

## ISL6294A

High Input Voltage Charger

FN6821

Rev.2.00

December 11, 2008

The ISL6294A is a cost-effective, fully integrated high input voltage single-cell Li-ion battery charger. The charger uses a CC/CV charge profile required by Li-ion batteries. The charger accepts an input voltage up to 28V but is disabled when the input voltage exceeds the OVP threshold, typically 7.3V, to prevent excessive power dissipation. The 28V rating eliminates the overvoltage protection circuit required in a low input voltage charger.

The charge current and the end-of-charge (EOC) current are programmable with external resistors. When the battery voltage is lower than typically 2.55V, the charger preconditions the battery with typically 20% of the programmed charge current. When the charge current reduces to the programmable EOC current level during the CV charge phase, an EOC indication is provided by the  $\overline{\text{CHG}}$  pin, which is an open-drain output. An internal thermal foldback function protects the charger from any thermal failure.

Two indication pins ( $\overline{\text{PPR}}$  and  $\overline{\text{CHG}}$ ) allow simple interface to a microprocessor or LEDs. When no adapter is attached or when disabled, the charger draws less than 1 $\mu$ A leakage current from the battery.

### Ordering Information

| PART NUMBER<br>(Note) | PART MARKING | TEMP. RANGE<br>(°C) | PACKAGE<br>(Pb-Free) | PKG. DWG. # |
|-----------------------|--------------|---------------------|----------------------|-------------|
| ISL6294AIRZ-T*        | 94A          | -40 to +85          | 8 Ld 2x3 DFN         | L8.2x3      |

\*Please refer to TB347 for details on reel specifications.

NOTE: These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil 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.

### Features

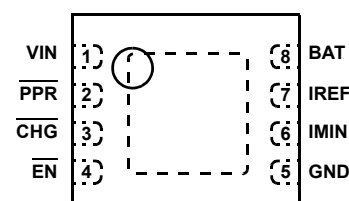
- Complete Charger for Single-Cell Li-ion/Polymer Batteries
- Integrated Pass Element and Current Sensor
- No External Blocking Diode Required
- Low Component Count and Cost
- 1% Voltage Accuracy
- Programmable Charge Current
- **Programmable End-of-Charge Current**
- **Charge Current Thermal Foldback for Thermal Protection**
- Trickle Charge for Fully Discharged Batteries
- **28V Maximum Voltage for the Power Input**
- Power Presence and Charge Indications
- Less Than 1 $\mu$ A Leakage Current off the Battery When No Input Power Attached or Charger Disabled
- Ambient Temperature Range: -40°C to +85°C
- **8 Ld 2x3 DFN Package**
- Pb-Free (RoHS Compliant)

### Applications

- Mobile Phones
- Blue-Tooth Devices
- PDAs
- MP3 Players
- Stand-Alone Chargers
- Other Handheld Devices

### Pinout

ISL6294A  
(8 LD DFN)  
TOP VIEW



**Absolute Maximum Ratings** (Reference to GND)

|                               |              |
|-------------------------------|--------------|
| VIN                           | -0.3V to 30V |
| IMIN, IREF, BAT, CHG, EN, PPR | -0.3V to 7V  |

**Recommended Operating Conditions**

|                                    |                |
|------------------------------------|----------------|
| Ambient Temperature Range          | -40°C to 85°C  |
| Maximum Supply Voltage (VIN Pin)   | 28V            |
| Operating Supply Voltage (VIN Pin) | 4.5V to 6.5V   |
| Programmed Charge Current          | 100mA to 900mA |

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

**NOTES:**

1.  $\theta_{JA}$  is measured in free air with the component mounted on a high effective thermal conductivity test board with "direct attach" features. See Tech Brief TB379.
2. For  $\theta_{JC}$ , the "case temp" location is the center of the exposed metal pad on the package underside.

**Thermal Information**

|  |   |                      |
|--|---|----------------------|
| Thermal Resistance                             | $\theta_{JA}$ (°C/W)  | $\theta_{JC}$ (°C/W) |
| DFN Package (Notes 1, 2)                       | 59  | 4.5                  |
| Maximum Junction Temperature (Plastic Package) | +150°C  |                      |
| Maximum Storage Temperature Range              | -65°C to +150°C   |                      |
| Pb-Free Reflow Profile                         | see link below  |                      |
|  | <a href="http://www.intersil.com/pbfree/Pb-FreeReflow.asp">http://www.intersil.com/pbfree/Pb-FreeReflow.asp</a> |                      |

