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Switch-Mode Single Cell Li-Ion Charger with USB-OTG

General Description

The RT9460 is a switch-mode single cell Li-Ion/Li-Polymer battery charger for portable applications. It integrates a synchronous PWM controller, power MOSFETs, input current sensing and regulation, and high accuracy voltage regulation and charge termination circuits. Besides, the charging current is regulated through the integrated sensing resistors. The RT9460 also features USB On-The-Go (OTG) support.

The RT9460 optimizes the charging task by using a control algorithm to vary the charge rate via different modes, including pre-charge mode, fast charge mode, and constant voltage mode. The key charge parameters are programmable via the I^2C interface. The RT9460 resumes the charge cycle whenever the battery voltage falls below an internal recharge threshold, and automatically enters sleep mode when the input power supply is removed.

Other features include under-voltage protection, over-voltage protection, thermal regulation and reverse leakage protection.

The RT9460 is available in the small WL-CSP-25B 2.52x2.52 packages.

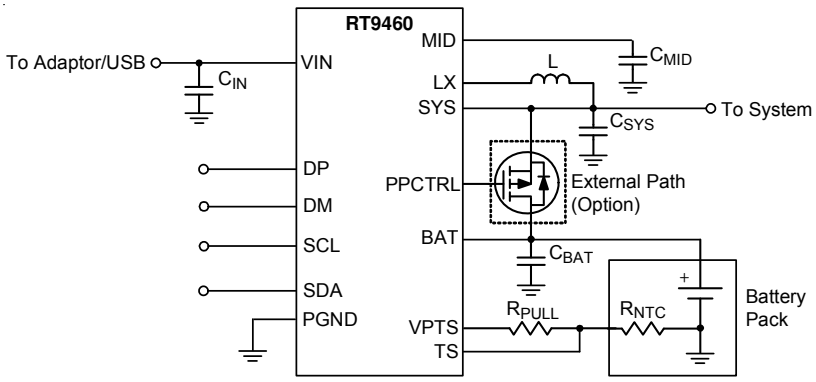
Features

- **High Accuracy Voltage/Current Regulation**
- **Average Input Current Regulation (AICR) : 0.1/0.15/ 0.5/ to 3A per 0.1A**
- **Minimum Input Voltage Regulation**
  - **For 5V Adaptor : 4V/4.25V/4.5V/4.75V**
  - **For 9V Adaptor : 7V/7.5V/8V/8.5V**
- **Charge Current Regulation Accuracy : ±5%**
- **Charge Voltage Regulation Accuracy : ±1% (0 to 85°C)**
- **Integrated Power MOSFETS for up to 3.125A Charge Rate**
- **Support USB Charging Detection**
- **Battery Temperature Sensing**
- **Synchronous 0.75/1.5MHz Fixed Frequency PWM Controller with Up to 95% Duty Cycle**
- **Reverse Leakage Protection to Prevent Battery Drainage**
- **Thermal Regulation and Protection**
- **Over Temperature Protection**
- **Input Over Voltage Protection**
- **IRQ Output for Communication with I^2C**
- **Automatic Charging**
- **RoHS Compliant and Halogen Free**

Applications

- Cellular Telephones
- Personal Information Appliances
- Tablet PC, Power Bank
- Portable Instruments

Simplified Application Circuit



Ordering Information

RT9460 □

Package Type
WSC : WL-CSP-25B 2.52x2.52 (BSC)

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.

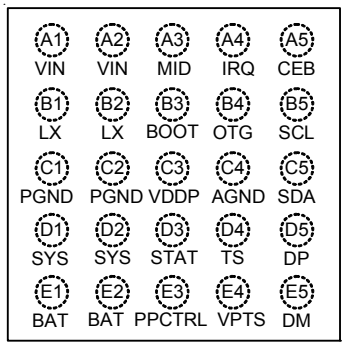
Marking Information

0E : Product Code

YMDNN : Date Code

Pin Configuration

(TOP VIEW)

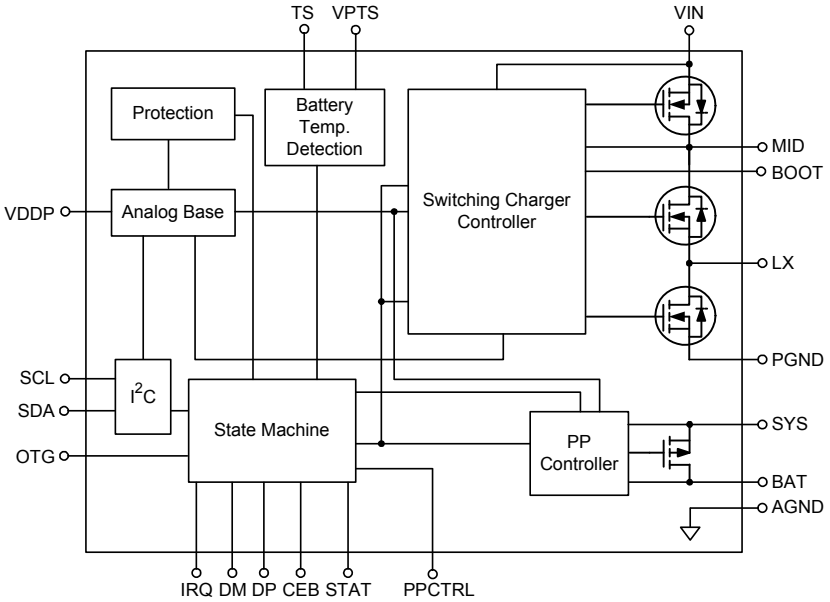


WL-CSP-25B 2.52x2.52 (BSC)

Functional Pin Description

Pin No.	Pin Name	Pin Description
A1, A2	VIN	Power input.
A3	MID	Connection point between reverse blocking MOSFET and high-side switching MOSFET.
A4	IRQ	IRQ output node.
A5	CEB	Enable control input. Low active. With internal 102kΩ pull low resistor.
B1, B2	LX	Switch node. Connect to an external inductor.
B3	BOOT	Bootstrap supply for high-side MOSFET. Connect a capacitor between BOOT and LX.
B4	OTG	Setting input pin OTG boost mode. With internal 102kΩ pull low resistor.
B5	SCL	Clock input for I^2C. Open-drain output. Connect a pull-up resistor.
C1, C2	PGND	Power ground for switching charger.
C3	VDDP	Internal power for power stage.
C4	AGND	Analog ground.
C5	SDA	Data input for I^2C. Open drain output. Connect a pull-up Resistor.
D1, D2	SYS	System voltage regulator node.
D3	STAT	Charge status indicator (open drain).
D4	TS	Battery temperature detection pin.
D5	DP	USB charger type detection pin.
E1, E2	BAT	Charging current output node. Battery charging voltage regulation feedback pin with power path.
E3	PPCTRL	Power path control pin (connect to external P-MOSFET gate).
E4	VPTS	Supply voltage for battery temperature detection.
E5	DM	USB charger type detection pin.

Functional Block Diagram



Operation

The RT9460 is an integrated single cell Li-ion battery switching charger with power path controller.

