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5A Single Cell Li-Ion Switching Battery Charger with Direct Charge, Power Path Management and USB OTG Boost Mode

General Description

The RT9468 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, high-accuracy voltage regulation, and charge termination. The charge current is regulated through integrated sensing resistors. The RT9468 also features USB On-The-Go (OTG) support. The RT9468 integrates an easy-to-use direct charge function, simply driving an external MOSFET to enable a direct charge path, as well as over-voltage protection, over-current protection, and watchdog functions.

The RT9468 optimizes for charging task by using a control algorithm to vary the charge rate for different modes, including pre-charge mode, fast charge mode (constant voltage and constant current). The key charge parameters are programmable through an I^2C interface. The RT9468 will resume the charge cycle whenever the battery voltage falls below an internal recharge threshold, and can automatically enter sleep mode if the input power supply is removed.

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

The RT9468 is available in a WQFN-32L 4x4 package.

Applications

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

Features

- **Direct Charge with Over-Voltage Protection, Over-Current Protection and Watchdog**
- **High Efficiency 5A, 1.5MHz Switching Charger with Output Inductor DFE252012F, TOKO**
  - **Charging Efficiency 90.25% at ICHG = 2A**
  - **Charging Efficiency 88.86% at ICHG = 3A**
  - **Charging Efficiency 84.2% at ICHG = 5A**
- **Synchronous 1.5MHz/0.75MHz Fixed-Frequency PWM Controller with Up to 95% Duty Cycle**
- **Power Path Management by BATFET Control**
- **Support High Voltage Input (9V/12V)**
- **Support High Voltage Input Adapter (Pump Express 1.0/2.0/3.0)**
- **Support IR Compensation Function from Charger Output to Cell Terminal**
- **Optimize Input Sourcing Capability to Prevent Overload**
  - **AICR Current Limit Setting via I^2C**
  - **ILIM Pin for Current Limit Setting**
  - **Average Input Current Limit Measurement**
- **Shipping Mode for Battery Leakage Reduction**
  - **Wake Up System, Exit Shipping Mode, and Reset System by $\overline{QON}$ Pin**
- **Automatic Charging**
- **Average Input Current Regulation (AICR) : 0.1A to 3.25A in 50mA Steps**
- **Charge Current Regulation Accuracy : ±7%**
- **Charge Voltage Regulation Accuracy : ±1% (0 to 85°C)**
- **Protection for Overall System Considerations**
  - **Thermal Regulation for Current Reduction and Over-Temperature Protection**
  - **Input Over-Voltage Protection**
  - **Input Bad Adapter Protection**
  - **Battery Over-Voltage Protection**
- **Support ADC Conversion for**
  - **VBUS, VBAT, VSYS, REGN, TS_BAT, IBUS, IBAT, TEMP_JC, TS_BUS,VBATS, IBATS**
- **INT Output for Communication with Host Through I^2C (Watch Dog / Polling Function)**

Ordering Information

RT9468 □□

Package Type
QW : WQFN-32L 4x4 (W-Type)

Lead Plating System
G : Green (Halogen Free and Pb Free)

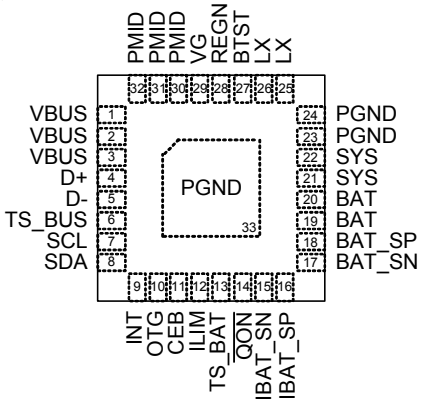
Note :

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.

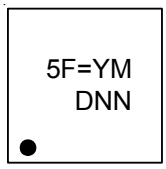
Pin Configuration

(TOP VIEW)



WQFN-32L 4x4

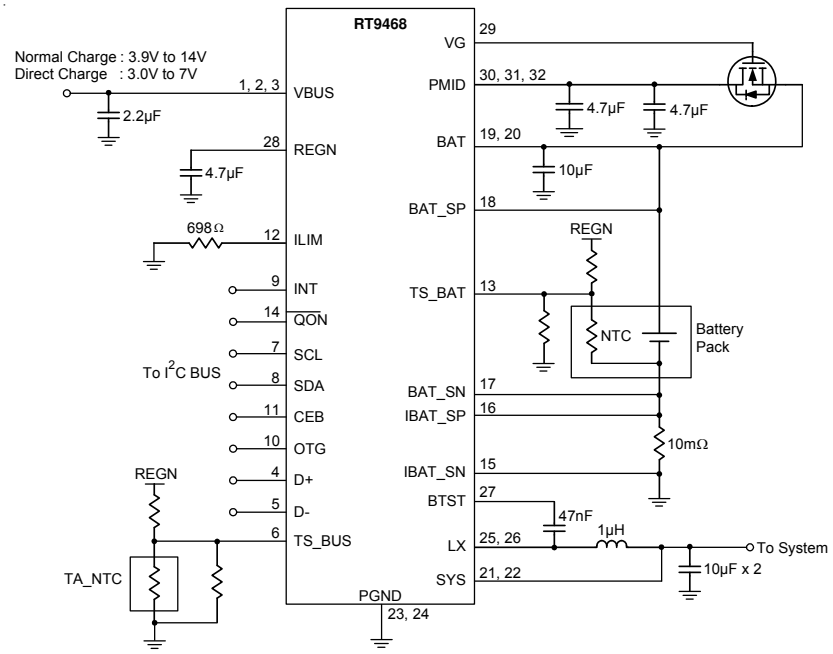
Marking Information



5F= : Product Code

YMDNN : Date Code

Typical Application Circuit



Below are recommended components information

Pin	Description	Part Number	Package	Manufacturer
VBUS	2.2µF/25V/X5R	GRM155R61E225KE11	0402	muRata
PMID	4.7µF/25V/X5R	GRM188R61E475KE11	0603	muRata
BTST	47nF/16V/X5R	GRM033R61C473KE84	0201	muRata
SYS	10µF/6.3V/X5R	GRM185R60J106ME15	0603	muRata
REGN	4.7µF/6.3V/X5R	GRM155R60J475ME47	0402	muRata

