Linear Single Cell Li-Ion Battery Charger with Input Over Voltage Protection

General Description

The RT9526 is a fully integrated low cost single cell Li-ion battery charger ideal for portable applications. The RT9526 is capable of being powered up from AC adapter and USB (Universal Serial Bus) port inputs. The RT9526 enters sleep mode when supplies are removed. The RT9526 optimizes the charging task by using a control algorithm including preconditioning mode, fast charge mode, and constant voltage mode. The charging task will remain in constant voltage mode to hold the battery in a full charge condition. The charge current can be programmed with an external resistor. The internal thermal feedback circuitry regulates the die temperature to optimize the charge rate under all ambient temperatures. The RT9526 features 28V maximum rating voltage for VIN. The other features are under voltage protection and over voltage protection for the AC adapter supply.

The RT9526 is available in WDFN-8L 2x2, WDFN-8L 2x3 and SOT-23-6 packages to achieve best solution for PCB space and total BOM cost saving considerations.

Ordering Information

RT9526 □□

- Package Type
  - E : SOT-23-6
  - QW : WDFN-8L 2x2 (W-Type)
  - QWA : WDFN-8L 2x3 (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

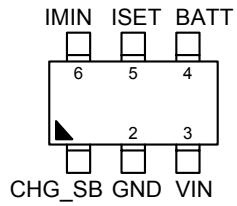
- **28V Maximum Rating for AC Adapter**
- **Internal Integrated Power FETs**
- **AC Adapter Power Good Status Indicator**
- **Programmed Charging Current**
- **Charge Status Indicator**
- **Programmed End of Charge Current**
- **Under Voltage Protection**
- **Over Voltage Protection**
- **Thermal Feedback Optimizing Charge Rate**
- **RoHS Compliant and Halogen Free**

Applications

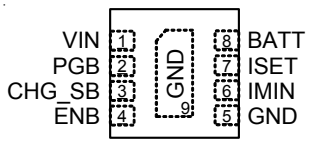
- Cellular Phones
- Digital Cameras
- PDAs and Smart Phones
- Portable Instruments

Pin Configurations

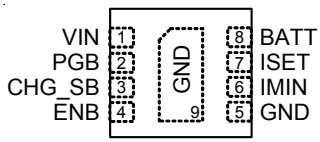
(TOP VIEW)



