

## **Single Cell Li-Ion Battery Charger with Adjustable Charging Current for Portable Applications**

### **General Description**

The RT9527 is a low cost single-cell Li-ion charger for low current charge applications.

The RT9527 can be powered up from an AC adapter or USB (Universal Serial Bus) port inputs. The RT9527 enters sleep mode when VIN power is removed. The RT9527 optimizes the charging task by using a control algorithm, which includes pre-charge mode, fast-charge mode and constant voltage mode. The charging task is kept in constant voltage mode to hold the battery in a full charge condition. The charge current is adjustable via an external resistor. The internal thermal feedback circuitry regulates the die temperature to optimize the charge rate for all ambient temperatures. The RT9527 features 28V maximum rating voltages for VIN. Other features include under voltage protection and over voltage protection for the AC adapter supply.

The RT9527 is available in a WDFN-8L 2x2 package.

### **Ordering Information**

RT9527□□

- Package Type  
QW : WDFN-8L 2x2 (W-Type)
- Lead Plating System  
G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

### **Features**

- 28V Maximum Rating for AC Adapter
- Internal Integrated Power FETs
- Adjustable Charging Current
- Programmable Safe Charge Timer
- NTC Thermistor Input
- Battery Reverse Protection
- ISET Pin Short Protection
- Charge Status Indicator
- AC Adapter Power Good Status Indicator
- End of Charge Current is 10% of Fast-Charge Current
- Under Voltage Protection
- Over Voltage Protection
- Thermal Feedback Optimized Charge Rate
- Small Thermally Enhanced 8-Lead WDFN Package
- RoHS Compliant and Halogen Free

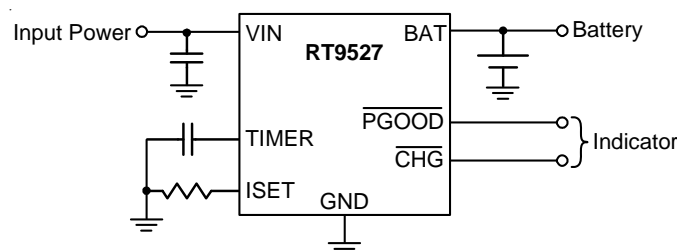
### **Applications**

- Cellular Phones
- Digital Cameras
- PDAs and Smart Phone
- Portable Instruments

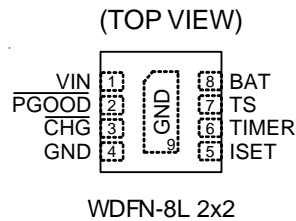
### **Marking Information**

|     |                   |
|-----|-------------------|
| 0SW | 0S : Product Code |
| ●   | W : Date Code     |

### **Simplified Application Circuit**



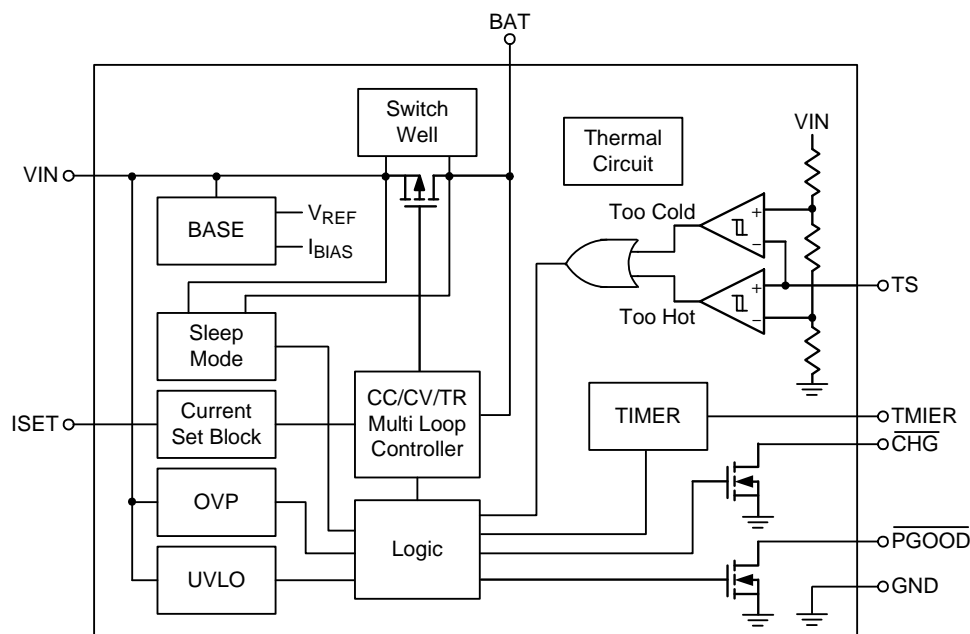
## Pin Configuration



## Functional Pin Description

| Pin No.               | Pin Name | Pin Function  |
|-----------------------|----------|---|
| 1                     | VIN      | Supply voltage input. VIN can withstand up to 28V input.  |
| 2                     | PGOOD    | Power good status output. Active-low, open-drain output.  |
| 3                     | CHG      | Charger status output. Active-low, open-drain output.   |
| 4,<br>9 (Exposed Pad) | GND      | Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.   |
| 5                     | ISET     | Charge current setting.   |
| 6                     | TIMER    | Safe-charge timer setting.  |
| 7                     | TS       | Temperature sense input. The TS pin connects to a battery's thermistor to determine whether the battery is too hot or too cold for charging operation. If the battery's temperature is out of range, charging is paused until it re-enters the valid range. |
| 8                     | BAT      | Charge current output for battery.  |

## Functional Block Diagram



## Operation

The RT9527 is a Li-ion charger that can support the input voltage range from 4.4V to 6V. It provides a wide fast-charge current setting ranging from 10mA up to 600mA.

### Change Current Setting

The charging current is adjustable via an external resistor between the ISET and GND pin.

### UVLO

If the input voltage ( $V_{IN}$ ) is lower than the threshold voltage  $V_{UVLO} - \Delta V_{UVLO}$ , the charger will stop charging until  $V_{IN}$  is larger than  $V_{UVLO}$ .