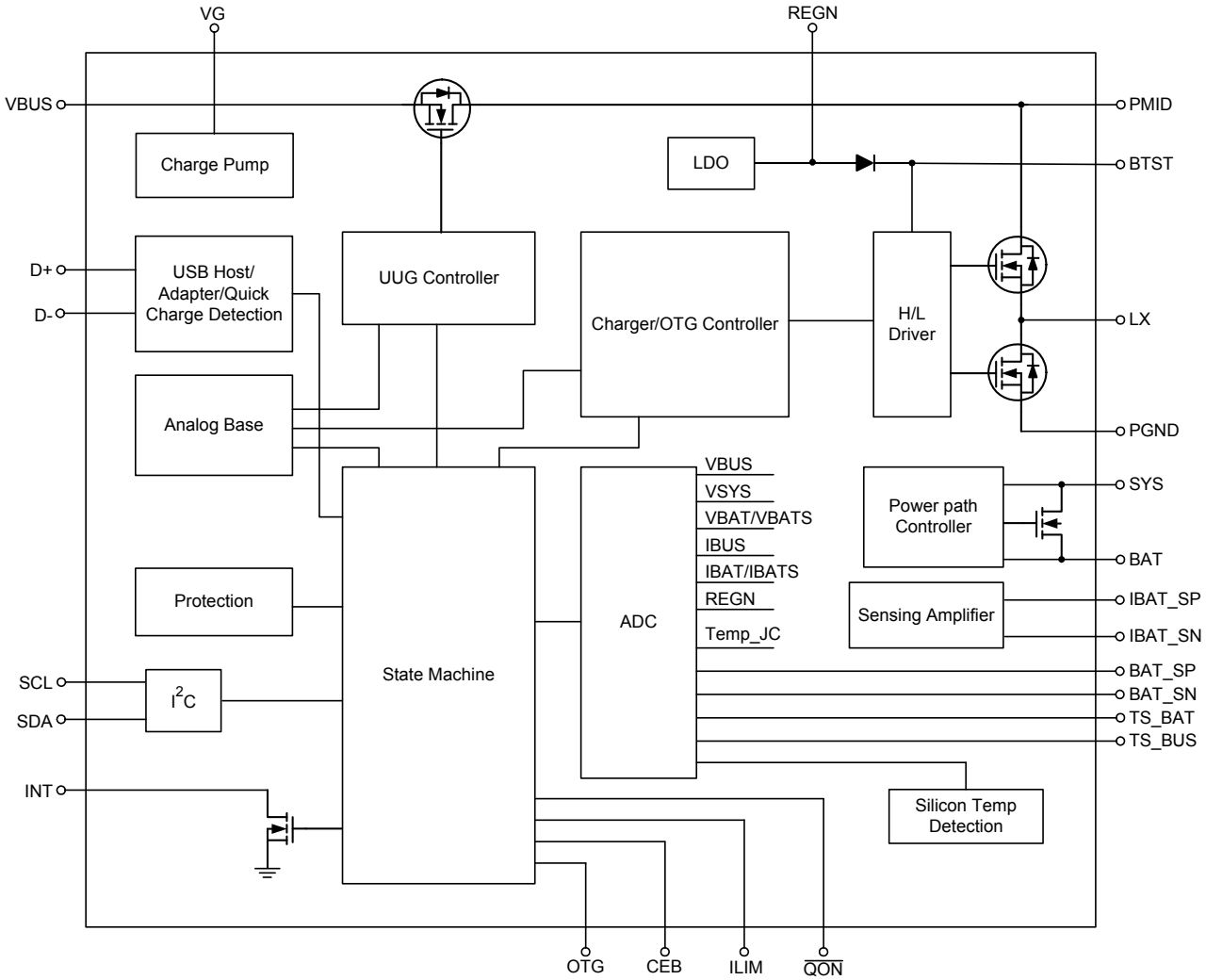
Pin	Description	Part Number	Package	Manufacturer
BAT	10μF/6.3V/X5R	GRM185R60J106ME15	0603	muRata
LX	1μH/20%	DFE252012F-1R0	2.5 x 2.0mm	TOKO
VG	NMOS	DMT2004UFDF_R0	2.0 x 2.0mm	DIODES
ILIM	698Ω/1%	RR0306S-6980-FNH	0201	CYNTEC

Functional Pin Description

Pin No.	Pin Name	Pin Description
1, 2, 3	VBUS	Power input.
4	D+	USB D+ Port Connected to USB Receptacle.
5	D-	USB D- Port Connected to USB Receptacle.
6	TS_BUS	BUS temperature-sense input, connected to a resistor divider for temperature programming. If there is no need for the battery temperature-sense function, a 50kΩ resistor is connected to REGN and another 50kΩ resistor to ground.
7	SCL	I^2C interface serial clock input. Open-drain. An external pull-up resistor is required.
8	SDA	I^2C interface serial data input/output. Open-drain. An external pull-up resistor is required.
9	INT	Interrupt output, active-low open-drain. Indicator of the charger/boost event for system processor.
10	OTG	OTG boost mode enable control, active-high. Act with OTG_PIN_EN (0x01[1]).
11	CEB	Charger enable input, active-low.
12	ILIM	Input current limit setting pin. A resistor is connected from ILIM pin to ground to set the maximum input current limit. The actual input current limit is the lower value set through the ILIM pin and IAICR register bits.
13	TS_BAT	Battery temperature-sense input, connected to a resistor divider for temperature programming. If there is no need for the battery temperature-sense function, a 50kΩ resistor is connected to REGN and another 50kΩ resistor to ground.
14	$\overline{QON}$	Internal BATFET enable control input. In shipping mode, $\overline{QON}$ is pulled Low for the duration of $t_{SHIPMODE}$ (typical 0.9s) to exit shipping mode.
15	IBAT_SN	Negative battery current sense.
16	IBAT_SP	Positive battery current sense.
17	BAT_SN	Negative battery voltage sense.
18	BAT_SP	Positive battery voltage sense.
19, 20	BAT	Battery connection node. Charging current output node. Internal BATFET is connected between SYS and BAT.
21, 22	SYS	System connection node. The internal BATFET is connected between SYS and BAT. Connect a 20μF ceramic capacitor between SYS and ground.
23, 24	PGND	Power ground connection.
25, 26	LX	Switch node for output inductor connection.
27	BTST	Bootstrap capacitor connection for high-side gate driver. Connect a capacitor from BTST to LX to power the internal gate driver.

Pin No.	Pin Name	Pin Description
28	REGN	Regulated output voltage to supply for the PWM low-side gate driver and the bootstrap capacitor. Connect a 4.7μF ceramic capacitor from REGN to GND. 1.If VBUS is plugged in, REGN will be powered by VBUS and regulated to 4.9V. 2.If VBUS is unplugged, the charger will operate in sleep mode and the REGN voltage will be 0V. * For #2. : Since the REGN voltage is also used to power the TS resistor, when the charger is in sleep mode, the REGN will be woken up (be reactivated) if VBAT is greater than forward voltage (V_F) of the internal high-side (HS) MOS diode by V_{SLEEP_EXIT} with all function of the internal ADC being activated and I^2C R/W. The REGN wake-up time is 500ms.
29	VG	Gate driver output for external N-MOSFET.
30, 31, 32	PMID	Connection point between the reverse blocking MOSFET and the high-side switching MOSFET.
33 (Exposed Pad)	PGND	Power ground. The exposed pad must be connected to GND and well soldered to a large PCB copper area for maximum power dissipation.

