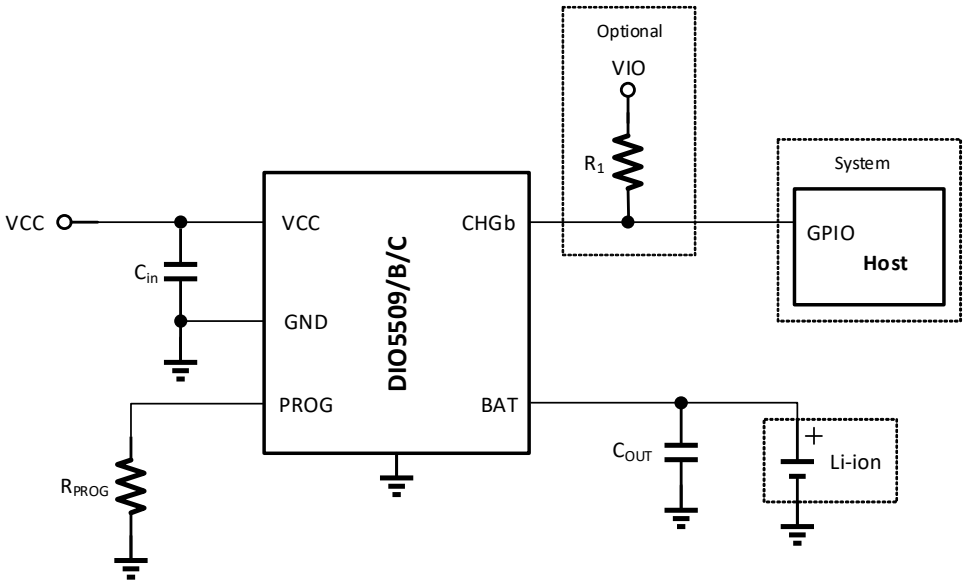


Figure 6. Typical applications W/T microprocessor detect

Note 1：C_{in}=4.7uF，C_{out}=4.7uF are recommended，not mandatory. Good layout and pure voltage can omit these capacitors. R_{PROG} is not needed for fixed CC current part.

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 100KΩ. 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 155°C. This feature protects the DIO5509/B/C 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 DIO5509/B/C. 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 DIO5509/B/C 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 DIO5509/B/C applications do not be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 150°C (Constant temperature mode).

V_{CC} 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 10μF 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.