**Electrical Specifications** Typical Values Are Tested at  $V_{IN} = 5V$  and the  $T_A$  at +25°C.

| PARAMETER                                  | SYMBOL        | TEST CONDITIONS  | MIN   | TYP  | MAX   | UNITS    |
|--|---------------|--|-------|------|-------|----------|
| <b>POWER-ON RESET</b>                      |               |  |       |      |       |          |
| Rising POR Threshold                       | $V_{POR}$     | $V_{BAT} = 3.0V$ , use $\overline{PPR}$ to indicate the comparator output. | 3.3   | 3.9  | 4.3   | V        |
| Falling POR Threshold                      | $V_{POR}$     |  | 2.7   | 3.4  | 3.6   | V        |
| <b>VIN-BAT OFFSET VOLTAGE</b>              |               |  |       |      |       |          |
| Rising Edge                                | $V_{OS}$      | $V_{BAT} = 4.0V$ , use CHG pin to indicate the comparator output (Note 3)  | -     | 90   | 150   | mV       |
| Falling Edge                               | $V_{OS}$      |  | 10    | 50   | -     | mV       |
| <b>OVERVOLTAGE PROTECTION</b>              |               |  |       |      |       |          |
| Overvoltage Protection Threshold           | $V_{OVP}$     | (Note 4)   | 6.9   | 7.3  | 7.7   | V        |
| OVP Threshold Hysteresis                   |               | Use PPR to indicate the comparator output                                  | 100   | 240  | 400   | mV       |
| <b>STANDBY CURRENT</b>                     |               |  |       |      |       |          |
| BAT Pin Sink Current                       | $I_{STANDBY}$ | Charger disabled or the input is floating<br>$V_{BAT} = 4.2V$              | -     | -    | 1.0   | $\mu A$  |
| VIN Pin Supply Current                     | $I_{VIN}$     | Charger disabled   | -     | 350  | 600   | $\mu A$  |
| VIN Pin Supply Current                     | $I_{VIN}$     | Charger enabled  | -     | 500  | 800   | $\mu A$  |
| <b>VOLTAGE REGULATION</b>                  |               |  |       |      |       |          |
| Output Voltage                             | $V_{CH}$      | Charge current = 20mA  | 4.158 | 4.20 | 4.242 | V        |
| PMOS ON-Resistance                         | $r_{DS(ON)}$  | $V_{IN} = 4.1V$ , charge current = 0.3A                                    | -     | 0.6  | -     | $\Omega$ |
| <b>CHARGE CURRENT (Note 5)</b>             |               |  |       |      |       |          |
| IREF Pin Output Voltage                    | $I_{IREF}$    | $V_{BAT} = 3.8V$   | 1.18  | 1.22 | 1.26  | V        |
| Constant Charge Current                    | $I_{CHG}$     | $V_{IN} = 5V$ , $R_{IREF} = 24.3k\Omega$ , $V_{BAT} = 2.8V$ to 4.0V        | 450   | 500  | 550   | mA       |
| Trickle Charge Current                     | $I_{TRK}$     | $V_{IN} = 5V$ , $R_{IREF} = 24.3k\Omega$ , $V_{BAT} = 2.4V$                | 70    | 95   | 130   | mA       |
| End-of-Charge Current                      | $I_{MIN}$     | $V_{IN} = 5V$ , $R_{IMIN} = 243k\Omega$                                    | 33    | 45   | 57    | mA       |
| EOC Rising Threshold                       |               | $V_{IN} = 5V$ , $R_{IMIN} = 243k\Omega$                                    | 325   | 380  | 415   | mA       |
| <b>PRECONDITIONING CHARGE THRESHOLD</b>    |               |  |       |      |       |          |
| Preconditioning Charge Threshold Voltage   | $V_{MIN}$     |  | 2.45  | 2.55 | 2.65  | V        |
| Preconditioning Voltage Hysteresis         | $V_{MINHYS}$  |  | -     | 250  | -     | mV       |
| <b>INTERNAL TEMPERATURE MONITORING</b>     |               |  |       |      |       |          |
| Charge Current Foldback Threshold (Note 6) | $T_{FOLD}$    |  | 100   | 115  | 130   | °C       |