Base Circuits

Base circuits provide the internal power, VDDP and reference voltage and bias current.

Protection Circuits

The protection circuits include the VINOVP, VINUVLO, BATOVP and OTP circuits. The protection circuits turn off the charging when the input power or die temperature is in abnormal level.

Buck Regulator for charging and Boost Regulator as OTG

The multi-loop controller controls the operation of charging process and current supply to the system. It also controls the circuits as a Boost converter for OTG applications.

Battery Detection

The RT9460 is capable of doing the battery absence detection. The detection protects the charger when battery is removed accidentally.

Adaptor Detection

If the poor input power source is connected to RT9460, the operation is shut down by the adaptor detection.

Power Path Management and Control

Once the battery voltage increase to a defined system minimum regulation voltage, the internal path between SYS and BAT will be fully turned on (Cool PPM operation). That is, a better charging efficiency can be derived. When end of charge occurs, the charing stops and the internal path will be off.

USB Charger Detection

The RT9460 detects and distinguishes SONY, APPLE NIKON and USB Charger (Standard Charger Port, Charging Downstream Port and Dedicated Charger Port) via DP and DM pins.

TS Detection

The RT9460 detects the temperature of the battery pack via TS and VPTS pins. The VPTS pin provides a constant voltage source used to drive the voltage divider composed of a pulled-high resister and a NTC resister. The RT9460 reports the sensing results via IRQ and status bits for COLD, COOL, WARM and HOT.

I²C Controller

The key parameters of charging and OTG are programmable through I²C commands.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VIN ---------- –0.3V to 28V
- MID, BOOT ---------- –0.3V to 28V
- LX ---------- –0.3V to 20V
- MID – VIN, BOOT – LX ---------- –0.3V to 6V
- Other Pins ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WL-CSP-25B 2.52x2.52 (BSC) ---------- 3.11W
  WQFN-32L 4x4 ---------- 3.59W
- Package Thermal Resistance (Note 2)
  WL-CSP-25B 2.52x2.52 (BSC), θ_{JA} ---------- 32.1°C/W
  WQFN-32L 4x4, θ_{JA} ---------- 27.8°C/W
  WQFN-32L 4x4, θ_{JC} ---------- 7°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
  MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Input Voltage, VIN ---------- 4.3V to 9V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{IN} = 5V, V_{BAT} = 4.2V, L = 2.2µH, C_{IN} = 2.2µF, C_{BATS} = 10µF, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Protection						
V_{IN} OVP Threshold Voltage			15	16	17	V
V_{IN} OVP Hysteresis			--	200	--	mV
Battery OVP			110	117	124	%
Battery OVP Hysteresis			--	10	--	%
Over-Temperature Protection	OTP		--	165	--	°C
OTP Hysteresis			--	10	--	°C
Thermal Regulation Threshold		Charge current begins to reduce	--	120	--	°C
System UVP Threshold Voltage	V_{SYS_UVP}		--	2.4	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Sleep Mode Comparator						
Sleep Mode Entry Threshold V_{IN} – V_{BATS}	V_{SLP}	2.5V < V_{BATx} < V_{BATREG}, V_{IN} falling	0	0.04	0.1	V
Sleep Mode Exit Hysteresis V_{IN} – V_{BATS}	$V_{SLPEXIT}$	2.5V < V_{BATx} < V_{BATREG}	40	100	200	mV
Sleep Mode Deglitch Time	T_{SLP}	V_{IN} rising above V_{SLP} + $V_{SLPEXIT}$	--	128	--	ms
Under-Voltage Lockout Threshold						
IC Active Threshold Voltage	V_{UVLO}	V_{IN} rising	3.05	3.3	3.55	V
IC Active Hysteresis	ΔV_{UVLO}	V_{IN} falling from UVLO	--	150	--	mV
Input Currents						
VIN Supply Current	I_Q	PWM switching, I_{CHG} = I_{BAT} = 0mA	--	10	--	mA
		PWM is not switching. I_{CHG} = I_{BAT} = 0mA	--	--	5	mA
		High impendence mode	--	--	150	μA
Leakage Current from Battery	I_{BAT}	V_{IN} = 0V, charger off.	--	--	25	μA
Input Power Regulation						
Input Voltage Regulation	V_{MIVR}	I^2C Programmable refer to Reg0x21[3:0]	4	--	8.5	V
VMIVR Accuracy			–5	--	5	%
Average Input Current Regulation Accuracy	I_{AICR}	USB charge mode, I_{AICR} = 100mA	80	--	100	mA
		USB charge mode, I_{AICR} = 500mA	400	--	500	
		USB charge mode, I_{AICR} = 1A	800	--	1000	
Battery Voltage Regulation						
Battery Voltage Regulation	V_{OREG}	I^2C programmable per 20mV.	3.5	--	4.62	V
VBATREG Accuracy		0 to 85°C	–1	--	1	%
Re-Charge Threshold	V_{RECH}	V_{BATx} falling, below V_{BATREG}	--	125	--	mV
Re-Charge Deglitch	T_{RECH}		--	128	--	ms
System Minimum Regulation Voltage						
System Minimum Regulation Voltage	V_{SYS}	I^2C programmable per 0.1V	3.5	--	3.8	V
Charging Current Regulation						
Output Charging Current	I_{CHG}	I^2C programmable per 0.125A	1.25	--	3.125	A
ICHG Accuracy		AICR is disabled	–5	--	5	%
Pre-Charge Threshold	V_{PREC}	I^2C programmable per 0.2V	2	--	3	V
VPREC Accuracy			–5	--	5	%
Pre-Charge Current	I_{PREC}	I^2C programmable per 50mA	100	--	850	mA
IPREC Accuracy			–30	--	30	%

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Charge Termination Detection						
End of Charge Current	I_{EOC}	I^2C programmable per 50mA	100	--	450	mA
Fixed IEOC		As I_{AICR} = 100mA	--	50	--	mA
IEOC Accuracy			–100	--	100	mA
Deglitch Time for EOC	T_{EOC}	$I_{CHG} < I_{EOC}$, $V_{BAT} > V_{REC}$	--	2	--	ms
PWM						
High-Side On-Resistance		From VIN to LX, Exclude I_{AICR} = 100mA	--	90	150	mΩ
Low-Side On-Resistance		From LX to PGND	--	60	100	mΩ
Charging Efficiency		V_{BATx} = 4V, and I_{CHG} = 2A,	--	85	--	%
Oscillator Frequency	OSC	I^2C Programmable 0.75/1.5 MHz	--	1.5	--	MHz
Frequency Accuracy			–10	--	10	%
Maximum Duty Cycle		At minimum voltage input	--	95	--	%
Minimum Duty Cycle			0	--	--	%
Peak OCP as Charger Mode	I_{CHGOCP}		--	4.5	--	A
Power Path On-Resistance		From SYS to VBAT	--	35	60	mΩ
Boost Mode Operation						
Output Voltage Level	V_{OTG}	To VIN	--	5.05	--	V
Output Voltage Accuracy			–3	--	3	%
Efficiency		V_{BATx} = 4V, and I_{IN} = 0.8A,	--	85	--	%
MAX Output Current		I^2C programmable, 0.5A/1A	1	--	--	A
Peak Over-Current Protection			--	4.5	--	A
VIN OVP as OTG Boost			--	6	--	V
VIN OVP Hysteresis			--	250	--	mV
Minimum Battery Voltage for Boost	V_{BATMIN}	As boost start-up	--	2.9	--	V
Minimum Battery Voltage Hysteresis			--	400	--	mV
I^2C Characteristics						
Output Low Voltage	V_{OL}	I_{DS} = 10mA	--	--	0.4	V
SCL, SDA Input Threshold Voltage – Logic-High	V_{IH}		1.3	--	--	V
SCL, SDA Input Threshold Voltage – Logic-Low	V_{IL}		--	--	0.4	V
SCL Clock			--	--	400	kHz