SOT-23-6



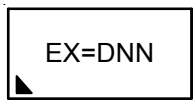
WDFN-8L 2x2



WDFN-8L 2x3

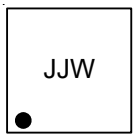
Marking Information

RT9526GE



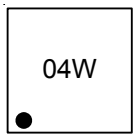
EN= : Product Code
DNN : Date Code

RT9526GQW



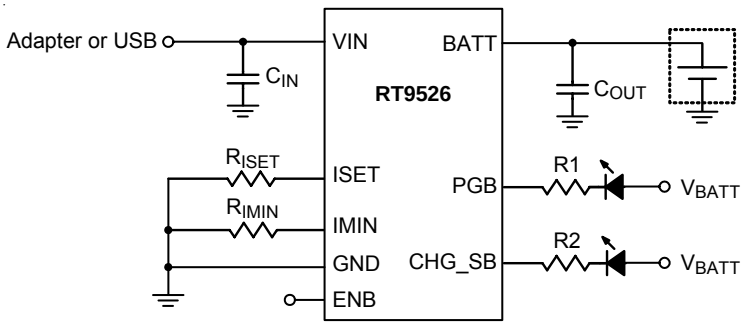
JJ : Product Code
W : Date Code

RT9526GQWA



04 : Product Code
W : Date Code

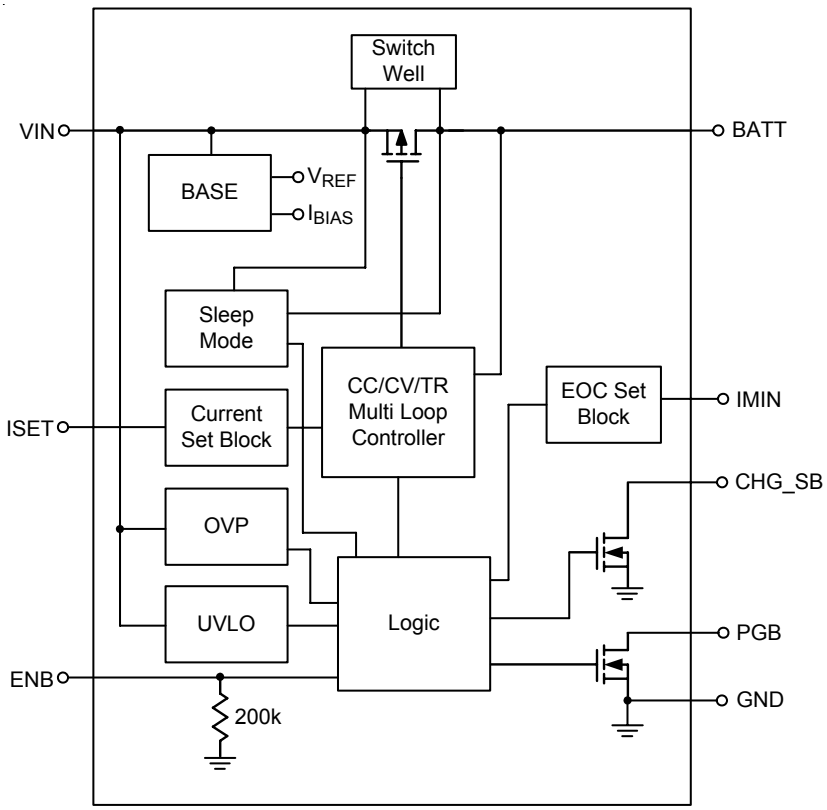
Typical Application Circuit



Function Pin Description

Pin No.		Pin Name	Pin Function
SOT-26-6	WDFN-8L 2x2 / WDFN-8L 2x3		
3	1	VIN	Supply Voltage Input. VIN can withstand up to 28V input.
--	2	PGB	Power Good Indicator. This pin connects to VIN with 10SL N-MOSFET as power good condition.
1	3	CHG_SB	Charge Status Indicator Output (Open drain). Indicate low when battery is charging; indicate high when battery charging finished or any fault happened.
--	4	ENB	Charge Enable (Active Low). Connect this pin with 200kΩ pull low resistor.
2	5, 9 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
6	6	IMIN	EOC Current Setting Pin.
5	7	ISET	Charge Current Set Point.
4	8	BATT	Battery Charge Current Output.