Functional Block Diagram



Operation

The RT9468 is an integrated single cell Li-ion battery switching charger with power path controller.

Base Circuits

Base circuits provide the internal power, VREGN 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 RT9468 is capable of doing the battery absence detection. The detection protects the charger when battery is removed accidentally.

Adapter Detection

If the poor input power source is connected to the RT9468, the operation will be shut down by the adapter detection.

Power Path Management and Control

Once the battery voltage increases to a defined system minimum regulation voltage, the internal path between SYS and BAT will be fully turned on. That is, a better charging efficiency can be achieved. When end of charge occurs, the charging will stop and the internal path will be turned off.

USB Charger Detection

The RT9468 can detect and distinguish Standard Downstream Port, Charging Downstream Port and Dedicated Charging Port via DP and DM pins.

TS Detection

The RT9468 detects the temperature of the battery pack via REGN and TS pins. The REGN pin provides a constant voltage source to drive the voltage divider composed of a pulled-high resister and a NTC resister. The RT9468 reports the sensing results via IRQ and status bits for COLD, COOL, WARM and HOT.

I^2C Controller

The key parameters of charging and OTG are programmable through I^2C commands.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VBUS ---------- –0.3V to 22V
- Supply Input Voltage, VBUS (Peak <100ns duration) ---------- –2V
- PMID, BTST ---------- –0.3V to 22V
- LX ---------- –0.3V to 16V
- LX (Peak < 100ns duration) ---------- –2V
- PMID – VBUS, BTST – LX ---------- –0.3V to 6V
- Other Pins ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WQFN-32L 4x4 ---------- 3.59W
- Package Thermal Resistance (Note 2)
  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

Recommended Operating Conditions (Note 4)

- Supply Input Voltage ---------- 4V to 14V
- Maximum Input Current (VBUS), I_{AICR} ---------- 3.25A
- Maximum VBUS to PMID Current ---------- 6A
- Maximum SYS Output Current (SW), I_{SYS} ---------- 5A
- Maximum Battery Voltage, VBAT ---------- 4.71V
- Maximum I_{BAT} Fast Charging Current ---------- 5A
- Maximum I_{BAT} Discharging Current ---------- 6A
- Maximum I_{BAT} Discharging Current peak,1sec duration ---------- 9A
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{BUS} = 5V, V_{BAT} = 4.2V, L = 1µH, C_{IN} = 2.2µF, C_{BATS} = 10µF, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Quiescent Current						
V_{BUS} Supply Current	I_{VBUS_SW}	V_{LX} is switching, V_{BUS} = 5V, V_{SYS} = 3.8V	--	8	--	mA
	$I_{VBUS\_NON\_SW}$	V_{LX} Is non-switching, V_{BUS} = 5V, V_{SYS} = 4.4V	--	--	5	mA
	I_{VBUS_HZ}	V_{LX} is in high-impendence mode, V_{BUS} = 5V, V_{SYS} = 3.8V	--	--	150	µA
Battery Leakage Current	I_{BAT_LEAK}	Power path is off, V_{BAT} = 4.2V	--	--	25	µA
Boost-Mode Battery Discharge Current	$I_{BAT\_BOOST\_SW}$	V_{BAT} = 4.2V, boost mode, I_{VBUS} = 0A, V_{LX} is switching	--	5	--	mA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
V_{BUS} / V_{BAT} Power-Up						
Sleep-Mode Entry Threshold, V_{BUS}-V_{BAT}	V_{SLEEP_ENTER}	2.5V < V_{BAT} < V_{OREG}, V_{BUS} falling	0	40	100	mV
Sleep-Mode Exit Threshold, V_{BUS}-V_{BAT}	V_{SLEEP_EXIT}	2.5V < V_{BAT} < V_{OREG}, V_{BUS} rising	40	100	200	mV
Direct Charge Sleep-Mode Entry Threshold, VBUS-VBAT	$V_{SLEEP\_ENTER\_DC}$		--	--	40	mV
Direct Charge Sleep-Mode Exit Threshold, VBUS-VBAT	$V_{SLEEP\_EXIT\_DC}$		40	--	--	mV
Sleep-Mode Exit Deglitch Time	$t_{D\_SLEEP\_EXIT}$	Exit sleep-mode	--	120	--	ms
V_{BUS} Bad Adapter Threshold	V_{BAD_ADP}		--	3.8	--	V
V_{BUS} Bad Adapter Hysteresis	$V_{BAD\_ADP\_HYS}$		--	150	--	mV
V_{BUS} Bad Adapter Sink Current	$I_{BAD\_ADP\_SINK}$		--	50	--	mA
V_{BUS} Bad Adapter Detection Time	$t_{BAD\_ADP\_DET}$		--	30	--	ms
Input Current Limit Factor	K_{ILIM}	Input current regulation 508mA by ILIM pin with resistance = 698Ω	320	355	390	AΩ
Input Current Limit Regulation	I_{ILIM_MIN}	Minimum input current for regulation on ILIM pin	0.5	--	--	A
Input Power Regulation						
Minimum Input Voltage Regulation (MIVR) Threshold Range	V_{MIVR}	I^2C programmable in 0.1V steps	3.9	--	13.4	V
Default Minimum Input Voltage Regulation Threshold	V_{MIVR_DEF}	Default	--	4.4	--	V
Minimum Input Voltage Regulation Accuracy	$V_{MIVR\_ ACC}$	VMIVR = 4.4V, 9V	–3	--	3	%
Average Input Current Regulation Accuracy	I_{AICR_ACC}	USB charge mode, I_{AICR} = 100mA	86	93	100	mA
		USB charge mode, I_{AICR} = 500mA	440	470	500	
		USB charge mode, I_{AICR} = 1000mA	880	940	1000	mA
		Adapter 1.5A charge mode, I_{AICR} = 1500mA	1300	1400	1500	mA
Direct Charge						
Direct Charge UC Level	I_{DIRCHG_UC}		--	650	--	mA
Direct Charge OV Level	V_{DIRCHG_OV}	(V_{DIRCHG_Rising} – V_{OREG})/V_{OREG}	104	108	112	%
Direct Charge OC Setting Range	I_{DIRCHG_OC}		4	--	6.5	A
Direct Charge VBUSOV Setting Range	V_{DIRCHG_VBUSOV}		3.9	--	7	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Direct charge Watch Dog Timer Range	t_{DIRCHG_WDT}		0	--	8	s
Deviation between VG and Battery (V_{VG} – V_{BAT})	V_{VG} – V_{BAT}	V_{BAT} > 3.4V,(0x18,bit[1] = 0)	4.5	5	7	V
		V_{BAT} > 3.4V,(0x18,bit[1] = 1)	8	10	12	V
Protection						
V_{BUS}						
V_{BUS} Under-Voltage Protection Threshold	V_{UVLO}	V_{BUS} rising	3.05	3.3	3.55	V
V_{BUS} Under-Voltage Protection Hysteresis	V_{UVLO_HYS}	V_{BUS} falling from UVLO	--	150	--	mV
V_{BUS} Over-Voltage Protection Threshold	V_{BUS_OVP}	V_{BUS} rising	13.5	14.5	15.5	V
V_{BUS} Over-Voltage Protection Hysteresis	$V_{BUS\_OVP\_HYS}$	V_{BUS} falling	--	250	--	mV
V_{BAT}						
Battery Over-Voltage Protection Threshold	V_{BAT_OVP}	V_{BAT} rising, as percentage of V_{OREG}, as (V_{BAT_OVP}-V_{OREG})/V_{OREG}	106	108	110	%
Battery Over-Voltage Protection Hysteresis	$V_{BAT\_OVP\_HYS}$	V_{BAT} falling, as ($V_{BAT\_OVP\_HYS}$)/V_{OREG}	--	4	--	%
Thermal Protection						
Over-Temperature Protection Threshold	T_{OTP}	Thermal shutdown threshold temperature	--	160	--	°C
Over-Temperature Protection Hysteresis	T_{OTP_HYS}	Thermal shutdown hysteresis temperature	--	30	--	°C
Thermal Regulation Threshold	T_{TR}	Charge current starts decreasing	--	120	--	°C
V_{SYS}						
V_{SYS} Over-Voltage Protection Threshold	V_{SYS_OVP}	V_{SYS} rising	--	5.25	--	V
V_{SYS} Under-Voltage Protection Threshold	V_{SYS_UVP}	V_{SYS} falling	--	2.4	--	V
Battery Charging Stages						
End of Charge						
Regulated Battery Voltage Range	V_{OREG}	I^2C programmable in 10mV steps	3.9	--	4.71	V
Regulated Battery Voltage	V_{OREG_DEF}	Default	--	4.2	--	V
Regulated Battery Voltage Accuracy	V_{OREG_ACC}	Temperature = 0 to 85°C	–1	--	1	%
Re-Charge Mode Threshold	V_{RECH}	V_{BAT} falling, the difference below VOREG , (0x0B[2:0] = 00)	50	100	150	mV
Re-Charge Deglitch Time	t_{D_RECH}		--	120	--	ms