Typical Performance Characteristics

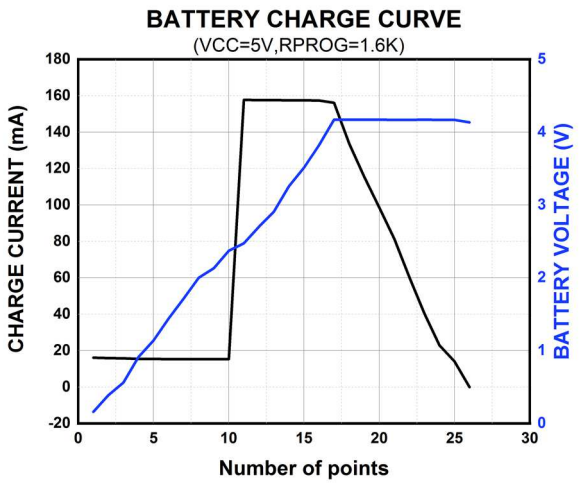


Figure 7. Battery Charge Curve

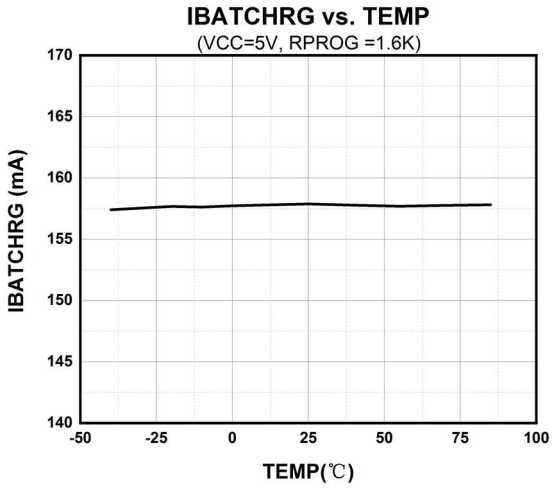


Figure 8. IBATCHRG vs. TEMP

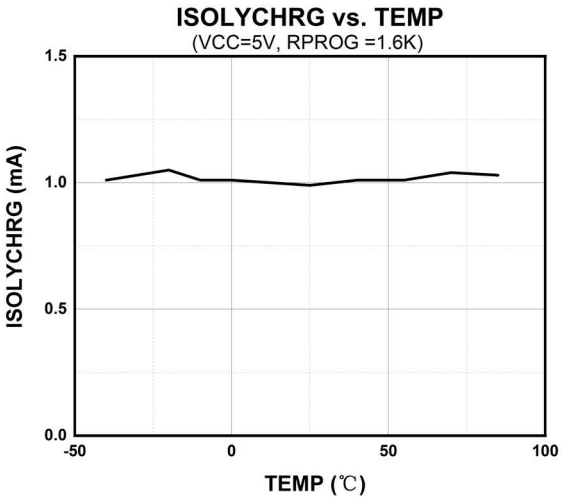


Figure 9. ISOLYCHRG vs. TEMP

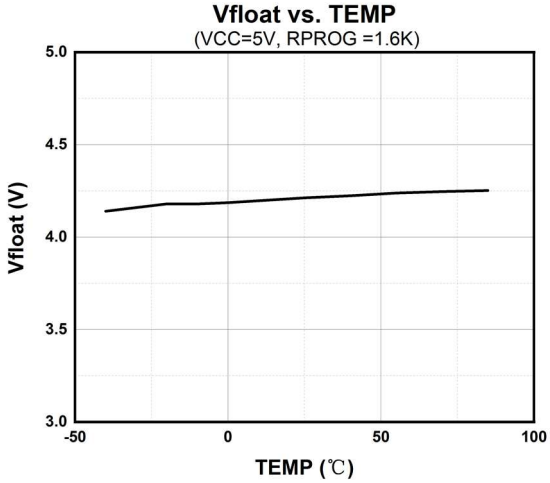


Figure 10. Vfloat vs. TEMP

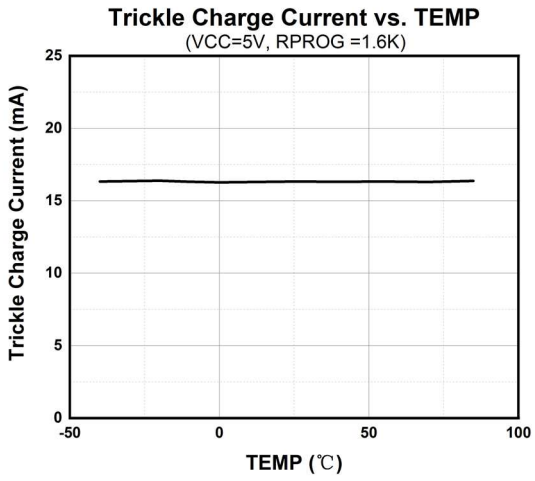


Figure 11. Trickle Charge Current vs. TEMP

(VIN=5V, RPROG=1.6KΩ, CIN=4.7uF, COUT=10000uF)

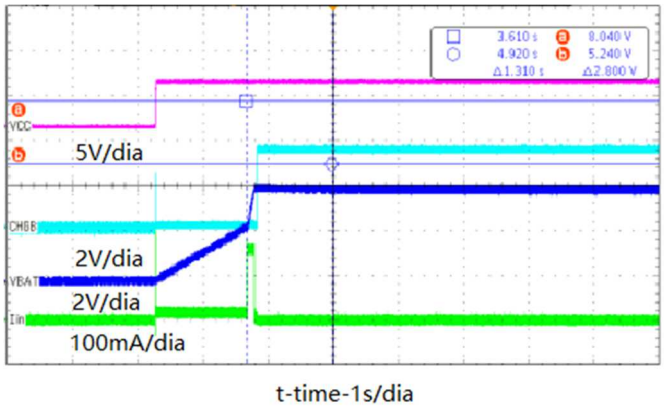


Figure 12. Charging and discharging process

(VCC=5V, CIN=COUT=4.7uF, RPROG=1.6K)