Function Block Diagram



Flow Chart

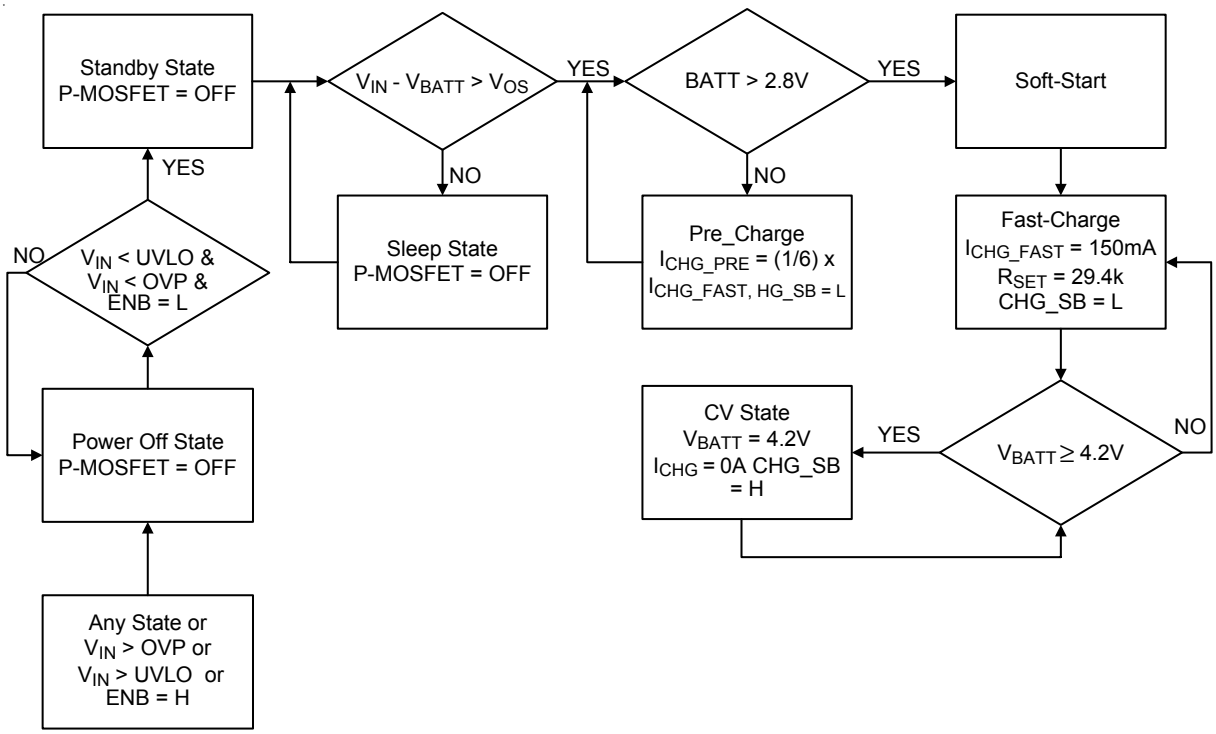


Figure 1. Operation State Diagram for Charger function

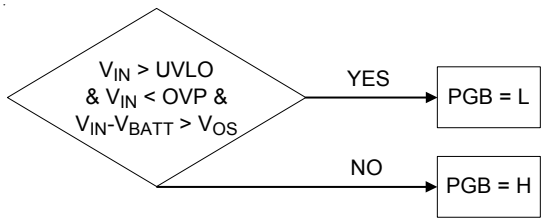


Figure 2. PGB State

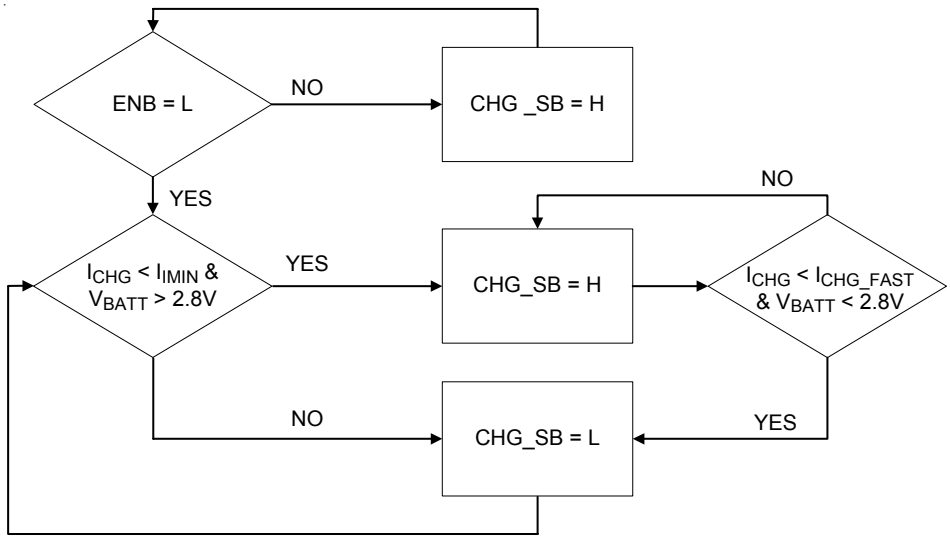


Figure 3. CHG_SB State

Absolute Maximum Ratings (Note 1)

- Supply Voltage, VIN ---------- –0.3V to 28V
- CHG_SB, PGB Pins ---------- –0.3V to 7V
- Others ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  - SOT-23-6 ---------- 0.4W
  - WDFN-8L 2x2 ---------- 0.606W
  - WDFN-8L 2x3 ---------- 0.833W
- Package Thermal Resistance (Note 2)
  - SOT-23-6, θ_{JA} ---------- 250°C/W
  - WDFN-8L 2x2, θ_{JA} ---------- 165°C/W
  - WDFN-8L 2x2, θ_{JC} ---------- 8.2°C/W
  - WDFN-8L 2x3, θ_{JA} ---------- 120°C/W
  - WDFN-8L 2x3, θ_{JC} ---------- 8.2°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C

Recommended Operating Conditions (Note 3)

- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{IN} = 4.5V, T_A = 25°C unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
VIN POR Rising Threshold Voltage		V_{POR_H}		3.4	3.8	4.2	V
VIN POR Falling Threshold Voltage		V_{POR_H}		3.1	3.5	3.9	V
VIN – V_{BATT} VOS Rising		V_{OS_H}		--	90	150	mV
VIN – V_{BATT} VOS Falling		V_{POR_L}		10	50	--	mV
VIN Standby Current			V_{BATT} = 4.5V	--	300	500	μA
BATT Sleep Leakage Current		I_{SLEEP}		--	1	5	μA
Battery Regulation Voltage		V_{REG}		4.158	4.2	4.242	V
VIN Power FET On-Resistance		$R_{DS(ON)}$	I_{BATT} = 0.5A	--	0.6	--	Ω
ISET Set Voltage (Fast Charge Phase)		V_{ISET}		--	1.21	--	V
Charge Current Accuracy			R_{ISET} = 29.4kΩ	135	150	165	mA
BATT Pre-Charge Threshold		V_{CHG_PRE}		2.7	2.8	2.9	V
BATT Pre-Charge Threshold Hysteresis		ΔV_{CHG_PRE}		40	100	150	mV
Pre-Charge Current		I_{CHG_PRE}		12	16.7	21.3	%
ENB Input Threshold Voltage	Logic-High	V_{IH}	V_{IN} = 4.2V to 24V	1.5	–	--	V
	Logic-Low	V_{IL}		--	–	0.4	