**Electrical Specifications** Typical Values Are Tested at  $V_{IN} = 5V$  and the  $T_A$  at  $+25^{\circ}C$ . (Continued)

| PARAMETER   | SYMBOL | TEST CONDITIONS  | MIN | TYP | MAX | UNITS      |
|---|--------|------------------|-----|-----|-----|------------|
| <b>LOGIC INPUT AND OUTPUTS</b>                    |        |                  |     |     |     |            |
| $\overline{EN}$ Pin Logic Input High              |        |                  | 1.3 | -   | -   | V          |
| $\overline{EN}$ Pin Logic Input Low               |        |                  | -   | -   | 0.5 | V          |
| $\overline{EN}$ Pin Internal Pull-Down Resistance |        |                  | 100 | 200 | 400 | k $\Omega$ |
| $\overline{CHG}$ Sink Current when LOW            |        | Pin Voltage = 1V | 10  | 20  | -   | mA         |
| $\overline{CHG}$ Leakage Current when HIGH        |        | $V_{CHG} = 6.5V$ | -   | -   | 1   | $\mu A$    |
| $\overline{PPR}$ Sink Current when LOW            |        | Pin Voltage = 1V | 10  | 20  | -   | mA         |
| $\overline{PPR}$ Leakage Current when HIGH        |        | $V_{PPR} = 6.5V$ | -   | -   | 1   | $\mu A$    |

## NOTES:

- The 4.0V  $V_{BAT}$  is selected so that the  $\overline{CHG}$  output can be used as the indication for the offset comparator output indication. If the  $V_{BAT}$  is lower than the POR threshold, no output pin can be used for indication.
- For junction temperature below  $+100^{\circ}C$ .
- The charge current can be affected by the thermal foldback function if the IC under the test setup cannot dissipate the heat.
- Limits should be considered typical and are not production tested.

**Pin Descriptions**

**VIN** - Power input. The absolute maximum input voltage is 28V. A 0.47 $\mu F$  or larger value X5R ceramic capacitor is recommended to be placed very close to the input pin for decoupling purpose. Additional capacitance may be required to provide a stable input voltage.

**PPR** - Open-drain power presence indication. The open-drain MOSFET turns on when the input voltage is above the POR threshold but below the OVP threshold and off otherwise. This pin is capable to sink 10mA (minimum) current to drive an LED. The maximum voltage rating for this pin is 7V. This pin is independent of the  $\overline{EN}$  pin input.

**CHG** - Open-drain charge indication pin. This pin outputs a logic LOW when a charge cycle starts and turns to HIGH when the end-of-charge (EOC) condition is qualified. This pin is capable to sink 10mA minimum current to drive an LED. When the charger is disabled, the  $\overline{CHG}$  outputs high impedance.

**EN** - Enable input. This is a logic input pin to disable or enable the charger. Drive to HIGH to disable the charger. When this pin is driven to LOW or left floating, the charger is enabled. This pin has an internal 200k $\Omega$  pull-down resistor.

**GND** - System ground.

**IMIN** - End-of-charge (EOC) current program pin. Connect a resistor between this pin and the GND pin to set the EOC current. The EOC current  $I_{MIN}$  can be programmed by Equation 1:

$$I_{MIN} = \frac{11000}{R_{IMIN}} \quad (\text{mA}) \quad (\text{EQ. 1})$$

Where  $R_{IMIN}$  is in k $\Omega$ . The programmable range covers 5% (or 10mA, whichever is higher) to 50% of  $I_{REF}$ . When

programmed to less than 5% or 10mA, the stability is not guaranteed.

**IREF** - Charge-current program and monitoring pin. Connect a resistor between this pin and the GND pin to set the charge current limit determined by Equation 2:

$$I_{REF} = \frac{12089}{R_{IREF}} \quad (\text{mA}) \quad (\text{EQ. 2})$$

Where  $R_{IREF}$  is in k $\Omega$ . The  $I_{REF}$  pin voltage also monitors the actual charge current during the entire charge cycle, including the trickle, constant-current, and constant-voltage phases. When disabled,  $V_{IREF} = 0V$ .

**BAT** - Charger output pin. Connect this pin to the battery. A 1 $\mu F$  or larger X5R ceramic capacitor is recommended for decoupling and stability purposes. When the  $\overline{EN}$  pin is pulled to logic HIGH, the BAT output is disabled.

**EPAD** - Exposed pad. Connect as much as possible copper to this pad either on the component layer or other layers through thermal vias to enhance the thermal performance.