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
DP DM Detection							
D+ Voltage Source		V_{DP_SCR}		0.5	0.6	0.7	V
D+ Voltage Source Output Current				200	--	--	μA
D- Current Sink		I_{DM_SINK}		50	100	150	μA
Input Capacitance		C_I	DM pin, switch open	--	4.5	5	pF
			DP pin, switch open	--	4.5	5	
Input leakage		I_I	DM pin, switch open	−1	--	1	μA
			DP pin, switch open	−1	--	1	
DP Low Comparator Threshold		V_{DP_LOW}		0.8	--	--	V
DM High Comparator Threshold		V_{DM_HIGH}		0.8	--	--	V
DM Low Comparator Threshold		V_{DM_LOW}		--	--	475	mV
NTC Monitor							
HOT Threshold		V_{VTS_HOT}	VTS falling, the ratio of VPTS, VIN > $V_{IN(MIN)}$	29	30	31	%VPTS
WARM Threshold		V_{VTS_WARM}	VTS falling, the ratio of VPTS, VIN > $V_{IN(MIN)}$	37	38	39	%VPTS
COOL Threshold		V_{VTS_COOL}	VTS rising, the ratio of VPTS, VIN > $V_{IN(MIN)}$	55	56	57	%VPTS
COLD Threshold		V_{VTS_COLD}	VTS rising, the ratio of VPTS, VIN > $V_{IN(MIN)}$	59	60	61	%VPTS
Low Temperature Hysteresis		ΔV_{VTS}		--	1	--	%VPTS
Disable Threshold		V_{VTS_OFF}	TS function disable	2	3	4	%VPTS
Control I/O Pin							
Output Low Voltage for STAT		V_{OL}	I_{DS} = 10mA	--	--	0.4	V
CE Input Threshold Voltage	Logic-High	V_{IH}		1.3	--	--	V
	Logic-Low	V_{IL}		--	--	0.4	

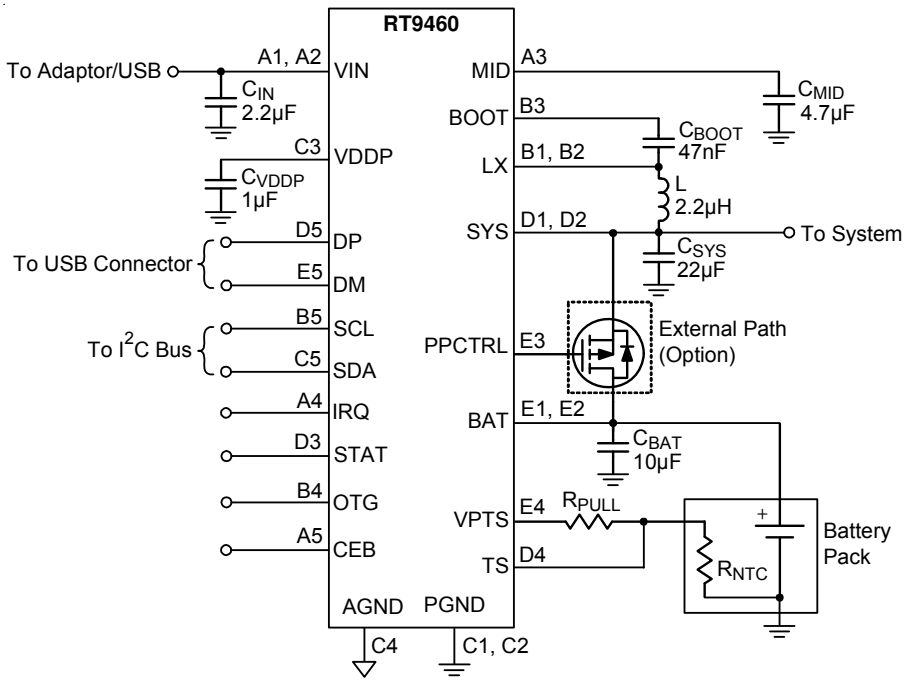
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.

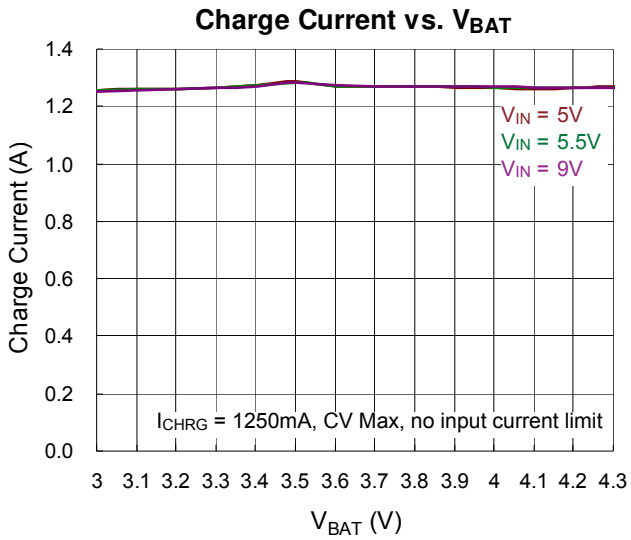
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

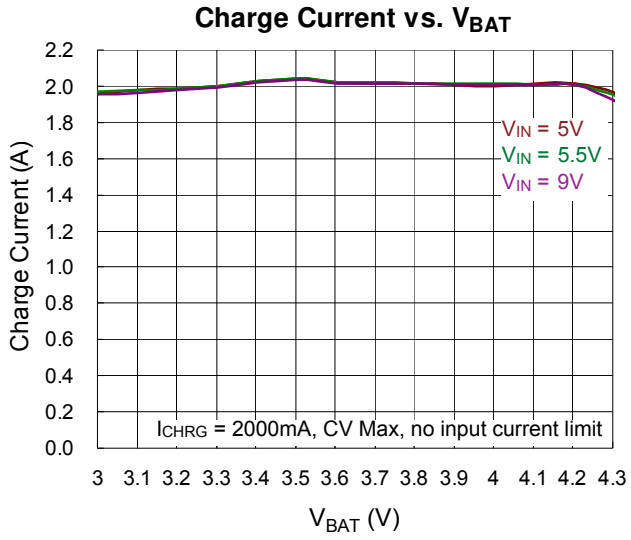
Note 4. The device is not guaranteed to function outside its operating conditions.