To be continued

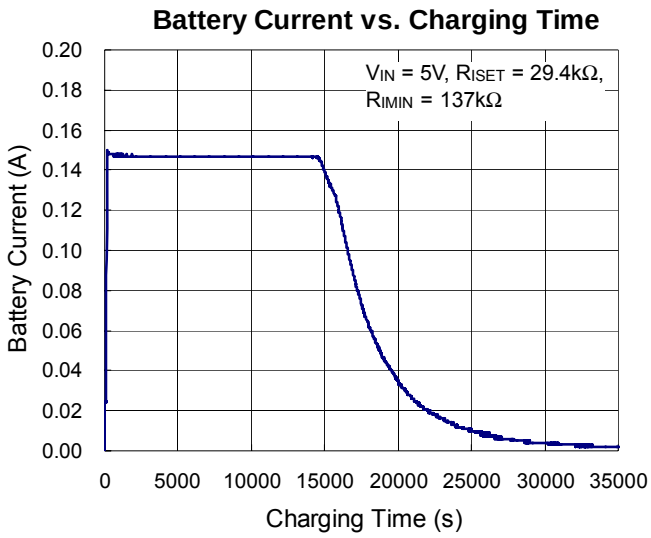
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Thermal Regulation	T_{REG}		--	115	--	°C
VIN Over Voltage Protection Threshold	V_{OVP}		10	11	13	V
VIN OVP Hysteresis	ΔV_{OVP}		--	0.4	--	V
PGB Pull Down Voltage		5mA	--	200	--	mV
CHG_SB Pull Down Voltage		5mA	--	200	--	mV
EOC Current Setting	I_{IMIN}	R_{IMIN} = 137kΩ	20	30	40	mA
EOC Rising Threshold		R_{IREF} = 29.4kΩ	90	110	130	mA

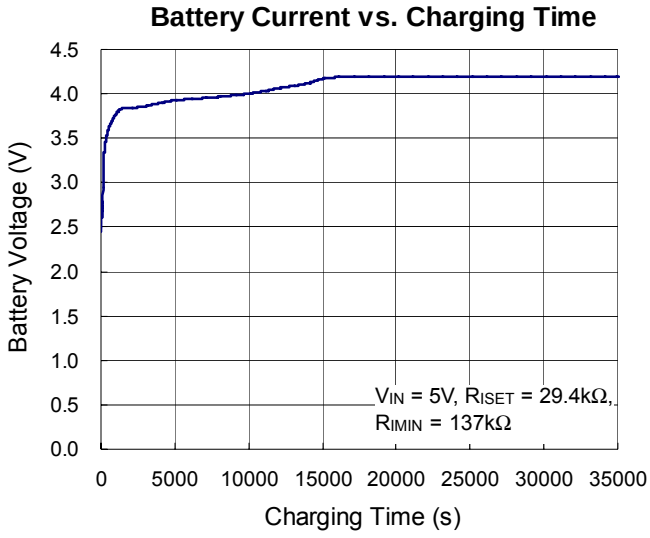
Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

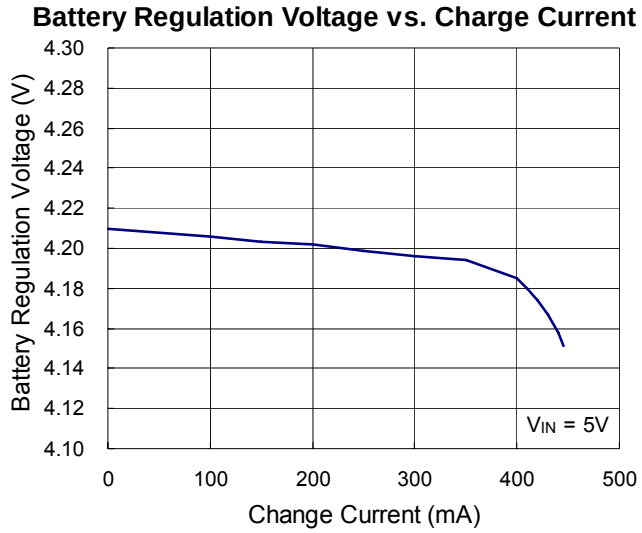
Note 2. θ_{JA} is measured in natural convection at T_A = 25°C on a low-effective thermal conductivity single-layer test board of JEDEC 51-3 thermal measurement standard. The measurement case position of θ_{JC} is on the exposed pad of the packages.

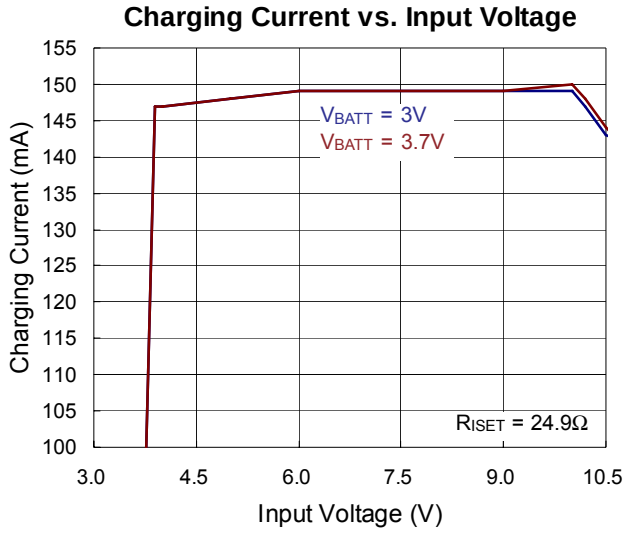
Note 3. The device is not guaranteed to function outside its operating conditions.

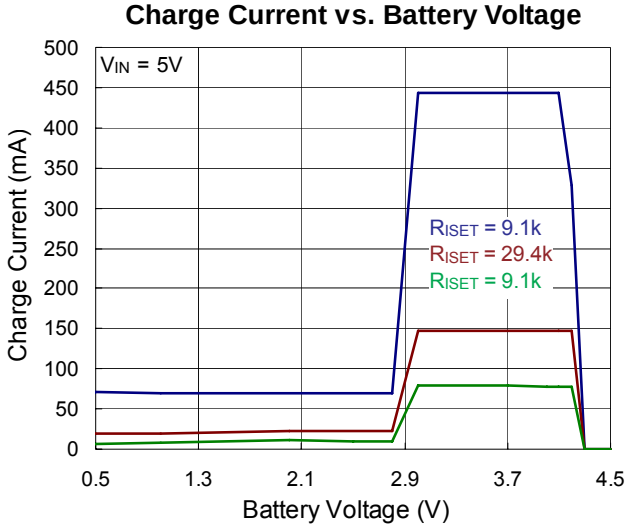
Typical Operating Characteristics

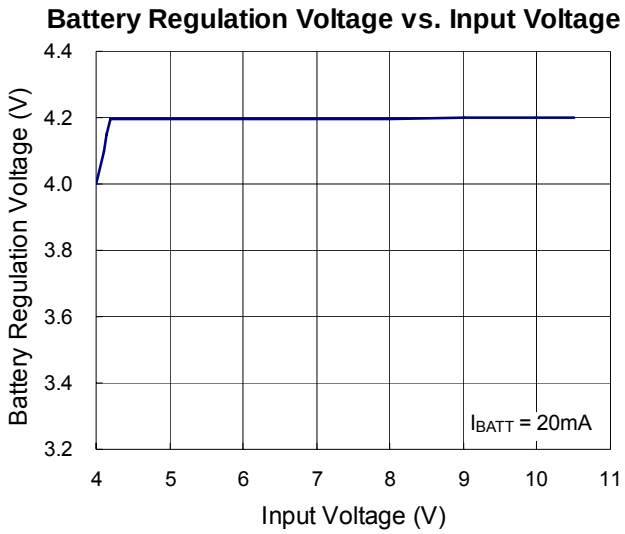




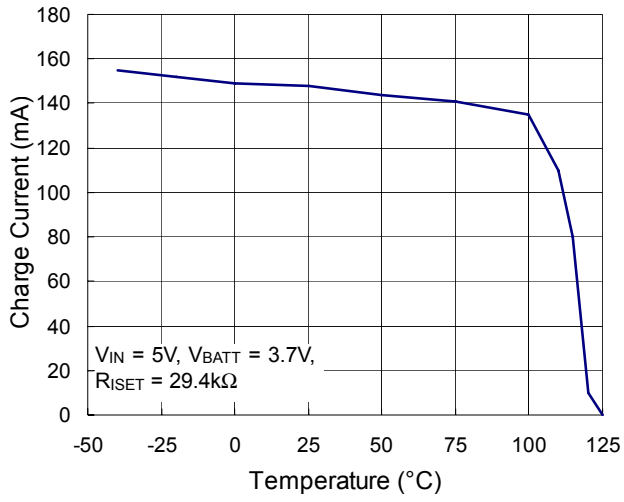




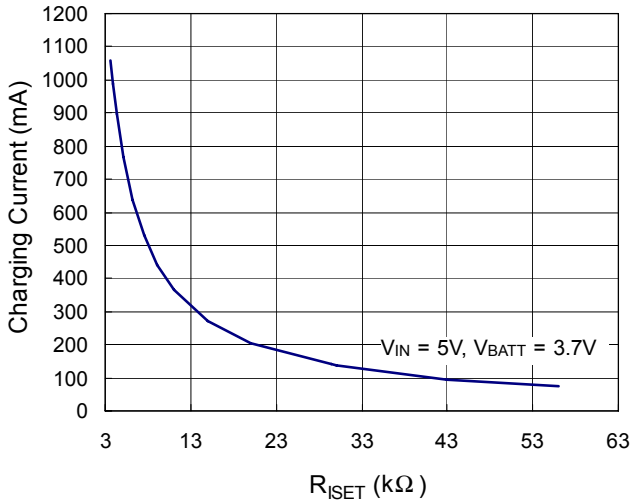




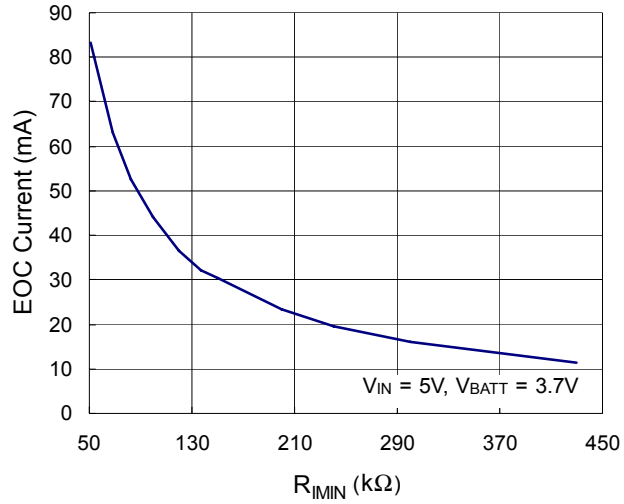
Charge Current vs. Temperature



Charge Current vs. R_{ISET}



EOC Current vs. R_{ISET}



Application Information

The RT9526 is a fully integrated low cost single cell Li-ion battery charger operable in Constant Current (CC) mode or Constant Voltage (CV) mode. The CC mode current is set with the external resistor, R_{ISET}, and the CV mode voltage is fixed at 4.2V. If the battery voltage is below a typical 2.8V pre-charge threshold, the RT9526 charges the battery with a trickle current until the battery voltage rises above the pre-charge threshold. The RT9526 is capable of being powered up from AC adapter and USB (Universal Serial Bus) port inputs.

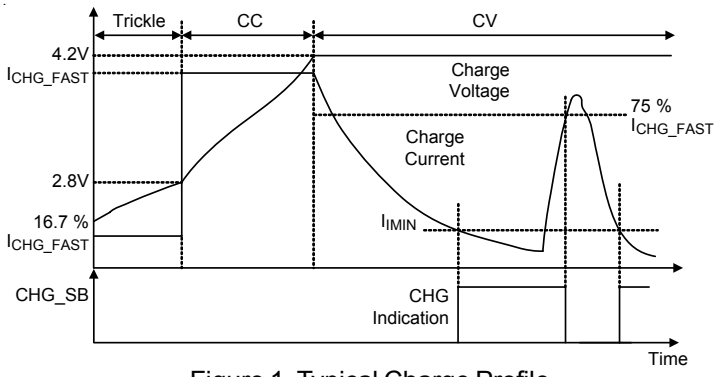


Figure 1. Typical Charge Profile

VIN Over Voltage Protection

The input voltage is monitored by the internal comparator. The OVP threshold is set at 11V (typ.). When the input voltage exceeds the threshold, the controller outputs a logic signal to turn off the power P-MOSFET to prevent high input voltage from damaging the electronics in the handheld system. Nevertheless, an AC input voltage over 28V will still damage the RT9526. When the input over voltage condition is removed, the controller will enable the output again by running through soft-start.

Charger Enable Input

ENB is an active-low logic input to enable the charger. Drive the ENB pin low or leave it floating to enable the charger. This pin has a 200kΩ internal pull down resistor. So when left floating, the input is equivalent to logic-low. Drive this pin high to disable the charger.

Battery Charge Profile