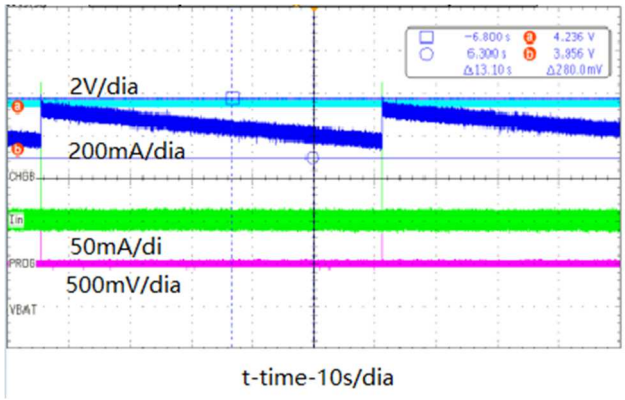
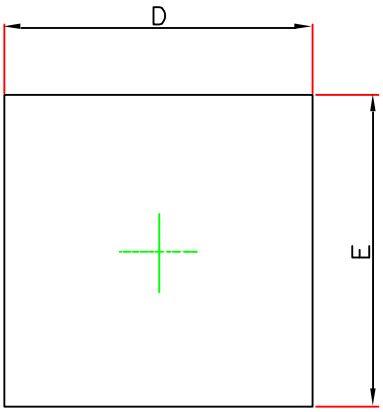
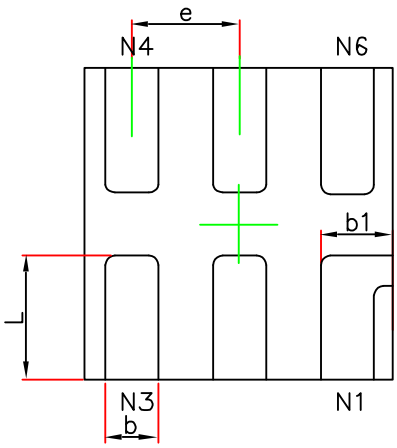


Figure 13. VBAT_FLOAT

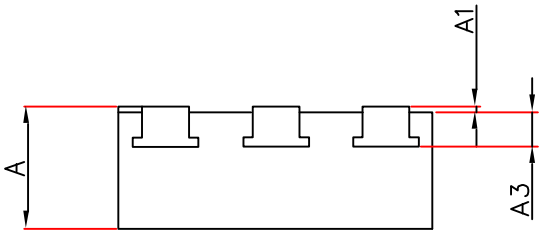
Physical Dimensions: DFN1*1-6



TOPVIEW

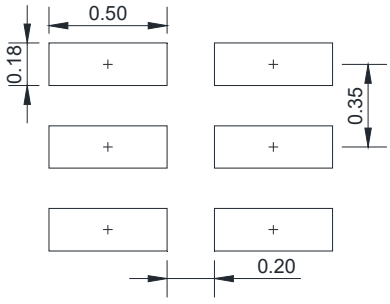


BOTTOMVIEW



SIDEVIEW

COMMON DIMENSIONS (UNITS OF MEASURE=MILLIMETER)			
Symbol	**MIN**	**NOM**	**MAX**
A	0.34	-	0.40
A1	-0.004	-	0.046
A3	0.11REF.		
D	0.95	-	1.05
E	0.95	-	1.05
b	0.12	-	0.22
b1	0.185	-	0.285
e	0.35TYP.		
L	0.35	-	0.45



RECOMMENDED LAND PATTERN (unit: mm)

CONTACT US

Dioo is a professional design and sales corporation for high-quality and performance analog semiconductors. The company focuses on industry markets, such as, cell phone, handheld products, laptop, and medical equipment and so on. Dioo's product families include analog signal processing and amplifying, LED drivers and charger IC. Go to http://www.dioo.com for a complete list of Dioo product families.

For additional product information, or full datasheet, please contact with our Sales Department or Representatives.