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
End-of-Charge Current	I_{EOC}	I^2C programmable in 50mA steps		100	--	850	mA
Default End-of-Charge Current	I_{EOC_DEF}	Default		--	250	--	mA
End-of-Charge Current Accuracy	I_{EOC_ACC}			–20	--	20	%
Default End-of-Charge Deglitch Time	t_{D_EOC}	Default		--	2	--	ms
Fast Charge							
Charge Current Range	I_{CHG}	I^2C programmable in 0.1A steps		0.1	--	5	A
Charge Current Accuracy	I_{CHG_ACC}	V_{BAT} = 3.8V	I_{CHG} < 500mA	–20	--	20	%
			500mA < I_{CHG} < 1000mA	–10	--	10	%
			I_{CHG} > 1000mA	–7	--	7	%
Pre-Charge							
Pre-Charge Mode Threshold	V_{PRECHG}	I^2C programmable in 0.1V steps		2	--	3.5	V
Pre-Charge Mode Hysteresis	V_{PRECHG_HYS}	Pre-charge hysteresis, falling		--	0.2	--	V
Pre-Charge Mode Threshold Accuracy	V_{PRECHG_ACC}			–5	--	5	%
Pre-Charge Current Range	I_{PRECHG}	I^2C programmable in 50mA steps		100	--	850	mA
Default Pre-Charge Current	I_{PRECHG_DEF}	Default		--	150	--	mA
Pre-Charge Current Accuracy	I_{PREC_ACC}			–20	--	20	%
Trickle Charge							
Trickle Charge Threshold	V_{TRICHG}	VBAT falling		--	2	--	V
Trickle Charge Threshold Hysteresis	V_{TRICHG_HYS}	VBAT rising		--	200	--	mV
Trickle Charge Threshold Accuracy	V_{TRICHG_ACC}			–5	--	5	%
Trickle Current	I_{TRICHG}	VBAT < 2V, charge with ICC = 100mA VBAT < 1.6V, charge with AICR = 100mA		--	100	--	mA
Trickle Current Accuracy	I_{TRICHG_ACC}			–20	--	20	%
V_{SYS}							
System Regulation Voltage	V_{SYSREG}	Minimum system regulation voltage, I^2C programmable in 0.1V steps		3.3	--	4	V
Default System Regulation Voltage	V_{SYSREG_DEF}	Default minimum system regulation voltage		--	3.6	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
System Regulation Accuracy	V_{SYSREG_ACC}		–5	--	5	%
Battery Charger						
UUG On-Resistance	R_{ON_UUG}	From VBUS to PMID	--	15	30	mΩ
High-Side On-Resistance	$R_{ON\_UUG\_UG}$	From VBUS to LX	--	42	79	mΩ
Low-Side On-Resistance	R_{ON_LG}	From LX to PGND	--	28	40	mΩ
Power-Path-Side On-Resistance	R_{ON_PPMOS}	From SYS to BAT	--	13	30	mΩ
Switching Frequency (1.5MHz)	f_{OSC1}	I^2C programmable to 1.5 MHz (0x01[7] = 0)	--	1.5	--	MHz
Switching Frequency (750kHz)	f_{OSC2}	I^2C programmable to 0.75MHz (0x01[7] = 1)	--	0.75	--	MHz
Frequency Accuracy	f_{OSC_ACC}		–10	--	10	%
Maximum Duty Cycle	D_{MAX}	At minimum input voltage	--	97	--	%
Minimum Duty Cycle	D_{MIN}		0	--	--	%
REGN Regulation	V_{REGN}	V_{BUS} = 5V / 9V / 12V	--	4.9	--	V
REGN Current Limit	I_{LIM_REGN}	V_{BUS} = 5V / 9V / 12V	50	--	--	mA
Sink Current for Battery Detection	I_{BAT_SINK}		--	300	--	μA
Internal $\overline{QON}$ Pull-Up Resistance	$R_{\overline{QON}}$		--	200	--	kΩ
Internal $\overline{QON}$ Pull-Up	$V_{\overline{QON}}$	Battery only	--	V_{BAT}	--	V
		V_{BUS} = 5V/9V	--	4.8	--	
$\overline{QON}$ Exit Shipping Mode Time	$t_{SHIPMODE}$	$\overline{QON}$ Low for BATFET on-time to exit shipping mode	--	0.9	--	sec
System Reset by $\overline{QON}$ Pin	$t_{\overline{QON}\_RST}$	$\overline{QON}$ low time to enable full system reset	--	10	--	sec
BATFET Reset Time	t_{BATFET_RST}	BATFET off-time during full system reset	--	0.41	--	sec
Shipping Mode Entry Deglitch Time	$t_{D\_SM\_ENTER}$	Enter shipping mode	--	9	--	sec
AICL	V_{AICL}	V_{BUS} rising, I^2C programmable	--	4.6	--	V
AICL Hysteresis	V_{AICL_HYS}		--	50	--	mV
OTG Boost Mode Operation						
OTG Boost-Mode Output Regulation Voltage Range	V_{OTGBST}	To VBUS	4.425	--	5.825	V
OTG Boost-Mode Output Regulation Voltage Accuracy	V_{OTGBST_ACC}		–3	--	3	%
OTG Boost-Mode Over-Load Protection Threshold	I_{OTG_OLP}	I^2C programmable	0.5	--	2.4	A