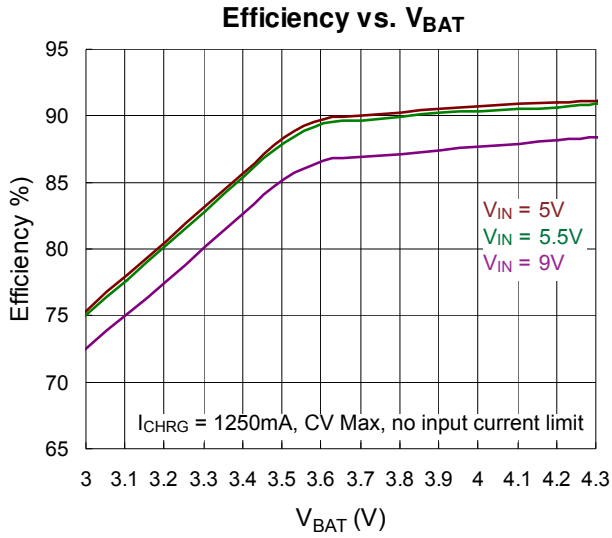
Typical Application Circuit

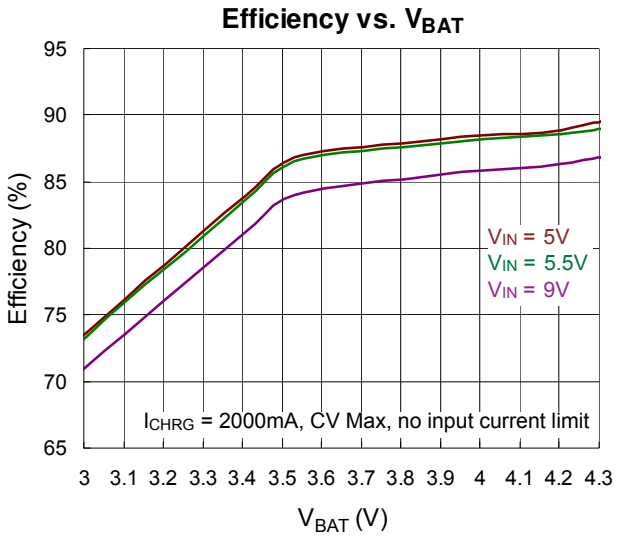


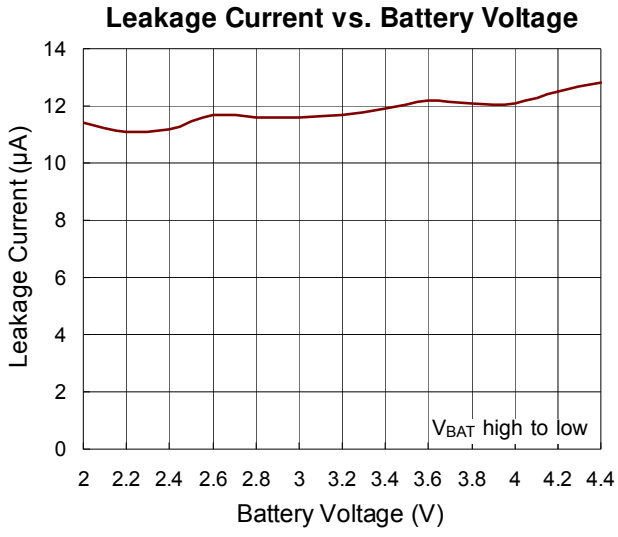
Typical Operating Characteristics

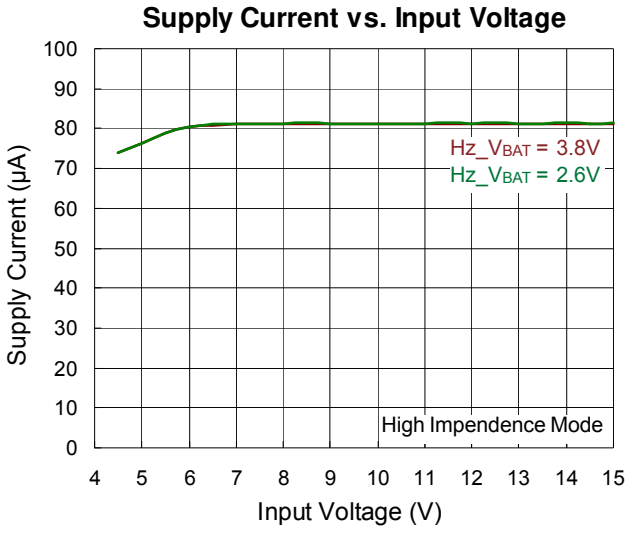


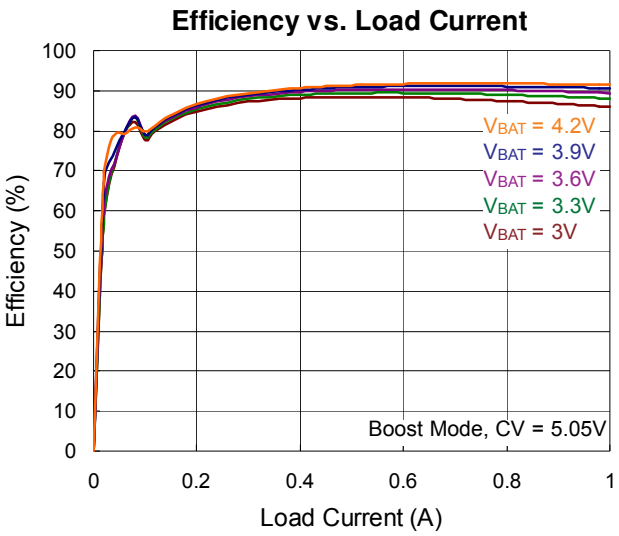


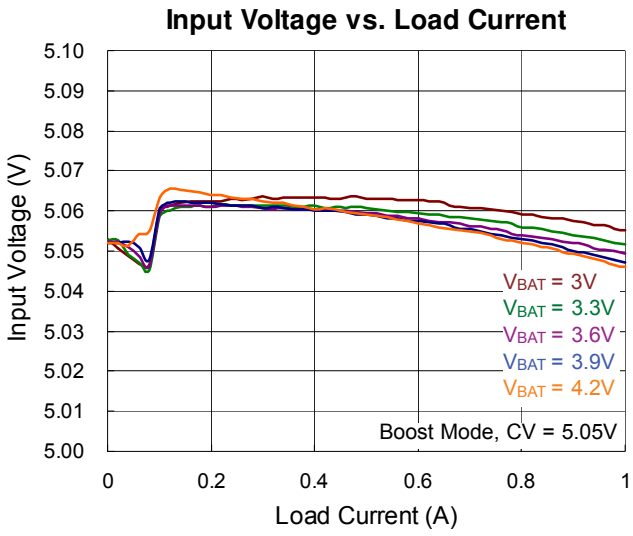












Applications Information

The RT9460 switching charger integrates a synchronous PWM controller with power MOSFETs to provide input voltage MIVR (Minimum Input Voltage Regulation), input current AICR (Active Input Current Regulation), high accuracy current and voltage regulation, and charge termination. The charger also features USB OTG (On-The-Go).