**Typical Applications**

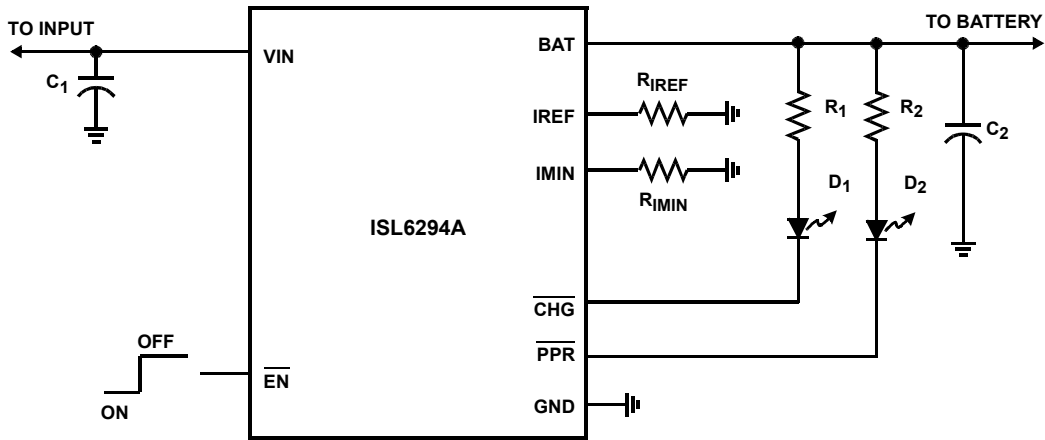


FIGURE 1. TYPICAL APPLICATION CIRCUIT INTERFACING TO INDICATION LEDs

TABLE 1. COMPONENT DESCRIPTION FOR FIGURE 1

| PART                            | DESCRIPTION                          |
|---------------------------------|--------------------------------------|
| C <sub>1</sub>                  | 1μF X5R ceramic capacitor            |
| C <sub>2</sub>                  | 1μF X5R ceramic capacitor            |
| R <sub>IREF</sub>               | 24.3kΩ, 1%, for 500mA charge current |
| R <sub>IMIN</sub>               | 243kΩ, 1%, for 45mA EOC current      |
| R <sub>1</sub> , R <sub>2</sub> | 300Ω, 5%                             |
| D <sub>1</sub> , D <sub>2</sub> | LEDs for indication                  |

TABLE 2. COMPONENT DESCRIPTION FOR FIGURE 2

| PART                            | DESCRIPTION                          |
|---------------------------------|--------------------------------------|
| C <sub>1</sub>                  | 1μF X5R ceramic capacitor            |
| C <sub>2</sub>                  | 1μF X5R ceramic capacitor            |
| R <sub>IREF</sub>               | 24.3kΩ, 1%, for 500mA charge current |
| R <sub>IMIN</sub>               | 243kΩ, 1%, for 45mA EOC current      |
| R <sub>1</sub> , R <sub>2</sub> | 100kΩ, 5%                            |