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
OTG Boost-Mode Default Over-Load Protection Threshold	$I_{OTG\_OLP\_DEF}$	0x0A [2:0] = 000	--	0.5	--	A
OTG Low Battery Protection Threshold	V_{OTG_LBP}	I^2C programmable, hysteresis = 0.4 V	2.3	--	3.8	V
OTG Default Low Battery Protection Threshold	$V_{OTG\_LBP\_DEF}$	OTG_LBP = 2.8V (Addr0x0A[7:4] = 0101)	--	2.8	--	V
OTG Low Battery Protection Threshold Accuracy			–5	--	5	%
OTG PMID Over-Voltage Protection	$V_{OTG\_PMID\_OVP}$	V_{PMID} rising	--	6	--	V
OTG PMID Over-Voltage Protection Hysteresis	$V_{OTG\_PMID\_OVP\_HYS}$		--	200	--	mV
Inductor Over-Current Protection Threshold	I_{OCP}	Inductor OCP level for both buck and boost modes	--	6	--	A
Current Pulse Control, PE1.0						
Current Pulse Control Stop Pulse	t_{PUMPX_STOP}		430	--	570	ms
Current Pulse Control Long On Pulse	t_{PUMPX_ON1}		240	--	360	ms
Current Pulse Control Short On Pulse	t_{PUMPX_ON2}		70	--	130	ms
Current Pulse Control Off Pulse	t_{PUMPX_OFF}		70	--	130	ms
Current Pulse Control Stop Start Delay	t_{PUMPX_DLY}		80	--	225	ms
I^2C Characteristics						
Output Low Threshold Voltage	$V_{OL\_I^2C}$	I_{DS} = 10mA	--	--	0.4	V
SCL, SDA Input Logic High Threshold Voltage	$V_{IH\_I^2C}$		1.3	--	--	V
SCL, SDA Input Logic Low Threshold Voltage	$V_{IL\_I^2C}$		--	--	0.4	V
SCL Clock	f_{SCL}		--	--	400	kHz
High-Level Leakage Current	I_{BIRS}	V_{PULL_UP} = 1.8V, SDA and SCL	--	--	1	µA
Load Capacitance	C_{LOAD}	V_{PULL_UP} = 1.8V	--	--	1	pF
Default Wait Time for Watch Dog Reset	t_{WDT_DEF}	Watch dog timer selection, Default : 0x0D[6] = 1	--	500	--	ms
NTC Monitor						
Battery Temperature HOT Threshold	V_{VTS_HOT}	V_{TS} falling, the ratio of V_{REGN}	33.5	34.5	35.5	%