The RT9460 has three operation modes : charge mode, boost mode (USB OTG), and high impedance mode. In charge mode, the RT9460 supports a precision charging system for single cell. In boost mode, the RT9460 works as the boost converter and boosts the voltage from battery to VIN pin for sourcing the OTG devices. In high impedance mode, the RT9460 stops charging or boosting and operates in a mode with low current from VIN or battery to reduce the power consumption when the portable device is in standby mode.

Notice that the RT9460 integrate input power source (AC adapter or USB input) detection. Thus, the RT9460 can automatically set the charge current by option. The charge current needs to be set via I^2C interface by the host. The RT9460 application mechanism and I^2C compatible interface are introduced in later sections.

Charge Mode Operation

Minimum Input Voltage Regulation (MIVR)

The RT9460 features input voltage MIVR function to prevent input voltage drop due to insufficient current provided by the adaptor or USB input. If MIVR function is enabled, the input voltage decreases when the over current of the input power source occurs. VIN is regulated at a predetermined voltage level which can be set as 4V to 8.5V by I^2C interface. At this time, the current drawn by the RT9460 equals to the maximum current value that the input power can provide at the predetermined voltage level, instead of the set value.

Charge Profile

The RT9460 provides a precision Li-ion or Li-polymer charging solution for single-cell applications. Input current limit, charge current, termination current, charge voltage and input voltage MIVR are all programmable via the I^2C interface. In charge mode, the RT9460 has five control loops to regulate input current (AICR), charge current, charge voltage, input voltage (MIVR) and device junction temperature. During the charging process, all five loops (if MIVR is enabled) are enabled and the dominant one will take over the control.

For normal charging process, the Li-ion or Li-polymer battery is charged in three charging modes depending on the battery voltage. At the beginning of the charging process, the RT9460 is in pre-charge mode. When the battery voltage rises above pre-charge threshold voltage (V_{PREC}), the RT9460 enters fast-charge mode. Once the battery voltage is close to the regulation voltage (V_{OREG}), the RT9460 enters constant voltage mode.

Pre-Charge Mode

For life-cycle consideration, the battery can not be charged with large current under low battery condition. When the BATS pin voltage is below pre-charge threshold voltage (V_{PREC}), the charger is in pre-charge mode with a weak charge current witch equals to the pre-charge current (I_{PREC}). There are two control loops in Pre-charge mode. One is the ICC and the other is the MIN_SYS. If the battery voltage is lower than the SYS voltage, the MOSFET won't fully turn-on to prevent the battery voltage to influence the SYS voltage. It features that the charger can also provide the current to the load from SYS even the battery voltage is too low. In pre-charge mode, the charger basically works as an LDO. The pre-charge current also acts as the current limit when the BATS pin is shorted. The Pre-Charge current levels are 100mA - 850mA programmed by I^2C.

Fast-Charge Mode and Settings

As the BAT pin rises above VPREC, the charger enters fast-charge mode and starts charging. Notice that the MUIC integrates input power source (AC adapter or USB input) detection. Thus, the switching charger can set the charge current by option automatically. Unlike the linear charger (LDO), the switching charger (Buck converter) is a current amplifier. The current drawn by the switching charger is different from the current into the battery.

The user can set the Average Input Current Regulation (AICR) and output charge current (I_{CHRG}) respectively.

Cycle-by-Cycle Current Limit

The charger of the RT9460 has an embedded cycle-by-cycle current limit for inductor. Once the inductor current touches the threshold (4.5A typ.), the charger stops charging immediately to prevent over current from damaging the device. Notice that, the mechanism can not be disabled by any way.

Average Input Current Regulation (AICR)

The AICR setting is controlled by I^2C. The AICR100 mode limits the input current to 100mA. The AICR500 mode limits the input current to 500mA. If the application does not need input current limit, it can be disabled also. The AICR levels programmed by I^2C and suitable for USB port and several TA types.

Charge Current (I_{CHG})

The charge current into the battery is determined by the power path sensing RON and ICC setting by I^2C. The voltage between the SYS and BAT pins is regulated to the voltage control by ICC setting. (I_{CC} x R_{ON}, R_{ON} : power path R_{ON})

At RT9460, the R_{ON} is 35mΩ and the Fast-Charge currents is set by the I^2C interface from 1.25A to 3.125A per 125mA.

Constant Voltage Mode and Settings

The RT9460 enters constant voltage mode when the BATS voltage is close to the output-charge voltage (V_{OREG}). In this mode, the charge current begins to decrease. For default settings (charge current termination is disabled), the RT9460 does not turn off and always regulates the battery voltage at VOREG. However, once the charge current termination is enabled, the charger terminates if the charge current is below termination current (I_{EOC}) in constant-voltage mode. The charge current termination function is controlled by the I^2C interface.

After termination, a new charge cycle restarts when one of the following conditions is detected :

- The BATS pin voltage falls below the V_{OREG} - V_{RECH} threshold.
- VIN Power On Reset (POR).
- CHG_EN bit toggle or RST bit is set (via I^2C interface).

Output Charge Voltage (V_{OREG})

The output-charge voltage is set by the I^2C interface from 3.5V to 4.62V per 25mV. The default value is 4V (011001).

Termination Current (I_{EOC})

If the charger current termination is enabled (TE bit = " 1" of REG0x01[3]), the end-of-charge current is determined by both termination current sense voltage (V_{EOC}) and power path sense resistor (R_{ON}). General R_{ON} is 35mΩ, IEOC is set by the I^2C interface from 100mA to 450mA per 50mA.

Input Voltage Protection in Charge Mode

During charge mode, there are two protection mechanisms against if input power source capability is less than the charging current setting. One is AICR and the other is minimum input voltage regulation. A suitable level of AICR can prevent VBUS drop by the insufficient capability. As the AICR setting is not suitable, MIVR will regulate the VBUS in the setting level and sink the maximum current of power source.

Sleep Mode (V_{IN} - V_{BATS} < V_{SLP})

The RT9460 enters sleep mode if the voltage drop between the VIN and BATS pins falls below V_{SLP}. In sleep mode, the reverse blocking switch and PWM are all turned off. This function prevents battery drain during poor or no input power source.

Input Over Voltage Protection

When VBUS rises above the input over voltage threshold, the switching charger stops charging and sets the fault status bits. The condition is released when VBUS falls below OVP threshold. The switching charger then resumes charging operation.

Boost Mode Operation (OTG)

Trigger and Operation

The RT9460 features USB OTG support. When OTG function is enabled, the synchronous boost control loop takes over the power MOSFETs and reverses the power flow from the battery to the VIN pin. In normal boost mode, the VIN pin is regulated to the level controlled by VOREG[5:0] from 4.425V to 5.825 per 25mV. The boost provides up to 1A current to support other OTG devices connected to the USB connector.

Output Over Voltage Protection

In boost mode, the output over voltage protection is triggered when the VIN voltage is above the output OVP threshold. When OVP occurs, the boost converter stops switching and turns off immediately.