The RT9526 charges a Li-ion battery under Constant Current (CC) mode or Constant Voltage (CV) mode. The constant current of ISET is set via the external resistor, R_{ISET}, and the constant voltage is fixed at 4.2V. If the battery voltage is below a typical 2.8V pre-charge threshold, the RT9526 charges the battery with a trickle current until the battery voltage rises above the pre-charge threshold. When the battery voltage reaches 4.2V, the charger enters CV mode and regulates the battery voltage at 4.2V to fully charge the battery without the risk of over charge.

a. Battery Pre-Charge Current

During a charge cycle, if the battery voltage is below the pre-charge threshold, the RT9526 applies a pre-charge mode to the battery. This feature revives deeply discharged cells and protects battery life. The internally determined pre-charge rate of the RT9526 is 16.7% of the constant charge current.

b. Battery Fast-Charge Current (CC Mode)

The RT9526 offers ISET pin to determine the fast-charge current via an external resistor, R_{ISET}, connected between ISET and GND. The fast-charge current can be calculated by the following equation :

$$I_{CHG_FAST} = K_{ISET} \times \frac{V_{ISET}}{R_{ISET}} \quad (mA)$$

K_{SET} = 3640; V_{SET} = 1.21 (typ.)

c. Battery Voltage Regulation (CV Mode)

The battery voltage regulation feedback is through the BATT pin. The RT9526 monitors the battery voltage between the BATT and GND pins. When battery voltage is close to battery regulation voltage threshold, the voltage regulation phase begins and the charging current begins to taper down. When battery voltage is over battery regulation voltage threshold and charge mode stops, the RT9526 still monitors the battery voltage. Charge current is resumed when the battery voltage falls under battery regulation voltage threshold.

