

# ISL9203A

Li-Ion/Li Polymer Battery Charger

The [ISL9203A](#) is an integrated single-cell Li-ion or Li-polymer battery charger capable of operating with an input voltage as low as 2.4V. This charger is designed to work with various types of AC adapters.

The ISL9203A operates as a linear charger when the AC adapter is a voltage source. The battery is charged in a Constant Current/Constant Voltage (CC/CV) profile. The charge current is programmable with an external resistor up to 1.5A. The ISL9203A can also work with a current-limited adapter to minimize the thermal dissipation, in which case the ISL9203A combines the benefits of both a linear charger and a pulse charger.

The ISL9203A features charge current thermal foldback to ensure safe operation when the Printed Circuit Board (PCB) is space limited for thermal dissipation. Additional features include preconditioning of an over-discharged battery and thermally enhanced DFN package.

## Related Literature

For a full list of related documents, visit our website:

- [ISL9203A](#) device page

## Features

- Complete charger for single-cell Li-ion batteries
- Very low thermal dissipation
- Integrated pass element and current sensor
- No external blocking diode required
- 1% voltage accuracy
- Programmable current limit up to 1.5A
- Charge current thermal foldback
- Accepts multiple types of adapters
- Operation down to  $V_{IN} = 2.65V$  after startup
- Ambient temperature range:  $-20^{\circ}C$  to  $+70^{\circ}C$
- Thermally-enhanced DFN packages
- Pb-free (RoHS compliant)

## Applications

- Handheld devices, including medical handhelds
- PDAs, cell phones, and smartphones
- Portable instruments and MP3 players
- Self-charging battery packs
- Stand-alone chargers
- USB bus-powered chargers

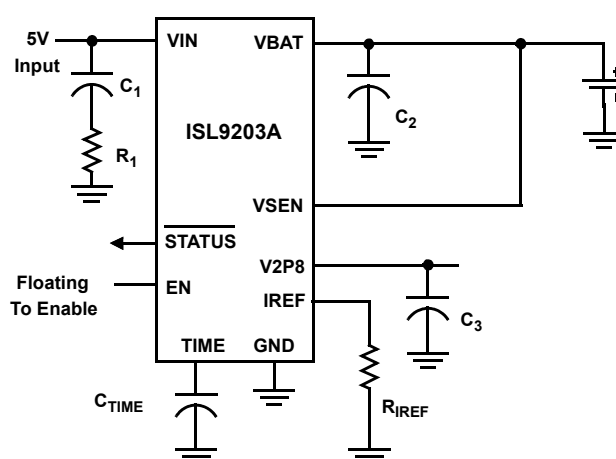
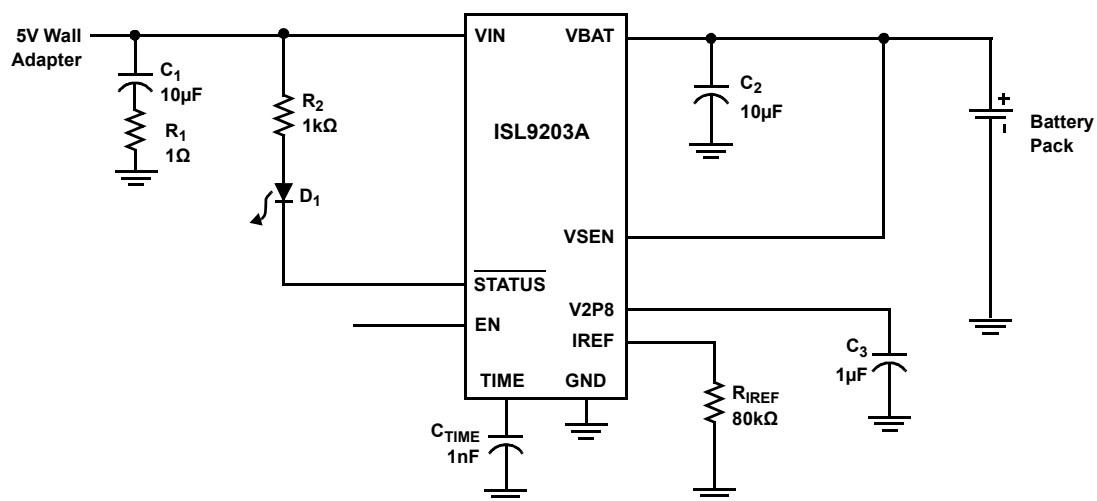


Figure 1. Typical Application Circuit

## 1. Overview

### 1.1 Typical Application



## 1.2 Block Diagram

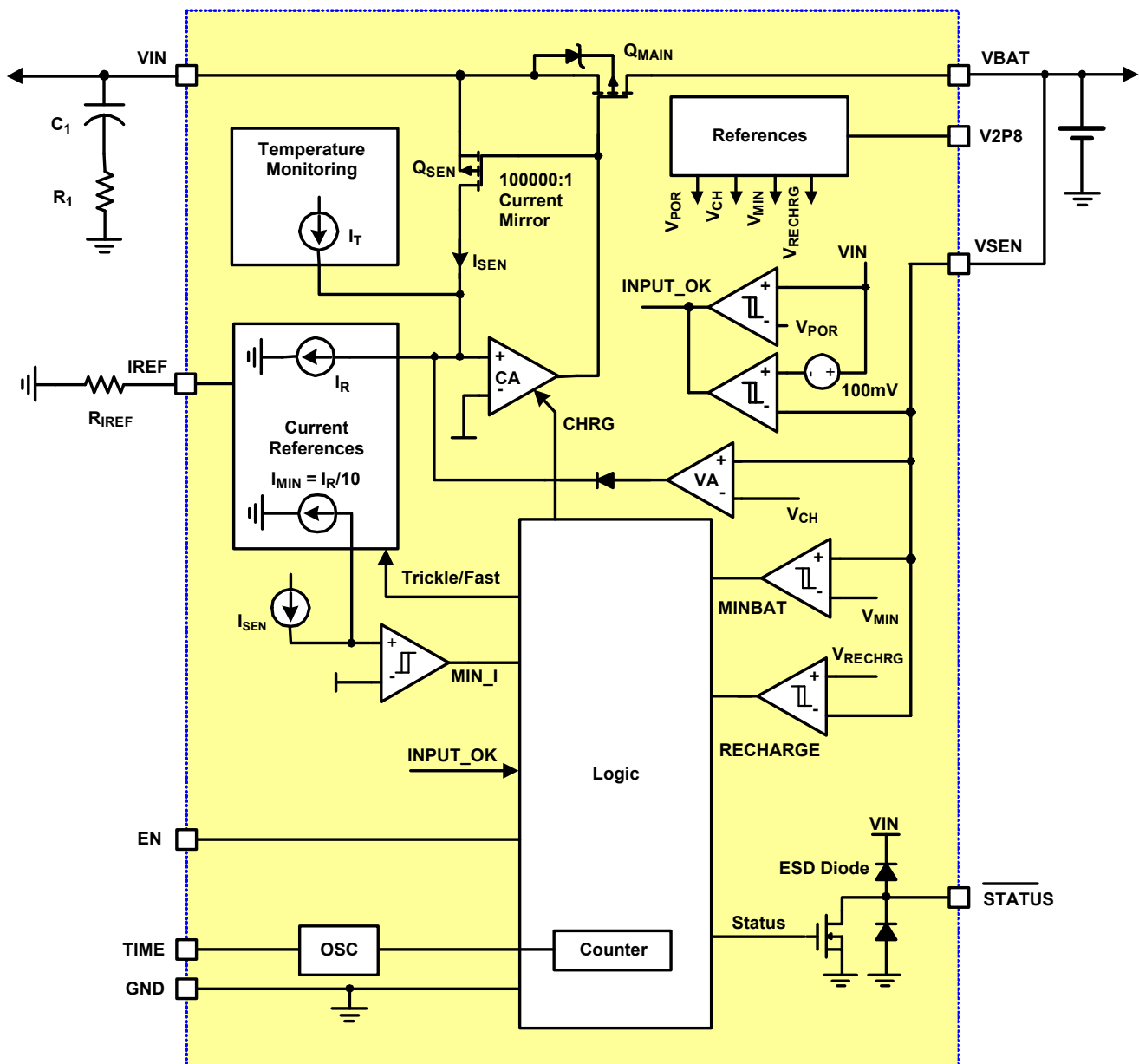


Figure 2. Block Diagram

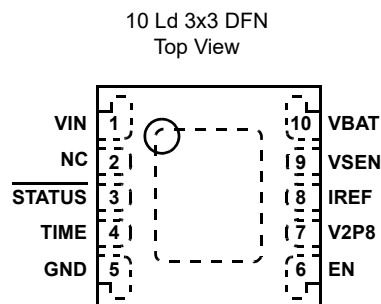
### 1.3 Ordering Information

| Part Number ( <a href="#">Notes 2, 3</a> ) | Part Marking | Temp. Range (°C) | Tape and Reel (Units) ( <a href="#">Note 1</a> ) | Package (RoHS Compliant) | Pkg Dwg. # |
|--------------------------------------------|--------------|------------------|--------------------------------------------------|--------------------------|------------|
| ISL9203ACRZ                                | 03AZ         | -20 to +70       | -                                                | 10 Ld 3x3 DFN            | L10.3x3    |
| ISL9203ACRZ-T                              | 03AZ         | -20 to +70       | 6k                                               | 10 Ld 3x3 DFN            | L10.3x3    |

Notes:

- See [TB347](#) for details about reel specifications.
- Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC-J STD-020.
- For Moisture Sensitivity Level (MSL), see the [ISL9203A](#) device page. For more information about MSL, see [TB363](#).