Output Overload Protection

The RT9460 provides an overload protection to prevent the device and battery from damage when VIN is overload. Once overload condition is detected, the reverse blocking switch operates in linear region to limit the output current while the MID voltage remains in voltage regulation. If the overload condition lasts for more than 32ms, the RT9460 will recognize the overload fault condition and resets registers to the default settings.

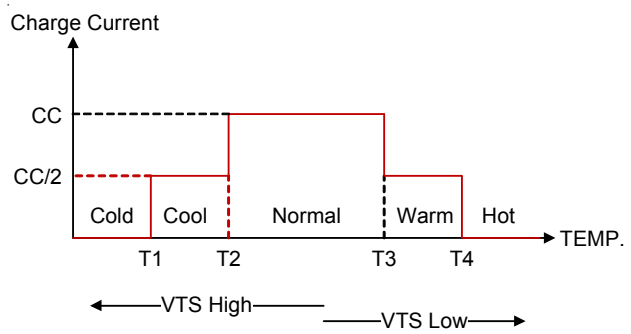
Battery Detection During Normal Charging

The RT9460 provides a battery absent detection scheme to detect insertion or removal of the battery pack. The battery detection scheme is valid only when both TE = 1 and BATD_EN = 1.

During normal charging process, once the charge done condition is satisfied (V_{BATS} > V_{OREG} - V_{RECH} and termination current is detected), the RT9460 turns off the PWM converter and initiates a discharge current (detection current) for a detection time period. After that, the RT9460 checks the BATS voltage. If it is still above the recharge threshold, the battery is present and charge done is detected. If the BATS voltage is below the recharge threshold, the battery is absent. Thus, the RT9460 stops charging and the charge parameters are reset to the default values. The charge resumes after a period of tDET (2sec. typ.).

JEITA Protection

To enhance thermal protection of battery, JEITA function is implemented in theRT9460. JEITA guideline was released in 2007. It includes Warm and cool protection (cool section is between T1 and T2; warm section is between T3 and T4, see the figure as below). When battery's temperature is in warm or cool section, the RT9460 will reduce charging current (by a half of CC mode current). The RT9460 stop charging if temperature is lower than T1 or is higher than T4.

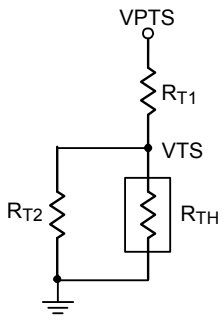


Thermal of battery can be monitored by TS PIN. There are 4 sections should be implemented in JEITA function. Base on R_{hot} and R_{cold}, RT1 and RT2 can be determined by equation (1) and equation (2).

(R_{hot} mean that system trigger battery OTP, R_{cold} mean that system trigger battery low temperature protection.)

$$R_{T1} = VPTS \times [(1/ V_{T1} - 1/ V_{T4})/(1 / R_{Cold} - 1 / R_{Hot})] \quad (1)$$

$$R_{T2} = R_{T1} \times [1 / (VPTS / V_{T1} - R_{T1} / R_{Cold} - 1)] \quad (2)$$



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 θ_{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, θ_{JA}, is layout dependent. For WL-CSP-25B 2.52x2.52 package, the thermal resistance, θ_{JA}, is 32.1°C/W on a standard JEDEC 51-7 four-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) / (32.1°C/W) = 3.11W for WL-CSP-25B 2.52x2.52 package

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

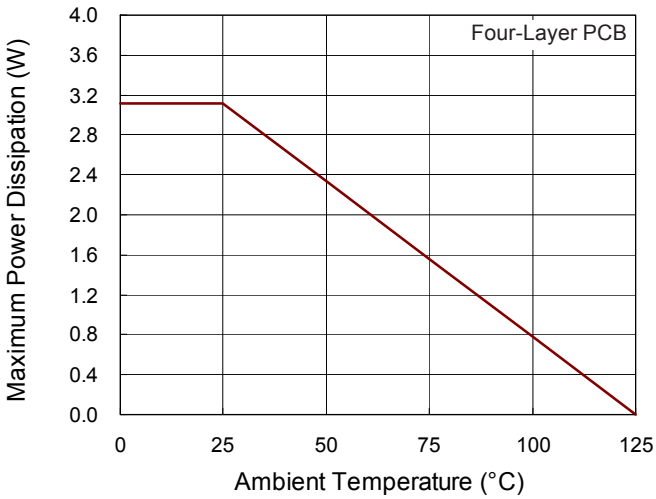


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Considerations

- For AGND noise reduction, PGND and AGND should connect directly at top layer.
- For AGND noise reduction, PGND and AGND should be connected by ground plane at inner layer1. And this ground plane should be connected to system ground plane by via.
- VBUS and VMID (capacitor GND) should be connected to IC PGND directly at top layer.
- The output inductor and bootstrap capacitor should be placed close to the RT9460 and LX pins.