Sleep Mode

The RT9526 enters sleep mode if both AC and USB are removed from the input. This feature prevents draining the battery during the absence of input supply.

Power Good

This open-drain output pin is used to indicate the input voltage status. The PGB output asserts low when

1. $V_{IN} > V_{POR}$
2. $V_{IN} – V_{BATT} > V_{OS}$
3. $V_{IN} < V_{OVP}$

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

CHG_SB Indication

The CHG_SB pin 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 CHG_SB signal is interfaced either with a micro processor GPIO or an LED for indication.

End-Of-Charge Current (EOC)

Connect a resistor between the IMIN pin and GND to set the EOC current. The EOC current level, I_{IMIN}, is programmable via the external resistor, R_{IMIN}, as shown in the following equation :

$$I_{IMIN} = \frac{4148}{R_{IMIN}} \quad (mA)$$

Upon reaching the End-Of-Charge (EOC) current, the charger indicates charge completion via the CHG_SB pin, but the charger continues to output 4.2V voltage. Figure 1 shows the typical charge profile and the EOC/reset event. The CHG_SB signal asserts low when the trickle charge starts and changes to high at EOC. After EOC is reached, the charge current has to rise above 75% of I_{CHG_FAST} before the CHG_SB signal is allowed to turn on again. A current surge after EOC may occur due to a load connected to the battery.

Temperature Regulation and Thermal Protection

In order to maximize charge rate, the RT9526 features a junction temperature regulation loop. If the power dissipation of the IC results in junction temperature greater than the thermal regulation threshold (115°C), the RT9526 will cut back on the charge current and disconnect the battery in order to maintain thermal regulation at around 115°C. This operation continues until the junction temperature falls below thermal regulation threshold (115°C) by the hysteresis level. This feature prevents the maximum power dissipation from exceeding typical design conditions.

Selecting the Input and Output Capacitors

In most applications, a 1μF high frequency decoupling capacitor placed in close proximity to the input is sufficient. However, depending on the power supply characteristics and cable length, it may be necessary to add an additional 10μF ceramic capacitor to the input. For the RT9526, a small output capacitor is required for loop stability. A 1μF ceramic capacitor placed between the BATT pin and GND is typically sufficient.

Thermal Considerations

For recommended operating condition specifications of the RT9526, the maximum junction temperature is 125°C and T_A is the ambient temperature. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For SOT-23-6 packages, the thermal resistance, θ_{JA}, is 250°C/W on a standard JEDEC 51-3 single-layer thermal test board. For WDFN-8L 2x2 packages, the thermal resistance, θ_{JA}, is 165°C/W on a standard JEDEC 51-3 single-layer thermal test board. For WDFN-8L 2x3 packages, the thermal resistance, θ_{JA}, is 120°C/W on a standard JEDEC 51-3 single-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (250°C/W) = 0.400W for SOT-23-6 package

$P_{D(MAX)}$ = (125°C – 25°C) / (165°C/W) = 0.606W for WDFN-8L 2x2 package

$P_{D(MAX)}$ = (125°C – 25°C) / (120°C/W) = 0.833W for WDFN-8L 2x3 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J\ (MAX)}$ and thermal resistance, θ_{JA}. For the RT9526 packages, the derating curves in Figure 2 allow the designer to see the effect of rising ambient temperature on the maximum power dissipation.

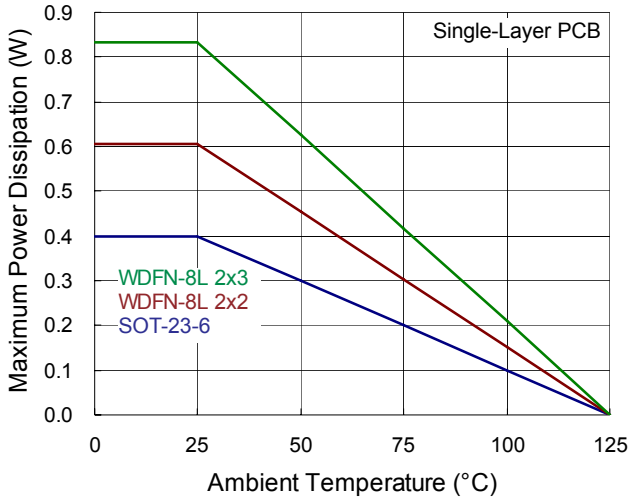


Figure 2. Derating Curve for RT9526 Package

Layout Consideration

The RT9526 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 should be strictly followed when designing a PCB layout for the RT9526.

- Input capacitor should be placed close to the IC and connected to the ground plane. The trace of input on 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.
- Output capacitor should be placed close to the IC and connected to the ground plane to reduce noise coupling.