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Battery Temperature WARM Threshold	V_{VTS_WARM}	V_{TS} falling, the ratio of V_{REGN}	44	45	46	%
Battery Temperature COOL Threshold	V_{VTS_COOL}	V_{TS} rising, the ratio of V_{REGN}	67.5	68.5	69.5	%
Battery Temperature COLD Threshold	V_{VTS_COLD}	V_{TS} rising, the ratio of V_{REGN}	72.5	73.5	74.5	%
Battery Temperature Hysteresis	V_{VTS_HYS}		--	2	--	%
Control I/O Pin (INT)						
Output Low Voltage	V_{OL_CTRL}	I_{DS} = 10mA	--	--	0.4	V
Control I/O Pin (OTG, CEB, $\overline{QON}$)						
Input Threshold Voltage	V_{IH_CTRL}	Logic high threshold	1.3	--	--	V
	V_{IL_CTRL}	Logic low threshold	--	--	0.4	
Battery Charge Detection Spec (D+/D-)						
VDP_SRC Voltage	V_{DP_SRC}	With I_{DAT_SRC} = 0 to 250μA	0.5	0.65	0.7	V
VDAT_REF Voltage	V_{DAT_REF}		0.25	0.325	0.4	V
VLGC Voltage	V_{LGC}		0.8	1.2	2	V
IDM SINK Current	I_{DM_SINK}	May be a resistance if desired	50	100	150	μA
Data Contact Timeout	t_{DCDT}	Setting by register 0x12[5:4]	--	600	--	ms
ADC						
ADC Conversion Time each Channel	t_{CONV}		35	200	--	ms
Number of Bits for ADC Resolution	RES	Logic high threshold	--	10	--	bit
ADC Accuracy and Measurement Range						
VBUS_DIV5 Measurement Range	$V_{VBUS\_DIV5ADC\_Range}$		1	--	22	V
VBUS_DIV5 Resolution	$V_{VBUS\_DIV5ADC\_RES}$		--	25	--	mV
VBUS_DIV5 Accuracy	$V_{VBUS\_DIV5ADC\_ACC}$		–2	--	2	LSB
VBUS_DIV2 Measurement Range	$V_{VBUS\_DIV2ADC\_Range}$		1	--	9.8	V
VBUS_DIV2 Resolution	$V_{VBUS\_DIV2ADC\_RES}$		--	10	--	mV
VBUS_DIV2 Accuracy	$V_{VBUS\_DIV2ADC\_ACC}$		–2	--	2	LSB
VBAT Measurement Range	$V_{VBAT\ ADC\_Range}$		0	--	4.9	V
VBAT Resolution	$V_{VBAT\ ADC\_RES}$		--	5	--	mV
VBAT Accuracy	$V_{VBAT\ ADC\_ACC}$		–2	--	2	LSB
VSYS Measurement Range	$V_{VSYS\ ADC\_Range}$		0	--	4.9	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
VSYS Resolution	$V_{VSYS\ ADC\_RES}$		--	5	--	mV
VSYS Accuracy	$V_{VSYS\ ADC\_ACC}$		–2	--	2	LSB
REGN Measurement Range	$V_{REGN\ ADC\_Range}$		0	--	4.9	V
REGN Resolution	$V_{REGN\ ADC\_RES}$		--	5	--	mV
REGN Accuracy	$V_{REGN\ ADC\_ACC}$		–2	--	2	LSB
TS_BAT Measurement Range	$Rate_{TS\_BAT}$		0	--	100	%
TS_BAT Resolution	$Rate_{TS\_BAT\_RES}$		--	0.25	--	%
TS_BAT Accuracy	$Rate_{TS\_BAT\ ACC}$		–2	--	2	LSB
IBUS Measurement Range	$I_{IBUS\ ADC\_Range}$		0	--	5	A
IBUS Resolution	$I_{IBUS\ ADC\_RES}$		--	50	--	mA
IBUS Accuracy	$I_{IBUS\ ADC\_ACC}$		–2	--	2	LSB
IBAT Measurement Range	$I_{IBAT\ ADC\_Range}$		0	--	5	A
IBAT Resolution	$I_{IBAT\ ADC\_RES}$		--	50	--	mA
IBAT Accuracy	$I_{IBAT\ ADC\_ACC}$	ICHG[5:0] setting ≥ 1000mA	–2	--	2	LSB
TEMP_JC Measurement Range	$T_{TEMP\_JC\ ADC\_Range}$		–40	--	120	°C
TEMP_JC Resolution	$T_{TEMP\_JC\ ADC\_RES}$		--	2	--	°C
TEMP_JC Accuracy	$T_{TEMP\_JC\ ADC\_ACC}$	Temperature < 85 °C	–2	--	2	LSB
VBATS Measurement Range	$V_{VBATS\_ADC\_Range}$		0	--	4.9	V
VBATS Resolution	$V_{VBATS\_ADC\_RES}$		--	5	--	mV
VBATS Accuracy	$V_{VBATS\_ADC\_ACC}$		–2	--	2	LSB
TS_BUS Measurement Range	$Rate_{TS\_BUS}$		0	--	100	%
TS_BUS Resolution	$Rate_{TS\_BUS\_RES}$		--	0.25	--	%
TS_BUS Accuracy	$Rate_{TS\_BUS\_ACC}$		–2	--	2	LSB
IBATS Measurement Range	$I_{IBAT\ ADC\_Range}$		0	--	5	A
IBATS Resolution	$I_{IBAT\ ADC\_RES}$		--	50	--	mA
IBATS Accuracy	$I_{IBAT\ ADC\_ACC}$		–2	--	2	LSB
External N-MOSFET Selection Specification						
On-Resistance for DS Path	$R_{DS(ON)}$	VGS = 4.5V	--	7	--	mΩ
Drain-to-Source Voltage (AMR)	V_{DS}		--	--	24	V
Gate-to-Source Voltage (AMR)	V_{GS}		–12	--	12	V
Continuous Drain Current	I_D	VGS = 4.5V	8	10	--	A

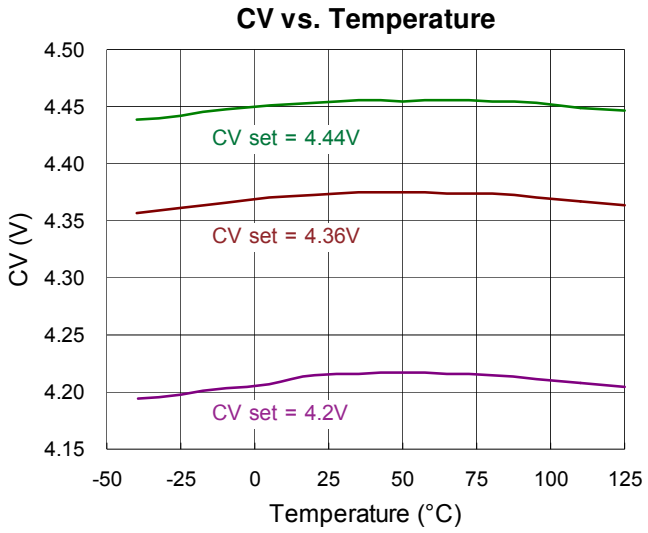
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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

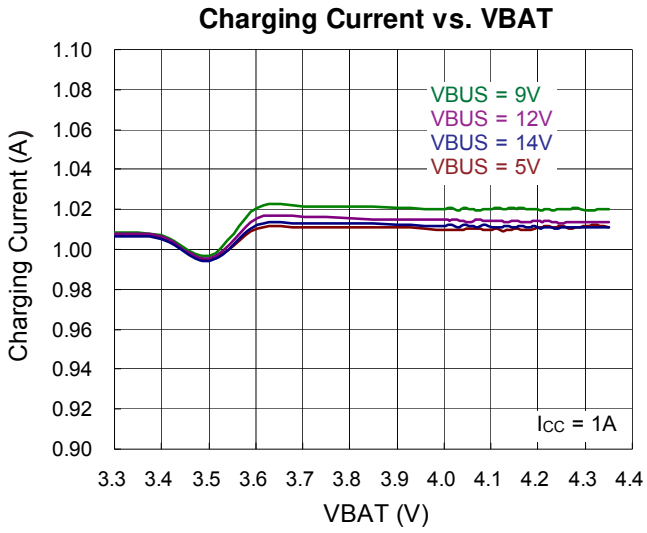
Note 2. θ_{JA} is measured under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard. θ_{JC} is measured at the exposed pad of the package.

