RICHTEK
your power partner.

Product Selection Guide

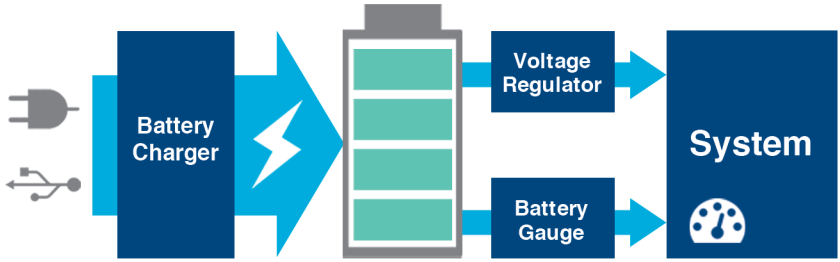
Power Management Components for Lithium-Ion Battery Powered Applications

Oct 2015

RICHTEK

Richtek Technology Corporation is one of the world's leading analog IC companies. The company consistently delivers inventive power management solutions that improve the performance of consumer electronics, computers, and communications equipment. Richtek adds value to end equipment by synthesizing technological innovation, uncompromised quality, and devotion to customer service. Founded in 1998, the Company is headquartered in Taiwan with additional offices in Asia, the U.S., and Europe. For more information about Richtek and its analog IC solutions, please visit the Company's Web site at www.richtek.com.

Power Management Components for Lithium-Ion Battery Powered Applications



Richtek provides a wide range of power management solutions for Li-Ion battery powered applications from battery front-end chargers and protection ICs to DC/DC converters and low quiescent LDOs.

Designing with Li-ion Batteries

Advantages of Li-ion batteries

Advantages of Li-ion batteries:

- → Light weight
- → No memory effect
- → Compared to NiMH batteries:
  - → Twice energy density typically
  - → 6~8 times less self-discharge
- → The high cell voltage of 3.6 volts is often sufficient to power applications from a single cell

These properties make Li-Ion batteries very popular in modern portable electronic applications. When designing applications with Li-Ion cells, it is important to understand the battery characteristics during charging and discharging, to ensure safe application and best battery life time.

Figure 1. Battery Capacities from 200mAh to 2800A

Battery capacity

Figure 1 shows several types of Lithium cells, used in different applications, with capacities ranging from 200mAh to 2800Ah. Standard Li-Ion batteries normally use a rigid case, while Li-Polymer batteries often use the flexible foil type or pouch cell case, which reduces size and weight.

Figure 2 shows the typical discharge curves of a 2000mAh Li-Ion battery, from fully charged (4.2V) to fully discharged (3.0V) condition. The discharge rates are expressed as a ratio of battery capacity (C). At high discharge currents, the battery capacity cannot be fully utilized and the battery voltage will drop due to battery internal resistance.

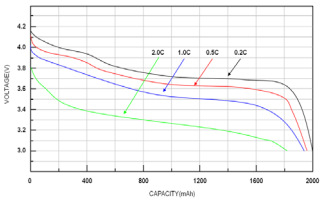


Figure 2. Typical Discharge Curves of a 2000mAh Li-Ion Battery

Single Li-Ion cell as power source

When powering your application from a single Li-Ion cell, the application input range must consider the voltage fluctuation of the battery, which for most Li-Ion batteries ranges from 4.2V fully charged down to 3.0V fully discharged.

Most applications will require some form of voltage regulation. Richtek offers a wide range of LDOs, buck, boost and buck-boost converters that can operate from the typical Li-Ion battery cell voltage range and provide a stable output voltage.

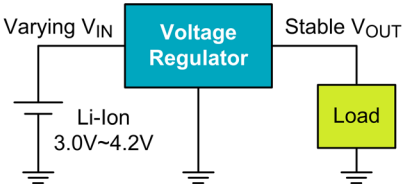
General application remarks

Li-Ion batteries are sensitive to over-discharge, which is why many cells have build-in under-voltage protection circuits that switch off the cell when the cell is discharged below 2.5V. It is recommended to re-charge the battery or disconnect the battery from the system well before this battery internal protection is activated.