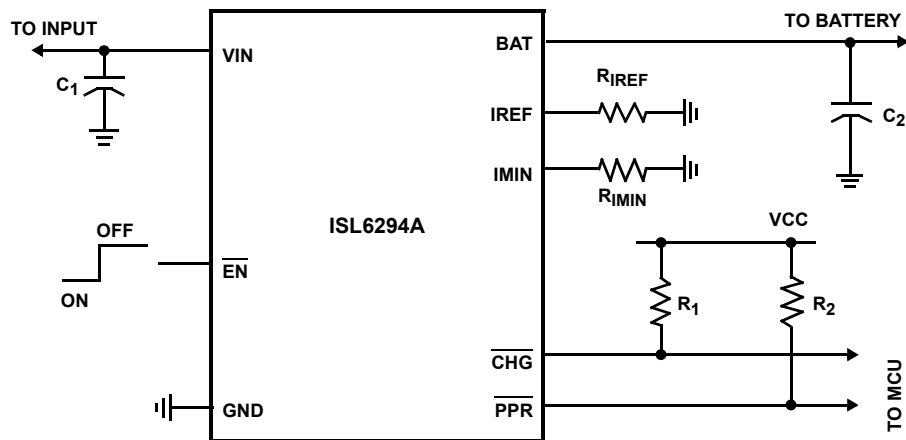


FIGURE 2. TYPICAL APPLICATION CIRCUIT WITH THE INDICATION SIGNALS INTERFACING TO A MCU

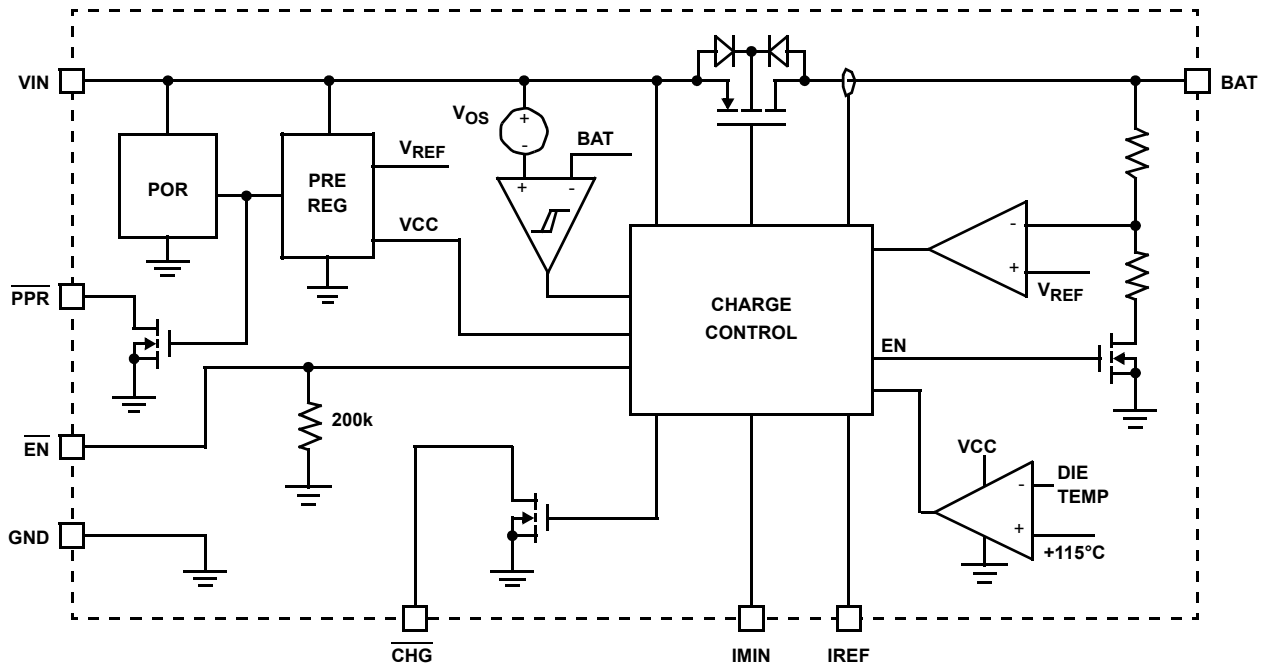


FIGURE 3. BLOCK DIAGRAM

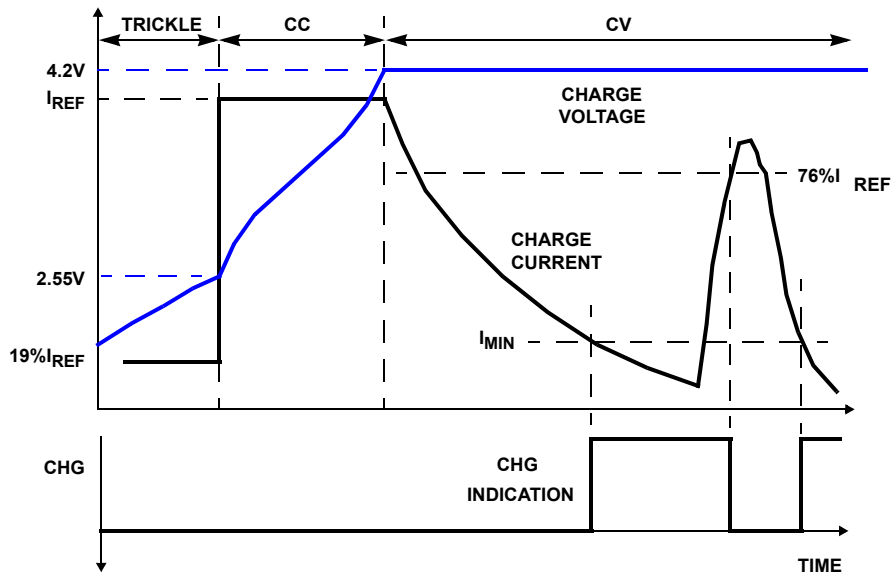


FIGURE 4. TYPICAL CHARGE PROFILE

**Description**

The ISL6294A charges a Li-ion battery using a CC/CV profile. The constant current  $I_{REF}$  is set with the external resistor  $R_{IREF}$  (see Figure 1) and the constant voltage is fixed at 4.2V. If the battery voltage is below a typical 2.55V trickle-charge threshold, the ISL6294A charges the battery with a trickle current of 19% of  $I_{REF}$  until the battery voltage rises above the trickle charge threshold. Fast charge CC mode is maintained at the rate determined by programming  $I_{REF}$  until the cell voltage rises to 4.2V. When the battery

voltage reaches 4.2V, the charger enters a CV mode and regulates the battery voltage at 4.2V to fully charge the battery without the risk of over charge. Upon reaching an end-of-charge (EOC) current, the charger indicates the charge completion with the  $\overline{CHG}$  pin, but the charger continues to output the 4.2V voltage. Figure 4 shows the typical charge waveforms after the power is on.