### OVP

If the input voltage ( $V_{IN}$ ) is higher than the threshold voltage  $V_{OVP}$ , the internal OVP signal will go high and the charger will stop charging until  $V_{IN}$  is below  $V_{OVP} - \Delta V_{OVP}$ .

### Switch Well

The switch well will choose the highest voltage between  $V_{IN}$  and  $BAT$  to prevent the power switch from damage.

### Sleep Mode

When the voltage difference between  $V_{IN}$  and  $BAT$  is under  $V_{OS\_L}$ , the charger will enter sleep mode to save the system power consumption.

### CC/CV/TR Multi Loop Controller

There are constant current loop, constant voltage loop and thermal regulation loop to control the charging current.

### Too Hot or Too Cold

The temperature sense input TS pin can be connected a thermistor to determine whether the battery is too hot or too cold for charging operation. If the battery's temperature is out of range, charging is paused until it re-enters the valid range.

### PGOOD

The PGOOD is an open-drain output used to indicate the input voltage status. PGOOD will assert low when  $V_{IN}$  is in the proper working range.

### CHG

The CHG pin is an open-drain output. CHG will assert low when the charger starts to charge the battery and become high impedance when the termination current is reached.

### TIMER

The charger contains the safety timer. When the charging time is longer than  $t_{PCHG}$  in the pre-charge mode or  $t_{FCHG}$  in the fast-charge mode, time fault happens. Then, the charger will be turned off and the CHG pin will become high impedance.

**Absolute Maximum Ratings** (Note 1)

|   |                |
|---|----------------|
| • Supply Input Voltage, $V_{IN}$ -----                | -0.3V to 28V   |
| • CHG, PGOOD, TS -----                                | -0.3V to 28V   |
| • Other Pins -----                                    | -0.3V to 6V    |
| • Power Dissipation, $P_D$ @ $T_A = 25^\circ\text{C}$ |                |
| WDFN-8L 2x2 -----                                     | 2.19W          |
| • Package Thermal Resistance (Note 2)                 |                |
| WDFN-8L 2x2, $\theta_{JA}$ -----                      | 45.5°C/W       |
| WDFN-8L 2x2, $\theta_{JC}$ -----                      | 11.5°C/W       |
| • Lead Temperature (Soldering, 10 sec.) -----         | 260°C          |
| • Junction Temperature -----                          | 150°C          |
| • Storage Temperature Range -----                     | -65°C to 150°C |
| • ESD Susceptibility (Note 3)                         |                |
| HBM (Human Body Model) -----                          | 2kV            |

**Recommended Operating Conditions** (Note 4)

|  |                |
|--|----------------|
| • Supply Input Voltage, $V_{IN}$ ----- | 4.4V to 6V     |
| • Junction Temperature Range -----     | -40°C to 125°C |
| • Ambient Temperature Range -----      | -40°C to 85°C  |

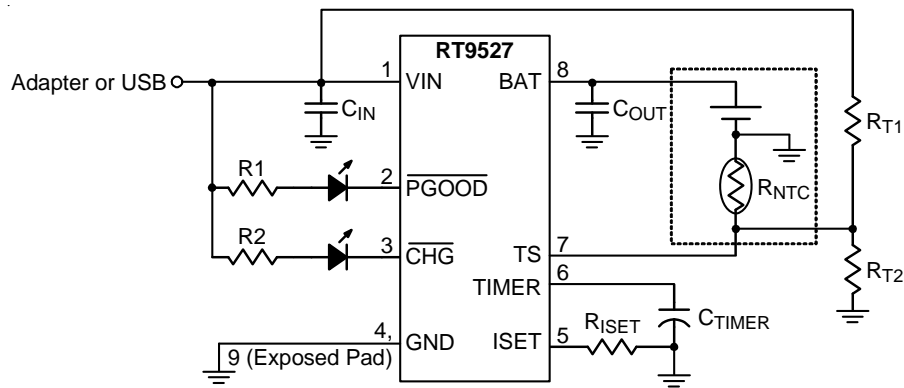
**Electrical Characteristics**(V<sub>IN</sub> = 5V, V<sub>BAT</sub> = 4V, T<sub>A</sub> = 25°C, unless otherwise specified)

| Parameter                            | Symbol               | Test Conditions  | Min   | Typ | Max   | Unit |
|--------------------------------------|----------------------|--|-------|-----|-------|------|
| <b>Supply Input</b>                  |                      |  |       |     |       |      |
| VIN Under Voltage Lockout Threshold  | V <sub>UVLO</sub>    | V <sub>IN</sub> = 0V to 5V   | 3.1   | 3.3 | 3.5   | V    |
| VIN Under Voltage Lockout Hysteresis | ΔV <sub>UVLO</sub>   | V <sub>IN</sub> = 5V to 0V   | --    | 240 | --    | mV   |
| VIN – BAT VOS Rising                 | V <sub>OS_H</sub>    |  | --    | 100 | 200   | mV   |
| VIN – BAT VOS Falling                | V <sub>OS_L</sub>    |  | 10    | 50  | --    | mV   |
| VIN Standby Current                  | I <sub>STANDBY</sub> | V <sub>BAT</sub> = 4.5V  | --    | 1   | 2     | mA   |
| BAT Sleep Leakage Current            | I <sub>SLEEP</sub>   | V <sub>IN</sub> = 0V   | --    | --  | 1     | μA   |
| <b>Voltage Regulation</b>            |                      |  |       |     |       |      |
| Battery Voltage Regulation           | V <sub>REG</sub>     | 0°C to 85°C  | 4.158 | 4.2 | 4.242 | V    |
| Re-Charge Threshold                  | ΔV <sub>REGCHG</sub> | Battery Regulation – Recharge Level  | 60    | 100 | 140   | mV   |
| VIN Power FET On-Resistance          | R <sub>DS(ON)</sub>  | I <sub>BAT</sub> = 450mA   | --    | 0.8 | --    | Ω    |
| <b>Current Regulation</b>            |                      |  |       |     |       |      |
| VIN Charge Setting Range             | I <sub>CHG</sub>     |  | 10    | --  | 600   | mA   |
| Fast-Charge Current Factor           | K <sub>CHG_F1</sub>  | I <sub>CHG_F1</sub> = K <sub>CHG_F1</sub> / R <sub>ISET</sub> ,<br>I <sub>CHG_F1</sub> = 10mA to 50mA  | 510   | 600 | 690   | AΩ   |
|                                      | K <sub>CHG_F2</sub>  | I <sub>CHG_F2</sub> = K <sub>CHG_F2</sub> / R <sub>ISET</sub> ,<br>I <sub>CHG_F2</sub> = 50mA to 600mA | 570   | 600 | 630   |      |