When Li-Ion batteries are not used for a prolonged time period, it is better to discharge them to around 40% (~3.7V) to reduce their aging effect.

Switching and Linear Regulators

Product portfolio for Li-ion battery powered applications

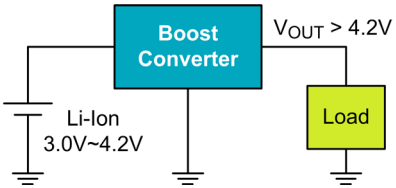


Most Richtek switching regulators have enhanced light load efficiency, thereby increasing the battery span.

Boost converters, such as RT9276 can be used to produce a stable USB 5V supply at varying battery voltage and provide battery monitoring function. Buck-boost regulators like RT6150A or RT6154A can be used when the output voltage lies in between the battery max and min voltage range, and with four internal switches, they seamlessly switch over from buck to boost mode. Most low voltage buck converters will operate in 100% duty-cycle mode when battery voltage approaches the output voltage, increasing the useful battery range, such as RT8059.

Low quiescent current LDOs like RT9063 can be used to regulate the output voltage for micro power applications with minimal battery loading. The 1μA ground current ensures minimal battery drain in low power standby mode.

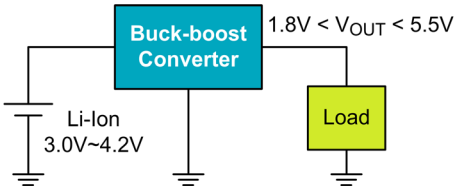
Boost Converters



- → Low EMI
- → Up to 45V V_{OUT}
- → Additional detection features included
- → Enhanced light load efficiency

V_{OUT}	I_{SW_MAX}	Product	Key Features	P/N
Up to 5V	2A	Synchronous Boost Converter with Bypass mode	→ Low BOM solution with small external components → Smooth transition between boost mode and bypass mode → Less than 1μA quiescent current in shutdown mode → I²C control to optimise target V_{OUT} → WL-CSP-16B 1.67x1.67 (BSC) package	RT4803A
Up to 5.5V	2A	Synchronous Boost Converter with current limit control	→ CMCOT topology for fast transient response → Small output ripple when V_{IN} is close to V_{OUT} → Adjustable 1A/2A, two level current limit threshold → PSM for enhanced light load efficiency → TSOT-23-8 package	RT4812
Up to 6.5V	1.6A	Synchronous Boost Converter with LDO Controller	→ For All One-Cell, Two-Cell and Three-Cell Alkaline, NiCd, NiMH and Single-Cell Li+ batteries powered applications → True load disconnection during shutdown to extend battery power	RT9296
		Synchronous Boost Converter with Voltage Detector	→ Output voltage is monitored by a PGOOD signal → Enhanced light load efficiency at power save mode → Low EMI → WDFN-10L 3x3 package	RT9276 Sample
Up to 16V	1.6A	PWM Asynchronous Boost Converter	→ Component size or efficiency consideration by optional 640kHz/1.2MHz operation frequency	RT9277B
		PSM Asynchronous Boost Converter	→ Internal or External programmable Soft-Start → Loop responses can be optimized by external compensation	RT9277C
Up to 24V	3.0A	Asynchronous Boost Converter	→ MSOP-8, WDFN-8L 3x3 and WDFN-10L 3x3 packages	RT9297
Up to 36V	1.2A	Asynchronous Boost Converter	→ Small package and PCB footprint → 550kHz operation frequency → Internal power N-MOSFET switch → Supports up to 10 WLED strings → PWM-Analog dimming (RT4503) → 32 step pulse dimming (RT4503A) → WDFN-6L 2x2 package	RT4503/A
Up to 45V	1.0A	Asynchronous Boost Converter	→ Small package and simple external circuit design → 1MHz operation frequency → Internal power N-MOSFET switch → Supports up to 10 WLEDs for backlighting and OLED power application → TSOT-23-6 and WDFN-8L 2x2 packages	RT9293