The EOC current level  $I_{MIN}$  is programmable with the external resistor  $R_{IMIN}$  (see Figure 1). The CHG signal turns

to LOW when the trickle charge starts and rises to HIGH at the EOC. After the EOC is reached, the charge current has to rise to typically 76%  $I_{REF}$  for the  $\overline{CHG}$  signal to turn on again, as shown in Figure 4. The current surge after EOC can be caused by a load connected to the battery.

A thermal foldback function reduces the charge current anytime when the die temperature reaches typically +115°C. This function guarantees safe operation when the printed-circuit board (PCB) is not capable of dissipating the heat generated by the linear charger. The ISL6294A accepts an input voltage up to 28V but disables charging when the input voltage exceeds the OVP threshold, typically 7.3V, to protect against unqualified or faulty AC adapters.

### **$\overline{PPR}$ Indication**

The  $\overline{PPR}$  pin is an open-drain output to indicate the presence of the AC adapter. Whenever the input voltage is higher than the POR threshold, the  $\overline{PPR}$  pin turns on the internal open-drain MOSFET to indicate a logic LOW signal, independent on the  $\overline{EN}$ -pin input. When the internal open-drain FET is turned off, the  $\overline{PPR}$  pin should leak less than 1 $\mu$ A current. When turned on, the  $\overline{PPR}$  pin should be able to sink at least 10mA current under all operating conditions.

The  $\overline{PPR}$  pin can be used to drive an LED (see Figure 1) or to interface with a microprocessor.

### **Power-Good Range**

The power-good range is defined by the following three conditions:

1.  $V_{IN} > V_{POR}$
2.  $V_{IN} - V_{BAT} > V_{OS}$
3.  $V_{IN} < V_{OVP}$

where the  $V_{OS}$  is the offset voltage for the input and output voltage comparator, discussed shortly, and the  $V_{OVP}$  is the overvoltage protection threshold given in the “Electrical Specifications” table on page 2. All  $V_{POR}$ ,  $V_{OS}$ , and  $V_{OVP}$  have hysteresis, as given in the “Electrical Specifications” table on page 2. The charger will not charge the battery if the input voltage is not in the power-good range.

### **Input and Output Comparator**

The charger will not be enabled unless the input voltage is higher than the battery voltage by an offset voltage  $V_{OS}$ . The purpose of this comparator is to ensure that the charger is turned off when the input power is removed from the charger. Without this comparator, it is possible that the charger will fail to power-down when the input is removed and the current can leak through the PFET pass element to continue biasing the POR and the Pre-Regulator blocks, as shown in Figure 3.

### **$\overline{CHG}$ Indication**

The  $\overline{CHG}$  is an open-drain output capable to at least 10mA current when the charger starts to charge and turns off when the EOC current is reached. The  $\overline{CHG}$  signal is interfaced either with a microprocessor GPIO or an LED for indication.

### **$\overline{EN}$ Input**

$\overline{EN}$  is an active-low logic input to enable the charger. Drive the  $\overline{EN}$  pin to LOW or leave it floating to enable the charger. This pin has a 200k $\Omega$  internal pull-down resistor so when left floating, the input is equivalent to logic LOW. Drive this pin to HIGH to disable the charger. The threshold for HIGH is given in the “Electrical Specifications” table on page 2.

### **$I_{REF}$ Pin**

The  $I_{REF}$  pin has the two functions as described in the “Pin Descriptions” on page 3. When setting the fast charge current, the charge current is guaranteed to have 10% accuracy with the charge current set at 500mA. When monitoring the charge current, the accuracy of the  $I_{REF}$  pin voltage vs the actual charge current has the same accuracy as the gain from the  $I_{REF}$  pin current to the actual charge current. The accuracy is 10% at 500mA and is expected to drop to 30% of the actual current (not the set constant charge current) when the current drops to 50mA.