| Parameter                                      | Symbol                 | Test Conditions  | Min   | Typ   | Max   | Unit        |
|--|------------------------|--|-------|-------|-------|-------------|
| Pre-Charge Current Factor                      | $K_{CHG\_P}$           | $I_{CHG\_P} = K_{CHG\_P} / R_{ISET}$   | 30    | 60    | 90    | $A\Omega$   |
| <b>Pre-Charge</b>                              |                        |  |       |       |       |             |
| BAT Pre-Charge Threshold                       | $V_{PRECH}$            | $V_{BAT}$ Falling  | 2.7   | 2.8   | 2.9   | V           |
| BAT Pre-Charge Threshold Hysteresis            | $\Delta V_{PRECH}$     |  | --    | 200   | --    | mV          |
| <b>Charge Termination</b>                      |                        |  |       |       |       |             |
| Termination Current Ratio                      | $I_{TERMI}$            | $V_{BAT} > V_{PREC}$ , $I_{CHG} < I_{TERMI}$ ,<br>$CHG = L$ to $H$                         | 5     | 10    | 15    | %           |
| <b>Protection</b>                              |                        |  |       |       |       |             |
| Thermal Regulation                             | $T_{REG}$              |  | --    | 125   | --    | $^{\circ}C$ |
| Over Voltage Protection                        | $V_{OVP}$              |  | 6.2   | 6.5   | 6.8   | V           |
| Over Voltage Protect Hysteresis                | $\Delta V_{OVP}$       |  | --    | 0.2   | --    | V           |
| ISET Pin Short Protection                      | $R_{SHORT}$            |  | 375   | 500   | 625   | $\Omega$    |
| <b>NTC</b>                                     |                        |  |       |       |       |             |
| Cold Temperature Fault Threshold Voltage       | $V_{COLD}$             | Rising Threshold   | 60    | 61    | 62    | $\%V_{IN}$  |
| Cold Temperature Fault Threshold Hysteresis    | $\Delta V_{COLD}$      |  | --    | 2     | --    | $\%V_{IN}$  |
| Hot Temperature Fault Threshold Voltage        | $V_{HOT}$              | Falling Threshold  | 29    | 30    | 31    | $\%V_{IN}$  |
| Hot Temperature Fault Threshold Hysteresis     | $\Delta V_{HOT}$       |  | --    | 2     | --    | $\%V_{IN}$  |
| <b>Timer</b>                                   |                        |  |       |       |       |             |
| Pre-Charge Fault Time                          | $t_{PCHG}$             | $C_{TIMER} = 1\mu F (1 / 8 \times t_{FCHG})$   | 1440  | 1800  | 2160  | s           |
| Fast-Charge Fault Time                         | $t_{FCHG}$             | $C_{TIMER} = 1\mu F$   | 11520 | 14400 | 17280 | s           |
| <b>Other</b>                                   |                        |  |       |       |       |             |
| $\overline{PGOOD}$ Pull Down Voltage           | $V_{\overline{PGOOD}}$ | $I_{\overline{PGOOD}} = 5mA$   | --    | 200   | --    | mV          |
| $\overline{CHG}$ Pull Down Voltage             | $V_{\overline{CHG}}$   | $I_{\overline{CHG}} = 5mA$   | --    | 200   | --    | mV          |
| $\overline{PGOOD}$ Deglitch Time               | $t_{\overline{PGOOD}}$ | Time measured from the edge<br>$V_{IN} = 0V$ to $5V$ in $1\mu s$ to $\overline{PGOOD} = L$ | --    | 2     | --    | ms          |
| Input Over Voltage Blanking Time               | $t_{OVP}$              |  | --    | 50    | --    | $\mu s$     |
| Input Over Voltage Recovery Time               | $t_{OVP\_R}$           |  | --    | 2     | --    | ms          |
| Pre-Charge to Fast-Charge Deglitch Time        | $t_{PF}$               |  | --    | 25    | --    | ms          |
| Fast-charge to Pre-Charge Deglitch Time        | $t_{FP}$               |  | --    | 25    | --    | ms          |
| Termination Deglitch Time                      | $t_{TERMI}$            |  | --    | 25    | --    | ms          |
| Recharge Deglitch Time                         | $t_{RECHG}$            |  | --    | 100   | --    | ms          |
| Sleep Deglitch Time                            | $t_{NO-IN}$            |  | --    | 25    | --    | ms          |
| Pack Temperature Fault Detection Deglitch Time | $t_{TS}$               |  | --    | 25    | --    | ms          |

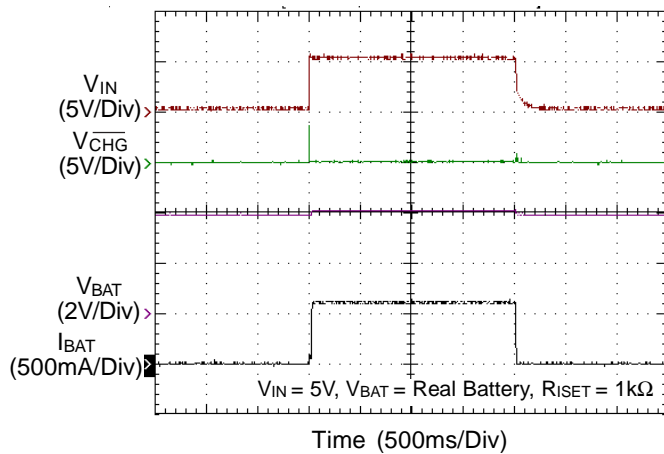
- Note 1.** Stresses beyond those listed “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.
- Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^\circ\text{C}$  on a high effective thermal conductivity four-layer test board per JEDEC 51-7.  $\theta_{JC}$  is measured at the exposed pad of the package.
- Note 3.** Devices are ESD sensitive. Handling precaution is recommended.
- Note 4.** The device is not guaranteed to function outside its operating conditions.