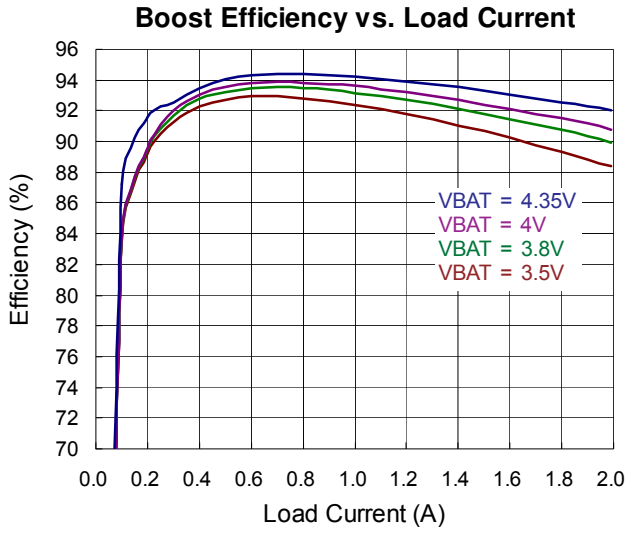
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

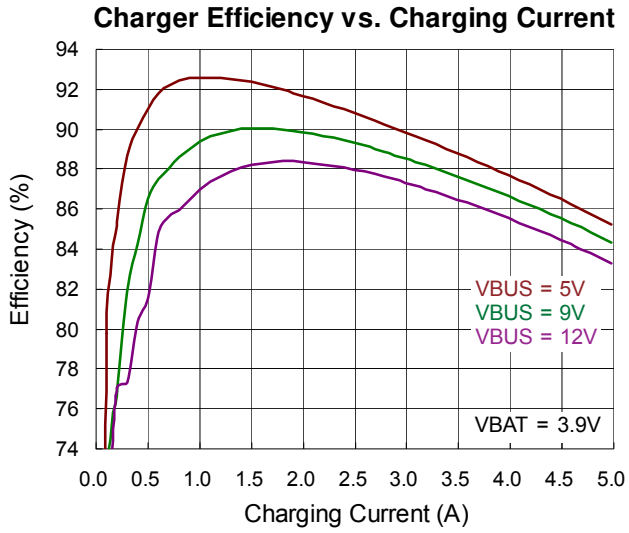
Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics









Register Description

I²C Slave Address : 1011100 (5CH)

Name		Function	Addr	Reset
CORE_CTRL0		Control 0	0x00	0x00
Bit	**Mode**	**Name**	**Reset Value**	**Description**
7	R/W	RST_REG	0	All registers reset bit. 0: Don't reset all registers. 1: Reset all registers. (Notice: 1.This bit will be reset to "0" after reset procedure finish. 2. In high-impedance mode, this bit reset all registers after leave high-impedance mode.)
[6:0]	R/W	Reserved	0000000	Reserved

Name		Function	Addr	Reset
CHG_CTRL1		Control 1	0x01	0x10
Bit	**Mode**	**Name**	**Reset Value**	**Description**
7	R/W	SEL_SWFREQ	0	The switching frequency selection bit (Charger/OTG) 0 : The switching frequency is 1.5MHz. (Default) 1 : The switching frequency is 0.75MHz.
6	R/W	FIXFREQ	0	Charger switching frequency 0 : Charger switching frequency would be varied if VBUS is closed to VBAT(default) 1 : Charger switching frequency is fixed
5	R/W	Reserved	0	Reserved
4	R/W	STAT_EN	1	Charger STAT pin function 0 : Disable 1 : Enable (default)
3	R/W	IRQ_PULSE	0	IRQ reminder function 0 : IRQ reminder is disabled (default) 1 : IRQ reminder is enabled. If IRQ is triggered but no check action, INT pin will be released as well as being triggered again with every 2s intervals
2	R/W	HZ	0	High-impedance selection 0 : No high-impedance mode (default) 1 : High-impedance mode
1	R/W	OTG_PIN_EN	0	Boost mode enable with OTG pin 0 : Enable Boost mode by OPA_MODE (default) 1 : Enable Boost by both OPA_MODE bit and OTG pin
0	R/W	OPA_MODE	0	Boost mode enable 0 : Charge mode (default) 1 : Boost mode for OTG

Name		Function	Addr	Reset
CHG CTRL 2		Charger Control 2	0x02	0x07
Bit	**Mode**	**Name**	**Reset Value**	**Description**
7	R/W	SHIP_MODE	0	Shipping mode enable, force BATFET OFF 0 : Allow BATFET turn on (default) 1 : Force BATFET turn off
6	R/W	BATDET_DIS_DLY	0	BATFET turn off delay 0 : BATFET turn off immediately (default) 1 : BATFET turn off with 10s delay after SHIP_MODE bit is set
5	R/W	BYPASS_MODE	0	"Bypass mode enable, disable the buck but force BATFET on 0 : Bypass mode disable (default) 1 : Bypass mode enable"
4	R/W	TE	0	Termination enable 0 : Disable charge current termination (default) 1 : Enable charge current termination
[3:2]	R/W	IINLMTSEL	01	Input current limit selection bit 00 : Input limit is set as 3.25A 01 : CHG_TYP results is applied D+D- detection (default) 10 : IAICR[5:0] results is applied 11 : Input limit is set by the lowest among above
1	R/W	CFO_EN	1	Charger and OTG enable 0 : CFO is disabled 1 : CFO is enabled (default)
0	R/W	CHG_EN	1	Charger enable 0 : Charger is disabled 1 : Charger is enabled (default)

Name		Function	Addr	Reset
CHG_CTRL3		Control 3	0x03	0x23
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:2]	R/W	IAICR[5:0]	001000	AICR setting 000000 : 100mA 000001 : 150mA 000010 : 200mA 000011 : 250mA ... 001000 : 500mA (default) 001001 : 550mA ... 100110 : 2A ... 111010 : 3A ... 111111 : 3.25A
1	R/W	AICR_EN	1	AICR loop enable 0 : AICR loop disable 1 : AICR loop enable (default)
0	R/W	ILIM_EN	1	ILIM function enable 0 : ILIM function disable 1 : ILIM function enable (default)

Name		Function	Addr	Reset
CHG_CTRL4		Control 4	0x04	0x3C
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:1]	R/W	VOREG[6:0]	0011110	Battery regulation voltage. The battery regulation voltage step is 10mV. 0000000 : 3.9V 0000001 : 3.91V 0000010 : 3.92V 0000011 : 3.93V … 0011101 : 4.19V 0011110 : 4.2V (default) 0011111 : 4.21V … 0101100 : 4.34V 0101101 : 4.35V 0101110 : 4.36V ... 1010001 : 4.71V 1010001 ~ 1111111 : 4.71V
0	R/W	Reserved	0	Reserved

Name		Function	Addr	Reset
CHG_CTRL5		Control 5	0x05	0x67
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:2]	R/W	VOTGBST[5:0]	011001	OTG boost-mode output regulation voltage. The OTG regulation voltage step is 25mV. 000000 : 4.425V 000001 : 4.45V 000010 : 4.475V … 010111 : 5V 011000 : 5.025V 011001 : 5.05V (default) 011010 : 5.075V 011011 : 5.1V ... 111000 : 5.825V 111001 to 111111 : 5.825V
[1:0]	R/W	THREG[1:0]	11	Charger thermal regulation threshold 00 : 60°C 01 : 80°C 10 : 100°C 11 : 120°C (default)

Name		Function	Addr	Reset
CHG_CTRL6		Control 6	0x06	0x0B
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:1]	R/W	VMIVR[6:0]	0000101	Input MIVR threshold setting 0000000 : 3.9V 0000001 : 4V 0000010 : 4.1V 0000011 : 4.2V 0000100 : 4.3V 0000101 : 4.4V (default) 0000110 : 4.5V … 0011110 : 6.9V 0011111 : 7V … 0110010 : 8.9V 0110011 : 9V … 1010000 : 11.9V 1010001 : 12V … 1011111 : 13.4V 1100000 to 1111111 : 13.4V
0	R/W	MIVR_EN	1	MIVR loop enable 0 : MIVR loop disable 1 : MIVR loop enable (default)

Name		Function	Addr	Reset
CHG_CTRL7		Control 7	0x07	0x4C
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:2]	R/W	ICHG[5:0]	010011	Charging regulation current 000000 : 0.1A 000001 : 0.2A 000010 : 0.3A ... 001000 : 0.9A 001001 : 1A 001010 : 1.1A ... 010010 : 1.9A 010011 : 2A (default) ... 011100 : 2.9A 011101 : 3A … 100110 : 3.9A 100111 : 4A … 110000 : 4.9A 110001 : 5A 110010 to 111111 : 5A Note : When ICHG is set above 2.5A, recommend the OCP to set higher level. (Addr 0x0D[2] = 1)
[1:0]	R/W	EOC_TIMER[1:0]	00	EOC back-charge time 00 : 0mins (default) 01 : 30mins 10 : 45mins 11 : 60mins

Name		Function	Addr	Reset
CHG_CTRL8		Control 8	0x08	0xA1
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:4]	R/W	VPREC[3:0]	1010	Pre-charge voltage threshold 0000 : 2V 0001 : 2.1V 0010 : 2.2V 0011 : 2.3V 0100 : 2.4V 0101 : 2.5V 0110 : 2.6V 0111 : 2.7V 1000 : 2.8V 1001 : 2.9V 1010 : 3.0V (default) 1011 : 3.1V 1100 : 3.2V 1101 : 3.3V 1110 : 3.4V 1111 : 3.5V
[3:0]	R/W	IPREC[3:0]	0001	Pre-charge current threshold 0000 : 100mA 0001 : 150mA (default) 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

Name		Function	Addr	Reset
CHG_CTRL9		Control 9	0x09	0x3C
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:4]	R/W	IEOC[3:0]	0011	EOC current setting 0000 : 100mA 0001 : 150mA 0010 : 200mA 0011 : 250mA (default) 0100 : 300mA 0101 : 350mA 0110 : 400mA 0111 : 450mA 1000 : 500mA 1001 : 550mA 1010 : 600mA 1011 : 650mA 1100 : 700mA 1101 : 750mA 1110 : 800mA 1111 : 850mA
3	R/W	EOC_EN	1	IEOC enable/disable 0: Disable 1: Enable (default)
[2:0]	R/W	CHG_TDEG_EOC[2:0]	100	EOC deglitch time 000 : 32μs 001 : 64μs 010 : 128μs 011 : 256μs 100 : 2ms (default) 101 : 4ms 110 : 8ms 111 : 16ms

Name		Function	Addr	Reset
CHG_CTRL10		Control 10	0x0A	0x58
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:4]	R/W	OTG_LBP[3:0]	0101	OTG Low battery protection voltage selection (falling edge threshold, hysteresis voltage = 0.4V) 0000 : 2.3V 0001 : 2.4V 0010 : 2.5V 0011 : 2.6V 0100 : 2.7V 0101 : 2.8V (default) 0110 : 2.9V 0111 : 3.0V 1000 : 3.1V 1001 : 3.2V 1010 : 3.3V 1011 : 3.4V 1100 : 3.5V 1101 : 3.6V 1110 : 3.7V 1111 : 3.8V
3	R/W	OTG_LBP_EN	1	OTG low-battery protection (LBP) enable/disable 0 : Disable 1 : Enable (default)
[2:0]	R/W	OTG_OLP[2:0]	000	OTG over-load threshold (Minimum) 000 : 0.5A (default) 001 : 0.7A 010 : 1.1A 011 : 1.3A 100 : 1.8A 101 : 2.1A 110 : 2.4A 111 : Reserved Note : When OTG_OLP is set 2.1A or 2.4A, recommend the OCP to set higher level. (Addr 0x0D[2] = 1)

Name		Function	Addr	Reset
CHG_CTRL11		Control 11	0x0B	0x2C
Bit	**Mode**	**Name**	**Reset Value**	**Description**
7	R/W	ADP_DIS	0	Charger adapter-detection disable 0 : Adapter-detection is enabled (default) 1 : Adapter-detection is disabled
6	R/W	BATD_EN	0	Charger battery-detection when charge done 0 : Battery-detection is disabled (default) 1 : Battery-detection is enabled
5	R/W	SYSUV_HW_SEL	1	System under-voltage protection (UVP) selection bit 0 : Buck switching is not turned off when system UVP occurs 1 : Buck switching is turned off when system UVP occurs (default)
[4:2]	R/W	SYSREG[2:0]	011	Minimum system regulation voltage 000 : 3.3V 001 : 3.4V 010 : 3.5V 011 : 3.6V (default) 100 : 3.7V 101 : 3.8V 110 : 3.9V 111 : 4.0V
[1:0]	R/W	VRECH	00	Recharge voltage threshold with VOREG 00 : 100mV (default) 01 : 200mV 10 : 300mV 11 : 400mV

Name		Function	Addr	Reset
CHG_CTRL12		Control 12	0x0C	0x02
Bit	**Mode**	**Name**	**Reset Value**	**Description**
[7:5]	R/W	WT_FC[2:0]	000	Fast charge timer 000 : 4hrs (default) 001 : 6hrs 010 : 8hrs 011 : 10hrs 100 : 12hrs 101 : 14hrs 110 : 16hrs 111 : 20hrs
[4:3]	R/W	WT_PRC[1:0]	00	Pre-charge timer 00 : 30mins (default) 01 : 45mins 10 : 60mins 11 : 60mins
2	R/W	TMR2X_EN	0	Double charger timer during MIVR, AICR, and thermal regulation 0 : Disable 2x extended charger timer (default) 1 : Enable 2x extended charger timer
1	R/W	TMR_EN	1	Charger timer enable/disable 0 : Disable 1 : Enable (default)
0	R/W	TMR_PAUSE	0	Timer control bit 0 : Timer is active (default) 1 : Timer is paused