### 1.4 Pin Configuration



### 1.5 Pin Descriptions

| Pin Number | Pin Name | Description                                                                                                                                                                                                                                                                                             |
|------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1          | VIN      | Input power source. Connect to a wall adapter.                                                                                                                                                                                                                                                          |
| 2          | NC       | No connection.                                                                                                                                                                                                                                                                                          |
| 3          | STATUS   | Open-drain output indicating the charging and inhibit states. The STATUS pin is pulled LOW when the charger is charging a battery. It is forced to high impedance when the charge current drops to $I_{MIN}$ . This high impedance mode is latched until a recharge cycle or a new charge cycle starts. |
| 4          | TIME     | Determines the oscillation period by connecting a timing capacitor between this pin and GND. The oscillator also provides a time reference for the charger.                                                                                                                                             |
| 5          | GND      | Connection to system ground.                                                                                                                                                                                                                                                                            |
| 6          | EN       | Enable logic input. Connect the EN pin to LOW to disable the charger or leave it floating to enable the charger.                                                                                                                                                                                        |
| 7          | V2P8     | 2.8V reference voltage output. This pin outputs a 2.8V voltage source when the input voltage is above the POR threshold, otherwise it outputs zero. The V2P8 pin can be used as an indication for adapter presence.                                                                                     |
| 8          | IREF     | Programming input for the constant charging current. This pin maintains at 0.8V when the charger is in normal operation.                                                                                                                                                                                |
| 9          | VSEN     | Remote voltage sense pin. Connect this pin as close as possible to the battery pack positive connection. If the VSEN pin is floating, its voltage drops to 0V and the charger operates in trickle mode.                                                                                                 |
| 10         | VBAT     | Connection to the battery. Typically a 10μF tantalum capacitor is needed for stability a battery is not attached. When a battery is attached, only a 0.1μF ceramic capacitor is required.                                                                                                               |

## 2. Specifications

### 2.1 Absolute Maximum Ratings

| Parameter                                               | Minimum      | Maximum | Unit        |
|---------------------------------------------------------|--------------|---------|-------------|
| Supply Voltage (VIN)                                    | -0.3         | +7      | V           |
| Output Pin Voltage (BAT, VSEN, V2P8)                    | -0.3         | +5.5    | V           |
| Signal Input Voltage (TIME, IREF)                       | -0.3         | +3.2    | V           |
| Output Pin Voltage (STATUS)                             | -0.3         | +7      | V           |
| Charge Current                                          |              | +1.6    | A           |
| <b>ESD Rating</b>                                       | <b>Value</b> |         | <b>Unit</b> |
| Human Body Model (Tested per MIL-STD-883 Method 3015.7) | 4.5          |         | kV          |
| Machine Model (Tested per EIAJ ED-4701 Method C-111)    | 200          |         | V           |

CAUTION: Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

### 2.2 Thermal Information

| Thermal Resistance (Typical)                         | $\theta_{JA}$ (°C/W) | $\theta_{JC}$ (°C/W) |
|------------------------------------------------------|----------------------|----------------------|
| 10 Ld 3x3 DFN Package ( <a href="#">Notes 4, 5</a> ) | 46                   | 4                    |

Notes:

4.  $\theta_{JA}$  is measured in free air with the component mounted on a high-effective thermal conductivity test board with “direct attach” features. See [TB379](#).

5. For  $\theta_{JC}$ , the “case temp” location is the center of the exposed metal pad on the package underside. See [TB379](#).

| Parameter                                      | Minimum                   | Maximum | Unit |
|------------------------------------------------|---------------------------|---------|------|
| Maximum Junction Temperature (Plastic Package) |                           | +150    | °C   |
| Maximum Storage Temperature Range              | -65                       | +150    | °C   |
| Pb-Free Reflow Profile                         | see <a href="#">TB493</a> |         |      |

CAUTION: +150°C max junction temperature is intended for short periods of time to prevent shortening the lifetime. Operation close to +150°C junction may trigger the shutdown of the device even before +150°C because this number is specified as typical.

### 2.3 Recommended Operation Conditions

| Parameter                 | Minimum | Maximum | Unit |
|---------------------------|---------|---------|------|
| Ambient Temperature Range | -20     | +70     | °C   |
| Supply Voltage, VIN       | 4.3     | 6.5     | V    |

### 2.4 Electrical Specifications

Typical values are tested at  $V_{IN} = 5V$  and +25°C ambient temperature. Maximum and minimum values are ensured across -20°C to +70°C ambient temperature with a supply voltage in the range of 4.3V to 6.5V, unless otherwise noted.

| Parameter                  | Symbol        | Test Conditions                 | Min | Typ | Max  | Unit |
|----------------------------|---------------|---------------------------------|-----|-----|------|------|
| <b>Power-On Reset</b>      |               |                                 |     |     |      |      |
| Rising $V_{IN}$ Threshold  |               |                                 | 3.0 | 3.4 | 4.0  | V    |
| Falling $V_{IN}$ Threshold |               |                                 | 2.3 | 2.4 | 2.65 | V    |
| <b>Standby Current</b>     |               |                                 |     |     |      |      |
| VBAT Pin Sink Current      | $I_{STANDBY}$ | VIN floating or EN = LOW        | -   | -   | 3.0  | μA   |
| VIN Pin Supply Current     | $I_{VIN}$     | VBAT floating and EN pulled low | -   | 30  | 250  | μA   |

Typical values are tested at  $V_{IN} = 5V$  and  $+25^{\circ}C$  ambient temperature. Maximum and minimum values are ensured across  $-20^{\circ}C$  to  $+70^{\circ}C$  ambient temperature with a supply voltage in the range of 4.3V to 6.5V, unless otherwise noted. **(Continued)**