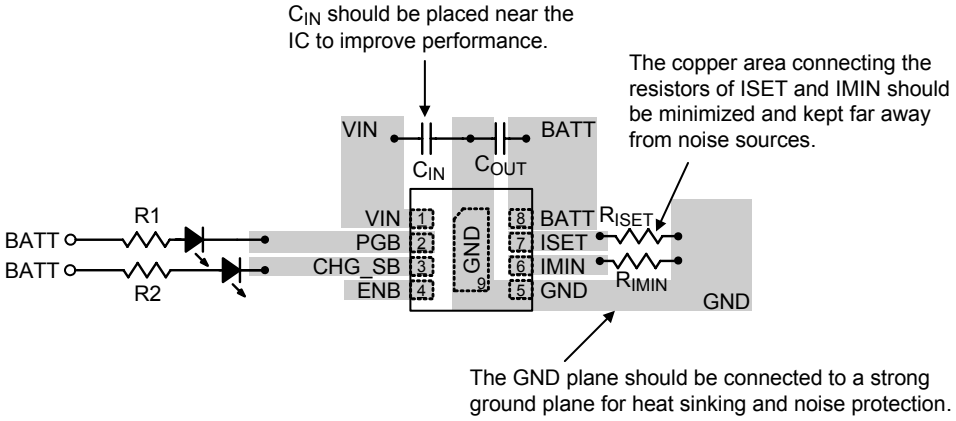
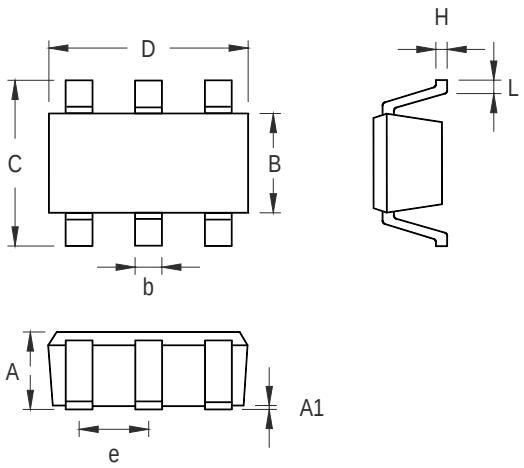


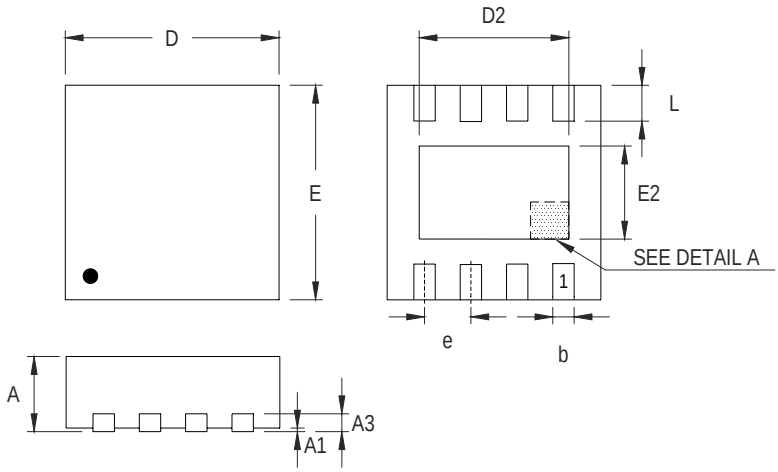
Figure 3. PCB Layout Guide

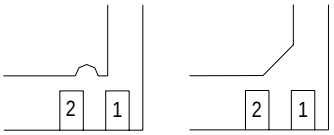
Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.031	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.250	0.560	0.010	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

SOT-23-6 Surface Mount Package





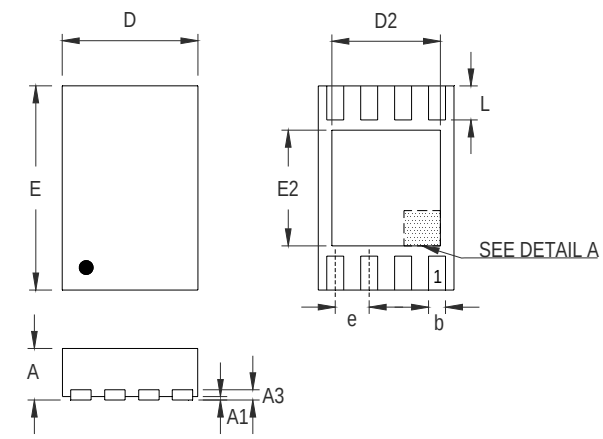
DETAIL A

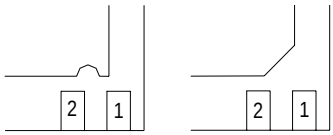
Pin #1 ID and Tie Bar Mark Options

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





DETAIL A

Pin #1 ID and Tie Bar Mark Options

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	1.900	2.100	0.075	0.083
D2	1.550	1.650	0.061	0.065
E	2.900	3.100	0.114	0.122
E2	1.650	1.750	0.065	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 8L DFN 2x3 Package

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