## Typical Application Circuit

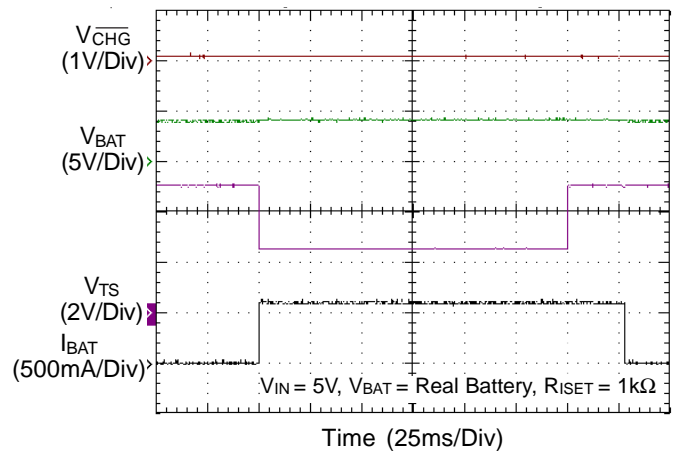
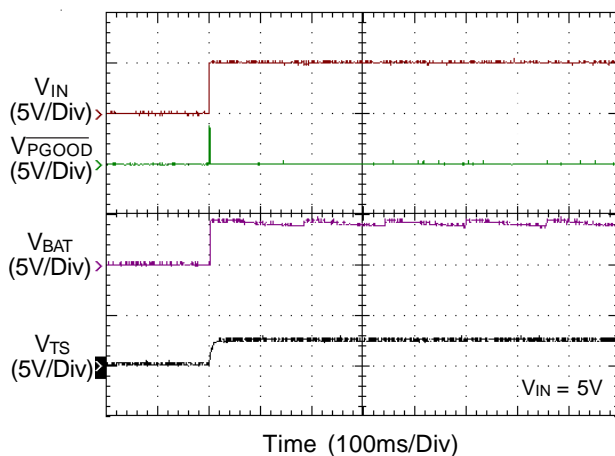
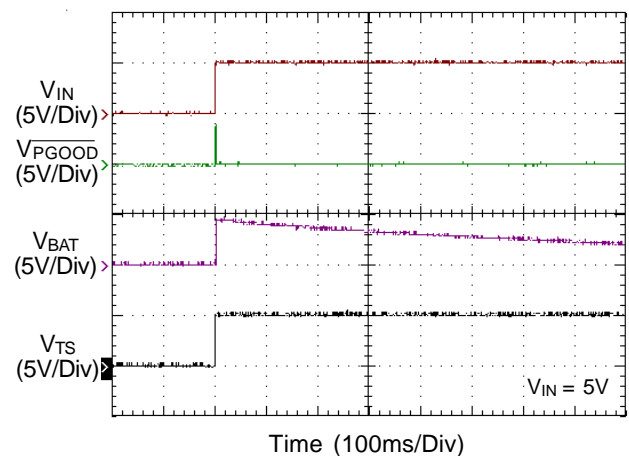
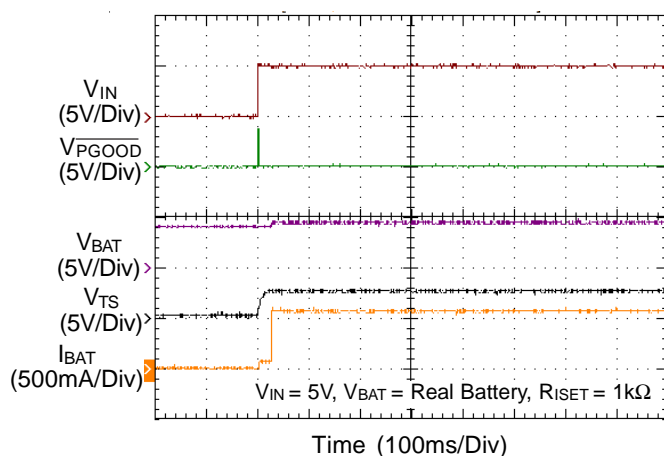
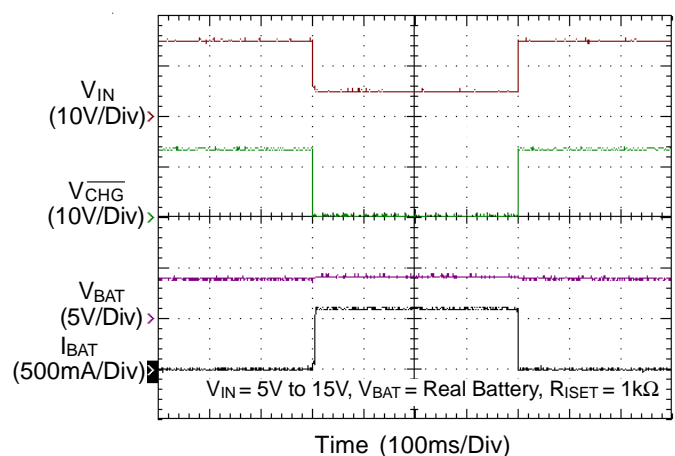