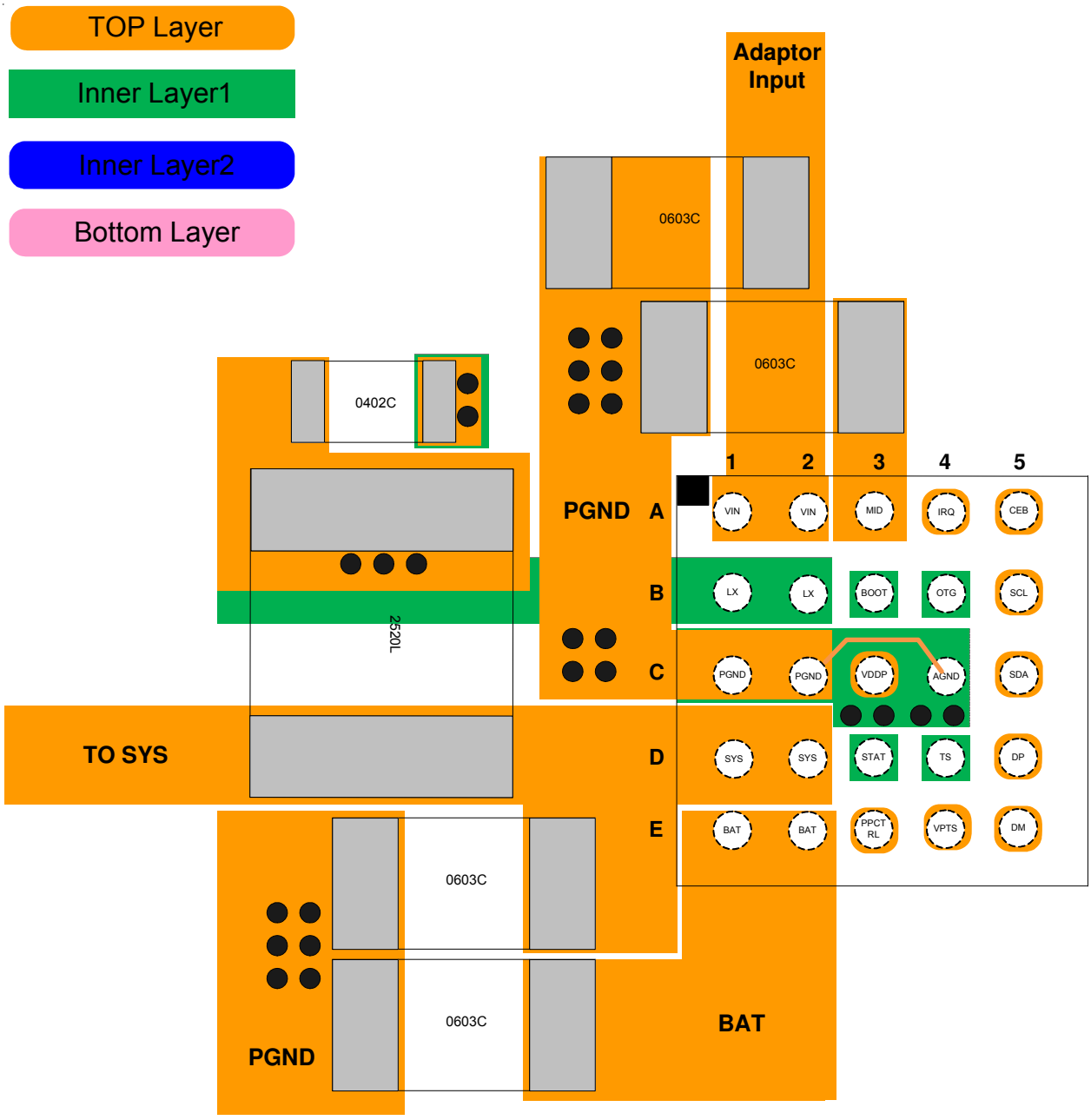


Figure 2. PCB Layout Guide

Control Register (Control)