| Parameter                                  | Symbol        | Test Conditions                             | Min   | Typ  | Max   | Unit            |
|--------------------------------------------|---------------|---------------------------------------------|-------|------|-------|-----------------|
| VIN Pin Supply Current                     | $I_{VIN}$     | VBAT floating and EN floating               | -     | 1    | 2     | mA              |
| <b>Voltage Regulation</b>                  |               |                                             |       |      |       |                 |
| Output Voltage                             | $V_{CH}$      |                                             | 4.158 | 4.20 | 4.242 | V               |
| Dropout Voltage                            |               | VBAT = 3.7V, charge current = 1A            | -     | 320  | 550   | mV              |
| <b>Charge Current</b>                      |               |                                             |       |      |       |                 |
| Constant Charge Current (Note 6)           | $I_{CHARGE}$  | $R_{IREF} = 80k\Omega$ , $V_{BAT} = 3.7V$   | 0.9   | 1.0  | 1.1   | A               |
| Constant Charge Current                    | $I_{CHARGE}$  | $R_{IREF} = 1.21M\Omega$ , $V_{BAT} = 3.7V$ | 33    | 66   | 100   | mA              |
| Trickle Charge Current                     | $I_{TRICKLE}$ | $R_{IREF} = 80k\Omega$ , $V_{BAT} = 2.0V$   | 85    | 110  | 135   | mA              |
| Trickle Charge Current                     | $I_{TRICKLE}$ | $R_{IREF} = 1.21M\Omega$ , $V_{BAT} = 2.0V$ | 2     | 7    | 15    | mA              |
| End-of-Charge Threshold                    | $I_{MIN}$     | $R_{IREF} = 80k\Omega$                      | 85    | 110  | 135   | mA              |
| End-of-Charge Threshold                    | $I_{MIN}$     | $R_{IREF} = 1.21M\Omega$                    | 2     | -    | 30    | mA              |
| <b>Recharge Threshold</b>                  |               |                                             |       |      |       |                 |
| Recharge Voltage Threshold                 | $V_{RECHRG}$  |                                             | 3.85  | 4.00 | 4.10  | V               |
| <b>Trickle Charge Threshold</b>            |               |                                             |       |      |       |                 |
| Trickle Charge Threshold Voltage           | $V_{MIN}$     |                                             | 2.1   | 2.3  | 2.5   | V               |
| <b>V2P8 Pin Voltage</b>                    |               |                                             |       |      |       |                 |
| V2P8-Pin Voltage                           | $V_{V2P8}$    |                                             | 2.7   | 2.9  | 3.1   | V               |
| <b>Temperature Monitoring</b>              |               |                                             |       |      |       |                 |
| Charge Current Foldback Threshold (Note 7) | $T_{FOLD}$    |                                             | -     | 100  | -     | $^{\circ}C$     |
| Current Foldback Gain (Note 7)             | $G_{FOLD}$    |                                             | -     | 100  | -     | mA/ $^{\circ}C$ |
| <b>Oscillator</b>                          |               |                                             |       |      |       |                 |
| Oscillation Period                         | $T_{OSC}$     | $C_{TIME} = 15nF$                           | 2.4   | 3.0  | 3.6   | ms              |
| <b>Logic Outputs</b>                       |               |                                             |       |      |       |                 |
| STATUS Logic Low Sink Current              |               | Pin Voltage = 0.8V                          | 5     | -    | -     | mA              |
| STATUS Leakage Current                     |               | $V_{VIN} = V_{STATUS} = 5V$                 | -     | -    | 1     | $\mu A$         |
| EN Input Logic High                        |               |                                             | 2.0   | -    | 3.3   | V               |
| EN Input Logic Low                         |               |                                             | -     | -    | 0.8   | V               |
| EN Pin Current When Driven Low             |               |                                             | -     | -    | 100   | $\mu A$         |

Notes:

- The accuracy includes all errors except the programming resistance tolerance. The actual charge current may be affected by the thermal foldback function if the thermal dissipation capability is not enough or by the on resistance of the power MOSFET if the charger input voltage is too close to the output voltage.
- Ensured by characterization.

### 3. Typical Operating Performance

Test conditions:  $V_{IN} = 5V$ ,  $T_A = +25^\circ C$ ,  $R_{IREF} = R_{IMIN} = 80k\Omega$ ,  $V_{BAT} = 3.7V$ , unless otherwise noted.

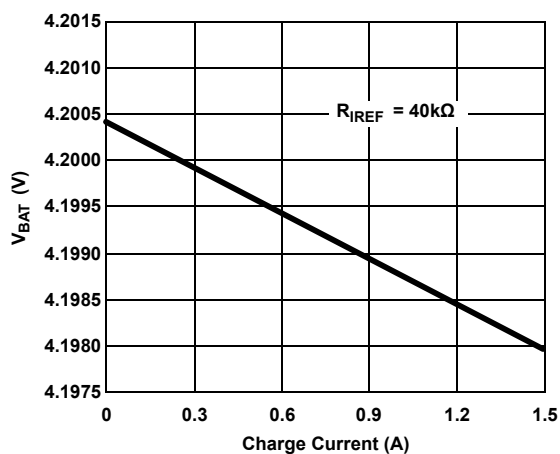


Figure 3. Charger Output Voltage vs Charge Current

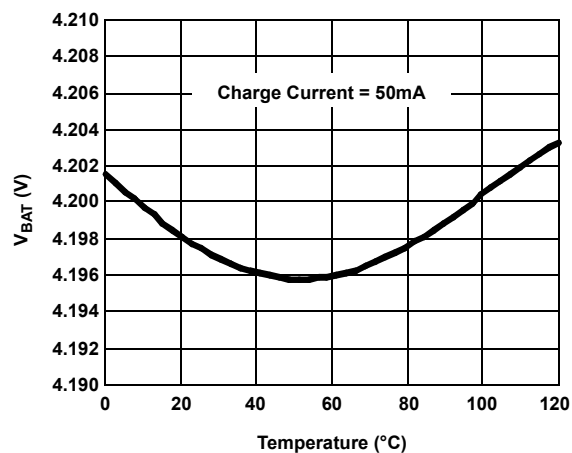


Figure 4. Charger Output Voltage vs Temperature

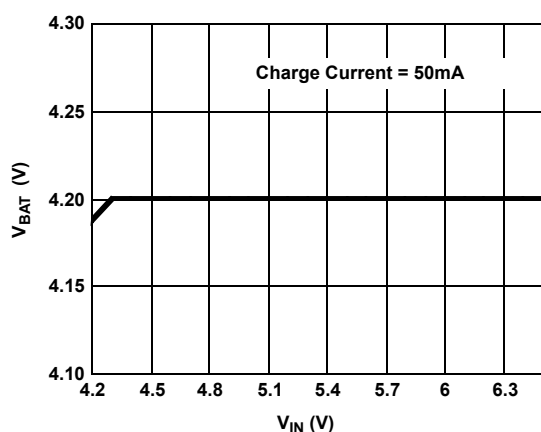


Figure 5. Charger Output Voltage vs Input Voltage  
Charge Current is 50mA

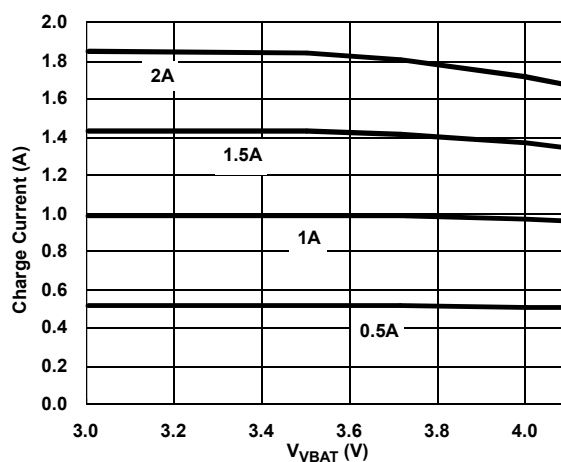


Figure 6. Charge Current vs Output Voltage

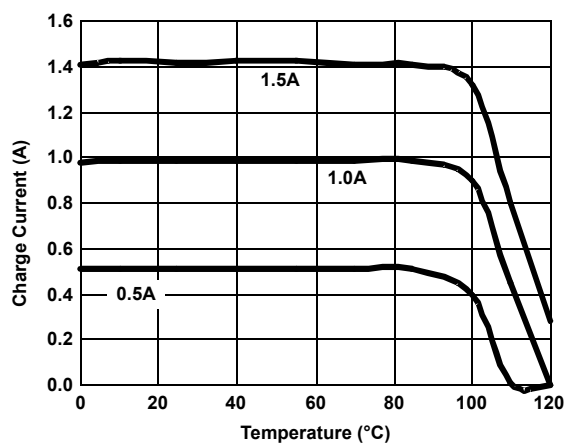


Figure 7. Charge Current vs Ambient Temperature

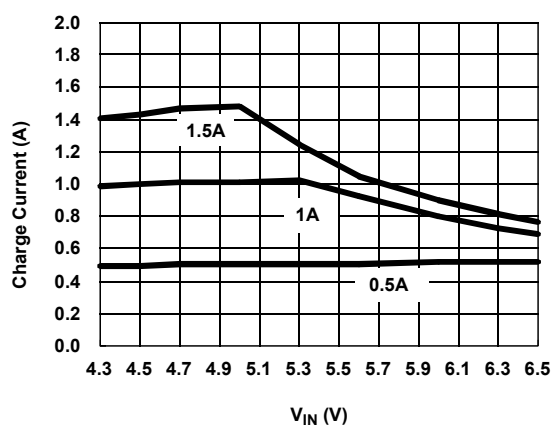


Figure 8. Charge Current vs Input Voltage

Test conditions:  $V_{IN} = 5V$ ,  $T_A = +25^\circ C$ ,  $R_{IREF} = R_{IMIN} = 80k\Omega$ ,  $V_{BAT} = 3.7V$ , unless otherwise noted. (Continued)

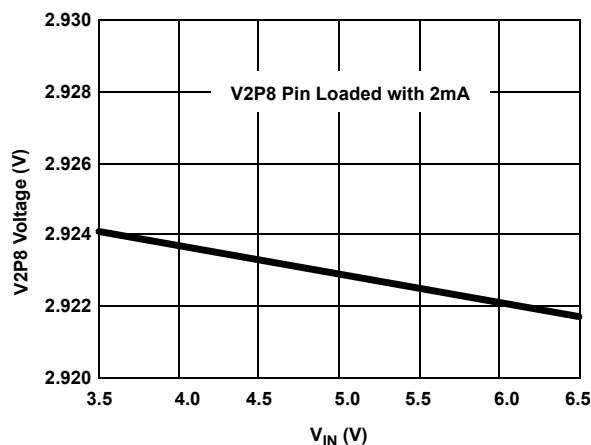


Figure 9. V2P8 Output vs Input Voltage

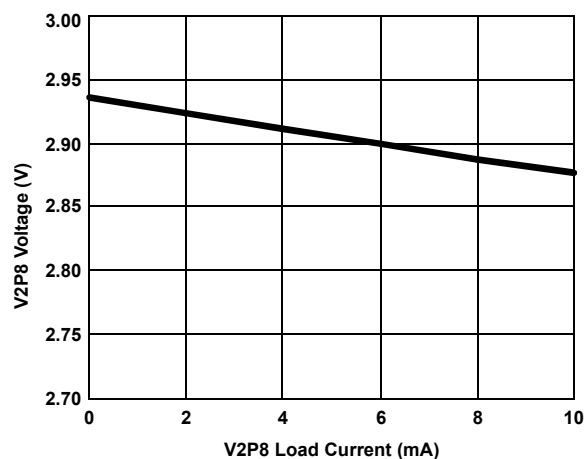


Figure 10. V2P8 Output vs Load Current

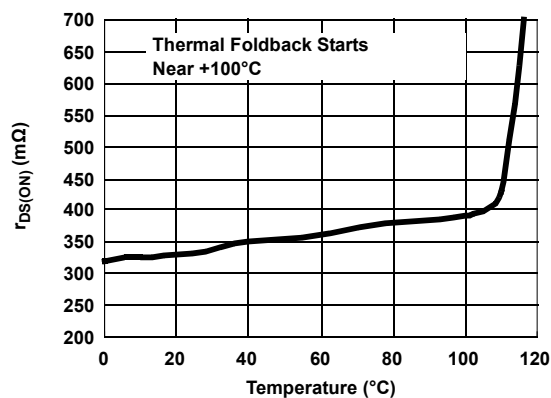


Figure 11.  $r_{DS(ON)}$  vs Temperature at 3.7V Output

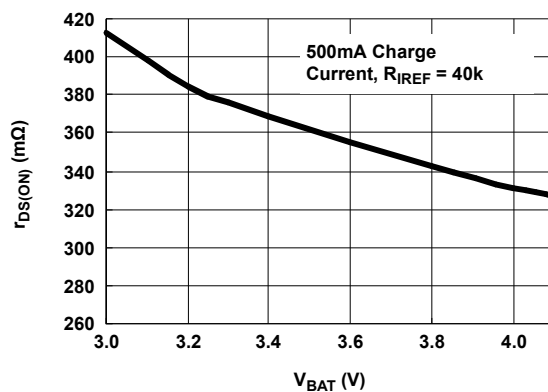


Figure 12.  $r_{DS(ON)}$  vs Output Voltage Using Current Limited Adapters

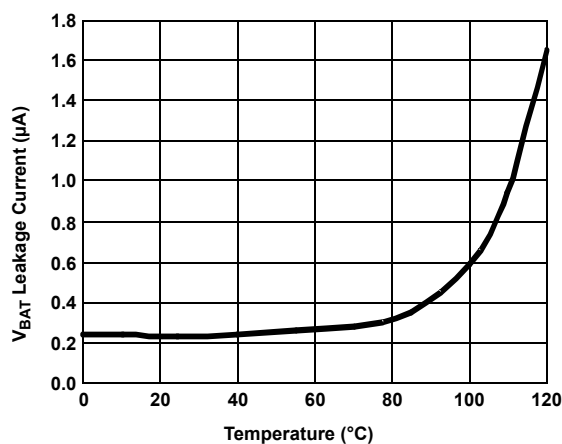


Figure 13. Reverse Current vs Temperature

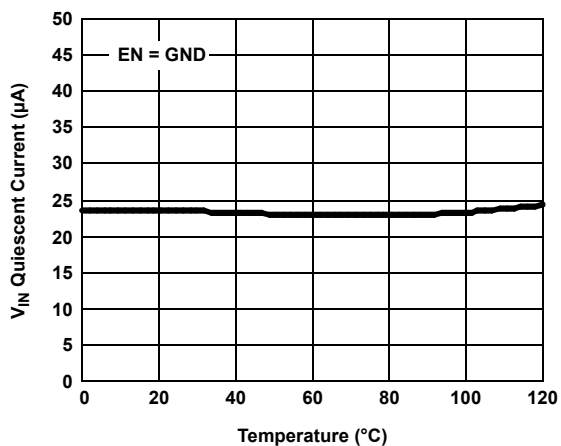


Figure 14. Input Quiescent Current vs Temperature



Test conditions:  $V_{IN} = 5V$ ,  $T_A = +25^\circ C$ ,  $R_{IREF} = R_{IMIN} = 80k\Omega$ ,  $V_{BAT} = 3.7V$ , unless otherwise noted. (Continued)

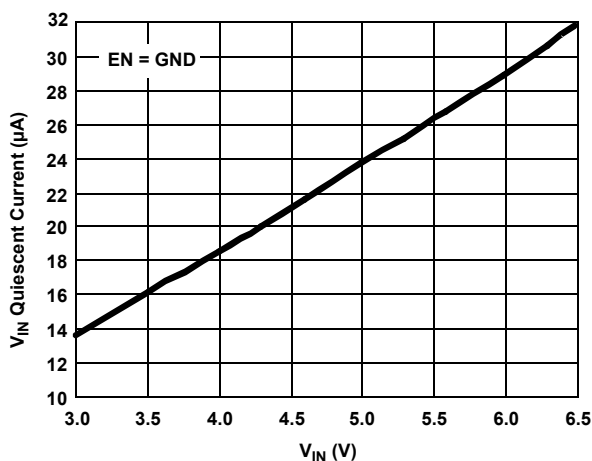


Figure 15. Input Quiescent Current vs Input Voltage When Shut Down

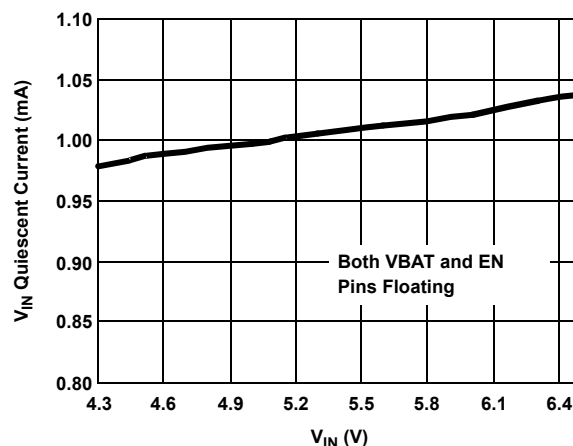


Figure 16. Input Quiescent Current vs Input Voltage When Not Shut Down

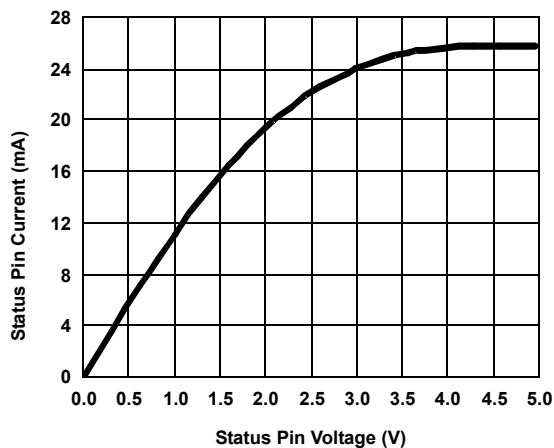


Figure 17. Status Pin Voltage vs Current When the Open-Drive MOSFET Turns On

## 4. Theory of Operation

The ISL9203A is an integrated charger for single-cell Li-ion or Li-polymer batteries. The ISL9203A functions as a traditional linear charger when powered with a voltage-source adapter. When powered with a current-limited adapter, the charger minimizes the thermal dissipation commonly seen in traditional linear chargers.

As a linear charger, the ISL9203A charges a battery in the popular Constant Current (CC) and Constant Voltage (CV) profile. The constant charge current  $I_{REF}$  is programmable up to 1.5A with an external resistor. The charge voltage  $V_{CH}$  has 1% accuracy across the entire recommended operating condition range. The charger always preconditions the battery with 10% of the programmed current at the beginning of a charge cycle until the battery voltage is verified to be above the minimum fast charge voltage,  $V_{MIN}$ . This low-current preconditioning charge mode is called trickle mode. The verification takes 15 cycles of an internal oscillator with a period that is programmable with the timing capacitor.

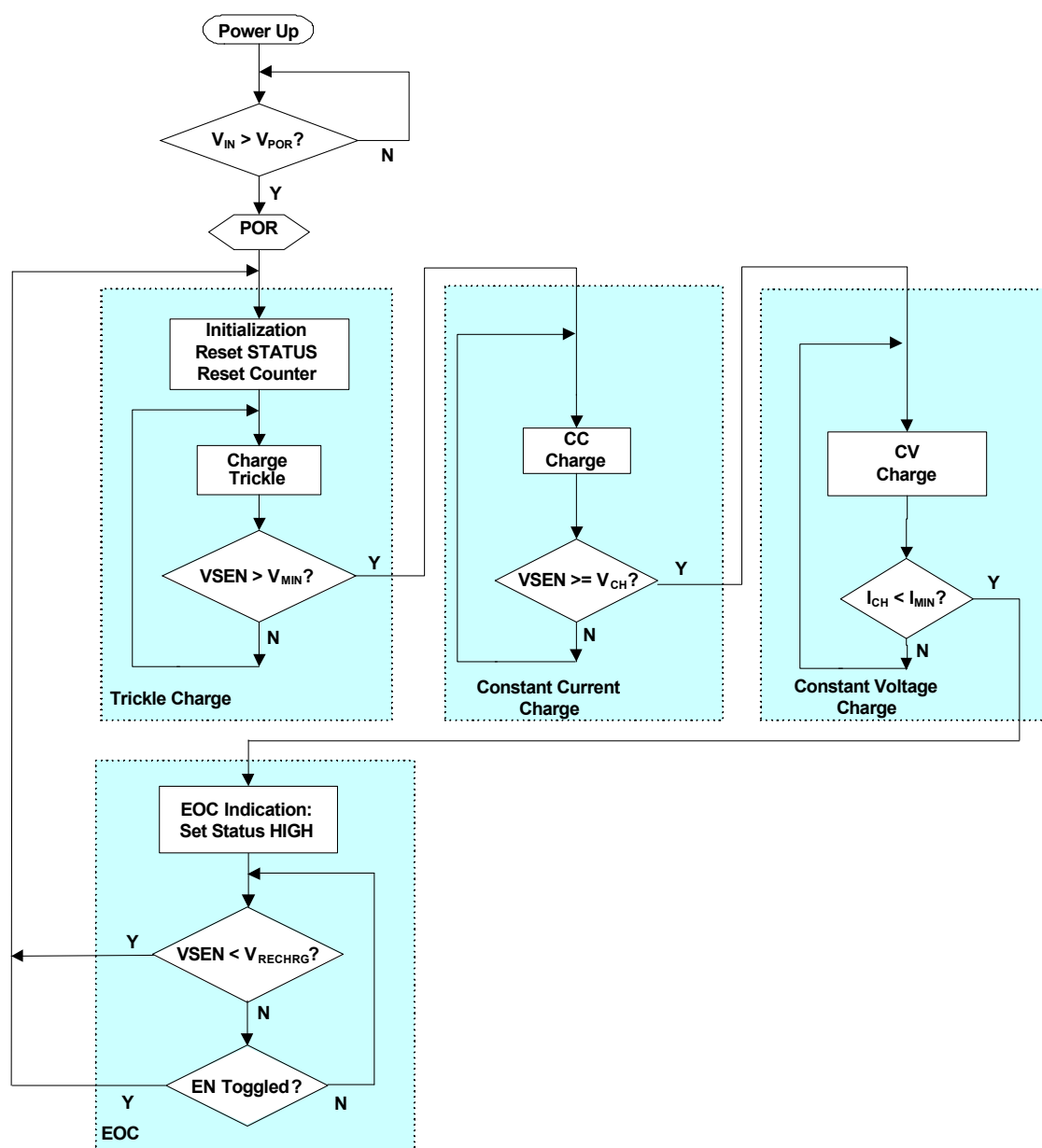


Figure 18. Charging State Diagram

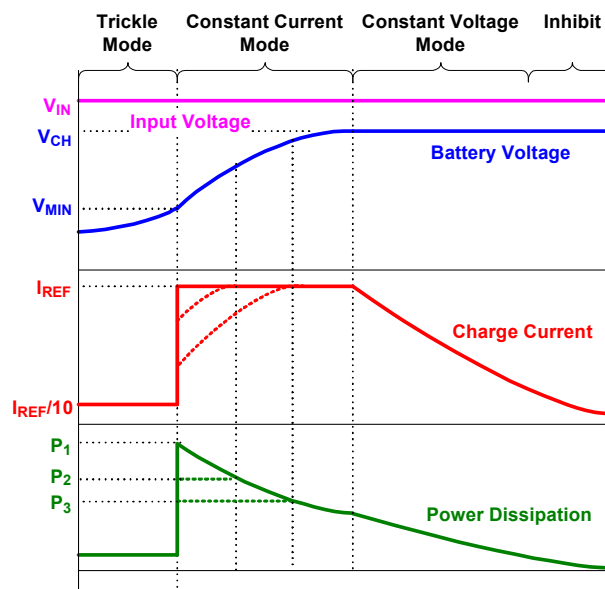
A thermal-foldback feature removes the thermal concern typically seen in linear chargers. The charger reduces the charge current automatically as the IC internal temperature rises above +100°C to prevent further temperature rise. The thermal-foldback feature ensures safe operation when the PCB is space-limited for thermal dissipation.

Two indication pins are available from the charger to indicate the charge status. The V2P8 pin outputs a 2.8V DC voltage when the input voltage is above the Power-On Reset (POR) level and can be used as a power-present indication. The V2P8 pin can source a 2mA current, so it can also be used to bias external circuits. The STATUS pin is an open-drain logic output that goes LOW at the beginning of a charge cycle and stays LOW until the end-of-charge (EOC) condition is qualified. The EOC condition is met when the battery voltage rises above a recharge threshold and the charge current falls below an EOC current threshold. When the EOC condition is qualified, the STATUS output goes HIGH and is latched. The latch is released at the beginning of a recharge cycle, when the EN is toggled, or after the chip is power cycled.

If the ISL9203A has not been power cycled and the EN pin is not toggled, but the VSEN voltage drops below the recharge level, the device re-enters charge mode. In this condition, the charger indicates a recharge cycle by bringing the STATUS pin LOW.

When the wall adapter is not present, the ISL9203A draws less than 1µA of current from the battery.

[Figure 19](#) shows the typical charge curves in a traditional linear charger powered with a constant-voltage adapter.



**Figure 19. Typical Charge Curves Using a Constant-Voltage Adapter**

From the top to bottom, the curves represent the constant input voltage, the battery voltage, the charge current, and the power dissipation in the charger.

The power dissipation  $P_{CH}$  is given by the following equation:

$$(EQ. 1) \quad P_{CH} = (V_{IN} - V_{BAT}) \cdot I_{CHARGE}$$

where  $I_{CHARGE}$  is the charge current. The maximum power dissipation occurs during the beginning of CC mode. The maximum power the ISL9203A is capable of dissipating is dependent on the thermal impedance of the Printed-Circuit Board (PCB). The dotted lines in [Figure 19](#) show two cases where the charge currents are limited by the maximum power dissipation capability due to the thermal foldback.

When using a current-limited adapter, the thermal situation in the ISL9203A is totally different. [Figure 20](#) shows the typical charge curves when a current-limited adapter is used. The operation requires the  $I_{REF}$  to be programmed higher than the limited current  $I_{LIM}$  of the adapter, as [Figure 20](#) shows. The key difference of the charger operating under such conditions occurs during CC mode.

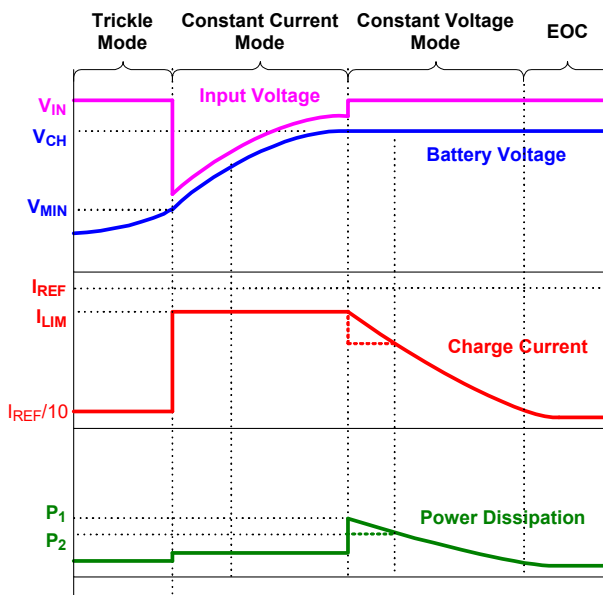


Figure 20. Typical Charge Curves Using a Current Limited Adapter

The block diagram ([Figure 2 on page 3](#)) aids in understanding the operation of the ISL9203A. The current loop consists of the current amplifier CA and the sense MOSFET  $Q_{SEN}$ . The current reference  $I_R$  is programmed by the  $I_{REF}$  pin. The current amplifier CA regulates the gate of the sense MOSFET  $Q_{SEN}$  so that the sensed current  $I_{SEN}$  matches the reference current  $I_R$ . The main MOSFET  $Q_{MAIN}$  and the sense MOSFET  $Q_{SEN}$  form a current mirror with a ratio of 100000:1; that is, the output charge current is 100,000 times  $I_R$ .

In CC mode, the current loop tries to increase the charge current by enhancing the sense MOSFET  $Q_{SEN}$  so the sensed current matches the reference current. However, the adapter current is limited, so the actual output current never reaches what is required by the current reference. As a result, the current error amplifier CA keeps enhancing the  $Q_{SEN}$  and the main MOSFET  $Q_{MAIN}$  until they are fully turned on. Therefore, the main MOSFET becomes a power switch instead of a linear regulation device. The power dissipation in CC mode becomes:

$$(EQ. 2) \quad P_{CH} = r_{DS(ON)} \cdot I_{CHARGE}^2$$

where  $r_{DS(ON)}$  is the resistance when the main MOSFET is fully turned on. This power is typically much less than the peak power in the traditional linear mode.

The worst power dissipation when using a current-limited adapter typically occurs at the beginning of the CV mode, as [Figure 20](#) shows. [Equation 1 on page 11](#) applies during the CV mode. When using a very small PCB with a relatively large thermal impedance, it is possible for the internal temperature to reach the thermal foldback threshold. In that case, the IC is thermally protected by lowering the charge current, as shown by the dotted lines in the charge current and power curves in [Figure 20](#). Appropriate adapter design can further reduce the ISL9203A peak power dissipation. See the Application Information section of the [ISL6292 datasheet](#) for more information.

[Figure 21 on page 13](#) shows the typical signal waveforms for the linear charger from power-up to a recharge cycle. See [“Application Information” on page 13](#) for more detailed application information.

## 5. Application Information

### 5.1 Power-On-Reset (POR)

The ISL9203A resets itself as the input voltage rises above the POR rising threshold. The V2P8 pin outputs a 2.8V voltage, the internal oscillator starts to oscillate, the internal timer is reset, and the charger begins to charge the battery. The STATUS pin indicates a LOW logic signal. [Figure 21](#) shows the startup of the charger between  $t_0$  to  $t_2$ .

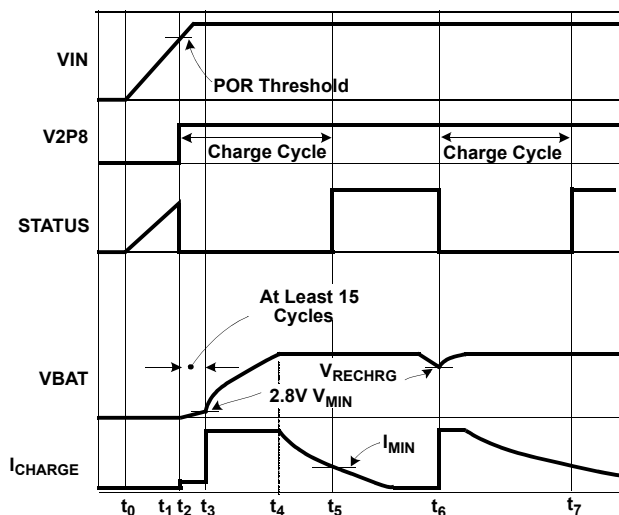


Figure 21. Operation Waveforms

The ISL9203A has a typical rising POR threshold of 3.4V and a falling POR threshold of 2.4V. The 2.4V falling threshold ensures charger operation with a current-limited adapter to minimize the thermal dissipation.

### 5.2 Charge Cycle

A charge cycle consists of three charge modes:

- Trickle mode
- Constant Current (CC) mode
- Constant Voltage (CV) mode

The charge cycle always starts with trickle mode until the battery voltage stays above  $V_{MIN}$  (2.3V typical) for 15 consecutive cycles of the internal oscillator. If the battery voltage drops below  $V_{MIN}$  during the 15 cycles, the 15-cycle counter is reset and the charger stays in trickle mode. The charger moves to the CC mode after verifying the battery voltage is above  $V_{MIN}$ .

When the battery pack terminal voltage rises to the final charge voltage  $V_{CH}$ , CV mode begins. The terminal voltage is regulated at the constant  $V_{CH}$  in the CV mode and the charge current declines. After the charge current drops below  $I_{MIN}$  (1/10 of  $I_{REF}$ , see [“End-of-Charge \(EOC\) Current” on page 15](#) for more detail) the ISL9203A indicates the end-of-charge with the STATUS pin. The charging operation does not terminate. Signals in a charge cycle are shown in [Figure 21](#) between points  $t_2$  and  $t_5$ .

The end of charge indicator (STATUS) is not set if the charging current is below  $I_{MIN}$  within the first 16 cycles after  $V_{BAT}$  exceeds the  $V_{RECHRG}$  voltage. If the charge current is still below  $I_{MIN}$  after these 16 cycles, STATUS goes high to indicate end of charge.

The following events initiate a new charge cycle:

- POR
- The battery voltage drops below a recharge threshold
- The EN pin is toggled from GND to floating

See the following sections for more information about these events.

### 5.3 Recharge

After a charge cycle completes, the charger continues to regulate the output at the constant voltage, but the STATUS pin indicates that the charging is completed. The STATUS pin stays high until the battery voltage drops to below the recharge threshold,  $V_{RECHRG}$  (see [“Electrical Specifications” on page 5](#)). The STATUS pin then goes low and a new charge cycle starts at point  $t_6$ . The charge cycle ends at point  $t_7$  with the STATUS pin again going high, as shown in [Figure 21 on page 13](#).

### 5.4 Internal Oscillator

The internal oscillator establishes a timing reference. The oscillation period is programmable with an external timing capacitor,  $C_{TIME}$ , as shown in [“Typical Application” on page 2](#). The oscillator charges the timing capacitor to 1.5V and discharges it to 0.5V in one period, both with 10μA current. The period  $T_{OSC}$  is:

$$(EQ. 3) \quad T_{OSC} = 0.2 \cdot 10^6 \cdot C_{TIME} \quad (\text{seconds})$$

A 1nF capacitor results in a 0.2ms oscillation period. The accuracy of the period is mainly dependent on the accuracy of the capacitance and the internal current source.

### 5.5 Charge Current Programming

The charge current in the CC mode is programmed by the IREF pin. The voltage of IREF is regulated to a 0.8V reference voltage. The charging current during the constant current mode is 100000 times that of the current in the  $R_{IREF}$  resistor. Therefore, the charge current is:

$$(EQ. 4) \quad I_{REF} = \frac{0.8V}{R_{IREF}} \times 10^5 (A)$$

[Table 1](#) shows the charge current vs selected  $R_{IREF}$  values. The typical trickle charge current is 10% of the programmed constant charge current.

**Table 1. Charge Current vs  $R_{IREF}$  Values**

| $R_{IREF}$ (kΩ) | Charge Current (mA)      |                                                         |                           |
|-----------------|--------------------------|---------------------------------------------------------|---------------------------|
|                 | Min                      | Typ                                                     | Max                       |
| 267 ~ 160       | 17% lower than Typ value | = $I_{REF}$<br>in <a href="#">Equation 5 on page 15</a> | 17% higher than Typ value |
| 160             | 450                      | 500                                                     | 550                       |
| 100             | 720                      | 800                                                     | 880                       |
| 88.9            | 810                      | 900                                                     | 990                       |
| 80              | 900                      | 1000                                                    | 1100                      |

[Table 2](#) shows the trickle charge current tolerance guidance at given  $R_{IREF}$  values, when the battery voltage is between 0V and 2.5V.

**Table 2. Trickle Charge Current vs  $R_{IREF}$  Values**

| $R_{IREF}$ (k $\Omega$ ) | Trickle Charge Current (mA) |     |     |
|--------------------------|-----------------------------|-----|-----|
|                          | Min                         | Typ | Max |
| 267                      | 15                          | 30  | 60  |
| 160                      | 30                          | 50  | 80  |
| 100                      | 40                          | 80  | 120 |
| 88.9                     | 45                          | 90  | 135 |
| 80                       | 70                          | 100 | 150 |

Note:

8. The values in [Tables 1](#) and [2](#) are not tested and are only for guidance in selecting resistor values for mass production tests or in customer's products.

## 5.6 End-of-Charge (EOC) Current

The EOC current  $I_{MIN}$  sets the level at which the charger starts to indicate the end of the charge with the STATUS pin, as shown in [Figure 21 on page 13](#). The charger does not actually terminate charging. In the ISL9203A, the EOC current is internally set to 1/10 of the CC charge current, that is:

$$(EQ. 5) \quad I_{MIN} = \frac{1}{10} \cdot I_{REF}$$

At the EOC, the STATUS signal rises to HIGH and is latched. The latch is not reset until a recharge cycle or a new charge cycle starts. The tolerance guidance for the EOC current at selected  $R_{IREF}$  values are given in [Table 3](#).

**Table 3. EOC Current vs  $R_{IREF}$  Values**

| $R_{IREF}$ (k $\Omega$ ) | EOC Current (mA) |     |     |
|--------------------------|------------------|-----|-----|
|                          | Min              | Typ | Max |
| 267                      | 15               | 30  | 60  |
| 160                      | 30               | 50  | 80  |
| 100                      | 40               | 80  | 120 |
| 88.9                     | 45               | 90  | 135 |
| 80                       | 70               | 100 | 150 |

Note:

9. The values in this table are not tested and are only for guidance in selecting resistor values for mass production tests or in customer's products.

## 5.7 Charge Current Thermal Foldback

Overheating is always a concern in a linear charger. The maximum power dissipation usually occurs at the beginning of a charge cycle when the battery voltage is at its minimum but the charge current is at its maximum. The ISL9203A's charge current thermal foldback function prevents overheating.

[Figure 22 on page 16](#) shows the current signals at the summing node of the current error amplifier CA in the block diagram.

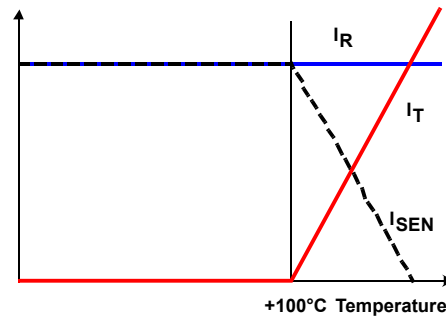


Figure 22. Current Signals at the Amplifier CA Input

$I_R$  is the reference and  $I_T$  is the current from the Temperature Monitoring block.  $I_T$  has no impact on the charge current until the internal temperature reaches approximately  $+100^{\circ}\text{C}$ ; then  $I_T$  rises at a rate of  $1\mu\text{A}/^{\circ}\text{C}$ . When  $I_T$  rises, the current control loop forces the sensed current  $I_{SEN}$  to reduce at the same rate. As a mirrored current, the charge current is 100000 times that of the sensed current and reduces at a rate of  $100\text{mA}/^{\circ}\text{C}$ . For a charger with the constant charge current set at 1A, the charge current is reduced to zero when the internal temperature rises to  $+110^{\circ}\text{C}$ . The actual charge current settles between  $+100^{\circ}\text{C}$  to  $+110^{\circ}\text{C}$ .

The charge current should not drop below  $I_{MIN}$  because of the thermal foldback. If the charge current does drop below  $I_{MIN}$  in extreme cases, the charger does not indicate end-of-charge unless the battery voltage is already above the recharge threshold.

## 5.8 2.8V Bias Voltage

The ISL9203A provides a 2.8V voltage for biasing the internal control and logic circuit. This voltage is also available for external circuits such as the NTC thermistor circuit. The maximum allowed external load is 2mA.

## 5.9 Indications

The ISL9203A has two indications: the input presence and the charge status. The input presence is indicated by the V2P8 pin and the charge status is indicated by the STATUS pin. [Figure 23](#) shows the V2P8 pin voltage vs the input voltage.

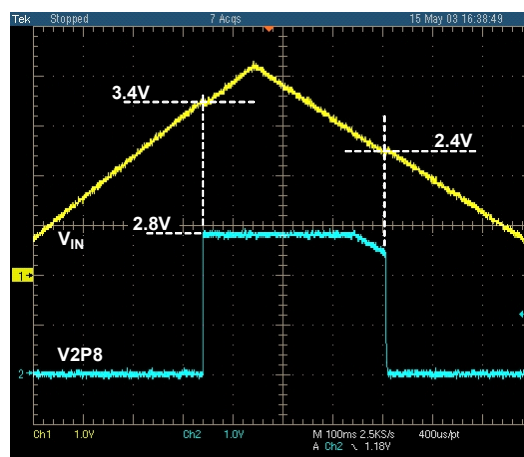


Figure 23. V2P8 Pin Output vs Input Voltage at the VIN Pin.  
Vertical: 1V/Div, Horizontal: 100ms/Div

## 5.10 STATUS Pull-Up Resistor

The STATUS pin is an open-drain output that needs an external pull-up resistor. Renesas recommends pulling this pin up to the input voltage or the 2.8V from the V2P8 pin. If the STATUS pin has to be pulled up to other voltages, carefully examine whether the ESD diodes form a leakage current path to the battery when the input power is removed. If the leakage path does exist, an external transistor is required to break the path.



Figure 24 shows the implementation of the pull-up circuit. If the STATUS pin is directly pulled up to the  $V_{CC}$  voltage (not shown in Figure 24), a current flows from  $V_{CC}$  to the STATUS pin, then through the ESD diode to the VIN pin. Any leakage on the VIN pin caused by an external or internal current path results in a current path from  $V_{CC}$  to ground.

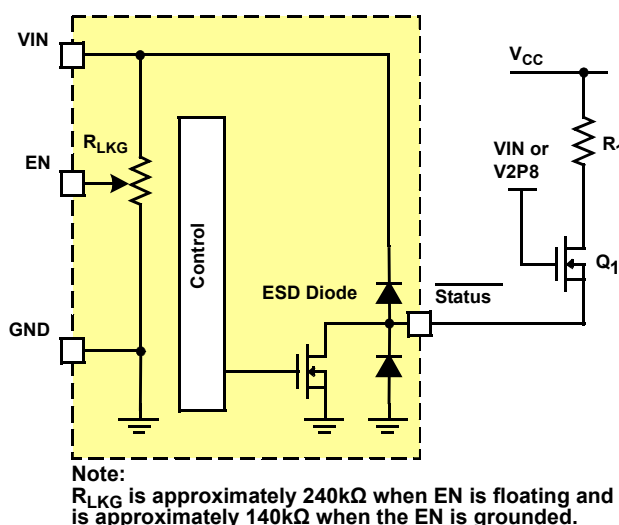


Figure 24. Pull-Up Circuit to Avoid Battery Leakage Current in the ESD Diodes

The N-Channel MOSFET  $Q_1$  buffers the STATUS pin. The  $Q_1$  gate is connected to VIN or the V2P8 pin. When the STATUS pin outputs a logic low signal,  $Q_1$  is turned on and its drain outputs a low signal as well. When STATUS is high impedance,  $R_1$  pulls the  $Q_1$  drain to high. When the input power is removed, the  $Q_1$  gate voltage is also removed, so the  $Q_1$  drain stays high.

### 5.11 Shutdown

The ISL9203A can be shut down by pulling the EN pin to ground. When shut down, the charger draws typically less than 30 $\mu$ A current from the input power and the 2.8V output at the V2P8 pin is also turned off. The EN pin must be driven with an open-drain or open-collector logic output, so that the EN pin is floating when the charger is enabled. If the EN pin is driven by an external source, the POR threshold voltage is affected.

### 5.12 Input and Output Capacitor Selection

Due to the inductance of the power leads of the wall adapter or USB source, the input capacitor type must be properly selected to prevent high voltage transient during a hot-plug event. A tantalum capacitor is a good choice for its high ESR and provides damping to the voltage transient. However, multi-layer ceramic capacitors have a very low ESR; when used as input capacitors, you must use a 1 $\Omega$  series resistor to provide adequate damping, as shown in Figure 1 on page 1.

The output capacitor can be any ceramic type with the value higher than 0.1 $\mu$ F. However, if there is a chance the charger will be used as an LDO linear regulator, a 10 $\mu$ F tantalum capacitor is recommended.

**Note:** The charger always steps through the 15-cycle  $V_{MIN}$  verification time before the charge current rises to the constant charge current. Therefore, when the system is used as an LDO, it should not load the charger heavily until the 15-cycle verification is complete.

### 5.13 Working with Current-Limited Adapters

The ISL9203A can work with a current-limited adapter to significantly reduce the thermal dissipation during charging. See the [ISL6292 datasheet](#) for more details.

### 5.14 Board Layout Recommendations

The ISL9203A internal thermal foldback function limits the charge current when the internal temperature reaches approximately +100°C. To maximize the current capability, it is very important that the exposed pad under the package is properly soldered to the board and is connected to other layers through thermal vias. More thermal vias and more copper attached to the exposed pad usually result in better thermal performance. However, the number of vias is limited by the size of the pad. The 3x3 DFN package allows eight vias to be placed in two rows. Because the pins on the 3x3 DFN package are on only two sides, connect as much top layer copper as possible to the exposed pad to minimize the thermal impedance. See the [ISL6292 evaluation boards](#) for layout examples.

## 6. Revision History

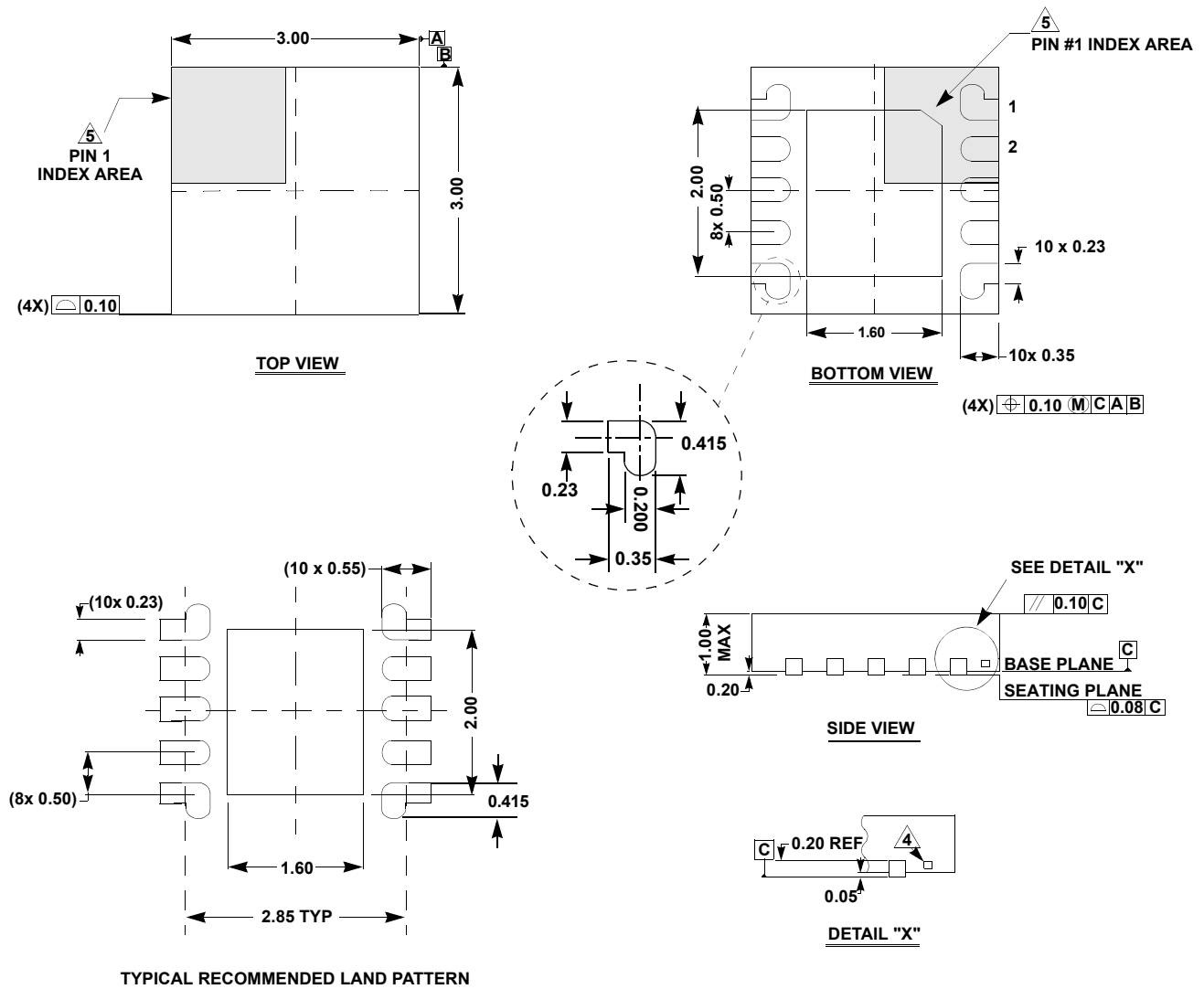
| Rev. | Date      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.00 | Jun.14.19 | <p>Updated Related Literature section.</p> <p>Updated links throughout document.</p> <p>Updated ordering information table on page 4:</p> <ul style="list-style-type: none"> <li>Corrected part marking numbers.</li> <li>Added Tape and Reel quantity column.</li> <li>Added MSL note.</li> </ul> <p>Added revision history.</p> <p>Updated package outline drawing from revision 3 to revision 11. Changes are as follows:</p> <ul style="list-style-type: none"> <li>-Revision 3: POD created from L10.3X3</li> <li>-Revision 4: Added Typical Recommended Land Pattern</li> <li>-Revision 5: New Revision, Converted to newer standard</li> <li>-Revision 6: <ul style="list-style-type: none"> <li>Changed Note 4 from "Dimension b applies..." to "Lead width applies..."</li> <li>Changed Note callout in Detail X from 4 to 5</li> <li>Changed height in side view from 0.90 MAX to 1.00 MAX</li> <li>Added Note 4 callout next to lead width in Bottom View</li> <li>In Land Pattern, corrected lead shape for 4 corner pins to "L" shape (was rectangular and did not match bottom view)</li> </ul> </li> <li>-Revision 7: <ul style="list-style-type: none"> <li>Removed package outline and included center to center distance between lands on recommended land pattern.</li> <li>Removed Note 4 "Dimension b applies to the metallized terminal and is measured between 0.18mm and 0.30mm from the terminal tip." since it is not applicable to this package. Renumbered notes accordingly.</li> </ul> </li> <li>-Revision 8: Corrected L-shaped leads in Bottom view and land pattern so that they align with the rest of the leads (L shaped leads were shorter)</li> <li>-Revision 9: Added missing dimension 0.415 in Typical Recommended land pattern.</li> <li>-Revision 10: Shortened the e-pad rectangle on both the recommended land pattern and the package bottom view to line up with the centers of the corner pins.</li> <li>-Revision 11: Tiebar Note 4 updated <ul style="list-style-type: none"> <li>From: Tiebar shown (if present) is a non-functional feature.</li> <li>To: Tiebar shown (if present) is a non-functional feature and may be located on any of the 4 sides (or ends).</li> </ul> </li> </ul> <p>Applied new template.</p> |

## 7. Package Outline Drawing

L10.3x3

10 LEAD DUAL FLAT PACKAGE (DFN)

Rev 11, 3/15

For the most recent package outline drawing, see [L10.3x3](#).

### NOTES:

1. Dimensions are in millimeters.  
Dimensions in ( ) for Reference Only.
2. Dimensioning and tolerancing conform to ASME Y14.5m-1994.
3. Unless otherwise specified, tolerance : Decimal  $\pm 0.05$
4. Tiebar shown (if present) is a non-functional feature and may be located on any of the 4 sides (or ends).
5. The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.

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