## Typical Operating Characteristics

Charge On/Off Control from VIN

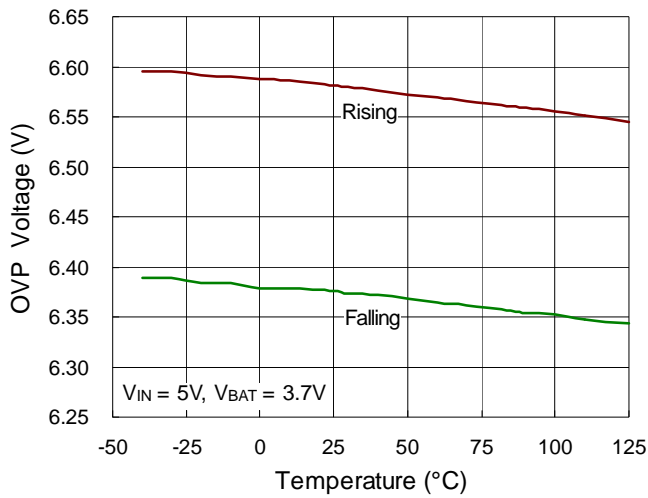


TS Inserted/Removed

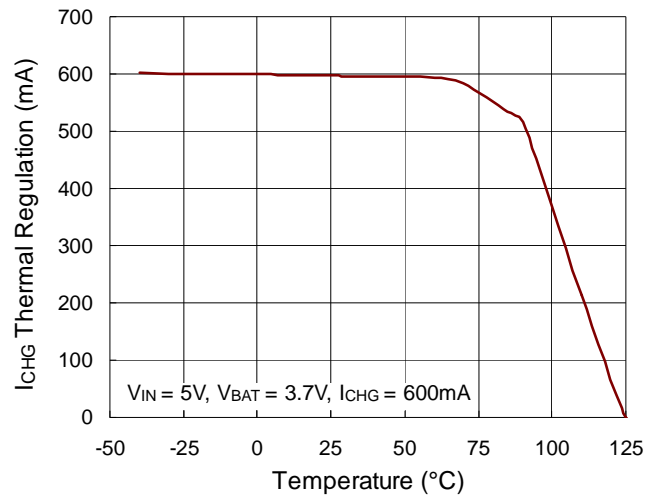
 $V_{IN}$  Hot-Plug with NTC/Without Battery $V_{IN}$  Hot-Plug Without NTC/Battery $V_{IN}$  Hot-Plug with NTC/Battery $V_{IN}$  Over Voltage Protection



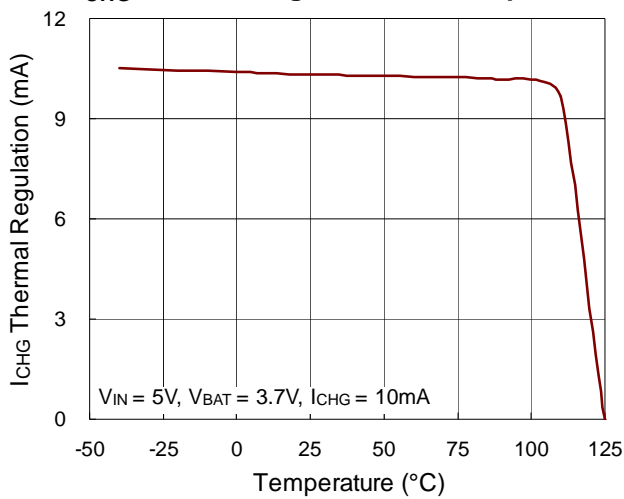
OVP Threshold Voltage vs. Temperature



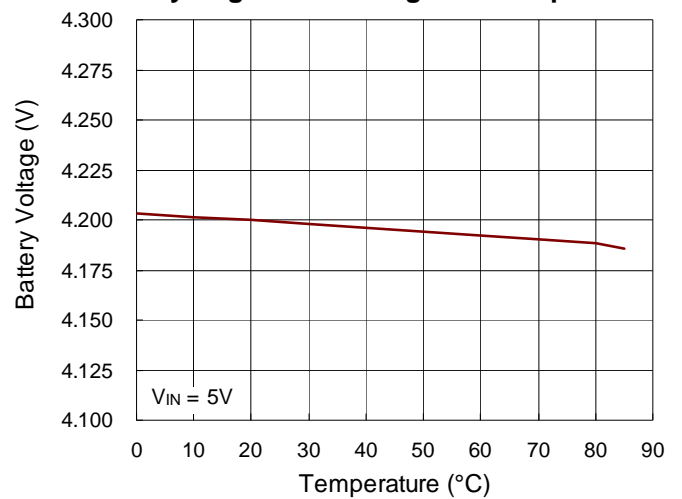
$I_{CHG}$  Thermal Regulation vs. Temperature



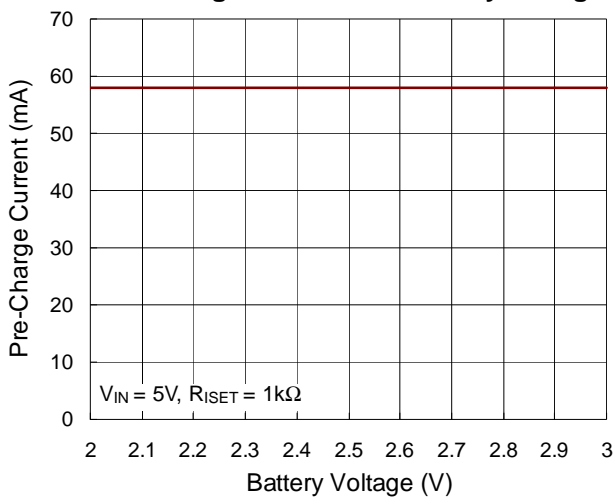
$I_{CHG}$  Thermal Regulation vs. Temperature



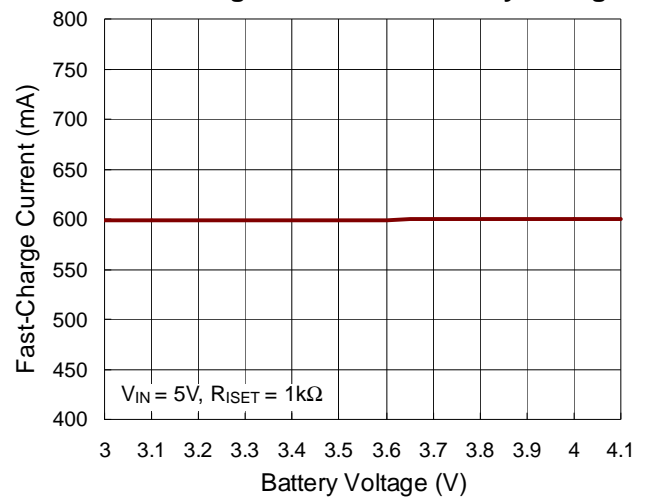
Battery Regulation Voltage vs. Temperature



Pre-Charge Current vs. Battery Voltage



Fast-Charge Current vs. Battery Voltage



## Application Information

The RT9527 is a fully integrated low cost single-cell Li-ion battery charger ideal for portable applications. The internal thermal feedback circuitry regulates the die temperature to optimize the charge rate at all ambient temperatures. The RT9527 features 20V maximum rating voltages for VIN. Other features include under voltage protection and over voltage protection for AC adapter supply, as well as a charging time monitor.

### Pre-Charge Mode

When the output voltage becomes lower than 2.8V, the charging current reduces to 10% of the setting current to protect the battery life time as shown below :

$$I_{CHG\_P} = K_{CHG\_P} / R_{ISET}$$

where  $K_{CHG\_P}$  is the pre-charge current factor.

### Fast-Charge Mode

When the output voltage becomes higher than 3V, the charging current will be equal to the setting current which is determined by  $R_{ISET}$ .

$$I_{CHG\_F} = K_{CHG\_F} / R_{ISET}$$

where  $K_{CHG\_F}$  is the fast-charge current factor.

### Constant Voltage Mode

As the output voltage is near 4.2V, the charging current will be reduced to maintain the output voltage. The charger remains active and maintains the output voltage at 4.2V in order to keep the battery in a full charge state.

### Recharge Mode

When the chip is in charge termination mode, the charging current goes down to zero and the battery voltage drops to 4.1V. After a deglitch time of 100ms (typ.), the battery begins recharging. However, when recharge happens, the indicator  $\overline{CHG}$  remains in logic high.

### $\overline{CHG}$ Indicator

The  $\overline{CHG}$  pin is an open-drain output.  $\overline{CHG}$  will assert low when the charger starts to charge the battery and become high impedance when the charge termination current is reached. The  $\overline{CHG}$  signal is interfaced either with a microprocessor GPIO or an LED for indication.

| Charge State                       | $\overline{CHG}$ Output       |
|------------------------------------|-------------------------------|
| Charging                           | Low (for first charger cycle) |
| Charging suspended by thermal loop |                               |
| Safety timers expired              | High impedance                |
| TS fault                           | Low (for first charger cycle) |
| Charging done                      | High impedance                |
| Recharging after termination       |                               |
| No valid input power               |                               |

### $\overline{PGOOD}$ Indicator

This open-drain output pin is used to indicate the input voltage status.  $\overline{PGOOD}$  output asserts low when

1.  $V_{IN} > V_{UVLO}$
2.  $(V_{IN} - V_{BAT}) > V_{OS\_H}$
3.  $V_{IN} < V_{OVP}$

It can be used to drive an LED or communicate to the host processor. Note that "LOW" indicates the open-drain transistor is turned on and the LED is bright.

### Charge Termination

When the charge current is lower than the charge termination current ratio ( $10\% = I_{CHG} / I_{CHG\_F}$ ) for  $V_{BAT} > 4.1V$  and the time is larger than the deglitch time (25ms),  $\overline{CHG}$  transits from low to high.  $\overline{CHG}$  will be latched high unless the power is re-toggled.

### ISET Pin Short Protection

After VIN power plugs in, RT9527 will detect that ISET pin is short to ground or not. If  $R_{ISET}$  is smaller than  $R_{SHORT}$ , RT9527 regard that ISET pin is short to ground. Then, RT9527 will disable charge function until VIN power reset.

If  $R_{ISET}$  is larger than  $R_{SHORT}$ , RT9527 will charge. If RT9527 begins charge status and ISET pin is short to ground, thermal regulation will work to limit junction temperature around 125°C.

### Battery Connect Reverse

If battery is connected reversely, it causes that the voltage of BAT pin is negative. RT9527 will disable charger function until battery voltage is normal.

### Temperature Regulation

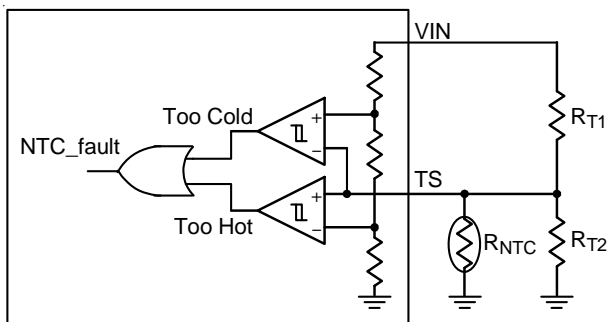
In order to maximize charge rate, the RT9527 features a junction temperature regulation loop. If the power dissipation of the IC results in junction temperature greater than the thermal regulation threshold (125°C), the RT9527 will cut back on the charge current and disconnect the battery in order to maintain thermal regulation at around 125°C. This operation continues until the junction temperature falls below the thermal regulation threshold (125°C) by the hysteresis level. This feature prevents the maximum power dissipation from exceeding typical design conditions.

### Sleep mode

The RT9527 enters sleep mode if both the AC and USB ports are removed from the input. This feature prevents draining the battery during the absence of an input supply.

### Battery Pack Temperature Monitoring

The RT9527 features an external battery pack temperature monitoring input. The TS input connects to the NTC thermistor in the battery pack to monitor battery temperature and prevent danger over temperature conditions. If at any time the voltage at TS falls outside of the operating range, charging will be suspended. The timers maintain their values but suspend counting. When charging is suspended due to a battery pack temperature fault, the  $\overline{\text{CHG}}$  pin remains low and continues to indicate charging.



$$R_{T2} = \frac{310R_{TC}R_{TH}}{117R_{TC} - 427R_{TH}}$$

$$R_{T1} = \frac{7R_{TH}R_{T2}}{3(R_{TH} + R_{T2})}$$

### Time Fault

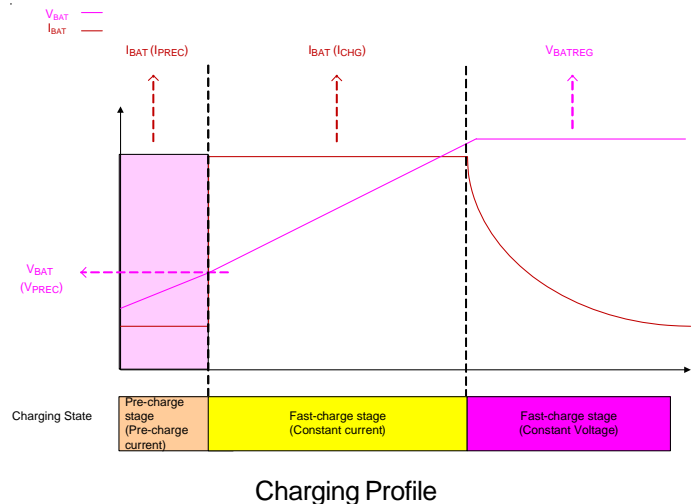
The Fast-Charge Fault Time is set according to the following equations :

$$\text{Fast-Charge Fault Time : } t_{FCHG} = 14400 \times C_{TIMER} \text{ (s)}$$

$$\text{Pre-Charge Fault Time : } t_{PCHG} = 1 / 8 \times t_{FCHG} \text{ (s)}$$

where the  $C_{TIMER}$  unit is in  $\mu\text{F}$ .

When time fault happens, the charger cycle will be turned off and the  $\overline{\text{CHG}}$  pin will become high impedance.



### Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

where  $T_{J(MAX)}$  is the maximum junction temperature,  $T_A$  is the ambient temperature, and  $\theta_{JA}$  is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance,  $\theta_{JA}$ , is layout dependent. For

WDFN-8L 2x2 package, the thermal resistance,  $\theta_{JA}$ , is 45.5°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by the following formula :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (45.5^\circ\text{C/W}) = 2.19\text{W for WDFN-8L 2x2 package}$$

The maximum power dissipation depends on the operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance,  $\theta_{JA}$ . The derating curve in Figure 1 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

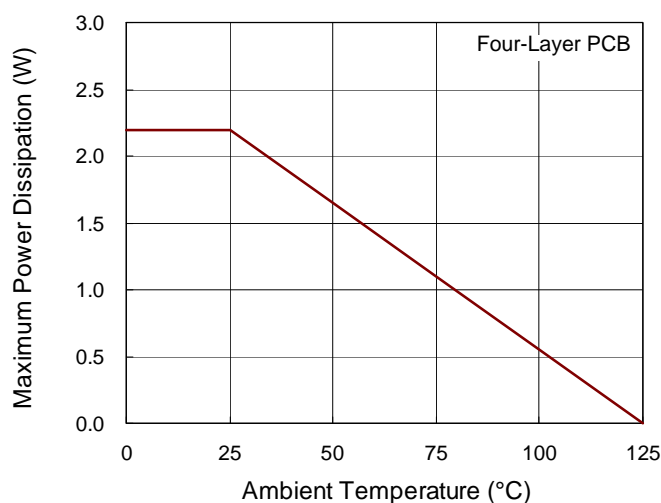


Figure 1. Derating Curve of Maximum Power Dissipation

## Layout Considerations

The RT9527 is a fully integrated low cost single cell Li-Ion battery charger ideal for portable applications. Careful PCB layout is necessary. For best performance, place all peripheral components as close to the IC as possible. A short connection is highly recommended. The following guidelines must be strictly followed when designing a PCB layout for the RT9527.

- ▶ Input and output capacitor should be placed close to IC and connected to ground plane. The trace of input in the PCB should be placed far away from the sensitive devices and shielded by the ground.
- ▶ The GND and exposed pad should be connected to a strong ground plane for heat sinking and noise protection.

- ▶ The connection of  $R_{ISET}$  should be isolated from other noisy traces. A short wire is recommended to prevent EMI and noise coupling.

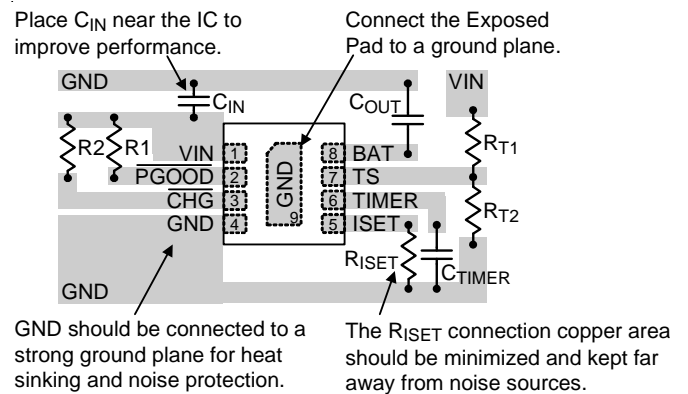


Figure 2. PCB Layout Guide

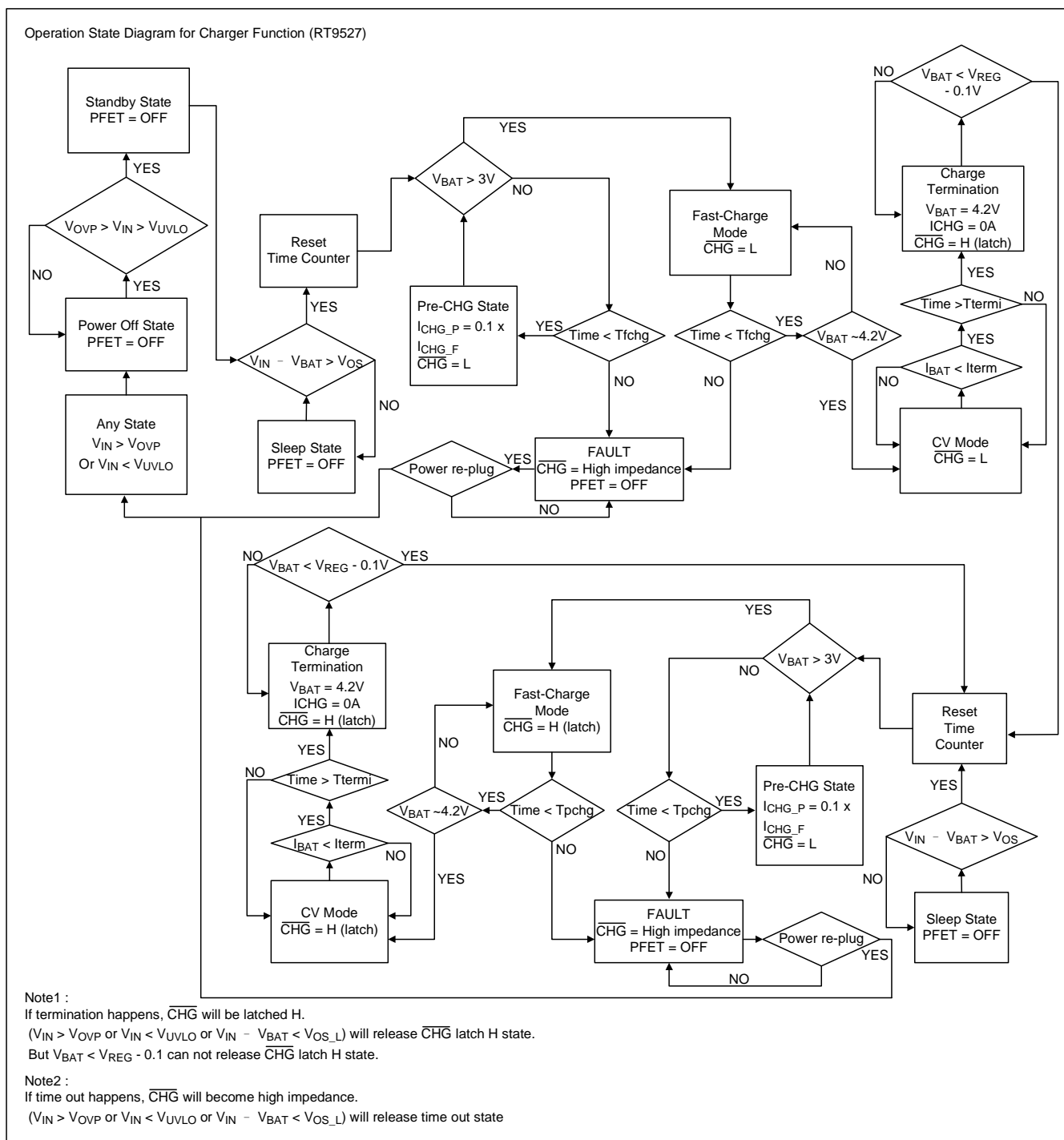
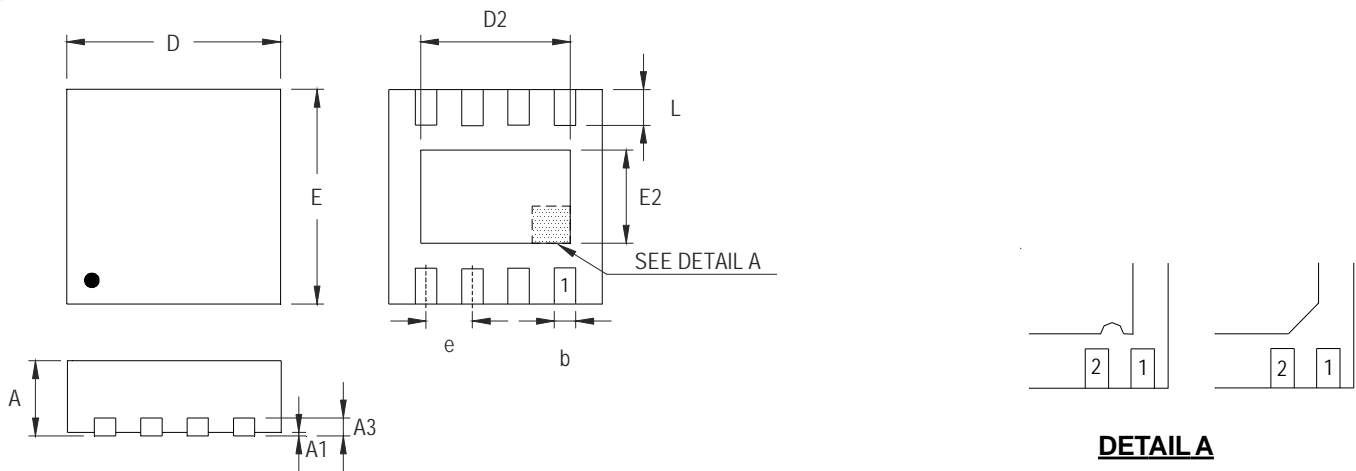


Figure 3. Operation State Diagram for Charging

## Outline Dimension



Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

| Symbol | Dimensions In Millimeters |       | Dimensions In Inches |       |
|--------|---------------------------|-------|----------------------|-------|
|        | Min                       | Max   | Min                  | Max   |
| A      | 0.700                     | 0.800 | 0.028                | 0.031 |
| A1     | 0.000                     | 0.050 | 0.000                | 0.002 |
| A3     | 0.175                     | 0.250 | 0.007                | 0.010 |
| b      | 0.200                     | 0.300 | 0.008                | 0.012 |
| D      | 1.950                     | 2.050 | 0.077                | 0.081 |
| D2     | 1.000                     | 1.250 | 0.039                | 0.049 |
| E      | 1.950                     | 2.050 | 0.077                | 0.081 |
| E2     | 0.400                     | 0.650 | 0.016                | 0.026 |
| e      | 0.500                     |       | 0.020                |       |
| L      | 0.300                     | 0.400 | 0.012                | 0.016 |

**W-Type 8L DFN 2x2 Package**

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