I²C Slave Address : 0100101

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x03	Device ID	VENDOR_ID				CHIP_REV			
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
0x00	Control1	Sel_ SWFreq	EN_ STAT	STAT		BOOST	PWR_ Rdy	OTG_ PinP	MIVR
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R	R	R	R	R	R
0x01	Control2	IEOC[2:0]			Higher_ OCP	TE	IIN_INT	HZ	OPA_ MODE
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x02	Control3	VOREG[5:0]						OTG_PL	OTG_EN
	Reset Value	0	1	1	0	0	1	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x04	Control4	RST	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x05	Control5	SYSUVP_ HW_SEL	OTG_OC	SYS_Min[1:0]		IPREC[3:0]			
	Reset Value	1	0	0	1	0	0	1	1
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x06	Control6	ICHRG[3:0]				EN_OSCSS	VPREC[2:0]		
	Reset Value	0	0	0	0	0	0	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x07	Control7	CC_JEITA	BATD_EN	Chip_EN	CHG_EN	TS_HOT	TS_ WARM	TS_COOL	TS_COLD
	Reset Value	0	0	1	1	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x1C	Control8	Reserved	Reserved	Reserved	Reserved	Reserved	PPSenseNode [2:0]		
	Reset Value	1	0	0	1	1	1	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x08	IRQ1	TSDI	VINOVPI	WakeUpI	WatchDogI	Reserved	CHTERM_ TMRI	SYSUVP	BATAB
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x09	IRQ2	CHRVPI	CHBADI	CHBATOVI	CHTERMI	CHRCHGI	CHTMRI	CHTREGI	SYSWAKEUPI
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
0x0A	IRQ3	BSTVINOVI	BSTOLI	BSTLOWVI	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
0x0B	Mask 1	TSDIM	VINOVPIM	WakeUpIM	WatchDogIM	Reserved	CHTERM_TMRIM	SYSUVPIM	BATABM
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x0C	Mask 2	CHRVPIM	CHBADIM	CHBATOVIM	CHTERMIM	CHRCHGIM	CHTMRIM	CHTREGIM	SYSWAKEUPIM
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x0D	Mask 3	BSTVINOVIM	BSTOLIM	BSTLOWVIM	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x0E	Control-DPDM	CHG_TYP[2:0]			IINLMTSEL[1:0]		CHG_2DET	CHG_1DET	CHGRUN
	Reset Value	0	0	0	1	0	1	1	0
	Read/Write	R	R	R	R/W	R/W	R/W	R/W	R
0x21	Control 9	Reserved	PPC_CTRL_SEL	EN_PPCTRL	MIVR_ENB	MIVR_LVL[3:0]			
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x22	Control 10	CLR_DP	DP_STAT	WT_FC[2:0]			WT_PRC[1:0]		TMR_Pause
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R	R/W	R/W	R/W	R/W	R/W	R/W
0x23	Control 11	AICR[4:0]					Reserved		
	Reset Value	0	0	1	0	1	1	1	1
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x24	Control 12	EOC_Timer[1:0]		WakeUp_Timer[2:0]			WK_ Timer_EN	IRQ_ Pulse	IRQ_REZ
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x25	Control 13	WDT_EN	Reserved	Reserved	TWDTRST	Reserved	Reserved	TWDT[1:0]	
	Reset Value	0	0	0	1	0	0	1	1
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x26	STAT IRQ	TSHOTI	TSWARMI	TSCOOLI	TSCOLDI	PWR_RdyI	MIVRI	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
0x27	STAT IRQ Mask	TSHOTIM	TSWARMIM	TSCOOLI M	TSCOLDI M	PWR_ RdyIM	MIVRIM	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x00	Control 1	Sel_ SWFreq	EN_ STAT	STAT		BOOST	PWR_ Rdy	OTG_ Pinp	MIVR
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R	R	R	R	R	R
Sel_SWFreq		The switching frequency selection bit (Charger/OTG) 0 : The switching frequency is 1.5MHz 1 : The switching frequency is 750kHz							
EN_STAT		0 : Disable STAT pin function 1 : Enable STAT pin function							
STAT		Charger status bit 00 : Ready 01 : Charge in progress 10 : Charge done 11 : Fault							
BOOST		0 : Not in boost mode 1 : Boost mode							
PWR_Rdy		Power status bit 0 : Input power is bad, VIN > VOVP or VIN < VUVLO or VIN < BATS + VSLP 1 : Input power is good, UVLO < VIN < VOVP & VIN > BATS + VSLP							
OTG_PinP		OTG pin polarity 0 : OTG input pin is low 1 : OTG input pin is high							
MIVR		MIVR status pin : 0 : MIVR regulation is inactive 1 : MIVR regulation is active							
0x01	Control 2	IEOC[2:0]			Higher_ OCP	TE	IIN_INT	HZ	OPA_ MODE
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
IEOC		EOC current level setting 000 : 100mA 001 : 150mA 010 : 200mA 011 : 250mA 100 : 300mA 101 : 350mA 110 : 400mA 111 : 450mA							
Higher_OCP		Charger/OTG OCP level selection 0 : OCP = 4.5A 1 : OCP = 6A							
TE		Charge current termination detection and IRQ control 0 : Disable charge current termination 1 : Enable charge current termination							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
IIN_INT		IAICR setting bit 0 : Decided by external OTG pin, 500mA current limit when OTG pin is low and 1A current limit when OTG pin is high 1 : Decided by I^2C IAICR[4:0] and DPDM results, refer to REG0x0E							
HZ		0 : Not high impedance mode 1 : High impedance mode							
OPA_MODE		0 : Charger mode 1 : Boost mode							
0x02	Control 3	VOREG[5:0]						OTG_PL	OTG_EN
	Reset Value	0	1	1	0	0	1	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
VOREG[5:0]		Battery regulation voltage / Boost output voltage. 00 0000 : 3.50V / 4.425V 00 0001 : 3.52V / 4.45V 00 0010 : 3.54V / 4.475V ..... 01 1000 : 3.98V / 5.025 V 01 1001 : 4.00V / 5.05V 01 1010 : 4.02 / 5.075V ..... 10 0111 : 4.28V / 5.4V 10 1000 : 4.30V / 5.425V 10 1001 : 4.32V / 5.45V ..... 10 1110 : 4.42V / 5.575V 10 1111 : 4.44V / 5.6V ..... 11 0110 : 4.58V / 5.775V 11 0111 : 4.60V / 5.8V 11 1000 : 4.62V / 5.825V ..... 11 1111 : 4.62V / 5.825V							
OTG_PL		0 : Active at low level 1 : Active at High level							
OTG_EN		0 : Disable OTG Pin 1 : Enable OTG Pin							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x03	Device ID	VENDOR_ID				CHIP_REV			
	Reset Value	0	1	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
VENDOR_ID		Vendor Identification : Richtek : 0100b							
CHIP_REV		Chip Revision							
0x04	Control 4	RST	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
RST		Write : 1-Charger in reset mode, 0-No effect, Read : always get "0"							
0x05	Control 5	SYSUVP_HW_SEL	OTG_OC	SYS_Min[1:0]		IPREC[3:0]			
	Reset Value	1	0	0	1	0	0	1	1
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
SYSUVP_HW_SEL		System UV protection selection bit 0 : Switching is not turned off when System UVP 1 : Switching is turned off when System UVP							
OTG_OC		Over current protection threshold 0 : 0.5A 1 : 1A							
SYS_Min[1:0]		System minimum regulation voltage 00 : 3.5V 01 : 3.6V 10 : 3.7V 11 : 3.8V							
IPREC[3:0]		0000 : 100mA 0001 : 150mA 0010 : 200mA 0011 : 250mA 0100 : 300mA 0101 : 350mA 0110 : 400mA 0111 : 450mA 1000 : 500mA 1001 : 550mA 1010 : 600mA 1011 : 650mA 1100 : 700mA 1101 : 750mA 1110 : 800mA 1111 : 850mA							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x06	Control 6	ICHRG[3:0]				EN_OSCSS	VPREC[2:0]		
	Reset Value	0	0	0	0	0	0	1	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
ICHRG[3:0]		Charging current setting (Recommed to set REG0x1C [2:0] = 111) 0000 : 1.25A 0001 : 1.375A 0010 : 1.5A …… 0110 : 2A …… 1010 : 2.5A …… 1110 : 3A 1111 : 3.125A							
EN_OSCSS		Enable signal of oscillator spread spectrum 0 : Disable spread spectrum 1 : Enable spread spectrum							
VPREC[2:0]		Pre-Charge voltage threshold 000 : 2V 001 : 2.2V 010 : 2.4V 011 : 2.6V 100 : 2.8V 101 : 3.0V …... 111 : 3.0V							
0x07	Control 7	CC_JEITA	BATD_EN	CHIP_EN	CHG_EN	TS_HOT	TS_WARM	TS_COOL	TS_COLD
	Reset Value	0	0	1	1	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R	R	R	R
CC_JEITA		Charging current setting bit 0 : ICHRG 1 : ICHRG/2							
BATD_EN		Battery detection when charge done 0 : Disable battery detection 1 : Enable battery detection							
CHIP_EN		Chip enable bit 0 : Chip is disabled 1 : Chip is enabled							
CHG_EN		Charger enable bit : 0 : Charger is disabled 1 : Charger is enabled							
TS_HOIT		Temperature status read bit 0 : Normal temperature 1 : Temperature is hot							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
TS_WARM		Temperature status read bit 0 : Normal temperature 1 : Temperature is warm							
TS_COOL		Temperature status read bit 0 : Normal temperature 1 : Temperature is cool							
TS_COLD		Temperature status read bit 0 : Normal temperature 1 : Temperature is cold							
0x1C	Control 8	Reserved	Reserved	Reserved	Reserved	Reserved	PPSenseNode [2:0]		
	Reset Value	1	0	0	1	1	1	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
PPSenseNode [2:0]		Power path current sensing adjustment 100 : default setting …… 111 : recommended setting							
0x08	IRQ 1	TSDI	VINOVPI	WakeUpI	WatchDogI	Reserved	CHTERM_TMRI	SYSUVPI	BATABI
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
TSDI		Thermal shutdown fault. Set if the die temperature exceeds the thermal shutdown threshold							
VINOVPI		VIN over voltage protection 0 : Normal 1 : VINOVP is detected							
WakeUpI		WakeUp timer fault 0 : Normal 1 : WakeUp timer is expired							
WatchDogI		WatchDog timer fault 0 : Normal 1 : WatchDog timer is expired							
CHTERM_TMRI		EOC timer fault 0 : Normal 1 : EOC timer is expired							
SYSUVPI		System UVP fault 0 : Normal 1 : SYSUVP is triggered							
BATABI		Battery absence fault bit 0 : Normal 1 : Battery absence							

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0x09	IRQ 2	CHRVPI	CHBADI	CHBATOVI	CHTERMI	CHRCHGI	CHTMRI	CHTREGI	SYSWAKEUPI
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
CHRVPI		Charger fault. Reverse protection (VIN < BATS + VSLP)							
CHBADI		Charger fault. Bad adaptor (Poor Input source or VIN < VUVLO)							
CHBATOVI		Charger fault. Battery OVP							
CHTERMI		Charge terminated							
CHRCHGI		Recharge request (VBATS < VOREG – VRECH)							
CHTMRI		Charger fault. Timer time-out							
CHTREGI		Charger warning. Thermal regulation loop active							
SYSWAKEUPI		Battery voltage is high enough to wakeup system							
0x0A	IRQ 3	BSTVINOVI	BSTOLI	BSTLOWVI	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R	R	R	R	R	R	R	R
BSTVINOVI		Boost fault. VIN OVP (VIN > VIN_BOVP)							
BSTOLI		Boost fault. Over load							
BSTLOWVI		Boost fault. Battery voltage is too low							
0x0B	Mask 1	TSDIM	VINOVPIM	WakeUpIM	WatchDogIM	Reserved	CHTERM_TMRIM	SYSUVPIM	BATABIM
	Reset Value	0	0	0	0	0	0	0	0
	Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
TSDIM		TSDI fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked							
VINOVPIM		VIN OVP fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked							
WakeUpIM		WakeUp timer interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked							
WatchDogIM		WatchDog timer interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked							
CHTERM_TMRIM		EOC timer interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked							