

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

General Description

The RT9466 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 RT9466 also features USB On-The-Go (OTG) support.

The RT9466 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 I²C interface. The RT9466 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 RT9466 is available in a WQFN-24L 4x4 package.

Applications

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

Ordering Information

RT9466 □ □

- Package Type
QW : WQFN-24L 4x4 (W-Type)
(Exposed Pad-Option 2)
- Lead Plating System
G : Green (Halogen Free and Pb Free)

Note :

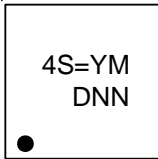
Richtek products are :

- ▶ 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

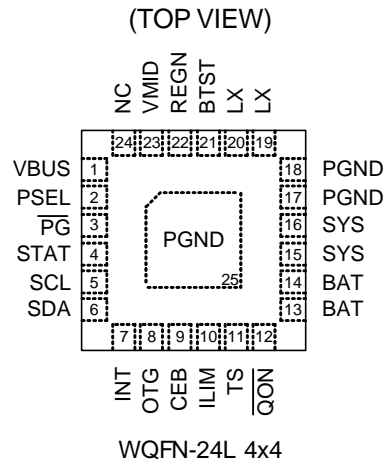
- High Efficiency 5A, 1.5MHz Switching Charger with Output Inductor DFE252012F, TOKO
 - ▶ Charging Efficiency 90.25% at ICHG = 2A
 - ▶ Charging Efficiency 88.86% at ICHG = 3A
 - ▶ Charging Efficiency 84.2% at ICHG = 5A
- Synchronous 1.5MHz/0.75MHz Fixed-Frequency PWM Controller with Up to 95% Duty Cycle
- Power Path Management by BATFET Control
- Support High Voltage Input (9V/12V)
- Support High Voltage Input Adapter (Pump Express 1.0/2.0)
- Support IR Compensation Function from Charger Output to Cell Terminal
- Optimize Input Sourcing Capability to Prevent Overload
 - ▶ AICR Current Limit Setting via I²C
 - ▶ 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 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
- INT Output for Communication with Host Through I²C (Watch Dog/Polling Function)

Marking Information

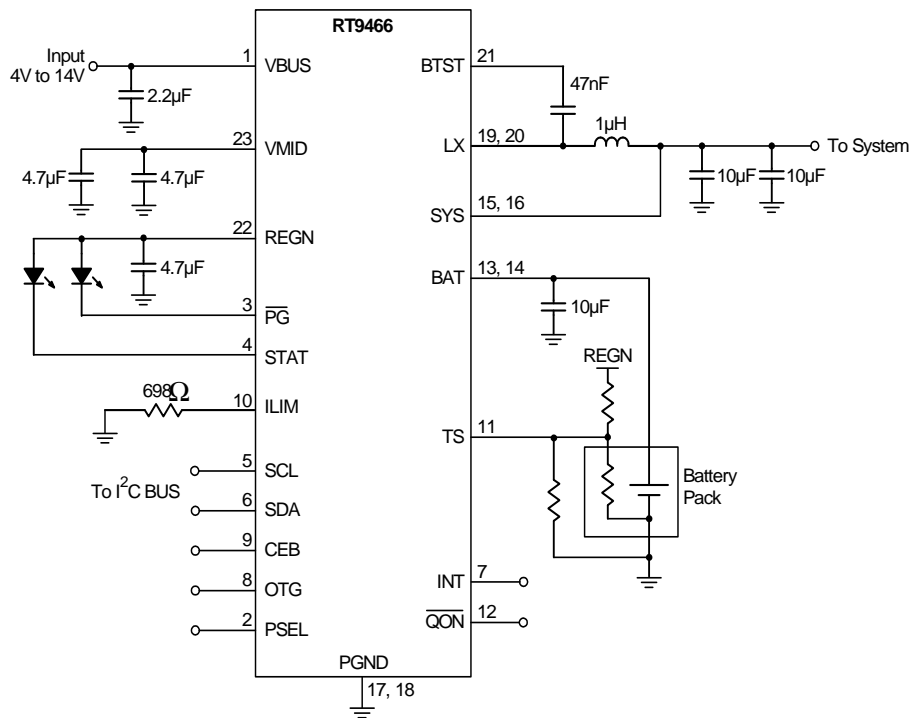


4S= : Product Code
YMDNN : Date Code

Pin Configuration



Typical Application Circuit



Below are recommended components information

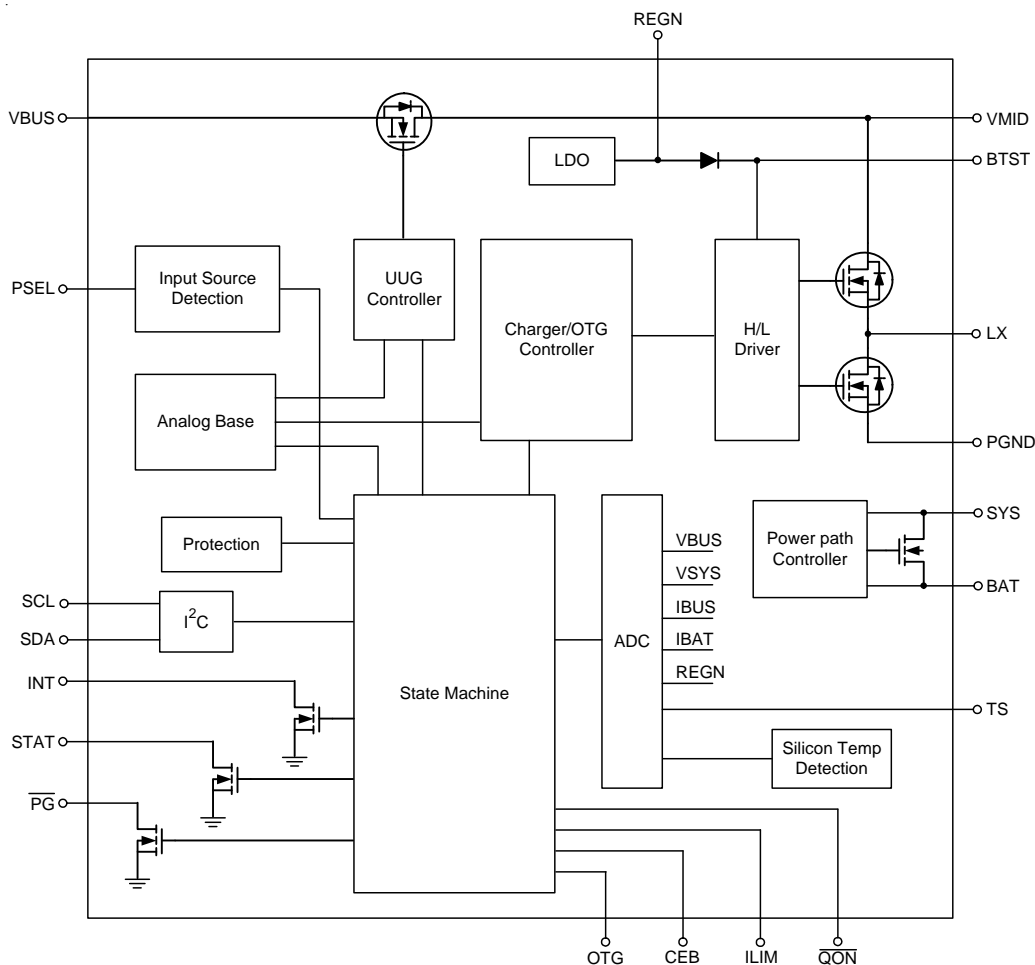
| Pin | Description | Part Number | Package | Manufacturer |
|------|----------------|-------------------|-----------|--------------|
| VBUS | 2.2µF/25V/X5R | GRM155R61E225KE11 | 0402 | muRata |
| VMID | 4.7µF/25V/X5R | GRM188R61E475KE11 | 0603 | muRata |
| BTST | 47nF/16V/X5R | GRM033R61C473KE84 | 0201 | muRata |
| SYS | 10µF/6.3V/X5R | GRM185R60J106ME15 | 0603 | muRata |
| BAT | 10µF/6.3V/X5R | GRM185R60J106ME15 | 0603 | muRata |
| REGN | 4.7µF/6.3V/X5R | GRM155R60J475ME47 | 0402 | muRata |
| LX | 1µH/20% | DFE252012F-1R0 | 2.5 x 2mm | TOKO |
| ILIM | 698Ω/1% | RR0306S-6980-FNH | 0201 | CYNTec |

Functional Pin Description

| Pin No. | Pin Name | Pin Description |
|---------|-------------------------|---|
| 1 | VBUS | Power input. |
| 2 | PSEL | Power source selection input : High : USB host, I _{BUS} = 500mA; Low : adapter source, I _{BUS} = 3.25A, and ILIM select minimum current value. (Internal pull down 102kΩ) |
| 3 | $\overline{\text{PG}}$ | Open-drain output. Low if the VBUS voltage is between V _{UVLO} and V _{VBUS_OVP} ; VBUS is higher than VBAT. VBUS current capability is larger than 50mA. |
| 4 | STAT | Charge status indication, open-drain output that indicates charge is in progress when held low and charge is finished when held High. If any fault occurs, CHG_STAT will blink at the frequency of 1Hz. Connect a 2.2k-10kΩ pull-up resistor. |
| 5 | SCL | I ² C interface serial clock input. Open-drain. An external pull-up resistor is required |
| 6 | SDA | I ² C interface serial data input/output. Open-drain. An external pull-up resistor is required. |
| 7 | INT | Interrupt output, active-low open-drain. Indicator of the charger/Boost event for system processor. |
| 8 | OTG | OTG boost mode enable control, active-high. Act with OTG_PIN_EN (Addr0x01[1]). (Internal pull down 102kΩ) |
| 9 | CEB | Charger enable input, active-low. (Internal pull down 102kΩ) |
| 10 | 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, and PSEL select minimum current value. |
| 11 | TS | 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. |
| 12 | $\overline{\text{QON}}$ | Internal BATFET enable control input. In shipping mode, $\overline{\text{QON}}$ is pulled Low for the duration of t _{SHIPMODE} (typical 0.9s) to exit shipping mode. |
| 13, 14 | BAT | Charge current output node for battery connection. The internal BATFET is connected between VSYS and BAT. Connect a 10μF ceramic capacitor between BAT and ground. |
| 15, 16 | SYS | System connection node. The internal BATFET is connected between SYS and BAT. Connect a 20μF ceramic capacitor between SYS and ground. |
| 17, 18 | PGND | Power ground. |
| 19, 20 | LX | Switch node for output inductor connection. |
| 21 | 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 |
|---------------------|----------|--|
| 22 | 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 (VF) of the internal high-side (HS) MOS diode by VSLEEP_EXIT with all function of the internal ADC being activated and I ² C RW. The REGN wake-up time is 500ms. |
| 23 | VMID | Connection point between the reverse blocking MOSFET and the high-side switching MOSFET. |
| 24 | NC | No internal connection. |
| 25 (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 RT9466 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 RT9466 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 RT9466, 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.

TS Detection

The RT9466 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 resistor and a NTC resistor. The RT9466 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, V_{BUS} ----- -0.3V to 22V
- Supply Input Voltage, V_{BUS} (Peak <100ns duration) ----- -2V
- VMID, BTST ----- -0.3V to 22V
- LX ----- -0.3V to 16V
- LX (Peak <100ns duration) ----- -2V
- VMID – V_{BUS}, BTST – LX ----- -0.3V to 6V
- Other Pins ----- -0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
 - WQFN-24L 4x4 ----- 4.54W
- Package Thermal Resistance (Note 2)
 - WQFN-24L 4x4, θ_{JA} ----- 22°C/W
 - WQFN-24L 4x4, θ_{JC} ----- 5.4°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 (V_{BUS}), I_{AICR} ----- 3.25A
- Maximum SYS Output Current (SW), I_{SYS} ----- 5A
- Maximum Battery Voltage, V_{BAT} ----- 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-impedance mode, V _{BUS} = 5V, V _{SYS} = 3.8V | -- | -- | 170 | μA |
| Battery Leakage Current | I _{BAT_LEAK_OFF} | V _{BAT} = 4.2V, power path is off. SCL and SDA pull low, no V _{BUS} . | -- | -- | 25 | μA |
| | I _{BAT_LEAK_ON} | V _{BAT} = 4.2V. SCL and SDA pull low, no V _{BUS} . | -- | -- | 60 | μA |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--|---------------------------|---|------|------|------|------|
| Boost-Mode Battery Discharge Current | I _{BAT_BOOST_SW} | V _{BAT} = 4.2V, boost mode, I _{VBUS} = 0A, V _{LX} is switching | -- | 5 | -- | mA |
| 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 |
| 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 ² C 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} | V _{MIVR} = 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 |
| 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 |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|--------------------------|---|-----|------|------|------|
| V _{BUS} Over-Voltage Protection Threshold | V _{BUS_OVP} | V _{BUS} rising | 14 | 14.5 | 15 | 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 ² C 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°C to 85°C | -1 | -- | 1 | % |
| Re-Charge Mode Threshold | V _{RECH} | V _{BAT} falling, the difference below V _{OREG} , (Addr 0x0B[2:0] = 00) | 50 | 100 | 150 | mV |
| Re-Charge Deglitch Time | t _{D_RECH} | | -- | 120 | -- | ms |
| End-of-Charge Current | I _{EOC} | I ² C 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 ² C programmable in 0.1A steps | 0.1 | -- | 5 | A |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit | |
|-------------------------------------|-------------------------|---|-----------------------------------|-----|-----|------|---|
| 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 ² C 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 ² C 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} | V _{BAT} falling | -- | 2 | -- | V | |
| Trickle Charge Threshold Hysteresis | V _{TRICHG_Hys} | V _{BAT} rising | -- | 200 | -- | mV | |
| Trickle Charge Threshold accuracy | V _{TRICHG_acc} | | -5 | -- | 5 | % | |
| Trickle Current | I _{TRICHG} | V _{BAT} < 2V, charge with ICC = 100mA V _{BAT} < 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 ² C programmable in 0.1V steps | 3.3 | -- | 4 | V | |
| Default System Regulation Voltage | V _{SYSREG_DEF} | Default minimum system regulation voltage | -- | 3.6 | -- | V | |
| System Regulation Accuracy | V _{SYSREG_ACC} | | -5 | -- | 5 | % | |
| Battery Charger | | | | | | | |
| UUG On-Resistance | R _{ON_UUG} | From V _{BUS} to V _{MD} | -- | 17 | 32 | mΩ | |
| High-Side On-Resistance | R _{ON_UUG_UG} | From V _{BUS} 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 ² C programmable to 1.5 MHz (Addr 0x01[7] = 0) | -- | 1.5 | -- | MHz | |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|--------------------------|---|-------|------------------|-------|------|
| Switching Frequency (750kHz) | f _{OSC2} | I ² C programmable to 0.75MHz (Addr 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 QON Pull-Up Resistance | R _{QON} | | -- | 200 | -- | kΩ |
| Internal QON Pull-Up | V _{QON} | Battery only | -- | V _{BAT} | -- | V |
| | | V _{BUS} = 5V/9V | -- | 4.8 | -- | |
| QON Exit Shipping Mode Time | t _{SHIPMODE} | QON Low for BATFET on-time to exit shipping mode | -- | 0.9 | -- | sec |
| System Reset by QON Pin | t _{QON_RST} | 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 ² C programmable | -- | 4.6 | -- | V |
| AICL Hysteresis | V _{AICL_HYS} | | -- | 50 | -- | mV |
| Inductor Over-Current Protection Buck Threshold | I _{OCP_BUCK} | Inductor OCP level for buck mode | -- | 6 | -- | A |
| OTG Boost Mode Operation | | | | | | |
| OTG Boost-Mode Output Regulation Voltage Range | V _{OTGBST} | To V _{BUS} | 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 ² C programmable | 0.5 | -- | 2.4 | A |
| OTG Boost-Mode Default Over-Load Protection Threshold | I _{OTG_OLP_DEF} | Addr 0x0A [2:0] = 000 | 0.5 | -- | -- | A |
| OTG Low Battery Protection Threshold | V _{OTG_LBP} | I ² C 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 |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--|------------------------|---|------|------|------|------|
| OTG Low Battery Protection Threshold Accuracy | | | -5 | -- | 5 | % |
| OTG VMID Over-Voltage Protection | VOTG_VMID_OVP | VVMID rising | -- | 6 | -- | V |
| OTG VMID Over-Voltage Protection Hysteresis | VOTG_VMID_OVP_HYS | | -- | 200 | -- | mV |
| Inductor Over-Current Protection Boost Threshold | I _{OCP_BOOST} | Inductor OCP level for boost mode | -- | 5.5 | -- | A |
| Current Pulse Control, PE1.0 | | | | | | |
| Current Pulse Control Stop Pulse | tPUMPX_STOP | | 430 | -- | 570 | ms |
| Current Pulse Control Long On Pulse | tPUMPX_ON1 | | 240 | -- | 360 | ms |
| Current Pulse Control Short On Pulse | tPUMPX_ON2 | | 70 | -- | 130 | ms |
| Current Pulse Control Off Pulse | tPUMPX_OFF | | 70 | -- | 130 | ms |
| Current Pulse Control Stop Start Delay | tPUMPX_DLY | | 80 | -- | 225 | ms |
| I²C Characteristics | | | | | | |
| Output Low Threshold Voltage | V _{OL_I2C} | I _{DS} = 10mA | -- | -- | 0.4 | V |
| SCL, SDA Input Logic High Threshold Voltage | V _{IH_I2C} | | 1.3 | -- | -- | V |
| SCL, SDA Input Logic Low Threshold Voltage | V _{IL_I2C} | | -- | -- | 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 | % |
| 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 | % |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--|-------------------------------------|------------------------|-----|------|-----|------|
| Battery Temperature Hysteresis | VVTS_HYS | | -- | 2 | -- | % |
| Control I/O Pin (STAT, PG , INT) | | | | | | |
| Output Low Voltage | VOL_CTRL | I _{DS} = 10mA | -- | -- | 0.4 | V |
| Control I/O Pin (OTG, CEB, PSEL, QON) | | | | | | |
| Input Threshold Voltage | V _{IH_CTRL} | Logic high threshold | 1.3 | -- | -- | V |
| | V _{IL_CTRL} | Logic low threshold | -- | -- | 0.4 | |
| 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_R} ange | | 1 | -- | 22 | V |
| VBUS_DIV5 Resolution | V _{VBUS_DIV5ADC_R} ES | | -- | 25 | -- | mV |
| VBUS_DIV5 Accuracy | V _{VBUS_DIV5ADC_A} CC | | -2 | -- | 2 | LSB |
| VBUS_DIV2 Measurement Range | V _{VBUS_DIV2ADC_R} ange | | 1 | -- | 9.8 | V |
| VBUS_DIV2 Resolution | V _{VBUS_DIV2ADC_R} ES | | -- | 10 | -- | mV |
| VBUS_DIV2 Accuracy | V _{VBUS_DIV2ADC_A} CC | | -2 | -- | 2 | LSB |
| VBAT Measurement Range | V _{VBAT ADC_R} ange | | 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_R} ange | | 0 | -- | 4.9 | V |
| VSYS Resolution | V _{VSYS ADC_RES} | | -- | 5 | -- | mV |
| VSYS Accuracy | V _{VSYS ADC_ACC} | | -2 | -- | 2 | LSB |
| REGN Measurement Range | V _{REGN ADC_R} ange | | 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 |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---------------------------|--------------------------------|--------------------|-----|-----|------|------|
| IBUS Measurement Range | I _{IBUS} ADC_Range | | 0 | -- | 3.25 | 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 | | -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 |

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.

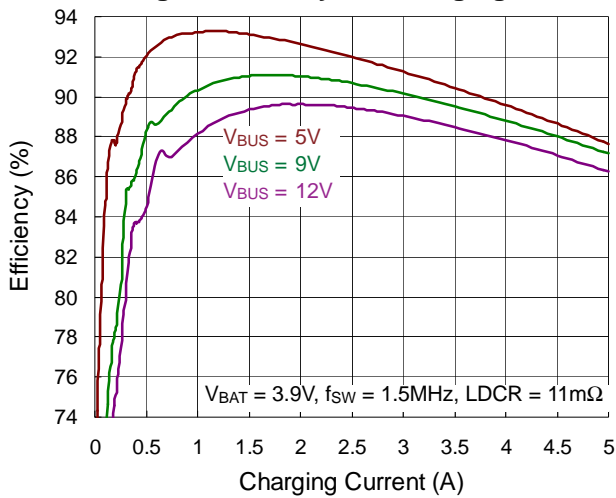
Note 2. θ_{JA} is measured in the natural convection at $T_A = 25^\circ\text{C}$ on a Four-layer Richtek Evaluation Board. θ_{JC} is measured at the Top of the package.

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

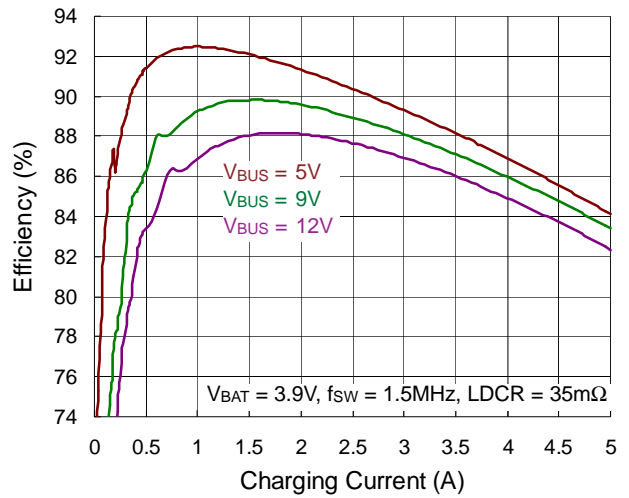
Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

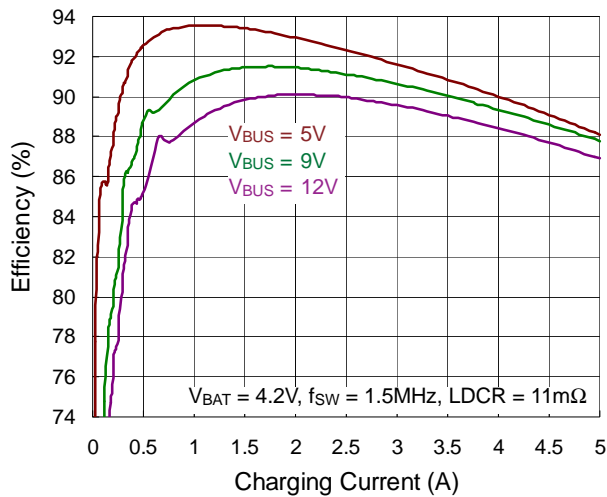
Charger Efficiency vs. Charging Current



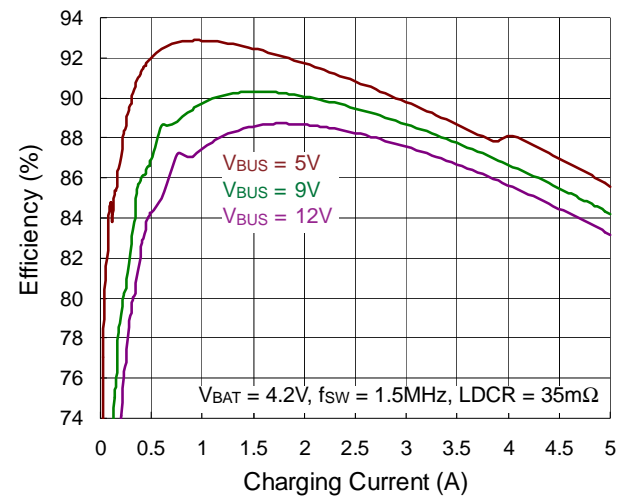
Charger Efficiency vs. Charging Current



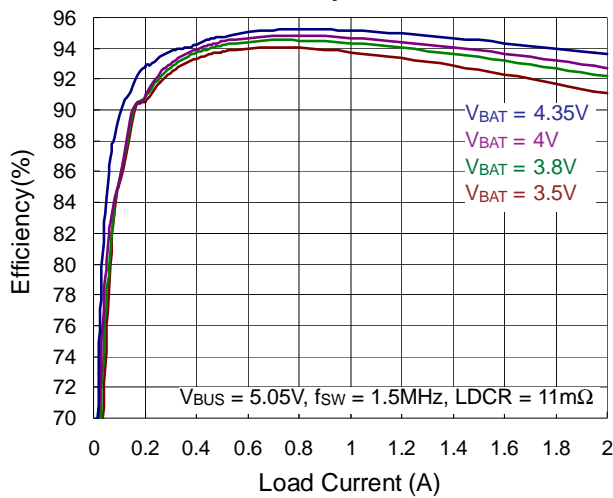
Charger Efficiency vs. Charging Current



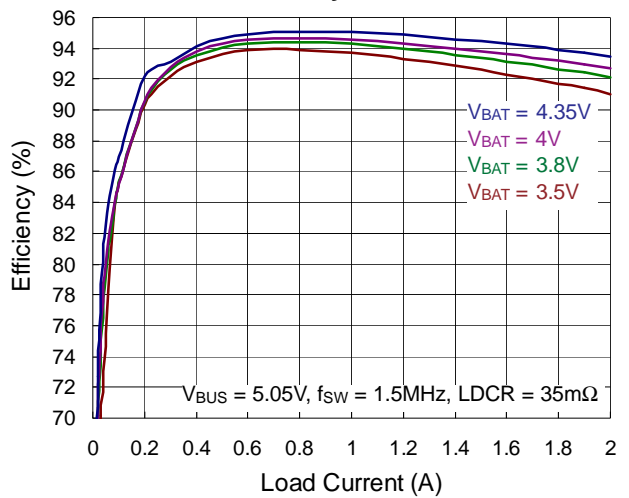
Charger Efficiency vs. Charging Current



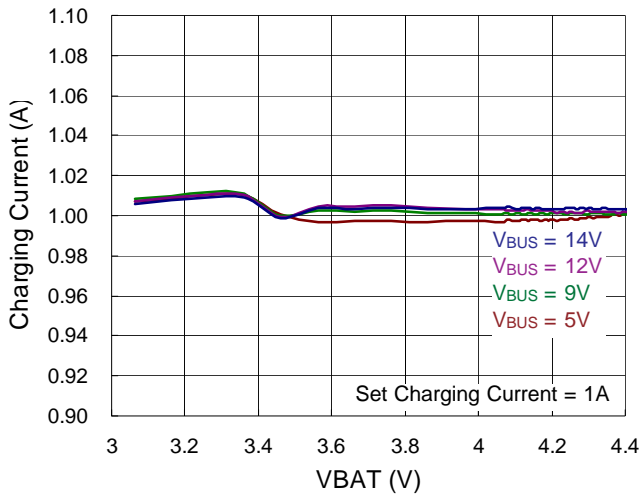
Boost Efficiency vs. Load Current



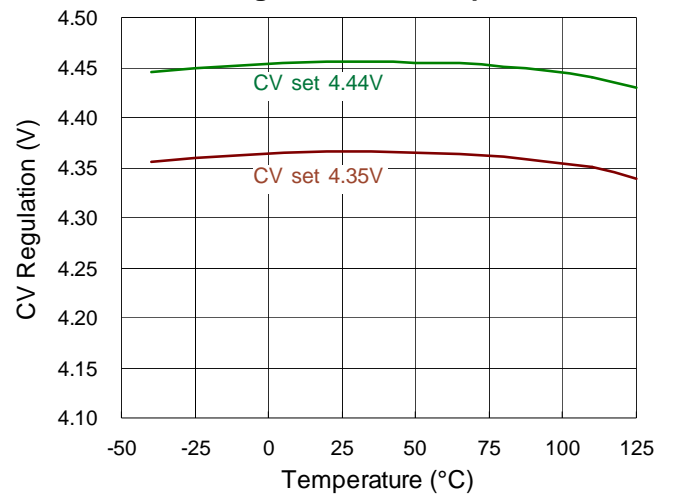
Boost Efficiency vs. Load Current



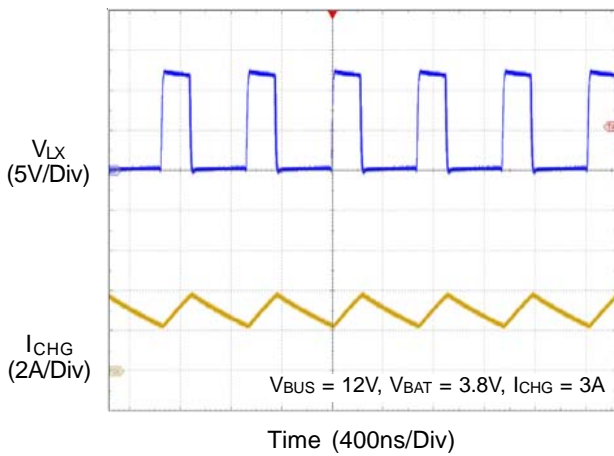
Charging Current vs. VBAT



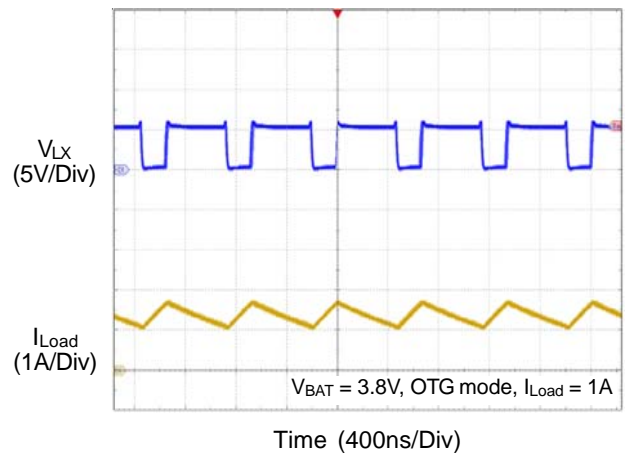
CV Regulation vs. Temperature



PWM Switching



Boost Mode Switching



Register Descriptions

I²C Slave Address : 1010011 (53H)

| 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 | Reversed | 0000000 | Reversed |

| 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 | Reversed | 0 | Reversed |
| 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_CTRL2 | | Charger Control 2 | 0x02 | 0x03 |
| 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 | Reserved | 0 | Reserved |
| 4 | R/W | TE | 0 | Termination enable 0 : Disable charge current termination (default) 1 : Enable charge current termination |
| [3:2] | R/W | IINLMTSEL | 00 | Input current limit selection bit 00 : PSEL pin result is applied (default) 01 : AICR 500 mode 10 : IAICR[5:0] results is applied 11 : Input limit is set by the lower level of these three |
| 1 | R/W | CFO_EN | 1 | Charger and OTG enable 0 : Charger and OTG disable 1 : Charger and OTG enable (default) |
| 0 | R/W | CHG_EN | 1 | Charger enable 0 : Charger disabled 1 : Charger 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 delta-V of the Battery regulation voltage 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 delta-V of the OTG regulation voltage 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-charging 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 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 UV protection selection bit 0 : Buck Switching is not turned off when System UVP 1 : Buck Switching is turned off when System UVP (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 | Charging 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 pause |

| Name | | Function | Add | Reset |
|------------|------|------------|-------------|--|
| CHG_CTRL13 | | Control 13 | 0x0D | 0x52 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | WDT_EN | 0 | Charger and Boost watch dog timer enable/disable 0 : Disable (default) 1 : Enable |
| 6 | R/W | WDT_TRST | 1 | Waiting timer to reset I ² C setup after watchdog is asserted 0 : 200ms 1 : 500ms (default) |
| [5:4] | R/W | WDT[1:0] | 01 | Watch dog timer, from WDTEN is enabled to watch dog IRQ 00 : 8s 01 : 40s (default) 10 : 80s 11 : 160s |
| 3 | R/W | AJITA | 0 | Charger current setting of JEITA 0 : ICHG value is kept (default) 1 : ICHG value becomes half |
| 2 | R/W | OCP | 0 | Inductor OCP current level 0 : OCP(Buck mode / Boost mode) = 6A / 5.5A (default) 1 : OCP(Buck mode / Boost mode) = 7.5A / 7A |
| 1 | R/W | UUG_ON | 1 | UUG enable/disable control 0 : Force UUG turn off 1 : Allow UUG turn on (default) |
| 0 | R/W | INT_REZ | 0 | INT pin re-trigger control. Any event triggers but system does not to check 0 : No action (default) 1 : Release INT pin, then will re-triggers after 2ms if any event exists (this bit will auto reset to 0 when the re-trigger is done) |

| Name | | Function | Addr | Reset |
|-------------|------|---------------------|-------------|--|
| CHG CTRL 14 | | Charger Control 14 | 0x0E | 0x05 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | AICL_MEAS | 0 | AICL measurement mechanism 0 : No operation (default) 1 : Execute AICL measurement |
| [6:5] | R/W | TDEG_AICL_MEAS[1:0] | 00 | Comparator output deglitch time 00 : 2ms (default) 01 : 4ms 10 : 8ms 11 : 16ms |
| [4:3] | R/W | AICL_MAX_MEAS_INTVL | 00 | Detection internal time 00 : 50ms (default) 01 : 100ms 10 : 200ms 11 : 400ms |
| [2:0] | R/W | AICL_VTH[2:0] | 101 | Detection comparator threshold 000 : 4.1V 001 : 4.2V 010 : 4.3V 011 : 4.4V 100 : 4.5V 101 : 4.6V (default) 110 : 4.7V 111 : 4.8V |

| Name | | Function | Addr | Reset |
|-------------|------|--------------------|-------------|--|
| CHG CTRL 15 | | Charger Control 15 | 0x0F | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | ICHG_MEAS | 0 | ICHG measurement mechanism 0 : No operation (default) 1 : Execute ICHG measurement |
| [6:3] | R | ICHG_RPT[3:0] | 0000 | Report the ICHG measurement result 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 |
| [2:0] | R/W | Reversed | 000 | Reversed |

| Name | | Function | Addr | Reset |
|-------------|------|--------------------|-------------|---|
| CHG CTRL 16 | | Charger Control 16 | 0x10 | 0x10 |
| Bit | Mode | Name | Reset Value | Description |
| [7:5] | R/W | Reserved | 000 | Reserved |
| 4 | R/W | JEITA_EN | 1 | JEITA function enable/disable 0 : Disable 1 : Enable (default) |
| 3 | R/W | JEITA_COOL_ISET | 0 | JEITA current setting in COOL region 0 : Set Charge Current to ICHG/2 (default) 1 : Set Charge Current to ICHG |
| 2 | R/W | JEITA_WARM_ISET | 0 | JEITA current setting in WARM region 0 : Set Charge Current to ICHG/2 (default) 1 : Set Charge Current to ICHG |
| 1 | R/W | JEITA_COOL_VSET | 0 | JEITA voltage setting in COOL region 0 : Set Charge Voltage to VOREG-0.2V (default) 1 : Set Charge Voltage to VOREG |
| 0 | R/W | JEITA_WARM_VSET | 0 | JEITA voltage setting in WARM region 0 : Set Charge Voltage to VOREG-0.2V (default) 1 : Set Charge Voltage to VOREG |

| Name | | Function | Addr | Reset |
|---------|------|-----------------|-------------|--|
| CHG ADC | | ADC | 0x11 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| [7:4] | R/W | ADC_IN_SEL[3:0] | 0000 | ADC channel selection 0000 : Reserved (default) 0001 : VBUS/5 0010 : VBUS/2 0011 : VSYS 0100 : VBAT 0101 : Reserved 0110 : TS_BAT 0111 : Reserved 1000 : IBUS 1001 : IBAT 1010 : Reserved 1011 : REGN 1100 : TEMP_JC 1101 to 1111 : Reserved |
| [3:1] | R/W | Reversed | 000 | Reversed |
| 0 | R/W | ADC_START | 0 | ADC start control 0 : ADC conversion not active (default) 1 : Start ADC conversion (auto clear when conversion done) |

| Name | | Function | Addr | Reset |
|------------|------|--------------------|-------------|--|
| CHG_CTRL17 | | Charger Control 17 | 0x19 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | EN_PUMPX | 0 | Enable MTK pump express pulse 0 : Disable (default) 1 : Allow MTK pump express pulse |
| 6 | R/W | PUMPX_2.0_1.0 | 0 | MTK pump express 2.0 / 1.0 enable 0 : PE1.0 Enable (default) 1 : PE 2.0 Enable |
| 5 | R/W | PUMPX_UP_DN | 0 | MTK pump express 1.0 voltage up/down enable 0 : PE 1.0 voltage down enable (default) 1 : PE 1.0 voltage up enable |
| [4:0] | R/W | PUMPX_DEC | 00000 | MTK pump express 2.0 voltage request setting 00000 : 5.5V (default) 00001 : 6V 00010 : 6.5V ... 00111 : 9V ... 01101 : 12V 01110 : 12.5V 01111 : 13V 10000 : 13.5V 10001 : 14V 10010 : 14.5V 10011 : Reserved ... 11101 : Reserved 11110 : Adapter healthy self-testing 11111 : Disable cable drop compensation |

| Name | | Function | Addr | Reset |
|------------|------|--------------------|-------------|--|
| CHG_CTRL18 | | Charger Control 18 | 0x1A | 0x40 |
| Bit | Mode | Name | Reset Value | Description |
| [7:6] | R/W | Reserved | 01 | Reserved |
| [5:3] | R/W | BAT_COMP | 000 | Battery IR compensation resistor setting 000 : 0mΩ (default) 001 : 25mΩ 010 : 50mΩ 011 : 75mΩ 100 : 100mΩ 101 : 125mΩ 110 : 150mΩ 111 : 175mΩ |
| [2:0] | R/W | VCLAMP | 000 | Battery IR compensation maximum voltage clamp 000 : 0mV (default) 001 : 32mV 010 : 64mV 011 : 96mV 100 : 128mV 101 : 160mV 110 : 192mV 111 : 224mV |

| Name | | Function | Addr | Reset |
|------------|------|--------------------|-------------|--|
| CHG_CTRL19 | | Charger Control 19 | 0x18 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | PPOFF_RST_DIS | 0 | System reset function disable bit 0 : System reset enable (default) 1 : System reset disable |
| [6:0] | R/W | Reserved | 0000000 | Reserved |

| Name | | Function | Addr | Reset |
|-----------|------|---------------|-------------|---|
| DEVICE_ID | | DEVICE_ID | 0x40 | 0x84 |
| Bit | Mode | Name | Reset Value | Description |
| [7:4] | R | VENDOR[3:0] | 1000 | Vendor IC |
| [3:0] | R | CHIP_REV[3:0] | 0100 | Chip version : 0001 = A, 0010 = B, 0011 = C...etc |

| Name | | Function | Addr | Reset |
|----------|------|-----------------|-------------|--|
| CHG_STAT | | CHG_STAT | 0x42 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| [7:6] | R | CHG_STAT | 00 | Charger status bit 00 : Ready 01 : Charge in progress 10 : Charge done 11 : Fault |
| 5 | R | VBAT_LVL | 0 | Battery voltage level for operation mode 0 : Charger operate in pre-charge 1 : Charger operate in fast-charge level |
| 4 | R | VBAT_TRICKLE | 0 | Battery voltage level for operation mode 0 : Charger does not operate in trickle level 1 : Charger operates in trickle level |
| 3 | R | BOOST_STAT | 0 | Boost mode status 0 : Does not in boost mode 1 : in boost mode |
| 2 | R | BST_VBUSOV_STAT | 0 | Boost mode VBUS over-voltage protection (VBUS OVP) status 0 : Boost VBUS OVP does not occur 1 : Boost VBUS OVP occurs |
| 1 | R | Reserved | 0 | Reserved |
| 0 | R | ADC_STAT | 0 | ADC status 0 : ADC is idle 1 : ADC is under conversion |

| Name | | Function | Addr | Reset |
|---------|------|--------------------|-------------|---|
| CHG_NTC | | CHG_NTC | 0x43 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R | Reserved | 0 | Reserved |
| [6:4] | R | BAT_NTC_FAULT[2:0] | 000 | BAT_NTC fault status 000 : Normal 010 : Warm 011 : Cool 101 : Cold 110 : Hot |
| [3:0] | R | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|------------|------|----------------|-------------|--------------------|
| ADC_DATA_H | | ADC_DATA_H | 0x44 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| [7:0] | R | ADC_CODEH[7:0] | 00000000 | ADC code high byte |

| Name | | Function | Addr | Reset |
|------------|------|----------------|-------------|-------------------|
| ADC_DATA_L | | ADC DATA L | 0x45 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| [7:0] | R | ADC_CODEL[7:0] | 00000000 | ADC code low byte |

| Name | | Function | Addr | Reset |
|-----------|------|-----------|-------------|---|
| CHG_STATC | | CHG STATC | 0x50 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R | PWR_RDY | 0 | Power ready status bit 0 : Input power is bad, VBUS > VOVP or VBUS < VUVLO or VBUS < BATS + VSLP 1 : Input power is good, UVLO < VBUS < VOVP & VBUS > BATS + VSLP |
| 6 | R | CHG_MIVR | 0 | Charger warning. Input voltage MIVR loop active. 0 : MIVR loop is not active 1 : MIVR loop is active |
| 5 | R | CHG_AICR | 0 | Charger warning. Input current AICR loop active. 0 : AICR loop is not active 1 : AICR loop is active |
| 4 | R | CHG_TREG | 0 | Charger warning. Thermal regulation loop active. 0 : Thermal regulation loop is not active 1 : Thermal regulation loop is active |
| [3:0] | R | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|-----------|------|------------|-------------|---|
| CHG_FAULT | | CHG FAULT | 0x51 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R | CHG_VBUSOV | 0 | VBUS over voltage protection. Set when VBUS > VBUS_OVP is detected. 0 : VBUS is not over voltage 1 : VBUS is over voltage |
| 6 | R | CHG_VBATOV | 0 | Charger fault. Battery OVP. 0 : Battery is not OVP 1 : Battery is OVP |
| 5 | R | CHG_VSYSOV | 0 | Charger fault. System OVP. 0 : System is not OVP 1 : System is OVP |
| 4 | R | CHG_VSYSUV | 0 | Charger fault. System UVP. 0 : System is not UVP 1 : System is UVP |
| [3:0] | R | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|----------|------|-------------|-------------|--|
| TS_STATC | | TS_STATC | 0x52 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R | TS_BAT_HOT | 0 | BAT temperature status read bit 0 : Normal temperature 1 : Temperature is hot |
| 6 | R | TS_BAT_WARM | 0 | BAT temperature status read bit 0 : Normal temperature 1 : Temperature is warm |
| 5 | R | TS_BAT_COOL | 0 | BAT temperature status read bit 0 : Normal temperature 1 : Temperature is cool |
| 4 | R | TS_BAT_COLD | 0 | BAT temperature status read bit 0 : Normal temperature 1 : Temperature is cold |
| [3:0] | R | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|----------|------|-------------|-------------|---|
| CHG_IRQ1 | | CHG_IRQ 1 | 0x53 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/C | OTPI | 0 | Thermal shutdown fault 0 : No operation 1 : Event occurs |
| 6 | R/C | CHG_RVPI | 0 | Charger reverse protection fault 0 : No event occurs 1 : Event occurs |
| 5 | R/C | CHG_ADPBADI | 0 | Charger bad adapter fault 0 : No event occurs 1 : Event occurs |
| 4 | R/C | CHG_BATABSI | 0 | Battery absence fault 0 : No event occurs 1 : Event occurs |
| 3 | R/C | CHG_TMRI | 0 | Charger timer time-out fault 0 : No event occurs 1 : Event occurs |
| 2 | R/C | CHG_STATCI | 0 | Status of each CHG_STATC register (Reg0x50) is changed 0 : No event occurs 1 : Event occurs |
| 1 | R/C | CHG_FAULTI | 0 | Status of each CHG_FAULT register (Reg0x51) is changed 0 : No event occurs 1 : Event occurs |
| 0 | R/C | TS_STATCI | 0 | Status of each TS_STATC register (Reg0x52) is changed 0 : No event occurs 1 : Event occurs |

| Name | | Function | Addr | Reset |
|----------|------|---------------|-------------|---|
| CHG_IRQ2 | | CHG IRQ 2 | 0x54 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/C | CHG_IEOCI | 0 | Charging current is lower than EOC current ever occurs 0 : No event occurs 1 : Event occurs |
| 6 | R/C | CHG_TERMI | 0 | Charge terminated event 0 : No event occurs 1 : Event occurs |
| 5 | R/C | CHG_RECHGI | 0 | Re-Charge behavior ever occurs. 0 : No event occurs 1 : Event occurs |
| 4 | R/C | SSFINISHI | 0 | Charger or boost-mode soft-start finishes event 0 : no event occurs 1 : event occurs |
| 3 | R/C | WDTMRI | 0 | Watch dog timer timeout fault 0 : No event occurs 1 : Event occurs |
| 2 | R/C | Reserved | 0 | Reserved |
| 1 | R/C | CHG_ICHGMeasI | 0 | ICHG measurement function done event 0 : No event occurs 1 : Event occurs |
| 0 | R/C | CHG_AICLMeasI | 0 | AICL measurement function done event 0 : No event occurs 1 : Event occurs |

| Name | | Function | Addr | Reset |
|----------|------|-------------|-------------|---|
| CHG_IRQ3 | | CHG IRQ 3 | 0x55 | 0x00 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/C | BST_OLPI | 0 | Boost over-load protection event 0 : No event occurs 1 : Event occurs |
| 6 | R/C | BST_MIDОВI | 0 | Boost VMID OVP fault event 0 : No event occurs 1 : Event occurs |
| 5 | R/C | BST_BATUVI | 0 | Boost low voltage input fault event 0 : No event occurs 1 : Event occurs |
| [4:2] | R/W | Reserved | 000 | Reserved |
| 1 | R/C | PUMPX_DONEI | 0 | MTK pump express function done event 0 : No event occurs 1 : Event occurs |
| 0 | R/C | ADC_DONEI | 0 | ADC measurement done event 0 : No event occurs 1 : Event occurs |

| Name | | Function | Addr | Reset |
|----------------|------|----------------|-------------|---|
| CHG_STATC_CTRL | | CHG STATC CTRL | 0x60 | 0xF0 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | PWR_RDYM | 1 | Power ready interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | CHG_MIVRM | 1 | Input voltage MIVR loop active interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | CHG_AICRM | 1 | Input current AICR loop active interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 4 | R/W | CHG_TREGM | 1 | Thermal regulation loop active interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| [3:0] | R/W | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|----------------|------|----------------|-------------|---|
| CHG_FAULT_CTRL | | CHG FAULT CTRL | 0x61 | 0xF0 |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | CHG_VBUSOVM | 1 | VBUS over voltage protection interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | CHG_VBATOVM | 1 | Battery OVP interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | CHG_VSYSOVM | 1 | System OVP interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 4 | R/W | CHG_VSYSUVM | 1 | System UVP interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| [3:0] | R/W | Reserved | 0000 | Reserved |

| Name | | Function | Addr | Reset |
|---------------|------|---------------|-------------|---|
| TS_STATC_CTRL | | TS STATC CTRL | 0x62 | 0xFF |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | TS_BAT_HOTM | 1 | BAT temperature status interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | TS_BAT_WARMM | 1 | BAT temperature status interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | TS_BAT_COOLM | 1 | BAT temperature status interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 4 | R/W | TS_BAT_COLDM | 1 | BAT temperature status interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| [3:0] | R/W | Reserved | 1111 | Reserved |

| Name | | Function | Addr | Reset |
|---------------|------|----------------|-------------|---|
| CHG_IRQ1_CTRL | | CHG IRQ 1 CTRL | 0x63 | 0xFF |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | OTPM | 1 | Thermal shutdown fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | CHG_RVPM | 1 | Charger reverse protection fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | CHG_ADPBADM | 1 | Charger bad adapter fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 4 | R/W | CHG_BATABSM | 1 | Battery absence fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 3 | R/W | CHG_TMRM | 1 | Charger timer time-out fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 2 | R/W | CHG_STATCM | 1 | Status of each CHG_STATC register (Reg0x50) changed interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 1 | R/W | CHG_FAULTM | 1 | Status of each CHG_FAULT register (Reg0x51) changed interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 0 | R/W | TS_STATCM | 1 | Status of each TS_STATC register (Reg0x52) changed interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |

| Name | | Function | Addr | Reset |
|---------------|------|----------------|-------------|--|
| CHG_IRQ2_CTRL | | CHG IRQ 2 CTRL | 0x64 | 0xFF |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | CHG_IEOCM | 1 | Charging current is lower than EOC current interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | CHG_TERMM | 1 | Charge terminated event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | CHG_RECHGM | 1 | Re-Charge behavior interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 4 | R/W | SSFINISHM | 1 | Charger or boost-mode soft-start finishes event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 3 | R/W | WDTMRM | 1 | Watch dog timer timeout fault interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 2 | R/W | Reserved | 1 | Reserved |
| 1 | R/W | CHG_ICHGMeasM | 1 | ICHG measurement function done event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 0 | R/W | CHG_AICLMeasM | 1 | AICL measurement function done event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |

| Name | | Function | Addr | Reset |
|---------------|------|----------------|-------------|---|
| CHG_IRQ3_CTRL | | CHG IRQ 3 CTRL | 0x65 | 0xFF |
| Bit | Mode | Name | Reset Value | Description |
| 7 | R/W | BST_OLPM | 1 | Boost overload protection event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 6 | R/W | BST_MIDOVVM | 1 | Boost VMID OVP fault event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 5 | R/W | BST_BATUVM | 1 | Boost low voltage input fault event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| [4:2] | R/W | Reserved | 111 | Reserved |
| 1 | R/W | PUMPX_DONEM | 1 | MTK pump express function done event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |
| 0 | R/W | ADC_DONEM | 1 | ADC measurement done event interrupt mask 0 : Interrupt is not masked 1 : Interrupt is masked |

Application Information

Switching Charger

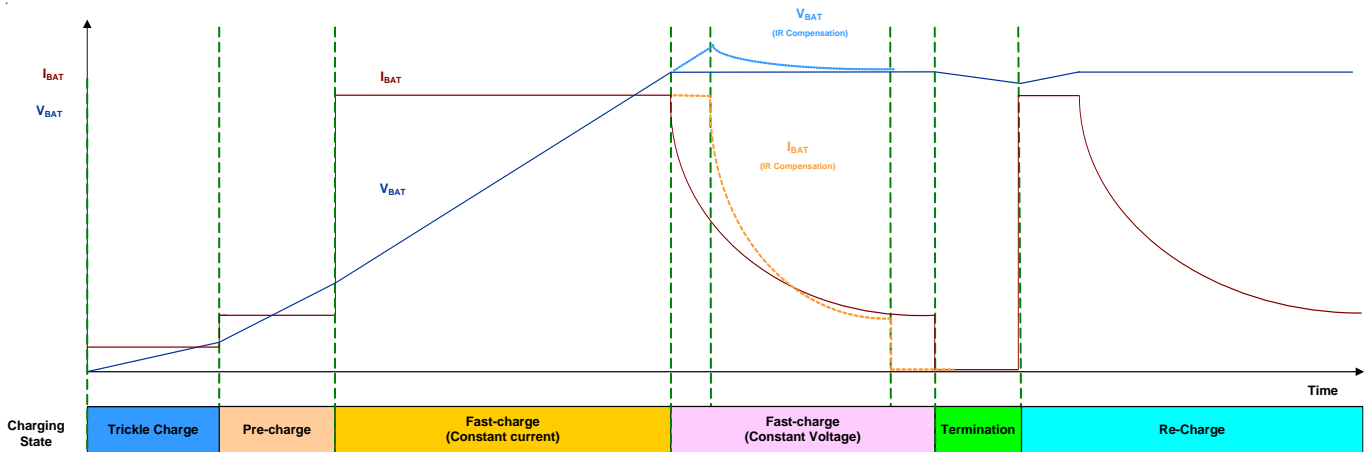
The switching charger integrates a synchronous PWM controller with power MOSFETs to provide Minimum Input Voltage Regulation (MIVR), Average Input Current Regulation (AICR), high-accuracy current and voltage regulation, and charge termination. The charger also features OTG (On-The-Go) Boost Mode.

The switching charger has three operation modes: charge mode, boost mode (OTG-Boost), and high-impedance mode. In charge mode, the charger supports a precision charging system for single cell batteries. In boost mode, the charger works as a boost converter to boost the battery voltage back to the VBUS pin for sourcing OTG devices. In high-impedance mode, the charger stops charging or boosting and operates at a low current sinking from the VBUS pin or the battery to reduce power consumption when the device is in standby mode.

Charge Mode Operation

Battery Charge Profile

The device charges battery in four state : trickle charge, pre-charge, constant current, constant voltage. Users can set the voltage threshold and charge current rating in pre-charge, constant current, and constant voltage by I²C interface. In portable device applications, host changes adapter's output to high than 5V is a general solution to achieve fast charge. For this kind of applications, users must have to set VBUS back to 5V when charger enter to constant voltage and charge current lower than 1A. Please refer to application note document [AN065](#) for detail information.



Minimum Input Voltage Regulation (MIVR)

The switching charger features Minimum Input Voltage Regulation function to prevent input voltage drop due to insufficient current provided from the adapter or USB input. If MIVR function is enabled, the input voltage decreases when the over-current conditional of the input power source occurs. The VBUS voltage is regulated at a predetermined voltage level which can be set as 3.9V to 13.4V per 0.1V by I²C interface. At this time, the current drawn by the switching charger equals to the maximum current value that the input power can provide at the predetermined voltage level, instead of the set value.

Pre-Charge Mode

For life-cycle consideration, the battery cannot be charged with large current under low-battery condition. When the BAT voltage is below pre-charge threshold voltage, the charger is in pre-charge mode with a weak charge current, which equals to the pre-charge current.

There are two control loops in pre-charge mode : ICHG and SYSREG. If the battery voltage is lower than the SYS voltage, the MOSFET will not be fully turned on so that the V_{SYS} is not equal to V_{BAT}. That is, the V_{SYS} can be powered from the buck rather than the low battery, which

is in pre-charge mode. As a result, the system power can be guaranteed in this low-battery condition.

Fast-Charge Mode and Settings

As the BAT voltage rises above V_{PRECHG} , 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 via options automatically. Unlike the linear charger (LDO), the switching charger (buck converter) is like a current amplifier, where the current drawn by the switching charger is different from the current into the battery.

Average Input Current Regulation (AICR) level and output charge current (I_{CHG}) can be set independently.

Cycle-by-Cycle Current Limit

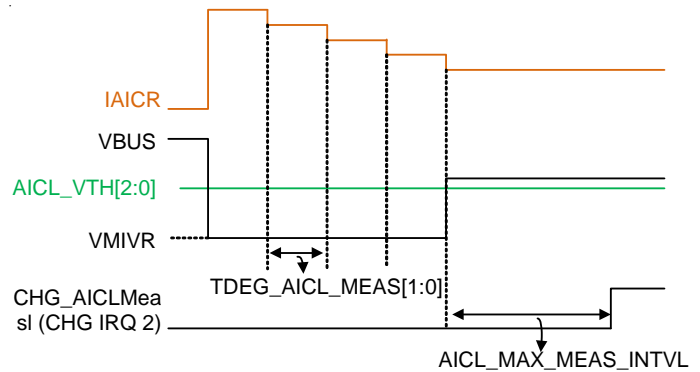
The switching charger has included a cycle-by-cycle current limit for output inductor. Once the inductor current reaches the current limit, the charger stops charging immediately to prevent from over-current condition and damaging the device. Note that this protection can never be disabled.

Average Input Current Regulation (AICR)

The AICR levels can be set via the I²C interface. For example, AICR100 mode limits the input current to 100mA, and AICR500 mode to 500mA. This function can be disabled, if not needed. The AICR current levels are in the range of 100mA to 3250mA with a resolution of 50mA.

Average Input Current Level (AICL)

The AICL levels can be set via the I²C interface (0x0E[7:0]). When IAICR is set to large current and the VBUS voltage drops to the VMIVR level, AICL measurement mechanism will decrease IAICR level step by step automatically until the VBUS voltage exceeds AICL threshold voltage.



Charge Current (I_{CHG})

The charge current into the battery is determined by the power path sensing R_{ON} and I_{CHG} setting by I²C. The voltage between the SYS and BAT pins is regulated to the voltage control by I_{CHG} setting and the Fast-Charge currents are 100mA to 5000mA programmed by I²C per 100mA.

Constant Voltage Mode

The switching charger enters constant voltage mode when the BAT voltage is closed 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 switching charger does not turn off and always regulates the battery voltage at V_{OREG} . 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 output-charge voltage is set by the I²C interface. Its range is from 3.9V to 4.71V per 10mV.

End-of-Charge Current (I_{EOC})

If the charger current termination is enabled, the end-of-charge current is determined by the termination current sense voltage (V_{EOC}). I_{EOC} is set by the I²C interface from 100mA to 850mA per 50mA.

Charge Trip

When input power source is plugged in, the RT9466 checks the current sourcing capability of the input power source when V_{BUS} exceeds 3.3V. The following conditions should be met to start battery charge.

1. V_{BUS} is below 14V (i.e. V_{BUS_OVP}).
2. V_{BUS} is above 3.8V (i.e. V_{BAD_ADP}) when sinking 50mA (i.e. $I_{BAD_ADP_SINK}$) during 30ms of detection period, t_{BADADP_DET} . And this detection function can be disabled by ADP_DIS (0x0B, bit7) register bit.

The charge modes as below, and the charge mode which the charger operates in will be determined according to the V_{BAT} level :

| | Battery Voltage Level V_{BAT} | Battery Charge Current I_{BAT} |
|--------------------|---------------------------------------|---|
| Trickle mode | $V_{BAT} < 2V$ | 100mA |
| Pre-charge mode | $V_{BAT} < V_{PREC}$ (0x08, bit[7:4]) | IPREC (0x08, bit[3:0]) |
| Fast-charge mode | $V_{BAT} < V_{OREG}$ (0x04, bit[7:1]) | Charge current is determined by several control loops |
| End-of-charge mode | $V_{BAT} = V_{OREG}$ (0x04, bit[7:1]) | Charge current decreases naturally |

In fast-charge mode, the input current limit can be selected by IINLMTSEL (0x02, bit[3:2]). This flexible setting is suitable for wide applications of adapters. In addition, the RT9466 also provides charger warning statuses, such as MIVR, AICR and TREG (0x50, bit[6:4]), to host.

There are 2 register bits, related to the LX switching of the RT9466 :

1. SEL_SWFREQ (0x01, bit7) :
 - ▶ If SEL_SWFREQ is disabled (set to 0), the switching frequency is 1.5MHz (default).
 - ▶ If SEL_SWFREQ is enabled (set to 1), the switching frequency is 0.75MHz.
2. FIXFREQ (0x01, bit6) :
 - ▶ If FIXFREQ is disable (set to 0), the charge switching frequency would be varied when V_{BUS} is closed to V_{BAT} .
 - ▶ If FIXFREQ is enable (set to 1), the charger switching frequency is fixed.

There are 3 enable bits, related to the charger.

1. CFO_EN (0x02, bit1) : This bit is used to enable or disable the charger and boost.
2. CHG_EN (0x02, bit0) : When CHG_EN bit is disabled, power path MOS will be turned off so that the zero charging current is derived. At this time, input power source continuously delivers power to the system without charging the battery. However, if the system load is larger than the input source current limit, the power path MOS will be turned back on immediately to

supply power to system. The CHG_EN bit function is same as CEB pin.

3. HZ (0x01, bit2) : When HZ bit is enabled, the most of the charger internal circuits will be turned off in order to reduce quiescent current.

In end-of-charge mode, if EOC_EN (0x09, bit3) is enabled, once the charge current is lower than IEOC (0x09, bit[7:4]) level and within CHG_TEDG_EOC (0x09, bit[2:0]), the RT9466 will send out INT and CHG_IEOCI = 1 (0x54, bit7). Then, the RT9466 will start to check statuses of the following three bits.

1. TE (0x02, bit4) : If this bit is enabled, the power path will be turned off, and the buck of the charger will keep providing power to the system.
2. EOC_TIMER (0x07, bit[1:0]) : With CHG_IEOCI = 1, the power path will not be turned off. The RT9466 can keep charging the battery for 30 to 60 minutes to extend battery charging capacity.
3. BATD_EN (0x0B, bit6) : After charge is done, the RT9466 will start to sink a sink current of I_{BAT_SINK} 375 μ A for about 256ms from the battery. If V_{BAT} drops to trigger the recharge function, it is to say the battery is not connected to the charger. The RT9466 will continue on battery detection for every two seconds.

OTG Mode

The RT9466 also supports OTG mode. It not only provides several output current limit protection levels, but also has low battery protection for overall system considerations. The RT9466 can select switching frequency via SEL_SWFREQ (0x01, bit7), whether the RT9466 already operates in OTG mode or not.

There are two ways to enable OTG mode :

1. By way of software : through I²C to set OPA_MODE (0x01, bit0).
2. By way of hardware : through I²C to set OTG_PIN_EN (0x01, bit1) and OPA_MODE (0x01, bit0). Users can then use GPIO to change the OTG pin level to enter / exit OTG mode.

The RT9466 also provides UUG_ON (0x0D, bit1) bit, which can be applied to different applications

1. If OTG mode and UUG_ON are enabled, the boost-mode output is on the VBUS pin, which can be used for OTG (On-the-Go) mode in mobile phones.
2. If OTG mode is enabled and UUG_ON bit is disabled, the boost-mode output is on the VMID pin. , which can be used in power banks, that is, adapter power can be delivered to PD (Powered Device) directly.

Shipping Mode

From manufacture to an end user, it may take long time for products to travel. In view of this, the RT9466 provides shipping mode to further minimize battery leakage. After enabling SHIP_MODE (0x02, bit7), the RT9466 will shut down internal circuits to reduce quiescent current. The delay time for BATFET to be turned off can be selected by BATDET_DIS_DLY (0x02, bit6). Below list several ways to exit shipping mode.

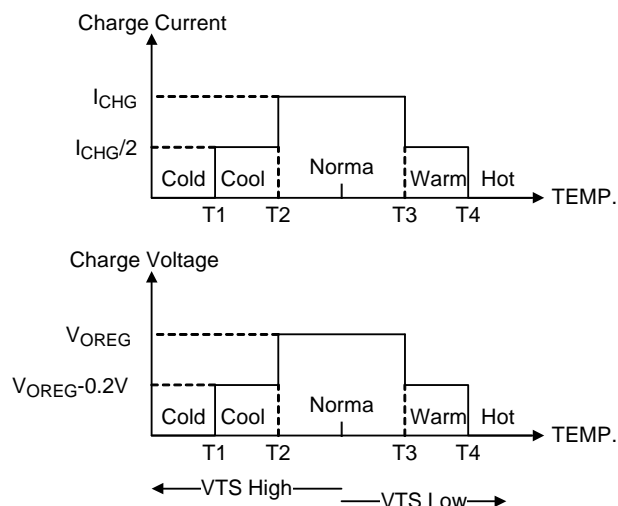
1. Input power source is plugged in.
2. Disable SHIP_MODE bit.
3. QON pin is pulled from Logic High to Logic Low within 1 second.
4. Enable RST_REG (0x00, bit7) to reset all registers to default values.

MeidaTek Pump Express+ (MTK, PE+)

The RT9466 can provides an input current pulse to communicate with an MTK-PE+ high voltage adapter. When EN_PUMPX (0x19, bit7) is enabled, the host can increase or decrease adapter output voltage by setting PUMPX_UP_DN to the desired value. After enabling either one of them, the RT9466 will generate a VBUS current pattern for the MTK-PE+ adapter to automatically identify whether to increase or decrease output voltage (VBUS pin). Once the current pattern is finished, INT will be triggered accordingly to request the processor to read the registers.

JEITA Protection

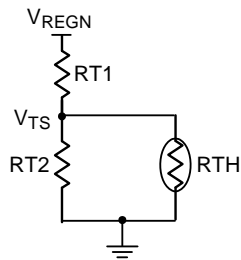
JEITA protection is implemented in the RT9466 to achieve battery thermal protection. JEITA guidelines were released in 2007. It includes warm and cool protection (Cool section is between T1 and T2; warm section is between T3 and T4, see the figure below). When battery temperature is in warm section, the RT9466 will lower the charge voltage (V_{OREG}) by 200mV. If the battery is in cool section, the charger will reduce charge current (by half of CC mode current). The RT9466 will stop charging the battery if the battery temperature is lower than T1 or higher than T4.



Thermal condition of a battery can be monitored by TS pin. There are four sections which are implemented for JEITA protection. Based on R_{HOT} and R_{COLD} , R_{T1} and R_{T2} can be calculated with equation (1) and equation (2). Herein, R_{HOT} is the NTC resistance of the battery over-temperature threshold, and R_{COLD} is the NTC resistance of the battery under-temperature threshold.

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

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



Analog IR Drop Compensation

Since resistance between charger output and battery cell terminal will force to move from constant current mode to constant voltage mode too early and increase charging time. To speed up charging cycle, RT9466 provides analog IR drop compensation function to delivery maximum power to battery for extend constant current mode charging time. Host(AP) can set IR compensation function by BAT_COM (0x1A bit[5:3]) and VCLAMP (0x1A bit[2:0]).

$$V_{ACTUAL} = V + \min(I_{CHG_ACTUAL} \times BAT_COM, V_{CLAMP})$$

The respective percentages of the voltages at T1 to T4 are shown in the following table.

| No. | Parameter | Symbol | Condition | $\frac{V_{TS}}{V_{REGN}}$ | Units |
|-----|---------------------|---------------|---|---------------------------|-------|
| 1 | T1 (0°C) Threshold | V_{T1} | V_{TS} rising, as percentage to V_{REGN} | 73.5 | % |
| 2 | T1 Hysteresis | V_{T1_HYS} | Hysteresis, V_{TS} falling | 2 | % |
| 3 | T2 (10°C) Threshold | V_{T2} | V_{TS} rising, as percentage to V_{REGN} | 68.5 | % |
| 4 | T2 Hysteresis | V_{T2_HYS} | Hysteresis, V_{TS} falling | 2 | % |
| 5 | T3 (45°C) Threshold | V_{T3} | V_{TS} falling, as percentage to V_{REGN} | 45 | % |
| 6 | T3 Hysteresis | V_{T3_HYS} | Hysteresis, V_{TS} rising | 2 | % |
| 7 | T4 (60°C) Threshold | V_{T4} | V_{TS} falling, as percentage to V_{REGN} | 34.5 | % |
| 8 | T4 Hysteresis | V_{T4_HYS} | Hysteresis, V_{TS} rising | 2 | % |

STAT Pin

There are two ways to check RT9466's status :

1. By way of hardware : The RT9466's STAT pin is an open-drain output to indicate charge statuses, which are summarized in Table 1, for charge mode only.

Table 1. Charge Statuses Indication

| Charge Status | STAT Pin Output |
|------------------------|-----------------|
| Charge is in progress. | LOW |
| Charge is done. | HIGH |
| Charge is disabled. | HIGH |
| Any fault occurs. | Blink at 1Hz |

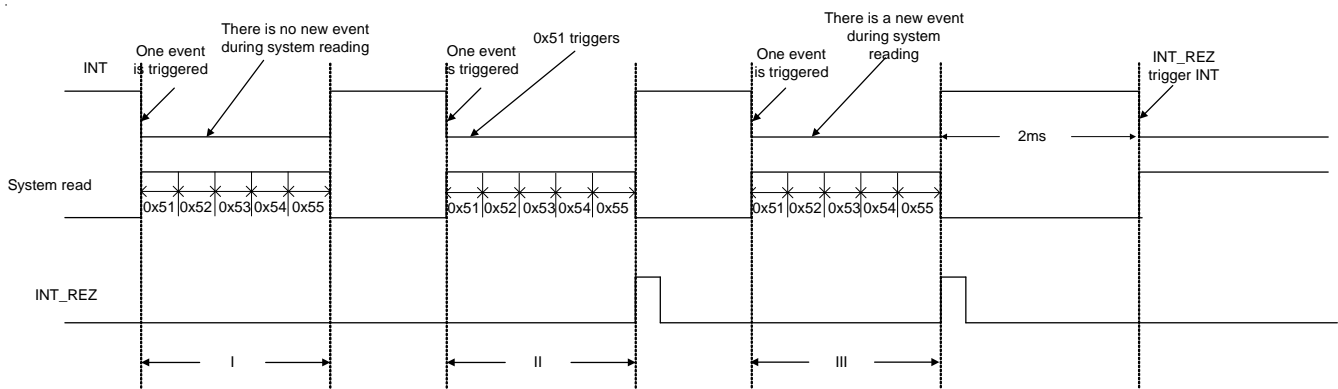
2. By way of software : The RT9466 status is indicated in the register of address 0x42 as below.

- ▶ CHG_STAT : Charger status
- ▶ BOOST_STAT : Boost mode status
- ▶ ADC_STAT : ADC status. Check whether ADC is active or idle

Interrupt

The RT9466 reports status to host (CPU, MCU, EC, or...etc.) by the INT (interrupt to host) pin, which is an open-drain output. The INT pin goes low when any fault occurs. It will be automatically reset when all the fault flags are cleared. The IRQ_Pulse (0x01, bit3) provides a reminder function. If the system interrupts by the interrupt signal but does not take any action to check the registers, the INT pin will be released with every 2 seconds and be triggered again.

The RT9466 INT pin is used to indicate whether the any charging events occur. When AP (Access Point) detects a falling edge on the INT pin, AP starts to read the INT register 0x51 to 0x55 sequentially. However, if any of the events is triggered again during this checking period, it will be a miss. If any of the INT registers does not be checked, the INT_REZ bit can help release the INT pin with 2ms then reset it again in order to remind hot the missing events again.



ILIM Pin

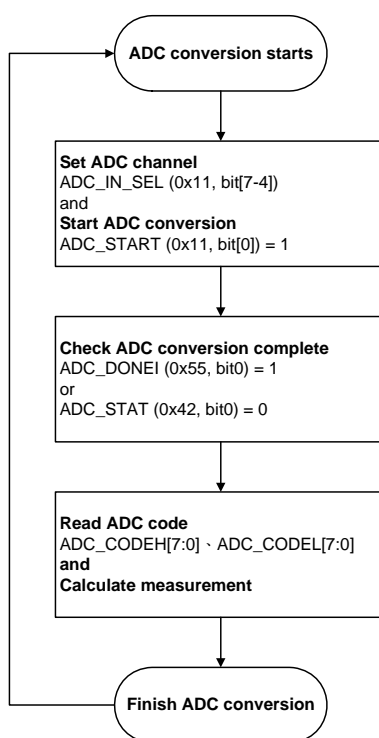
For hardware protection, the RT9466 supports input current limit setting on the ILIM pin by way of a resistor from ILIM pin to ground.

$$I_{INMAX} = K_{ILIM} / R_{ILIM}$$

For example, if the input current limit is to be set as 2A with a typical input current limit factor K_{ILIM} as $355A\Omega$, a resistor of 180Ω will then be chosen as the resistor from the ILIM pin to ground. The actual input current limit is the minimum between the result of IINLMTSEL (0x02, bit[3:2]) and ILIM.

ADC Conversion Operation Flow

The figure below shows the flow chart of ADC conversion operation. ADC conversion starts from selecting an ADC channel by setting ADC_IN_SEL (0x11, bit[7:4]) and enabling ADC_START (0x11, bit0). After about 200ms of ADC conversion time for a conversion to be completed, ADC_DONE1 (0x55, bit0) will be enabled and ADC_STAT (0x42, bit 0) will be disabled. The host can be informed that ADC conversion is completed by reading the register bits.



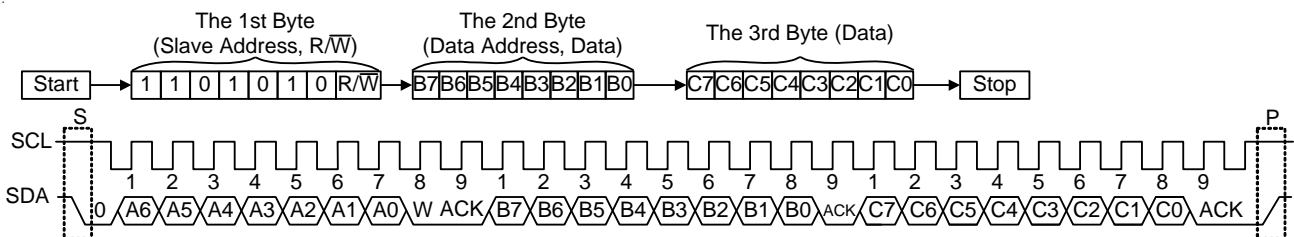
The host can read ADC high-byte codes from ADC_CODEH (0x44, bit 7-0) and low-byte codes from ADC_CODEL (0x45, bit 7-0) to calculate the measured voltage / current / temperature data with respect to each ADC channel. The table below shows measurement equations for various ADC channels. When measuring IBUS, the AICR setting need large 350mA at least. When measuring IBAT, the ICHG setting need large 1A at least.

| ADC Channel | Measurement Equation | Measurement Range |
|--|--|-------------------|
| VBUS_DIV5 | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 25mV$ | 1V to 22V |
| VBUS_DIV2 | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 10mV$ | 1V to 9.8V |
| VBAT | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 5mV$ | 0V to 4.9V |
| VSYS | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 5mV$ | 0V to 4.9V |
| REGN | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 5mV$ | 0V to 4.9V |
| TS_BAT | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 0.25\%$ | 0% to 100% |
| IBUS IAICR[5:0] setting < 400mA | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 50mA \times 0.67$ | 0A to 0.4A |
| IBUS IAICR[5:0] setting ≥ 400mA | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 50mA$ | 0A to 3.25A |
| IBAT ICHG[5:0] setting 100mA to 450mA | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 50mA \times 0.57$ | 0A to 0.45A |
| IBAT ICHG[5:0] setting 500mA to 850mA | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 50mA \times 0.63$ | 0A to 0.85A |
| IBAT ICHG[5:0] setting ≥ 900mA | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 50mA$ | 0A to 5A |
| TEMP_JC | $[(ADC_CODEH \times 256) + ADC_CODEL] \times 2^\circ C - 40^\circ C$ | -40 to 120°C |

I²C Interface Timing Diagram

The RT9466 acts as an I²C -bus slave. The I²C -bus master configures the settings for charge mode and boost mode by sending command bytes to the RT9466 via the 2-wire I²C -bus. After the START condition, the I²C master sends

a chip address. This address is seven bits long followed by an eighth bit which is a data direction bit (R/W). The second byte selects the register to which the data will be written. The third byte contains data to the selected register.



Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using 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 continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA} , is highly package dependent. For a WQFN-24L 4x4 package, the thermal resistance, θ_{JA} , is 22°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at $T_A = 25^\circ\text{C}$ can be calculated as below :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (22^\circ\text{C/W}) = 4.54\text{W for a WQFN-24L 4x4 package.}$$

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

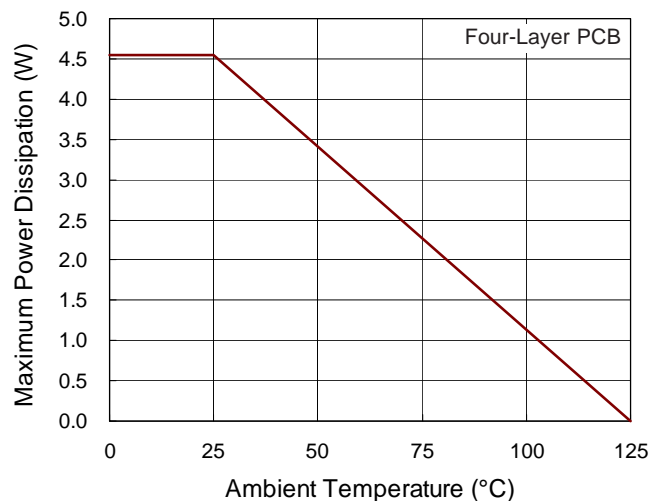


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Considerations

The RT9466 layout guidelines are shown as below, and several suggestions are provided.

- ▶ The bypass capacitor, connected from the REGN pin to AGND, should be placed as close to the IC.
- ▶ AGND should be connected to PGND via GND plane.
- ▶ The capacitor, connected to VMID pin should be placed as close as possible to the IC to reduce EMI and the recommend trace length from IC VMID Pads to VMID Cap does not longer than 100 mil.
- ▶ The boot capacitor, connected from the BTST pin to Lx pin, should be placed as close to the IC and the recommend trace length from IC BTST Pads to BTST Cap does not longer than 40 mil.
- ▶ The inductor should be placed as close to the IC and the recommend shape length from IC Lx Pads to inductor does not longer than 180 mil.
- ▶ The GND paths of both capacitors, connected to the VMID pin and the VBUS pin, need to be connected together at the TOP layer.
- ▶ PGND is connected to thermal heat sink to improve thermal performance.

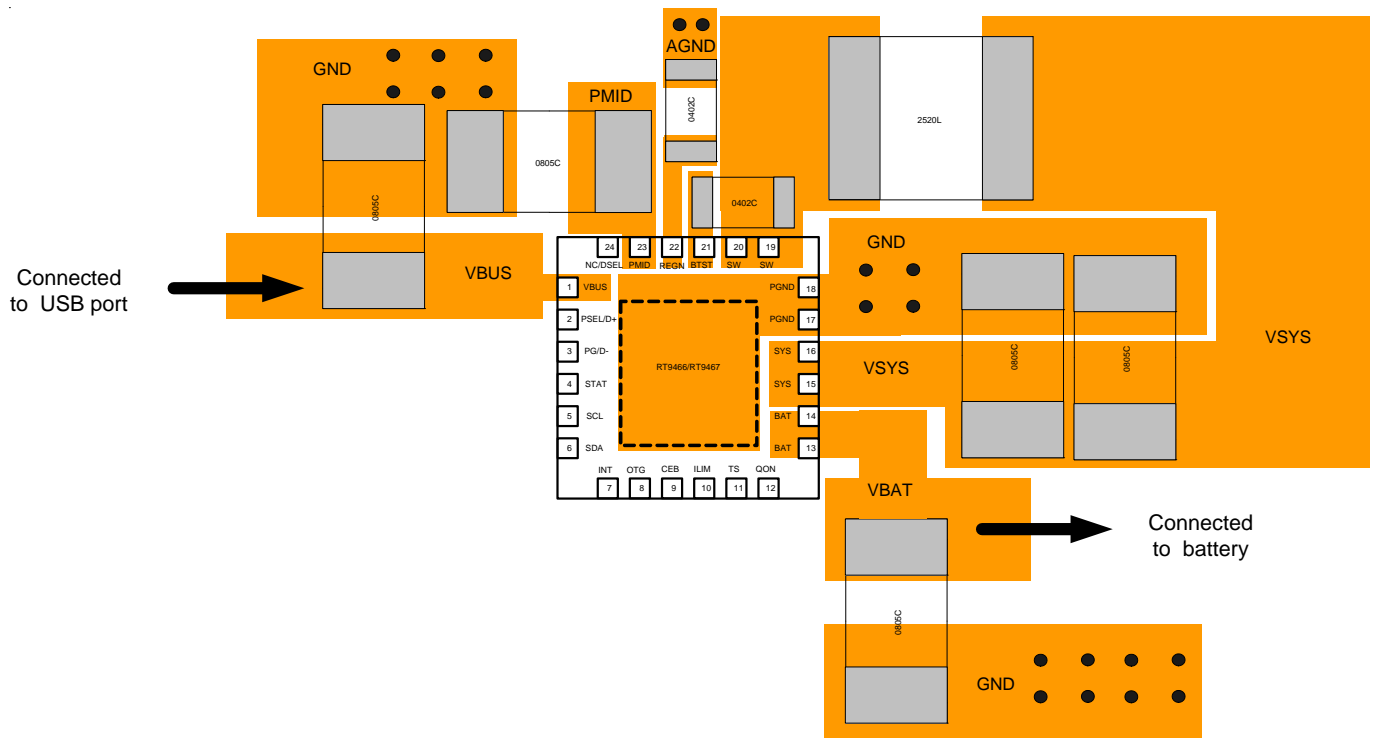
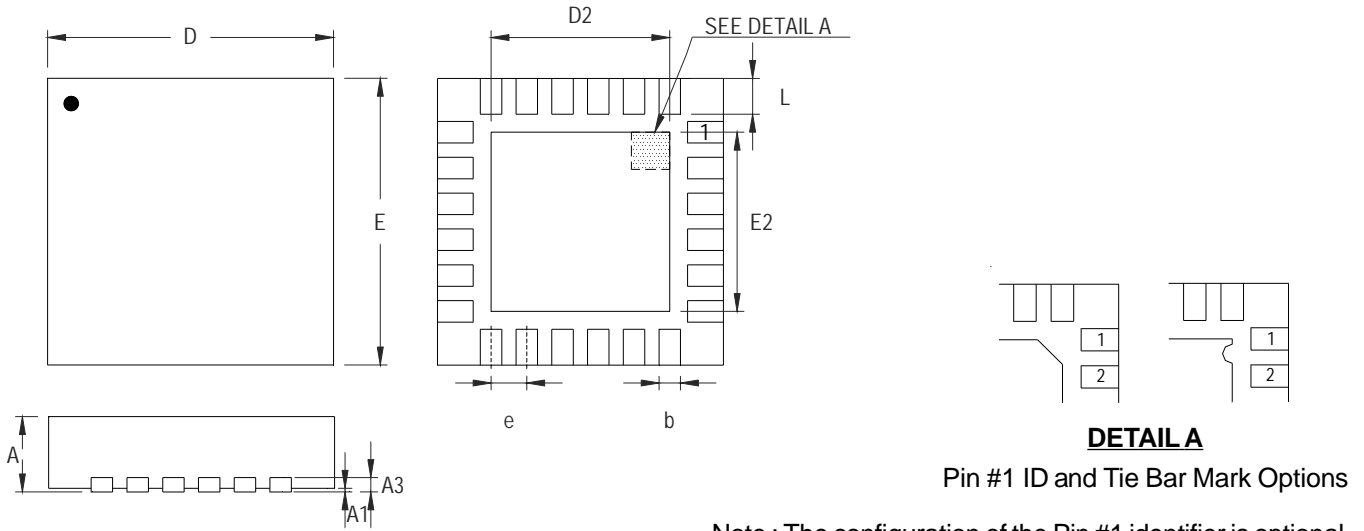


Figure 2. PCB Layout Guide

Outline Dimension



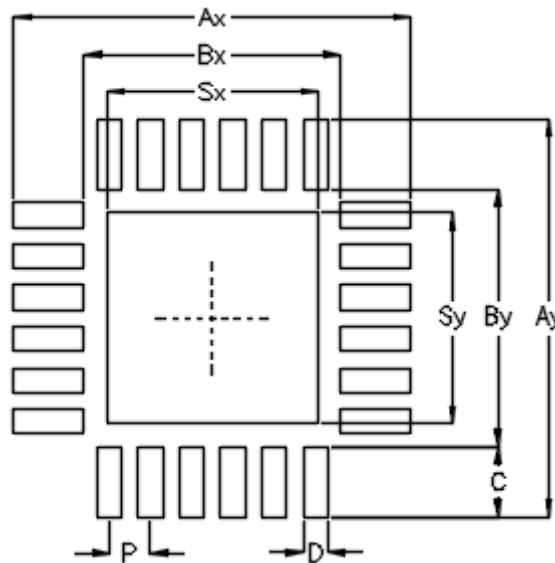
Pin #1 ID and Tie Bar Mark Options

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 | 0.180 | 0.300 | 0.007 | 0.012 | |
| D | 3.950 | 4.050 | 0.156 | 0.159 | |
| D2 | Option 1 | 2.400 | 2.500 | 0.094 | 0.098 |
| | Option 2 | 2.650 | 2.750 | 0.104 | 0.108 |
| E | 3.950 | 4.050 | 0.156 | 0.159 | |
| E2 | Option 1 | 2.400 | 2.500 | 0.094 | 0.098 |
| | Option 2 | 2.650 | 2.750 | 0.104 | 0.108 |
| e | 0.500 | | 0.020 | | |
| L | 0.350 | 0.450 | 0.014 | 0.018 | |

W-Type 24L QFN 4x4 Package

Footprint Information



| Package | | Number of Pin | Footprint Dimension (mm) | | | | | | | | Tolerance | |
|------------------|---------|---------------|--------------------------|------|------|------|------|------|------|------|-----------|-------|
| | | | P | Ax | Ay | Bx | By | C | D | Sx | | |
| V/W/U/XQFN4*4-24 | Option1 | 24 | 0.50 | 4.80 | 4.80 | 3.10 | 3.10 | 0.85 | 0.30 | 2.55 | 2.55 | ±0.05 |
| | Option2 | | | | | | | | | 2.60 | 2.60 | |

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