### **Operation Without the Battery**

The ISL6294A relies on a battery for stability and is not guaranteed to be stable if the battery is not connected. With a battery, the charger will be stable with an output ceramic decoupling capacitor in the range of 1 $\mu$ F to 200 $\mu$ F. The maximum load current is limited by the dropout voltage or the thermal foldback.

### **Dropout Voltage**

The constant current may not be maintained due to the  $r_{DS(ON)}$  limit at a low input voltage. The worst case ON-resistance of the pass FET is 1.2 $\Omega$  the maximum operating temperature, thus if tested with 0.5A current and 3.8V battery voltage, constant current could not be maintained when the input voltage is below 4.4V.

### **Thermal Foldback**

The thermal foldback function starts to reduce the charge current when the internal temperature reaches a typical value of +115°C.

## **Applications Information**

### **Input Capacitor Selection**

The input capacitor is required to suppress the power supply transient response during transitions. Mainly this capacitor is selected to avoid oscillation during the start-up when the input supply is passing the POR threshold and the  $V_{IN}-V_{BAT}$  comparator offset voltage. When the battery voltage is above the POR threshold, the  $V_{IN}-V_{BAT}$  offset voltage dominates

the hysteresis value. Typically, a 1 $\mu$ F X5R ceramic capacitor should be sufficient to suppress the power supply noise.

### Output Capacitor Selection

The criteria for selecting the output capacitor is to maintain the stability of the charger as well as to bypass any transient load current. The minimum capacitance is a 1 $\mu$ F X5R ceramic capacitor. The actual capacitance connected to the output is dependent on the actual application requirement.

### Charge Current Limit

The actual charge current in the CC mode is limited by several factors in addition to the set  $I_{REF}$ . Figure 5 shows three limits for the charge current in the CC mode. The charge current is limited by the ON-resistance of the pass element (power P-Channel MOSFET) if the input and the output voltage are too close to each other. The solid curve shows a typical case when the battery voltage is 4.0V and the charge current is set to 700mA. The non-linearity on the  $r_{ON}$ -limited region is due to the increased resistance at higher die temperature. If the battery voltage increases to higher than 4.0V, the entire curve moves towards the right side. As the input voltage increases, the charge current may be reduced due to the thermal foldback function. The limit caused by the thermal limit is dependent on the thermal impedance. As the thermal impedance increases, the thermal-limited curve moves towards the left, as shown in Figure 5.

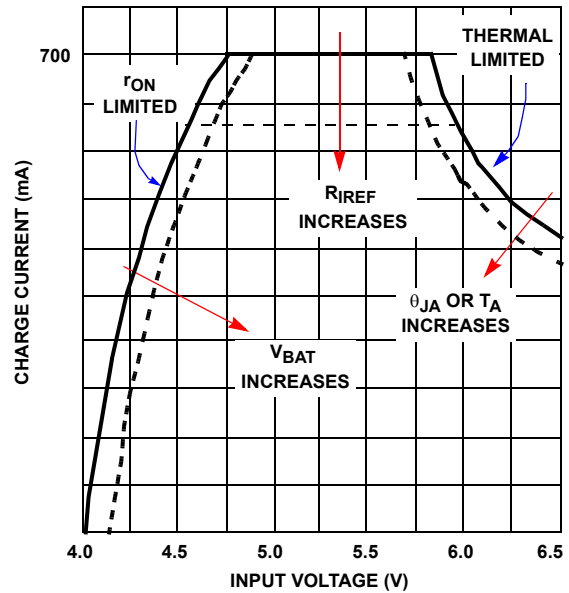


FIGURE 5. CHARGE CURRENT LIMITS IN THE CC MODE

### Layout Guidance

The ISL6294A uses a thermally-enhanced DFN package that has an exposed thermal pad at the bottom side of the package. The layout should connect as much as possible to copper on the exposed pad. Typically the component layer is more effective in dissipating heat. The thermal impedance can be further reduced by using other layers of copper connecting to the exposed pad through a thermal via array. Each thermal via is recommended to have 0.3mm diameter and 1mm distance from other thermal vias.

### Input Power Sources

The input power source is typically a well-regulated wall cube with 1-meter length wire or a USB port. The input voltage ranges from 4.25V to 6.5V under full-load and unloaded conditions. The ISL6294A can withstand up to 28V on the input without damaging the IC. If the input voltage is higher than typically 7.3V, the charger stops charging.

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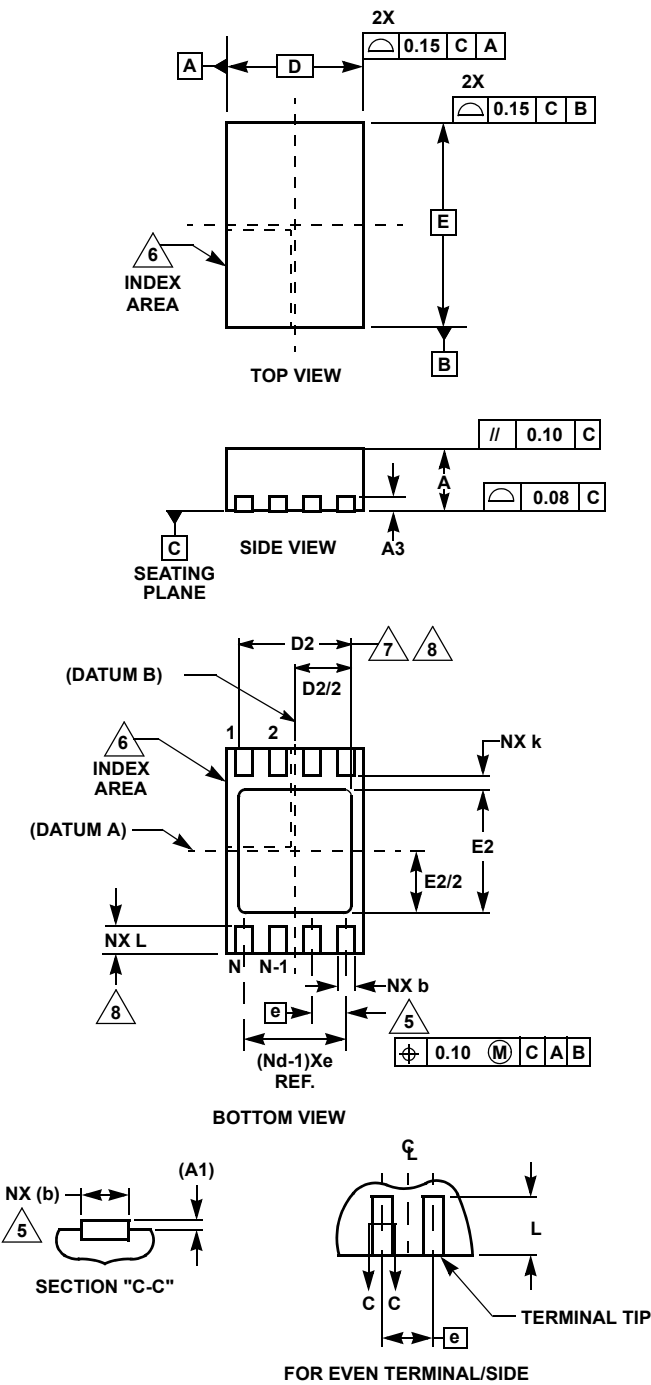
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Dual Flat No-Lead Plastic Package (DFN)



L8.2x3

8 LEAD DUAL FLAT NO-LEAD PLASTIC PACKAGE

| SYMBOL | MILLIMETERS |         |      | NOTES |
|--------|-------------|---------|------|-------|
|        | MIN         | NOMINAL | MAX  |       |
| A      | 0.80        | 0.90    | 1.00 | -     |
| A1     | -           | -       | 0.05 | -     |
| A3     | 0.20 REF    |         |      | -     |
| b      | 0.20        | 0.25    | 0.32 | 5,8   |
| D      | 2.00 BSC    |         |      | -     |
| D2     | 1.50        | 1.65    | 1.75 | 7,8   |
| E      | 3.00 BSC    |         |      | -     |
| E2     | 1.65        | 1.80    | 1.90 | 7,8   |
| e      | 0.50 BSC    |         |      | -     |
| k      | 0.20        | -       | -    | -     |
| L      | 0.30        | 0.40    | 0.50 | 8     |
| N      | 8           |         |      | 2     |
| Nd     | 4           |         |      | 3     |

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NOTES:

1. Dimensioning and tolerancing conform to ASME Y14.5-1994.
2. N is the number of terminals.
3. Nd refers to the number of terminals on D.
4. All dimensions are in millimeters. Angles are in degrees.
5. Dimension b applies to the metallized terminal and is measured between 0.25mm and 0.30mm from the terminal tip.
6. 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.
7. Dimensions D2 and E2 are for the exposed pads which provide improved electrical and thermal performance.
8. Nominal dimensions are provided to assist with PCB Land Pattern Design efforts, see Intersil Technical Brief TB389.