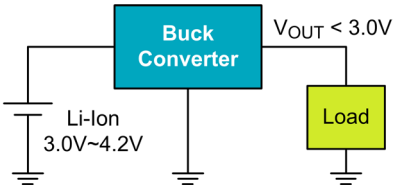
Support up to 5A peak current



- → Seamlessly switching between Buck and Boost mode
- → Power save mode enable control
- → Support up to 5A peak current (3A max load capability)

V_{OUT}	I_{SW_MAX}	Product	Key Features	P/N
1.8V ~ 5.5V	1.6A	Current Mode Buck-boost Converter	→ Up to 90% efficiency → Fixed frequency at 1MHz → WDFN-10L 3x3 and WDFN-10L 2.5x2.5 package	RT6150A/B
	5.0A	Current Mode Buck-boost Converter	→ Up to 96% efficiency → Fixed frequency at 2.4MHz → Can be synchronized to external clock 2.2MHz to 2.6MHz for low interference solution → WDFN-14L 4x3 package	RT6154A/B

Buck Converters



- → Low profile and small footprint
- → Up to 95% Efficiency
- → No Schottky diode required 100% duty-cycle mode

V_{OUT}	I_{OUT}	Product	Key Features	P/N
0.5V ~ V_{IN}	0.4A	1.25MHz Buck Converter	→ PSM enhanced light load efficiency → SOT-23-5 / TSOT-23-5 packages	RT8025 Sample
0.6V ~ V_{IN}	0.6A	1.5MHz Buck Converter	→ PSM enhanced light load efficiency → SOT-23-5 / TSOT-23-5 packages	RT8008 Sample
0.7V ~ V_{IN}	0.6A	1.5MHz Buck Converter	→ PWM mode / low-dropout auto switch and shutdown mode → Auto discharge function → 0.5mm height low profile, ideal for applications with height limitations → UDFN-6L 1.6x1.6 packages	RT8099
0.6V ~ V_{IN}	1.0A	1.5MHz Buck Converter	→ PSM enhanced light load efficiency → WDFN-6L 2x2 package	RT8016 Sample
0.6V ~ V_{IN}	1.0A	2.25MHz Buck Converter	→ 2.25MHz high operating frequency for reducing external component size → PWM operation → TSOT-23-5 / WDFN-6SL 2x2 packages	RT8057A
0.6V ~ V_{IN}	1.0A	1.5MHz Buck Converter	→ PWM enhanced light load efficiency → TSOT-23-5 package	RT8059
0.6V ~ V_{IN}	1.0A	1.5MHz Buck Converter	→ PWM mode/ low-dropout auto switch and shutdown mode → WDFN-6L 2x2 package	RT8080 Sample

Dual Buck Converters

V_{OUT}	I_{OUT}	Product	Key Features	P/N
0.6V ~ V_{IN}	1A + 1A	Dual Buck Converter	→ 50μA Quiescent Current per channel → 1.5MHz Fixed frequency PWM operation → WDFN-12L 3x3 package	RT8020 Sample
0.8V ~ V_{IN}	1A + 1.5A	Dual Buck Converter	→ Power Good output voltage monitor → 1.2MHz Fixed frequency PWM operation → WQFN-16L 4x4 package	RT8012A Sample

Linear Regulators

General LDO

V_{IN}	V_{OUT}	I_{OUT}	I_Q	Key Features	P/N
2.5V ~ 5.5V	1.5V ~ 5.0V	300mA	90μA	→ Auto discharge function → SC-70-5, SC-82, SOT-23-3, SOT-23-5, TSOT-23-3, TSOT-23-5, MSOP-8, & WDFN-6L 2x2 packages	RT9198
2.5V ~ 5.5V	1.5V ~ 5.0V	300mA	90μA	→ Bypass pin for ultra low noise → Auto discharge function → SC-70-5, SOT-23-5, TSOT-23-5, MSOP-8 & WDFN-6L 2x2 packages	RT9193

Special LDO

V_{IN}	V_{OUT}	I_{OUT}	I_Q	Key Features	Action
2.2V ~ 5.5V	1.2V ~ 3.3V	500mA	25μA	→ Auto discharge function: 5mA discharge current of V_{OUT} when shutdown → SOT-23-5 & SC-70-5 packages	RT9020
1.5V ~ 5.5V	0.9V ~ 3.5V	300mA + 300mA	29μA + 29μA	→ Dual LDO regulator → In tiny CSP package → WL-CSP-6B 0.8x1.2 package	RT9055

Ultra Low Quiescent Current LDO

V_{IN}	V_{OUT}	I_{OUT}	I_Q	Key Features	P/N
2.0V ~ 6.0V	1.2V ~ 5.0V	100mA	4μA	→ T0-92, SOT-89, SOT-23-3 & SOT-23-5 packages	RT9169 Sample
				→ With enable pin active high → SOT-23-5 package	RT9169H
2.5V ~ 6.0V	1.2V ~ 3.3V	200mA	1μA	→ SOT-23-3 & SOT-89-3 packages	RT9063
1.2V ~ 5.5V	0.9V ~ 3.3V	250mA	1μA	→ SOT-23-5, SC-70-5 & SC-82 packages → With EN pin	RT9073

Battery Management Products

Battery charging

Charging Li-Ion cells needs special care, as overcharge can lead to unsafe conditions. Most Li-Ion chargers have pre-conditioning - constant current - constant voltage - current cut-off –recharge functionality as shown in Figure 3.

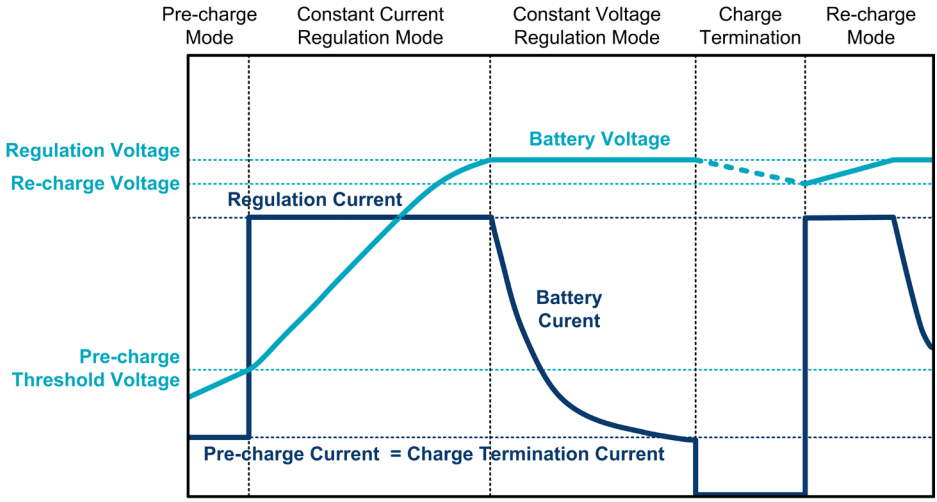


Figure 3. Battery Charger Operation Modes

The charger maximum regulation voltage needs to be accurately controlled. In case of deep discharge, the battery charger will first provide a low pre-charge current, to pre-condition the battery for normal charging. This low preconditioning current can also reset the battery internal under-voltage protection.

During the constant current mode, the battery is charged with a defined current. When the battery voltage comes close to the regulation voltage (4.2V or 4.35V depending on battery type), the charge current drops gradually and the charger will work in constant voltage mode. This maximum regulation voltage needs to be accurately controlled to avoid over-charging which would damage the battery and result in unsafe conditions.

The battery is considered fully charged when the battery voltage is at its regulation voltage and charging current is less than a user defined percentage of rated charge current and charging is terminated. It is not recommended to continuously trickle charge Li-Ion cells, as this will reduce battery life. Most chargers will start a re-charge cycle when the battery voltage drops below a certain level (usually 0.1V ~ 0.2V below the regulation voltage).

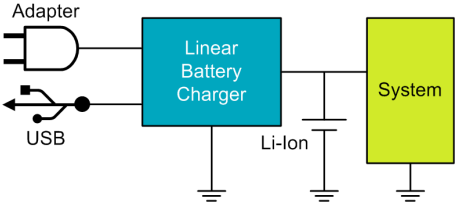
When Li-Ion batteries are not used for a prolonged time period, it is better to discharge them to around 40% (~3.7V) to reduce their aging effect.

Battery temperature during charging needs to be monitored and too high or too low battery temperature should stop the charging process. For most Li-Ion batteries, normal charging conditions can be applied within the 10°C ~ 45°C temperature range. Charging is normally cut-off when battery temperature is below 0°C or above 60°C.

Selected battery management components

Richtek has a wide range of Li-Ion chargers from linear to switching types. Linear charger topology is often used with batteries up to 1000mAh, while switching chargers are used for larger capacity batteries which can be charged with higher currents (>1A), or when using adapters with higher output voltage.

Linear Charger IC



→ Ideal for 1000mAh batteries
→ Up to 1.2A current charger ICs
→ Auto power path management

AC and USB Dual Input Supplies Charger ICs

Product	Key Features	P/N
1.2A Linear Single Cell Li-ion Battery Charger	→ Automatic input supplies selection between AC and USB → Integrated selectable 100mA and 500mA USB charge current and 1A AC adapter charge current → NTC sense for battery temperature monitor → AC Power Good and charge status indicators → WDFN-10L 3x3 package	RT9502 Sample
1.2A Linear Single Cell Li-ion Battery Charger with Input Over Voltage Protection	→ Cost effective solution → 28V(max) input rating for AC adapter → Power good and charge status indicators → Programmable charging current → Adjustable end-of-charge(EOC) current → Thermal feedback optimizing charge rate → WDFN-8L 2x3 & SOT-23-6 package	RT9526A
1.2A Linear Single Cell Li-ion Battery Charger with 4.9V/50mA LDO	→ 28V(max) input rating for AC adapter → 4.2V/2.3A factory mode → 50mA LDO to support the power of peripheral circuit → Programmable charging current → Integrated selectable 100mA and 500mA USB charge current → Power good and charge status indicators → WDFN-10L 3x2 package	RT9532 Sample RT9536

Linear charger with auto power path management

Auto Power Path feature allows the application to be run from adapter power, but it will gradually move back to battery power when the adapter input current limit is exceeded. These ICs also include many protection features like input overvoltage protection, output short protection and load disconnect function.

Product	Key Features	P/N
1.2A Linear Single Cell Li-ion Battery Charger with Auto Power Path Management and System Off	→ 28V(max) input rating for AC adapter → Auto Power Path Management(APPM) with system off → Adjustable Power current limit 0.1/0.5/1.5A → NTC sense for battery temperature monitor → Power good and charge status indicators → WQFN-16L 3x3 package	RT9525 Sample
1.2A I^2C Linear Single Cell Li-ion Battery Charger with Auto Power Path Management and USB/AV Switch	→ 28V(max) input rating for AC adapter → Integrated 3.3V LDO for NTC sense circuitry → Auto Power Path Management(APPM) → USB/Audio/Video switches → Termination, timer, charge current and VSYS settings through I^2C → Interrupt status, power good and charge status indicators → WQFN-28L 4x4 package	RT9528

Switching Charger

The switching charger with I²C control allows flexible selection of charging conditions and system control.

In some devices the switching MOSFETs can also be set in boost mode where a stable 5V can be supplied from battery to the VIN pin for powering USB-on-the-Go (OTG) devices.

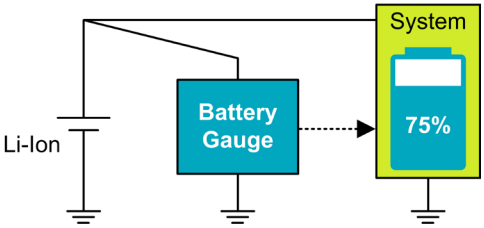
Li-ion Switching Charger

Product	Key Features	P/N
1.5A, I²C Switch-Mode Single Cell Li-Ion Battery Charger with USB On-The-Go (OTG)	→ 4V-6V Input voltage → Synchronous 3MHz fixed frequency with up to 99.5% duty cycle → Ideal for 2000mAh battery capacity	RT9450A
1.55A, I²C Switch Mode Single Cell Li-ion Battery Charger with USB-OTG	→ 4.3V-6V Input voltage → Synchronous 1.5MHz fixed frequency with up to 95% duty cycle → State machine controls via IRQ output → Ideal for 2,000mAh battery capacity → All charge parameters can be executed via the I²C interface → WL-CSP-16B 1.7x1.77 package	RT9455
4.0A, I²C Switch Mode Single Cell Li-ion Battery Charger with USB-OTG	→ 4.3V-12V Input voltage → Synchronous 375kHz fixed frequency with up to 99.0% duty cycle → USB OTG mode boosts the battery voltage to 5V and provides up to 1.6A current to the USB input → Ideal for 2,000mAh ~ 4,000mAh capacity batteries → All charge parameters can be executed via the I²C interface → WQFN-32L 4x4 package	RT9451

Generic Switching Charger

Product	Key Features	P/N
2A Asynchronous Switch Mode Battery Charger	→ 4.5V-28V input voltage → Adjustable battery voltages from 2.5V-22V → Internal Power MOSFETs → 500kHz switching frequency → NTC sense for battery temperature monitor → WQFN-16L 4x4 package	RT9535A
2A Asynchronous Switch Mode Battery Charger	→ 4.5V-28V input voltage → Adjustable battery voltages from 2.5V-25V → External Power MOSFETs → Input current limit maximizes charging rate → 475kHz switching frequency → Flag indicates Charging status → WQFN-16L 4x4 package	RT9538

Battery Gauge



→ SOC based on dynamic voltage measurements and battery voltaic model

→ ±7.5mV highly accurate voltage measurement

→ In many battery applications it is important to know how much charge is left in the battery.

Conventional Coulomb Counting Method

Checking the state of charge (SOC) of Li-Ion cells is often done by coulomb counting method. These methods are accurate in theory, but suffer from accumulation errors over time. In addition, the circuit is complicated due to the current sense circuit.

Richtek Solution

An alternative way to determine the SOC is using a dynamic voltage based battery gauge, which measures the battery voltage over time, and uses the dynamic voltage measurements in combination with a battery model to calculate the relative SOC. This topology does not suffer from error accumulation, and is used in RT9420 and RT9428 battery gauge ICs.

These ICs are simply connected to the battery terminals, and monitor the battery voltage very accurately. They use an internal algorithm to calculate the relative SOC and communicate it back to the host microcontroller via I^2C.

For best SOC accuracy, the application battery pack needs to be characterized during design stage, and battery specific compensation as well as temperature and charge/discharge effects can be included in the SOC calculation.

Product	Key Features	P/N
I^2C Host-side Single Cell Li-ion Battery gauge	→ ±3% State-of-Charge (SOC) error under general charging/discharging → Precise voltage measurement ±12.5mV accuracy → Accurate relative capacity(RSOC) calculated from Voltaic Gauge algorithm with temperature compensation → No accumulation error on capacity calculation → No battery relearning necessary and no current sense resistor required → WDFN-8L 2x3 package	RT9420
I^2C Host-side Single Cell Li-ion Battery gauge	→ ±3% State-of-Charge (SOC) error under general charging/discharging → Precise voltage measurement ±7.5mV accuracy → Accurate relative capacity(RSOC) calculated from Voltaic Gauge algorithm with temperature compensation → No accumulation error on capacity calculation → No battery relearning necessary and no current sense resistor required → WL-CSP-8B 1.6x1.52 (BSC) package	RT9428

EZPBS™ Power Bank Solution

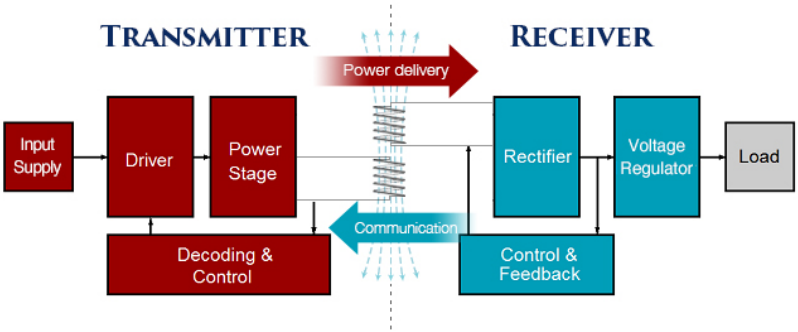
→ EZPBS™ highly integrated single chip solution

→ Ideal for 3,000mAh battery capacity

Product	Key Features	P/N
EZPBS™ Integrated Chip with Two Ports Output	→ Easy-to-use Power Bank Solution (EZPBS™) → Compact BOM elements with EZPBS™ single chip → Support charging and discharging at the same time by smart algorithm → 1.2A linear charger, asynchronous Boost with dual output load management and a torch function support included → Support dual USB output (Total 2.5A) → Support one sync-boost up to 2.5A → Battery state of charge(SoC) indicator by 4LEDs → WQFN-24L 4x4 package	RT9480
4.0A, I²C Switch Mode Single Cell Li-ion Battery Charger with USB OTG	→ Provide up to 1.6A USB output current in OTG mode for power bank → WQFN-32L 4x4 package	RT9451
EZPBS™ Integrated Chip with Switch Charger	→ Easy-to-use Power Bank Solution (EZPBS™) → Built-in USBOUT DCP Controller, Attach/Detach Detection, Light Load Detection → Built-in Adapter Detection with BC1.2 → Charge Voltage Regulation form 3.65V to 4.6V → Charge Current Regulation form 0.7A to 2.7A → All charge parameters can be executed via the I²C interface → 750kHz switching frequency → Current Regulation of Load Switch for 3A → WQFN-24L 4x4 package	RT9481

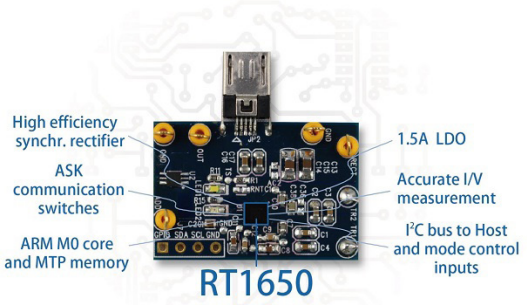
Wireless Power Receiver Solution

Robust and flexible WPC Qi compliant 7.5W wireless power receiver



Product	Key Features	P/N
Wireless power receiver	→ Highly integrated with on-board 32-bit ARM-Cortex-M0 MCU → Very flexible with a user configurable MTP memory → Compliant with the WPC1.1 for low power up to 5W and WPC1.2.0 for medium power up to 7.5W → A high efficiency fully synchronous rectifier stage and a low drop 1.5A linear post regulator stage → A special headroom control system regulates the LDO headroom for optimal balance between transient response and system efficiency up to 80% → Supporting both adapter input and wireless power transfer input → CSP 3.0mmx3.4mm 48B (pitch=0.4mm) in 0.55mm low profile	RT1650

Find out more in the application note for the basic principles of Wireless Power Transfer, Wireless Power standards and the Qi WPC1.1 low power standard, and a practical example of the WPC1.1 5W application where a Nokia DT601 wireless power transmitter is paired with the wireless power receiver RT1650 evaluation board.



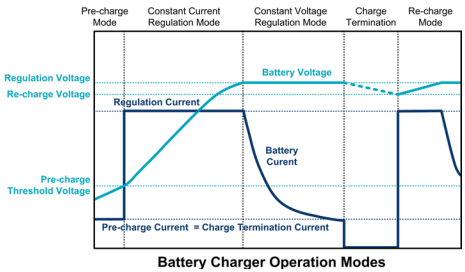
Front-end Protection IC

RT9718 is fully integrated circuit designed to provide protection to Li-ion batteries powered applications from up to 28V abnormal high input voltage.

RT9718 monitors the input voltage, battery voltage and the charging current. In case of an input over-voltage condition, RT9718 will turn off the power MOSFET within 1μs to remove the power before any damage occurs. Additionally, RT9718 can provide a voltage output without the existence of battery.

Product	Key Features	P/N
28V Over Voltage Protection IC	→ Fully integrated protection function: programmable OCP, input OVP and battery OVP → Over voltage turn off time less than 1μs → High accuracy protection threshold → WDFN-8L 2x2 package	RT9718

Design Support



Battery Charger Operation Modes

Understanding the characteristics of Li-ion batteries and Richtek power management solutions

by Gary Zheng, Project Manager

Lithium-ion/polymer rechargeable batteries, which have been widely used today, have distinguished properties, but are very delicate and have to be used with extreme care. Improper use of Li-ion batteries will bring about catastrophic consequences....

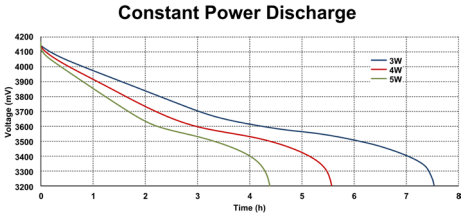
http://www.richtek.com/Design Support/Technical Document/AN023

Designing Applications with Lithium Ion Batteries

by Roland van Roy

Li-Ion batteries have several advantages when compared with other battery types: The energy density of lithium-ion is typically twice that of the standard nickel-cadmium. Li-Ion batteries have no memory effect, and the self-discharge is less than half compared to nickel-cadmium. The high cell voltage of 3.6 volts is often sufficient to power applications from a single cell...

http://www.richtek.com/Design Support/Technical Document/AN025



Li-ion Battery and Gauge Introduction

by Vincent Ho

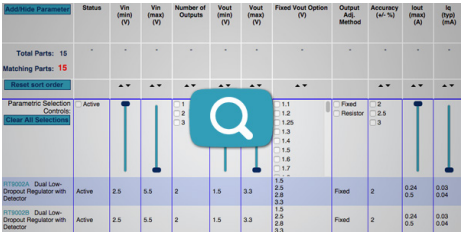
SOC (State-Of-Charge) is defined as the status of available energy in the battery and usually expressed as percentages. Because the available energy change depends on different charging/discharging currents, temperatures and aging effects, the SOC could be defined more clearly as ASOC (Absolute State-Of-Charge) and RSOC (Relative State-Of-Charge)...

http://www.richtek.com/Design Support/Technical Document/AN024

DIY - How to Make a Power Bank by Yourself

How to make a safe and efficient power bank? The safety and performance of power bank is critical. It's easy to DIY a power bank, but how to select the key control IC for your power bank?...

https://www.youtube.com/watch?v=SHYyogri-04



Parametric Search

Filter component by your requirements

http://www.richtek.com/Parametric Search/Parametric Search?tree_ID=27

Wireless Application : How to Make a Wireless LED Light

The video introduces wireless charging principle and explains the application of Richtek RT1650, a flexible Qi compliant wireless power receiver for power transfer up to 7.5W.

https://www.youtube.com/watch?v=y4gS0xCHOxA

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